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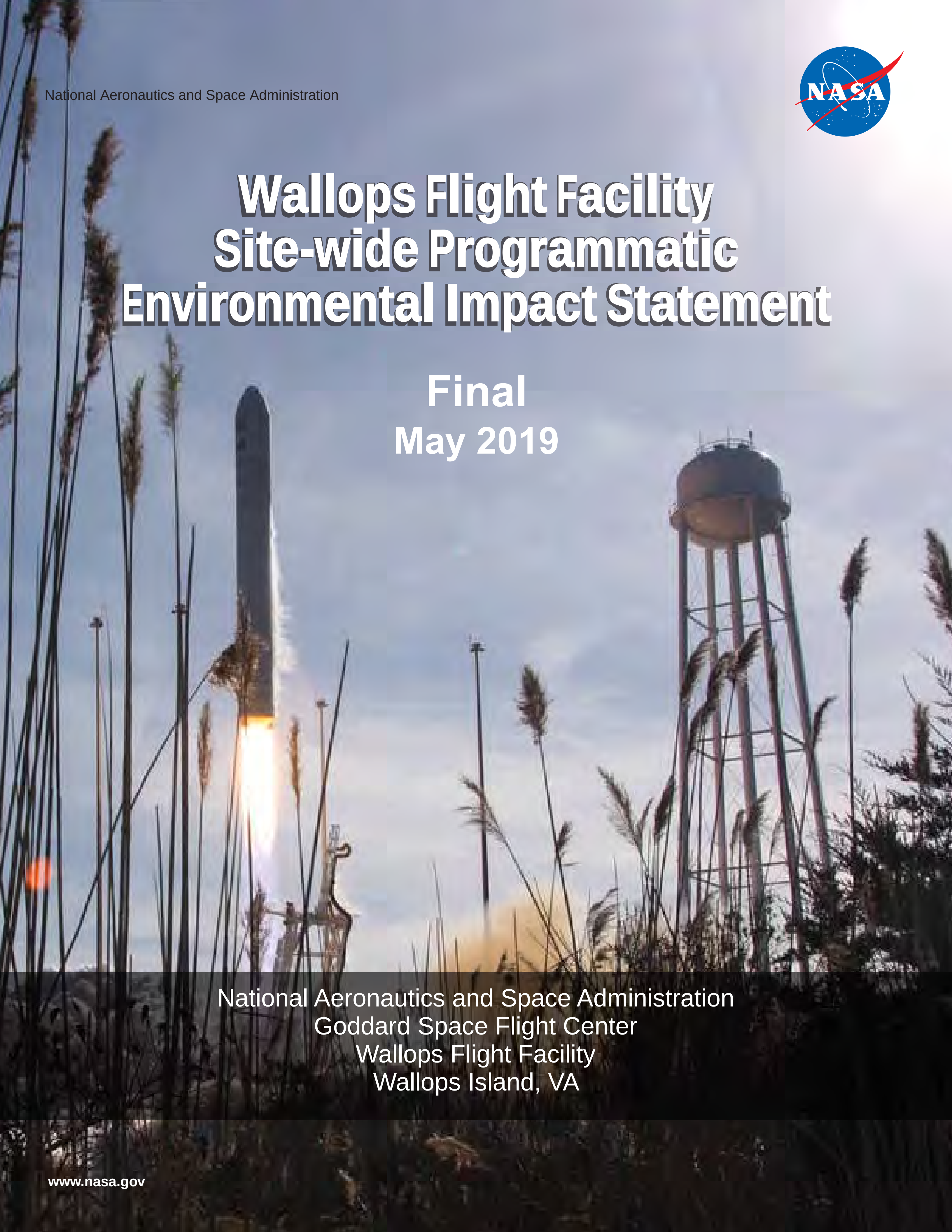

# Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

## Final

## May 2019

National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA

www.nasa.gov

Cover Images:

Front cover
Antares rocket with Cygnus cargo spacecraft – Photo Credit: Chris Perry

Back cover (background, top, bottom):
Antares rocket with Cygnus cargo spacecraft – Photo Credit: Chris Perry
Mid-Atlantic Regional Spaceport following 2012 beach renourishment – Photo Credit: NASA
NASA WFF Main Base runways – Photo Credit: NASA

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

Reply to Attn of: 250.W May 2019

Dear Reader:

This is the NASA Goddard Space Flight Center's Wallops Flight Facility (WFF) Final Site-wide Programmatic Environmental Impact Statement (PEIS). Prepared in accordance with the National Environmental Policy Act (NEPA), the Final PEIS evaluates the environmental consequences of constructing and operating new facilities and infrastructure at WFF in Accomack County, Virginia, to support a growing mission base in the areas of civil, commercial, defense, and academic aerospace while also preserving NASA's ability to safely conduct its historical baseline of operations.

NASA considered all comments received on the Draft PEIS in preparing the Final PEIS. Comments received on the Draft PEIS and NASA's responses to those comments are included as Appendix I.

In consideration of both public input offered during scoping and review of the Draft PEIS and the results of the environmental analysis in Chapter 3 of the Final PEIS, NASA has identified the Proposed Action as its Preferred Alternative.

NASA will issue a Record of Decision (ROD) based on the Final PEIS no sooner than 30 days from the date of publication in the *Federal Register* of the U.S. Environmental Protection Agency's Notice of Availability (NOA) of the Final PEIS. NASA's ROD will be made available, once issued, on the project's website (address provided below) and upon request.

The Final PEIS is available for review online at **https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis**. You may also request a hard copy or compact disc.

*All requests for copies of the Final PEIS should be submitted by one of the following options:*

Mail: NASA Wallops Flight Facility
Site-wide PEIS – Shari Miller
Mailstop: 250.W
Wallops Island, VA 23337

Email: Shari.A.Miller@nasa.gov
Fax: (757) 824-1819

If you have any questions regarding the Final EIS, please call (757) 824-2327 or toll-free at (800) 521-3415. When using the toll-free number, please follow the menu options and enter the "pound sign (#)" followed by extension numbers "2327."

*Thank you for your participation in this process!*

# NASA WFF SITE-WIDE PROGRAMMATIC
# FINAL ENVIRONMENTAL IMPACT STATEMENT

**Lead Agency:** National Aeronautics and Space Administration (NASA)

**Cooperating Agencies:**
Federal Aviation Administration
Federal Highway Administration
National Oceanic and Atmospheric Administration
National Environmental Satellite Data Information Service
United States (U.S.) Army Corps of Engineers
U.S. Coast Guard
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Navy, Fleet Forces Command
U.S. Navy, Naval Sea Systems Command
U.S. Navy, Naval Air Systems Command
U.S. Air Force, Space Command/Space and Missile Systems Center
Virginia Commercial Space Flight Authority

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**Date:** May 2019

**Abstract:**
In accordance with the National Environmental Policy Act, NASA has prepared a 20-year planning horizon Site-wide Programmatic Environmental Impact Statement to evaluate the environmental consequences of constructing and operating new facilities and infrastructure at WFF, Accomack County, Virginia. Many of the proposed projects are needed to support a growing mission base at WFF in the areas of civil, commercial, defense, and academic aerospace while also preserving NASA's ability to safely conduct its historical baseline of operations. Numerous agencies have served as cooperating agencies in preparing this Programmatic Environmental Impact Statement. The potential effects to physical, biological, and socioeconomic resources resulting from the implementation of NASA's Proposed Action and a No Action Alternative are presented.

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# EXECUTIVE SUMMARY

The National Aeronautics and Space Administration (NASA) is proposing to implement a suite of new construction and demolition projects and new operational missions and activities that are needed to ensure continued growth at NASA Goddard Space Flight Center's Wallops Flight Facility (WFF) while also preserving the ability to safely conduct its historical baseline of operations. This Site-wide Programmatic Environmental Impact Statement (PEIS) addresses the most reasonably foreseeable actions at WFF within a 20-year planning horizon.

This Site-wide PEIS has been prepared by NASA in accordance with the requirements of the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S. Code [U.S.C.] 4321-4347); the Council on Environmental Quality (CEQ) regulations implementing NEPA (Title 40 of the Code of Federal Regulations [CFR] Parts 1500-1508); NASA procedures for implementing NEPA (14 CFR 1216.3); and NASA Procedural Requirements 8580.1 effective August 1, 2012.

The following agencies have served as cooperating agencies in preparing this PEIS: Federal Aviation Administration, Federal Highway Administration, National Oceanic and Atmospheric Administration National Environmental Satellite Data Information Service, United States (U.S.) Army Corps of Engineers, U.S. Coast Guard, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Navy Naval Air Systems Command, U.S. Navy Naval Sea Systems Command, U.S. Navy U.S. Fleet Forces Command, U.S. Air Force Space Command/Space and Missile Systems Center, and Virginia Commercial Space Flight Authority. NASA, as the property owner and project proponent, is the lead agency and is responsible for ensuring overall compliance with the applicable environmental statutes.

## PURPOSE AND NEED FOR PROPOSED ACTION

WFF developed a set of strategic management goals with a focus on providing its direction for the future. These strategic management goals include:

- Be the Nation's preferred provider of suborbital and small orbital research carriers and mission services.
- Develop and infuse technologies that increase capability and reduce risk or cost of WFF carriers and range systems.
- Conduct and support meaningful science that is appropriate to the carriers, location, special capabilities, and partnerships that are available at or through WFF.
- Provide, through partnerships, hands-on authentic experiences in aerospace for students and educators to increase interest in science, technology, engineering, and mathematics disciplines and careers.
- Provide quality training and leadership development for NASA's workforce, WFF employees, and education stakeholders.
- Provide a workforce and capabilities that can enable WFF to be a leader in its field.

The purpose of the Proposed Action is to continue to meet these goals and increase WFF's ability to support a growing mission base in the areas of civil, commercial, defense, and academic aerospace research. Implementing the Proposed Action would support the Facility's plan for the future as developed in the Agency-approved 2008 WFF Facility Master Plan, which is currently under review and revision. The resulting improvements would provide facilities and infrastructure that would directly support existing missions, as well as modernize functionality to meet future operational mission requirements in direct support of WFF's strategic management goals. To achieve these goals, WFF, its partners, and tenants are proposing to construct new facilities and remove outdated facilities on the Main Base, Mainland, and Wallops Island; strategically place additional rocket launch pads on Wallops Island to permit concurrent hazardous activities; and focus new construction, to the maximum extent practicable, to previously disturbed and developed sites.

## PROPOSED ACTION (PREFERRED ALTERNATIVE) AND NO ACTION ALTERNATIVE

The Proposed Action, NASA's preferred alternative, considers a number of institutional support projects ranging from new construction, demolition, and renovation throughout the installation to include the replacement of the Causeway Bridge and maintenance dredging between the boat docks at the Main Base and Wallops Island. In addition to continuing the existing operational missions, the Proposed Action also considers several new operational and mission activities including expansion of Department of Defense (DoD) programs such as the Navy's standard missile rocket (SM-3); introduction of a new weapons system currently under development comprised of a high energy laser and high power microwave (Directed Energy); future opportunities within the Expanded Space Program involving the potential for Liquid Fueled Intermediate Class (LFIC) launch vehicles (LVs) and Solid Fueled Heavy Class (SFHC) LVs; and consideration of commercial human spaceflight missions from WFF.

CEQ regulations require that an agency "include the alternative of no action" as one of the alternatives it considers (40 CFR 1502.14[d]). The No Action Alternative serves as a baseline against which the impacts of the Proposed Action are compared. For the Site-wide PEIS, the No Action Alternative signifies that the activity level of institutional support projects and operational missions and activities at WFF would remain at present levels and within previously established envelopes analyzed in prior NEPA documents, such as the 2005 Site-Wide Environmental Assessment.

## SUMMARY OF IMPACTS

The actions considered in this Site-wide PEIS are at various stages of conceptual maturity. Therefore, the level of discussion, and subsequent impact summary, varies from project to project. In some cases, the level of discussion may be such that the environmental consequences can be adequately considered and an informed decision made, eliminating the need for additional NEPA documentation. For others, only high-level, cursory treatment can be given, warranting more focused analysis in the future, once design plans become more certain. Accordingly, future tiered NEPA documents may be prepared for specific actions related to this Site-wide PEIS.

**Table ES-1** provides a comparison of the potential impacts by resource. Institutional support projects in the summary table encompass planned general construction and demolition projects; however, when necessary, projects such as the Causeway Bridge Replacement and maintenance dredging are discussed separately.

| Table ES-1. Summary of Impacts | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Noise | No change to the existing noise environment beyond impacts analyzed in previous NEPA documents. | Institutional Support Projects<br>• Temporary increases in noise from general construction for institutional support projects are not likely to adversely alter the surrounding noise environment.<br>• Potential increase in airborne and underwater noise associated with Causeway Bridge Replacement, barge route maintenance dredging, and dredging for development of the North Wallops Island Deep-water Port and Operations Area. Site-specific NEPA analysis would be required.<br>Operational Missions and Activities<br>• No significant impact anticipated from DoD SM-3.<br>• An increase in noise associated with Expanded Space Program, including LFIC LVs and SFHC LVs is anticipated.<br>• Potential for sonic boom during LV horizontal landing.<br>• During launch of LFIC LVs and SFHC LVs, no residences would be exposed to 115 dBA or greater noise levels (the OSHA threshold for 15 minute exposure). |
| Air Quality | No change to existing emissions or sources beyond those analyzed in previous NEPA documents. Greenhouse Gas (GHG) emissions data will continue to be collected. | Institutional Support Projects<br>• Short-term impacts to air quality from construction-related to institutional support projects would be expected. However, these projects would be phased in over time and emissions are not anticipated to have significant impacts on regional air quality.<br>• Institutional support projects have the potential to incrementally contribute to global emissions of GHGs. However, no significant impacts are anticipated.<br>Operational Missions and Activities<br>• LVs and RLVs criteria pollutant emissions under the Expanded Space Program would not exceed the comparable thresholds.<br>• Operational missions and activities have the potential to incrementally contribute to global levels of GHGs. However, total emissions are anticipated to be insignificant in terms of global GHG levels. |
| Hazardous Materials, Toxic Substances, and Hazardous Waste | Daily operations would continue as they are. Impacts from hazardous materials, substances, and hazardous waste generated by installation maintenance activities and existing operations would continue to be managed in accordance with the guidelines set forth in federal and state hazardous material, substance, and hazardous waste regulations. | Institutional Support Projects<br>• Any hazardous materials, substances, and hazardous waste generated by institutional support projects would be managed in accordance with current procedures. Therefore, there would be no significant impact.<br>Operational Missions and Activities<br>• There is potential for slight increases in the types and quantities of hazardous materials, substances, and hazardous waste from proposed operational missions and activities. Types of hazardous materials, substances, and hazardous waste would be similar to those used or generated during current operations at WFF and would continue to be managed according to standard procedures. Additional training and BMPs would be implemented as necessary. No significant impacts are anticipated. |

| Table ES-1. Summary of Impacts (cont.) | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Health and Safety | Daily operations would continue as is and current protocols for continued human health and safety would not change. | Institutional Support Projects<br>• Institutional support projects would occur and contactors would be required to adhere to established protocols and safety measures while working at WFF.<br>Operational Missions and Activities<br>• Operational missions and activities would follow established protocols at WFF. Most operations would fall within approved envelopes.<br>• Operation of LFIC LVs and SFHC LVs would involve risks to safety similar to previously analyzed rocket launch activities. Commercial human spaceflight missions would require new safety processes and procedures. WFF would implement protective measures to ensure risks to personnel and the general public from these operations are minimized. LFIC LVs/RLVs, SFHC LVs, and horizontal launch and landing from Main Base Runway 04/22 may require temporary road closures.<br>• Directed Energy operations and testing are projects that are still under development. WFF would continue to operate using established protocols for safety, but additional analysis may be necessary as more information about this operational activity is gathered. |
| Water Resources | Daily operations would continue as they are. There would be no impacts to water resources generated by installation maintenance activities and existing operations beyond what has been analyzed in previous NEPA documents. The Town of Chincoteague wells located in the Columbia aquifer have been affected by chemicals related to fire fighting and fire training activities; these shallow water wells are no longer used for potable water. NASA is working with Federal and state environmental regulatory agencies to monitor the plumes, which are receding, and to restore groundwater to natural conditions. Site-specific Stormwater Pollution Prevention Plans (SWPPPs) would continue to be generated as necessary and site-specific BMPs would be implemented for previously evaluated institutional support projects and operational missions and activities beach renourishment and maintenance would continue to take place at Wallops Island as needed. | Institutional Support Projects<br>• No long-term impacts to water resources from general construction-related to institutional support projects are anticipated due to the implementation of site-specific SWPPPs, BMPs, and wetlands avoidance and minimization measures. If impacts are identified, NASA would implement wetland mitigation to ensure no net loss of wetlands.<br>• Potential impacts to wetlands associated with the Causeway Bridge Replacement project, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D. As required by the 404(b)(1) guidelines, only the Least Environmentally Damaging Practicable Alternative (LEDPA) can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable. Avoidance and minimization measures would be followed. If potential unavoidable wetland impacts are identified, NASA would implement wetland mitigation to ensure no net loss of wetlands. Site-specific NEPA analysis would be required.<br>• All proposed construction projects at the Main Base would avoid development in the floodplain. Wallops Island is located entirely within the 100-year floodplain. As such, there is no practicable alternative to avoid development within the floodplain.<br>• Institutional support projects have the potential to contribute to sea-level rise. These impacts to Wallops Island infrastructure are mitigated through continuation of the SRIPP. The proposed projects would not cause an appreciable increase in the factors that affect sea-level rise. As such, no significant impacts are anticipated.<br>Operational Missions and Activities<br>• No long-term impacts to water resources from operational missions and activities are anticipated due to the implementation of site-specific SWPPPs, BMPs, and wetlands avoidance and minimization measures.<br>• In the unlikely event of an LV failure, potential impacts to water resources could be locally substantial but clean-up efforts after |

| Table ES-1. Summary of Impacts (cont.) | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| | | the launch failure and restoration measures taken would prevent long-term effects to aquatic ecosystems.<br>• Operational missions and activities have the potential to contribute to sea-level rise; these impacts to Wallops Island infrastructure are mitigated through continuation of the SRIPP. It is not believed the proposed projects would cause an appreciable increase in the factors that affect sea level. No significant impacts are anticipated. |
| Land Use | Operations at WFF would remain unchanged. No changes to land use beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• Institutional support projects would fall within compatible land uses already designated by the 2008 WFF Facility Master Plan.<br><u>Operational Missions and Activities</u><br>• The instantaneous noise during launch of LFIC LVs and SFHC LVs would not exceed OSHA noise exposure limits. In addition, impacts at receptor areas would likely not be significant or result in land use changes including future planning and zoning.<br>• LV launch activities would not significantly impact parks, recreation areas, wildlife refuges or National Register of Historic Places (NRHP)-eligible structures: no adverse impact to DOT 4(f) properties would occur.<br>• DoD SM-3 missiles and drones and Directed Energy would be directed over the ocean. The placement of this activities would be in Navy Assets area of Wallops Island. No impacts to land use would occur.<br>• Operational missions and activities to include SODAR would continue to occur in the areas designated for such operations. |
| Land Resources | Daily operations would continue as they are. There would be no impacts to land resources generated by installation maintenance activities, existing operations, and previously evaluated construction projects beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• No long-term impacts to land resources from general construction-related to institutional support projects are anticipated due to the implementation of site-specific SWPPPs, BMPs, and Erosion and Sediment Control Plans.<br><u>Operational Missions and Activities</u><br>• No long-term impacts to land resources from operational missions and activities are anticipated. |
| Vegetation | Daily operations would continue as they are. There would be no impacts to vegetation generated by installation maintenance activities and previously evaluated projects beyond what has been analyzed in previous NEPA documents. Current management actions would continue. | <u>Institutional Support Projects</u><br>• No significant long-term impacts to vegetation on the Main Base are anticipated from general construction-related to institutional support projects.<br>• Ground disturbance on the Mainland and Wallops Island has the potential to increase the spread of the invasive species *Phragmites australis*. Control plans would be implemented in these areas.<br>• Causeway Bridge Replacement, barge route maintenance dredging, dredging for development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D have the potential to disturb tidal and non-tidal wetland vegetation. The amount of disturbance depends on the final design. Further NEPA analysis would likely be required.<br><u>Operational Missions and Activities</u><br>• No long-term, significant impacts to vegetation from operational missions and activities are anticipated. |

**Table ES-1. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Terrestrial Wildlife, Special-Status Species, and Marine Mammals and Fish | Daily operations would continue as is. There would be no impacts to biological resources beyond those evaluated in previous NEPA documents, regardless of whether or not those actions have been implemented. | Institutional Support Projects<br>• Land-based institutional support projects would have insignificant adverse effects on vegetation, terrestrial wildlife, or special-status species. These projects may have minor, indirect adverse effects on marine mammals and fish. Regulatory agency consultations would occur as necessary in order to minimize impacts to these species.<br>• Causeway Bridge Replacement, maintenance dredging, and development of the North Wallops Island Deep-water Port and Operations Area may have effects on marine special-status species, marine mammals, and Essential Fish Habitat. However, impacts would be dependent on final designs and locations of both projects. Further analysis would be required as project details are confirmed.<br>Operational Missions and Activities<br>• Noise from launch operations would generally impact biological resources. Terrestrial wildlife and special-status species would be disturbed by noise and vibration from launch activities. Marine mammals are unlikely to be affected by LV and RLV launch operations.<br>• Directed Energy specifics are largely unknown, but based on current information and target scenarios, impacts to biological resources are unlikely. Additional NEPA analysis may be required to better assess potential impacts to biological resources from these weapon systems. |
| Airspace Management | Operations from the Main Base airfield and from Wallops Island would continue as they are. There would be no impacts to airspace management beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• No long-term impacts to airspace management from institutional support projects are anticipated.<br>Operational Missions and Activities<br>• Operation of LVs and DoD SM-3 and Directed Energy would be coordinated with VACAPES FACSFAC.<br>• Airspace management would not be affected by increased operations from the North Wallops Island UAS airstrip. |
| Transportation | Daily operations involving roads, rail, and air transport would continue as they are. There would be no impacts to transportation resources beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• Institutional support projects may cause short-term impacts to traffic from construction/demolition activities.<br>• Replacement of the Causeway Bridge may temporarily cause road or waterway closures from demolition activities.<br>• Waterway closures may be required during maintenance dredging and dredging for development of the North Wallops Island Deep-water Port and Operations Area.<br>Operational Missions and Activities<br>• LFIC LVs/RLVs, SFHC LVs, and horizontal launch and landing from runway 04/22 may require temporary road closures. Waterways may need to be temporary closed during delivery of the LVs or LV components and during LV launch and landing. |

**Table ES-1. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Infrastructure and Utilities | Daily operations would continue as they are. There would be no impacts to infrastructure and utilities beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• Institutional support projects would create short-term spikes in demand for potable water and power; however, long-term impacts would be countered by use of efficient technologies and greener building methods, per all pertinent Executive Orders.<br>Operational Missions and Activities<br>• An increase in operations would occur; however, it is unlikely that infrastructure or utilities would be negatively impacted.<br>• With the implementation of the previously analyzed Alternative Energy Project, NASA should see an overall reduction in the amount of energy purchased from the local utility provider.<br>• Future assessment of the energy requirements for Directed Energy would be needed as more information is available, to ensure that existing infrastructure could handle power needs, or if alternative power sources would be required. |
| Socioeconomics | There would be no change to the socioeconomic environment beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• Positive economic impacts (e.g., expenditures, tax revenue, job creation, tourism, etc.) may be experienced in the Region of Influence (ROI) from institutional support projects.<br>Operational Missions and Activities<br>• Positive economic impacts (e.g., expenditures, tax revenue, job creation, tourism, etc.) may be experienced in the ROI from the proposed operational missions and activities. |
| Environmental Justice | Activities with the potential for impacts within the local communities would remain unchanged and there would be no disproportionate impact to minority or low-income populations or children beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• There would be no disproportionate impact to minority or low-income populations or children from institutional support projects.<br>Operational Missions and Activities<br>• There would be no disproportionate impact to minority or low-income populations or children from operational missions and activities. |
| Visual Resources and Recreation | Daily operations would continue as they are. There would be no impacts to visual resources or recreation beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• All construction would be consistent with the 2008 WFF Facility Master Plan and impacts to visual resources would be negligible.<br>• Minor short-term impacts to boaters and fishermen from dredging operations and Causeway Bridge construction.<br>Operational Missions and Activities<br>• Short-term, negligible impacts to recreational resources from temporary closure of Wallops Island beach, Chincoteague Inlet, downrange ocean areas, and portions of the CNWR and Assateague Island National Seashore during launch operations.<br>• Addition of an LV launch pad and deluge systems or development of the north end of the Island would change the viewshed of Wallops Island. However, the change would not be out of character with the surrounding visual aspects of the area. |

| Table ES-1. Summary of Impacts (cont.) | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Cultural Resources | Daily operations would continue as they are. There would be no impacts to Cultural Resources beyond what has been analyzed in previous NEPA and National Historic Preservation Act (NHPA) documents. | Institutional Support Projects<br>• Impacts to archaeological or traditional cultural properties are unlikely. However, if inadvertent discovery were made during construction, activities would cease and NASA would consult with Virginia Department of Historical Resources (VDHR).<br>Operational Missions and Activities<br>• Architectural resources that are listed on the NRHP would be within areas subject to noise from LV launches. NASA has developed a Programmatic Agreement with VDHR and Advisory Council on Historic Preservation that would address potential impacts to these structures. |

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| $\mu g/m^3$ | micrograms per cubic meter |
| AAOC | Administrative Agreement on Consent |
| ac | acres |
| ACM | asbestos-containing material |
| AFB | Air Force Base |
| AFTT | Atlantic Fleet Training and Testing |
| AGL | above ground level |
| AINS | Assateague Island National Seashore |
| Al | aluminum |
| $Al_2O_3$ | aluminum oxide |
| ANSI | American National Standards Institute |
| AOC | Areas of Concern |
| AP | ammonium perchlorate |
| AQCR | Air Quality Control Region |
| ARTCC | Air Route Traffic Control Center |
| AST | aboveground storage tank |
| ATC | Air Traffic Control |
| AUV | Autonomous Underwater Vehicle |
| BCC | Birds of Conservation Concern |
| BGEPA | Bald and Golden Eagle Protection Act |
| BMP | Best Management Practice |
| BO | Biological Opinion |
| BRRC | Blue Ridge Research and Consulting |
| °C | Celsius |
| CAA | Clean Air Act |
| CalTrans | California Department of Transportation |
| CBFS | Chincoteague Bay Field Station |
| CCB | Common Core Booster |
| CCDev | Commercial Crew Development |
| CDAS | Command and Data Acquisition Station |
| CEA | Cumulative Effects Analysis |
| CEQ | Council on Environmental Quality |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulation |
| $CH_4$ | methane |
| cm | centimeter |
| CNWR | Chincoteague National Wildlife Refuge |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| CO2e | carbon dioxide equivalent |
| CRP | Conservation Reserve Program |
| CST-100 | Crew Space Transportation 100 |
| CTPB | Carboxyl-terminated polybutadiene |
| CWA | Clean Water Act |
| CZM | Coastal Zone Management |
| DARPA | Defense Advanced Research Projects Agency |
| dB | decibel |
| dB re:1µ Pa-m | sound pressure level in dB, referenced to a pressure of 1 micropascal at 1 meter |
| dB re: 1 $\mu Pa^2$-s | sound pressure level in dB referenced to a pressure level of 1 $micropascal^2$ per second |
| dBA | A-weighted decibels |
| $dB_{peak}$ | peak sound pressure |
| $dB_{RMS}$ | Root Mean Square |
| DNH | Division of Natural Heritage |
| DNL | Day-Night Average Sound Level |
| DoD | Department of Defense |
| DOT | Department of Transportation |
| EA | Environmental Assessment |
| ECR | Environmental Compliance and Restoration |
| EFH | Essential Fish Habitat |
| EIS | Environmental Impact Statement |
| EMRG | Electromagnetic Railgun |
| LV | launch vehicle |
| EO | Executive Order |
| EPA | Environmental Protection Agency |
| ESA | Endangered Species Act |
| ESSM | Evolved Sea Sparrow Missile |
| °F | Fahrenheit |
| FAA | Federal Aviation Administration |
| FACSFAC | Fleet Area Control and Surveillance Facility |
| FCLP | Field Carrier Landing Practice |
| FEMA | Federal Emergency Management Agency |
| FFTA | Former Fire Training Area |
| FHWA | Federal Highway Administration |
| FICUN | Federal Interagency Committee on Urban Noise |
| FIRM | Flood Insurance Rate Map |
| FMC | Fishery Management Council |

| | |
|---|---|
| FONSI | Finding of No Significant Impact |
| ft | feet |
| $ft^2$ | square feet |
| FUDS | Formerly Used Defense Sites |
| FWPCA | Federal Water Pollution Control Act |
| FY | fiscal year |
| gal | gallon |
| GCM | Global Climate Model |
| GHG | Green House Gas |
| GIS | Geographic Information Systems |
| GO | Generation Orbit |
| gpd | gallons per day |
| gpm | gallons per minute |
| GPR | Goddard Procedural Requirement |
| GPS | Global Positioning System |
| GSFC | Goddard Space Flight Center |
| GTM | Global Traffic Manager |
| GTM | Generic Transport Sub-scale Model |
| GWP | Global Warming Potential |
| ha | hectare |
| HAP | Hazardous Air Pollutant |
| HAPS | Hydrazine Auxiliary Propulsion System |
| HAZMAT | hazardous material |
| HCl | hydrogen chloride |
| HEL | High Energy Laser |
| HFRP | Healthy Forests Reserve Program |
| HIF | Horizontal Integration Facility |
| hp | horsepower |
| HPM | High Power Microwave |
| HUC | Hydrologic Unit Code |
| HTPB | Hydroxyl-terminated polybutadiene |
| ICP | Integrated Contingency Plan |
| IEEE | Institute of Electrical and Electronic Engineers |
| in | inch |
| IPT | Integrated Project Team |
| ISS | International Space Station |
| JLUS | Joint Land Use Study |
| JPA | Joint Permit Application |
| kgs | kilogram |
| kHz | kilohertz |
| km | kilometer |
| $km^2$ | square kilometer |
| kPa | kilopascal |
| LADEE | Lunar Atmosphere and Dust Environment Explorer |
| LBP | lead-based paint |
| lb | pound |
| LEDPA | Least Environmentally Damaging Practicable Alternative |
| LEO | low earth orbit |
| LFIC | Liquid Fueled Intermediate Class |
| LID | low impact development |
| LMCLS | Lockheed Martin Commercial Launch Service |
| LOX | liquid oxygen |
| lpd | liters per day |
| LPG | liquefied petroleum gas |
| lpm | liters per minute |
| m | meter |
| $m^2$ | square meter |
| $m^3$ | cubic meter |
| $mi^2$ | square mile |
| MARS | Mid-Atlantic Regional Spaceport |
| MBTA | Migratory Birds Treaty Act |
| MEC | Munitions and Explosives of Concern |
| mi | mile |
| MLLW | mean lower low water |
| mm | millimeter |
| MMH | monomethylhydrazine |
| MMPA | Marine Mammal Protection Act |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MSAT | Mobile Source Air Toxic |
| MSL | mean sea level |
| MTR | Military Training Route |
| MW | megawatt |
| $N_2O$ | nitrous oxide |
| na | not applicable |
| NA | Not Available |
| NAAQS | National Ambient Air Quality Standard |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| NASA-STD | NASA Standard |
| NAVAIR | Naval Air Command |
| NAVSEA | Naval Sea Systems Command |

| | |
|---|---|
| NC | nitrocellulose |
| NEPA | National Environmental Policy Act |
| NESDIS | National Environmental Satellite Data Information Service |
| NFSAM | Nuclear Flight Safety Assurance Manager |
| NG | nitroglycerin |
| NGIS | Northrup Grumman Innovation Systems |
| NGU | nitroguanadine |
| NHPA | National Historic Preservation Act |
| NLCD | National Land Cover Database |
| nm | nautical mile |
| $nm^2$ | square nautical mile |
| NMFS | National Marine Fisheries Service |
| $NO_2$ | nitrogen dioxide |
| NOA | Notice of Availability |
| NOAA | National Oceanic and Atmospheric Administration |
| NOI | Notice of Intent |
| NOTAM | Notice-to-Airmen |
| NOTMAR | Notice-to-Mariner |
| $NO_x$ | nitrogen oxide |
| NPD | NASA Policy Directive |
| NPDES | National Pollutant Discharge Elimination System |
| NPR | NASA Procedural Requirement |
| NPS | National Park Service |
| NRHP | National Register of Historic Places |
| NWI | National Wetlands Inventory |
| $O_3$ | ozone |
| OASPL | Overall Sound Pressure Level |
| OB | Open Burning |
| OBIS SEAMAP | Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Population |
| OEIS | Overseas Environmental Impact Statement |
| OSHA | Occupational Safety and Health Administration |
| pa | pascal |
| Pb | lead |
| PCB | polychlorinated biphenyl |
| PEIS | Programmatic Environmental Impact Statement |
| PFOS/PFOA | perfluorooctane sulfonate/perfluorooctanoic acid |
| $PM_{2.5}$ | particulate matter less than or equal to 2.5 microns in diameter |
| $PM_{10}$ | particulate matter less than or equal to 10 microns in diameter |
| ppb | parts per billion |
| PPF | Payload Processing Facility |
| ppm | parts per million |
| ppt | parts per thousand |
| psf | pounds per square foot |
| psi | pounds per square inch |
| PU | polyurethane |
| R- | Restricted Airspace |
| R&D | research and development |
| RBR | Repair-by-Replacement |
| RCRA | Resource Conservation and Recovery Act |
| RDT&E | research, development, test, and evaluation |
| REC | Record of Environmental Consideration |
| RLV | Reusable Launch Vehicle |
| RMS | root mean square |
| ROD | Record of Decision |
| ROI | Region of Influence |
| RP-1 | Rocket Propellant (kerosene) |
| RTLS | return to launch site |
| SAA | Space Act Agreement |
| SAIC | Science Applications International Corporation |
| SAV | Submerged Aquatic Vegetation |
| SCSC | Surface Combat Systems Center |
| SEL | Sound Exposure Level |
| SFHC | Solid Fueled Heavy Class |
| SHPO | State Historic Preservation Officer |
| SM-3 | Standard Missile-3 |
| SODAR | Sonic Detection and Ranging |
| $SO_2$ | sulfur dioxide |
| SOP | Standard Operating Procedure |
| SR | State Route |
| SR | Slow Route |
| SRIPP | Shoreline Restoration and Infrastructure Protection Program |
| SRM | solid rocket motor |
| SS2 | SpaceShipTwo |
| STEM | science, technology, engineering and math |
| SWPPP | Stormwater Pollution Prevention Plan |

| | |
|---|---|
| TBD | to be determined |
| TNC | The Nature Conservancy |
| TPH | Total Petroleum Hydrocarbon |
| TSCA | Toxic Substance Control Act |
| TSS | Traffic Separation Scheme |
| UAS | Unmanned Aerial System |
| ULA | United Launch Alliance |
| U.S. | United States |
| U.S.C. | U.S. Code |
| USACE | U.S. Army Corps of Engineers |
| USCB | U.S. Census Bureau |
| USDA | U.S. Department of Agriculture |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| UST | underground storage tank |
| UXO | unexploded ordnance |
| V- | Victor Airway |
| VAC | Virginia Administrative Code |
| VACAPES OPAREA | Virginia Capes Operating Area |
| VDACS | Virginia Department of Agriculture and Consumer Service |
| VDCR | Virginia Department of Conservation and Recreation |
| VDEQ | Virginia Department of Environmental Quality |
| VDGIF | Virginia Department of Game and Inland Fisheries |
| VDHR | Virginia Department of Historic Resources |
| VDOT | Virginia Department of Transportation |
| VIMS | Virginia Institute of Marine Science |
| VMRC | Virginia Marine Resources Commission |
| VOC | Volatile Organic Compound |
| VPDES | Virginia Pollution Discharge Elimination System |
| VSMP | Virginia Stormwater Management Program |
| W- | warning area |
| WFF | Wallops Flight Facility |
| WK2 | White Knight 2 |
| WRP | Wallops Research Park |
| WSDOT | Washington State Department of Transportation |
| WWTP | Waste Water Treatment Plant |
| $y^3$ | cubic yard |

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# 1.0 PURPOSE AND NEED FOR PROPOSED ACTION

## 1.1 INTRODUCTION

The National Aeronautics and Space Administration (NASA) is proposing to implement a suite of construction and demolition projects at Wallops Flight Facility (WFF), introduce new mission opportunities, and expand the envelope of existing programs. This Site-wide Programmatic Environmental Impact Statement (PEIS) evaluates the environmental effects of implementing the proposed projects that would support existing and future NASA goals and objectives.

The Site-wide PEIS has been prepared by NASA in accordance with the requirements of the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S. Code [U.S.C.] 4321-4347); the Council on Environmental Quality (CEQ) regulations implementing NEPA (Title 40 of the Code of Federal Regulations [CFR] Parts 1500-1508); NASA procedures for implementing NEPA (14 CFR 1216.3); and NASA Procedural Requirements (NPR) for NEPA Management, NPR 8580.1, effective August 1, 2012.

## 1.2 BACKGROUND

The National Aeronautics and Space Act is the United States (U.S.) federal statute that created NASA. The Space Act gives the responsibility for planning, directing, and conducting the nation's civilian space program and aeronautics and aerospace research activities to NASA. It also gives NASA the authorization to enter into cooperative agreements, leases, and contracts with public and private entities in the use of NASA's services, equipment, and facilities in support of scientific research and discovery.

NASA Goddard Space Flight Center (GSFC) manages WFF, the oldest active launch range in the continental U.S. and the only rocket testing and launch range owned and operated by NASA. For over 70 years, WFF has flown thousands of research vehicles in the quest for information on the flight characteristics of airplanes, launch vehicles, and spacecraft, and to increase the knowledge of the Earth's upper atmosphere and the near space environment. WFF supports aeronautical research, and science, technology, engineering, and math (STEM) education programs by providing other NASA centers and other U.S. government agencies access to resources such as special use (i.e., controlled/restricted) airspace, runways, and launch pads. WFF regularly provides launch support for the emerging commercial launch industry, either directly or through the Mid-Atlantic Regional Spaceport (MARS), a commercial launch site on Wallops Island. WFF facilitates a wide array of U.S. Department of Defense (DoD) research, development, testing, and evaluation (RDT&E) and training missions, including target and missile launches, and aircraft development. The flight programs and projects conducted by WFF Range from small sounding rockets and suborbital rockets, unmanned scientific balloons, unmanned aerial systems (UAS), manned aircraft, and orbital spacecraft to next generation launch vehicles (LVs), and small- and medium-classed LVs. Many of these programs are conducted from the WFF Research Airport or the WFF Launch Range.

Services provided by WFF include technical expertise, project oversight and management, engineering, fabrication, testing, meteorological studies, hydrospheric and biospheric sciences, and operational support. Additionally, WFF supports numerous aircraft companies that utilize the research airport for flight test and training activities. WFF also assists the scientific community with mobile campaigns, as well as providing commercial and other government activities with mobile range equipment.

### 1.2.1 GEOGRAPHICAL SETTINGS

WFF is located in the northeast portion of Accomack County, Virginia on the Delmarva Peninsula. The facility is comprised of three distinct land masses: the Main Base, Wallops Mainland, and Wallops Island (**Figure 1.2-1**). The Main Base includes offices, laboratories, maintenance and service facilities, an airport, air traffic control facilities, hangars, runways, aircraft maintenance and ground support buildings, and water and sewage treatment plants. Wallops Mainland has long-range radar, communications, and optical tracking facilities. Wallops Island includes launch and testing facilities, rocket storage buildings, assembly and integration shops, fueling facilities, two UAS runways, and other related support structures. Numerous tidal inlets, marshes, bays, and creeks are found in and around all three installation areas of WFF.

### 1.2.2 TENANTS AND OTHER ONSITE ORGANIZATIONS

NASA has several tenant/partners and customers that use the WFF Research Airport and WFF Launch Range, its facilities, and airspace. The activities of these tenant/partners are described below.

**Chincoteague Bay Field Station**

Formerly known as the Marine Science Consortium, the Chincoteague Bay Field Station (CBFS) was founded in 1968 by a consortium of three Pennsylvania colleges. The primary objective of CBFS is to promote and encourage learning and research in the marine and environmental sciences. Thirteen academic institutions now comprise the CBFS, which is located adjacent to the WFF Main Base and consists of over 23 hectares (ha) (57 acres [ac]) containing classrooms, wet and dry laboratories, a computer laboratory, residence buildings, faculty and staff residences, a cafeteria, library, recreational facilities, and an administrative building. Licensed captains employed by CBFS frequently operate boats from behind the WFF Visitor Center to transport CBFS students conducting research in the nearby marshes and waterways. CBFS students and faculty also conduct research on Wallops Island.

**Mid-Atlantic Regional Spaceport**

The Virginia Commercial Space Flight Authority (Virginia Space) holds and maintains an active Launch Site Operator License with the Federal Aviation Administration (FAA) to operate MARS. The license authorizes Virginia Space to operate a launch site at the orbital Launch Complex 0, which includes Pads 0-A and 0-B, and to operate small and medium payload weight classes (less than or equal to 5,035 kilograms [kgs] [11,100 pounds {lbs}]) of orbital LVs from Launch Complex 2. MARS provides facilities and services for NASA, DoD, and commercial launches of payloads into space. Activities include launch vehicle and payload preparation, integration and testing, pre-launch operations, launch range integration, and launch and post-launch operations.

**National Oceanic and Atmospheric Administration – National Environmental Satellite Data Information Service**

The National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data Information Service (NESDIS) operates environmental satellites, which collect information on atmospheric, oceanic, and terrestrial environmental conditions. This data is distributed to various organizations worldwide to prepare short-term and long-range meteorological forecasts, monitor important environmental parameters, provide information critical to aviation and maritime safety, aid search and rescue missions, and assist in national defense and security.


**Figure 1.2-1. Location of NASA's Wallops Flight Facility**

NOAA-NESDIS satellites track the movement of storms, volcanic ash, and icebergs; measure cloud cover; measure temperature profiles in the atmosphere and temperature of the ocean surface; collect infrared and visual information; and measure atmospheric ozone ($O_3$) levels.

The Wallops Command and Data Acquisition Station (WCDAS), an 11.7 ha (29 ac) facility operated by NOAA-NESDIS, gathers the data from environmental satellites via radio downlinks utilizing 21 antennas (including four that are operated remotely from the WCDAS), 18 of which are also capable of transmitting data. Three of the remotely controlled antennas are located in Fairmont, West Virginia, six in Fairbanks, Alaska, and the other is at NASA GSFC.

**U.S. Coast Guard**

The U.S. Coast Guard maintains housing units on 2.8 ha (7 ac) south of the Main Base Entrance for personnel assigned to the Chincoteague Station.

**U.S. Navy Surface Combat Systems Center**

The U.S. Navy Surface Combat Systems Center (SCSC) is WFF's largest partner. They provide a broad range of support for the conduct of Aegis and Ships Self-Defense System combat system activities. These facilities contain sufficient equipment to duplicate the combat systems of all Aegis ships and Ships Self-Defense System MK1 and MK2 systems. These capabilities support the installation of prototype upgrades to verify they are effective and ready for fleet introduction, commissioning and replacement crew training, fleet operations, research and development initiatives and major test exercises in a maritime environment. Other technical missions include Lifetime Support Engineering, In-Service Engineering, Systems Level operations, and maintenance training. WFF also provides missile launch support for the U.S. Navy. Drone vehicles launched from Wallops Island are used for target tracking and can be engaged by operational naval forces.

**U.S. Navy Fleet Area Control and Surveillance Facility**

The Virginia Capes Operating Area (VACAPES OPAREA) is a U.S. Navy surface and subsurface combat test and training operations area off the Virginia and North Carolina coasts (**Figure 1.2-2**). This 94,875 square kilometer ($km^2$) (27,661 square nautical miles [$nm^2$]) area of the Atlantic Ocean extends from Rehoboth Beach, Delaware, to Cape Fear, North Carolina. The boundary starts 6 kilometers (km) (3 nautical miles [nm]) off the coast and terminates approximately 275 km (150 nm) east in certain areas. It includes the area covered by FAA Warning Areas (W-) 386, W-387, W-72, W-50, W-110, and the Submarine Transit Lanes.

VACAPES OPAREA is managed by the U.S. Navy Fleet Area Control and Surveillance Facility (FACSFAC) VACAPES, located in Virginia Beach, Virginia. Restricted Area (R-) 6604, located west of W-386, is controlled by WFF. The VACAPES OPAREA is used by the Navy for air-to-air, air-to-surface, surface-to-air, and surface-to-surface missile, gunnery, and rocket exercises using conventional ordnance. VACAPES FACSFAC provides full Air Traffic Control (ATC) services over the OPAREA and, as such, it is required to provide air traffic separation consistent with the guidelines used by the FAA controllers, and provide for the safe, efficient, and expeditious flow of air traffic.

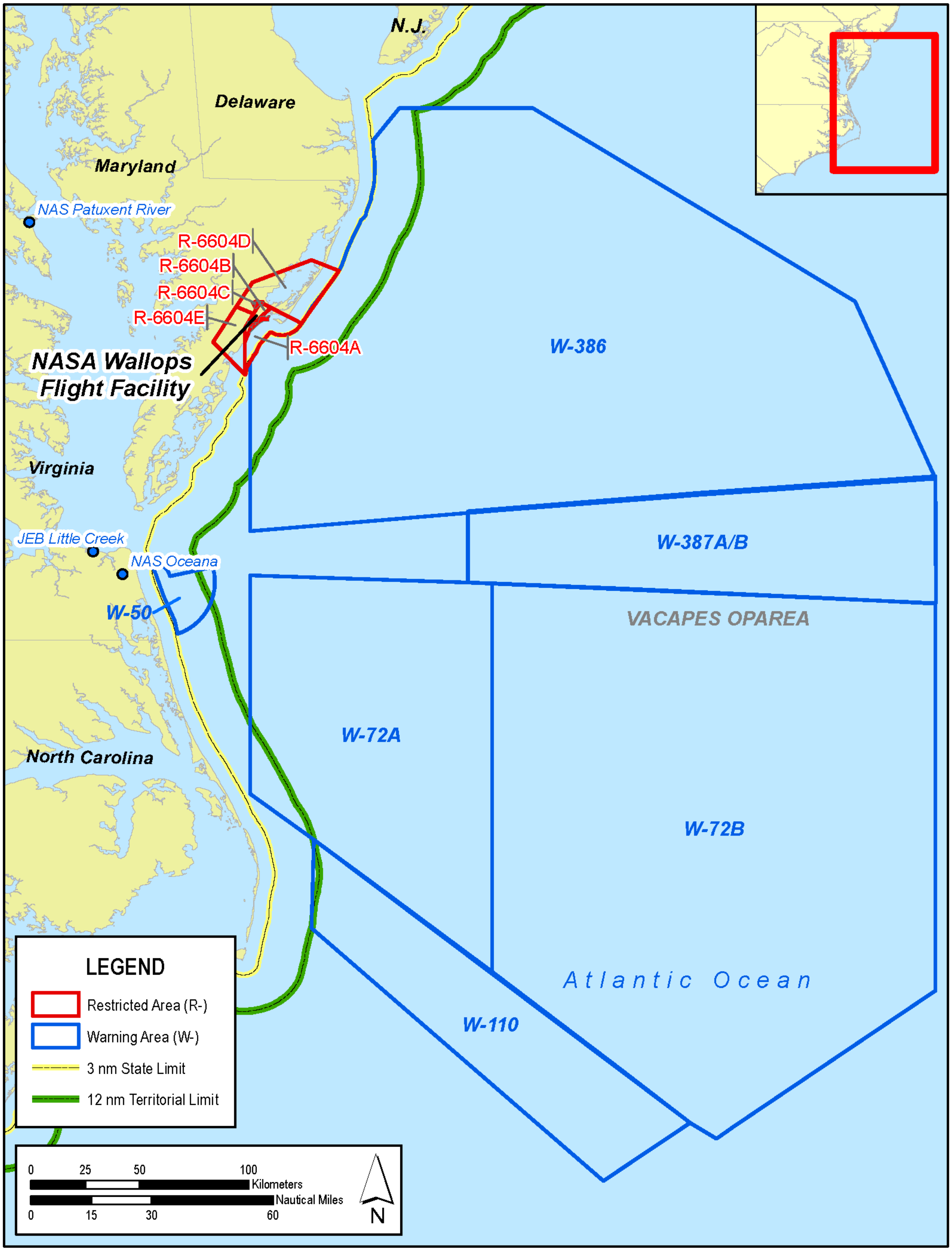



**Figure 1.2-2. VACAPES OPAREA**

W-386 is the special use airspace over VACAPES OPAREA most frequently requested by WFF for its operations. W-386 extends from the surface to unlimited altitude, except a small portion of the area west of 75° 30'W which is surface to, but not including, 610 meters (m) (2,000 feet [ft]) above mean sea level (MSL).

## 1.3 PURPOSE OF THE PROPOSED ACTION

WFF has developed a set of strategic management goals with a focus on providing the Center's direction for the future. These strategic management goals include:

- Be the Nation's preferred provider of suborbital and small orbital research carriers and mission services.
- Develop and infuse technologies that increase capability and reduce risk or cost of WFF carriers and range systems.
- Conduct and support meaningful science that is appropriate to the carriers, location, special capabilities and partnerships that are available at or through WFF.
- Provide, through partnerships, hands-on authentic experiences in aerospace for students and educators to increase interest in STEM disciplines and careers.
- Provide quality training and leadership development for NASA's workforce, WFF employees, and education stakeholders.
- Provide a workforce and capabilities that can enable WFF and its tenants and partners to be leaders in the field.

***The purpose of the Proposed Action is to continue to meet these goals and increase WFF's ability to support a growing mission base in the areas of civil, commercial, defense, and academic aerospace***. Proposed increases in WFF's operational envelopes[1] would drive NASA to implement a suite of construction and demolition projects. The resulting improvements would provide facilities and infrastructure that would directly support existing missions, as well as modernize functionality to meet future operational mission requirements in direct support of WFF's strategic management goals. WFF would consolidate like functions/facilities together in the core areas of the installation in order to provide increased work efficiency and better separation from existing and/or future hazardous operations or activities. Obsolete and inefficient facilities would be replaced with new, energy efficient facilities and or demolished for reuse of the land for future operational test and training missions. A key component of the Proposed Action is to facilitate such growth while still enabling the safe conduct of WFF's historic lines of business.

## 1.4 NEED FOR PROPOSED ACTION

The mission of today's WFF is to "drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth." WFF's mission drives its programs and objectives which in turn drive its facilities and infrastructure. In addition to fulfilling its own mission, WFF provides unique services to NASA, civil and commercial customers,

[1] A range or "envelope" of activities is identified for each type of operation conducted at WFF. An envelope presents the scenario with the greatest potential for environmental impacts.

defense, and academia, many of which are guided at some level by the 2010 U.S. National Space Policy. The discussion below presents the underlying need for proposing to expand WFF's operational capacities.

**Growing U.S. Focus on Commercial Space**

A guiding principle of the 2010 U.S. National Space Policy is for federal agencies to facilitate the commercial space industry. A robust and competitive commercial space sector is vital to continued progress in space. The U.S. is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation driven entrepreneurship.

The 2013 U.S. National Space Transportation Policy provides further guidance for federal agencies in the space transportation sector. Of the twelve Commercial Space Guidelines in the 2010 U.S. National Space Policy, two Guidelines (updated in the 2013 U.S. National Space Transportation Policy) are specifically relevant to WFF, the first of which is:

- Purchase and use U.S. commercial space transportation capabilities and services and facilitate multiple U.S. commercial providers of space transportation services across a range of launch vehicle classes, to the maximum extent practicable.

This directive guides all federal agencies to utilize commercial space services when they are available. A recent NASA example of this in action at WFF is the renewed Commercial Orbital Transportation Services Agreement and follow-on Commercial Resupply Services contract that were both awarded to three commercial space companies, one of which has based its operations at the commercial spaceport, MARS, at WFF. Over a term of at least five years, commercial launches delivering cargo to the International Space Station (ISS) will be conducted from WFF. It is expected that as more U.S. government space missions are provided by commercial companies, an increased demand would be placed on active commercial spaceports like MARS. As a result, greater demands would be placed on existing infrastructure and new support infrastructure would be needed to meet the needs of this growing endeavor.

The second commercial space guideline applies to the sharing of government owned technologies and infrastructure with the private sector. More specifically, NASA is directed by the 2010 U.S. National Space Policy and 2013 U.S. National Space Transportation Policy to:

- Ensure availability of U.S. Government space transportation technologies, capabilities, and facilities for non-federal use on a reimbursable, non-interference, equitable, and predictable basis to the maximum practical extent, consistent with applicable law and national security.

Sharing of government owned infrastructure at WFF with the private sector has been ongoing for many years; however, in the past several years, the magnitude and frequency has grown markedly. A prime example of government private partnership is the recently constructed Horizontal Integration Facility (HIF) on Wallops Island. Although a NASA-owned facility, the occupants of the building are employed by a commercial space company. Through this sharing of resources, the commercial company now has the resources it needs to efficiently do its work, while the customer, NASA, benefits in the end by the successful completion of the mission. Again, as the commercial space sector grows, and as more such work is based at WFF, NASA would have a continuing obligation to meet the directives contained in the 2010 National Space Policy by allowing commercial use of WFF facilities and infrastructure.

**More Frequent Partnerships with Defense Agencies**

Of the five guiding principles of the 2010 U.S. National Space Policy, the last principle directs the U.S. government to:

- Employ a variety of measures to help assure the use of space for all responsible parties, and, consistent with the inherent right of self-defense, deter others from interference and attack, defend our space systems and contribute to the defense of allied space systems…

In order to help the U.S. meet that goal, NASA and other federal agencies are directed by the Policy to:

- Improve their partnerships through cooperation, collaboration, information sharing, and/or alignment of common pursuits. Departments and agencies shall make their capabilities and expertise available to each other to strengthen our ability to achieve national goals, identify desired outcomes, leverage U.S. capabilities, and develop implementation and response strategies.

From its beginning as a former U.S. Navy base, WFF has a long history of sharing government owned infrastructure with other federal agencies, mostly from the DoD. WFF has partnered with the U.S. Navy, Air Force, Army, Coast Guard, Defense Advanced Research Projects Agency, Missile Defense Agency, and others to facilitate a wide array of research and development (R&D) and training missions including target, missile, test article, and spacecraft launches; aircraft development and pilot training; and launch systems testing (e.g., communications, telemetry, guidance, etc.). R&D of these systems mutually benefits NASA by improving its existing launch systems support capabilities and by offsetting NASA's costs through interagency lines of business.

**Continued Role in Academia, Civil Space Science, Exploration and Discovery**

The 2010 U.S. National Space Policy also directs NASA to fulfill various key civil space roles regarding space science, exploration, and discovery. A number of these critical roles have been a regular business line for WFF for decades, and can be thought of as its baseline operations. However, with the addition of larger orbital missions, particularly through commercial ventures, relocation or reconfiguration of these core operations may be needed to facilitate this growth. Below are excerpts of the 2010 U.S. National Space Policy and how WFF fulfills that role for the agency.

- Implement a new space technology development and test program, working with industry, academia, and international partners to build, fly, and test several key technologies that can increase the capabilities, decrease the costs, and expand the opportunities for future space activities…

WFF's scientific balloon and sounding rockets programs regularly partner with industry, academia, and international entities in conducting low cost, high return on investment aerospace research. Balloons and sounding rockets serve as a cost-effective test bed for emerging technologies prior to their implementation on larger orbital or extraplanetary missions.

- Conduct R&D in support of next generation launch systems…

WFF's flexibility to support low cost, fast turnaround missions make it an ideal range for testing components of new launch systems. An example of such a mission is the Max Launch Abort System test, during which a new methodology for safely separating a crew capsule from its rocket during flight was conducted. It is expected that more of such missions may be requested of WFF in the future.

- Continue a strong program of space science for observations, research, and analysis of our Sun, solar system, and universe to enhance knowledge of the cosmos, further our understanding of fundamental natural and physical sciences, understand the conditions that may support the development of life, and search for planetary bodies and Earth like planets in orbit around other stars; and
- …enhance U.S. global climate change research and sustained monitoring capabilities, advance research into and scientific knowledge of the Earth by accelerating the development of new Earth observing satellites, and develop and test capabilities for use by other civil departments and agencies for operational purposes.

WFF's sounding rockets and scientific balloon programs provide the platform for a variety of Earth and space science applications. Especially in the case of sounding rockets, the launch window is driven by the particular phenomena or parameter to be measured. Having the ability to safely and effectively fly payloads when the science presents itself will continue to be of utmost importance in fulfilling this objective.

**Safely Increasing Operation Frequency on Wallops Island**

The ability to safely conduct multiple operations more frequently on Wallops Island is the most critical component underlying the proposed expansion. Because Wallops Island is an operational facility, typically a number of hazardous operations occur there. The increased activity is challenged by limits due to range safety imposed hazard arcs; primarily during launch preparation activities. It is expected that as the tempo of larger LV missions on Wallops Island increases, other missions that have historically been conducted on South Wallops Island (i.e., sounding rockets and UAS) could not be performed concurrently. The Proposed Action would separate the various launch platforms/facilities allowing concurrent hazardous operations to occur. Implementing the Proposed Action would enable different range operations to proceed when a safety arc is activated, thereby avoiding disruption of various missions and/or lost opportunities.

**Aging Infrastructure**

The commitment to supporting a growing mission base at WFF presents unique operational challenges which are driven primarily by range safety criteria. The most notable institutional challenge, however, is the facility's aging infrastructure. Over 65% of the operational buildings on WFF are over 40 years old; these buildings had an intended life of 15 to 20 years (**Figure 1.4-1**). Over their lifespan, these facilities have been modified extensively to meet program requirements; however, many were designed for specialized purposes when WFF was a Naval Auxiliary Air Station or when NASA first increased its presence on Wallops Island in the 1950s and 1960s. Accordingly, such facilities are both costly to operate and may not meet all requirements of today's users without substantial modification. Depending upon operational requirements, modification is often not practical or even feasible.

NASA's strategic facilities objectives are to renew, sustain, and consolidate infrastructure. A component of this future vision is "Repair-by-Replacement" (RBR), which is the replacement of a building or buildings badly needing repair/renovation by demolishing the existing facility or facilities and building a new facility. This is done when the cost of repairs/renovation would exceed the cost of new construction, thus making new construction more economically feasible and functionally operational. Many of the aging facilities with functions still planned for use meet the criteria for RBR. The modernization of the installation's buildings, expansion of existing programs, and the introduction of new opportunities would enable WFF and other federal and commercial organizations to maximize, to the fullest extent possible, the available WFF R&D resources.

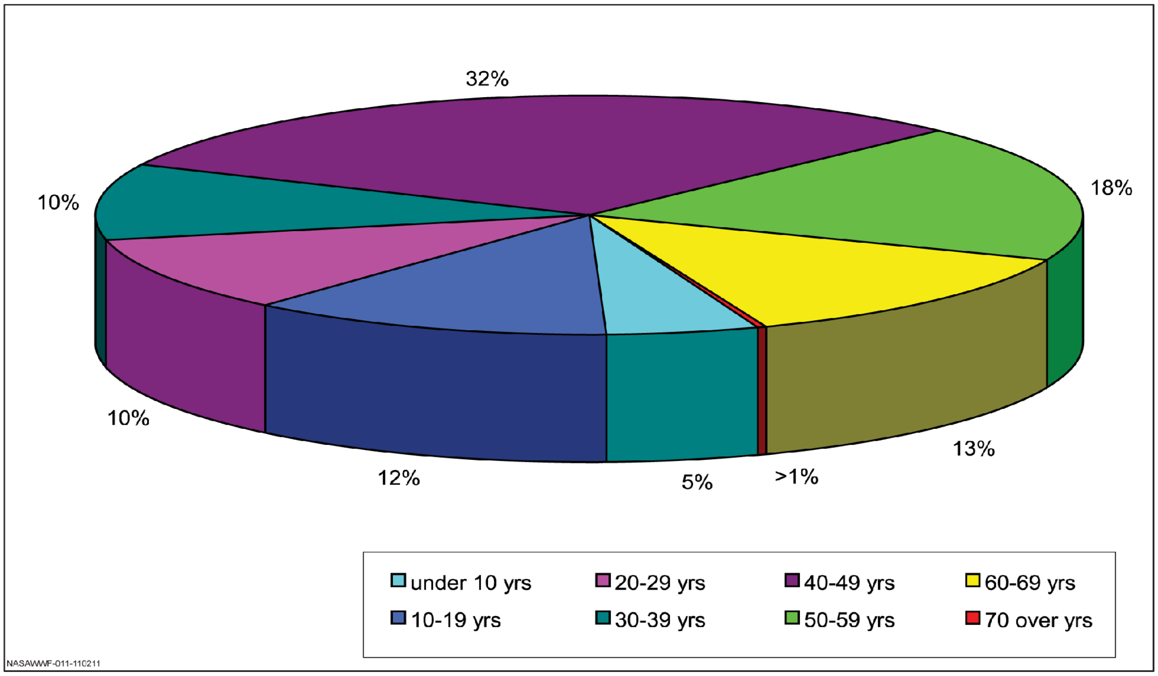



**Figure 1.4-1. Facility Age at Wallops Flight Facility**

## 1.5 Scope of this Site-wide PEIS

Both CEQ and NASA NEPA regulations allow the preparation of NEPA documents for broad actions, such as agency programs and sets of related or similar actions. Broad actions can often be grouped by geographic location, relevant similarities, and state of technical development.

These NEPA documents are referred to as "Programmatic," and are often broad in scope, and may be followed by more site- or action-specific documents as appropriate. This approach, referred to as tiering, can be compared to a funnel, with the broader, Programmatic NEPA document at the top and the more focused documents below it. When a broad Environmental Impact Statement (EIS) has been prepared by an agency and a subsequent document is then prepared on an action included within the entire program, the subsequent document only needs to summarize the issues discussed in the broader document, incorporate discussions from the broader document by reference, and concentrate on the issues specific to the subsequent action. As such, tiering will allow NASA or its Cooperating Agencies to eliminate repetitive discussions of the same issues and focus on the issues which are ripe for decision.

This Site-wide PEIS addresses the most reasonably foreseeable actions at WFF within a 20-year planning horizon, both proposed by NASA as well as its onsite tenant/partner agencies (e.g., U.S. Navy and NOAA-NESDIS). The actions listed in this PEIS are for long-term planning purposes only. Listing of the actions in the PEIS does not commit NASA or any Cooperating Agency to funding these actions in the future. The actions considered within this document are at various stages of conceptual maturity, and therefore the level of discussion may vary from project to project. In some cases, the level of discussion may be such that the environmental consequences can be adequately considered and an informed decision made, therefore eliminating the need for additional NEPA documentation. For others, only high-level, cursory treatment can be given thereby warranting more focused analysis in the future once plans become more certain. Accordingly, future tiered NEPA documents may be prepared for specific actions related to this Site-wide PEIS. Additionally, if WFF experiences unpredicted future changes in mission or direction, NASA or any Cooperating Agency may propose additional projects that are not analyzed in this PEIS. As such, NASA or a Cooperating Agency would supplement this Site-wide PEIS in the future to consider the effects of these actions prior to their implementation.

When NASA or any Cooperating Agency has determined that NEPA analysis is required for a specific action at WFF, the action will be evaluated for coverage under this Site-wide PEIS. The WFF Site-wide PEIS NEPA Checklist will be completed for proposed actions at WFF to determine if the actions are adequately addressed under this Site-wide PEIS (**Appendix A**). If the action is accurately and adequately discussed under this Site-wide PEIS (as determined by the checklist) and all applicable sections have been completed, no further NEPA documentation will be required. If a specific action is outside of the scope of the Site-wide PEIS or is expected to create impacts greater in magnitude, extent, or duration than those described in this Site-wide PEIS, then tiered NEPA documentation such as a separate Environmental Assessment (EA) or EIS would be prepared for that action.

## 1.6 Related Environmental Documentation

Existing NEPA and environmental resource documents were used as the basis for presenting the current operations and existing conditions as described in this Site-wide PEIS. The 2008 WFF Facility Master Plan was used to identify future facility growth and operational missions and activities. The following NEPA documents were prepared for actions at NASA WFF. These documents were reviewed in preparing this Site-wide PEIS:

- 2000 Supplemental EIS for Sounding Rocket Program/Record of Decision (ROD) (NASA 2000)
- 2003 EA for AQM-37 Operations at the NASA GSFC WFF /Finding of No Significant Impact (FONSI) (NASA 2003)
- 2004 EA for DD(X) Radar Test Facility at Surface Combat Systems Center /FONSI (U.S. Navy 2004)
- 2005 Site-Wide EA/FONSI (NASA 2005)
- 2008 GSFC Center Master Plan, Volume 2 for NASA's WFF (NASA 2008a)
- 2008 EA for the Wallops Research Park/FONSI (NASA 2008b)
- 2009 EA for the Expansion of the WFF Launch Range/FONSI (NASA 2009)
- 2010 Programmatic EA for the NASA Balloon Program/FONSI (NASA 2010a)
- 2010 PEIS for the Shoreline Restoration and Infrastructure Protection Program (SRIPP)/ROD (NASA 2010b)
- 2011 EA for the WFF Alternative Energy Project/FONSI (NASA 2011a)
- 2011 EA for Reconfiguration of the WFF Main Entrance/FONSI (NASA 2011b)

- 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles/FONSI (NASA 2011c)
- 2012 EA for North Wallops Island UAS Airstrip/FONSI (NASA 2012)
- 2013 EA for Wallops Island Post-Hurricane Sandy Shoreline Repair/FONSI (NASA 2013)
- 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF/FONSI (NASA 2015)
- 2016 Environmental Resources Document (NASA 2016a)
- 2016 EA for Establishment of Restricted Area Airspace R-6604C/D/E at WFF/FONSI (NASA 2016b)

The following reports and NEPA documents were also reviewed in preparation of this Site-wide PEIS:

- 2005 Suborbital Reusable Launch Vehicles and Emerging Markets (FAA 2005a)
- 2005 Final PEIS for Horizontal Launch and Reentry of Reentry Vehicles (FAA 2005b)
- 2006 Final EA for the Orbital/Sub-Orbital Program (U.S. Air Force 2006)
- 2009 VACAPES Range Complex EIS/Overseas EIS (OEIS)/ROD (U.S. Navy 2009)
- 2010 The Economic Impact of Commercial Space Transportation on the U.S. Economy in 2009 (FAA 2010)
- 2011 EA for Electrical and Operational Upgrade, Space Addition, and Geostationary Operational Environmental Satellite Installation Projects at the Wallops CDAS/FONSI (NOAA 2011)
- 2013 EA for E-2/C-2 Field Carrier Landing Practice Operations at NASA WFF/FONSI (U.S. Navy 2013)
- 2014 EA for Testing Hypervelocity Projectiles and an Electromagnetic Railgun at NASA WFF/FONSI (U.S. Navy 2014)
- 2016 EA for MQ-4C Triton Unmanned Aircraft System East Coast Home Basing /FONSI (U.S. Navy 2016)
- 2017 Annual Compendium of Commercial Space Transportation (FAA 2017)
- 2017 EA for the Proposed Construction and Operation of Instrumentation Tower at Wallops Island (U.S. Air Force 2017)
- 2017 Environmental Assessment for Installation and Operation of Air and Missile Defense Radar AN / SPY-6/FONSI (U.S. Navy 2017)
- 2018 Atlantic Fleet Training and Testing (AFTT) Final EIS/OEIS/ROD (U.S. Navy 2018)

## 1.7 LEAD AND COOPERATING AGENCIES

NASA, as the lead agency for preparation of the Site-wide PEIS, has requested the cooperation of multiple tenant and partner agencies in preparation of the Site-wide PEIS. **Appendix B** provides the Cooperating Agency correspondence. A Cooperating Agency, as defined in 40 CFR §1508.5, is "any

Federal agency other than a lead agency which has jurisdiction by law or special expertise with respect to any environmental impact involved in a proposal (or a reasonable alternative) for legislation or other major Federal action significantly affecting the quality of the human environment. A state or local agency of similar qualifications… may by agreement with the lead agency become a Cooperating Agency." The following tenants and partners are cooperating agencies in preparation of this PEIS:

- **FAA** has served as a Cooperating Agency in the preparation of this Site-wide PEIS because of its role in issuing licenses for operation of commercial space launch sites and commercial launch vehicles.
- **Federal Highway Administration (FHWA)**, a division of the Department of Transportation (DOT) has served as a Cooperating Agency in the preparation of this Site-wide PEIS because of its role in undertaking design and oversight of the construction of the new Causeway Bridge and approach road.
- **NOAA-NESDIS** has served as a Cooperating Agency in the preparation of this Site-wide PEIS because the Wallops CDAS is a permanent tenant on the Wallops Main Base and may undertake additional operations or improvements to its existing infrastructure.
- **U.S. Army Corps of Engineers (USACE)** has served as a Cooperating Agency due to the components of the Proposed Action that have the potential for dredging or placement of fill in waters of the U.S.; those actions would require a permit under Section 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act. USACE is also involved in the design and oversight of WFF's SRIPP.
- **U.S. Coast Guard** has served as a Cooperating Agency because it is a permanent tenant on the Wallops Main Base and may undertake additional operations or improvements to its existing infrastructure, would issue a bridge permit for the Causeway Bridge reconstruction, and assumes Captain of the Port Authority for clearing the launch range during operations.
- **U.S. Environmental Protection Agency (EPA)** has served as a Cooperating Agency due to its role in overseeing permits related to components of the Proposed Action that have the potential for dredging or placement of fill in waters of the U.S. Additionally, under Section 309 of the Clean Air Act, EPA has an obligation to review and comment on all Federal EISs. As such, EPA possesses special expertise as it relates to NEPA.
- **U.S. Fish and Wildlife Service (USFWS)** has served as a Cooperating Agency on this Site-wide PEIS because of its role in issuing incidental take statements, providing management of special-status species, and partnering with NASA on mutually beneficial projects related to Chincoteague National Wildlife Refuge (CNWR). CNWR works with partners to explore how best to advance the study, information exchange, and project resources for adaptive management practices that sustain the resiliency of this unique barrier island system including but not limited to Assateague, Wallops, Assawoman, and Metompkin Islands in the face of dynamic coastal processes and climate change.
- **U.S. Navy, Naval Air Systems Command (NAVAIR)** has served as a Cooperating Agency on preparation of this Site-wide PEIS due to the potential increase in existing personnel training, aircraft operations, and RDT&E mission tempos and new missions and weapons systems.

- **U.S. Navy, Naval Sea Systems Command (NAVSEA)** has served as a Cooperating Agency on preparation of this Site-wide PEIS because SCSC is a permanent tenant with numerous missions at WFF including the Directed Energy system currently under development. The role of NAVSEA is in undertaking a broad range of activities in support of Aegis and the Ships Self-Defense System combat system activities and other technical missions, improvements to infrastructure in support of mission activities, and providing support to RDT&E and Fleet training exercises in the VACAPES OPAREA. WFF often supplies range services and target launches in support of Fleet training exercises and RDT&E events in the VACAPES OPAREA. These Navy actions have been further assessed in the AFTT EIS/OEIS (U.S. Navy 2018).
- **U.S. Navy, U.S. Fleet Forces Command** has served as a Cooperating Agency on preparation of this Site-wide PEIS because of its presence at WFF in conducting pilot proficiency training missions at the Main Base airfield and Navy personnel training shipboard in the VACAPES OPAREA. WFF often supplies range services and target launches during these training exercises. These Navy actions have been further assessed in the EA for E-2/C-2 Field Carrier Landing Practice Operations at NASA WFF and AFTT EIS/OEIS (U.S. Navy 2013 and 2018, respectively).
- **U.S. Air Force, Space Command/Space and Missile Systems Center** has served as a Cooperating Agency on preparation of this Site-wide PEIS because of its role and interest in using the Wallops launch range for further missions.
- **Virginia Commercial Space Flight Authority (Virginia Space)** has served as a state Cooperating Agency on preparation of this Site-wide PEIS because of its partnership with NASA WFF and its role in the development, operation, and expansion of MARS.

## 1.8 Public Involvement

The steps taken to involve the public in the preparation of this Site-wide PEIS are outlined below.

- **Notice of Intent (NOI)** – A notice that announced NASA's intent to prepare a Site-wide PEIS was published in the *Federal Register* on July 11, 2011. The NOI formally initiated the public scoping process.
- **Scoping** – This is an early and open process for determining the scope of issues and identifying the significant issues related to the Proposed Action. Federal, state, and local agencies and members of the public were encouraged to provide input. Informational meetings were held to provide an opportunity for members of the public to become informed of and to comment on the issues that need to be addressed in the PEIS. The official scoping period began with the publication of the NOI and ended September 2, 2011; however, comments received after the end of the scoping period were considered in preparation of the Draft PEIS. NASA received 20 comment letters. Two were received from the general public; all other comment letters were from federal, state, and local agencies. Two scoping meetings were conducted on August 3, 2011; one for the regulatory agencies (17 in attendance) and one for the general public (19 in attendance). An advertisement was published a week before the meetings in the Eastern Shore News and The Daily Times on July 27, 2011, and in the Chincoteague Beacon on July 28, 2011. Electronic versions of all information from the public

meetings were uploaded to the public website https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis. A summary of the issues raised and comment letters received during the scoping period is provided in **Appendix C**.

- **Draft PEIS** – This draft document analyzes the environmental consequences of the Proposed Action and the No Action Alternative. It includes the purpose and need for the Proposed Action, the description of each of the new institutional and operational missions and activities being proposed, the existing environmental conditions where the institutional and operational missions and activities under the Proposed Action would take place, and the environmental consequences of implementing the new institutional and operational missions and activities. The Draft PEIS is supported by various detailed technical studies.
- **Draft PEIS Notice of Availability (NOA) and Notice of Public Meeting** – A formal notice was placed in the *Federal Register* on May 4, 2018, announcing the availability of the Draft PEIS for review by the public and federal, state, and local agencies. NOA advertisements were placed in the *Eastern Shore News, Chincoteague Beacon*, *Eastern Shore Post*, and *The Daily Times*. The advertisements announced the availability of the Draft PEIS as well as the date, time, and location of the public meeting. An electronic version of the Draft PEIS along with the advertisement of the public meeting was made available to the public on the project website and a limited number of print copies were made available for review at local public libraries and upon request.
- **Public Comment Period** – Federal, state, and local agencies and members of the public were invited to provide comments on the Draft PEIS over a 45-day period. Electronic versions of all public meeting materials were made available to the public on the project website. Written comments were accepted throughout the public comment period. A stenographer was available to record oral comments at the public meeting; no oral comments were provided.
- **Final PEIS** – The Final PEIS documents the comments received on the Draft PEIS and includes a response to all relevant comments (**Appendix I**). Responses resulted in supplementing and improving the analyses in the PEIS; and factual corrections.
- **Final PEIS NOA** – A formal notice will be placed in the *Federal Register* and advertisements will run in the *Eastern Shore News, Chincoteague Beacon, Eastern Shore Post,* and *The Daily Times* newspapers to announce that the Final PEIS is available for public review. An electronic version of the Final PEIS will be available to the public on the project website and a limited number of print copies will be available for review at local public libraries and upon request. This is then followed by a 30-day waiting period.
- **ROD** – The ROD states what the decision is; identifies the alternatives considered, including the environmentally preferred alternative; and discusses mitigation measures and monitoring commitments. An electronic version of the ROD will be available to the public on the project website and a limited number of print copies will be available upon request.

### 1.8.1 SCOPING COMMENT PERIOD SUMMARY

**Table 1.8-1** provides a brief summary of comments made by Federal, state, and local agencies and the general public during the scoping period. The complete Scoping Summary Report can be found in **Appendix C**.

| Table 1.8-1. Summary of Scoping Comments | | |
|---|---|---|
| **Comment** | **Addressed in PEIS?** | **If yes, location in PEIS; if no, rationale** |
| NASA must provide a Federal Consistency Determination which includes an analysis of the proposed activities in light of the foreseeable policies of the Virginia Coastal Zone Management (CZM) Program and a commitment to comply with the enforceable policies. | Yes | A Federal Consistency Determination (FCD) will be submitted to Virginia Department of Environmental Quality (VDEQ); this document is included in the PEIS as **Appendix G**. |
| EPA offers its expertise on NEPA and the CWA Section 404, and encourages NASA to work with cooperating agencies on the project. | Yes | 1.7<br>**Appendix B** |
| Virginia Department of Game and Inland Fish (VDGIF) provided a table of listed species for consideration in the PEIS and recommends further coordination as the project scope evolves and more site-specific information becomes available. | Yes | 3.10.1.3 |
| **Alternatives** | | |
| NASA should consider, as an element of both alternatives, development of an Atlantic UAS Test Range at WFF. * | No | The Atlantic UAS Test Range at WFF was considered under separate analysis. Refer to http://sites.wff.nasa.gov/code250/UAS_FEA.html for North Wallops Island UAS Airstrip EA and FONSI. |
| The potential development of launch infrastructure for orbital human spaceflight at WFF is duplicative and competes with infrastructure already in place in the State of Florida. Development of a duplicate site also goes against the NASA Authorization Act of 2011. | No | This PEIS only considers the potential of commercially sponsored human spaceflight. |
| Include an alternative that evaluates the costs and benefits of locating new infrastructure off of Wallops Island and strategically relocating existing infrastructure to more secure and protected locations within Accomack County. This alternative should also evaluate the costs and benefits associated with locating certain critical launch infrastructure in the coastal bay and NASA-owned salt marsh west of Wallops Island. | No | Based upon operational safety and feasibility (refer to Section 2.7.1 [Reloacting Infrastructure to Wallops Mainland]), as well as the limited planning horizon for this PEIS, this alternative is outside the scope of this analysis. |

| Table 1.8-1. Summary of Scoping Comments (cont.) | | |
|---|---|---|
| **Comment** | **Addressed in PEIS?** | **If yes, location in PEIS; if no, rationale** |
| Under Alternative 2, the Assawoman Island land swap could potentially align with one of the alternatives being presented in the Comprehensive Conservation Plan for the Chincoteague and Wallops Island National Wildlife refuges but is opposed to development of the north end of Assawoman Island. * | No | The Assawoman Island land swap was not carried forward due to numerous environmental, financial, and logistical concerns. |
| Develop and implement mobile launch technology for rocket launches or develop a small launch pad on the Wallops Mainland for launching sounding rockets. | Yes | 2.5.1.2<br>2.5.2.2 |
| WFF should develop an additional alternative focused on accomplishing its mission while contributing to the conservation value of the area. This could include relocating infrastructure inland whenever possible to reduce sea level rise risks to mission critical infrastructure; acquiring lands to better buffer WFF from sensitive natural resource areas as well as reducing potential safety and security concerns; developing cooperative resource management approaches that would facilitate conservation, public use of the resources in the area, and the NASA mission; and planned responsible development in the area that would help support and protect the NASA mission and local economy. | Yes | 2.7<br>3.6<br>5.0 |
| Commonwealth of Virginia owned land west of Wallops Island that will need clearly defined boundaries before any land swap can take place under Alternative 2. * | No | The Assawoman Island land swap was not carried forward due to numerous environmental, financial, and logistical concerns. |
| Why doesn't NASA use facilities at Andrews Air Force Base (AFB) or at the White Sands Range in New Mexico that are immune to natural disasters? | Yes | 1.4 |
| ***Noise*** | | |
| Noise analysis should be included under the Health and Safety analysis in the EIS. | Yes | 3.1<br>3.4 |
| ***Climate Change/Sea-Level Rise*** | | |
| The effects of sea level rise on areas surrounding NASA WFF needs to be considered. | Yes | 2.2<br>3.5.1.9 |
| NASA needs to consider the dynamics of barrier islands and the impacts these dynamics may have on Wallops Island and surrounding barrier islands. | Yes | 3.5.1.8<br>3.5.2.2.1 |
| The past 50 years have shown an 8 inch increase in sea level in the Mid-Atlantic region. Based on this information, a 1 meter sea level rise for the project area is not out of the question in the near future. | Yes | 3.5.1.9<br>3.5.2.2.1 |

| Table 1.8-1. Summary of Scoping Comments (cont.) | | |
|---|---|---|
| **Comment** | **Addressed in PEIS?** | **If yes, location in PEIS; if no, rationale** |
| Why would NASA want to spend hundreds of millions to billions of dollars on facilities that are most certainly in mortal peril insofar as climate driven sea level rise is concerned? | Yes | 1.3<br>1.4<br>2.2<br>2.7<br>3.5.1.9<br>3.5.2.2.1 |
| ***Water Resources*** | | |
| How does WFF plan on addressing stormwater runoff issues as facilities are consolidated at WFF and hard surfaces are moved or altered? | Yes | 3.5.1.2<br>3.5.2.2.1 |
| ***Biological Resources*** | | |
| Need to consider impacts to wildlife due to potential operations on Assawoman Island. | No | The Assawoman Island land swap was not carried forward due to numerous environmental, financial, and logistical concerns. |
| NASA should consider the possibility of restricting sounding rocket launches to times when piping plovers and other protected species are not in the area. | Yes | 3.10.1.3<br>3.10.2.2.2 |
| USFWS is concerned about the impacts to wildlife (beach nesting shorebirds in particular) | Yes | 3.9<br>3.10<br>5.4.5 |
| The PEIS should consider direct and indirect impacts to sea turtles from any future in-water work. | Yes | 3.10.2.2<br>3.11.1.2.2 |
| There are several natural heritage resources located within the project area. NASA should undertake ecological surveys of Assawoman Island, the Main Base, and Wallops Mainland so that planning could consider, to the maximum extent practicable, the protection of natural heritage communities. | Yes and No | 3.8.1.3<br>3.10.1.3.6<br>The Assawoman Island land swap was not carried forward. |
| ***Airspace Management*** | | |
| Encroachment issues that the Accomack County Board of Supervisors is facing and how they might impact operations and airspace at WFF should be included. | Yes | 3.12.2.2 |
| ***Utilities and Infrastructure*** | | |
| Does WFF see an increase in the demand for wastewater treatment in the 20-year plan? | Yes | 3.14.2 |
| The proposed Atlantic Town Center Wastewater Facility to address wastewater treatment issues in the Towns of Atlantic and Chincoteague, as well as other surrounding areas, may fall within the approach to Runway 220 and NASA needs to make sure that appropriate county officials know that this is not acceptable. | No | This is outside of the scope of this PEIS. |
| ***Socioeconomics*** | | |
| Commercial manned spaceflight will spur economic development in Accomack County without adversely affecting the environment. | Yes | 3.15.2.2 |

| Table 1.8-1. Summary of Scoping Comments (cont.) | | |
|---|---|---|
| **Comment** | **Addressed in PEIS?** | **If yes, location in PEIS; if no, rationale** |
| Some of the potential alternatives represent a direct threat to the economic well-being of the people of the Space Coast, and to the fiscal health of the U.S. population. | No | This PEIS only considers the potential of commercially sponsored human spaceflight. |
| NASA should analyze socioeconomic impacts, as opposed to socioeconomic benefits, to Accomack County resulting from the Proposed Action and action alternatives. * | Yes | 3.15.2.2 |
| ***Mitigation and Monitoring*** | | |
| NASA should consider the resource management activities (e.g., species monitoring, habitat management) as part of the list of "Institutional Project Support." | Yes | 3.10.1.3<br>3.10.2.1.1<br>3.10.2.1.2<br>4.1.8<br>4.4<br>5.4.6 |
| The PEIS should highlight any mitigation measures to reduce the affects to listed species. | Yes | 3.10<br>4.1 |
| NASA should begin an intensive effort to limit the spread of *Phragmites* by requiring advanced treatment and follow-up treatment prior to construction activities. | Yes | 3.8.1.3<br>3.9.2.2.1<br>3.10.2.2.1<br>3.11.2.2.1<br>4.1.7<br>5.3.2.2<br>5.4.3.2<br>5.4.5.2<br>5.4.5.3<br>5.4.7.3 |

Note: * Since the 2011 scoping meeting, Alternative 2 has been removed as an alternative to the Proposed Action. The PEIS evaluates the Proposed Action and No Action Alternative.

### 1.8.2 Public Comment Period Summary

NASA WFF sought public comments on the analysis and findings presented in the Draft Site-wide PEIS during the 45-day public comment period which ran from May 4 through June 18, 2018. An NOA was placed in the *Federal Register* on May 4, 2018, and public notices were published in the *Eastern Shore News, Chincoteague Beacon, Eastern Shore Post,* and *The Daily Times*.

A public meeting was held at the NASA Wallops Flight Facility Visitor Center on May 23, 2018, from 6:00 to 8:00 p.m. One member of the public attended the meeting. There were no comments received during the public meeting. A total of nine comment letters were received. One letter was from a private citizen, one letter was from Somerset County, and the remaining seven were from the following state and federal agencies: USACE, EPA, VMRC, U.S. Navy SCSC, NOAA-NESDIS, NOAA NMFS, and VDEQ.

**Appendix I** provides the public notices, meeting materials, and comment letters received during the public review period. The comments that identified major issues or concerns have been notated and are summarized with NASA responses in **Appendix I**.

In accordance with 15 CFR 930.2, VDEQ invited the public to participate in the review of the FCD submitted for NASA's proposed action. A public notice was published in the VDEQ's Office of

Environmental Impact Review Program Newsletter and on the VDEQ website from May 11 through June 21, 2018. No public comments were received in response to the notice. In accordance with 40 CFR 1506.9, EPA published an NOA of the NASA WFF Site-wide PEIS in the *Federal Register* on May 4, 2018. No public comments were received in response to the notice.

# 2.0 DESCRIPTION OF PROPOSED ACTION AND NO ACTION ALTERNATIVE

## 2.1 INTRODUCTION

The Proposed Action is to increase WFF's mission base in the areas of commercial, defense, and academic aerospace. To support this growth, NASA and its partners are proposing to provide facilities and infrastructure, as detailed in the Agency-approved 2008 WFF Facility Master Plan. Implementing the Proposed Action would support the Facility's plans by sustaining existing missions as well as modernizing functionality to meet future operational mission requirements in direct support of WFF's strategic management goals. As such, this PEIS analyzes institutional and operational missions that could occur within NASA WFF's property, managed airspace, and water resources. Although, as discussed in Section 3.0, Affected Environment and Environmental Consequences, impacts of these actions may occur off-site, no off-site actions are proposed or analyzed in this PEIS.

## 2.2 IDENTIFICATION OF ALTERNATIVES

Much like the approach NASA employed during development of the 2008 WFF Facility Master Plan, the alternatives selection for the Site-wide PEIS followed a phased process of exploration, validation, hypothesis and testing, consideration of climate change, and primary development concept, as described below. The phased approach allows the Site-wide PEIS to be based on WFF's current abilities to support its mission, and to further develop realistic alternatives that enable WFF to support future requirements.

***Exploration* –** During the exploration phase, the integrated project team (IPT) (or "the Steering Committee") was established. The IPT was composed of individuals who lead the major programs supported by WFF and its tenant partners, as well as representatives from the Facilities Management Division and the Environmental Office. The initial task of the IPT was to help the planning team develop a broad concept of the Facility's future and the steps necessary to achieve it, including overseeing development of the actions incorporated into the Proposed Action. The IPT still plays an active role throughout the process of reviewing and revising the Site-wide PEIS.

***Validation* –** The validation phase was the "information gathering" stage of the planning process. The project team conducted interviews in January 2011 and developed questionnaires to collect data from the IPT to determine existing conditions at WFF and potential changes to the missions over the next 20-year planning horizon. The gathered information was reviewed in terms of WFF's mission, assets, and community context in May and August 2015, August 2016, and again in January 2017.

***Hypothesis and Testing* –** During the hypothesis and testing phase, a list of actions was developed from the interview and questionnaire responses. This list encompassed a planning approach for the future use of the Facility's real property, infrastructure, and assets as well as areas of future mission growth. The IPT then reviewed the list to determine if the actions presented were reasonable and if they met WFF's mission, vision, and goals.

***Consideration of Climate Change* –** Because of its location on the Atlantic coast, climate change may be the greatest threat to WFF's long-term sustainability as a national launch asset. The area has always been subject to hurricanes and nor'easters, and the associated high winds and flooding. Wallops Island has experienced shoreline changes throughout the six decades that NASA has occupied the site, losing an average of approximately 3 m (10 ft) of shoreline per year (NASA 2010). Currently, the highest elevation on Wallops Island is approximately 4.6 m (15 ft) above MSL. Most of the island is less than 3.0 m (10 ft) above MSL (NASA 2010).

Accordingly, it is expected, that without an adaptation strategy, the combination of rising sea level and severe storms may produce detrimental impacts on WFF and its high profile infrastructure, assets, human capital, and natural resources.

To this end, when identifying actions to be considered in this PEIS, WFF considered the potential effects of climate change. While most climate change forecasts, including those prepared specifically for WFF (Goddard Institute for Space Studies [GISS] 2013), do not predict substantial changes in sea level and storm intensity within the 20-year planning horizon that is the subject of this PEIS (rather more on the centennial scale), NASA established a primary tenet for planning future projects at WFF – only infrastructure with a demonstrated need to be built on Wallops Island would be allowed (NASA 2008). For example, allowable Wallops Island infrastructure investments could include support systems essential for WFF's often hazardous launch site operations or those facilities that must be installed in a maritime environment, as in the case of many U.S. Navy operations. Additionally, for any new construction on Wallops Island, climate change-related design considerations would apply, which include a requirement to elevate critical facility support systems (e.g., HVAC, electrical, etc.) such that they would not be subject to flooding, and in many cases, finished floor elevations of occupied facilities would be built at an elevation that is at least one foot above the 100-year flood zone elevation.

Despite the relatively short (in terms of climate change) 20-year planning horizon for the actions considered in this PEIS, WFF recognizes that much more research is needed to support a well-informed adaptation strategy for the longer-term. As such, WFF has become a member of the Eastern Shore of Virginia Climate Adaptation Working Group and in November 2012, held a climate change workshop engaging scientists, local leaders, agencies, and organizations to discuss climate change-related issues with a particular focus on the WFF area. Additionally, on a larger geographic scale, in partnership with agencies and institutions in the Mid-Atlantic region (e.g., USFWS, National Park Service [NPS], CBFS, The Nature Conservancy [TNC]), WFF formed the Mid-Atlantic Coastal Resilience Institute. The Institute plans to collaborate to develop and implement adaptation strategies for a climate resilient Eastern Shore through resource and data sharing. Outputs of the Institute's research are expected to support applied science and policy related to coastal resilience in the context of sea-level rise, extreme weather events, and coastal ecosystem degradation in the Mid-Atlantic. Accordingly, the results of these research partnerships could be employed to guide decision-making in the implementation of the 2008 WFF Facility Master Plan, the alternatives in this PEIS, and actions yet to be identified but which could be necessary either within or beyond the temporal scope of this PEIS.

***Primary Development Concept* –** After the actions were determined, a consensus was reached on how they would be grouped for alternatives analysis. These action alternatives became the basis for the Site-wide PEIS. This Site-wide PEIS evaluates the potential environmental impacts from the set of reasonable alternatives that were identified by the IPT through the identification process. The Proposed Action meets NASA's need to ensure continued growth at WFF while also preserving the ability to safely conduct its historical baseline of operations.

This chapter describes the alternatives considered in detail in this PEIS: the Proposed Action and a No Action Alternative. In addition to including all actions analyzed in the No Action Alternative, the Proposed Action would comprise a number of institutional support projects ranging from new construction, demolition, and renovation throughout the installation to include the replacement of the Causeway Bridge and maintenance dredging in the existing channel between the two boat basins at the Main Base and Wallops Island as well as channels around the north end of Wallops Island. The Proposed Action would also support several operational and mission activities including expansion of the existing DoD standard missile rocket (SM-3) program and introduction of a new Navy weapons system proposal: Directed Energy, a High Energy Laser (HEL) and High Power Microwave (HPM) system currently under development. The Proposed Action would also assess future opportunities for commercial space involving the potential for intermediate and heavy-class launch vehicles and consideration of commercial human spaceflight missions from WFF. The final component of the Proposed Action is the potential use of new hybrid fuels. Under the No Action Alternative, the level of activity at WFF would remain at present levels and within existing envelopes. Chapter 3 “Affected Environment and Environmental Consequences” of this PEIS assesses only those impacts from the Proposed Action that are in addition to the impacts of the No Action Alternative. Chapter 4 details potential "Mitigation and Monitoring" approaches for impacts that may be caused by implementing elements of the Proposed Action. Chapter 5 “Cumulative Impacts” assesses the impacts of the Proposed Action in combination with impacts of the No Action Alternative and other reasonably foreseeably actions.

## 2.3 NEPA Trigger and Envelope Concept

The envelope concept is applied at WFF since missions at the facility are constantly evolving and, while the basic outline of a project may be known during the NEPA analysis, its details often have not been finalized. The envelope concept facilitates the environmental analysis documentation process by providing a threshold below which, if not exceeded, further in-depth NEPA analysis is not needed.

In its 2005 Site-Wide EA, NASA assessed the impacts of current and future operations at WFF. The proposed action for the Site-Wide EA included two categories - institutional support and operational components. Institutional support incorporated ground disturbance, routine site activities and maintenance, demolition, and construction. A number of institutional support projects have been analyzed since the 2005 Site-Wide EA; those NEPA documents are listed in Section 1.6. If, during future project planning, the project is reviewed and the NEPA review trigger is not met, the action would rely on its existing NEPA document. If, however, the review identifies project components beyond the scope of the existing environmental analysis, supplemental project-specific NEPA documentation would be triggered. Operational missions and activities components in the 2005 Site-Wide EA included scientific and research programs, mission operations, airfield and airfield operations, piloted aircraft, UAS, rocket operations, projectile testing, payloads, tracking and data systems, balloons, and autonomous underwater vehicles (AUV). A range or “envelope” of activities was identified for each type of operation conducted at WFF and presented the scenario with the greatest potential for environmental impacts. In contrast to the qualitative NEPA trigger approach for institutional support projects, the envelope concept was based on quantitative analyses. Subsequent NEPA analysis revised some of the 2005 envelopes. For example, the Taurus II, a medium-class LV, (now known as Antares in its operational phase) was identified as the largest rocket anticipated to be launched from MARS Pad 0-A and has been used as the model for assessing impacts from rocket launches (NASA 2009, 2015).

For both institutional support and operational components, use of an environmental checklist (see **Appendix A**) is the procedure by which a proposed project is reviewed to see if that project triggers additional NEPA analysis or falls within the envelope.

NASA has concluded that some actions anticipated in this document have already been adequately analyzed, as described in the referenced documents, if they provide sufficient detail to allow NASA to analyze their environmental impacts and to conduct required consultations consistent with the requirements of NEPA and other relevant environmental statutes. Proposed actions that have not been adequately analyzed will require additional study and documentation to comply with environmental planning standards.

## 2.4 NO ACTION ALTERNATIVE

CEQ regulations require that an agency "include the alternative of no action" as one of the alternatives it considers (40 CFR 1502.14[d]). The No Action Alternative serves as a baseline against which the impacts of the Proposed Action are compared. For this Site-wide PEIS, the No Action Alternative signifies that the level of "institutional support projects" and "operational mission and activities" at WFF would remain at present levels and within previously established envelopes. The following sections summarize the existing actions at WFF and the triggers or envelopes established in the 2005 Site-Wide EA as well as subsequent NEPA documents.

### 2.4.1 INSTITUTIONAL SUPPORT PROJECTS

#### 2.4.1.1 Construction and Demolition

The major goals of the construction program are to restore aging infrastructure, improve efficiency and sustainability, and support the enhancement of WFF's R&D capabilities. Construction consists of new facility construction, renovation, and RBR. Many structures at WFF are obsolete and it is impractical to repair or renovate them. These structures may have to undergo RBR to maintain ongoing facility operations or support new operations. In these cases, WFF repairs the existing structure by remediating all potential hazardous materials within the structure (i.e., lead-based paints [LBP] and asbestos-containing materials [ACM] and replaces the structure by demolishing the old structure and rebuilding (i.e., replacing) in place. The process of RBR meets the goals of NASA's Recapitalization Plan in that before a new structure can be built, another "in-kind" structure must be demolished.

**Table 2.4-1** lists the construction and demolition projects which have been analyzed in previous NEPA documents but that have either not yet been initiated or are in progress.

**Table 2.4-1. Summary of Existing Institutional Support Projects**

| Institutional Support Projects | Actions |
|---|---|
| *Construction* | • ***2005 Site-Wide EA:*** the following construction projects were evaluated; however, they have not yet been implemented: Project Support Building; Administration Building; Addition to the Management Education Center and proposed roads; Commons Facility; Science Building; Central Chiller Plant for E-Area; Advanced Materials and Electronics Laboratory; Range Administration Building; Rocket Motor Inspection Building; Replacement of Buildings N-222 and F-002; and Technical Support Building.<br>• ***2008 Wallops Research Park EA*****:** proposal for the Wallops Research Park (WRP) to develop a multi-use research and industrial park to include educational facilities, aviation use and a recreational component. To date, roads, buildings, utilities, and an administration building have been constructed. When fully implemented, similar infrastructure components will be constructed as part of the WRP development.<br>• ***2009 EA for the Expansion of the WFF Launch Range*****:** infrastructure was needed to support medium large class suborbital and orbital LV launches. The following projects have not been implemented: modifications to North Wallops boat dock, payload processing facility (PPF), new roads and improvements to existing road from the North Wallops Island boat dock. |

| Table 2.4-1. Summary of Existing Institutional Support Projects (cont.) | |
|---|---|
| **Institutional Support Projects** | **Actions** |
| *Construction (cont.)* | • ***2010 PEIS for the SRIPP:*** the following construction projects were evaluated and considered within an adaptive management framework due to the 50 year life cycle of this shoreline protection strategy: extension of the existing sea wall up to1,400 m (4,600 ft) south of its southernmost point. A renourishment frequency of 3 to 7 years would be implemented. The timing of renourishment, and the potential for offshore breakwater, would be based on the frequency and magnitude of storm events and shoreline monitoring results.<br>• ***2011 Alternative Energy EA***: proposal to install a system of solar panels at the Main Base capable of generating 10 gigawatt-hour of energy per year along with two 2.4 kilowatt residential-scale wind turbines. Construction has not begun on this alternative energy project.<br>• ***2011 EA for Reconfiguration of the WFF Main Entrance:*** the following construction projects were evaluated: badge office, truck inspection area, and parking areas (completed), guard house, traffic roundabout, and shipping and receiving facility (pending).<br>• ***2012 North Wallops Island UAS Airstrip EA:*** a new UAS airstrip on the north end of Wallops Island in Accomack County, Virginia has been constructed. The new airstrip measures approximately 900 m (3,000 ft long [2,500 ft plus an additional 500 ft clear zone]) by 25 m (75 ft) wide. The airstrip became operational in 2017.<br>• ***2014 EA for Testing Hypervelocity Projectiles and an Electromagnetic Railgun***: the proposal to install a 5" powder gun and an electromagnetic railgun to test and integrate hypervelocity projectiles fired into the VACAPES OPAREA from Pad 5 has not been initiated.<br>• ***2017 EA for Installation and Operation of Air and Missile Defense Radar AN/SPY-6***: the proposal to install and test a new air and missile defense radar in the Navy Assets area on Wallops Island has not been initiated. |
| *Demolition* | • ***2005 Site-Wide EA:*** The following demolition projects were evaluated in the 2005 Site-Wide EA; however, these projects have not yet been implemented: A-027, Y-038A, Y-050, and Y-060. |

### 2.4.1.2 Routine/Recurring Activities

Routine site activities at WFF include recurring actions that are conducted to support facility operations mission activities. These recurring activities include Fabrication and Processing; Storage and Fueling; Maintenance and Improvements; and Safety and Security. The following provides a brief description of each of these processes.

#### 2.4.1.2.1 Fabrication and Processing

The Payload Fabrication and Integration Laboratory located in Building F-010 on the Main Base includes facilities for mechanical and electrical component construction of sounding rocket payloads. The Payload Laboratory also provides quality assurance and quality control inspections for assembled payloads. The laboratory can support multiple payload processes simultaneously, including telemetry ground stations and clean room facilities. The laboratory includes a fully equipped machine shop capable of fabricating sounding rockets, payloads, and launch vehicle components. Building F-010 houses the fabrication of electrical components such as circuit boards, cables, and custom interfaces used between experimental and standard sounding rocket components.

Testing of balloon materials is conducted in Building F-007. Machine shops in Building F-007 fabricate, test, verify, and integrate mechanical hardware such as circuit boards, cables, and custom interfaces with electrical software for balloon components.

WFF can support multiple sounding rocket payloads and LV spacecraft processes simultaneously including fabrication, environmental testing, and integration within clean room facilities; storage; transportation; and fueling. These actions take place at the Main Base, Mainland, and Wallops Island. Payload processing occurs in Buildings E-109, F-007, F-010, H-100, M-016, M-020, N-159, V-055, W-040, W-065, X-079 and Y-015. Quality assurance and quality control inspections are performed for assembled payloads. Work areas are available to perform preparatory and post integration inspections; Buildings H-100 and V-055 provide different levels of Class 10,000 or 100,000 certified clean rooms for processing spacecraft.

Spacecraft arrive at WFF via truck or military aircraft. Once the payloads are unloaded, they are placed either in the Hazardous Processing Facility on Wallops Island (Y-015) or in the Payload Processing Facility (PPF) (H-100) on the Main Base. If liquid fueling of the payload is required, this operation would be conducted at Building V-055. The payload is then transported to Building W-065 or X-079 for integration with the upper launch vehicle stages or for payload assembly (NASA 2005; 2009).

Building X-079 is a HIF situated in the middle of Wallops Island. The HIF supports pre-flight processing, horizontal integration and preparation of launch vehicles and payloads (NASA 2009). The HIF is designed to accommodate temporary storage of fueled spacecraft and vehicle stages. Activities in the HIF include, but are not limited to, removal of flight hardware from cargo containers, inspection, testing, and encapsulation of launch vehicle motors and stages, and final integration of the payload within the launch vehicle. An emergency water deluge system is located in Building X-079 and Building V-055.

- **NEPA Review Trigger**: Fabrication and processing activities that do not fall within existing processes or within existing facilities to support the activity are reviewed to determine if such activities require further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2008 EA for the Wallops Research Park; 2009 EA for the Expansion of the WFF Launch Range; 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles; 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF.

#### 2.4.1.2.2 Storage and Fueling

Storage facilities are located throughout WFF. Materials stored can include miscellaneous supplies, water, government vehicles, maintenance vehicles, hazardous materials or wastes, rockets, motors, payloads, spacecraft or spacecraft components, and fuels.

Fueling activities at WFF occur throughout the facility. Liquid fuels (e.g., heating, aviation, rocket propellant) are stored in aboveground storage tanks (ASTs), underground storage tanks (USTs), and within mobile units. Secondary containment is required at WFF for ASTs, drum storage areas, and for mobile tanker storage areas for any individual container over 208 liters (55 gallons [gal]). There is a central storage facility for liquefied petroleum gas (LPG) on the Main Base. A portable hydrazine fueling storage system is used for fueling spacecraft prior to launch operations and to support the special fueling needs of the Earth Resources 2 (ER-2) High Altitude Airborne Science aircraft. Hazardous fueling operations for the ER-2 are conducted on the Main Base in Building N-159.

Spacecraft are fueled on Wallops Island in Buildings Y-015 and V-055. When performing hydrazine fueling operations, personnel wear Self Contained Atmospheric Protective Ensemble to prevent accidental inhalation of fumes. WFF stores a maximum of 2,300 kgs (5,000 lbs) of hydrazine in Department of Transportation (DOT) shipping containers within Building Z-025 on Wallops Island and up to 270,000 kgs (600,000 lbs) of oxidizer in DOT shipping containers within Building Z-020. Emergency water deluge fire suppression systems are located in each building where fuels are stored or routinely use.

Petroleum oil and liquid fuel storage and use must remain compliant with the WFF Integrated Contingency Plan (ICP). Propellant fuel (both solid and liquid) storage complies with NASA Safety

Standard NASA-STD-8719.12 "Safety Standard for Explosives, Propellants, and Pyrotechnics;" Air Force Manual 91-201 "Explosive Safety Standards;" DoD Safety Standards DoD 6055.09-STD "Ammunition and Explosives Safety Standards;" and DoD Explosives Safety Standard ADA513291 "Explosives Safety Standards for Energetic Liquids Program." The LPG tank farm is inspected daily by the Facilities Management Branch.

- **NEPA Review Trigger**: Changes in storage and fueling activities that have not been considered in previous NEPA documentation or analyses are reviewed to determine if the activities require further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2008 EA for the Wallops Research Park; 2009 EA for the Expansion of the WFF Launch Range; 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles; 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF.

###### 2.4.1.2.3 Maintenance and Improvements

The diverse functions and the magnitude of WFF activities require continuous routine repairs and ongoing maintenance of buildings, grounds, roads, utilities, equipment and instrumentation, aircraft, vehicles, and laboratory equipment. Both infrastructure and buildings are managed by the Facilities Management Branch. Existing buildings require ongoing maintenance. Buildings may be rehabilitated or upgraded to meet specific project needs. Brush and trees may need to be removed to construct a new building, keep the airfield's clear zone free of intrusions, manage wildlife, maintain boresight tower line of sight, or enhance operation of radar and other radio frequency equipment. Routine repairs are often required after hurricanes or nor'easters. NASA contractors and heavy equipment are used to clear roads, clear stormwater systems, and move beach sand and/or sea wall rock back to its original pre-storm location.

Existing infrastructure such as roads and utilities are maintained on a regular basis to ensure the ongoing operation of the facility. WFF Main Base and Mainland are connected by approximately 9.5 km (6 mi) of State Route 679, a paved, two-lane road maintained by the Commonwealth of Virginia. Virginia has established the Wallops Island Space Transit Overlay Corridor between the Main Base and Wallops Island for the purposes of providing safe transit for over-sized loads. Virginia Department of Transportation (VDOT) limits any development or vegetation along the corridor (Article XXIV Accomack County Code). A NASA-owned road, bridge, and causeway link the Mainland to Wallops Island. NASA maintains all hard surface roads, as well as the sidewalks and parking lots, within the facility. The transportation infrastructure may be repaired, upgraded, removed, or new infrastructure constructed, as needed. WFF maintains a perpetual right-of-way agreement with the VDOT for the portion of State Route 175 that borders WFF property.

Utility infrastructure is essential to the operation, safety, and mission goals at WFF. This infrastructure is continuously being upgraded or replaced as the need arises. Infrastructure systems currently in place at WFF include a storm drainage system; potable water supplied by deep wells on site; sanitary sewer systems that include a federally owned treatment works, pump station, force mains, and septic systems; diesel boilers, ultra-low sulfur diesel boilers, and LPG fired boilers; electrical lines supplied by private power companies with facility-owned generators; telephone systems; and communications that run on a T-3 local area network system over all three facility land masses. During a static fire test or LV rocket launch event, electrical power on the launch range is suspended and the two 3-megawatt (MW) generators on Wallops Mainland are activated in order to ensure consistent, reliable power to LV fueling and monitoring equipment, command control center systems, and range surveillance assets. The generators are activated for approximately 20 hours during the pre-launch, launch, and post-launch periods.

- **NEPA Review Trigger**: Changes in utility and transportation infrastructure and maintenance and improvement activities that have not been considered in previous NEPA analysis are reviewed to determine if the activities require further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2008 EA for the Wallops Research Park; 2009 EA for the Expansion of the WFF Launch Range; 2010 PEIS for the SRIPP; 2011 EA for Reconfiguration of the WFF Main Entrance; 2012 EA for North Wallops Island UAS Airstrip 2013 EA for Wallops Island Post-Hurricane Sandy Shoreline Repair; 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF.

2.4.1.2.4 Safety and Security

The Protective Services Division provides both institutional and operational program security. Protective service is provided 24 hours a day, 7 days a week at two fixed posts and throughout the facility. Access to the WFF Main Base is controlled by a guard post at the Main Gate entrance. The entrance to the Main Gate was recently upgraded to alleviate safety concerns for pedestrians and motorists from the increase in traffic to WFF (NASA 2011a). A second guard post is located at the common entrance to the Mainland and Wallops Island. Security cameras are mounted on towers and buildings throughout the facility to monitor activity on the Main Base, Mainland, and Wallops Island. Cameras are also used to monitor activity at the gate entrances and along the beachfront on Wallops Island. The entire Main Base is surrounded by a security fence, as is the west side of the Mainland. Wallops Island is motor vehicle accessible only by the NASA-owned causeway. Security systems and measures may be upgraded (e.g., addition of barriers and fencing) as needed at WFF.

The WFF Fire Department maintains ambulances, fire trucks, crash trucks, a hazardous material (HAZMAT) truck and support trailers, a utility/runway check vehicle, an emergency medical services equipped amphibious off road vehicle, and a technical rescue trailer. In addition to the fire suppression capabilities of the WFF Fire Department, the majority of buildings on the installation have automatic sprinkler systems. In the future, all new buildings and any existing building that lacks a fire suppression system will be provided with an automatic means of fire control. On the Main Base, a foam suppression system is in design for Hangar D-001 with plans to eventually incorporate the same system in the N-159 Hangar. The D-001 and N-159 hangars currently have water deluge fire suppression systems that deliver approximately 22,000 liters per minute (lpm) (6,000 gallons per minute [gpm]) of water. WFF has upgraded to a facility-wide addressable fire alarm system.

- **NEPA Review Trigger**: WFF fire prevention and protection program implements federal standards in the design, construction, and maintenance of all facilities and grounds. Changes in safety and security measures that have not been considered in previous NEPA analysis are reviewed to determine if the activities require further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2011 EA for Reconfiguration of the WFF Main Entrance.

### 2.4.2 Operational Missions and Activities

Operations at WFF are program and project driven and can change from year to year as missions evolve or change. The Suborbital and Special Orbital Projects Directorate, located at WFF, leads NASA's

Suborbital and Special Orbital Programs. Sounding rockets, balloons, aircraft, and orbiting spacecraft are used in NASA programs investigating space science, Earth science, advanced technologies, and aeronautical research. WFF provides support for mission and payload management, engineering, payload design and development, launch vehicle systems, and payload recovery systems.

WFF consists of a launch range, UAS test airstrips on the north and south ends of Wallops Island, an aeronautical research airport on the Main Base, and associated tracking, data acquisition, and control instrumentation systems on the Mainland and throughout the facility. An orbital tracking station operates continuously in support of several scientific satellites. WFF aircraft and UAS, used as aerial platforms, support the development of remote sensing techniques and instruments to measure ocean and atmospheric parameters and to conduct scientific missions. The WFF Launch Range is located on the southern end of Wallops Island and extends for 4.8 km (3 miles [mi]) over the Atlantic Ocean, using the surface area and airspace above to conduct flight operations. The principal Wallops Island facilities are those required to process, qualify, and launch rockets carrying scientific payloads on orbital or suborbital trajectories. Support facilities for the launch range include launch pads, launchers (mobile and fixed), blockhouses, rocket preparation and payload processing and integration buildings, dynamic balancing equipment, meteorological equipment, communications and control instrumentation, television and optical tracking stations, surveillance and radar tracking units, and other mission essential facilities. Additional special use facilities are located on the northern portion of Wallops Island. Occasionally, ground-based scientific equipment that requires isolation from other activities is temporarily located on the northern half of the Island.

The primary purpose of the launch range is to provide the infrastructure, data services, logistics, and safety services necessary for flight projects supporting NASA science, technology, and exploration programs; DoD and other government agency needs; and academic and commercial industry needs. Facilities on Wallops Island are used to support other NASA science and research programs that involve the use of rockets or UAS to carry instruments to desired altitudes. Additionally, the launch range is used cooperatively for non-rocket programs which typically include drone launch and tracking and projectile testing for the U.S. Navy and the U. S. Army.

The primary operations at WFF are discussed below and include Scientific Research and Education Programs, Airfield and Airfield Operations including management of special use/restricted airspace; Piloted Aircraft; UAS; Rocket Operations; Projectile Testing; Payloads; Tracking and Data Systems; Balloons; and AUVs/autonomous surface vehicles (ASVs).

### 2.4.2.1 Scientific Research and Education Program

#### 2.4.2.1.1 Scientific Research Programs

WFF's scientific research programs are essential to the ongoing missions to understand the Earth and to advance space exploration. Specific programs and facilities include Atmospheric Sciences Research, Unique Facilities and Laboratories, and R&D Programs.

Atmospheric sciences research at WFF supports scientific investigations of the atmosphere. The unique capabilities for data acquisition, processing, display, and recording have produced significant results in research conducted by governmental and non-governmental agencies. The instrumentation systems and technical support personnel have made important contributions to the understanding of atmospheric turbulence, cloud and precipitation development and dynamics, lightning discharge characteristics and distribution patterns, and the effects of precipitation on the transmission of electromagnetic radiation.

Permanent data acquisition systems include high-power radar systems and a data acquisition and recording system.

Unique facilities and laboratories at WFF support a variety of changing research programs. The following facilities and laboratories are currently operating at WFF: upper air instrumentation laboratory, airborne light detection and ranging, instrumentation fabrication and testing, and precipitation radar. R&D programs at WFF include satellite altimetry, upper air instrumentation research, cryospheric research, Coastal Zone research, precipitation research, and research involving new measurement platforms and their capabilities.

- **Envelope**: Envelopes for the scientific research programs are the same as payloads for radio frequencies, lasers, radioactive materials, biological agents, and chemical releases. Scientific research programs with activities not previously analyzed are reviewed to determine if further NEPA documentation is needed.
- **Post 2005 Site-Wide EA NEPA Coverage**: No additional coverage.

##### 2.4.2.1.2 Education Programs

Education programs at WFF include the NASA Management Education Center and Educational Outreach. The Management Education Center, located on the Main Base, is used to conduct the NASA Management Education Program, the Goddard Leadership Education Series, and the Langley Research Center's Management and Supervisory Training Program. As for Educational Outreach, WFF participates in a number of flight education programs designed to excite youth about NASA's space related activities. In many of these programs, students design, fabricate, test and integrate payloads into a WFF carrier system, then acquire, analyze, and present the experimental data. These outreach programs include the NASA Student Involvement program; the Student Experiment Module Balloon program; the FreeSPACE project; and the Student Launch Initiatives. NASA also sponsors internships and cooperative education programs (i.e., STEM) at WFF.

- **Envelope**: Envelopes for the education programs are the same as payloads for radio frequencies, lasers, radioactive materials, biological agents, and chemical releases. Educational programs with activities not previously analyzed are reviewed to determine if further NEPA documentation is needed.
- **Post 2005 Site-Wide EA NEPA Coverage**: No additional coverage.

#### 2.4.2.2 Airfield and Piloted Aircraft

##### 2.4.2.2.1 Airfield

NASA operates three runways at the WFF Main Base. Runway 10/28, which is the primary use runway; Runway 04/22, which is used for friction testing and touch-and-go tests; and Runway 17/35, which is an infrequently used crosswind runway. The airfield is used by NASA, NASA's partners and customers, and the DoD to conduct real-time tests in support of aeronautical research activities and pilot proficiency training. WFF's airport infrastructure provides communications, telemetry, radar tracking, and flight path guidance, as well as refueling and maintenance facilities for various types of aircraft. Typical support components of the airfield include the hangars, fueling systems, security, tracking systems, and an operations control tower. The airfield is also used as an emergency divert field for aircraft (commercial, private, and military) experiencing difficulties in flight.

The WFF airfield airspace environment is comprised of FAA designated Class "D" airspace. Class D airspace generally surrounds airports with an operations control tower. Class D airspace for NASA is above the WFF runways extending from surface to 750 m (2,500 ft) MSL in a 9.25 km (5 mi) radius of the airport. R-6604A/B/C/D/E is NASA controlled/restricted airspace that overlies all of Wallops Island, the Mainland, and the Main Base runways (**Figure 2.4-1**).

R-6604A/B is NASA controlled/Restricted Area Airspace that overlies all of Wallops Island, the majority of the Mainland, and a portion of the Main Base runways. The airspace connects to W-386, managed by the Navy's offshore FACSFAC VACAPES. R-6604A/B is available 24 hours a day, 7 days a week from the surface to unlimited altitude, while W-386 is from the surface to unlimited altitude with hours of use being intermittent. R-6604C is linked to R-6604A/B, extends from the surface to 1,065 m (3,500 ft) MSL, and extends through and beyond WFF's Class D airspace. R-6604D extends from 30 m (100 ft) above ground level AGL) to 1,065 m (3500 ft) MSL; and R-6604E extends from 213 m (700 ft) AGL to 1,065 m (3,500 ft) MSL. Each section of the airspace is activated separately, as needed. Activation of any section of R-6604 would be accomplished by issuing a Notice-to-Airmen (NOTAM) at least 12 hours prior to the activation.

Washington Air Route Traffic Control Center (ARTCC) is the sole controlling agency for NASA utilized airspace. When "hot" or "active", non-participating aircraft must contact the WFF Range Control Center or the Washington ARTCC to obtain clearance to transit through any portion of the R-6604 airspace. When training or WFF-specific use is not active, the restricted airspace is made available to general aviation and commercial air traffic.

- **Envelope**: Changes in FAA designated airspace or runways would require additional NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2008 EA for the Wallops Research Park; 2016 EA for Establishment of Restricted Area Airspace R-6604C/D/E at WFF.

2.4.2.2.2 Piloted Aircraft

The WFF aircraft fleet is operated, maintained, and managed by qualified flight crews and personnel with the goal of providing efficient and safe airborne operations for both transportation of NASA personnel and scientific data collection. The maintenance and operation of the aircraft are the responsibility of the Aircraft Office. WFF piloted aircraft operations can include employee transportation, payload delivery, rocket launching platforms, and inflight scientific experiments. Science mission aircraft are modified and upgraded, as needed, for mission requirements. Many of these same activities are performed by NASA customers.

NASA-owned aircraft operating at WFF include the following (not an all-inclusive list): 4-engine turboprop, heavy lift P-3 and C-130 aircraft; 2-engine turboprop, 30-passenger Short C-23 Sherpa aircraft, which support science missions; a single turboshaft engine, two-bladed main rotor and tail rotor; UH-1 helicopter to support science missions and range surveillance; a single engine turboprop T-34 aircraft for UAS chase and pilot proficiency training; and 2-engine turboprops, 9-passenger Beechcraft-200 King Air aircraft to support range surveillance and employee transportation on Agency missions.

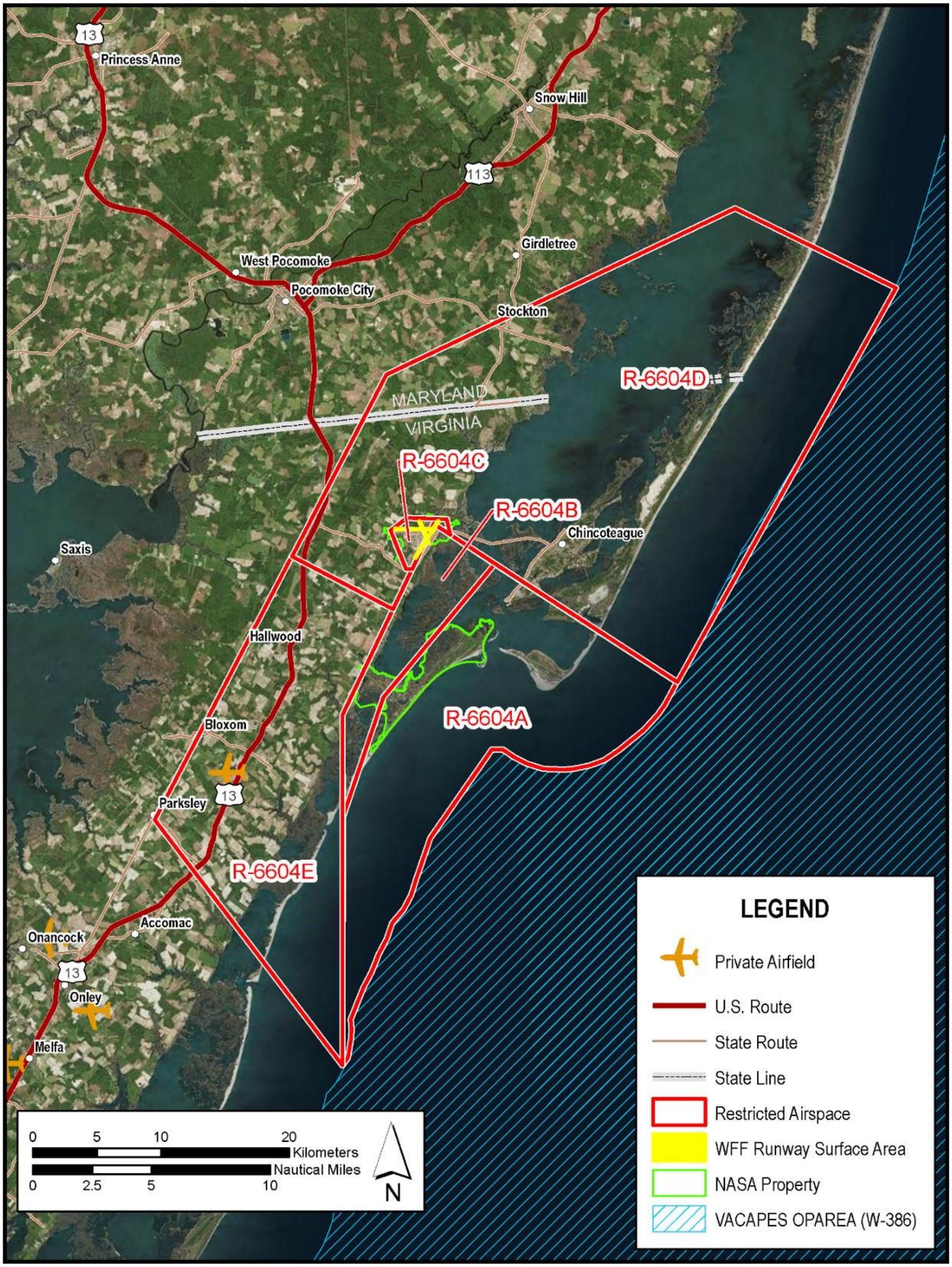



**Figure 2.4-1. NASA Controlled/Restricted Airspace**

Many of the airfield operations (i.e., flights) conducted at WFF are for military pilot proficiency training. Pilot proficiency training consists primarily of touch and goes in which the aircraft wheels touch down on the airstrip but the aircraft does not come to a complete stop. Branches of the military that conduct pilot proficiency training at WFF runways include the U.S. Air Force, Air National Guard, Army, Coast Guard, and the Navy. Aircraft involved in touch-and-go exercises at WFF may include but are not limited to E2/C2 turbo props, A-10, F-15, F-16, F-18, F-22, and F-35.

An airfield operation represents the single movement or individual portion of a flight in the WFF airfield airspace environment such as one takeoff, one landing, or one transit of the airport traffic area. The baseline airfield operation level for WFF of 12,843 was established in 2004 using annual airfield operations data for that year with an envelope that included a 25 percent increase above the total. In 2013, the baseline airfield operation level was increased to include an additional 45,000 annual U.S. Navy E-2/ C-2 Field Carrier Landing Practice operations.

- **Envelope**: Flight operations cannot exceed a maximum of approximately 61,000 annual airfield operations at WFF. A change in annual airfield operations that exceeds approximately 61,000 requires further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2008 EA for the Wallops Research Park; 2013 EA for E-2/C-2 Field Carrier Landing Practice Operations at NASA WFF; 2016 Record of Environmental Consideration (REC) for Patuxent River Naval Air Station F-35 Detachment to NASA WFF.

###### 2.4.2.2.3 Unmanned Aerial Systems

UAS perform a wide variety of functions; they are most frequently used as aerial platforms to support the development of remote sensing techniques and instruments for measuring ocean and atmospheric parameters, and other scientific missions. The majority of these functions are some form of remote sensing (e.g., atmospheric monitoring and testing, hurricane analysis, etc.). Commercial UAS manufacturers and others come from around the world to WFF to conduct product trials, pilot training, and science missions. UAS are frequently designed, fabricated, and tested at WFF. UAS currently operate from an airstrip on the south end of Wallops Island. A new UAS airstrip has been constructed on the north end of Wallops Island. In 2016, the FAA published its final rule (FAA Order 107, *Operation and Certification of Small Unmanned Aircraft Systems*) integrating small UAS (i.e., less than 25 kgs [55 lbs]) into the National Airspace System (NAS). Small UAS at WFF can operate in any open area of the base subject to approval by the Range Safety Office; outside of the base, small UAS must operate under FAA rules. **Table 2.4-2** provides examples of UAS currently operating from the Main Base runways and authorized to operate from the North Wallops Island UAS airstrip.

**Table 2.4-2. Examples of UAS Operating at Wallops Flight Facility**

| Model | Wingspan (m/ft) | Length (m/ft) | Maximum Weight with Payload (kgs/lbs) | Takeoff/Landing Minimum Requirement (m/ft) | Power | Endurance (hours) |
|---|---|---|---|---|---|---|
| **North Wallops Island UAS Airstrip** | | | | | | |
| Aerosonde[1] | 3.0 / 9.5 | 1.7 / 5.6 | 14 / 30 | None | .06 hp | 40 |
| GTM AirSTAR[2] | 2.0/7.0 | 2.5/8.0 | 23/50 | 450/1,500 | 32 lbs thrust | 10-12 minutes |
| Viking 100[3] | 4.5/15.0 | 2.5/8.0 | 68/150 | 450/1,500 | 16 hp | 10-14 |
| Viking 300[3] | 5.5/17.5 | 4.0/13.5 | 144/3618 | 450/1,500 | 25 hp | 8-10 |
| Viking 400[3] | 6.0/20.0 | 4.5/14.7 | 240/530 | 760/2,500 | 38 hp | 8-12 |
| Exdrone[4] | 3.0/9.5 | 1.9/6.2 | 41/91 | 100/300 | 8 hp | 2 |
| ScanEagle[5] | 3.0/9.5 | 1.7/5.6 | 14/30 | 10/30 | 1.5hp | 40 |
| Small quad-copter | 350 mm /14in | 350 mm /14 in | 1.5/3 | na | 6.4 volt battery | 25 minutes |
| FAA Part 107 Small UAS | variable | variable | 25/55 | na | variable | na |
| Shadow 200[6] | 6.2/20.4 | 3.6/11.8 | 208/460 | 10/30 | 38 hp | 4 |
| Blimp (tethered) | 2.1/7.0 | 7.0/23.0 | 40/18 | na | na | na |
| Schiebel Camcopter S-100 | 3.4/11.2 | 3.11/10.2 | 200/441 | na | 55 hp | 6 |
| **Main Base Runways** | | | | | | |
| Vanilla | 11/36 | 4/14 | 270/600 | 1,220/4,000 | 10 hp | 240 |
| Pioneer | 5.2/16.9 | 4.3/14.0 | 188/416 | 600/2,000 | 26 hp | 5.5 |
| Altus | 16.5/55.3 | 7.2/23.6 | 967/2,130 | 1,500/5,000 | 65 hp | 48 |
| Gnat 750 | 10.8/35.3 | 5.0/16.4 | 520/1,140 | 1,500/5,000 | 85 hp | 30 |
| Global Hawk | 35.4/116.2 | 13.5/44.4 | 12,111/26,700 | 2,400/8,000 | 7,050 lbs thrust | 30 |
| AeroStar | 8.5/28 | 4.5/15 | 220/485 | 1,500/5,000 | 38 hp | 12 |
| MQ-4C Triton | 39.9/130.9 | 14.5/47.6 | 14,660/32,250 | 2,400/8,000 | 8,500 lbs thrust | 28 |
| MQ-8C Fire Scout | 10.7/35 | 12.6/41.4 | 2,722/6,000 | na | 250 hp | 12 |
| MQ-1 Predator | 14.8/48.7 | 8.2/27 | 1,020/2,250 | 1,524/5,000 | 115 hp | 24 |

Notes: [1] Manufactured by Aerosonde; [2] Generic Transport Sub-scale Model (GTM) AirSTAR is manufactured by NASA Langley Research Center. The GTM AirSTAR is similar to an upscale model airplane and is the smallest of the UAS piloted at WFF; [3] Manufactured by L3 BAI Systems; [4] Launched via catapult; stopped by chute or skid; [5] Launched via catapult; stopped via SkyHook; [6] Launched via catapult; wheel landing.

Legend: kgs = kilograms, lbs = pounds, hp = horsepower, na = not applicable.

- **Envelope**: UAS flight operations from the Main Base runways are included in the 61,000 annual airfield operations at WFF. A change in annual airfield operations that exceeds approximately 61,000 requires further NEPA documentation. UAS flown from the North Wallops Island UAS airstrip cannot exceed the noise generated by the Viking 300 or the size (in terms of physical size and quantities of onboard materials) of the Viking 400. UAS annual sortie operations (i.e., a single UAS flight operation from takeoff through landing) cannot exceed 1,040. A change in vehicle size or annual sortie operations that exceeds 1,040 would require further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2012 EA for North Wallops Island UAS Airstrip; 2014 REC for AeroStar UAS; 2014 REC for Scan Eagle; 2015 REC for Small Off-the-Shelf UAS; 2016 REC for Vanilla UAS; 2016 EA for MQ-4C Triton UAS East Coast Home Basing.

### 2.4.2.3 Rocket Operations

#### 2.4.2.3.1 Orbital Rockets

Numerous LVs and Reusable Launch Vehicles (RLVs) could be used at WFF to support payload delivery to orbit. An LV is composed of stages, each of which contains its own engines and fuel (also known as propellant). A launch vehicle or stage is considered to be "expendable" if it is not retrieved and refurbished and "reusable" if any part of it returns to a landing site for refurbishment and relaunch. Stages are either mounted on top of one another, or attached alongside another stage (i.e., strap-on motors). The first stage is at the bottom and is usually the largest, which may consist of a single motor or a core motor with strap-on motors to increase the lift capacity of the first stage. The second stage and subsequent upper stages are above it, usually decreasing in size. In a typical case, the first stage engines fire to propel the entire rocket upward. As each engine runs out of fuel, it is detached from the rest of the rocket (usually with some kind of small explosive charge) and falls away into a prescribed drop zone. This leaves a smaller rocket, with the second stage on the bottom, which then fires; this process is repeated until the final stage's motor burns to completion.

**Table 2.4-3** lists the orbital rockets that have been launched or have been approved for launch from Wallops Island; **Figure 2.4-2** provides illustrations of approved orbital launch vehicles at Wallops Island. For launch vehicle families, only the launch vehicle with the largest propellant load is listed.

- **Envelope**: 18 orbital rocket launches per year is the envelope with 6 launches from Pad 0-A and 12 launches from Pad 0-B. Antares is the current envelope liquid-fueled LV to be launched from Pad 0-A. Athena III (in design) is the current envelope solid-fueled LV to be launched from Pad 0-B. A change in the annual number of orbital launches or the pad from which the orbital launches would occur requires further NEPA documentation.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2006 EA for the Orbital/Sub-Orbital Program; 2009 EA for the Expansion of the WFF Launch Range; 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles; 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF.

**Table 2.4-3. Orbital Rockets, Motors, and Propellants**

| Orbital Rockets | Motor Type | Propellant | Maximum Quantity | |
|---|---|---|---|---|
| | | | kgs | lbs |
| Athena II | Stage 1: 2-CASTOR 120 solid motor | AP/Al | 48,596 | 107,137 |
| | Stage 2: CASTOR 120 solid motor<br>Orbit Adjust Module | HTBP | 12,814 | 28,250 |
| | Stage 3: CASTOR 30 solid motor | Hydrazine | 435 | 960 |
| Athena III (in design) | Stage 1: 1- CASTOR 120 solid motor with 8-CASTOR IVA strap-on motors<br>Orbit Adjust Module (optional) | AP/Al/HTPB<br>Hydrazine | 388,768<br>435 | 857,096<br>960 |
| Falcon 9 | Stage 1:<br>Space Exploration Technologies Corporation (SpaceX) Merlin engine | RP-1/LOX | 395,700 | 872,369 |
| | Stage 2: SpaceX Merlin engine | RP-1/LOX | 92,670 | 204,302 |
| Minotaur I | Stage 1: Minuteman II M-55A-1 | AP/Al | 20,788 | 45,830 |
| | Stage 2: Minuteman II SR-19-AJ-1<br>Orion-50-XLG | CTPB | 9,545 | 21,043 |
| | Stage 3: Pegasus XL Orion-50XL | HTPB | 27,169 | 47,332 |
| | Stage 4: Pegasus XL Orion-38 | AP/Al | 1,700 | 770 |
| | Additional Stage 3, 4 or 5motors | HTPB/HAPS | 985 | 2,171 |
| | HAPS | Liquid Hydrazine and pressurized helium gas | 59 | 130 |
| | M57A-1 | Solid fuel (variable constituents) | 1,660 | 3,660 |
| | SR73-AJ-1 | AP/Cyclotetramethylene | 3,307 | 7,290 |
| | Star 48 G (upper bounding case) | Tetranitramine, Al, NC, NG, Triacetin | 2,010 | 4,431 |
| Minotaur IV, V, and VI* | Stage 1: Peacekeeper SR-118 | AP/Al/HTPB | 44,662 | 98,462 |
| | Stage 2: Peacekeeper SR-119 | AP/Al/HTPB | 44,662 | 98,462 |
| | Stage 3: Peacekeeper SR-120 | AP/Al/HTPB | 24,557 | 54,138 |
| | Stage 4: Peacekeeper SUPER HAPS (Minotaur III); Orion 38 (Minotaur IV); Star 48 motor (Minotaur V) | AP/Al/Cyclotetramethylene Tetranitramine, NG, Polyethylene Glycol | 7,069 | 15,584 |
| | Stage 5: Star 37 | AP/Al/HTPB | 2,430 | 5,357 |
| | or HAPS | Liquid Hydrazine and pressurized helium gas | 59 | 130 |
| Pegasus* | Stage 1: Orion 50S XL | HTPB | 15,048 | 33,105 |
| | Stage 2: Orion 50 XL | HTPB | 3,934 | 8,655 |
| | Stage 3: Orion 38 | HTPB | 771 | 1,710 |
| Taurus | Stage 0: CASTOR 120 | HTPB | 50,000 | 110,000 |
| | Stage 1: Orion 50S-G | HTPB | 12,152 | 26,734 |
| | Stage 2: Orion 50 | HTPB | 3,029 | 6,664 |
| | Stage 3: Orion 38 | HTPB | 771 | 1,710 |
| Antares 200 Configuration | Stage 1: 2-RD 181 | LOX | 174,000 | 383,600 |
| | | RP-1 | 65,000 | 143,300 |
| | Stage 2: CASTOR 30B /XL | AP/Al/HTPB | 25,000 | 55,115 |
| | Stage 3: if solid | AP/Al/HTPB | 2,010 | 4,431 |
| | Stage 3: if liquid | Hydrazine /Nitrogen Tetroxide | 350 | 772 |

Sources: NASA 2005; 2009; 2011b; 2015.

Notes: * Minotaur VI is in development; its characteristics are within the already established WFF LV envelope. Pegasus is launched from L-1011 aircraft (NASA 2005).

Legend: Al = Aluminum; AP = Ammonium Perchlorate; CTPB = Carboxyl-terminated polybutadiene; HAPS=Hydrazine Auxiliary Propulsion System; HTPB = Hydroxyl-terminated polybutadiene; LOX = liquid oxygen; MMH = Monomethylhydrazine; NC = Nitrocellulose, NG = Nitroglycerin; SR = rocket stage; SRM=solid rocket motor; RP-1 = Rocket Propellant 1.


**Figure 2.4-2. Examples of Wallops Flight Facility Approved Orbital Launch Vehicles**

#### 2.4.2.3.2 Suborbital Rockets

Suborbital rockets carry research payloads with scientific instruments to altitudes up to 1,600 km (1,000 mi). Scientific data are collected and returned to Earth by telemetry links. Parachutes and beacons (e.g., audible, visual, Global Positioning System [GPS]) may be used to recover the payloads. Scientific mission requirements determine the particular type of rocket used to deliver a specific payload. Criteria evaluated include payload weight, size, and trajectory. Each launch vehicle system is a combination of separated rocket motors that combine to provide unique weight and altitude performance capabilities for various experiments. Multiple launch vehicles or motor combinations could be used to support the suborbital rocket program. The rockets are matched to meet the scientific requirements of each project. Suborbital rockets are divided into large suborbital class and sounding rockets. There are currently two larger suborbital rockets launched from Pad 0-B and one smaller suborbital rocket launched from Launch Complex 2 at WFF as shown in **Table 2.4-4.**

**Table 2.4-4. Large Suborbital Rockets, Motors, and Propellants**

| Suborbital Rockets | Motor Type | Propellant | Maximum Quantity | |
|---|---|---|---|---|
| | | | kgs | lbs |
| Minotaur II | Stage 1: Minuteman II M-55A-1 | AP/Al | 20,788 | 45,830 |
| | Stage 2: Minuteman II SR-19 | CTPB | 9,545 | 21,043 |
| | Stage 3: M57A-1 | Solid fuel (variable constituents) | 1,660 | 3,660 |
| | or Orion-50XL | HTPB | 27,169 | 47,332 |
| Minotaur III | Stage 1: Peacekeeper SR-118 | AP/Al/HTPB | 44,662 | 98,462 |
| | Stage 2: Peacekeeper SR-119 | AP/Al/HTPB | 44,662 | 98,462 |
| | Stage 3: Peacekeeper SR-120 | AP/Al/HTPB | 24,557 | 54,138 |
| | Stage 4: Peacekeeper SUPER HAPS | Liquid Hydrazine and pressurized helium gas | 59 | 130 |
| Electron | Stage 1: Rutherford engine | RP-1/LOX | 6,418 | 14,150 |
| | Stage 2: Rutherford engine | RP-1/LOX | 6,418 | 14,150 |

Sources: NASA 2005; 2009; 2011b; 2015; 2018.

Notes: Minotaur VI is in development; its characteristics are within the already established WFF LV envelope. Pegasus is launched from L-1011 aircraft (NASA 2005). Electron is designed and manufactured by Rocket Lab (Rocket Lab 2018).

Legend: Al = Aluminum; AP = Ammonium Perchlorate; CTPB = Carboxyl-terminated polybutadiene; HAPS=Hydrazine Auxiliary Propulsion System; HTPB = Hydroxyl-terminated polybutadiene; SR = rocket stage.

The NASA Sounding Rockets Program Office provides overall management of smaller suborbital rockets and flight projects for campaigns conducted at WFF and for mobile campaigns that occur around the world. The NASA Sounding Rockets Program primarily operates for NASA, but serves other government agencies, universities, industry, and foreign countries as well. The program has the flexibility and capability to respond quickly to scientific requirements for launch operations from practically any place on Earth using either permanent or mobile range facilities. Currently, there are 11 types of sounding rocket launch vehicle systems in the WFF inventory. **Table 2.4-5** provides the suborbital rocket motors typically launched from Wallops Island.

**Table 2.4-5. Suborbital Rocket Motors**

| Motor Name | Propellant Composition | Propellant Weight kgs (lbs) |
|---|---|---|
| Standard Black Brant | AP/PU/Al | 1,001 (2,207 ) |
| Black Brant Mk series | AP/HTPB/Al | 1,005 (2,215 ) |
| Improved Malemute | AP/HTPB/Al | 499 (1,100) |
| Improved Orion | AP-NGU/PU/Al | 293 (647) |
| Lynx, MK104 | AP/HTPB/Al | 379 (835) |
| Malemute | AP/HTPB/Al | 506 (1,116) |
| MLRS M-26 | AP/HTPB/Al | 98 (216) |
| Nihka (Mod 0, 1, 2, &3) | AP/HTPB/Al | 314 (692) |
| Oriole | AP/HTPB/Al | 983 (2,168) |
| Orion (Standard) | AP-NGU/PU/Al | 293 (647) |
| Peregrine | AP/HTPB/Al | 1,351 (2,978) |
| Star 3 | AP/CTPB/Al | 0.48 (1) |
| Super Arcas | AP | 25 (55) |
| Super Loki | AP/Al | 17 (37) |
| Talos | NC/NG | 1,271 (2,803) |
| Taurus | NC/NG | 754 (1,663) |
| Terrier MK 12 | NC/NG | 536 (1,181) |
| Terrier MK 70 | AP/HTPB/Al | 680 (1,500) |
| Viper IIIA Dart | AP/Al | 26 (57) |
| Zombie | AP/HTPB/Al | 727 (1,603) |

Source: NASA 2009.
Legend: Al = Aluminum; AP = Ammonium Perchlorate; CTPB = Carboxyl-terminated polybutadiene; HTPB = Hydroxyl-terminated polybutadiene; NC = Nitrocellulose, NG = Nitroglycerin; NGU = nitroguanadine; PU = polyurethane.

- **<u>Envelope</u>**: The envelope for suborbital rocket launches is 60 per year. The four-stage Black Brant XII is the envelope suborbital rocket.
- **<u>Post 2005 Site-Wide EA NEPA Coverage</u>**: No additional coverage.

2.4.2.3.3 Drone Targets and Missiles

Drone targets are used at WFF in the VACAPES OPAREA (refer to **Figure 1.2-2**) as part of missile training exercises conducted by the U.S. Navy and supported by NASA. Targets are used to test the performance of shipboard combat systems, as well as to provide simulated real-world targets for ship defense training exercises. Drone targets are either launched from the WFF Launch Range or air-launched from military aircraft in the VACAPES OPAREA controlled airspace. Targets travel on a preprogrammed flight path and can be tracked or intercepted. In the case of an intercept, shipboard interceptor missiles engage the target over the VACAPES OPAREA and all debris from the intercept falls within the VACAPES OPAREA boundary. These Navy actions have been further assessed in the AFTT EIS/OEIS which is incorporated by reference into this PEIS.

The AQM-37, BQM-34, and GQM-163 are the most commonly used drone targets at WFF. The AQM-37 is a hypergolic propellant fueled vehicle. It arrives at WFF pre-fueled, with a self-contained hypergolic propellant system consisting of mixed amine fuel and inhibited red fuming nitric acid as an oxidizer. The AQM-37 measures approximately 4.3 m (14 ft) long and 0.3 m (13 inches [in]) in diameter, with a wingspan of 1 m (3.3 ft) and weighs 280 kgs (620 lbs) when flight ready. It is capable of being launched from an aircraft at altitudes between 300 and 18,000 m (1,000 and 59,000 ft) and at speeds between 835 and 2,150 km per hour (Mach 0.7 to 1.8). The assembled BQM-34 is approximately 7 m (23 ft) long and 2 m (7 ft) in diameter with a wingspan of 4 m (13 ft). The drone target weighs 1,100 kgs (2,425 lbs) when flight ready and contains 400 liters (100 gal) of JP-5 jet fuel. The BQM-34 drone target is capable of reaching altitudes between 3 and 15,000 m (10 and 50,000 ft) and speeds of 1,120 km per hour (Mach 0.9) over 115 minute endurance. The GQM-163A is a non- recoverable, supersonic aerial target, capable of Mach +2 at altitudes of 4 to 20 m (13 to 66 ft) AGL. This supersonic sea skimming target can also perform a high altitude diving threat profile, climbing to 15,850 m (52,000 ft) and then executing a 15 to 55 degree dive at Mach 3 to 4. It is a two-stage, solid-fueled rocket consisting of a Terrier MK 70 suborbital rocket booster and a ducted rocket sustainer.

- **Envelope**: AQM-37 is the envelope drone target; no more than 30 drone target flights are to be flown per year.
- **Pre and Post 2005 Site-Wide EA NEPA Coverage**: 2003 EA for AQM-37 Operations; 2009 VACAPES Range Complex EIS/ OEIS; 2013 AFTT EIS/OEIS; 2014 EA for Testing Hypervelocity Projectiles and an Electromagnetic Railgun at NASA WFF; 2018 AFTT EIS/OEIS.

#### 2.4.2.3.4 Fuel Types

Fuels used at WFF include but are not limited to LPG and ultra-low sulfur diesel for heating; gasoline and diesel fuel for ground vehicles; and JP-5 and JP-8 for jet aircraft and UAS turbine engines. The suborbital and orbital vehicles launched from WFF utilize liquid and/or solid propulsion systems. Fuels used include hydrocarbon propellants Jet-A, hydrazine, kerosene (RP-1), and liquid methane; cryogenic fuels liquid hydrogen, liquid nitrogen, and liquid oxygen (LOX); solid rocket fuels; and hypergolic fuels for spacecraft and exoatmospheric aircraft. Hybrid fuels (a mixture of different fuel types) would continue to be utilized at WFF. Hybrid fuels can include fuels that have not been engineered or are not currently utilized at WFF.

A solid propulsion system is the envelope propulsion system since it represents a greater potential environmental impact from emissions than a liquid system. However, liquid fuels (e.g., LOX, RP-1, hybrid fuels) may pose a greater toxicity risk than solid fuels. Hydrazines (e.g., anhydrous hydrazine, MMH, unsymmetrical dimethyl hydrazine) are toxic liquids that are commonly used in payload attitude adjustment systems, which are used to control the orientation of a spacecraft. The solid propellant system is based on either an AP/Al combination or a NC/NG combination. The emissions from the AP/Al propellant combination include hydrogen chloride (HCl) and aluminum oxide ($Al_2O_3$) and are generally considered to be more environmentally damaging than emissions from the NC/NG propellant combinations (NASA 2000).

- **Envelope**: Introduction of a new fuel or new hybrid fuel at WFF requires evaluation to determine the level of NEPA analysis needed. A new fuel must have fewer potential environmental impacts than the solid fuels and pose a reduced safety risk than current liquid fuels, fueling systems, and hybrid fuels.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2009 EA for the Expansion of the WFF Launch Range; 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles; 2015 Supplemental EA for Antares 200 Configuration Expendable Launch Vehicle at WFF.

#### 2.4.2.3.5 Static Fire Testing

Static fire tests are performed so that observations of the rocket motor engine or motor components can be made in a non-flight position. Refer to Tables 2.4-3 and 2.4-4 for the types of orbital and sounding rockets and associated motors launched from WFF. MARS has been authorized to perform rocket motor static firing events on liquid propellant orbital rocket motors from Launch Pad 0-A under the MARS State Operating Permit (registration number 61602). Static fire tests at Launch Pad 0-A are conducted for up to 52 seconds (NASA 2009). WFF has been authorized to perform static fire tests on solid propellant sounding rocket motors from Pad 2 under the Wallops Island State Operating Permit (registration number 40909). A condition of the Permit is annual reporting, including reporting of Pad 2 static fire tests. **Table 2.4-6** presents the maximum allowable throughput for propellant type consumed during rocket motor static fire or test events at Pad 2 and open burn events at the Open Burn Area; the propellant throughput has been calculated on a rolling 12-month period. Composite and double-base propellant can be used in the same year. **Table 2.4-7** provides a summary of static fire test activity at the WFF Launch Range since 2008. The envelopes for static fire tests are governed by the limits set forth in the respective state operating permits.

Small, model rocket grade motors are those that contain very small quantities of propellant similar to the propellant used in sounding rockets. These motors are test fired at Building F-010. The model motor test fire activity is an exempted emission source under State Operating Permit 40909 (VDEQ 2016).

**Table 2.4-6. Propellant Throughput Authorized for Static Fire Tests**

| Propellant | Launch Pad 0-A | Pad 2 / Open Burn Area |
|---|---|---|
| Composite Propellant (Al/AP) | na | 34,925 kgs (77,000 lbs) |
| Double-Base Propellant (NC/NG) | na | 30,390 kgs (67,000 lbs) |
| Liquid (LOX/RP-1) | 29,920 kgs (65,968 lbs) | na |

Sources: NASA 2014; *MARS 2010.
Legend: na = not applicable.

**Table 2.4-7. Summary of Static Fire Tests**

| Year | Test Article | Propellant | Weight in kgs (lbs) | Location |
|---|---|---|---|---|
| 2008 | None | na | na | na |
| 2009 | Improved Terrier-Malemute | Al/AP | 500 (1,100) | Pad 2 |
| 2010 | None | na | na | na |
| 2011 | None | na | na | na |
| 2012 | None | na | na | na |
| 2013 | Antares | LOX | 5,551 (12,238) | Launch Pad 0-A |
| 2014 | Barium-Cupric Oxide ampules<br>Hall ampules | Ba-CuO<br>Ba-CuO-Sr | 5 (11.0)<br>0.80 (1.76) | Pad 2<br>Pad 2 |
| 2015 | Small model rocket | Al/AP/HTPB | 0.472 (1.04) | F-010 |
| 2016 | Peregrine<br>Small model rocket<br>Super Soaker<br>Antares | Al/AP/HTPB<br>Al/AP/HTPB<br>Smokeless Powder<br>LOX | 12.54 (27.65)<br>1.32 (2.92)<br>0.1 (3.0)<br>7,315 (16,126) | Pad 2<br>F-010<br>Pad 2<br>Launch Pad 0-A |

Source: Miller 2017a, b.
Legend: na = not applicable.

- **Envelope**: Static fire tests may only occur from Wallops Island Launch Pad 0-A and Pad 2. Propellant throughput at Pad 2 must fall within those volumes governed by the 2010 MARS Regional Spaceport State Operating Permit and the 2014 NASA Wallops Island State Operating Permit. Near Building F-010 on the Main Base, static fire tests of small model rocket motors have been authorized under the 2011 Main Base State Operating Permit that is currently being updated. The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2009 EA for the Expansion of the WFF Launch Range; 2016 REC for Model Rocket Motor Static Firing at the WFF Main Base.

2.4.2.3.6 Open Burn Area

In October 2005, VDEQ issued a treatment, storage, and disposal facility under the Resource Conservation and Recovery Act (RCRA) permit to WFF for Open Burning (OB) treatment of waste solid rocket motors. WFF completed a Human Health and Ecological Risk Assessment for the OB area as part of the permit process (NASA 2005). All OB activities fall under the RCRA Part B permit. WFF coordinated with VDEQ for renewal of the OB Area permit. The OB Area permit has been renewed for a period of ten years effective April 13, 2018 (Miller 2018).

Through a Waste Minimization Plan, each rocket motor is evaluated for flight and non-flight uses at WFF and other federal locations before declaration as a hazardous waste. Rocket motors which may not meet performance standards for one mission may be used on missions in which minor flight performance is not an issue (e.g., university, student, or other missions). Rocket motors may be tested to determine the extent of deviation from performance standards. In addition, off-specification rocket motors manufactured by commercial manufacturers can be returned to the manufacturer.

The OB area is located at the extreme south end of Wallops Island. Solid rocket motors which are deemed not suitable for flight and have no other use are classified as reactive hazardous waste. Hazardous waste rocket motors are treated at the OB area to remove their reactivity. The motors are placed either on the burn pad or in a subunit. Once properly secured, the motors are ignited to burn off the solid propellant. Once the burn is complete, the metal motor casing is allowed to cool before an inspection of the motor is made to determine the success of the OB process. WFF typically uses the OB area, up to four times a year, to dispose of motors. **Table 2.4-8** summarizes the recent OB activities at WFF.

**Table 2.4-8. Summary of Open-Burns**

| Year | Rocket Motor Types | Propellant | Weight in kg (lbs) |
|---|---|---|---|
| 2008 | Test rocket<br>Arcas propellant Nike | AP/Al (composite)<br>NC/NG (double-base) | 2,200 (4,850) |
| 2009 | Nike | NC/NG (double-base) | 2,180 (4,800) |
| 2010 | Super Loki<br>Arcas propellant | AP/Al (composite) | 340 (750) |
| 2011 | None | na | 0 |
| 2012 | Nike | NC/NG (double-base) | 530 (1,425) |
| 2012 | Orion | AP/Al | 274 (604) |
| 2013 | Orion | AP/Al | 497 (1,096) |
| 2013 | Taurus | NC/NG | 18,858 (41,575) |
| 2014 | None | na | 0 |
| 2015 | M-37 Spin Motor | AP/Al | 3.6 (8) |

| Table 2.4-8. Summary of Open-Burns (cont.) | | | |
|---|---|---|---|
| **Year** | **Rocket Motor Types** | **Propellant** | **Weight in kg (lbs)** |
| 2016 | Arcas | AP/Al | 0.05 (0.125) |
| 2016 | Spin | AP/Al | 9 (20) |
| 2016 | Orion | AP/Al | 274 (604) |
| 2016 | Taurus | NC/NG | 1,509 (3,326) |

Source: Miller 2016b.
Legend: na = not applicable.

- **Envelope**: The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year.
- **Post 2005 Site-Wide EA NEPA Coverage**: Mainland/Wallops Island State Air Operating Permit.

#### 2.4.2.4 Projectile Testing

The U.S. Army and the U.S. Navy periodically conduct conventional rocket-boosted projectile tests from Wallops Island. These tests consist of firing 155 millimeter (mm) (6 in) projectiles over the VACAPES OPAREA. Projectiles resemble small solid propellant carbon graphite based rocket motors carrying electronic communications payloads. Determining the initial velocity of the test projectile is critical. Typical test scenarios involve warming up the gun barrel by firing 2 solid steel slugs followed by velocity calculations based on firing blunt front end slugs calibrated to be the same weight as the test article. Lastly, the test article is fired. All objects follow a ballistic trajectory. The range of the articles varies; the warm up slugs travel less than 1.6 km (1 mi), the velocity test slug impacts 10 to 13 km (6 to 8 mi) downrange, while the current maximum range of the rocket-boosted projectiles is 103 km (64 mi). Test articles and projectiles are rarely recovered. Electromagnetic railgun (EMRG) technology uses high-power electrical energy to launch projectiles long-range. To fire the railgun, the system builds up an electrical charge to expel 56 cm by 9 cm (22 in by 3.5 in) sabot petals from the barrel.

- **Envelope**: Projectile testing cannot exceed 270 combined firings from conventional, EMRG, or RDT&E systems per year.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2014 EA for Testing Hypervelocity Projectiles and an Electromagnetic Railgun at NASA WFF.

#### 2.4.2.5 Payloads

For the purpose of this Site-wide PEIS, payloads consist of spacecraft or scientific equipment designed, tested, and/or launched at WFF using rockets, balloons, aircraft, UAS, AUVs and ASVs. Payloads may be suborbital or orbital, or may re-enter the Earth's atmosphere. WFF can build, test, and fly payloads that exceed 5,750 kgs (12,680 lbs) (NASA 2009). Payloads may contain: mechanical structures, batteries or solar power cells, reentry fuel sources, transmitters, receivers, antennas, other communication system components, small radioactive sources, recovery systems, in-space maneuvering systems, and science and technology instruments (lasers, sensors, atmospheric sampling devices, optical devices, and biological experiments) (NASA 2011b). Since payloads can contain many different variants that could result in environmental impacts, there are multiple envelopes. The envelopes for payloads are discussed below.

#### 2.4.2.5.1 Radio Frequency

Payloads use radio frequencies to transmit data back to receivers on the ground. Payloads may carry a variety of low-power radio transmitters (for telemetry, tracking, and data downlink) and high-power radar transmitters (for remote studies of planetary surfaces). The power and operating characteristics of these transmitters are within defined limits to assure that their operation meets the American National Standards Institute (ANSI) recognized acceptable levels as stated in Institute of Electrical and Electronic Engineers (IEEE) C95.1-2005 standards for human health and safety. Payload communication devices must adhere to IEEE standards.

#### 2.4.2.5.2 Lasers

Payloads may utilize lasers to conduct innovative research, such as measuring chemical and biological concentrations in terrestrial and oceanic plants. Lasers must meet ANSI Z136.1-2007, *American National Standards for Safe Use of Lasers*, ANSI Z136.6-2005, *Safe Use of Lasers Outdoors*, and applicable Federal and Virginia Occupational Safety and Health Administration regulations and safety standards.

#### 2.4.2.5.3 Radiation

Payloads may carry small quantities of encapsulated radioactive materials for instrument calibration or similar purposes. The amount and type of radioactive material that can be carried is strictly limited by the approval authority level delegated to the NASA Nuclear Flight Safety Assurance Manager (NFSAM) in accordance with NPR 8715.3. As part of the approval process, the spacecraft program manager must prepare a Radioactive Materials Report that describes all of the radioactive materials to be used on the payload. The NFSAM must certify that preparation and launching of routine payloads carrying small quantities of radioactive materials does not present a substantial risk to public health or safety.

#### 2.4.2.5.4 Biologicals

Payloads may also carry biological agents, insects, and fungi into orbit for scientific experiments. The biological agents must fall under the National Institutes of Health and the Centers for Disease Control Biosafety in Microbiological and Biomedical Laboratories established safety ratings.

#### 2.4.2.5.5 Chemicals

Payloads may also utilize chemicals or release chemicals into the atmosphere. NASA commonly conducts sounding rocket campaigns that employ metal vapors (e.g., barium, strontium, samarium, lithium) and trimethyl aluminum chemical release modules. Puffs of such chemicals are generally released from altitudes of 80 to 150 km (50 to 95 mi). An instrumented payload would collect data on the release, such as plasma density, temperature, collision frequency, electric field profiles, neutral density, and electron, ion, and particle environmental mechanisms. Prior to a new chemical release, an analysis would be performed to determine if a substantial hazard would occur. Only those chemicals that would not pose a substantial hazard would be authorized for release into the atmosphere.

#### 2.4.2.5.6 Propulsion

Payloads may utilize propellants to adjust their final trajectory into a prescribed orbit or to carry them further into space. Propellants may be liquids such as hydrazine, monomethylhydrazine, and/or nitrogen tetroxide (combined limit of 3,200 kgs (7,055 lbs)) or solids such as a Star-48 kick stage, descent engines, an extra-terrestrial ascent vehicle (limit of 3,000 kgs [6,614 lbs] ammonium perchlorate-based solid propellant).

2.4.2.5.7 Reentry

Reentry payloads may be either an orbital or suborbital payload that, upon receiving a signal from command control, de-orbits, reenters the Earth's atmosphere, deploys a parachute, lands or splashes down, and is recovered; is ejected or released from a suborbital rocket, deploys a parachute, then lands or splashes into the ocean; or it may resemble a space shuttle type vehicle that orbits the Earth, completes its mission, then de-orbits, returns to Earth, and lands on an aircraft runway. Reentry payloads require fuel to break orbit, and, in the case of the reentry-type craft, they need fuel to land. Fuel sources would be identical to those used on the launch vehicle (e.g., solid rocket fuel, LOX/kerosene, LOX/liquid hydrogen, hypergolic fuels, or a hybrid fuel).

Ocean salvage/recovery of the parachute and payload would begin immediately after reentry. Recovery aids attached to the payload may include GPS beacons and/or audible beacons and in the event of a water recovery, strobe lights, and/or dye markers may be used.

- **Envelope**: Payloads have multiple envelopes.
- **Post 2005 Site-Wide EA NEPA Coverage**: 2009 EA for the Expansion of the WFF Launch Range; 2011 EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles.

### 2.4.2.6 Tracking and Data Systems

WFF maintains multiple tracking and data systems. These systems include: Wallops Orbital Tracking System, Data Systems, Radar, Telemetry, Optics, Meteorological Support, Command System, Range Control, and Communications Systems Program.

2.4.2.6.1 Wallops Orbital Tracking System

This ground-based satellite tracking station acquires telemetry from satellites to support several important programs, including the Transition Regional and Coronal Explorer the Quick Scatterometer, Sea-Viewing Wide Field-of-View Sensor, Gravity Recovery and Climate Experiment, and ISS tracking. Telemetry data are delivered in real-time or near real-time.

2.4.2.6.2 Data Systems

Data are acquired during operations from radar, telemetry, optical, meteorological, timing, and communications systems. These data are processed by computers at WFF to provide operations support and information for scientific experiments. A variety of data systems acquire, record, and display information in real-time for command, control, and monitoring of flight performance.

2.4.2.6.3 Radar

Radar systems provide space position and/or target characteristic information for a variety of applications, including surveillance, tracking, weather observation, and scientific remote sensing. The radar functions are performed by a variety of ground-based and airborne systems in support of the Wallops Test Range, Earth Science, and U.S. Navy programs. The frequency bands in which these systems operate include UHF and L-, S-, C-, X-, Ku-, and Ka-band. Surveillance and tracking radars provide data for both range safety and customer requirements for missions on the Wallops Test Range. These systems are located on the Main Base, Wallops Mainland, and Wallops Island. The targets that are tracked include aircraft, balloons, drones, LVs, RLVs, satellites, and sounding rockets. Position data are recorded at the radar sites and transmitted to the WFF Range Control Center on the Main Base in real-time in support of mission operations.

#### 2.4.2.6.4 Telemetry

Telemetry systems provide downlink data services from instruments and payloads flying onboard aircraft, balloons, drones, LVs, RLVs, UAS, satellites, and sounding rockets. Telemetry downlink services are available in the following frequency bands: VHF, UHF, L-, S-, and X-band. Uplink data services are also available in the S-band. The WFF fixed telemetry systems are all located in and around Building N-162 and Wallops CDAS on the Main Base. The available NASA systems include antennas with the following diameters: 2.4, 5, 7.3, 8, 9, and 11 m (7.9, 16.4, 24, 26.2, 29.5, and 36 ft, respectively). The available Wallops CDAS systems include antennas with the following diameters: 1.2, 5, 7, 8, 13, 14.2, 16.4, 18 and 26 m (4, 16.4, 23, 26.2, 42.6, 46.6, 53.8, 59, and 85.3 ft, respectively). The telemetry facilities support both range operations and low Earth orbiting satellites. The satellite tracking and data functions are continuous operations (24 hours per day, 365 days per year).

#### 2.4.2.6.5 Optics

WFF's optical, photographic, and video facilities and its radar instrumentation provide a range of services to visually record events for analysis and historical record. Remote-controlled television cameras monitor range operations and provide safety-related information. Tracking cameras with long-range video recording systems provide visual information from remote locations for project and range support.

#### 2.4.2.6.6 Meteorological Support

A fully qualified staff of meteorologists provides detailed local forecasts to support launch and other range activities. Wind data systems are used to support launch operations. Fixed, balloon-borne, and optical sensors are available for coordinating experimental data with existing conditions. Current weather data from WFF weather sensors on the Main Base and Wallops Island are continuously displayed on the local WFF closed-circuit television system. An ionospheric sounding station provides detailed data on ionosphere characteristics. A Dobson $O_3$ spectrophotometer provides total $O_3$ measurements. Balloon-launched radiosondes provide vertical profiles of atmospheric temperature and humidity. Several lightning detection systems display lightning conditions locally and throughout the U.S. An electric field measuring system is used with the lightning detection systems to quantify the probability of both local, naturally occurring lightning and lightning triggered by range operations.

#### 2.4.2.6.7 Command System

A command system allows flight termination and control of an airborne vehicle's onboard experimental devices (e.g., sounding rockets, LVs, balloons, UAS). In the case of rockets and balloons, the WFF Range Safety Officer can terminate flights in the unlikely event that a malfunction presents a safety hazard.

#### 2.4.2.6.8 Range Control

The WFF Range Control Center located on the Main Base controls rocket and drone target launch, tracking and data acquisition operations. It is the focal point for communications, operational management, and range safety. The ATC Operations on the Main Base controls aircraft using the WFF Research Airport. Instantaneous communication with all participants in a mission allows coordination of complex operations.

#### 2.4.2.6.9 Communications Systems

WFF operates space-to-ground, ground-to-ground, air-to-ground, ship-to-shore, and inter-station communications systems. These systems are composed of radios, cables, microwave links, closed-circuit television systems, command and control communication ground stations, frequency shift tone keying systems, high speed data circuits, fiber optics, and the WFF NASA Communications System Network terminal. WFF also makes use of satellite communications and fiber optics. From a cable plant on the Main Base, buried and above ground copper and fiber optic cables extend to and throughout the Main Base, Mainland, and Wallops Island. These systems provide the means for managing operations at WFF and communication and coordination with related operations in other geographic areas; for example, providing communications and tracking support for the ISS. The U.S. Navy's SCSC also operates ship–to-shore and air-to-ground communication systems in support of Fleet operations and RDT&E events in the VACAPES OPAREA.

- **Envelope**: New data and tracking systems implemented at WFF must be within acceptable levels for human exposure to radio frequency electromagnetic fields (3 kilohertz [kHz] to 300 gigahertz) and must be in compliance with IEEE C95.1-2005.
- **Pre and Post 2005 Site-Wide EA NEPA Coverage**: 2004 EA for DD(X) Radar Test Facility at Surface Combat Systems Center; 2009 EA for the Expansion of the WFF Launch Range; 2017 EA for Installation and Operation of Missile Defense Radar AN / SPY-6 at Surface Combat Systems Center.

#### 2.4.2.7 Balloons

The WFF Balloon Program Office conducts several types of balloon operations. The WFF staff manages, engineers, designs, and conducts limited tests for large scientific balloons, which are launched from Palestine, Texas; Fort Sumner, New Mexico; and around the world. Wind conditions must be carefully monitored during science balloon missions in order to keep the large balloon over unpopulated areas. For safety considerations, the majority of these balloons cannot be launched from WFF.

National Weather Service meteorological balloons and small scientific balloons are launched from WFF. The meteorological balloons, which are 600 grams (1.3 lbs) latex balloons with 350 grams (0.8 lbs) radiosonde payloads, are launched twice a day to gather data on the temperature, humidity, and pressure at certain altitudes with typical altitude limit of approximately 30 km (20 mi). These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package. The most common scientific balloon-launched from WFF is a 1,200 gram (2.7 lbs) latex ozonesonde balloon with a 900 gram (2.0 lbs) payload (radiosonde plus an electrochemical concentration cell). At least one balloon is launched per week, with a maximum of three launches per week. One of the largest scientific balloons currently launched from WFF is 3,000 grams (6.6 lbs) ozonesonde balloons with 4.5 kgs (10 lbs) payloads used for science operations. Approximately five of these balloons are launched per year.

- **Envelope**: Meteorological balloons launched cannot exceed 886 each year. Scientific balloons cannot be larger than 1,000,000 cubic meters ($m^3$) (1,307,952 cubic yards [$y^3$]); payloads cannot weigh more than 4,000 kgs (8,000 lbs) per flight.
- **Post 2005 Site-Wide EA NEPA Coverage**: No additional coverage.

#### 2.4.2.8 Autonomous Underwater Vehicles / Autonomous Surface Vehicles

AUVs are small uninhabited submarines used to explore and study deep water and coastal environments. AUVs use single-beam echo sounders and multi-beam sonar units to avoid obstacles. These vehicles can detect a large variety of chemical and biological compounds, and measure and monitor salinity, conductivity, temperature, depth, currents, and small-scale turbulence. ASVs operate at or just below the water surface and are generally used for shallow water surveying. AUVs/ASVs range in size. The largest of these vehicles is the Theseus AUV from International Submarine Engineering, Limited, with a diameter of 1.3 m (4 ft); length of 10 m (35 ft); weight of 8,600 kgs (19,000 lbs); depth of 1,000 m (3,000 ft); and typical speed of 7 km per hour (4 knots).

- **Envelope**: AUVs/ASVs cannot exceed the size and depth capability of International Submarine Engineering, Limited, Theseus vehicle.
- **Post 2005 Site-Wide EA NEPA Coverage**: No additional coverage.

## 2.5 PROPOSED ACTION (PREFERRED ALTERNATIVE)

This section provides a description of the actions that are being evaluated under the Proposed Action. The Proposed Action is NASA's preferred alternative. The full scope of the institutional support projects and operational missions and activities presented under the Proposed Action will be analyzed and compared against existing envelopes of impact (refer to Section 2.3) previously defined in the No Action Alternative (refer to Section 2.4). The majority of projects described in the Proposed Action (Section 2.5) are analyzed as programmatic actions in that they are in various stages of conceptual maturity with varying levels of detail for discussion. Information for these projects is provided in as much detail as is currently available. Future NEPA analysis may be required for all actions that have been analyzed programmatically and for those cases where the impact envelopes established through this PEIS process are exceeded (see Section 2.6).

The Proposed Action would implement all the actions described in the No Action Alternative as well as a number of institutional support projects (i.e., construction, demolition, and RBR) as identified in the 2008 WFF Facility Master Plan (which is currently under review and revision), as well as those institutional support projects identified by WFF tenants and partners, and new or expanded operational missions and activities. The institutional support projects presented in Section 2.5.1 include replacement of the Causeway Bridge, maintenance dredging in the channel between the boat docks at the Main Base and Wallops Island, and development of a deep-water port and operations area on North Wallops Island. Several of the institutional support projects would directly correlate with new operational missions and activities presented in Section 2.5.2. These include the construction and operation of Launch Pad 0-C and Launch Pier 0-D to accommodate larger LVs, smaller launch pads to accommodate DoD initiatives, and construction of a Commercial Space Terminal and extension of Runway 04/22 for horizontal launch and landing vehicles in support of the Expanded Space Program.

Although the Proposed Action includes the implementation of the No Action Alternative, this PEIS analyzes only those impacts from the Proposed Action that are in addition to the impacts of the No Action Alternative. Chapter 5, "Cumulative Impacts" will assess the impacts of the Proposed Action in combination with the impacts attributed to the No Action Alternative and other reasonably foreseeably actions.

### 2.5.1 INSTITUTIONAL SUPPORT PROJECTS

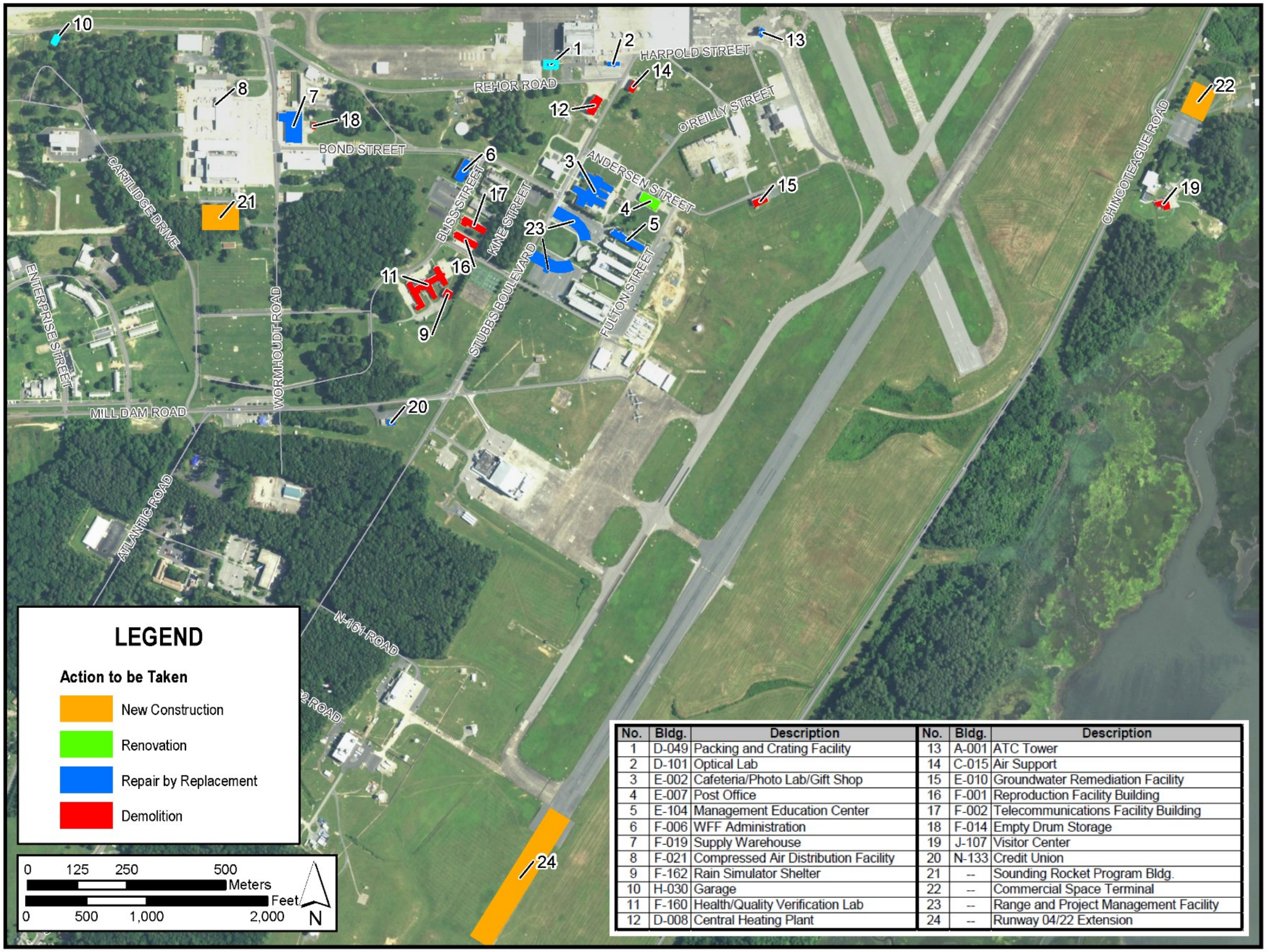
#### 2.5.1.1 Main Base

As identified through the 2008 WFF Facility Master Plan, **Table 2.5-1** provides planned construction and demolition projects at the Main Base under the Proposed Action. A description of the Commercial Space Terminal and Runway 04/22 extension is provided following **Table 2.5-1**. **Figure 2.5-1** shows the

**Table 2.5-1. Construction, Demolition, and RBR Projects at Main Base**

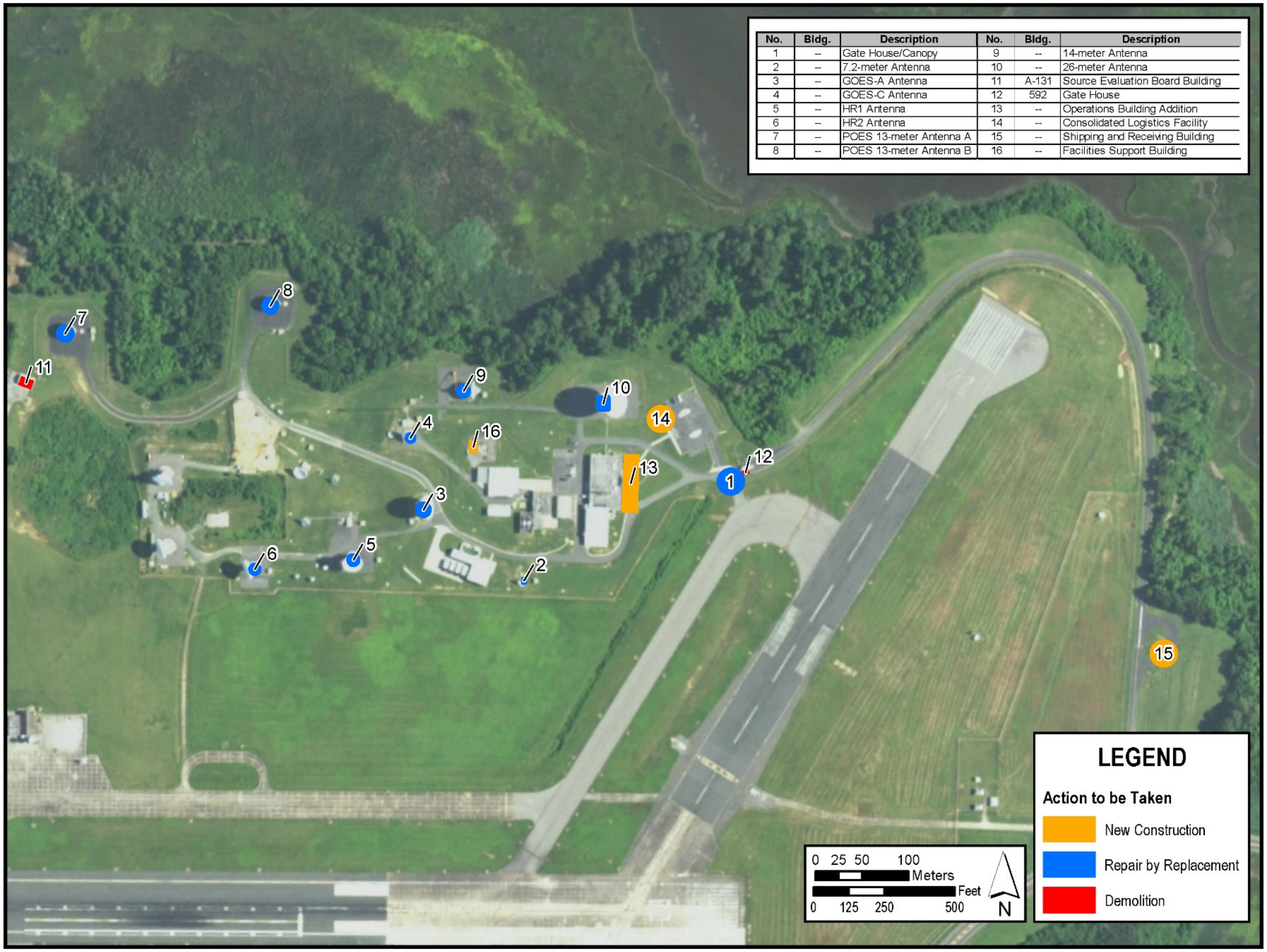
| Projects | Building Number | $m^2$ ($ft^2$) | Action to be Taken | Anticipated FY |
|---|---|---|---|---|
| **Main Base Projects** | | | | |
| Commercial Space Terminal | NA | 3,250 (35,000) | New | TBD |
| Runway 04/22 Extension | NA | 17,420 (187,500) | New | TBD |
| Sounding Rocket Program Building | NA | 1,860 (20,000) | New | TBD |
| Range and Project Management Facility | NA | 6,040 (65,000) | RBR | 20 |
| Consolidated Laboratories | NA | 1,115 (12,000) | RBR | 20 |
| New ATC Tower | NA | TBD | RBR | TBD |
| Central Heating Plant | D-008 | 663 (7,137) | Demo | 18 – 19 |
| Health/Quality Verification Lab | F-160 | 2,075 (22,337) | Demo | 22 |
| ATC Tower | A-001 | 393 (4,232 | Demo | TBD |
| Source Evaluation Board Building | A-131 | 82 (882) | Demo | TBD |
| Air Support | C-015 | 473 (5,097) | Demo | TBD |
| Packing and Crating Facility | D-049 | 300 (3,200) | Demo | TBD |
| Optical Lab | D-101 | 195 (2,100) | Demo | TBD |
| Cafeteria/Photo Lab/Gift Shop | E-002 | 2,235 (30,520) | Demo | TBD |
| Post Office | E-007 | 734 (7,902) | Demo | TBD |
| Groundwater Remediation Facility | E-010 | 363 (3,909) | Demo | TBD |
| Management Education Center | E-104 | 3,250 (35,000) | Demo | TBD |
| Reproduction Facility Building | F-001 | 551 (5,940) | Demo | TBD |
| Telecommunications Facility Building | F-002 | 603 (6,495) | Demo | TBD |
| WFF Administration | F-006 | 1,360 (14,613) | Demo | TBD |
| Empty Drum Storage | F-014 | 89 (960) | Demo | TBD |
| Supply Warehouse | F-019 | 2,080 (22,400) | Demo | TBD |
| Compressed Air Distribution Facility | F-021 | 10 (110) | Demo | TBD |
| Rain Simulator Shelter | F-162 | 232 (2,500) | Demo | TBD |
| Garage | H-030 | 192 (2,068) | Demo | TBD |
| Visitors Center | J-017 | 346 (3,728) | Demo | TBD |
| Credit Union | N-133 | 134 (1,446) | Demo | TBD |
| **NOAA Projects** | | | | |
| Facilities Support Building | NA | 110 (1,200) | New | 25 |
| Consolidated Logistics Facility | NA | 466 (5,000) | New | TBD |
| Gate House | NA | 11 (120) | New | TBD |
| Gate House Canopy | NA | 100 (1,100) | New | 21 |
| Operations Building Addition | NA | 350 (3,800) | New | TBD |
| Shipping and Receiving Building | NA | 557 (6,000) | New | TBD |
| Repair Roads and Parking Pavement | NA | 3,925 (42,240) | RBR | 18-22 |
| Replace Fencing | NA | 1,370 m (4,500 ft) | RBR | 20-24 |
| Antennas (9) | NA | TBD | RBR | TBD |

Note: Highlighted projects are further defined below.
Legend: FY = fiscal year; NA = Not Available; TBD = to be determined.




| No. | Bldg. | Description | No. | Bldg. | Description |
|---|---|---|---|---|---|
| 1 | D-049 | Packing and Crating Facility | 13 | A-001 | ATC Tower |
| 2 | D-101 | Optical Lab | 14 | C-015 | Air Support |
| 3 | E-002 | Cafeteria/Photo Lab/Gift Shop | 15 | E-010 | Groundwater Remediation Facility |
| 4 | E-007 | Post Office | 16 | F-001 | Reproduction Facility Building |
| 5 | E-104 | Management Education Center | 17 | F-002 | Telecommunications Facility Building |
| 6 | F-006 | WFF Administration | 18 | F-014 | Empty Drum Storage |
| 7 | F-019 | Supply Warehouse | 19 | J-107 | Visitor Center |
| 8 | F-021 | Compressed Air Distribution Facility | 20 | N-133 | Credit Union |
| 9 | F-162 | Rain Simulator Shelter | 21 | -- | Sounding Rocket Program Bldg. |
| 10 | H-030 | Garage | 22 | -- | Commercial Space Terminal |
| 11 | F-160 | Health/Quality Verification Lab | 23 | -- | Range and Project Management Facility |
| 12 | D-008 | Central Heating Plant | 24 | -- | Runway 04/22 Extension |

**Figure 2.5-1. Main Base Construction, Demolition, and RBR Locations**




| No. | Bldg. | Description | No. | Bldg. | Description |
|---|---|---|---|---|---|
| 1 | -- | Gate House/Canopy | 9 | -- | 14-meter Antenna |
| 2 | -- | 7.2-meter Antenna | 10 | -- | 26-meter Antenna |
| 3 | -- | GOES-A Antenna | 11 | A-131 | Source Evaluation Board Building |
| 4 | -- | GOES-C Antenna | 12 | 592 | Gate House |
| 5 | -- | HR1 Antenna | 13 | -- | Operations Building Addition |
| 6 | -- | HR2 Antenna | 14 | -- | Consolidated Logistics Facility |
| 7 | -- | POES 13-meter Antenna A | 15 | -- | Shipping and Receiving Building |
| 8 | -- | POES 13-meter Antenna B | 16 | -- | Facilities Support Building |

**Figure 2.5-2. Main Base Construction, Demolition, and RBR Locations**

location of proposed WFF construction and demolition projects on the Main Base. NOAA has identified several planned construction projects at the Main Base and these projects are also included in **Table 2.5-1** and shown on **Figure 2.5-2**.

The 2008 WFF Facility Master Plan includes RBR projects, demolition of several of the engineering buildings, and construction of new facilities. The primary purpose of the 2008 WFF Facility Master Plan is to consolidate personnel into a core area. The plan suggests four new office buildings: a range management facility, a consolidated program support facility, an institutional support building, and a currently unspecified program building. The 2008 WFF Facility Master Plan also includes the construction of an approximately 4,000 $m^2$ (43,000 square foot [$ft^2$]) office facility to accommodate WFF Range and Project Management personnel currently occupying E-106, E-107, and F-006. When completed, the building would provide space for various WFF departments.

**Commercial Space Terminal**

To accommodate the possibility of WFF hosting commercial partners whose missions focus on sending civilian scientists into space on commercial vehicles, a terminal may be located on the east side of the WFF airfield (refer to **Figure 2.5-1**). The Commercial Space Terminal would measure approximately 3,250 $m^2$ (35,000 $ft^2$) and may include lodging, dining areas, and training facilities such as pools, classroom space, mission specific training equipment, and other required facilities. Operational aspects of the terminal are not known at this time; however, if the terminal should support FAA-licensed vehicle operations, the operating entity (e.g., Virginia Space) may need to acquire a new FAA Launch Site Operator License.

**Runway 04/22 Extension**

Main Base Runway 04/22 currently measures 8,750 ft long and 150 ft wide (refer to **Figure 2.5-1**) and includes an arrestor system. This mechanical system is used to rapidly decelerate an aircraft as it lands. To accommodate horizontal launch and landing vehicles, Runway 04/22 would be lengthened to add an additional 1,250 ft to the runway surface. The completed runway would measure 10,000 ft long by 150 ft wide.

#### 2.5.1.2 Mainland and Wallops Island

**Table 2.5-2** provides planned construction and demolition projects at the Mainland and Wallops Island under the Proposed Action. **Figure 2.5-3** provides an overview of these projects. Projects on the Mainland and south end of the Island are featured on **Figure 2.5-4**; projects on the north end of the Island are featured on **Figure 2.5-5**; and the full extent of the Maintenance Dredging project and North Wallops Island Deep-water Port and Operations Area are illustrated on **Figure 2.5-6** and **Figure 2.5-7**, respectively.

**Table 2.5-2. Construction, Demolition, and RBR Projects at Mainland and Wallops Island**

| Construction Projects | Building Number | m² (ft²) | Action to be Taken | Anticipated FY |
|---|---|---|---|---|
| **Mainland and Wallops Island Projects** | | | | |
| Causeway Bridge Replacement | NA | 6,500 (70,000) | RBR | 23 – 25 |
| Maintenance Dredging | NA | 530,980 (5,715,400) | Infrastructure | 19 – 23 |
| AN FSP-16 Radar Station | Y-055 | 326 (3,510) | Demo | 19 |
| Sewer Ejector Station | Y-061 | 18 (195) | Demo | 19 |
| Storm Drainage Pump | Y-046 | 4 (48) | Demo | 19 – 23 |
| Rocket Flight Hardware Storage | Y-050 | 90 (955) | Demo | 19 – 23 |
| Fire Pump House | X-091 | 22 (235) | Demo | 19 – 23 |
| Former Coast Guard Station | V-065 | 384 (4,140) | Demo | 19 – 23 |
| Rocket Motor Storage Facility | V-067 | 761 (8,200) | Demo | 19 – 23 |
| Fire Department Support Building | X-005 | 95 (1,024 | Demo | 19 – 23 |
| Paint Shop | X-030 | 223 (2,410) | Demo | 19 – 23 |
| Paint Shop Storage | X-036 | 39 (422) | Demo | 19 – 23 |
| Electrical Storage Building | X-140 | 93 (1,000) | Demo | 19 – 23 |
| NSEC Performance Test Facility | Z-041 | 1,080 (11,617) | Demo | 19 – 23 |
| Block House 1 | Z-065 | 306 (3,300) | Demo | 19 – 23 |
| Moveable Launch Shelter Building | Z-071 | 175 (1,890) | Demo | 19 – 23 |
| Launch Control Building | Z-072 | 22 (240) | Demo | 19 – 23 |
| Block House 3 | W-020 | 1,939 (20,872) | Demo | TBD |
| Terminal Cubicle | W-049 | 9 (97) | Demo | TBD |
| Cable Terminal | W-050 | 50 (541) | Demo | TBD |
| Fuel Storage Magazine | Y-010 | 156 (1,681) | Demo | TBD |
| Island Radar Control Building | Y-060 | 325 (3,503) | Demo | TBD |
| Camera Stand | Z-100 | 37 (400) | Demo | TBD |
| **Navy Projects** | | | | |
| DoD SM-3 Vertical Launch System Pad** | NA | 10 (105) | New | TBD |
| DoD ESSM Launch System Pad and Blockhouse** | NA | 1,860 (20,000) | New | TBD |
| Sensor Test Site | V-95 | (5,000) | Renovate | 2018 |
| Radar and Computer Facility (Aegis)** | NA | 1,115 (12,000) | New | TBD |
| Navy Support Facility** | U-090 | 557 (6,000) | Renovate* | TBD |
| Ship Self-Defense System Addition** | V-024 | TBD | New | TBD |
| Building Renovation/Power Upgrade with New Reliability Rotary UPS/Generator | V-10 | 1,860 (20,000) | Renovate/ New | TBD |
| **MARS Projects** | | | | |
| North Wallops Island Deep-water Port and Operations Area* | NA | TBD | New | TBD |
| LV Launch Pad 0-C | NA | 12,870 (138,500) | New | TBD |
| LV Launch Pier 0-D* | NA | TBD | New | TBD |
| LV Project Support Building | NA | TBD | New | TBD |
| LV Processing Facility | NA | TBD | New | TBD |

Notes: Highlighted projects are further defined below.

*These projects are included in this PEIS for long-term planning purposes only and does not commit NASA or MARS to funding these projects in the future.

**These Navy projects are included in this PEIS for long-term planning purposes only and does not commit the Navy to funding these projects in the future.

Legend: FY = fiscal year; NA = Not Available; TBD = to be determined; SM-3 = Standard Missile-3; ESSM = Evolved Sea Sparrow Missile; UPS = uninterruptible power source.

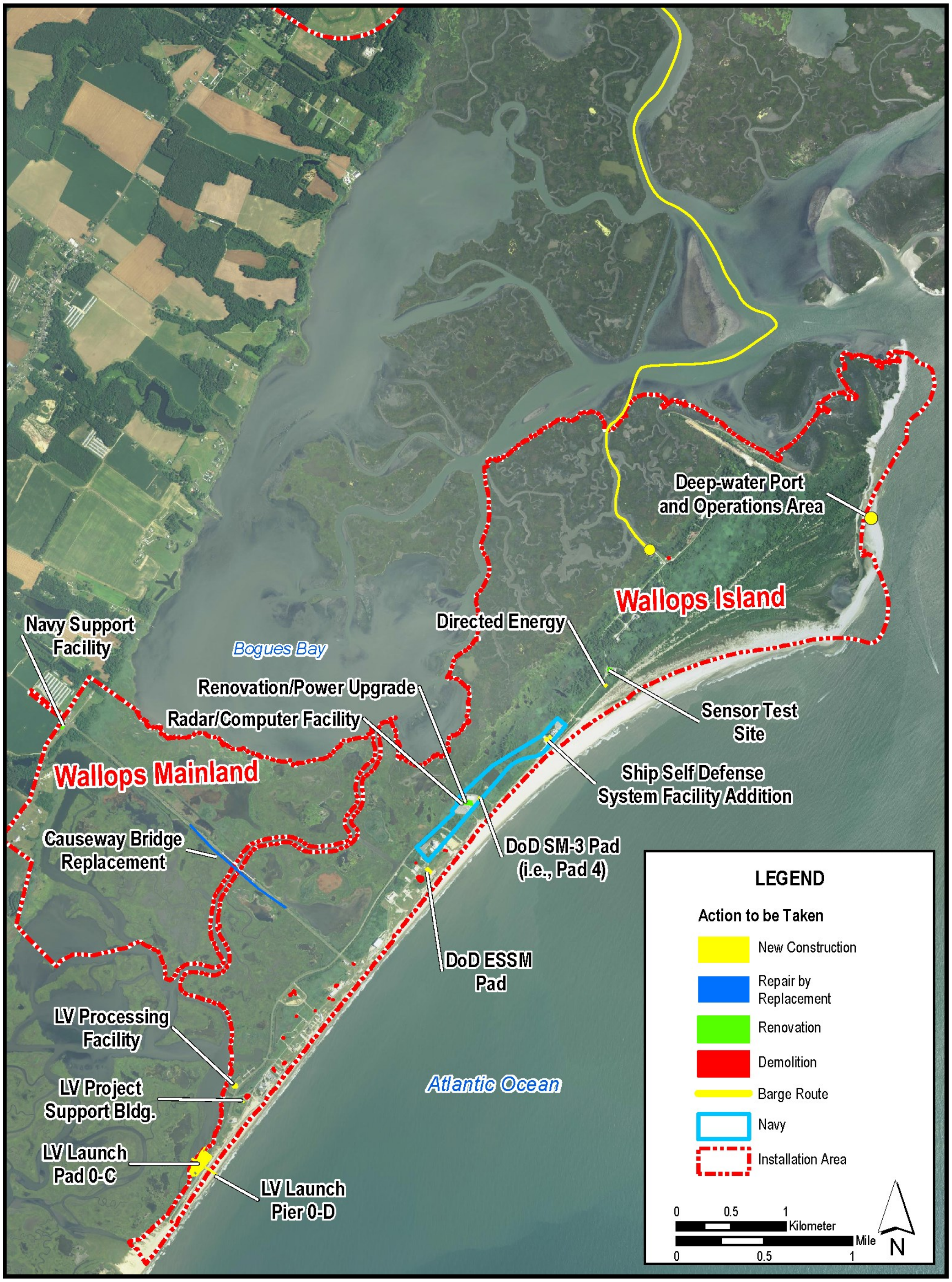



**Figure 2.5-3. Mainland and Wallops Island Construction, Demolition, and RBR Locations - Overview**

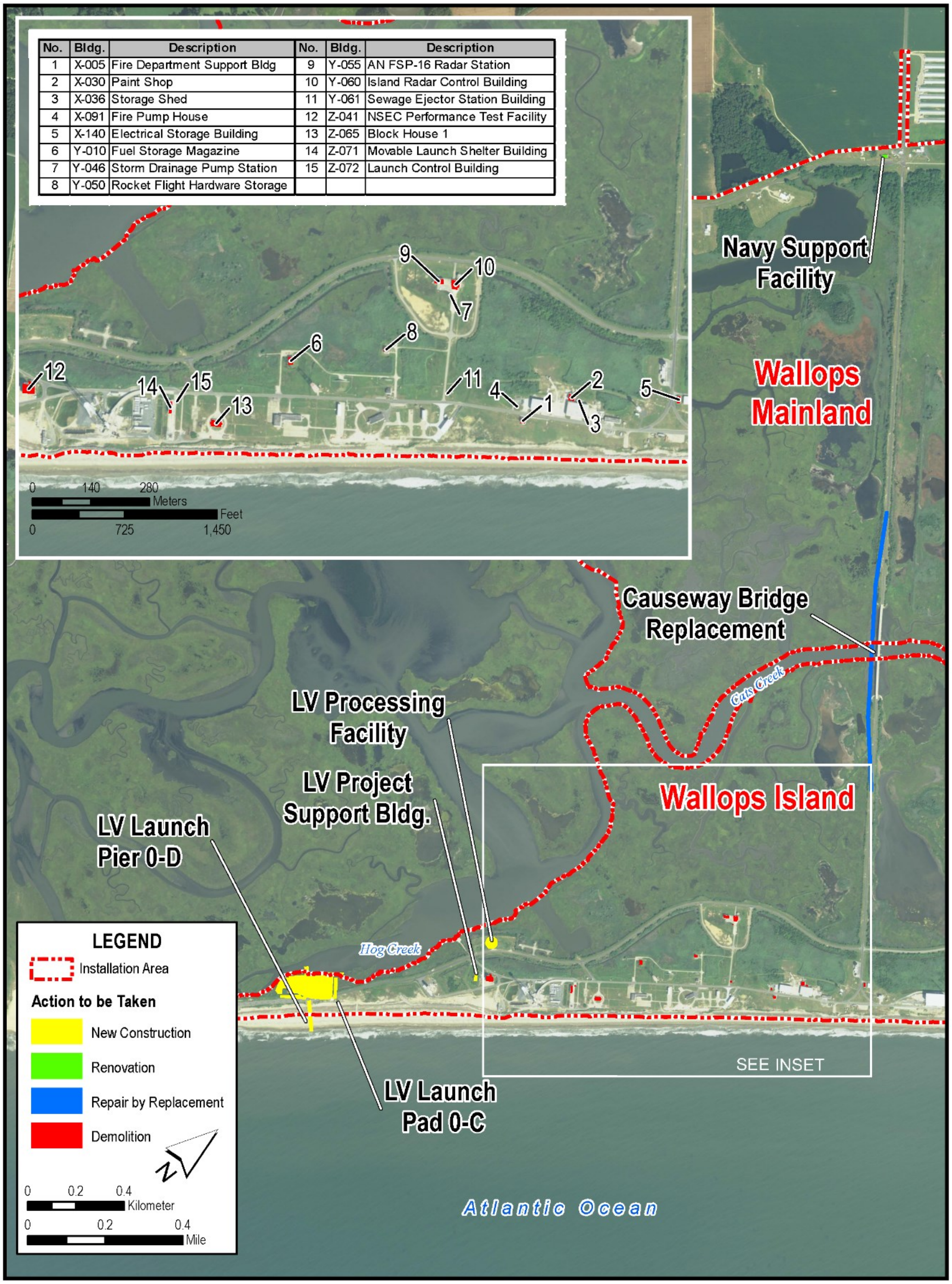



**Figure 2.5-4. Mainland and South Wallops Island Construction, Demolition, and RBR Locations**

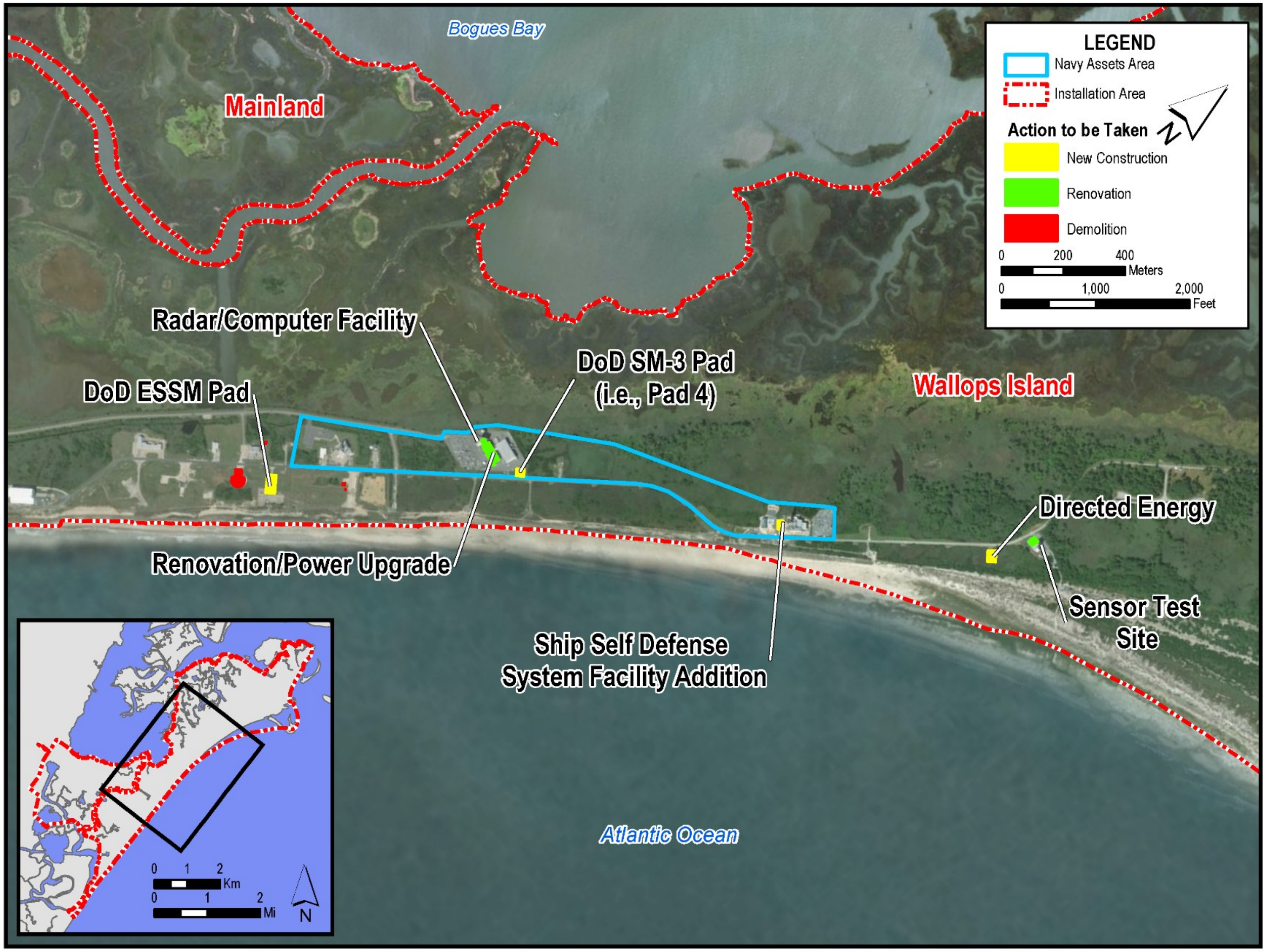



**Figure 2.5-5. North Wallops Island Construction and Demolition Locations**

**Causeway Bridge Replacement**

**Background on Proposal**

**Causeway Bridge**

The Causeway Bridge is over 50 years old (circa 1960), at the end of its design life, and is showing signs of accelerated deterioration of the bridge components. Even with ongoing biennial maintenance and repairs to the bridge, a 2010 study described a significant risk to the mission of the MARS if superstructure replacement or complete bridge replacement is not considered within the next 10 years. The amount of vehicular traffic, the size of transport trucks, and the frequency of "super-loads" crossing the bridge has increased significantly in the last decade.

**Description of the Proposed Action**

A new bridge would be constructed parallel to the existing bridge, using the same Wallops Island causeway road for ingress and egress. NASA and FHWA (2018) conducted a value analysis study for design of the new bridge that considered various design concepts and two bridge height profiles: high and low. The study yielded that the preferred alternative would be a low profile, precast concrete pre-stressed bulb-T bridge with 46 m (150 ft) long spans. While this is the preferred bridge design concept, the U.S. Coast Guard would determine the vertical and horizontal clearance of the new bridge and impose any necessary conditions relating to the construction, maintenance, and operation of the bridge that would be in the interest of public navigation. Construction of the new Causeway Bridge would be anticipated to occur from 2023-2025. Once the construction and transfer of utilities to the new bridge is complete and the bridge is fully operational and open to traffic, the existing bridge would be demolished; dismantling and removal would take approximately 9 months to complete. The amount of demolition debris generated would be approximately 18,000 metric tons (20,000 tons). Following Leadership in Environmental and Energy Design principles instituted at WFF, the demolition debris would be segregated into usable and non-reusable components. Concrete piles or pieces of concrete debris created during removal of the bridge and support piles would be loaded onto a barge, brought to shore, transferred to a dump truck, and hauled either to an onsite stockpile area or directly to a recycling facility. Materials determined not recyclable or reusable would be properly disposed of at an approved landfill consistent with local, state, and federal regulations.

There are two methods of bridge construction that could be used for this bridge replacement: Top-Down Method or the Temporary Trestle Method. With the Top-Down Method, the approach would be to install sediment and erosion control measures before beginning construction. Clearing of brush for the temporary construction laydown areas proximal to either end of the existing bridge would take place. The cleared vegetation would be transferred to an approved landfill for disposal. Subgrade excavation would be required to remove unsuitable soils if they exist and placement of subgrade foundation rock for footings and ramps on either side of the waterway would occur. Earth-moving equipment would be needed to establish new grades leading to the on-ramp for each end of the Causeway Bridge. With the Top-Down Method, bridge segments would be built in stages. As each new section is completed that section would then be used to extend out for construction of the next new section. This approach could be used starting at one end and building across the waterway to the other side or construction could begin on both sides and meet in the middle. The other type of bridge construction that could be used, the Temporary Trestle Method, follows the same initial approach for temporary laydown clearing, subgrade work, and grading for the on-ramps but a temporary trestle would be constructed from which the cranes and other equipment would be placed to build a new bridge adjacent to the trestle. The trestle would be supported by temporary piles driven in the ground to support the trestle network. Once the new Causeway Bridge was completed, the temporary trestle and supporting temporary piles would be removed. Restoration of wetlands that may have been temporarily impacted by the trestle construction may be required. Under an environmentally worst-case scenario, the construction design could call for a temporary earthen causeway into the marsh to begin construction of the trestle system.

Erosion control measures would be implemented following the guidelines found in VDEQ's-approved BMPs and design information presented in its *Virginia Erosion and Sediment Control Field Manual*. The manual includes 19 minimum standards required by Virginia law for projects having erosion and sediment control measures and includes a "Minimum Standards Quick Reference Checklist" that inspectors for the project must complete during construction. These standards include detailed design criteria for road stabilization, sediment barriers, dike and diversions details, sediment trap and basin design, flume design to control erosion, waterway and outlet protection measures, stream protection designs, site preparation for vegetation establishment, grass establishment designs, and mulching techniques.

In addition to the VDEQ standards, the Causeway Bridge Replacement project would follow the guidelines found in the FHWA's Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects FP-14 manual. This is a very detailed manual that covers a wide range of elements for roadway and bridge design and construction. Within this manual, Division 550 addresses detailed design and permanent construction considerations for Bridge Construction. This section addresses various support piles that could be used in bridge design, structural and pre-stressed concrete considerations, paint and painting, waterproofing, removal of concrete by hydro-demolition, concrete overlays for bridge decks, and structural concrete injection and crack repair, among many other topics. Division 250 addresses slope re-enforcement and retaining walls, use of riprap, rock embankments and buttresses, and reinforced retaining walls. Division 200 addresses "Earthwork" in general but has specific guidelines with respect to structural excavation and backfill for major structures. In the demolition of the old bridge structure, it is possible that cofferdams would be used to drive sheet walls around the base support structures which would allow the inner surrounding area to be dewatered to enable demolition of the structure. Another option would be to cut the support pilings in place several feet below the water bottom. Division 700 covers the broad topic of "Material" for bridge design and construction. This section provides detailed instruction on the appropriate American Society for Testing and Materials and American Association of State Highway and Transportation Officials materials standards for the design and construction of bridges. Examples of materials covered in this section include cement, asphalts, aggregate materials, types of pipes, curing and admixture materials, sealants and joint materials, geosynthetic materials appropriate for bridge construction, permanent anchoring materials, as well as epoxies, resins, adhesives, and penetrating staining paints.

The Causeway Bridge Replacement project is in the very early stage of development. A notional evaluation is presented. As project planning and design details became more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts. Additional analyses may involve:

- construction noise and traffic impacts,
- assessment of proposed construction staging and/or stockpile areas,
- assessment of proposed dredged material upland placement sites,
- characterization and placement of the materials dredged during the demolition and construction phases, and
- other environmental impacts such as wetland, water quality, private oyster leases, public shellfish grounds, Essential Fish Habitat (EFH), and listed species impacts.

<ins>**Maintenance Dredging**</ins>

**Background on Proposal**

**Transport Barge**

There are two existing boat docking facilities at WFF. One is a 98 $m^2$ (1,055 $ft^2$) concrete platform at the boat basin behind the WFF Visitor Center on the Main Base. The other boat docking facility is the same size and is located at the boat basin on North Wallops Island. **Figure 2.5-6** provides the location for each boat dock. These facilities are utilized for docking and unloading cargo that is too large (e.g. wide, long, or heavy) for transport between the Main Base and Mainland/Wallops Island via local roads or the Causeway Bridge. The existing approach channel and basin area on the north end of Wallops Island (labeled as "Maintained Barge Route" on **Figure 2.5-6**) is dredged as needed to maintain a water depth of at least 1.2 m (4 ft) at low tide. Adequate water depths in the Main Base approach channel and boat basin have historically precluded the need to perform maintenance dredging at this facility (NASA 2009). Long-term sedimentation of the channel from the Main Base Visitor Center to the Wallops Island boat basin dictates the need for maintenance dredging to support the transfer of cargo that is too large for overland transport between the Main Base and Mainland/Wallops Island.

**Description of Proposed Action**

Maintenance dredging of the entire Barge Route from the Main Base Visitor Center to the North Wallops Island boat basin may involve the use of either a mechanical (e.g., clamshell bucket) and/or a hydraulic (e.g., pipeline/cutterhead) dredge with upland placement of the dredged material. The same method of maintenance dredging would be used for the southern barge basin on the north end of Wallops Island. The entire length of the maintained barge channel is 10.8 km (6.7 mi) although naturally deep water occurs within several reaches of the channel. The maintenance dredging would re-establish a safe navigation channel which supports a channel depth of -2.4 m (-8 ft) Mean Lower Low Water (MLLW) having 3:1 side slopes with a minimum channel width of 50 m (160 ft). This channel depth and width would support barges having a dimension of 11 by 60 m (35 by 195 ft) that would be large enough to carry LV rocket motors. Tugboats needed to steer the barges would draft less than 2 m (7 ft).

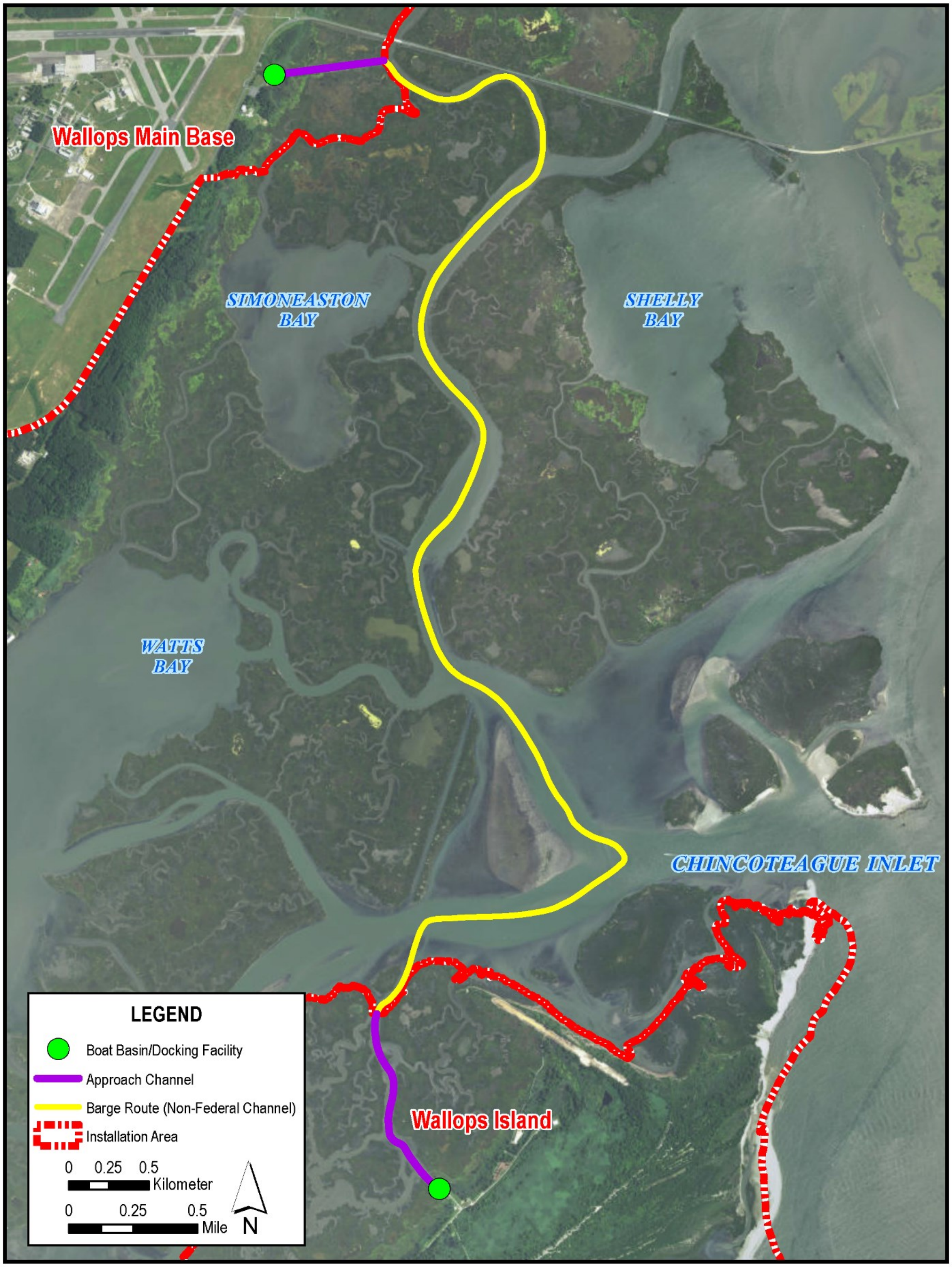



**Figure 2.5-6. Location of Boat Docks and Areas to be Maintained**

Based upon previous review of the dredged sediments by NASA, the dredged material from the barge basins and entrance channels leading to these basins is expected to be mostly silty material unsuitable for reuse or placement on nearby beaches.

The general areas where maintenance dredging is expected to occur is shown on **Figure 2.5-6**. The exact locations for the placement of the dredged materials would be determined in the future. For purposes of this PEIS, two upland material transfer sites, each adjacent to the existing north and south barge basins, would be located as shown on **Figure 3.5-8** and **Figure 3.5-10** in Section 3.5, Water Resources and discussed in detail in that section. It is anticipated that these sites would not be permanent confined disposal facilities but would be in place to temporarily hold and dewater dredged materials from the barge basins and the entrance channels to them.

The excavated materials could then be trucked out of the area for either storage at another upland location on WFF for reuse or disposal at an approved landfill. Although a majority of the dredge material is not likely suitable directly for beneficial reuse, it is possible that blending of this dredge material with other more coarse materials may render the final blended material useful to construction or as landfill cover.

Another potential method of handling the dredge material would involve the direct placement of the material into lined, sealed dump trucks that would remove the material and dispose of it either in an approved landfill or be beneficially reused at WFF. It may be possible to stockpile the dredged material on the WFF Mainland for use in construction of the Causeway Bridge Replacement project if the material is suitable either directly or through blending with other soil and that the material is available in advance of the replacement bridge construction. Once the maintenance dredging is complete, the berms used to contain the dredge material could be removed until the next maintenance dredging cycle or left in place.

Although not planned at this time, the use of thin layer deposition of dredged material in open shallow water has been used in the past as a beneficial reuse of dredged material to convert open water shallow areas into salt water marshlands. If this were an acceptable means of reuse, WFF would consult with the natural resource agencies (e.g., EPA and USACE); further NEPA analysis would be prepared to assess the environmental impacts of this method of reuse and disposal.

Soundings along the Maintained Barge Route indicate that shoaling has occurred at the north end of the entrance channel to the south barge basin. Due to current velocities and proximity to the open ocean, it is possible that this material may be suitable for beach renourishment. Depending on the availability of the equipment, exact amount of shoal material to be removed, and the cost for removal, it is reasonably conceivable for long-term planning purposes that a hydraulic pipeline dredge could be used to remove shoaling in this area and place it on the beach in a manner consistent with the activities described in the SRIPP PEIS (NASA 2010).

For all of the dredging currently anticipated, it is estimated that approximately 380,000 $m^3$ (500,000 $y^3$) of material would be removed over an extended period of time. The extended period of time to perform this dredging is due to the lack of sufficiently large existing or expected upland storage capacity. It is anticipated that the dredging would begin in 2019 and would take place over a series of dredging events, several weeks each, to complete.

The maintenance dredging project is in the very early stage of development. A notional evaluation is presented. As project planning and design details became more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts. Additional analyses may involve:

- assessment of proposed construction staging and/or stockpile areas,
- assessment of each proposed dredging method,
- characterization of the materials to be dredged during any construction dredging,
- assessment of proposed dredged material upland placement site alternatives once the dredge volumes and expected maintenance volumes are predicted, and
- other environmental impacts such as wetland, water quality, private oyster leases, public shellfish grounds, EFH, and listed species impacts.

**North Wallops Island Deep-water Port and Operations Area**

**Background on Proposal**

Development of a deep-water port and operations area is under consideration for the north end of Wallops Island. This deep-water port would provide barge access and berthing via a new dock to offload large launch vehicle components and related equipment. Future vessels using the deep-water port would be expected to require 3.5 – 4.5 m (12 – 15-ft) MLLW drafts. The port facility would provide dedicated spaces for work, lab, and storage.

The deep-water port and operations area would also support AUV/ASV testing and operational capabilities for the U.S. Coast Guard, Navy, NOAA, and other customers. Operating these vehicles from the deep-water port would permit direct access to the Navy's offshore test range via the USACE maintained dredge route. Utilities at the site of the port facility would include potable water and sanitary sewer, electricity, water, and a high speed fiber optic network with some classified capability. These utilities would tie in with those of the North Wallops Island UAS airstrip.

**Description of the Proposed Action**

Three notional pathways are being considered for the deep-water port and access to it (**Figure 2.5-7**).

**Port Path 1** would have direct access to the ocean, with future access roads placed in the adjacent uplands to connect to all points south on Wallops Island. Essentially, this deep-water port option would involve a substantial pile-supported concrete berthing structure in the Atlantic Ocean at the north end of Wallops Island. This port location alternative has the least wetland impact and the least amount of construction and future maintenance dredging of the three alternatives, but is the most exposed to ocean wind and surf. There is currently no available survey data that describes the actual depths in the nearshore area where the deep-water port might be placed. Such survey data and additional level of impact investigation would occur at a later date if the deep-water port is pursued further at this location. **Figure 2.5-8** shows the locations of the federal channels in the vicinity of WFF. Chincoteague Inlet has an entrance channel depth of 3.5 m (12 ft) and a 61 m (200 ft) width. The Chincoteague Inner Channel authorized depth is 3 m (9 ft) deep with a 18 m (60 ft) width. The U.S. Army Corps of Engineers maintains the Chincoteague Harbor of Refuge to its federally-authorized 2.5 m (8 ft) project depth and a 18 m (60 ft) project width.

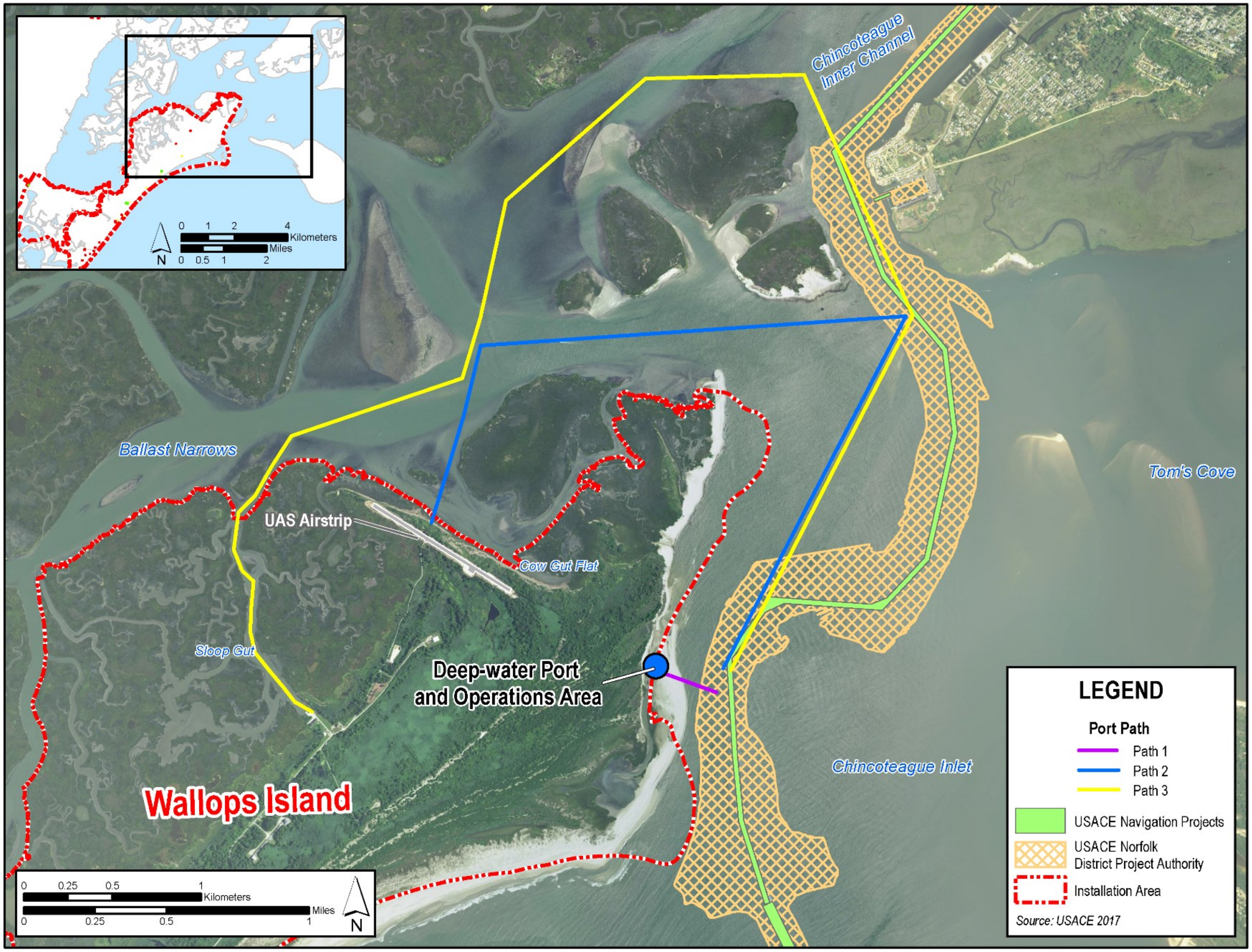
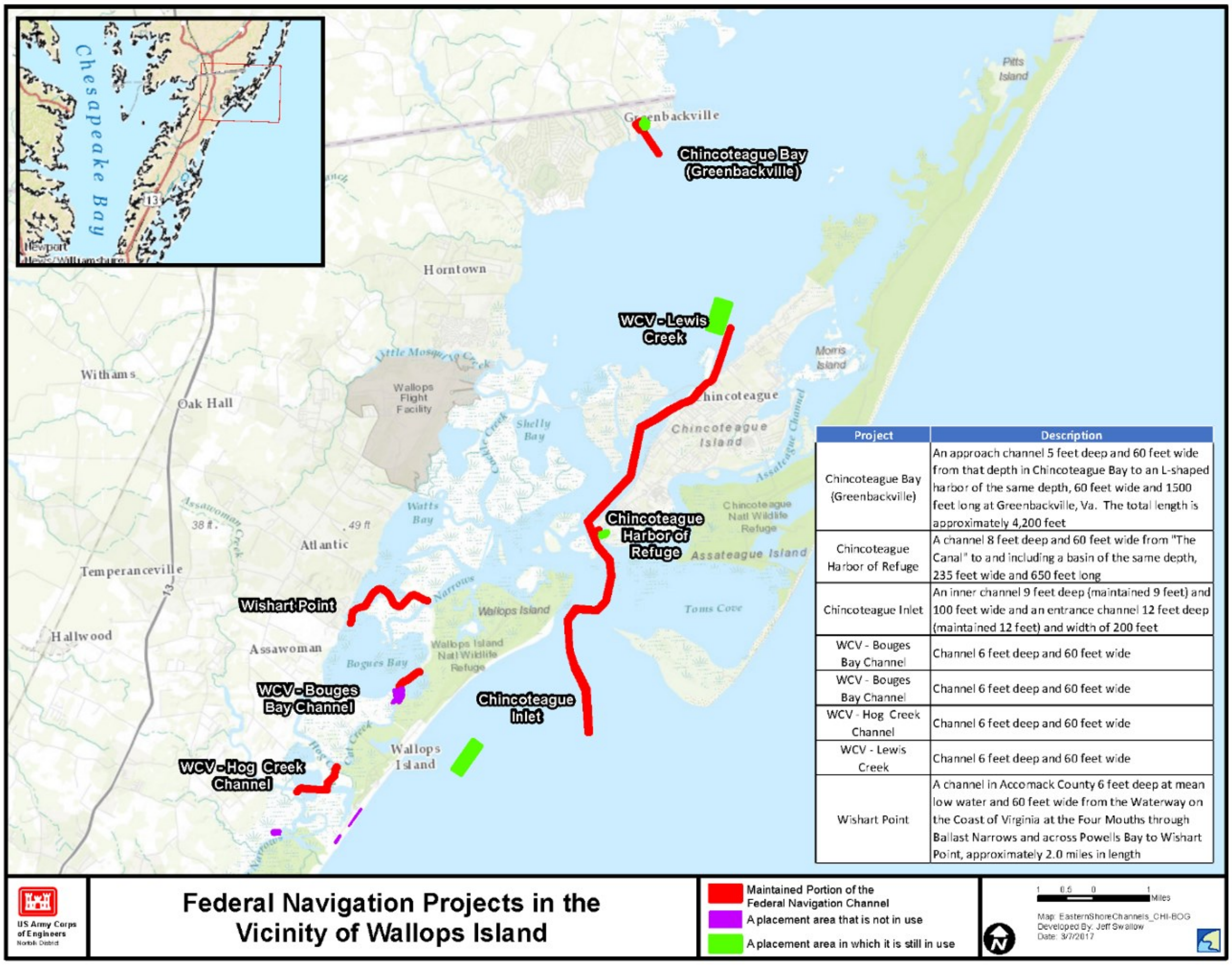



**Figure 2.5-7. Location of North Wallops Island Deep-water Port and Operations Area**




| Project | Description |
|---|---|
| Chincoteague Bay (Greenbackville) | An approach channel 5 feet deep and 60 feet wide from that depth in Chincoteague Bay to an L-shaped harbor of the same depth, 60 feet wide and 1500 feet long at Greenbackville, Va. The total length is approximately 4,200 feet |
| Chincoteague Harbor of Refuge | A channel 8 feet deep and 60 feet wide from "The Canal" to and including a basin of the same depth, 235 feet wide and 650 feet long |
| Chincoteague Inlet | An inner channel 9 feet deep (maintained 9 feet) and 100 feet wide and an entrance channel 12 feet deep (maintained 12 feet) and width of 200 feet |
| WCV - Bouges Bay Channel | Channel 6 feet deep and 60 feet wide |
| WCV - Bouges Bay Channel | Channel 6 feet deep and 60 feet wide |
| WCV - Hog Creek Channel | Channel 6 feet deep and 60 feet wide |
| WCV - Lewis Creek | Channel 6 feet deep and 60 feet wide |
| Wishart Point | A channel in Accomack County 6 feet deep at mean low water and 60 feet wide from the Waterway on the Coast of Virginia at the Four Mouths through Ballast Narrows and across Powells Bay to Wishart Point, approximately 2.0 miles in length |

**Figure 2.5-8. Federal Channels in the Vicinity of Wallops Flight Facility**

**Port Path 2** would follow the existing Chincoteague Inlet Entrance Channel through the lower portion of the Chincoteague Harbor of Refuge channel through a portion of Ballast Narrows and terminate at Cow Gut Flat. There is no existing federal channel in the area from Ballast Narrows to Cow Gut Flat. No soundings are currently available in the vicinity of Cow Gut Flat, but the waters approaching Cow Gut Flat are expected to be relatively shallow and construction dredging would be required. Without the soundings, it is not possible to provide an estimate of the amount of dredged material that would be required to support this alternative. Limited wetland impacts would occur along the north face of Cow Gut Flat by the construction of a barge berth to offload deliverables at the Port Path 2 landside terminus.

The benefits of this location are that it is shielded from direct exposure to the east and northeast winds and ocean surf. A surficial review of historical aerials of Cow Gut Flat shows it to be a relatively stable land mass compared to other locations north of it and south of Chincoteague Inlet.

**Port Path 3** would follow the same initial access route as Port Path 2 except that it would loop north and counter-clockwise around the cluster of existing unnamed islands adjacent to Chincoteague Inlet and terminate farther south in a narrow open water course in Sloop Gut. Port Path 3 would connect to the existing offloading platform as shown in **Figure 2.5-8**. With the exception of the initial entrance from the ocean via Chincoteague Inlet, the majority of this pathway does not involve an existing federal channel.

Due to its narrow configuration, a new navigational channel wide enough to support MLLW drafts of 3.5 – 4.5 m (12 – 15-ft) would result in substantial wetland and habitat impacts in Sloop Gut. Similar to Port Path 2, Port Path 3 is shielded from direct exposure to the east and northeast winds and ocean surf. Currently no soundings are available in Sloop Gut. Construction dredging for Port Path 3 would be required. The utility of the existing offloading platform for larger draft barges would also have to be reviewed during a later planning/NEPA phase.

Future Congressional action would be required to increase the authorized federal channel dimensions and segments to match any of the three port paths under consideration by WFF for the Corps to be able to maintain the deeper depths as part of its maintenance dredging program. An increase in project depth would also result in the need for an increase in project width due to the angle of the side slopes associated with navigational channels.

If Congress does not authorize the increase in depths and widths of the federal channel and authorize a new federal channel segment from Chincoteague Inlet to Cow Gut Flat or the terminus of Port Path 3, NASA WFF would be required to obtain the necessary permits for the construction and maintenance dredging of the deeper and wider channels and pay for the additional costs of the dredging beyond that federally authorized.

The dock area for barge access and berthing from the port would be constructed in a manner similar to the Top-Down Method described for the Causeway Bridge Replacement during which dock segments and support pilings would be built in stages. As each new section is completed, that section would then be used to extend out for construction of the next new section.

The North Wallops Island Deep-water Port and Operations Area project and the associated notional pathways are in the very early stages of development. A notional evaluation is presented. As project planning and design details become more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts. Additional analyses for all three port path alternatives may involve:

- assessment of proposed construction staging and/or stockpile areas,
- assessment of each proposed dredging method,
- characterization of the materials to be dredged during any construction dredging,
- hydrodynamic modeling to assess the effects of any proposed new channel creation (Port Paths 2 and 3) or barge access and berthing dock,
- assessment of proposed dredged material upland placement alternatives once the dredge volumes and expected maintenance volumes are predicted,
- assessment of any ancillary facilities and/or roads which may be required for each alternative, and
- other environmental impacts such as water quality, wetland, private oyster leases, public shellfish grounds, EFH, and listed species impacts.

## LV Launch Pad 0-C

### Background on Proposal

As presented in Section 1.2.2, Virginia Space holds an active Launch Site Operator License with the FAA[2] to operate MARS. MARS currently operates two LV launch pads (Pad 0-A and Pad 0-B) at the south end of Wallops Island. As rocket technology advances and new business opportunities present themselves, launch activity on Wallops Island is anticipated to increase.

### Description of the Proposed Action

With respect to the current launch pad configuration, the increased activity is challenged by limits due to hazard arcs; specifically, launch preparation activities may not commence simultaneously within overlapping hazard arcs. In an ideal environment, one mission could be setting up without the risk of equipment being disrupted by the launch preparation activities of another mission. Stand-off distances are vital to this safety function. In order to minimize scheduling conflicts, reduce the operational impact to concurrent activities at WFF, and accommodate new LV technology, a third LV Launch Pad (Pad 0-C) is proposed at the current location of the UAS airstrip at the south end Wallops Island (see **Figure 2.5-4**).


The new pad could resemble either of the existing launch pads 0-B or 0-A, where construction mirroring Launch Pad 0-A would be more extensive and include a pad access ramp, launch pad, and deluge system (sound and vibration suppression water spray). If the new pad were to resemble Launch Pad 0-B, it would most likely consist of a pile-supported concrete launch stool and apron as well as moveable service gantry. A HIF may also be constructed close to the new pad. If the new pad resembles Launch Pad 0-A, approximately 1.3 ha (3.2 ac) of impervious surface would be added within the pad complex footprint, whereas a Launch Pad 0-B-type complex would add approximately 0.7 ha (1.7 ac) of impervious surface. The estimated size of the Launch Pad 0-C complex footprint could be up to 2.6 ha (6.4 ac). Launch Pad 0-C would require an approximately 3,050 m (10,000 ft) hazard arc and would either accommodate the largest vehicles (see Section 2.5.1.2.4) to be launched at WFF (if it were to resemble Launch Pad 0-A) or a medium-class LV (if it were to resemble Launch Pad 0-B). This pad may be designed for the "new" envelope rocket (not yet defined) and would use the most up-to-date technologies available at the time of project inception. The need for a liquid fueling facility for Launch Pad 0-C has not yet been determined and would be dependent on the type of

[2] The FAA could use the information in this document to support a decision about modifying or renewing the Virginia Commercial Space Flight Authority's launch site operator license and issuing or renewing licenses or experimental permits to support commercial space launch and reentry activities. If necessary, the FAA could supplement or tier from this document if the level of information and analysis is not sufficient to cover the environmental review requirements of future actions.

LV proposed for the pad. An LV processing facility and LV project support building (refer to **Figure 2.5-4**) may be constructed; however, details of these two facilities are not fully known.

The LV Launch Pad 0-C project is in the very early stage of development. A notional evaluation is presented. As project planning and design details became more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts. Additional analyses may involve:

- wetland impacts, and
- other environmental impacts such as water quality, EFH, and listed species impacts.

**<u>LV Launch Pier 0-D</u>**

**Background on Proposal**

With the limited amount of space remaining on Wallops Island and the need to have safe distances between active launch pads, consideration has been given to an alternative where an LV launch pier, Launch Pier 0-D, could provide additional launch capability at WFF.

**Description of the Proposed Action**

Two options for the development of an LV launch pier pad on South Wallops Island are being introduced. The approximate locations are shown on **Figure 2.5-9**. Option One would construct a launch pier pad in the nearshore waters of the Atlantic Ocean at the south end of Wallops Island. Option Two would construct a similar launch pier pad in Hog Creek on the opposite side of the potential Atlantic Ocean location.

Launch Pier 0-D in its oceanside location would require a robust design due to its placement in nearshore waters subject to a wide range of normal ocean currents, tidal action, and wind exposure as well as a wide range of potentially extreme storm events. The design of the pier pad would likely require a very dense configuration of steel reinforced concrete piles to withstand both the natural ocean conditions to remain structurally sound as well as withstanding the extreme dynamic forces placed on the pad during launch. It is probable that a mobile service structure would be used to provide one or more access platforms to service the launch vehicle while on the pad. It is likely, using current technologies, that liquid fueling of the launch vehicle would occur prior to its over-ocean roll-out just prior to launch. Umbilical systems containing communications, electrical, telemetry, and other launch control systems would be used to connect the launch vehicle to the launch control center while on the pier pad. The deluge system to dampen the vibrational effects of launch to protect both the launch vehicle and the launch pad would have to be designed to capture the deluge water and direct it landward for treatment. It is not known at this time whether a flame deflector would be required or any specifics about how the flame detector, if necessary, would be directed and details associated with its potential impacts. The actual length of the access ramp to the pier, actual position of the pier pad, and whether any dredging to support the pier pad launch complex might be needed is not currently known.

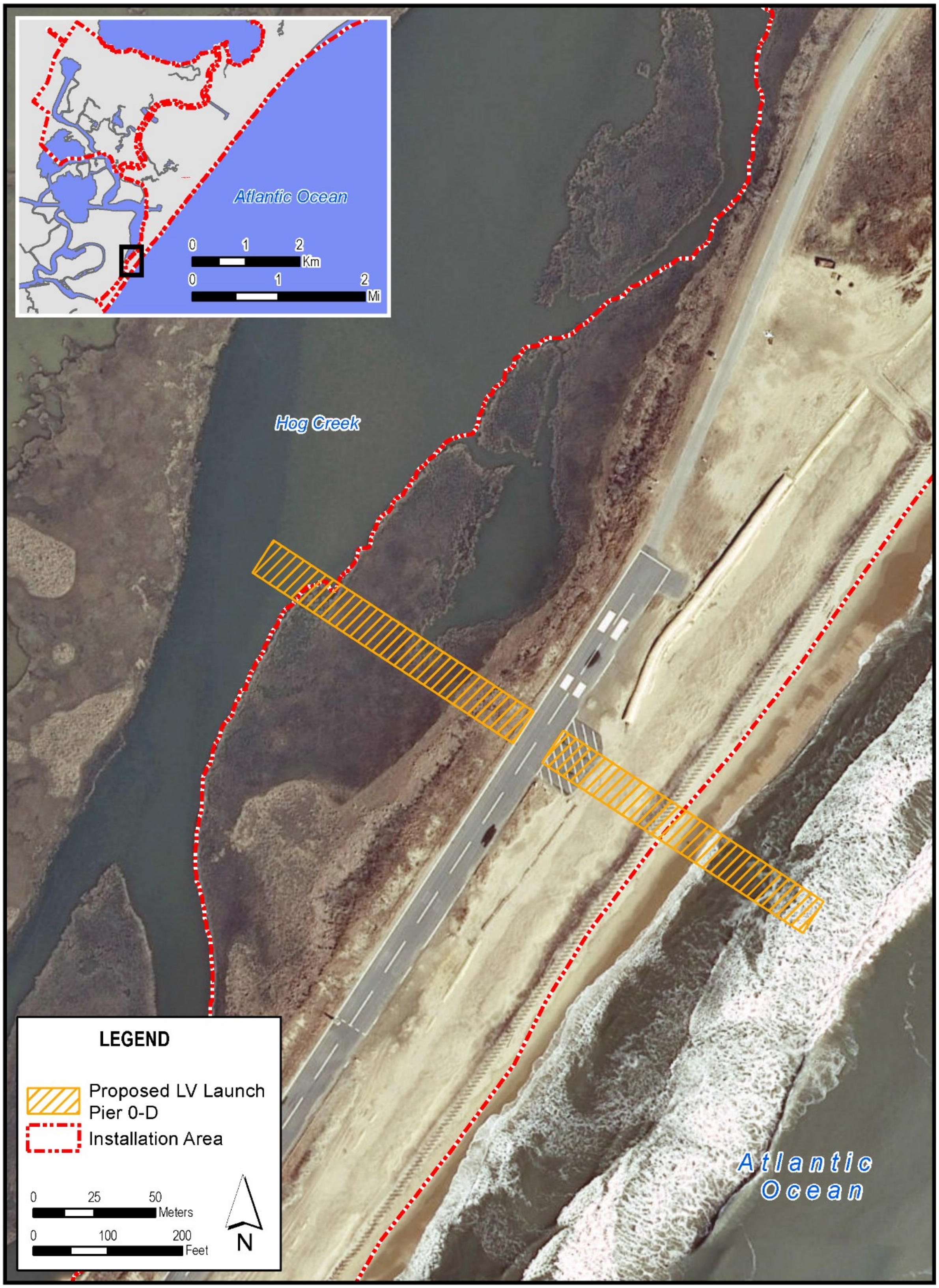



**Figure 2.5-9. Notional Optional Locations of LV Launch Pier 0-D**

The creekside option would have similar requirements as the oceanside pier pad system except that the location would not be as exposed to the wave action and storm surge. The creekside option would not require as robust a structure to maintain its integrity during launch and major storm events. However, this option would have the potential for more wetland and estuary-related impacts during construction and launches. Similar to the oceanside option, it is not currently known if any dredging would be required to support the creekside pier pad option.

The LV Launch Pier 0-D project is in the very early stage of development. A notional evaluation is presented. As project planning and design details became more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts at either location. Additional analyses may involve:

- wetland impacts,
- nearshore sediment transport, and
- other environmental impacts such as water quality, EFH, private oyster leases, public shellfish grounds, and listed species impacts.

**<u>DoD Launch Pads</u>**

**Background on Proposal**

Advances in DoD technology and training systems have resulted in increased activity in the Navy Assets area of Wallops Island. Navy training systems often require dedicated launch areas and pads to execute training missions. The addition of the two launch pads would provide additional opportunities for the Navy at Wallops Island.

**Description of the Proposed Action**

The U.S. Navy SCSC would construct two launch pads within the Navy Assets area on Wallops Island (refer to **Figure 2.5-5**). The first would be a dedicated launch pad to support a land-based vertical launch training system using a proven interceptor missile system (DoD SM-3). DoD SM-3 would be a new operational activity and is described in Section 2.5.2.1. The DoD SM-3 launch pad would measure approximately 10 $m^2$ (105 $ft^2$) and would be located near the Navy's Aegis facility on existing Pad 4. A blockhouse with electric and water connections would also be constructed. Approximately 52 kilowatt-hours of energy would be required for each missile launch.

A second launch pad and block house would be constructed to support a land-based guided missile launching system for ESSM. The permanent pad would replace a mobile launch system currently used for this activity. Construction of the ESSM launch pad would occur within the Navy Assets area on Wallops Island (refer to **Figure 2.5-5**). The guided missile launching system pad would measure 13 $m^2$ (144 $ft^2$); the pad and blockhouse would require electric and water connections. Approximately 73 kilovolt-amps of energy would be required for each missile launch.

## 2.5.2 OPERATIONAL MISSIONS AND ACTIVITIES

Personnel increases in support of the Expanded Space Program (i.e., larger LVs and commercial human spaceflight missions) are anticipated to include approximately 60 civil servants and 16 full-time, onsite contractors, with up to 36 transient personnel supporting the operations. Additional minor personnel increases would be associated with the other operational proposals such as increased UAS operations at the North Wallops Island UAS airstrip.

#### 2.5.2.1 Main Base

**Expanded Space Program**

Under the Expanded Space Program, horizontal lift and horizontal landing vehicles that operate the same as standard aircraft could launch and land from extended Runway 04/22 at the Main Base airfield. These launch vehicles may be used for commercial human spaceflight missions under an emerging suborbital space tourism industry. Refer to Section 2.5.2.2, Expanded Space Program for more information relating to these proposals.

#### 2.5.2.2 Mainland and Wallops Island

**DoD Standard Missile-3**

**Background on Proposal**

**SM-3 Launcher**

WFF and the NASA Sounding Rocket Operations Contract II provide mission management and engineering support to Terrier sounding rocket operations (a launch vehicle identical to the SM-3). The SM-3 is being developed as part of the Aegis Ballistic Missile Defense System used by DoD to provide a forward-deployable, mobile capability to detect and track ballistic missiles of all ranges. The SM-3 has the ability to destroy short to intermediate-range ballistic missile threats in the midcourse phase of flight. Although not currently in place at WFF, the SM-3 is used by the Navy as part of a missile training exercise, in conjunction with a drone target (e.g., the Aegis Readiness Assessment Vehicle – Class A). Both the SM-3 and the drone target are compatible with the Vertical Launching System, which can be found aboard many Navy and international surface combatants. Drone targets are either launched from the WFF Range or air-launched from military aircraft in the VACAPES OPAREA controlled airspace. Targets travel on a preprogrammed flight path. Shipboard interceptor missiles engage the target over the VACAPES OPAREA and all debris from the intercept falls within the VACAPES OPAREA boundary. When combined, the SM-3 intercept missile and the drone target are used to test the performance of shipboard combat systems, as well as to provide simulated real-world targets for ship defense training exercises. WFF is the preferred location for an SM-3 Vertical Launching System missile launcher to be used for Navy training on the newer SM-3 interceptor missile system (U.S. Navy 2009).

The SM-3 is a three-stage vehicle which is capable of achieving an altitude of 75 km (45 mi) with a 400 kgs (800 lbs) payload and 225 km (140 mi) with a 90 kgs (200 lbs) payload. Typically, this system is used for 35 centimeters (cm) (14 in) payload configurations.

**Description of the Proposed Action**

To increase training value and de-conflict SM-3 training schedules with other WFF operations, WFF plans to construct a dedicated launch pad for SM-3 missiles and drone targets. This permanent launch pad and the associated training operations are considered connected actions to MISSILEX (surface-to-air) training operations presented in the 2009 VACAPES Range Complex EIS/OEIS, where missile firing ships armed with surface-to-air missiles are required to engage each of three different presentations of aerial threats using drone targets. The launch pad would be located near the Navy's Aegis facility at WFF's Pad 4 (see **Figure 2.5-5**).

**<u>Directed Energy</u>**

**Background on Proposal**

The DoD and the Navy are pursuing a variety of HEL and HPM weapon system technologies that are in various stages of development. The HEL systems have the potential to add unique capabilities to the Navy and DoD. Precision engagement at the speed of light with a deep magazine brings new options to address difficult threats in non-traditional ways. Technology advances in both the military and civilian sectors have led to improvements in key HEL system components and fueled innovative approaches to the present development of HEL weapons. The Directed Energy Warfare Office at the Naval Surface Warfare Center, Dahlgren Division is a leader in the transition of this new capability from science and technology to DoD systems.

**High Energy Laser**

HPM offers a unique capability for non-lethal, non-kinetic missions. HPM systems are capable of engaging multiple targets, re-attack, and dramatically reduced collateral damage and reconstruction costs. This capability opens targets for which no engagement option currently exists. Potential mission sets for HPM include disruption of communications networks, infrastructure, and sensors. The Directed Energy Warfare Office has demonstrated effectiveness against a wide variety of electronic systems across multiple source technologies.

Wallops Island's maritime atmospheric conditions are ideal for a variety of early HEL and HPM developmental experiments. In addition, as new Directed Energy systems are developed, they would require integration and testing with systems in a maritime environment. Wallops Island's open air range provides a unique and potentially valuable location for testing HEL and HPM systems.

**Description of the Proposed Action**

Wallops Island is being considered for future HEL and HPM experiments and developmental tests. Specific test scenarios are dependent on actual test requirements and are currently unknown. The following scenarios are provided as potential representative examples of such requirements. Infrastructure requirements would be dependent on the testing scenario desired.

Scenario 1: Attenuation and Wave propagation experiments. A small HEL system would be mounted on an existing roof or mast infrastructure and shine a fixed beam along the shoreline to a piece of test equipment located approximately 1.6 km (1 mi) away.

Scenario 2: Engagement of airborne target. An HEL or HPM weapon system would be temporarily located at a suitable site and tested against an air target (UAS or Drone) with the intent of disrupting and disabling the target.

As project planning and design details became more developed, further NEPA analysis may be required in the future to fully evaluate the potential impacts.

**SODAR System**

**Background on Proposal**

A sonic detection and ranging (SODAR) system is a meteorological instrument that measures the scattering of sound waves by atmospheric turbulence. SODAR systems are used mainly to measure the speed and direction of the wind at various heights up to approximately 800 m (2,625 ft) above the ground but the systems can also determine sudden changes in the structure of the lower atmosphere (Physics and Radio-Electronics 2017). Operating frequencies range from less than 1,000 Hz to over 4,000 Hz (1 kHz to 4 kHz) with power levels up to several hundred watts. SODAR systems are now being used to gather data for development of wind power projects. Used in this manner, data are gathered in the 50 to 200 m (165 to 655 ft) above ground range. The SODAR system is similar to a radar system except that sound waves instead of radio waves are used for detection (Physics and Radio-Electronics 2017). Sounder, echosounder, and acoustic radar are other names used to describe the SODAR system.

**Sonic Detection and Ranging System**

**Description of Proposed Action**

A SODAR system would be placed on Wallops Island. The system would be oriented along the flight trajectory of guided and unguided systems which are oriented generally southeast, over the Atlantic Ocean. This project is in the planning stage. A notional evaluation is presented. When the type of system has been determined, further NEPA analysis may be required in the future to fully evaluate the potential impacts.

**North Wallops Island UAS Airstrip Increased Operations**

**Background on Proposal**

An EA was prepared for the construction and operation of a UAS airstrip on North Wallops Island (NASA 2012). The 900 m (3,000 ft) by 25 m (75 ft) airstrip would support year round UAS operations. On average, four UAS sorties would be flown each day for a maximum of 1,040 UAS sortie operations each year. The number and frequency of operations would be dictated by the type of UAS test and UAS-based research being conducted in a given year. UAS would operate generally Monday through Friday, 6:00 a.m. to 6:00 p.m. Night operations would be probable but infrequent. Virginia Space owns and will operate the UAS airstrip.

Construction of the North Wallops Island UAS airstrip was completed in 2016; operations at the airstrip began in mid-2017 (Virginia Space 2017). Refer to **Table 2.4-2** for examples of UAS operating from the North Wallops Island UAS airstrip. The Viking 300 was established as the envelope against which future UAS would be compared for noise affects to sensitive receptors. The Viking 400 was established as the largest UAS (in terms of physical size and quantities of onboard materials) that would operate from the new airstrip, and would be the envelope against which future UAS would be compared for other impacts (e.g., hazardous materials).

**Description of the Proposed Action**

Virginia Space proposes to increase the annual sortie operations to 3,900 with increased night operations. Rotor and vertical takeoff and landing UAS would operate from the airstrip. The Viking 300 would remain the envelope for noise. The envelope for size would be determined by the type of UAS that could safely operate from and within the runway allowance.

**Expanded Space Program**

**Background on Proposal**

Due to its coastal location and longstanding history of enabling aerospace research and development, WFF has a unique opportunity to provide its services to the commercial launch industry upon which NASA, civil, defense, and academic customers are more frequently relying. As the commercial space sector continues to grow both nationally and at WFF, NASA has an obligation under both the 2010 and 2013 National Space Policies to assess its capabilities and limitations to support such LV growth at WFF. During the initial scoping phase of this PEIS, WFF surveyed both flight-proven and developmental LVs that could utilize its facilities for launches in the foreseeable future. Several small launch vehicles are in the advanced stages of development. These include Vector Space Systems' Vector-R and -H, liquid-fueled LVs intended for remote sensing satellite delivery in LEO and Sun-synchronous orbit (FAA 2017). Though WFF has historically supported small- (e.g., Minotaur I) and medium-class (e.g., Antares) LVs, for this effort it specifically considered larger intermediate- and heavy-class launch vehicles and intermediate-class return to launch site (RTLS) RLVs.

**Orbital Vehicles**

Under the Proposed Action, up to 6 LFIC LV launches/LFIC RTLS landings and 12 SFHC LV launches per year would be distributed among launch Pads 0-A, 0-B, 0-C (proposed), or Launch Pier 0-D (proposed).

**LFIC LV and SFHC LV**

A **LFIC LV** is the proposed liquid-fueled envelope to be considered in this PEIS. One such vehicle, the Atlas V 401 series, is manufactured by Lockheed Martin Commercial Launch Services (LMCLS)/United Launch Alliance (ULA). LMCLS/ULA markets this vehicle to both U.S. government customers and commercial users (FAA 2017). This example LFIC LV uses a Common Core Booster (CCB) first stage and an upper stage Centaur vehicle. It can launch up to 18,800 kgs (41,500 lbs) into LEO and up to 8,900 kgs (19,600 lbs) to geosynchronous transfer orbit (FAA 2017). The Atlas V 401 series is commonly relied upon by commercial aerospace companies to launch their payloads into space. Additionally, in 2010, ULA began the process of certifying Atlas V for commercial human spaceflight missions and currently has agreements with Boeing and Sierra Nevada Corporation to launch their crewed orbital vehicles on an Atlas V. The Atlas V 401 series first stage booster would have a maximum of 284,089 kgs (626,309 lbs) RP-1 and LOX (ULA 2010). The preferred launch site at WFF for this intermediate class launch vehicle is the proposed Launch Pad 0-C or a modification of Launch Pad 0-B[3] (refer to Section 2.5.1.2).

A **SFHC LV** is the proposed solid-fueled envelope to be considered in this PEIS. Northrup Grumman Innovation Systems (NGIS), formerly named Orbital ATK, Inc.[4], is in the development of new 3- and 4-stage launch vehicles. Built upon existing Ares-based design, these new vehicles would use refurbished reusable SRM case segments. The 3-stage launch vehicle would have LEO capability while the 4-stage launch vehicle would have geosynchronous orbit capability. Both launch vehicles would rely on existing technology upgrades to the NGIS CASTOR family of rocket motors with the introduction of the CASTOR 1200 first stage motor for the 4-stage launch vehicle. The NGIS SFHC LV would have a maximum of 502,130 kgs (1,107,000 lbs) of polybutadiene acrylonitrile Class 1.3 solid propellant (Orbital ATK 2016). The preferred launch site at WFF for this heavy-class launch vehicle is modification of Launch Pad 0-B or the proposed Launch Pad 0-C.

**Vertical Launch and Landing Vehicles**

Resembling either a more conventional rocket or a powered space capsule, vertical launch and vertical landing vehicles are currently in development by multiple U.S. commercial companies. In some cases, these vehicles require support gantry structures that may be installed permanently in place or roll out and rotate up for launch. Those vehicles intended for reuse could undertake either soft landings using parachutes or rocket motor controlled deceleration.

**New Shepard**

Examples of reusable vertical launch and landing vehicles could include the *Blue Origin New Shepard*, which would contain a crew capsule atop a propulsion module. Following approximately two and a half minutes of thrust, the propulsion module shuts off its rocket engines and separates from the crew capsule. The propulsion module then descends to Earth and performs a rocket-powered vertical landing. After descent and reentry into Earth's atmosphere, the crew capsule would land under parachutes near the launch site.

SpaceX, founded in 2002, designed the concept vertical launch and vertical landing vehicle known as Grasshopper. The initial development of the Grasshopper led to the current use of the Falcon 9 LV. The Falcon 9 is a fully-reusable two-stage heavy lift LV which is powered by LOX/RP-1 engines. The Falcon 9 is capable of delivering 9,500 kg (21,000 lbs) in its capsule, known as Dragon, to LEO. SpaceX also developed a heavy-lift version, Falcon 9 Heavy, capable of lifting a payload of 25,000 kg (55,000 lbs) to LEO, geo-stationary orbit, and to the ISS.

[3] The modification of Launch Pad 0-B is not considered in this PEIS. If modification of Launch Pad 0-B is considered in the future, NEPA documentation would be required.
[4] Orbital AFK was renamed Northrup Grumman Innovation Systems on June 5, 2018, following the Federal Trade Commission's approval of Northrup Grumman's acquisition of Orbital ATK.


**Falcon 9**

The Falcon 9 is considered fully reusable due to its ability to return its first stage via soft landing back to Earth after delivering the Dragon capsule to its delivery objective such as the ISS. After first stage separation, the Falcon 9 first stage thruster reverses its trajectory and releases foldable heat resistant wings called grid fins to steer the first stage back through Earth's atmosphere to its landing pad. The same thruster that reversed the direction of the first stage are then used to facilitate the slowing of the first stage for a gentle landing. The return control systems are totally automated once the rocket is launched and automatically make adjustments to atmospheric conditions during the descent to the landing site (SpaceX 2015).

Vector Space Systems is a micro satellite commercial space launch company offering customers two variants of small sized launch vehicles. The Vector-R (Rapide) and Vector-H (Heavy) make up the series of small launch vehicles being offered by Vector Launch Systems. The Vector-R is a two-stage, liquid oxygen-liquid propylene vehicle, cable of delivering up to 66 kg (145 lbs) Cubesats and small satellites to 100 km (60 mi) altitude. The Vector-R is anticipated to be available to the commercial aerospace market in 2018. Vector Launch Systems anticipates their capability to provide Vector-R LVs for up to 100 launches per year. The Vector-H also a two-stage liquid oxygen-liquid propylene vehicle, can loft 150 kg (330 lb) payloads to approximately 500 km (310 mi) above the Earth. Vector promotes the Vector-H for users going into LEO and launching small deep space missions. It is anticipated that the Vector-H will be available in mid-2019 with the ability to support up to 25 flights per year (Vector Launch, Inc. 2018).

Firefly Aerospace is another company that is focusing on the development of small to medium-sized LVs. Created in 2017 and based in Austin, Texas, its predecessor company, Firefly Space Systems, was working on a delivery system, Alpha, for a small satellite payload of approximately 400 kg (880 lbs) to LEO. Firefly Aerospace is currently working to develop a large capacity payload of up to 1,000 kg (2,200 lbs) to LEO using a LOX/methane propellant system using a two-stage launch platform.

**Suborbital Vehicles**

### Horizontal Launch and Landing Vehicles

Horizontal lift and horizontal landing vehicles operate the same as standard aircraft that take off and land at private and commercial airports and do not require vertical gantry structures. It is envisioned that companies operating horizontal lift and landing vehicles would utilize the existing Main Base airfield at WFF.

Potential concepts of operation at WFF could resemble that of Virgin Galactic's *SpaceShipTwo (SS2)/WhiteKnightTwo (WK2)*. This launch vehicle system employs a conventional jet airplane carrying a rocket-powered spacecraft to an altitude of 14 km (8.7 mi) before releasing the spacecraft. SS2, at approximately 18 m (60 ft) long with a wingspan of 8.3 m (27 ft), can carry a crew of two plus six passengers into LEO with a maximum payload weight of 600 kgs (1,320 lbs) and into Sun-synchronous orbit with a maximum weight of 300 kg (661 lbs) (FAA 2017).

Testing, processing, and launching of horizontal flight vehicles could occur at WFF in the future. However, the specifics of such operations have not been developed sufficiently for detailed analysis at this time. It is expected that minor improvements to existing facilities and infrastructure may be required to provide adequate office space and parking. Construction of a Commercial Space Terminal for the purpose of hosting commercial partners is currently under consideration (Section 2.5.1.1).

**SpaceShipTwo/WhiteKnightTwo**

In addition to SpaceShipTwo/WhiteKnightTwo, Virgin Galactic has a sister company, Virgin Atlantic, that is developing the LauncherOne LV. LauncherOne is a two-stage LV capable of delivering a payload of 225 kg (500 lbs) into orbit. This LV uses a modified 747-400 series passenger jet, called CosmicGirl. Original plans by Virgin Galactic were to have LauncherOne be attached to WhiteKnightTwo which would have provided a payload capability of between 100 kg to 300 kg (220 lbs to 660 lbs) pounds) to polar/Sun-synchronous or equatorial orbits. With the switch to CosmicGirl, Virgin Atlantic will be able to increase its payload capacity to 330 kg (660 lbs) to Sun-synchronous orbit and a 450 kg (990 lbs) payload to equatorial orbit. After reaching an altitude of 35,000 ft, LauncherOne is released from CosmicGirl with the ignition of its single main engine comprised of a LOX/RP-1 rocket engine. After stage separation, a single LOX/RP-1 upper stage deploys satellites into orbit. CosmicGirl would return to a pre-designated airport where it would be prepared for another launch (NASA Spaceflight.com 2016).


**Generation Orbit**

Generation Orbit Launch Services, Inc. (GO) is considering WFF as a possible site for its horizontal launch operations on the Mid-Atlantic east coast. The candidate GO Launcher systems, referred to as GO1 and GO2, were unveiled in October 2011 when Generation Orbit Launch Services announced the opening of their operations in Atlanta, Georgia (MARS 2012). The GO1 is a suborbital service that will carry nanosatellites in the 15 to 100 kgs (33 to 220 lbs) payload class along high altitude suborbital trajectories. The GO2 is a dedicated orbital launch service for nanosatellite payloads in the 5 to 45 kgs (12 to 100 lbs) range depending on altitude and inclination. In both cases, expendable rockets would be carried to an offshore release point by a subsonic business jet such as the Gulfstream III or IV (MARS 2012).

The U. S. Government's Defense Advanced Research Projects Agency (DARPA) is in the development stage of implementing its Experimental Spaceplane program, formerly known as the XS-1, to fly an entirely new class of hypersonic aircraft as a means to strengthen national security by providing a short-notice, low cost access to space. While in the early stages of development, the goal of DARPA's

Experimental Spaceplane is intended to provide the U.S. with the ability to recover from a catastrophic loss of commercial or military satellites upon which the nation's defense is so reliant. DARPA's Experimental Spaceplane is expected to be a fully reusable unmanned launch vehicle the size of a commercial business jet. This vehicle would take off vertically from a clean pad with minimal fixed support required. The power source would include self-contained cryogenic propellants with no external boosters. This launch vehicle would eventually have the capacity to deploy a 1,360 kg (3,000 lb) satellite to polar orbit, and return the reusable first stage to Earth landing like a typical aircraft and be prepared to launch again in a matter of hours (DARPA 2018).

**Commercial Human Spaceflight Missions**

The U.S. government has taken steps to develop a U.S. commercial crew transportation capability with the goal of achieving safe, reliable and cost-effective access to and from the ISS and LEO. In August 2009, NASA announced that the Human Exploration Office planned to utilize Federal stimulus funds to finance development of commercial crew transport concepts. NASA announced the award of Commercial Crew Development (CCDev) Space Act Agreements (SAAs) in February 2010 to Blue Origin, The Boeing Company, Paragon Space Development Corporation, Sierra Nevada Corporation, and ULA. Subsequent to the initial CCDev, in 2011, NASA executed a second round of both funded and unfunded SAAs with Blue Origin, Sierra Nevada Corporation, SpaceX, NGIS (formerly Orbital ATK), ULA, and Excalibur Almaz, Inc. The CCDev agreements have enabled both technical development and information sharing with the ultimate goal of developing a commercial crew transport capability for NASA.

In addition to those commercial human spaceflight developments directly enabled by NASA funding, there is an emerging suborbital space tourism industry. Similar to purchasing an airline ticket, an individual would purchase a ticket from a commercial company for a "seat" to travel into space along a suborbital flight path. While, at the current time, commercial space tourism vehicles are largely in their developmental phases, in the future, WFF, which is relatively close to major metropolitan areas (e.g., Washington, D.C; Baltimore, Maryland; Philadelphia, Pennsylvania, etc.), could become a desirable test or operational site for companies offering these services to the public.

**Description of the Proposed Action**

In support of the 2010 U.S. National Space Policy, as updated by the 2013 U.S. National Space Transportation Policy and the 2017 Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, WFF would make its facilities available to commercial customers for research, development, and operation of each of the orbital and suborbital vehicles described under the Expanded Space Program.

Each of the activities under the Expanded Space Program are in the planning stage. A notional evaluation is presented. As project design details became more developed, further NEPA analysis may be required in the future to fully evaluate the potential impacts.

**<u>Hybrid Fuels</u>**

**Background on Proposal**

Conventional cryogenic propellants present technical challenges in handling, storage and distribution. Compatibility and reactivity issues limit the materials that can be used for LOX storage and transfer. Currently available alternatives, such as hypergolics, are toxic and require special handling. Recent developments have demonstrated the feasibility of using nanoscale energetic materials, such as a slurry of nanoscale aluminum particles in ice, as propellants. Nanoscale metal particles are highly reactive materials. While this is desirable for propellants, it can create safety hazards. NASA has collaborated with other government agencies to mature this technology (NASA 2012b). NASA is currently developing a "green" alternative to hydrazine. The hydroxyl ammonium nitrate fuel/oxidizer blend known as AF-M315E, has significantly reduced toxicity levels compared to hydrazine making it easier and safer to store and handle (NASA 2017). Another green liquid propellant under development is called LMP-103S. NGIS (formerly Orbital ATK), in partnership with a subsidiary of Swedish Space Corporation, developed LMP-103S which contains a mixture of ammonium dinitramide, water, ammonia, and methanol. It is not sensitive to air or water vapor and can be stored for long periods without degradation or pressure buildup (Orbital ATK 2015).

**Description of the Proposed Action**

Testing of the newest advances in hybrid fuels is ongoing. Significant technical challenges remain, however, before hybrid fuels such as these can be used in NASA missions. As such, a notional evaluation is presented. As details for the use of hybrid fuels became more developed, further NEPA analysis may be required in the future to fully evaluate the potential impacts.

## 2.6 SUMMARY OF COMPARISON OF ENVELOPES AND POTENTIAL ENVIRONMENTAL IMPACTS

**Table 2.6-1** provides the current envelope (baseline) and indicates if there would be an envelope change under the actions proposed.

**Table 2.6-1. Baseline and Proposed Envelopes**

| *Activity* | *Baseline (No Action)* | *Change (Proposed Actions)* |
|---|---|---|
| ***Institutional Support Projects*** | | |
| Construction and Demolition | Existing construction design projects analyzed in previous NEPA documentation. | All new construction, demolition, and RBR projects proposed including Causeway Bridge Replacement, development of North Wallops Island Deep-water Port and Operations Area, and Launch Pad 0-C and Launch Pier 0-D. |
| ***Routine/Recurring Activities*** | | |
| Fabrications | Existing fabrication processes/existing facilities. | No change. |
| Maintenance and Improvements | Existing maintenance and improvement activities. | Maintenance dredging. |
| Payload Processing Facilities | Existing payload processing activities. | No change. |
| Transportation Infrastructure | Existing transportation infrastructure. | Causeway Bridge Replacement; maintenance dredging; North Wallops Island Deep-water Port and Operations Area. |
| Utility Infrastructure | Existing utility infrastructure. | No change. |
| Safety and Security | Existing WFF fire prevention and protection programs. | No change. |
| Storage | Existing storage activities. | Hybrid fuels; greater capacity for liquid fuel for LFIC LV. |

| Table 2.6-1. Baseline and Proposed Envelopes (cont.) | | |
|---|---|---|
| ***Activity*** | ***Baseline (No Action)*** | ***Change (Proposed Actions)*** |
| ***Operational Missions and Activities*** | | |
| Scientific Research Programs and Education Programs | Existing payload envelopes established for radio frequencies, lasers, radioactive materials, biological agents, and chemical releases. | No change. |
| Airfield | Existing FAA designated airspace and runways. | No change. |
| Main Base Piloted and Unmanned Aircraft | Approximately 61,000 annual airfield operations. | No change in annual operations. |
| North Wallops Island UAS Operations | 1,040 sorties per year. Limited night operations. The Viking 300 is the noise envelope; the Viking 400 is the vehicle size envelope. | • Increase to 3,900 sorties per year.<br>• Increase in night operations.<br>• Vehicle size is limited to runway allowance.<br>• Addition of rotorcraft and vertical takeoff and landing craft. |
| Orbital Rockets | 18 orbital rocket launches per year (6 from Launch Pad 0-A; 12 from Pad 0-B). Antares is the envelope liquid-fueled LV to be launched from Launch Pad 0-A; Athena III is the envelope solid-fueled LV to be launched from Pad 0-B. | • 18 orbital rocket launches per year distributed among launch pads 0-A, 0-B, 0-C and Launch Pier 0-D.<br>• LFIC is the envelope liquid-fueled LV to be launched; and landed (RTLS); limit of 6 LFIC LV launches/RTLS landings per year.<br>• SFHC is the envelope solid-fueled LV to be launched. Limit of 12 SFHC LV launches per year.<br>• Horizontal launch and landing from Main Base Runway 04/22.<br>• Commercial human spaceflight. |
| Sounding Rockets / Suborbital Rockets | 60 launches per year. The four-stage Black Brant XII is the envelope sounding rocket. Includes 5 launches per year of Minotaur III, the envelope suborbital vehicle. | No change. |
| Drone Targets and Missiles | 30 drone target flights per year. The AQM-37 is the envelope drone target. | No change. |
| Fuel Types | Existing solid and liquid fuels evaluated in previous NEPA documentation. | Hybrid fuels; larger quantities of liquid fuels. |
| Static Fire Testing | Occurs at Launch Pad 0-A, Pad 2, and F-010. Propellant throughput governed by the 2010 MARS Regional Spaceport Air State Operating Permit and the 2010 Wallops Island State Operating Permit. The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year. | No change. |

| Table 2.6-1. Baseline and Proposed Envelopes (cont.) | | |
|---|---|---|
| ***Activity*** | ***Baseline (No Action)*** | ***Change (Proposed Actions)*** |
| OB Area | The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year. | No change. |
| Projectile Testing | Testing cannot exceed a maximum average of 270 combined firings from conventional, EMRG, or RDT&E systems per year. | Addition of Directed Energy. |
| Payloads | Multiple envelopes established in previous NEPA documentation. | No change in existing payloads. |
| Tracking and Data Systems | Data and tracking systems established in previous NEPA documentation. | Addition of Sonic Detection and Ranging. |
| Balloons | Balloons cannot be larger than 1,000,000 $m^3$ (40,000,000 $ft^3$); payloads cannot weigh more than 4,000 kgs (8,000 lbs) per flight. Meteorological balloons launched cannot exceed 886 per year. | No change. |
| AUVs/ASVs | The Theseus, International Submarine Engineering Limited's AUV is the envelope vehicle. | No change. |

**Table 2.6-2** summarizes and presents the potential environmental impacts of the Proposed Action and the No Action Alternative in a comparative form. For brevity, institutional support projects in the summary table encompass planned construction and demolition projects, Commercial Space Terminal, Causeway Bridge Replacement, maintenance dredging, Launch Pad 0-C, Launch Pier 0-D, and DoD launch pads. When necessary, the Causeway Bridge Replacement and maintenance dredging projects are called out separately.

| Table 2.6-2. Summary of Impacts | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Noise | No change to the existing noise environment beyond impacts analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• Temporary increases in noise from general construction for institutional support projects are not likely to adversely alter the surrounding noise environment.<br>• Potential increase in airborne and underwater noise associated with Causeway Bridge Replacement, barge route maintenance dredging, and dredging for development of the North Wallops Island Deep-water Port and Operations Area. Site-specific NEPA analysis would be required.<br><u>Operational Missions and Activities</u><br>• No significant impact anticipated from DoD SM-3.<br>• An increase in noise associated with Expanded Space Program, including LFIC LVs and SFHC LVs is anticipated.<br>• Potential for sonic boom during LV horizontal landing.<br>• During launch of LFIC LVs and SFHC LVs, no residences would be exposed to 115 dBA or greater noise levels (the OSHA threshold for 15 minute exposure). |

| Table 2.6-2. Summary of Impacts (cont.) | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Air Quality | No change to existing emissions or sources beyond those analyzed in previous NEPA documents. Greenhouse Gas (GHG) emissions data will continue to be collected. | Institutional Support Projects<br>• Short-term impacts to air quality from construction-related to institutional support projects would be expected. However, these projects would be phased in over time and emissions are not anticipated to have significant impacts on regional air quality.<br>• Institutional support projects have the potential to incrementally contribute to global emissions of GHGs. However, no significant impacts are anticipated.<br>Operational Missions and Activities<br>• LVs and RLVs criteria pollutant emissions under the Expanded Space Program would not exceed the comparable thresholds.<br>• Operational missions and activities have the potential to incrementally contribute to global levels of GHGs. However, total emissions are anticipated to be insignificant in terms of global GHG levels. |
| Hazardous Materials, Toxic Substances, and Hazardous Waste | Daily operations would continue as they are. Impacts from hazardous materials, substances, and hazardous waste generated by installation maintenance activities and existing operations would continue to be managed in accordance with the guidelines set forth in federal and state hazardous material, substance, and hazardous waste regulations. | Institutional Support Projects<br>• Any hazardous materials, substances, and hazardous waste generated by institutional support projects would be managed in accordance with current procedures. Therefore, there would be no significant impact.<br>Operational Missions and Activities<br>• There is potential for slight increases in the types and quantities of hazardous materials, substances, and hazardous waste from proposed operational missions and activities. Types of hazardous materials, substances, and hazardous waste would be similar to those used or generated during current operations at WFF and would continue to be managed according to standard procedures. Additional training and BMPs would be implemented as necessary. No significant impacts are anticipated. |
| Health and Safety | Daily operations would continue as is and current protocols for continued human health and safety would not change. | Institutional Support Projects<br>• Institutional support projects would occur and contactors would be required to adhere to established protocols and safety measures while working at WFF.<br>Operational Missions and Activities<br>• Operational missions and activities would follow established protocols at WFF. Most operations would fall within approved envelopes.<br>• Operation of LFIC LVs and SFHC LVs would involve risks to safety similar to previously analyzed rocket launch activities. Commercial human spaceflight missions would require new safety processes and procedures. WFF would implement protective measures to ensure risks to personnel and the general public from these operations are minimized. LFIC LVs/RLVs, SFHC LVs, and horizontal launch and landing from Main Base Runway 04/22 may require temporary road closures.<br>• Directed Energy operations and testing are projects that are still under development. WFF would continue to operate using established protocols for safety, but additional analysis may be necessary as more information about this operational activity is gathered. |

| Table 2.6-2. Summary of Impacts (cont.) | | |
|---|---|---|
| **Resource** | **No Action Alternative** | **Proposed Action** |
| Water Resources | Daily operations would continue as they are. There would be no impacts to water resources generated by installation maintenance activities and existing operations beyond what has been analyzed in previous NEPA documents. The Town of Chincoteague wells located in the Columbia aquifer have been affected by chemicals related to fire fighting and fire training activities; these shallow water wells are no longer used for potable water. NASA is working with Federal and state environmental regulatory agencies to monitor the plumes, which are receding, and to restore groundwater to natural conditions. Site-specific Stormwater Pollution Prevention Plans (SWPPPs) would continue to be generated as necessary and site-specific BMPs would be implemented for previously evaluated institutional support projects and operational missions and activities beach renourishment and maintenance would continue to take place at Wallops Island as needed. | Institutional Support Projects<br>• No long-term impacts to water resources from general construction-related to institutional support projects are anticipated due to the implementation of site-specific SWPPPs, BMPs, and wetlands avoidance and minimization measures. If impacts are identified, NASA would implement wetland mitigation to ensure no net loss of wetlands.<br>• Potential impacts to wetlands associated with the Causeway Bridge, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D. As required by the 404(b)(1) guidelines, only the Least Environmentally Damaging Practicable Alternative (LEDPA) can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable. Avoidance and minimization measures would be followed. If potential unavoidable wetland impacts are identified, NASA would implement wetland mitigation to ensure no net loss of wetlands. Site-specific NEPA analysis would be required.<br>• All proposed construction projects at the Main Base would avoid development in the floodplain. Wallops Island is located entirely within the 100-year floodplain. As such, there is no practicable alternative to avoid development within the floodplain.<br>• Institutional support projects have the potential to contribute to sea-level rise. These impacts to Wallops Island infrastructure are mitigated through continuation of the SRIPP. The proposed projects would not cause an appreciable increase in the factors that affect sea-level rise. As such, no significant impacts are anticipated.<br>Operational Missions and Activities<br>• No long-term impacts to water resources from operational missions and activities are anticipated due to the implementation of site-specific SWPPPs, BMPs, and wetlands avoidance and minimization measures.<br>• In the unlikely event of an LV failure, potential impacts to water resources could be locally substantial but clean-up efforts after the launch failure and restoration measures taken would prevent long-term effects to aquatic ecosystems.<br>• Operational missions and activities have the potential to contribute to sea-level rise; these impacts to Wallops Island infrastructure are mitigated through continuation of the SRIPP. It is not believed the proposed projects would cause an appreciable increase in the factors that affect sea level. No significant impacts are anticipated. |

**Table 2.6-2. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Land Use | Operations at WFF would remain unchanged. No changes to land use beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• Institutional support projects would fall within compatible land uses already designated by the 2008 WFF Facility Master Plan.<br>Operational Missions and Activities<br>• The instantaneous noise during launch of LFIC LVs and SFHC LVs would not exceed OSHA noise exposure limits. In addition, impacts at receptor areas would likely not be significant or result in land use changes including future planning and zoning.<br>• LV launch activities would not significantly impact parks, recreation areas, wildlife refuges or National Register of Historic Places (NRHP)-eligible structures: no adverse impact to DOT 4(f) properties would occur.<br>• DoD SM-3 missiles and drones and Directed Energy would be directed over the ocean. The placement of this activities would be in Navy Assets area of Wallops Island. No impacts to land use would occur.<br>• Operational missions and activities to include SODAR would continue to occur in the areas designated for such operations. |
| Land Resources | Daily operations would continue as they are. There would be no impacts to land resources generated by installation maintenance activities, existing operations, and previously evaluated construction projects beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• No long-term impacts to land resources from general construction-related to institutional support projects are anticipated due to the implementation of site-specific SWPPPs, BMPs, and Erosion and Sediment Control Plans.<br>Operational Missions and Activities<br>• No long-term impacts to land resources from operational missions and activities are anticipated. |
| Vegetation | Daily operations would continue as they are. There would be no impacts to vegetation generated by installation maintenance activities and previously evaluated projects beyond what has been analyzed in previous NEPA documents. Current management actions would continue. | Institutional Support Projects<br>• No significant long-term impacts to vegetation on the Main Base are anticipated from general construction-related to institutional support projects.<br>• Ground disturbance on the Mainland and Wallops Island has the potential to increase the spread of the invasive species *Phragmites australis*. Control plans would be implemented in these areas.<br>• Causeway Bridge Replacement, barge route maintenance dredging, dredging for development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D have the potential to disturb tidal and non-tidal wetland vegetation. The amount of disturbance depends on the final design. Further NEPA analysis would likely be required.<br>Operational Missions and Activities<br>• No long-term, significant impacts to vegetation from operational missions and activities are anticipated. |

**Table 2.6-2. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Terrestrial Wildlife, Special-Status Species, and Marine Mammals and Fish | Daily operations would continue as is. There would be no impacts to biological resources beyond those evaluated in previous NEPA documents, regardless of whether or not those actions have been implemented. | Institutional Support Projects<br>• Land-based institutional support projects would have insignificant adverse effects on vegetation, terrestrial wildlife, or special-status species. These projects may have minor, indirect adverse effects on marine mammals and fish. Regulatory agency consultations would occur as necessary in order to minimize impacts to these species.<br>• Causeway Bridge Replacement, maintenance dredging, and development of the North Wallops Island Deep-water Port and Operations Area may have effects on marine special-status species, marine mammals, and EFH. However, impacts would be dependent on final designs and locations of both projects. Further analysis would be required as project details are confirmed.<br>Operational Missions and Activities<br>• Noise from launch operations would generally impact biological resources. Terrestrial wildlife and special-status species would be disturbed by noise and vibration from launch activities. Marine mammals are unlikely to be affected by LV and RLV launch operations.<br>• Directed Energy specifics are largely unknown, but based on current information and target scenarios, impacts to biological resources are unlikely. Additional NEPA analysis may be required to better assess potential impacts to biological resources from these weapon systems. |
| Airspace Management | Operations from the Main Base airfield and from Wallops Island would continue as they are. There would be no impacts to airspace management beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• No long-term impacts to airspace management from institutional support projects are anticipated.<br>Operational Missions and Activities<br>• Operation of LVs and DoD SM-3 and Directed Energy would be coordinated with VACAPES FACSFAC.<br>• Airspace management would not be affected by increased operations from the North Wallops Island UAS airstrip. |
| Transportation | Daily operations involving roads, rail, and air transport would continue as they are. There would be no impacts to transportation resources beyond what has been analyzed in previous NEPA documents. | Institutional Support Projects<br>• Institutional support projects may cause short-term impacts to traffic from construction/demolition activities.<br>• Replacement of the Causeway Bridge may temporarily cause road or waterway closures from demolition activities.<br>• Waterway closures may be required during maintenance dredging and dredging for development of the North Wallops Island Deep-water Port and Operations Area.<br>Operational Missions and Activities<br>• LFIC LVs/RLVs, SFHC LVs, and horizontal launch and landing from runway 04/22 may require temporary road closures. Waterways may need to be temporary closed during delivery of the LVs or LV components and during LV launch and landing. |

**Table 2.6-2. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Infrastructure and Utilities | Daily operations would continue as they are. There would be no impacts to infrastructure and utilities beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• Institutional support projects would create short-term spikes in demand for potable water and power; however, long-term impacts would be countered by use of efficient technologies and greener building methods, per all pertinent Executive Orders.<br><u>Operational Missions and Activities</u><br>• An increase in operations would occur; however, it is unlikely that infrastructure or utilities would be negatively impacted.<br>• With the implementation of the previously analyzed Alternative Energy Project, NASA should see an overall reduction in the amount of energy purchased from the local utility provider.<br>• Future assessment of the energy requirements for Directed Energy would be needed as more information is available, to ensure that existing infrastructure could handle power needs, or if alternative power sources would be required. |
| Socioeconomics | There would be no change to the socioeconomic environment beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• Positive economic impacts (e.g., expenditures, tax revenue, job creation, tourism, etc.) may be experienced in the Region of Influence (ROI) from institutional support projects.<br><u>Operational Missions and Activities</u><br>• Positive economic impacts (e.g., expenditures, tax revenue, job creation, tourism, etc.) may be experienced in the ROI from the proposed operational missions and activities. |
| Environmental Justice | Activities with the potential for impacts within the local communities would remain unchanged and there would be no disproportionate impact to minority or low-income populations or children beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• There would be no disproportionate impact to minority or low-income populations or children from institutional support projects.<br><u>Operational Missions and Activities</u><br>• There would be no disproportionate impact to minority or low-income populations or children from operational missions and activities. |
| Visual Resources and Recreation | Daily operations would continue as they are. There would be no impacts to visual resources or recreation beyond what has been analyzed in previous NEPA documents. | <u>Institutional Support Projects</u><br>• All construction would be consistent with the 2008 WFF Facility Master Plan and impacts to visual resources would be negligible.<br>• Minor short-term impacts to boaters and fishermen from dredging operations and Causeway Bridge construction.<br><u>Operational Missions and Activities</u><br>• Short-term, negligible impacts to recreational resources from temporary closure of Wallops Island beach, Chincoteague Inlet, downrange ocean areas, and portions of the CNWR and Assateague Island National Seashore (AINS) during launch operations.<br>• Addition of an LV launch pad and deluge systems or development of the north end of the Island would change the viewshed of Wallops Island. However, the change would not be out of character with the surrounding visual aspects of the area. |

**Table 2.6-2. Summary of Impacts (cont.)**

| Resource | No Action Alternative | Proposed Action |
|---|---|---|
| Cultural Resources | Daily operations would continue as they are. There would be no impacts to Cultural Resources beyond what has been analyzed in previous NEPA and National Historic Preservation Act (NHPA) documents. | Institutional Support Projects<br>• Impacts to archaeological or traditional cultural properties are unlikely. However, if inadvertent discovery were made during construction, activities would cease and NASA would consult with Virginia Department of Historical Resources (VDHR).<br>Operational Missions and Activities<br>• Architectural resources that are listed on the NRHP would be within areas subject to noise from LV launches. NASA has developed a Programmatic Agreement with VDHR and Advisory Council on Historic Preservation that would address potential impacts to these structures. |

## 2.7 Alternatives Not Carried Forward

The facilities on Wallops Island have been strategically sited to support the flow of materials and employees needed for a successful launch, and to allow for maximum support of multiple simultaneous operations. Rockets and spacecraft launched from Wallops Island contain both solid and liquid propellants. SRM storage and spacecraft fueling and processing facilities, which all pose fire and explosive hazards, are located in North Wallops Island so in the event that a mishap occurs, it would have minimal impact on the public or the employees on Wallops Island. A hazard area buffer must be constantly maintained around these facilities effectively prohibiting the siting of occupied facilities within the buffer. Central Wallops Island contains the U.S. Navy's ship training facilities, storage and assembly buildings, and the launch blockhouses. Although this area typically contains the least hazardous of Wallops Island operations, its role in supporting launch operations is critical to mission success. South Wallops Island contains WFF's rocket launch pads, additional hazardous materials storage areas, and blockhouses. Rocket launch pads are sited far enough apart to allow simultaneous pre-launch work to occur on multiple pads. To meet the required safety offsets, these facilities must be appropriately distant from one another. The launch pads located on South Wallops Island are also buffered with a hazard area prohibiting the siting of occupied facilities within the buffer.

Relocating infrastructure on Wallops Island (including launch pads) farther inland to a location less susceptible to storm damage and sea-level rise requires consideration of many factors, including the condition and functions of Wallops Island facilities; employee and public safety; interrelationship among Wallops Island, Mainland, and Main Base facilities; and multiple mission support requirements. To meet both safety and mission needs, the assets on Wallops Island must remain in their same general configuration.

NASA evaluated these factors as part of a hypothetical move of Wallops Island's orbital launch pads from their current location to Wallops Mainland and areas within the region in the 2010 WFF SRIPP PEIS (NASA 2010).

### 2.7.1 Relocating Infrastructure to Wallops Mainland

Since NASA WFF was established in 1945, its geographic location has been a critical factor in its continued ability to safely and successfully conduct science, technology, and educational flight projects aboard rockets, balloons, and UAS, using the Atlantic waters for operations. Its location immediately on the Atlantic Ocean, its controlled airspace, and its direct access to the VACAPES OPAREA, provide a unique ability for WFF to perform all aspects of its mission (e.g., testing unproven flight vehicles, handling explosive and toxic materials, etc.) that could not be done elsewhere.

As part of the alternatives analysis conducted in preparing the 2010 WFF SRIPP PEIS, NASA evaluated the feasibility of moving Wallops Island assets to a nearby location less susceptible to storm damage and sea level rise. The first step in the analysis involved taking an inventory of the types of facilities currently on Wallops Island. NASA's primary concern is limiting the risk of harm to private property, its employees, and the general public resulting from its often hazardous operations. As Wallops Island is the WFF landmass farthest away from the general public, it is also the safest for such operations.

The primary function of infrastructure on Wallops Island is to enable operations leading up to, during, and following the execution of a flight. The launch pad can be thought of as the core of the launch range infrastructure and is characteristically the most difficult to site as it is the location at which the most hazardous operations take place. Launch support structures are generally built as close to the launch pad as possible as 1) the systems they house (e.g., high speed cameras, noise level monitors, etc.) must be close to the pad to effectively collect data, and 2) to provide the shortest travel distance once the launch vehicle and spacecraft are ready to be transported to the pad for final pre-launch preparations. Ensuring the shortest possible distance between a processing facility and the pad substantially reduces the risk of damage to highly sensitive instruments onboard the vehicle and spacecraft.

NASA began its investigation into suitable facility relocation sites by assessing the potential for moving facilities to Wallops Mainland, approximately 3.5 km (2.2 miles) west of their current location. To better understand the potential effects that this would have on neighboring property owners, NASA first evaluated the current conditions and then a hypothetical facility move scenario. Employing a Geographic Information System (GIS) – based approach, NASA overlaid the current Wallops Island facility footprint over the 2005 Accomack County 911 address map. In this exercise, the same general size and layout of current facilities was used in order to optimize the deconfliction between missions and operations. If infrastructures were relocated from Wallops Island to the Mainland, 166 residential addresses would be displaced. Of these addresses, 26 would be within a hazardous storage and operational buffer. Eighty-seven addresses would be within the 3,050 m (10,000 ft) launch hazard arc established for LVs. NASA would be required to purchase or condemn property within the hazard arc since the launch hazard area must be clear of people and private or public structures prior to launch. Residents within the operational buffer would be evacuated while the buffer is active. There would also be 1,815 ha (4,480 ac) of non-improved private land within the hazardous storage and hazard arc, and 645 addresses would be within an area of equivalent size as the current unpopulated natural wetland buffer between Wallops Island and Mainland. Additionally, up to 24 addresses could be affected if a small release of toxics occurred at a hypothetical fueling facility on Wallops Mainland; up to 770 addresses could be affected in the event of a large toxic release. As a result of the potential impacts to the local population in the vicinity of Wallops Mainland, this alternative was not carried forward for analysis in this Site-wide PEIS.

### 2.7.2 Relocating Infrastructure to Other Regional Sites

NASA also investigated the potential for upland sites with the same approximate longitude of Wallops Island within the region (NASA 2010). All properties at least as distant from populated areas on the Eastern Shore of Maryland and Virginia include the other eleven of Virginia's barrier islands and the AINS, all of which are publicly or privately owned for conservation purposes. Each of these areas would require substantial infrastructure development, while still being susceptible to the same storm damage and sea level rise risks that Wallops Island has faced throughout its history. As such, NASA eliminated analysis of movement of its Wallops Island to other regional sites. This alternative was not carried forward for further consideration or analysis in this Site-wide PEIS.

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# 3.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

**Analysis Approach**

This Site-wide PEIS considers reasonably foreseeable actions at WFF within a 20-year planning horizon. The analysis in this PEIS considers the current (i.e., baseline) conditions of the affected environment and compares those to conditions that might occur should NASA implement the Proposed Action. Baseline conditions provide a benchmark against which an agency measures the effects of a proposed action. The differences in the conditions between the baseline and the Proposed Action reflect the magnitude of impacts relative to the various resources analyzed. For the Proposed Action, establishing a baseline at WFF meant consideration of the conditions of each resource at the facility as they exist in 2017 based on the best available information.

**Regulatory Framework**

The regulations and Executive Orders listed below include, but are not limited to, the regulatory framework that serves as the basis for analysis for the affected resources that follow:

- NEPA (42 U.S.C. sections 4321-4370h)
- CEQ Regulations for Implementing the Procedural Provisions of NEPA (40 CFR parts 1500-1508)
- Clean Air Act (CAA) (42 U.S.C. section 7401 et seq.)
- CWA (33 U.S.C. section 1251 et seq.)
- Coastal Zone Management Act (CZMA) (16 U.S.C. section 1451 et seq.)
- National Historic Preservation Act (NHPA) (54 U.S.C. section 306108 et seq.)
- Endangered Species Act (ESA) (16 U.S.C. section 1531 et seq.)
- Marine Mammal Protection Act (MMPA) (16 U.S.C. section 1361 et seq.)
- Migratory Bird Treaty Act (MBTA) (16 U.S.C. section 703-712)
- Bald and Golden Eagle Protection Act (16 U.S.C. section 668-668d)
- Energy Independence and Security Act (42 U.S.C. chapter 152)
- Executive Order (EO) 11988, Floodplain Management
- EO 12088, Federal Compliance with Pollution Control Standards
- EO 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
- EO 13045, Protection of Children from Environmental Health Risks and Safety Risks
- EO 13175, Consultation and Coordination with Indian Tribal Governments
- EO 13834, Efficient Federal Operations

**Affected Resources**

Some components of the actions proposed at WFF, such as construction projects, essentially affect only the installation due to their limited geographic scope. Changes in NASA personnel or the temporary influx of research scientists or NASA customers would not only affect WFF, but the economic and social effects would extend out into the local communities. Noise from rockets launched from Wallops Island have the potential to reach past the local communities. **Table 3.0-1** provides the resources analyzed in this Site-wide PEIS and indicates the potential for impacts to extend outside the boundaries of WFF.

**Table 3.0-1. Resources Analyzed in this Site-wide PEIS**

| Resource | Potential Impacts | |
|---|---|---|
| | WFF | Local Communities |
| Noise | Yes | Yes |
| Air Quality | Yes | Yes |
| Hazardous Materials, Toxic Substances, and Hazardous Waste | Yes | Yes |
| Health and Safety | Yes | Yes |
| Water Resources | Yes | Yes |
| Land Use | Yes | Yes |
| Land Resources | Yes | No |
| Vegetation | Yes | No |
| Terrestrial Wildlife | Yes | Yes |
| Special-Status Species | Yes | Yes |
| Marine Mammals and Fish | Yes | Yes |
| Airspace Management | Yes | Yes |
| Transportation | Yes | Yes |
| Infrastructure and Utilities | Yes | No |
| Socioeconomics | Yes | Yes |
| Environmental Justice | Yes | Yes |
| Visual Resources and Recreation | Yes | Yes |
| Cultural Resources | Yes | No |

According to Section 1508.27 of the CEQ Regulations for Implementing NEPA (CEQ 1979), determining the level of significance of an environmental impact requires that both context and intensity be considered. These are defined in Section 1508.27 as follows.

- "Context. This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the Proposed Action. For instance, in the case of a site-specific action significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant."
- "Intensity. This refers to the severity of the impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:
    - Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect would be beneficial.
    - The degree to which the Proposed Action affects public health or safety.

- Unique characteristics of the geographic area such as proximity to historic or Cultural Resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
- The degree to which the effects on the quality of the human environment are highly uncertain or involve unique or unknown risks.
- The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
- Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
- The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in NRHP or may cause loss or destruction of significant scientific, cultural, or historical resources.
- The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined critical under the ESA of 1973.
- Whether the action threatens a violation of Federal, state, or local law or requirements imposed for the protection of the environment."

NASA developed a resource matrix to focus the impact analysis on the resources potentially impacted by implementing the proposed institutional support projects and operational missions and activities. If one or more of the projects proposed would have no impact on a particular resource, that action is not evaluated under that resource. For example, the demolition and reconstruction of the Causeway Bridge would not have an impact on Airspace Management; therefore, impacts to this resource from implementing that particular project are not evaluated. **Table 3.0-2** provides the Site-wide PEIS resource matrix.

Several of the institutional support projects presented in the PEIS are in the very early stages of development. For those projects, a notional evaluation is presented; further NEPA analysis would be required in the future to fully evaluate the potential impacts. In addition, the majority of operational missions and activities presented in the PEIS are in the planning stage. As project design details become more developed, further NEPA analysis may be required in the future to fully evaluate the potential impacts. The institutional support projects and operational missions and activities that may require further NEPA analysis were identified in Section 2.5-1 and Section 2.5-2 and are noted in **Table 3.0-2**.

**Table 3.0-2. Site-wide PEIS Resource Matrix**

| Projects and Activities | Noise | Air Quality | Hazardous Materials, Toxic Substances, and Hazardous Waste | Health and Safety | Water Resources | Land Use | Land Resources | Vegetation | Terrestrial Wildlife | Special-Status Species | Marine Mammals and Fish | Airspace Management | Transportation | Infrastructure and Utilities | Socioeconomics | Environmental Justice | Visual Resources and Recreation | Cultural Resources |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Institutional Support Projects** | | | | | | | | | | | | | | | | | | |
| Construction, Demolition, and RBR Projects | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | √ |
| Commercial Space Terminal | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | √ |
| Runway 04/22 extension | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | | √ |
| [x] Causeway Bridge Replacement | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | √ |
| [x] Maintenance Dredging | √ | √ | √ | √ | √ | | | √ | | √ | √ | | √ | | √ | | √ | √ |
| [x] North Wallops Island Deep-water Port and Operations Area | √ | √ | √ | √ | √ | | | √ | | √ | √ | | √ | | √ | | √ | √ |
| [x] Launch Pad 0-C | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | √ |
| [x] Launch Pier 0-D | √ | √ | √ | √ | √ | | | √ | | √ | √ | | √ | | √ | | √ | √ |
| DoD Launch Pads | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | √ |
| **Operational Missions and Activities** | | | | | | | | | | | | | | | | | | |
| DoD SM-3 | √ | √ | | √ | √ | | | √ | √ | √ | √ | √ | √ | | | | | |
| [y] Directed Energy | | | | √ | | | | | √ | √ | √ | √ | | √ | | | | |
| [y] SODAR System | √ | | | √ | √ | | | | √ | √ | | | | | | | | |
| North Wallops Island UAS Airstrip Increased Operations | √ | √ | √ | √ | | | | | | | | √ | | | √ | | | |
| [y] Expanded Space Program | | | | | | | | | | | | | | | | | | |
| [y] LFIC LV and SFHC LV | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| [y] Vertical Launch and Landing Vehicles | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| [y] Horizontal Launch and Landing Vehicles | √ | √ | √ | √ | | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| [y] Commercial Human Spaceflight Missions | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| [y] Hybrid Fuels | | | √ | √ | | | | | | | | | | | | | | |

Notes: [x] denotes projects that are in the very early stage of development. As project planning and design details became more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts.

[y] denotes projects that are in the planning stage. As project design details become more developed, further NEPA analysis may be required in the future to fully evaluate the potential impacts.

## 3.1 NOISE

Noise is often defined as any sound that is undesirable because it interferes with communication, is intense enough to damage hearing, diminishes the quality of the environment, or is otherwise annoying. Noise may be intermittent or continuous, steady or impulsive, and may be generated by stationary or mobile sources. The individual response to similar noise events can vary widely and is influenced by the type and characteristics of the noise source, distance between source and receptor, receptor sensitivity, and time of day.

Sound, expressed in decibels (dB), is created by vibrations traveling through a medium such as air or water. A-weighting (dBA) provides a good approximation of the response of the average human ear and correlates well with the average person's judgment of the relative loudness of a noise event. **Table 3.1-1** provides typical noise levels from a variety of sources. A sound level of 0 dBA is the approximate threshold of human hearing and is barely audible under extremely quiet conditions. By contrast, normal speech has a sound level of approximately 60 dBA. Sound levels above 100 dBA begin to be felt inside the human ear as discomfort. Sound levels between 110 and 130 dBA are felt as pain; levels exceeding 140 dBA could involve tissue damage to the ear (Berglund and Lindvall 1995). The minimum change in the sound level of individual noise events that an average human ear can detect is about 3 dB. On average, a person perceives a doubling (or halving) of a sound's loudness when there is a 10 dB change in sound level.

**Table 3.1-1. Typical Noise Levels of Familiar Noise Sources and Public Responses**

<table>
<tr><th>Thresholds/Noise Sources</th><th>Sound Level (dBA)</th><th>Subjective Evaluation[a]</th><th>Possible Effects on Humans[a]</th></tr>
<tr><td>Human threshold of pain</td><td>140</td><td rowspan="4">Deafening</td><td rowspan="7">Continuous exposure to levels above 70 dBA can cause hearing loss in the majority of the population</td></tr>
<tr><td>Siren at 30 m (100 ft)</td><td>130</td></tr>
<tr><td>Jet takeoff at 61 m (200 ft)<br>Auto horn at 1 m (3 ft)</td><td>120</td></tr>
<tr><td>Chain saw or noisy snowmobile</td><td>110</td></tr>
<tr><td>Lawn mower at 1 m (3 ft)<br>Noisy motorcycle at 15 m (50 ft)</td><td>100</td><td rowspan="2">Very Loud</td></tr>
<tr><td>Heavy truck at 15 m (50 ft)</td><td>90</td></tr>
<tr><td>Pneumatic drill at 15 m (50 ft)<br>Busy urban street, daytime</td><td>80</td><td rowspan="2">Loud</td></tr>
<tr><td>Normal automobile at 80 km per hour (50 mi per hour)<br>Vacuum cleaner at 1 m (3 ft)</td><td>70</td><td rowspan="2">Speech interference</td></tr>
<tr><td>Air conditioning unit at 6 m (20 ft)<br>Conversation at 1 m (3 ft)</td><td>60</td><td rowspan="2">Moderate</td></tr>
<tr><td>Quiet residential area<br>Light auto traffic at 30 m (100 ft)</td><td>50</td><td rowspan="2">Sleep interference</td></tr>
<tr><td>Library or quiet home</td><td>40</td><td rowspan="2">Faint</td></tr>
<tr><td>Soft whisper at 5 m (15 ft)</td><td>30</td><td rowspan="4">None</td></tr>
<tr><td>Slight rustling of leaves</td><td>20</td><td rowspan="3">Very Faint</td></tr>
<tr><td>Broadcasting studio</td><td>10</td></tr>
<tr><td>Threshold of Human Hearing</td><td>0</td></tr>
</table>

Source: EPA 1974.
Note: [a] Both the subjective evaluations and the physiological responses are continuums without true threshold boundaries. Consequently, there are overlaps among categories of response that depend on the sensitivity of the noise receivers.

### 3.1.1 Noise Metrics

The impact of noise is described through the use of noise metrics which depend on the nature of the event and who or what is affected by the sound. The following section provides metrics for airborne noise (includes criteria regarding sonic booms) and underwater acoustics.

**Airborne Noise**

Airborne noise is represented by a variety of metrics that are used to quantify the noise environment. Human hearing is more sensitive to medium and high frequencies than to low and very high frequencies, so it is common to use maximum dBA metrics (also shown as dB $L_{Amax}$) representing the maximum A-weighted sound level over a duration of an event such as an aircraft overflight. A-weighting provides a good approximation of the response of the average human ear and correlates well with the average person's judgment of the relative loudness of a noise event. A-weighted Sound Exposure Level (SEL) represents both the magnitude of a sound and its duration. The Day-Night Average Sound Level (DNL)[5] is a cumulative noise metric that accounts for all noise events over an average 24-hour period. This is often shown as dB DNL. DNL is used to predict human annoyance and community reaction to unwanted sound (i.e., noise).

**Sonic Booms, Sound Overpressures and Low Frequency Sounds**

A sonic boom is created when an object (e.g., rocket) travels faster than the speed of sound. A sonic boom differs from other sounds in that it is impulsive and very brief, lasting less than one second. Shock waves, or sound overpressures, associated with sonic booms (boom load) have the potential to cause structural damage. Most damage claims from sonic booms are for brittle objects such as glass and plaster. There is a large degree of variability in damage experience, and the degree of damage depends on the pre-existing condition of an object or structure. Breakage data for glass, for example, spans a range of two to three orders of magnitude at a given overpressure. At 7 kiloPascals (kPa) (1 pound per square foot [psf]), the probability of a window breaking ranges from one in a billion (Sutherland 1990) to one in a million (Hershey and Higgins 1976). These damage rates are associated with a combination of boom load and glass condition. At 70 kPa (10 psf), the probability of breakage is between one in a 100 and one in a 1,000 (Haber and Nakaki 1989). Laboratory tests of glass have shown that properly installed window glass will not break at overpressures below 70 kPa (10 psf), even when subjected to repeated booms (White 1972). Because a sonic boom is not generated until the rocket reaches supersonic speeds, the launch site itself does not experience a sonic boom. Rather, the boom occurs over the ocean, downrange of the launch site, along the trajectory of the rocket.

**Underwater Acoustics**

Underwater acoustics behave much like sound in the air but, due to the denser medium, the sound waves can propagate much farther in water. Unlike airborne noise, underwater noise is not weighted to match frequencies that can be heard by the human ear. Two common descriptors of underwater noise are instantaneous peak sound pressure level ($dB_{peak}$) and the root mean square ($dB_{RMS}$) pressure level during the impulse. The $dB_{peak}$ is the instantaneous maximum overpressure or underpressure observed during each sound pulse and can be presented in Pascals (Pa) or sound pressure level in dB, referenced to a pressure of 1 micropascal at one meter (dB re:1μPa-m). The $dB_{RMS}$ is the square root of the energy

[5] DNL combines the levels and durations of noise events, and the number of events over a 24-hour time period; it is the community noise metric recommended by the EPA (EPA 1974).

divided by the duration of the sound pulse. This level is often used by the NMFS to describe disturbance related effects to marine mammals from underwater impulse sounds. Potential injury to fish from noise is estimated using the $dB_{peak}$ metric (Washington State Department of Transportation [WSDOT] 2015).

### 3.1.2 Noise Thresholds and Guidelines

Noise in the U.S. is regulated under a number of different statutes and regulations. The Noise Control Act of 1972, and as amended by the Quiet Communities Act of 1978, set forth the policy of the U.S. to promote an environment for all citizens that is free from noise that jeopardizes human health and welfare. Specific noise regulations can be imposed by Federal agencies and state and local governments. Thresholds and guidelines for airborne noise and underwater acoustics applicable to activities at WFF along with standard thresholds are provided below.

**Accomack County Noise Ordinance**

The Accomack County Code provides noise threshold guidelines based on the different zoning districts within the County. The County Code provides noise levels for both day and nighttime activities, and activities that will exceed these thresholds are generally prohibited. Article 38-35 of the Code states that the thresholds shown in **Table 3.1-2** do not apply to commercial or industrial operations except if noise from those operations emanates beyond the boundaries of the commercial or industrial site and affect persons who are not working onsite (Accomack County 2001). No specific noise thresholds have been established for any sensitive receptors but the Code states that noise would be deemed excessive if it "unreasonably interferes with the workings of such institution or building, provided that conspicuous signs are displayed on or near such building or institution indicating that such is a school, church, hospital, clinic, or other public building" (Accomack County 2001).

**Table 3.1-2. Accomack County Noise Guidelines by Land Use**

| Zoning District | Daytime Level (dBA) | Nighttime Level (dBA) |
|---|---|---|
| Residential | 65 | 55 |
| Agricultural | 65 | 55 |
| Business | 70 | 60 |
| Industrial | 70 | 60 |
| Barrier Island | 65 | 55 |

Source: Accomack County 2001.

**OSHA Noise Guidance**

The Occupational Safety and Health Act (OSHA) of 1970 assures safe and healthy working conditions by enforcing standards and by providing training, education, outreach, and assistance. OSHA regulates noise impacts to workers, and establishes thresholds for a safe work environment. OSHA standard (29 CFR 1910.95) provides noise exposure limits for employees in noisy environments or workplaces. According to OSHA, an employee should not be subjected to continuous noise exceeding 90 dBA for durations lasting more than 8 hours per day (**Table 3.1-3**). As the level increases, the allowed duration of exposure decreases. The maximum limit is 115 dBA for duration of 15 minutes or less.

OSHA standards are the most well documented requirements in regards to long-term human noise exposure. Although they are not specifically designed to assess the impact of intermittent launch noise, the OSHA limit of 115 dBA appears to be the most appropriate standard available for human exposure to launch noise levels. A maximum noise level of 115 dBA is used to identify potential locations where hearing protection should be considered for a rocket launch.

| Table 3.1-3. OSHA Permissible Noise Exposures | |
|---|---|
| **Duration per Day (hours)** | **Sound Level (dBA)** |
| 8 | 90 |
| 6 | 92 |
| 4 | 95 |
| 3 | 97 |
| 2 | 100 |
| 1.5 | 102 |
| 1 | 105 |
| 0.5 | 110 |
| 0.25 | 115 |

Source: OSHA 2012.

### Federal Interagency Committee on Urban Noise

In June 1980, an ad hoc Federal Interagency Committee on Urban Noise (FICUN) published guidelines relating DNL to compatible land uses (FICUN 1980). This committee was composed of representatives from DoD, DOT, Department of Housing and Urban Development, EPA, and Veterans Administration. Since their issuance, Federal agencies have generally adopted the guidelines for their noise analyses. According to a study conducted by FICUN, noise levels between 65 and 70 dB DNL are compatible with educational services, such as schools, provided that measures are taken to provide noise level reduction of 25 dB in the buildings (FICUN 1980).

### Federal Aviation Administration Significant Impact Threshold for Noise

Some of the activities included as part of the Proposed Action in this Site-wide PEIS would require the FAA to issue an experimental permit and/or launch license. These FAA actions are subject to FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures* which states that special consideration needs to be given to the evaluation of the significance of noise impacts on noise sensitive areas, including wildlife refuges. A noise sensitive area is defined by the FAA as an area where noise interferes with normal activities associated with its use. Normally, noise sensitive areas include residential, educational, health, and religious structures and sites, parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites. FAA Order 1050.1F adds guidance that gives special consideration to the evaluation of the significance of noise impacts on noise sensitive areas within national parks, national wildlife refuges, and historic sites including traditional cultural properties.

### Federal Highway Administration Regulations for Highway Traffic Noise

The Federal-Aid Highway Act of 1970 (Public Law 91-605) required the FHWA, an agency within the U.S. DOT, to develop noise regulations. The regulation, 23 CFR 772, *Procedures for Abatement of Highway Traffic Noise and Construction Noise* applies to highway construction projects where a state DOT has requested federal funding for participation in the project. The regulation requires FHWA to investigate traffic noise impacts in areas where proposed construction or reconstruction of an existing federally-aided highway would either significantly change the horizontal or vertical alignment of the highway or increase the number of traffic lanes. NASA along with VDOT has requested federal funding for implementing the Causeway Bridge Replacement project. Guidelines and standards developed by the FHWA would be integrated into the planning and design of the Causeway Bridge.

**U.S. Navy and NMFS Noise Guidance**

While no clear federally recognized threshold for human exposure exists for underwater noise, the U.S. Navy prohibits exposure of un-hooded Navy divers to sound pressure levels in excess of 200 dB re:1µPa-m (U.S. Navy 2008). Underwater thresholds have been established by NMFS for behavioral disruption and potential injury for marine wildlife, specifically, marine mammals and fish. These thresholds and impacts are discussed in Sections 3.10, Special-Status Species and 3.11, Marine Mammals and Fish.

### 3.1.3 AFFECTED ENVIRONMENT

There are several noise sources discussed in this PEIS. The first is noise generated by vehicles and equipment used during construction and demolition activities throughout WFF. The second is noise generated by aircraft at the Main Base and launch activities on Wallops Island, Navy activities north of the launch range, and operations at the North Wallops Island UAS airstrip. Below is a general description of the baseline noise environments and major noise sources from the Main Base, Mainland, and Wallops Island. A brief description of the underwater noise environment for the Mainland and Wallops Island is also provided.

#### 3.1.3.1 Main Base

Vehicular traffic and construction-related activities at WFF are considered minor sources of noise. Typically, the dBA value for vehicle operations would range from 50 dBA (for light traffic) to 80 dBA for diesel trucks. Construction noise varies greatly depending on the construction process, type and condition of equipment used, and the layout of the construction site. Overall, construction noise levels are governed primarily by the noisiest pieces of equipment (e.g., dump truck, excavator, and grader).

Airfield operations, primarily pilot proficiency training, account for the majority of noise generated at the Main Base. According to the Navy Region Mid-Atlantic, between November 2013 and December 2016, a total of 158 noise complaint calls were received from 63 callers with most of these complaint calls originating from five callers. The majority of the calls were from residential areas within approximately 1.5 km (0.75 nm) west of the approach end of Runway 10. Most complaints focused on Navy FCLP operations with the majority of calls received by the hotline that the Navy established in 2013 solely for the purpose of Navy FCLP complaint calls (Easterbrooks 2017). According to the WFF Office of Communications during this same period, WFF received no noise complaints in response to NASA operational missions or activities (Eggers 2017).

#### 3.1.3.2 Mainland and Wallops Island

##### 3.1.3.2.1 Airborne Noise

Rocket activities generate the greatest noise levels on Wallops Island. Large rockets have the potential to produce sonic booms. Trajectories for rockets launched from WFF follow a predominantly southeastern course over the Atlantic Ocean. The boom footprint or "carpet", if generated, would occur over the open ocean (NASA 2009). Rocket operations that have the potential to create sonic booms must be coordinated through the Navy's FACSFAC VACAPES (NASA 2009).

In October 2011, Blue Ridge Research and Consulting (BRRC) collected noise data for WFF. The effort focused mainly on the baseline acoustic environment of the Mainland and Wallops Island (BRRC 2011). Generally, the noise environments at the Mainland and Wallops Island are relatively quiet with the dominant noise sources being naturally occurring wind and wave action, due to their coastal location.

Ambient noise is below 52 dB DNL (BRRC 2011). Those activities that generate noise above ambient conditions include UAS flight operations, Navy rocket and target launches, and NASA and MARS rocket launch activities. Noise generated by rocket launches is short-term in duration lasting less than 10 minutes with the peak noise levels occurring within the first one to two minutes. WFF has received no noise complaints in response to NASA operational missions or activities (Eggers 2017).

#### 3.1.3.2.2 Underwater Acoustics

The ambient underwater acoustic environment is affected by many natural and man-made activities. Generally, the waters surrounding WFF are relatively quiet, with the major human-generated noise sources coming from commercial fishing vessels, recreational boats, and personal watercraft. During the initial SRIPP beach fill in summer 2012, NASA partnered with Bureau of Ocean Energy Management and USACE to record background in-water sound levels at both the offshore borrow area (18 km [11 mi] northeast of Wallops Island) and the nearshore pump-out area (between 2-4 km [1.2-2.4 mi]) east of Wallops Island). Data were collected at two listening depths at each site: approximately 3 m (10 ft) and 9 m (30 ft) depths at the offshore shoal; and 3m (10 ft) and 6 m (20 ft) at the nearshore sites. During the study, the majority of data were collected when winds were at least 6-11 km (4-7 mi) per hour and wave heights were at least 0.5 – 0.6 m (1-2 ft). Therefore, the data do not reflect “calm” sea conditions.

Background sound pressure levels (SPLs) averaged 117 dB across all sampling days, sites, water depths and weather conditions. Minimum measured sound levels ranged from 91 dB to 107 dB depending on sampling location and water depth; maximum levels ranged from approximately 128 dB to just under 148 dB (Reine et al. 2014). Highest SPLs were found at frequencies of less than 200 hertz.

The authors note that sea state and the associated sounds generated by waves interacting with the survey vessel likely contributed to the elevated readings. A few natural sound sources that may be found near WFF are from rain and breaking waves (~91 dB to 148 dB re:1μPa-m), bottlenose dolphin whistles (125 to 173 dB re:1μPa-m), humpback whale fluke slaps (183-192 dB re:1μPa-m), and lightning striking the water surface (~260 dB re:1μPa-m). A range of anthropogenic sources, though not necessarily found near WFF, are a barge and dredge (maximum ~171 dB re:1μ Pa-m), a supply ship underway (181 dB re:1μPa-m), and a U.S. Navy tactical mid-frequency sonar (235 dB re:1μPa-m) (Discovery of Sound in the Sea 2012).

### 3.1.4 ENVIRONMENTAL CONSEQUENCES

Noise-related impacts would be considered significant if the Proposed Action generated noise levels that were incompatible with surrounding land uses or created a situation that endangered human health and safety. Potential noise impacts to terrestrial, as well as special-status species and marine wildlife are discussed in Sections 3.9 through 3.11.

Per FAA Order 1050.1F, a significant noise impact would occur if analysis shows that the Proposed Action would cause noise sensitive areas to experience an increase in noise of 1.5 dB DNL or more at or above 65 dB DNL noise exposure when compared to the No Action Alternative for the same timeframe. For this analysis, LV launch noise impacts were modeled as single events. As such, DNL metrics have not been applied to LV launch operations in this PEIS. Should the FAA determine that DNL metrics are necessary, DNL noise modeling would be accomplished as part of the FAA licensing process.

#### 3.1.4.1 No Action Alternative

Under the No Action Alternative, baseline conditions would continue, as described in Section 2.4. This includes a number of ongoing actions that can be divided into two main areas regarding noise impacts. These are discussed in more detail below. Existing and previously analyzed activities would continue or would be implemented. Refer to Section 2.4 for actions that have been analyzed but not yet implemented.

##### 3.1.4.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. As such, no new noise impacts would occur and baseline noise conditions would continue.

##### 3.1.4.1.2 Operational Missions and Activities

All operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Airfield operations, UAS flight operations, and rocket launch activities would continue within the documented envelopes.

**Figure 3.1-1** provides the operational baseline noise contours for the Main Base airfield and Wallops Island Launch Range.

**<u>Airfield Operations</u>**

Noise generated from airfield operations are shown as contours in **Figure 3.1-1**. The 65 dB DNL noise contour extends beyond the Main Base boundary, mostly over lands zoned for agricultural use. The 65 dB DNL contour does extend over a residential area to the west, but 65 dBA is within the daytime noise ordinance limits for Accomack County (Accomack County 2001).

The 70 dB DNL contour extends only slightly beyond the base boundary at the terminal end of runways 10, 22, and 28 and the 75 dB DNL noise contour is confined to the Main Base boundary. **Figure 3.1-1** also indicates the numerous points of interest surrounding WFF. As shown in **Table 3.1-4**, 24 points of interest were identified during a baseline noise monitoring survey, as comparisons, baseline dB DNL values (i.e., normally occurring background levels) are presented for 22 of the points. With an average DNL of approximately 50 dB, none of the points of interest had DNL values that exceeded 65 dB DNL.

**<u>Launch Range Operations</u>**

The Antares (formerly Taurus II) launch vehicle has been analyzed for operations at WFF and is the envelope liquid-fueled launch vehicle; therefore, baseline conditions have been modeled with the Antares. The 2009 *EA for the Expansion of the Wallops Flight Facility Launch Range,* which is incorporated by reference into this PEIS, presented conservative noise predictions for the Antares launch vehicle. These predictions were based on a methodology that equated noise to the overall thrust of the rocket motor with the assumption that the noise levels would be evenly distributed radially (NASA 2009). In 2015, the Antares LV was modeled using the latest technology for assessing rocket launch noise (BRRC 2015). Additionally, to help assess the community impact, BRRC modeled the noise impact relative to the overall sound pressure level (OASPL) at the nearest house location approximately 3.0 km (1.9 mi) west of the WFF Launch Range, as a specific point of interest (BRRC 2015). **Appendix D** contains the BRRC 2015 report.

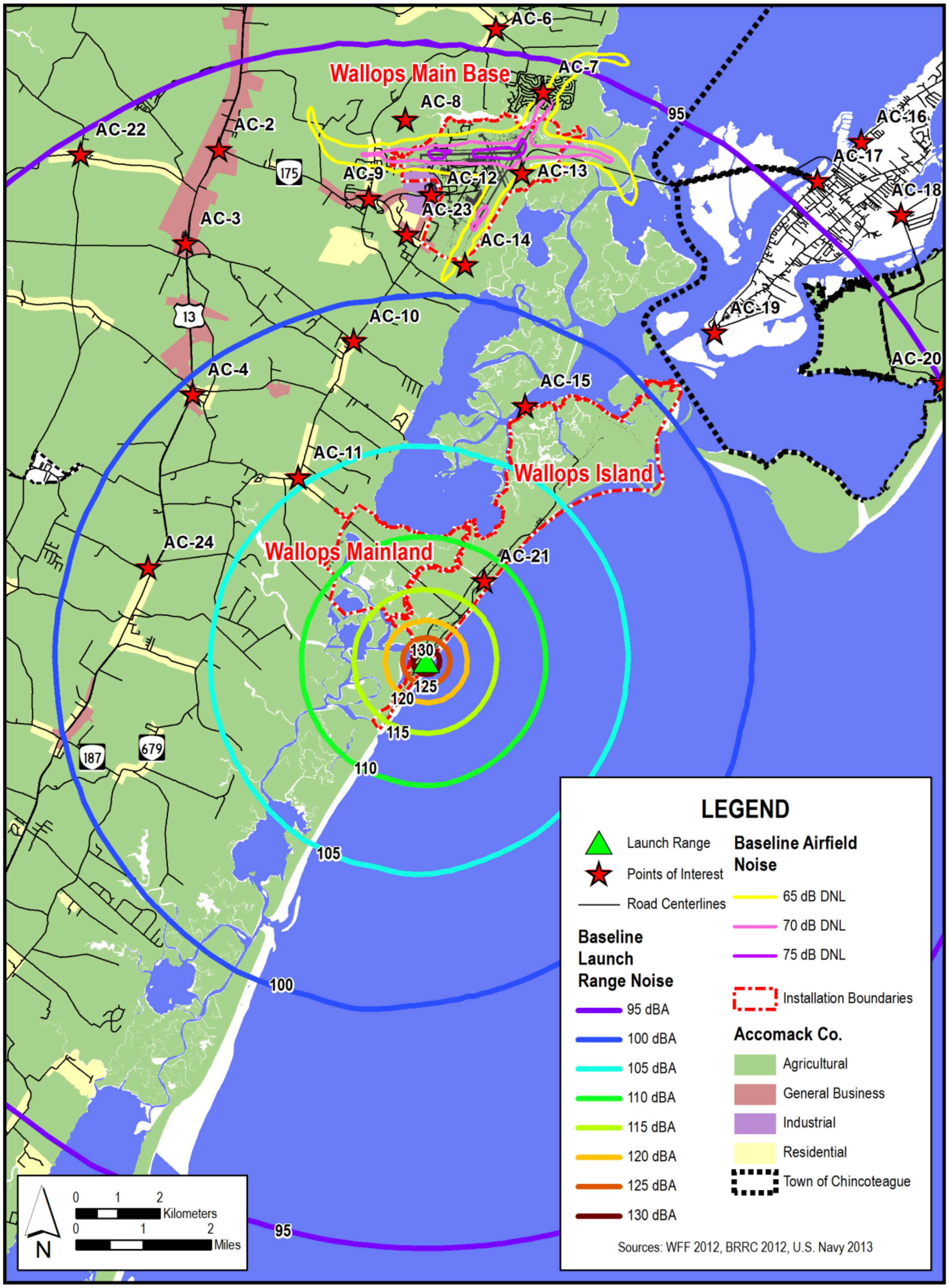


**Figure 3.1-1. Baseline Noise Environment and Points of Interest at Wallops Flight Facility**

| Location ID | Description | Latitude | Longitude | Baseline dB DNL |
|---|---|---|---|---|
| AC-1 | Intersection of U.S. 13 and SR 709 | 37.979862 | 75.530116 | <45 |
| AC-2 | T's Corner (east of intersection of U.S. 13 and Chincoteague Road) | 37.945590 | 75.539688 | 49.1 |
| AC-3 | Arcadia High School | 37.925653 | 75.549588 | 48.2 |
| AC-4 | Temperanceville at Intersection of U.S. 13 and SR 695 | 37.892998 | 75.548880 | <45 |
| AC-5 | Captain's Cove Community Pool | 37.990629 | 75.421811 | <45 |
| AC-6 | Horntown at Intersection of SR 679 and SR 709 | 37.969714 | 75.463103 | 52.8 |
| AC-7 | Trail's End Campground/Community Pool | 37.955769 | 75.450846 | 62.4 |
| AC-8 | Olde Mill Pointe Traffic Circle | 37.950772 | 75.488573 | 56.1 |
| AC-9 | Wattsville at Intersection of SR 679 and Chincoteague Road | 37.934026 | 75.499244 | 61.2 |
| AC-10 | Atlantic at Intersection of SR 679 and Nocks Landing Road | 37.903404 | 75.504567 | 45.1 |
| AC-11 | Assawoman at Intersection of SR 670 and Wallops Island Road | 37.874388 | 75.520869 | <45 |
| AC-12 | CBFS | 37.934410 | 75.482184 | 55 |
| AC-13 | NASA WFF Visitor Center | 37.938484 | 75.457344 | 63.5 |
| AC-14 | USFWS Maintenance Yard at Wallops Island National Wildlife Refuge | 37.919021 | 75.473680 | 62.4 |
| AC-15 | Ballast Narrows at Wallops Island National Wildlife Refuge | 37.888266 | 75.458558 | <45 |
| AC-16 | Chincoteague High School | 37.942804 | 75.364619 | <45 |
| AC-17 | Chincoteague Waterfront Park | 37.934675 | 75.376869 | <45 |
| AC-18 | Chincoteague Chamber of Commerce on Piney Island | 37.926754 | 75.354520 | <45 |
| AC-19 | Curtis Merritt Harbor, Chincoteague Island | 37.902697 | 75.406283 | <45 |
| AC-20 | Tom's Cove Visitor Center | 37.890114 | 75.344757 | <45 |
| AC-21 | MARS (located on the launch range) | 37.850806 | 75.471128 | <45 |
| AC-22 | Withams at Intersection of SR 693 and SR 703 | 37.945463 | 75.577460 | <45 |
| AC-23* | Emma's World Daycare and Preschool (closed) | 37.926485 | 75.489265 | No data |
| AC-24* | Kegotank Elementary School | 37.855931 | 75.562478 | No data |

**Table 3.1-4. DNL Values for Points of Interest around Wallops Flight Facility**

Source: U.S. Navy 2013.
Note: *Points not included in BRRC's noise modeling effort, therefore no baseline data exists in DNL.
Legend: AC = Accomack County; SR=State Route.

The nearest house does not receive noise from the launch event until close to 9 seconds after the event has started due to the time it takes the noise to travel from the rocket to the receiver. The received OASPL is a result of the distance between the house (receiver) and the launch vehicle (source) as well as the vehicle's orientation. Although the vehicle is always moving farther away from the house, its orientation to the ground is shifting so that more acoustic energy is directed towards the house based on the angle from the source to receiver. A maximum predicted A-weighted OASPL of 114 dBA would be perceived at the nearest house for the Antares launch (BRRC 2015).

Time above OASPL 66 dBA is a supplemental metric that estimates the noise that can potentially interfere with speech. Outdoor speech interference can be expressed as a percentage of sentence intelligibility between two people speaking in normal voices at approximately 1 m (3.3 ft) apart. The model results indicate that sentence speech intelligibility will drop below 95% for a time period of up to 80 seconds per launch for the Antares. Ninety-five percent sentence intelligibility usually permits reliable communication because of the redundancy in normal conversation (BRRC 2015).

**Occupied Structures and Populations Affected during Antares Launch**

To determine the number of occupied structures (i.e., homes, business, etc.), including the nearest house, and population that could be affected by noise generated by rockets and projectiles launched from Wallops Island, 2010 Census data was used in combination with 911 emergency address GIS data obtained from Accomack, Northampton, Somerset, Wicomico, and Worcester counties (USCB 2010). As part of a ground-truthing effort, WFF plotted all homes within a 5 km (3.1 mi) radius of the launch range and verified that no occupied structures exist within the 115 dBA contour.

**Figure 3.1-1** provides the dBA noise contours for the baseline noise environment at Wallops Island. **Table 3.1-5** provides the total land area, occupied structures, and estimated population under the noise contours ranging from 115 dBA (the OSHA threshold for 15 minute exposure) to 130 dBA, within Accomack County. A total of 413 ha (1,018 ac) of land area is within the 115 to 130 dBA contours; however, there are no occupied structures or people located within the 115 dBA and greater noise contours. No land area, occupied structures, or people in Northampton, Somerset, Wicomico, or Worcester counties are located within the 115 to 130 dBA noise contours. From the noise modeling study (BRRC 2015), the maximum noise level at the nearest home to the launch range would be less than 115 dBA in within the first 80 seconds.

**Table 3.1-5. Land Area, Occupied Structures, and Estimated Population within Modeled Noise Contours (dBA) for the Antares Launch Vehicle**

| Peak Noise Contour (dBA) < 100 seconds | Land Area ha (ac) | Occupied Structures | Estimated Population |
|---|---|---|---|
| 115 | 270 (666) | 0 | 0 |
| 120 | 91 (224) | 0 | 0 |
| 125 | 26 (64) | 0 | 0 |
| 130 | 26 (64) | 0 | 0 |

Sources: BRRC 2015; USCB 2010.

### 3.1.4.2 Proposed Action

In addition to the actions currently taking place under the No Action Alternative, implementation of the Proposed Action involves numerous institutional support projects and operational missions and activities; however, only those proposed actions that have the potential to generate noise impacts are addressed in detail below. Potential impacts to marine wildlife, specifically, marine mammals and fish are discussed in Section 3.10, Special-Status Species and Section 3.11, Marine Mammals and Fish.

#### 3.1.4.2.1 Institutional Support Projects

Under the Proposed Action, construction activities would take place at the Main Base, as well as at the Mainland and Wallops Island. Few specifics are known at this time as to construction methods and if there would be any novel construction efforts. However, as shown in **Table 2.5-1** and **Table 2.5-2**, the types of construction required would be assumed to be typical building construction and would not require any new construction method that would generate excessive noise. Details on development of Launch Pad 0-C are not known; however, the new pad could be constructed similar to existing pads 0-A or 0-B; the description of this project is provided in Section 2.5.1.6. Development of the two DoD launch pads would be typical of other small pads constructed on Wallops Island. The Causeway Bridge Replacement project, maintenance dredging in the channel between the Main Base and Wallops Island boat docks, North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D would not be considered typical construction projects. These projects are discussed below.

**Construction, Demolition, and RBR Projects**

Typical construction and demolition practices would include the use of heavy equipment; however, the assumption is that no explosives or exceedingly loud practices would be needed. These construction efforts would generally be non-hardened buildings to house administrative or similar activities. Construction/demolition noise would be temporary over the course of the individual projects and would be confined to within the WFF boundaries. Construction-related noise can range from 74 to 101 dBA when measured 15 m (50 ft) from the respective piece of equipment. The noise associated with construction and demolition activities would be most likely confined to general working hours (8:00 a.m. to 5:00 p.m.) and are unlikely to adversely alter the surrounding noise environment. Refer to **Appendix E** for a table of in-air construction-related noise emissions.

A standard model for the attenuation of noise is a reduction of 6 dB for each doubling of distance (i.e., if the noise level is 85 dBA at 15.25 m [50 ft] from a point source, it is 79 dBA at 30.5 m [100 ft]) from that point source (EPA 1971). For a soft site (one with natural vegetation) and a point noise source (stationary, such as building construction, as opposed to a roadway) an additional 1.5 dB reduction can be added (WSDOT 2015). A noise attenuation table was generated using the methodology outlined by WSDOT for assessing construction noise impacts (**Appendix E**). Because construction and demolition methods have not been determined, the type and number of construction and demolition equipment required is unknown. Conservatively, the three loudest pieces of equipment were chosen to develop the noise attenuation table (WSDOT 2015). As shown, construction noise levels associated with equipment likely to be used during the institutional support projects would attenuate to background levels (conservatively, approximately 55 dBA) in approximately 500 m (1,600 ft). Noise would attenuate below the OSHA 8-hour exposure limit of 90 dBA within approximately 30 m (100 ft). Standard effort to minimize entry into an active construction zone (i.e., fencing) would create a general buffer around the construction/demolition area and ensure that non-construction/demolition personnel would not be exposed to unsafe noise levels during construction/demolition activities. Therefore, it is unlikely that noise generated from construction activities associated with the Proposed Action would create any significant impacts to the noise environment at any of the project locations.

**Causeway Bridge Replacement**

Noise produced from roadway construction, bridge construction in particular, can cause significant impacts to the surrounding noise environment. Generally, these impacts are from pile driving noise, which is impulsive, but also occurs over long durations (e.g., months for installing all necessary piles). Pile driving can cause noise impacts both in the terrestrial noise environment, as well as the underwater acoustic environment. At this time, there are no available design plans for the replacement bridge. A number of parameters are required in developing any estimation for pile driving noise impacts, including the size and type of piles to be driven, the number of piles required, and the average number of strikes per day from the impact pile driving equipment that would occur. Since these exact parameters are unknown at this time, general marine pile driving noise data was used to provide an example of typical sound pressures that can be produced during marine construction activities. These tables are provided in **Appendix E**. Additional analysis would be required once project details for the Causeway Bridge Replacement become known.

As stated, the number and type of piles driven, pile strikes per day, bottom type, and equipment used are all very important in determining the level of underwater noise that would be generated from this part of the Proposed Action. Site-specific NEPA analysis would be required, as much more specific data is needed to provide a reliable estimate of underwater noise impacts. Underwater noise from pile driving is unlikely to create any impacts to humans; however, the potential for impacts to protected species, marine mammals, and fish exists. These impacts are discussed in Section 3.10, Special-Status Species and Section 3.11, Marine Mammals and Fish.

Using the U.S. DOT's FHWA Road Construction Noise Model (FHWA 2006), airborne noise can be roughly estimated by assuming construction equipment required and providing a distance to a noise sensitive receptor. For this estimation, it was assumed that typical bridge construction equipment would be used (e.g., impact pile driver, crane, excavator, dump truck, etc.). Using this model, it was determined that airborne construction noise would attenuate to less than 60 dBA in approximately 2,135 m (7,000 ft). Since the closest residence to the Causeway Bridge is approximately 1.6 km (1 mi) to the west, it is unlikely that any impacts to the surrounding communities would occur. OSHA 8-hour thresholds (90 dBA) would only be exceeded within 53 m (175 ft) of bridge construction activity. Some minor annoyance to personnel working on Wallops Island could occur from construction noise, but noise levels would be well within OSHA noise guidelines and would not present an adverse impact. The Causeway Bridge would replace the existing bridge and would not be constructed to increase traffic capacity. As such, the post-construction traffic noise on the Causeway Bridge is not anticipated to increase.

**Maintenance Dredging**

Noise due to dredging activities would be caused by the dredging equipment, watercraft (tugboats and barges), and human activity. This maintenance dredging would be limited to the Barge Route between the Main Base and Wallops Island boat docks. At this time, there are no details on the exact methods to be used during dredging operations; however, two common dredging methods are clamshell dredging and hydraulic cutterhead dredging. No blasting would be required. Airborne noise levels from clamshell dredging would be approximately 87 dBA at 15 m (50 ft) dropping to 61 dBA at 300 m (1,000 ft) and to 55 dBA at 610 m (2,000 ft) from the source and would not impact any noise sensitive receptors. Hydraulic dredges would have similar noise due to diesel engines required to operate the dredge and similar supporting equipment such as survey boats.

Dredging of the boat docking facilities at WFF would also produce impacts to the underwater acoustic environment. Different types of mechanical dredging produce different underwater noise impacts, with clamshell dredging generally being noisier than hydraulic cutter head dredging. Studies have shown clam shell dredging sound levels of 124 dB re:1µPa-m at 158 m (520 ft) when the bucket strikes bottom (Dickerson et al. 2001). However, many factors, such as benthic substrate, water depth, sea state, and other ambient noise conditions would dictate how much underwater noise would be generated from dredging activities at WFF. Repair of the boat/barge docking facilities may also require pile driving. Pile driving impacts would be similar to those described for the Causeway Bridge Replacement. As with that part of the Proposed Action, more project-specific information would be required before a reliable estimation of underwater noise impacts could be undertaken. Project-specific NEPA analysis would be required as design information became available in the future. The in-water construction noise impacts to marine mammals and fish from maintenance dredging and other in-water dredging activities are discussed in Section 3.11.

**North Wallops Island Deep-water Port and Operations Area**

Details on development of the North Wallops Island Deep-water Port and Operations Area are not known; however, the project would involve dredging and in-water construction activities similar to those described for the Causeway Bridge and maintenance dredging proposals described above. In-water construction noise would be expected. Project-specific NEPA analysis would be required as design information became available in the future.

**Launch Pier 0-D**

Details on development of LV Launch Pier 0-D are not known; however, the project would involve dredging and in-water construction activities similar to those described for the Causeway Bridge and maintenance dredging proposals described above. In-water construction noise would be expected. Project-specific NEPA analysis would be required as design information became available in the future.

3.1.4.2.2 Operational Missions and Activities

There are several operational proposals under the Proposed Action that would have little to no impact on the noise environment at WFF. These include Directed Energy, SODAR System, and use of hybrid fuels. As such, only those proposals with potential impacts are described here.

**DoD SM-3**

Under the Proposed Action, the Navy would construct a dedicated SM-3 launch pad on Wallops Island. Currently, a vehicle similar to the Navy's SM-3, the Terrier sounding rocket, is launched from Wallops Island using one of the existing launch facilities. Launch operations would remain within the existing envelope of 60 annual suborbital rocket launches. Though this would now be a permanent facility at Wallops Island it is unlikely to affect the local noise environment. Noise generated from the SM-3 would occur at the launch pad and attenuate rapidly. Missiles would be launched out over the Atlantic Ocean into the VACAPES OPAREA controlled airspace. Wallops Island launch facilities are located 11 km (7 mi) from the Main Base and are intentionally not located near heavily populated areas. Therefore, it is unlikely that this aspect of the Proposed Action would create a significant noise impact to the community.

**North Wallops Island UAS Airstrip Increased Operations**

In 2012, WFF completed an EA for construction and operation of the North Wallops Island UAS airstrip (NASA 2012). The EA evaluated 1,040 annual UAS sortie operations that include few night operations. The Viking 300 was determined to be the loudest UAS that would operate from the new airstrip. SEL values for the Viking 300 were estimated to range between 56 dBA to 88 dBA at a 150 m (500 ft) minimum cruise altitude near the airstrip (BRRC 2010). Based on 1,040 annual UAS sorties, the estimated noise levels from the Viking 300 would not exceed 43 dB DNL (NASA 2012). Under the Proposed Action, UAS operations at the North Wallops Island UAS airstrip would increase to 3,900 annual sorties with increased night operations. Assuming that all 3,900 UAS operations involved the Viking 300 operating at a 150 m (500 ft) minimum cruise altitude near the airstrip, the estimated noise levels would not exceed 48 dB DNL. It is not anticipated that the 65 dBA daytime or 55 dBA nighttime noise ordinance limits for Accomack County would be exceeded.

**Expanded Space Program**

The Expanded Space Program has the potential to impact the noise environment due to the requirement for larger rocket launch vehicles. As payloads and mission objectives change, so do the launch vehicle specifications to allow heavier payloads to be launched into space. A new envelope launch vehicle has the potential to alter noise levels at WFF and in the surrounding areas. The potential impact of a larger launch vehicle (i.e., LFIC LV and SFHC LV) and LFIC RTLS is described in greater detail below. For purposes of this PEIS, the maximum number of combined LV orbital launches that would occur at WFF is 18 (6 LFIC LV/RTLS and 12 SFHC LV) per 12-month period.

***LFIC LV***

Under the Proposed Action, WFF would construct Launch Pad 0-C or Launch Pier 0-D to support the launching of a LFIC LV. The launching of the LFIC LV would exceed the current rocket motor envelope at Wallops Island. Noise modeling was completed to illustrate the potential noise impacts due to the launch of a LFIC LV from WFF. **Figure 3.1-2** shows the predicted single event A-weighted noise contours for this launch vehicle. As is shown, the 115 dBA noise contour (the OSHA threshold for 15 minute exposure) for the LFIC LV extends approximately 2.5 km (1.6 mi) from the launch site on Wallops Island (BRRC 2015). However, this noise level would not extend out into any areas with residential zoning or areas with occupied structures. The maximum A-weighted OASPL from a LFIC LV is predicted to be 100 dBA at the nearest house to the launch range with a time frame of greater than 80 seconds above OASPL 66 dBA.

These expected noise impacts are similar to what is currently experienced at the launch range from the Antares LV (BRRC 2015). No more than 6 LFIC LV/RTLS events would be authorized in a 12-month period (see Section 2.5.2.2, Vertical Launch and Landing Vehicles).

***SFHC LV***

Under the Proposed Action, WFF would construct Launch Pad 0-C or Launch Pier 0-D to support the launching of a SFHC LV. The launching of the SFHC LV would exceed the current rocket motor envelope at Wallops Island. The SFHC LV SRM would represent the largest rocket motor proposed for use at WFF. The SFHC LV noise impacts would be very similar to those created from the use of the LFIC LV, but would be slightly greater in scope. **Figure 3.1-3** shows the predicted noise contours that would be generated if a launch vehicle utilized the SFHC LV. The 115 dB contour extends out to almost 3 km (1.8 mi). Peak noise from the SFHC LV launches would be experienced for a duration of one to two minutes. No more than 12 SFHC LV launch events would be authorized in a 12-month period.

**Occupied Structures and Populations Affected During LFIC LV and SFHC LV Launches**

The same methodology described for the baseline conditions analysis (Section 3.1.4.1.2) was used to determine the number of occupied structures, including the nearest house, and population that could be affected by noise generated by rockets and projectiles launched from Wallops Island. 2010 Census data was used in combination with 911 emergency address GIS data obtained from Accomack, Northampton, Somerset, Wicomico, and Worcester counties (USCB 2010). As part of a ground-truthing effort, WFF plotted all homes within a 5 km (3.1 mi) radius of the launch range and verified that no homes exist within the 115 dBA to 130 dBA noise contours.

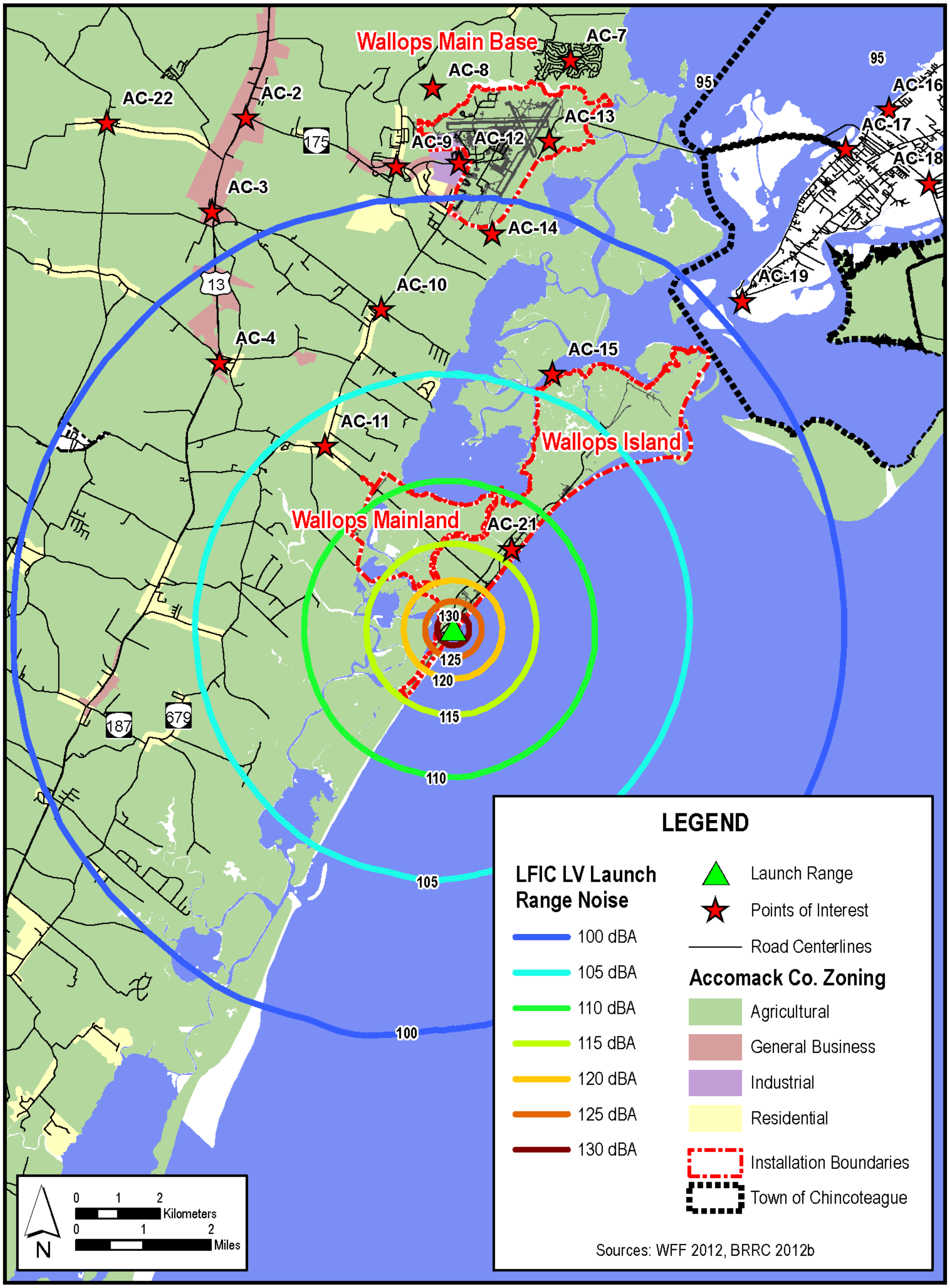


**Figure 3.1-2. Single Event Noise Contours Generated from the LFIC LV**

**Table 3.1-6** shows the total for land area, occupied structures, and estimated population under the LFIC LV and SFHC LV noise contours ranging from 115 dBA (the OSHA threshold for 15 minute exposure) to 130 dBA in Accomack County. Similar to the baseline, there are no occupied structures or people located within the 115 dBA and greater noise contours. From the BRRC study for noise impacts on the nearest home to the launch range, noise from the event is modeled to attenuate to the background average of 50 dBA in approximately 500 seconds with peak noise levels dropping drastically in the first 100 seconds. No land area, occupied structures, or people in Northampton, Somerset, Wicomico, or Worcester counties are located within the 115 to 130 dBA noise contours.

**Table 3.1-6. Land Area, Occupied Structures, and Estimated Population within Modeled Noise Contours (dBA) for the LFIC LV or SFHC LV**

| Peak Noise Contour (dBA) < 100 seconds in duration | Land Area ha (ac) | | Occupied Structures | | Estimated Population | |
|---|---|---|---|---|---|---|
| | LFIC | SFHC | LFIC | SFHC | LFIC | SFHC |
| 115 | 356 (879) | 362 (895) | 0 | 0 | 0 | 0 |
| 120 | 134 (332) | 137 (338) | 0 | 0 | 0 | 0 |
| 125 | 35 (87) | 36 (90) | 0 | 0 | 0 | 0 |
| 130 | 26 (63) | 26 (65) | 0 | 0 | 0 | 0 |

Sources: BRRC 2015; USCB 2010.

Noise associated with the launch of a LFIC LV would result in a net increase in land area of 137 ha (343 ac) within the 115 to 130 dBA contours when compared to the baseline Antares LV (refer to **Table 3.1-5**). There would be no increase in occupied structures or population exposed to noise levels of 115 dBA or greater during a LFIC LV launch at WFF, when compared to the baseline Antares launch.

As shown in **Table 3.1-7**, all of the points of interest from the baseline survey are located in areas below the OSHA established 15-minute exposure threshold of 115 dBA. Additionally, as shown in **Table 3.1-7** and in **Figure 3.1-2** and **Figure 3.1-3**, all points of interest and most of Accomack County are above the FICUN and EPA established guidelines of 65 dB or less for residential, public use, or recreational areas. These guidelines, however, are in DNL which provides 24-hour cumulative noise impacts for events throughout the day. Rocket noise impacts are modeled as single events in this PEIS. As such, DNL metrics have not been applied. These noise levels are also below the OSHA noise exposure limits. In the past and with the recent launches of the Antares LV, rocket launches have not resulted in noise complaints or known annoyance to the communities surrounding WFF (Eggers 2017).

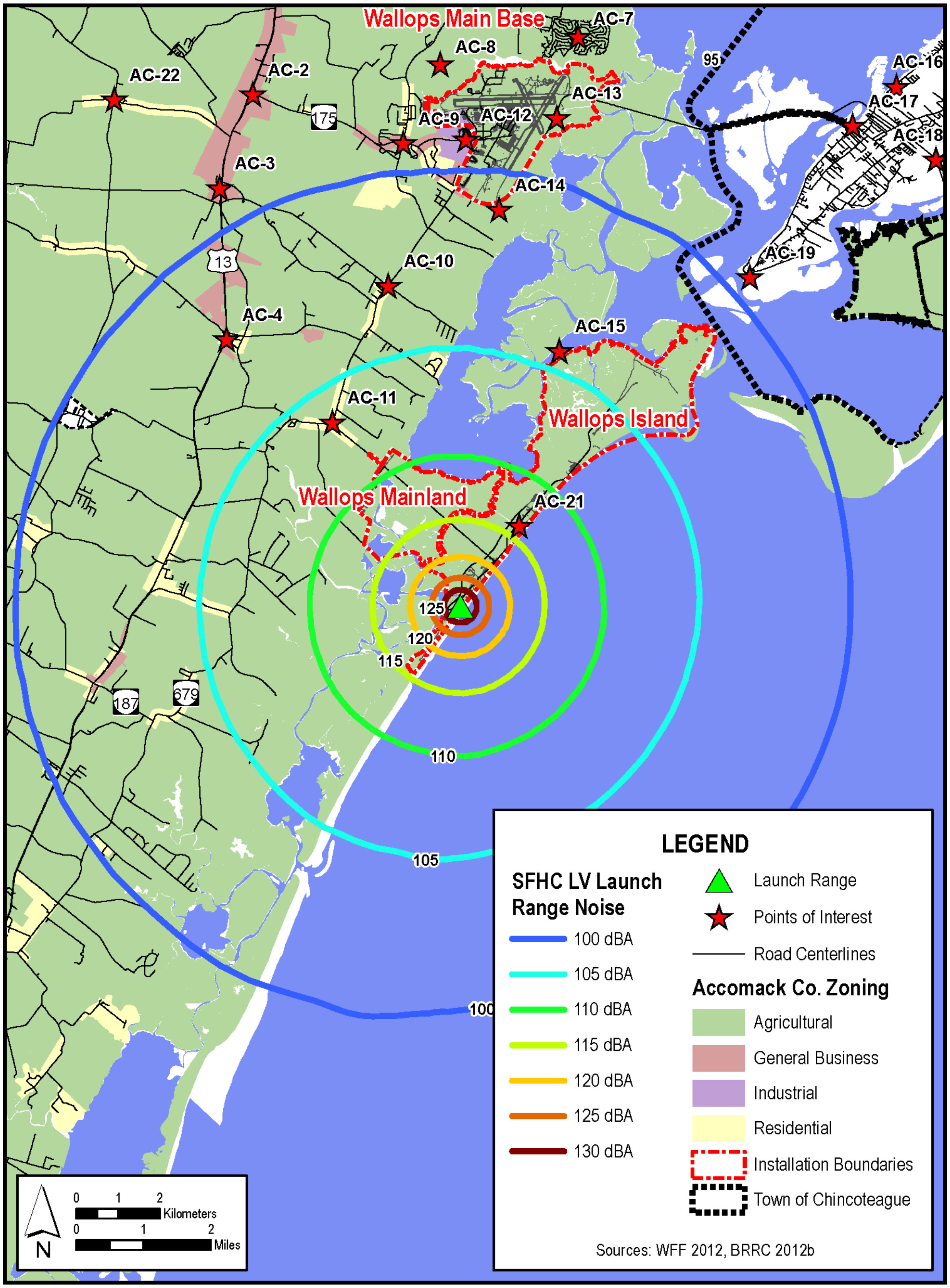


**Figure 3.1-3. Single Event Noise Contours Generated from the SFHC LV**

**Table 3.1-7. Points of Interest and Peak Noise Contours for LFIC LV and SFHC LV**

| Location ID | Description | LFIC Modeled Noise Contour (dBA) | SFHC Modeled Noise Contour (dBA) |
|---|---|---|---|
| AC-1 | Intersection of U.S. 13 and SR 709 | 95-100 | 95-100 |
| AC-2 | T's Corner (east of intersection of U.S. 13 and Chincoteague Road) | 95-100 | 100-105 |
| AC-3 | Arcadia High School | 95-100 | 100-105 |
| AC-4 | Temperanceville at Intersection of U.S. 13 and SR 695 | 100-105 | 105-110 |
| AC-5 | Captain's Cove Community Pool | 95-100 | 95-100 |
| AC-6 | Horntown at Intersection of SR 679 and SR 709 | 95-100 | 95-100 |
| AC-7 | Trail's End Campground/Community Pool | 95-100 | 95-100 |
| AC-8 | Olde Mill Pointe Traffic Circle | 95-100 | 100-105 |
| AC-9 | Wattsville at Intersection of SR 679 and Chincoteague Road | 95-100 | 100-105 |
| AC-10 | Atlantic at Intersection of SR 679 and Nocks Landing Road | 100-105 | 105-110 |
| AC-11 | Assawoman at Intersection of SR 670 and Wallops Island Road | 105-110 | 105-110 |
| AC-12 | CBFS | 95-100 | 100-105 |
| AC-13 | NASA WFF Visitor Center | 95-100 | 100-105 |
| AC-14 | USFWS Maintenance Yard at Wallops Island National Wildlife Refuge | 100-105 | 100-105 |
| AC-15 | Ballast Narrows at Wallops Island National Wildlife Refuge | 100-105 | 105-110 |
| AC-16 | Chincoteague High School | 95-100 | 95-100 |
| AC-17 | Chincoteague Waterfront Park | 95-100 | 95-100 |
| AC-18 | Chincoteague Chamber of Commerce on Piney Island | 95-100 | 95-100 |
| AC-19 | Curtis Merritt Harbor, Chincoteague Island | 95-100 | 100-105 |
| AC-20 | Tom's Cove Visitor Center | 95-100 | 95-100 |
| AC-21 | MARS (located on the launch range) | 110-115 | 115-120 |
| AC-22 | Withams at Intersection of SR 693 and SR703 | 95-100 | 100-105 |
| AC-23* | Emma's World Daycare and Preschool (closed) | 100-105 | 100-105 |
| AC-24* | Kegotank Elementary School | 100-105 | 105-110 |

Source: BRRC 2012.
Note: *Points not included in BRRC's noise modeling effort, therefore no baseline data exists in DNL.
Legend: AC = Accomack County; SR=State Route.

Though the launch of either the LFIC LV or SFHC LV would be loud, it would be for a short duration, less than ten minutes depending on weather conditions, location of the listener, and time of day with peak noise occurring in the first one to two minutes. Impacts decrease as distance from Wallops Island increases. The timing of launch vehicle operations (i.e., day versus night) is not currently known; however, the Wallops Public Information Line ([757] 824-2050) is available to provide the public with scheduled launch times and NASA WFF publishes launch events on their website (http://www.nasa.gov/centers/wallops/events). The public would not be allowed within the 3,050 m (10,000 ft) hazard arc established around the launch site for launch vehicles of this size (refer to Section 3.4 Health and Safety) and, therefore, would not be exposed to noise greater than 105 dB. However, people viewing the event outdoors would be encouraged to wear hearing protection throughout the duration of the launch event. Accomack County is preparing a plan for ensuring public safety on non-NASA property.

**Sonic Booms from LFIC LV and SFHC LV Launches**

Both the LFIC LV and SFHC LV would be capable of reaching supersonic speeds and therefore creating a sonic boom. Sonic boom modeling was undertaken in the 2015 noise modeling exercise and determined that it was unlikely to cause any adverse impacts to the human environment (BRRC 2015). The reasons for this are several. First, the trajectory of the launch vehicle is generally southeast, over the Atlantic Ocean. Second, it takes time for the launch vehicle to reach supersonic speeds. In that time, the vehicle is moving out over the ocean and away from populated areas. The launch vehicle would reach supersonic speeds out over the open ocean, while continuing to climb. Sonic booms from either LV would be equal to or less than military aircraft that currently train in the VACAPES OPAREA (BRRC 2015). With the known trajectories, the sonic booms that would occur would intercept the ocean surface well offshore. The propagation angles of the booms would be very shallow so only negligible energy would be transmitted into the water. Thus, the sonic boom exposure in the ocean would be at the surface (BRRC 2015). Notice-to-Mariners (NOTMARs), NOTAMs, activation of R-6604, and FASFAC VACAPES scheduling procedures would prevent potential impacts to personal, commercial, and DoD ships and aircraft. It is unlikely that any significant noise impacts would occur from sonic booms generated from these operational missions as described under the Proposed Action.

**Summary of Noise Impacts from LFIC LV and SFHC LV Launches**

**Table 3.1-8** provides a summary of the noise impacts shown as increases in land area, occupied structures, and estimated population within the modeled noise contours for LFIC LV and SFHC LV launches, when compared to the baseline noise produced by an Antares launch. As shown, there would be a minor increase in affected land area; the land area is without occupied structures, noise sensitive areas, or populations. No significant noise impacts would be anticipated from this type of operational mission as described under the Proposed Action.

**Table 3.1-8. Increase in Noise (dBA) for LFIC LV and SFHC LV Launches Over Baseline**

| Peak Noise Level (dBA) < 100 seconds | Land Area ha (ac) | | Occupied Structures | | Population | |
|---|---|---|---|---|---|---|
| | LFIC | SFHC | LFIC | SFHC | LFIC | SFHC |
| 115 | 86 (212) | 92 (227) | 0 | 0 | 0 | 0 |
| 120 | 43 (106) | 46 (114) | 0 | 0 | 0 | 0 |
| 125 | 9 (22) | 10 (25) | 0 | 0 | 0 | 0 |
| 130 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **138** | **148** | **0** | **0** | **0** | **0** |

***Vertical Launch and Landing Vehicles***

Under the Expanded Space Program, NASA is considering the mission of vertical launch and landing vehicles at WFF. Vertical launch and landing vehicles would take off like typical vertically launched rockets; however, rocket motors would ignite to control the descent to the launch (refer to Section 2.5.2.2). A study was conducted in 2017 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island (BRRC 2017). The noise study employed the same metrics, impact criteria, and input parameters used in the 2015 noise study (BRRC 2015). The results indicate the returning LFIC LV noise levels would exceed 115 dBA within a distance of approximately 0.6 km (0.4 mi) from the landing site. **Appendix D** contains the BRRC 2017 modeling report. No structures are located within the 115 dBA noise contour.

LFIC RTLS noise would be similar to the noise described above for a LFIC LV launch. However, a sonic boom could be generated during an RTLS supersonic descent. Application of notional LFIC RTLS event from the southeasterly direction indicate the Atlantic Ocean would intercept the majority of the sonic boom overpressure. Land areas within 9.5 km (6 mi) of the descent trajectory landing site could potentially experience overpressure levels greater than 0.1 kPa (2 psf). Overpressures greater than 0.1 kPa (2 psf) have the potential to cause structural damage. Additionally, there is a potential for hearing damage (to humans) within 3.2 km (2 mi) of the landing site, where sonic boom overpressure levels may be greater than the approximately 0.2 kPa (4 psf) impulsive hearing conservation noise criteria. However, the intensity of a potential sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). To minimize exposure from sonic booms during an RTLS event, WFF would continue to adhere to procedures to protect the public and staff by implementing controls to minimize or eliminate the associated risks such as enforcing hazard area clearance for the public, mariners, and airmen, and limiting launches to times when favorable meteorological conditions are present. A 3,050 m (10,000 ft) hazard arc would be established around the launch site for launch vehicles of this size. The public would not be allowed within the hazard arc; no populations would be located within the 3,050 m (10,000 ft) hazard arc. Moreover, under the Proposed Action, no more than six LFIC LV/RTLS events would be authorized in a 12-month period. It is unlikely that any significant noise impacts would be generated from this type of operational mission as described under the Proposed Action.

***Horizontal Launch and Landing Vehicles***

Under the Expanded Space Program, NASA is considering the mission of horizontal launch and landing vehicles at WFF. Horizontal launch and landings vehicles would take off and land like a standard aircraft. This type of mission would take place at the Main Base. Runway 04/22 would be extended to accommodate the vehicles (refer to Section 2.5.1.2 [Mainland and Wallops Island]).

The noise associated with the horizontal launch and landings would be typical of existing jet aircraft that utilize WFF; however, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. Future NEPA analysis would address such conditions to prevent unacceptable adverse impacts from sonic booms to humans and structures, land and marine protected species, and vessels on the open water.

NOTMARs, NOTAMs, activation of R-6604, and FASFAC VACAPES scheduling procedures would prevent potential impacts to personal, commercial, and DoD ships and aircraft. Therefore, it is unlikely that any significant noise impacts would be generated from this type of operational mission as described under the Proposed Action.

***Commercial Human Spaceflight Missions***

Under the Expanded Space Program, NASA is considering the use of commercial human spaceflight missions that could consist of commercial space tourism and commercial crew transport to the ISS and LEO. A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) for commercial human spaceflight. All of these platforms would be launched with technologies within the established noise envelope or within the new envelope for the above noted LFIC LV and SFHC LV.

Refer to **Section 4.1.1** (Noise) for measures to mitigate impacts to noise under the Proposed Action.

## 3.2 AIR QUALITY

The Earth's atmosphere consists of four main layers: the troposphere, stratosphere, mesosphere, and ionosphere. For the purposes of this PEIS, the discussion of air quality within the lower troposphere is defined as at or below 914 m (3,000 ft) AGL, which the EPA accepts as the nominal height of the atmosphere mixing layer in assessing contributions of emissions to ground level ambient air quality under the CAA (EPA 1992) for criteria and hazardous air pollutants (HAPs). The mixing layer (sometimes referred to as the boundary layer) is the layer of air directly above the Earth that is relatively well mixed. This layer extends to a height referred to as the mixing height, above which the free troposphere extends up 9 to 17 km (6 to 11 mi) to the tropopause. Typically, temperature and density decrease with altitude in the atmosphere up to the mixing height. At the mixing height, however, the temperature begins to increase with altitude and creates an inversion which prevents air borne emissions from rising past the mixing height (Visconti 2001). Although launch vehicle emissions from operations at or above 914 m (3,000 ft) above ground surface would occur as part of the Proposed Action, these emissions would not result in appreciable ground level pollutant concentrations of criteria and HAPs due to dispersion of pollutants by wind. However, any emissions of GHGs would be relevant at all elevations as the influence of these gases is not restricted to the lower atmosphere.

**Criteria Pollutants**

Air quality is defined by ambient air concentrations of specific pollutants determined by the EPA to be of concern in relation to the health and welfare of the general public and the environment. Widespread across the U.S., the primary pollutants of concern are called "criteria pollutants" and include carbon monoxide (CO), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), $O_3$, suspended particulate matter less than or equal to 10 microns in diameter ($PM_{10}$), fine particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$), and lead (Pb). Under the CAA, the EPA has established National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50) for these criteria pollutants. These standards represent the maximum allowable atmospheric concentrations that may occur while ensuring protection of public health and welfare, with a reasonable margin of safety. Short-term standards (1-, 8-, and 24-hour periods) are established for pollutants contributing to acute health effects, while long-term standards (quarterly and annual averages) are established for pollutants contributing to chronic health effects. Areas with air pollution problems typically have one or more criteria pollutants consistently present at levels that exceed the NAAQS. These areas are designated as nonattainment areas for the standards. The VDEQ Air Division has adopted the NAAQS that are presented in **Table 3.2-1**.

| Table 3.2-1. National Ambient Air Quality Standards | | | |
|---|---|---|---|
| POLLUTANT | AVERAGING TIME | NATIONAL PRIMARY | NATIONAL SECONDARY |
| [1]$O_3$ | 8 Hours | 0.070 ppm | Same as Primary |
| CO | 8 Hours (Maximum) | 9 ppm | --- |
| | 1 Hour (Maximum) | 35 ppm | |
| [2]$NO_2$ | Annual Mean | 53 ppb | Same as Primary |
| | 1 Hour Average | 100 ppb | --- |
| [3]$SO_2$ | 3 Hours (Maximum) | --- | 0.5 ppm |
| | 1 Hour (Maximum) | 75 ppb | --- |
| $PM_{10}$ | 24 Hours (Maximum) | 150 μg/m$^3$ | Same as Primary |
| $PM_{2.5}$ | Annual (Mean) | 12 μg/m$^3$ | 15 μg/m$^3$ |
| | 24 Hours (Average) | 35 μg/m$^3$ | Same as Primary |
| [4]Pb | Rolling 3-month Average | 0.15 μg/m$^3$ | Same as Primary |

Source: EPA 2016a.

Notes: [1] Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) $O_3$ standards additionally remain in effect in some areas. Revocation of the previous (2008) $O_3$ standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.

[2] The level of the annual NO2 standard is 0.053 ppm. It is shown here in terms of ppb for the purposes of clearer comparison to the 1-hour standard level.

[3] The previous $SO_2$ standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2) any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous $SO_2$ standards or is not meeting the requirements of a SIP call under the previous $SO_2$ standards (40 CFR 50.4(3). A SIP call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

[4] In areas designated nonattainment for the Pb standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 μg/m3 as a calendar quarter average) also remain in effect.

Legend: ppm = parts per million; ppb = parts per billion; μg/m$^3$= micrograms per cubic meter.

**Hazardous Air Pollutants**

In addition to the ambient air quality standards for criteria pollutants, national standards exist for HAPs, which are regulated under Section 112(b) of the 1990 CAA Amendments. The National Emission Standards for Hazardous Air Pollutants regulate HAP emissions from stationary sources (40 CFR Part 61). HAPs emitted from mobile sources are called Mobile Source Air Toxics (MSATs). These compounds, emitted from highway vehicles and non-road equipment (including aircraft engines), are known or suspected to cause cancer or other serious health and environmental effects. In 2001, EPA issued its first MSAT Rule, which identified 21 compounds as being HAPs that required regulation. In February 2007, EPA issued a second MSAT Rule, which generally supported the findings in the first rule and provided additional recommendations of compounds having the greatest impact on health. The rule also identified several engine emission certification standards are required to be implemented. The primary control methodologies for MSATs involve reducing their content in fuel and altering engine operating characteristics to reduce the volume of pollutants generated during combustion. MSATs considered in this analysis would be the primary HAPs emitted by mobile sources during construction and operations. The equipment used during construction would likely vary in age and have a range of pollution reduction effectiveness. However, construction equipment would be operated intermittently over a large area and would produce negligible ambient HAPs in a localized area. Operational equipment, including vehicles driven by commuters, is anticipated to be primarily newer equipment (post-2010 model year) that generate lower emissions and would also produce negligible ambient HAPs.

**Climate Change**

Climate change refers to long-term shifts in temperature, precipitation, and weather patterns which are the result of numerous natural and anthropogenic (human-induced) factors. Natural factors include how much solar energy reaches Earth (i.e., changes in the sun's intensity, Earth's orbit, Earth's tilt, or position of Earth's axis), how sunlight is reflected or absorbed (as a result of cloud cover, surface albedo, ratio of land to water, etc.), and natural sources of aerosols and particulate matter (e.g., oceans, forest fires, and volcanoes). Human factors include changes to land use and land cover (e.g., deforestation, reforestation, desertification, damming, and urbanization) and releasing combustion byproducts into the atmosphere (EPA 2016b). Many predictive computer models implicate GHGs and soot as anthropogenic contributions to a warming global climate. GHGs are gases that trap heat in the atmosphere and include water vapor, carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and fluorinated gases (i.e., hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride).

The effect each GHG can have on climate change depends on its concentration in the atmosphere, as well as its residence time (how long it can remain in the atmosphere) and how strongly it absorbs heat energy (EPA 2017b). The Global Warming Potential (GWP) of a substance is a function of its residence time and its ability to absorb heat energy (EPA 2017b), usually over 100 years, compared to $CO_2$, which has a GWP of 1 (EPA 2012e). The larger the GWP, the more warming the gas causes over a 100-year period. For example, $CH_4$ has a GWP 25 times higher than $CO_2$, and $N_2O$ has a GWP 298 times that of $CO_2$ (International Panel on Climate Change 2007). Thus, to simplify an understanding commensurate with GWP, total GHG emissions are often expressed in terms of $CO_2$ equivalent ($CO_2e$) units. The $CO_2e$ is calculated by multiplying the quantity of emissions for each GHG emission by its GWP and summing the results to produce a combined rate to represent all GHGs emitted by an activity.

In addition to GHGs, other pollutants have climate change impacts. Black carbon, or soot, is known to be second only to carbon dioxide as a contributor driving climate change (Bond et al. 2013). The largest sources of black carbon are open burning of forests and savannas, and combustion of fossil fuels and biofuels. Black carbon from these ground level sources typically remains in the atmosphere for only a few weeks (Ross 2010).

EO 13834, *Efficient Federal Operations,* issued on May 17, 2018, establishes policy for federal agencies to maintain federal leadership in sustainability and GHG reductions. On December 21, 2007, Virginia's governor, Timothy Kaine, issued EO 59, creating the Governor's Commission on Climate Change and setting a target of reducing statewide GHG emissions to 30% below business-as-usual (year 2000 levels) by 2025. On July 1, 2014, Governor McAuliffe signed EO 19, convening the Climate Change and Resiliency Update Commission. The Commission was tasked with reviewing, updating and prioritizing the recommendations of the 2008 Climate Change Action Plan that was the concluding work of the Commission established in 2007. The Commission received a one year work extension to July 1, 2016, and published their Report and Final Recommendations to the Governor on December 21, 2015. The GHG emission reduction goals established in the 2007 EO remain in effect.

On August 1, 2016, the CEQ issued final guidance on the consideration of GHG emissions and climate change in NEPA review (CEQ 2016). The guidance clarified that NEPA review requires federal agencies to consider the effects of GHG emissions and climate change when evaluating Proposed Actions: "Analyzing a proposed action's GHG emissions and the effects of climate change relevant to a proposed action—particularly how climate change may change an action's environmental effects—can provide useful information to decision makers and the public."

The guidance also emphasized that agency analyses should be commensurate with projected GHG emissions and climate impacts, and should employ appropriate quantitative or qualitative analytical methods to ensure useful information is available to inform the public and the decision-making process in distinguishing between alternatives and mitigations (CEQ 2016). However, pursuant to EO 13783, *Promoting Energy Independence and Economic Growth*, CEQ's guidance was withdrawn for further consideration in March of 2017. Regardless, it is NASA's policy to continue to follow the CEQ guidance on GHG emissions and climate change in NEPA review until directed otherwise by amendments to the guidance or regulation.

### 3.2.1 AFFECTED ENVIRONMENT

Air quality in a given location is described by the concentration of various pollutants in the atmosphere, specifically, within the mixing layer. A region's air quality is influenced by many factors including the type and amount of pollutants emitted into the atmosphere, the size and topography of the air basin, and the prevailing meteorological conditions. Pollutant emissions typically refer to the amount of pollutants or pollutant precursors introduced into the atmosphere by a source or group of sources. Pollutant emissions contribute to the ambient air concentrations of criteria pollutants, either by directly affecting the pollutant concentrations measured in the ambient air or by interacting in the atmosphere to form criteria pollutants. Primary pollutants, such as CO, $SO_2$, Pb, and some particulates, are emitted directly into the atmosphere from emission sources. Secondary pollutants, such as $O_3$, $NO_2$, and some particulates are formed through chemical reactions that are influenced by meteorology, ultraviolet light, and other atmospheric processes. Airborne emissions of Pb are not addressed in this PEIS because there are no significant Pb emission sources associated with the proposed action.

The ROI for the air quality analysis is limited to the Northeastern Virginia Intrastate Air Quality Control Region (AQCR), as defined in 40 CFR Part 81.144, which includes Accomack County. The air quality analysis for the affected area of the action focuses on the impacts to Accomack County and its immediate vicinity. Ambient air quality stations operated as part of the National Ambient Monitoring System/State and Local Air Monitoring System network exist within this AQCR, though none are located in Accomack County. The closest monitoring site is located in Hampton, Virginia, which is part of the Hampton Roads Intrastate AQCR. The Northeastern Virginia Intrastate AQCR is designated in attainment/unclassifiable for all criteria pollutants. Because the region is in attainment, the CAA General Conformity Rule (40 CFR Parts 51 and 93) does not apply and is not addressed in the impact analysis.

WFF maintains two synthetic minor operating permits, one for the Main Base and one for the combined Mainland and Wallops Island. A "synthetic minor source" is an emissions generating source that has taken measures to limit its potential-to-emit air pollutants to less than major source thresholds of 227 metric tons (250 tons) per year of a single criteria pollutant. **Table 3.2-2** presents annual permit limits (VDEQ 2011, 2014) and air emissions for WFF for the year 2016 (NASA 2017 a, b).

**Table 3.2-2. WFF Permit Limits and 2016 Annual Emissions in Metric Tons (Tons) per Year**

| | VOCs | CO | $NO_2$ | $SO_2$ | PM | $PM_{10}$ | $PM_{2.5}$ | Pb | HAPs |
|---|---|---|---|---|---|---|---|---|---|
| Main Base Permit Limits | 41.0 (45.2) | 35.1 (38.7) | 59.7 (65.8) | na | 5.4 (5.9) | 5.0 (5.5) | na | na | 9/23 (10/25)[a] |
| 2016 Main Base Emissions | 2.30 (2.54) | 1.36 (1.50) | 7.65 (8.43) | 0.08 (0.09) | na | 0.15 (0.17) | 0.07 (0.08) | 0.00 (0.00) | 0.15 (0.17) |
| WFF Permit Limits | 4.3 (4.8) | 36.1 (39.8) | 71.7 (79.0) | 16.3 (18.0) | 11.8 (13.0) | 2.0 (2.2) | na | 0.8 (0.9) | 8.5 (9.4)[b]; 0.0168 (0.0185)[c]; 8.6 (9.5)[d] |
| 2016 WFF Emissions | 0.67 (0.74) | 3.22 (3.55) | 7.73 (8.52) | 0.14 (0.15) | na | 0.45 (0.50) | 1.65 (1.82) | 0.03 (0.04) | 0.24 (0.26) Total |
| MARS | na | (26.2) | na | 0.090 (0.099)[e] | na | na | na | na | na |

Source: VDEQ 2011, 2014; NASA 2017a, b.
Note: VOCs = volatile organic compounds.
Legend: na = not applicable.
[a] 9 metric tons (10 tons) per individual HAP; 23 metric tons (25 tons) aggregate HAPs;
[b] limit is for HCl;
[c] limit is for hydrazine;
[d] limit is for total HAPS;
[e] limit is specifically for sulfur.

Total GHG emissions, expressed as CO2*e*, for calendar years 2011 through 2016 for WFF Main Base and the Mainland and Wallops Island are listed in **Table 3.2-3**.

**Table 3.2-3. Total GHG Emissions as CO2*e* at WFF in Metric Tons (Tons) per Year**

| Year | Main Base | Mainland and Wallops Island |
|---|---|---|
| 2012 | 3,914 (4,314) | 1,512 (1,667) |
| 2013 | 6,900 (7,606) | 1,375 (1,516) |
| 2014 | 9,773 (10,773) | 666 (734) |
| 2015 | 4,244 (4,678) | 512 (564) |
| 2016 | 6,694 (7,379) | 530 (584) |

Source: NASA 2017c.
Note: Totals have been rounded up.

### 3.2.2 Environmental Consequences

Air quality impacts would be significant if emissions associated with the Proposed Action would increase ambient air pollution concentrations above the NAAQS or exceed the permit limits for HAPs. For HAPs, these emission limits include:

- 9 metric tons (10 tons) per year of any HAP from a permitted Main Base source,
- 23 metric tons (25 tons) per year of any combination of HAPs from a permitted Main Base source or sources,
- 8.5 metric tons (9.4 tons) per year of HCl from permitted Mainland and Wallops Island sources,
- 0.0168 metric tons (0.0185 tons) per year and 0.0080 kgs (0.0176 pounds) per 30 minutes of hydrazine fueling from permitted Mainland and Wallops Island sources, and
- 8.6 metric tons (9.5 tons) per year total HAPs from permitted Mainland and Wallops Island sources.

To quantitatively assess air quality impacts, a 227 metric tons (250 tons) per year comparative value has been used in the analysis for criteria pollutant emissions. The 227 metric tons (250 tons) per year is used by the EPA in their New Source Review standards as an indicator for impact analysis for listed new major stationary sources in attainment areas. Mobile source emissions are the primary sources of emissions for the Proposed Action. No similar regulatory values are available to compare mobile source emissions. Lacking any mobile source emission regulatory values, the 227 metric tons (250 tons) per year New Source Review comparative value was used in this analysis to equitably assess and compare the significance of mobile source emissions under the Proposed Action. GHG emissions are quantified for both construction activities and operations, where applicable. **Appendix F** contains the detailed emission calculations prepared to assess the air quality impacts of the Proposed Action.

#### 3.2.2.1 No Action Alternative

##### 3.2.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. No additional impacts to air quality from institutional support projects under this alternative would be anticipated.

##### 3.2.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope. All operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS; therefore, there would be no additional impacts to air quality from operational missions and activities under this alternative.

#### 3.2.2.2 Proposed Action

The Proposed Action would support all actions under the No Action Alternative including a number of institutional construction, demolition, and renovation projects analyzed in previous NEPA documents (refer to **Table 2.4-1**). The Proposed Action also includes construction and operational components that would involve the expansion of existing operational missions and activities and the introduction of new mission opportunities.

##### 3.2.2.2.1 Institutional Support Projects

**Construction, Demolition, and RBR Projects**

Under the Proposed Action, construction, demolition, and renovation projects on WFF Main Base, Mainland, and Wallops Island would result in temporary impacts to air quality. The proposed projects are listed in **Table 2.5-1** and **Table 2.5-2**. Information for the projects, including the year of proposed construction, have been provided in as much detail as is currently available. Under the Proposed Action, institutional support projects would be implemented over a multi-year period with the majority of projects being implemented between 2019 and 2023. The analysis of the air emission impacts for these institutional support projects focuses on the emissions that occur during the dredging, construction, demolition, or renovation phases. A discussion of emissions resulting from operational activities is presented in Section 3.2.2.2.2.

Emissions from construction activities include temporary emissions from on- and off road heavy diesel-powered construction equipment and trucks, emissions from the commute of construction workers to and from the site, and fugitive dust emissions during construction. All emissions are calculated on an annual basis and take into account all projects that would be planned for that year. It is assumed that most projects would be completed within the individual years listed in **Table 2.5-1** and **Table 2.5-2**. The Causeway Bridge construction project, however, would be a multi-year project occurring within the 2023-2025 timeframe. For additional information on the methodology used to calculate emissions from construction equipment and vehicles used for commuting construction workers, refer to **Appendix F**.

**Table 3.2-4** lists the results of the emission calculations for each year for the WFF Main Base, Mainland, and Wallops Island. The emissions from all projects have been totaled to estimate the annual total criteria pollutant emissions from construction and demolition. HAPs were not quantified as the only HAPs that would be generated would come from mobile sources and the temporary nature of the construction/demolition would result in very low levels of HAPs generated. Additionally, lead was not included since construction equipment would run on unleaded gasoline. Projects that do not have designated years have been placed together in a "to be determined" (TBD) category and analyzed together. Specifically, all new construction TBD projects were evaluated together and all TBD demolition projects were evaluated together and as occurring in the year following the completion of the construction. No construction and demolition projects are listed for the Main Base in years 2021 and 2023.

**Table 3.2-4. Calculated Annual Construction Emissions for the Proposed Action in Metric Tons (Tons) per Year**

| Year | Area | VOC | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|---|---|---|---|
| TBD | Main Base - Construction | 0.92 (1.01) | 4.40 (4.85) | 13.26 (14.62) | 0.18 (0.20) | 13.19 (14.54) | 1.94 (2.14) |
| TBD | Mainland and Wallops Island - Construction | 0.11 (0.12) | 0.49 (0.54) | 1.45 (1.60) | 0.02 (0.02) | 6.08 (6.70) | 0.67 (0.74) |
| **TBD Construction total** | | **1.03 (1.13)** | **4.89 (5.39)** | **14.71 (16.22)** | **0.20 (0.22)** | **1.27 (21.24)** | **2.61 (2.88)** |
| TBD | Main Base - Demolition | 0.10 (0.11) | 0.66 (0.73) | 1.16 (1.28) | 0.02 (0.03) | 12.10 (13.34) | 1.30 (1.43) |
| TBD | Mainland and Wallops Island - Demolition | .009 (0.01) | 0.0 (0.10) | 0.14 (0.15) | 0.00 (0.00) | 0.24 (0.27) | 0.03 (0.04) |
| **TBD Demolition total** | | **0.11 (0.12)** | **0.75 (0.83)** | **1.29 (1.42)** | **0.02 (0.03)** | **12.35 (13.61)** | **1.33 (1.47)** |
| 2019 | Main Base | 0.02 (0.02) | 0.12 (0.13) | 0.19 (0.21) | 0.00 (0.00) | 0.11 (0.12) | 0.02 (0.03) |
| | Mainland and Wallops Island | 0.43 (0.47) | 2.00 (2.92) | 10.25 (11.30) | 1.57 (1.73) | 0.34 (0.37) | 0.32 (0.35) |
| **2019 Total** | | **0.44 (0.49)** | **2.77 (3.05)** | **10.43 (11.50)** | **1.57 (1.73)** | **0.44 (0.49)** | **0.34 (0.38)** |

| Table 3.2-4. Calculated Annual Construction Emissions for the Proposed Action in Metric Tons (Tons) per Year (cont.) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Area** | **VOC** | **CO** | **$NO_x$** | **$SO_2$** | **$PM_{10}$** | **$PM_{2.5}$** |
| 2020 | Main Base | 0.06 (0.07) | 0.34 (0.37) | 0.95 (1.05) | 0.02 (0.02) | 0.10 (0.11) | 0.05 (0.06) |
| | Mainland and Wallops Island | 0.44 (0.48) | 2.75 (3.03) | 10.41 (11.48) | 1.57 (1.73) | 0.80 (0.88) | 0.38 (0.42) |
| **2020 Total** | | **0.51 (0.56)** | **3.08 (3.39)** | **11.37 (12.53)** | **1.59 (1.75)** | **0.90 (0.99)** | **0.44 (0.48)** |
| 2021 | Mainland and Wallops Island | 0.43 (0.47) | 2.64 (2.91) | 10.23 (11.28) | 1.57 (1.73) | 0.33 (0.36) | 0.32 (0.35) |
| 2022 | Main Base | 0.009 (0.01) | 0.08 (0.09) | 0.12 (0.13) | 0.00 (0.00) | 0.89 (0.98) | 0.10 (0.11) |
| | Mainland and Wallops Island | 0.43 (0.47) | 1.91 (2.91) | 10.23 (11.28) | 1.57 (1.73) | 0.33 (0.36) | 0.32 (0.35) |
| **2022 Total** | | **0.44 (0.48)** | **2.71 (2.99)** | **10.35 (11.41)** | **1.57 (1.73)** | **1.22 (1.34)** | **0.42 (0.46)** |
| 2023 | Mainland and Wallops Island | **0.71 (0.78)** | **4.67 (5.15)** | **19.09 (21.04)** | **1.4 (2.14)** | **0.65 (0.72)** | **0.63 (0.69)** |
| **Major Source Values for Comparative Analysis** | | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** |
| **Exceed Comparative Values in Any Year?** | | **No** | **No** | **No** | **No** | **No** | **No** |

The year of greatest emissions would be 2023. The emissions in this year would be well below the 227 metric tons (250 tons) per year comparative mobile source threshold. Annual emissions from construction, demolition, renovation, and dredging during all of the proposed years would have a less than significant impact on regional air quality.

**GHG**

Total GHG emissions were projected for the Main Base and the Mainland and Wallops Island to estimate NASA's contribution as a result of implementation of institutional support projects under the Proposed Action (**Table 3.2-5**). No construction and demolition projects are listed for the Main Base in years 2021 and 2023.

| Table 3.2-5. Projected Total Annual GHG Emissions as $CO_2e$ from Institutional Support Projects Under the Proposed Action in Metric Tons (Tons) per Year | | | |
|---|---|---|---|
| **Year** | **Main Base** | **Mainland and Wallops Island** | ***Total $CO_2e$ Emissions*** |
| TBD Construction | 1,291 (1,423) | 140 (154) | 1,431 (1,577) |
| TBD Demolition | 157 (157) | 19 (11) | 176 (194) |
| 2019 | 25 (28) | 2,518 (2,776) | 2,543 (2,803) |
| 2020 | 94 (104) | 2,540 (2,800) | 2,634 (2,903) |
| 2021 | - | 2,515 (2,772) | 2,515 (2,772) |
| 2022 | 17 (19) | 2,515 (2,772) | 2,532 (2,791) |
| 2023 | - | 3,148 (3,470) | 3,148 (3,470) |

The CEQ Guidance of 2016 (CEQ 2016) recommends that agencies quantify a proposed action's projected direct and indirect GHG emissions, taking into account available data and GHG quantification tools that are suitable/available, and then select the appropriate level of NEPA review to assess the broad-scale effects of GHG emissions and climate change, either to inform decisions or to set forth a reasoned explanation for the agency's approach. Further, the guidance counsels agencies to use the "rule of reason" to determine how to consider an environmental effect and prepare an analysis based on available information. NASA continues to follow the Guidance until otherwise required by regulation or policy.

Implementing the institutional support projects as presented under the Proposed Action would not significantly impact regional air quality or significant contribute to global emissions of GHGs. Refer to **Section 4.1.2** (Air Quality) for measures to mitigate impacts to air quality under the Proposed Action.

3.2.2.2.2 Operational Missions and Activities

Operational missions and activities that would require additional air quality analysis because of a deviation of one or more established envelope parameters are discussed below. Operational missions and activities that would not deviate from the established envelope parameters would not effect a change to the existing air environment and are not included in this analysis. For additional information on the methodology used to calculate emissions from operational missions and activities, please refer to **Appendix F**.

**North Wallops Island UAS Airstrip Increased Operations**

Annual sortie operations at the UAS airstrip would increase from 1,040 to 3,900. To assess the impacts of the increase, representative UAS were evaluated. The representative UAS scenario evaluated the Viking 300 and the MQ-4C (Triton). These were selected because the Viking 300 engine power represents the mid-range of the Viking models used and the MQ-4C is the largest UAS considered. The representative scenario assumed that half of the 3,900 flights used the Viking 300 and half the MQ-4C. Additionally, the Viking 300 was characterized with a longer flight time of 12 hours to better represent all of the UAS in that size range. **Table 3.2-6** presents the current envelope emissions and the maximum amount of emissions that would be generated under the new envelope. The proposed increased use of UAS at WFF would result in a small increase in criteria pollutant emissions.

**Table 3.2-6. Calculated Annual Emissions for Current and Proposed UAS Envelopes in Metric Tons (Tons) per Year**

| Emissions | VOCs | CO | $NO_x$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
|---|---|---|---|---|---|---|
| Current Envelope | 0.02 (0.03) | 0.18 (0.20) | 0.36 (0.40) | 0.04 (0.05) | 0.04 (0.05) | 8.7 (9.6) |
| New Envelope | 0.32 (0.35) | 2.00 (2.20) | 2.15 (2.37) | 0.08 (0.09) | 0.08 (0.09) | 92 (101) |
| Net Change | 0.29 (0.32) | 1.81 (2.00) | 1.79 (1.97) | 0.03 (0.04) | 0.03 (0.04) | 83.2 (91.7) |
| **Comparative Threshold** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** |
| **Exceed Threshold?** | **No** | **No** | **No** | **No** | **No** | **No** |

**DoD SM-3**

Air emissions from the proposed SM-3 launch operations would include emissions from the commute of staff and training personnel as well as emissions from launches of the SM-3. This operational initiative would require a small amount of new construction (impact analyzed in Section 3.2.2.2.1). The proposed launch operations would fall within existing operational envelopes, representing no net increase in operations. No significant impact to air quality from emissions related to the commute of staff or from operations would be expected; therefore, emissions associated with these launch operations were not calculated.

**<u>Expanded Space Program</u>**

A maximum of 18 LVs, including those currently launched, could be launched annually from WFF. New launch vehicle emissions would exceed the current envelope. As such, a new rocket launch envelope is proposed based on this analysis. The new envelope includes a liquid-fueled LV capable of return to launch site (i.e., LFIC RLV) and a solid-fueled launch vehicle.

**Normal Launch Emissions Scenario**

The normal launch emissions scenario assumes that a fully configured launch vehicle with payload is ignited on the launch pad. The vehicle may be initially secured by hold-down bolts as the first stage motor builds thrust. After sufficient thrust is built, the hold-down bolts are released, allowing the vehicle to begin ascent. The exhaust product emissions rate varies with the steadily increasing vehicle velocity. Initially, the rocket engine exhaust is largely directed into and through the flame ducts. As the vehicle lifts off the launch pad and clears the launch tower, a portion of the exhaust plume impinges on the pad structure and is directed radially around the launch pad stand. The portion of the rocket plume that interacts with the launch pad and flame ducts is referred to as the "ground cloud." As the vehicle climbs to an altitude several hundred feet above the pad, the rocket plume reaches a point where the gases no longer interact with the ground surface. The exhaust plume at that point is referred to as the "contrail cloud". Criteria pollutants and HAP generated by rocket emissions below 914 m (3,000 ft) AGL can have an effect on air quality at ground level.

**Liquid-fueled Launch Vehicle**

Both the Antares (current envelope) and the LFIC LV (new envelope) use RP-1/LOX as the first stage booster fuel. Emissions from the first stage for both launch vehicles are primarily composed of $CO_2$. The standard launch scenario for a vehicle fueled with RP-1/LOX generates the combustion products CO, $CO_2$, hydrogen gas, and water. Inefficient combustion resulting from fuel-rich mixtures could produce small amounts of soot and polyaromatic hydrocarbons composed of four carbons or less. However, the amount of soot and polyaromatic hydrocarbons released during a nominal launch of the LFIC LV is projected to be insignificant due to the closed-cycle design of the engine's main chamber; the high operational pressures maintained in the chamber which tend to minimize soot formation; and the afterburning of any unburned hydrocarbon upon exit of the chamber via the nozzle (U.S. Air Force 1998). Emissions of $CO_2$ were calculated for the entire profile because GHGs are not limited by the mixing layer of the atmosphere. The proposed LFIC LV with RTLS is estimated to generate 5,160 metric tons (5,689 tons) of $CO_2$ per launch (NASA 2011; SpaceX 2007). By comparison, the Antares LV is estimated to generate 23 metric tons (25 tons) of CO and 646 metric tons (712 tons) of $CO_2$ per launch (ACTA 2009). Refer to **Appendix F** for the detailed emission calculations.

**Solid-fueled Launch Vehicle**

The SFHC LV (new envelope) generates the combustion products $Al_2O_3$, CO, $CO_2$, and HCL. **Table 3.2-7** illustrates the tons per launch that would be emitted below the mixing height, based on the 18-second interval used to traverse that distance from ground to 914 m (3,000 ft) AGL. Refer to **Appendix F** for the detailed emission calculations.

The SFHC LV motor is modeled to have 505,350 kgs (1,114,115 lbs) mass of ammonium perchlorate/aluminum solid propellant. The total burn time for the SFHC LV motor for the first stage is 132.8 seconds. The time to reach 3,050 m (10,000 ft) AGL is 20 seconds (ATCA 2012). In order to assess the volume of pollutants that the launch vehicle may introduce into the atmosphere below the mixing height (914 m; 3,000 ft), a burn time of 18 seconds has been used. This is to conservatively account for the initial slow rise of the launch vehicle for the first few thousand feet, and represents 90% of the time required for the launch vehicle to reach 3,050 m (10,000 ft) AGL.

**Table 3.2-7. Calculated Per Launch Emissions for SFHC LV in Metric Tons (Tons)**

| Chemical | Approximate Tons per Launch | Comparative Threshold | Number of Launches to Reach Comparative Threshold |
|---|---|---|---|
| $Al_2O_3$ | 11.5 (12.7) | 227 (250) | 20 ($PM_{10}$) |
| CO | 5.2 (5.7) | 227 (250) | 44 |
| $CO_2$ | 8.5 (9.4) | 227 (250) | 27 |
| HCl | 8.1 (8.9) | na | na |

Legend: na = not applicable.

Aluminum powder, which is part of the fuel component in the SFHC LV propellant, is oxidized during combustion to $Al_2O_3$ and generates small particulates of solid $Al_2O_3$ in the rocket engine plume after the plume expands and cools. All of the $Al_2O_3$ particulate matter is assumed to fall within the $PM_{10}$ size distribution, with 70% falling within the $PM_5$ distribution. It is unknown what portion of the $PM_5$ profile would meet the $PM_{2.5}$ distribution, as the Rocket Exhaust Effluent Diffusion Model does not include this particle size category. Therefore, $PM_{2.5}$ is conservatively estimated at 100% of the $PM_5$ distribution.

Because HCl quickly dissociates to hydrogen, chlorine, and chloride radicals, the movement of a rocket in the lower atmosphere would have different impacts than a stationary source where the emissions are much closer to ground level and emitted continuously at the same height. While **Table 3.2-7** indicates a total emission mass of 8.1 metric tons (8.9 tons) per launch of HCl for the SFHC LV, this mass is distributed over far greater vertical and horizontal profiles than would be expected for a stationary source such as a power plant or chemical manufacturing facility.

HCl and $Al_2O_3$ were further analyzed for human toxicity at ground level. ATCA (2012) evaluated the peak HCl and $Al_2O_3$ releases for normal launch scenario versus health protection standards. The peak HCl concentration would be 2 to 5 parts per million (ppm). Approximately 63% of launches would result in a peak HCl concentration of less than 1 ppm (ATCA 2012). The duration of HCl exposure would be less than a 60-minute exposure and the maximum downwind distance to peak concentration would be 11 to 18 km (7 to 11 mi), extending outside the base boundaries. Assuming a launch scenario where HCl concentrations are at a maximum of 2 to 5 ppm, this airborne concentration could cause acute effects in the general population if located within the downwind path, including susceptible individuals. The impacts would include inhalation discomfort or irritation. The effects, however, are not disabling, and are transient and reversible upon cessation of exposure. The rapid dissolution of HCl in the ambient air would result in decline of this concentration within 60 minutes to a nonhazardous level (ATCA 2012). Section 3.5, Health and Safety, presents additional discussion relative to the health and safety effects of HCl and other pollutants.

The peak $Al_2O_3$ concentration would be 2 to 6 $\mu g/m^3$. Approximately 67% of launches would result in a peak $Al_2O_3$ concentrations of less than 1 $\mu g/m^3$ (ATCA 2012). The duration of $Al_2O_3$ exposure would be less than a 90-minute exposure and the maximum downwind distance to peak concentration would be 10 to 32 km (6 to 20 mi), extending outside the base boundaries. There are no comparable acute exposure limits for $Al_2O_3$ or particulate matter in general. Industrial limits are three orders of magnitude higher (5 mg/$m^3$ for 8-hour exposure). The NAAQS for $PM_{2.5}$ (the respirable fraction of particulate matter) is a 24-hour limit of 35µg/$m^3$. The modeled concentration of $Al_2O_3$ is well below this threshold and the time frame is considerably shorter, 90 minutes as compared to 24 hours (ATCA 2012). Therefore, the impacts of exposure to any population immediately downwind of the launch site would be deemed less than significant.

Acidic precipitation would be possible if rain occurred in the area shortly after launch, with rain falling through the exhaust clouds, which would contain high concentrations of HCl. The pH scale is used to measure acidity and ranges from 0-14 with a pH measurement less than 7 considered to be acidic. An acid rain event was recorded in 1975 following the launch of a Titan III from Cape Canaveral Air Station (U.S. Air Force 1990). In that instance, rain showers fell through the exhaust cloud, resulting in acidic precipitation of pH=1 about 5 km (3 mi) from the launch site. At a distance of approximately 10 km (6 mi), the pH was higher, but was still very acidic at a pH=2. Discussion of the potential impacts of low pH to health and safety, water quality, vegetation, and wildlife can be found in Sections 3.5, 3.6, 3.9, and 3.10 respectively.

While the preceding discussion has focused on emissions at ground level and within the mixing layer, the bulk of propellant emissions would actually occur above the mixing height, including in the stratosphere, which is the ozone layer. The dissociation of HCl to chlorine and chloride radicals, the contribution of particle matter, and the direct injection of water ($H_2O$) would result in an incremental increase in the potential for ozone depletion in the stratosphere. The formation of rocket plume wake ozone mini-holes in the ozone layer is immediate and well known (Ross et al. 2009). These ozone mini-holes occur over hundreds of square miles and last for several days after launch. The cumulative effect of these small ozone holes is not known when compared to the global steady-state chemical effects of the emissions. Generally, it is understood there is a global effect from the depletion of ozone and an increase in the chlorine loading of the stratosphere. Emissions from rockets have a much longer lifetime and larger steady state stratospheric burden, at greater altitude. This is also true compared to aircraft burning the same amount of fuel (Ross 2010). However, the long-term contribution of individual rocket launches, which result in the introduction of chemicals that may reside in the stratosphere for considerably longer periods, is too small to be assessed for the potential for ozone depletion (Ross et al. 2009).

The normal launch scenario generates relatively benign toxic results due to the limited amount of propellant that is burned while the vehicle is ascending through the mixing height. In conclusion, the air quality impact from launch of the SFHC LV would likely be less than significant in the long term for near-ground impacts and upper atmosphere impacts would be expected at a very small, incremental scale based upon current knowledge.

**Launch Vehicle Summary**

The Antares liquid-fueled LV launch scenario has been previously described and results in the release of predominantly CO and $CO_2$. The Athena III solid-fueled LV, powered by Castor IV engines, emits 12 metric tons (13 tons) of $Al_2O_3$, 12 metric tons (13 tons) of CO, and 9 metric tons (10 tons) of HCl at launch to 914 m (3,000 ft) AGL (NASA 1997). These two LVs comprise the current launch vehicle envelope.

Under the Proposed Action, there would be up to 6 LFIC LV and 12 SFHC LV launches per year; each of the LFIC LV launches would include a RTLS landing. The launch events would be distributed among launch Pads 0-A, 0-B, 0-C (proposed), or Launch Pier 0-D (proposed). **Table 3.2-8** compares the emissions of the current launch vehicle envelope to the emissions from the proposed new launch vehicle envelope and provides the net change in emissions for the new launch envelope compared to the current launch envelope.

**Table 3.2-8. Calculated Annual Launch Emissions for Current and Proposed Launch Vehicle Envelope in Metric Tons (Tons) per Year**

| Emissions | [1]CO | [2]$CO_2$ | $NO_x$ | $AL_2O_3$ | HCL |
|---|---|---|---|---|---|
| Current Envelope | 167 (184) | 646 (712) | na | 140 (154) | 113 (125) |
| New Envelope | 62 (68) | 5,253 (5,790) | 6 (7) | 138 (152) | 97 (107) |
| Net Change | -105 (-116) | +4,607 (+5,078) | +6 (+7) | -2 (-2) | -16 (-18) |
| **Comparative Threshold** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **na** |
| **Exceed Threshold?** | **No** | **No** | **No** | **No** | **-** |

Sources: ACTA 2009; NASA 1997; SpaceX 2007.
Notes: [1] CO, $NO_x$ and $Al_2O_3$ emissions calculated up to 914 m (3,000 ft) AGL.
[2] $CO_2$ emissions calculated for the entire ascent of the first stage engine.
Legend: na = not applicable.

Emissions from the new launch envelope would introduce a small amount of $NO_x$ emissions, and reduce CO emission by about 62%. $CO_2$ emissions would increase by 4,607 metric tons (5,078 tons) per year. The increase in $NO_x$ emissions would be below the 227 metric tons (250 tons) per year comparative threshold and would not result in significant impacts.

**Annual Operational Emissions Summary**

In summary, potential annual operation emissions were calculated for the Proposed Action. UAS emissions associated with an increase from 1,040 to 3,900 sortie operations per year were assessed. Launch vehicle operations, using a maximum scenario of 12 SFHC LV launches and 6 LFIC LV launches, that would include 6 LFIC RTLS landings, were evaluated. A total of three 3-MW generators would also be run in conjunction with the launches. At Wallops Island, two 3-MW generators would operate for approximately 20 hours per launch event, for a total of 360 hours each per year. One additional 3-MW generator would run at the Main Base at a 50-60% load for approximately 8 hours per launch event, or a total of 144 hours. Additionally, total GHG emissions were projected for the Main Base and the Mainland and Wallops Island to estimate NASA's contribution as a result of implementation of operational missions and activities under the Proposed Action. The total potential annual emissions are presented in **Table 3.2-9**. For the criteria pollutants, the total annual emissions that would be generated as a result of the proposed operations do not exceed the comparative threshold and are therefore considered less than significant.

Refer to **Section 4.1.2** (Air Quality) for measures to mitigate impacts to air quality under the Proposed Action.

| Table 3.2-9. Proposed Action Potential Annual Operations Emissions in Metric Tons (Tons) per Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Activity** | **VOC** | **CO** | **$NO_x$** | **$SO_2$** | **$PM_{10}$** | **$PM_{2.5}$** | ***$CO_2e$*** |
| 2019-2025 | 3-MW Generators (2 at Wallops Island) | 0.86 (0.95) | 7.56 (8.33) | 1.44 (1.59) | ND | 0.22 (0.24) | 0.22 (0.24) | 1,422 (1,567) |
| 2019-2025 | 3-MW Generator (1 at Main Base) | 0.44 (0.48) | 3.78 (4.17) | 0.73 (0.80) | ND | 0.11 (0.12) | 0.11 (0.12) | 710 (783) |
| 2019-2025 | Annual Launches | na | na | 6.5 (7.2) | na | 138.1 (152.2) | ≤138.1 ≤(152.2) | 4,775 (5,263) |
| 2019-2025 | Annual UAS Operations | 0.32 (0.35) | 2.00 (2.20) | 2.15 (2.37) | 0.09 (0.19) | 0.08 (0.09) | 0.08 (0.09) | 92 (101) |
| **2019-2025 Annual Total** | | **1.61 (1.78)** | **75.14 (82.83)** | **10.85 (11.96)** | **0.17 (0.19)** | **138.47 (152.64)** | **≤138.47 ≤(152.64)** | **6,998 (7,714)** |
| **Comparative Threshold** | | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | **227 (250)** | na |
| **Exceed Threshold in Any Year?** | | **No** | **No** | **No** | **No** | **No** | **No** | |

Legend: ND = not determined; na = not applicable.

## 3.3 HAZARDOUS MATERIALS, TOXIC SUBSTANCES, AND HAZARDOUS WASTE

This section of the PEIS analyzes impacts related to hazardous materials, toxic substances, hazardous waste, and regulated storage tanks. Specifically, this section analyzes the potential for hazardous materials to be introduced to WFF during the course of site development and construction activities; for toxic and hazardous wastes to be generated as a result of construction and demolition activities; and for encounter with contaminated media during the course of site preparation and construction/demolition activities.

This PEIS also analyzes impacts related to the continuing use of hazardous materials and generation of hazardous wastes during rocket launch preparation and subsequent operations, aircraft operation and maintenance, laboratory activities, equipment and facility maintenance activities, and various other sources. The number and type of rocket launch operations (increased launches and frequency of operations) may affect the amount of hazardous materials used and stored at WFF, as well as the amount and types of hazardous waste generated. Changes in rocket motor sizes and stages could change the use of hazardous or toxic substances or the generation of hazardous wastes at WFF as compared to the existing conditions (refer to **Table 2.4-3**, Orbital Rockets, Motors, and Propellants).

The terms *hazardous materials, toxic substances, and hazardous waste* are often used interchangeably when used informally to refer to contaminants, industrial wastes, dangerous goods, and petroleum products. Each of these terms, however, has a specific technical meaning based on the relevant regulations.

**Hazardous Materials**

A hazardous material is defined as any substance that is:

1. Listed in Section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA);
2. Designated as a biological agent or other disease causing agent which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any person, either

directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction), or physical deformations in such persons or their offspring;

3. Listed by the U.S. DOT as hazardous materials under 49 CFR 172.101 and appendices; or
4. Defined as a hazardous waste per 40 CFR 261.3 or 49 CFR 171.

Hazardous material handling, storage, and disposal are federally regulated by the EPA in accordance with the Federal Water Pollution Control Act; CWA; Toxic Substance Control Act (TSCA); RCRA; CERCLA; and CAA.

**Toxic Substances**

The promulgation of TSCA (40 CFR Parts 700-766) represented an effort by the Federal government to address those chemical substances and mixtures for which it was recognized that the manufacture, processing, distribution, use, or disposal may present unreasonable risk of personal injury or health of the environment, and to effectively regulate these substances and mixtures in interstate commerce. The TSCA Chemical Substances Inventory lists information on more than 62,000 chemicals and substances. Asbestos and Pb are among the toxic chemical substances regulated by EPA under TSCA; the most common forms are found in buildings, namely ACM and LBP. ACM includes materials that contain more than one percent asbestos and are categorized as either friable or non-friable. LBP includes paint having Pb levels equal to or exceeding 0.5% by weight.

In addition to asbestos and Pb, renovation/demolition activities have the potential to disturb mercury and polychlorinated biphenyls (PCBs). Buildings may contain liquid mercury in thermostats and thermometers. Fluorescent lighting fixtures typically contain elemental mercury in the fluorescent light bulb; compact fluorescent lamps also contain mercury. In addition, fluorescent lighting fixture ballasts have the potential to contain PCBs.

**Hazardous Waste**

RCRA 40 CFR 261.3 and Virginia's 9 VAC 20-60 govern Virginia's hazardous waste management. RCRA defines hazardous waste as wastes or combination of wastes that, because of quantity or concentration; or physical, chemical, or infectious characteristics, may either cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible illness, or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. All hazardous wastes are classified as solid wastes. A solid waste is any material that is disposed, incinerated, treated, or recycled except those exempted under 40 CFR 261.4.

As a special note, military munitions used for their intended purposes on ranges or collected for further evaluation and recycling are not considered hazardous waste per the Military Munitions Rule; (40 CFR 266.202). The Military Munitions Rule amended portions of RCRA (40 CFR Parts 260 through 270) and defined when conventional and chemical military munitions become solid waste potentially subject to RCRA.

**Storage Tanks**

The 1984 Hazardous and Solid Waste Amendments to RCRA regulate USTs, including requirements for tank notification, reporting and record-keeping for existing tanks; corrective action; financial responsibility; compliance monitoring and enforcement; and approval of state programs. In addition, bulk storage containers and tanks are regulated under 40 CFR 112, which requires preparation of a Spill Prevention, Control, and Countermeasure Plan.

Virginia's UST Technical Regulation (9 VAC 25-580-10 *et seq.*) is similar to the Federal regulation, except it requires notifications from owners of all regulated USTs that remain in the ground. The latest UST amendments effective September 15, 2010, incorporate the Federal Energy Policy Act of 2005 requirements of secondary containment, delivery prohibitions, and operator training. Since May 8, 1986, each existing UST, any new USTs, any changes to USTs, and any closure of USTs must be reported to the VDEQ (VDEQ 2017a).

Virginia's Facility and AST Regulation (9 VAC 25-91) requires registration of ASTs having an aggregate AST capacity, or an individual AST, of more than 2,500 liters (660 gal) of oil. The Virginia AST requirements were updated on November 1, 2015, in order to incorporate new performance standards and to align Virginia's regulatory requirements with Federal requirements and current industry standards (VDEQ 2017b).

### 3.3.1 AFFECTED ENVIRONMENT

The affected environment includes the Main Base, Mainland, and Wallops Island. The WFF ICP, developed by NASA to meet the requirements of 40 CFR Part 112 (Oil Pollution Prevention and Response), 40 CFR Part 265 Subparts C and D (Hazardous Waste Contingency Plan), and 9 VAC 25-91-10 (Oil Discharge Contingency Plan), serves as the facility's primary guidance document for the prevention and management of oil, hazardous material, and hazardous waste releases (NASA 2017).

#### 3.3.1.1 Hazardous Materials Management

Hazardous materials are used at WFF for solid rocket propellants; during payload processing operations and spacecraft integration; and in machine shops, paint booths, and laboratories. Hazardous materials used include AP/Al, NC/NG, hydrazine, cutting fluids, solvents, flammables, paint thinners, and laboratory reagents (NASA 2016).

The 2017 ICP update includes the following procedures for hazardous materials management at WFF:

- Complete daily, weekly, monthly, and annual site inspections, as outlined in the Facility Inspection, Tests, and Records section of the ICP using facility inspection checklists.
- Perform preventive maintenance of equipment, secondary containment systems, and discharge prevention systems described in the ICP, as needed, to keep them in proper operating conditions.
- Conduct annual employee training, as outlined in the Discharge Response, Equipment and Training section of the ICP.
- If either of the following occurs, submit the Spill Prevention, Control, and Countermeasure Plan to the EPA Regional Administrator, along with other information.

  - The facility discharges more than 3,800 liters (1,000 gal) of oil from aboveground storage containers into or upon the navigable waters of the United States or adjoining shorelines in a single spill event; or
  - The facility discharges oil in a quantity greater than 160 liters (42 gal) in each of two spill events from aboveground storage containers into or upon the navigable waters of the United States or adjoining shorelines within any 12-month period.
- Review the ICP on an annual basis. Update the Plan to reflect any "administrative changes" that are applicable, such as personnel changes or revisions to contact information, such as phone numbers. Administrative changes must be documented in the Plan Review Log, but do not have to be certified by a Professional Engineer.
- Review the Spill Prevention, Control, and Countermeasure Plan at least once every five years and amend it to include more effective prevention and control technology, if such technology will significantly reduce the likelihood of a spill event and has been proven effective in the field at the time of the review. ICP amendments, other than administrative changes discussed above, must be recertified by a Professional Engineer.
- Amend the Spill Prevention, Control, and Countermeasure Plan within six months whenever there is a change in facility design, construction, operation, or maintenance that materially affects the facility's spill potential. The revised Plan must be recertified by a Professional Engineer (NASA 2017).

With respect to liquid propellants such as petroleum, cryogenic, and hypergolic propellants, the propellant and oxidizer are stored in separate tanks per WFF's *Range Safety Manual* (NASA 2013). Storage and handling of all three types of liquid propellants adheres to WFF procedures. Currently, there is a liquid fueling facility located adjacent to Launch Pad 0-A. Fueling of launch vehicles with petroleum or cryogenic propellants is performed at Launch Pad 0-A and refilling of these propellant tanks occurs onsite. Up to 2,270 kgs (5,000 lbs) of hypergolic propellants would be stored in Building Z-025 and 27,200 kgs (60,000 lbs) of nitrogen tetroxide in Building Z-020 on Wallops Island, or hypergolic propellants would be transported to WFF months prior to fueling and would be stored in DOT-approved shipping containers inside controlled access facilities on Wallops Island. Payloads would be fueled directly from these containers. In the event of a hypergolic propellant release, WFF's Hydrazine Contingency Plan would be followed.

#### 3.3.1.2 Toxic Substances Management

Over 65% of the operational buildings on WFF are over 40 years old. Inspections were performed at WFF for suspect ACM in May/June 2007, September 2008, October 2008, and March 2009. In addition, a survey for potential LBP hazards was conducted during the 2007 effort. Results of the 2007 Main Base inventory indicate the known presence of ACM in Building E-107 and the presence of suspected ACM in Buildings D-049, D-101, E-002, E-106, and D-107 (AH Environmental Consultants 2007). The 2008 Mainland and Wallops Island inventory noted suspected ACM in Buildings X-091 and X-115 (AH Environmental Consultants 2009a).

LBP, mercury, and PCB inspections were conducted on Building E-106 in September 2009. The results of those inspections indicate the presence of ACM (based on September 2008 inspection), LBP, and mercury-containing fluorescent lighting. No PCB-containing lighting ballasts were identified (AH Environmental Consultants 2009b).

#### 3.3.1.3 Hazardous Waste Management

Wallops Main Base is separated from Mainland/Wallops Island by approximately 11.2 km (7 mi) of public roadway. As the Main Base and Mainland/Wallops Island are not contiguous, each has been assigned its own EPA hazardous waste generator number (VA8800010763 and VA7800020888, respectively). The Main Base and Mainland/Wallops Island areas are both classified as Large Quantity Generators; each area has the potential to generate more than 1,000 kgs (2,205 lbs) of hazardous waste and/or 1 kg (2.2 lbs) of acute hazardous waste per month. To facilitate the transportation of rocket motors declared hazardous waste from the Main Base to Wallops Island, NASA has its own hazardous waste transporter license (VA8800010763). However, NASA uses licensed hazardous waste transporters to transport hazardous waste off-site to licensed treatment, storage, and disposal facilities (NASA 2008).

At WFF, hazardous waste generators are responsible for:

- placing hazardous waste in proper containers,
- labeling containers as to contents, and including the words "hazardous waste",
- storing hazardous waste in a satellite accumulation area at or near the point of generation under the control of a RCRA and ICP trained operator and ensuring that the waste is transported by the Environmental Office to a less-than-90-day accumulation area within 3 days of accumulating 208 liters (55 gal) of hazardous waste or 0.95 liters (1 quart) of acutely hazardous waste, and
- properly completing and submitting a disposal inventory sheet to the Environmental Office.

Following transfer from the satellite accumulation area, hazardous wastes generated on the Main Base are stored at accumulation areas located at Building B-029 and Building N-223, although Building N-223 is employed primarily for the storage of used oil. Hazardous wastes generated on the Mainland/Wallops Island are stored at Building U-081 (NASA 2017).

In calendar year 2016, a total of 14,463 kgs (31,885 lbs) of hazardous waste was generated at WFF. This includes a total of 10,341 kgs (22,797 lbs) from the Main Base and 4,122 kgs (9,088 lbs) from Mainland/Wallops Island (Simko 2017). Hazardous waste generated included rags containing Pb, crushed fluorescent tubes, acetic acid, jet fuel from maintenance activities, chemicals associated with tank cleaning, paint, and paint thinners. When the hazardous materials in rocket motors are declared hazardous waste (i.e., unsafe for transport to a facility specializing in disposal of rocket motors), they are open burned at the RCRA permitted OB area on the south end of Wallops Island until all the rocket propellant is burned and the hazardous characteristic of reactivity is removed (refer to **Table 2.4-8,** Summary of Open-Burns). The rocket motor casings are recycled as scrap metal (NASA 2008).

#### 3.3.1.4 Environmental Compliance and Restoration Program

The WFF Environmental Compliance and Restoration (ECR) Program is responsible for the planning, implementation, and oversight of the investigation of past site activities to ensure the protection of human health and the environment. Projects include former NASA sites and Navy sites related to past operations. Projects are prioritized to ensure sites with the highest priority are assessed first.

The ECR Program manages the investigation, response, and remedial activities at the former NASA operational areas at WFF under the Administrative Agreement on Consent (AAOC) executed between NASA and EPA [EPA Docket Number: RCRA-03-2004-0201TH] (EPA 2004). The AAOC applies to past releases of hazardous substances, waste and/or constituents by NASA at WFF and identifies CERCLA response requirements, policies, and guidance as the primary process for planning for and performing the work necessary to complete remedial and corrective actions appropriate to those releases.

As part of the AAOC, NASA, EPA, and the VDEQ have agreed that investigation, response, and remedial activities for sites resulting from former Navy activities at WFF (prior to NASA ownership) will be addressed as Formerly Used Defense Sites (FUDS) managed by the USACE. The FUDS program authorizes the USACE as the lead DoD agency for the environmental restoration of properties that were formerly under DoD control. In February 2015, NASA and the Department of the Army signed a Memorandum of Agreement which divided responsibilities for response actions between NASA and USACE. NASA agreed to assume responsibility of 104 structures (i.e., buildings, tanks, substructures, etc.) and to assume responsibility for further investigations and actions for AOCs related to transformers left in place when the Navy ceased operations on Wallops Island. For Wallops FUDS, NASA agreed to complete the future investigation and response actions using Environmental Restoration, FUDS funds appropriated to the DoD and transferred to NASA.

For sites involving only past petroleum contamination or releases, NASA manages the investigation, response, and remedial activities with oversight from VDEQ, Tidewater Regional Office, located in Virginia Beach, Virginia. NASA follows guidelines in general accordance with the VDEQ October 4, 2001, *Guidance Document #01-2024 Petroleum Storage Tank Program Technical Manual* and the VDEQ October 12, 2001, *Guidance Document #01-2025 Petroleum Storage Tank Program Compliance Manual.*

Since 1988, a series of facility-wide surveys, assessments, and inspections have been performed by NASA, under the oversight of EPA and VDEQ, between 1988 and 1996. The purpose of these investigations was to evaluate the WFF facilities and identify Areas of Concern (AOC) that may pose a risk to human health or the environment. Thirty AOCs were initially identified at WFF as a result of these assessments. Since 1998, USACE has also conducted a series of ongoing assessments and investigations to determine responsibility and eligibility for AOCs under the FUDS program. Each of the 12 FUDS Projects established in this program include multiple sites or AOCs with similar contaminants, sources, and/or locations. Currently there are seven active CERCLA sites managed under the AAOC, one active petroleum site, and 11 active FUDS Projects. **Figure 3.3-1** provides the location of the AOCs at WFF. NASA has coordinated activities at these AOCs with EPA and VDEQ, and has taken actions to address potential risks, on a priority basis, under the appropriate environmental and regulatory programs. Actions conducted at the AOCs include supplemental investigations, sampling programs, removals, product recovery, remedial investigations, feasibility studies, remediation, and closeout. Land use restrictions and institutional controls exist at the active sites to prevent future development and groundwater usage (NASA 2008).

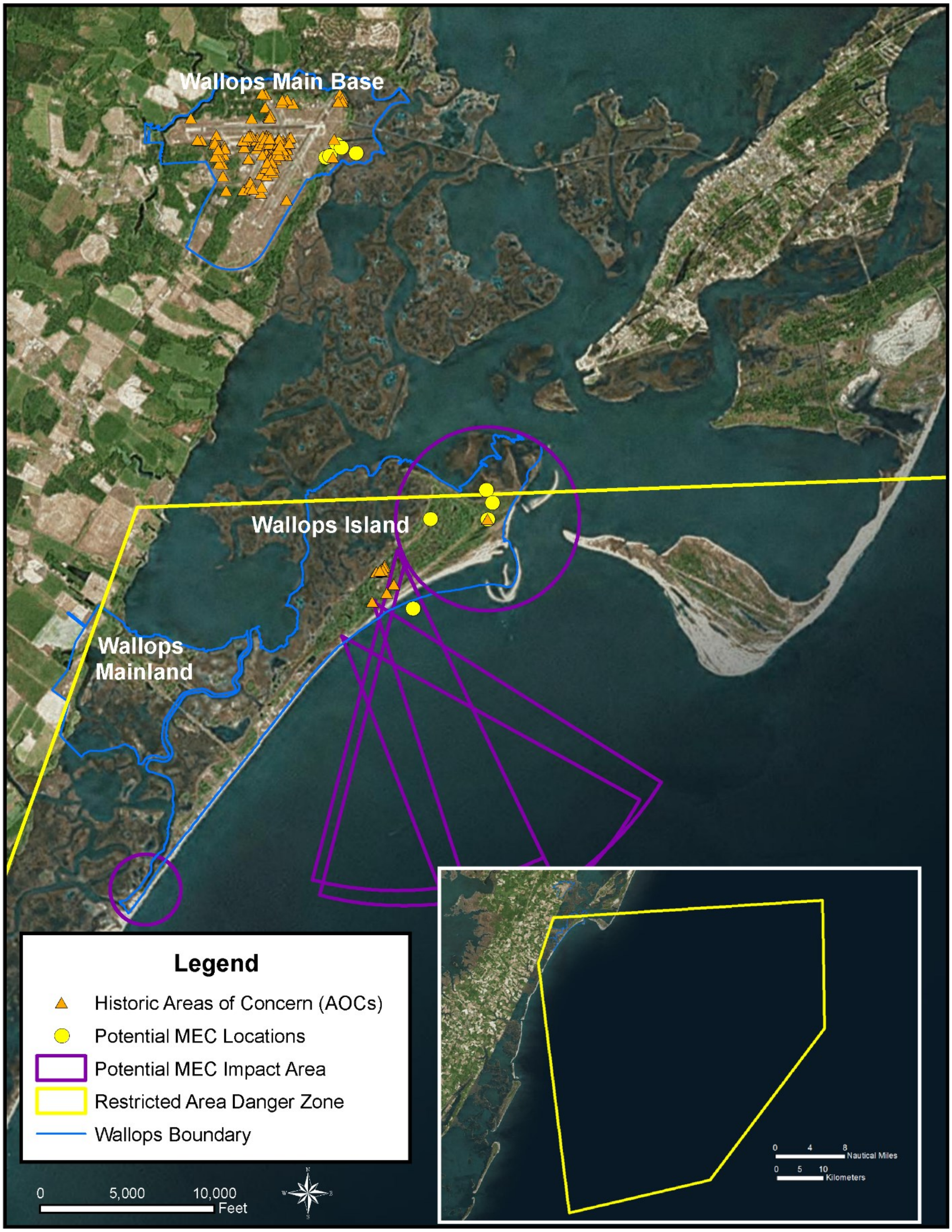


**Figure 3.3-1. Existing Hazardous Areas of Concern for Wallops Flight Facility**

#### 3.3.1.5 Munitions and Explosives of Concern

Munitions and Explosives of Concern (MEC) are explosive munitions (i.e., bombs, shells, grenades, etc.) that did not function as designed and may pose a risk of detonation. MEC is composed of unexploded ordnance (UXO) and discarded military munitions.

In 2007, the USACE completed a study assessing relevant information regarding suitability of various borrow site options considered on WFF for the SRIPP (NASA 2010a). The USACE study identified several reported UXO sites, one explosive ordnance disposal area, and two uncharacterized UXO sites (USACE 2007). In addition, there are several known historic live fire and bombing areas off Wallops Island. None of these are currently active (USACE 2007). **Figure 3.3-1** illustrates the location of these areas of potential MEC.

#### 3.3.1.6 Storage Tank Management

WFF has an active and ongoing project to reduce the number of petroleum storage tanks on the facility. WFF (and specified partners/tenants) own and operate 44 ASTs and 7 USTs of various sizes with a maximum AST storage capacity of 796,810 liters (210,495 gal) and maximum UST storage capacity of 102,000 liters (27,000 gal). Both ASTs and USTs primarily store heating oil for buildings with the next most common usage to store fuel oil for emergency generators (NASA 2017). Occasionally, portable ASTs containing diesel fuel and gasoline are brought to WFF by outside construction contractors for the duration of their contract. Prior to commencing work, these contractors are required to submit a health and safety plan for approval by the WFF Safety Office. Contractors are required to notify WFF of containers brought to the facility with a capacity greater than 208 liters (55 gal) and ASTs of 2,500 liters (660 gal) or greater must have Facilities Management Branch approval and include a SWPPP or other approved spill response plan. WFF requires that all containers include 110% secondary containment. If the tank will be in use on WFF for more than 120 days, the contractor must provide proof that the tank is registered with the VDEQ.

### 3.3.2 Environmental Consequences

The magnitude of potential impacts associated with hazardous materials, toxic substances, hazardous waste, and regulated storage tanks depends on the toxicity, transportation, storage, and disposal of these substances. The threshold of significance would be met if hazardous materials, hazardous waste, or interaction with restoration sites substantially increase the human health risk or environmental exposure through storage, use, transportation, or disposal of these substances. An increase in the quantity or toxicity of hazardous materials and/or hazardous waste handled by a facility may also signify a potentially adverse effect, especially if a facility was not equipped to handle the new waste stream. For contaminated sites, impacts would be adverse if the site was disturbed such that the extent and/or degree of contamination is increased.

#### 3.3.2.1 No Action Alternative

##### 3.3.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Hazardous materials, toxic substances, and hazardous waste would continue to be managed in accordance with current procedures and WFF would continue to implement institutional support projects that are within the installation's current envelope.

3.3.2.1.2 Operational Missions Activities

Under the No Action Alternative, operational missions and activities would remain at current levels and within documented envelopes; all operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Hazardous materials, toxic substances, and hazardous waste would continue to be managed in accordance with current procedures.

### 3.3.2.2 Proposed Action

3.3.2.2.1 Institutional Support Projects

As listed in **Table 2.5-1** and **Table 2.5-2**, the Proposed Action would support a number of construction, demolition, and renovation projects on the Main Base, Mainland, and Wallops Island. These projects include construction of a Commercial Space Terminal and extension of Runway 04/22 (Main Base), demolition and reconstruction of the Causeway Bridge, maintenance dredging of the Barge Route between the two boat docks, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, Launch Pier 0-D, and two DoD launch pads (Mainland/Wallops Island).

**Hazardous Materials Management**

Under the Proposed Action, established procedures for the management of hazardous materials would be followed during construction and demolition activities. Specifically, the construction and demolition contractors would be responsible for notifying WFF prior to bringing any hazardous materials onto the property, and for the proper handling of hazardous materials while onsite. Any potential increase in hazardous materials usage during construction or demolition activities would be temporary and would be managed in accordance with standard procedures. It is not anticipated that the amount of hazardous materials to be used during construction and demolition activities under the Proposed Action would impact human health or the environment or the ability for these materials to be managed in accordance with current procedures; therefore, there would be no significant impact to hazardous materials management from implementation of the Proposed Action.

**Toxic Substances Management**

As listed in **Table 2.5-1** and **Table 2.5-2**, numerous structures are proposed for demolition under the Proposed Action. The majority of the structures to be demolished were constructed between 1943 and 1964 (NASA 2008). Due to the age of the structures and results of previous hazardous materials inventories, it is likely the demolition projects may include the removal of ACM, LBP, mercury-containing lighting or switches, and PCB-containing lighting ballasts. All structures considered for demolition would be evaluated for toxic substances prior to demolition; removal and proper disposal of these materials would be completed in accordance with GPR 8500.3 (NASA 2010b). Because LBP inhibits the rusting and corrosion of iron and steel, Pb continues to be used on bridges. Therefore, it is anticipated LBP is present on the Causeway Bridge. Demolition of the Causeway Bridge would be performed in accordance with OSHA's *Lead Standard for the Construction Industry* (29 CFR 1926.62). Following demolition, the contractor would be responsible for sampling the waste to determine whether it must be managed as a RCRA hazardous waste.

ACM would be properly removed and disposed of prior to or during demolition in accordance with 40 CFR 61.40 through 157 and GPR 8500.3 (Waste Management). All LBP would also be managed and disposed of in accordance with the TSCA and OSHA regulations and GPR 8500.3. All fluorescent light tubes/bulbs and high-intensity discharge lamps requiring removal would be considered a universal waste and would be removed and sent to an approved recycling facility. However, due to the mercury content, broken or crushed fluorescent and high-intensity discharge lamps would be managed as hazardous waste in accordance with GPR 8500.3. In addition, any mercury-containing thermostats could be sent to an approved recycling facility or disposed of as hazardous waste in accordance with GPR 8500.3. The removal of toxic substances as part of demolition activities would be conducted in accordance with all applicable regulations. Therefore, no significant impact to human health or the environment is anticipated from the removal of toxic substances under the Proposed Action.

**Hazardous Waste Management**

Under the Proposed Action, established procedures for the management of hazardous wastes would be followed during construction and demolition activities. Specifically, the construction and demolition contractors would be responsible for coordinating with WFF for the disposal of any hazardous wastes generated. It is not anticipated that the amount of hazardous materials used or hazardous waste generated during construction and demolition activities under the Proposed Action would impact human health or the environment or the ability for these wastes to be managed in accordance with current procedures.

**ECR Program and MEC**

In terms of potentially contaminated sites, as stated previously, WFF has an active ECR Program. As part of the ECR Program, 46 AOCs have been identified at WFF (refer to **Figure 3.3-1**). Land use restrictions and institutional controls exist at the active sites to prevent future development and groundwater usage (NASA 2008). The proposed construction and demolition projects are not expected to affect these AOCs or MEC. The proposed location of the DoD ESSM pad would be near environmental restoration site W-32 (former transformer pad). The location of the pad would be adjusted to avoid this site. Therefore, no impact associated with AOCs or MEC would be anticipated under the Proposed Action. Details on the proposed North Wallops Island Deep-water Port and Operations Area are not known at this time; however, the project location would be within the potential MEC impact area. Future NEPA analysis would be required to address the potential impacts as project planning and design details became more developed.

**Storage Tank Management**

In addition to the oil and fuel (including cryogenic and hypergolic) storage systems maintained at the facility, outside construction contractors occasionally bring portable ASTs of varying capacities onto the facility for the duration of their contract. The notification, registration, and secondary containment requirements discussed in Section 3.3.1.4 would continue to be followed under the Proposed Action. WFF has an active and ongoing project to reduce the number of petroleum storage tanks on the facility. However, construction of Launch Pad 0-C may require a liquid fueling facility that would contain ASTs. See Section 3.3.2.2.2, Expanded Space Program for a discussion of the liquid fueling facility.

In summary, no significant impact to human health or the environment would result from institutional support projects as presented under the Proposed Action. Refer to **Section 4.1.3** (Hazardous Materials, Toxic Substances, and Hazardous Waste) for measures to mitigate impacts associated with hazardous materials, toxic substances, and hazardous waste under the Proposed Action.

3.3.2.2.2 Operational Missions and Activities

The proposed operational missions and activities would involve the continued use of hazardous materials such as solvents, hydraulic fluid, oil, antifreeze, paint, hydrocarbon propellants (e.g., Jet-A, hydrazine, RP-1, and liquid methane), cryogenic fuels (e.g., liquid hydrogen, liquid nitrogen, and liquid oxygen), solid rocket fuels, and hypergolic fuels for spacecraft and exoatmospheric aircraft (refer to Section 2.4.2.3.4, Fuel Types). Several operational proposals have the potential to impact the management of hazardous materials, toxic substances, tanks, hazardous wastes or contaminated sites. These include increased UAS operations at the North Wallops Island UAS airstrip, operational missions under the Expanded Space Program, and use of hybrid fuels (refer to Section 2.5.2.2, Hybrid Fuels). The greatest risks from the use of most hazardous materials are associated with spills or leaks; however, the procedures outlined in the ICP would be followed to minimize environmental effects. Moreover, all hazardous materials would continue to be managed according to standard procedures.

**Hazardous Materials Management**

Although an increase in the number and type of operational missions would correspond to an increase in the amount of hazardous materials used and hazardous waste generated, some materials such as fuel, propellant, and payloads would be consumed during the operational missions and activities. Therefore, the greatest potential for impact to the environment due to the release of hazardous material would result from an accident at the storage location; accidental release during fueling, payload processing, launch or landing activities; or through an emergency release.

***North Wallops Island UAS Airstrip Increased Operations***

Fuels would be stored onsite in portable tanks or drums for UAS operating from the North Wallops Island UAS airstrip. Proper fuel storage and handling procedures would be followed by trained personnel.

***Expanded Space Program***

Under the Expanded Space Program, LVs could be used to support payload delivery to orbit (i.e., LFIC LV or SFHC LV), vertical launch and landing vehicles (i.e., Blue Origin New Shepherd and the SpaceX Falcon 9) or use of horizontal launch and landing vehicles for commercial human spaceflight missions.

Although unlikely, it is possible that launch debris containing hazardous materials such as solid rocket propellant could be deposited in areas surrounding the launch pad or in the ocean in the event of a launch failure. Depending on the size and composition of the debris, it is possible that this debris, with hazardous materials attached to it, would either sink or float. The potential environmental effects would vary greatly depending upon the type of accident and substance involved. However, the procedures for hazardous materials management at WFF listed in Section 3.3.1.1 would be employed to minimize spill size, duration, and possible environmental exposure both on land and in the water.

In October 2014, an Antares rocket failed during launch at Pad 0-A. Field sampling analysis conducted following the mishap supported the conclusion that soil contamination would most likely be localized to the Pad 0-A complex. Virginia Space also determined that the levels of metals and perchlorate in the soil after the mishap did not go above background levels on Wallops Island or conservatively applied screening levels, and soil removal was not warranted. Petroleum contaminated soil from the mishap was limited to a several hundred square meter area adjacent to Pad 0-A, and was removed shortly following the mishap and disposed of at a licensed treatment facility (NASA 2015).

Due to the required low temperatures in which cryogenic propellants must be stored, any spill could cause localized environmental damage such as vegetation loss. In addition, LOX may explode if improperly mixed with combustible materials such as liquid hydrogen and the gaseous oxygen evaporating from a liquid spill would intensify any existing fires. No known long-term environmental impacts have not been reported due to spills of LOX or liquid hydrogen.

Payload fueling would take place at one of the PPFs currently in use at WFF or in a facility not yet constructed but analyzed in previous NEPA documents. Specific to hypergolic propellants, the greatest likelihood of a release would be during fueling operations. Hypergolic fueling personnel are in scape suits, and during hypergolic fueling operations, the NASA Safety Office would employ weather data and computer models to predict the effects of an unintentional release. Based on the results of the analysis, access-controlled hazard areas would be established and maintained to ensure public safety is not affected in the event of a mishap. All personnel working near PPFs and those who transport, fuel, and maintain the spacecraft systems would receive Hazardous Communication training. The procedures outlined in WFF's *Hydrazine Contingency Plan* would be followed in the event of a release of hypergolic propellants (NASA 2009).

A liquid fueling facility may be required for the LFIC LV at Launch Pad 0-C; plans for construction of these facilities would be considered during the design phase for the pad. It is anticipated that if a liquid fueling facility is necessary, it would include infrastructure similar to the liquid fueling facility located adjacent to Launch Pad 0-A. This may include the presence of RP-1; cryogenic storage for LOX, liquid hydrogen, liquid nitrogen, and liquid $CH_4$; and high-pressure storage for gaseous helium and gaseous nitrogen. Support equipment would likely include piping, pumps, heat exchangers, vaporizers, valves, control systems, concrete pads and pedestals, and other miscellaneous items. Fueling and launch vehicle processing operations would be the primary sources of hazardous waste and materials, and fueling would take place at the liquid fueling facility as is currently done at the liquid fueling facility located adjacent to Launch Pad 0-A. All personnel working near launch pads and those who transport and maintain the launch vehicles would receive Hazard Communication training per 29 CFR 1910.1200.

***Hybrid Fuels***

Nanoscale metal particles are highly reactive materials. While this class of substance is desirable for propellants, it can create safety hazards. Potential impacts from hybrid fuels under development are not currently known. As this technology develops and its use at WFF is considered, further NEPA analysis may be required to analyze the potential impacts from these fuel sources in the future.

**Toxic Substances Management**

Any toxic substances needed for WFF operations would be managed according to standard procedures for hazardous materials.

**Hazardous Waste Management**

Hazardous waste generated from operations could include liquid hazardous wastes such as those resulting from fuel and oxidizer transfer operations and rinseate (i.e., water generated from cleaning equipment), as well as solid hazardous wastes such as pads, wipes, and rags. Management of rocket motors would continue to follow current hazardous waste management procedures described in Section 3.3.1.1. With regards to hypergolic propellants, once the propellant has been loaded, equipment and lines used to transfer it undergo potable water flushes followed by an isopropyl alcohol/demineralized water flush.

Similarly, potable water would be used to flush oxidizer transfer equipment and lines after the hypergolic oxidizer has been transferred to the spacecraft. VDEQ has concurred that rinseate resulting from potable water flushing of the propellant lines and equipment can be discharged to the WFF sanitary sewer. Isopropyl alcohol rinseate would be disposed of as hazardous waste (NASA 2009).

All hazardous wastes would continue to be managed in accordance with standard procedures to protect human health and the environment. NASA would be responsible for identifying, containing, labeling, and accumulating the hazardous wastes in accordance with all applicable federal, state, and local regulations. All hazardous wastes generated from WFF operations would be transported by a licensed contractor to a treatment storage and/or disposal facility. It is not anticipated that the slight increase in hazardous waste generated by an increase in operational activities under the Proposed Action would impact human health or the environment or the ability for these wastes to be managed in accordance with current procedures.

In addition, the proposed operational activities are not expected to affect AOCs or MEC. Therefore, no impact associated with AOCs or MEC from either institutional or operational activities are anticipated under the Proposed Action. Therefore, there would be no significant impact to hazardous waste management from implementation of the Proposed Action.

**Storage Tank Management**

If additional storage tanks are deemed necessary, WFF would ensure all tanks are operated in accordance with Virginia storage tank regulations (9 VAC 25-91 [AST] and 9 VAC 25-580 [UST]), including the preparation of a Spill Prevention, Control, and Countermeasure Plan. Therefore, no significant impact to tank management would result from implementation of the Proposed Action.

In conclusion, the types of hazardous materials that would be present under the Proposed Action are similar to the types of hazardous materials presently used at WFF. Current hazardous materials procedures, as described previously, would be implemented to ensure safe operations. WFF would follow the ICP, ground safety plans, etc. to minimize safety hazards. Any potential increase of hazardous materials use under the Proposed Action would be managed in accordance with standard procedures and is not anticipated to significantly impact human health or the environment. Therefore, there would be no significant impact to hazardous materials management from implementation of the Proposed Action. Refer to **Section 4.1.3** (Hazardous Materials, Toxic Substances, and Hazardous Waste) for measures to mitigate impacts associated with hazardous materials, toxic substances, and hazardous waste under the Proposed Action.

## 3.4 HEALTH AND SAFETY

The health and safety analyses at WFF address/consider the following:

- potential hazards associated with operations and maintenance activities such as fueling, handling, assembly, and checkout for all launch activities;
- occupational hazards;
- facility fire, crash, and rescue; and
- risks to the public, NASA personnel, contractors, and civilians from potentially hazardous activities such as flight operations, flight trajectory and dispersion, and launch failures at WFF.

The WFF Safety Office plans, develops, and provides functional management of policies and procedures for safety and establishes and approves safety procedures for the protection of property and the public.

### 3.4.1 AFFECTED ENVIRONMENT

Day-to-day institutional operations and maintenance activities conducted at WFF are performed in accordance with applicable NASA institutional safety and mission programs and controls. The WFF Safety Office plans, develops, and implements facility programs and controls for the safety of personnel, protection of property, and operations of facilities. This organization develops, plans, and promotes occupational health and safety and emergency (i.e., fire, crash, and rescue) planning and operations. It also reviews contractor prepared safety plans for construction, modification, or demolition of facilities and infrastructure. Safety controls are established to minimize the potential hazards associated with institutional and workplace activities.

The WFF Safety Office is responsible for the application of safety policies, principles, and techniques to assure the safety and integrity of the public, workforce, and infrastructure. The WFF Safety Office has the responsibility to ensure safe mission activities from preparation through operation and post-operations, both for missions launched from the WFF Range and those supported off range. NASA has established mission specific ground safety guidelines. These guidelines outline ground safety requirements, range user and tenant/partner responsibilities, and safety data requirements to which all range users must comply. In addition, WFF requires all range users to submit formal documentation pertaining to their proposed operations for safety review. Mission specific safety plans are prepared by the WFF Safety Office and address all potential ground hazards related to a given mission in accordance with the WFF Range Safety Manual. The Ground Safety Plan outlines controls for minimizing risks to human health and specifically addresses topics such as hazard arcs; hazardous materials handling; explosive safety; personal protective equipment; health and safety monitoring; and training.

**Range Safety**

A common safety practice is to establish restricted-access hazard arcs around the location of these activities to separate the hazardous procedures from other operations and from the general public. For example, once a launch vehicle is erected on a launch pad, a hazard arc whose size is calculated based upon the potential hazards of that vehicle (e.g., the types and quantities of propellant onboard, rocket reliability, flight trajectory, and types of debris expected if the flight were terminated) is activated around the launch pad. Operational controls (e.g., evacuation areas, temporary road closures, etc.) are established within and at the perimeter of the hazard arc to minimize the potential hazards associated with the operations of the launch range. Recent LV launches from WFF (e.g., Antares, Minotaur V) have required hazard arcs ranging from approximately 2,600 m (8,500 ft) to 2,750 m (9,000 ft). **Figure 3.4-1** depicts common hazard arcs that are activated throughout WFF.

The WFF Safety Office typically reopens a hazard area within 2 to 3 hours following a nominal launch. However, in the case of a launch incident or failure, it may be days before the WFF Safety Office deems the area safe enough for personnel to enter.

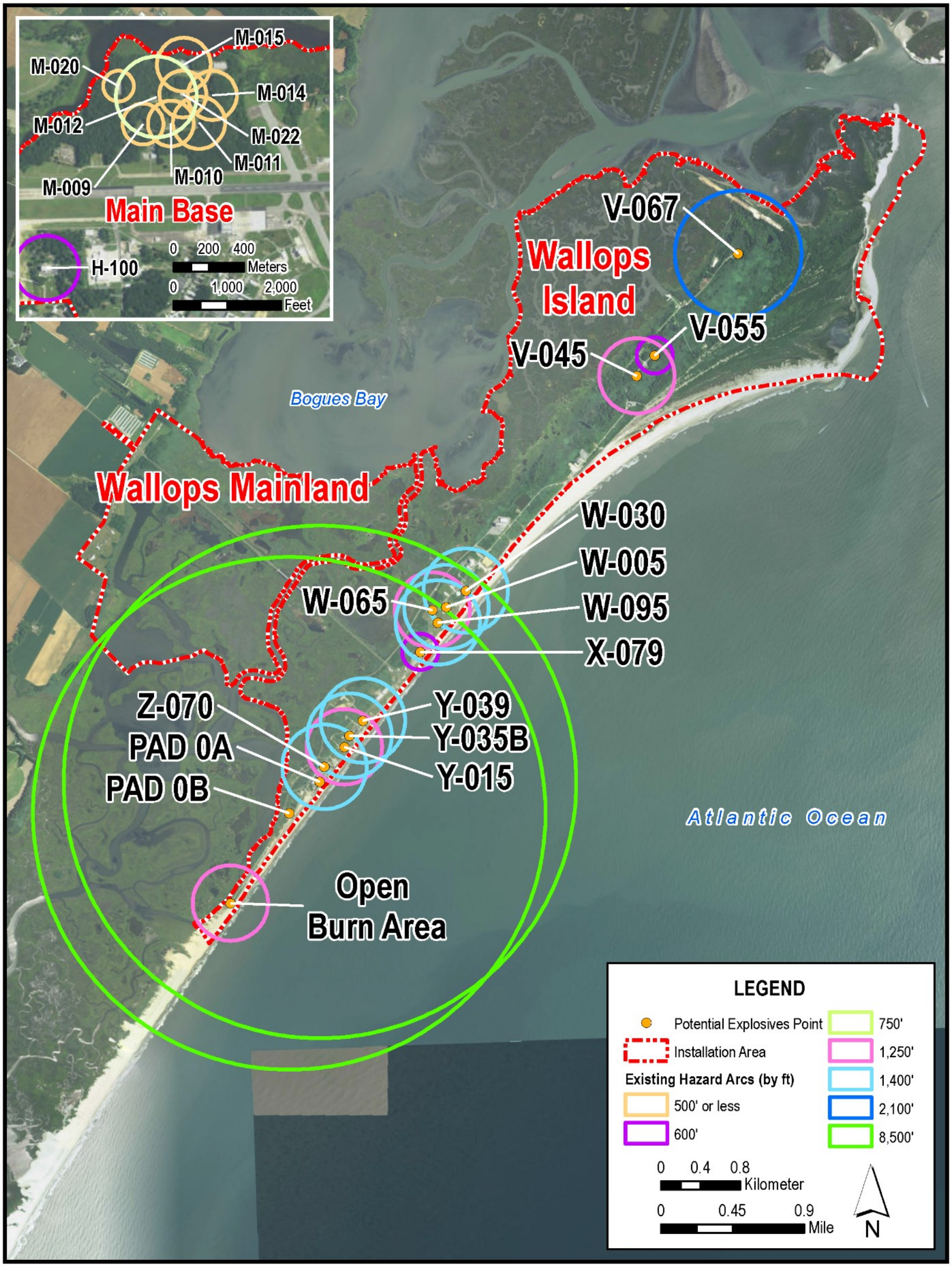


**Figure 3.4-1. Existing Wallops Island Hazard Arcs**

Payload operations may involve lasers, radioactive materials, biological specimens, and chemicals, all of which require specialized safety procedures when used at WFF. Laser use must comply with NPR 1800.1, NASA Occupational Health Program Procedures, Chapter 4, *ANSI Z136.1-2007, American National Standards for Safe Use of Lasers and ANSI Z136.6-2005, Safe Use of Lasers Outdoors*, as well as applicable Federal and Virginia OSHA regulations regarding laser use. Radioactive materials must be licensed by the Nuclear Regulatory Council and if flown, must be approved by the NASA Nuclear Flight Safety Approval Manager. Biological specimens must be properly categorized and handled in accordance with Centers for Disease Control protocol. Tracking and data systems operations must be within the accepted levels for human exposure to radio frequency electromagnetic fields, and comply with all IEEE standards.

All personnel involved with operational programs at WFF follow appropriate safety protocols, including OSHA regulations and training requirements. The handling, processing, storage, and disposal of hazardous materials or hazardous wastes from operations and maintenance activities are accomplished in accordance with all applicable Federal and state requirements. A full description and subsequent analyses of the management of hazardous materials, toxic substances, and hazardous waste is provided in Section 3.3, Hazardous Materials, Toxic Substances, and Hazardous Waste.

Flight-related risks for each type of WFF project are distinct; NASA has specialized procedures applicable to LVs, sounding rockets, balloon operations, piloted aircraft and UAS, and projectile tests. WFF coordinates all operations with the FAA, U.S. Navy, Coast Guard, and other organizations as required in order to clear potential hazard areas. If necessary, NOTMARs and NOTAMs depicting the hazard areas are published at least 24 hours prior to an operation. Additionally, the WFF Office of Communications regularly distributes both electronic and faxed notices of launch-related hazard areas to a group of more than 100 recipients that includes local watermen, marinas, and marine transportation companies.

Risk criteria have been established by NASA in order to protect the public, mission essential and critical operations personnel, and property from risks associated with operations. These criteria are consistent with the National Range Commanders Council guidelines.

A flight trajectory analysis is completed prior to each flight to define the flight safety limits for guided and unguided systems. Launch vehicles with Flight Termination Systems are terminated by destruction of the vehicle if the flight is deemed erratic or crosses the established destruct boundary. All stages are required to be equipped with Flight Termination Systems unless the maximum range of the vehicle is within established launch range boundaries or the vehicle is determined to be inherently safe. Flight termination boundaries are designed to protect the public and personnel by ensuring that vehicle destruction occurs within a predetermined safety zone.

Safety considerations for LV launches also include toxic materials dispersion, and distance focusing overpressure considerations. Toxics include a variety of hazardous materials that could be transported through the atmosphere from either a normal or terminated flight, and may include rocket exhaust products such as HCl and CO, or propellants such as hydrazine and oxides of nitrogen. The effects of toxic materials cannot be contained within a certain pre-defined hazard area as they are dictated by atmospheric conditions. Distance focusing overpressure analyses determine the risk to the public given the potential for a shock wave to strengthen in the far field after reflecting off of temperature gradients in the atmosphere. As such, the effects of these hazards are analyzed real-time during launch countdown using industry accepted computer models. As the extent of potential hazard could change with the weather, the areas requiring clearance are also subject to change. To ensure maximum operational flexibility while also upholding NASA's rigorous safety standards during variable weather conditions, one concept prevails: the farther the hazardous activity is from the general public, the smaller the risk of harm. It is standing NASA safety policy that hazardous activities must be conducted as far away from the public as possible and only performed within the boundaries established by NASA safety guidelines.

To further enhance WFF's range safety program, at WFF's request the USACE amended an existing permanent danger zone in the waters of the Atlantic Ocean off Wallops Island and Chincoteague Inlet that protects the public from hazards associated with rocket launching operations (see **Figure 3.3-1**). The amendment increases the danger zone to a 56 km (30 nm) sector (USACE 2012).

In addition to the NASA range safety processes that apply to all WFF missions, the FAA Office of Commercial Space Transportation conducts a safety review of proposed commercial space operations as part of an applicant's application for a commercial space launch license or permit. NASA and FAA have entered into multiple Memoranda of Agreement (FAA 2013) outlining each agency's specific roles and responsibilities to avoid duplication of effort or to streamline safety reviews of commercial launch operations at WFF.

**Aviation Safety**

In addition to complying with all applicable FAA aviation safety guidance, WFF has an established Aviation Safety Program that must be followed during all piloted aircraft and UAS operations. Defined in GPR 8715.2, *Aviation Safety Program*, the program is overseen by an Aviation Safety Council and coordinated by an onsite Aviation Safety Officer. Key program elements include aircraft safety training, education, and awareness; airfield driver safety training and certification; hazard and mishap reporting and investigation; and airworthiness reviews following changes in aircraft design or configuration.

Another important component of aviation safety at WFF is its ongoing wildlife hazard management program, sometimes referred to as the Bird Aircraft Safety Hazard program. Performed on NASA's behalf by the USDA, Animal and Plant Health Inspection Service's Wildlife Services Division, the purpose of the program is to mitigate both short- and long-term hazards to aviation. Since the development of WFF's Wildlife Hazard Management Plan in 2001, USDA has maintained a full-time presence at WFF to disperse and remove birds and mammals from the airfield. Program objectives include reducing the attractiveness of WFF to birds and wildlife by minimizing food sources, nesting sites, and roosting habitat within the airfield clear zones. USDA personnel regularly implement various management techniques within and adjacent to the WFF airfield, which can include: identifying and manipulating species habitat and roosts, employing techniques to disperse species, and, if deemed necessary, removal of birds and/or mammals that pose a hazard to human health and aviation safety under appropriate Federal and state permits.

**Crash, Fire and Rescue Response**

The Safety Office also manages the WFF Fire Department which provides crash, fire, and rescue response to the facility along with emergency services to the neighboring community. The WFF Fire Department also has a Mutual Aid Agreement with the Accomack-Northampton Fireman's Association for any outside assistance needed at WFF (NASA 2013). The local fire companies closest to WFF are in the towns of Atlantic, Chincoteague, and New Church, Virginia. First responders to a mishap consider such factors as rescue, evacuation, fire suppression, safety and security of the area, and other actions immediately necessary to prevent loss of life or further property damage.

WFF Fire Department personnel are housed in two buildings on the facility, one on Wallops Island and one on the Main Base. There are 24-hour fire and protection services, and personnel are also trained as first responders for hazardous materials, waste, and oil spills. All are Emergency Medical Technicians and at least two employees per shift are Advanced Life Support certified. Rescue vehicles include structural engines, aircraft firefighting vehicles, ambulances, HAZMAT trucks and trailers, technical rescue trailers, utility pickup trucks, and tracked all-terrain vehicles (NASA 2013).

**Facility Security**

While not under the Safety Office, the Protective Services Division ensures the safety of personnel, property, and the public. WFF maintains a security force that is responsible for the internal security of the base and provides 24-hour per day protection services. Entry onto the Main Base is restricted through entry control points at the main entrance gate to WFF, an entrance gate to NOAA Wallops CDAS, and an entrance gate to the U.S. Navy controlled property at WFF. These gates are used to control and monitor daily employee and visitor traffic. One entrance gate serves as the single entry control and monitoring point for the Mainland and Wallops Island. Other services provided by the security force include security patrols, employee and visitor identification, afterhours security checks, maintaining mission driven safety cordons, and police services. Badges are provided to all WFF personnel, contractors, range users, tenants, and visitors. Only persons authorized by the WFF Safety Office are permitted to enter potentially hazardous areas of the facility (NASA 2016).

## 3.4.2 Environmental Consequences

For the purposes of this analysis, impacts would be considered significant if institutional or operational activities would present a substantial or potential hazard to personnel or the general public. Regardless of which Alternative is chosen, facility security would not be adversely affected. Facility security would continue to be implemented and adjusted as needed to ensure the safety of personnel, property, and the public. Therefore, facility security is not analyzed further.

### 3.4.2.1 No Action Alternative

#### 3.4.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents (presented in **Table 2.4-1)** that are incorporated by reference into this PEIS. Current procedures would continue to ensure protection of human health and safety.

#### 3.4.2.1.2 Operational Missions and Activities

Under the No Action Alternative, operational missions and activities would remain at current levels within documented envelopes. Current procedures would continue to ensure protection of human health and safety.

### 3.4.2.2 Proposed Action

#### 3.4.2.2.1 Institutional Support Projects

As listed in **Table 2.5-1** and **Table 2.5-2**, the Proposed Action would support a number of construction, demolition, and renovation projects. These projects include construction of a Commercial Space Terminal, extension of Runway 04/22, demolition and reconstruction of the Causeway Bridge, maintenance dredging of the Maintained Barge Route between the Main Base and Wallops Island boat docks, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, Launch Pier 0-D, and two DoD launch pads. Project details specific to health and safety for the North Wallops Island Deep-water Port and Operations Area and Launch Pier 0-D remain unknown. These projects, therefore, are not included in detail in the Health and Safety resource analysis and additional NEPA analysis would be completed in the future as required.

**<u>Construction, Demolition and RBR Projects</u>**

A project-specific health and safety plan would be developed prior to any construction activity. In general, these plans would identify health and safety hazards including LBP and ACM, fall protection associated with cranes or platforms, electrical hazards, mechanized equipment and hand and power tools risks; define fire and rescue protection and prevention including water safety; outline safety inspections; establish safety equipment requirements such as personal protective equipment, lighting, signs, and barricades; designate materials containment, handling, storage, use, and disposal processes; and provide necessary training and communication to ensure the safety of construction workers as well as personnel working or visiting WFF.

A project-specific health and safety plan would also define standard operating procedures (SOPs) for construction, demolition, and renovation projects. Some examples of general SOPs can be found below.

- All construction personnel and visitors must wear protective helmets while on the construction site unless otherwise indicated in the site-specific safety plan.
- Suspended scaffolds may be used for bridge painting or other purposes only if other means are not practical. All personnel must wear approved fall protection harnesses at all times while on suspended scaffolding.
- The minimum clearance between live power lines and any construction equipment is 3 m (10 ft).
- Supervisory personnel will ensure that all equipment is inspected at predetermined intervals to ensure that it is in safe operating condition.
- Firefighting equipment should be properly maintained, conspicuously located, and easily accessible to all personnel at all times.
- Only qualified welders should be authorized for welding or cutting activities.
- Identify underground utilities (e.g., water, sewer, natural gas, etc.) prior to digging or dredging.
- Accessible areas within the swing radius of a crane's rotating superstructure must be barricaded in order to prevent construction personnel from being struck during crane operation.

- When working over or near water, U.S. Coast Guard-approved life jackets or buoyant work vests shall be provided. Ring buoys and a small rescue boat must be present and located such that they are available for immediate use in an emergency situation.

On at least a weekly basis, a designated Safety Officer would document that all health and safety measures are followed for the duration of these projects. Regular inspections to ensure proper safety apparel, such as hard hats, gloves, hearing protection, safety glasses, orange vests, and safety boots, would be documented. Communication between management and construction crews would occur by radio and/or cellular telephones. The health and safety plans would provide all necessary emergency contact information including directions to the closest first aid station and closest hospital. Regular safety meetings, not less than weekly, would be performed to encourage accident prevention and accident awareness.

Proposed construction activities could present safety risks to construction personnel and WFF personnel, contractors, and/or guests in nearby facilities. To minimize risks to safety and human health, all construction activities would be performed by qualified personnel who are trained to safely operate the appropriate equipment. Additionally, all activities would be conducted in accordance with Federal OSHA regulations and Virginia OSHA regulations. Federal contractors would follow regulations defined in Federal Acquisition Regulation 52.236-13, *Accident Prevention.* Appropriate signage, signal lights, and fencing would be placed to alert pedestrians and motorists of project activities, as well as any changes in traffic patterns. Health and safety plans would be submitted by contractors for approval by the WFF Safety Office prior to work onsite. A safety briefing would be held at the pre-construction meeting with the WFF Facilities Management Branch and all contractors and subcontractors. Therefore, negligible impacts to health and safety are anticipated from construction and demolition activities proposed under the Proposed Action.

**Causeway Bridge Replacement**

In addition to the above safety practices, bridge construction would also follow the procedures presented in *Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects* administered by the FHWA, including (but may not be limited to) the following. The new bridge rail design would meet current crash worthiness standards determined by crash testing. A 1.8 m (6 ft) shoulder would be added on each side in order to provide enough space for two-way traffic to continue if a vehicle is stopped on the shoulder. While the proposed bridge would not be designed to accommodate pedestrians, the shoulders would provide increased safety for maintenance workers and bridge inspectors who occasionally require foot access to the bridge. The proposed bridge would include heavier allowable stress and design load capacity to provide improved resilience.

The U.S. Coast Guard issues permits that approve the location and plans of bridges and causeways and impose any necessary conditions relating to the construction, maintenance, and operation of these bridges in the interest of public navigation. NASA would obtain and follow the requirements of a Coast Guard Bridge Permit. Under the bridge permit, NOTMARs would be issued to warn boaters who may be in the vicinity of the Causeway Bridge to proceed with caution for the duration of the construction activities. Additionally, bridge designers would coordinate with the U.S. Coast Guard to ensure adequate vertical clearance and navigational lights and markers are included.

**Maintenance Dredging**

The USACE issues permits for dredging in federal navigable waters. NASA would obtain the appropriate permit for this project. During maintenance dredging, NOTMARs would be issued to warn boaters who may be in the vicinity of the activity to proceed with caution for the duration of the dredging operations.

No significant impact to human health and safety would be anticipated from implementing the institutional support projects under the Proposed Action. Established protocols and safety measures would continue to be observed. Refer to **Section 4.1.4** (Health and Safety) for measures to mitigate impacts to health and safety under the Proposed Action.

#### 3.4.2.2.2 Operational Missions and Activities

Operational proposals under the Proposed Action with a potential impact to human health and safety include DoD SM-3, Directed Energy, SODAR System, increased UAS operations at the North Wallops Island UAS airstrip, and orbital and suborbital launches under the Expanded Space Program that would include larger LVs, and nanoparticle fuel.

**DoD SM-3**

The Navy DoD SM-3 launcher would be placed on a dedicated pad located in the Navy Assets area on Wallops Island (see **Figure 2.5-5**). Navy SOPs currently in place to protect public health and safety would be observed. FACSFAC VACAPES is responsible for the scheduling of offshore warning areas and operating areas, and preparing NOTAMs and NOTMARs for broadcast by the FAA and U.S. Coast Guard, respectively. FACSFAC VACAPES would ensure the proper coordination is achieved. No significant impact to human health and safety would be anticipated. Additionally, NASA would activate restricted airspace R-6604 to prevent aircraft from entering the hazard area.

**Directed Energy**

Specific details needed to fully assess potential safety and health impacts associated with Directed Energy's HEL and HPM developmental experiments are currently unknown, the extent of potential health and safety impacts are unknown. While WFF would continue to adhere to procedures to protect the public and staff, including assigning appropriate personal protective equipment to workers, if it is determined that current procedures are not sufficient to ensure protection of human health and safety for the proposed operational mission, additional NEPA analysis may be required.

**SODAR System**

A SODAR system would be placed either on Wallops Island (refer to Section 2.5.2.2). SODAR systems emit sound waves at varying frequencies. It is anticipated that the system used by WFF would emit a low frequency that would not present a harmful affect to humans. However, the operating frequency of the SODAR system being considered is not currently known. As more details on this proposal become clear, further NEPA analysis may be required to analyze the potential impacts in the future.

**North Wallops Island UAS Airstrip Increased Operations**

The envelope for UAS operations at the North Wallops Island UAS airstrip would change under the Proposed Action. Annual operations would increase from 1,040 to 3,900 annual sortie operations. The increase would include night operations. The type and size of the UAS operating at the airstrip would be limited to the runway allowance. The Safety Office develops a flight safety plan and flight safety risk analysis that defines the operations, restrictions, and precautions to be observed during UAS operations at

Wallops Island prior to each UAS flight (NASA 2013). This analysis ensures that UAS risks during flight operations are identified and eliminated, or at least mitigated to the lowest practical level. Additionally, UAS flight operations are arranged so that if an incident were to occur, it would cause the least possible injury to personnel and damage to facilities or surrounding property. UAS flown from Wallops Island are not authorized to operate over Chincoteague Island, CNWR, or over populated areas if the risk is too high. Avoidance of population centers would continue to ensure the safety of the general public and protection of property. UAS equipped with the WFF mandated radar tracking system would conform to the radio frequency utilization and applicable procedures for UAS would continue to be observed. WFF would continue to adhere to safety procedures currently in place to protect the public and staff. The proposed changes to operations and the type of UAS operating from the North Wallops Island UAS airstrip would not result in adverse impacts to the health and safety of personnel or the public. Therefore, the potential risk from implementation of the Proposed Action would be negligible.

**Expanded Space Program**

Operational missions and activities involving the larger LVs under the Proposed Action would follow current procedures to ensure the safety of the public, NASA personnel, contractors, and civilians. In accordance with the WFF Range Safety Manual, mission specific safety plans would continue to be prepared by WFF's Ground and Flight Safety Groups to address all potential ground and flight hazards related to a given mission. Risks to human health and safety would be thoroughly addressed and managed by the Ground Safety Plan and Flight Safety Plan. Hazard arcs would be established to minimize the potential hazards associated with the operations of the launch range. The hazard arc around the launch of either the LFIC LV or SFHC LV would be approximately 3,050 m (10,000 ft). **Figure 3.4-2** provides the hazard arc for the launch of a these larger LVs from Launch Pad 0-C and Launch Pier 0-D along with the largest expected hazard arc (3,050 m [10,000 ft]) that would be established around launch Pads 0-A and 0-B. The additional area in the hazard arc around Launch Pad 0-C and Launch Pier 0-D is illustrated with harsh markings.

In accordance with existing procedures, NOTMARs and NOTAMs would continue to be published at least 24 hours prior to launch. USACE would activate the offshore danger zone, FAA Washington ARTCC would redirect flights away from R-6604, and launches would be coordinated with VACAPES FACSFAC. In addition, WFF would coordinate with law enforcement agencies and utilize its own surveillance assets (e.g. aircraft, ships, and cameras) to ensure that the general public remains clear of designated danger zones during launch operations. RTLS vertical landings would quickly follow second stage separation and all safety procedures would remain active through landing.

Horizontal launch and landing vehicles generally operate the same as standard aircraft. The proposed extension of Runway 04/22 at the Main Base for horizontal launch and landing vehicles may require the temporary closure of State Route 175 to reduce the risk to human health and safety.

### LFIC LV

Proposed LFIC LV launch activities would involve similar hazardous materials and waste to those currently encountered at WFF. Examples of hazardous materials used include fuel, liquid hypergolic propellants, cryogenic propellants, compressed gases, and solvents. Hazardous waste generated from operations could include liquid hazardous wastes such as those resulting from fuel and oxidizer transfer operations and rinseate, as well as solid hazardous wastes such as pads, wipes, and rags.

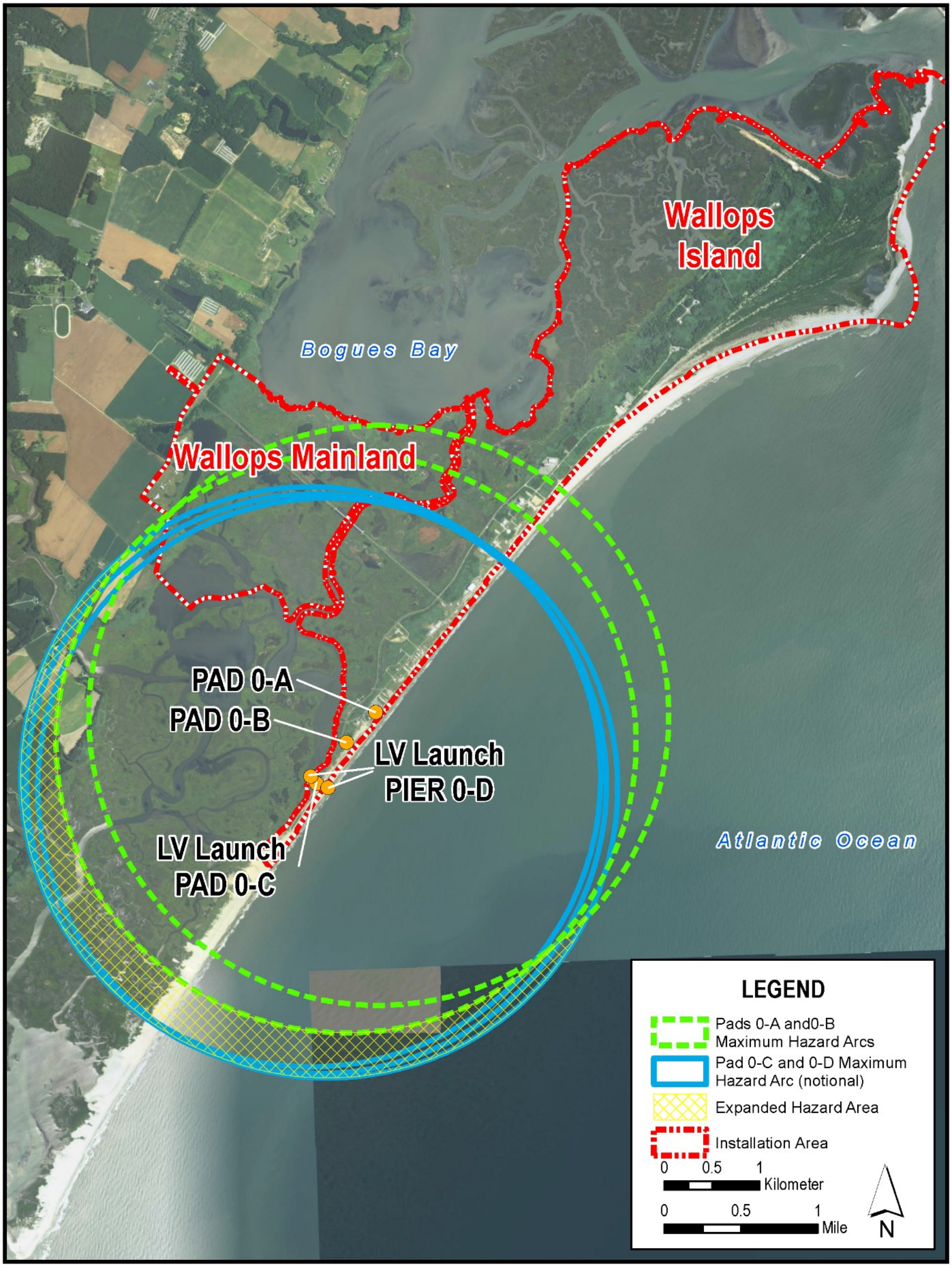


**Figure 3.4-2. Proposed Wallops Island Hazard Arcs**

Although an increase in the number of operational missions would correspond with an increase in the amount of hazardous materials used and hazardous waste generated, some materials such as fuel, propellant, and payloads would be consumed during the operational mission and activity. Current safety procedures for operations requiring the handling and management of hazardous materials and hazardous waste would continue to be employed.

WFF would continue to adhere to procedures to protect the public and staff, including assigning appropriate personal protective equipment to workers and implementing controls to minimize or eliminate the associated risks. Operations are arranged so that if an incident were to occur, it would cause the least possible injury to personnel and damage to facilities or surrounding property. A 3,050 m (10,000 ft) hazard arc would be established around the launch site for launch vehicles of this size. The public would not be allowed within the hazard arc; no populations would be located within the 3,050 m (10,000 ft) hazard arc.

**SFHC LV**

The solid propellant launch vehicle is not a new technology, but this particular launch vehicle has a larger motor than prior vehicles that have launched at the site. The SFHC LV first stage motor would contain polybutadiene acrylonitrile Class 1.3 solid propellant. The chemicals of concern in the combustion products produced by burning this solid propellant are HCl and $Al_2O_3$. The $Al_2O_3$ would be emitted as particulate matter. A study was conducted in August 2012 to determine the potential safety risks associated with a normal launch and a launch failure of a SFHC LV (ACTA 2012). The study concluded that a normal launch scenario would generate no adverse safety or health risks. However, during an early launch failure (within the first 20 seconds into flight), the vehicle's solid propellant "conflagration" and the payload's liquid propellant "deflagration" modes generated some cases where ground level concentrations were high enough to pose a toxic hazard to humans (and presumably other animals). The toxic hazards would be a result of exposure to the HCl and $Al_2O_3$ emissions at ground level.

Both HCl and $Al_2O_3$ are generated from the combustion of the SFHC LV propellant. At relatively low concentrations, HCl is an upper respiratory irritant and at higher concentrations may cause damage to the lower respiratory tract. Because HCl is very soluble in water, an aqueous solution of HCl is highly corrosive. Approximately 70% of the $Al_2O_3$ particulate matter would fall in the $PM_5$ size range. Particulate material up to size $PM_5$ is considered to be respirable, meaning the particles can lodge in the lungs. Chemically, $Al_2O_3$ is not classified as a health hazard, so the hazard of concern is based on its physical form (respirable particulate matter).

*Conflagration*. In a conflagration scenario, the rocket explodes shortly after takeoff and the buoyant gases rise hundreds to thousands of feet before mixing in the atmosphere and descending to ground level downwind of the explosion. Both gases such as HCl and suspended fine particulate matter in the form of $Al_2O_3$ are contained within the resultant plume and can result in simultaneous exposure of receptors to both HCl and $Al_2O_3$. The 2012 study evaluated a number of conflagration scenarios from an explosion at the launch pad to an explosion 20 seconds after launch. The worst-case scenario for conflagration occurs with an explosion at 4 seconds after launch (ACTA 2012).

The 2012 study determined that far field concentrations of HCl from a toxic plume and debris fallout as a result of the early launch failure would cause notable, but temporary, distress to any humans downwind of the launch pad (i.e., concentrations between 1.8 and 100 ppm). In this scenario, the peak HCl concentrations range from 31 to 315 ppm. The maximum downwind distance to peak concentration ranging from 40 m to 2.3 km (131 ft to 1.4 mi), depending on conditions such as whether the explosion occurred during the day or night, the season, and the predominant weather conditions at the time. For a daytime scenario, over 71% of all meteorological scenarios result in ground level HCl concentrations below 10 ppm, and for nighttime scenarios, 66% result in ground level HCl concentrations below 10 ppm. The HCl concentration continues to decrease with greater distance and predicted HCl levels drop to below 1 ppm between 6 and 10.6 km (3.7 to 6.6 mi) from the explosion area. For both the daytime and nighttime conflagration scenarios, transport of the exhaust plume oceanward, to the northeast, is favored. The least likely direction for the plume to be transported, for both scenarios, is westward, over populated areas (ACTA 2012).

The 2012 study determined there would be a high probability that $Al_2O_3$ concentrations would cause notable, but temporary, distress to any humans downwind of the launch pad (i.e., concentrations between 1.5 and 15 mg/m$^3$) for a distance ranging from 5 to 13 km (3 to 8 mi) downwind from the launch site. The $PM_5$ concentrations would range from 4.7 to 20.9 mg/m$^3$, depending on time of day, season and predominant weather conditions at the time of the rocket explosion. Transport of the $Al_2O_3$ to the northeast, east, and southeast are favored. This would tend to carry the particulate cloud in an offshore direction.

The nearest residence is located approximately 3.0 km (1.9 mi) west of the WFF Launch Range, Pad 0 Complex. Most of the distance between the Pad 0 Complex and populated areas to the north in Chincoteague consists of vacant land and open water. To the east and southeast of the Pad 0 Complex lies open water (ACTA 2012). In summary, concentrations of HCl and $Al_2O_3$ would not be expected to impact the general population since harmful concentrations are unlikely to extend as far as the populated areas of Chincoteague or would be over open ocean. The permanent danger zone in the waters of the Atlantic Ocean off Wallops Island and Chincoteague Inlet that protects the public from hazards associated with rocket launch operations would be activated prior to a launch event (including NOTMARs and NOTAMs and activation of R-6604) and would remain in effect until the designated area was clear of any hazards before reopening for public use.

*Deflagration.* Actual early flight launch failures have demonstrated that payloads may survive the breakup of the first rocket stage during early flight failure. The resulting rupture of payload propellant tanks would result in a small liquid propellant fireball (deflagration) from the release of hypergolic fuel and oxidizer (ACTA 2012). About 20 to 25% of the hypergol mass would react and the remainder would be subject to thermal decomposition or vaporization reactions. While complete hypergol combustion produces benign combustion products, it is the vaporized (unreacted) portion of the material that presents a toxic hazard. Typically, the vaporized payload fuel would consist of $NO_2$ and monomethylhydrazine (MMH). The 2012 study determined that for a deflagration scenario, there would be a high probability that $NO_2$ and MMH concentrations would cause notable, but temporary, distress to any humans downwind of the launch pad (i.e., concentrations between 0.5 and 20 ppm, and up to 1.8 ppm, respectively) for up to a maximum of 2 km (1.3 mi) and at an average distance of approximately 1.2 km (0.8 mi). Transport of the $NO_2$ and MMH plume to the north and northeast is favored for the daytime deflagration scenario and the northeast for the nighttime scenario (ACTA 2012).

*Payload Spill*. Ground impact may rupture the propellant tanks. If combustion of the fuel and oxidizer does not occur, the liquid propellant would spill onto the ground, producing an evaporating pool. The evaporation model used in the 2012 study recognized the oxidizer, nitrogen pentoxide, as a unique case and converted the evaporated gas to $NO_2$ rather than $N_2O_4$ vapor. Under an evaporation pool scenario, a

5 ppm peak $NO_2$ concentration plume could persist up to a maximum of 2.4 km (1.5 mi) and at an average distance of approximately 1.1 km (0.7 mi). A 5 ppm peak MMH concentration plume could persist up to a maximum of 0.3 km (0.2 mi) and at an average distance of approximately 0.1 km (0.1 mi). The daytime payload pool evaporation scenario favors transport of the exhaust plume to the north. The nighttime scenario favors transport of the exhaust plume toward a wide range from the northeast, clockwise to the south. This is a reflection of prevailing nighttime wind directions near the ground surface. (ACTA 2012).

To minimize exposure in the event of a SFHC LV launch failure, WFF would continue to adhere to procedures to protect the public and staff, including assigning appropriate personal protective equipment to workers and implementing controls to minimize or eliminate the associated risks such as enforcing hazard area clearance for the public, mariners, and airmen, and limiting launches to times when favorable meteorological conditions are present. A 3,050 m (10,000 ft) hazard arc would be established around the launch site for launch vehicles of this size. The public would not be allowed within the hazard arc; no populations would be located within the 3,050 m (10,000 ft) hazard arc.

**Vertical Launch and Landing Vehicles**

Under the Expanded Space Program, NASA is considering the mission of vertical launch and landing vehicles at WFF. Vertical launch and landing vehicles would take off like typical vertically launched rockets; however, shortly after second stage separation, the first stage motor would re-ignite to control descent to the landing pad (refer to Section 2.5.2.2). A noise study was conducted in 2017 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island. The results indicate the LFIC RTLS noise levels would exceed 115 dBA within a distance of approximately 0.6 km (0.4 mi) from the landing site (BRRC 2017). LFIC RTLS noise would be similar to the noise described above for a LFIC LV launch. However, a sonic boom could be generated during an RTLS supersonic descent that could present the potential for hearing damage (to humans) within 3.2 km (2 mi) of the landing site, where sonic boom overpressure levels may be greater than the approximately 0.2 kPa (4 psf) impulsive hearing conservation noise criteria. The intensity of a potential sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). To minimize exposure from sonic booms during an RTLS event, WFF would continue to adhere to procedures to protect the public and staff by implementing controls to minimize or eliminate the associated risks such as enforcing hazard area clearance for the public, mariners, and airmen, and limiting launches to times when favorable meteorological conditions are present. A 3,050 m (10,000 ft) hazard arc would be established around the launch site for launch vehicles of this size. The public would not be allowed within the hazard arc; no populations would be located within the 3,050 m (10,000 ft) hazard arc. Additionally, under the Proposed Action, no more than six LFIC LV/RTLS events would be authorized in a 12-month period. It is unlikely that any significant noise impacts would be generated from this type of operational mission as described under the Proposed Action.

Landing failure health impacts would be less than those described above as less fuel would remain in the motor prior to landing. Additional NEPA analysis may be needed to fully assess the potential health and safety risks from vertical landing or return to launch site rockets.

**Horizontal Launch and Landing Vehicles**

Under the Expanded Space Program, NASA is considering the mission of horizontal launch and landing vehicles at WFF. Horizontal launch vehicles would take off like a standard aircraft. However, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. Future NEPA analysis would address such conditions to prevent unacceptable adverse impacts from sonic booms to humans. It is unlikely that any significant impacts to human health and safety would be generated from this type of operational mission as described under the Proposed Action. As such, health and safety risks would be expected to be similar to those experienced by aircraft currently operating at the Main Base airfield.

**Commercial Human Spaceflight Missions**

Under the Expanded Space Program, NASA is considering the use of spaceflight missions that could consist of commercial space tourism and commercial crew transport to the ISS and LEO. A number of launch vehicles have the potential to utilize WFF both for manned horizontal launch and landings (Main Base) and vertical launch and landings (Wallops Island). All of these platforms would be launched with technologies within the established noise envelope or within the new envelope for the above noted LFIC LV and SFHC LV. Details for this emerging mission are limited; further NEPA documentation will be needed to fully assess the potential health and safety risks from this operational mission.

**Hybrid Fuels**

Nanoscale metal particles are highly reactive materials. While this is desirable for propellants, it can create safety hazards. Hybrid fuels AF-M315E and LMP-103S may be safer substitute for hydrazine; however, the potential impacts from these hybrid fuels are not currently known. As the technology develops and its use at WFF is considered, further NEPA analysis may be required to analyze the potential impacts from these fuel sources in the future.

In summary, no significant impact to human health and safety would be anticipated. Operational missions and activities would follow established protocols. Health and safety risks would occur from LFIC LV and SFHC LV launches; WFF would implement protective measures to ensure risks to personnel and the general public are minimized. The protective measures include activation of 3,050 m (10,000 ft) hazard arc; issuance of NOTMARs, NOTAMs, activation of R-6604, and FASFAC VACAPES scheduling procedures to prevent potential impacts to personal, commercial, and DoD ships and aircraft; and temporary road closures during LV launches and landings.

Refer to **Section 4.1.4** (Health and Safety) for measures to mitigate impacts to health and safety under the Proposed Action.

## 3.5 WATER RESOURCES

Water resources for this PEIS refer to surface and subsurface waters, wetlands, marine waters, floodplains, and the coastal zones that exist in and around WFF. The CWA of 1972 is the primary Federal law that protects the nation's waters, including lakes, rivers, aquifers, and coastal areas. The primary objective of the CWA is to restore and maintain the integrity of the nation's waters.

### 3.5.1 AFFECTED ENVIRONMENT

WFF is located in the Eastern Lower Delmarva and Chincoteague watersheds. The entire Main Base, portions of Wallops Mainland north of State Route 803 (Wallops Causeway Road), and the western portion of Wallops Island north of State Route 803 are part of the Chincoteague watershed drainage. The portions of Wallops Mainland and Wallops Island south of State Route 803 and along the eastern edge of the island are part of the Eastern Lower Delmarva watershed drainage (NASA 2016a).

No wild or scenic rivers are located on, or adjacent to, WFF; therefore, the Wild and Scenic Rivers Act (16 U.S.C. 1271-1287) does not apply and will not be discussed further. The Nationwide Rivers Inventory is a listing of more than 3,400 free-flowing river segments in the U.S. that are believed to possess one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance. No Nationwide Rivers Inventory-listed rivers are found in Accomack County (NPS 2014).

#### 3.5.1.1 Surface and Subsurface Waters

Numerous tidal inlets, marshes, bays, and creeks are found in and around all three installation areas of WFF (see **Figure 1.2-1**). A section of the Virginia Inside Passage, a federally maintained navigation channel, connects Wallops Island and Wallops Mainland. The Atlantic Ocean lies to the east of Wallops Island. Surface waters in the vicinity of WFF are primarily saline to brackish and are influenced by the tides and surface runoff.

The VDEQ has designated the surface waters in the vicinity of WFF as Class I – Open Ocean and Class II – Estuarine Waters. Surface waters in Virginia must meet the water quality criteria specified in 9 VAC 25-260-50. This set of criteria establishes limits for minimum dissolved oxygen concentrations, pH, and maximum temperature for the different surface water classifications in Virginia. In addition, Virginia surface waters must meet the surface water criteria specified in 9 VAC 26-260-140. This set of criteria provides numerical limits for various potentially toxic parameters. For the Class I and II waters in the vicinity of WFF, the saltwater numerical criterion is applied. Both sets of standards are used by the Commonwealth of Virginia to protect and maintain surface water quality.

Little Mosquito Creek primarily forms the northern border of the Main Base while an unnamed tributary of Little Mosquito Creek forms the western border. Additional unnamed tributaries to Little Mosquito Creek flow through areas in the western and northern portions of the Main Base. Little Mosquito Creek discharges directly to the Chincoteague Bay which flows into the Atlantic Ocean. The surface waters of Little Mosquito Creek were listed on Virginia's 303(d) Water Quality Assessment Report as an impaired water body in 2014. Little Cat Creek is also listed in the 2014 report and is located just east of Wallops Island.

The Main Base drains primarily into Little Mosquito Creek to the west and north, and borders Simoneaston Bay tidal marsh to the east. The southeastern portion of the Main Base includes stormwater swales and ditches that drain to Watts Bay. The surface water on the Mainland drains to and includes portions of Bogues Bay to the north, Cat Creek to the east, and Hog Creek to the south. Surface water on Wallops Island flows through numerous tidal tributaries that subsequently flow to the Atlantic Ocean. The northern boundary of Wallops Island is formed by Chincoteague Inlet and its western side is bounded by a series of water bodies that include (from north to south) Ballast Narrows, Bogues Bay, Cat Creek, and Hog Creek which separate the Island from the Mainland. No natural perennial streams or permanent open water ponds exist on the Island. However, intermittent water bodies may form after storms or in response to other physical forces such as tides.

#### 3.5.1.2 Stormwater Management

Stormwater discharges associated with industrial activities must be permitted under the National Pollutant Discharge Elimination System (NPDES) (33 U.S.C. 1342). The VDEQ is authorized to carry out NPDES permitting under the Virginia Pollutant Discharge Elimination System (VPDES) as administered under 9 VAC 25-151. WFF currently holds VPDES permit number VA0024457 for 11 industrial stormwater outfalls on the Main Base. There are three industrial stormwater outfalls and six non-industrial stormwater outfalls located on Wallops Island. Main Base Outfall 003 and Island outfalls 037, 038, and 039 are currently WFF's only stormwater outfalls with permit required sampling and chemical analysis under VPDES permit VA0024457. Sample results and observations are submitted to VDEQ on a quarterly and biannual basis. Currently, there are no permitted stormwater outfalls located on the Mainland; however, NASA maintains a SWPPP to ensure that its operations have minimal impact on stormwater quality (NASA 2016b). Since 1992, when NASA submitted its initial VPDES permit application, permit limits have been exceeded twice: once in 1995 related to 1970s pesticide usage and again in 2017 related to maintenance on a wastewater treatment plant meter resulting in copper exceedance. Immediate corrective actions were implemented and communicated to VDEQ. VDEQ has subsequently closed both exceedance issues. No discharge violations were reported during the most recent permit term (Borowicz 2017a).

The Virginia Stormwater Management Program (VSMP) regulations (9 VAC 25-870), administered by the VDEQ, require that construction and land development activities incorporate measures to protect aquatic resources from the effects of increased volume, frequency, and peak rate of stormwater runoff and from increased non-point source pollution carried by stormwater runoff. The VSMP also requires that land-disturbing activities of 0.4 ha (1 ac) or greater develop a SWPPP and acquire a permit (9 VAC 25-880) from the VDEQ prior to construction.

#### 3.5.1.3 Stormwater Drainage

The Main Base has both natural and man-made drainage patterns and stormwater drains to intercept and divert stormwater flow. On the northern portion of the Main Base, stormwater flows drain to Little Mosquito Creek and eventually flows reach the Atlantic Ocean. On the eastern and southeastern portions of the Main Base, the natural drainage pattern flows to Jenneys Gut and Simoneaston Bay, then into Cockle Creek, Shelly Bay, and Chincoteague Bay before reaching the Atlantic Ocean. On the western and southwestern portions of the Main Base, the natural drainage pattern is toward Wattsville Branch, then to Little Mosquito Creek, and on to the Atlantic Ocean. Stormwater drains on the Main Base intercept natural drainage ditches and divert the flow to numerous discharge locations. The Main Base's extensive storm drainage network discharges into Little Mosquito Creek to the north and west, and into Simoneaston Bay to the south and east (NASA 2008).

With the exception of several cross-culverts, storm drainage at Wallops Mainland is primarily toward Bogues Bay, Hog Creek, and Cat Creek, which all separate Wallops Island from Wallops Mainland. Wallops Island has storm drains that divert stormwater flow to several individual discharge locations. The northern portion of Wallops Island drains by overland flow to Bogues Bay and Chincoteague Inlet via Sloop Gut and Ballast Narrows. The central portion of the Island drains primarily to the west toward Bogues Bay. On the southern portion of Wallops Island, cross-culverts under the Island Road drain stormwater collected by culverts and ditches and flap gates have been installed west of Island Road to release stormwater to Bogues Bay via Hog Creek (NASA 2009).

#### 3.5.1.4 Groundwater

Groundwater is subsurface water that occupies the space between sand, clay, and rock formations. Groundwater, an essential resource in many areas, is used for water consumption, agricultural irrigation, and industrial applications. Groundwater properties are often described in terms of depth to aquifer, aquifer or well capacity, water quality, and surrounding geologic composition. The term aquifer is used to describe the geologic layers that store or transmit groundwater, to wells, springs, and other water sources. Aquifers are areas of mostly high porosity soil where water can be stored between soil particles and within soil pore spaces.

The VDEQ manages groundwater withdrawals in designated Groundwater Management Areas under the Groundwater Management Act of 1992. WFF lies within the Eastern Shore Groundwater Management Area, which includes Accomack and Northampton counties. Any person or entity wishing to withdraw 1,135,000 liters (300,000 gal) per month or more in a declared management area must obtain a permit from VDEQ (VDEQ 2014).

The VDEQ has identified four major aquifers on the Eastern Shore of Virginia: the Columbia aquifer and the three aquifers comprising the Yorktown-Eastover aquifer system. The water table aquifer, known as the Columbia aquifer, primarily consists of Pleistocene sediments of the Columbia Group (Richardson 1992). It is unconfined and typically overlain by wind-deposited beach sands, silts, and gravel. The aquifer occurs between depths of 2 to 18 m (5 to 60 ft) below the ground surface. The shallow water table ranges from depths of 0 to 9 m (0 to 30 ft) below the ground surface. Groundwater flow is generally east and north toward nearby creeks and the marsh area that separates Chincoteague Island from the Mainland. The Yorktown-Eastover aquifer system is a multi-aquifer unit consisting of late Miocene and Pliocene deposits and is composed of the sandy facies of the Yorktown and Eastover Formations (Meng and Harsh 1988). The top of the shallowest confined Yorktown-Eastover aquifer at WFF is found at depths of approximately 30m (100 ft) below the ground surface. It is separated from the overlying Columbia aquifer by a 6 to 9 m (20 to 30 ft) confining layer (aquitard) of clay and silt. The Yorktown-Eastover aquifers are classified as the upper, middle, and lower respectively. Correspondingly, each Yorktown-Eastover aquifer is overlain by the upper, middle, and lower Yorktown-Eastover aquitards. In the Wallops area, the lower Yorktown-Eastover aquifer contains the freshwater/saltwater interface, which occurs at a depth of approximately 90 m (300 ft) below MSL.

In general, the water table (Columbia) aquifer on the Delmarva Peninsula is recharged by surface waters and infiltration of precipitation. The confined aquifers are recharged by the same process, but from more distant areas located beyond the immediate vicinity of WFF (NASA 2005).

Flowing under the entire Delmarva Peninsula, groundwater from the Columbia and Yorktown-Eastover multi-aquifer system is the sole source of potable water for Accomack and Northampton counties. No major streams or other fresh surface water supplies are available as alternative sources of water for human consumption. The Columbia and Yorktown-Eastover multi-aquifer system is designated and protected by the EPA as a sole source aquifer (EPA 2007). A sole source aquifer is a drinking water supply located in an area with few or no alternative sources to the groundwater resource, and where if contamination occurred, using an alternative source would be extremely expensive. The designation protects an area's groundwater resource by requiring the EPA to review any proposed projects within the designated area that are receiving federal financial assistance, to ensure they do not endanger the water source. Additionally, the VDEQ and the Accomack-Northampton Planning District Committee established a groundwater management program for the entire Eastern Shore that included the development of a Groundwater Committee in 1990 to ensure that an optimal balance exists between groundwater withdrawals and recharge rates. This balance helps to minimize the problems of water quality due to saltwater intrusion, aquifer de-watering, and well interference in the general area (NASA 2008).

WFF receives all of its potable water from seven groundwater supply wells; five wells are located within and serve the Main Base while two wells are located within the Mainland and serve both the Mainland and Wallops Island. Seven supply wells are operated, under easement, by the Town of Chincoteague. Four of the Town of Chincoteague supply wells are between 45 and 80 m (150 and 270 ft) deep and are constructed to withdraw water from one of the Yorktown aquifers. Three of the wells operated by the Town of Chincoteague (located near the eastern boundary of the Main Base) are 18 m (60 ft) or less in depth and withdraw water from the Columbia aquifer (NASA 2008). Although NASA as a Federal agency is not subject to permitting under the Virginia Groundwater Management Act, WFF voluntarily complies with historic groundwater withdrawal permits issued by VDEQ.

The chemical laboratory at WFF performs analytical sampling and testing of the groundwater well systems in accordance with Federal and state requirements and submits the results to the VDEQ Groundwater Division for review.

Past contamination at three sites on the Main Base has affected groundwater quality in the Columbia aquifer. Releases at the: Former Fire Training Area (FFTA) affected approximately 0.5 ha (1.25 ac) with benzene, 3- and 4-methylphenol, naphthalene, arsenic, and manganese; Waste Oil Dump affected approximately 0.1 ha (0.25 ac) with arsenic; and the Old Aviation Fuel Tank Farm affected less than 0.2 ha (0.5 ac) with benzene and lead (NASA 2005). These chemical releases have resulted in contaminant plumes. NASA, in partnership with EPA, VDEQ, and USACE has successfully completed active remediation of each of these contaminant plumes and is currently performing long-term monitoring at each area.

Perfluorooctane sulfonate/perfluorooctanoic acid (PFOS/PFOA), chemicals associated with firefighting foams, have been detected in the Columbia aquifer on the Main Base, including the FFTA. NASA has developed a work plan to conduct a facility-wide investigation to better understand the extent of the plume. Water quality in the underlying Yorktown aquifer has not been affected by contamination due to the presence of an aquitard, the geologic layer that prevents groundwater movement from the Columbia aquifer downward into the Yorktown aquifer.

The water supply wells located at the Main Base have not been affected by the contaminant plumes. All of the supply wells are located in the Yorktown aquifer, which is isolated from the overlying Columbia aquifer. The Town of Chincoteague wells located in the Columbia aquifer have been affected by chemicals related to firefighting and fire training activities; these shallow water wells are no longer used for potable water. NASA regularly samples the water supply wells and area groundwater to ensure that the contaminant plumes are not expanding and that there is no adverse effect on the drinking water supply. NASA is working with Federal and state regulatory agencies to monitor the plumes and to restore groundwater to natural conditions.

The Town of Chincoteague seeks to establish their own water supply source, and as such, the town purchased a 32-acre plot of land in Accomack County (2018). The town is currently awaiting the necessary permits to begin drilling test wells.

#### 3.5.1.5 Wetlands

In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands are transitional areas between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin et al. 1979). Freshwater, brackish and tidal wetland functions and values include: 1) surface water detention, 2) stream flow maintenance, 3) nutrient transformation, 4) sediment and other particulate retention, 5) coastal storm surge detention, 6) shoreline stabilization, 7) providing fish and shellfish habitat, 8) providing waterfowl and water bird habitat, 9) providing other wildlife habitat, and 10) conservation of biodiversity (Tiner 2005).

The most important of the brackish and tidal wetland functions and values (Perry and Atkinson 2009) are: 1) primary production and detritus availability, 2) wildlife and waterfowl habitat, 3) shoreline erosion buffering, and 4) water quality control. Primary productivity in tidal marshes can reach 4 metric tons per ha (9 tons per ac) per year, with an average range of 0.4-2.4 metric tons per ha (0.9-5.4 tons per ac) per year. This high level of primary productivity results in a high level of detritus production, which is the basis of the major food pathway for crabs, other shellfish, finfish, and waterfowl.

In addition to providing food resources, tidal marshes provide spawning and nursery habitat for a variety of wildlife. It has been estimated that 95% of Virginia's annual harvest of fish (commercial and sport) from tidal waters is dependent to some degree on wetlands (Wass and Wright 1969). Some of the important wetland-dependent fisheries in the Chesapeake Bay Region include blue crabs, oysters, clams, striped bass, spot, croaker, and menhaden (Perry and Atkinson 2009).

The Mid-Atlantic coastal region wetlands, along the Atlantic Flyway, is home to approximately 1 million waterfowl each winter. The ducks and geese benefit both directly and indirectly from the productivity and habitat provided by the Region's marshes. Marsh-nesting birds include Virginia and clapper rails, mallard and black ducks, willet, marsh wren, seaside sparrow, red-winged blackbird, boat-tailed grackle, and northern harrier (Watts 1992). The Chesapeake Bay Region marshes are also used by herons and egrets year round and by transient shorebirds such as yellowlegs, semi-palmated sandpiper, least sandpiper, dowitcher, dunlin, and sharp-tailed sparrow (Watts 1992). Muskrats are the most visible marsh dependent mammals.

Tidal marshes dissipate incoming wave energy, thereby providing a buffer against shoreline erosion. Knutson et al. (1982), studying salt marsh cordgrass marshes in the Chesapeake Bay, found that over 50% of wave energy was dissipated within the first 2.5 m (8.2 ft) of the marshes. Rosen (1980) found that marsh margins form the least erodible shorelines (Perry and Atkinson 2009).

Marshes in the Chesapeake Bay Region play a very important role in maintaining and improving water quality by trapping sediment from upland runoff and from the water column, thereby reducing siltation of shellfish beds, submerged aquatic vegetation beds, and navigation channels. Pollutants may also be filtered from runoff and the water column and taken up by marsh plants (Perry and Atkinson 2009).

EO 11990, *Protection of Wetlands*, directs Federal agencies to minimize the destruction, loss, and degradation of wetlands and to preserve and enhance the natural and beneficial values of wetland communities. At WFF, projects that impact wetlands may require permits from the USACE, the Virginia Marine Resources Commission (VMRC), the Accomack County Wetlands Board, or VDEQ. A Joint Permit Application (JPA) is filed with VMRC. The agency plays a central role as an information clearinghouse for Federal, state, and local levels of review where JPAs submitted to VMRC receive independent yet concurrent reviews by local wetland boards, VMRC, VDEQ, and USACE. NASA wetland regulations (14 CFR Subpart 1216.2) outline the required procedures for evaluating actions of NASA that impact wetlands.

Primarily tidal and, to a lesser degree, non-tidal wetlands at WFF have been identified by the National Wetlands Inventory (NWI), a nation-wide wetlands mapping effort conducted by the USFWS. Wetlands at WFF have been remotely delineated using aerial imagery (USFWS 2012). Additional site-specific delineations (Timmons Group 2009a, 2009b, 2009c) have been conducted in support of development activities. Confirmed jurisdictional determinations have been obtained from the USACE for portions of the wetlands at WFF. The remaining delineations are for planning purposes only and must be verified by the USACE prior to conducting activities with the potential to impact wetlands. All of the wetland delineations at WFF prior to 2009 were conducted in accordance with the USACE *Wetlands Delineation Manual* (USACE 1987) and after 2009 using the new *Regional Supplement to the Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region* (USACE 2010a).

Wetland classifications were assigned using the USFWS system: *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979). Under the USFWS system, wetlands are divided into five major systems: (1) marine, (2) estuarine, (3) riverine, (4) lacustrine, and (5) palustrine. A total of 1,550 ha (3,940 ac) of wetlands have been delineated at WFF: 1.6% are classified as marine, 83.6% as estuarine, and 14.8% as palustrine. No lacustrine or riverine wetlands have been identified.

Wetlands are also classified by the types of dominant vegetation that grow within them. Typical wetland vegetation types encountered on WFF are:

- emergent—dominated by erect rooted herbaceous, usually perennial plants,
- scrub-shrub—dominated by woody plants less than 6 m (20 ft) in height, and
- forested—dominated by woody plants greater than 6 m (20 ft) in height.

**Figure 3.5-1, Figure 3.5-2, and Figure 3.5-3** illustrate the general locations of wetlands at the Main Base, the Mainland, and Wallops Island.

The Main Base has tidal and non-tidal wetlands along its perimeter in association with Little Mosquito Creek, Jenneys Gut, Simoneaston Bay, and Simoneaston Creek. The tidal wetlands are divided into high marsh, low marsh, and open water areas. The low marsh areas are located between the mean low and mean high tide elevations and are typically flooded twice daily. Low marsh habitat on the Main Base is predominantly covered by salt marsh cordgrass. High marsh habitat is located just above the mean high tide elevation and is predominantly salt meadow hay, salt grass, common reed, and groundsel tree (Timmons Group 2009a). Much of the non-tidal wetlands in and around the Main Base are highly disturbed and dominated by species of low ecological value. The non-tidal wetlands areas are predominantly common reed at the lower elevations; thickets of common greenbriar, poison ivy, blackberry, and wax myrtle found in higher elevation emergent/scrub-shrub systems; and loblolly pine, red maple and sweetgum occurring at the higher forested areas (Timmons Group 2009a).

WFF is in the process of developing a wetland management plan. The plan would include avoidance measures and appropriate wetland mitigations to ensure no net loss of wetlands and would consider the potential impacts to protected species. As the plan progresses, WFF would consult with EPA, USACE, and USFWS.

#### 3.5.1.6 Marine Waters

For the purposes of this PEIS, marine waters are those of the Atlantic Ocean in the vicinity of WFF. There are distinct differences in stratification of the Mid-Atlantic Ocean between summer and winter. In the winter, the water column is vertically well mixed, with water temperatures averaging 14° Celsius (°C) (57° Fahrenheit [°F]) at the surface and 11° C (52°F) at depths greater than 200 m (660 ft). In summer (August), the water column is vertically stratified with 25°C (77°F) water near the surface and 10° C (50°F) water at depths greater than 200 m (660 ft) (Paquette et al. 1995). Among the large rivers and estuaries that discharge fresh water into the Mid-Atlantic Ocean are the Hudson River, Delaware Bay, and Chesapeake Bay. The salinity over the continental shelf ranges from 28 to 36 parts per thousand (ppt), with lower salinities found near the coast and highest salinities found near the continental shelf break. Salinities are highest in continental shelf waters during winter and lowest in the spring. Variability in this area is due to the intrusion of saltier (greater than 35 ppt) water from the continental slope waters and freshwater input from coastal sources (U.S. Navy 2009).

Water flows from the Chesapeake and Delaware Bays exit out of these estuaries in the form of fresh or brackish plume water. This less dense (due to lower salinity) water flow turns south in response to the Coriolis force (Earth's rotation), resulting in southward flowing, coastally trapped currents. An increase in river flow and ebbing tides force more water out of the respective bays; predominant southwesterly winds cause a seaward expansion of the plume over the continental shelf, creating a well-stratified, two-layer system. The warm surface waters are constantly replaced by deeper, more saline, nutrient-rich water (U.S. Navy 2009).

#### 3.5.1.7 Floodplains

Floodplains are lowland areas located adjacent to bodies of water in which the ordinary high water level fluctuates on an annual basis. Along streams and creeks the ordinary high water level may fluctuate as a result of a precipitation event. Tidally influenced waters may fluctuate due to spring tides or as a result of a large storm event (e.g., storm surge). When one of these events is large enough, it causes the water level to exceed the ordinary high water mark and enter the adjacent floodplain. As a result, functioning floodplains provide critical protection for surrounding communities because of their ability to dissipate energy and water from flooding.

Any fill to floodplains results in the decrease of the effectiveness of a floodplain to mitigate flooding. Floodplains are often discussed in terms of the 100-year and 500-year floodplain zones. The 100-year flood is a flood having a 1% chance of occurring in any given year. The 100-year flood is also known as the base flood. The 500-year floodplain designates the area inundated during a storm having a 0.2% chance of occurring in any given year. Floodplains are valued for their natural flood and erosion control, enhancement of biological productivity, and socioeconomic benefits and functions.

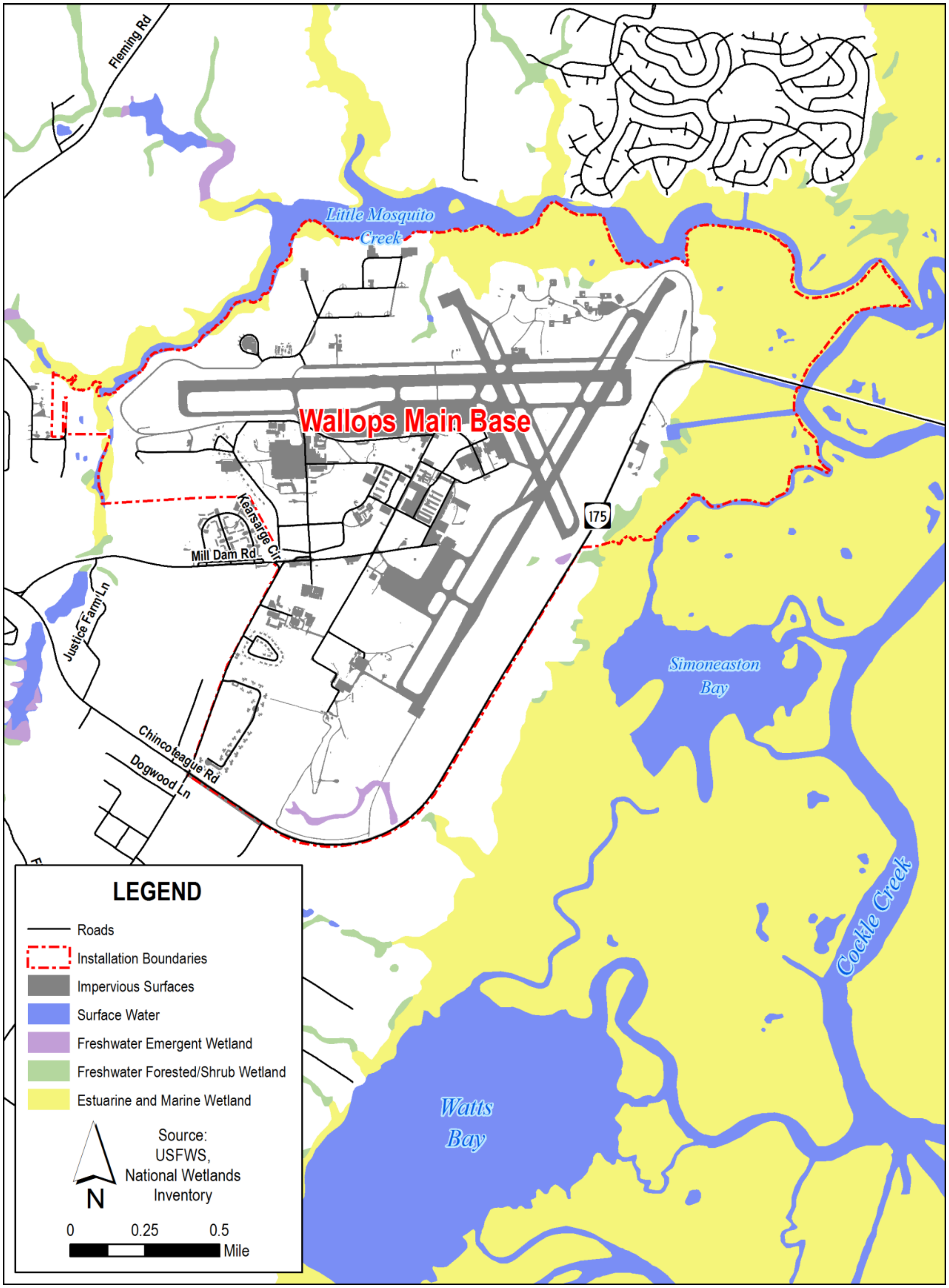


**Figure 3.5-1. Location of Wetlands at the Main Base**


**Figure 3.5-2. Location of Wetlands at the Mainland and South Wallops Island**


**Figure 3.5-3. Location of Wetlands at North Wallops Island**

EO 11988, *Floodplain Management*, requires Federal agencies to take action to minimize occupancy and modification of the floodplain. Specifically, EO 11988 prohibits Federal agencies from funding construction in the 100-year floodplain unless there are no practicable alternatives. FHWA floodplain regulations established standards for the cost-effective design of bridges and highways in floodplains consistent with EO 11988 and the National Flood Insurance Program standards (23 CFR 650 A – *Location and Hydraulic Design of Encroachments on Flood Plains*). NASA floodplain regulations (14 CFR 1216.2) outline the required procedures for evaluating actions of NASA that impact the floodplain. Flood Insurance Rate Maps (FIRMs) are produced by the Federal Emergency Management Agency (FEMA). **Figure 3.5-4** and **Figure 3.5-5** illustrate the 100- and 500-year flood zones at the Main Base, the Mainland, and Wallops Island (FEMA 2015). Zone A is defined as "areas subject to inundation by the 1-percent-annual-chance flood event. Because detailed hydraulic analyses have not been performed, no base flood elevations or flood depths are shown." Zone V is defined as "Areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves."

FIRM Community Panel 5100C (2015 data) shows that the 100-year and 500-year floodplains are along portions of the perimeter of the Main Base to the northwest, north and northeast and include lower elevation areas primarily defined by topographic ravines of Zone A. Large areas of tidal marsh located to the east are mapped as Zone V along Little Mosquito Creek and Jenneys Gut. The same FIRM Community Panels indicate the 100-year and 500-year floodplains include much of the area identified as Wallops Mainland; however, these areas are primarily tidal marsh along Hog Creek, Oyster Bay and Bogues Bay. The developed portions of Wallops Mainland are mapped as no flood zone. Wallops Island is located entirely within the 100-year floodplain Zones A and V. Because detailed hydraulic analyses have not been performed, no base flood elevations or flood depths are shown. The Zone A areas are primarily the more developed higher locations on the Island and the Zone V areas include the beaches and tidal marsh areas.

#### 3.5.1.8 Coastal Zone

Barrier islands such as Metopkin, Assawoman, Wallops, and Assateague Islands are elongated, narrow landforms that consist largely of unconsolidated and shifting sand and lie parallel to the shoreline between the open ocean and the mainland. These islands provide protection to the mainland, prime recreation resources, important natural habitats to unique species, and valuable economic opportunities to the county. The northern end of Wallops Island also contains coastal primary sand dunes that serve as protective barriers from the effects of flooding and erosion caused by coastal storms. The Coastal Barrier Resources Act (Public Law 97-348, 16 U.S.C. 3501-3510), enacted in 1982, designated various undeveloped coastal barrier islands as units in the Coastal Barrier Resources System. Designated units are ineligible for direct or indirect federal financial assistance programs that could support development on coastal barrier islands; exceptions are made for certain emergency and research activities.

Wallops Island is not included in the Coastal Barrier Resources System; therefore, the Coastal Barrier Resources Act does not apply.

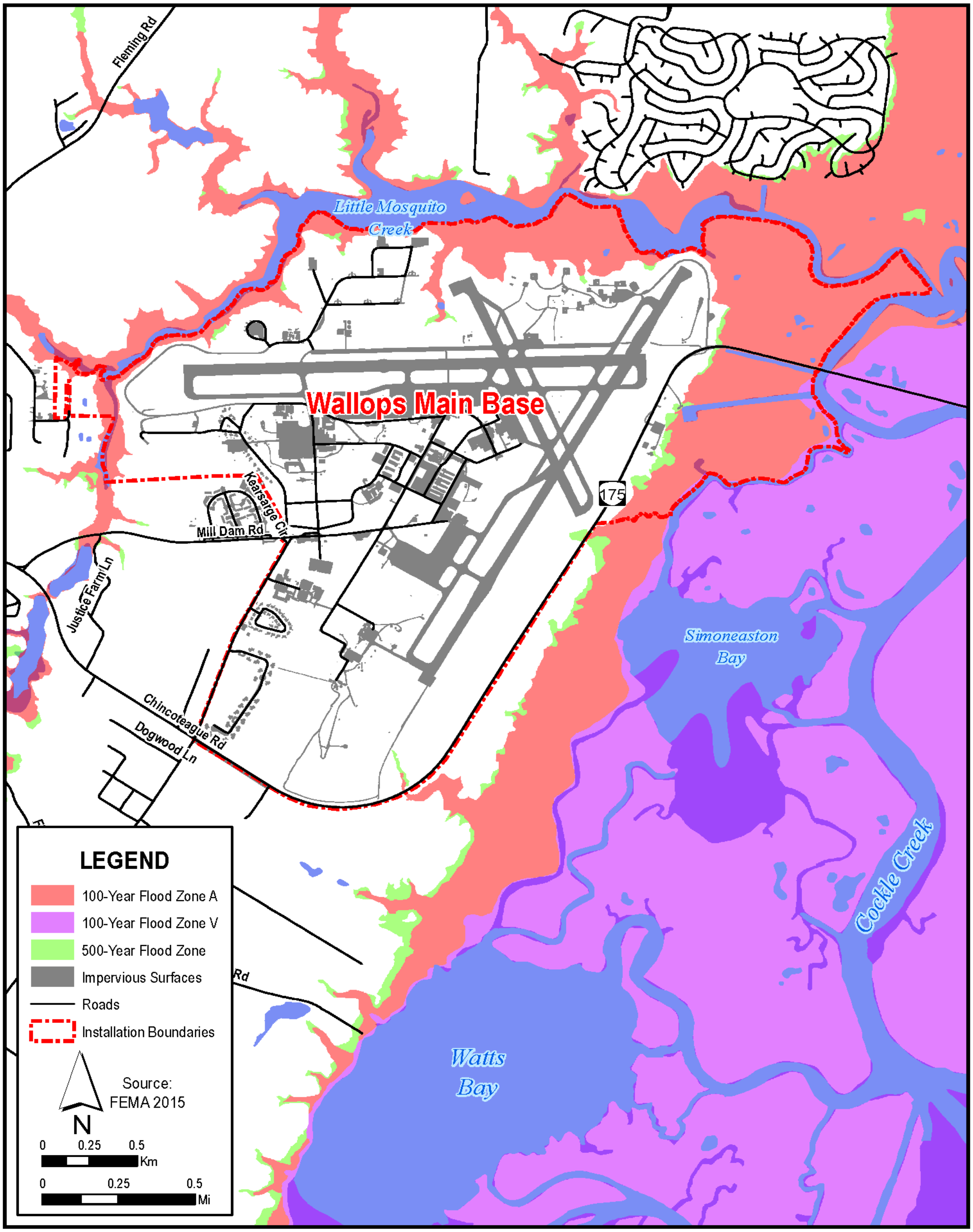


**Figure 3.5-4. Flood Zones at the Main Base**

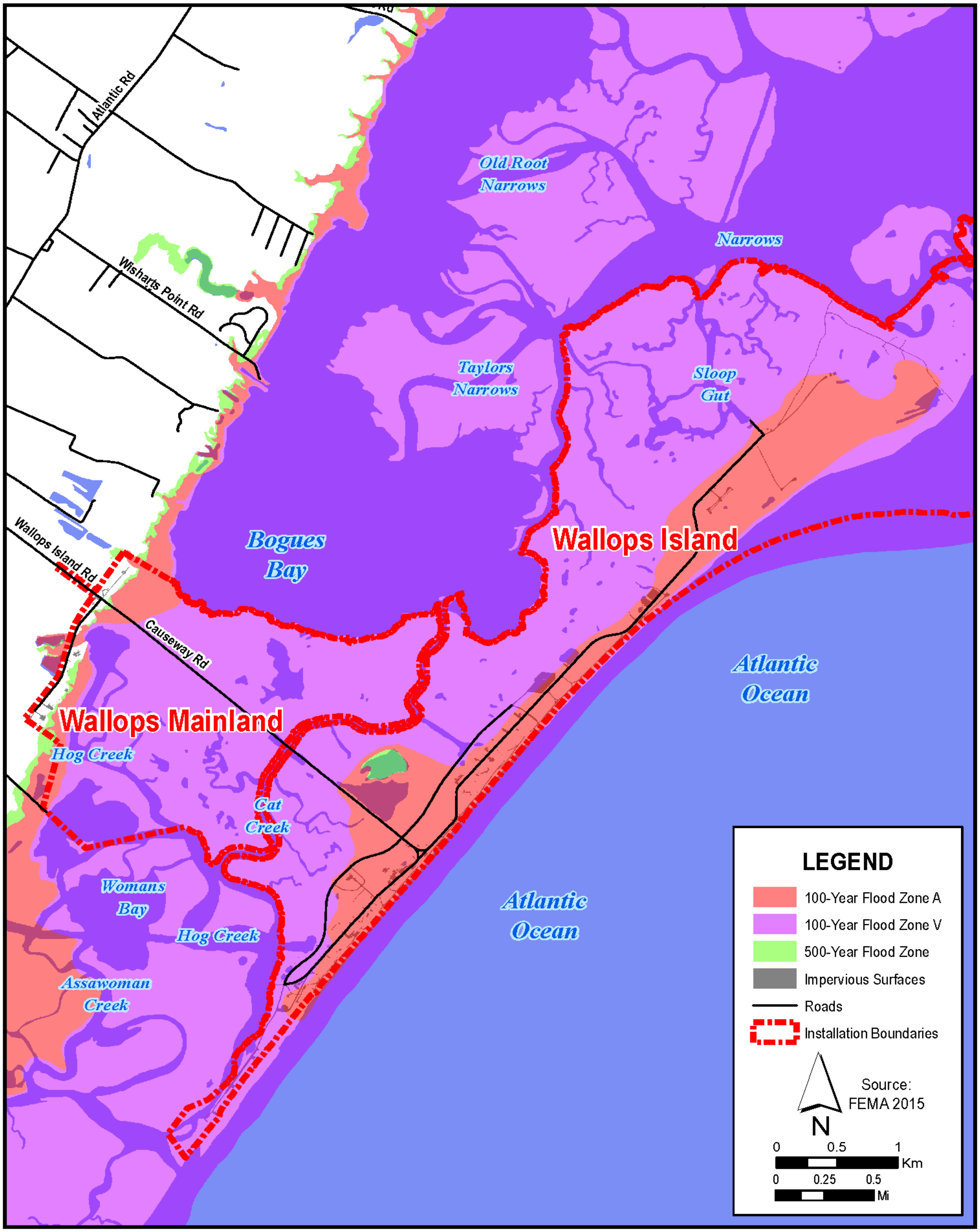


**Figure 3.5-5. Flood Zones at the Mainland and Wallops Island**

VDEQ is the lead agency for the Virginia CZM Program, which is authorized by NOAA to administer the CZM Act of 1972. Although Federal lands are excluded from Virginia's CZM Program , any activity on Federal land that has reasonably foreseeable coastal effects must be consistent with the enforceable policies of the CZM Program (VDEQ 2017). Enforceable policies of the CZM Program that must be considered when making an FCD include the following:

- **Fisheries Management.** Administered by VMRC, this program stresses the conservation and enhancement of shellfish and finfish resources and the promotion of commercial and recreational fisheries.
- **Subaqueous Lands Management**. Administered by VMRC, this program establishes conditions for granting permits to use state-owned bottomlands.
- **Wetlands Management**. Administered by VMRC and VDEQ, the wetlands management program preserves and protects tidal wetlands.
- **Dunes Management**. Administered by VMRC, the purpose of this program is to prevent the destruction or alteration of primary dunes.
- **Non-Point Source Pollution Control**. Administered by the VDCR, the Virginia Erosion and Sediment Control Law is intended to minimize non-point source pollution entering Virginia's waterways.
- **Point Source Pollution Control**. Administered by VDEQ, the VPDES permit program regulates point source discharges to Virginia's waterways.
- **Shoreline Sanitation**. Administered by the Virginia Department of Health, this program regulates the installation of septic tanks to protect public health and the environment.
- **Air Pollution Control**. Administered by VDEQ, this program implements the Federal CAA through a legally enforceable State Implementation Plan.
- **Coastal Lands Management**. Administered by the Chesapeake Bay Local Assistance Department, the Chesapeake Bay Preservation Act guides land development in coastal areas to protect the Chesapeake Bay and its tributaries.

Because many activities at WFF may affect the surrounding coastal areas, these actions are subject to the FCD requirement.

In February 2009, Accomack County expanded its Chesapeake Bay Preservation zoning ordinance to include those lands in the County that drain easterly to the Atlantic Ocean forming the Chesapeake/Atlantic Preservation Area. Any lands designated by the Accomack County board of supervisors pursuant to Part III of the Chesapeake Bay Preservation Area Designation and Management Regulations, VAC 10-20 et seq. and Code of Virginia, § 10.1-2107 are subject to the provisions of the expanded ordinance.

#### 3.5.1.9 Sea-Level Rise

A number of factors affect sea level, including changes in sea temperature, salinity, and total water volume and mass. Sea level rises with warming sea temperatures and falls with cooling. Changes in the total volume and mass of ocean water also result from the melting or accumulation of continental ice sheets and non-polar glaciers and changes in the amount of water stored in lakes, rivers, and ground water

(EPA 2012a). Rising sea levels may cause greater damages from hurricanes due to higher storm surge (EPA 2012b). A June 2012 report from the U.S. Geological Survey (USGS) states that since about 1990, sea-level rise in the 965 km (600 mi) stretch of Coastal Zone from Cape Hatteras, North Carolina to north of Boston, Massachusetts, has increased 2 to 3 mm (0.08 to 0.12 in) per year whereas the global increase over the same period was 0.6 to 1.0 mm (0.02 to 0.04 in) per year (Sallenger et al. 2012; USGS 2012). This stretch of the Atlantic coast has been deemed a "hotspot" since the rate of sea-level rise is increasing three-to-four times faster than globally. The increase in sea-level rise is consistent with slowing of parts of the Atlantic Ocean circulation, suggesting that local sea-level rise is not just an effect of melting glaciers and ice caps, but also regional changes in water temperature, salinity, and density (Sallenger et al. 2012; USGS 2012).

Coastal environments are highly dynamic and particularly vulnerable to climate change. The impacts at WFF would likely include rising sea levels, more frequent flooding, and increasingly intense, unevenly distributed rain events. The combination of rising sea level and severe storms could produce detrimental impacts on WFF and the surrounding high profile infrastructure, assets, human capital, and natural resources. Wallops Island has experienced shoreline changes throughout the six decades that NASA has occupied the site. Currently, the sandy portion of Wallops Island has an elevation of about 2.1 m (6.9 ft) above MSL. The highest elevation on Wallops Island is approximately 4.6 m (15 ft) above MSL. Most of the island is less than 3.0 m (10 ft) above MSL (NASA 2005). Along with sea-level rise, storm surges from hurricanes and nor'easters may increasingly make natural and built systems vulnerable to disruption or damage.

NOAA collects MSL trend data for coastal states. For the purposes of this PEIS, data collected from two stations nearest to WFF were used; this includes Kiptopeke, Virginia, (approximately 109 km [68 mi] from WFF) and Ocean City, Maryland (approximately 79 km [49 mi] from WFF). As shown in **Figure 3.5-6**, data collected from long-term tidal gauges in Kiptopeke indicate that between 1951 and 2006, the average relative sea-level rise for this location was 3.48 mm per year +/- 0.42 mm per year (0.137 in per year +/- 0.017 in per year) (NOAA 2012a). The 100-year projected local sea-level rise at Kiptopeke is 0.35 m (1.14 ft) (NOAA 2012a). Data collected from long-term tidal gauges in Ocean City indicate that between 1975 and 2006, the average relative sea-level rise for this location was 5.48 mm per year +/- 1.67 mm per year (0.216 in per year +/- 0.066 in per year) (NOAA 2012b). Cumulatively, data from Kiptopeke show that sea level has risen about 18 cm (7 in) during the past 60 years. Climate models project continued sea-level rise in the region. The 100-year projected local sea-level rise at Ocean City is 0.55 m (1.80 ft) (NOAA 2012b).

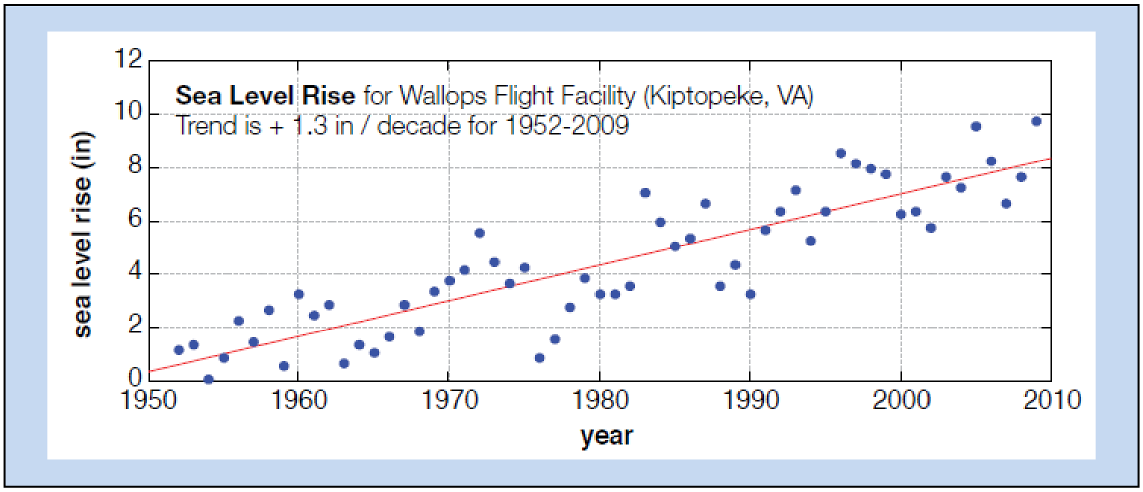


**Figure 3.5-6. Wallops Flight Facility Observed and Projected Sea-Level Rise**

Scientists from NASA's GISS used local data to refine global climate model (GCM) outputs, making the projections WFF-specific, as shown in **Figure 3.5-7** (NASA GISS 2013). This "downscaling" process provides a more precise projection for a specific location (in this case the WFF area), than modeling for an entire region, such as the East Coast. Using these models, scientists project rising average sea levels for the Wallops area.

**Figure 3.5-7** shows the combined observed (black line) and projected sea-level rise for two future sea-level rise scenarios. Local projections are joined to the observed historical data from Kiptopeke, Virginia. Dark blue shows the range of projections for the rapid ice-melt scenario while light blue shows the range of projections for the GCM-based sea-level rise approach. The three thick lines (green, red, and blue) within each sea-level rise scenario show the average for each emissions scenario across 7 GCMs. A ten-year filter has been applied to the observed data and modeled output.

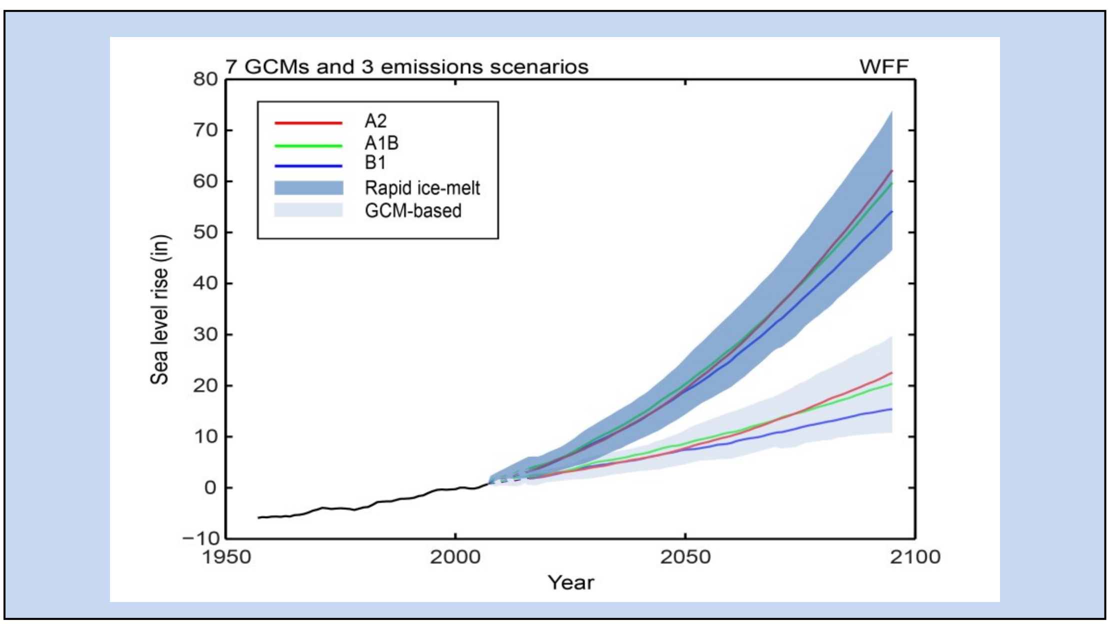


**Figure 3.5-7. Wallops Flight Facility-Specific Projected Sea-Level Rise Scenarios**

While little change is expected in average annual precipitation, heavy rainfall events may be more intense, leading to increased risks of flooding. Precipitation projections reflect a 30-year average centered on the specified decade; sea levels are averages for the specific decade (**Table 3.5-1**). Data for 1971-2000 from WFF provide a baseline for annual precipitation (102 cm [40 in]). Sea level data are for Gloucester Point and Kiptopeke, Virginia, and include the impacts of subsidence in the area. Precipitation projections are rounded to the nearest five percent, and sea-level rise to the nearest inch.

**Table 3.5-1. Projected Changes in Climate Variables**

| | 2020's | 2050's | 2080's |
|---|---|---|---|
| Average Annual Precipitation | 0 to +10% | 0 to +10% | 0 to +15% |
| Sea Level, cm (in) | +5 to +12<br>(+2 to +5) | +17 to +28<br>(+7 to +11) | +30 to +53<br>(+12 to +21) |
| Sea Level-Rapid Ice-Melt Scenario, cm (in) | +12 to +22<br>(+5 to +9) | +48 to +71<br>(+19 to +28) | +106 to +142<br>(+42 to +56) |

Sources: NOAA 2012b; NASA 2012.

During a recent storm damage reduction project design effort by USACE for Wallops Island, the USACE took historical MSL trend data from Lewes, Delaware; Solomons Island, Maryland; and Portsmouth, Virginia. These locations are near Wallops Island but in widely different compass directions. Using this data, the 50-year projected local sea-level rise was calculated to range from 0.17 to 0.69 m (0.56 to 2.25 ft). Since the early 1990s, part of Wallops Island has been protected with a stone rubble mound seawall. However, because the seawall structure was being undermined and little or no protective sand beach remained, in 2012 NASA completed an approximately 2.5 million $m^3$ (3.2 million $y^3$) beach replenishment program. As part of the beach renourishment planning process, the USACE used a 50-year projected sea-level rise of 0.58 m (1.91 ft) to offset effects of sea-level rise on Wallops Island (USACE 2010b).

After the initial sand placement in 2010, NASA began implementing an adaptive management and monitoring shoreline restoration program. The first renourishment was performed in 2014 to counteract damage caused by Hurricane Sandy. Approximately, 510,000 $m^3$ (667,000 $y^3$) of sand were harvested from the offshore shoal to renourish Wallops Island (NASA 2013). The beach profile in front of the present shoreline would be re-nourished with sand every three to seven years; to account for sea-level rise impacts to the shoreline at Wallops Island, additional sediment volume would be placed during each beach renourishment event (USACE 2010b). Modifications would be made as needed to ensure the viability of the long-term project meant to reduce the potential for damage to, or loss of, NASA, U.S. Navy, and MARS assets on Wallops Island from storm-induced wave action and sea-level rise impacts (NASA 2010).

### 3.5.2 Environmental Consequences

The ROI for water resources for this PEIS is defined as surface water, groundwater, wetlands, marine waters, and floodplains within or adjacent to WFF. Determination of significance of potential impacts to water resources would be those actions that would have large scale adverse impacts on hydrologic function of the proposed project area. Significance determination would depend on the nature of the water resource, its importance to the ecosystem, and the ability of the system to function if that resource were altered or removed completely.

New infrastructure and facilities to support mission requirements on Wallops Island would be sited within previously disturbed areas, to the extent practicable. To reduce potential environmental impacts, BMPs and avoidance and minimization measures, as described for resource areas in Chapter 3, Affected Environment and Environmental Consequences and in Chapter 4, Mitigation and Monitoring would be incorporated and implemented, to the maximum extent practicable under the Proposed Action. As required by the 404(b)(1) guidelines, only the LEDPA can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable.

The in-water projects (i.e., Causeway Bridge Replacement, barge route maintenance dredging, North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D) described under the Proposed Action are analyzed as programmatic actions in that they are in various stages of conceptual maturity with varying levels of detail for discussion. Information for these projects is provided in as much detail as is currently available. As project planning and design details become more developed, further NEPA analysis will occur, along with all relevant consultation and permitting, prior to construction.

### 3.5.2.1 No Action Alternative

#### 3.5.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS; therefore, there would be no additional impacts to water resources from institutional support projects under this alternative. Any substantial changes to the design of approved construction projects would require site-specific NEPA analysis.

#### 3.5.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope. All operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS; therefore, there would be no additional impacts to water resources from operational missions and activities under this alternative.

### 3.5.2.2 Proposed Action

#### 3.5.2.2.1 Institutional Support Projects

**Surface Water, Subsurface Waters, and Stormwater**

Water quality impacts can include stormwater runoff that degrades the quality of surface and subsurface waters. Since these topics are interrelated, they are combined for the purpose of this analysis.

**Construction, Demolition, and RBR Projects**

Construction and demolition associated with the institutional support projects listed in **Table 2.5-1** and **Table 2.5-2** to include the Commercial Space Terminal, extension of Runway 04/22, and construction of two DoD launch pads would involve clearing, grading, filling, and excavation. These actions would result in disturbance of the ground surface and would have the potential to cause soil erosion with the possibility for transport of sediment or pollutants into waterways via stormwater. This may smother fish eggs, aquatic insects, and oxygen producing plants resulting in decreased oxygen levels. To minimize potential short-term impacts prior to construction, NASA would, if necessary, obtain VSMP construction site stormwater permits, develop a site-specific SWPPP, and implement site-specific BMPs. The SWPPP would identify all stormwater discharges at the site, actual and potential sources of stormwater contamination, and would require the implementation of BMPs to reduce the impact of stormwater runoff on nearby receiving waters. BMPs could include using vegetative and structural protective covers (e.g., permanent seeding, groundcover), sediment barriers (e.g., straw bales, silt fencing, brush), constructing water conveyances (e.g., slope drains, check dam inlet, and outlet protection), and quickly repairing bare and slightly eroded areas.

Contractors would comply with NPR 8820.2D, *Design and Construction of Facilities*, NPR 8500.1C, *NASA Environmental Management*, and NPR 8570.1A, *NASA Energy Management Program*. In addition, contractors would comply with Section 438 of the Energy Independence and Security Act of 2007. This Act requires that any development or redevelopment project involving a Federal facility with a footprint exceeding 1,525 $m^2$ (5,000 $ft^2$) shall use site planning, design, construction, and maintenance strategies to maintain or restore the predevelopment hydrology of the property with regard to temperature, rate, volume, and duration of flow. Compliance with this requirement can be met through the implementation of Low Impact Development (LID) and green infrastructure technologies. LID and green infrastructure techniques would maintain or restore natural hydrologic functions of a site and achieve natural resource protection. Examples include, but are not limited to, minimizing total site impervious areas, directing building drainage to vegetative buffers, bioswales, biofiltration, using permeable pavements where practical, and breaking up flow directions from large paved surfaces.

***Causeway Bridge Replacement***

Surface construction for the replacement Causeway Bridge would include grading, clearing, filling, and excavation and would have the potential to cause soil erosion with the potential transport of sediment into waterways via stormwater. To mitigate potential short-term impacts, prior to construction, NASA would obtain a VSMP construction site stormwater permit, develop a site-specific SWPPP, and implement site-specific BMPs as described previously for institutional support projects. The site-specific BMPs could include silt fencing, soil stabilization blankets, matting around areas of soil disturbance. Riprap may be used to protect abutments from scour and from slope stabilization. Bare soils would be vegetated after construction to reduce erosion and stormwater runoff velocities. New bridge and new ramps would have increased surface area due to a wider bridge surface and wider on-ramps. The contaminants in the stormwater runoff from the new bridge would be similar to the existing contaminants currently found in the bridge runoff. NASA would comply with all state and federal requirements for impervious surface runoff associated with the new bridge including the use of a drainage system that would consist of collectors, oil/water separator, and other filters as required to capture the runoff from the bridge surface and avoidance of direct discharge into the water body below and associated wetland areas surrounding the replacement bridge. Any water quality treatment requirements for the discharge of stormwater runoff from the bridge would be met by NASA.

In addition, turbidity control measures, such as turbidity curtains (also referred to as sediment curtains) would be implemented to prevent suspended sediments from exceeding water quality standards, and frequent monitoring during construction to ensure the effectiveness of suspended sediment containment would be performed. Turbidity curtains are designed to contain or deflect suspended sediments or turbidity in the water column and, when properly deployed and maintained, can effectively control the flow of turbid water. Sediment containment within a limited area is intended to provide residence time to allow soil particles to settle out of suspension and reduce flow to other areas where negative impacts could occur. Suspended solids can also conceivably be diverted from areas where environmental damages could occur from the settlement of these suspended particles. Turbidity curtains may also be used to protect specific areas (e.g., sensitive habitats, water intakes, or recreational areas) from suspended sediment and particle-associated contamination. The use of turbidity curtains around sensitive resources in addition to around the construction area would further reduce or eliminate the potential impacts from sediments that may be released beneath the turbidity curtain at the point of construction/demolition.

Erosion control measures would be implemented following the guidelines found in VDEQ's-approved BMPs and design information presented in its Virginia Erosion and Sediment Control Field Manual. The manual includes 19 minimum standards required by Virginia law for projects having erosion and sediment control measures and includes a "Minimum Standards Quick Reference Checklist" that inspectors for the project must complete during construction. These standards include detailed design criteria for road stabilization, sediment barriers, dike and diversions details, sediment trap and basin design, flume design to control erosion, waterway and outlet protection measures, stream protection designs, site preparation for vegetation establishment, grass establishment designs, and mulching techniques.

Other potential impacts to surface waters may include contamination from spills or leaks of pollutants from the vehicles or equipment used during construction activities and transportation of construction materials. NASA would implement site-specific construction and industrial SWPPPs that would include BMPs for fueling and maintenance of vehicles and equipment as well as spill prevention and control measures to reduce potential impacts to surface water during construction. BMPs would include measures such as ensuring equipment is in good working condition, maintaining spill kits and clean-up materials on site, and using drip pans and absorbent pads. Additionally, all personnel and visitors responsible for handling fuels, hazardous material, or hazardous waste receive annual training on implementation of the WFF ICP. If a leak or spill should occur, NASA would immediately implement the procedures outlined in the ICP.

Pile driving for the new Causeway Bridge and likely removal of existing piles during removal of the existing bridge would have the potential to disturb the aquatic environment. BMPs would be employed during pile removal and disposal activities. The piles would be removed either with a vibratory hammer, by direct pull with a crane, or cut approximately 0.6 m (2 ft) below the mudline using pneumatic shears or an underwater chainsaw so that the broken tip would not be exposed. Depending on the embedment, the use of a high-pressure water jet may be required to loosen or remove mud keeping some of the piles stuck in place. Any falling debris from the removed piles would be contained using tarps and a floating boom. It is anticipated many of the concrete piles may be reused; therefore, these piles would be stockpiled onsite at a construction staging area. The final determination on how many piles could be cut versus pulled would be based on the new Causeway Bridge design to be determined at a later date.

For concrete piles removed from open water areas under the bridge, the concrete piles or pieces of concrete debris created during the pile removal would be loaded onto a barge, brought to shore, transferred to an end-dump truck, and hauled either to an onsite stockpile area or directly to a recycling facility. Typically, the stockpile area would be worked by two pieces of equipment: a loader and an excavator. The excavator would separate the different types of materials and cut them into manageable sizes. The loader would take demolished materials from the stockpile site and place them into piles for the excavator, and then load the trucks for off-site disposal and/or recycling. The number of loaders and excavators will be determined during the future design and specifications preparation for the new Causeway Bridge. At that time, the final disposition of the removed piles either for recycling and/or trucking off-site would be determined and the transportation related impacts of the transport of those materials assessed.

Debris booms would be placed around the Causeway Bridge construction work area in accordance with appropriate BMPs for such construction/demolition. It is anticipated the debris booms would be attached around the pile structures; however, the specific locations of the debris booms would be dependent on the type of equipment, wave action, and currents anticipated during the construction/demolition. WFF will consult with NMFS and USFWS regarding the location of the debris booms prior to the implementation with respect to their potential impacts to listed species under their purview.

Regarding pile driving activities, the number and type of pre-stressed concrete piles will be determined during the design phase of the new Causeway Bridge. The construction of the new bridge would use equipment, such as tugboats, barge mounted cranes, construction crew support vessels, and pile driving equipment, with the potential to cause increased temporary turbidity in shallow areas during pile driving activities. The pile driving activity can also result in increased turbidity from the pressure of the blows to the piles to drive the piles down into the channel bottom. The pile driving would result in water column disturbance by way of re-suspension of bottom sediments and cause underwater noise disturbance to fish and marine mammals from elevated sound generated in the water column (see Section 3.11.2.2.2). It is anticipated that these impacts would be temporary and localized to the area directly around each pile installed or removed.

NASA would obtain all necessary permits for construction/demolition of the Causeway Bridge which may include an Accomack County Wetlands Board permit, VMRC permit, a Virginia Water Protection Permit/401 certification and a construction general permit from VDEQ, a USACE Section 404 permit and a permit from the Coast Guard. The requirement for a Section 10 River and Harbors permit would also be considered. FHWA design of the bridge and highway would ensure compliance with EO 11988 and standards established in 23 CFR 650 A.

***Maintenance Dredging***

Two methods of dredging could be employed for the proposed maintenance dredging between the two existing boat basins: hydraulic dredging (e.g., pipeline/cutterhead dredge) or mechanical dredging (e.g., clamshell bucket dredge). The choice of dredge method depends on the amount and type of dredge material to be removed, availability and cost of the dredge equipment, and the location and availability of dredge disposal sites. Selection and operation of the type of dredge equipment would affect the degree of adverse impacts to surface waters during dredging. However, the decision of which dredging method to employ would be made following the completion of the PEIS; therefore, this analysis assumed mechanical dredging using a traditional clamshell bucket would be used because it represents the worst-case scenario (i.e., maximum potential adverse effects in terms of marine water quality impacts).

A brief general discussion of hydraulic dredging is presented to provide a comparison of potential effects between hydraulic and mechanical dredging methods. During hydraulic dredging, material is loosened from its in situ state and lifted in suspension through a pipe system connected to a centrifugal pump. Hydraulic dredging is most efficient when working with fine materials and sands since they are easily held in suspension. Coarser materials, including gravel, may be hydraulically dredged; however, these materials require a greater demand of pump power and can cause excessive wear on pumps and pipes. The two main types of hydraulic dredges are pipeline and hopper dredges. Due to the shallow depth and width of the project channels and barge basins, hopper dredges would be precluded from their use in this project area and are not discussed further.

Cutterhead pipeline dredges, or cutter suction dredges, work best in large areas, and use a device consisting of rotating blades or teeth, called a cutterhead, to break up or loosen bottom material. A large centrifugal pump removes the material from the bottom of the channel and pumps the sediment-water slurry through a discharge pipeline. Material dredged by a cutter suction dredge is directly placed into the permanent or temporary disposal site by the discharge pipeline. Since the slurry mixture (10% to 20% solids in water) has a higher density than the ambient water, it descends to the bottom of the placement area in a manner dependent on the sediment characteristics. Typically, cutter suction dredges operate continuously and are cost-effective if the placement site is in relatively close proximity to the dredge area. However, because the pipeline is often floated on the water surface, pipeline dredges may not be suited for work in high traffic areas where they would pose an obstruction to navigation. To avoid these problems, pipelines can be weighted to the open water floor. Special notice regarding the placement of the temporarily submerged pipeline must be made prior and during dredge events. Care must be taken to ensure proper anchoring and control of the pipeline for the duration of the dredging and final removal of all pipeline sections after the dredging is complete. These types of dredges are not recommended for areas with heavy debris that can clog pumps and impair efficiency.

Mechanical dredging excavates in situ sediments with a grab or bucket. Mechanical dredges operate best in consolidated, hard packed material since dredging buckets have difficulty retaining loose, fine (silty) material that is often washed away as the bucket is raised. Depending on the bucket and scow (hopper) characteristics, the water content of the dredged material is approximately 10%. Mechanical dredges are often used in tightly confined areas, such as harbors, around docks and piers, and in relatively protected channels. This type of dredge is not suitable for rough seas or may not be suitable for areas of high vessel traffic where a stationary dredge and dredge scow may impede other vessel movements. By using a number of scows with one dredge, mechanical dredging can proceed continuously. As one scow is being filled, another can be towed to the placement site.

One of the most common types of mechanical dredges is the clamshell dredge, which is named for the type of bucket used in the dredging operation. Typically, a large barge is loaded with the bucket dredge and transported to the dredging site with tugs. The barge is then secured in place. The dredging process consists of lowering the bucket to the channel or basin floor, closing the bucket and raising it back to the water surface, and depositing the dredged material into a scow or, if appropriate, directly into an adjoining placement site. The efficiency and capacity of this type of dredging is determined by the capacity of the bucket, which varies between 1 and 20 $m^3$ (1.5 and 25 $y^3$), scow capacity, which typically varies from 100 to 2,500 $m^3$ (130 to 3,300 $y^3$), and the number of available scows.

The primary physical impact from mechanical dredging involves a re-suspension of sediments and increased turbidity that could adversely affect marine life and water quality. Sediment loss to the water column reduces the efficiency of the dredging process, increases the size of the residual sediment plume, and compounds the impacts to the marine environment.

The nature, degree, and extent of sediment re-suspension that occurs during dredging operations are controlled by many factors including: the particle size distribution, solids concentration, and composition of the dredged material; the dredge type and size, operational procedures used; and finally the characteristics of the receiving water in the vicinity of the operation, including density, turbidity, and hydrodynamic forces (i.e., waves, currents, etc.) causing vertical and horizontal mixing. The relative importance of the different factors will vary significantly from site to site (Science Applications International Corporation [SAIC] 2001). Shoal material removed from channel dredging would likely include coarse material, limiting the re-suspension of materials and turbidity in the water column. Dredging in the barge basin is likely to include finer material combined with coarse materials and increase the likelihood of increased turbidity levels during dredging.

Even under ideal conditions, substantial losses of loose and fine sediments will usually occur with mechanical dredging. Sediment loss during a typical mechanical bucket dredging operation occurs throughout the water column from the following specific sources: impact of the bucket on the bottom of the dredge area; material disturbance during bucket closing and removal from the bed; material spillage from the bucket during hoisting; material washed from the outer surfaces of the bucket during hoisting; leakage and dripping during bucket swinging; aerosol formation during bucket reentry; and residual material washed during bucket lowering (SAIC 2001).

Maximum concentrations of suspended solids in the surface turbidity would occur in the immediate vicinity of the dredging areas and decrease rapidly with distance from the operation due to settling and dilution of the material. An array of operational turbidity control measures could be implemented to prevent suspended sediments from exceeding water quality standards. Frequent monitoring would be performed during dredging to ensure the effectiveness of the selected suspended sediment control methods. Examples of operational controls for dredges include the following:

- Reducing the dredging rate to slow down the dredging operation (this is especially important with respect to bucket speed approaching the sediment surface and bucket removal from the surface after closing).
- Reducing bucket over-penetration, which can cause sediment to be expelled from the vents in the bucket or cause sediment to become piled on top of the bucket, then eroded during bucket retrieval.
- Eliminating overflow from barges during dredging or transport.
- Changing the method of operating the dredge, based on changing site conditions such as tides, waves, currents, and wind.
- Modifying the depth of the cutterhead for hydraulic dredging, rate of swing of the ladder and of the rotating cutterhead, and reducing the speed of advance of the dredge.
- Modifying the descent or hoist speed of a wire-supported bucket.
- Sequencing the dredging by moving upstream to downstream.
- Varying the number of dredging passes (vertical cuts) to increase sediment capture.
- Using properly sized tugs and support equipment.
- Using GPS location technology on dredging equipment to avoid over dredge.

Application of operational controls is potentially costly and can significantly reduce overall production rates and efficiency. Further, the improper use of controls can have direct negative impacts on a project and the environment by concentrating total suspended solids in a localized area, reducing visibility and potentially reducing localized dissolved oxygen. The degree of controls needed is a site-specific or area-specific decision. Therefore, such controls should be applied only when conditions clearly indicate their need and should not be set as a requirement solely because they can be applied (USACE 2005). With proper monitoring as established by the Joint Permits (see Section 3.5.1.5), the potential for the dredging project to have significant water quality impacts would be minor. Any exceedances of water quality standards would result in the interruption of the construction activities until the total suspended solids levels returned to acceptable levels. The sedimentation controls would prevent significant impacts to aquatic communities and water quality outside of the project area.

The Maintained Barge Route is approximately 10.8 km (6.7 mi) long with a minimum channel width of 50 m (160 ft) and a project depth of -2.4 m (-8 ft) MLLW. Hydrographic surveys have identified areas of shoaling along the Barge Route. **Figure 3.5-8, Figure 3.5-9** and **Figure 3.5-10** show the locations of the areas to be dredged and the possible temporary holding sites which are referred to as “Material Transfer Site(s)” on **Figure 3.5-8** and **Figure 3.5-10**. These material transfer sites are referred to as temporary since they are not large enough to handle all of the material expected to be dredged over the 20-year planning horizon covered in this PEIS. It would be expected that the dredged material would be harvested for either beneficial reuse or transfer to another upland disposal site on WFF to allow for additional dredged material holding capacity at these two locations. Further NEPA analysis would be prepared when the planning and design details for the dredging activities are more developed. The Joint Permits could include authorization for a return flow discharge from these confined upland disposal areas to de-water the dredged material if necessary. Monitoring of this discharge would be performed by the dredge contractor to ensure that state water quality criteria are not exceeded.

In a 1979 study, Bohlen, et al., determined that the total suspended load in an estuarine system after a storm event is an order of magnitude greater than that produced by dredging activities (e.g., bucket load leakage, dredge-induced plume). The study also detected that sediment concentration along the centerline of the dredge-induced plume decreased rapidly to background levels within 700 m (2,300 ft) (Bohlen et al. 1979). Therefore, the turbidity generated by sediment dredged along the Barge Route would have a short suspension time during dredging, transport, and placement in the temporary material transfer sites.

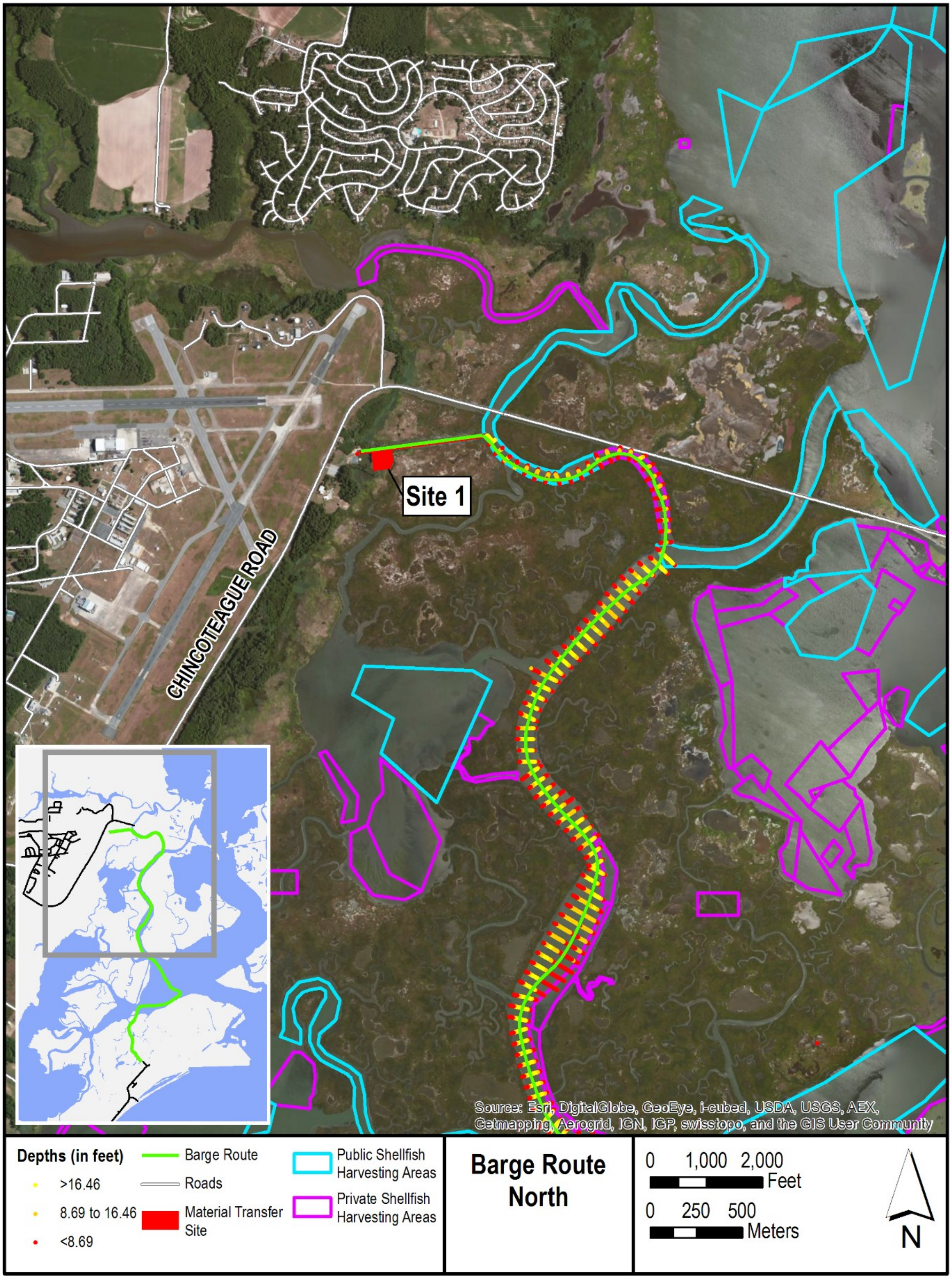


**Figure 3.5-8. Location of Barge Route North**

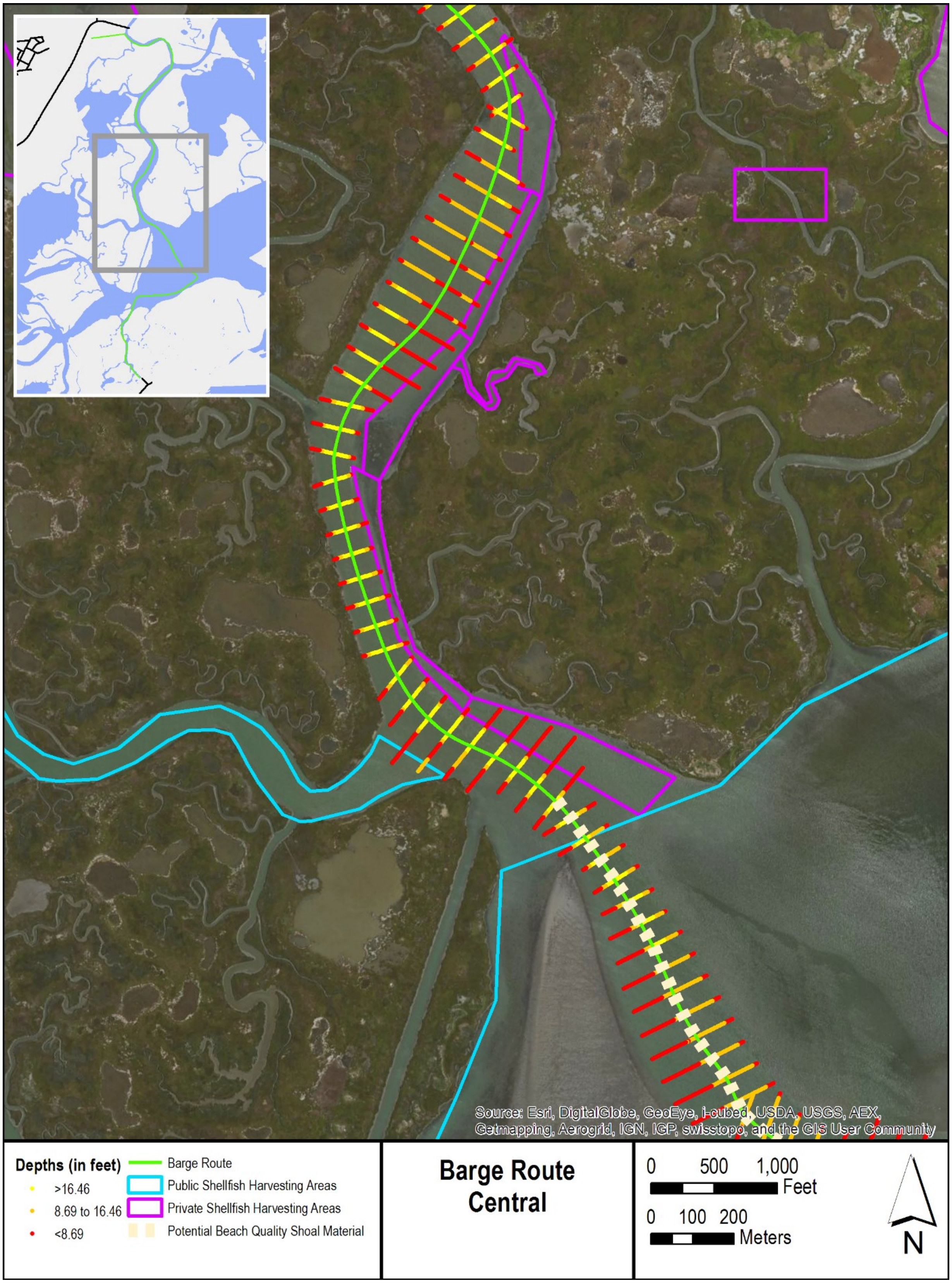


**Figure 3.5-9. Location of Barge Route Central**

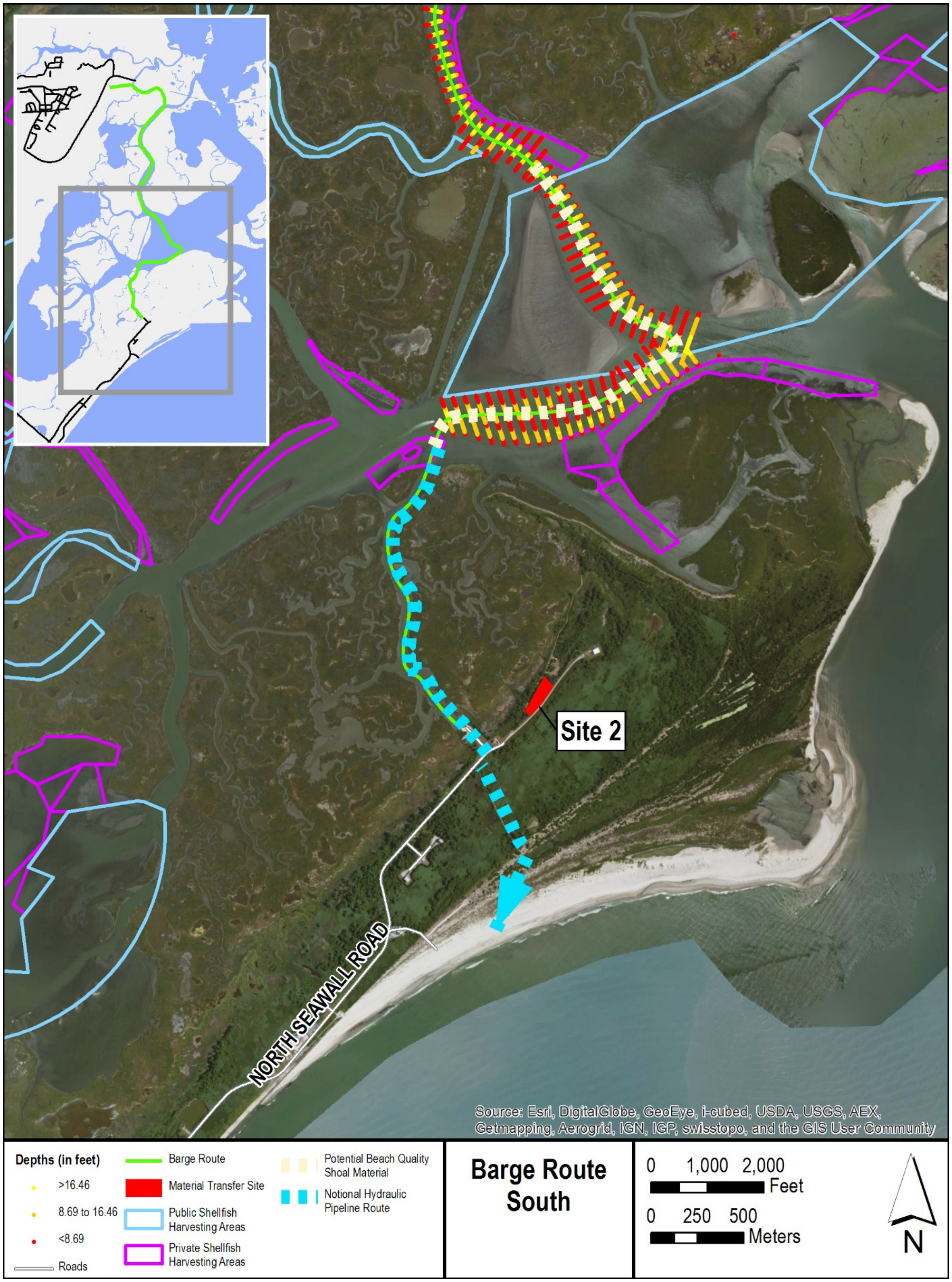


**Figure 3.5-10. Location of Barge Route South**

No other water quality parameters are anticipated to be substantially impacted during the maintenance dredging of the Barge Route.

NASA would obtain all necessary permits for sediment placement in the nearshore environment, which may include an Accomack County Wetlands Board permit, VMRC permit, a Virginia Water Protection Permit/401 certification from VDEQ, and a USACE Section 404 permit. An evaluation report based on Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material*, would be submitted to permitting agencies to address impacts associated with the Proposed Action. The requirement for a Section 10 River and Harbors permit would also be considered.

Under these guidelines, dredged or fill materials should not be discharged into the aquatic ecosystem unless it can be demonstrated that the discharge will not have an unacceptable impact from either individual or in combination with known and/or probable impacts from other activities affecting the ecosystem. **Figure 3.5-9** and **Figure 3.5-10** show the location where it is expected that beach quality material may be removed by hydraulic pipeline dredge with possible beach disposal.

The possible pipeline route layout to avoid wetland impacts is also shown on **Figure 3.5-10**. It is anticipated that shoal material unsuitable for beach renourishment removed during dredging would be placed in temporary upland material transfer sites.

***North Wallops Island Deep-water Port and Operations Area***

The potential impacts to impacts to surface, subsurface and stormwater as described above for the Causeway Bridge Replacement and maintenance dredging projects, would be likely to occur under this proposal. As details for the North Wallops Island Deep-water Port and Operations Area are unknown, further analysis would be required as the details for this project becomes solidified. In conclusion, with implementation of site-specific SWPPPs and BMPs, adherence with the WFF ICP, Joint Permits, NPRs, and Section 438 of the Energy Independence and Security Act, any impacts to surface waters, subsurface waters, or stormwater from institutional support projects under the Proposed Action would be temporary and minor and would not result in significant impacts.

***Launch Pier 0-D***

Regarding Launch Pier 0-D, no design specifications for either of the two optional locations are available at this time. Future planning and design would include measures to minimize, to the extent practicable, impacts to sediment and sand transport of from the creekside or oceanside option, respectively. As details for the Launch Pier 0-D are unknown, further analysis would be required as the details for this project becomes solidified.

In conclusion, with implementation of site-specific SWPPPs and BMPs, adherence with the WFF ICP, EO 13514, Joint Permits, and Section 438 of the Energy Independence and Security Act, any impacts to surface waters, subsurface waters, or stormwater from institutional support projects under the Proposed Action are anticipated to be temporary and minor and would not result in significant impacts.

**Groundwater**

Under the Proposed Action, NASA would provide potable water to the new facilities for drinking water supply and industrial water use. In order to determine the additional amount of potable water the new personnel (see Section 3.15, Socioeconomics) would require, the analysis assumed the average daily water consumption is the same as the wastewater flow rates. Therefore, it was assumed each person would consume an average of 13 gal per day (EPA 2002). In addition, it was assumed the total amount of days worked in a year totaled 250 days (i.e., 5-day work week with 10 federal holidays). An additional 76 people (i.e., civil servants and full-time, onsite contractors) would consume 3,740 liters (988 gal) per day or approximately 77,800 liters (20,550 gal) per month. The combined Mainland and Wallops Island withdrawals average 15,711,000 liters (4,154,000 gal) per month. Therefore, the additional demand from these 76 workers would be within the limits established by WFF's historic VDEQ issued groundwater withdrawal permits.

No short- or long-term impacts are expected to the Columbia and Yorktown-Eastover multi-aquifer system. Furthermore, the potable water consumption estimates are considered conservative since they do not take into account implementation of requirements detailed NPR 8820.2D, *Design and Construction of Facilities*, NPR 8500.1C, *NASA Environmental Management*, and NPR 8570.1A, *NASA Energy Management Program*. Specifically, water management strategies that would minimize the amount of potable water consumed, such as the use of water-efficient and low-flow fixtures. NASA would also encourage water use conservation practices in facility design and operation, such as the use of native plants in landscaping that are adapted to the local precipitation levels and educating employees about water conservation methods.

The proposed institutional support projects would institute BMPs to minimize impacts to surface waters, subsurface waters, and stormwater that may be located near recharge areas. Therefore, there should not be any increases in risk of groundwater pollutants as a result of the proposed institutional support projects under the Proposed Action.

**Wetlands**

As listed in **Table 3.5-2**, several institutional support projects would likely impact wetlands. These projects include the replacement of the existing Causeway Bridge, proposed maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D. Any wetlands near the proposed North Wallops Island Deep-water Port and Operations Area and Launch Pad 0-C or Launch Pier 0-D would be delineated and the limits confirmed by the USACE. NASA would implement wetland mitigation for proposed projects to ensure no net loss of wetlands.

No design or detailed planning that would allow for in-depth analysis of construction of the Causeway Bridge, proposed maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D is available at this time. As such, the actual magnitude of the impacts for these projects is unknown and the level of significant impact cannot be fully determined at this time. Future planning and design would include avoidance and minimization of wetland impacts to the greatest extent practicable and only then would unavoidable impacts be considered for mitigation. Once a design for these projects is known, additional NEPA analysis would be required prior to permitting and construction.

**Table 3.5-2. Potential Wetland Impacts from Institutional Support Projects**

| Construction Activity | Location | Wetland Type | Potential Wetlands and Waters of U.S. Impacts – Areas in Ha (Ac) | | | Permits | Mitigation |
|---|---|---|---|---|---|---|---|
| | | | Direct Impacts | Shading | Scour | | |
| Causeway Bridge Direct | Mainland / Island | E2EM, E1UB | < 0.1 ha - 2.0 ha (1.5-5.0 ac.) | < 0.1 ha (< 1.0 ac.) | < 0.1 ha (< 1.0 ac.) | U.S. Coast Guard, USACE, VDEQ, VMRC | Yes, in kind or in lieu |
| Causeway Bridge Temporary Staging Areas[1] | Mainland / Island | E2EM | < 0.1 ha (< 1.0 ac.) | NA | NA | USACE, VDEQ, VMRC | Yes, restore areas if impacted |
| Dredge Disposal Temporary Transfer Site 2[2] | Island | PEM | < 1.0 (< 0.5 ac.) | NA | NA | USACE, VDEQ, VMRC | Yes, restore areas used for temporary pipeline access if impacted |
| Launch Pad 0-C | Island | E2EM, E1UB | 2.0 ha (5.0 ac) | NA | NA | USACE and VDEQ | Yes, in kind or in lieu |
| Launch Pier 0-D | Island | E2EM, E1UB, PEM | .02 ha (.5 ac) | NA | NA | U.S. Coast Guard, USACE, VDEQ VMRC | Yes, in kind or in lieu |
| North Wallops Island Deep-water Port and Operations Area | Island | E2EM, E1UB, PEM | NA | NA | NA | U.S. Coast Guard, USACE, VDEQ VMRC | Yes, in kind or in lieu |

Notes: [1] Assumes impact of 100%.
[2] Assumes minor impact due to possible placement of hydraulic pipeline across marsh to access beach placement area.
Legend: NA = Not Available.

**Causeway Bridge Replacement**

The new Causeway Bridge would likely be constructed by either the "Top-Down" or "Temporary Trestle" method. With top-down construction, the bridge is built from itself. As each section is completed, the equipment reaches out and constructs the next section. The Temporary Trestle Method involves installing the metal framework for a temporary trestle adjacent to where the new bridge would be constructed and the construction equipment works from the trestle to construct the new bridge. Due to the uncertainty of the design and construction approach for the new Causeway Bridge, an estimated range of less than 1.0 ha (approximately 1.5 ac) to 2.0 ha (5.0 ac) of direct wetland impacts could occur from pilings, abutments, rip rap, and fill material. To avoid and minimize impacts to wetlands during the replacement of the existing Causeway Bridge, any wetlands present in the bridge replacement project area would be delineated and the limits confirmed by the USACE. Project designs would include an evaluation of practicable alternatives that would include avoidance and minimization measures to reduce impacts to wetlands. Unavoidable impacts to wetlands would be permitted through the USACE, VDEQ, and Accomack County regulatory processes. NASA would implement wetland mitigation measures to ensure no net loss of wetlands. Additional permits from the U.S. Coast Guard and the VMRC would be required because the bridge crosses a tidal navigable waterway. Additional mitigation measures would likely be required as a part of the permit to protect the aquatic resources during and after construction.

**Maintenance Dredging**

With regards to maintenance dredging, temporary impacts to wetlands could occur by the placement of the dredge pipe crossing wetlands along the route from the dredge to the upland disposal areas. These temporary impacts could be avoided by placing the pipeline along the open channel edge and staying in the open water versus crossing wetlands. The actual pipeline placement would be determined when the dredge design specifications are prepared. However, it is understood that wetland impacts must be avoided to the greatest extent practicable during the design and permitting phase.

**North Wallops Island Deep-water Port and Operations Area**

Construction of the North Wallops Island Deep-water Port and Operations Area is proposed on the northeast side of the island (See **Figure 2.5-7**). The estimated footprint is unknown at this time. It is anticipated that the construction would include impacts to tidal and non-tidal wetlands and would require a confirmed wetland delineation by the USACE and CWA Section 404/401 permits from USACE, and VDEQ. The design would include avoidance and minimization measures and appropriate mitigation would also be provided.

**Launch Pad 0-C**

Launch Pad 0-C is proposed at the current location of the UAS airstrip at the south end of Wallops Island (refer to **Figure 2.5-4**). It is anticipated that Launch Pad 0-C could be as large in size and configuration as Launch Pad 0-A with an estimated footprint of 2.6 ha (6.4 ac). The new pad could include construction of a pad access ramp, launch pad, and deluge system resulting in approximately 1.3 ha (3.2 ac) of impervious surface within the pad complex footprint. **Figure 3.5-11** shows the Launch Pad 0-A layout on top of the general area where Launch Pad 0-C could be built and represents a notional placement of the new pad rather than a final design layout. This figure and the associated wetland impacts of approximately 2.0 ha (5.0 ac) represent the most conservative scenario for wetland impacts.

**Launch Pier 0-D**

Construction of Launch Pier 0-D is proposed on either the creekside or oceanside on South Wallops Island (See **Figure 2.5-9**). The launch pier could include construction of a pad access ramp, launch pad, and deluge system. The estimated footprint is unknown at this time. It is anticipated that the landward side construction location would include impacts to tidal wetlands and would require a confirmed wetland delineation by the USACE and CWA Section 404/401 permits from USACE and VDEQ. The design would include avoidance and minimization measures and appropriate mitigation would also be provided.

**<u>Marine Waters</u>**

It is anticipated the construction of the seaward location for Launch Pier 0-D and North Wallops Island Deep-water Port and Operations Area would include impacts to beach and marine waters habitat. As stated above, the project would require a confirmed wetland delineation by the USACE and CWA Section 404/401 permits from USACE, and VDEQ as well as permits from VMRC and the U.S. Coast Guard as this area is considered navigable water. The design would include avoidance and minimization measures and appropriate mitigation would also be provided.

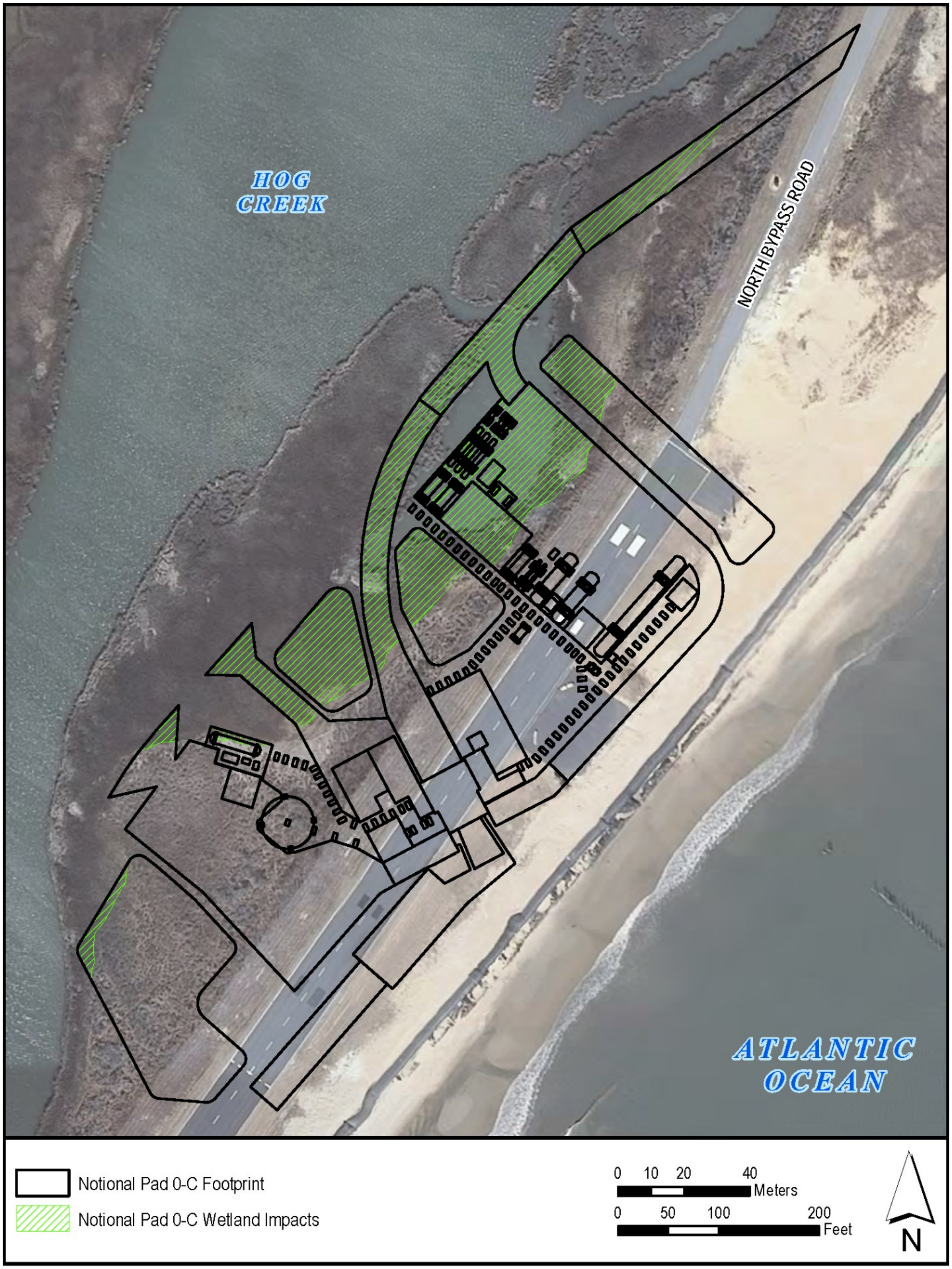


**Figure 3.5-11. Notional Location of Proposed LV Launch Pad 0-C**

**Floodplains**

No construction within the 100-year floodplain is proposed on the Main Base. The proposed Commercial Space Terminal, located at the Main Base would be sited on an existing parking lot to avoid expanding the footprint of fill within the floodplain. The new Causeway Bridge, located directly adjacent to the existing bridge would be located in Flood Zone V. The effect should be minimal as the Causeway Bridge is located within a large expanse of tidal marsh which would dissipate any flood water effects.

As stated previously, Wallops Island is located entirely within the 100-year floodplain. As listed in **Table 2.5-2**, there are several structures planned for construction on Wallops Island. Since mission requirements limit the location of these facilities and Wallops Island is located entirely within the 100-year floodplain, there is no practicable alternative to avoid development within the floodplain. However, projects whose locations are known at this time with planned construction on Wallops Island would occur at locations where construction was performed in the past. Some projects are not defined in enough detail to know exactly where they would occur on Wallops Island and would require future NEPA analysis as they become more defined. In accordance with EO 11988, new construction would be designed to reduce the risk of flood loss and to minimize the impact of floods on human safety, health, and welfare and provide mitigation if warranted.

**Coastal Zone**

Federal agencies must prepare consistency determinations if their activities can have any reasonably foreseeable effects on Virginia's coastal uses and resources. Construction and demolition for institutional support projects would affect resources within Virginia's Coastal Zone. Therefore, NASA has prepared an FCD that finds its proposed action to be consistent with the enforceable policies of Virginia's CZM Program (**Appendix G**). NASA submitted its FCD with the Draft PEIS to VDEQ for concurrence. VDEQ concurred with the FCD findings provided all applicable permits and approvals are obtained prior to implementing the actions proposed (see **Appendix I**).

**Sea-Level Rise**

Studies show that natural defenses reduce some of the impacts of sea-level rise. For example, beach nourishment, sea grass meadows, oyster reefs, and salt marshes can significantly reduce wave energy which would be exacerbated by sea-level rise (Barbier et al. 2011). Appropriately placed and sufficiently vegetated land cover slows erosion. Healthy sand dunes can reduce storm surge impacts. Siting and constructing buildings to use natural buffers as an adaptation strategy reduce the risk to the structures. Natural defenses are self-renewing and respond positively to change over the long term. When established, protected, and nurtured, eelgrass, oyster reefs and salt marshes continue to accrete and grow in elevation as sea-level rises. Furthermore, a beneficial reuse of dredged materials as "thin layer deposition" has been shown to increase and encourage salt marsh resiliency to sea-level rise and could provide a valuable usage for onsite dredged material (Virginia Institute of Marine Science [VIMS] 2014). Barrier islands move and migrate as storms and currents shift the sands. Vegetated shorelines can shift upslope as salt marsh migrates into uplands. Wetlands can help absorb and mitigate flooding, growing in response to inundation.

WFF and its participating partners in the Mid-Atlantic region (e.g., USFWS, NPS, CBFS, TNC) have formed the Mid-Atlantic Coastal Resilience Institute. The Institute plans to collaborate to develop and implement adaptation strategies for a climate resilient Eastern Shore through resource and data sharing. Outputs of the Institute's research are expected to support applied science and policy related to coastal resilience in the context of sea-level rise, extreme weather events, and coastal ecosystem degradation in the Mid-Atlantic. The results of these research partnerships could be employed to guide decision-making in the implementation of the 2008 WFF Facility Master Plan, the alternatives in this PEIS, and actions yet to be identified but which could be necessary either within or beyond the temporal scope of this PEIS.

NASA would continue to implement an adaptive management and monitoring strategy for the shoreline restoration program at WFF. Throughout the 50-year term of the SRIPP project, the beach profile in front of the present shoreline would be re-nourished with sand every three to seven years, or as needed (NASA 2010). To account for sea-level rise impacts to the shoreline at Wallops Island, additional sediment volume would be placed during each beach renourishment event. Modifications would be made as needed to ensure the viability of the long-term project meant to reduce the potential for damage to, or loss of, NASA, U.S. Navy, and MARS assets on Wallops Island from storm-induced wave action and sea-level rise impacts. Additionally, NASA established that only infrastructure with a demonstrated need would be allowed to be constructed on Wallops Island. For example, allowable Wallops Island infrastructure investments could include support systems essential for WFF's often hazardous launch site operations or those facilities that must be installed in a maritime environment, as in the case of many U.S. Navy operations (NASA 2016a).

In summary, no significant impact long-term impacts to water resources would be anticipated from institutional support projects under the Proposed Action. Site-specific SWPPPs, BMPs, and wetlands avoidance and mitigation measures would be implemented. Refer to **Section 4.1.5** (Water Resources) for measures to mitigate impacts to water resources under the Proposed Action.

3.5.2.2.2 Operational Missions and Activities

**<u>Surface Water, Subsurface Waters, and Stormwater</u>**

Water quality impacts can include stormwater runoff that degrades the quality of surface and subsurface waters. Since these topics are interrelated, they are combined for the purposes of this analysis. This analysis will include a discussion of the proposed Launch Pad 0-C and Launch Pier 0-D operations, launching of LFIC and SFHC LVs, and other launch vehicles and missions related to the Expanded Space Program.

**Launch Pad 0-C and Launch Pier 0-D**

Operations at the launch pads would include maintenance activities, launch vehicle preparation, and launches on impervious surfaces. The SWPPP would implement the use of BMPs during launch activities, which would prevent indirect impacts from erosion and sedimentation to the nearby water bodies. Any impacts associated with an increase in stormwater runoff to surface waters would be minimized by implementation of the SWPPP and BMPs and would not have significant adverse impacts to surrounding surface waters.

Potential impacts to surface water quality during launches include contamination from accidental spills or leaks from operating vehicles and machinery. As discussed in Section 3.3. Hazardous Materials, Toxic Substances, and Hazardous Waste, implementation of the WFF ICP would reduce the potential for accidental spills or leaks. Therefore, contamination from accidental spills or leaks due to daily operations would not have adverse impacts to surrounding surface waters.

**Expanded Space Program**

***LFIC LV***

Launch of a LFIC LV, with a liquid propellant first stage using RP-1, would result in the emission of CO and $CO_2$. When CO and $CO_2$ combine with water vapor in the air, carbonic acid may form which could result in the deposition of carbonic acid on the ground in the area surrounding the launch pad. The effects of carbonic acid deposition on the adjacent tidal wetland area would be minimal as carbonic acid is a weak acid (approximate pH of 6.4) and is normally found in rainwater. Previous studies of surface waters surrounding launch pads have indicated minimal pH changes after rocket launches. Nearby surface waters have a natural buffering capacity and wetlands have a natural ability to resist substantial changes in pH (NASA 2009). Therefore, the effects of LFIC LV launches on pH in the adjacent surface waters, including tidal wetland area, would be minor and short-term. Additionally, stormwater within the launch pad would be retained in basins designed to encourage infiltration and evaporation. No direct discharges to surface waters are anticipated.

Deluge water for LFIC LV static fires and launches would be discharged to a lined retention basin where it would be allowed to cool. Under the WFF Wallops Island VPDES permit, after cooling the retained water would be tested for temperature (at ambient); pH (between 6 and 9); and, if a visible sheen is present from RP-1 fuel, for total petroleum hydrocarbons (TPH) (0.0 ppm) before being released to the unlined infiltration and evaporation basin. If required, the deluge water would be treated (e.g., pH adjustment) before release or removed for disposal if it does not meet the standards for discharge to surface waters as stipulated in the VPDES permit. To increase the pH prior to discharge into surface waters, sodium bicarbonate (baking soda) would be used. The release may occur over a period of several days due to the large quantity of water to be discharged (NASA 2009). If TPH is detected above 0 ppm, the deluge water would be containerized and disposed of at a licensed Treatment Storage and Disposal Facility. Additionally, WFF would comply with the stipulation of the Wallops Island VPDES permit to perform and report TPH and pH monitoring of the outfall from the infiltration basin to Hog Creek.

LFIC LV launch failures could result in impacts on surface waters due to contamination from rocket propellants both from the lower and upper stages. A launch failure of a liquid rocket motor or spilled liquid fuel could result in liquid fuel entering surface waters and tidal wetlands close to the launch pad as well as below the flight trajectory of the launch vehicle. In accordance with WFF's ICP, appropriate containment measures would be implemented if this unlikely event were to occur. Procedures may include containing the spill using disposable containment materials such as absorbent pigs and berms, fences, trenches, sandbags, and cleaning the area with absorbents or other material to reduce the magnitude and duration of any impacts. Due to the potential volume of this release into the nearby tidal wetlands, temporary impacts on water quality in the tidal wetlands may be adverse; however, because mitigation and clean-up measures would be implemented quickly, the potential long-term impacts on tidal wetlands would not be significant (NASA 2009).

***SFHC LV***

Launch of an SFHC LV containing a first stage SRM would result in the release of HCl emissions near the launch pad and downwind of the launch pad. HCl is a strong acid (approximate pH of 1.0). $Al_2O_3$ deposition would also occur in the same areas within minutes after a launch. The Air Force previously researched the effects of HCl and $Al_2O_3$ in surface waters in the *Final Supplemental EIS for the Evolved Expendable Launch Vehicle Program* (U.S. Air Force 2000). The Air Force determined that the amounts of HCl deposited could cause temporary reductions in pH in small surface water bodies (U.S. Air Force 2000). In addition, $Al_2O_3$, which is known to gather water vapor to form acidic droplets could also cause temporary reductions in pH in small surface water bodies. Similar to Vandenberg AFB's location, WFF is located on the coast in close proximity to the ocean. Findings in the 2000 Supplemental EIS indicate that the proximity of WFF's location to the ocean would cause the deposition of acid-neutralizing sea salt. This acid-neutralizing sea salt along with the salt present within estuarine waters would provide a buffering capacity. Therefore, the effects of HCl and $Al_2O_3$ deposition to surrounding surface waters would be minor and temporary. Additionally, stormwater within the proposed launch pad would be retained in basins designed to facilitate infiltration and evaporation. A temporary decrease in pH may occur to stormwater but these effects would be short-term and minor.

Deluge water for SFHC LV launches would be discharged to a lined retention basin and would be allowed to cool. It would then be tested for potential release to an unlined infiltration and evaporation basin. NASA would coordinate with VDEQ regarding specific water quality requirements and treatment of the deluge water prior to discharge and would modify its existing VPDES permit if necessary. If required, the deluge water would be treated (e.g., pH adjustment) before release or removed for disposal if it does not meet the standards for discharge to surface waters as permitted by VDEQ. The pH would be managed so that the pH of the water to be discharged does not go below a pH of 6. To increase the pH prior to discharge into surface waters, sodium bicarbonate (baking soda) would be used. The release may occur over a period of several days due to the large quantity of water to be discharged (NASA 2009).

A launch failure of a SFHC LV SRM would result in the deposition of burning solid propellant into areas below the trajectory of the launch vehicle with temporary surface water impacts. In accordance with WFF's ICP, appropriate containment measures and procedures to reduce the magnitude and duration of any impacts would be implemented if this were to occur. Due to the potential volume of this release into the nearby tidal wetlands, temporary impacts on water quality in the tidal wetlands may be adverse. However, because mitigation and clean-up measures would be implemented quickly, the potential long-term impacts on tidal wetlands would not be significant (NASA 2009).

**Groundwater**

Launch activities could potentially affect groundwater if fuels leach into the aquifer after an accidental release of RP-1 during LFIC LV fueling. The impact would likely be minor and localized because the majority of the launch complex would be concrete, and personnel performing fueling would be trained in the emergency response and clean-up procedures specified in the WFF ICP. LFIC LV and SFHC LV launches would require the use of deluge water (sound and vibration suppression water spray) that would be injected into the rocket exhaust plume and flame trench and sprayed on the pad deck. If an above ground storage tank is proposed at Launch Pad 0-C or Launch Pier 0-D, NASA's existing potable water system could potentially be employed to provide 1,135,000 liters (300,000 gal) of deluge water per launch. The amount of deluge water is based on the maximum of 18 LV launches per year. As LV launches per year would remain unchanged, groundwater usage for deluge systems would not be anticipated to increase. The proposed operational missions and activities involving LFIC LV, SFHC LV and other launch vehicles under the Expanded Space Program would involve the implementation of BMPs to minimize impacts to surface waters, subsurface waters, and stormwater that may be located near recharge areas. As such, there would be negligible impacts to groundwater as a result of the proposed operational missions and activities under the Proposed Action.

**Wetlands**

No unavoidable impacts to wetlands are anticipated from launch vehicles under the Expanded Space Program. Any potential impacts associated with launch emissions or launch failures is previously analyzed under the surface waters discussion. Future design of Launch Pad 0-C and Launch Pier 0-D would include an orientation of the flame duct so that the flame trench would be directed over the beach and not over the wetlands to avoid scorching them.

**Marine Waters**

**DoD SM-3**

Navy DoD SM-3 rockets would be launched out over the VACAPES OPAREA for testing or to intercept an airborne target. Upon detonation, the airborne debris would fall into the ocean and sink rapidly to the ocean floor. Changes to water quality from metal components would be negligible based on slow breakdown rates of the metals and the enormous dilution capacity of the surrounding sea water (U.S. Navy 2009; 2018).

**Expanded Space Program**

***LFIC LV and SFHC LV***

The larger LVs launched at WFF would be multi-stage vehicles, and with the exception of the LFIC RTLS events, the spent LV stages would fall into the ocean. Rocket stages are designed to burn propellant until entirely consumed; however, complete combustion may not always occur and residual trace amounts of propellant and emission products may remain in the engine after separation and splashdown. Therefore, the LFIC LV stages are a potential source of petroleum pollution to marine environments from residual RP-1, and CO, and $CO_2$ emission products. Residual propellant and trace emission products from combustion of the SFHC EV solid propellant includes HCl, which becomes highly corrosive as an aqueous solution. Short-term impacts may result; however, impacts to marine waters would be localized and temporary due to the mixing and dilution associated with wave movement and the vastness of the ocean environment. Corrosion of hardware and spent rocket stages into toxic concentrations of metal ions would be localized and temporary because corrosion rates are slow in comparison to the mixing and dilution rates associated with marine environments (NASA 2009). The presence of miscellaneous materials such as battery electrolytes and hydraulic fluids are in such small quantities that only temporary effects would be expected. Long-term impacts would be negligible due to the extremely small amount of residual fuel and to the buffering capacity of the ocean.

If a launch failure were to occur, debris and unspent fuel would be removed from the nearshore ocean environment as practicable and disposed of in accordance with Federal, state, and local regulations. Short-term impacts on the nearshore environment may result but long-term impacts would be negligible due to the buffering capacity of the Atlantic Ocean (NASA 2009).

**Floodplains**

In the event of a flood or storm, WFF would implement flood control measures such as locating water-sensitive equipment, supplies, chemicals, etc. above flood level, and moving hazardous waste outside of the floodplain when substantial storms are imminent. The implementation of these measures would reduce the likelihood that a flood or storm event might result in loss of life, injury to persons, or damage to property or otherwise be considered a "critical action" as defined in EO 11988, *Floodplain Management*. Launch operations including potential launch failures would have no impact on floodplains.

**Coastal Zone**

Operational missions and activities would likely have effects on the Virginia Coastal Zone. As such, NASA has prepared an FCD that finds that the Proposed Action in this PEIS would be consistent with the enforceable policies of Virginia's CZM Program. An FCD (**Appendix G**) was submitted to VDEQ for concurrence; VDEQ concurred with the FCD findings (see **Appendix I**).

**Sea-Level Rise**

Operational missions and activities would be impacted by sea-level rise and storm surge. Refer to the discussion in Section 3.5.1.9. As noted for the discussion of impacts for institutional projects, smart planning and preparedness incorporate multiple solutions that combine and blend nature-based and engineered approaches, taking advantage of the strengths of both working in tandem.

No significant long-term impacts to water resources would be anticipated from implementation of the operational missions and activities as described under the Proposed Action. NASA would implement site-specific SWPPPs, BMPs, and wetlands avoidance and mitigation measures. Refer to **Section 4.1.5** (Water Resources) for measures to mitigate impacts to water resources under the Proposed Action. In the event of an chemical or petroleum release, immediate clean-up and restoration efforts would prevent long-term effects to aquatic ecosystems.

## 3.6 LAND USE

Land use generally refers to human modification of the land, often for residential or economic purposes. It can also refer to use of land for preservation or protection of natural resources such as wildlife habitat, vegetation, or other unique features. Human land uses include residential, commercial, industrial, agricultural, or recreational uses. Some natural features are protected under designations such as national parks, national forests, wilderness areas, or other designated areas. Land uses are frequently regulated by management plans, policies, and ordinances that determine the types of uses that are allowable or required to protect specially designated or environmentally sensitive attributes. The 2008 WFF Facility Master Plan was used to identify future facility growth and operational missions and activities (NASA 2008).

NASA recently participated with Accomack County and the Navy's SCSC in the Accomack County/Wallops Island Joint Land Use Study (JLUS). Funded by a grant from the DoD's Office of Economic Adjustment, the primary objective of the JLUS was to identify land use issues that may impact the operational capabilities of WFF, and to identify actions participating agencies can pursue to ensure that incompatible development does not impact the facility's future mission requirements. The JLUS was completed in May 2015 (Accomack County 2015).

**Department of Transportation Section 4(f) Properties**

Established by the Department of Transportation Act of 1966, Section 4(f), which applies only to agencies within the DOT, was designed to protect publicly owned parks, recreational areas, wildlife and waterfowl refuges, and public and private historical sites. Any project that receives funding from or requires the approval of the DOT, including the FHWA and FAA, must be analyzed for compliance with Section 4(f). To comply with Section 4(f), it must first be determined if there are any Section 4(f) properties within the affected environment. If a Section 4(f) property is present, then it must be determined whether the Proposed Action "uses" the Section 4(f) property. "Use" within the meaning of the statute (49 U.S.C. § 303(c)) includes taking permanent ownership of or applying a permanent easement to land from a Section 4(f) property for transportation purposes.

FAA Order 1050.1F outlines the policies and procedures for assessing environmental impacts resulting from FAA projects. The Order places responsibility of determining impacts on Section 4(f) properties with the FAA and defines a use as either direct (actual physical taking of lands) or constructive (indirect impacts). If there would be a constructive use, the FAA must determine if the impacts would substantially impair the Section 4(f) property. Substantial impairment occurs when the activities, features, or attributes of the property that contribute to its significance or enjoyment are substantially diminished.

The DOT cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless the following conditions apply:

- There is no feasible and prudent alternative to the use of the land, and
- The action includes all possible planning to minimize harm to the property resulting from use.

### 3.6.1 AFFECTED ENVIRONMENT

WFF is located in Accomack County, Virginia and encompasses approximately 2,440 ha (6,030 ac) in the northern area of Virginia's Eastern Shore on the Delmarva Peninsula. The facility is divided into three distinct land areas: Main Base, Mainland, and Wallops Island. **Figure 3.6-1** shows the land uses within WFF overlaying Accomack County Zoning.

#### Main Base

The Main Base is largely developed, consists of various land uses, and is zoned industrial by Accomack County (Accomack County 2014). Most acreage at the Main Base is dedicated to airfield operations. There is a large area of undeveloped land along the eastern boundary, but this is predominately marsh lands. The Main Base consists of an airfield and various structures that include management and administration buildings, maintenance and service facilities, engineering and design laboratories, research laboratories, airfield and associated support infrastructure, and radar. Additionally, the Main Base supports water and sewage treatment facilities, rocket motor storage magazines, U.S. Navy administration and housing facilities, U.S. Coast Guard housing, NOAA Wallops CDAS buildings, and other miscellaneous support structures.

#### Mainland

Wallops Mainland is home to long-range radar, communications, and optical tracking facilities. Wallops Mainland consists mostly of marshland and is bordered by agricultural land to the west, Bogues Bay to the north, and an estuary to the south. The area between Wallops Mainland and Wallops Island consists of a large marsh complex and is considered an official conservation area. This area has been designated as undeveloped in the Accomack County's Comprehensive Plan (Accomack County 2014).

#### Wallops Island

Wallops Island consists primarily of marshland and includes launch and testing facilities, blockhouses, rocket storage buildings, assembly shops, dynamic balancing facilities, tracking facilities, two UAS airstrips, OB area, U.S. Navy facilities, U.S. Air Force Instrumentation Tower, and other related support structures. Wallops Island is zoned as agricultural by Accomack County (Accomack County 2014).

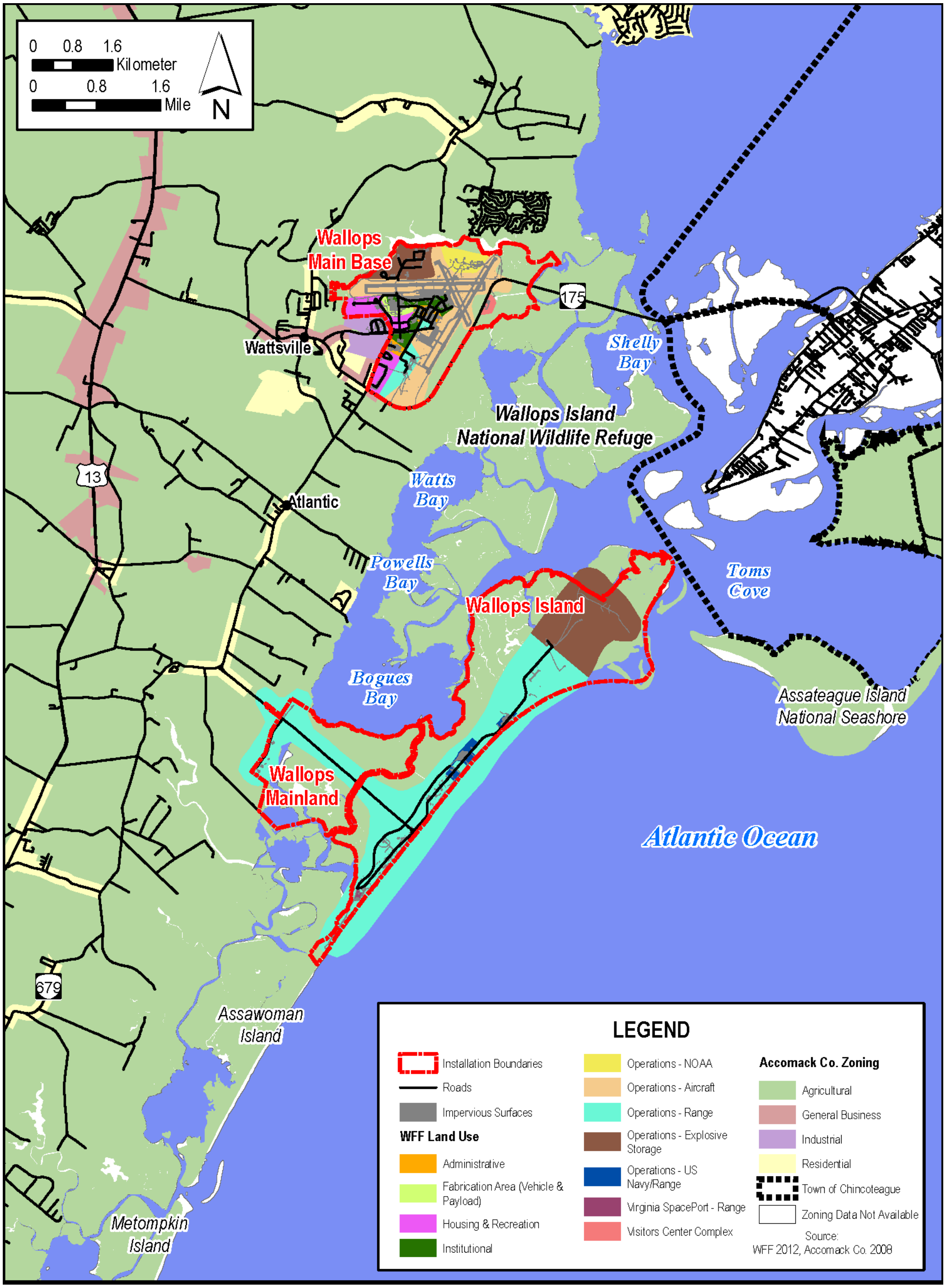


**Figure 3.6-1. Existing Land Uses at Wallops Flight Facility and in Accomack County**

The Island is adjacent to a number of areas managed for conservation purposes. Northeast of Wallops Island is Assateague Island, managed by the USFWS as part of the CNWR, which lies mostly east and north of Wallops Island. Immediately south of Wallops Island is Assawoman Island, a 580 ha (1,420 ac) parcel also managed as part of the CNWR by the USFWS. A string of undeveloped barrier islands, managed by TNC as part of the Virginia Coast Reserve, extends down the coast to the mouth of the Chesapeake Bay.

The Wallops Island National Wildlife Refuge is located south of the NASA WFF Visitor Center and is under the jurisdiction of the USFWS. This refuge is not open to the general public and consists of approximately 151 ha (373 ac) of mostly salt marsh and some forested land across State Route 175 from the Main Base. Additionally, the USFWS, through the CNWR, has an agreement with NASA to use Wallops Island on a non-interference basis for research and management of declining wildlife species in need of special protection.

**Department of Transportation Section 4(f) Properties**

Several wildlife refuges that are Section 4(f) properties are located within the vicinity of WFF. Immediately adjacent to the Main Base is the USFWS Wallops Island National Wildlife Refuge. Assawoman Island, which lies immediately south of Wallops Island, and the northern portion of Metompkin Island, which lies immediately south of Assawoman Island, are also owned by the USFWS as part of the CNWR. Assawoman Island is closed year round except for seasonal boat and fishing access on the southern tip. The northern part of Metompkin Island is owned by the USFWS and the southern half is owned by TNC; both portions are open to the public for low impact, recreational daytime activities, such as hiking, bird watching, fishing, and photography. The CNWR's Assateague Island is located across the Chincoteague Inlet approximately 9.6 km (6 mi) northeast of Wallops Island. In conjunction with USFWS, NPS manages AINS, the public beach portion of CNWR. The seashore consists of 24 km (15 mi) of undeveloped beach habitat and shoreline in Virginia and Maryland.

**Surrounding Areas**

Land use surrounding WFF is predominately zoned agricultural and forested with rural farmland and small villages making up the majority of the surrounding areas (Accomack County 2014). Corn, wheat, soybeans, cabbage, potatoes, cucumbers, and tomatoes are examples of the commodities produced on the surrounding farms. Small tracts of land to the west, directly abutting WFF, are zoned industrial, residential, or general business by Accomack County. However, the majority of the adjacent land is zoned agricultural (Accomack County 2014). Unincorporated towns near the facility are Wattsville, 1.6 km (1 mi) west of the Main Base; Horntown, 4 km (2.5 mi) north of the Main Base; and Atlantic, 4.4 km (2.8 m) southwest of the Main Base. Each of these towns has a population of fewer than 500 people. Area businesses include fuel stations, retail stores, markets, and restaurants.

The Town of Chincoteague, located approximately 8 km (5 mi) east of the Main Base and 24 km (15 mi) northeast of Wallops Island, is the largest community in the area, with approximately 4,300 permanent residents. The island attracts a large tourist population during the summer months to visit the public beaches and attend the annual pony swim and roundup in July. During the summer months, the Island population expands to approximately 15,000 (Town of Chincoteague 2010). Numerous hotels and restaurants, as well as other seasonally based tourist businesses, can be found on Chincoteague.

The 2015 JLUS prepared by Accomack County lists the following recommendations to address existing and future potential incompatible land use:

Short-Term Recommendations

- Establish an Accomack-Wallops Working Group.
- Amend/Update the Accomack County Comprehensive Plan to incorporate information contained in the JLUS Study.
- Pursue available grants and/or supplemental funding sources for JLUS recommendations.
- Establish a process for mitigating existing incompatibilities within the WFF aircraft clear zones.
- Establish a collaborative review process for requests relating to development of commercial wind turbines, cell towers, radio frequency emitters or structures.
- NASA and/or Navy notify Accomack County and Working Group of offshore energy development to identify potential operational interference.

Short-to-Mid-Term Recommendations

- Establish a Rocket Range Hazard notification area and provide notifications of hazards associated with rocket launches.

Mid-Term Recommendations

- Establish a WFF Aircraft Operations Overlay District and amend the Accomack County Zoning Ordinance and Subdivision Ordinance for compatible land use in Clear Zone, APZ 1, and APZ 2, and other affected areas.
- Adopt measures for early and full real estate disclosure with respect to properties located within aircraft accident potential and noise zone. Pursue Commonwealth of Virginia legislation to amend 55-517/55-519 (Required disclosures) to include military aircraft operations on non-military airfields.
- Provide information regarding incentives for retrofits to windows on existing buildings within the Rocket Range Hazard Area.
- Encourage the application of noise attenuation measures within the aircraft noise zones as part of the permitting process for new construction.

Long-Term Recommendations

- Develop a plan for mitigating and/or accommodating the effects of recurrent flooding, storm surge events, and sea level rise for the Navy, NASA, Mid-Atlantic Regional Spaceport/VCSFA facilities on WFF Wallops Island.
- Develop a plan for mitigating and/or accommodating the effects of recurrent flooding, storm surge events, and sea level rise for the coastal areas of Accomack County within the study area.

On-Going Recommendations

- Provide an annual update to the Accomack County Board of Supervisors regarding JLUS implementation progress.
- Update the Accomack County GIS database with JLUS Report data following adoption by the County Board of Supervisors.

### 3.6.2 ENVIRONMENTAL CONSEQUENCES

Impacts to land use would be considered significant if the Proposed Action created a situation where land uses were incompatible with 2008 WFF's Master Plan, or if land uses outside the WFF boundary were detrimentally impacted by WFF operations.

#### 3.6.2.1 No Action Alternative

3.6.2.1.1 Institutional Support Projects

**Main Base, Mainland, Wallops Island**

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Therefore, there would be no additional impacts to land use from institutional support projects under this alternative. Any substantial changes to the design of approved construction projects would require site-specific NEPA analysis.

**Department of Transportation Section 4(f) Properties and Surrounding Areas**

Areas surrounding WFF would continue to be utilized as they currently are, consistent with future land uses and zoning approved by USFWS, NPS, the Town of Chincoteague, or Accomack County, respectively. Institutional support projects would be compatible with Accomack County's zoning ordinances, with the exception of infrequent rocket launches, which would not exceed OSHA noise standards at sensitive receptors (see Section 3.1, Noise). The No Action Alternative would have no impacts to land use or Section 4(f) properties in the areas surrounding WFF.

3.6.2.1.2 Operational Mission Activities

**Main Base, Mainland, Wallops Island**

There would be no impacts to land use or changes to existing land use due to current operational missions and activities at WFF. All operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS and they are within the parameters outlined by the 2008 WFF Facility Master Plan. WFF will work with Accomack County, the Navy and partner members that participated in the Accomack County/Wallops Island JLUS on any potential changes in zoning or other appropriate land use controls around the installation.

**Department of Transportation Section 4(f) Properties and Surrounding Areas**

Areas surrounding WFF would continue to be utilized as they currently are, consistent with zoning and future land uses approved by Accomack County. Ongoing operational missions and activities would be compatible with Accomack County's zoning ordinances, with the exception of infrequent rocket launches, which would not exceed OSHA noise standards at sensitive receptors (see Section 3.1, Noise). The No Action Alternative would have no impacts to land use or Section 4(f) properties in the areas surrounding WFF.

#### 3.6.2.2 Proposed Action

##### 3.6.2.2.1 Institutional Support Projects

**Construction, Demolition, and RBR Projects**

A number of proposed construction and demolition projects would take place at the Main Base, as well as at the Mainland and Wallops Island (refer to **Table 2.5-1** and **Table 2.5-2**). These include construction of the Commercial Space Terminal, extension of Runway 04/22, replacement of the Causeway Bridge, and construction of Launch Pad 0-C and two DoD launch pads.

**Main Base, Mainland, Wallops Island**

Institutional support projects would include construction, demolition, or RBR projects to update aging infrastructure and to accommodate the future missions of WFF. These projects would occur in areas currently zoned as either agricultural or industrial by Accomack County. According to Accomack County's future land use plans, Wallops Island would be designated as a "conservation area." This type of land use is aimed at "preserving and protecting Accomack County's areas of ecological importance" by causing as little disturbance as possible. These areas include marshland and undeveloped barrier islands such as Wallops Island (Accomack County 2014).

Accomack County has taken a "pro-WFF" stance on matters such as land use and encroachment. In its 2014 Comprehensive Plan Update, the County states that "(NASA's) need to operate these facilities in an area with low population density is also compatible with local goals to foster the agricultural industry, conserve wildlife habitat, and promote tourism" (Accomack County 2014). Therefore, implementation of the institutional projects under the Proposed Action would be consistent with Accomack County's land use plans. Additionally, no construction projects associated with the Proposed Action would require changes to land use designations. Therefore, there would be no impacts to land use within WFF boundaries.

**Department of Transportation Section 4(f) Properties and Surrounding Areas**

Implementation of the institutional support projects associated with the Proposed Action would have no impacts to land uses or Section 4(f) properties in the areas surrounding WFF. All projects would occur within the WFF boundaries, with the exception of maintenance dredging. Maintenance dredging activities would impact state-owned subaqueous lands that are leased and managed by the VMRC. Some of the areas along the maintained dredge route are currently leased for shellfish harvesting and/or aquaculture. The subaqueous land leases that would be impacted from maintenance dredging would require individual mitigations or other compensation for losses of productivity due to the maintenance dredging. These impacts are described further in Section 3.11, Marine Mammals and Fish.

In conclusion, no land use changes would be required, no change in land use designations would be needed, and no NHRP-eligible structures would be impacted with implementation of institutional support projects under the Proposed Action. No DOT 4(f) properties would be either directly or indirectly impacted from implementation of institutional support projects under the Proposed Action. As such, no significant impact to land use would occur.

3.6.2.2.2 Operational Missions and Activities

**Main Base, Mainland, Wallops Island**

Several new operational proposals are being considered. DoD SM-3, Directed Energy, SODAR System, and increased UAS operations from the North Wallops Island UAS airstrip would not impact land use at WFF, as these projects would occur within the areas designated for such operations.

**Expanded Space Program**

Under the Expanded Space Program, launching of LFIC LVs and SFHC LVs from proposed Launch Pad 0-C would have similar impacts as current rocket launch activities. Launch Pad 0-C would be constructed south of Pad 0-B, where the current UAS airstrip is located. It is unlikely that this new hazard arc would cause any operational impacts on Wallops Island, as most of the area that would encompass the arc from Launch Pad 0-C is already included in the largest anticipated hazard arc (i.e., 3,050 m [10,000 ft]) for Launch Pad 0-B as illustrated in **Figure 3.4-2**. However, the addition of Launch Pad 0-C and the associated maximum hazard arc (see **Figure 3.4-2**) would extend outside the Wallops Island boundary and onto the private lands adjacent to Wallops Mainland that are zoned for agricultural use. Although much of this area is already encompassed by the Range Accident Potential Zone defined in the 2014 Accomack County Comprehensive Plan for Launch Pad 0-B, the Launch Pad 0-C hazard arc would extend slightly beyond this Zone. WFF would work with Accomack County as it did in establishing the current Range Accident Potential Zone, to either extend or expand the Zone to limit development inside the Zone. The JLUS recommendations will be integral in providing guidance for future planning efforts at WFF. Details for Launch Pier 0-D are not known; however, the location currently proposed is near Launch Pad 0-C; this location would be mostly encompassed in the Launch Pad 0-B hazard arc (refer to **Figure 3.4-2**) and as such would not be expected to impact launch operations on the Island. If the Launch Pier 0-D proposal is considered in the future, WFF would work with Accomack County to either extend or expand the Range Accident Potential Zone to encompass the associated hazard arc.

An increase in noise and affected land areas associated with Expanded Space Program, including larger LVs is anticipated (refer to **Table 3.1-8)**. Operational noise would not exceed OSHA noise standards at sensitive receptors; noise from the larger LV launches would be experienced for a duration of less than 10 minutes with peak noise occurring in the first couple of minutes. WFF notifies the public in advance of these launches. Given that rocket launches already occur and no noise complaints from rocket launches have been filed with WFF in recent years (Eggers 2017), it is unlikely that activities under the Expanded Space Program would create an adverse impact.

Vertical launch and landing vehicles, horizontal launch and landing vehicles, and use of launch vehicles for commercial human spaceflight missions would not require changes to land use since the launch vehicles would be operated in areas designated for such operations; therefore, there would be no impacts to land use within WFF boundaries and there would be no impacts to land use in the areas surrounding WFF.

**Department of Transportation Section 4(f) Properties**

According to Section 4(f), substantial impairment would occur when impacts are sufficiently serious that the value of the site in terms of its prior significance and enjoyment are substantially reduced or lost. Section 4(f) prohibits park and recreation lands, and wildlife and waterfowl refuges from being converted to non-recreational use on Federal lands or other public land holdings (e.g., State forests) unless approval is received from the Secretary of the DOT. Mitigation measures that eliminate or reduce the effects of a physical or constructive use are considered when evaluating impacts. The FHWA and FAA consult with all appropriate Federal, state, and local officials having jurisdiction over affected Section 4(f) properties when determining the potential impact on the properties.

The Proposed Action would not be considered a physical or constructive use of 4(f) properties as impacts from the Proposed Action would not adversely impact parks, recreation areas, wildlife refuges or NRHP-eligible structures. Closures of the southern end of CNWR and AINS could be required for LV launches or RLV landings from Launch Pad 0-C or from Launch Pier 0-D. Additionally, USFWS overland access to adjacent Assawoman Island (also part of CNWR) could be restricted when pre-launch and launch day hazard arcs are activated. NASA has an established agreement with USFWS and NPS for such closures and coordinates with USFWS and NPS personnel during mission planning to ensure that closures do not adversely affect CNWR and AINS activities. The value of CNWR and AINS in terms of its significance and enjoyment is not substantially reduced or lost due to launch activities at WFF. Instead, the northern area of CNWR and AINS has become a popular observation location for viewing NASA and MARS launches (NASA 2009).

USFWS concurs with the determination that the Proposed Action would not be considered a physical or constructive use of 4(f) properties as described above (see **Appendix B**).

**Surrounding Areas**

Operational proposals are generally unlikely to have significant impacts to land uses outside the WFF boundary. Activities from the DoD SM-3 and Directed Energy proposals would occur over the Atlantic Ocean in the VACAPES OPAREA and would have no impacts to land use outside of WFF. SODAR System would be utilized within the boundaries of WFF and would not impact the surrounding areas. UAS operating from the North Wallops Island UAS airstrip would operate primarily in the NASA controlled restricted airspace or in the VACAPES OPAREA; UAS would not overfly populated areas or be expected to impact land use in the surrounding areas.

In conclusion, no land use changes would be required, no change in land use designations would be needed, and no NHRP-eligible structures or DOT 4(f) properties would be impacted with implementation of operational missions and activities as described under the Proposed Action. As such, no significant impact to land use would occur. Neither FHWA or FAA would be required to prepare a 4(f) evaluation.

## 3.7 LAND RESOURCES

Land resources for this PEIS describe physical surface characteristics such as topography, geology, seismology, and soils of the affected land areas.

### 3.7.1 AFFECTED ENVIRONMENT

**Topography**

The topography at WFF is typical of the Mid-Atlantic coastal region, generally low-lying with elevations ranging from sea level to 15 m (50 ft) above MSL. The Main Base, Mainland, and Wallops Island all lay within the Tidewater region of the embayed section of the Atlantic Coastal Plain Physiographic Province. The three major landforms found at the WFF site are mainland, tidal marsh, and barrier island.

The majority of the Main Base is located on a high terrace landform (8 to 12 m [25 to 40 ft] above MSL) with the northern and eastern portions located on low terraces (0 to 8 m [0 to 25 ft] above MSL) and tidal marsh. The Mainland is primarily located on low terrace and tidal marsh and Wallops Island is a barrier island with extensive tidal marshes between Wallops Island and the Mainland.

The Mainland includes low and high terraces separated by a discontinuous escarpment (transition zone) between different physiogeographic provinces. Low terraces are found on the extreme eastern edge of Wallops Mainland. The low terrace consists of broad to narrow flats bordered by tidal marshes on the east and a discontinuous escarpment on the west. The high terrace ranges in elevation from 8 to 15 m (25 to 50 ft) above MSL. The high terrace topography is more complex than the low terrace and is generally characterized by broad, nearly level terraces that are broken by narrow elliptical ridges (Carolina Bay features), gentle escarpments, tidal creeks, and drainage ways (NASA 2016).

Extensive tidal marshes are located between the Mainland and barrier islands. The marshes flood regularly with the tides, are drained by an extensive system of meandering creeks, and have immature soils. Barrier islands are generally parallel to the mainland and are usually less than 3 m (10 ft) above MSL. Topography varies from nearly level to steep.

Wallops Island is separated from the Main Base and Wallops Mainland by numerous inlets, marshes, bays, creeks, and tidal estuaries. Wallops Island is a barrier island approximately 11 km (7 mi) long and 810 m (2,650 ft) wide. It is bordered by Chincoteague Inlet to the north, Assawoman Island to the south, the Atlantic Ocean to the east, and marshland to the west. During storms, flood water from the Atlantic Ocean moves through these inlets and across the marshes to low-lying areas along the coast. Previously, Assawoman Inlet would intermittently open during and after major storm events. However, the inlet is now closed in and connects Assawoman and Wallops Islands. The sandy portion of Wallops Island has an elevation of about 2 m (7 ft) above MSL. Presently, the highest elevation on Wallops Island is approximately 5 m (15 ft) above MSL. However, most of the island is less than 3 m (10 ft) above MSL (U.S. Department of Agriculture [USDA] 1994, 2004).

**Geology**

Located within the Atlantic Coastal Plain Physiographic Province, WFF is underlain by approximately 2,100 m (7,000 ft) of sediment. The sediment lies atop crystalline basement rock. The sedimentary section, ranging in age from Cretaceous to Quaternary, consists of a thick sequence of terrestrial, continental deposits overlain by a much thinner sequence of marine sediments. These sediments are generally unconsolidated and consist of clay, silt, sand, and gravel. The regional dip of the sediments is to the east, toward the ocean. The two uppermost stratigraphic deposits at WFF are the Yorktown Formation and the Columbia Group, which is not subdivided into formations. The Yorktown Formation is the uppermost unit in the Chesapeake Group and was deposited during the Pliocene epoch of the Tertiary Period. The Yorktown Formation generally consists of fine to coarse, glauconite quartz sand, which is greenish gray, clayey, silty, and, in part, shelly. The Yorktown Formation occurs at depths of 20 to 40 m (60 to 140 ft) in Accomack County (Virginia Division of Minerals 1972).

**Seismology**

Virginia is located centrally on the North American Plate (where the Earth's crust is thicker than at the edges) and has not had a history of seismic activity. In 1993, Texaco, Inc. and Exxon Exploration Company were exploring beneath the Chesapeake Bay for structures that might contain oil and gas. As part of their search, they created a seismic profile of the Chesapeake Bay Impact Crater. These profiles showed clearly that a huge peak-ring impact crater is buried beneath the Bay and is centered near the town of Cape Charles on Virginia's Eastern Shore. The crater is approximately 85 km (53 mi) in diameter and about 1.3 km (0.8 mi) deep (USGS 2016). The largest earthquake to strike Virginia occurred on August 23, 2011, and registered a magnitude of 5.8 at the epicenter near Mineral, located in Louisa County, Virginia. On March 15, 2015, an earthquake registered a magnitude of 2.8 at the epicenter located approximately 8 km (5 mi) southeast of Louisa County, Virginia (USGS 2017).

**Soils**

Coastal Plain soils of the Eastern Shore are generally very level and many types are classified by the USDA as prime farmland – land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and that is available for these uses. Prime and unique farmlands in Accomack County are classified as the following soil types:

- Bojac fine sandy loam soils,
- Bojac loamy sand soils,
- Munden fine sandy soil,
- Munden loamy sand,
- Dragston fine sandy loam, if adequately drained, and
- Nimmo fine sandy loam, well-drained.

The predominant soil types at WFF are shown in **Table 3.7-1**. The dominant soils are high in sand content, resulting in a highly leached condition, an acidic pH, and a low natural fertility (USDA 2004).

**Table 3.7-1. Predominant Soil Types at Wallops Flight Facility**

| Location | Soil Type | Typical Slopes | Description |
|---|---|---|---|
| Main Base – inland areas | Bojac fine sandy loam | 0-2% | Nearly level, very deep, well-drained soils. Suitable for agriculture. |
| Main Base – perimeter areas | Molena loamy sand | 6-35% | Very deep and somewhat excessively drained. The severe erosion potential and low availability of water make it unsuitable for cultivation. |
| Wallops Mainland –western portion | Bojac loamy sand | 2-6% | Gently sloping, very deep, well-drained; can be used for cultivation; sloping and erodibility limit its productivity. |
| Wallops Mainland –middle portion | Magotha fine sandy loam | 0-2% | Nearly level, very deep, poorly drained hydric soils. This soil provides a suitable wildlife habitat. |

**Table 3.7-1. Predominant Soil Types at Wallops Flight Facility (cont.)**

| Location | Soil Type | Typical Slopes | Description |
|---|---|---|---|
| Wallops Mainland – eastern and Wallops Island western portions | Chincoteague silt loam | 0-1% | Nearly level, very deep, very poorly drained hydric soils. This soil provides a suitable wildlife habitat. |
| Wallops Island –eastern portion | Chincoteague silt loam | 0-1% | Nearly level, very deep, very poorly drained hydric soils. This soil provides a suitable wildlife habitat. |
| Wallops Island – east of Chincoteague silt loam | Udorthents and Udipsamments | 0-35% | Nearly level to steep, very deep, and range from well-drained to somewhat poorly drained. |
| Wallops Island –southern end | Fisherman Assateague fine sands complex | 0-35% | Nearly level to steep, very deep, moderately well-drained, to excessively drained. This soil provides wildlife habitat and recreation. |
| Wallops Island – depressions and areas associated with dunes and salt marshes | Fisherman Comacca fine sands complex | 0-6% | Very poorly to moderately well-drained. |
| Wallops Island – central and western portions in depressions and on flats associated with dunes and marshes | Comacca fine sand | 0-2% | Nearly level, very deep, very poorly drained. The soil provides wildlife habitat and recreation. |
| Wallops Island –eastern portion | Assateague fine sand | 2-35% | Gently to steeply sloping, very deep, excessively drained. This soil is rarely flooded and provides wildlife habitat and recreation. |
| Wallops Island – eastern portion | Beaches | 1-5% | Moderately sloping and provides wildlife habitat. |

Source: USDA 2004.

### 3.7.2 Environmental Consequences

Impacts to land resources would be considered significant if major changes to topography or underlying geology occurred. This would involve the alteration of unique geologic formations or creating a situation that would cause the degradation or irreparable damage to natural land forms, topography, or exceptional loss of soils through erosion.

#### 3.7.2.1 No Action Alternative

##### 3.7.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation’s current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS; therefore, there would be no additional impacts to land resources from institutional support projects under this alternative. Any substantial changes to the design of approved construction projects would require site-specific NEPA analysis.

##### 3.7.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational programs that are within the installation’s current envelope. All operational programs under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS; therefore, there would be no additional impacts to land resources from operational missions and activities under this alternative.

### 3.7.2.2 Proposed Action

#### 3.7.2.2.1 Institutional Support Activities

**Construction, Demolition, and RBR Projects**

Under the Proposed Action, institutional support projects at WFF would include a wide range of construction, demolition, and RBR projects (refer to **Table 2.5-1** and **Table 2.5-2**). The majority of these projects would occur on lands that already contain buildings or have been previously disturbed; however, some institutional support projects would occur on previously undisturbed land. The specific amounts and types of soils that would be impacted by these projects would depend on final design plans and building footprints. Construction activities have the potential to cause soil erosion; therefore, a site-specific Erosion and Sediment Control Plan would be developed and utilized to ensure that soil erosion during construction is minimal. This plan would implement BMPs that are outlined in the facility's SWPPP and Erosion and Sediment Control Plan. These BMPs could include using silt fencing, soil stabilization blankets, and matting around areas of land disturbance during construction. Bare soils would be vegetated after construction to reduce erosion and stormwater runoff velocities. Minor changes to topography would occur in areas that would be graded for new construction. There would be no impacts to geology from institutional support projects. NASA or other local building codes and engineering standards would compensate for seismic risks.

Regarding Launch Pier 0-D, no design specifications for either of the two optional locations are available at this time. Future planning and design would include measures to minimize, to the extent practicable, impacts to sediment and sand transport from the oceanside option. Once design plans are known, additional NEPA analysis would be performed prior to permitting and construction. With the proper use of BMPs, impacts to land resources from institutional support projects under the Proposed Action would be minor; no significant impacts to land resources would be anticipated. Refer to **Section 4.1.6** (Land Resources) for measures to mitigate impacts to land resources under the Proposed Action.

#### 3.7.2.2.2 Operational Missions and Activities

**Expanded Space Program**

Most operational missions that would be conducted under the Proposed Action would not impact land resources at WFF. However, under the Expanded Space Program, the preferred launch site for the LFIC LV is the proposed Launch Pad 0-C or a modification of Pad 0-B[6]. Launch of a LFIC LV, with a liquid propellant first stage using RP-1, would result in the emission of CO and $CO_2$.

When CO and $CO_2$ combine with water vapor in the air, carbonic acid may form which could result in the deposition of carbonic acid on the ground in the area surrounding the launch pad. The effects of carbonic acid deposition on the adjacent tidal wetland area soils would be minimal as carbonic acid is a weak acid (approximate pH of 6.4) and is normally found in rainwater. This impact would be limited to a small area adjacent to the launch pad.

[6] The modification of Launch Pad 0-B is not considered in this PEIS. If modification of Launch Pad 0-B is considered in the future, NEPA documentation would be required.

The preferred launch site at WFF for the SFHC LV is modification of Pad 0-B[1] or the proposed Launch Pad 0-C. With the launch of the larger SFHC, its exhaust plume would contain large concentrations of HCl and $Al_2O_3$. The plume created by a rocket launch has the potential to cause deposition of HCl and $Al_2O_3$ on the soil adjacent to the launch pad (refer to Section 3.6.2.2.2).

This could result in temporary acidification and an increase in aluminum in these soils; however, the potential deposition of HCl and $Al_2O_3$ per launch would be minimal (U.S. Air Force 1998). This impact would be limited to a small area adjacent to the launch pad.

Potential impacts to land resources from vertical launch and landing vehicles and launch vehicles used for commercial human spaceflight missions would likely be similar to those described for the LFIC LV or SFHC LV. Impacts would be limited to a small area adjacent to the launch/return site. Horizontal launch and landing vehicles generally operate the same as standard aircraft. The proposed extended Runway 04/22 at the Main Base would be used for these vehicles. No impact to land resources adjacent to the runway would be anticipated.

In summary, no significant impact to land resources would be anticipated as WFF would implement site-specific SWPPPs, BMPs, and Erosion and Sediment Control Plans as required for the operational missions and activities as described under the Proposed Action. Refer to **Section 4.1.6** (Land Resources) for measures to mitigate impacts to land resources under the Proposed Action.

## 3.8 VEGETATION

Vegetation refers to the native and anthropogenic plant material that exists at WFF. Since the Proposed Action would occur at all three distinct locations of WFF, a general description of the vegetation communities that exist throughout WFF are provided below. Area calculations for vegetation communities are taken from the continually updated WFF GIS database (WFF 2017).

### 3.8.1 AFFECTED ENVIRONMENT

The vegetation communities at WFF vary depending on the location. The affected environment section has been divided into Main Base, Mainland, and Wallops Island. A full description of the vegetation communities is provided for each geographic area. In addition, separate sections have been included to discuss submerged aquatic vegetation (SAV) and invasive species.

#### 3.8.1.1 Main Base

The 778 ha (1,924 ac) Main Base is composed of three main vegetation communities: managed/maintained, forests, and wetlands (**Table 3.8-1** and **Figure 3.8-1**). The Main Base is dominated by vegetation classified as managed/maintained or anthropogenic/planted vegetation.

The majority of these areas are maintained as open grassland necessary for the mission; however, some areas are landscaped. In addition, there are approximately 103 ha (255 ac) of impervious surfaces consisting of roads, parking lots, airfield runways, buildings, and unpaved parking areas and roads with no vegetation (WFF 2017). Forested areas cover 22% of the Main Base and vary in composition based on historical land use and site conditions, but three main classifications prevail: hardwood, pine, and mixed pine-hardwood. The remaining area is comprised of wetlands which include emergent and scrub-shrub wetland areas; wetland vegetation and wetland impacts are discussed in detail in Section 3.5, Water Resources and will not be further discussed in this section.

| Table 3.8-1. Vegetation Communities at Wallops Flight Facility Main Base | |
|---|---|
| **Community** | **Main Base** |
| Managed/Maintained | 344 ha (850 ac) |
| Forests | 175 ha (432 ac) |
| Wetlands (Emergent estuarine and Scrub-Shrub) | 156 ha (387 ac) |
| Impervious Surfaces and Unpaved Roads/Parking* | 103 ha (255 ac) |
| **Total** | **778 ha (1,924 ac)** |

Source: WFF 2017.
Note: *This line item was included so that the total acreage for the Main Base was taken into account.

Managed/maintained vegetation at the Main Base occurs in areas that are either mission critical (i.e., runway clear zones) or are landscaped for aesthetic or stormwater management purposes. Common species that occur in areas maintained by mowing are crabgrass (*Digitaria sanguinalis*), Bermuda grass (*Cynodon dactylon*), meadow fescue (*Schedonorus pratensis*), bluegrasses (*Poa* spp.), sheep sorrel (*Rumex acetosella*), chickweeds (*Cerastium* spp.), and other non-native weedy species. A variety of landscape and ornamental trees and shrubs are utilized in areas that are maintained for aesthetic purposes. Commonly used native species are loblolly pine (*Pinus taeda*) and American holly (*Ilex opaca*).

Non-native species used for landscaping include Bradford pear (*Pyrus calleryanaI*), autumn olive (*Elaeagnus umbellata*), thorny olive (*Elaeagnus pungens*), ornamental cherry (*Prunus sp*.), and privet (*Ligustrum spp.*). There are three areas of wetlands on the Main Base that function as part of the stormwater management system around the airfield. These semi-natural communities are classified as managed/maintained vegetation because they are within the runway clear zones; therefore, the vegetation height is maintained by mowing or brush cutting (NASA 2008).

Forested areas on the Main Base can be broken down into hardwood forests and mixed pine-hardwood forests. The species composition of hardwood forests in the area varies by specific location. Hardwood forests that occur on upland ridges and slopes contain red oak (*Quercus rubra*), southern red oak (*Q. falcata*), white oak (*Q. alba*), hickories (*Carya* spp.), yellow poplar (*Liriodendron tulipifera*), black cherry (*Prunus serotina*), sweetgum, and scattered loblolly pine. Mid-story species include dogwood (*Cornus florida*) and American holly. Under-story shrub species include dwarf huckleberry (*Gaylussacia dumosa*) and strawberry bush (*Euonymus americanus*). Herbaceous vegetation in these areas can vary greatly between sites and by season but some common species for the area are mayapple (*Podophyllum peltatum*), partridgeberry (*Mitchella repens*), Christmas fern (*Polystichum acrostichoides*), Solomon's seal (*Polygonatum biflorum*), bellwort (*Uvularia perfoliata*), and false lily of the valley (*Maianthemum racemosum*) (NASA 2008).

Hardwood forests that are found in floodplains and other wet areas contain a different set of species than upland hardwood forests; however, some species are common to both habitat types. The over-story in these areas contains blackgum (*Nyssa sylvatica*), sweetgum, red maple, black willow (*Salix nigra*), and willow oaks (*Quercus phellos*). Smaller trees and shrubs in this habitat include American hornbeam (*Carpinus caroliniana*), spice bush (*Lindera bezoin*), blue huckleberry (*Gaylussacia frondosa*), viburnums (*Viburnum* spp.), and sweet pepperbush (*Clethra alnifolia*). Herbaceous under-story vegetation in this habitat includes sensitive fern (*Onoclea sensibilis*), cinnamon fern (*Osmunda cinnamomea*), sedges (*Cyperaceae*), rushes (*Juncaceae*), and other grasses and forbs. Robin's plantain (*Erigeron pulchellus*) was also observed in one hardwood stand on WFF Main Base.

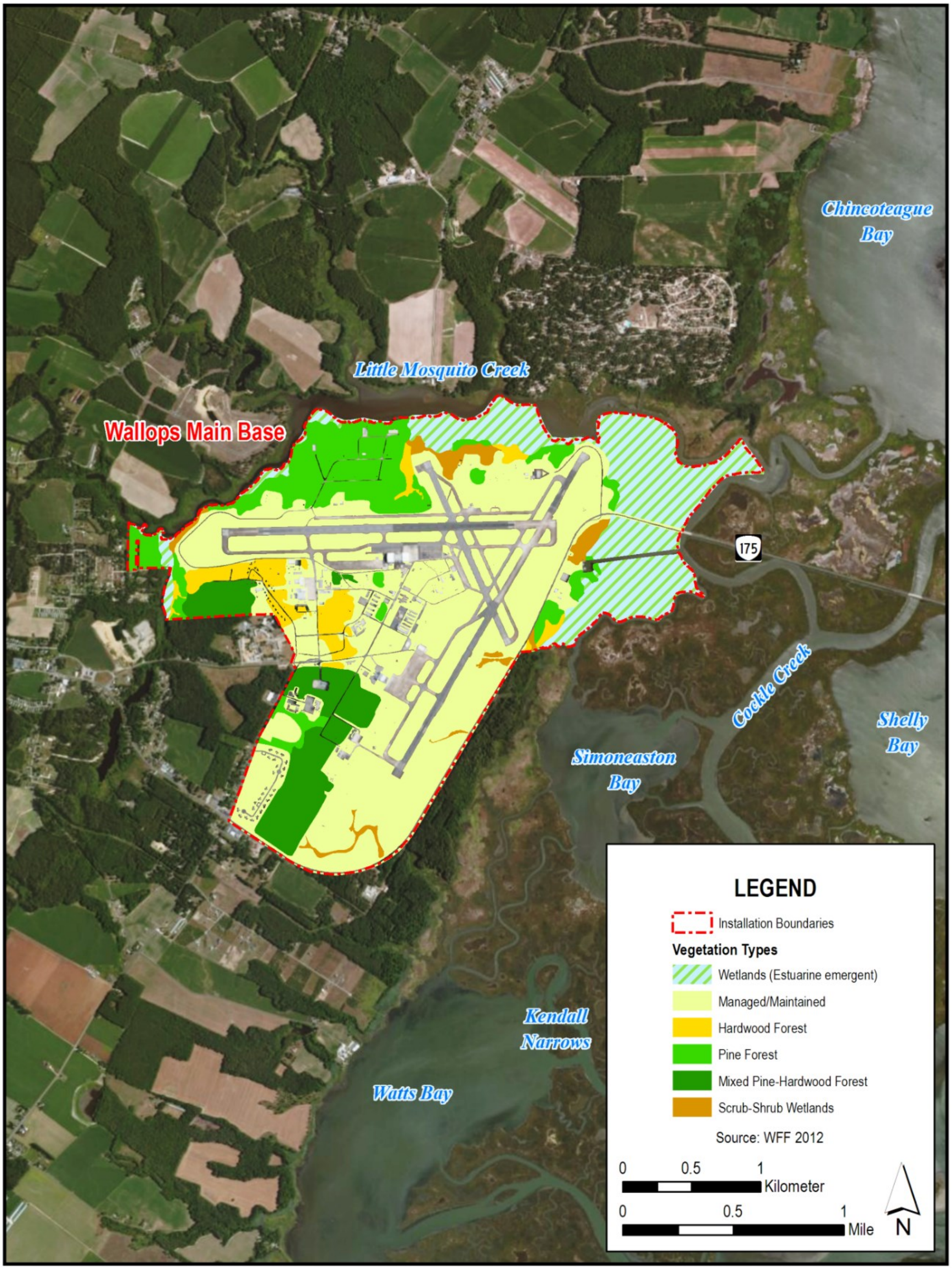


**Figure 3.8-1. Vegetation Communities at Wallops Flight Facility Main Base**

Pine forests at the Main Base are composed mostly of loblolly pine, but can also contain Virginia pine (*Pinus virginiana*) and hardwood species. Common hardwood species in pine forests are yellow poplar and sweetgum and older pine stands can contain oaks and hickories. Mid-story and under-story cover in dense pine stands is usually sparse. However, the species composition is variable, as it is with hardwood forests. One site at the Main Base contains a large population of pink ladyslippers (*Cypripedium acaule*). Other under-story species found in pine stands include vines like muscadine grape (*Vitis rotundifolia*) and trumpet creeper (*Campsis radicans*) (NASA 2016).

The mixed pine-hardwood forests at the Main Base mostly contain a mix of the species described above for the hardwood and pine forests and are usually transitional between pine and hardwood. Succession usually favors hardwoods unless there is disturbance in the area. Wet areas contain a mix of sweetgum, red maple, yellow poplar, and loblolly pine. Under-story species in wet areas include northern bayberry (*Morella pensylvanica*), wax myrtle (*Morella cerifera*), groundsel tree, and devil's walkingstick (*Aralia spinosa*). Drier sites are usually first colonized by pine but over time red oak and white oak develop and become co-dominants. Under-story species in dry areas include mountain laurel (*Kalmia laurifolia*), fetterbush (*Leucothoe racemosa*), and maleberry (*Lyonia ligustrina*) (NASA 2016).

### 3.8.1.2 Mainland

The majority (90%) of the Mainland consists of estuarine emergent wetland vegetation with some managed/maintained areas, scrub-shrub, and hardwood forests (**Table 3.8-2** and **Figure 3.8-2**). Wetland vegetation is discussed in detail in Section 3.5, Water Resources.

**Table 3.8-2. Vegetation Communities at Wallops Flight Facility Mainland**

| Community | Mainland |
|---|---|
| Managed/Maintained | 29 ha (72 ac) |
| Hardwood Forest | 5 ha (13 ac) |
| Wetlands(Estuarine emergent) | 460 ha (1,135 ac) |
| Scrub-Shrub | 15 ha (36 ac) |
| Impervious Surfaces* | 1 ha (2 ac) |
| **Total** | **510 ha (1,258 ac)** |

Source: WFF 2017.
Note: *This line item was included so that the total acreage for the Main Base was taken into account.

The managed/maintained vegetation at the Mainland consists of grass fields and lawns. These areas are maintained by mowing and are required for mission support. Plant species that exist in these areas are similar to those mentioned for the managed/maintained vegetation community at the Main Base (NASA 2016).

The forests at the Mainland are composed of upland and swamp forests. Upland forests are composed of mixed pine-hardwood species in the over-story. These include loblolly pine, black cherry, and red maple. The under-story consists mostly of sassafras (*Sassafras albidum*) and bayberries. The swamp forests at the Mainland have hardwoods such as black willow and red maple in the over-story. The under-story of the swamp forests contains similar species as those listed above for the floodplain hardwood forests at WFF Main Base. A major invasive species that occurs in the forests at the Mainland is Asiatic tearthumb (*Polygonum perfoliatum*), which is also referred to as mile-a-minute (NASA 2016).

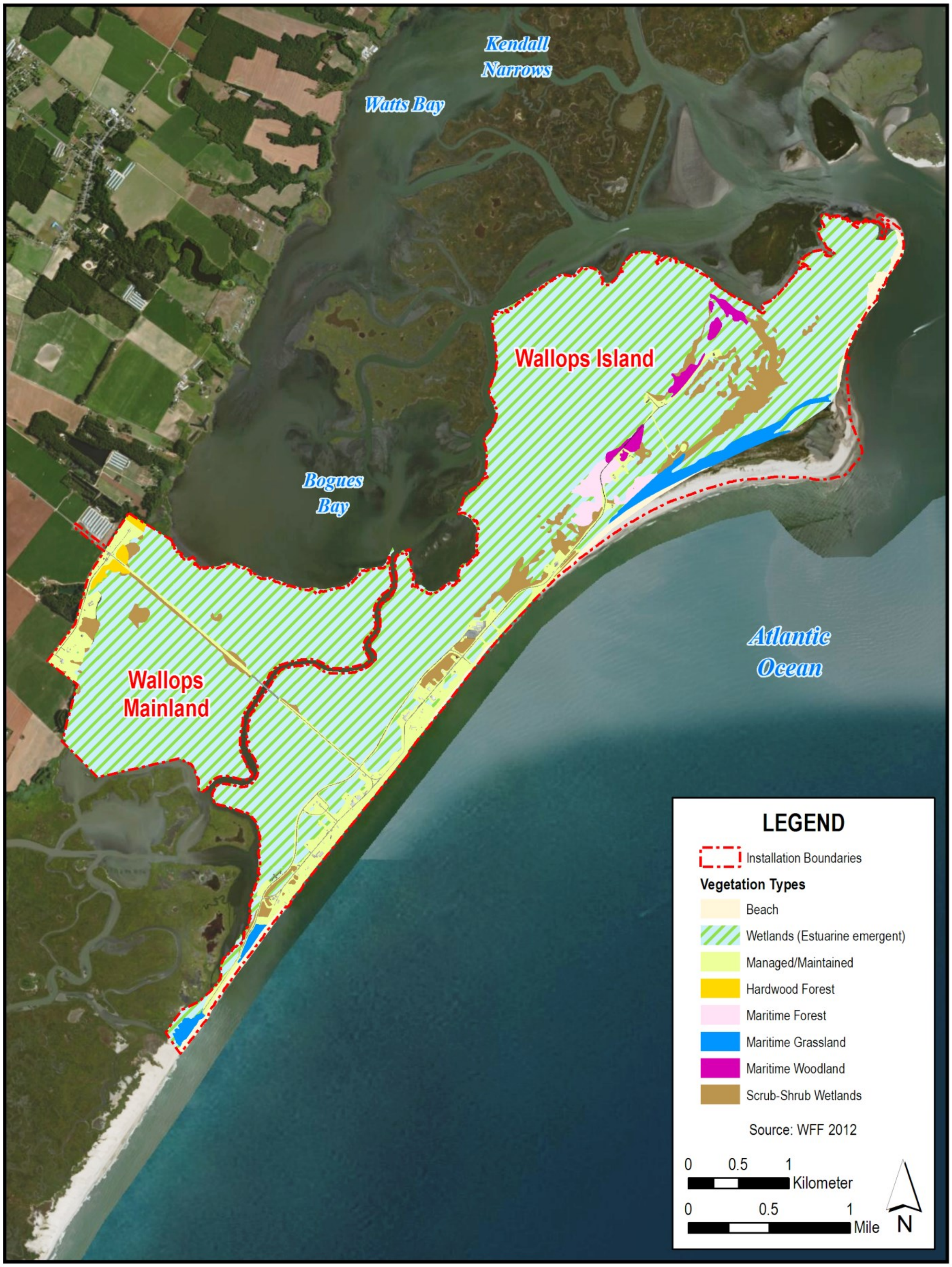


**Figure 3.8-2. Vegetation Communities at Wallops Flight Facility Mainland and Wallops Island**

### 3.8.1.3 Wallops Island

Wallops Island is a coastal barrier island that contains some similar vegetation communities found on the Main Base and Mainland; however, there are a variety of habitat types found on Wallops Island that do not occur in other areas of WFF. The approximately 1,335 ha (3,300 ac) Wallops Island consists of beaches, maritime grassland, maritime scrub, maritime woodland, maritime forest, wetlands (estuarine emergent), and managed/maintained areas (**Table 3.8-3** and **Figure 3.8-2**). There are also interdune ponds also referred to as sea swales, on Wallops Island, which are seasonally flooded or semi-permanently flooded areas of herbaceous wetland (NASA 2016). There are roughly 40.5 ha (100 ac) of impervious surface making up the remaining land area on Wallops Island. The majority of Wallops Island is wetlands (predominately estuarine emergent) vegetation and is discussed in detail in Section 3.5, Water Resources.

**Table 3.8-3. Vegetation Communities at Wallops Flight Facility Wallops Island**

| Community | Wallops Island |
|---|---|
| Managed/Maintained | 97 ha (240 ac) |
| Beach | 30 ha (74 ac) |
| Maritime Grassland | 32 ha (79 ac) |
| Maritime Scrub | 75 ha (186 ac) |
| Maritime Woodland | 15 ha (36 ac) |
| Maritime Forest | 18 ha (45 ac) |
| Wetlands (Estuarine Emergent) | 1,017 ha (2,514 ac) |
| Roads/Impervious Surfaces* | 51 ha (125 ac) |
| **Total** | **1,335 ha (3,300 ac)** |

Source: WFF 2017.
Note: *This line item was included so that the total acreage for Wallops Island was taken into account.

Managed/maintained vegetation on Wallops Island is composed mostly of meadows, lawn, and open roadside. Species found in the meadows include bushy bluestem (*Andropogon glomeratus*), little bluestem (*Schizachyrium scoparium*), thoroughworts and bonesets (*Eupatorium* spp.), and goldenrods. Invasive species found in the meadows are similar to those found in managed/maintained communities at WFF Main Base and WFF Mainland, but may also include sericea lespedeza (*Lespedeza cuneata*) and clovers (*Trifolium* spp.). There are also a few man-made ponds on Wallops Island that are dominated by widgeon grass (*Ruppia maritima*) and duckweed (*Lemna minor*) (NASA 2016).

Beach habitat at Wallops Island consists of upper beaches and overwash flats. Overwash flats are areas above the high tide line that are occasionally flooded by storm surges and high spring tides. These areas have sparse vegetation, which includes American searocket (*Cakile edentula*) and seabeach orach (*Atriplex arenaria*). Russian thistle (*Salsola kali*) is an invasive species that is also common in these areas (NASA 2008). Though not shown in **Figure 3.8-2**, beach habitat has expanded through the SRIPP; a long-term project to maintain an elevated beach within the approximately 6 km (3.7 mi) long area of Wallops Island that was previously rock seawall. This effort began in 2010 and will continue for the next 50 years (NASA 2010).

Maritime grasslands occur on the foredunes and secondary dunes of Wallops Island. Vegetation in these areas includes American beachgrass (*Ammophila breviligulata*), saltmeadow cordgrass (*Spartina patens*), beach panic grass (*Panicum amarum*), and seaside goldenrod (*Solidago sempervirens*). The northern end of Wallops Island contains some areas of relatively pristine maritime grasslands. Dixie sandmat

(*Chamaesyce bombensis*), also known as southern beach spurge, is a relatively rare plant species that has been documented in these more pristine areas (NASA 2016).

Maritime scrub on Wallops Island occurs on secondary dunes and is sometimes mixed with maritime grasslands. The scrub communities are composed mostly of bayberry, marsh elder (*Iva frutescens*), and poison ivy. Species that are less dominant include winged sumac (*Rhus copallina*), groundsel tree, stunted black cherry, and stunted loblolly pine (NASA 2016).

An isolated area of maritime woodlands is found on a secondary dune on Wallops Island. Tree species in this habitat include scattered black cherry, loblolly pine, and scrubby oaks (*Quercus nigra* and *Q.falcata*). Species found in sandy openings in this area include prickly-pear (*Opuntia humifusa*), yellow thistle (*Cirsium horridulum*), seaside needlegrass (*Aristida tuberculosa*), eastern jointweed (*Polygonella articulate*), and seaside little bluestem (*Schizachyrium littorale*) (NASA 2016). A recent reinventory of the North Wallops Island Conservation Area also identified 1.6 ha (4 ac) of Maritime Dune Woodland, more specifically, black cherry xeric dune woodland communities, within the areas designated as Maritime Woodland in **Figure 3.8-2**. This reinventory also identified the occurrence of *Eupatorium anamolum*, a state-listed rare plant species (VDCR 2012). This species is discussed further in Section 3.10, Special-Status Species.

There are a few small patches of maritime forest on Wallops Island that occur in isolated stands or are inter-mixed with the maritime scrub habitat. The over-story of the maritime forests consists almost entirely of loblolly pine. The under-story is composed of trees like red maple, black cherry, and sassafras, and common vines in this habitat include greenbrier (*Smilax* spp.), poison ivy, Japanese honeysuckle (*Lonicera japonica*), Virginia creeper (*Parthenocissus quinquefolia*), and grapes (*Vitis* spp.) (NASA 2016). Interdune ponds primarily occur in the northern and north-central parts of Wallops Island. Typical vegetation in these areas includes common threesquare (*Schoenoplectus pungens = Scirpus pungens*), sedges, switchgrass (*Panicum virgatum*), saltmeadow cordgrass, rushes (*Juncus* spp.), sea pink (*Sabatina stellaris*), saltmarsh fimbristylis (*Fimbristylis spadicea*), and seaside goldenrod. State rare species that have been documented in this habitat include Carolina fimbry (*Fimbristylis caroliniana*), long-awned sprangletop (*Leptochloa fusca* ssp. *Fascicularis*), and big-headed rush (*Juncus megacephalus*) (NASA 2016).

**Submerged Aquatic Vegetation**

Grasses that grow to the surface of, but do not emerge from, shallow water are called SAV. SAV beds are an important component of the estuarine ecosystem. SAV is a diverse assemblage of marine and bay grasses that occur in shallow areas of the Chesapeake Bay, Delmarva Peninsula bays, and the Atlantic Ocean. SAV beds are an important resource that provide habitat for juvenile and adult fish and shellfish; grant protection from predators for fish and shellfish; produce food for waterfowl, fish, and mammals; absorb wave energy and nutrients; produce oxygen and improve water clarity; and help settle suspended sediments in the water and stabilize bottom sediments (NOAA 2012).

VIMS has been mapping SAV in the Chesapeake Bay and Delmarva Peninsula Bays since the 1970s using aerial photo-interpretation and ground surveys. The most recent report of SAV mapping was 2015 and shows that eelgrass (*Zostera marina*) and widgeon grass are both dominant SAV species in the Delmarva Peninsula bays that can be found in waters near WFF (VIMS 2016). According to the VIMS aerial surveys, SAV beds throughout the Chesapeake and Delmarva Peninsula Bays are generally in decline, though surveys from 2015 showed an increase in cover over the previous year (VIMS 2016).

SAV beds are present in the waters north of the Mainland, near the mouth of Little Mosquito Creek, and further east in the waters of Chincoteague Bay, but none are located in the waterways on or adjacent to WFF (VIMS 2016).

**Invasive Species**

Invasive species are any species that are not native to a given ecosystem and whose introduction causes, or is likely to cause, economic or environmental harm and/or harm to human health (EO 13112 of February 3, 1999, Invasive Species and EO 13751 of December 5, 2016, Safeguarding the Nation from the Impacts of Invasive Species). Because of their ability to alter natural ecosystems and diminish the abundance or survival of native species, aggressive non-native species can readily displace native species and can create monoculture habitats. By lowering natural biodiversity and lessening the value of habitat to wildlife, invasive species are recognized as a threat to biodiversity and in some instances, to native species survival. It is estimated that over 40 percent of the species protected by the ESA are at risk primarily because of non-native, invasive species (Pimentel 2005). Due to the extensive historic disturbance, land use history, and landscaping practices that occurred at all WFF locations, invasive species have colonized large areas of the facilities.

Although a variety of non-native species occur at WFF, including landscape and groundcover plants such as privet (*Ligustrum spp*.), English ivy (*Hedera heli*x), Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), autumn olive, and ornamental cherry (*Prunus sp*.) (NASA 2008), some pose a greater threat to biodiversity and NASA's assets than others and not all are problematic and warrant control. Therefore, assessing the extent of damage caused by the presence of invasive species and prioritizing management activities are important steps to ensure the greatest environmental and safety benefits and the success of the invasive species control program. The primary considerations for prioritizing actions are: the potential impact of invasive species to the NASA mission; the severity of threat to natural ecosystems and rare, threatened, and endangered species; and the feasibility of control.

In 2007 and 2008, a combination of field surveys and aerial photograph interpretation were employed to estimate the real extent of invasive species infestation at WFF. Of the approximately 320 ha (790 ac) of invasive species identified, *Phragmites australis* (*Phragmites*) accounted for 88 percent of the acreage with a total of 278 ha (687 ac) on Wallops Island, 0.4 ha (1 ac) on the Mainland, and 4.5 ha (11 ac) at the Main Base (NASA 2008). A Natural Heritage Survey of North Wallops Island conducted in the summer and fall of 2011 by the Natural Heritage Division of VDCR came to a similar conclusion, noting that large portions of the study area were dominated by *Phragmites* (VDCR 2012).

According to Warren et al. (2001), *Phragmites* has been a minor component of Mid-Atlantic brackish tidal wetlands for over 3,000 years. However, due to the introduction of new genotypes, which are invasive, and human disturbance of coastal areas, *Phragmites* has recently become a problematic invasive species with expansion rates of 1 to 3 percent per year. The invasive genotype of *Phragmites* is a tall (5 m [15 ft]) perennial grass with creeping rhizomes that may make a dense vegetative mat. Thick rhizomal growth and the accumulation of litter from the aerial shoots, prevent other species from becoming established. *Phragmites* is an opportunistic species, taking advantage of the disturbances to the local vegetative community caused by disruptions of the natural state, such as those caused by fire or Earth-moving activities.

A literature review by Weinstein and Balleto (1999) states that *Phragmites* alters the ecology and function of the wetland by building up the wetland plain, filling in the microtopographic relief of the wetland surface and by sequestering nitrogen. In addition to the environmental damage caused by *Phragmites*, stands of the plants present a fire hazard. The dead shoots left standing after the previous growing season ignite readily and flames spread rapidly through the densely packed, dry vegetation. The height of the plants contributes to this spread, as breezes can quickly fan elevated sparks to new areas.

NASA has worked with the VDCR in an effort to map, control, and monitor *Phragmites* at WFF as part of an ongoing project on Virginia's Eastern Shore (VDCR 2011). The 2011 VDCR report summarizing these activities indicates from 2006 to 2008 a total of 130 ha (322 ac) of *Phragmites* on Wallops Island was treated aerially with an herbicide. Furthermore, with the goal of reducing the spread of *Phragmites* and of the hazards that *Phragmites*-fueled wildfires present to flight-related infrastructure, fragile marsh ecosystems, wildlife, property owned by WFF and its neighbors, and, most importantly, human life, WFF has recently developed a *Phragmites Control Plan* (NASA 2014). The control methods outlined in the Plan include a combination of the following:

- Aerial application of an imazapyr[7]-based herbicide in late summer to early fall (August – September),
- Hand herbicidal spraying, to treat small stands of *Phragmites* or stands in locations inaccessible to aerial spraying (e.g., close to structures, underneath the Launch Pad 0-A ramp, or in small patches surrounded by non-*Phragmites* plants),
- Post-herbicide application controlled burning,
- Mowing of small infestations,
- Requiring special considerations for operating heavy equipment in *Phragmite*s-infested areas (e.g., restricting construction equipment from areas prone to invasion, cleaning of construction equipment of all visible dirt and plant debris prior to leaving the construction site, and post-construction monitoring and mowing), and
- Annual monitoring and reporting of *Phragmites* growth.

Though the primary goal of this Control Plan is to protect NASA's launch infrastructure assets, it will also protect marsh ecosystems and native plant and animal species from invasive species consistent with EO 13112 and EO 13751.

### 3.8.2 Environmental Consequences

Determination of the significance of potential impacts to vegetation is based on 1) the importance of the resource (i.e., legal, commercial, recreational, ecological, or scientific importance); 2) the proportion of the resource that would be affected relative to its occurrence in the region; 3) the sensitivity of the resource to proposed activities; and 4) the duration of ecological ramifications. Impacts to vegetation would be considered significant if species or habitats of concern were substantially affected over relatively large areas or habitat disturbances resulted in reductions in the population size or distribution of a special-status species, or the introduction of invasive species (i.e., *Phragmites australis*) to sensitive habitats on the facility.

[7]Imazapyr is an EPA-approved, non-selective, broad-spectrum herbicide marketed under various trade names including *Chopper*, *Arsenal*, *Stalker*, and *Assault*. It was first registered for use in the U.S. in 1984.

### 3.8.2.1 No Action Alternative

#### 3.8.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Any substantial changes to the design of approved construction projects may require site-specific NEPA analysis. Operational Missions and Activities

#### 3.8.2.1.2 Operational Missions and Activities

Under the No Action Alternative, activity at WFF would remain at present levels and WFF would conduct operational missions and activities that are within the installation's current envelope and have been assessed in previous NEPA documents. Proposed operational missions and activities detailed in Section 2.5 would not be implemented. Consequently, baseline vegetation conditions, as described in Section 3.8.1, would remain unchanged.

### 3.8.2.2 Proposed Action

#### 3.8.2.2.1 Institutional Support Projects

**Main Base**

**Construction, Demolition, and RBR Projects**

Under the Proposed Action, institutional support projects at WFF would include construction, RBR, and demolition projects. RBR and demolition would occur in already disturbed areas and would have no anticipated adverse impacts to vegetation at the Main Base. New construction of several support facilities to include a Commercial Space Terminal would also occur at the Main Base. Construction details for all new construction projects are not known at this time. As depicted in Figures 2.5-1A and 2.5-1B, a number of projects have general locations and footprints associated with them. Approximately 2 ha (5 ac) of new construction would occur on managed/maintained lands at the Main Base. New construction to support the Sounding Rocket Program Building would require the clearing of approximately 0.2 ha (0.6 ac) of hardwood trees surrounded by maintained areas. Extension of Runway 04/22 would occur within the maintained areas at the ends of the runway and would disturb approximately 1.1 ha (2.7 ac) of maintained vegetation.

**Mainland and Wallops Island**

**Construction, Demolition, and RBR Projects**

Institutional support projects located on the Mainland and Wallops Island would also mostly occur in previously disturbed areas or maintained areas. Approximately 0.6 ha (1.5 ac) of maintained habitat would be impacted by new facility construction (refer to **Table 2.5-2**). While many details of construction requirements remain unknown, some new projects have known footprints and general locations where they would be placed along Wallops Island (refer to **Figure 2.5-2, Figure 2.5-3,** and **Figure 2.5-4**).

***Causeway Bridge Replacement***

The Causeway Bridge Replacement would potentially disturb tidal wetland vegetation that borders the existing bridge. Some of these areas would be permanently filled and lost. It is estimated that approximately 0.5 to 2 ha (1.5 to 5 ac) of tidal wetlands would be impacted by the construction of the replacement bridge (WFF 2017). The range of the wetland impacts is due to the lack of certainty as to the type of construction and construction footprint of the new Causeway Bridge. The discussion of potential impacts to wetland vegetation can be found in Section 3.5, Water Resources. No SAV has been identified from VIMS aerial surveys in the areas that would be impacted by the Causeway Bridge Replacement. Additional NEPA analysis would be required in the future as the Causeway Bridge design elements become more developed.

Wetland areas that are disturbed may become more susceptible to colonization by invasive species, especially *Phragmites.* As was shown in **Table 3.5-2** , a total of approximately 3 ha (6 ac) of wetlands may be disturbed from the proposed projects and would be subject to the potential for *Phragmites* invasion due to the disturbance. Project-specific *Phragmites* management/control would be implemented, as needed, for new construction projects to minimize the potential for the spread of the invasive species.

***Maintenance Dredging***

Maintenance dredging of the barge channel between the two boat basins at the Main Base and North Wallops Island would occur. SAV beds are present in the waters north of the Mainland, near the mouth of Little Mosquito Creek, and further east in the waters of Chincoteague Bay. According to VIMS, there are no known SAV beds in the maintained barge channel or the two existing boat basins (VIMS 2016). However, the dredge route would be reviewed for the possible presence of SAV during the permitting phase of the dredging project.

***North Wallops Island Deep-water Port and Operations Area***

No specific details exist at this time for the North Wallops Island Deep-water Port and Operations Area construction. However, the port would require the construction of a pile-supported structure to moor ships or barges. The port would be sited to reduce the impacts to wetlands and wetland vegetation, but would cause a permanent loss of vegetation where it is sited. At this time, vegetation type and amount cannot be accurately determined. Dredging would likely be required for this project as well, and while no SAV appears to be present within the three paths for access to the deep-water port, the dredge route would be reviewed for possible presence of SAV during the permitting phase of the dredging related to this project.

***Launch Pad 0-C***

Launch Pad 0-C has no available design specifications at this time, but would be similar in size and configuration to Launch Pad 0-A. This pad is proposed to be constructed at the location of the existing UAS airstrip on the south end of Wallops Island. The estimated size of the Launch Pad 0-C complex footprint is approximately 2.6 ha (6.4 ac). **Figure 3.5-11** (refer to Section 3.5, Water Resources) shows the layout of Launch Pad 0-A on top of the general area where Launch Pad 0-C would be built. It is estimated that approximately 2.0 ha (5.0 ac) of tidal wetland would be impacted by the construction of Launch Pad 0-C at the shown location. Future planning and design would include avoidance and minimization of vegetative impacts to the extent practicable. Once design plans are known, additional NEPA analysis would be performed prior to permitting and construction. Launch Pad 0-C would be sited to avoid wetlands to the greatest extent practicable, but ultimately, given the chosen location and size, unavoidable impacts to wetland vegetation may be likely.

***Launch Pier 0-D***

Launch Pier 0-D has no available design specifications for either of the two optional locations at this time. Future planning and design would include avoidance and minimization of vegetative impacts to the extent practicable. Once design plans are known, additional NEPA analysis would be performed prior to permitting and construction.

***DoD Launch Pads***

The two DoD launch pads for Navy operations would be constructed in the Navy Assets area of Wallops Island. General locations for the small launch pads are depicted in **Figure 2.5-5**. Each of these pads would be sited to avoid wetland areas to the maximum extent practicable. However, the locations identified for the ESSM and DoD SM-3 pads are bordered by scrub-shrub wetland areas. The ESSM and DoD SM-3 pads would require a total of 23 $m^2$ (250 $ft^2$) and affected approximately 0.2 ha (.06 ac) of natural vegetation These pads would be placed to minimize impacts to wetland habitats, but could potentially require filling of some wetland areas (see Section 3.5, Water Resources for a description of wetland impacts). If design plans or project locations changed significantly, additional NEPA analysis may be required.

In summary, the majority of the proposed institutional support projects would occur in previously disturbed areas or managed/maintained areas with little natural vegetation. The amount of disturbance to natural vegetation from new construction under the Proposed Action (5 ha [12 ac]) would constitute a small fraction of the natural habitats found at WFF. Analysis for construction impacts to vegetation from implementation of the Proposed Action is based on the best available data at this time and impacts may change as designs for specific projects become finalized.

Any substantial changes to the design plans or locations of the proposed institutional support projects may require further NEPA analysis. Based on the best available data, application of the WFF *Phragmites Control Plan* on a project by project basis, and implementation of design approaches to limit the disturbance of vegetation from the development of the institutional support projects, impacts to vegetation from implementation of the Proposed Action would not be significant. Refer to **Section 4.1.7** (Vegetation) for measures to mitigate impacts to vegetation under the Proposed Action.

#### 3.8.2.2.2 Operational Missions and Activities

Most operational programs that would be conducted under the Proposed Action would not impact vegetation at WFF. Only those operational missions and activities with the potential to impact vegetation are discussed below.

**Main Base**

None of the proposed operational missions would be anticipated to impact vegetation on the Main Base.

**Mainland and Wallops Island**

None of the proposed operational missions would be anticipated to impact vegetation on the Mainland. Proposed operational missions that may impact vegetation on Wallops Island are discussed below.

**DoD SM-3**

Launch of the DoD SM-3 has never occurred at Wallops Island but the launch vehicle used would be identical to the Terrier motor used by the sounding rocket program at WFF. These rockets would be launched from a small launch pad located in the Navy Assets area on Wallops Island out into the VACAPES OPRAEA. Vegetation surrounding the launch pad may be affected. However, the impacts to vegetation from this operation would be negligible.

**Expanded Space Program**

***LFIC LV and SFHC LV***

Proposed launching of the LFIC LV and SFHC LV would represent the largest LVs ever launched from WFF. It is possible that launches of either vehicle would cause small brush fires in the vicinity of the pad based on historic experience at Pads 0-A and 0-B. To reduce the potential for uncontrolled fires, the future design of Launch Pad 0-C would include an orientation of the flame duct so that the flame trench would be directed over the beach and not over the wetland vegetation to avoid scorching it. Additionally, WFF crash, fire, and rescue units are routinely stationed outside the immediate launch hazard area such that they can respond as soon as the pad is cleared for their entry. Since a majority of the fires during launch involve *Phragmites,* WFF would actively manage this invasive species in accordance with its *Phragmites Control Plan* (NASA 2014).

In the case of a SFHC LV launch, vegetation that is sensitive to acidic deposition (from HCl in the exhaust) would be disturbed and potentially killed. Schmalzer et. al. (1998) noted that HCl concentrations above 5 ppm would cause injury to plants if exposure time was greater than 60 minutes. Higher concentrations require less exposure time to induce injury to plants (Schmalzer et. al. 1998). Vegetation browning could occur but hardier species would likely recover. Direct observations of vegetation impacts from Titan, Delta, and some Atlas V ELVs at Kennedy Space Center have shown that in the near-field areas occasional damage to vegetation can occur from fires and/or heat from the launch and wet deposition of HCl and $Al_2O_3$ associated with solid-fueled rocket motors. Vegetation community structure changes are possible with the loss of some tree species and an increase in grasses and sedges that appear to be more resistant to the impacts from ground clouds (Schmalzer et.al. 1998). Furthermore, deluge water is sometimes used during the launch to suppress noise and can aid in precipitating out HCl in the immediate launch pad environment.

Therefore, in summary, based on the best available information for the larger solid- and liquid- fueled LVs proposed, adverse impacts to vegetation would likely occur. However, they would be infrequent and likely confined to an area approximately 300 m (1,000 ft) around the launch pad. Areas east of the launch pads are shoreline and are devoid of vegetation. Deluge water for LFIC LV and SFHC LV launches would be discharged to a lined retention basin and would be allowed to cool prior to being tested for potential release to an unlined infiltration and evaporation basin.

***Vertical Launch and Landing Vehicles***

Potential impacts to vegetation resources from vertical launch and landing vehicles would likely be similar to those described for the LFIC LV or SFHC LV. Impacts would likely be limited to a small area adjacent to the launch/return site.

***Commercial Human Spaceflight Missions***

A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) for commercial human spaceflight. Potential impacts to vegetation resources from vertical launch vehicles for commercial human spaceflight from the launch range would likely be similar to those described for the LFIC LV or SFHC LV. Impacts would likely be limited to a small area adjacent to the launch/return site.

In conclusion, impacts from DoD SM-3 and operational missions and activities under the Expanded Space Program have the potential to impact vegetation; however, no long-term significant impacts would be anticipated. Refer to **Section 4.1.7** (Vegetation) for measures to mitigate impacts to vegetation under the Proposed Action.

## 3.9 TERRESTRIAL WILDLIFE

Terrestrial wildlife includes all common animal species, with the exception of those identified as special-status species (see Section 3.10, Special-Status Species). The terrestrial wildlife category includes amphibians, reptiles, mammals, and birds, including native bird species protected under the MBTA. Virtually all native birds are protected under the MBTA. The MBTA was designed to protect migratory birds and birds of conservation concern (BCC), including their eggs, nests, and feathers. BCC birds are species that, without additional conservation measures, are likely to become candidates for listing under the ESA. If an agency determines that implementation of a Proposed Action may result in a significant adverse effect on a population of a migratory bird species or BCC, they must confer and cooperate with the USFWS to develop appropriate and reasonable conservation measures to minimize or mitigate identified significant adverse effects. USFWS recommends that BCC lists be reviewed in accordance with Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds* so that proactive management and conservation actions may be implemented.

### 3.9.1 AFFECTED ENVIRONMENT

A variety of terrestrial wildlife species occur within the habitat or vegetation types found at WFF. See Section 3.8, Vegetation, for a detailed discussion of vegetation types found on WFF. Representative mammal, reptile, bird, and invertebrate species found within the vegetation communities at WFF are discussed below.

**Mammals**

The only large mammal that occurs at WFF is the white-tailed deer (*Odocoileus virginianus*). Other mammals found on WFF property include the red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), eastern grey squirrel (*Sciurus carolinesis*), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), river otter (*Lontraauruses*), and eastern cottontail (*Sylvilagus floridanus*) (NASA 2016).

**Reptiles and Amphibians**

Reptiles and amphibians found at WFF include Fowler's toad (*Anaxyrus fowleri*), green treefrog (*Hyla cinerea*), eastern ratsnake (*Pantherophis alleghaniensis*), eastern hognose snake (*Heterodon platirhinos*), fence lizard (*Sceloporus undulates*), eastern box turtle (*Terrapeneaurue*), and northern diamond-backed terrapin (*Malaclemys terrapin*). Green treefrogs are often found in freshwater depressions on Wallops Island and Fowler's toads are found under stands of bayberry. Eastern ratsnakes, hognose snakes, and box turtles are often found in scrub-shrub habitat and the diamondback terrapin utilizes saltmarsh, tidal flats, and lagoons (NASA 2016).

**Birds**

WFF is home to a wide variety of bird species. In fact, much of WFF is located within the boundaries of the Barrier Island Lagoon System Important Bird Area (Audubon 2017) and the path of the coastal route of the Atlantic Flyway, a regular avenue of travel for migrating land and water birds that winter on the waters and marshes south of Delaware Bay. The barrier islands, including Wallops, Assateague, Chincoteague, and Assawoman Islands, are particularly important for migratory birds including BCC. Some species use these islands as a stopover point, while others use the islands and surrounding habitats as an overwintering area. The bay (west) side of the islands tends to contain the highest concentrations of migratory and BCC birds. In addition to its Important Bird Area status, the area has also been designated as a United Nations Educational, Scientific, and Cultural Organization Biosphere Reserve and a Western Hemisphere Shorebird Reserve Site.

In 2014, a CNWR biologist compared the BCC 2008 list; the Bird Conservation Region 30 (New England/Mid-Atlantic Coast) Priority Species (2008) list; Potential Resources of Concern list at Chincoteague and Wallops Island NWRs; CNWR bird brochure; and eBird sightings (Holcomb 2014). **Table 3.9-1** is based upon CNWR's comparison and lists the BCC species known to inhabit the areas around the WFF Main Base, Mainland, and Wallops Island.

**Table 3.9-1. BCC Species That May Occur on or within the Vicinity of Wallops Flight Facility**

| Species | Habitat | Species | Habitat |
|---|---|---|---|
| American Bittern | wading bird | Prairie Warbler | woodland |
| American Oystercatcher | shorebird | Red Knot (rufa ssp.) (a) (nb) | shorebird |
| Bald Eagle (b) | woodland | Red-headed Woodpecker | woodland |
| Black Skimmer | shorebird | Red-throated Loon (nb) | marshland |
| Blue-winged Warbler | woodland | Rusty Blackbird (nb) | woodland |
| Brown-headed Nuthatch | woodland | Saltmarsh Sharp-tailed Sparrow | marshland |
| Buff-breasted Sandpiper (nb) | shorebird | Seaside Sparrow I | marshland |
| Gull-billed Tern | shorebird | Sedge Wren | marshland |
| Horned Grebe (nb) | wading bird | Semipalmated Sandpiper (nb) | shorebird |
| Hudsonian Godwit (nb) | shorebird | Short-billed Dowitcher (nb) | marshland |
| Kentucky Warbler | woodland | Short-eared Owl (nb) | grassland |
| Least Bittern | marshland | Snowy Egret | marshland |
| Least Tern I | shorebird | Solitary Sandpiper (nb) | marshland |
| Marbled Godwit (nb) | marshland | Whimbrel (nb) | shorebird |
| Nelson's Sharp-tailed Sparrow | marshland | Wilson's Plover | shorebird |
| Peregrine Falcon (b) | woodland | Wood Thrush | woodland |
| Pied-billed Grebe | wading bird | Worm-eating Warbler | woodland |

Sources: USFWS 2008; Holcomb 2014.

Notes: (a) Federal ESA threatened, (b) Federal ESA de-listed, (c) non-listed Federal ESA subspecies or population, (d) MBTA protection uncertain or lacking, (nb) non-breeding in this region.

Songbirds found at WFF include saltmarsh sharp-tailed sparrow (*Ammodramus caudacutus*), swamp sparrow (*Melospiza Georgiana*), common yellowthroat (*Geothlypis trichas*), white-eyed vireo (*Vireo griseus*), ruby-crowned kinglet (*Regulus calendula*), and white-breasted nuthatch (*Sittaauruses*). Other birds that commonly utilize open and urban areas at WFF Mainland and Main Base include northern mockingbird (*Mimus polyglottos*), American robin (*Turdus migratorius*), northern cardinal (*Cardinalis cardinalis*), northern bobwhite (*Colinus virginianus*), barn swallow (*Hirundo rustica*), brown-headed cowbird (*Molothrus ater*), house sparrow (*Passer domesticus*), house finch (*Carpodacus mexicanus*), rock dove (*Columba livia*), and European starling (*Sturus vulgaris*). Non-native bird species such as house sparrow, rock dove, and European starling are not protected under the MBTA.

Raptor species commonly found at WFF include turkey vulture (*Cathartes aura*), black vulture (*Coragyps atratus*), sharp-shinned hawk (*Accipiter striatus*), red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk (*Buteo lineatus*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), barn owl (*Tyto alba*), bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and peregrine Falcon (*Falco peregrinus*). These species are found mainly in the marsh areas to the west of Wallops Island. Great horned owls (*Bubo virginianus*) have been observed in the coastal forest (NASA 2016). Bald eagles and peregrine falcons are discussed further in Section 3.10, Special-Status Species.

A large number of waterfowl species are found at WFF due to the abundance of wetlands and surface water on and adjacent to the properties. Waterfowl that occur at WFF include loons (*Gavia spp.*), Canada goose (*Brantaauruses*), snow goose (*Chen caerulescens*), gadwall (*Anas strepera*), American black duck (*Anas rubripes*), blue-winged teal (*Anas discors*), bufflehead (*Bucephala albeola*), common goldeneye (*Bucephala clangula*), canvasback (*Aythya valisineria*), scaup (*Aythya* spp.), and mergansers (*Mergus spp.*). These waterfowl commonly overwinter in areas around WFF.

The marshes and shorelines at WFF also provide habitat for a variety of shorebirds and wading birds including least sandpiper (*Calidris minutilla*), upland sandpiper (*Bartramia longicauda*), short-billed dowitcher (*Limnodromus griseus*), least tern (*Sterna antillarum*), great-black-backed gull (*Larus marinus*), American oystercatcher (*Haematopus aurues*), willet (*Catoptrophorus semipalmatus*), glossy ibis (*Plegadis falcinellus*), ring-billed gull (*Larus delawarensis*), double-crested cormorant (*Phalacrocorax auritus*), horned grebe (*Podiceps auritus*), great blue heron (*Ardea auruse*), snowy egret (*Egretta thula*), and green heron (*Butorides striatus*) (NASA 2016).

**Invertebrates**

Invertebrates are found in all habitat types at WFF. However, invertebrate diversity is highest in marsh and wetlands areas. Common insects found at WFF include the salt marsh grasshopper (*Orchelium fidicinium*), planthoppers (*Prokelisia* spp.), salt marsh mosquitoes (*Ochlerotatus* spp.), greenhead flies (*Tabanus nigrovittatus*), and various wasps, and parasitic flies. Spiders and mites are also common invertebrates at WFF (NASA 2016). Common coastal invertebrates at Wallops Island include ghost crabs (*Ocypode quadrata*), calico crabs (*Ovalipes ocellatus*), fiddler crabs (*Uca* spp.), sand shrimp (*Crangon septemspinosa*), moon jelly (*Aurelia aurita*), and coffee bean snails (*Melamups bidentatus*). The federally listed northeastern beach tiger beetle does not inhabit the Atlantic Ocean beaches of the Delmarva Peninsula, including Wallops Island, but is instead found on Chesapeake Bay beaches (USFWS 2009). Special-status species are discussed in Section 3.10.

### 3.9.2 Environmental Consequences

Determination of the significance of potential impacts to terrestrial wildlife is based on the sensitivity of the wildlife to the proposed activities. Impacts to terrestrial wildlife would be considered significant if species or habitats of concern were substantially affected over relatively large areas or disturbances resulted in reductions in the population size or distribution of a special-status species. An activity has a significant adverse effect with respect to MBTA and BCC birds if, over a reasonable period of time, it diminishes the capacity of a population of a migratory bird species to maintain genetic diversity or will limit the ability of a local or regional population to sustain itself.

### 3.9.2.1 No Action Alternative

#### 3.9.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Any substantial changes to the design of approved construction projects would require site-specific NEPA analysis. Proposed institutional support projects detailed in Section 2.5 would not be implemented. Consequently, baseline terrestrial wildlife, as described in Section 3.9.1, would remain unchanged.

#### 3.9.2.1.2 Operational Missions and Activities

Under the No Action Alternative, activity at WFF would remain at present levels and WFF would conduct operational programs that are within the installation's current envelopes that have been assessed in previous NEPA documents. Proposed operational missions and activities detailed in Section 2.5 would not be implemented. Consequently, baseline terrestrial wildlife, as described in Section 3.9.1, would remain unchanged.

### 3.9.2.2 Proposed Action

#### 3.9.2.2.1 Institutional Support Projects

**Main Base**

Institutional support projects at the Main Base would mostly occur in managed/maintained areas or areas that have been previously disturbed by construction. Specific locations of all proposed new construction projects are unknown at this time. However, as shown in **Figure 2.5-1** and **Figure 2.5-2**, general locations for most proposed construction is known. Approximately 2 ha (5 ac) of new construction would occur on managed/maintained lands at the Main Base. New construction to support the Sounding Rocket Program Building would require the clearing of approximately 0.2 ha (0.6 ac) of hardwood trees surrounded by maintained areas. Extension of Runway 04/22 would occur within the maintained areas at the ends of the runway and would disturb approximately 1.1 ha (2.7 ac) of maintained vegetation.

The permanent loss of natural habitat from new construction under the Proposed Action at the Main Base would be minimal; however, the removal of forest habitat would cause forest dwelling species, including BCC listed in **Table 3.9-1**, in the area to be permanently displaced once the land is cleared. Smaller, less mobile species and those seeking refuge in burrows could inadvertently be killed during construction activities. Wildlife residing in habitat on the periphery of construction sites may be temporarily disturbed or displaced by noise associated with proposed construction activities and may experience a temporary cessation of normal behaviors (e.g., breeding, foraging). However, long-term, permanent impacts to populations of such species would not result because these species are abundant in the surrounding areas and would rapidly repopulate suitable portions of the affected area.

**Mainland and Wallops Island**

Institutional support projects on the Mainland and Wallops Island would involve new construction, demolition, and renovations to existing structures. These activities may result in temporary disturbance of wildlife from noise. These impacts would be temporary and would not be significant. Approximately 0.6 ha (1.5 ac) of maintained habitat would be impacted by new facility construction (refer to **Table 2.5-2**).

**Causeway Bridge Replacement**

It is estimated that approximately 0.5 to 2 ha (1.5 to 5 ac) of tidal wetlands and some upland habitat would be impacted by the construction of the replacement bridge (WFF 2017). The replacement of the Causeway Bridge would occur between Wallops Mainland and Wallops Island. Although design specifics do not exist for this project at this time; and therefore no detailed environmental impact analysis can be performed, some general impacts can be determined. Noise generated during construction would likely startle nearby birds, and should construction occur during breeding season, it is possible that such disturbances could adversely affect nesting birds, particularly marsh-nesting and some BCC species (see **Table 3.9-1**), in the immediate vicinity of the project site. The project would disturb tidal wetland habitat that borders the existing bridge (see Section 3.5.2.2.1). Some of these areas would likely be permanently filled and lost. The range of the wetland and upland habitat impacts is due to the lack of certainty as to the type of construction and construction footprint of the new causeway. Though wetland and upland habitat loss would be permanent from the Causeway Bridge Replacement, long-term negative impacts to wildlife would likely not be significant, given the abundance of available wetland and upland habitat in the vicinity. The removal of the old Causeway Bridge could restore some wetland/vegetation habitats by removing old bridge components from wetlands and aquatic environments.

**Launch Pad 0-C**

Launch Pad 0-C would be constructed on the south end of Wallops Island. The notional location of Launch Pad 0-C is shown in **Figure 3.5-11**. The estimated size of the Launch Pad 0-C complex footprint is approximately 2.6 ha (6.4 ac). It is anticipated that Launch Pad 0-C would be very similar in size to Launch Pad 0-A but its configuration is not yet known. As such, it is estimated that approximately 2.0 ha (5.0 ac) of tidal wetland would be impacted by the construction of Launch Pad 0-C at the shown location. The removal of wetland habitat would cause species in the area to be permanently displaced if the wetland is cleared and filled. Smaller, less mobile species and those seeking refuge in burrows could inadvertently be killed during construction activities. Wildlife residing in habitat on the periphery of construction sites may be temporarily disturbed or displaced by noise associated with proposed construction activities.

Additionally, *Phragmites* could invade areas disturbed during construction and further limit available habitat. Meyerson, et al. (2000) compared species diversity in freshwater, brackish, and *Phragmites* marshes and found that, although the number of species per plot was significantly lower in *Phragmites*-dominated wetlands, a variety of species did use the habitat including several bird species (herons, bitterns, ducks, rails, gulls, sparrows, wrens, terns, and shorebirds), mammals (white-tailed deer, muskrat, and cottontail), and a number of insects. However, Meyerson et al. (2000) concluded that the decrease in plant species diversity in *Phragmites*-dominated marshes may contribute to the loss of rare plant and animal species already threatened with small population sizes. To prevent the spread of *Phragmites*, all construction and demolition on the Island would follow the 2014 WFF *Phragmites Control Plan*.

**DoD Launch Pads**

Two DoD launch pads for Navy operations would occur in the Navy Assets area of Wallops Island. General locations for the small launch pads are depicted in **Figure 2.5-5**; analysis of impacts to wildlife from the development of these areas is based on these proposed locations. Each of these pads would be sited to avoid wetland areas to the maximum extent practicable. However, the locations identified for the ESSM and DoD SM-3 pads are bordered by scrub-shrub wetland areas. The ESSM and DoD SM-3 pads would only require a total of 23 $m^2$ (250 $ft^2$) and could affect approximately 0.002 ha (.006 ac) of natural habitat.

In summary, the permanent loss of natural habitat from new construction under the Proposed Action at Wallops Mainland and Wallops Island is estimated to be approximately 5 ha (12 ac). The specific amount of habitat disturbance under the Proposed Action would depend on final design plans for new facilities. The majority of the proposed institutional support projects would occur in previously disturbed areas or managed/maintained areas. The amount of disturbance to natural habitats would constitute a small fraction of the natural habitats found at WFF. Additionally, wildlife species are abundant in the surrounding areas and would rapidly repopulate suitable portions of the affected area, so that long-term, permanent impacts to populations of wildlife species would not result. Noise impacts from institutional support projects would be temporary. As sited and planned, institutional support projects would not create significant impacts to terrestrial wildlife. However, if designs or project locations changed significantly, additional NEPA analysis may be required. Refer to Section 5.4.5, Terrestrial Wildlife for the discussion on the cumulative effects associated with habitat loss, noise, and predation.

###### 3.9.2.2.2 Operational Missions and Activities

Generally, noise would be the primary impact to wildlife from operational missions and activities. Noise from operational missions would likely startle or flush mobile species and those species would likely avoid areas of activity. Birds in particular are sensitive to noise, because of their use of calls for communication. Therefore, birds are given a more robust analysis below.

Little is known about the general hearing of birds, but research suggests an in-air maximum auditory sensitivity between 1 and 5 kHz for most bird species (NMFS 2003). Moreover, Hayden et al. (2009) evaluated physiological response in free-living endangered and common passerine species to human disturbance. Specifically, one of the studies was designed to determine whether continuous human presence, i.e., a human on foot continuously for 1 hour, causes stress to vireos (black-capped and white-eyed) and golden-cheeked warblers. After the hour had passed, the birds were captured and blood was analyzed for corticosterone; the results indicated there was no significant increase in plasma corticosterone concentrations. Therefore, it was concluded that while the hour of constant human exposure altered the birds' behavior, there was no clear physiological stress response in these three birds (Hayden et al. 2009). In another study, the authors measured heart rate shortly after the start of a 4-hour chase. In the white-eyed and black-capped vireos, there was an initial alarm response to the chase, but there was no evidence of elevated energetic costs to human disturbances (Hayden et al. 2009). In another study conducted between the DoD and USFWS, red-cockaded woodpeckers were found to successfully acclimate to military noise events (Pater et al. 1999). Cues appearing just before loud sounds might cause animals to temporarily vacate an area to reduce potential exposure (Larkin 1996).

Larkin (1996) described the results of experiments conducted on nocturnally migrating songbirds. When exposed to a recorded sound of bird vocalizations, observed reactions included changes in height; when exposed to a recorded sound of thunder, some birds turned away from the source, suggesting that the sound exposure elicited a physical response. When the sound stopped, some birds re-corrected their course while some did not re-correct their course (Larkin 1996). In another experiment using intense tone bursts, migrating birds showed few responses to the sound exposure; responses observed included a slight change in height or rate of climb (Larkin 1996). While migratory birds may experience minor, short-term intermittent disturbance associated with noise, such potential effect is lessened in the context of an environment where the background noise and operational activity levels are high, and any wildlife present would generally be tolerant/acclimated to these noise and activity levels.

Operational components of the Proposed Action that have the potential to impact terrestrial wildlife are the operations at the DoD SM-3 pad, Directed Energy, and LFIC LV and SFHC LV launches from Launch Pad 0-C on the south end of Wallops Island. Each of these operational mission activities and potential impacts to terrestrial wildlife are described below.

**Main Base**

The proposed operational mission that may impact terrestrial wildlife on the Main Base is horizontal launch and landing vehicles.

**Horizontal Launch and Landing Vehicles**

Horizontal launch and landings vehicles would take off and land like a standard aircraft from the Runway 04/22 at the Main Base. Impacts to wildlife would be expected to be similar to those generated by aircraft currently operating at the Main Base airfield. The noise associated with the horizontal launch and landings would be typical of existing jet aircraft that utilize WFF. However, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. In the event that a proposed horizontal vehicle would produce a supersonic landing, future NEPA analysis would be performed to prevent unacceptable adverse impacts.

**Mainland and Wallops Island**

Proposed operational missions that may impact terrestrial wildlife on the Mainland or Wallops Island are discussed below.

**DoD SM-3**

The Terrier rocket, a vehicle similar to the Navy's SM-3, is currently launched from Wallops Island using existing launch facilities. These rockets are launched from Wallops Island out into the VACAPES OPAREA. Wildlife would be temporarily disturbed from launch preparation activities and noise associated with the rocket launch. Wildlife in the vicinity of these facilities is likely habituated to the rocket noise generated by these activities since it already occurs. The sound level of an SM-3 launch would be similar to that of a Terrier sounding rocket launch. Significant impacts to wildlife from DoD SM-3 operations are unlikely.

**Directed Energy**

Use of either the HEL or HPM at WFF would likely have negligible impacts to terrestrial wildlife. These weapon systems are in various stages of development and little information exists on their impacts to the general environment. However, these weapon systems have the ability to direct concentrated energy to a specified target. As with any weapon system, the potential exists for harm, or incidental mortality to terrestrial wildlife. As proposed, the HEL or HPM would be affixed to the top of an existing facility on Wallops Island and the energy beam would be directed down the beach to a target up to 1.6 km (1 mi) away. At this time, the width of the beam, or how long the device would be active are unknown. Impacts would occur if terrestrial wildlife strayed into the active beam. However, impacts to terrestrial wildlife cannot be quantified based on current information. As the HEL and HPM devices become more operational and proposals more finalized, additional NEPA analysis may be required to better assess potential impacts from these weapon systems.

**SODAR System**

Operating frequencies for SODAR systems can range between 1 kHz to 4 kHz with power levels up to several hundred watts (refer to Section 2.5.2.2). As stated above, research suggests an in-air maximum auditory sensitivity between 1 and 5 kHz for most bird species (NMFS 2003). Additionally, radar similar to SODAR has been used to track bird groups in flight. Larkin (1979) concluded that there the impacts to migrating birds from a pulsed acoustic sounder on nocturnally migrating birds was minimal except for the birds directly in the beam. Utilization of SODAR would be unlikely to cause impacts to birds or bats. The equipment emits and audible "chirp" or sound, upward toward the sky. Most SODAR systems can only reach a few hundred meters into the atmosphere, and are only measuring a small area of the sky. Temporary disturbance may occur to wildlife, from the audible sound that is emitted. However, the SODAR is not likely to be run continuously. Although specifics for the type of SODAR system or its placement on Wallops Island are unknown at this time, there are no indications that there would be any permanent harm caused from the audible sound, as no hearing protection is required for human operators. Therefore, there may be some temporary, short-term disturbance during the SODAR use, but long-term or significant impacts are highly unlikely.

**Expanded Space Program**

***<u>LFIC LV and SHFC LV</u>***

Proposed launching of the LFIC LV and SFHC LV would represent the largest LVs ever launched from WFF. Disturbance to wildlife would occur from pre-launch activities, night lighting, launch noise and vibration, and potential toxicant deposition from the exhaust plume generated by these large LVs. Noise modeling of both LVs (BRRC 2015) indicated that launches would create noise levels exceeding 130 dBA at the launch site, with the noise levels of approximately 115 dBA extending outward to a radius of 2.5 km (1.6 mi) from the launch site for the LFIC LV and almost 3 km (1.8 mi) for the SFHC LV. The noise would be intense but would be short in duration. Wildlife would be negatively impacted from these launch activities. Wildlife in the vicinity would likely flee, or be startled and retreat to safer areas. The potential exists for injury or mortality to any wildlife that may be directly in the path of the flame duct and exposed to rocket exhaust. This would most likely occur within 200 to 300 m (650 to 1,000 ft) of the rocket exhaust (USFWS 2010, 2016). The intense, instantaneous noise could produce temporary deafness in animals near the launch pad which could lead to disorientation or increased likelihood of predation (Schmalzer et al. 1998). Pre-launch activities would disturb terrestrial species; with highly mobile species (e.g., birds) fleeing the launch area. Depending on frequency of launch activities, this may decrease the amount of wildlife within the adjacent areas. Wildlife would likely avoid areas during launch activities, but re-enter after launches are complete.

Launch of a LFIC LV, with a liquid propellant first stage, would result in the emission of CO and $CO_2$. When CO and $CO_2$ combine with water vapor in the air, carbonic acid may form which could result in the deposition of carbonic acid on the ground in the area surrounding the launch pad. The effects of carbonic acid deposition on the adjacent areas would be minimal as carbonic acid is a weak acid (approximate pH of 6.4) and is normally found in rainwater. Launch of a SFHC LV would result in acid deposition from HCl in the exhaust. This exhaust has not been shown to have long-term impacts on wildlife. It is assumed that species that occur within the SFHC LV ground cloud may suffer eye and respiratory tract membrane irritation. This impact would likely affect more stationary organisms, as highly mobile species like birds and mammals would flee at the sound of rocket ignition (Schmalzer et al. 1998).

While launches of these LVs may result in direct mortality and disturbance of wildlife, due to the rather infrequent launches of the ELVs, it is unlikely to cause any population level impacts to any wildlife occupying WFF habitats. Therefore, there would be no significant long-term impacts to wildlife from these LVs.

***Vertical Launch and Landing Vehicles***

Potential impacts to wildlife from noise and emissions associated with vertical launch vehicles from Wallops Island would likely be similar to those described for the LFIC LV or SFHC LV. A noise study was conducted in 2017 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island. The results indicate the LFIC RTLS noise levels would exceed 115 dBA within a distance of approximately 0.6 km (0.4 mi) from the landing site (BRRC 2017). LFIC RTLS noise would be similar to the noise described above for a LFIC LV launch. However, a sonic boom could be generated during an RTLS supersonic descent.

The results of the 2017 study indicate that the intensity of a sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). Wildlife may be startled by the sonic boom; however, the impact to terrestrial wildlife would not be considered significant (Manci et al. 1988).

***Horizontal Launch and Landing Vehicles***

Horizontal launch and landings vehicles would take off and land like a standard aircraft from the Runway 04/22 at the Main Base. Impacts to wildlife would be expected to be similar to those generated by aircraft currently operating at the Main Base airfield. The noise associated with the horizontal launch and landings would be typical of existing jet aircraft that utilize WFF; however, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. In the event that a proposed horizontal vehicle would produce a supersonic landing, future NEPA analysis would be performed to prevent unacceptable adverse impacts.

***Commercial Human Spaceflight Missions***

A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) of commercial human spaceflight missions. Potential impacts to wildlife would be similar to those described for LVs launched from Wallops Island and horizontal launch vehicles reentering the airspace and landing at the Main Base.

In summary, operational mission activities proposed under the Proposed Action would negatively impact wildlife to varying degrees, with the greatest impacts arising from the launching of the larger LVs. Most impacts would occur from noise generated from operational activities. Though the noise would be intense, it would be short in duration lasting approximately 10 minutes with peak noise levels occurring in the first one to two minutes. Direct mortality of nearby wildlife is possible during launch activities but given that LV launches would be infrequent (18 per year), impacts to terrestrial wildlife would not be considered significant.

Section 5.4.5, Terrestrial Wildlife provides a discussion on the potential for cumulative effects associated with habitat loss, noise, and predation.

## 3.10 Special-Status Species

Special-status species include any species which is listed, or proposed for listing, as threatened or endangered by the USFWS or NMFS under the provisions of the Federal ESA; species protected under other Federal laws including the Bald and Golden Eagle Protection Act (BGEPA); species that are considered to be threatened or endangered under Virginia's ESA; or those species or habitats of conservation concern identified by the Commonwealth of Virginia. Marine mammals are also protected under Federal regulations and are discussed in Section 3.11, Marine Mammals and Fish.

### 3.10.1 Affected Environment

#### 3.10.1.1 Federal Regulatory Framework

Under Section 7 of the Federal ESA, as amended (16 U.S.C. 1531-1544), Federal agencies, in consultation with the USFWS, are required to evaluate the effects of their actions on federally listed species of fish, wildlife, plants and designated critical habitat and to take steps to conserve and protect these species and habitat. Species that are protected under the Federal ESA include plants or animals that are candidates for, proposed as, or listed as threatened or endangered by USFWS. Bald eagles, which have been de-listed under the Federal ESA, are still federally protected under the BGEPA (16 U.S.C. 668-668c).

#### 3.10.1.2 State Regulatory Framework

The Virginia ESA (29 VAC 1-563 – 29.1-570) is administered by VDGIF and prohibits the taking, transportation, processing, sale, or offer for sale of any federally or state-listed threatened or endangered species. As a Federal agency, NASA voluntarily complies with Virginia's ESA. In addition, NASA also recognizes any species listed by the Commonwealth of Virginia in a category implying potential danger of extinction.

Both the VDCR and VDGIF place emphasis on species considered to be "Species of Greatest Conservation Need" within the Commonwealth of Virginia's *Comprehensive Wildlife Conservation Strategy* (VDGIF 2005).

The strategy/action plan breaks down species of greatest conservation need into four Tiers, as follows:

- **Tier I** – Species of Critical Conservation Need face an extremely high risk of extinction or extirpation.
- **Tier II** – Species of Very High Conservation Need have a high risk of extinction or extirpation.
- **Tier III** – Species of High Conservation Need for which extinction or extirpation is possible.
- **Tier IV** – Species of Moderate Conservation Need that may be rare in parts of their range, particularly on the periphery.

The VDCR's Division of Natural Heritage (VDCR-DNH) is the state agency responsible under the Virginia Natural Area Preserves Act (Section 10.1-209 through 217, Code of Virginia) for inventory, protection, and management of Virginia's natural heritage resources. One of VDCR-DNH's responsibilities is to designate conservation sites for the Commonwealth of Virginia. A conservation site may include one or more rare plants, animals, or natural communities. Conservation sites are given a biodiversity significance ranking based on rarity, quality, or number of element occurrences they contain; on a scale of 1 to 5, with 1 being the most significant.

#### 3.10.1.3 Special-Status Species and Habitats at WFF

Special-status species that may occur on or within the vicinity of WFF are summarized in **Table 3.10-1**. **Figure 3.10-1** and **Figure 3.10-2** show the known locations of protected species in the vicinity of the Main Base and the Mainland and Wallops Island, respectively; however, the entire beach area is suitable nesting and/or foraging habitat for a number of special-status species that are described in more detail in Section 3.10.1.3 below.

In 2016, the USFWS issued a combined BO for the SRIPP and expanded operations at WFF, to include the Proposed Action of this PEIS (USFWS 2016b). As part of the terms and conditions of the BO to manage special-status species, WFF administers a *Protected Species Monitoring Plan* (NASA 2011a). The Plan is reviewed annually in cooperation with USFWS and revised if applicable.

Due to lack of special-status species habitat on the Main Base and Mainland, the plan only applies to Wallops Island. Wallops Island is further divided into four distinct monitoring areas: North End, Recreational Beach, New Beach, and South End. Procedures are outlined for monitoring a number of protected species that are likely to occur at Wallops Island including: seabeach amaranth, red knot, piping plover, northern long-eared bat, and sea turtles. Monitoring reports for the protected species are prepared annually. Procedures for marine mammal stranding are also outlined in the Plan. The *Protected Species Monitoring Plan* also outlines mission specific monitoring. The purpose of mission specific monitoring is to survey the area adjacent to a planned rocket launch on Wallops Island for a protected species listed in this plan. As soon as safety permits following launches, monitoring staff would conduct surveys for injured, dead, or impaired birds and sea turtles. Post-launch beach surveys would be conducted between March 15 and November 30 of every year to coincide with plover and sea turtle nesting seasons. The survey area would include the beach within 1,000 ft, to the north and south, of the respective launch pad for sounding and orbital-class rocket launches. Reports of survey results would be provided to the Service in digital format, within 15 business days of each launch event (USFWS 2016b).

**Table 3.10-1. Protected Species That May Occur on or within the Vicinity of Wallops Flight Facility**

| Common Name | Scientific Name | Status† | Expected Occurrence* | Notes |
|---|---|---|---|---|
| **PLANTS** | | | | |
| Seabeach Amaranth | *Amaranthus pumilus* | FT, ST | Assateague Island beach | Only documented within ROI at Assateague Island (NASA 2016a; USFWS 2012a). |
| **INVERTEBRATES** | | | | |
| Northeast Beach Tiger Beetle | *Cicindela d. dorsalis* | FT, ST | Chesapeake Bay beaches | Only documented on Chesapeake Bay beaches; closest beach known to be occupied by species is approximately 23 km (14 mi) west of WFF (USFWS 2011). |
| **MAMMALS** | | | | |
| Northern Long-eared Bat | *Myotis septentrionalis* | FT, PT | May roost under bark, or in cavities or crevices of both live and dead trees during summer months | Acoustic bat surveys in 2008 determined that 0.3 percent of calls could be attributed to myotis bats. It could be presumed that a portion of these calls may have been from the northern long-eared bat (NASA 2016a). |
| **SEA TURTLES** | | | | |
| Loggerhead Sea Turtle | *Caretta caretta* | FT, ST | Coastal and offshore ocean waters; Wallops, Assateague Island beaches | Most prevalent sea turtle species in ROI; has nested on Wallops and regularly nests on Assateague Island beaches (NASA 2016a; USFWS 2012a); greatest in- water concentrations over continental shelf (Shoop and Kenney 1992), however species is also found in deeper waters (Mansfield et al. 2009). |
| Leatherback Sea Turtle | *Dermochelys coriacea* | FE, SE | Coastal and offshore ocean waters | Nesting unlikely; only one individual demonstrating nesting behavior documented on Assateague Island in 1996 (Rabon et al. 2003); generally considered oceanic, however will forage in coastal areas if prey species are available in high densities (Eckert et al. 2006). |
| Hawksbill Sea Turtle | *Eretmochelys imbricata* | FE, SE | Coastal ocean waters | Most unlikely sea turtle species in ROI; only two observations in Virginia since 1979 (Mansfield 2006). |
| Kemp's Ridley Sea Turtle | *Lepidechelys kempi* | FE, SE | Coastal ocean waters | Second most prevalent sea turtle species in ROI; traditionally nests in Mexico, however first Virginia nest discovered in 2012 at Virginia Beach (USFWS 2012b); generally, found in more sheltered, shallower water habitats than other sea turtle species (Ogren 1989). |
| Atlantic Green Sea Turtle | *Chelonia mydas* | FT, ST | Coastal ocean waters | Nesting unlikely; only one nest documented nest in Virginia at Virginia Beach in 2005 (Marine Turtle Newsletter 2006). |

| Table 3.10-1. Protected Species That May Occur on or within the Vicinity of Wallops Flight Facility (cont.) | | | | |
|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Status†** | **Expected Occurrence*** | **Notes** |
| **BIRDS** | | | | |
| Red Knot | *Calidris canutus* | FT, SGCN IV | Wallops, Assateague, Assawoman Island beaches | Regularly forages on Wallops, Assateague, and Assawoman Islands during migration (NASA 2015). |
| Piping Plover | *Charadrius melodus* | FT, ST | Wallops, Assateague, Assawoman Island beaches | Regularly nests and forages on Wallops, Assateague, Assawoman Island beaches (NASA 2015; USFWS 2012a). |
| Roseate Tern | *Sterna d. dougallii* | FT, ST | Offshore ocean waters | Rarely observed along the U.S. coast south of New Jersey; may transit through oceanic portion of ROI during seasonal migration (Nisbet 1984) |
| Bald Eagle | *Haliaeetus leucocephalus* | BGEPA, ST | Main Base, Wallops Island | Active nests on Wallops Main Base and Island (NASA 2016a; 2012b) |
| Wilson's Plover | *Charadrius wilsonia* | SE | Assawoman Island beach | No active nests detected on Wallops Island (NASA 2015); active nests on Assateague Island and two adjacent islands to the south (Boettcher 2013). |
| Peregrine Falcon | *Falco peregrinus* | ST | Wallops Island | Regularly nests on hacking tower on west side of North Wallops Island (NASA 2016a). |
| Loggerhead Shrike | *Lanius ludovicianus* | ST | Wallops Main Base, Wallops Mainland | Historic occurrence in Accomack County, however recent Virginia occurrences have only been in the Shenandoah Valley (Fraser 1991). |
| Gull-billed Tern | *Gelochelidon nilotica* | ST | Assateague Island beach | No active nests detected on Wallops Island; active nests on Assateague Island (NASA 2013; USFWS 2012a). |
| **FISH** | | | | |
| Atlantic Sturgeon | *Acipenser o. oxyrinchus* | FE, SCGN II | Coastal ocean waters | Most likely found in water depths less than 50 m (Stein et al. 2004). |
| Giant Manta Ray | *Manta birostris* | FE | Offshore ocean waters | Global distribution; lives in open waters and near productive coastlines. |
| Oceanic Whitetip Shark | *Carcharhinus longimanus* | FE | Offshore ocean waters | Global distribution; lives near the surface in warm open waters. |

Notes: †FC = Federal Candidate; FT = Federal Threatened; FE = Federal Endangered; ST = State Threatened; SE = State Endangered; BGEPA = Bald & Golden Eagle Protection Act; SGCN = Species of Greatest Conservation Need.

*For in-water species, the term "coastal ocean waters" in this table generally corresponds with the neritic zone, which in standard oceanographic terms is between water depths of 0-200 m and usually includes the continental shelf, "offshore ocean waters" generally corresponds with the oceanic zone beyond the 200 m depth contour.

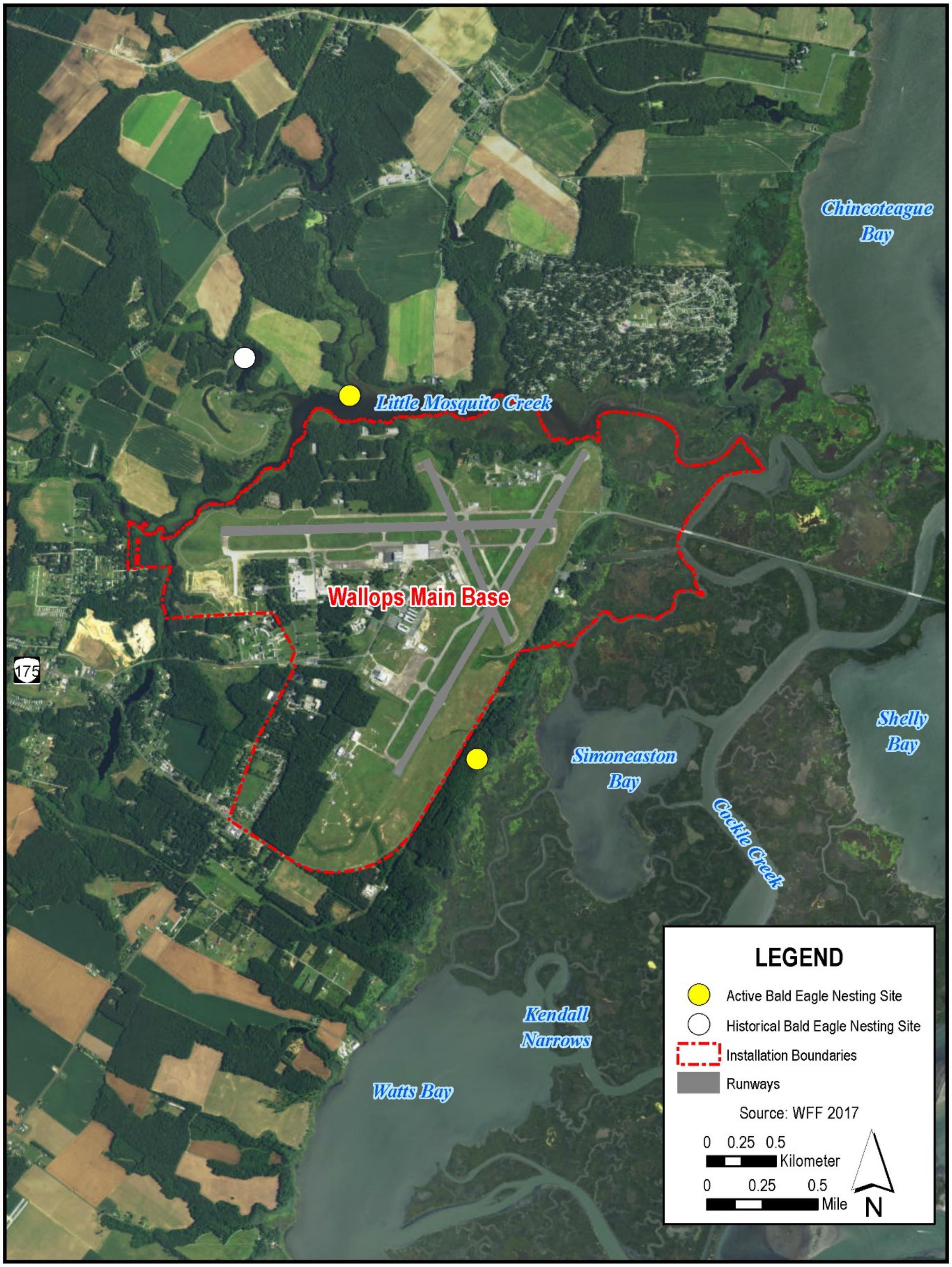


**Figure 3.10-1. Special-Status Species at Wallops Flight Facility Main Base**

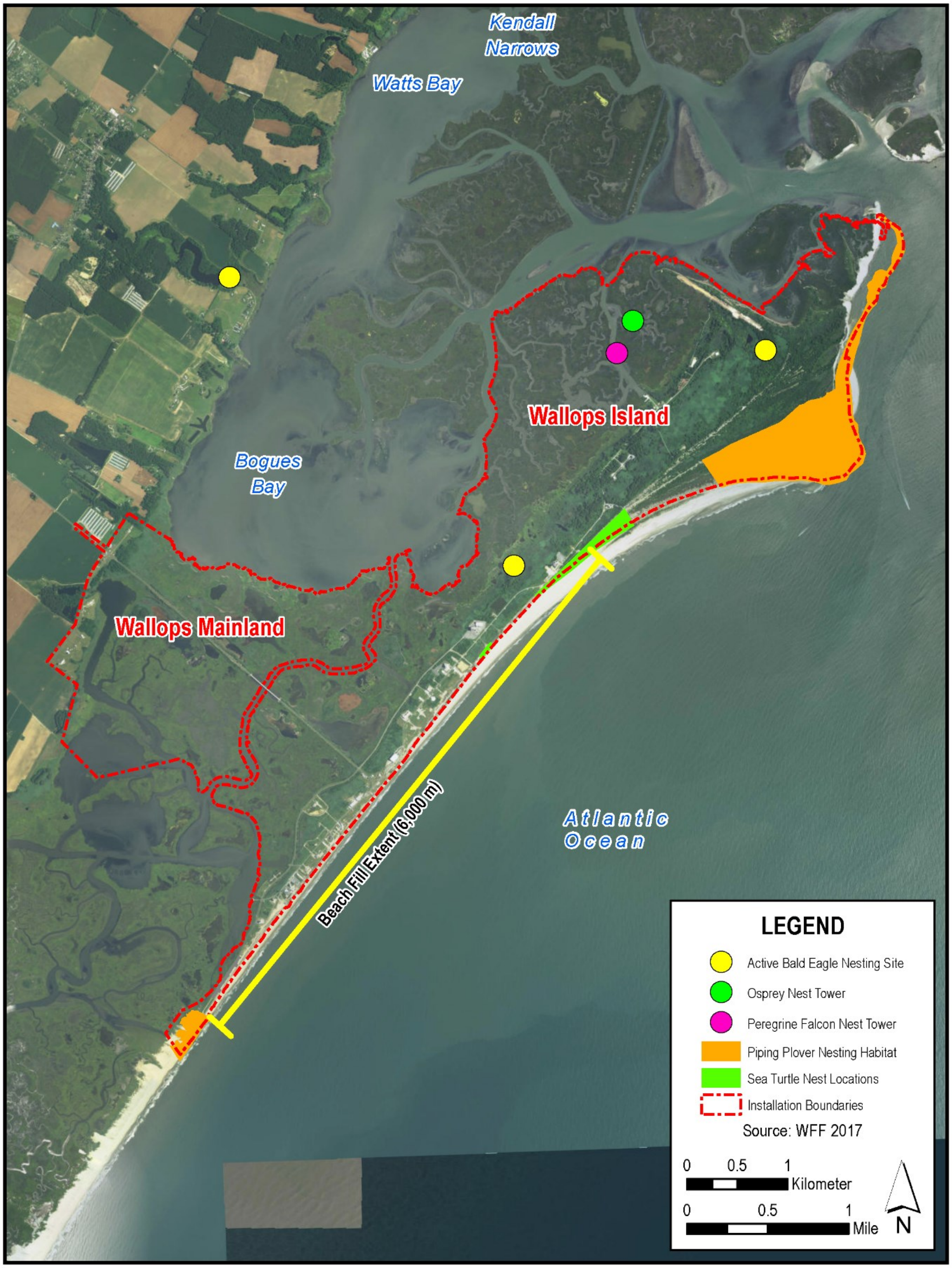


**Figure 3.10-2. Special-Status Species at Wallops Flight Facility Mainland and Wallops Island**

3.10.1.3.1 Plants

**Seabeach Amaranth**

The threatened seabeach amaranth is an herbaceous plant, which colonizes and stabilizes the areas seaward of the primary dunes, growing closer to the high tide line than any other coastal plant. An annual plant and fugitive species, seabeach amaranth appears to need extensive beach and inlet areas that function in a relatively natural and dynamic manner. It often grows in the same areas selected for nesting by shorebirds such as plovers, terns, and skimmers. It emerges on sand dunes, inlets, and overwash flats in summer and early fall. Its distribution varies from year to year, influenced by seed dispersal and locally favorable conditions for germination, growth, and flowering. Flowering begins as soon as plants are mature, sometimes as early as June, but more typically beginning in July and continuing into late fall. Seed production begins in July or August and peaks in September. Seabeach amaranth occurs on barrier islands and beaches, where its primary habitat consists of overwash flats at the accreting ends of islands, and the lower foredunes and upper strands of non-eroding beaches. This species appears to be intolerant of competition and does well on sites with low vegetative cover. Seabeach amaranth requires extensive areas of barrier island beaches and inlet areas, and is most successful at colonizing unaltered beach landscapes which are inherently dynamic. These characteristics allow it to “move around” in the landscape as a fugitive species, occupying suitable habitat as it becomes available.

3.10.1.3.2 Sea Turtles

**Loggerhead Sea Turtle**

Both USFWS and VDGIF consider loggerhead sea turtles a threatened species. NMFS has divided the population into nine distinct population segments (DPS), four of which are threatened and five that are considered endangered. The population near WFF belongs to the threatened northwest Atlantic DPS. On average, adults in the southeastern U.S. weigh 113 kgs (250 lbs) and grow to a length of 1 m (3 ft). Loggerhead sea turtles feed on hard-shelled prey such as whelks and conch. The species spends the majority of its life in the open ocean or nearshore coastal areas, but nests on beaches and occasionally on estuarine shorelines (NMFS 2013a). In the southeastern U.S., they mate from March to early June, and females lay eggs between late April and early September. Female sea turtles leave the ocean only to lay eggs and, for most species, nest only at night. A female may nest every two to three years. Nesting can take between one and three hours. After a female turtle drags herself up the beach, she hollows out a pit with her back legs and deposits 50 to 200 eggs. When the last egg is laid, the turtle covers the eggs with sand, tamps down the sand with her plastron, and flings more sand about with her flippers to erase any signs of the nest and crawls back out to sea. After about two months, typically between late June and mid-November, the hatchling turtles emerge at night. The light reflected off the water from the sky guides them to the sea.

The major nesting concentrations in the U.S. occur from North Carolina to southwest Florida. However, the species has been known to range northward to Virginia and westward to Texas. On July 18, 2013, NMFS proposed 36 critical habitat units for loggerhead sea turtles. No critical habitat was proposed along or off the shore of WFF (NMFS 2013b). The most northerly proposed habitat unit is off the Diamond Shoals in North Carolina. In July of 2014, NMFS issued the Final Rule for in water critical habitat for the loggerhead sea turtle. In total, 38 critical habitat areas were designated within occupied marine areas for the range of the northwest Atlantic DPS (NMFS 2014). Also in July of 2014, the Final Rule for critical nesting habitat for loggerhead sea turtles was passed by the USFWS. This included 88 nesting beaches in coastal counties in North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi (USFWS 2014). None of these areas were in the vicinity of WFF.

Current threats to the species include incidental capture in fishing gear, direct harvest, disease, consumption of marine debris, and environmental contamination. Threats to nesting include loss or degradation of nesting habitat, beach armoring, artificial lighting, and non-native vegetation on beaches (NMFS 2016a). One loggerhead sea turtle nest was observed on Wallops Island in 2008 and four were observed in 2010 (NASA 2010b). In 2012, two loggerhead nests were observed including one on the re-nourished beach near the Navy's Aegis facility; the first nest was predated during the hatch window while the second nest had a 78% hatch rate, with 5 hatchlings directly observed by WFF personnel. In 2013, two loggerhead nests were identified farther south on the Wallops Island beach between building X-79 and Launch Pad 0-A. The southernmost nest had a hatch rate of 79%, whereas the more northern nest was less successful (hatch rate approximately 4%) due to its relatively lower elevation on the beach, which resulted in its exposure to storm-induced flooding (NASA 2013). No loggerhead turtle nests were observed in years 2014 through 2016 (NASA 2014, 2015b, 2016b). The area where loggerhead sea turtle nests have been observed on Wallops Island is depicted in **Figure 3.10-2**.

**Leatherback Sea Turtle**

The leatherback sea turtle is federally and state endangered and is the largest sea turtle, and the largest living reptile, reaching up to 2 m (6.5 ft) in length and weighing up to 900 kgs (2,000 lbs). Leatherbacks are the only sea turtle that lack a bony shell, with the carapace being made up of thick, leathery, oil-saturated connective tissue overlaying loosely interlocking dermal bones. The carapace has seven distinctive longitudinal ridges and tapers to a blunt point. The front flippers lack both claws and scales and are proportionally longer than those of other sea turtles and the rear flippers are paddle shaped. Leatherback morphology makes the species uniquely suited to long distance foraging migrations. They feed on soft bodied pelagic prey, such as jelly fish and salps (NMFS 2016a). Leatherbacks are commonly known as oceanic creatures but they also forage in coastal waters. They are the most migratory and wide ranging of all sea turtle species. Nesting typically occurs in tropical waters. After nesting, females migrate to more temperate waters that support high densities of jellyfish (NMFS 2016a). Leatherbacks have never been sighted on WFF but are known to occur in the waters offshore of Accomack County (NASA 2016a).

**Hawksbill Sea Turtle**

The hawksbill sea turtle is a federally and state endangered sea turtle that can reach up to 1 m (3 ft) in length and weigh up to 80 kgs (180 lbs). Hawksbills have an elongated head that tapers to a point with a beak-like mouth that gives the species its name. The morphology of the head and mouth allows the hawksbill to reach into holes and crevices of coral reefs to find sponges, their primary food source, and other invertebrates. Hawksbills are unique among sea turtles in that they have two pairs of prefrontal scales on the top of the head and each of the flippers typically has two claws. Females return to natal beaches to lay their eggs every 2 to 3 years. A female will typically lay 3 to 5 nests per season, laying one every 14 to 16 days. They typically nest high up on the beach under beach/dune vegetation. Hawksbills are a circumtropical species typically occurring between 30°S latitude and 30°N latitude in the Atlantic; however, they have been sighted as far north as Massachusetts (NMFS 2016a). Hawksbills have never been directly observed by WFF personnel (NASA 2016a). They may occur in offshore waters, but the preferred tropical habitat does not exist near WFF. Therefore, they are unlikely to occur.

**Kemp's Ridley Sea Turtle**

Kemp's ridley sea turtles are federally and state endangered. Adult Kemp's ridley sea turtles are considered the smallest of all sea turtles; growing to 70 cm (28 in) long and weighing up to 45 kgs (100 lbs). They have a relatively round shape, with five pairs of costal scutes. Each front flipper has one claw, while back flippers may have one or two claws. Kemp's ridleys feed on crabs, fish, jellyfish, and mollusks. They range from the Gulf of Mexico to the U.S. Atlantic seaboard from Florida to Maine. They are found in the neritic zone; that is, in areas that typically contain muddy or sandy bottoms where their prey can be found. Kemp's ridley turtles nest from May to July, laying two to three clutches of about 100 eggs. These turtles utilize synchronized nesting techniques, where many females come ashore to nest along the same beach at the same time. Large groups are known to nest in the state of Tamaulipas, Mexico, where 95% of the worldwide nesting of Kemp's ridley turtles occurs. Occasional nests have been documented in North Carolina, South Carolina, and Gulf and Atlantic Coasts of Florida (NFMS 2016a), and most recently, Virginia (USFWS 2012b). The Kemp's ridley sea turtle has never been directly observed at WFF (NASA 2016a). The species may occur offshore in relatively shallow waters (less than 50 m [160 ft]) where habitat exists for prey species (NMFS 2016a).

**Atlantic Green Sea Turtle**

Atlantic Green sea turtles are federally and state threatened. These sea turtles are the largest of all the hard shelled marine turtles, growing to a length of 1 m (3 ft) and weighing up to 160 kgs (350 lbs). Green sea turtles are unique among marine turtles in that they feed exclusively on plants, primarily sea grasses and algae. Nesting locations vary in the southeastern U.S. but nesting generally occurs between June and July. Females lay an average of five nests per season. In the U.S., green sea turtles primarily nest along the central and southern coast of Florida. They have a global distribution and are generally found in tropical and subtropical waters along continental coasts and islands between 30°S latitude and 30°N latitude. The species utilize open ocean convergence zones and coastal areas for benthic feeding on sea grasses and algae (NMFS 2016a). Atlantic Green sea turtles have been directly observed in waters off WFF (NASA 2016a). These turtles are likely to inhabit the waters off WFF during the warmer months when sea grasses and algae are plentiful. However, nesting habitat occurs farther south in tropical waters.

3.10.1.3.3 Birds

**Red Knot**

The red knot was listed as federally threatened on December 11, 2014. It is a medium sized sandpiper and one of the longest-distance migrants known in the world. Red knots have a red head and breast during breeding plumage and are grey during the rest of the year. These small birds have wingspans of approximately 51 cm (20 in) and fly more than 15,000 km (9,300 mi) from south to north each spring and in reverse each autumn. They feed on small mussels and other mollusks for a large percentage of the year and horseshoe crab eggs during migration (USFWS 2005). Based on survey data, during the mid-1990s, 8,000 to 10,000 individuals would migrate through the barrier islands of coastal Virginia. Surveys conducted in 2005 and 2006 recorded similar numbers (NASA 2015).

Red knots do not breed in the vicinity of Accomack County, although they have been appearing regularly during spring migration on Wallops Island beaches, mostly during the second half of May (NASA 2015). On May 8, 2009, there was a flock of approximately 1,300 individuals seen on North Wallops Island and again in late May 2009, flocks of approximately 20 to 200 red knots were observed (NASA 2009a).

Survey data for 2010 indicate that approximately 900 individuals were observed on the northern end of Wallops Island in May. Survey data for 2011 indicate that red knots began arriving on May 6 (3 birds sighted), and the last bird seen was on July 19. The largest flock observed in 2011 was on May 29 and was comprised of 216 individuals. In 2011, a total of 1,167 red knots were counted throughout the months of May through July (NASA 2011b). Nearly 3,500 red knots were counted in 2012; however recent years has seen many fewer with 1,091 counted in 2015 and 1,255 observed in 2016 (NASA 2016b).

**Piping Plover**

Piping plovers are federally and state threatened. Piping plovers are small, beige and white shorebirds with a black band across their breast and forehead. They typically feed on invertebrates such as marine worms, beetles, fly larvae, crustaceans, and mollusks. Habitat generally consists of ocean beaches, sand, or algal flats in protected bays, while breeding occurs mainly on gently sloping foredunes or blowout areas behind dunes. In late March or early April, after they have established territories and conducted courtship rituals, plover pairs form shallow depressions for nests where they lay their eggs in the sand. Nests can be found above the high tide line on coastal beaches, sandflats at the end of spits and barrier islands, gently sloping foredunes, blowout areas behind dunes, and overwash areas between dunes. Nest site substrates may include a range of materials from fine grained sands up to shells and cobbles. Nests are typically found in areas with little or no vegetation; however, occasionally nests have been found under beach grass and other vegetation (NASA 2015).

The piping plover is a common transient and summer resident of the upper Virginia barrier islands and is known to inhabit the coastal habitats of the nearby CNWR. **Figure 3.10-2** depicts piping plover nesting habitat areas. Piping plovers are known to use the sandy beaches and tidal flats along the coast of Wallops Island. They were first identified on northeast Wallops Island in a survey in June 1995. In 2008, two pairs of piping plovers began nesting attempts at the north end of Wallops Island but no eggs were laid. In 2009, three pairs nested successfully on the northern beaches (NASA 2009a). In 2010, there were three nesting attempts, including one that was successful (NASA 2010b). In 2011, there were three documented piping plover nesting attempts on Wallops Island: two nests on the north end and one on the south end. One nest on the north end had four eggs; however, three were lost to a storm but one chick fledged. The second nest on the north end had four eggs; three hatched and two chicks fledged. The nest on the south end had three eggs; all hatched but the chicks were lost to a storm (NASA 2011b). Six piping plover nests were attempted in 2012. Of the 16 eggs laid, 3 chicks successfully fledged. Monitoring efforts in 2013 identified four piping plover nests on North Wallops Island, resulting in 8 chicks fledged (NASA 2013). Fledging success rates in years 2014, 2015, and 2016 have averaged 30 percent (NASA 2014, 2015b, 2016b).

**Wilson's Plover**

Wilson's plover is considered endangered by VDGIF. Wilson's plover is a small to medium sized plover and is a coastal wader. Its range is both the east and west coasts of the U.S., with abundant breeding populations along the Gulf Coast. Wilson's plover has been documented as occurring on South Wallops Island, and, although no nests have been documented on Wallops Island, they are historically known to nest with piping plover (NASA 2016a).

**Bald Eagle**

The bald eagle was formerly federally listed as endangered but has been de-listed and is now considered recovered; however, bald eagles are provided protection under the Federal BGEPA. Bald eagles also remain listed in Virginia as a threatened species. Active bald eagle nests are located within or adjacent to all three portions of WFF. Nesting activities typically begin in November and conclude in the summer when the young fledge (NASA 2016a).

**Peregrine Falcon**

Peregrine falcons were formerly listed as endangered but have been de-listed and are now considered recovered; however, they remain listed in Virginia as a threatened species. One man-made peregrine Falcon nesting tower is located on Wallops Island, and has been historically utilized by a pair of falcons. Peregrine falcons are also known to occur on Wallops Island during migration (NASA 2016a).

**Gull-billed Tern**

The gull-billed tern is state-listed as threatened and is a medium sized, black-capped, heavy-billed, and long-legged tern, now placed by most authorities in the monotypic genus *Gelochelidon,* but was formerly placed in the larger genus *Sterna*. It has a broad distribution breeding in scattered localities in Europe, Asia, northwest Africa, Australia, and the Americas. In the U.S. it nests only in coastal colonies along the Atlantic and Gulf coasts; in California it is restricted to one coastal location and one location in the interior of the state. North American gull-billed terns winter along the Gulf Coast, Pacific coast of Mexico, and into Central and South America. Breeding and nesting takes place on sandy beaches in spring and summer (Molina et al. 2009). Gull-billed terns are possible summer residents along Virginia's Eastern Shore; uncommon transients on the coast south of Cape Henry; and rare in the Lower Chesapeake Bay. Breeding activity has been recorded on the coast of the Eastern Shore but not on Wallops Island (VDGIF 2012).

3.10.1.3.4 Fish

**Atlantic Sturgeon**

The Atlantic sturgeon is a federally- and state-listed endangered (state Tier II SGCN), long-lived, estuarine dependent, anadromous fish that can grow to approximately 4 m (14 ft) in length and weigh up to 360 kgs (800 lbs). There are five DPS for the Atlantic sturgeon, and the population near WFF is part of the endangered Chesapeake Bay DPS. They are similar in appearance to shortnose sturgeon but are distinguished by their larger size, smaller mouth, different snout shape, and scutes. These fish range from Newfoundland to the Gulf of Mexico and are highly migratory. Adults migrate to natal rivers and spawn in flowing waters between the salt front and fall line. Adults spawn in freshwater in the spring and early summer and migrate into estuarine and marine waters where they spend the majority of their lives. Atlantic sturgeon are benthic feeders and typically forage on benthic invertebrates (e.g., crustaceans, worms, mollusks, etc.). Though historically abundant, the slow reproducing populations have been depleted due to overfishing, water pollution, and commercial bycatch (NMFS 2016b). Atlantic sturgeon are known to occur and have been documented in the deeper waters off WFF.

**Giant Manta Ray**

The giant manta ray is listed as threatened under the ESA. In January 2018, NOAA published its final rule (NMFS 2018a). The largest of the ray family, the giant manta ray can reach a disc size of up to 7 m (23 ft) across and weigh over 1,350 kg (2,980 lbs). The species is found worldwide; on the U.S. east coast, the giant manta ray has been documented as far north as New Jersey. Mantas remain in the open ocean waters and travel with the currents. They may travel alone or in groups of up to 50 individuals. The giant manta ray grows slowly and may live up to 30 years. The biggest threat to the species over the last twenty years is overfishing (artisanal, targeted, and bycatch). This is detrimental to a species which has a low fecundity rate and produces a single pup about every two to three years.

**Oceanic Whitetip Shark**

The oceanic whitetip shark is listed as threatened under the ESA. In January 2018, NOAA published its final rule (NMFS 2018b). The oceanic whitetip shark is a stocky, slow-moving species that can reach up to 3.4 m (11.2 ft) in length and weigh over 230 kg (500 lbs). The species is easily distinguishable from other sharks by its whitish-tipped first dorsal, pectoral, pelvic, and caudal fins. They are found worldwide in warm tropical and subtropical waters between 20° North and 20° South latitude, but can be found up to about 30° North and South latitude during seasonal movements to higher latitudes in the summer months. They tend to remain in the open ocean well offshore. The lifespan is up to 19 years with maturity between years 4 to 7; mothers typically give birth with every two years with pup litter sizes ranging from 1 to 14. The oceanic whitetip shark was historically one of the most abundant shark species; however, due to inadequate regulations and overpressure in the fishing industry from bycatch related mortality, estimates of decline range from 50 to 80 percent across the Atlantic Ocean with higher declines across the Pacific Ocean and variable declines across the Indian Ocean.

#### 3.10.1.3.5 Terrestrial Mammals

**Northern Long-eared Bat**

The northern long-eared bat is currently listed as threatened by the USFWS. In February 2016, the USFWS published a final 4(d) rule further defining "takes" and "incidental takes". ESA 4(d) rules allow the USFWS the ability to provide more specific rules or measures to protect a species that is threatened (not endangered). The ESA 4(d) rule was passed due to the mortality faced by this species from white-nose syndrome, a fungal disease that is poorly understood at this time.

This bat is medium-sized, measuring roughly 8 to 9 centimeters (3 to 3.7 inches) in length and weighing approximately 5.7 to 8.5 grams (0.2 to 0.3 ounces). Its fur color can be medium to dark brown on the back and tawny to pale-brown on the underside. The northern long-eared bat is distinguished by its long ears, particularly as compared to other bats in its genus. Like the Indiana bat, this species spends winter hibernating in caves and abandoned mines. During the summer, they tend to roost singly or in colonies underneath loose tree bark and in the cavities or crevices of both live and dead trees. Males and non-reproductive females may also roost in cooler places such as caves or mines. Northern long-eared bats seem to be flexible in selecting roosts, choosing roost trees based on suitability to retain bark or provide cavities or crevices. This bat has also rarely been found roosting in structures, like barns or sheds (USFWS 2016a). Threats that have contributed to the species decline include commercialization of caves, loss of summer habitat, pesticides and other contaminants, and most recently, the disease known as white-nose syndrome. The disease is named for the white fungus that infects skin of the muzzle, ears, and wings of hibernating bats. Bats infected with the disease exhibit abnormal behaviors in their hibernacula that result in the loss of stored fat reserves causing emaciation and ultimately death.

3.10.1.3.6 Marine Mammals

**Fin Whale**

The fin whale is federally- and state-listed as endangered and is considered depleted under the MMPA. Fin whales are the second largest species of whale, grow to a maximum length of approximately 23 m (75 ft) in the Northern Hemisphere, and can weigh from 35 to 75 metric tons (40 to 80 tons). This species is found in social groups that range from two to seven individuals. They feed on krill, small schooling fish, and squid in the summer and fast during the winter migration. Little is known about fin whale migration patterns. Fin whales are found in deep, offshore waters primarily in temperate and polar latitudes and less commonly in the tropics. Currently, the minimum population estimate for fin whales in the North Atlantic Ocean is 1,678 individuals. Historically, the fin whale population was diminished through commercial whaling. Current threats to the species include collision with vessels, entanglement in fishing gear, reduced prey abundance due to overfishing, habitat degradation, and disturbance from low-frequency noise (NMFS 2016c). Fin whales may be found in ocean waters over the continental shelf off the coast of WFF (Waring et al. 2009) and have been documented as close as 1.5 km (1 mi) offshore when following prey species such as rockfish (Whealton 2013).

**Humpback Whale**

The humpback whale is federally- and state-listed as endangered and is considered depleted under the MMPA. Humpback whales grow to lengths of up to 18 m (60 ft) and have long pectoral fins that can grow to 4.5 m (15 ft) in length. Humpback whales spend summer months in high-latitude feeding grounds building fat reserves by feeding on krill, plankton, and small fish. The species migrates seasonally and spends the winter months in tropical or subtropical waters where they congregate and engage in mating activities. Humpback whales stay near the surface of the ocean during migration and prefer shallow waters for feeding and calving. The best available population estimate for humpback whales in the North Atlantic Ocean is currently 11,570 individuals; however, the species is believed to be increasing in abundance in much of its range. Threats to humpback whales include entanglement in fishing gear, collision with vessels, whale watch harassment, and habitat impacts (NMFS 2016c). Humpback whales may be found in ocean waters off the coast of WFF during migration and recent data suggests that habitat off the Mid-Atlantic states (Virginia and North Carolina) may be important for juvenile humpbacks (Waring et al. 2009). A juvenile humpback whale was stranded on North Wallops Island beach in September 2012 (Whealton 2013). In December of 2016, NMFS established 14 DPS for humpback whales. The West Indies DPS, which includes habitat in the Mid-Atlantic region is no longer listed by NMFS.

**North Atlantic Right Whale**

The North Atlantic right whale is federally- and state-listed as endangered and is considered depleted under the MMPA. North Atlantic right whales grow to lengths of 14 to 17 m (45 to 55 ft) and weigh up to 65 metric tons (70 tons). The species spends winter months in lower latitudes and coastal water, where calving occurs. There is still much uncertainty about the exact whereabouts of much of the population during winter months. North Atlantic right whales migrate to higher latitudes during the spring and summer to feed on zooplankton. Current estimates indicate that there are between 300 and 400 North Atlantic right whales and there is evidence to suggest a slight growth in the population size. Threats to North Atlantic right whales include entanglement in fishing gear, collision with vessels, whale watch harassment, habitat impacts, and noise from industrial activities (NMFS 2016c). No North Atlantic right whales have been observed adjacent to WFF (NASA 2016a). However, they have the potential to occur in shallow coastal waters within VACAPES.

**Sperm Whale**

The sperm whale is federally- and state-listed as endangered and is considered depleted under the MMPA. Sperm whales are the most sexually dimorphic cetaceans, with males growing to 16 m (52 ft) in length and weighing up to 41 metric tons (45 tons), and females growing to 11 m (36 ft) in length and weighing up to 14 metric tons (15 tons). Sperm whales generally inhabit areas with a water depth of 600 m (2,000 ft) or more and are uncommon in waters less than 300 m (1,000 ft). The North Atlantic stock of sperm whales concentrates east and northeast of Cape Hatteras during the winter. During the spring, the population shifts northward to the east of Delaware and Virginia, and is widespread throughout the central portion of the Mid-Atlantic Bight and the southern portion of Georges Bank. During the summer, there is a similar distribution, which also includes areas east and north of Georges Bank, into the Northeast Channel region and the continental shelf south of New England. In the fall, occurrences south of the New England continental shelf are at their highest and there are occurrences along the continental shelf edge of the Mid-Atlantic Bight. The best available estimate for the North Atlantic population of sperm whales is 4,702 individuals. Historic threats to the species were mainly from whaling, but current threats include collision with vessels, fishing gear entanglement, anthropogenic noise, and pollution (NMFS 2016c). Sperm whales have not been observed near WFF; however, they could potentially occur at the edge of the continental shelf in VACAPES.

**Sei Whale**

The sei whale is federally- and state-listed as endangered and is considered depleted under the MMPA. Sei whales grow to lengths of 12 to 18 m (40 to 60 ft) and weigh up to 45 metric tons (50 tons). Sei whales are usually observed in deep waters along continental shelf edges in subtropical and sub-polar latitudes; however, it is believed that they prefer temperate waters in the mid-latitudes. Distribution and movement of the species is not well known, but it is believed that they seasonally migrate to lower latitudes during winter and higher latitudes during summer. Sei whales opportunistically feed on plankton, small schooling fish, and cephalopods. There are no current estimates for the western North Atlantic stock of sei whales but the current worldwide estimate is 80,000 individuals. Threats to sei whales include collision with vessels and fishing gear entanglement (NMFS 2016c). Sei whales have not been observed near WFF; however, they could potentially occur at the edge of the continental shelf in VACAPES.

**Blue Whale**

The blue whale is federally- and state-listed as endangered and is considered depleted under the MMPA. Blue whales are the largest whales in the world. In the North Atlantic, blue whales grow to lengths of up to 27 m (88 ft) and can weigh more than 150 metric tons (165 tons). Blue whales inhabit sub-polar and subtropical latitudes. The species migrates to higher latitudes during the spring in order to feed on krill during the summer and then migrates back to the sub-tropics in the fall. Blue whales can be found in coastal waters but are generally believed to occur offshore.

The current minimum estimate for the blue whale population in the western North Atlantic is 308 individuals and there is insufficient data to determine an overall population trend. Threats to blue whales include ship strikes, fishing gear entanglement, anthropogenic noise, competition for prey, and habitat degradation (NMFS 2016c). Blue whales have not been observed near WFF; however, they could be found in the coastal and deeper waters in VACAPES.

**Florida Manatee**

Florida manatees (*Trichechus manatus latirostris*) are listed as threatened under the ESA and protected under the MMPA. Manatees are large, slow-moving herbivores with a low metabolic rate and high thermal conductance, which limits their ability to maintain core body temperatures in cold waters. Manatees depend on seagrass and other aquatic vegetation for food. In the winter, they congregate around warm water springs and man-made sources of warm water such as power plant discharges. Manatees can live for several decades. Adult females give birth to a calf about once every three years. The current best available population count for the Florida manatee is 4,834 individuals, with a modeled long-term decline in population and a change in their regional distribution throughout Florida (Cummings et al. 2014). Manatees are known to range north into the Mid-Atlantic during warmer summer and fall months. Of the 112 Florida manatee sightings in Virginia between 1991 and 2012, most occurred between June and October in rivers and creeks followed by sightings in the open ocean, sounds and bays, Intracoastal Waterway, and marinas (Cummings et al. 2014). The most northerly-recorded Virginia sighting noted by Cummings et al. (2014) was from Metompkin Island, approximately 12 km (7.5 mi) southwest of Wallops Island.

3.10.1.3.7 Virginia Natural Heritage Sites

VDCR-DNH has identified five Conservation Sites at WFF – North Wallops Island and North Assawoman/South Wallops Island on Wallops Island; Little Mosquito Creek and Wallops Main Base Airfield Swale on the Main Base; and Wallops Island Causeway Marshes on the Mainland and west side of central Wallops Island (Fleming 1996). The two Conservation Sites most likely affected by the actions in this PEIS (and therefore discussed in more detail) are the 648 ha (1,600 ac) Wallops Island Causeway Marshes, and the approximately 40 ha (100 ac) North Assawoman/South Wallops Island site. The Causeway Marshes site has been assigned a biodiversity significance ranking of B4, representing a site of moderate significance. The natural heritage resources of concern at this site are the saltmarsh sharp-tailed sparrow and northern harrier. The North Assawoman/South Wallops Island site was assigned a biodiversity significance ranking of B3, representing a site of high significance. Its species of concern are piping plover, Wilson's plover, and least tern (Fleming 1996).

Subsequent to its 1994 and 1995 natural heritage survey at WFF (Fleming 1996), in 2011 VDCR performed an inventory of rare plant species and habitat in the northern portion of Wallops Island. This inventory found occurrences of Florida thoroughwort and Maritime Dune Woodland habitat in northern Wallops Island. Although not listed as threatened or endangered by the Commonwealth or USFWS, Florida thoroughwort is considered rare in Virginia and globally (VDCR 2012). In coordination with VDCR, WFF created the *Rare Species and Community Action Plan for Northern Wallops Island*. This plan stipulates that WFF will maintain open areas to promote the growth of Florida thoroughwort near the North Wallops Island UAS airstrip. The plan also states that after UAS airstrip construction (addressed in a separate NEPA document), all remaining areas of Maritime Dune Woodland will be protected (NASA 2012).

### 3.10.2 ENVIRONMENTAL CONSEQUENCES

Determination of the significance of potential impacts to special-status species is based on the sensitivity of the wildlife to the proposed activities. Impacts would be considered significant if an unauthorized take were to occur of a federally listed species or if habitats of concern were substantially affected over relatively large areas or disturbances resulted in reductions in the population size or distribution of a special-status species.

#### 3.10.2.1 No Action Alternative

3.10.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Any substantial changes to the design of approved construction projects may require additional site-specific NEPA analysis. Proposed institutional support projects detailed in Section 2.5 would not be implemented. Consequently, baseline special-status species impacts would remain unchanged.

3.10.2.1.2 Operational Missions and Activities

Under the No Action Alternative, activity at WFF would remain at present levels and WFF would conduct operational programs that are within the installation's current envelope that have been assessed in previous NEPA documents and the 2016 Revised Biological Opinion (BO). Proposed operational missions and activities detailed in Section 2.5 would not be implemented. Consequently, baseline special-status species impacts would remain unchanged. WFF would continue monitoring, management, and reporting of special-status species on WFF.

In the July 2010 BO offered by USFWS during NEPA and ESA consultations for the SRIPP, the Service authorized the incidental take of piping plovers and loggerhead sea turtles anticipated from ongoing operations at WFF. From a combination of all baseline operations on Wallops Island (e.g., rocket launches, UAS operations, etc.), the Service anticipated the incidental take of these species. In 2016, the Service re-issued a combined BO for the SRIPP and expanded operations at WFF, to include the Proposed Action of this PEIS. This new BO also included determinations on the northern long-eared bat and red knot, in addition to the piping plover and loggerhead sea turtle. The Service concluded that there could be incidental takes of the piping plover, red knot, and loggerhead sea turtle from the expanded actions at WFF; however, the northern long-eared bat would not incur incidental takes (USFWS 2016b).

#### 3.10.2.2 Proposed Action

Per the USFWS Revised BO (USFWS 2016b), reinitiation of formal consultation would be undertaken if: "(1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action."

The majority of projects described under the Proposed Action are in various stages of conceptual maturity with varying levels of detail for discussion. As project planning and design details become more developed, further NEPA analysis, along with all relevant consultation, would occur prior to construction or implementation.

3.10.2.2.1 Institutional Support Projects

Under the Proposed Action, institutional support projects at WFF would include construction, demolition, and RBR projects. Due to the varied habitats at WFF, construction, demolition, and RBR impacts are broken down into potential impacts from Main Base institutional support projects and those occurring on the Mainland and Wallops Island. The Causeway Bridge Replacement and maintenance dredging are discussed separately, due to the nature of the potential impacts to special-status species.

**Main Base**

**Construction, Demolition, and RBR Projects**

Construction and demolition activities at the Main Base would have the potential to impact bald eagles and the northern long-eared bat, but no suitable habitat exists for the other species listed in **Table 3.10-1**. Institutional support projects at Wallops Main Base would occur mostly in maintained areas with anthropogenic vegetation or areas that have been previously disturbed by construction. Approximately 0.2 ha (0.5 ac) of hardwood trees would be removed to accommodate institutional support projects (refer to **Figure 2.5-1** and **Figure 2.5-2** in Chapter 2 for specific locations of institutional support projects at Wallops Main Base). While there are two active bald eagle nests located off the installation near the installation boundary, there are no active eagle nests within 200 m (600 ft) of areas designated for institutional support projects. WFF would conduct tree removal of trees 7.6 cm (3 in) in diameter at breast height or greater, outside of the June 1 to July 31 timeframe, or through consultation with USFWS and by conducting a bat emergence or presence/absence survey to reduce any impacts to the northern long-eared bat (USFWS 2016a). Construction noise would be temporary and unlikely to change the surrounding airfield noise environment. NASA would maintain the USFWS's recommended 200 m (660 ft) buffer zone around active bald eagle nests. No construction, demolition, or RBR would occur within the USFWS recommended buffers around any of the active bald eagle nests.

**Mainland and Wallops Island**

**Construction, Demolition, and RBR Projects**

Construction, demolition, and RBR projects occurring on the Mainland and Wallops Island have the potential to impact a number of special-status species, including sea beach amaranth, sea turtles (specifically loggerhead sea turtles), and any of the shorebird species listed in **Table 3.10-1**. Specific impacts to these species or groups of species are described in more detail below. Generally, institutional support projects located on the Mainland and Wallops Island would occur in previously disturbed areas or maintained areas with anthropogenic vegetation.

There is the potential for disturbance to wetland habitat at the Mainland and Wallops Island under the Proposed Action (refer to **Figure 2.5-4** and **Figure 2.5-5** in Chapter 2 for specific locations of institutional support projects at the Mainland and Wallops Island). The permanent loss of natural habitat from new construction under the Proposed Action at the Mainland and Wallops Island would be approximately 5.0 ha (12.0 ac), as currently planned. Of this total, an estimated 2.0 ha (5.0 ac) would be wetlands. If the removal of wetland habitat were required, this would cause species in the area to be permanently displaced once the wetland is cleared and filled. Special-status species that utilize wetlands, such as peregrine falcons and gull-billed terns, would permanently lose small amounts of foraging habitat. Additionally, *Phragmites* could invade areas disturbed during construction and further limit available habitat. NASA would also ensure implementation of the 2014 *Phragmites Control Plan* to limit the expansion of the invasive species.

**Seabeach Amaranth**

Seabeach amaranth has never been documented on Wallops Island, but has been found on nearby Assateague Island. Though not found, the necessary habitat does exist on Wallops Island. WFF currently performs annual surveys for this plant species to ensure no unintended impacts occur. Beach renourishment activities have also created a new primary dune over what was once a seawall along the southern edge of Wallops Island. As this habitat stabilizes and becomes more established, natural recruitment of seabeach amaranth is possible. Therefore, Launch Pad 0-C construction areas could have suitable habitat adjacent to them. The primary concern during construction would be unintended crushing or burial of individual plants. As such, the areas within and adjacent to the anticipated construction footprints would be surveyed prior to disturbance. If plants are identified, potential mitigation measures could include avoiding land-disturbing activities within the area or transplantation of plants to suitable, unaffected areas. All such actions would be performed in consultation with USFWS.

**Sea Turtles**

Though all species of sea turtles listed in **Table 3.10-1** have the potential to exist in the waters off WFF, only the loggerhead turtle has been documented nesting on the Wallops Island beach. Man-made ambient lighting can impact sea turtle nesting and hatchling sea-finding activities by interfering with the visual cues sea turtles use to find nesting beaches and those cues used by hatchlings to find the sea (Witherington and Martin 2003; Bartol and Musick 2003; USFWS 2010b). The majority of new construction would occur during daylight hours negating the need for exterior night lighting. However, if nighttime construction is required during turtle nesting and hatching season, the construction area would likely be lit to ensure worker safety. As such, some level of missed nesting attempts or hatchling disorientation could occur. In this event, NASA would ensure that appropriate shading is installed around all nests during their hatch windows to mitigate potential disorientations. Should construction sites require area lighting during non-work hours, NASA would require its contractors to employ a combination of low pressure sodium vapor lamps and amber light emitting diodes. These exterior light sources are the least disruptive to sea turtles among commonly used commercially available light sources, however they should not be considered a substitute for beach darkening efforts, as they have been shown to attract, thereby disorienting, hatchlings (Witherington and Martin 2003).

Noise from construction would be temporary in nature and would likely only occur during daytime hours. This would limit the potential impact to sea turtles, as nesting females would generally utilize the beaches at night. However, atmospheric noise has been demonstrated to prevent sea turtles from entering an area (USFWS 2016b). Consultation with USFWS and NMFS would be required prior to initiating construction of the new launch facilities on Wallops Island. Though the probability would be low, dredging has the potential to startle or effect in-water sea turtles.

**Birds**

Construction along the oceanfront of Wallops Island has the potential to impact all of the shore birds listed in **Table 3.10-1.** These impacts would generally be limited to temporary construction-related impacts such as disturbance from noise, which would most likely result in a startle response. Startled species could temporarily suspend or relocate foraging activities, or in the case of nesting, vacate the nest, potentially exposing the incubating eggs to extreme temperatures or predation. Based upon experience from the recently constructed Launch Pad 0-A, the entire construction process for Launch Pad 0-C could take several years or more, with the most intense noise levels generated during pile driving, which could last for 2-3 months depending on the final pad design. As such, if pile driving were to occur during nesting season, it would only cover one season, whereas the larger construction process could span two to three nesting seasons.

There is historic piping plover nesting habitat present at the south end of Wallops Island in the vicinity (approximately 500 m [1,600 ft] south) of where construction of Launch Pad 0-C would occur (see **Figure 3.10-2**). Though this area has not supported much nesting activity in recent years (one nest in the last ten years), it is possible that the newly re-established beach could be used as nesting habitat by piping plovers in the future. As such, the WFF Environmental Office personnel routinely monitor for piping plovers and nesting activity and would note if piping plovers were observed in areas adjacent to construction per the *Protected Species Monitoring Plan* administered by WFF. Any identified nests would be clearly marked, and if within the construction footprint, avoided until the chicks fledged. In other areas of the construction site, work would likely continue, and resultant noise-induced disturbances would be unavoidable. However, in consideration of the relatively low numbers of piping plovers nesting on Wallops Island, and in particular, the south end of the Island, it is unlikely that construction efforts would create any significant impacts to piping plovers or any of the other shorebirds listed in **Table 3.10-1**.

There are two active bald eagle nests on Wallops Island, one in the northern portion of the island, and one near the middle of the island west of Aegis (see **Figure 3.10-2**). However, no construction would occur in the vicinity of this nest site under the Proposed Action. Therefore, there would be no impact to bald eagles due to construction activities under the Proposed Action.

**Northern Long-eared Bat**

The institutional support projects on the Mainland and Wallops Island would occur in previously developed areas or would occur in areas that do not support forest vegetation. As such, there is little chance that the northern long-eared bat would be impacted from any construction projects in these locations. However, if tree removal would be required, WFF would not conduct tree removal between June 1 and July 31 to prevent impacts to roosting northern long-eared bats (USFWS 2016a). Should NASA deem it necessary to remove trees of 7.6 cm (3 in) diameter at breast height or greater between June 1 and July 31, it will either:

1. Conduct a bat emergence survey (1 surveyor per 10 trees) 1 to 2 days prior to the scheduled tree removal and report results to USFWS; or
2. Conduct a presence/absence survey of the affected area, employing a qualified bat surveyor and report results to USFWS.

***<u>Causeway Bridge Replacement</u>***

Replacement of the Causeway Bridge would require substantial in-water work for pile driving during construction and demolition activities that may result in temporary or permanent impacts.

**Birds**

As discussed in Section 3.1.2.2.1, airborne noise can be roughly estimated by assuming construction equipment required and providing a distance to a noise sensitive receptor. For the replacement of the Causeway Bridge, noise from piling driving is estimated at 101 dBA at 15.25 m (50 ft). In its Programmatic BO on the SRIPP (NASA 2010a), USFWS set protected species monitoring requirements at the 100 dB contours from a rocket launch. As the nearest nesting habitat for federally listed avian species (i.e., piping plover) would be greater than 1,200 m (4,000 ft) from pile driving activities, no airborne noise impacts are anticipated to these species.

The replacement of the Causeway Bridge would occur within the boundaries of the VDCR-DNH's designated Wallops Island Causeway Marshes Conservation site (see Section 3.10, Special-Status Species) and would disturb tidal wetland habitat that borders the existing bridge. Some of these areas would be permanently filled and lost. Extents of the habitat loss are unknown at this time as a formal design for the replacement bridge does not exist. The permanent loss of natural wetland habitat from the Causeway Bridge Replacement would likely be minimal; however, the removal of wetland habitat would cause species in the area to be permanently displaced once the wetland is cleared and filled. Special-status species, including saltmarsh sharp-tailed sparrow and northern harrier, that utilize wetlands would permanently lose up to 2 ha (5 ac) of nesting and foraging habitat. Species residing in habitat on the periphery of construction sites may be temporarily disturbed or displaced by noise resulting from construction activity. The sensitivity of such species to construction-induced disturbances would be greatest between approximately May through August, when both marsh-nesting species are known to nest (Bazuin 1991; Wilds 1991).

**Atlantic Sturgeon**

Over the past decade, concerns have been raised by both NMFS and USFWS over the impacts in-water work activities have on fish and marine mammals. Fish kills from in-water pile driving activities that have been reported in Puget Sound, Washington; San Francisco Bay, California; and Vancouver Harbor in British Columbia, Canada, have highlighted the need to understand underwater noise impacts and determine a way to estimate underwater noise levels to ensure minimal impacts to the underwater noise environment (WSDOT 2015).

It is possible, though unlikely, that Atlantic sturgeon could be affected by the proposed Causeway Bridge Replacement. Recent studies (Dunton et al. 2010; Erickson et al. 2011) have suggested that the shallow waters off the Atlantic coast could be an important migratory corridor to/from spawning, foraging, and overwintering grounds. As there are no known spawning areas (freshwater rivers) or congregation areas (e.g., mouths of Chesapeake and Delaware Bays) within the project vicinity, it is expected that any individuals encountered would be opportunistically foraging during migration. The potential impact of construction and demolition activities on Atlantic sturgeon would depend on the time of year these activities were conducted, with the likelihood of encountering a sturgeon greatest during fall and early spring, which are times of peak migration.

The exact construction methods for the new Causeway Bridge have not been determined; however, pile driving activities would generate a significant amount of underwater noise, which could impact Atlantic sturgeon if any were in the area. Underwater noise threshold criteria for injury and behavioral impacts to fish and the distance to threshold from pile driving are listed in **Table 3.10-2**.

**Table 3.10-2. Underwater Noise Thresholds Related to Fish**

| Noise Impact | Underwater Threshold | Distance to Threshold |
|---|---|---|
| Injury[(a)] | | |
| All | 206 dB re:1µPa-m (peak) | 18 m (60 ft) |
| Fish ≥2 grams | 187 dB re: 1 µPa$^2$-s (SEL) | 1,585 m (5,200 ft) |
| Fish <2 grams | 183 dB re: 1 µPa$^2$-s (SEL) | 1,585 m (5,200 ft) |
| Behavior[(b)] | 150 dB re:1µPa-m (RMS) | 7.4 km (4.5 mi) |

Sources: (a) Fisheries Hydroacoustic Working Group 2008; (b) Hastings 2002.
Note: dB re: 1 µPa2-s = sound pressure level in dB referenced to a pressure level of 1 micropascal$^2$ per second.

The specific amount of underwater noise created during bridge construction would depend on the types of pilings used and construction methods. Noise levels were calculated assuming the noisiest underwater pile driving conditions, that is, steel piles and impact pile driving (refer to Section 3.1.2.2.1 and Section 3.11.2 for a general description of assumptions and **Appendix E** for additional noise tables). It should be noted that the distance to threshold for fish less than and greater than 2 grams (0.07 ounces) is the same. This is because this measurement is a cumulative noise metric and is generated partially based on the number of pile strikes per day. As pile strikes per day decreases, these numbers would also change. Site-specific NEPA analysis would be required before the action could occur, and consultation with NMFS would be required to determine any mitigation efforts. The disturbance of foraging habitat and creation of underwater noise from construction of the Causeway Bridge have the potential to cause an adverse impact to Atlantic sturgeon; however, the specific impacts to these species would depend on final design plans and time of year that construction takes place. No spawning or critical habitat for Atlantic sturgeon exists near WFF, and it is unlikely that the species would be found in the waters near the Causeway Bridge (Hopper 2016).

Pile driving and the deconstruction and pile removal of the old Causeway Bridge would also cause temporary increase in suspended sediment, thereby increasing local turbidity. As is discussed in Section 3.5.2.2.1, increased turbidity from construction activities would likely be short-lived and with proper, required controls, such as turbidity curtains (also referred to as sediment curtains), turbidity impacts would be reduced. Sediment plumes from construction would likely settle out in a few hours making increased turbidity short-term (NMFS 2009). Increased turbidity has the potential to temporarily impact forage habitat of the Atlantic sturgeon. Atlantic sturgeon may avoid the area entirely if the sediment load is extremely high. However, given the fairly small size and rather isolated nature of Cat Creek, it is unlikely that any adverse impacts to Atlantic sturgeon would occur.

**Sea Turtles**

The hearing capabilities of sea turtles are poorly known and there is little available information on the effects of noise on sea turtles. Current thresholds for determining impacts to marine mammals and sea turtles typically center around root mean square (RMS) levels of 180 dB re:1µPa-m for potential injury, 160 dB re:1µPa-m for behavioral disturbance/harassment from a non-continuous noise source, and 120 dB re:1µPa-m for behavioral disturbance/harassment from a continuous noise source. As part of the expansion of the WFF Launch Range (NASA 2009b), WFF had proposed modifications to the boat dock on the north end of Wallops Island. The project entailed non-continuous pile driving of steel sheet piles. Sound levels were calculated to potentially be as high as 160 dB within 10 m (33 ft) of the pile being driven but were lower than 160 dB within 1,000 m (3,280 ft) or less of the pile being driven.

During consultation for this project, NMFS required NASA to implement the following measures to minimize any potential effects to sea turtles:

- Each day prior to pile driving, or prior to resuming pile driving after a greater than 30 minute pause, a trained observer will perform a visual sweep of the adjacent waterways. If listed sea turtles are observed within 457 m (500 yd) of the project site, pile driving will be suspended until the turtle has moved outside of this 457 m (500 yd) exclusion zone.
- During pile driving, a trained observer will be stationed at a point at which the Wallops Island boat basin canal intersects the Virginia Inside Passage, approximately 410 m (450 yd) northwest of the project site. If turtles are observed entering the exclusion zone, this information will be immediately communicated to the construction contractor and work will be halted until the turtle is back outside of the 457 m (500 yd) buffer.
- To the greatest extent practicable, NASA will direct its construction contractor to install pilings by vibratory techniques rather than hammer methods as this will reduce the noise and vibration within and adjacent to the project site.

Sediment disturbance would also occur during Causeway Bridge construction, as well as deconstruction and pile removal of the old Causeway Bridge. Impacts to sea turtles would be similar to those described for Atlantic sturgeon, above, with sediment plumes possibly causing area avoidance and potentially hampering foraging ability due to decreased visibility. With proper, required controls, such as turbidity curtains, impacts would be reduced. Sediment plumes from these activities would likely settle out in a few hours making increased turbidity short-term (NMFS 2009).

***Maintenance Dredging***

Maintenance dredging under the Proposed Action also has the potential to impact Atlantic sturgeon and sea turtles. No federally threatened or endangered marine mammals are likely to occur along the proposed dredge route. The Florida manatee has an extremely slight potential to be found in the waters of Virginia, but typical habitat for manatees does not exist at WFF. The entire channel length, as well as the boat basins at the Main Base and on Wallops Island, would be dredged to a depth of 2.4 m (8 ft) MLLW and a channel width of 50 m (160 ft). Dredging would most likely be done using a clamshell dredge. Impacts from dredging would be due to underwater noise, sediment disturbance, temporary increases in turbidity, and possible entrainment in the dredge itself. Potential impacts to Atlantic sturgeon and sea turtles are described below.

**Atlantic Sturgeon**

Although no spawning or critical habitat for Atlantic sturgeon exists near WFF, and it is unlikely that the species would be found in the waters near the maintenance dredging, it is possible that Atlantic sturgeon could be affected by the proposed maintenance dredging.

The proposed dredging project would be short-lived (8 weeks) and would only disturb a limited amount of potential foraging habitat. Though dredging would remove prey species of Atlantic sturgeon, it is likely that re-colonization and recruitment of benthic organisms would occur rather quickly, as the depth of sediment to be removed would be small in most cases. Newell et al. (1998) noted that in estuarine waters where disturbance was common, re-colonization of benthos takes 6 to 8 months. Furthermore, available data summarizing sturgeon entrainment in dredges indicates that the majority of recorded incidents occurred with hopper dredges (USACE, unpublished data, as cited in NASA 2011b), which are not expected to be employed for the project.

The noise generated during dredging operations could potentially affect Atlantic sturgeon. Richardson et al. (1995) noted that dredging operations can produce sound levels of 160 to 180 dB re:1µPa-m at 1 m (3 ft). Clamshell dredging has different noise levels associated with different aspects of the procedure. The bucket striking the bottom is generally the loudest part of the operation and has been recorded at 128 dB re: 1 µPa at 150 m (500 ft) (Dickerson et al. 2001).

In its BO for the SRIPP at WFF, NMFS used 150 dB root mean square (rms) as guidance for assessing potential behavioral impacts on Atlantic sturgeon (NMFS 2010). Using a conservative spreading loss equation for underwater noise and assuming a 4.5 dB reduction with a doubling of distance, the threshold of 150 dB re: 1 µPa would be limited to within approximately 5 m (16 ft) from the dredge. In consideration of the highly mobile life stage of sturgeon that would most likely be encountered in the project area (sub-adults and adults), it is expected that individuals could quickly relocate. Therefore, not being exposed to elevated sound levels for any measurable duration.

In summary, given the location of the dredging, its short duration, and relatively small volume of material to be removed, significant impacts to Atlantic sturgeon would be unlikely. Nevertheless, NASA would consult with NMFS prior to the start of dredging activities.

**Sea Turtles**

The number of interactions between a dredge operation and sea turtles is highly influenced by the amount of dredge material to be removed, which is related to the length of time a dredge operation is ongoing. The volume of material to be removed is positively correlated to negative impacts on sea turtles; i.e., the greater volume of material to be removed, the greater the risk for negative impacts to sea turtles. The time of year or season during which the dredge operation is planned also affects the chances for impacts to sea turtles (NMFS 2010). In the recent BO for the SRIPP, NMFS concluded that for every 1.47 million $m^3$ (1.5 million $y^3$) of material removed from an offshore shoal, 1 sea turtle would be injured or killed during dredging operations, with a 90% chance for a loggerhead turtle to be the species impacted during dredging activities in the shoals offshore of WFF (NMFS 2010). Given the location of the proposed dredge route (interior waterways), the much smaller dredge volume (about one-third of the 1.47 million $m^3$ [1.5 million $y^3$] stated), and the short time required to complete dredging (8 weeks), it is unlikely that any sea turtles would be killed or injured from the proposed maintenance dredging. NMFS also noted that while re-suspension of sediments from dredging may cause a temporary alteration in normal movement, it would be unlikely to cause any significant impact to sea turtles (NMFS 2010).

Though there are no formally established thresholds for injury or behavioral disturbance to sea turtles, NMFS used 166 dB rms from McCauley et al. (2000) as guidance for assessing potential impacts (both physiological and behavioral) in the SRIPP BO (NMFS 2010). Using a conservative spreading loss equation for underwater noise, assuming a 4.5 dB reduction with a doubling of distance, the threshold of 166 dB re: 1 µPa would not be reached during dredging, even at the source. Therefore, impacts to sea turtles from dredging noise are unlikely. Even though the chances for impacts to sea turtles from dredging would be small, NASA would consult with NMFS prior to dredging operations.

***North Wallops Island Deep-water Port and Operations Area***

The potential impacts to Atlantic sturgeon and sea turtles as described above for the Causeway Bridge Replacement and maintenance dredging projects, would be likely to occur under this proposal. As details for the North Wallops Island Deep-water Port and Operations Area are unknown, further analysis would be required as the details for this project becomes solidified.

***Launch Pier 0-D***

The potential impacts to Atlantic sturgeon and sea turtles as described above for the Causeway Bridge Replacement and maintenance dredging projects, would be likely to occur under this proposal. As details for Launch Pier 0-D are unknown, further analysis would be required as the details for this project are developed.

Land-based institutional support projects would have insignificant adverse effects on special-status species. Regulatory agency consultations would occur as necessary in order to minimize impacts to these species. Causeway Bridge Replacement, maintenance dredging, and development of the North Wallops Island Deep-water Port and Operations Area may have effects on marine special-status species. Impacts would be dependent on final designs and locations of the projects. Further analysis would be required as project details are confirmed. Refer to **Section 4.1.8** (Special-Status Species) for measures to mitigate impacts to special-status species under the Proposed Action.

3.10.2.2.2 Operational Missions and Activities

Operational mission and activities included in the Proposed Action that have the potential to impact special-status species include DoD SM-3, Directed Energy, SODAR System, and LV launches under the Expanded Space Program. Operational components of rocket launches have two elements with respect to potential impacts: 1) launch activity impacts which includes pre-launch and actual rocket ignition, and 2) offshore impacts from rocket stages being jettisoned or the production of debris from an expended rocket. The USFWS concurred that ongoing and proposed operations on Wallops Island would be unlikely to have adverse impacts on the northern long-eared bat, other than those construction projects requiring tree removal. Therefore, the northern long-eared bat is not discussed below.

***DoD SM-3***

U.S. Navy's DoD SM-3 rocket launch operations have never occurred at Wallops Island. The rocket utilized by the DoD SM-3 is identical to some used in WFF's current sounding rocket program. These rockets are launched from Wallops Island out into the VACAPES OPAREA. The pad for the DoD SM-3 would be located well off the beach; no special-status species are known to occur in the immediate vicinity of the proposed DoD SM-3 pad. Wildlife adjacent to the launch site would be temporarily disturbed from launch preparation activities and noise associated with the rocket launch. Impacts to special-status species from DoD SM-3 operations are unlikely.

The rockets would be launched out over the VACAPES OPAREA for testing or to intercept an airborne target. Upon detonation, the airborne debris would fall into the ocean and sink rapidly to the ocean floor. A small chance exists for sea turtles and federally listed marine mammals to be present in the ocean where impact/detonation occurs. Recent documentation by the U.S. Navy for the AFTT activities has determined the low density of marine mammals and sea turtles in the VACAPES OPAREA; combined with the relatively small number of DoD SM-3 launches would not result in any significant dangers to federally listed marine mammals or sea turtles due to falling debris, potential ingestion of debris, or possible entanglement hazards from falling debris (U.S. Navy 2009; 2013a; 2018a). A letter of authorization for AFTT activities was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b).

***Directed Energy***

The U.S. Navy's use of either the HEL or HPM at WFF would likely have negligible impacts to terrestrial special-status species. These weapon systems are in various stages of development and little information exists on their impacts to the general environment. However, these weapon systems have the ability to direct concentrated energy to a target. As with any weapon system, the potential exists for harm or incidental mortality to wildlife. The energy beam would be directed down the beach to a target approximately 1.6 km (1 mi) away or at an airborne target out over the ocean. Special-status species would have to pass directly through the energy beam in order to be impacted. Based on the current information available, adverse impacts from this operation to special-status species are unlikely; however, as the HEL and HPM devices become more operational and proposals more finalized, additional NEPA analysis may be required to better assess potential impacts from these weapon systems. Use of either the HEL or HPM at WFF would likely have negligible impacts to Atlantic sturgeon and sea turtles. The weapon is not planned to be directed at a floating target or to interact with the sea surface; therefore, little potential exists for harm or incidental mortality to species in the area. In recent Navy studies, it was determined that use of lasers in the marine environment would pose no environmental hazards to marine organisms (U.S. Navy 2009; 2013; 2017).

***SODAR System***

Operating frequencies for SODAR systems can range between (1 kHz to 4 kHz) with power levels up to several hundred watts (refer to Section 2.5.2.2). Research suggests an in-air maximum auditory sensitivity between 1 and 5 kHz for most bird species (NMFS 2003). Specifics for the type of SODAR system or its placement on Wallops Island are unknown at this time. However, few studies on impacts to birds and bats from radar have been completed and those that have, show inconsistent results. In-air electromagnetic devices, such as radar, can affect wildlife (chiefly birds and bats) in two ways, thermal (i.e., capable of causing damage by heating tissue) or non-thermal. The SODAR system would not be powerful enough to cause thermal impacts to wildlife. Potential non-thermal impacts would be unlikely. Manville (2016) performed a literature review of non-thermal effects and found the potential for 1) affecting behavior by preventing bird from using their magnetic compass, which could affect migration; 2) fragmenting DNA of reproductive cells, decreasing reproductive capacity; 3) increasing the permeability of the blood-brain barrier; 4) other general behavioral effects; 5) other molecular, cellular, and metabolic changes; and 6) increased cancer risk (Manville 2016). While these affects are possible, Manville also concluded that the effects reported from non-thermal electromagnetic radiation were inconsistent among the studies reviewed. Additionally, radar similar to SODAR has been used to track bird groups in flight. Larkin (1979) concluded that there the impacts to migrating birds from a pulsed acoustic sounder on nocturnally migrating birds was minimal except for the birds directly in the beam. Recent Navy documents have concluded that in-air electromagnetic devices would pose little risk to birds or bats and the effects would likely be temporary (U.S. Navy 2018a). NASA would also make efforts to place the SODAR systems in locations to minimize any potential impacts to special-status species.

***Expanded Space Program***

***LFIC LV and SFHC LV***

Proposed launching of the LFIC LV and SFHC LV would represent the largest LVs ever launched from WFF. Disturbance to wildlife would occur from pre-launch activities, night lighting, launch noise and vibration, and exhaust emissions generated by these LVs. Launching of the larger LVs would produce similar but greater impacts than current operational mission activities. These launches would impact piping plover habitat and potential sea turtle nesting areas through noise, vibration, and if near enough, mortality from heat due to rocket fuel combustion. Proposed Launch Pad 0-C and Launch Pier 0-D would be used to launch the larger LVs. As with other rocket activities at WFF, potential impacts occur on land and the nearshore environment from the immediate launch activities and offshore when the rocket or its constituent pieces fall into the ocean in the VACAPES OPAREA.

Potential impacts to piping plovers and sea turtles are described below for these two environments. The red knot does not nest at WFF and is only a temporary migrant. Therefore, impacts to the red knot would be unlikely. Federally listed marine mammals are discussed in Section 3.11, Marine Mammals and Fish.

***Nearshore Impacts***

Noise modeling of both LVs indicated that launches would create noise levels exceeding 130 dBA at the launch site, with the noise levels less than 115 dBA at the nearest residence (BRRC 2015). The noise would be intense but would be short in duration. Wildlife in the vicinity would likely flee, or be startled and retreat to safer areas.

**Piping Plover and Red Knot**

Any piping plovers in the immediate vicinity would likely be flushed from nesting areas due to pre-launch activities. Similarly, red knots would be flushed if in the vicinity as well.

Launch Pad 0-C would be located approximately 670 m (2,200 ft) north of the piping plover nesting habitat in the southern portion of Wallops Island. Wildlife would be impacted from the noise generated by LFIC LV launches from the new site. The noise impacts would cover a large area that overlaps areas already impacted by approved activities at Pads 0-A and 0-B. Again, as with construction impacts, beach re-establishment could create suitable habitat for nesting piping plovers on the southern portions of Wallops Island. WFF's *Protected Species Monitoring Plan* would continue to be followed and any occurrence of protected species would be documented. Additionally, WFF would continue to adhere to the terms and conditions of the Incidental Take Statement pursuant to the 2016 Revised BO (USFWS 2016b).

In the unlikely event that a nest is located in the immediate vicinity of a launch pad, chicks could experience permanent hearing damage or mortality, depending on proximity to the launch pad (USFWS 2016b).

As shown in **Table 3.10-3**, high noise levels would be experienced at sensitive habitats where known special-status species occur. Noise levels would be especially high at the southern piping plover habitat if either the LFIC LV or SFHC LV were launched from Launch Pad 0-C. With the recent beach re-establishment, all launch pads now have the potential to have suitable habitat for piping plover nesting.

**Table 3.10-3. Distances to Sensitive Habitats from Launch Pads and Predicted Noise Levels**

| Species Habitat | Launch Pad 0-A | | | Launch Pad 0-B | | | Launch Pad 0-C | | | Launch Pier 0-D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance m (ft) | Noise Range (dBA) | | Distance m (ft) | Noise Range (dBA) | | Distance m (ft) | Noise Range (dBA) | | Distance m (ft) | Noise Range (dBA) | |
| | | Baseline (Antares) | LFIC LV | | Baseline (Antares) | LFIC LV | | Baseline (Antares) | LFIC/SFHC LV | | Baseline (Antares) | LFIC/SFHC LV |
| Piping Plover Northern Habitat | 6,100 (20,000) | 100-105 | 110-120 | 6,500 (21,500) | 100-105 | 100-105 | 6,700 (22,000) | 95-100 | 95-100 | 6,800 (22,300) | 95-100 | 95-100 |
| Piping Plover Southern Habitat | 1,100 (3,600) | 110-115 | 125-130 | 1,000 (3,300) | 110-115 | 110-115 | 600 (2,000) | 120-125 | 120-125 | 600 (2,000) | 120-125 | 120-125 |
| Southernmost Sea Turtle Nest | 670 (2,200) | 120-125 | 135-140 | 300 (1,000) | 130+ | 130+ | 1,000 (3,300) | 110-115 | 120-125 | 1,200 (3,800) | 110-115 | 110-115 |

Noise levels exceeding 130 dBA could be experienced at the southern end of Wallops Island; these peak noise levels would last one to two minutes. Noise of this magnitude could cause temporary hearing loss and disorientation if piping plovers or red knots were within this noise range.

Piping plovers exposed to launches are expected to exhibit a startle response that could interfere with normal behaviors, including breeding, feeding, sheltering, incubating eggs, and courtship. Red knots exposed to launches are expected to exhibit a startle response that could interfere with normal feeding behaviors. Because the noise would be of short duration, plovers and red knots are expected to resume most normal behaviors within a few minutes. The sound, combined with the visual stimulus of a rocket in flight, would likely exacerbate the startle response. Piping plovers near launch sites may flush from nests but are not expected to permanently abandon them due to excessive noise. However, startle responses to noises and associated visual stimuli are expected to result in an incremental reduction in piping plover nest success and/or chick survival (USFWS 2016b).

Deafening is not expected at these decibel levels resulting from short-duration noises, but progressively closer to the rockets, the noise intensity may reach levels that could cause tissue damage. While not known in birds specifically, sound intensity of near 180 dBA can result in nearly instantaneous tissue damage. Exposure to noises within these radii could deafen piping plovers present during ignition if exposed to high intensity noise. Deafness would significantly impair a piping plover's or red knot's ability to breed, shelter, and behave normally. Because the launch range is located between areas of suitable habitat for plover breeding and feeding and red knot feeding, it is expected that individuals may occasionally fly through the area exposed to the highest sound levels during orbital launches, resulting in deafening. Birds may be able to recover from sound-induced deafening over time, but some period of deafness may result from loud noises (USFWS 2016b).

Exhaust gases from the launch vehicles have the potential for causing direct mortality to nesting piping plover and foraging red knots. Red knots and piping plover or their eggs exposed directly to the exhaust cloud could be burned by hot gas or by caustic combustion byproducts. To be exposed, plovers or red knots would have to be foraging or nesting within the plume's footprint along the beach or be flying through the plume at the time of ignition, but the likelihood of either occurring is low (USFWS 2016b).

**Sea Turtles**

Exterior night lighting from the proposed Launch Pad 0-C or Launch Pier 0-D could impact nesting female sea turtles and hatchlings. The BO for the *Wallops Flight Facility Proposed and Ongoing Operations and Shoreline Restoration/Infrastructure Protection* predicted that there would be impacts to nesting female sea turtles and potential disorientation of hatchlings due to lighting of launch facilities (USFWS 2016b). Impacts to sea turtles are likely to become more acute since appropriate nesting habitat would be located directly adjacent to the proposed Launch Pad 0-C. Prior to beach re-establishment sea turtle nesting habitat was well away from the launch range. During non-critical activities, Launch Pad 0-C or Launch Pier 0-D, like the other launch pads, would be lit with a combination of low pressure sodium vapor lamps and amber light emitting diodes. Several weeks prior to launch, the launch facility would be switched to brighter, broad spectrum (e.g., metal halide) lighting which could increase the potential for sea turtle disruption. USFWS expects lighting to cause some behavioral effects of adult turtles as well as potential disorientation for young turtles (USFWS 2016b). WFF would continue to adhere to its *Protected Species Monitoring Plan* and the terms and conditions of the Incidental Take Statement pursuant to the 2016 Programmatic BO on Proposed and Ongoing Operations and SRIPP. Beach surveys would be conducted for sea turtles and piping plover nests no more than 24 hours prior to a launch. If protected species are found, the WFF Environmental Office would notify USFWS to determine the next course of action. WFF is currently drafting a Sea Turtle Lighting Plan that would aim to minimize impacts from lighting along the beaches where launch activities occur (NASA 2017).

In-air noise has been demonstrated to prevent sea turtles from entering an area; however, the number of operations that would be conducted under the Proposed Action would be within WFF's current envelope (USFWS 2016b). Pre-launch activities would disturb sea turtles and decrease the likelihood of wildlife remaining within the adjacent areas during actual launch activities. In the unlikely event that a sea turtle nest is located in the immediate vicinity of a launch pad, hatchlings could experience permanent hearing damage or mortality. The severity of the impacts would depend on proximity of the nest to the launch pad and the timing of launch activities relative to the timing of sea turtle nesting and hatching.

**Table 3.10-3** shows the distances to sensitive habitats from the existing launch pads (Pads 0-A and 0-B) and proposed Launch Pad 0-C and Launch Pier 0-D, along with the predicted noise levels that would occur at the sensitive habitat locations. Noise from rocket launches was only modeled from Launch Pad 0-A and was projected for the noise contour bands shown by assuming that identical noise would occur from each of the launch pads with regard to rocket launch activities USFWS (2016) concluded in previous BOs that the effects from vibrations for rocket launches are likely to be confined to an additive disturbance to nesting sea turtles. USFWS concluded that because the distance from the launch pads to sea turtle habitat is generally greater than 150 m (500 ft), it is unlikely that vibrations would be significant enough to affect egg viability (USFWS 2016b). However, with beach re- nourishment, this may no longer be true. Given the high elevation of the newly constructed berm and beach when compared to the natural beaches, the new beachfront may be appealing to nesting female sea turtles (USFWS 2016b). USFWS expects that the newly created beach would be utilized by nesting females. As such, sea turtle nests could be within the 150 m (500 ft) of a launch pad. Vibration is also a significant cue for synchronized hatching in sea turtles. Hatching eggs create vibrations that trigger the hatching of others (Spencer and Janzen 2011). Therefore, a launch could induce daytime hatching of a nearby nest, which could significantly alter the survival of the hatchlings. Additionally, a night launch could also kill hatchlings from excessive noise and vibration or through the disruption of sea-finding behavior by hatchlings due to disorientation from required operational lighting at the launch pad.

Launch of a LFIC LV, with a liquid propellant first stage, would result in the emission of CO and $CO_2$. When CO and $CO_2$ combine with water vapor in the air, carbonic acid may form which could result in the deposition of carbonic acid on the ground in the area surrounding the launch pad. The effects of carbonic acid deposition on the adjacent areas would be minimal as carbonic acid is a weak acid (approximate pH of 6.4) and is normally found in rainwater.

Launch of a SFHC LV would result in acid deposition from HCl and $AlO_3$ in the exhaust. Air quality modeling predicts that peak HCl concentrations from SFHC LV launches would range from 2 to 5 ppm, and would have a maximum downwind distance to peak concentrations of 11 km (6.8 mi) to 19 km (12 mi), depending on specific meteorological conditions. Exposure time for peak HCl concentrations would be less than 60 minutes (ACTA 2012). The potential exists for injury or mortality to any wildlife that may be directly exposed to rocket exhaust. This would likely occur within 200 to 300 m (650 to 985 ft) of the rocket exhaust (USFWS 2016b). The SFHC LV rocket exhaust has not been shown to have long-term impacts on wildlife. It is assumed that species that occur within the ground cloud may suffer eye and respiratory tract membrane irritation (Schmalzer et al. 1998). Sea turtles, or their eggs, exposed directly to the exhaust cloud could be burned by hot gas or by caustic combustion byproducts, but the likelihood of this occurring is low (USFWS 2016b).

Any species that was located in the direct path of the flame duct during a launch would be killed. This would likely occur within 200 to 300 m (650 to 985 ft) of the rocket exhaust (USFWS 2016b). Schmalzer et al. (1998) conducted post Space Shuttle launch surveys at Kennedy Space Center, Florida, and found dead alligators, multiple bird species, as well as some small mammals. Direction of the flame and exhaust toward the ocean would reduce risk to terrestrial species. In the 2016 Revised BO*,* USFWS issued incidental take statements for sea turtles and piping plovers as it was concluded that mortality was likely to occur from ongoing activities at Wallops Island including rocket launches (USFWS 2016b). With the construction of Launch Pad 0-C, Launch Pier 0-D, and beach renourishment, these impacts are not expected to be exacerbated. LFIC LV/RTLS and SFHC LV events would be distributed among each of the launch pads and proposed launch pier. WFF would continue to adhere to the terms and conditions of the Incidental Take Statement pursuant to the 2016 Revised BO.

The *Protected Species Monitoring Plan* for WFF outlines procedures to monitor special-status species prior to, during, and after a rocket launch occurs. WFF Environmental Office staff would survey approximately 45 m (150 ft) north and south of the beach adjacent to a rocket launch at a maximum of 24 hours before the launch. A post-launch survey would be conducted as soon as safety allows within a 300 m (1,000 ft) radius of the launch pad, with WFF staff surveying for injured, dead, or impaired birds or sea turtles. If a special-status species were located, the WFF Environmental Office would coordinate with the Range and Mission Management Office and USFWS regarding the located species (NASA 2011a). Overall, orbital rocket launch activities at WFF under the Proposed Action are likely to have adverse impacts to piping plovers, red knots, and sea turtles. Therefore, WFF would continue beach surveys in accordance with the *Protected Species Monitoring Plan* and would continue to adhere to the terms and conditions of the Incidental Take Statement pursuant to the Programmatic BO on the SRIPP.

***Offshore Impacts***

Offshore federal waters are those beyond 5.5 km (3 nm) to 22 km (12 nm) extending to the maritime zone adjacent to the territorial sea. For the current PEIS effort, **Figure 3.10-3**, depicts a square geographic area approximately 29,000 km$^2$ (8,500 nm$^2$) where offshore impacts may occur due to WFF activities and was drawn using the following bounding coordinates:

38.00°N 75.50°W, 36.50°N 75.50°W, 36.50°N 73.50°W, 38.00°N 73.50°W

**Figure 3.10-3. Potential Offshore Impact Area**

The most southerly edge of the potential impact area is 36.50º N latitude. The most northerly of the 36 critical habitat units proposed by NMFS for loggerheads is off Albemarle Sound, North Carolina at 36.00º N. Approximately 90 km (55 mi) separate the potential impact area from the proposed critical habitats. Therefore, no impacts are anticipated to the NMFS proposed loggerhead critical habitat areas.

Once the larger LVs have launched, they would follow a general southeasterly trajectory over the Atlantic Ocean. These vehicles would reach supersonic speeds and create a sonic boom out over the ocean within the VACAPES OPAREA. Though no distance to the start of the boom footprint or 'carpet' was calculated, it was determined that sonic boom energy generated from the launching of these vehicles would be equal to or less than that of the military aircraft that occasionally create sonic booms in the VACAPES OPAREA (BRRC 2015). Sonic boom modeling analysis efforts for the Air Force's *Final EIS for the EELV Program*, which launches the Atlas family of rockets (including vehicle molded for the LFIC), found that the sonic boom footprint started over 48 km (30 mi) from the launch site (U.S. Air Force 1998). Due to the rocket's trajectory, sonic booms would reach the ocean surface at a shallow angle, and negligible sound energy would pass into the water (BRRC 2015). Boom energy would also be greatest directly under the rocket, and would dissipate as lateral distance from the trajectory increased.

As the rocket ascends, rocket stages would be jettisoned and would fall into the ocean. Rocket stages and any associated debris would rapidly sink to the ocean floor and would be unlikely to create any significant hazards to Atlantic sturgeon; sea turtles or their habitat; or endangered marine mammals to include fin whales, North Atlantic right whales, sperm whales, sei whales, or blue whales (U.S. Navy 2018a). With recent Navy findings, as well as the letter of authorization issued by NMFS in 2018, expended materials are highly unlikely to be ingested or cause long-term impacts that could be considered significant (U.S. Navy 2018b).

NASA consulted with USFWS regarding potential impacts of Antares launch operations on protected special-status species (USFWS 2016b). After reviewing the status of the piping plover, green sea turtle, leatherback sea turtle, loggerhead sea turtle, and seabeach amaranth, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, the Service's BO stated that the ongoing and expanded orbital rocket program at WFF and other ongoing operations and use of the facility, as proposed, is not likely to jeopardize the continued existence of the piping plover, red knot, or loggerhead sea turtle, and is not likely to destroy or adversely modify designated critical habitat (USFWS 2016b). Critical habitat for the piping plover and sea turtles has been designated, including offshore areas for sea turtles. No critical habitat has been identified on Wallops Island or in the nearshore area. This action does not affect land-based critical habitat area and no destruction or adverse modification of that critical habitat is anticipated. Offshore critical habitat could be affected from payloads or rocket stages landing in the ocean, but given the infrequency of this occurrence, it is unlikely to affect offshore critical habitat for sea turtles. Although, the LFIC LV and SFHC LV are both larger launch vehicles than the Antares, launching of these larger vehicles would have similar impacts to special-status species as vehicles currently launched from WFF.

***Vertical Launch and Landing Vehicles***

Potential impacts to special-status species from noise and emissions associated with vertical launch vehicles from Wallops Island would be similar to those described for the LFIC LV or SFHC LV. Vehicles returning to WFF to perform a vertical landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. A noise study was conducted in 2017 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island. The results of the 2017 study indicate that the intensity of a sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). Wildlife may be startled by the sonic boom (Manci et al. 1988); however, the impact to special-status species would not be considered significant, due to the limited number of events per year. Future NEPA analysis would address such conditions to prevent unacceptable adverse impacts.

***Horizontal Launch and Landing Vehicles***

Horizontal launch and landings vehicles would take off and land like a standard aircraft from the Runway 04/22 at the Main Base. Impacts to special-status species would be expected to be similar to those generated by aircraft currently operating at the Main Base airfield. The noise associated with the horizontal launch and landings would be typical of existing jet aircraft that utilize WFF; however, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. In the event that a proposed horizontal vehicle would produce a supersonic landing, future NEPA analysis would be performed to prevent unacceptable adverse impacts.

***Commercial Human Spaceflight Missions***

A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) of commercial human spaceflight missions. Potential impacts to special-status species would be similar to those described for LVs launched from Wallops Island and horizontal launch vehicles reentering the airspace and landing at the Main Base.

Refer to **Section 4.1.8** (Special-Status Species) for measures to mitigate impacts to special-status species under the Proposed Action. Section 5.4.6, Special-Status Species provides a discussion on the potential for cumulative effects associated with habitat loss, noise, and predation.

## 3.11 Marine Mammals and Fish

Marine mammals are protected under the MMPA of 1972. The MMPA protects all marine mammals and prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas. The MMPA also prohibits the importation of marine mammals and marine mammal products into the U.S. NMFS maintains jurisdiction of the majority of the marine mammal species found worldwide. The USFWS has jurisdiction for eight marine mammal species that are not regulated by NMFS (i.e., walrus, polar bear, two marine otter species, three manatee species, and the dugong) (NMFS 2016a).

EFH is regulated under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1976. The MSA established eight regional Fishery Management Councils (FMCs), which are responsible for the management and protection of marine fishes. The Sustainable Fisheries Act of 1996, which amended the MSA, created a new mandate for the regional FMCs to identify and provide protection to important marine and anadromous fisheries habitat or EFH. The eight regional FMCs, with assistance from NMFS, are required to delineate EFH for all federally managed fisheries in an effort to conserve and enhance those habitats. EFH may be applied to an individual species or an assemblage of species and is defined in the MSA as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." NMFS and the FMCs also identify habitat areas of particular concern. These are considered high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development, or important to ecosystem function.

### 3.11.1 Affected Environment

#### 3.11.1.1 Nearshore Environment

Nearshore, or Virginia Commonwealth, water extends from the shoreline out to 5.5 km (3 nm). Six marine mammal species that VMRC has identified in the waters around Virginia's Eastern Shore/Accomack County include: fin whale, humpback whale, Florida manatee, bottlenose dolphin (*Tursiops aurus*), harbor seal (*Phoca vitulina*), and harbor porpoise (*Phocoena phocoena*). The fin whale and Florida manatee are listed endangered under the Federal ESA and were described in detail in Section 3.10, Special-Status Species.

##### 3.11.1.1.1 Marine Mammals

**Bottlenose Dolphin**

The western North Atlantic coastal stock of bottlenose dolphin is considered depleted under the MMPA. Bottlenose dolphins range in length from 1.8 to 3.8 m (6 to 12.5 ft) and can weigh between 136 and 635 kgs (300 and 1,400 lbs). The species is found in temperate and tropical waters around the world. Inshore bottlenose dolphins are smaller and lighter in color, and are commonly found in groups of 2 to 15 individuals. Offshore individuals are larger, darker in color, have smaller flippers, and can be found in pods that contain several hundred dolphins. Coastal populations of bottlenose dolphins migrate into bays, estuaries, and river mouths and offshore populations inhabit pelagic waters along continental shelves. Bottlenose dolphins are considered generalists and eat a variety of prey species that are endemic to their habitat. Coastal populations generally feed on benthic invertebrates and fish, and offshore populations feed on pelagic squid and fish. Bottlenose dolphins in the Western Atlantic Ocean face threats from incidental injury and mortality from fishing gear, exposure to pollutants and biotoxins, and viral outbreaks (NMFS 2016a). The primary habitat for the coastal morphotype of the bottlenose dolphin extends from New Jersey south to Florida during summer months and in waters less than 20 m (65 ft) in depth; this includes estuarine and inshore waters (Waring et al. 2009).

**Harbor Seal**

Harbor seals range from 1.7 to 1.9 m (5.6 to 6.3 ft) in length and weigh up to 110 kgs (245 lbs). The species eats a variety of prey including fish, shellfish, and crustaceans. Harbor seals live in temperate coastal habitats and use rocks, reefs, and beaches as haul out sites. These sites are utilized for rest, thermal regulation, social interaction, and pupping. In the West Atlantic Ocean, harbor seals are found from the Canadian Arctic to southern New England and New York, although they are occasionally spotted as far south as the Carolinas. The harbor seal population in the New England area is believed to be increasing, and there are an estimated 91,000 seals in this population. Threats to harbor seals include incidental capture in fishing gear, boat strikes, oil spill exposure, chemical contaminants, power plant entrainment, and human harassment (NMFS 2016a). Harbor seals would be considered an infrequent visitor to WFF and generally the only reports of the species occurring from New Jersey south to Cape Hatteras, North Carolina are from strandings (Waring et al. 2009).

**Harbor Porpoise**

Harbor porpoises range from 1.5 to 1.7 m (5 to 5.5 ft) in length and weigh between 61 and 77 kgs (135 and 170 lbs). Harbor porpoises are found in northern temperate and subarctic coastal and offshore waters, and are commonly found in bays, estuaries, and harbors less than 200 m (650 ft) deep. The species is usually seen in groups composed of two to five individuals. In the western North Atlantic, harbor porpoises range from West Greenland south to Cape Hatteras. The main threat to this species is bycatch in fishing gear, specifically gillnets and trawls (NMFS 2016a). In winter months (January through March), intermediate densities of harbor porpoises can be found in coastal ocean waters from New Jersey to North Carolina (Waring et al. 2009).

#### 3.11.1.2 Offshore Environment

##### 3.11.1.2.1 Marine Mammals

As described in Section 3.10.2.2.2, **Figure 3.10-3**, depicts a square geographic area approximately 29,000 $km^2$ (8,500 $nm^2$) where offshore impacts (e.g., early rocket stage impacts) may occur due to WFF activities.

The Navy has undertaken a large-scale modeling effort to determine the density of marine mammals within Navy training ranges and OPAREAs in the Atlantic and Pacific Oceans and the Gulf of Mexico. The modeling effort is referred to as “Navy at-sea Operating Area Density Estimates” and has recently been used to create the Navy’s Marine Species Density Database (U.S. Navy 2012). The Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations, which is a spatially referenced online database aggregating marine mammal, seabird, and sea turtle observation data from across the globe (OBIS SEAMAP 2012), was used to generate marine mammal densities by season in the potential offshore impact area as shown in **Figure 3.10-3**. The results are shown in **Table 3.11-1**. Modeled densities are reported in the number of animals per 1 $km^2$ (0.3 $nm^2$). The densities vary by season but for the most part are extremely low (all significantly less than 1).

**Table 3.11-1. Marine Mammal Densities in Waters off Wallops Flight Facility**

| Common Name | Modeled Density in Geographic Range (animals per 1 $km^2$ [0.3 $nm^2$]) | | | |
|---|---|---|---|---|
| | Spring | Summer | Fall | Winter |
| Atlantic Spotted Dolphin | 0.112 | 0.112 | 0.112 | 0.112 |
| Atlantic White-sided Dolphin | 0 | 0 | 0 | 0 |
| Blainville's Beaked Whale | 0.001032 | 0.000943 | 0.001032 | 0.001032 |
| Blue Whale* | no data | no data | no data | no data |
| Bottlenose Dolphin | 0.04616 | 0.05087 | 0.04616 | 0.04616 |
| Bryde's Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Clymene Dolphin | 0.009137 | 0.009137 | 0.009137 | 0.009137 |
| Common Dolphin | 0.2973 | 0.2973 | 0.2973 | 0.2973 |
| Cuvier's Beaked Whale | 0.001032 | 0.000943 | 0.001032 | 0.001032 |
| Dwarf Sperm Whale | no data | no data | no data | no data |
| False Killer Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Fin Whale* | 0.00044 | 0.00044 | 0.00044 | 0.00044 |
| Fraser's Dolphin | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Gervais' Beaked Whale | 0.001032 | 0.000943 | 0.001032 | 0.001032 |
| Gray Seal | 0 | 0 | 0 | 0 |
| Harbor Porpoise | 0 | 0 | 0 | 0 |
| Harbor Seal | 0 | 0 | 0 | 0 |
| Harp Seal | no data | no data | no data | no data |
| Humpback Whale | 0.000998 | 0 | 0.000998 | 0.000499 |
| Killer Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Long-finned Pilot Whale | 0.04326 | 0.04814 | 0.04326 | 0.04326 |
| Melon-headed Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Minke Whale | 0.000034 | 0.000034 | 0.000034 | 0.000034 |
| North Atlantic Right Whale* | 0.0003 | 0 | 0 | 0.0003 |
| Pantropical Spotted Dolphin | 0.01913 | 0.01913 | 0.01913 | 0.01913 |
| Pygmy Killer Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Pygmy Sperm Whale | no data | no data | no data | no data |
| Risso's Dolphin | 0.02188 | 0.02188 | 0.02086 | 0.02188 |
| Rough-toothed Dolphin | 0.000413 | 0.000413 | 0.000413 | 0.000413 |
| Sei Whale* | 0 | 0 | 0 | 0 |
| Short-finned Pilot Whale | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Sowerby's Beaked Whale | 0.001032 | 0.000943 | 0.001032 | 0.001032 |

**Table 3.11-1. Marine Mammal Densities in Waters off Wallops Flight Facility (cont.)**

| Common Name | Modeled Density in Geographic Range (animals per km$^2$ [0.4 nm$^2$]) | | | |
|---|---|---|---|---|
| | Spring | Summer | Fall | Winter |
| Sperm Whale* | 0.01113 | 0.01845 | 0.01113 | 0.01113 |
| Spinner Dolphin | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] | GOMEX ONLY[1] |
| Striped Dolphin | 0.284 | 0.284 | 0.284 | 0.284 |
| True's Beaked Whale | 0.001032 | 0.000943 | 0.001032 | 0.001032 |
| Florida Manatee* | no data | no data | no data | no data |

Source: OBIS SEAMAP 2012.
Notes: * Federally threatened or endangered.
[1]GOMEX ONLY = species only modeled for the Gulf of Mexico, not the Western Atlantic.

#### 3.11.1.2.2 Fish

Due to its proximity to the Atlantic Ocean, the area around WFF has the potential to provide habitat for a wide variety of fish species. Common fish in the waters near WFF include Atlantic croaker (*Micropogonias undulates*), sand shark (*Carcharias aurus*), smooth dogfish (*Mustelus canis*), smooth butterfly ray (*Gymnura micrura*), bluefish (*Pomatomidae saltatrix*), spot (*Leiostomus xanthurus*), and summer flounder (*Paralichthys dentatus*). During summer months, salinity and water depth play a major role in determining if coastal fish species are present in the bays and inlets that surround WFF (Ellis 2003).

#### 3.11.1.2.3 Aquaculture

VMRC promotes and regulates clam and oyster farming and gardening, also known as shellfish aquaculture, in the subaqueous lands of Virginia. VMRC provides oyster ground leases to individuals who wish to conduct aquaculture in approved areas. The locations of both public and private oyster beds were identified in Section 3.5, Water Resources, on **Figure 3.5-8, Figure 3.5-9,** and **Figure 3.5-10**, in order to show their location relative to the existing barge channel. VMRC also issues permits and licenses depending on location, aquaculture method, and whether or not the shellfish will be sold commercially (VMRC 2012). The waters surrounding WFF contain numerous privately leased shellfish aquaculture beds.

#### 3.11.1.2.4 EFH

In accordance with the MSA, Federal agencies must consult with NMFS for activities that may adversely affect EFH that is designated in a Federal Fisheries Management Plan. EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The NOAA Northeast Regional Office provides species lists with designated EFH divided into 10-minute by 10-minute (10' x 10') geographic squares (**Figure 3.11-1**). The waters near WFF fall within two of these 10' x 10' squares of latitude and longitude.

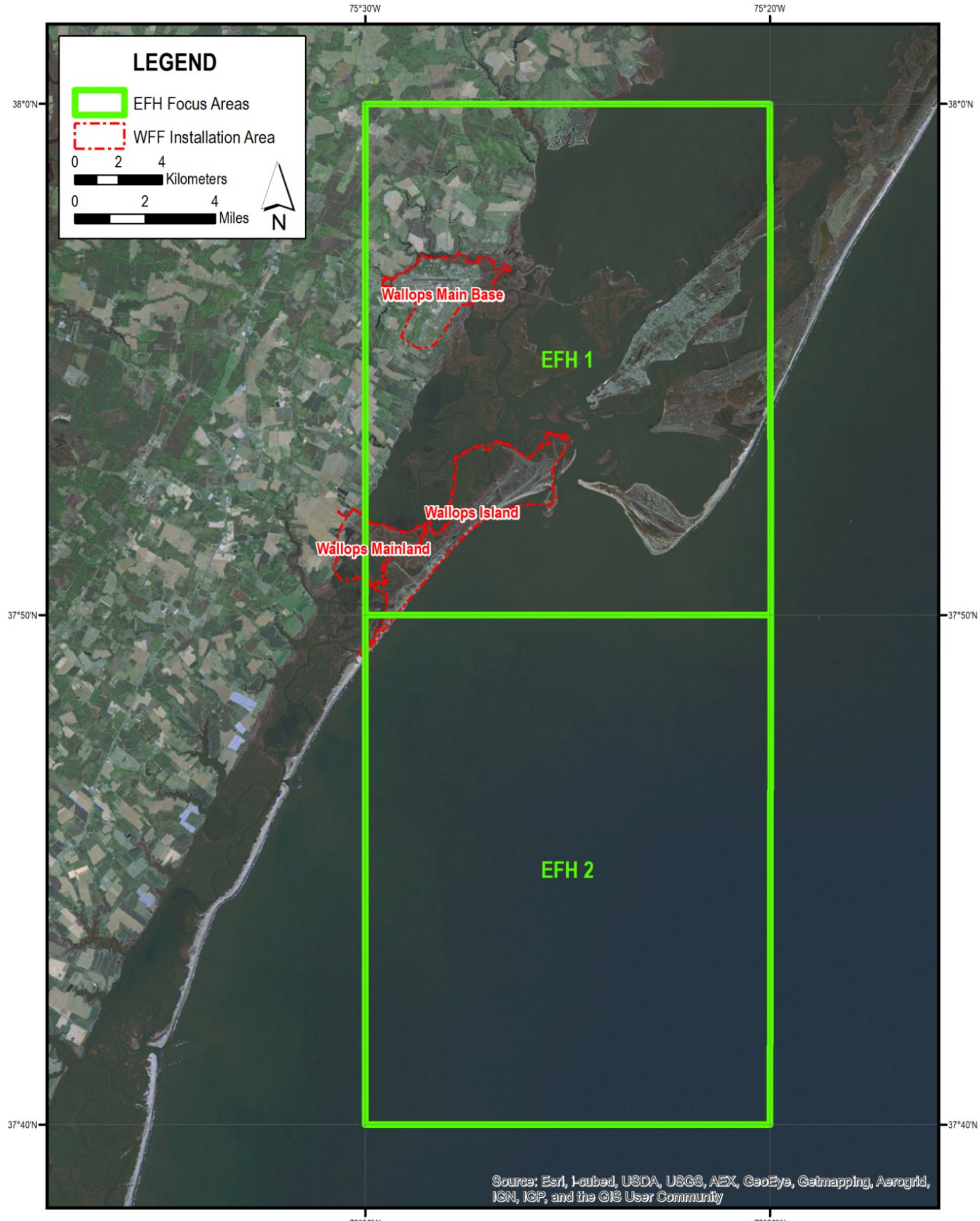


**Figure 3.11-1. Essential Fish Habitat Management Squares Adjacent to Wallops Flight Facility**

One or more life stages of 26 federally managed fish species have designated EFH within the area depicted in **Figure 3.11-1**. The list of the species and life-stages with designated EFH is provided in **Table 3.11-2**.

**Table 3.11-2. Species and Life-Stages with Designated Essential Fish Habitat in Waters Surrounding Wallops Flight Facility**

| Species | Eggs | Larvae | Juveniles | Adults |
|---|---|---|---|---|
| Atlantic Butterfish (*Peprilus triacanthus*) | | | X | X |
| Atlantic sea herring (*Clupea harengus*) | | | | X |
| Atlantic sharpnose shark (*Rhizopriondon terraenovae)* | | | | X |
| Black sea bass (*Centropristus striata)* | | | X | X |
| Bluefish (*Pomatomus saltatrix*) | | X | X | X |
| Clearnose skate (*Raja eglanteria*) | | | X | X |
| Cobia (*Rachycentron canadum*) | X | X | X | X |
| Dusky shark (*Charcharinus obscurus*) | | X | X | |
| King mackerel (*Scomberomorus cavalla*) | X | X | X | X |
| Little skate (*Leucoraja erinacea*) | | | X | X |
| Monkfish (*Lophius americanus*) | X | X | | |
| Red drum (*Sciaenops occelatus*) | X | X | X | X |
| Red hake (*Urophycis chuss*) | X | X | X | |
| Sand tiger shark (*Odontaspis 3-174aurus*) | | X | | X |
| Sandbar shark (*Charcharinus plumbeus*) | | X | X | X |
| Scalloped hammerhead shark (*Sphyrna lewini*) | | | X | |
| Scup (*Stenotomus chrysops*) | | | X | X |
| Spanish mackerel (*Scomberomorus maculatus*) | X | X | X | X |
| Spiny dogfish (*Squalus acanthias*) | | | | X |
| Surf clam (*Spisula solidissima*) | | | X | |
| Summer flounder (*Paralicthys dentatus*) | | | X | X |
| Tiger shark (*Galeocerdo cuvieri*) | | X | | |
| Windowpane flounder (*Scopthalmus aquosus)* | | | X | X |
| Winter flounder (*Pleuronectes americanus*) | X | X | X | X |
| Winter skate (*Leucoraja ocellata*) | | | X | X |
| Witch flounder (*Glyptocephalus cynoglossus*) | X | | | |

Source: NMFS 2016b.
Note: "X" indicates that EFH has been designated within the square for a given species and life stage.

### 3.11.2 Environmental Consequences

Impacts to marine mammals and fish would be considered significant if the Proposed Action created a situation that routinely endangered marine mammals, fish, or impacted a significant amount of EFH in the waters off WFF. Significance would ultimately be determined through agency coordination (USFWS and NMFS) with regard to marine mammals and EFH.

For this PEIS, underwater noise has the greatest potential to impact the marine environment. Sound underwater behaves much like airborne noise, but due to the denser medium, the sound waves can propagate much farther than in the air. Unlike airborne noise, underwater noise is not weighted to match frequencies that can be heard by the human ear. Therefore, underwater noise levels are measured over a particular frequency range of interest and may extend beyond what is audible to humans or other organisms.

Broadly, fish can be categorized as either hearing specialists or hearing generalists (Popper 2008). Fish in the hearing specialist category have a broad frequency range with a low auditory threshold due to a mechanical connection between an air filled cavity, such as a swim bladder, and the inner ear. Specialists detect both the particle motion and pressure components of sound and can hear at levels above 1 kHz. Generalists are limited to detection of the particle motion component of low frequency sounds at relatively high sound intensities (Amoser and Ladich 2005). It is possible that a species will exhibit characteristics of generalists and specialists and will sometimes be referred to as an “intermediate” hearing specialist. For example, most damselfish are typically categorized as generalists, but because some larger damselfish have demonstrated the ability to hear higher frequencies expected of specialists, they are sometimes categorized as intermediate. Studies indicate that hearing specializations in marine species are rare and that most marine fish are considered hearing generalists (Popper 2003; Amoser and Ladich 2005).

NMFS and USFWS have raised concerns over the impacts in-water work activities have on fish and marine mammals. Reported fish kills from in-water pile driving have highlighted the need to understand underwater noise impacts and determine a way to estimate underwater noise levels to ensure minimal impacts to the underwater noise environment (WSDOT 2015).

In July of 2016, NMFS released its *Technical Guidance for Assessing the Effects of Anthropomorphic Sound on Marine Mammal Hearing*. This guidance document lays out the recently revised and updated permanent threshold shift exposure thresholds for marine mammals. Previously, NMFS used conservative thresholds for underwater SPLs from broad band sounds that may cause behavioral disturbance and/or injury to marine organisms. The new thresholds are much more specific and classify marine mammals into five functional hearing groups and provides acoustic thresholds for permanent threshold shifts only (permanent threshold shifts would constitute irreparable hearing loss). The thresholds shown in **Table 3.11-3** are those used for MMPA permitting activities and ESA Section 7 consultations by NMFS. NMFS is also continuing to monitor the best available data and will update thresholds for impacts to marine mammals as new data becomes available (NMFS 2016c).

**Table 3.11-3. Underwater Acoustic Thresholds for Cetaceans, Pinnipeds, and Fish**

| Functional Hearing Group | Impulsive | Non-Impulsive |
|---|---|---|
| ***Marine Mammals***[(a)] | | |
| Low Frequency Cetaceans | 219 dB PK<br>183 dB $SEL_{cum}$ | 199 dB $SEL_{cum}$ |
| Mid Frequency Cetaceans | 230 dB PK<br>185 dB $SEL_{cum}$ | 198 dB $SEL_{cum}$ |
| High Frequency Cetaceans | 202 dB PK<br>155 dB $SEL_{cum}$ | 173 dB $SEL_{cum}$ |
| Phocid Pinnipeds | 218 dB PK<br>185 dB $SEL_{cum}$ | 201 dB $SEL_{cum}$ |
| Otariid Pinnipeds | 232 dB PK<br>185 dB $SEL_{cum}$ | 219 $SEL_{cum}$ |
| ***Fish*** | | |
| Injury[(b)] | **Underwater Threshold** | |
| All | 206 dB re: 1 µPa (Peak) | |
| Fish ≥ 2 grams | 187 dB re: 1 $\mu Pa^2$ –s (SEL) | |
| Fish < 2 grams | 183 dB re: 1 $\mu Pa^2$ –s (SEL) | |
| Behavioral Disruption[(c)] | 150 dB re: 1 µPa (RMS) | |

Sources: [(a)] NMFS 2016a; [(b)] Fisheries Hydroacoustic Working Group 2008; [(c)] NMFS 2016c.

### 3.11.2.1 No Action Alternative

3.11.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Any substantial changes to the design of approved construction projects would require site-specific NEPA analysis.

3.11.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational programs that are within the installation's current envelope. All operational programs under the No Action Alternative have been addressed in previous NEPA documents; therefore, there would be no new or additional impacts to marine mammals or fish from operational programs under the No Action Alternative.

### 3.11.2.2 Proposed Action

The majority of projects described under the Proposed Action are in various stages of conceptual maturity with varying levels of detail for discussion. As project planning and design details become more developed, further NEPA analysis, along with all relevant consultation, would occur prior to construction or implementation.

3.11.2.2.1 Institutional Support Projects

**Construction, Demolition, and RBR Projects**

Under the Proposed Action, institutional support projects at WFF would include construction, demolition, and RBR projects. New construction would occur at each of the three facility locations: Main Base, Mainland, and Wallops Island. Most of the construction projects would occur on areas that are already developed and would not impact the waters surrounding WFF. These include the Commercial Space Terminal, Runway 04/22 extension, Launch Pad 0-C, and the two DoD launch pads. Stormwater and any subsequent water quality impacts from construction activities are noted in Section 3.5, Water Resources. These impacts would be minor with the use of proper BMPs, permit requirements, and any necessary mitigation measures. Therefore, impacts to marine mammals, fish, and EFH from construction runoff under the Proposed Action for these projects would be minor. Two institutional support projects, the North Wallops Island Deep-water Port and Operations Area and Launch Pier 0-D, would have the potential to impact marine mammals and fish; however, insufficient details are available at this time to conduct a resource-specific analysis. These proposals warrant more focused analysis in the future once plans become more certain. Two other institutional support projects (Causeway Bridge Replacement and maintenance dredging) involve in-water activities and therefore have the potential to impact marine mammals and fish. These projects and potential impacts are discussed below.

**Causeway Bridge Replacement**

Construction activities in water would produce pulsed (i.e. impact pile driving) sounds. Fish react to sounds which are especially strong and/or intermittent low-frequency. Short duration, sharp sounds can cause overt or subtle changes in fish behavior and local distribution. Several studies suggest fish may relocate to avoid certain areas of noise energy (Hastings and Popper 2005; Popper and Hastings 2009). Additional studies have documented the general effects of pile driving (or other types of continuous sounds), although several are based on studies in support of large, multi-year bridge construction projects

(Scholik and Yan 2002; Hawkins 2006; Hastings 2007; Popper et al. 2006; Popper and Hastings 2009). There are no studies of long-term effects of pile driving sounds on fish (California Department of Transportation [CalTrans] 2015). SPLs of sufficient strength have been known to cause injury to fish and fish mortality (CalTrans 2001). Exposure to high levels of sound can alter the physiology and structure of fish, including but not limited to the rupturing or tearing of the swim bladder. Carlson et al. (2007) noted that there was non-auditory tissue damage at SELs of 185 and 189 dB in hearing specialists and generalists, respectively, and full recovery of hearing loss due to a temporary threshold shift occurred within 18 hours.

No current design plans for the replacement of the Causeway Bridge exist. Therefore, site-specific impacts to marine mammals, fish, and EFH are not possible to determine at this time. Cat creek is considered EFH for winter flounder, red hake, clearnose skate, window pane flounder, and little skate. Common environmental impacts from bridge construction result from construction noise, untreated stormwater runoff, over water shading, and permanent fill of wetlands. Underwater noise impacts from pile driving activities have the potential to significantly impact all marine species in the vicinity of the proposed bridge construction. Though construction would only be temporary, pile driving activities could occur over a number of months in order to drive the necessary number of piles to support the bridge. In order to estimate the potential noise impacts from pile driving, many parameters of the construction project must be known (e.g., the number of piles required, the type and length of piles, the equipment used to drive the piles, and the numbers of pile strikes per day). Underwater noise is a concern for both NMFS and USFWS. As mentioned in 3.11.2, fish kills that resulted from in-water pile driving activities have been reported in Puget Sound, Washington; San Francisco Bay, California; and Vancouver Harbor in British Columbia, Canada, and have raised the issue in recent years (WSDOT 2015). Disturbance or injury of nearby marine mammal species is also a possibility from pile driving. As such, until more information about the bridge construction methods are obtained, no precise estimate of impacts from pile driving can be derived. Coordination with NMFS and USFWS would be undertaken to determine the extent of impacts and any potential mitigation measures required.

Even though specific bridge designs do not exist, generalized underwater acoustic impacts can be calculated; these are based on many assumptions and should not be taken as an accurate portrayal of actual impacts. Once bridge design specifics are known (i.e., number and types of piles, bottom composition, pile driving equipment, etc.) a detailed noise analysis could be performed. Conservative assumptions for pile driving are as follows:

- 1 m (36 in) cast-in-shell pilings (see **Appendix E** for noise levels),
- 2,400 strikes per pile, and
- 4 piles per day.

Results using NMFS underwater acoustic calculator with the above assumptions are presented in **Table 3.11-4**. The calculator uses open water spreading loss, which is not the case in the project area for the Causeway Bridge. Cat Creek is a very narrow, fairly shallow waterway with significant bends both north and south of the bridge location. These factors, in addition to the soft sediment bottom and surrounding wetland vegetation, further aid in attenuating noise. From the results, it can be assumed that marine mammals and fish within 1,600 m (5,200 ft) would be impacted to varying degrees. Bridge designs are not known at this time but it is assumed that only four to six support piles would be constructed in open water, with the rest being driven into the adjacent tidal marsh. This would further limit the length of time open water pile driving would be necessary, and thereby limit in-water impacts to any species in the project area.

**Table 3.11-4. Underwater Acoustic Thresholds for Cetaceans, Pinnipeds, and Fish**

| Functional Hearing Group | Underwater Threshold | Distance to Threshold |
|---|---|---|
| ***Cetaceans and Pinnipeds(a, d)*** | | |
| Injury | 190 dB re 1 µPa (RMS) pinnipeds<br>180 dB re 1 µPa (RMS) cetaceans | 16 m (53 ft)<br>74 m (243 ft) |
| Behavior Disruption (Impulsive Noise) | 160 dB re 1 µPa (RMS) | 1,585 m (5,200 ft) |
| Behavioral Disruption (Non-pulse Noise) | 120 dB re 1 µPa (RMS) | 735 km (460 mi) |
| ***Fish*** | | |
| Injury(b) | | |
| All | 206 dB re 1 µPa (Peak) | 18 m (60 ft) |
| Fish ≥ 2 g | 187 dB re 1 µPa • sec (SEL) | 1,585 m (5,200 ft) |
| Fish < 2 g | 183 dB re 1 µPa • sec (SEL) | 1,585 (5,200 ft) |
| Behavioral Disruption(c) | 150 dB re 1 µPa (RMS) | 7.4 km (4.5 mi) |

Sources: [(a)] Fisheries Hydroacoustic Working Group 2008; [(b)] Hastings 2002.
Note: Distances generated using NMFS Underwater Noise Calculator (NMFS 2009a).

Marine mammals (namely bottlenose dolphins), if in Cat Creek during pile driving, would experience noise levels above the NMFS thresholds for disturbance and potentially above the threshold for injury (as shown in **Table 3.11-4**). This would constitute Level B harassment, under the MMPA, and could potentially injure marine mammals within 74 m (243 ft). Mitigation measures such as a marine mammal observer or time of year restrictions for pile driving activities may be required by NMFS or USFWS, depending on marine mammal species occurrence. Marine mammals are highly mobile and would likely relocate. However, consultation with NMFS and possibly USFWS would be undertaken prior to pile driving activities to ensure that necessary mitigation measure to reduce impacts are initiated.

Marine mammals and fish could also be affected by erosion, sediment, and stormwater runoff; however, these impacts would be minor with the use of proper BMPs (e.g. silt fencing, soil stabilization blankets and matting, and vegetating bare soils after construction to reduce erosion and stormwater runoff). A search of NOAA's EFH Mapper (NOAA 2017) showed that a number of the managed species listed in **Table 3.11-2** have EFH present in the estuarine tidal wetlands in the vicinity of the Causeway Bridge. This includes clearnose skate, little skate, red hake, window pane flounder, and winter flounder. Erosion, stormwater runoff, and filling of estuarine tidal wetlands would present a direct impact to designated EFH for a number of managed species. These species utilize a variety of habitats that are important for multiple life stages. Site-specific assessments would be required and coordination with NMFS and USFWS would be undertaken to determine the extent of impacts and required mitigations. Additionally, disturbance and filling of wetlands could lead to further invasion by *Phragmites* into EFH, thereby negatively impacting fish species. NASA would implement its *Phragmites Control Plan* (NASA 2014) in consultation with USACE, VMRC, and VDCR to control propagation of *Phragmites* in these areas.

**Maintenance Dredging**

Maintenance dredging has the potential to impact marine mammals and fish. It is assumed that the boat basins, connector channels, and the entire length of the Barge Route would require some dredging to reach a depth of 2.4 m (8 ft) (see **Figure 2.5-6** for Barge Route and boat docks). Impacts to marine mammals and fish would depend on where the maintenance dredging would occur along the route, as marine mammals (namely bottlenose dolphins) are unlikely to be within the boat basin areas, but may be present at other areas along the navigational channel route.

Different dredging methods result in differing impacts to marine species. As discussed in Section 3.5, Water Resources, clamshell dredging represents the greatest environmental impact scenario; impacts from dredging assume this type of dredging would be used. Impacts to the marine environment from dredging occur in a number of ways: direct disturbance to species from dredging activity, sediment disturbance and increased turbidity from dredging activity, and noise impacts from the dredging operation. Impacts from maintenance dredging to marine mammals, EFH, fish, and shellfish are discussed below.

***Marine Mammals***

Marine mammals are not likely to be in the boat basins or connector channels that are outlined in the Barge Route; however, the possibility does exist for bottlenose dolphins and harbor seals to be present in the deeper, more open water areas of the Barge Route. While infrequent, harbor seals have been documented in these areas of WFF. Impacts from dredging activities would be general disturbance from the active dredging, increased turbidity, and potential noise impacts. Marine mammals that may be in the vicinity of dredging operations are highly mobile and would likely move away from areas being dredged.

Turbidity increases would impact marine mammals that rely primarily on sight for feeding purposes. Turbidity generated from dredging operations is generally no greater than that experienced during heavy storm events and estuarine species are typically habituated to great fluctuations in turbidity (LaSalle et al. 1991). Dredging activities would be temporary and turbidity increases are unlikely to adversely impact marine mammals.

Noise impacts to marine mammals would likely be the most severe impact from dredging operations. Richardson et al., (1995) noted that dredging operations can produce sound levels of 160 to 180 dB re: 1 µPa at 1 m (3 ft). Clamshell dredging has different noise levels associated with different aspects of the procedure. The bucket striking the bottom is generally the loudest part of the operation and has been recorded at 128 dB re: 1 µPa at 150 m (500 ft) (Dickerson et al. 2001). Sound propagates great distances underwater and is influenced by the physical characteristics of the basin that is being dredged. In this case, shallow water and softer substrate would help to attenuate noise levels rapidly but levels above the thresholds noted in **Table 3.11-3** would be possible from dredging activities. Using a conservative spreading loss equation for underwater noise, which assumes a 4.5 dB reduction with a doubling of distance, the behavioral disturbance threshold of 120 dB re: 1 µPa would extend out approximately 512 m (1,680 ft) from the dredge location. Dredging volumes for this project would be relatively small, and work would be completed in approximately eight weeks. Coordination with NMFS would be undertaken during development of the dredging permit and mitigation methods for minimizing impacts to marine mammals may be required. Though the potential would be low, the possibility does exist to harm or injure marine mammals through a direct vessel strike during maintenance dredging activities. The marine mammals likely to be along the dredge path (bottlenose dolphins) are highly mobile and would likely avoid the noise associated with dredging activities.

***<u>EFH, Fish, and Shellfish</u>***

***Direct Impacts***

Dredging impacts to EFH, fish, and shellfish could occur from direct entrainment (fish being captured by the dredge bucket), increased turbidity and subsequent sedimentation, direct habitat loss, and disturbance from noise and in-water activity. Impacts to fish and shellfish would depend on the season during which the dredging occurred and the life stages of organisms that occupy the project area. Wilbur and Clarke (2001) identified that effects from re-suspension of sediments varied widely among marine species. Generally, high levels of suspended solids and long exposure times produced the most drastic mortality. Typically, eggs, larval stages, and sessile or sedentary species are most susceptible to entrainment (LaSalle et al. 1991). Entrainment rates tend to be low and are typically found to be more problematic in cutter/suction dredging, due to its continuous nature, than in clamshell bucket dredging. However, fish species that lay demersal eggs (those that are laid on the bottom or attached to substrate) in the project area may experience direct mortality during dredging operations if entrained. Dredging along the Maintained Barge Route may impact privately leased aquaculture beds. Once specific information about dredging activities becomes available, impacts to these leased beds would need to be quantified to determine if mitigation or possible remediation measures would be required.

As stated, increases in turbidity from dredging are generally similar to that experienced during strong storm events. Consequently, estuarine organisms have habituated to a wide range of turbidity. Though unlikely, impacts to fish could result from increased turbidity (LaSalle et al. 1991). Decreased visibility could lead to increased predation risk for some species and could impact species that rely on phytoplankton and filter feeding by damaging feeding structures or reducing feeding efficiency (Erftemeijer and Lewis 2006). Abundance of prey species may also be altered temporarily within the project area. Additionally, sedimentation of greater than 0.5 mm (0.2 in) on demersal eggs has been shown to produce 50% mortality in some species (LaSalle et al. 1991). Adverse impacts from turbidity and sedimentation to shellfish are unlikely, as the dredging activity would be short in duration and not cover a large area.

The re-suspension of anoxic sediments can also alter dissolved oxygen content in the immediate vicinity of the dredging operation, with deeper areas typically having lower dissolved oxygen than surface areas (LaSalle et al. 1991). This impact is generally short-lived, as mixing occurs, but may be more of an issue if the area being dredged is tidally restricted or is considered to be slack water. Mobile species would likely relocate but some larval stages or eggs could be adversely impacted or killed from extended periods of low dissolved oxygen.

Dredging may impact EFH directly through the removal or destruction of designated EFH or secondarily through increased turbidity or possible sedimentation of SAV beds. Direct impacts to marine vegetation from dredging occur from both light reduction and sedimentation. This can affect the marine vegetation and any associated epiphytes, microphytobenthos, and macroalgae (Erftemeijer and Lewis 2006). Though no SAV beds occur along the dredge corridor, the closest SAV beds lie approximately 1.4 km (0.85 mi) from the Maintained Barge Route and could be secondarily impacted from suspended sediments (VIMS 2016).

Of the 26 species that have designated EFH within the two 10′ by 10′ grids shown in **Table 3.11-2** and **Figure 3.11-1**, 17 species have EFH with potential to occur along the Barge Route. **Table 3.11-5** lists those 17 species and the life stages that are likely to occur on the Barge Route, based on EFH descriptions for each species as outlined in the individual Fisheries Management Plans and summarized by NMFS. These habitats range from estuarine wetlands, sandy and mud bottoms, and the water column. Coordination with USACE and VMRC for dredging permits would be undertaken. Consultation with NMFS may also be required and a site-specific EFH assessment may be necessary to determine the extent of impacts to any managed species or habitats.

**Table 3.11-5. Species and Life-Stages with Designated Essential Fish Habitat that may Occur Along Barge Route**

| Species | Eggs | Larvae | Juveniles | Adults |
|---|---|---|---|---|
| Black sea bass (*Centropristus striata*) | | | L | L |
| Bluefish (*Pomatomus saltatrix*) | | NL | L | L |
| Clearnose skate (*Raja eglanteria*) | | | L | L |
| Cobia (*Rachycentron canadum*) | | | L | L |
| Dusky shark (*Charcharinus obscurus*) | | L | L | NL |
| King mackerel (*Scomberomorus cavalla*) | | | L | L |
| Little skate (*Leucoraja erinacea*) | | | L | L |
| Red drum (*Sciaenops occelatus*) | L | L | L | L |
| Sand tiger shark (*Odontaspis aurus*) | | L | | L |
| Sandbar shark (*Charcharinus plumbeus*) | | L | L | L |
| Scup (*Stenotomus chrysops*) | | | L | L |
| Spanish mackerel (*Scomberomorus maculatus*) | | | L | L |
| Surf clam (*Spisula solidissima*) | | | L | |
| Summer flounder (*Paralicthys dentatus*) | | | L | L |
| Windowpane flounder (*Scopthalmus aquosus*) | | | L | L |
| Winter flounder (*Pleuronectes americanus*) | NL | NL | L | L |
| Winter skate (*Leucoraja ocellata*) | | | L | L |

Note: Only those species expected to occur around WFF are rated in this table. A blank cell denotes that no EFH for that life-stage exists in this area.
Legend: NL = Not Likely; L = Likely.

A search of NOAA's EFH Mapper indicated that no designated EFH was present at either boat basin location (NOAA 2017). However, as the project designs develop and more information is known, a site-specific EFH assessment may be required along with consultation with NMFS to quantify any potential impacts to EFH or managed species from improving these boat docks.

***Indirect Impacts***

Disturbance of wetlands and fringe areas under the Proposed Action could lead to further invasion by *Phragmites* into EFH indirectly affecting fish species. *Phragmites* typically outcompetes native wetland vegetation and changes the function of the habitat it invades. Despite the findings of some studies (e.g., Fell et al. 1998; Meyer et al. 2001) that have found no difference in use between *Phragmites* and *Spartina* marshes by mummichog (*Fundulus heteroclitus*), other studies have shown that *Phragmites* has deleterious effects on larval and juvenile fish use of the marsh (Able 2003). Abel et al. (2003) proposed a four-stage progression over which the habitat value of a *Phragmites*-invaded area is altered. The first phase, during which *Phragmites* is present, but not dominant, is expected to have little effect on EFH as feeding, reproduction, and nursery functions continue. However, during the later stages of invasion, as the affected area transitions to a *Phragmites* monoculture, standing water is reduced, intertidal creeks are filled, and topography is raised such that the area is only flooded rarely, eventually eliminating all habitat functions.

Given that regular flooding by salt water restricts *Phragmites* development to higher tidal elevations, it is expected that the areas of greatest risk for colonization would be the marsh fringes around the boat basins and placement sites for dredged material. As such, NASA would implement its *Phragmites Control Plan* (NASA 2014) in consultation with USACE, VMRC, and VDCR to control propagation of *Phragmites* in these areas.

**North Wallops Island Deep-water Port and Operations Area**

Similar potential impacts to marine mammals and fish as described above for the Causeway Bridge Replacement and maintenance dredging projects, would likely occur under this proposal. As details for the North Wallops Island Deep-water Port and Operations Area are unknown, further NEPA analysis would be required as the details for this project becomes solidified.

**Launch Pier 0-D**

Similar potential impacts to marine mammals and fish as described above for the Causeway Bridge Replacement and maintenance dredging projects, would likely occur under this proposal. As details for Launch Pier 0-D are unknown, further analysis would be required as the details for this project becomes solidified.

In-water institutional support projects would have insignificant adverse effects on marine mammals and fish. Regulatory agency consultations would occur as necessary in order to minimize impacts to these species. Causeway Bridge Replacement, maintenance dredging, and development of the North Wallops Island Deep-water Port and Operations Area may have effects on marine species. Impacts would be dependent on final designs and locations of the projects. Further analysis would be required as project details are confirmed. Refer to **Section 4.1.9** (Marine Mammals and Fish) for measures to mitigate impacts to marine mammals and fish under the Proposed Action.

3.11.2.2.2 Operational Missions and Activities

Most operational programs that would be conducted under the Proposed Action would not impact marine mammals or EFH species adjacent to WFF. However, a few new operational activities have the potential to impact these resources. Directed Energy, a new weapons system proposed for Wallops Island, is discussed below. LVs are currently launched from Wallops Island, however, the launching of the LFIC LV and SFHC LV would exceed the current envelope at WFF. Both LVs would present similar impacts to marine mammals and fish and as such, they are discussed together.

**DoD SM-3**

DoD SM-3 rockets would be launched out over the VACAPES OPAREA for testing or to intercept an airborne target. Upon detonation, the airborne debris would fall into the ocean and sink rapidly to the ocean floor. A small chance exists for marine mammals and fish to be present in the ocean where impact/detonation occurs. Recent documentation by the U.S. Navy for AFTT activities has determined the low density of marine mammals in the VACAPES OPAREA combined with the relatively small number of DoD SM-3 launches would not result in any significant dangers to marine mammals or fish due to falling debris, potential ingestion of debris, or possible entanglement hazards from falling debris (U.S. Navy 2009; 2013a; 2018a). A letter of authorization for AFTT activities was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b).

**Directed Energy**

Although these weapon systems are in various stages of development and little information exists on their impacts to the general environment, use of either the HEL or HPM at WFF would likely have negligible impacts to EFH species and marine mammals. The HEL or HPM would be mounted to the top of an existing structure at Wallops Island and direct concentrated energy to a specified target up to 1.6 km (1 mi) along the beach or at an airborne target over the ocean. The length of time the beam would be active is unknown. Directed Energy activities would not likely penetrate into the water and, therefore, impacts from this operation to marine mammals, fish, or EFH would be negligible. In recent Navy studies, it was determined that use of lasers in the marine environment would pose no environmental hazards to marine organisms (U.S. Navy 2009; 2018). A 2013 BO was issued by NMFS to the Navy with regard to testing these devices and concluded that it was unlikely to cause any significant impacts to marine mammals or fish. A letter of authorization for AFTT activities under the 2013 BO was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b). However, as the HEL and HPM devices become more operational and proposals more finalized, additional NEPA analysis may be required to better assess potential impacts from these weapon systems.

**Expanded Space Program**

***LFIC LV and SFHC LV***

The LFIC LV and SFHC LV would be the largest launch vehicles ever launched from Wallops Island. They have environmental impacts similar to but greater than rockets currently launched from WFF. These vehicles would be launched from either a modified Launch Pad 0-B or from the proposed Launch Pad 0-C or Pier 0-D, all of which are immediately adjacent to estuarine and oceanic waters. Launch of an LFIC LV, with a liquid propellant first stage, would result in the emission of CO and $CO_2$. When CO and $CO_2$ combine with water vapor in the air, carbonic acid may form which could result in the deposition of carbonic acid on the surface waters in the area surrounding the launch pad. The effects of carbonic acid deposition on the adjacent tidal areas would be minimal as carbonic acid is a weak acid (approximate pH of 6.4) and is normally found in rainwater. Nearby surface waters have a natural buffering capacity and a natural ability to resist substantial changes in pH (NASA 2009). Previous studies of surface waters surrounding launch pads have indicated minimal pH changes after rocket launches. Therefore, the effects of carbonic acid deposition on the adjacent surface waters, including tidal wetland areas, would be minor and short-term.

However, for the SFHC LV, acid deposition resulting from gaseous HCl emission is of particular concern to the aquatic environment in the vicinity of the launch pad. Schmalzer et al. (1998) provided a detailed literature review, as well as direct observations of the environmental effects of rocket launches from Delta, Atlas, and Titan launch vehicles at Kennedy Space Center, Florida. The deposition of HCl in waters near the launch complex could alter the pH and cause fish kills. Schmalzer et al. (1998) noted that after each Space Shuttle launch, a fish kill occurred as a direct result of surface water acidification, which often exceeded 5 pH units; these were in direct relation to the spatial pattern of the near-field acid deposition footprint or ground cloud. While the SFHC LV would produce a much smaller launch plume than the Space Shuttle, the potential does exist for impacts to the nearby estuarine waters that may receive limited tidal flushing. Acidification would be temporary and the pH would return to normal levels due to the buffering capacity of estuarine and ocean waters.

The air modeling effort associated with this PEIS indicated that peak HCl concentrations of 2 to 5 ppm were possible and that the maximum downwind distance to peak concentrations was estimated to be 11 km (6.8 mi) to 19 km (11.8 mi) (ACTA 2012). At Kennedy Space Center, far field chloride deposition ranged from 25 to 5,300 mg/m$^2$ and was indicated by acid spotting on vegetation (Hall et al. 2014). Hall et al. (2014) noted that at Kennedy Space Center acid deposition from a launch impacted waters to a depth of 1.5 m (4.9 ft) by dropping pH up to 5 units, causing fish kills in the shallower waters of the lagoons around the launch pads. It appeared that in deeper waters, fish avoided the acidified water by diving to deeper waters and moving out of the area (Hall et al. 2014). Due to the size and buffering capacity of the Atlantic Ocean, it is unlikely that any acidification impacts would be perceptible in ocean waters. Far field impacts from launches at Kennedy Space Center were limited to periodic spotting on plant leaves, with no visible impacts to water quality (Hall et al. 2014).

Acidification is unlikely to impact marine mammals, even if they were in nearby estuarine waters such as the estuaries located west of Wallops Island. Fish mortality from acid deposition associated with rocket launches at Kennedy Space Center were attributed to severely damaged gills (Schmalzer et al. 1998). While marine mammals do not have gills, it is possible that overly acidic environments would cause irritation to the eyes or other areas of the body.

Both the LFIC LV and SFHC LV would reach supersonic speeds, which would create a sonic boom. The launch trajectory for these types of launch vehicles is generally southeast, over the Atlantic Ocean, through the VACAPES OPAREA. As discussed in Section 3.1, Noise*,* sonic boom modeling was conducted as part of the noise modeling effort associated with this PEIS. Because the rocket takes time to reach supersonic speeds and due to the southeastern trajectory, the sonic boom occurs entirely over the open ocean. Though no distance to the start of the boom footprint or 'carpet' was calculated, it was determined that sonic boom energy generated from the launching of these vehicles would be equal to or less than that of military aircraft that occasionally create sonic booms in the VACAPES OPAREA (BRRC 2015). Sonic boom modeling analysis for the Air Force's *Final EIS for the EELV Program*, which launches Atlas family rockets, found that the sonic boom footprint started over 48 km (30 mi) from the launch site (U.S. Air Force 2000). Due to the rocket's trajectory, sonic booms would reach the ocean surface at a shallow angle and negligible sound energy would pass into the water (BRRC 2015). Boom energy would also be greatest directly under the rocket and would dissipate as lateral distance from the trajectory increased.

While marine mammals could be under the trajectory of the larger LVs, impacts would be related to the mammals' location in relation to the trajectory and whether or not they are at or below the ocean's surface at the time of the boom. Little is known about how marine mammals react to sonic booms in the open ocean but sonic booms may elicit a startle response. It is thought that marine mammal behavior in the open ocean would not be significantly impacted from sonic booms (Cummings 1993).

Laney and Cavanagh (2000) modeled the F/A-18 Hornet in supersonic flight to obtain $dB_{peak}$ at the water surface and at depth. The results of this analysis are shown in **Table 3.11-6.**

**Table 3.11-6. Sonic Boom Underwater Sound Levels Modeled for F/A-18 Hornet Supersonic Flight**

| Mach Number | Aircraft Altitude km (mi) | Peak Pressure (dB re: 1 μPa-m) | | |
|---|---|---|---|---|
| | | At Surface | 50 m (164 ft) Depth | 100 m (328 ft) Depth |
| 1.2 | 1 (0.6) | 176 | 138 | 126 |
| | 5 (3) | 164 | 132 | 121 |
| | 10 (6) | 158 | 130 | 119 |
| 2 | 1 (0.6) | 178 | 146 | 134 |
| | 5 (3) | 166 | 139 | 128 |
| | 10 (6) | 159 | 135 | 124 |

Source: Laney and Cavanagh 2000.

Laney and Cavanagh (2000) determined that a very loud sonic boom over the ocean would be on the order of 450 Pa (10 psf) and that anything above 2,400 Pa (50 psf) would be difficult to actually produce. Even the worst-case scenario of a sonic boom generating an overpressure of 2,400 Pa (50 psf) at the surface would equate to a maximum in water pressure wave of approximately 4,800 Pa (100 psf) or about 0.7 pounds per square inch (psi) (about 194 dB re: 1 μPa). This is well below the 82 kPa (12 psi) that has been a commonly established threshold for injury and harassment of marine mammals and sea turtles (12 psi equates to approximately 182 dB re: 1 $\mu Pa^2$-s, the threshold for injury to cetaceans is 180 dB re:1 $\mu Pa^2$-s) (Laney and Cavanagh 2000). According to Laney and Cavanagh (2000), "the principal reason for the lack of impact (to marine mammals) from sonic boom energy under water is that even for the strongest booms and good coupling to the water, the peak pressure and energy flux density are not sufficient to cause injury or harassment, at least under currently accepted criteria and thresholds." Hall et al. (2014) also noted that for rocket launch and reentry, the sonic boom energy at the water's surface was calculated to be 14 kPa (2 psi) to 20 kPa (3 psi), well below the threshold of 83 kPa (12 psi) cited in Laney and Cavanagh (2000). Given that sonic booms generated by LFIC LV and SFHC LV would be on the same order as sonic boom energies of jets currently operating in the VACAPES OPAREA, it is unlikely that the sonic booms generated by these launch vehicles would significantly impact marine mammals.

As the rocket ascends, rocket stages would be jettisoned and would fall back into the ocean. Depending on the vehicle launched, some of the stages or payloads may be retrieved. Payloads from launch vehicles are sometimes recovered instead of inserted into an orbit. These payloads deploy a drogue chute to release a parachute. Once the payload has landed in the ocean, different markers may be deployed to aid in recovery including visual (dye markers, strobe lights), audible (pingers), and/or GPS. The Navy recently concluded that the use of marine markers within VACAPES OPAREA, would have little to no impact to federally listed marine mammals and that vessel movements may affect federally listed marine mammals, but are not expected to result in Level A or Level B MMPA defined harassment (U.S. Navy 2009; 2013; 2017). Rocket stages, parachutes, and associated debris would rapidly sink to the ocean floor and are unlikely to create significant hazards to the marine mammal species listed in **Table 3.11-1**. There is an extremely small potential for marine mammals to be impacted from the falling debris or rocket stages, or disturbed from retrieval activities, given the relatively low density of marine mammals per unit area in the Atlantic Ocean offshore from WFF. Densities of various species fluctuate seasonally, but are low year round, making direct strike probabilities from WFF activities correspondingly low. NMFS concluded that WFF operations are infrequent enough to not warrant the need for an Incidental Take Statement for marine mammals or sea turtles from over-ocean rocket operations (NMFS 2009b).

In summary, NASA consulted with NMFS regarding potential impacts of Antares launch operations on protected marine species (NMFS 2009b). These consultations concluded that the action was not likely to adversely affect these species. The LFIC LV and SFHC LV are larger launch vehicles than the Antares. However, the launching of these larger vehicles would have similar impacts to marine mammals and fish as vehicles currently launched from WFF.

***Vertical Launch and Landing Vehicles***

Potential impacts to marine mammals and fish associated with vertical launch and landing vehicles from Wallops Island would likely be similar to those described for the LFIC LV or SFHC LV.

Vehicles returning to WFF to perform a vertical landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom. A noise study was conducted in 2017 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island. The results of the 2017 study indicate that the intensity of a sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). It is likely that any noise associated with the sonic boom would transmit from the air to water and propagate some distance in the water column. A sonic boom at the surface of 0.1 kPa (2 psf) would decay to approximately 152 dB re 1 µPa at a depth of 7 m (23 ft). By 22 m (72 ft), the received levels would be approximately 140 dB re 1 µPa and at 37 m (121 ft) or equal to ambient noise levels (U.S. Air Force 2016).

All of these SPLs are below the current NMFS threshold for potential permanent injury (under current NMFS guidance [NMFS 2016c]), the lowest received sound level that would cause temporary threshold shift in marine mammals is 153 dB for high-frequency cetaceans). Wildlife may be startled by the sonic boom; however, the impact to marine mammals and fish would not be considered significant, due to the limited number of events per year. Future NEPA analysis would address such conditions to prevent unacceptable adverse impacts.

***Horizontal Launch and Landing Vehicles***

Horizontal launch and landings vehicles would take off and land like a standard aircraft from the Runway 04/22 at the Main Base. Impacts to marine mammals and fish would be unlikely; however, vehicles returning to WFF to perform a horizontal landing in the future could re-enter the airspace at supersonic speeds capable of creating a sonic boom (BRRC 2017). The intensity of a sonic boom would be highly dependent on the reentry trajectory and atmospheric conditions at the time of flight. Given that sonic booms would be on the same order as sonic boom energies of jets currently operating in the VACAPES OPAREA, it is unlikely that the sonic booms generated by these launch vehicles would significantly impact marine mammals, as discussed in above. Future NEPA analysis would address such conditions to prevent unacceptable adverse impacts.

***Commercial Human Spaceflight Missions***

A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) of commercial human spaceflight missions. Potential impacts to marine mammals and fish would be similar to those described for LVs launched from Wallops Island and horizontal launch vehicles reentering the airspace and landing at the Main Base.

In conclusion, it is unlikely that the proposed operational missions and activities would have a significant impact on marine mammals and fish. Refer to **Section 4.1.9** (Marine Mammals and Fish) for measures to mitigate impacts to marine mammals and fish under the Proposed Action. Section 5.4.7, Marine Mammals and Fish provides a discussion on the potential for cumulative effects associated with habitat loss, noise, and predation.

## 3.12 Airspace Management

Just as the use of the nation's highway system is governed by traffic laws and rules for operating vehicles, the safe, orderly, and compatible use of the nation's airspace is made possible through a system of flight rules and regulations, airspace management actions, and air traffic control procedures. The NAS is designed and managed to protect aircraft operations around most airports and along air traffic routes connecting these airports, as well as within special areas where activities such as military flight testing and training are conducted. The FAA has the overall responsibility for managing the NAS and accomplishes this through close coordination with state aviation and airport planners, military airspace managers, and other organizations. There are two categories of airspace or airspace areas: regulatory and non-regulatory. Within these two categories, there are four types of airspace: controlled, uncontrolled, special use, and other.

***Controlled airspace*** has defined dimensions within which air traffic control service is provided; it is categorized into five separate classes: Classes A through E (**Figure 3.12-1**). These classes identify airspace that is controlled, airspace supporting airport operations, and designated airways affording enroute transit from place to place. ***Uncontrolled airspace*** is designated Class G. ***Special Use Airspace*** has defined dimensions where activities must be confined because of their nature, or where limitations may be imposed upon aircraft operations that are not a part of those activities. Certain categories of special use airspace within the NAS include restricted areas and warning areas. Restricted Areas separate potentially hazardous activities, such as air-to-ground training, from other aviation activities. General aviation or civilian aircraft must have permission from ATC to enter a restricted area when it is active or "hot." A warning area is airspace of defined dimensions, extending from 5.5 km (3 nm) outward from the coast of the U.S. that contains an activity that may be hazardous to non-participating i.e., general aviation and civilian aircraft). ***Other Airspace*** is a general term referring to the majority of the remaining airspace.

### 3.12.1 Affected Environment

#### 3.12.1.1 Airfield

Airfield runway clear zones are to be kept free of vegetation and obstructions. Accomack County has established zoning ordinances and permitting procedures for all structures proposed in the county. The County limits any structure or vegetation that encroaches into the height of the FAA Part 77 airfield surfaces (defined in Title 14 CFR Part 77) surrounding the WFF airfield. The FAA has additional permitting regulations in 14 CFR 77.9 for any structure in the U. S. proposed to be 60 m (200 ft) AGL or greater. These regulations have been established regardless of overlying airspace designation.

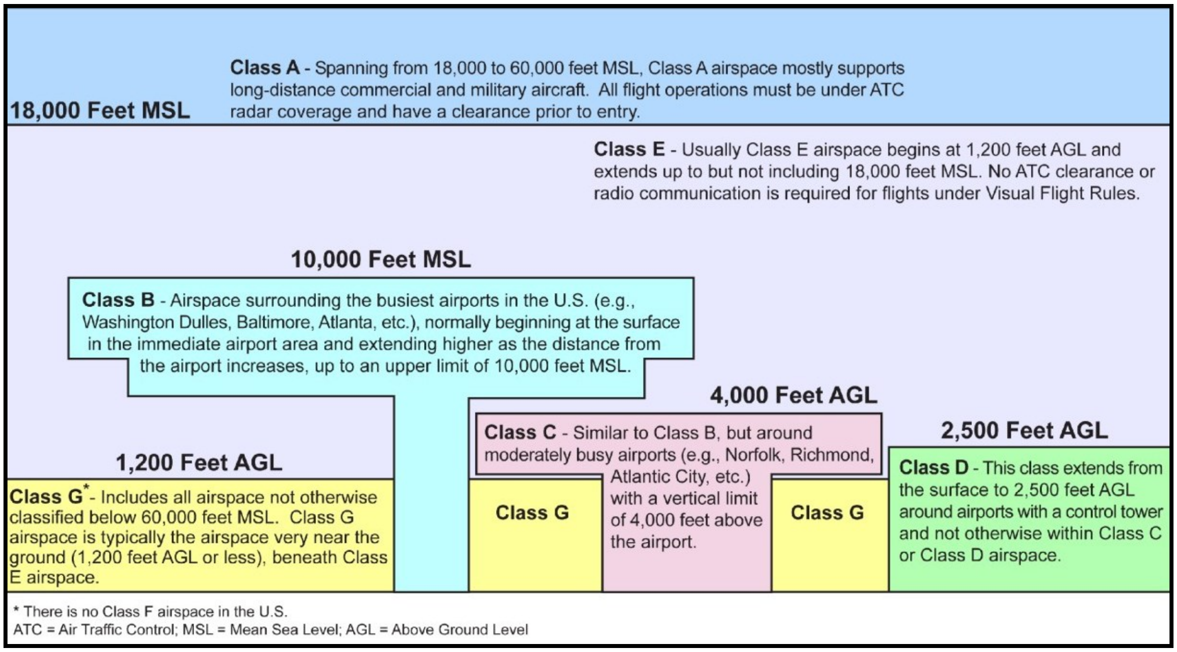


**Figure 3.12-1. Cross Section of Airspace Classes and Their Relationships**

Around the Main Base airfield, WFF operates controlled Class D airspace which extends from the surface vertically to 760 m (2,500 ft) in a 9.25 km (5 nm) radius around the center of the airfield. Prior to entering the airspace, pilots are required to establish and maintain two-way radio communications with the WFF airport tower, which serves as the ATC facility. Aircraft operations at the airfield include takeoff, landing, or practice approach, each of which count as one operation. Outside of Class D airspace, and after ATC operating hours, the FAA assigns the responsibility for units of airspace to ARTCCs. The WFF airfield is located within the Washington ARTCC (AirNav 2017a).

WFF conducts testing of unproven and experimental manned and unmanned aircraft systems from the airfield. Modifications to the exterior of the aircraft system (e.g., science testing platforms) change the flight characteristics and handling quality of the aircraft, which can produce hazardous flying conditions. Additionally, the majority of UAS at WFF are in developmental and experimental stages and have not been proven airworthy or safe to fly within the NAS. These potentially hazardous flight operations routinely require assessment of the air-to-ground transition phase of flight (takeoff, departure, approach, wave-off, and landing) which can only be performed in the immediate vicinity of the airfield itself.

Due to the nature of the experimental aircraft, a Certificate of Authorization must be granted by the FAA. Under a Certificate of Authorization, operations involving experimental aircraft can be conducted in the NAS, usually with very strict limitations, under the guidance of ATC. WFF may also conduct aeronautical research on experimental manned and unmanned aircraft that have not yet been proven airworthy. A typical scenario would be for the pilot to fly the aircraft to a minimum altitude to determine stability and meet initial test conditions. The number and frequency of flights would depend on the number of flights required to demonstrate that the experimental manned or unmanned aircraft could operate safely including satisfactory takeoff, controlled flight, and satisfactory landing. Airfield operations at WFF average 44 per day for an approximate 61,000 annual airfield operations, the flight operations envelope at WFF (refer to Section 2.4.2.2.2).

#### 3.12.1.2 Airspace

R-6604 A/B/C/D/E (R-6604 A-E) is NASA controlled/restricted airspace (**Figure 3.12-2**). This restricted airspace is comprised of five independent airspace units that may be activated individually or together. R-6604 A-E is available 24 hours a day, 7 days a week from the surface to unlimited altitude. Non-participating aircraft must contact the WFF Range Control Center or the Washington ARTCC to obtain clearance to transit through any portion of an activated restricted area.

The Navy FACSFAC VACAPES controls and schedules the offshore warning areas, including W-386. As a designated ATC facility, FACSFAC is responsible for all aircraft (general, military, and commercial) operating within its area of responsibility, the scheduling of offshore warning areas and military operating areas, and the preparation of NOTAMs and NOTMARs for broadcast by the FAA and U.S. Coast Guard, respectively. FACSFAC VACAPES also coordinates ATC and flight monitoring. W-386 is available from the surface to unlimited altitude. R-6604 A-E connects to the VACAPES

OPAREA offshore warning area W-386. Close coordination between FACSFAC, NASA, and FAA ATC facilities enables effective, real-time, joint use of R-6604 A-E and the VACAPES Range Complex warning areas. When in use by NASA or the Navy, R-6604 A-E and W-386 are “hot” and the scheduled airspace blocks are closed to all non-participating users. When not in use, R-6604 A-E and W-386 are “cold” and the airspace blocks are returned to the NAS allowing civilian aircraft to transit through R-6604 A-E or that portion of W-386.

General aviation pilots traveling north and south along the Delmarva Peninsula may choose to follow either the Atlantic coastline, Airway V-1, or Airway V-139. The FAA’s Performance Data Analysis and Reporting System (PDARS) is a NAS system designed as an integrated performance measurement tool that facilitates operational analysis to improve the NAS. The system consists of a dedicated network of computers located at FAA sites that use specialized software for collecting detailed air traffic management system data. A PDARS analysis was performed for air traffic between March 1, 2015, and March 1, 2016.

The survey area included the portion of V-139 that is adjacent to R-6604 A-E, as well as portions of the coastline and V-1. The PDARS concluded that air traffic flying in this area below an altitude of approximately 914 m (3,000 ft) MSL, averaged 18 visual flight rule flights and 14 instrument flight rule flights per day for a total of approximately 32 flights per day (FAA 2016). According to the FAA, most general aviation traffic on V-139 occurs at altitudes between approximately 3,050 and 4,000 m (10,000 and 13,000 ft) MSL (FAA 2016).

The 113th Wing at Andrews AFB owns and operates Military Training Route (MTR) visual route (VR) 1712 that crosses the southwestern corner of R-6604E airspace (**Figure 3.12-2**). Typically, MTRs are aerial corridors across the U.S. in which military aircraft can operate below 3,050 m (10,000 ft) faster than the maximum FAA safe speed of 250 knots (288 miles per hour) to which all other aircraft at that height are restricted. VR1712 is solely a visual route where visibility must be greater than or equal to 8 km (5 mi) and the cloud ceiling must be greater than or equal to 914 m (3,000 ft) AGL. The 113th Wing operates MTR VR1712 daily from 7:30 a.m. to sunset. The operating altitude is 150 to 460 m (500 to 1,500 ft) AGL.

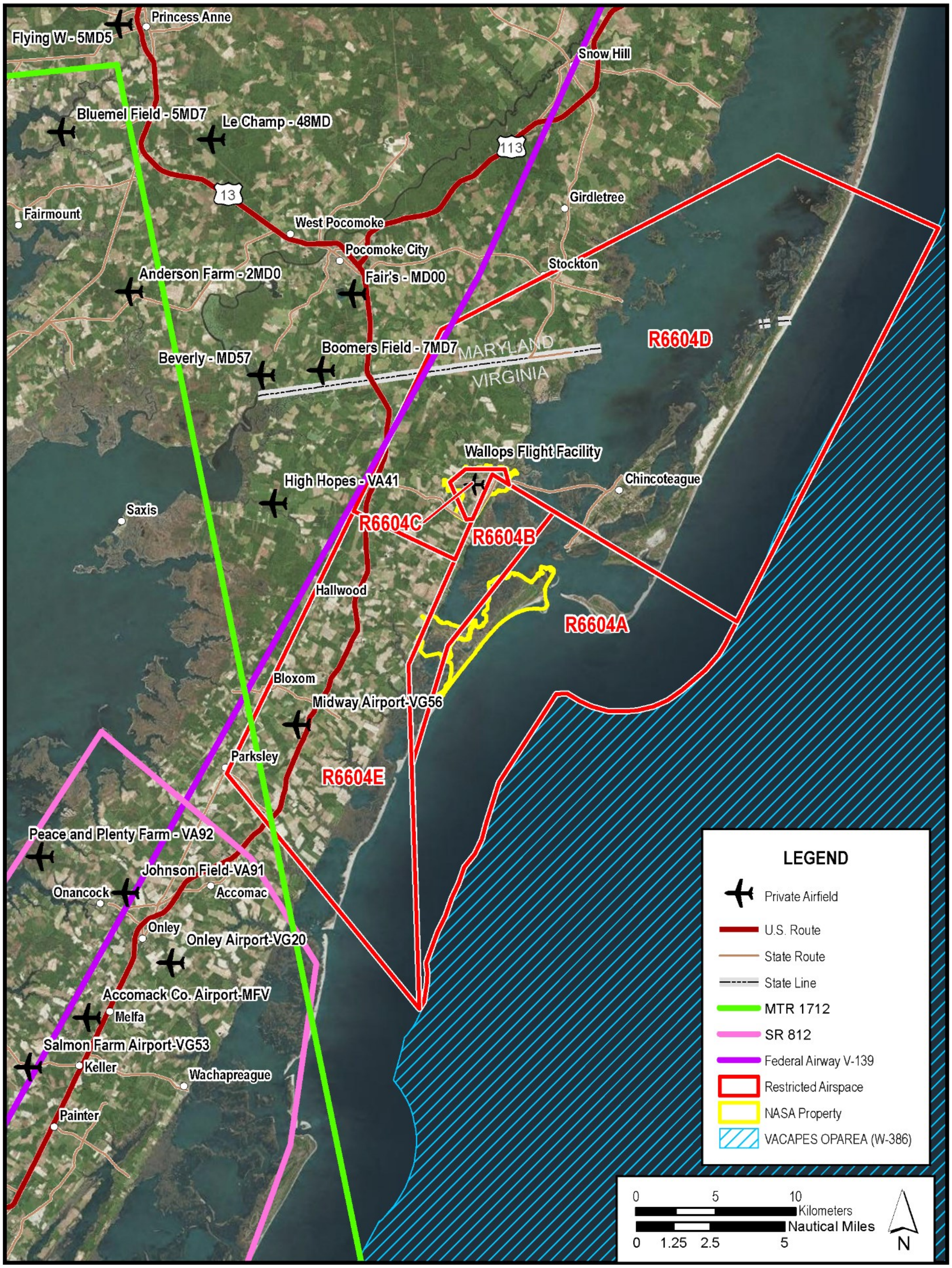


**Figure 3.12-2. NASA Controlled/Restricted Airspace**

Slow Routes (SR) are similar to VRs except SRs are flown at airspeeds of 250 knots (288 miles per hour) or less. Unlike instrument routes and VRs, SRs are not part of the MTR system and therefore have no directive guidance in the Aeronautical Information Manual or FAA Order JO 7610.4x, including weather minima. Weather minima for flight on SR routes are specified in appropriate service directives (although some routes may list weather minimums in the Remarks/Special Operating Procedures). Also unlike instrument routes or VRs, Flight Service Stations are not notified of a scheduled SR. SR812 lies southwest of R-6604E and is bidirectional. The combat helicopter wing at Naval Station Norfolk schedules SR812 through FACSFAC VACAPES and flies the route at 150 m (500 ft) AGL approximately twice weekly out of Norfolk and Chambers Field.

Accomack County airport lies approximately 16.7 km (9 nm) off the southwestern edge of R-6604E and would be outside the FAA required 5.5 km (3 nm) airport exclusion zone. This airport averages approximately 17,155 operations per year (AirNav 2017b). In addition, three private airfields (Taylor, Midway, and Crippen Creek Farm) underlie the R-6604 C/D/E airspaces. Midway and Crippen Creek Farm airfields lie under the MTR corridor for VR1712.

Aircraft transiting through a Restricted Area or Warning Area can transit several airspace units on a single mission, each counting as one airspace operation. Thus, an aircraft passing through both R-6604A and R-6604B would constitute two airspace operations. This is true even if the units can be scheduled and used as a group; each unit is counted as a separate operation. Between October 2014 and September 2015, R-6604A was activated 324 times for a total of 5,457 hours and R-6604B was activated 246 times for a total of 2,182 hours (Dickerson 2016). W-386 currently supports approximately 1,720 manned and 400 unmanned sorties, while the entire VACAPES currently supports approximately 8,200 manned and 630 unmanned flights per year (Daugherty 2016). All airspace outside the U.S. territorial limit is located in international airspace. Because the offshore airspace is in international airspace, the procedures outlined in *International Civil Aviation Organization Document 444, Rules of the Air and Air Traffic Services*, are followed. The FAA acts as the U.S. agent for aeronautical information to the International Civil Aviation Organization and air traffic in the overwater areas is managed by the Washington ARTCC.

### 3.12.2 Environmental Consequences

This airspace analysis considers the potential impacts to general and civil aviation from proposals presented under the Proposed Action. Impacts on air traffic are considered with respect to the potential for disruption of air transportation patterns and systems and changes in existing levels of airspace safety. Impacts to air traffic might occur if an action has potential to result in an increase in the number of flights that could be accommodated within established operational procedures and flight patterns; requires airspace modification; or results in an increase in air traffic that might increase collision potential between military and non-participating general/civilian flight operations.

NASA's restricted airspace (R-6604 A-E) is used to safely segregate civilian air traffic from the flight testing of unproven and experimental aerial systems, including unmanned and launched vehicle systems. NASA's Expanded Space Program may also conduct horizontal launches and landings from the WFF Main Base airfield. Additionally, through partnerships with the DoD, operational and developmental test and evaluation of military aircraft are performed from WFF. These tests routinely require assessment of aircraft stability and control while remaining in close proximity to the airfield.

#### 3.12.2.1 No Action Alternative

##### 3.12.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. No institutional support projects would extend into the clear airspace around the Main Base airfield or into runway approach zones. Therefore, no aspect of implementing any or all of the institutional support projects would affect airspace management or use.

##### 3.12.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope. All operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Both military and non-military entities have been sharing the use of the airspace that encompasses R-6604 A-E and FACSFAC VACAPES for more than 30 years. Military, commercial, and general aviation activities have established an operational co-existence consistent with federal, state, and local plans and policies and compatible with each interest's varying objectives. The No Action Alternative includes training and testing operations that are, and have been, routinely conducted in the area for decades. WFF recognized that continued testing of unproven and experimental aircraft systems would increase the risk to non-participating aircraft and in 2016 coordinated with the FAA to add R-6604 C/D/E (NASA 2016). Ongoing, continuing operations identified in this PEIS will continue to use R-6604 A-E and offshore W-386. Although the nature and intensity of use varies over time and by an individual area, the continuing training operations represent precisely the kinds of operations for which these areas were created (i.e., those that present a hazard to other aircraft).

Through close coordination with the FAA, WFF and FACSFAC VACAPES ensure that hazardous activities are carefully scheduled to avoid conflicts with civilian activities and that safety standards are maintained while allowing the maximum amount of civilian access to overland and overwater airspace.

Conditions under which general aviators or civilian pilots would need to request permission to enter R-6604 A-E or W-386 when active would remain unchanged. Flight monitoring at WFF ATC, WFF Range Control Center, Washington ARTCC, and FACSFAC VACAPES would continue. NOTAMs and NOTMARs that are broadcast by the FAA and U.S. Coast Guard, when needed for operations in R-6604 A-E and W-386, would also remain unchanged. As such, implementation of the No Action Alternative would have no impact on airspace management resources in R-6604 A-E or W-386.

#### 3.12.2.2 Proposed Action

##### 3.12.2.2.1 Institutional Support Activities

The Runway 04/22 extension would prevent use of the airspace surrounding the Main Base for a limited time. No institutional support projects would extend into the airspace or clear zone around the Main Base airfield or into the runway approach zone. Therefore, no aspect of implementing any or all of the institutional support projects would affect or have a significant impact on airspace management.

##### 3.12.2.2.2 Operational Missions and Activities

Most operational programs that would be conducted under the Proposed Action would not impact airspace management at WFF. Only those operational missions and activities with the potential to impact this resource are discussed below.

**DoD SM-3**

Missile and drone targets launched from a proposed dedicated launch pad at Wallops Island in support of the SM-3 launcher would remain within the existing envelope of 30 annual launches. As with current procedures, shipboard interceptor surface-to-air missiles would engage the targets over the VACAPES OPAREA and all debris from the intercept would fall within the VACAPES OPAREA boundary. Refer to Section 2.5.2.1 for the description of the DoD SM-3 proposal and **Figure 2.5-2** for the location of the DoD SM-3 pad. No impact to airspace management from this new operational mission would be anticipated.

**Directed Energy**

The proposed Directed Energy systems (i.e., HEL and HPM) are compatible with current operations that occur within the WFF restricted airspace and VACAPES offshore areas. Although FAA clearance may be required for the use and testing of the HEL and HPM, these actions would occur within R-6604A and W-386. Therefore, the Directed Energy projects would not interfere with current airspace management.

**North Wallops Island UAS Airstrip Increased Operations**

The increase in UAS operations would not impact airspace management. FAA Part 107 compliant UAS would operate in the NAS; the majority of these flights would be contained within a 0.75 nm (0.86 mi) circle centered on the middle of the airstrip. Larger UAS would continue to operate in R-6604 A-E and in W-386. Use of other VACAPES warning areas is possible, depending on mission requirements, but use of these areas would be infrequent. Flight monitoring and ATC responsibilities at WFF Range Control Center, Washington ARTCC, and FACSFAC VACAPES would continue. NOTAMs and NOTMARs for broadcast by the FAA and U.S. Coast Guard, when needed for UAS operations in R-6604A/B and W-386, would also remain unchanged (NASA 2012).

**Expanded Space Program**

Under the Expanded Space Program, NASA would continue to coordinate with the FAA and FACSFAC VACAPES. NOTAMS would continue to be issued whenever R-6604 A-E and W-386 are activated.

**LFIC LV and SFHC LV**

WFF has a long history of launching orbital and suborbital rockets. Many of the future Earth and space exploration missions planned by NASA or its partners would require spacecraft that are similar in overall design, materials, and engineering as well as instrument or payload systems. Likewise, these spacecraft would be launched using LVs selected from a group of domestic launch vehicles. The missions would also have other common elements, including spacecraft pre-launch processing, launch scenarios, and resource use.

The Proposed Action would limit SFHC LV launches to 12 per year. Refer to Section 2.4.2.3 for descriptions of the current and proposed LVs projected for Wallops Island. Impacts to airspace management would remain unchanged from those already associated with ongoing launch operations.

**Vertical Launch and Landing Vehicles**

Resembling either a more conventional rocket or a powered space capsule, vertical launch and vertical landing vehicles are currently in development by multiple U.S. commercial companies, including both the Blue Origin New Shepherd and the SpaceX Falcon 9. Operations of these launch vehicles would be comparable to LV operations at the WFF Launch Range.

**Horizontal Launch and Landing Vehicles**

Several potential methods to launch suborbital aircraft into space are envisioned for WFF operations. The first would employ a conventional “mothership” jet aircraft takeoff, carrying a rocket-powered spacecraft, and after releasing the spacecraft at approximately 14 km (8.7 mi), returns to the WFF airfield like a traditional aircraft. The second method would employ a space shuttle-like vehicle with liquid-fueled engines that takes off in a horizontal trajectory for a suborbital flight, before gliding and landing at the same airport where it took off. Similar in operation to the first launch method is a concept from Generation Orbit Launch Services, Inc., where expendable rockets would be carried to an offshore release point by a subsonic business jet such as the Gulfstream III or IV. Details of these concepts have not been totally developed, but the horizontal launch and landing aspects are similar to current aircraft operations occurring at WFF Main Base airfield.

**Commercial Human Spaceflight Mission**

A number of launch vehicles have the potential to utilize WFF for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) of commercial human spaceflight missions. These activities would be consistent with current WFF operations and would not impact airspace management.

In summary, implementing the operational missions and activities as described under the Proposed Action would not have a significant impact on airspace management.

## 3.13 TRANSPORTATION

Transportation resources generally refer to the infrastructure and equipment required for the movement of people and goods in a geographical area. For purposes of evaluation in this Site-wide PEIS, transportation refers to the movement of goods and services via roads, rail systems, and water transport. Air traffic is discussed in Section 3.12, Airspace Management.

### 3.13.1 AFFECTED ENVIRONMENT

#### 3.13.1.1 Roads

The Eastern Shore of Virginia is connected to mainland Virginia by the Chesapeake Bay Bridge Tunnel, a 32 km (20 mi) long, four-lane bridge/tunnel crossing between Virginia Beach and Northampton County. The primary north/south route that spans the Delmarva Peninsula is U.S. Route 13, a four-lane divided highway. Local traffic travels by arteries branching off U.S. Route 13. Primary access to WFF is provided by State Route 175, a two-lane secondary road. Activities at Wallops Mainland and Wallops Island also generate traffic along State Route 803. Traffic in the region varies with the seasons: during the winter and early spring, traffic is minimal; during the summer and early fall, traffic surges due to increased tourism and agricultural operations in the area.

Wallops Main Base and Mainland are connected by approximately 10 km (6 mi) of the paved, two-lane State Route 679. The Wallops Space Transit Corridor overlay district runs along the VDOT right-of-way from Main Base, through the town of Atlantic, to Wallops Island. Accomack County has buried existing utility lines and cleared the overhead path along the Space Transit Corridor. The zoning district overlay ensures a clear pathway free from overhead obstruction along the route taken by large rockets and payloads.

A NASA-owned road, bridge, and causeway link the Mainland to Wallops Island. Hard surface roads provide access to most buildings at WFF and are maintained by NASA and its tenants/partners. Most organizations at WFF own and maintain a variety of vehicles, including sedans, vans, and trucks. There is no public transportation on the facility. Many WFF employees carpool to and from the facility.

#### 3.13.1.2 Rails

Regional rail freight service is provided to the Delmarva Peninsula by Bay Coast Railroad via the eleven motor freight carriers that are authorized to provide service to the Accomack-Northampton District; however, no rail freight or passenger service is available to WFF. The closest railhead to WFF (and typically the one most frequently used for unloading cargo) is the LeCato site in New Church, Virginia, located approximately 11 km (7 mi) to the northwest. Rail freight bound for WFF is offloaded at the LeCato site and hauled by truck to its final destination.

#### 3.13.1.3 Water

Commercial, recreational, and military maritime traffic all use the area off the coast of Virginia, one of the busiest areas in the world for maritime traffic. Traffic Separation Schemes (TSSs), specified in 33 CFR Part 167 – *Offshore Traffic Separation Schemes*, are one-way ship traffic lanes that are marked by buoys. The purpose of the TSS system is to prevent vessels from colliding with each other while underway. The nearest TSS lanes to WFF are the southernmost approaches to the Delaware Bay, which are approximately 90 km (50 nm) north of Wallops Island, and the northernmost lanes of the Chesapeake Bay approach, which are approximately 100 km (55 nm) south of Wallops Island.

Ocean cargo shipments are typically offloaded at the Port of Baltimore, Maryland, or Cape Charles, Virginia, and transferred to commercial trucks or rail for transport to WFF. A sea-based option also exists utilizing Chincoteague Inlet and offloading cargo at the boat docks at WFF (see **Figure 2.5-6**). The triangle shaped Wallops Island Approach Zone is located at the mouth of Chincoteague Inlet and is designed to encourage boaters to exercise caution while traversing the Inlet. Numerous small harbors are located throughout Accomack and Northampton counties, which are used primarily for commercial or recreational fishing and boating.

As specified in 33 CFR Part 334 – *Danger Zone and Restricted Area Regulations*, the USACE has the authority to designate maritime danger zones and to set specific requirements, limit access, and control navigation activities within those waters by closing the danger zone to the public on a full-time or intermittent basis. In October 2012, the USACE expanded the Atlantic Ocean danger zone around Wallops Island and Chincoteague Inlet, Virginia, to a 56 km (30 nm) sector (USACE 2012) necessary to protect the public from hazards associated with WFF's rocket launch operations (see **Figure 3.3-1**). NOTMARs are published prior to the temporary USACE closure of an area of interest within or for the entire danger zone. Typically, during launch operations only an area of interest within the danger zone would be closed. During the closure, a combination of light beacons, stationary warning balloons, and patrol water and aircraft may be used to warn the public to remain out of the danger zone until the designated area is clear and reopened for public use. On an annual basis, portions of the danger zone would be closed for the shortest duration possible for a maximum of 60 sounding rockets; 18 orbital LV events; 30 drone launches; 270 combined firings from conventional, EMRG, or RDT&E systems (refer to **Table 2.6-1**, Baseline and Proposed Envelopes).

## 3.13.2 Environmental Consequences

### 3.13.2.1 No Action Alternative

#### 3.13.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. No changes to the transportation network are anticipated to occur under the No Action Alternative.

#### 3.13.2.1.2 Operational Missions and Activities

Under the No Action Alternative, operational missions and activities would remain at current levels. WFF would conduct operational missions and activities that are within the installation's current envelope and that have been covered by previous NEPA documents that are incorporated by reference into this PEIS. No changes to the transportation network are anticipated to occur under the No Action Alternative.

### 3.13.2.2 Proposed Action

#### 3.13.2.2.1 Institutional Support Projects

**Roads**

Under the Proposed Action, construction, demolition, and renovation projects on the Main Base, Mainland, and Wallops Island would result in temporary decreases in the level of service in the vicinity of WFF from construction-related traffic. Construction-related traffic could include heavy equipment and transport vehicles, cranes, concrete trucks, dump/haul trucks, personnel transport vehicles, and others as necessary. Local and WFF traffic lanes could be temporarily closed or rerouted during construction and the operation/staging of construction equipment could interfere with typical vehicle flow. Decreases in the level of service from general institutional construction, demolition, and renovation projects would be short-term in nature and would be considered negligible as the projects are phased in over the 2019 to 2025 timeframe as presented in **Table 2.5-1** and **Table 2.5-2**. No significant impacts in the level of service would occur to local roads including U.S. Route 13 and State Route 175.

The Causeway Bridge is over 50 years old, at the end of its design life, and is showing signs of accelerated deterioration of the bridge components. Even with ongoing biennial maintenance and repairs to the bridge, a 2010 study described a significant risk to WFF's missions if superstructure replacement or complete bridge replacement is not considered within the next 10 years. The amount of vehicular traffic, the size of transport trucks, and the frequency of "super-loads" crossing the bridge have increased significantly in the last decade. The Causeway Bridge would remain open to vehicular traffic during construction of the new bridge. There may be a short-term initial decrease in the level of service during the construction period; however, when completed, the level of service would return without an increase in capacity. The replacement Causeway Bridge would result in an overall beneficial impact and would ensure continued safe access from the Mainland to Wallops Island.

The materials dredged during the proposed maintenance dredging and dredging for the proposed North Wallops Island Deep-water Port and Operations Area may be transported via dump trucks from Wallops Island to the Mainland using the Causeway Bridge. If this transfer method is employed, a traffic plan would be prepared to avoid peak traffic hours in the morning and afternoons and would be coordinated to avoid any interference with ongoing operations on Wallops Island.

NASA would coordinate off-site activities, including closures, traffic control, safety issues, etc. with Accomack County and the VDOT Accomack Residency Office. To mitigate potential delays, NASA would:

- Provide adequate advance notification of upcoming activities for all areas that would be affected by construction-related traffic, temporary closures, or re-routing,
- Coordinate any traffic lane or pedestrian corridor closures with all appropriate officials,
- Place construction equipment and vehicle staging so as to not hinder traffic and pedestrian flow, and
- Minimize the use of construction vehicles in residential areas.

In conclusion, there would be no significant impact to road networks levels of service from the implementation of institutional support projects under the Proposed Action.

**Rail**

Under the Proposed Action, there would be no impact to the regional rail freight service.

**Water**

The existing Causeway Bridge would remain open during construction of the new bridge. However, waterways in the vicinity of the Causeway Bridge may be temporarily closed during construction and demolition activities. The U.S. Coast Guard issues Bridge Permits that approve the location and plans of bridges and causeways and impose any necessary conditions relating to the construction, maintenance, and operation of these bridges in the interest of public navigation. NASA would obtain and follow the requirements of a U.S. Coast Guard Bridge Permit. Under the Bridge Permit and during maintenance dredging, NOTMARs would be issued to warn boaters who may be in the vicinity of those construction activities of the need to proceed with caution for the duration of the construction activities and to the greatest extent practicable, an alternate route would be offered. In addition, staging areas for construction equipment and materials could temporarily interfere with Wallops Island water access and navigation in the vicinity of the bridge; however, BMPs would be implemented to ensure that any interference is kept to a minimum. The exact location and engineering design details such as the number of piles, pile spacing, bridge height, and length of the bridge span are not known at this time. However, it is anticipated that the replacement bridge would be constructed near the same location and would be built when funds are available. It is anticipated that the replacement bridge would be approximately 5 to 10% longer than the existing bridge and that the current width of 8 m (27 ft) would be increased to 15 m (50 ft) with a lesser slope than the current 6% slope. The potential impacts to water transportation would be reconsidered as those engineering design details are defined at a later date.

In addition to the replacement of the Causeway Bridge, WFF and its commercial partners must maintain the capability of transporting large LVs to the launch facilities on Wallops Island via barge; therefore, maintenance dredging is required on the Barge Route and in the vicinity of the two boat basins at WFF. One boat basin is located behind the NASA WFF Visitor Center and the other boat basin is located at North Wallops Island (refer to **Figure 2.5-6**). The existing barge channel connects these two basins. During dredging activities, waterway access between the two boat basins may be temporarily restricted or rerouted. A NOTMAR would be issued by the U.S. Coast Guard whenever maintenance dredging activities occur that could interfere with normal vessel movements. Staging areas for dredging equipment and dredged material disposal activities could temporarily interfere with navigation in the vicinity of the boat basins; however, BMPs would be implemented to ensure that any interference would be kept to a minimum. The materials dredged from the proposed maintenance dredging at the southern boat basin and barge channel could be barged to the northern boat basin to avoid adding truck traffic to the transportation network connecting the Mainland to Wallops Island. In-water construction activities associated with the North Wallops Island Deep-water Port and Operations Area and Launch Pier 0-D would result in similar impacts as described above for the Causeway Bridge and maintenance dredging projects (refer to Section 3.5.2.2.1). Through the use of collaborative planning techniques, adequate scheduling and phasing, coordination with the U.S. Coast Guard, and the implementation of BMPs, no significant impact to water transportation is anticipated under the Proposed Action as a result of institutional support projects.

In conclusion, no significant impacts to transportation would be anticipated from implementing institutional support projects as described under the Proposed Action. Refer to **Section 4.1.10** (Transportation) for measures to mitigate impacts to transportation under the Proposed Action.

3.13.2.2.2 Operational Missions and Activities

**Roads**

The institutional support projects presented under the Proposed Action would correlate with several new mission opportunities, including the ability to accommodate larger LVs with increased launch pad flexibility for orbital, suborbital, and sounding rockets. In FY 2015, WFF employed a total of 1,119 NASA employees (see Section 3.15, Socioeconomics). Over the 20-year timeframe (beginning in 2019), full-time employment at WFF would increase by about 10% from FY 2015 levels. An increase of approximately 112 people (a 10% increase) would add additional vehicles to local road networks. However, launch crew and support team transportation could be accommodated by multi-person shuttles in order to maximize efficiency and keep traffic impacts to a minimum.

The launch of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) in September 2013 resulted in approximately 13,800 spectators gathered in Chincoteague and Assateague Island, Virginia; Ocean City, Maryland; and within various localized areas to observe the activity. Chincoteague hotels reported no-vacancies for the evening launch and area businesses reported that the event provided an economic boost. Similar crowds have been observed for Antares launch events (NASA 2013). LFIC LV and SFHC LV events would be anticipated to have similar attendance which would also increase traffic on local road networks. Crowds currently gather on AINS, at pull-offs on the Chincoteague Causeway, along and on roads branching off of State Route 679, and at the WFF Visitor Center which provides vehicle parking and an open field with bleacher seating. The WFF Visitor Center would continue to provide a primary location where viewers could congregate to minimize traffic impacts. In addition to personnel and tourist traffic, it is assumed the LVs associated with the Expanded Space Program would be transported to Wallops Island via truck or barge similar to how large LVs are currently transported to WFF. If roads are used, they could be temporarily closed and traffic could be temporarily rerouted during transport. Horizontal launch and landing vehicles generally operate the same as standard aircraft. The proposed extension of Runway 04/22 at the Main Base for horizontal launch and landing vehicles may require the temporary closure of State Route 175. As with institutional support projects that require road closures, NASA would coordinate all transportation activities, including closures, traffic control, safety issues, etc. with Accomack County, the Virginia State Police, and the VDOT Accomack Residency Office. To mitigate potential delays, NASA would:

- Provide adequate advance notification of upcoming activities for all areas that would be affected by temporary closures or re-routing,
- Coordinate any traffic lane or pedestrian corridor closures with all appropriate officials, and
- To the greatest extent practicable, transport large launch vehicles and payloads overnight to minimize impact to local traffic.

While the traffic is anticipated to increase, the most noticeable impacts would be during the summer and early fall due to the general increased tourism throughout the area. The Proposed Action would be consistent with NPR 8820.2D, *Design and Construction of Facilities*, NPR 8500.1C, *NASA Environmental Management*, and NPR 8570.1A, *NASA Energy Management Program*. NASA would coordinate with Accomack County, the Virginia State Police, and the VDOT Accomack Residency Office for launch activities that have the potential to impact the level of service of the local transportation network (NASA 2009).

Through the use of collaborative planning techniques, adequate scheduling, and implementation of BMPs, there would be no significant impact to transportation resources under the Proposed Action as a result of operational missions and activities.

**Rail**

Under the Proposed Action, there would be no effect to the regional rail freight service.

**Water**

It is assumed the LVs associated with the Expanded Space Program would be transported to Wallops Island via truck or barge. Transport by barge would require navigation from the boat basin at the Main Base or through Chincoteague Inlet and arrive at the boat dock on Wallops Island (NASA 2009). The barge transport route may require temporary closure resulting in minor impacts to offshore shipping, commercial fishing, and recreational boaters in the vicinity. Proposed DoD SM-3, North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D operations may result in similar impacts to offshore shipping, commercial fishing, and recreational boaters in the vicinity. NOTMARs would be issued by the U.S. Coast Guard whenever any of these operational activities would occur that could interfere with normal vessel movements. Existing procedures would continue to be followed. The impacts would be temporary; no significant impacts to water transportation are anticipated under the Proposed Action as a result of operational missions and activities.

In conclusion, no significant impacts to transportation would be anticipated from implementing the operational missions and activities as described under the Proposed Action. Refer to **Section 4.1.10** (Transportation) for measures to mitigate impacts to transportation under the Proposed Action.

## 3.14 INFRASTRUCTURE AND UTILITIES

Infrastructure and utilities include potable water systems, wastewater treatment systems, electric utilities, communications, and solid waste management. New construction and renovation projects and new missions as described in Section 2.5 may require usage of one or more of these services.

### 3.14.1 Affected Environment

#### 3.14.1.1 Potable Water

WFF receives all of its potable water from groundwater supply wells located within the boundaries of the installation. The Main Base system is a community water system serving approximately 1,625 persons. This system utilizes five groundwater wells to achieve a design capacity of 2,265,190 lpd (598,400 gpd) (**Table 3.14-1**). Four screened wells withdraw water from the Middle Yorktown-Eastover aquifer and one well (Well No. 2) withdraws water from the Upper Yorktown-Eastover aquifer. All of the wells were installed between February 1990 and December 1992 (NASA 2008).

**Table 3.14-1. Groundwater Wells at Wallops Flight Facility Main Base**

| Well Number | Depth | Submersible Pump Capacity |
|---|---|---|
| 1 | 80 m (260 ft) | 647 lpm (171 gpm) |
| 2 | 45 m (150 ft) | 208 lpm (55 gpm) |
| 3 | 77 m (253 ft) | 810 lpm (214 gpm) |
| 4 | 80 m (260 ft) | 617 lpm (163 gpm) |
| 5 | 80 m (260 ft) | 632 lpm (167 gpm) |

Source: NASA 2008.

Potable water is stored in a 1,900,000 liters (500,000 gal) aboveground tank (D-095) located adjacent to the treatment facility prior to being pumped to the 380,000 liters (100,000 gal) elevated water tank (F-165) for distribution to the facilities at the Main Base. Although NASA as a Federal agency is not subject to permitting under the Virginia Groundwater Management Act, WFF voluntarily complies with historic groundwater withdrawal permits issued by VDEQ. On the Main Base, WFF limits groundwater withdrawal to a maximum rate of 157,000,000 liters (41,400,000 gal) per year. Actual Main Base withdrawals totaled 71,432,158 liters (18,870,380 gal) for year 2016 representing approximately 45% of the capacity (Borowicz 2017). The distribution system consists of approximately 63 km (39 mi) of distribution piping, most of which was rehabilitated in the late 1990s.

The Mainland and Wallops Island potable water system is a non-transient, non-community water system that utilizes two groundwater wells and serves a peak population of 725 persons. The potable water supply wells are 75 m (245 ft) and 80 m (265 ft) below the ground surface and are screened within the Middle Yorktown-Eastover aquifer. Water is stored in a 300,000 liters (80,000 gal) aboveground tank (U-049) located adjacent to the treatment facility, prior to being pumped to one of three elevated distribution tanks. To maintain sufficient water pressure throughout the Wallops Island system, the elevated tanks are located at the north end, middle, and south end of the Island. The elevated tank on the north end (V-090) has a capacity of 190,000 liters (50,000 gal) and the other two (X-046 and W-055) have capacities of 380,000 liters (100,000 gal) and 570,000 liters (150,000 gal), respectively. Additionally, the elevated deluge tank at Pad 0-A stores 950,000 liters (250,000 gal) of potable water used for sound and heat suppression.

WFF limits the Mainland and Wallops Island potable water system groundwater withdrawal to 6,800,000 liters (1,800,000 gal) per month and 58,000,000 liters (15,500,000 gal) per year. Actual combined Mainland and Wallops Island withdrawals totaled 42,734,251 liters (11,289,195 gal) for year 2016 representing approximately 73% of the capacity (Borowicz 2017).

#### 3.14.1.2 Wastewater Treatment

NASA owns and operates a wastewater treatment plant (WWTP) on the Main Base that has the capacity to treat up to 1,100,000 lpd (300,000 gpd). The WWTP currently treats flows of approximately 230,000 lpd (60,000 gpd). Except for two septic tanks servicing small buildings on the northeast portion of the Main Base and one serving the Visitor Center, wastewater is pumped through a force main to the collection system. Treated wastewater from the WWTP is discharged via a single outfall to an unnamed freshwater tributary to Little Mosquito Creek under WFF's VPDES permit VA0024457. The WFF chemistry laboratory tests the wastewater discharge on a daily basis to ensure discharges do not exceed permitted limits (NASA 2016a).

With the exception of two septic tanks on the north end of Wallops Island, wastewater generated on the Island is sent to one of five pump stations that were rehabilitated in 2007. Wastewater is pumped through an 11 km (7 mi) force main to the Main Base collection system, where it is eventually treated in the WWTP. Wastewater generated on the Mainland is discharged into septic tanks. Throughout WFF, a total of 13 septic systems are maintained by the Facilities Management Branch. The septic systems are pumped out biennially, and the septage is transported to D-098 sludge drying beds for dewatering, with ultimate disposal in the Accomack County North Landfill (NASA 2016b).

#### 3.14.1.3 Electric Power

WFF Main Base is fed power from loop transmission lines supplied to the Wattsville Substation by Delmarva Power from the north and Dominion Energy from the south. Two A&N Electric Cooperative medium voltage feeders from the Wattsville Substation feed Wallops Main Base. Due to increased development in the Captain's Cove area, A&N Electric Cooperative has added a new substation on Sign Post Road fed from the Delmarva Power transmission line from the north. The load on the Wattsville Substation was thereby reduced. Although there is a two feeder connection from the Wattsville Substation, the Main Base only uses one of the two as the primary power source. The second feeder is used as a backup source. On a complete power outage, backup power for the Main Base is supplied by a 3-MW generator.

Electrical power is delivered to the Mainland and Wallops Island by A&N Electric Cooperative through the Wattsville Substation via a single transmission line to the Wallops Island Substation. The Wallops Island Substation then feeds Wallops Island through 12.47 kilovolt conductors. Accomack County has buried a portion of the existing electric lines under Atlantic Road for the Wallops Space Transit Corridor. This feeder is routed along the road and interconnects to NASA on a pole just outside of the Wallops Island and Mainland gate, where it transitions underground into the U-012 switching station. The Mainland and Wallops Island load is the primary consumer of power from the Wallops Island Substation and capacity is not currently an issue. In March 2013, NASA installed two 3-MW generators and added a control room to Building U-012 to provide centralized emergency power for the launch range and other mission critical infrastructure on Wallops Island and Mainland.

#### 3.14.1.4 Communication

Voice (i.e., phone, land mobile radio, and base intercom) and data (i.e., telemetry and network) communication services to WFF Main Base and the Mainland and Wallops Island are provided by commercial providers. Accomack County has buried existing communication lines along the Wallops Space Transit Corridor between the Main Base and the Mainland.

#### 3.14.1.5 Waste Collection and Disposal Services

Waste collection and disposal services for WFF are provided under contract with a private vendor. Solid waste from both commercial and construction sources at WFF may be taken to either the North Accomack County Landfill (in the town of Atlantic) or the South Accomack County Landfill. WFF has a single stream recycling program that was launched in 2011. Recycling containers are placed on each floor, in every building of the facility diverting plastic, aluminum, glass, cardboard, and paper from local landfills. Additional resources exist on the facility to recycle used oils and solvents, chemicals, florescent lights, batteries, toner cartridges, scrap metal and wood, and packing materials.

### 3.14.2 Environmental Consequences

The impact analysis for infrastructure and utilities compares existing capacity and demand on a utility to a projected capacity and demand. Changes in facility usage or new facility construction may contribute to the total projected demand. A determination of significance is made when the projected increase in demand for a utility would exceed the planned capacity for that utility such that the utility provider would not be able to service additional demands while maintaining the same level of service for existing customers.

#### 3.14.2.1 No Action Alternative

##### 3.14.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope; all construction and demolition efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. No additional changes to the utilities and infrastructure system are anticipated to occur under the No Action Alternative.

##### 3.14.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope and that have been covered by previous NEPA documents that are incorporated by reference into this PEIS. As such, there would be no additional changes to the utilities and infrastructure system under the No Action Alternative.

#### 3.14.2.2 Proposed Action

##### 3.14.2.2.1 Institutional Support Projects

Under the Proposed Action, construction, demolition, and renovation projects on WFF Main Base and Mainland/Wallops Island would result in both temporary and long-term impacts to utilities and infrastructure. Construction-related spikes in the demand for potable water, wastewater treatment, power, and disposal services would be short-term in nature; however, current utility infrastructure, including landfills, potable water, and wastewater, is under capacity and impacts would be considered negligible as the projects presented in **Table 2.5-1** and **Table 2.5-2** are phased in beginning in 2019.

Once constructed, institutional support projects presented as part of the Proposed Action could potentially increase utility demand on the Main Base and Wallops Island; however, the majority of the institutional projects are designed to replace existing buildings. All infrastructure upgrades would comply with EO 13834, *Efficient Federal Operations (May 2018)*, and NPR 8820.2D, *Design and Construction of Facilities*, NPR 8500.1C, *NASA Environmental Management*, and NPR 8570.1A, *NASA Energy*

*Management Program*. Both EO 13834 and the NPRs set forth guidelines designed to reduce resource and energy consumption. Any potential increase in utility demand from new construction could be counteracted through the use of energy and resource efficient green building methods. No significant impacts to infrastructure and utilities would be anticipated.

3.14.2.2.2 Operational Missions and Activities

The institutional support projects presented under the Proposed Action would correlate with new mission opportunities including Directed Energy and the ability to accommodate larger LVs and missions. These operational initiatives would require new construction and would result in personnel increases at WFF. Over a 20-year timeframe (beginning in 2019), full-time employment at WFF could increase by 10% from FY 2015 levels; therefore, the total increase in personnel as a result of new operational mission and activities would total approximately 112 people (see Section 3.15, Socioeconomics). An increase in personnel at WFF would increase the demand for utilities and infrastructure.

**Directed Energy**

A Directed Energy system would require the ability to store energy to be released quickly for weapon use. Wallops Island is being considered for future HEL and HPM experiments and developmental tests.

Specific test scenarios are dependent on actual test requirements and are currently unknown; however, an increase in the demand for electricity storage and use would be expected. The demand on Wallops Island utility infrastructure would have to be reanalyzed to determine whether or not improvements would be necessary.

**Expanded Space Program**

**LFIC LV and SFHC LV**

As proposed LV launch capabilities at WFF are expanded to include the LFIC LVs/RLVs and SFHC LVs, there is potential for increased demand on the utility infrastructure supplying power, water, wastewater treatment, and waste disposal to Wallops Island. The operation of proposed Launch Pad 0-C and proposed Launch Pier 0-D may require a water deluge system for launch vibration suppression. If similar to the system at Pad 0-A, the deluge systems would include an aboveground storage tank that may hold approximately 1,135,000 liters (300,000 gal) of potable water. The amount of deluge water is based on the maximum of 18 LV launches per year. As there would be no increase in the annual number of LV launches, potable withdrawal amounts would remain within NASA's existing groundwater withdrawal limits. Increases in wastewater treatment, electric power, communication, and waste collection and disposal services would be expected. As such, the demand on Wallops Island utility infrastructure would have to be reanalyzed for these services to determine whether or not improvements would be necessary.

**Vertical Launch and Landing Vehicles**

There is potential for increased demand on the utility infrastructure relating to vertical launch and landing vehicles. The demand on Wallops Island utility infrastructure is not currently known. As this concept matures, the need for additional infrastructure would have to be reanalyzed to determine whether or not improvements would be necessary.

**Commercial Human Spaceflight Missions**

Commercial human spaceflight missions have the ability to impact utilities due to the additional demand resulting from the operation of the Commercial Space Terminal on the Main Base. While little is known about the actual scope of the commercial human spaceflight mission at WFF, it can be assumed that the proposed Commercial Space Terminal (refer to Section 2.5.1.1) would consist of lodging, dining areas, and training facilities such as pools, classroom space, mission specific training equipment, which would result in an increase in the demand for potable water, power, communications capability, wastewater treatment, and waste disposal. The specific demand for these services would need to be addressed as the commercial human spaceflight mission matures and requirements are better defined.

In summary, the current utility infrastructure utilization is under capacity and any increased demand associated with the proposed operational missions and activities may be accommodated. However, as details regarding each of the proposed operational missions become more mature, potential demands on the utility infrastructure would be reevaluated. As such, no significant impact to utilities and infrastructure from operational missions and activities is expected from implementation of the Proposed Action.

## 3.15 SOCIOECONOMICS

Socioeconomics is defined as the study and analysis of the human environment, specifically the study of human population, employment, personal income, and housing.

### 3.15.1 AFFECTED ENVIRONMENT

The ROI for socioeconomic analysis is defined as the area in which the principal direct, indirect, and induced effects arising from implementation of the Proposed Action are likely to occur (**Figure 3.15-1**).

The Proposed Action has the potential to cause socioeconomic impacts to the communities around WFF through facility and infrastructure construction; expansion of existing missions or programs; and fluctuations in permanent and visiting personnel, scientists, and researchers. Most of WFF employees live and recreate throughout the five counties of the Delmarva Peninsula; therefore, socioeconomic analysis for this PEIS focuses on the general features of the economies of the Virginia Eastern Shore counties of Accomack and Northampton and the Maryland Eastern Shore counties of Somerset, Wicomico, and Worcester. Data presented have been collected from a variety of sources including the U.S. Census Bureau (USCB) 2010 Census, 2011-2015 American Community Survey 5-Year Estimates, Virginia Employment Commission, Maryland Department of Labor, Licensing and Regulation, U.S. Department of Commerce, and WFF.

#### 3.15.1.1 Population

**Table 3.15-1** provides the 2015 population of the five counties in the ROI with a comparison to the Commonwealth of Virginia and the State of Maryland. The 2015 population of the five counties was 224,806. Accomack, Northampton, and Somerset counties declined in population between 2010 and 2015 by 0.6%, 1.9%, and 2.7%, respectively. Wicomico and Worcester counties grew by 3.7% and 0.2%, respectively. Over the same time period, Virginia grew by 4.8% and Maryland by 4.0% (USCB 2017).

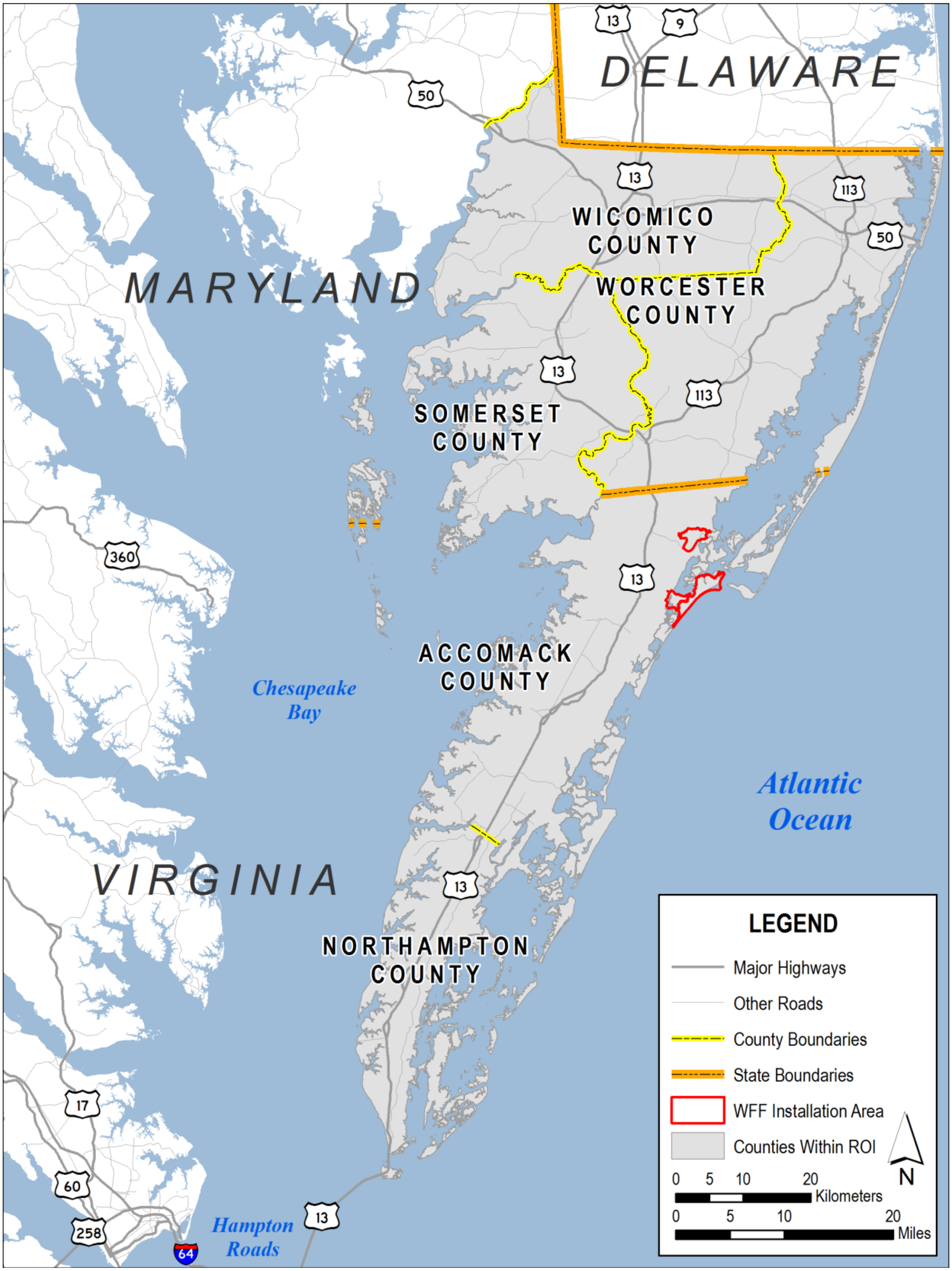


**Figure 3.15-1. Region of Influence**

**Table 3.15-1. Population in the Affected Region**

| Jurisdiction | 2010 | 2015 | Growth Rate 2010-2015 (%) |
|---|---|---|---|
| Accomack County, Virginia | 33,164 | 32,973 | -0.6 |
| Northampton County, Virginia | 12,389 | 12,155 | -1.9 |
| Somerset County, Maryland | 26,470 | 25,768 | -2.7 |
| Wicomico County, Maryland | 98,733 | 102,370 | 3.7 |
| Worcester County, Maryland | 51,454 | 51,540 | 0.2 |
| ***ROI Total*** | ***222,210*** | ***224,806*** | ***1.2*** |
| Virginia | 8,001,024 | 8,382,993 | 4.8 |
| Maryland | 5,773,552 | 6,006,401 | 4.0 |

Source: USCB 2017.

Population projections in the ROI are shown in **Table 3.15-2** . The population of the five counties is projected to be 238,615 in 2020; 254,164 in 2030; and 265,857 in 2040 (Weldon Cooper Center 2012, 2016; Maryland Department of Planning 2014). Overall, the population is anticipated to grow approximately 11.4% between 2020 and 2040. The growth rate for Accomack County from 2020 to 2040 is projected to be less than 1% (0.7%) while the growth rate for Northampton County over the same timeframe is anticipated to decline slightly (-2.0%). The populations in Somerset, Wicomico, and Worcester counties are expected to grow by 6.5%, 16.9%, and 12.5%, respectively. Over the same time period, Virginia is projected to grow by 16.7% and Maryland by 10.7% (Weldon Cooper Center 2012, 2016; Maryland Department of Planning 2014).

**Table 3.15-2. Population Projections in the Affected Region**

| Jurisdiction | 2020 Projection | 2030 Projection | 2040 Projection | Growth Rate 2020-2040 (%) |
|---|---|---|---|---|
| Accomack County, Virginia | 33,432 | 33,568 | 33,661 | 0.7 |
| Northampton County, Virginia | 12,133 | 11,996 | 11,896 | -2.0 |
| Somerset County, Maryland | 27,750 | 28,950 | 29,550 | 6.5 |
| Wicomico County, Maryland | 109,200 | 119,200 | 127,650 | 16.9 |
| Worcester County, Maryland | 56,100 | 60,450 | 63,100 | 12.5 |
| ***ROI Total*** | ***238,615*** | ***254,164*** | ***265,857*** | ***11.4*** |
| Virginia | 8,744,273 | 9,546,958 | 10,201,530 | 16.7 |
| Maryland | 6,224,550 | 6,612,200 | 6,889,700 | 10.7 |

Sources: Weldon Cooper Center 2012, 2016; Maryland Department of Planning 2014.

WFF is located in a rural area with no major urban centers. Year round densities of neighboring areas are low. **Table 3.15-3** shows the population and density of Accomack County and the neighboring counties. The village of Assawoman, approximately 8 km (5 mi) to the southwest of Wallops Island, is the closest residential community to Wallops Island. The towns of Wattsville and Atlantic are located approximately 13 km (8 mi) and 8 km (5 mi) northwest of Wallops Island, respectively.

| **Table 3.15-3. Population and Density** | | | |
|---|---|---|---|
| **Jurisdiction** | **2010 Population** | **Land Area km$^2$ (mi$^2$)** | **Population Density per km$^2$ (mi$^2$)** |
| Accomack County, Virginia | 33,164 | 1,165.5 (450) | 28.5 (73.8) |
| Northampton County, Virginia | 12,389 | 548.0 (211.6) | 22.6 (58.5) |
| Somerset County, Maryland | 26,470 | 828.8 (320) | 32.0 (82.8) |
| Wicomico County, Maryland | 98,733 | 969.8 (374.4) | 101.8 (263.7) |
| Worcester County, Maryland | 51,454 | 1,212.9 (468.3) | 42.4 (109.9) |
| ***ROI Total*** | ***222,210*** | ***4,725.0 (1824.3)*** | ***227.3 (588.7)*** |
| Virginia | 8,001,024 | 102,278.6 (39,490) | 78.2 (202.6) |
| Maryland | 5,773,552 | 25,141.6 (9,707.2) | 229.7 (594.8) |

Source: USCB 2011.

Chincoteague Island, Virginia, is approximately 8 km (5 mi) east of the Main Base. It is the largest densely populated area near WFF, with a 2015 resident population of approximately 3,000 people. Area populations fluctuate seasonally. During the summer months, the population increases to approximately 15,000 due to tourism and vacationers who visit the wildlife refuge and beaches of Assateague Island (Town of Chincoteague 2010). daily populations often triple during the summer months. Special events, such as the carnival and pony roundup and auction, sponsored by the Chincoteague Volunteer Fire Department in July, can draw crowds of up to 40,000.

### 3.15.1.2 Employment and Income

Total employment in the ROI was approximately 96,576 jobs in 2016 (**Table 3.15-4**). The industries that employed the most people in the five counties are government (20%); leisure and hospitality (18%); trade, transportation, and utilities (18%); and educational and health services (16%) (Virginia Employment Commission 2017; Maryland Department of Labor, Licensing and Regulation 2016).

| **Table 3.15-4. County Employment by Industry** | | | | | | |
|---|---|---|---|---|---|---|
| **Industry** | **Accomack** | **Northampton** | **Somerset** | **Wicomico** | **Worcester** | **TOTAL** |
| Agriculture, Fishing, and Mining | 145 | 768 | 175 | 298 | 115 | 1,501 |
| Construction | 406 | 92 | 265 | 2,033 | 1,208 | 4,004 |
| Manufacturing | 3,225 | 457 | 201 | 3,048 | 672 | 7,603 |
| Trade, Transportation, and Utilities | 1,756 | 523 | 1,081 | 9,563 | 4,201 | 17,124 |
| Information | 69 | * | 17 | 437 | 186 | |
| Financial Activities | 288 | 118 | 177 | 1,806 | 1,175 | 3,564 |
| Professional and Business Services | 1,279 | 95 | 130 | 4,329 | 1,484 | 7,317 |
| Educational and Health Services | 1,293 | 1,080 | 1,100 | 9,166 | 2,381 | 15,020 |
| Leisure and Hospitality | 1,451 | 644 | 383 | 4,925 | 10,359 | 17,762 |
| Other Services | 346 | 132 | 147 | 1,681 | 698 | 3,004 |
| Government | 2,893 | 933 | 3,137 | 8,296 | 3,709 | 18,968 |
| **Total** | **13,151** | **4,842** | **6,813** | **45,582** | **26,188** | **96,576** |

Sources: Virginia Employment Commission 2017; Maryland Department of Labor, Licensing and Regulation 2016.
Note: * indicates non-disclosable data.

NASA is the fifth largest employer in Accomack County following Perdue Products, Tyson Farms, Accomack County School Board, and County of Accomack, respectively (Virginia Employment Commission 2017).

Per capita income in the ROI increased from 2010 to 2015 by an average of 14.1% (**Table 3.15-5**). Per capita income in Virginia and Maryland grew by 17.6% and 14.2%, respectively over the same time period. All five counties have per capita incomes lower than their respective states (U.S. Department of Commerce 2016).

**Table 3.15-5. County Per Capita Income**

| Jurisdiction | 2010 Per Capita Income[a] | 2015 Per Capita Income[a] | Percentage Increase 2010-2015 |
|---|---|---|---|
| Accomack County, Virginia | 33,403 | 38,683 | 15.8 |
| Northampton County, Virginia | 35,498 | 37,804 | 6.5 |
| Somerset County, Maryland | 27,472 | 29,684 | 8.1 |
| Wicomico County, Maryland | 34,145 | 38,816 | 13.7 |
| Worcester County, Maryland | 41,857 | 52,847 | 26.3 |
| Virginia | 44,267 | 52,052 | 17.6 |
| Maryland | 49,023 | 55,972 | 14.2 |

Source: U.S. Department of Commerce 2012, 2016.
Note: [a] Not adjusted for inflation.

The median household income in 2015 was $39,412 for Accomack, $35,055 for Northampton, $35,154 for Somerset, $52,278 for Wicomico, and $56,773 for Worcester counties. The comparable median household incomes were $65,015 and $74,551 in Virginia and Maryland, respectively (U.S. Census Bureau 2017).

Unemployment rates in the ROI have declined over the last few years as shown in **Table 3.15-6**, dropping almost one-third from 2011 to 2015 in Accomack, Northampton, Somerset, and Wicomico counties. The unemployment rates for Virginia and Maryland also declined over the same time period. The 2015 unemployment rates of the counties within the ROI were higher than those for their respective states. The comparable 2015 unadjusted unemployment rate was 5.3% for the nation (U.S. Department of Labor 2016). It is also notable that employment fluctuates seasonally in this region (due to farm labor and summer tourism labor), with lower unemployment during the months of June through October (NASA 2016).

**Table 3.15-6. County Unemployment Rates[a]**

| Jurisdiction | 2011 | 2012 | 2013 | 2014 | 2015 | Percentage Change 2011-2015 |
|---|---|---|---|---|---|---|
| Accomack County, Virginia | 8.4 | 7.9 | 7.2 | 6.6 | 5.4 | -35.7 |
| Northampton County, Virginia | 8.9 | 9.2 | 9.1 | 7.6 | 6.1 | -31.5 |
| Somerset County, Maryland | 11.7 | 11.2 | 10.7 | 9.4 | 8.3 | -29.1 |
| Wicomico County, Maryland | 9.8 | 9.3 | 8.7 | 7.7 | 6.8 | -30.6 |
| Worcester County, Maryland | 13.7 | 12.9 | 12.6 | 11.5 | 10.6 | -22.6 |
| Virginia | 6.6 | 6.0 | 5.7 | 5.2 | 4.4 | -33.3 |
| Maryland | 7.2 | 7.0 | 6.6 | 5.8 | 5.2 | -27.8 |

Source: U.S. Department of Labor 2016.
Note: [a] Not seasonally adjusted.

In FY 2015, WFF employed a total of 1,119 employees comprised of 844 contractors and 275 civil servants (NASA 2016). The majority (58%) of WFF employees resides in Accomack County, 15% in Worcester County, 13% in Wicomico County, 4% in Somerset County, and 1% in Northampton County, and the remaining 9% reside in other locations (NASA 2016).

NASA employment categories at WFF consist largely of managerial, professional, and technical disciplines with higher than regional average salaries. The 2015 average salary for Civil Servants at WFF was $100,450.98. The range for the middle 50% of the Civil Servants' Salary was between $91,814 and

$115,072 (NASA 2016). WFF mean annual income exceeded the median family incomes in the ROI counties.

A 2011 study determined that WFF expenditures in FY 2010, including WFF-related tourism, generated approximately $188 million in ROI economic impact, 2,341 jobs (including tenant and temporary employment), state and local tax revenues of $7,107,087, and Federal tax revenues of $5,802,310 (Business, Economic, and Community Outreach Network 2011). Of these expenditures, approximately 60% were allocated to Virginia and 40% to Maryland (Koehler 2011). As a result of the increased rocket launches at WFF, the region is experiencing an increase in tourism related to launches (NASA 2016).

#### 3.15.1.3 Housing

Housing units in the ROI totaled 136,969 in 2015, of which approximately 38% were vacant (**Table 3.15-7**). The comparable vacancy rate for Virginia was 10.1%, and for Maryland, 10.5% (USCB 2015). The Eastern Shore is a popular vacation destination and the high vacancy rate reflects the high number of second, or vacation, homes in the area. Approximately 68% of occupied units are owned and 32% are rented, in line with the state averages.

**Table 3.15-7. Housing Units**

| Jurisdiction | Total Housing Units | Percent Vacant | Occupied Housing Units in 2015 | | |
|---|---|---|---|---|---|
| | | | Total | Percent Owner Occupied | Percent Renter Occupied |
| Accomack County, Virginia | 21,031 | 33.6 | 13,961 | 71.0 | 29.0 |
| Northampton County, Virginia | 7,323 | 28.3 | 5,248 | 68.9 | 31.1 |
| Somerset County, Maryland | 11,181 | 25.0 | 8,385 | 64.8 | 35.2 |
| Wicomico County, Maryland | 41,685 | 11.3 | 36,989 | 62.3 | 37.7 |
| Worcester County, Maryland | 55,749 | 62.7 | 20,773 | 75.3 | 24.7 |
| ***ROI Total*** | ***136,969*** | ***37.7*** | - | - | - |
| Virginia | - | 10.1 | - | 66.2 | 33.8 |
| Maryland | - | 10.5 | - | 66.8 | 33.2 |

Source: USCB 2015.

Similar to the rest of the nation, the housing market in the ROI was hit hard by the recession. Home construction slowed considerably. While recovering, residential building permits have not reached pre-recession levels (**Table 3.15-8**) (USCB 2012, 2017).

**Table 3.15-8. Residential Building Permits**

| Jurisdiction | 2005 Total Units | 2011 Total Units | 2015 Total Units |
|---|---|---|---|
| Accomack County, Virginia | 424 | 67 | 43 |
| Northampton County, Virginia | 135 | 44 | 50 |
| Somerset County, Maryland | 187 | 62 | 181 |
| Wicomico County, Maryland | 988 | 107 | 137 |
| Worcester County, Maryland | 568 | 121 | 266 |
| ***ROI Total*** | ***2,302*** | ***401*** | ***677*** |

Sources: USCB 2012, 2017.

U.S. Navy and Coast Guard housing areas are located adjacent to the WFF Main Base. The Navy Housing Center includes residences for both bachelors and families. The Unaccompanied Housing in Building R-010 contains five 2-bedroom units. Navy Gateway Inns and Suites has 63 total rooms comprised of 29 private rooms, 14 shared bath rooms, 18 standard suites, and 2 family suites. Each private room and shared bath room sleeps up to 2 guests and suites can accommodate 4 guests. In addition, dormitories in Buildings F-004 and F-005 are available to NASA researchers and other visiting personnel. The U.S. Coast Guard maintains housing units on 7 acres south of the Main Base entrance for personnel assigned to the local U.S. Coast Guard units (NASA 2016).

### 3.15.2 Environmental Consequences

This socioeconomic impact analysis focuses on the regional economic benefit of the Proposed Action. Economic impacts are defined to include direct effects, such as changes to employment and expenditures that affect the flow of dollars into the local economy and indirect effects, which result from the "ripple effect" of spending and re-spending in response to the direct effects. Factors considered in the analysis of socioeconomic impacts include:

- redistribution, influx, or loss of population within the study area;
- impacts to employment and income;
- availability of housing; and
- changes to the tax base.

Socioeconomic impacts, particularly impacts such as those being evaluated in this PEIS, are often mixed: beneficial in terms of gains in jobs, expenditures, tax revenues, etc., and potentially adverse in terms of growth management issues such as demands for housing. Thresholds for significant impacts to socioeconomics are specific to the capacity of the affected area to accommodate and respond to economic and social change. The focus for the socioeconomic analysis is related to the short- and long-term influx of construction personnel, researchers/engineers/students that would be expected to arrive at WFF for operational campaigns, and from tourists that arrive to view rocket launch events.

#### 3.15.2.1 No Action Alternative

##### 3.15.2.1.1 Institutional Support Projects

Under the No Action Alternative, the Proposed Action would not be implemented and existing conditions would continue. No changes to the existing socioeconomic conditions are anticipated to occur under the No Action Alternative.

##### 3.15.2.1.2 Operational Missions and Activities

Under the No Action Alternative, operational missions and activities would remain at current levels. No changes to the existing socioeconomic conditions are anticipated to occur under the No Action Alternative.

#### 3.15.2.2 Proposed Action

##### 3.15.2.2.1 Institutional Support Projects

The Proposed Action would support a number of facility projects ranging from building demolition and construction to maintenance dredging between the boat docks at the Main Base and Wallops Island, development of the North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D.

Refer to **Table 2.5-1** (Construction and Demolition Projects at Main Base) and **Table 2.5-2** (Construction and Demolition Projects at Mainland and Wallops Island). Under the Proposed Action, institutional support projects would be phased in beginning in 2019 with a 20-year construction window. Expenditures associated with the institutional support projects are not fully known at this time; however, the institutional support construction, demolition, and renovation activities would result in temporary economic benefits to the ROI.

Given the rates of unemployment in the ROI, institutional support activities would provide employment for some unemployed construction workers, including local workers. It is also possible that some construction workers would move into the ROI in response to the direct job effects in the construction industry. Given the estimated 20-year construction, demolition, and renovation timeframe, some workers may bring their families with them. Local institutional support expenditures, including construction wages, would have a beneficial impact on the ROI economy through direct spending and would generate economic activity that would lead to indirect temporary job creation.

However, the expected long-term increase in construction personnel would be minimal and would not significantly change the housing purchase or rental markets since population growth would occur over the 20-year construction, demolition, and renovation period and would be small relative to the ROI population. Minor effects on for-sale or rental housing would be further reduced by the gradual increase in personnel over the 20 years. Therefore, the increase in personnel would not have significant impacts on the ROI housing market, including temporary residences such as motels and recreational vehicle parks.

The expenditures associated with institutional support projects would result in increased tax revenue in the ROI in Virginia and Maryland. The direct and indirect workers would be taxed as would the income received by ROI businesses benefitting from the additional sale of goods and services.

Implementing the institutional support projects as described under the Proposed Action would not be anticipated to result in significant impacts in the ROI.

#### 3.15.2.2.2 Operational Missions

Personnel increases in support of the Expanded Space Program (i.e., larger LVs and commercial human spaceflight missions) are anticipated to include approximately 60 civil servants and 16 full-time, onsite contractors, with up to 36 transient personnel supporting the operations. Additional minor personnel increases would be associated with the other operational proposals such as increased UAS operations at the North Wallops Island UAS airstrip. Over the 20-year planning timeframe, full-time employment at WFF would be projected to increase by about 10% from FY 2015 levels, which would represent less than 1% of the ROI employment. Assuming that all full-time personnel move to the area (under a maximum case scenario) and using an average ROI household size of 2.4 persons (USCB 2017), the increase in population would be approximately 270 people, less than 1% of the ROI population.

Under a maximum case scenario, assuming that all full-time WFF employees enter the housing market at the same time, it would represent less than 1% of the total ROI housing units and less than 1% of the ROI vacant housing units (USCB 2015). This increase would be minimal and would not significantly change the housing purchase or rental markets. Any minor effects on for-sale or rental housing would be further reduced by the gradual increase in personnel over the 20-year planning horizon. Therefore, the increase in personnel would not have significant impacts on the ROI housing market.

Expenditures associated with the operational missions are not fully known at this time; however, the operational activities would result in economic benefits to the ROI. The salaries paid to the proposed personnel would represent direct annual income. Some of these earnings would be paid to taxes, and some would be saved and invested, but most would be spent on consumer goods and services in the ROI. Transient workers would also spend earnings in the ROI, particularly on accommodations, food, and rental vehicles. This spending would, in turn, "ripple" through the economy, generating additional indirect jobs and income and benefitting the ROI economy. Given the rates of unemployment in the ROI, it would be expected that many of these indirect positions would be filled by unemployed local residents. However, population in-migration could occur as a result of indirect job growth. Any minor increase in population due to indirect job creation would occur over 20 years and would not be expected to significantly change current trends in population growth or the for-sale or rental housing market.

The Proposed Action would be expected to attract tourists who would travel to the area specifically to view a rocket launch. Spending by these tourists would generate revenue for ROI businesses, particularly in the hospitality industry. Tourism expenditures would have a beneficial impact on the ROI economy. In September 2013, approximately 13,800 spectators gathered in Chincoteague and Assateague Island, Virginia; Ocean City, Maryland; and within various localized areas to observe the NASA LADEE launch resulting in an economic boost to the local economy. Similar crowds have been observed for Antares launch events (NASA 2013). LFIC LV and SFHC LV launches would be anticipated to have similar attendance.

The expenditures associated with operational proposals would result in increased tax revenue in the ROI in Virginia and Maryland. The direct and indirect workers would be taxed as would the income received by ROI businesses benefitting from the additional sale of goods and services. The economic impact in the ROI would result in a long-term positive impact; however, the overall impact would not be significant.

## 3.16 ENVIRONMENTAL JUSTICE

On February 11, 1994, President Clinton signed EO 12898, *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*. The general purposes of the EO are to 1) focus the attention of Federal agencies on the human health and environmental conditions in minority communities and low-income communities with the goal of achieving environmental justice; 2) foster nondiscrimination in Federal programs that substantially affect human health or the environment; and 3) give minority communities and low-income communities greater opportunities for public participation in and access to public information on matters relating to human health and the environment. EO 12898 directs Federal agencies to develop environmental justice strategies. NASA has developed an Environmental Justice Implementation Plan to comply with EO 12898.

EO 13045, *Protection of Children from Environmental Health Risks and Safety Risks,* was issued in 1997 to identify and address issues that affect the protection of children. Children may suffer disproportionately more environmental health and safety risks than adults because of various factors: children's neurological, digestive, immunological, and other bodily systems are still developing; children eat more food, drink more fluids, and breathe more air in proportion to their body weight than adults; children's behavior patterns may make them more susceptible to accidents because they are less able to protect themselves; and children's size and weight may diminish the protection they receive from standard safety features.

### 3.16.1 AFFECTED ENVIRONMENT

This section identifies minority or low-income populations that could be directly affected by the Proposed Action (i.e., direct noise impacts). For the purpose of this evaluation, minority refers to people who identified themselves in the Census as Black or African American, Asian, or Pacific Islander, American Indian or Alaskan Native, other non-White races, or as being of Hispanic or Latino origin. Persons of Hispanic and Latino origin may be of any race (CEQ 1997). The CEQ identifies these groups as minority populations when either 1) the minority population of the affected area exceeds 50% or 2) the minority population percentage in the affected area is meaningfully greater than the minority population percentage in the general population or appropriate unit of geographical analysis (most often the state of which the affected area is part). While not defined by the CEQ, the term “meaningfully greater” for the purposes of this PEIS has been interpreted to mean that the total minority population is 20% or more greater than the minority population of the geographic region of comparison. The geographical region for comparison in this analysis is the Commonwealth of Virginia.

The U.S. Census Bureau determines poverty status by using a set of dollar-value thresholds that vary by family size and composition. If a family’s total income is less than the dollar-value of the appropriate threshold, then that family and every individual in it are considered to be in poverty. Similarly, if an unrelated individual’s total income is less than the appropriate threshold, then that individual is considered to be in poverty. The poverty thresholds do not vary geographically. They are updated annually to allow for changes in the cost of living (inflation factor) using the Consumer Price Index (USCB 2015).

The discussion on the protection of children focuses on the potential for environmental health and safety risks to children under the age of 18 to be affected by institutional support projects (i.e., construction and demolition) or operational missions and activities (i.e., LV or RTLS events) under the Proposed Action.

The ROI for Environmental Justice was determined based on affected populations within noise contours greater than 115 dBA (the OSHA threshold for hearing protection). The 115 dBA noise contours remained within Accomack County. As such, populations within the four Accomack County Census Tracts that surround the Main Base, Mainland, and Wallops Island: Census Tracts 901, 902, 903, and 904, are evaluated. **Figure 3.16-1** illustrates the baseline noise contours in relation to Census Tracts 901, 902, 903, and 904.

#### 3.16.1.1 Minority and Low-Income Populations

Census data on the 2015 racial and ethnic composition of the ROI are summarized in **Table 3.16-1**. The percentage of total minorities in Census Tract 904 (64.9%) was the highest in the ROI. Census Tract 904 exceeds the rate for Virginia (37.3%). Since the total minority population in Census Tract 904 is meaningfully greater than the total minority population of Virginia, it would be considered a minority community according to the CEQ definition.

**Table 3.16-1. Percentage Race and Ethnicity, 2015[a]**

| Jurisdiction | White Alone | Black/ African American Alone | American Indian/ Alaska Native Alone | Asian Alone | Native Hawaiian/ Other Pacific Islander Alone | Hispanic or Latino | Two or More Races | *Total Minority |
|---|---|---|---|---|---|---|---|---|
| Census Tract 901 | 93.9 | 2.6 | 0.4 | 0.7 | 0.0 | 1.3 | 2.1 | 6.6 |
| Census Tract 902 | 73.9 | 25.7 | 0.0 | 0.0 | 0.0 | 5.1 | 0.1 | 30.7 |
| Census Tract 903 | 73.6 | 21.2 | 0.0 | 0.9 | 0.0 | 6.7 | 3.4 | 30.8 |
| Census Tract 904 | 53.4 | 38.9 | 0.0 | 0.0 | 0.0 | 24.2 | 1.9 | 64.9 |
| Virginia | 70.2 | 19.7 | 0.5 | 6.5 | 0.1 | 9.0 | 2.9 | 37.3 |

Source: USCB 2015.
Note: *Percentages may not add to 100% due to rounding.

Since poverty data are no longer collected in the decennial census, **Table 3.16-2** presents the 2011-2015 American Community Survey 5-Year Estimates for individuals in the ROI whose annual income in the past 12 months was below the poverty level.

With the exception of Census Tract 901, the other census tracts have higher percentages of individuals below the poverty rate than Virginia. The percentage of low-income populations in Census Tracts 902, 903, and 904 would be considered meaningfully greater than the Commonwealth of Virginia; therefore, environmental justice will be assessed for low-income populations in these census tracts.

**Table 3.16-2. Percentage Low-Income, 2015**

| Jurisdiction | Individuals Below Poverty Level |
|---|---|
| Census Tract 901 | 9.5 |
| Census Tract 902 | 18.7 |
| Census Tract 903 | 23.0 |
| Census Tract 904 | 20.5 |
| Virginia | 11.5 |

Source: USCB 2015.

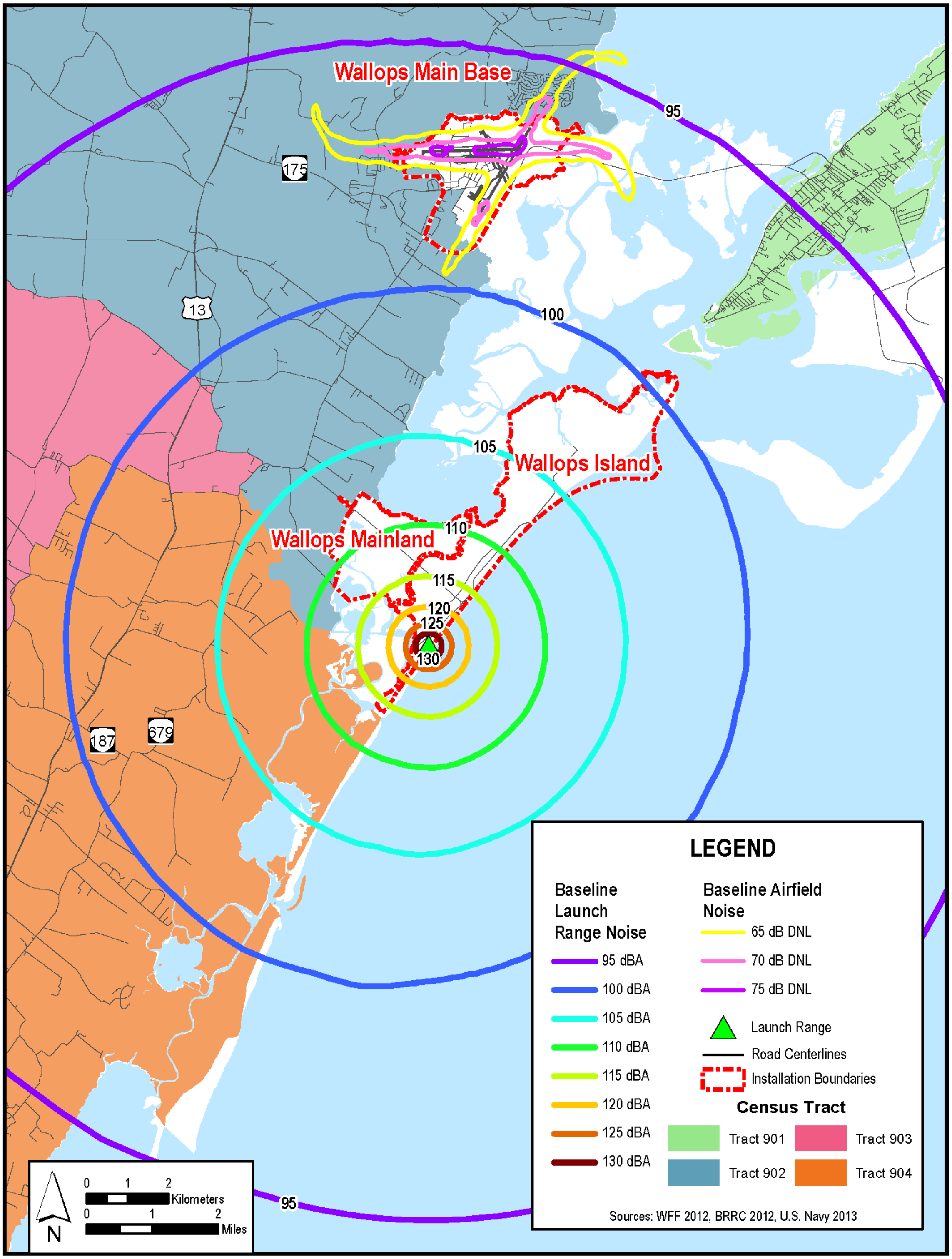


**Figure 3.16-1. Baseline Noise Environment**

#### 3.16.1.2 Protection of Children

This section identifies populations under the age of 18 in the ROI. As shown in **Table 3.16-3**, in 2015, Census Tracts 902 and 904 had a higher percentage of the population under 18 (23.8% and 23.1%, respectively) than Virginia (22.6%).

**Table 3.16-3. Percentage of Residents Under Age 18, 2015**

| Jurisdiction | Percentage Under Age 18 |
|---|---|
| Census Tract 901 | 15.3 |
| Census Tract 902 | 23.8 |
| Census Tract 903 | 19.5 |
| Census Tract 904 | 23.1 |
| Virginia | 22.6 |

Source: USCB 2015.

No schools, daycare centers, camps, etc. are located within 5 to 13 km (3 to 8 mi) of the southern end of Wallops Island where launch activities take place. One private campground, Trail's End, is located approximately 13 km (8 mi) northwest of Launch Complex 0. The closest schools are Arcadia High School, located approximately 11 km (7 mi) northwest of Launch Complex 0, and Kegotank Elementary School, located approximately 7 km (4.4 mi) west of Launch Complex 0 (NASA 2009).

### 3.16.2 Environmental Consequences

Significant impacts to minority and low-income populations would occur if there were disproportionately high and adverse human health and environmental effects to those populations. Significant impacts to children would occur if there was a disproportionate environmental, health, or safety risk to children. This analysis focuses on noise impacts associated with the Proposed Action's operational missions and activities since they have the potential to disproportionately affect minority and low-income populations, as well as the environmental health and safety of children.

In order to analyze the potential for disproportionate impacts to minority or low-income populations and children, the estimated population within noise contours greater than 115 dBA (the OSHA threshold for hearing protection) was analyzed using census data in combination with 911 emergency address GIS data obtained from Accomack County (USCB 2011). As part of a ground-truthing effort, WFF plotted all homes within a 5 km (3.1 mi) radius of the launch range and verified that no occupied structures exist within the 115 dBA contour (see Section 3.1, Noise).

#### 3.16.2.1 No Action Alternative

##### 3.16.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Under this alternative, there would be no disproportionate impacts to minority or low-income populations or to children's environmental health and safety.

##### 3.16.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope; all operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Noise generated from airfield operations are shown as contours in **Figure 3.1-2.** The 65 dB DNL noise contour extends beyond the Main Base boundary, mostly over lands zoned for agricultural use. The 65 dB DNL contour does extend over a residential area to the west, but 65 dB is within the daytime noise ordinance limits for Accomack County (Accomack County 2001). The 70 dB DNL contour extends only slightly beyond the base boundary at the terminal end of runways 10, 22, and 28 and the 75 dB DNL noise contour is confined to the Main Base boundary. Currently there are no populations in the ROI that may be exposed to rocket launch noise levels at or above 115 dBA (see Section 3.1, Noise). As such, no disproportionate impacts would occur to minority or low-income populations or to children's environmental health and safety.

### 3.16.2.2 Proposed Action

#### 3.16.2.2.1 Institutional Support Projects

This PEIS has determined that no potentially high or adverse impacts would occur to the surrounding community from activities associated with construction and demolition projects on the Main Base, Mainland, and Wallops Island; therefore, no disproportionately high or adverse impacts would occur to minority or low-income populations or to children's environmental health and safety.

#### 3.16.2.2.2 Operational Missions and Activities

Most operational programs that would be conducted under the Proposed Action would not impact communities surrounding WFF. However, a few new operational activities have the potential to impact these resources. As such, only those proposals with potential impacts are described here.

**<u>Expanded Space Program</u>**

The Expanded Space Program includes new missions that have the potential to alter noise levels at WFF and in the surrounding areas.

**LFIC LV and SFHC LV**

The primary operational mission that has the potential to affect populations beyond the perimeter of WFF would be noise associated with rocket launch operations. In the past, rocket launches have not resulted in noise complaints or reported annoyance to the communities surrounding WFF. Though the launches of the LFIC LV and SFHC LV would be loud, they would be for a short duration, most likely less than ten minutes depending on weather conditions, location of the listener, and time of day. Noise-related impacts would decrease as a launch vehicle's distance from Wallops Island increases. The launching of the LFIC LV and SFHC LV would exceed the current rocket motor envelope at Wallops Island (refer to Section 3.1, Noise). Noise modeling was conducted to identify any potential noise impacts due to the launch of these vehicles. **Figure 3.16-2** and **Figure 3.16-3** show the noise contours expected from the launch of the LFIC LV and SFHC LV, respectively. No populations are found within 115 dBA and greater noise contours (see Section 3.1.4.2.2) or within the 3,050 m (10,000 ft) hazard arc (see Section 3.4.2.2.2). In the event that a SFHC LV launch failed within the first 20 seconds into flight, ground level concentrations of HCl and $Al_2O_3$ emissions could pose a toxic hazard to humans. The nearest residence is located approximately 3.0 km (1.9 mi) west of the WFF Launch Range, Pad 0 Complex. Most of the distance between the Pad 0 Complex and populated areas to the north in Chincoteague consists of vacant land and open water. To the east and southeast of the Pad 0 Complex lies open water.

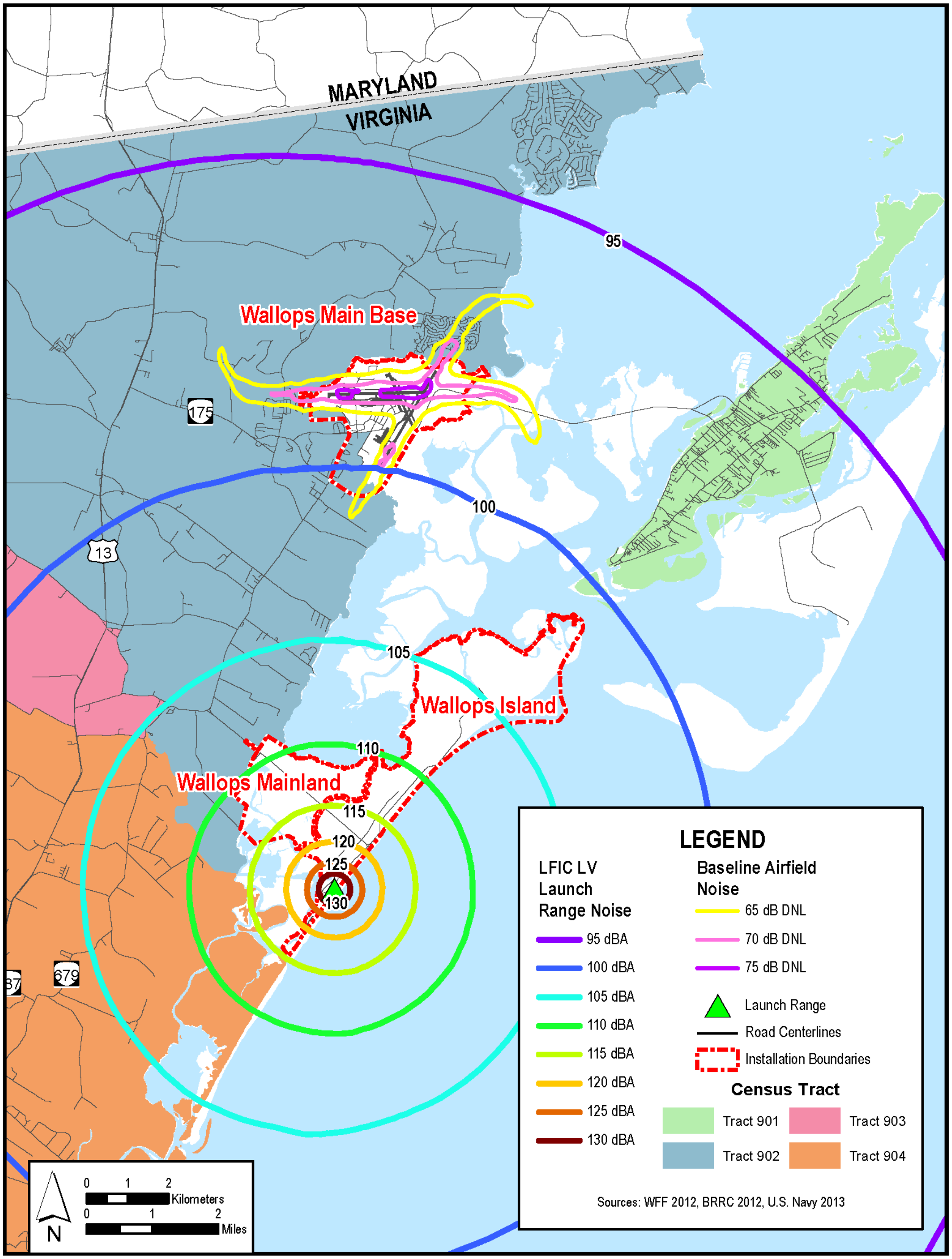


**Figure 3.16-2. Single Event LFIC LV Noise Contours**

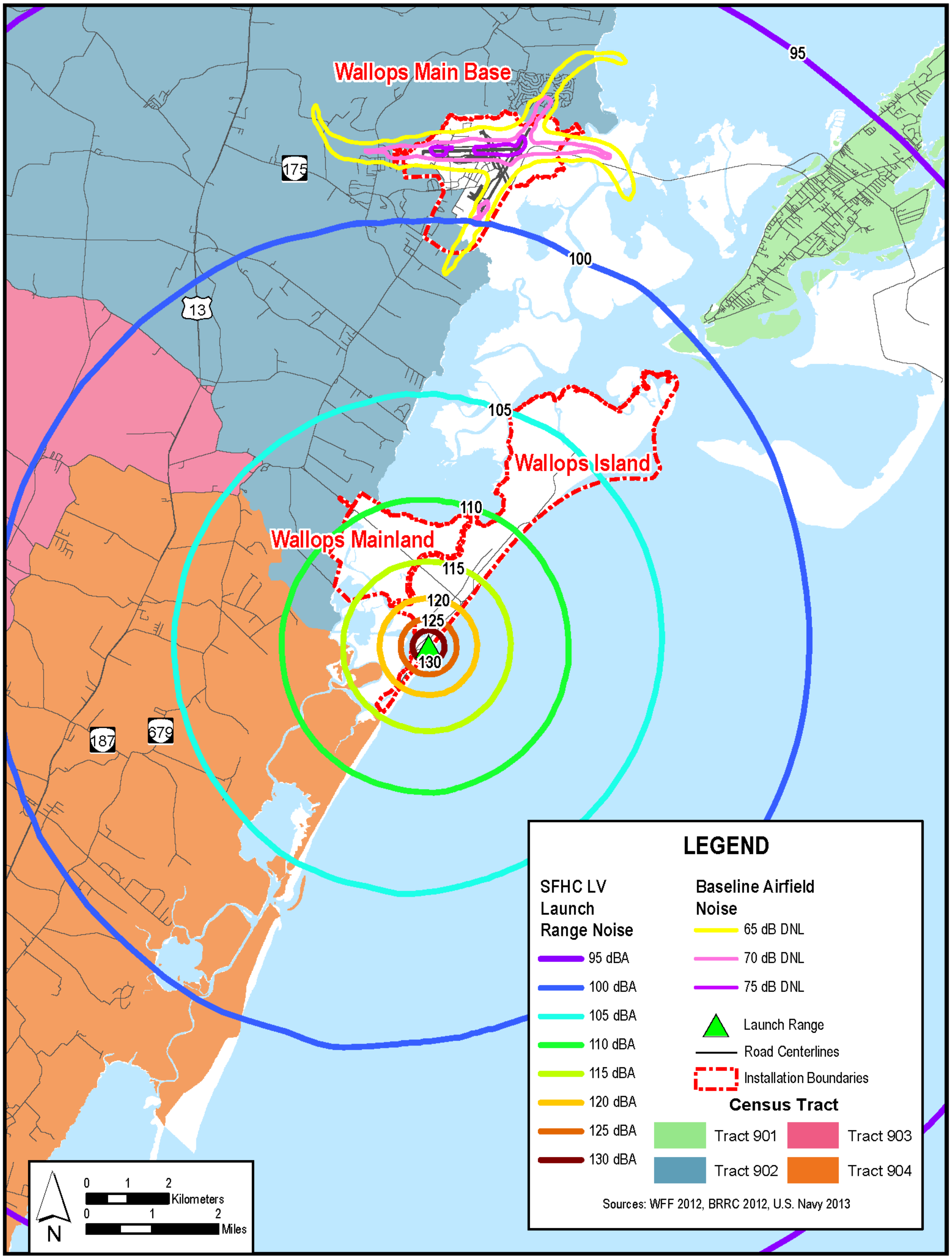


**Figure 3.16-3. Single Event SFHC LV Noise Contours**

Concentrations of HCl and Al2O3 would not be expected to impact the general population since harmful concentrations are unlikely to extend as far as the populated areas of Chincoteague or would be over open ocean (see Section 3.4.2.2.2). As such, there would be no disproportionate impacts to minority or low-income populations or to children's environmental health and safety.

**Vertical Launch and Landing Vehicles**

Vertical launches currently take place on Wallops Island. Vertical landing of vertical launch vehicles could occur on Wallops Island under the Proposed Action. A study was conducted in 2016 that modeled a representative LFIC LV returning to the proposed Launch Pad 0-C on Wallops Island. The results indicate the returning LFIC LV noise levels would exceed 115 dBA within a distance of approximately 0.6 km (0.4 mi) from the landing site (BRRC 2017). As part of a ground-truthing effort, WFF plotted all homes within a 5 km (3.1 mi) radius of the launch range and verified that no occupied structures exist within the 115 dBA or greater contour (see Section 3.1, Noise). LFIC RTLS noise would be similar to the noise described above for a LFIC LV launch. However, a sonic boom could be generated during an RLV supersonic descent. Application of notional LFIC RTLS event from the southeasterly direction indicate the Atlantic Ocean would intercept the majority of the sonic boom overpressure. Land areas within the descent trajectory could experience sonic boom overpressures; however, the intensity of the sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). Under the Proposed Action, no more than six LFIC LV/RTLS events would be authorized in a 12-month period. It is unlikely that any significant noise impacts would be generated from this type of operational mission as described under the Proposed Action. As such, no disproportionate impacts would occur to minority or low-income populations or to children's environmental health and safety.

**Horizontal Launch and Landing Vehicles**

Horizontal launch and landings would take place on the Main Base. The noise associated with the horizontal launch and landings would be typical of existing jet aircraft that utilize the Main Base runways. Operations at the Main Base airfield generate noise that extends beyond the Main Base boundary (refer to **Figure 3.1-1)**. The 65 dB DNL noise contour extends primarily over lands zoned for agricultural and industrial use; however, the 65 dB DNL contour does extend over a residential area to the west, but this is within the daytime noise ordinance limits for Accomack County. As such, no disproportionate impacts would occur to minority or low-income populations or to children's environmental health and safety.

**Commercial Human Spaceflight Missions**

NASA is considering the use of commercial human spaceflight missions that could consist of commercial space tourism and commercial crew transport to the ISS and LEO. A number of launch vehicles have the potential to utilize WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base). All of these platforms would be launched with technologies within the established noise envelope or within the new envelope for the above noted LFIC LV and SFHC LV. No disproportionate impacts would occur to minority or low-income populations or to children's environmental health and safety.

## 3.17 VISUAL RESOURCES AND RECREATION

Visual resources are defined as the natural and manufactured features that comprise the aesthetic qualities of an area. These features form the overall impression that an observer receives of an area or its landscape character. Visual resources consider the visual and aesthetic qualities of local resources and include the natural environment, such as trees, topography, and land structures, as well as any built structures that currently exist. Recreation resources include primarily outdoor recreational activities that occur away from a participant's residence. This includes natural resources and built facilities that are designated or available for public recreational use. The setting, activity, and other resources that influence recreation are also considered.

### 3.17.1 AFFECTED ENVIRONMENT

#### 3.17.1.1 Visual Resources

WFF Main Base is composed primarily of runways, hangars, and office and storage buildings. Structures on the Mainland consist of transmitter systems, tracking facilities, and related support buildings. Most of Wallops Island consists of marshland. The remainder hosts launch and testing facilities, blockhouses, rocket storage buildings, project space, assembly shops, U.S. Navy facilities, U.S. Air Force Instrumentation Tower, and other related support structures.

#### 3.17.1.2 Recreation

Current recreational amenities on the Main Base include a gymnasium, outdoor tennis and basketball courts, exercise trail, and a picnic pavilion (NASA 2008). In addition, the WFF Exchange and Morale Association offers a variety of activities to WFF employees and their families. There is one main area designated for recreational use on Wallop Island: a beach area north of the seawall and south of the beach cable barrier. In 2017, launch of non-motorized watercraft from U-070 and the North Island dock areas, and fishing and shell-fishing at the edge of these wetland areas was authorized. These areas are open after operational hours to permanently badged WFF employees and their guests unless temporarily restricted for mission/launch hazards. The northern portion of this recreational area is closed annually from March through August during piping plover nesting season. A second area designated for recreational use, the marsh under the Wallops Island Bridge that runs along the Virginia Inside Passage of the Intracoastal Waterway, is open year round; however, it may only be accessed via boat.

Virginia's Eastern Shore is a popular tourist destination. Many tourists and vacationers visit Accomack County throughout the late spring, summer, and early fall. Regional attractions include the AINS and CNWR. Winter hunting season draws people to hunt local game including dove, quail, deer, and many types of geese and ducks. The Wallops Island shoreline is also a popular location for local fishermen who surf fish or fish from boats in the nearshore environment. The Wallops Island National Wildlife Refuge is located south of the WFF Visitor Center and is under the jurisdiction of the USFWS. This refuge is not open to the general public. South of Wallops Island is Assawoman Island, a 580 ha (1,420 ac) parcel managed as part of the CNWR by the USFWS. The remainder of the CNWR lies mostly east and north of Wallops Island on Chincoteague Island. A string of undeveloped barrier islands, managed by TNC as part of the Virginia Coast Reserve, extends south down the coast to the mouth of the Chesapeake Bay.

### 3.17.2 ENVIRONMENTAL CONSEQUENCES

Impacts to visual resources would be considered significant if the Proposed Action would result in adverse impacts to the existing viewing environment. Impacts to recreational resources would be considered significant if a large portion of a particular type of recreational resource was lost and could not be suitably substituted with a similar activity or if demand could not be met by similar facilities or natural areas.

#### 3.17.2.1 No Action Alternative

##### 3.17.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope; all construction efforts under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Changes to the existing visual resources or recreation beyond those previously evaluated would not occur.

##### 3.17.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational missions and activities that are within the installation's current envelope; all operational missions and activities under the No Action Alternative have been covered by previous NEPA documents that are incorporated by reference into this PEIS. Changes to the existing visual resources or recreation beyond those previously evaluated would not occur.

#### 3.17.2.2 Proposed Action

##### 3.17.2.2.1 Institutional Support Projects

**Visual Resources**

Under the Proposed Action, all proposed construction and demolition would remain consistent with areas designated for development within the 2008 WFF Facility Master Plan. Minor impacts to visual resources would occur as a result of construction and demolition; however, the impacts would be localized. Where required for construction on the Main Base, any potential loss of vegetation would be offset by implementation of a vegetation plan, as required by the 2008 WFF Facility Master Plan (NASA 2008). Any construction proposed for the Mainland and Wallops Island would result in negligible impacts as the projects would remain consistent with the historical use of the areas.

Launch Pad 0-C is proposed at the current location of the UAS airstrip at the south end of Wallops Island. It is anticipated that Launch Pad 0-C could be as large in size and configuration as Launch Pad 0-A with an estimated footprint of 2.6 ha (6.4 ac) (refer to **Figure 3.5-11**). The location and configuration of Launch Pad 0-C would not be out of character with the surrounding land use or visual aspects of the area and would not result in negligible impacts to visual resources.

Launch Pier 0-D is proposed on the south end of Wallops Island on either Hog Creek or in the nearshore waters of the Atlantic Ocean (refer to **Figure 2.5-9**). No design specifications for either of the two optional locations are available at this time. In either location, oceanside or creekside, the pier pad would most likely consist of a pile-supported, steel reinforced concrete system. The configuration of Launch Pier 0-D would not be in character with the surrounding visual aspects of the shoreline; however, the location and type of operations from the pier pad would be in character with the existing land use and visual aspects of the WFF Launch Range, resulting in negligible impacts to visual resources.

**Recreation**

Under the Proposed Action, boaters and fishermen could be temporarily impacted by the Causeway Bridge demolition and reconstruction, maintenance dredging of the Maintained Barge Route channels between the Main Base and Wallops Island boat docks, and development of the North Wallops Island

Deep-water Port and Operations Area. NOTMARs would be issued by the U.S. Coast Guard to advise recreational vessel operators of the presence of construction equipment in the water and cautionary measures to take when near these activities. Additional permits from the U.S. Coast Guard and the VMRC would be required because the bridge crosses a tidal navigable waterway. The dredge contractors and bridge construction contractors would clearly identify where construction activities would occur and minimize their interference with watercraft. Overall, the impacts to recreational users from implementing the Causeway Bridge project and from maintenance dredging operations would be minor.

3.17.2.2.2 Operational Missions and Activities

**Visual Resources**

Individual operational mission activities (i.e., orbital and suborbital launches) would typically be short in duration and would not result in any long-term impacts to visual resources. The proposed operational mission activities would be similar in nature to those already occurring at WFF and conducive to DoD and NASA missions. Therefore, negligible impacts to visual resources are anticipated.

**Recreation**

**Expanded Space Program**

Current mandatory safety constraints require the closure of the Wallops Island beach, Chincoteague Inlet, downrange ocean areas, and portions of the CNWR and AINS during launch setup and launch operations. These constraints would not change under the Proposed Action and the beach would remain available to recreational activities during non-launch periods.

With the addition of the proposed Expanded Space Program (i.e., LFIC LV, SFHC LV, vertical and horizontal launch and landing vehicles, and commercial human spaceflight missions), a possible beneficial impact would result from the opportunity for the general public to partake in these launch events. Crowds currently gather on AINS, at pull-offs on the Chincoteague Causeway, along and on roads branching off of State Route 679, and at the WFF Visitor Center which provides vehicle parking and an open field with bleacher seating. In September 2013, crowds gathered in Chincoteague and Assateague Island, Virginia; Ocean City, Maryland; and within various localized areas to observe the launch of NASA's LADEE (NASA 2013). The WFF Visitor Center would continue to provide a primary location where viewers could congregate to minimize traffic impacts. Tourism and recreational vessel operators could be temporarily displaced by the increased hazard arcs associated with larger LV launches. The public would be informed of launches through local media outlets, the Wallops Public Information Line ([757] 824-2050), and the WFF website (http://www.nasa.gov/centers/wallops/events).

With respect to hazard zones, USACE amended an existing permanent danger zone in the waters of the Atlantic Ocean off Wallops Island and Chincoteague Inlet that protects the public from hazards associated with rocket launching operations (refer to **Figure 3.3-1**). The amendment increases the restricted area danger zone to a 56 km (30 nm) sector (USACE 2012). NOTMARs would be issued by the U.S. Coast Guard to advise recreational operators of hazard arcs associated with launch activities and cautionary measures to take when near these activities. NOTMARs are published prior to the temporary USACE closure of an area of interest within or for the entire danger zone. Typically, during launch operations only an area of interest within the danger zone would be closed. During the closure, a combination of light beacons, stationary warning balloons, and patrol water and aircraft may be used to warn the public to remain out of the danger zone until the designated area is clear and reopened for public use.

On an annual basis, portions of the danger zone would be closed for the shortest duration possible for a maximum of 60 sounding rockets; 18 orbital LV events; 30 drone launches; 270 combined firings from conventional, EMRG, or RDT&E systems (refer to **Table 2.6-1**, Baseline and Proposed Envelopes). Closures would amount to approximately 467 hours (or 5 percent) per year. The impacts to recreational tourism and recreational vessel operators from increased hazard arcs and hazard zones would be minor. Overall, implementation of the Proposed Action would result in negligible to beneficial impacts to recreation.

## 3.18 CULTURAL RESOURCES

Cultural resources are defined as prehistoric or historic sites, buildings, structures, objects, or other physical evidence of human activity that are considered important to a culture or community for scientific, traditional, or religious reasons. Cultural resources are divided into three resource categories: archaeological, architectural, and traditional cultural resources or properties. Archaeological resources are places where people changed the ground surface or left artifacts or other physical remains (e.g., arrowheads or bottles). Archaeological resources can be classed as either sites or isolates and may be either prehistoric or historic in age. The prehistoric period in Virginia is from circa 10,000 B.C. to 1606 A.D.; the historic period is from 1607 to the present. Isolates often contain only one or two artifacts, while sites are usually larger and contain more artifacts. Architectural resources are standing buildings, dams, canals, bridges, and other structures. Traditional cultural properties are resources associated with the cultural practices and beliefs of a living community that link that community to its past and help maintain its cultural identity. Traditional cultural properties may include archaeological resources, locations of historic events, sacred areas, sources of raw materials for making tools, sacred objects, or traditional hunting and gathering areas.

Section 106 of the NHPA of 1966, as amended, and as implemented by 36 CFR Part 800, requires Federal agencies to consider the effects of their actions on historic properties before undertaking a project. A historic property is defined as any cultural resource that is included in, or eligible for inclusion in, the NRHP. The NRHP, administered by the NPS, is the official inventory of cultural resources that are significant in American history, prehistory, architecture, archaeology, engineering, and culture. The NRHP also includes National Historic Landmarks. In consideration of 36 CFR 800, Federal agencies are required to initiate consultation with the State Historic Preservation Office (SHPO) informing them of the planned action and requesting their submittal of any comments or concerns.

In accordance with Sections 106 and 110 of the NHPA, NASA developed a Programmatic Agreement with the Virginia SHPO and Advisory Council on Historic Preservation to outline how WFF will manage its cultural resources as an integral part of its operations and missions (NASA 2014, 2016). As part of this process, NASA identified a number of parties who have an interest in, or knowledge of, cultural resources at WFF and included them in the development of the terms of the Programmatic Agreement. The Programmatic Agreement establishes the parameters for managing cultural resources at WFF including:

- Roles and responsibilities,
- Updates and requirements for the WFF Integrated Cultural Resources Management Plan,
- Activities not requiring review,
- Review process for potential impacts including professional qualifications, documentation, curation, etc.,

- Requirements for the treatment of the Wallops Beach Lifesaving Station,
- Resolution of adverse effects and disputes, and
- Emergency actions.

### 3.18.1 Affected Environment

The affected environment for archaeological resources would include those areas subject to ground disturbance from construction and operational activities. The affected environment for architectural resources would include those areas that are directly affected by ground disturbance and construction, as well as those areas indirectly affected by operational activities such as noise, vibration, and alterations to the existing setting. The affected environment for traditional cultural properties would include those areas subject to ground disturbance from construction and operational activities.

**Archaeological**

In order to assess possible impacts to archaeological sites, a predictive model was prepared for the WFF and accepted by the VDHR in 2003 (NASA 2003). This predictive model includes both prehistoric and historic models and indicates areas of low, moderate, and high archaeological potential, as explained in **Table 3.18-1** and **Table 3.18-2**.

**Table 3.18-1. Prehistoric Site Predictive Model for the Virginia Interior Coastal Plain**

| Sensitivity | Landform | Soil Drainage Type | Slope | Distance to Water |
|---|---|---|---|---|
| Low | Tidal Marsh, Topographically low areas | Poorly drained | <2% | na |
| | Terrace, knoll, ridge, and bluff edges | All types | >10% | na |
| | Terrace, knoll, ridge, bluff | All types | na | >160 m (>500 ft) |
| Moderate | Terrace, knoll, ridge, bluff, barrier island | Moderately drained | 2–10% | <160 m (<500 ft) |
| High | Terrace, knoll, ridge, bluff, barrier island | Well-drained | 2–10% | <160 m (<500 ft) |
| | Hummock or knoll in tidal marsh | Moderately to well-drained | 2–10% | na |

Source: NASA 2003.
Legend: na = not applicable.

**Table 3.18-2. Historic Site Predictive Model for the Virginia Interior Coastal Plain**

| Sensitivity | Landform | Slope | Distance to Water |
|---|---|---|---|
| Low | Any | >20% | na |
| Moderate | Ridges | 10–20% | na |
| High | Stream terraces, floodplains, ridges | 0–10% | <300 m ( 900 ft +/-) |

Source: NASA 2003.
Legend: na = not applicable.

Archaeological sensitivity maps have been created based on the predictive model, incorporated into GIS geodatabases, and are available for the entire WFF facility.

Over the years, several studies have been conducted identifying and evaluating cultural resources at WFF. Currently, eleven archaeological sites have been identified on WFF (**Table 3.18-3**). Four of the sites have been recommended as ineligible for listing on the NRHP. Three of the sites have not been the subject of further archaeological inquiry as these sites are located in protected areas not planned for development. In order to protect these archaeological sites, only general location information is included in the table.

**Table 3.18-3. Known Archaeological Sites on Wallops Flight Facility**

| Site Number | Site Type | Location | NRHP-Eligible | Cultural Period |
|---|---|---|---|---|
| 44AC0089 | Military Earthworks | Wallops Island/north | Recommended Eligible | Revolutionary War |
| 44AC0103 | Matthews House and associated grave/cemetery | Main Base south airfield | Not Evaluated | 18th Century (circa 1788) |
| 44AC0159 | Shell Pile | Wallops Island/south | Determined Not Eligible | Unknown Historic |
| 44AC0405 | Artifact Scatter | Main Base/Navy housing | Recommended Not Eligible | 19th Century |
| 44AC0437 | Artifact Scatter | Main Base | Not Evaluated | 18th and 19th Centuries |
| 44AC0459 | Trash scatter associated with U.S. Coast Guard Station | Wallops Island/north | Determined Not Eligible | Late 19th and 20th Centuries |
| 44AC0556 | Trash pit and Funerary, single grave | Main Base/NOAA | Determined Not Eligible | Late Woodland and 19th Century |
| 44AC0558 | Temporary Camp | Mainland | Recommended Eligible; Have not sought concurrence | Possible Middle Archaic; Woodland; possible Historic |
| 44AC0562 | Artifact Scatter | Mainland | Recommended not Eligible; Have not sought concurrence | 18th and 19th Centuries |
| 44AC0563 | Artifact Scatter | Mainland | Recommended not Eligible; Have not sought concurrence | 18th and 19th Centuries |
| 44AC0567 | Trash Dump | Mainland | Determined Not Eligible | 20th Century |

Source: NASA 2015.

**Architectural Resources**

In 2004, a comprehensive architectural survey and National Register eligibility evaluation of the WFF was conducted. The study consisted of a reconnaissance level architectural survey of 124 buildings, structures, and objects at WFF built before 1956, as well as a historic context of the facility. The *Historic Resources Survey and Eligibility Report for Wallops Flight Facility, Accomack County, Virginia* was prepared from the 2004 survey (NASA 2004).

In consultation with the VDHR, which is the Virginia SHPO, it was determined that there are no eligible historic districts within WFF and that all of the 124 resources surveyed were not eligible except for the Wallops Beach Lifesaving Station (V-065) and the associated steel frame Observation Tower (V-070). Since the Station and Observation Tower are located within a designated explosive hazard zone for an adjacent rocket motor storage facility, WFF considered various options for their disposition, including their removal from WFF and transfer from Federal ownership or demolition or deconstruction, and submitted its alternatives analysis to VDHR. WFF proposes to demolish/deconstruct the Station and Observation Tower. In accordance with the procedures outlined in the Programmatic Agreement, WFF prepared a Historic American Building Survey (HABS)/Historic American Engineer Record recordation of the Station and Observation Tower and short documentary video of their history. VDHR concurred with the demolition/deconstruction proposal (VDHR 2016).

In 2009, WFF performed a Phase I Archaeological Investigation for the then proposed North Wallops Island UAS airstrip. Based upon findings of the investigation and subsequent consultation with VDHR, WFF determined that a Revolutionary War earthworks (44AC0089) on the Island is eligible for listing on the NRHP. The undertaking was subsequently redesigned to avoid adverse effects to this site (NASA 2015). During the development of the Programmatic Agreement among NASA, the Virginia SHPO, and Advisory Council on Historic Preservation, Site 44AC0089 was identified as National Register-eligible, and for the purpose of NHPA compliance, the site is treated as an historic property.

In 2011, a supplemental historic context study and comprehensive architectural survey of 76 buildings and structures with dates of construction between 1956 and 1965 were completed for WFF. The *Historic Resources Eligibility Survey, Wallops Flight Facility, Accomack County, Virginia* (NASA 2011) used the historic context of the 2004 survey; however, the 2011 survey augmented the context with additional history pertinent to the period (1956 to 1965). In consultation with VDHR, it was determined that there are no eligible historic districts within WFF and that the 76 buildings and structures are not individually eligible for NRHP listing (VDHR 2011). WFF is currently in the process of conducting a historic context study and architectural survey of buildings and structures built between 1965 and 1981. Up to 89 architectural resources will be evaluated for their significance within the historic contexts of NASA and Wallops Station 1959–1974, and/or Wallops Flight Center 1974–1981.

**Traditional Cultural Properties**

WFF does not possess or manage Native American collections or cultural items, Native American remains, or Native American sacred sites or traditional cultural properties. The installation is not located within the lands of any state or Federally recognized Native American tribe (NASA 2015). During the process of developing the Programmatic Agreement, WFF contacted a variety of tribal councils around the country to invite their participation in the Programmatic Agreement process. Two Native American tribes requested to participate in this process and signed the Programmatic Agreement as a concurring party: the Catawba Indian Nation and the Pocomoke Indian Nation. Since the Programmatic Agreement was executed in November 2014, the following seven tribes have received Federal recognition: Pamunkey Indian Tribe, Chickahominy Indian Tribe, Chickahominy Tribe Eastern Division, Monacan Indian Nation, Nansemond Tribe, Rappahannock Tribe, and Upper Mattaponi Indian Tribe. NASA initiated Government-to-Government consultation with all of these tribes on the actions proposed in this PEIS.

### 3.18.2 Environmental Consequences

According to Section 106 of the NHPA, it is the responsibility of the Federal proponent to determine whether historic properties are located within the project area, assess whether the undertaking would result in an adverse effect to the resources, and consult with the SHPO, interested parties, and Federally recognized Native American tribes as appropriate, to develop measures to avoid, minimize, and/or mitigate the adverse effects of the undertaking. A historic property is a property that is an NRHP-eligible or listed cultural resource. The threshold also applies to any cultural resource that has not yet been evaluated for its eligibility to the NRHP.

Direct impacts may occur through physical alteration, damage, or destruction of all or a part of a historic property; alteration of characteristics of the surrounding environment that contribute to the property's significance; or introduction of visual or audible elements out of character with the property or which alter the property's setting that contribute to its historic significance. Alterations can include negligence resulting in the deterioration or destruction of the resource. Direct impacts can be assessed by identifying the types and locations of proposed activity and determining the exact location of NRHP-eligible cultural resources that could be affected. Indirect impacts generally result from increases in population that can lead to increased use of an area and are more difficult to quantify.

For cultural resources, the threshold for significant impacts includes any disturbance that cannot be mitigated and affects the integrity of a historic property. Impact analysis for cultural resources focuses on whether or not any of the activities under the Proposed Action have the potential to affect cultural resources identified as being eligible for nomination to the NRHP. Additionally, impact analysis also takes into account any traditional significance of a resource for Native American groups.

#### 3.18.2.1 No Action Alternative

##### 3.18.2.1.1 Institutional Support Projects

Under the No Action Alternative, WFF would implement institutional support projects that are within the installation's current envelope. All construction efforts under the No Action Alternative have been covered by previous NEPA and NHPA documents; no additional impacts to cultural resources from institutional support under the No Action Alternative would be anticipated. Any substantial changes to the design of approved construction projects would be performed in accordance with the Programmatic Agreement and may require additional NEPA analysis. If a construction, demolition, or infrastructure project involving ground disturbing activities results in an unanticipated discovery of archaeological resources, NASA would cease work and follow the procedures outlined in the Programmatic Agreement for post review discoveries, which include consulting with VDHR and other consulting parties, as appropriate, on the eligibility of the discovery and identifying the appropriate treatment measures. Additional NEPA analysis may be required.

##### 3.18.2.1.2 Operational Missions and Activities

Under the No Action Alternative, WFF would conduct operational programs that are within the installation's current envelope. All operational programs under the No Action Alternative have been covered by previous NEPA and NHPA documents; therefore, there would be no additional impacts to cultural resources from operational missions and activities under the No Action Alternative.

#### 3.18.2.2 Proposed Action

##### 3.18.2.2.1 Institutional Support Projects

**Archaeological**

With the exception of the Runway 04/22 extension, the institutional support projects proposed to be implemented under the Proposed Action would not affect any known NRHP-eligible archaeological sites. The proposed extension of Runway 04/22, however, is near one known archaeological site (44AC0103). Site 44AC0103 has not been evaluated to determine its NRHP eligibility. In accordance with the *WFF Programmatic Agreement for Management of Facilities, Infrastructure, and Sites* (NASA 2014, 2016), NASA would consult with VDHR prior to construction to determine whether further archaeological survey or evaluation is warranted. If after consultation with VDHR, NASA determines that further efforts are needed, then WFF would develop and implement an archaeological testing program sufficient to identify any potentially eligible sites present within the area of potential effects for the Runway 04/22 extension and determine conclusively the NRHP eligibility of those sites and site 44AC0103 in consultation with VDHR.

Although the remaining institutional support projects would not adversely affect known NRHP-eligible archaeological sites, there remains the possibility of encountering unknown sites through implementation of these actions. In accordance with the Programmatic Agreement, prior to commencing any ground disturbing activity, NASA would consult the predictive model and archaeological sensitivity maps to determine if there is a moderate to high probability of encountering archaeological materials, and, if so, would consult with VDHR to determine whether further archaeological survey is warranted. If consultation determines that further efforts are needed to identify archaeological sites, NASA would develop and implement an archaeological testing program in consultation with the SHPO. The testing program would be of a sufficient level to identify resources within the area of potential effects and determine conclusively their eligibility for listing on the NRHP. NASA would consult with the VDHR on the results of the identification survey and present a finding of effect to the VDHR. No ground disturbing activities would occur in areas of increased cultural sensitivity until the Section 106 process is completed.

NASA WFF personnel would make all reasonable efforts to avoid disturbing known gravesites including those containing Native American human remains and associated funerary artifacts. All human remains would be treated in a manner consistent with Section XIII Human Remains of the *WFF Programmatic Agreement for Management of Facilities, Infrastructure, and Sites* (NASA 2014, 2016). In the case of inadvertent discovery of human/ancestral remains and/or cultural resources during construction, the WFF Cultural Resources Manager would immediately halt activities and notify the appropriate Tribal governments; the VDHR; and, for remains, the coroner and local law enforcement, as to the treatment of the remains and/or archaeological resources.

Locations of piles for the Causeway Bridge or Launch Pier O-D (oceanside) have yet to be identified. Likewise, particular dredging methods have yet to be defined for maintenance dredging or development of the North Wallops Island Deep-water Port and Operations Area or Launch Pier O-D (creekside). It is possible that pile driving and dredging operations may affect unidentified cultural resources. If any of these projects were carried forward, NASA would consult with VDHR to develop an acceptable pile-driving plan or dredge plan applicable to each specific project that outlines applicable procedures in the event that unidentified cultural resources are identified in a pile-driving or dredging area.

**Architectural Resources**

The majority of buildings and structures included in the proposed demolition or renovation projects under the Proposed Action have been evaluated and determined to be not eligible for inclusion in the NRHP. WFF is in the process of inventorying and evaluating the NRHP eligibility of the remaining 8 structures (D-049, F-019, F-021, F-162, U-090, X-091, Y-046, and Y-061) that would be renovated or demolished under the Proposed Action as part of the architectural survey of buildings and structures built between 1965 and 1981 The results of the Historic Resources Eligibility Survey and Section 106 consultation with VDHR will be included in the Final PEIS.

**Traditional Cultural Properties**

No traditional cultural properties are known to exist in the project areas within the WFF boundaries; therefore, none would be impacted by implementation of the proposed institutional support projects under the Proposed Action. Should a tribal official determine unknown traditional cultural properties are located within the proposed project areas and would be potentially impacted, all undertakings would cease until appropriate consultation has been completed.

Refer to **Section 4.1.11** (Cultural Resources) for measures to mitigate impacts to cultural resources under the Proposed Action.

3.18.2.2.2 Operational Missions and Activities

As documented in **Appendix G** of the Programmatic Agreement, WFF, the SHPO, and Advisory Council on Historic Preservation, determined that the following NASA WFF activities have limited potential to affect historic resources and do not require review under the Agreement (NASA 2014).

Launch Operations:

- Launch and flight of orbital and suborbital rockets, missiles, projectiles, targets, or tethered or free-floating balloons from the WFF Launch Range on Wallops Island or from the Main Base airfield.
- Jettison of flight hardware (e.g., spent rocket motor, scientific payload, nosecone, etc.) into the Atlantic Ocean and subsequent recovery (if warranted).

Aircraft (Manned and Unmanned) Operations:

- Flight of manned fixed or rotary wing aircraft from either of the WFF Main Base runways.
- Flight of unmanned fixed or rotary wing aerial systems from either the WFF Main Base runways or the North Wallops Island UAS airstrip.

**Archaeological**

None of the operational missions and activities proposed to be implemented under the Proposed Action involves ground disturbing activities. Vibrations from launch noise would be attenuated by distance to the source and by the soils above the archaeological resources. Therefore, operational missions and activities under the Proposed Action would have no effect on NRHP-eligible archaeological resources.

**Architectural Resources**

Of the 200 architectural resources at WFF that have been previously evaluated for their NRHP eligibility, only two, the Wallops Beach Lifesaving Station (V-065) and the associated steel frame Observation Tower (V-070) have been determined NRHP-eligible. The remaining 198 resources were found to be not eligible for inclusion in the NRHP.

High noise levels produced from launching the LFIC LV and SFHC LV may result in a short-term, indirect effect to the setting of the Station and the Observation Tower. Although launching of a LFIC LV and SFHC LV would generate a substantial amount of noise, effects of the noise would be temporary and infrequent; no more than 18 launches would be scheduled per year. As part of ongoing preservation and maintenance, following consultation with the SHPO, all glass windows have been removed from the Station, are wrapped and stored in the Station's basement, and the windows have been filled with plywood. Additionally, all LBP coated plaster has been abated from the structure. Since window glass and plaster are no longer part of the structure, neither can be damaged by vibrations from LFIC LV launches/LFIC RTLS landings or SFHC LV launches. Therefore, WFF has determined that launches of these vehicles would not adversely affect either the Station or the steel frame Observation Tower.

The noise associated with the launches and landings of horizontal flight vehicles would be typical of existing jet aircraft that utilize WFF, and would not adversely affect the setting of the Station and Observation Tower. The effects of noise from the launches and landings of vertical lift vehicles would be similar to those described above for the LFIC LV and SFHC LV launches. LFIC RTLS noise would be similar to the LFIC LV launch noise. However, a sonic boom could be generated during an RTLS supersonic descent. Application of notional LFIC RTLS event from the southeasterly direction indicates the Atlantic Ocean would intercept the majority of the sonic boom overpressure. Land areas within the descent trajectory could experience sonic boom overpressures; however, the intensity of the sonic boom would be highly dependent on the RTLS actual mission trajectory and atmospheric conditions at the time of flight (BRRC 2017). Due to its temporary and intermittent nature, a sonic boom overpressure would not diminish the integrity of setting of the Station and Observation Tower. Therefore, WFF has determined that launches of these vehicles would not adversely affect either the Station or the steel frame Observation Tower.

Substantial changes to the visual character or physical features within the current setting of off-site historic properties from launch operations under the Proposed Action would not be expected. Vehicle launches would be from the north end of Wallops Island and over water within the restricted airspace. Vehicles would not fly over any populated areas. Therefore, operational missions and activities would have no effect to off-site historic properties.

**Traditional Cultural Properties**

No traditional cultural properties are known to occur in the project area and therefore none would be impacted by implementation of the proposed operational missions and activities under the Proposed Action. Should a tribal official determine unknown traditional cultural properties are located within the area and would be impacted, all undertakings would cease until appropriate consultation has been completed.

Refer to **Section 4.1.11** (Cultural Resources) for measures to mitigate impacts to cultural resources under the Proposed Action.

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# 4.0 MITIGATION AND MONITORING

Mitigation refers to additional action taken to avoid, minimize, rectify, reduce, eliminate, or provide compensation for an adverse impact. Specifically, CEQ regulations (40 CFR 1508.20) define mitigation to include 1) avoiding the impact altogether by not taking a certain action or parts of an action; 2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; 3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; 4) reducing or eliminating the impact over time by preservation and maintenance operations during the lifetime of the action; and 5) compensating for the impact by replacing or providing substitute resources or environments. Mitigation measures can be short- or long-term and include operational measures and/or technology based methods designed to avoid, minimize, remediate, or compensate for environmental impacts.

Section 4.1 describes NASA's proposed mitigation measures, by resource category, for implementing the Proposed Action. The mitigation measures described in this chapter also include measures implemented by NASA to avoid and minimize impacts to the extent practicable on an ongoing basis as part of BMPs and agreed upon approaches with appropriate agencies, compliance with permit requirements, and adherence to various management plans previously mentioned in the Environmental Consequences sections in Chapter 3 of this PEIS. Only those resource areas with mitigation measures proposed are included in this section.

Sections 4.2 and 4.3 provide descriptions of the potential Federal and state level programs that would be considered as possible avenues that WFF could use in a partnership role in the foreseeable future. Looking forward over the 20-year horizon envisioned by the 2008 WFF Facility Master Plan that this Site-wide PEIS addresses, there are a number of possibilities for creative partnerships with respect to future mitigation opportunities at both the Federal and state level. For example, to offset unavoidable wetland impacts, WFF would minimize and mitigate to the extent practicable. For unavoidable impacts, WFF may function as a contributor of funds consistent with an "in lieu fee" mitigation approach; act as a matching fund sponsor; or possibly secure grants from one of the Federal, state, or local programs that work to preserve wetlands to demonstrate resources stewardship.

Once implementation of a Proposed Action is underway, a Federal agency has a responsibility to continually monitor that implementation to ensure that mitigation or other protective measures are being employed. Section 4.4 provides a summary of NASA's proposed monitoring of various resource areas during implementation of the Proposed Action. Lastly, Section 4.5 provides a description of the adaptive management process in which NASA would implement new or modify existing mitigation measures. These measures would be identified through the monitoring process and by assessment of new data throughout the life cycle of the proposed projects.

## 4.1 MITIGATION MEASURES

### 4.1.1 NOISE

Due to the potential impacts from noise identified in Section 3.1, NASA may consider several mitigation measures designed to lessen the impact on the local environment and neighboring communities.

- Construction activities associated with institutional support projects may be limited to normal daytime working hours.

- Time of year restrictions for pile driving activities could be employed to reduce impacts on spawning marine mammals or nesting seabirds upon the recommendation of NMFS or USFWS.
- Pile driving associated with the Causeway Bridge Replacement may require the use of mitigation measures (e.g., bubble curtains) to minimize underwater noise impacts.
- NASA personnel and the public would be notified in advance of all static fire tests and suborbital and orbital rocket launch and landing dates and times.

### 4.1.2 Air Quality

As discussed in Section 3.2, construction activities related to institutional support projects have the potential to impact air quality due to increased emissions from construction equipment and fugitive particle emissions. The amount of these increases would depend on various factors including amount of construction-related traffic and other vehicle traffic, amount of exposed soil, and local climate conditions and weather patterns. During construction activities, BMPs would be implemented in order to mitigate all construction-related emissions and may include engine idling limitations, lower speed limits, traffic re-routing, and dust suppression techniques. Dust suppression techniques may include but not be limited to:

- use, where possible, of water or chemicals for dust control,
- installation and use of hoods, fans, and fabric filters to enclose and vent the handling of dusty materials,
- covering of open equipment for conveying soil and or dusty materials, and
- prompt removal of spilled or tracked dirt or other materials from paved streets and removal of dried sediments resulting from erosion.

WFF would accept permit limits on the amount of run hours for new generators or other systems (boilers, hot water heaters) as a measure to lower emissions of pollutants.

### 4.1.3 Hazardous Materials, Toxic Substances, and Hazardous Waste

The WFF ICP, developed by NASA to meet the requirements of 40 CFR Part 112 (Oil Pollution Prevention and Response), 40 CFR Part 265 Subparts C and D (Hazardous Waste Contingency Plan), and 9 VAC 25-91-10 (Oil Discharge Contingency Plan), serves as the facility's primary guidance document for the prevention and management of oil, hazardous material, and hazardous waste releases (NASA 2015). For those projects involving hazardous materials, toxic substances, and hazardous waste as addressed in Section 3.3, the ICP outlines procedures for dealing with hazardous materials and hazardous waste and would be implemented in all aspects of the Proposed Action in order to mitigate potential impacts from hazardous materials and hazardous waste.

### 4.1.4 Health and Safety

A complete list of potential impacts to human health and safety can be found in Section 3.4. Safety Plans would be prepared, implemented and followed for various institutional and operational projects. Federal contractors would follow regulations defined in Federal Acquisition Regulation 52.236-13, *Accident Prevention.* Causeway Bridge construction would follow the procedures presented in *Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects* administered by the FHWA. To ensure the health and safety of mariners and civil aircraft, NOTMARs and NOTAMs would continue to be issued whenever R-6604 airspace units A-E are activated.

### 4.1.5 WATER RESOURCES

A complete list of potential impacts to water resources can be found in Section 3.5. As required by the 404(b)(1) guidelines, only the LEDPA can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable. Potential mitigation measures for specific projects are listed below.

For each institutional support project (refer to **Table 2.5-1** and **Table 2.5-2**) that would disturb greater than 930 $m^2$ (10,000 $ft^2$) of land or would be located within 30.5 m (100 ft) of a wetland or drainage structure, a VSMP permit would be prepared during which NASA would identify all stormwater discharges at the site, actual and potential sources of stormwater contamination, and would require the implementation of BMPs to reduce the impact of stormwater runoff on nearby receiving waters. BMPs could include using vegetative and structural protective covers (e.g., permanent seeding, groundcover), sediment barriers (e.g., straw bales, silt fencing, brush), constructing water conveyances (e.g., slope drains, check dam inlet, and outlet protection), and repairing bare and slightly eroded areas quickly. NASA would implement BMPs for vehicle and equipment fueling and maintenance and spill prevention and control measures to reduce potential impacts to surface water during construction. BMPs would include items such as ensuring equipment is in good working condition, maintaining spill kits and clean-up materials on site, and using drip pans and absorbent pads. Additional BMPs may include:

- Machinery and construction vehicles would be operated outside of stream-beds and wetlands; synthetic mats may be used when in-stream work is unavoidable.
- The top 30 cm (12 inches) of trench material removed from wetlands would be preserved for use as wetland seed and root-stock in the excavated area.
- Erosion and sedimentation controls would be designed in accordance with the most current edition of the Virginia Erosion and Sediment Control Handbook. These controls would be in place prior to clearing and grading, and maintained in good working order to minimize impacts to state waters. The controls would remain in place until the area stabilizes.
- Heavy equipment, located in temporarily impacted wetland areas, would be placed on mats, geotextile fabric, or other suitable measures to minimize soil disturbance to the maximum extent practicable.
- All temporarily disturbed wetland areas would be restored to pre-construction conditions and planted or seeded with appropriate wetlands vegetation in accordance with the pre-disturbance cover type (emergent, scrub-shrub, or forested).
- All stabilization materials which are temporarily stockpiled in wetlands, would be placed on mats or geotextile fabric in order to prevent entry into state waters. These materials would be managed in a manner that prevents leachates from entering state waters. Within thirty days following completion of the construction activity, all stockpiled materials would be removed and disturbed areas would be returned to their original contours, stabilized, and restored to the original vegetated state.
- In-stream activities would be conducted during low or no-flow conditions, wherever feasible.

- No more than 50 percent of the streamflow would be blocked at any given time.
- Original streambed and streambank contours would be restored.
- All non-impacted surface waters within the project or right-of-way limits that are within 15 m (50 feet) of any clearing, grading, or filling activities would be clearly flagged or marked for the life of the construction activity within that area. The project proponent would notify all contractors that these marked areas are surface waters where no activities are to occur.
- Barren areas would be revegetated with native vegetation.
- Floodplain culverts would be installed to carry bank-full discharges.
- Stream crossings would be constructed using clear-span bridges to avoid future maintenance costs associated with culverts and the loss of riparian and aquatic habitat. However, if this is not possible, culverts would be countersank below the streambed at least 15 centimeters (6 inches) or bottomless culverts would be installed to allow the passage of aquatic organisms.
- Concrete would be installed "in the dry" using either the Tremie method (e.g., using a pipe through which concrete is placed below water level), grout bags, or wet concrete, to ensure the concrete has hardened and cured prior to contact with open water.
- Measures would be employed to prevent spills of fuels or lubricants into state waters.

Each of the water-related projects (i.e., Causeway Bridge Replacement, maintenance dredging of the existing barge channel and two boat basins, and development of the North Wallops Island Deep-water Port and Operations Area and Launch Pier 0-D) may require turbidity curtains or operational controls of the dredges to minimize the amount and extent of the elevated in-water turbidity during construction. Cofferdams could be used to drive sheet walls around the base support structures of the old Causeway Bridge, which would allow the inner surrounding area to be dewatered to enable demolition of the structure. For work that may increase vessel traffic, restrictions may be placed on the number of trips taken by each vessel and shallow draft vessels may be used. For dredging projects, the shoal material removed during dredging projects would be placed either in temporary upland holding areas or directly on the beach as a beneficial reuse if the material is beach quality and this disposal method is practicable. Past dredging practices have used thin layer deposition into shallow open waters with the intent of converting these open water areas to productive salt marsh. Although not planned at this time, the use of thin layer deposition of dredged material in open shallow water has been used in the past as a beneficial reuse of dredged material to convert open water shallow areas into salt water wetlands. If this were an acceptable means of reuse with the support of the natural resource agencies (e.g., USACE and EPA), further NEPA analysis may be needed to assess the environmental impacts of this method of reuse and disposal.

Any wetlands present in the areas of the construction projects not previously delineated would be delineated and the limits confirmed by USACE. Project designs would include evaluation of alternatives and avoidance and minimization measures to reduce potential impacts to wetlands. If after the avoidance and minimization process it is determined that wetlands would be unavoidably impacted, those wetlands proposed to be impacted would be addressed in CWA Section 404 permits secured from USACE, VDEQ and the Accomack County Wetlands Board. The placement of structures within navigable waters of the U.S. would be permitted by the USACE/VDEQ pursuant to Section 10 of the Rivers and Harbors Act.

Deluge water for LFIC LV and SFHC LV launches from Launch Pad 0-C or Launch Pier 0-D would be discharged to a lined retention basin where it would be allowed to cool. After cooling, the retained water would be tested for temperature (at ambient); pH (between 6 and 9); and, if a visible sheen is present from RP-1 fuel, for TPH (0.0 ppm) before being released to an unlined infiltration and evaporation basin. If required, the deluge water would be treated (e.g., pH adjustment) before release or removed for disposal if it does not meet the standards for discharge to surface waters as stipulated in the VPDES permit. To increase the pH prior to discharge into surface waters, sodium bicarbonate (baking soda) would be used. The release may occur over a period of several days due to the large quantity of water to be discharged (NASA 2009). If TPH is detected above 0 ppm, the deluge water would be containerized and disposed of at a licensed Treatment Storage and Disposal Facility. Additionally, WFF would comply with the stipulation of the Wallops Island VPDES permit to perform and report TPH and pH monitoring of the outfall from the infiltration basin to Hog Creek. Deluge systems would be evaluated against potable water withdraw limits.

WFF is in the process of developing a wetland management plan. The plan would include avoidance measures and appropriate wetland mitigations to ensure no net loss of wetlands and would consider the potential impacts to protected species and high functional value wetlands. As the plan progresses, WFF would consult with EPA, USACE, and USFWS.

### 4.1.6 Land Resources

In order to minimize the impacts of erosion from construction activities as addressed in Section 3.7, Land Resources, site-specific Erosion and Sediment Control Plans would be developed and utilized to ensure that soil erosion during construction is minimal. These plans would implement BMPs that are outlined in the facility's SWPPP and Erosion and Sediment Control Plan. These BMPs could include using silt fencing; soil stabilization blankets; and matting construction entrances, material laydown areas, and around areas of land disturbance during construction. Bare soils would be vegetated after construction to reduce erosion and stormwater runoff velocities.

### 4.1.7 Vegetation

To mitigate the potential for allowing the expansion of invasive species such as *Phragmites*, an invasive species management plan has been developed by WFF and would be followed at each construction and demolition project, if invasive species are located on the project site. These project-specific plans would be prepared consistent with the WFF *Phragmites Control Plan* (NASA 2014) and could include herbicidal spraying, burning, and mowing. None of the proposed projects would occur in or near a rare habitat; as such, the loss of rare habitats would not be anticipated.

### 4.1.8 Special-Status Species

A complete list of special-status species can be found in Section 3.10. To mitigate impacts to special-status species under the Proposed Action, NASA may adopt a variety of mitigation strategies applicable to the Main Base, Mainland, and Wallops Island. Specific mitigation measures may include, but are not limited to, the following:

- Installation of "turtle friendly" lighting and shielding where appropriate on all new facilities located near potential sea turtle nesting sites on Wallops Island. Illumination of these facilities would be kept at a minimum until operations or pre-launch preparations dictated their use. In addition, launch vehicle uplighting may be used on proposed Launch Pad 0-C and Launch Pier 0-D; however, it would only be in use when the LV is physically sitting on the launch pad, which would typically be no more than 5-10 days prior to launch.

- Both land and water based construction could be subject to both time of day and seasonal restrictions to mitigate impacts to special-status species. Restrictions could also be placed on construction materials and methods. Observers may also be required during pile driving and dredging activities and it is possible that all activity would be temporarily suspended in the event that a threatened or endangered species is identified in the vicinity of pile driving activities.
- Restrictions may be placed on the number of trips taken by each vessel and shallow draft vessels may be selected for water-related projects.
- Maintenance and/or new dredging activities would be required to adhere to dredging guidelines set forth by NMFS and the Commonwealth of Virginia. Dredging activity may also be subject to time of day and seasonal restrictions.
- NASA would continue beach surveys in accordance with the WFF Protected Species Monitoring Plan and would continue to adhere to the terms and conditions of the Incidental Take Statement pursuant to the USFWS Programmatic BO for proposed and ongoing operations and the SRIPP (USFWS 2016).
- NASA would maintain a 200 m (660 ft) buffer around bald eagle nest sites and would coordinate monitoring and results with USFWS to determine if mitigation measures are adequate or if they are in need of modification.
- NASA would not conduct tree removal activities between June 1 to July 31 to reduce any impacts to the northern long-eared bat. Should NASA deem it necessary to remove trees of 7.6 cm (3 inches) in diameter at breast height or greater between June 1 and July 31, it will either:
    - Conduct a bat emergence survey (1 surveyor per 10 trees) 1 to 2 days prior to the scheduled tree removal and report results to USFWS, or
    - Conduct a presence/absence survey of the affected area, employing a qualified bat surveyor and report results to USFWS.
- NASA would coordinate with VDCR-DNH as specific projects are planned, to determine potential impacts to natural heritage resources and if surveys are needed.
- NASA would coordinate with USFWS and VDGIF to ensure compliance with protected species legislation.
- NASA would contact VDCR-DNH to secure updated information on natural heritage resources if the scope of the proposal changes and/or six months has passed before it is implemented.
- NASA would coordinate with VDGIF and USFWS on projects proposed to impact undisturbed ground and wildlife habitats, and/or projects that may impact migratory flyways and foraging spaces for protected bird and bat species.

- NASA would continue to conduct agreed upon annual biological monitoring, in close coordination with VDGIF, NMFS, and the USFWS, to ensure that effective monitoring protocols are followed and that participants are appropriately permitted to perform the monitoring work.
- NASA would annually develop updated maps of documented species and their habitats, and provide these maps to WFF management and staff so that planning around protection of documented wildlife species and resources can occur.

### 4.1.9 MARINE MAMMALS AND FISH

To mitigate impacts to marine mammals and fish under the Proposed Action, NASA may adopt a variety of mitigation strategies applicable to the Main Base, Mainland, and Wallops Island. Specific mitigation measures may include, but are not limited to, the following:

- Both land and water based construction could be subject to both time of day and seasonal restrictions in order to mitigate impacts to special-status species. Restrictions could also be placed on construction materials and methods. Restrictions, including project-specific monitoring, would be established during consultation with the resource agencies. Observers may also be required during pile driving or dredging activities and it is possible that all activity would be temporarily suspended in the event that a marine mammal is identified in the vicinity of pile driving or dredging activities.
- Measures may be implemented to ensure no net loss of EFH due to construction activity.
- Maintenance and/or new dredging activities would be required to adhere to dredging guidelines set forth by NMFS and the Commonwealth of Virginia. Dredging activity may also be subject to time of day and seasonal restrictions.
- Restrictions may be placed on the number of trips taken by each vessel and shallow draft vessels may be used for water-related projects.

### 4.1.10 TRANSPORTATION

To mitigate impacts to transportation under the Proposed Action, NASA may adopt a variety of mitigation strategies applicable to the Main Base, Mainland, and Wallops Island. Specific mitigation measures may include, but are not limited to, the following:

- Coordinate all transportation activities, including road closures, traffic control, safety issues, etc. with Accomack County and VDOT Accomack Residency Office and issue NOTAMS or NOTMARs and activate R-6604, as necessary.
- Provide adequate advance notification to the public of upcoming construction-related activities or movement of launch vehicles or spacecraft that would affect traffic by temporary road closures or traffic re-routing.
- Coordinate any traffic lane or pedestrian corridor closures with all appropriate officials.
- Locate construction equipment and vehicle staging so as to not hinder traffic and pedestrian flow.
- Minimize the use of construction vehicles in residential areas.

- Develop a traffic plan for activities such as LFIC LV and SFHC LV launches to ensure that traffic congestion is minimized to the extent possible and that emergency vehicles and priority operational missions are not compromised.

### 4.1.11 CULTURAL RESOURCES

To mitigate impacts to cultural resources under the Proposed Action, NASA may adopt a variety of mitigation strategies applicable to the Main Base, Mainland, and Wallops Island. Specific mitigation measures may include, but are not limited to, the following:

- In accordance with the *WFF Programmatic Agreement for Management of Facilities, Infrastructure, and Sites* (NASA 2014, 2016), NASA would consult with VDHR prior to construction of the extension of Runway 04/22 to determine whether further archaeological survey or evaluation is warranted. If after consultation with VDHR, NASA determines that further efforts are needed, then WFF would develop and implement an archaeological testing program sufficient to identify any potentially eligible sites present within the area of potential effects for the Runway 04/22 extension and determine conclusively the NRHP eligibility of those sites as well as site 44AC0103 in consultation with VDHR.
- In accordance with the Programmatic Agreement, prior to commencing any ground disturbing activity, NASA would consult the predictive model and archaeological sensitivity maps to determine if there is a high probability of intact archaeological subsurface materials and undertake an archaeological survey to identify resources within the area of potential effects. NASA would consult with VDHR on the results of the identification survey and present a finding of effect to VDHR. No ground disturbing activities would occur in areas of increased cultural sensitivity until the Section 106 process is completed.
- In case of inadvertent discovery of human/ancestral remains and/or cultural resources during construction, the WFF Historic Preservation Officer would immediately halt activities and notify the appropriate Tribal governments, the VDHR, and, for remains the coroner and local law enforcement, as to the treatment of the remains and/or archaeological resources.
- While locations of piles or particular dredging methods have yet to be defined for any of the relevant projects, it is possible that either activity may affect unidentified cultural resources. If any of the relevant projects were carried forward, NASA would consult with VDHR to develop an acceptable pile-driving plan or dredge plan applicable to each specific project that outlines applicable procedures in the event that unidentified cultural resources are identified in a pile-driving or dredging area.

## 4.2 FEDERAL LEVEL CREATIVE PARTNERSHIPS UNDER CONSIDERATION FOR FUTURE

There are a number of possibilities for creative partnerships with respect to future mitigation opportunities at both the Federal and state level to offset unavoidable wetland impacts. This section provides descriptions of the potential programs at the Federal level that could be considered to offset wetland losses at WFF in the foreseeable future. For example, WFF might contribute funds consistent with an "in lieu fee" mitigation approach, become a matching fund sponsor, or secure grants.

### 4.2.1 USDA Conservation Reserve Program

The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Annual rental payments and cost-share assistance is provided for the establishment of long-term, resource conserving covers on eligible farmland. To be eligible for placement in the CRP, the land must either be cropland that is planted or capable of being planted with an agricultural product four of the previous six years or be marginal pastureland that is suitable for use as a riparian buffer or for similar water quality purposes (USDA 2017).

The Commodity Credit Corporation makes annual rental payments based on the agriculture rental value of the land and provides cost-share assistance for up to 50% of the participant's costs in establishing approved conservation practices. Participants enroll in CRP contracts for 10 to 15 years. Virginia had a total enrollment of 20,802 ha (51,403 ac) into the CRP program in 2016. Accomack County had 318 ha (787 ac) enrolled (USDA 2016).

### 4.2.2 USDA Healthy Forests Reserve Program

The USDA Healthy Forests Reserve Program (HFRP) was signed into law as part of the Healthy Forests Restoration Act of 2003; it was amended in the 2008 Farm Bill. The purpose of the HFRP is to assist landowners (on a voluntary basis) in restoring, enhancing, and protecting forestland resources on private lands through easements, 30-year contracts, and 10-year cost-share agreements. The objectives of HFRP are to:

- Promote the recovery of special-status species under the ESA.
- Improve plant and animal biodiversity.
- Enhance carbon sequestration.

Restoring and protecting forests contributes to the economy, provides biodiversity of plants and animal populations, and improves environmental quality (USDA 2017).

Landowner protections will be made available to landowners enrolled in HFRP who agree, for a specified period, to restore or improve their land for threatened or endangered species habitat. In exchange they avoid certain regulatory restrictions under the ESA on the use of that land. In addition, the HFRP provides financial assistance in the form of easement payments and cost-share for specific conservation actions completed by the landowner (USDA 2017). USDA offers three HFRP enrollment options:

- A 10-year restoration cost-share agreement, for which the landowner may receive 50% of the average cost of the approved conservation practices.
- A 30-year easement, for which the landowner may receive 75% of the easement value of the enrolled land plus 75% of the average cost of the approved conservation practices.
- Permanent easements, for which landowners may receive 100% of the easement value of the enrolled land plus 100% the average cost of the approved conservation practices (USDA 2017).

In 2015, the program expanded the eligibility of acreage owned by Indian tribes (USDA 2017).

### 4.2.3 USFWS Landscape Conservation Cooperatives

The CNWR is located in the North Atlantic Landscape Conservation Cooperative (LCC), of which USFWS is an active participant. LCCs are public-private partnerships composed of states, tribes, Federal agencies, non-governmental organizations, universities and others that were established by Department of the Interior (DOI) Secretarial Order Number 3289, signed on September 14, 2009. The cooperatives are intended to address landscape-scale stressors, including climate change, and to work interactively with DOI Climate Science Centers to help coordinate regional adaptation efforts. There are 22 LCCs, covering all states and territories of the U.S. and adjacent areas of Canada, Mexico and the Caribbean, and transcending political and jurisdictional boundaries to create a networked approach to conservation. The geographic areas were developed by a team of USFWS and USGS scientists and experts by aggregating Bird Conservation Regions. Other frameworks, such as the Freshwater Ecoregions of the World, were also referenced. The LCC effort is coordinated with other partnerships, such as the National Fish Habitat Action Plan, Migratory Bird Joint Ventures and the State and Tribal Wildlife Grants Program.

LCCs were developed with the recognition of the DOI and others that in order to ensure landscapes that are resilient and can sustain natural resources and cultural heritage into the future, conservation agencies and partners need to work together at landscape scales to address increasing land use pressures and widespread resource threats and uncertainties amplified by multiple effects of a rapidly changing climate including sea-level rise and increased frequency and intensity of coastal storms.

There are three components to the LCC initiative: the LCC network, the individual LCCs, and LCC partners. The LCC network provides a national forum for conservation planning and is intended to integrate the efforts of 22 LCCs organized, governed and operated in a consistent manner that promotes landscape conservation. LCCs are regional, science-management partnerships directed by a steering committee, supported by several technical teams and facilitated by a small staff. The LCCs improve data sharing, communication and coordination across and within agencies; provide and leverage funding, staff and resources; develop common goals, tools, and strategies; link science to management; and facilitate information exchange (USFWS 2017).

USFWS Region 5 is a member of the North Atlantic LCC steering committee and has the lead role for staffing and facilitating the partnership. The LCC has a science strategic plan, operations and development plan, and a number of collaborative active projects that are focused on providing science and information to guide conservation planning and actions in the face of change. These projects include regional habitat and species climate change vulnerability assessments, a project to forecast effects of accelerating sea-level rise on the habitat of Atlantic Coast piping plovers (with an initial focus on Assateague); the Designing Sustainable Landscapes project that is assessing landscape changes including climate change and urban growth on species, habitats and systems in the LCC, and a research and decision support framework to evaluate sea-level rise impacts in the northeastern U.S.

## 4.3 State Level Creative Partnership Under Consideration for the Future

As stated previously, there are a number of possibilities for creative partnerships with respect to future mitigation opportunities at both the Federal and state level to offset unavoidable wetland impacts. The Commonwealth of Virginia has enacted laws that are specifically targeted at land conservation. These programs are noted below.

### 4.3.1 Virginia Office of Farmland Preservation and Virginia Farmland Preservation Fund

Virginia Code Section 3.2-200 *et seq.* establishes the Office of Farmland Preservation within the Virginia Department of Agriculture and Consumer Services (VDACS), which has the following five missions:

- To work with other governmental and private organizations to help establish local purchase of development rights programs by creating model policies and practices, establishing criteria to certify programs as eligible to receive funds from public sources, and determining methods and sources of funding for localities to purchase agricultural conservation easements.
- To create programs to educate the public about the importance of farmland preservation.
- To help farmers with farmland preservation efforts.
- To assist local governments in developing additional farmland preservation policies and programs.
- To administer the Virginia Farm Link program, which provides assistance to retiring farmers and individuals seeking to become active farmers in the transition of farm businesses and properties from retiring farmers to active farmers (VDACS 2016).

The Virginia Farmland Preservation Fund was established in 2007 for the sole purpose of preserving farmland in the Commonwealth. Administered by VDACS, these funds are distributed as grants to support local purchase of development rights programs under policies, procedures, and guidelines developed by the Office of Farmland Preservation. In general, for each $1 in grant funds awarded by the Office of Farmland Preservation, the applicable local purchase of development rights program of the county or city is required to provide a $1 match. Since 2007, a total of $10.46 million in state matching funds from the Virginia Farmland Preservation Fund has been used to protect 11,401 acres of farmland (VDACS 2016). A total of $9.7 million in farmland preservation grants distributed from VDACS has been allocated since 2008, including funding of $1.58 million to 6 Virginia localities in 2015. More than 8,015 acres on 59 farms in 15 localities have been permanently protected in part with Virginia Farmland Preservation Funds (Commonwealth of Virginia 2015).

### 4.3.2 Virginia Land Conservation Foundation and Virginia Land Conservation Fund

Virginia Code Section 10.1-1017 *et seq*. addresses the foundation, which was established in 1999 to provide Commonwealth funding used to conserve certain open spaces and parks, natural areas, historic areas, and farmland and forest preservation. Funds from the foundation are used to establish permanent conservation easements and to purchase open spaces and parklands, lands of historic or cultural significance, farmlands and forests, and natural areas. Commonwealth of Virginia agencies, local governments, public bodies and registered (tax-exempt) nonprofit groups are eligible to receive matching grants from the foundation. The Virginia Land Conservation Fund is managed by the foundation (Virginia Land Conservation Foundation 2015).

Between 1999 and 2015, the General Assembly allocated more than $49.5 million to the Virginia Land Conservation Fund, including $10.3 million to the Virginia Outdoors Foundation. These funds leverage additional conservation dollars from Federal, local, and private sources. In 2015, the Virginia Land Conservation Foundation Grant Program approved $1.78 million and 14 grants. Applications may be submitted by public bodies (localities, regional park authorities, Soil and Water Conservation Districts) and registered tax-exempt nonprofit organizations (Virginia Land Conservation Foundation 2015).

### 4.3.3 Virginia Open-Space Land Act and Open-Space Lands Preservation Trust Fund

Virginia Code Section 10.1-1700 *et seq*. addresses open-space land, defined as any land which is provided or preserved for park or recreational purposes; conservation of land or other natural resources; historic or scenic purposes; assisting in the shaping of the character, direction, and timing of community development; wetlands; or agricultural and forest production. The code allows public bodies to acquire by purchase, gift, devise, bequest, grant, or otherwise title to or any interests or rights of not less than 5 years' duration in real property that will provide a means for the preservation or provision of open-space land. It also allows public bodies to designate any real property in which it has an interest of not less than 5 years' duration to be retained and used for the preservation and provision of open-space land. Any such interest may also be perpetual.

Virginia Code Section §10.1-1801.1 *et seq*. establishes the Virginia Open-Space Lands Preservation Trust Fund, which helps landowners cover costs of conveying conservation easements and the purchase of all or part of the value of the easements. Conservation easements preserve farmland, forestland, and natural and recreational areas by restricting intensive uses, such as development and mining, which would alter the conservation values of the land.

## 4.4 Monitoring

Under NEPA, a Federal agency has a continuing duty to gather and evaluate new information relevant to the environmental impact of its actions. For the SRIPP, NASA developed a monitoring reporting plan. This plan includes steps for notifying regulatory agencies prior to commencing offshore shoals and dredging operations, species monitoring of the offshore shoals during pre- and post-dredging, and reporting the pre- and post-dredging hydrographic data. Qualified personnel will monitor the activities to ensure consistency with regulatory requirements (NASA 2011b). Below is a summary of NASA’s proposed monitoring of various resource areas during institutional support projects and operational missions and activities. Monitoring and reporting plans may be developed for projects under the Proposed Action to ensure that mitigation or other protective measures are being employed.

### 4.4.1 Water Resources

NASA maintains a SWPPP to ensure that its operations have minimal impact on stormwater quality (NASA 2016b). Scheduled samplings of stormwater drainage areas are performed in accordance with VPDES water quality monitoring requirements. Sample results are submitted to VDEQ in a monthly Discharge Monitoring Report and would continue to be submitted under the Proposed Action. NASA would continue to monitor: groundwater for contamination; groundwater usage compared to withdraw limits; the federally owned treatment works; stormwater outfalls; and launch pad deluge collection. Dredge material discharge, whether to the temporary holding areas, beach disposal area, or possible thin layer deposition, would be monitored to ensure that state water quality criteria are not exceeded.

### 4.4.2 VEGETATION

As stated in Section 4.1.7, an invasive species management plan has been developed by WFF and would be followed at each construction and demolition project, if invasive species are located on the project site. While this plan would apply to all invasive species, it would mitigate the potential impacts associated with controlling the spreading of *Phragmites*. WFF environmental staff would be responsible for post-construction monitoring for those areas disturbed by construction and demolition projects at WFF.

### 4.4.3 SPECIAL-STATUS SPECIES

WFF has been monitoring special-status species at Wallops Island for many years, either solely or through partnerships with other agencies, institutions, or research groups. In 2016, the various monitoring efforts were organized into the Wallops Island *Protected Species Monitoring Plan* (NASA 2011a). WFF would continue beach post-launch surveys for protected species in accordance with the plan and as well as the requirements outlined in the SRIPP monitoring reporting plan (NASA 2011b).

In an effort to further manage protected species, the USFWS BO for proposed and ongoing operations and the SRIPP outline launch specific monitoring (USFWS 2016). Following rocket launches, WFF must conduct surveys for injured, dead, or impaired birds and sea turtles. The surveys must be conducted as soon as safety permits following rocket launches and must be done using protocols laid out in the WFF *Protected Species Monitoring Plan*. Post-launch beach surveys would be conducted between March 15 and November 30 of every year to coincide with plover and sea turtle nesting seasons. The survey area must include the beach within 300 m (1,000 ft) to the north and south of the respective launch pad for sounding and orbital-class rockets. A report of the survey must be provided to USFWS within 15 business days of the launch event.

If additional consultation becomes required as details of the Proposed Action are understood better, NASA will consult with the USFWS to discuss the potential impacts to all listed species. This consultation may determine that additional monitoring activities would be necessary due to the institutional support projects and operational missions and activities presented under the Proposed Action.

The U.S. Air Force Instrumentation Tower on Wallops Island would also require monitoring for avian fatalities due to collisions with guy wires. This monitoring is required for two years, post-construction and requires personnel to walk transects of the tower footprint in search of dead or injured birds. This monitoring effort is detailed in the Appendix C of the EA for the Instrumentation Tower on Wallops Island (U.S. Air Force 2017).

NASA would consult with NMFS during the design phase of the replacement Causeway Bridge, maintenance dredging, North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D in order to avoid and minimize impacts to EFH. If noise attenuation measures are established during the consultation period, WFF would require the construction contractor performing pile driving to incorporate appropriate noise attenuation technology and to monitor those devises in order to ensure that appropriate zones of influence for pile driving are maintained. During bridge construction and dredging activities, a

NMFS observer may be required to be on site for any activity occurring between April 1 and November 30. If required, the observer would monitor bridge construction and dredging operations for evidence of sea turtle takes and would advise the construction foreman or dredge operator on proper precautions required to safely operate if sea turtles or marine mammals should be in the vicinity.

## 4.5 ADAPTIVE MANAGEMENT

Adaptive management is a tool to help agencies and organizations make better decisions in a context of uncertainty as more information becomes available. Adaptive management utilizes ongoing data collection and analysis to assess and, if necessary, to modify existing processes. The results of project performance and the effectiveness of existing mitigation and monitoring measures could validate existing practices or reveal the need for alterations in project implementation or mitigation techniques. By monitoring and evaluating how measures are working, NASA would ensure that mitigation measures are optimized.

# 5.0 CUMULATIVE EFFECTS

This section provides 1) a definition of cumulative effects, 2) a description of past, present, and reasonably foreseeable future actions relevant to cumulative effects, 3) an analysis of the incremental interaction the Proposed Action may have with other actions, and 4) an evaluation of cumulative effects potentially resulting from these interactions.

## 5.1 DEFINITION OF CUMULATIVE EFFECTS

CEQ regulations stipulate that the cumulative effects analysis (CEA) within an EIS should consider the potential environmental impacts resulting from "the incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions" (40 CFR 1508.7). CEQ guidance in *Considering Cumulative Effects under the National Environmental Policy Act* (1997) affirms this requirement, stating that the first steps in assessing cumulative effects involve defining the scope of the other actions and their interrelationship with the Proposed Action. The scope must consider geographic and temporal overlaps among the Proposed Action and other actions. It must also evaluate the nature of interactions among these actions.

Cumulative effects are most likely to arise when a relationship or synergism exists between a Proposed Action and other actions expected to occur in a similar location or during a similar time period. Actions overlapping with or in close proximity to the Proposed Action would be expected to have more potential for a relationship than those more geographically separated. Similarly, actions that coincide, even partially, in time would tend to offer a higher potential for cumulative effects.

To identify cumulative effects, the analysis needs to address three fundamental questions:

1. Does a relationship exist such that affected resource areas of the Proposed Action might interact with the affected resource areas of past, present, or reasonably foreseeable future actions?
2. If one or more of the affected resource areas of the Proposed Action and another action could be expected to interact, would the Proposed Action affect or be affected by impacts of the other action?
3. If such a relationship exists, then does an assessment reveal any potentially significant impacts not identified when the Proposed Action is considered alone?

## 5.2 SCOPE OF CUMULATIVE EFFECTS

Consistent with CEQ's 1997 guidance document, NASA followed a general four-step process in scoping this CEA. The first of the four steps was to identify the significant cumulative effects *issues* associated with the Proposed Action. Leveraging input provided by agencies and organizations during the scoping process for this PEIS as well as other recent NEPA documents, NASA was able to narrow the focus of this CEA to the issues most important to the reviewing audience. In summary, the majority of issues raised have been related to the aquatic environment, with a particular focus on wetlands and the related resources (e.g., water birds and fish) to which they provide ecological services. By employing this "sliding-scale" approach, NASA applied varying levels of analysis based upon the resource areas at hand. For example, a more detailed quantitative analysis is provided for wetlands, invasive species, and wildlife, whereas for other resource areas, including air quality and socioeconomics, a more qualitative analysis is presented.

The second step in scoping this CEA involved establishment of the *geographic boundaries* for the analysis. Starting with the expected geographic extent of effects resulting from the Proposed Action, NASA then determined the geographic boundaries of those resources affected. In most cases, these boundaries were larger than the ROI of the Proposed Action and, therefore, determined to be the most appropriate for assessment of cumulative effects. While some resource areas may share a common geographic extent, each boundary was determined on a resource-specific basis. As such, a more detailed discussion of each resource's geographic boundaries is provided in its respective Section in this CEA.

The third step in scoping this CEA involved establishment of the *temporal boundaries* for the analysis. Regarding the extent of time in the past to consider, the historic baseline for a CEA is often set at a major event changing the local environment. In the case of activities at WFF, this boundary has been established at the approximate date of a Federal presence on the Main Base and Wallops Island, which occurred in the mid-1940s. The future temporal boundary of this CEA centers on the timing of the Proposed Action. Specifically, although the planning horizon for this PEIS is 20 years, construction, demolition, or renovation activities are proposed for 2019 through 2025, with no known projects after 2025. The proposed operational missions and activities would begin in 2019 through the planning horizon.

The fourth and final step in scoping this CEA was the identification of *other actions* affecting the resources in common with the Proposed Action and, therefore, warranting inclusion in the analysis. A particular challenge during this phase was the determination of past actions to be included. Due to its lengthy historical past, there are projects at WFF whose impacts to the environment have reached a steady state condition, meaning the resource has adequately recovered before being exposed to a subsequent action or actions. According to CEQ's June 24, 2005, memorandum entitled *Guidelines on the Consideration of Past Actions in Cumulative Effects Analysis,* past actions should be included in a CEA if there are identifiable present effects of those past actions and those effects are useful in determining whether there is a possibility of a continuing, additive, and significant relationship to a Proposed Action (CEQ 2005).

For example, the Causeway Bridge was constructed in 1959 with substantial environmental impact at the time. It took several years for resources to recover; some wetlands were permanently lost, tidal currents were significantly altered, and estuarine habitat in the area of construction was permanently changed. Over time, the natural system adapted to alterations brought on by the Causeway Bridge construction and achieved a steady state condition.

For resources that have reached a steady state, there is no ongoing adverse or beneficial effect which could result in a cumulative effect; therefore, according to CEQ guidance, only past actions that are considered relevant are included in this CEA (e.g., changes to the course of the waterway resulting from the original construction of the Causeway Bridge have reached a steady state and, therefore, are not considered in this CEA). Additionally, consistent with CEQ guidance, in most cases, the analysis considers the aggregate effect of past actions rather than providing specific details about individual historic projects or activities.

Present and future actions were included in this CEA when they were determined to be at a level of conceptual maturity such that their environmental effects could be readily discerned. In general, for an action to be included, its proponent must have at least participated in some level of public review, including those prescribed by a Federal (e.g., NEPA), state (e.g., wetlands permit), or local (e.g., subdivision application) review process. As such, public documents prepared by Federal, state and local government agencies form the primary sources of information regarding past, present and reasonably foreseeable future actions. Documents used to identify such actions included notices of intent to prepare NEPA documents (i.e., EISs and EAs), management plans, land use plans, and other related planning studies.

## 5.3 CUMULATIVE EFFECTS OF PAST, PRESENT, AND REASONABLY FORESEEABLE FUTURE ACTIONS

### 5.3.1 PAST ACTIONS

The property that is now considered the Main Base was acquired in 1942 for use as the 900 ha (2,230 ac) Chincoteague Naval Auxiliary Air Station. By 1943, three runways and numerous buildings were constructed to train naval aviation units. The Chincoteague Naval Auxiliary Air Station closed in July, 1959 (USACE 2000).

In 1945, NASA's predecessor, the National Advisory Committee on Aeronautics, established a launch site on Wallops Island and designated the facility the Pilotless Aircraft Research Station. From 1945 to 1957, the Pilotless Aircraft Research Station served as a high speed aeronautical launch site where rockets were used to launch models of aircraft for aerodynamic and heat transfer research (EPA 1996; USACE 2000; NASA 2012a). When NASA was established in 1958, the Pilotless Aircraft Research Station became known as Wallops Station and NASA became involved in the civilian space program (NASA 2012a).

During the period from 1975 to 1981, the station became known as Wallops Flight Center and the Main Base began Earth studies of ocean processes (EPA 1996; NASA 2012a; USACE 2000). Once the facility consolidated with GSFC in 1982, the facility changed its name to Wallops Flight Facility.

For the purposes of the wetland CEA, the temporal extent is divided into two periods: 1) Pre-Federal "settlement", 1938 to present and 2) present through 2039, which is the temporal extent of actions evaluated in this PEIS. It is noted that there are currently no known institutional support projects after 2025. A summary of the historical wetland impacts from launch pad and Causeway Bridge construction and infrastructure and dredging activities for these two periods is presented in **Appendix H**, Table 3. A more detailed presentation and methodology to this analysis is presented in **Appendix H**.

### 5.3.2 PRESENT AND REASONABLY FORESEEABLE FUTURE ACTIONS

#### 5.3.2.1 NASA Activities

**SRIPP**

A ROD for the NASA SRIPP PEIS was signed on December 13, 2010 (NASA 2010). As part of the PEIS process, NASA analyzed three action alternatives and the No Action Alternative. Under the preferred alternative, Alternative 1, the existing rock seawall on Wallops Island would be extended a maximum of 1,400 m (4,600 ft) south of its southernmost point and a 6.0 km (3.7 mi) length of shoreline would be filled with beach quality sand dredged from an offshore sand shoal.

An initial seawall extension of approximately 435 m (1,430 ft) was implemented between August 2011 and March 2012 during the first year of the SRIPP, prior to the placement of the initial beach fill (NASA 2016). Further seawall extension may be completed in the future as funding becomes available. In addition, between April and August 2012, approximately 2,446,000 $m^3$ (3,200,000 $y^3$) of fill was placed along the Wallops Island shoreline starting approximately 460 m (1,500 ft) north of the Wallops Island-Assawoman Island property boundary and extending north to the terminus of the existing rock seawall (NASA 2010). The placement of the fill created an approximately 30 m (100 ft) wide beach and dune.

The scope of the SRIPP PEIS included the project's 50-year design life. As such, it considered the effects of regularly scheduled beach renourishment at an approximate frequency of every three to seven years. Accordingly, over the next 20 years, approximately three to four renourishment activities may occur. As a component of renourishment, NASA may dredge additional sand from the offshore shoals or may remove sand, as needed, from the north end of Wallops Island and bring it to the south end of the island. Prior to renourishment additional NEPA analyses would be performed. To mitigate potential direct impacts to listed species, should NASA decide to move sand from the north end of Wallops Island to the south, it would only do so outside of piping plover and sea turtle nesting seasons. Renourishment from dredging offshore shoals may occur year round. NASA would continue to monitor the dredge site as material is pumped onto ships and onto the shoreline to ensure consistency with the regulatory requirements.

As a result of storm damage incurred during Hurricane Sandy in late October 2012, WFF evaluated the need to repair its existing rock seawall at its southernmost point and to renourish the southern two-thirds of the recently filled Wallops Island beach in spring and summer 2014 (NASA 2013). Between July and September 2014, approximately 510,000 $m^3$ (667,000 $y^3$) of material was dredged from the same location as the initial beach fill and placed along the southern 3,962 m (13,000 ft) of Wallops Island (NASA 2016). With the exception of a shortened period between initial fill and the first renourishment, the project is essentially the same as that described in the SRIPP PEIS, which estimated that up to 205,000 $m^3$ (806,000 $y^3$) of material would be needed every three to seven years. The source of fill material for future renourishments would be the same borrow area utilized for the initial beach fill (NASA 2010).

WFF is currently evaluating the next Wallops Island beach renourishment. Hurricane Joaquin (2015) and Winter Storm Jonas (2016) reduced the sand volume in the southern portion of the island by an average of 1,014,337 cubic yards as compared to volumes present after the 2014 shoreline repair (USACE 2018). Additional sand volume reduction occurred in early 2018 with Winter Storm Riley. The 2019 renourishment cycle would require approximately 1.3 million cubic yards of sand sourced from either the north Wallops Island beach or dredged from the same offshore sand source as the initial and secondary beach fills. A series of offshore parallel breakwaters approximately 200 feet offshore from the renourished beach is being considered to slow the rate of sediment transport northward (NASA 2019).

**Reconfiguration of WFF Main Entrance**

The 2011 EA addressed the reconfiguration of the main entrance to the WFF. Under the Proposed Action, NASA proposed to reconfigure the main entrance to the WFF and construct a badge office and accompanying parking area, a truck inspection area, security personnel parking area, guard house and canopy, traffic roundabout, and a shipping and receiving facility in a forested area along Atlantic Road. The preferred alternative was to complete in either two or four phases, with the number of phases directly related to available funding, resulting in the same design at final build out. The total project proposed to add 1.3 ha (3.3 ac) of impervious surfaces and remove 1.4 ha (3.5 ac) of trees at project completion (NASA 2011a). As of 2017, NASA has constructed the new badge office, parking area, guard house canopy, and truck inspection area.

**Alternative Energy Project**

The 2011 EA evaluated the potential environmental impacts from alternative energy sources that would be capable of generating electricity at WFF. Under the preferred alternative, NASA would install a system of solar panels at the Main Base that would be capable of generating approximately 10 gigawatt-hours per year of power. The solar panel system would have a life expectancy of 25 years and consist of approximately 38,000 panels, with each measuring 1.4 $m^2$ (15 $ft^2$) that would equal an area of approximately 6 ha (15 ac). Panel spacing requirements would increase the overall required land area dedicated to solar panels to approximately 32 ha (80 ac). Additionally, a residential-scale wind turbine would be installed at the WFF Visitor Center adjacent to the Main Base and at the entrance to the Wallops Mainland. A post-construction monitoring plan would be initiated for the two wind turbine locations to ensure that their operation would result in minimal adverse impacts to birds and bats (NASA 2011b). As of 2017, neither project component has been constructed.

**Expansion of the WFF Launch Range**

The 2009 EA addressed the proposed expansion of the launch range at WFF. Under the Proposed Action, the preferred alternative, NASA and MARS expanded and upgraded facilities to support medium to large class suborbital and orbital LV launch activities from WFF. Components of the Proposed Action included site work required to support launch operations (such as facility construction and infrastructure improvements); testing, fueling, and processing operations; up to two static fire tests per year; and launching of up to six LVs and associated spacecraft per year from Launch Pad 0-A. Orbital Sciences Corporation's Antares LV would be the largest LV that would be launched from Pad 0-A.

Implementation of the Proposed Action would result in a maximum of 18 orbital-class launches per year from MARS Launch Complex 0 distributed among launch Pads 0-A, 0-B, 0-C (proposed) and Launch Pier 0-D (proposed). Site improvements would include minor modifications to the boat dock on the north end of Wallops Island, construction of a PPF, construction of a dedicated payload fueling facility, construction of new roads and minor upgrades to existing roads, and minor interior modifications to launch support facilities. In 2012, construction of a HIF and a new launch pad to include a liquid fueling facility was completed (NASA 2009). Following the explosion of Antares ORB-3 in October 2014, NASA and the FAA prepared a supplement EA (NASA 2015) and, in 2016, completed the rehabilitation of the damaged portions of Launch Pad 0-A.

**Wallops Research Park**

The 2008 EA assessed the development of the WRP adjacent to the Main Base on approximately 82 ha (202 ac) of lands owned by NASA, Accomack County, and the CBFS. Portions of the proposed research park site have been previously developed and currently contain a NASA PPF, CBFS facilities, open space that is periodically mowed, a taxiway connecting to the WFF airfield, utility and road infrastructure, nature trails, a playground and baseball field, and a closed county-run landfill. Forested areas also occur within the WRP site. Upon full build out, WRP would consist of a multi-use development dedicated to public recreational areas and non-retail commercial and government space and science research, and educational facilities. Proposed land use categories within WRP include: 1) research and development/industrial use, 2) aviation use, 3) gateway research and development/industrial use, and 4) an Accomack County recreational park. Full build out of the WRP is anticipated to take approximately 20 years (NASA 2008).

As of 2017, an office building has been constructed in the CBFS parcel east of the WFF main entrance; and construction of an access road, utilities (e.g., water and sewer lines), and an aircraft taxiway have been completed. The project, funded by the Commonwealth of Virginia, connects the WRP to the existing WFF airfield.

**North Wallops Island UAS Airstrip**

The 2012 EA analyzed the potential environmental consequences resulting from the construction and operation of a new UAS airstrip on the north end of Wallops Island. As part of the Proposed Action, WFF proposed to construct an asphalt airstrip measuring approximately 900 m (3,000 ft) long and 25 m (75 ft) wide (NASA 2012b). UAS operations would typically be conducted year round. Approximately 0.9 ha (2.3 ac) of non-tidal wetlands would be filled (NASA 2012b). During the NEPA process, NASA secured all necessary permits for the project. In October 2015, NASA transferred ownership of the project along with all permits and monitoring requirements to MARS. MARS completed construction of the airstrip and improvements to the access road in early 2017 with first operations flying in May 2017.

**NASA Phragmites Control and Monitoring Program**

WFF has been involved with VDCR's effort to map, monitor, and educate landowners about *Phragmites* control since 2004. VDCR conducted aerial herbicide applications in 2006, 2007, and 2008 and established and sampled monitoring plots in 2007, 2008, and 2009 (VDCR 2011). VDCR acknowledged in its 2011 report that eradicating all the *Phragmites* is neither feasible nor probable. However, protecting native marsh areas and keeping *Phragmites* at controllable levels is completely feasible and very possible (VDCR 2011). As such, NASA is now implementing its own *Phragmites Control Plan*, which includes aerial herbicide application, controlled burning, and mowing of infested areas (NASA 2014).

#### 5.3.2.2 Projects and Actions by Others

There are ongoing and reasonably foreseeable projects led by other agencies and organizations that have been considered in evaluating cumulative effects on resources within the region.

**U.S. Navy Field Carrier Landing Practice**

The Navy's 2013 EA evaluated the potential environmental consequences of the Navy's Fleet Forces Command's proposed action to conduct regular, scheduled E-2C Hawkeye, E-2D Advanced Hawkeye, and C-2A Greyhound (E-2/C-2) FCLP operations at the Emporia-Greensville Regional Airport in Emporia, Virginia and the WFF Main Base airfield. The Navy selected WFF as their preferred alternative and, began conducting operations in the fall of 2013. Up to 45,000 operations will occur annually in combinations of three- and five-plane FCLP patterns. Up to 30,000 operations will be conducted using a five-plane FCLP pattern and up to 15,000 operations will be conducted using a three-plane FCLP pattern. Approximately half of the proposed Navy E-2/C-2 training will be conducted during daylight hours and half during hours of darkness. For purposes of FCLP, training during darkness begins one-half hour after sunset and could last up to approximately three hours. Because sunset occurs late during the long daylight hours of the summer months, FCLP training that begins after sunset may continue as late as 1:00 a.m. or later. Aircraft refueling and overnight detachments may occur at WFF Main Base (U.S. Navy 2013).

**U.S. Air Force Instrumentation Tower**

The U.S. Air Force proposes to construct, operate, and maintain a 750-foot tall, guyed instrumentation tower on Wallops Island. NASA, NAVAIR, and NAVSEA would install, operate, and maintain equipment on the proposed tower to enhance and support their capabilities at both WFF and offshore areas within which they conduct their test operations. The purpose of the action is to enhance current operating DoD RDT&E support capabilities for UAS and extended communication coverage in the Mid-Atlantic operating area, allowing for refined communications infrastructure. The increased operations of UAS have led the DoD to identify requirements to effectively support offshore UAS testing. Current systems are limited in providing airspace management, flight test control and range safety functions, and spectrum management (collectively referred to as "integrated capabilities"). Overall, the Proposed Action is needed for the DoD to meet current, emerging, and evolving requirements associated with the RDT&E of UAS, which necessitate more robust communications systems that cover areas that are larger and farther offshore than existing systems. In addition, extending the range of communication coverage would enable UAS to operate farther offshore, thereby minimizing the risk of crashes or other incidents over land and corresponding risks to human safety and personal property.

**Joint Land Use Study**

NASA recently participated with Accomack County and the Navy's SCSC in the Accomack County/Wallops Island JLUS. Funded by a grant from the DoD's Office of Economic Adjustment, the primary objective of the JLUS was to identify land use issues that may impact the operational capabilities of WFF, and to identify actions participating agencies can pursue to ensure that incompatible development does not impact the facility's future mission requirements. Through the JLUS process, an action plan to guide future county growth and planning efforts may be established. The JLUS was completed in May 2015 (Accomack County 2015).

**USACE Federal Navigation Projects**

The USACE occasionally dredges the navigation channel in Bogues Bay. Engineering estimates suggest that approximately 11,470 $m^3$ (15,000 $y^3$) of fine sand and silt material (i.e., 65% sand, 20% silt, and 15% clay) could be removed every 10 years (USACE 2003). The USACE estimates the long-term, 50-year quantity of dredged material would be no greater than 76,000 $m^3$ (100,000 $y^3$). The proposed long-term dredged material management plan for Bogues Bay Channel is the placement of dredged material overboard on state-owned bottomlands on a nearshore placement site located in public oyster ground #29. Although the USACE has not dredged the channel recently and NASA is unaware of available funding for this project, the potential exists for dredging to occur within the next 20 years; therefore, it is considered in the CEA. The anticipated disposal site for this long-term project is a bermed area 0.8 km (0.5 mi) south of the northernmost part of the channel.

Additionally, USACE routinely dredges the Chincoteague Inlet (just north of Wallops Island) to maintain channel depth. Occurring on a nearly annual basis, this federal navigation project typically removes 60,000-76,000 $m^3$ (80,000-100,000 $y^3$) from the channel and places the material in the Atlantic Ocean east of Wallops Island.

**U.S. Navy AFTT**

The Navy released a Final EIS/OEIS in September 2018 which evaluated the potential environmental effects associated with military readiness training and research, development, testing, and evaluation activities conducted within the AFTT study area (U.S. Navy 2018a). The AFTT study area includes existing range complexes, operating areas, and test ranges along the east coast of the U.S.; the Gulf of Mexico; and select pier side locations, port transit channels, and the Lower Chesapeake Bay. As it relates to this PEIS, the AFTT study area includes the VACAPES Range Complex.

The EIS/OEIS was prepared to renew and combine current regulatory permits and authorizations; address evolving training and testing requirements; update existing analyses with the best available science and most current acoustic analysis methods to evaluate the potential effects of training and testing activities on the marine environment; and obtain those permits and authorizations necessary to support force structure changes and emerging and future training and testing requirements, including those associated with the introduction of new ships, aircraft, and weapons systems. A letter of authorization for AFTT activities was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b).

In its November 2018 ROD, the Navy selected to implement the EIS/OEIS Proposed Action Alternative 1 which will allow for fluctuations in training cycles and deployment schedules. The AFTT EIS/OEIS will be renewed every five years; the next phase will cover years 2025 to 2030.

**U.S. Navy Powder Gun and Electromagnetic Railgun (EMRG) Installation and Operation**

WFF is being considered to support operational testing of an EMRG prototype. Naval Surface Warfare Center Dahlgren Division, in cooperation with NASA WFF, prepared an EA to evaluate the environmental consequences of the five-year powder gun and railgun testing at Wallops Island (U.S. Navy 2014). The Navy proposes to install a re-locatable EMRG facility on Pad 5, situated mid-Wallops Island east of Navy building V-3. Railgun technology uses high-power electrical energy to launch projectiles long-range. The launch package consists of an all-metal armature, a projectile, and sabot that fit the shape of the projectile to the shape of the Railgun barrel. To fire the Railgun, the system builds up an electrical charge. When the firing circuit closes the electrical current goes to one of the rails and the armature conducts the current to the other rail. As the circuit completes, a magnetic field is generated around each rail, and it interacts with the current passing through the armature. The interaction between the current in the armature and the magnetic field creates an electromagnetic force that drives the integrated launch package down the length of the rails and out of the barrel. No chemical propellants are used to fire the projectile. Blast overpressure from the gun is expected to be about 0.9 kg per $cm^2$ (13 psi); the EMRG has about the same acoustic signature as conventional 12.7 centimeter (5 inch) diameter guns that have been routinely fired from Wallops Island.

For the first two years of operation, approximately 100 inert rounds would be fired per year from the EMRG with up to 240 rounds inert and 10 live rounds fired the following three years. The live rounds would have a net explosive weight of less than approximately 0.9 kgs (2 lbs) each. All rounds would fall within the VACAPES OPAREA. As the armatures push the projectile down the rail, four non-aerodynamic, aluminum, sabot petals would be expelled out the barrel. Each 56 cm by 9 cm (22 in by 3.5 in) sabot would be expelled, with a maximum of approximately 1,000 sabots per year for five years that would be deposited in Wallops Island's nearshore environment.

**U.S. Navy Air and Missile Defense Radar AN / SPY-6 Installation and Operation**

The Navy, in cooperation with NASA, prepared an EA to evaluate the potential environmental effects of installing and testing an air and missile defense radar in the Navy Assets area on Wallops Island (U.S. Navy 2017). The Navy proposes to install and test the AN / SPY-6, the Navy's next generation multi-function, phased-array radar intended for integration with the Aegis Weapon System within an addition of Building V-003. Once installed, the system would be tested for integration. The radar array would be situated approximately 18 m (60 ft) above the ground and would be tested using targets of opportunity, such as Navy or NASA aircraft or rockets, targets, or projectiles used for other testing or training purposes.

**USACE Existing Permanent Danger Zone Amendment**

On October 11, 2011, the USACE published a notice of proposed rulemaking and request for comments for amending an existing permanent danger zone in the waters of the Atlantic Ocean off Wallops Island and Chincoteague Inlet. The amendment, adopted effective October 12, 2012, further protects the public from hazards associated with rocket launching operations by increasing the danger zone to a 56 km (30 nm) sector (USACE 2012).

**Accomack County Subdivision Development within the Vicinity of WFF**

Accomack County Planning and Zoning divides proposed subdivision development into those that have submitted a preliminary appraisal and those that have recorded the proposed subdivision plats. Each of these is further divided into those subdivisions proposed to contain 10 lots or more and those proposed to contain 9 lots or less. As potential impacts to water resources, especially to wetlands, was the largest concern expressed during the scoping process for this PEIS, the geographic extent of analyses for development in Accomack County is defined as the two, 12-digit Hydrologic Unit Codes (HUCs) (020403030504 and 020403040101) that surround WFF (refer to Section 5.4.4).

Based upon the latest available data within this boundary, 8 preliminary appraisals for subdivisions are under review by the County. All subdivisions would be divided into 10 lots or more. The subdivision with the most proposed lots, the Rolling Woods subdivision would contain 100 lots on 60 ha (147 ac) of land and would be located approximately 1.2 km (0.70 mi) northwest of the WFF Main Base. The closest subdivision, Old Mill Pointe, would consist of 99 lots on 84 ha (208 ac) and would be located immediately northwest of the Main Base, adjacent to Little Mosquito Creek. It is also worth noting that Amber Acres Phase II is proposed adjacent to the northern boundary of the Mainland; this 31 lot subdivision would cover approximately 38 ha (95 ac). On average, those subdivisions with preliminary appraisals would consist of approximately 50 lots over 45 ha (110 ac) of land (Accomack County 2017).

Based upon the latest available data, Accomack County has 9 recorded subdivisions that have not started construction; 6 of which would contain 10 lots or more and 3 would be made up of 9 lots or less. The largest of these proposed subdivisions, Whispering Woods, would be constructed in phases. Whispering Woods I would be a 78 lot subdivision over 40 ha (99 ac) and Whispering Woods II would contain 76 lots on 28 ha (70 ac). These subdivisions would be located approximately 1 km (0.6 mi) north of the entrance to the Mainland/Wallops Island. On average, those subdivisions with 10 lots or more that have been recorded with Accomack County (2017) would consist of approximately 38 lots over 17 ha (42 ac) of land. Those recorded subdivisions with 9 lots or less average 4 lots on 5 ha (12 ac).

## 5.4 POTENTIAL CUMULATIVE EFFECTS BY RESOURCE

Following CEQ's 2005 guidance, the scope of the CEA is related to the magnitude of the environmental impacts of the Proposed Action. Proposed actions of limited scope typically do not require as comprehensive an assessment of cumulative effects as proposed actions that have environmental impacts over a large area. Therefore, the following section addresses those resources that have been identified as having the potential to be affected from the incremental effects of the proposed institutional support projects and operational mission activities in combination with past, present, and reasonably foreseeable future activities. Only those resource areas upon which the Proposed Action would cause measurable effects are considered in detail in this CEA. **Table 5.4-1** provides a summary of those resources considered and whether they were included for detailed analysis in this CEA.

**Table 5.4-1. Summary of Resource Areas and Potential Cumulative Effects**

| Resource | Potential Cumulative Effect | Type of Impact | Analyzed in Detail in this CEA? |
|---|---|---|---|
| Land Use | None | Land use compatibility would not be affected. | No |
| Infrastructure and Utilities | None | No cumulative effects anticipated. | No |
| Environmental Justice | None | No cumulative effects anticipated. | No |
| Cultural Resources | None | No cumulative effects to the NRHP-eligible archaeological resources or the Wallops Coast Guard Lifesaving Station and the associated steel frame Observation Tower. | No |
| Hazardous Materials, Toxic Substances, and Hazardous Waste | Negligible | Established procedures for the managing of hazardous materials, toxic substances, and hazardous waste at WFF would continue to be followed. Any potential increase in the amount of hazardous materials used or hazardous waste generated would continue to be managed using existing procedures, resulting in negligible cumulative effects. | No |
| Health and Safety | Negligible | Expansion of the existing permanent danger zone as proposed by the USACE would further increase safety. | No |
| Airspace Management | Negligible | With the recent expansion of R-6604, no cumulative effects are anticipated. | No |
| Land Resources | Negligible | Site-specific Erosion and Sediment Control Plans and BMPs would be implemented to reduce erosion and stormwater runoff. | No |
| Transportation | Negligible | Short-term increases in vehicular and vessel traffic during construction and maintenance dredging activities; no long-term impacts are expected. | No |
| Vegetation | Negligible | Affected vegetation remains abundant at WFF and in the surrounding rural area. Rare vegetation communities are not planned to be impacted. Wetlands vegetation is addressed under Water Resources. | No |
| Socioeconomics | Negligible | Potential for short-term and long-term beneficial impacts anticipated from increases in housing, another area hospital, and employment growth. | No |
| Visual Resources and Recreation | Negligible | Any restriction to public access as a result of Proposed Action would be temporary and would be consistent with current WFF operations and surroundings. | No |
| Noise | Minor | Noise from construction activities would be minor, temporary, and localized; overlap between baseline operational aircraft and launch noise, along with LFIC and SFHC LV launches, EMRG operation, and AFTT activities would create minor cumulative noise impacts. | Yes |
| Air Quality | Minor | Short-term impacts during construction; regulatory standards would be met long term. | Yes |
| Water Resources | Minor | Short-term impacts from turbidity and erosion during construction projects; however, projects would employ BMPs to decrease sedimentation and erosion. Wetland permits would be obtained to ensure no net loss of wetlands. | Yes |

| Table 5.4-1. Summary of Resource Areas and Potential Cumulative Effects (cont.) | | | |
|---|---|---|---|
| **Resource** | **Potential Cumulative Effect** | **Type of Impact** | **Analyzed in Detail in this CEA?** |
| Terrestrial Wildlife | Minor | Terrestrial wildlife would experience temporary impacts during construction activities, but would not experience a long-term impact as they currently reside in an area dominated by WFF operations. | Yes |
| Special-Status Species | Minor to Moderate | Consultation with NMFS and USFWS would be undertaken to ensure appropriate mitigation and monitoring measures are implemented to minimize or eliminate impacts from the Causeway Bridge and maintenance dredging projects. The U.S. Air Force Instrumentation Tower project "may effect, but unlikely to adversely affect" the red knot and piping plover that may utilize WFF through the potential for fatalities from collisions with the guy wires. | Yes |
| Marine Mammals and Fish | Minor | With exception of Causeway Bridge and maintenance dredging, no significant cumulative effects to EFH or marine mammals are anticipated. Additional NEPA analysis would be conducted for the Causeway Bridge project and maintenance dredging. | Yes |

## 5.4.1 NOISE

### 5.4.1.1 Description of Geographic Study Area and Temporal Extent

For the purposes of analyzing cumulative effects associated with institutional support projects, the geographic study area includes the Main Base, Mainland, and Wallops Island. Although this PEIS is based upon a 20-year planning horizon, the proposed institutional projects would occur from 2019 through 2025 as there are currently no known projects past 2025. For analysis of impacts associated with operational missions and activities, the geographic study area includes Accomack, Northampton, Somerset, Wicomico and Worcester counties, as well as portions of the Atlantic Ocean adjacent to Wallops Island; the temporal extent would include all present and foreseeable actions that involve in-air noise through 2039, which is the temporal extent of this PEIS.

### 5.4.1.2 Relevant Past, Present, and Future Actions

Several construction projects have occurred and are planned to occur in communities surrounding WFF and on WFF. Federal maintenance dredging of the navigation channel occasionally (approximately every 10 years) occurs in Bogues Bay and federal maintenance dredging of Chincoteague Inlet (just north of Wallops Island) occurs on a near annual basis. SRIPP renourishment at Wallops Island would occur every three to seven years, as needed to maintain an elevated beach. Navy operations include FCLP at the Main Base runway and proposed SM-3 and EMRG operations in the Navy Assets area on Wallops Island. In addition, the Navy conducts military readiness training and RDT&E activities within the VACAPES Range Complex; however, the Navy did not define temporal restrictions and it is anticipated testing and training could occur year round.

### 5.4.1.3 Cumulative Effects Analysis

Construction projects that occur during the same time frame have the potential to contribute cumulatively to the potential impacts associated with the institutional support projects that would occur under the

Proposed Action. However, it is assumed that any noise generated from institutional support projects of the Proposed Action would be temporary over the course of the individual projects and largely within the WFF boundaries. The noise association with residential development located in nearby communities is expected to be localized and not extend to WFF property boundaries. This finding is based on evidence that construction noise levels associated with equipment likely to be used during general construction projects, including the proposed institutional support projects under the Proposed Action, would attenuate to background levels (conservatively, approximately 55 dBA) in 500 m (1,600 ft) of the noise source. In addition, noise from construction, demolition, renovation, and dredging activities generally occur during daylight hours. With regards to the demolition and reconstruction of the Causeway Bridge, it is anticipated the airborne construction noise would attenuate to less than 60 dBA in approximately 2,100 m (7,000 ft). Due to the location of the Causeway Bridge, it is unlikely that impacts on communities would occur because the closest residence is located 1.6 km (1 mi) to the west. With regards to maintenance dredging, airborne noise levels would attenuate to 55 dBA in 610 m (2,000 ft). Therefore, no significant cumulative noise impacts associated with the implementation of institutional support projects under the Proposed Action are anticipated. Other present and reasonably foreseeable projects identified above would not occur within this same area of impact.

The Wallops Island launch range is located approximately 11 km (7 mi) southeast of the Main Base airfield. Due to this distance, typical aircraft touch-and-go noise contours would not overlap launch noise contours. Additionally, aircraft flight patterns would be routed to the east/west runways, 10/28, versus the northeast/southwest runways, 4/22, to separate aircraft traffic from the launch range activity hazards. Therefore, there may be minor cumulative noise impacts associated with aircraft and launch range activities under the Proposed Action.

In terms of the Navy's activities, loud noises, sonic booms, and vibrations could be generated from EMRG firing, in-air explosions from testing and training activities, and aircraft transiting the VACAPES Range Complex. There are operational proposals under the Proposed Action that would have negligible adverse impacts on the noise environment: the dedicated DoD SM-3 launch pad, and increased operations from the North Wallops Island UAS airstrip. Proposed Expanded Space Program LVs (e.g., LFIC, SFHC, and vertical and horizontal launch and landing LVs) have the potential to result in an incremental cumulative effect when added to the Navy's EMRG testing and AFTT activities that occur in the VACAPES Range Complex. The Navy concluded in the 2018 EIS/OEIS that the public might intermittently hear noise from ships or aircraft overflights if they are in the general vicinity of training or testing, but the events would be infrequent. Therefore, their actions would have negligible impacts as they are temporary and conducted away from populated areas (U.S. Navy 2018a). Additionally, noise from EMRG firings would be focused along the projectile's trajectory over the ocean and away from populated areas (U.S. Navy 2014). Thus, a cumulative interaction is not considered likely since there is a separation of time between actions (i.e., the actions would not occur simultaneously). Specifically, when NASA conducts an operational mission, the airspace and permanent danger zone in the waters of the Atlantic Ocean off Wallops Island and Chincoteague Inlet are restricted by the Navy's FACSFAC VACAPES to prevent simultaneous mission operations and public access to the operations areas. In addition, since the Navy conducts the majority of its AFTT activities at least 22 km (12 nm) from shore, overlap of in-air noise is not likely. Therefore, there would not be significant cumulative noise impacts associated with implementation of operational missions and activities of the Proposed Action.

### 5.4.2 AIR QUALITY

#### 5.4.2.1 Description of Geographic Study Area and Temporal Extent

The study area considered in the cumulative analysis for this resource includes areas within the Northeastern Virginia Intrastate AQCR. This AQCR was selected because it includes Accomack County. Accomack County is considered in attainment status for all criteria pollutants. For the purposes of analyzing cumulative effects associated with institutional support projects, or short-term impacts, the temporal extent is considered 2019 through 2025, as there are no known projects past 2025. For the purposes of analyzing impacts associated with operational missions and activities, or long-term impacts, the temporal extent would include all present and foreseeable actions that involve release of air emissions through 2039, which is the temporal extent of this PEIS.

#### 5.4.2.2 Relevant Past, Present, and Future Actions

Several construction projects, including subdivision development, have occurred and are planned to occur in communities surrounding WFF. At WFF, numerous construction and demolition projects could occur under the Proposed Action and include the Causeway Bridge Replacement project, construction and operation of the North Wallops Island UAS airstrip, and development and operation of the North Wallops Island Deep-water Port and Operations Area. Federal maintenance dredging of the navigation channel occasionally (approximately every 10 years) occurs in Bogues Bay and maintenance dredging of Chincoteague Inlet (just north of Wallops Island) occurs on a near annual basis. SRIPP renourishment at Wallops Island would occur every three to seven years. UAS operations at the North Wallops Island UAS airstrip would increase by 73% under the Proposed Action. Expanding the space program could include LFIC LVs and SFHC LVs. Navy operations include FCLP at the Main Base runway and DoD SM-3, EMRG operations, and AN / SPY-6 radar testing in the Navy Assets area on Wallops Island. In addition, the Navy conducts military readiness training and research, development, testing, and evaluation activities on WFF and within the VACAPES Range Complex.

#### 5.4.2.3 Cumulative Effects Analysis

In terms of short-term cumulative effects, the institutional support projects associated with the Proposed Action and other regional construction projects could produce a short-term additive amount of emissions if they are concurrent. Several construction projects, including subdivision development in the surrounding area, have occurred and are planned to occur in communities surrounding WFF. These low density area projects along with prior construction of the North Wallops Island UAS runway and proposed extension of Runway 04/22 at the Main Base could incrementally increase air pollution levels in Accomack County. However, the low population density of the proposed subdivisions, flat geography and coastal location ensures minimal air pollution and its rapid dispersion. Much of aircraft (i.e., FCLP and UAS) operations activities at WFF would occur below the 914 m (3,000 ft) mixing layer. Additionally, the Navy currently conducts regular training and testing activities within the VACAPES Range Complex. As part of the 2018 AFTT EIS/OEIS, the Navy analyzed potential emissions associated with training and testing. Most training and testing-related emissions are produced at least 22 km (12 nm) from shore. Since the majority of Navy AFTT VACAPES Range Complex activities, with the exception of FCLP, are conducted approximately 22 km (12 nm) or greater from shore and the natural mixing would disperse pollutants, the contributions of air pollutants generated in the VACAPES Range Complex by the Navy are unlikely to cumulatively affect existing and new sources of air emissions from onshore activities proposed by WFF.

As discussed in Section 3.2, the projected annual emissions from both institutional support and operational proposed projects under the Proposed Action would be well below the 227 metric tons (250 tons) per year comparative mobile source threshold. It is not anticipated that air emissions from other present and future projects, when considered incrementally with the Proposed Action, would exceed any regulatory standards or affect the attainment status of Accomack County. Therefore, there would be no significant cumulative effects to air quality from implementation of the Proposed Action.

### 5.4.3 WATER RESOURCES

Water resources refer to surface and subsurface waters, wetlands, marine waters, floodplains, and the Coastal Zone. However, due to the extent of the CEA for wetlands, wetlands are analyzed separately in Section 5.4.4 and in a detailed study presented in **Appendix H**.

#### 5.4.3.1 Description of Geographic Study Area and Temporal Extent

Impacts to water resources are typically localized. The geographic boundary of the cumulative wetlands analysis is the two 12-digit HUCs (020403030504 and 020403040101) that encompass the Wallops Main Base, Mainland, and Wallops Island (20,539 ha [50,753 ac]) illustrated in **Figure 5.4-1.** The temporal extent of this analysis is limited from the 1972 enactment of the CWA to the 20-year planning horizon of this PEIS, 2019 through 2039. It is noted that there are currently no known institutional support projects after 2025.

#### 5.4.3.2 Relevant Past, Present, and Future Actions

Several construction projects, including subdivision development in the surrounding area, have occurred and are planned to occur in communities surrounding WFF. These area projects along with prior construction of the North Wallops Island UAS runway and proposed extension of Runway 04/22 at the Main Base could increase impervious surfaces in Accomack. Other relevant past, present, or future actions include SRIPP renourishment (every 3 to 7 years); federal maintenance dredging of the navigation channel in Bogues Bay (approximately every 10 years) and maintenance dredging of Chincoteague Inlet just north of Wallops Island (on a near annual basis); development and operation of the North Wallops Island Deep-water Port and Operations Area; and Navy activities (i.e., SM-3, EMRG, and AFTT within the VACAPES Range Complex).

VDCR has monitored efforts to control *Phragmites* and has conducted aerial herbicide applications in 2006, 2007, and 2008. WFF has implemented a *Phragmites Control Plan* that includes aerial and hand herbicide applications, controlled burning, mowing, and controls to prevent vehicles from spreading *Phragmites* seeds and rhizomes (NASA 2014).

#### 5.4.3.3 Cumulative Effects Analysis

In determining incremental cumulative effects, it is important to note that while the Federal Water Pollution Control Act (FWPCA) of 1948 was the first major U.S. law to address water pollution, the amended CWA was not promulgated until 1972. The 1972 amendments (33 U.S.C. Section 1251 et seq.) modified the FWPCA by stipulating broad national objectives to restore and maintain the chemical, physical, and biological integrity of the waters of the U.S.; expand provisions related to pollutant discharges; define liability for discharges of oil and hazardous substances; establish the NPDES which authorized EPA to issue discharge permits (Section 402); and authorize the USACE to issue permits for the discharge of dredged or fill material into navigable waters at specified disposal sites (Section 404) (EPA 2013).

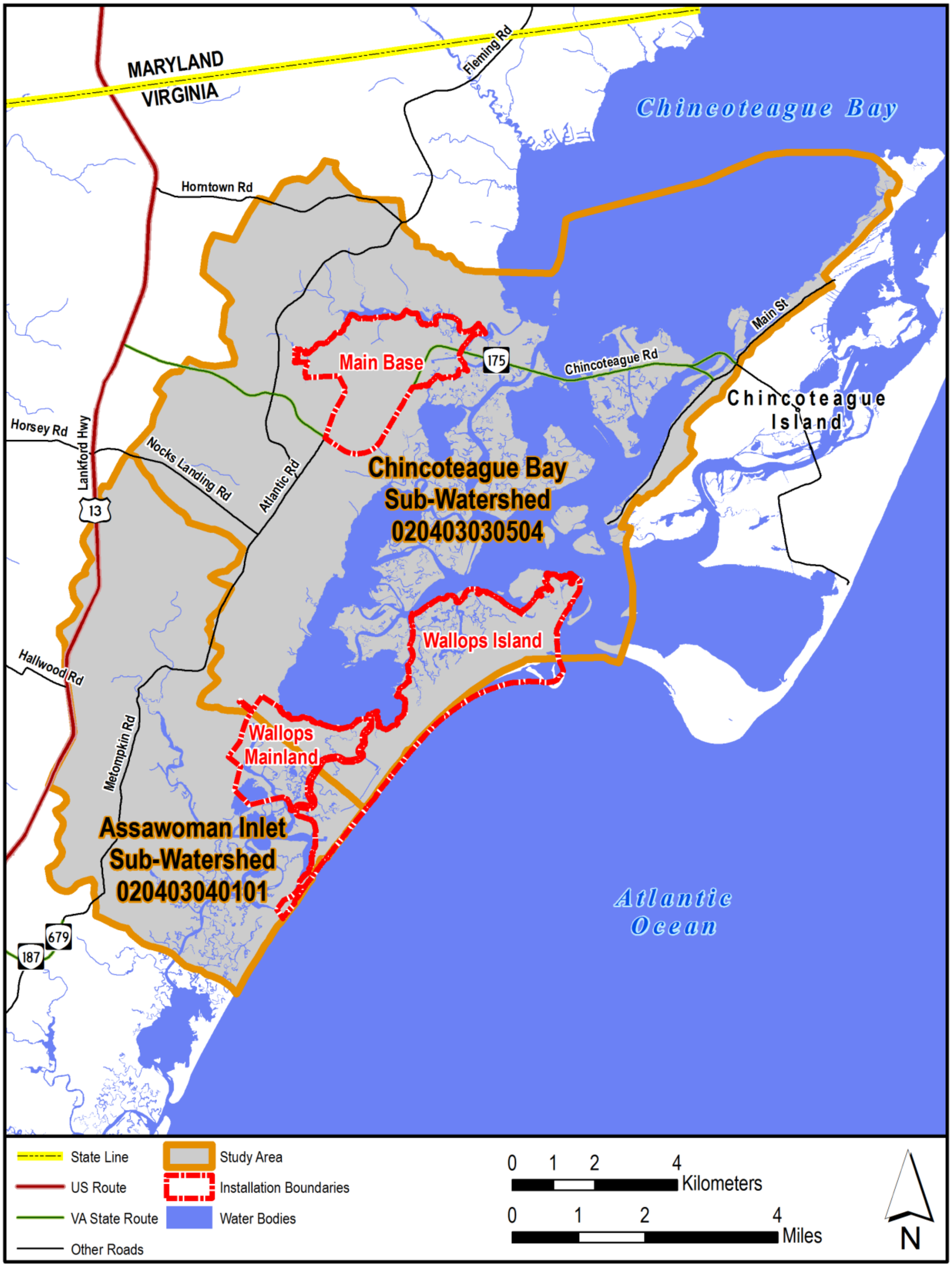


**Figure 5.4-1. Cumulative Water Resources Study Area**

However, it wasn't until the 1977 amendments to the FWPCA (Public Law 95-217) that a basic structure for regulating discharges of pollutants to waters of the U.S. was established (EPA 2013). The 1977 amendments also gave the common name of "Clean Water Act" to the FWPCA. The 1987 amendments to the CWA, among other provisions, provided administrative penalties for violation of Section 404 permits. In addition, in response to the 1987 amendments to the CWA, the EPA established the NPDES stormwater permit application process to address stormwater discharges (EPA 2012).

Impacts to marine water quality associated with Navy drones, EMRG, and AFTT actions could occur as a result of explosives and explosion byproducts, metal components, chemicals other than explosives (i.e., solid fuel propellants, PCBs, other chemicals associated with ordnance, and chemical stimulants), and other materials (e.g., marine markers and flares, chaff, towed and stationary targets). The Navy determined that AFTT activities could result in localized chemical, physical, or biological changes to water quality but would be below applicable standards, regulations, and guidelines (U.S. Navy 2018a). In addition, temporary direct impacts to marine waters would occur from incidental suspension of sediment during the Causeway Bridge Replacement project, maintenance dredging and dredging for projects such as the development of the North Wallops Island Deep-water Port and Operations Area and Launch Pier 0-D, and SRIPP beach renourishment. NASA would obtain a VSMP construction site stormwater permit, develop a site-specific SWPPP, and implement site-specific BMPs to minimize impacts to surface waters. Since the Navy's activities and the proposed operational mission activities would likely be separated in time (i.e., would not occur simultaneously) and space (i.e., would not occur in the same location as the Navy actions would occur offshore and construction actions would be in the nearshore and estuarine areas), cumulative effects to water resources are considered negligible.

Short-term cumulative effects to surface water quality from turbidity and erosion during construction and demolition activities could occur if the projects are located in close proximity and time. Conservatively, however, these impacts would be temporary. Turbidity curtains would contain or deflect suspended sediments in the water column; sediment containment within a limited area is intended to provide residence time to allow soil particles to settle out of suspension and reduce flow to other areas where negative impacts could occur. All institutional support projects or construction and demolition projects would be required to follow state and Federal guidelines for construction permitting to ensure water quality is protected from possible erosion and sedimentation. This includes implementing project-specific BMPs as part of the proposed infrastructure improvement projects to minimize impacts to water quality and using stormwater engineering controls (e.g., culvert/channels directing stormwater to retention basins) to decrease future impacts to water quality following construction. The details of the BMPs used during construction would be listed in the SWPPP that is required by the VSMP permit, for those projects that may have an impact to water quality. The use of spill prevention plans and SWPPPs during infrastructure improvements would also minimize impacts to water quality.

Past construction and operational activities at WFF resulted in adverse impacts to water resources. Documented in two EPA Region 3 aerial photographic analyses in 1996 and 2004, and the USACE 2000 historical photographic analysis, it is clear that considerable land disturbance occurred from 1938 through the present day (EPA 1996, 2004; USACE 2000). There were no requirements for construction or industrial activities (such as a SWPPP pursuant to NPDES regulations) for erosion control or BMPs to control runoff of contaminants into the surface waters at WFF prior to 1972. These historical reviews document evidence of pools of liquids, stained soils, and an open storage yard for vehicle maintenance activities that would have contributed pollutants to both surface waters and groundwater in the vicinity of

WFF. As described in Section 3.3.1.3, the WFF ECR Program and USACE have used these historical reviews as a tool to identify areas that required restoration to remove the past contaminants and eliminate them as contributors to surface and groundwater pollution.

Past expansion and proposed subdivision construction in the area surrounding WFF would create additional impervious surfaces, increase stormwater runoff, and result in adverse impacts to water resources. Based upon data derived from the Landsat satellite, the National Land Cover Database (NLCD) has been created through a cooperative project conducted by a consortium of federal agencies (Multi-Resolution Land Characteristics Consortium) consisting of the USGS, NOAA, EPA, USDA, NPS, USFWS, U.S. Forest Service, Bureau of Land Management, and USDA Natural Resources Conservation Service. The NLCD classification scheme has been applied consistently across the contiguous United States to create 16 classes of land cover including water, developed (from open space to high intensity), barren, vegetated, and wetlands. Data from the developed classification has been translated into permeable and impervious surface maps (Multi-Resolution Land Characteristics Consortium 2006). Accomack County's Chesapeake Atlantic Preservation Overlay District (Chapter 106, Article XVI of Accomack County Code) allows up to 60 percent imperviousness on a lot. Data from Accomack County's GIS for proposed subdivision development, new construction under the Proposed Action, and impervious surface data from the NLCD (Multi-Resolution Land Characteristics Consortium 2006) were bounded by the two, 12-digit HUCs that surround WFF (Accomack County 2017) and compared to determine the extent of existing versus potential impervious surface and, thereby, potential impacts to surface water resources (**Table 5.4-2**). The comparison shows an overall 1.3 percent increase of impervious surface within the geographic and temporal extent of the PEIS; representing an estimated 6.5 percent cumulative impervious surface cover.

New construction under the Proposed Action would contribute up to 1.3 ha (3.2 ac) of impervious surface. When considered along with the projected increase in impervious surface from subdivision development, the potential exists for surface water resources within HUCs 020403030504 and 020403040101) to be impacted. However, as described in Section 3.5.2.2.1, construction projects at WFF would include site-specific SWPPPs and BMPs to reduce the impact of stormwater runoff on nearby receiving waters. As such, there would be no significant cumulative effect to water resources from implementing the Proposed Action.

**Table 5.4-2. Existing and Projected Impervious Surface Totals**

| Subdivision Category | Number of Lots | Area ha (ac) | Impervious ha (ac) |
|---|---|---|---|
| Preliminary Appraisal (10 Lots or More)[a] | 397 | 355 (876) | 233 (575) |
| Recorded (10 Lots or More)[a] | 228 | 103 (254) | 62 (152) |
| Recorded (9 Lots or Less)[a] | 13 | 5 (12) | 4 (10) |
| WFF projected development | na | na | 4 (10) |
| Area in HUCs | na | 20,539 (50,753) | na |
| Baseline Impervious Surface in HUCs[b] | na | na | 1,060 (2,619) |
| Baseline Impervious Coverage in HUCs[b] | na | na | 5.2% |
| Cumulative Projected Impervious Surface in HUCs | na | na | 1,363 (3,368) |
| Projected Percentage Change in Impervious Surface in HUCs | na | na | +1.3% |
| Cumulative Projected Impervious Coverage in HUCs | na | na | 6.7% |

Sources: [a] Accomack County 2017; [b] Multi-Resolution Land Characteristics Consortium 2006. Legend: na = not applicable.

### 5.4.4 WETLANDS

A summary of the cumulative wetlands analysis is presented in this section. A more detailed presentation, tables, and methodology to this analysis is presented in **Appendix H**.

#### 5.4.4.1 Description of Geographic Study Area and Temporal Extent

The geographic boundary of the cumulative wetlands analysis is the two 12-digit HUCs (020403030504 and 020403040101) that was defined in the Water Resources analysis. With regards to the temporal extent of this analysis, a broad historic look was taken to fully analyze the changes development has had on wetland size and functional value. Therefore, for the purposes of the wetlands CEA, the temporal extent is divided into two periods: 1) Pre-Federal "settlement", 1938, to present and 2) present through 2025, which is the extent of known projects. It is noted that the temporal extent of the actions evaluated in this PEIS is based on a 20-year planning horizon from 2019 to 2039.

The first period beginning in 1938 establishes the timeframe in which the NASA site was relatively undisturbed with the exception of agricultural fields, the Wallops Coast Guard Lifesaving Station, and a hunt club.

#### 5.4.4.2 Relevant Past, Present, and Future Actions

Several construction projects under the Proposed Action are relevant to this analysis. These include the Causeway Bridge Replacement, Launch Pad 0-C and Launch Pier 0-D. Relevant past, present, or future actions include SRIPP renourishment (every 3 to 7 years); the completed construction of the North Wallops Island UAS airstrip; expansion of the WFF Launch Range; WRP; federal maintenance dredging of the navigation channel in Bogues Bay (approximately every 10 years); maintenance dredging of Chincoteague Inlet just north of Wallops Island (on a near annual basis); development of the North Wallops Island Deep-water Port and Operations Area; and Navy activities (i.e., SM-3, EMRG, and AFTT within the VACAPES Range Complex).

#### 5.4.4.3 Cumulative Effects Analysis

The overall objective of the wetland CEA was to compare the cumulative changes in the extent and function of wetlands over time. The analysis accomplished this objective using the following steps:

1. determine the historical extent of wetlands within the two 12-digit HUCs study area,
2. determine the historical wetland impacts within NASA boundaries and outside NASA boundaries,
3. assign a functional value to those wetlands, and
4. evaluate the change in total functional value from 1938 to 2039 attributable to the Proposed Action.

Historic aerial photography was used to calculate the wetland losses over time. A review of aerial photography identified "areas of disturbance" compared to the 1997 historic hydric soils limit (considered the historic wetland extent within the study area). These areas of disturbance were classified as: dredge area, fill area, impervious area, or miscellaneous disturbance. Based on the availability of photography, the wetland losses were divided into two categories, 1) losses within the NASA boundaries, and 2) losses outside of the NASA boundaries within the remainder of the study area. Within the NASA boundaries, historic aerial photographs were available for the years 1938, 1949, 1957, 1963, 1966, 1974, 1979, 1988, 1994, and 2010 (EPA 1996, 2004; USACE 2000). Historic aerial photography for areas outside of the NASA boundaries was only available for the years 1938 and 1974.

Assigning a functional value to wetlands employed a landscape level wetland assessment approach called Watershed-based Preliminary Assessment of Wetland Functions. This assessment approach applies general knowledge about wetland functions and values to emphasize wetlands of potential significance for 10 functions, described in detail in **Appendix H**, in a given study area (Tiner 2003). Wetlands were assigned a numerical quantity: low (0), moderate (1), and high (2) for the 10 wetland functions. The maximum value a wetland could score was 20; however, the wetlands within NASA boundaries could only score a maximum value of 18 due to the fact that there are no streams within the NASA boundaries and the wetland function of streamflow maintenance (i.e., maintaining existing flow volumes in streams) for all wetlands evaluated would have a score of 0 due to the absence of functioning streams.

Based on the analysis of wetlands identified on the 1998 NWI mapping (assumed as the current extent of wetlands), the majority of the wetlands present in the study area are estuarine intertidal and subtidal areas with a functions and values score of 17, classifying them as high value in 8 out of 10 functions and values parameters. The next most common habitat is palustrine forested with a functions and values total of 14. **Appendix H** provides a summary of all wetlands currently present in the study area.

To assess the change in the 10 functions from 1938 to 2025, the wetland losses by habitat type in 1938 and 2025 were multiplied by the value for each function (0, 1 or 2) to generate a "functional unit total" for each time period following the methodology in Fizzell (2007). The functional totals for each year were compared to calculate a percent change in the function over time. The percent change over time was calculated with and without the Proposed Action to determine the change in functional value attributable to the Proposed Action addressed in the Site-wide PEIS.

The results of the aerial photography review and calculation of historical wetland loss within the NASA boundaries for each year that photography was available were compared to potential cumulative loss of wetlands within NASA boundaries for present and reasonably foreseeable future projects as provided in Section 5.3.2. Within the NASA boundaries, a total of 507 ha (1,253 ac) of wetlands have been cumulatively impacted since pre-NASA development (1938) (including the Proposed Action). A total of 75% of the impacts (382 ha [944 ac]) that occurred on WFF happened between 1938 and 1974. The primary causes for historical wetland impacts within the NASA boundaries included development of the WFF buildings, runways, launch pads, infrastructure, construction of the Causeway Bridge, and dredging the access channels.

Outside of NASA boundaries the results of the aerial photography review and calculation for historical wetland loss was based on photography available for the years 1938 and 1974. In 1938, 1,007 ha (2,488 ac) of the hydric soils within the aerial photography coverage area were identified as converted to agricultural fields. The conversion of hydric soils to agricultural use (i.e., wetland loss) amounts to a 12.0% loss of wetlands. In 1974, 1,060 ha (2,620 ac) of the hydric soils were identified as agricultural areas totaling a 12.6% loss of wetlands.

Historical total wetland losses across the entire study area from 1938 to present (2010+) totaled 1,562 ha (3,859 ac); 502 ha (1,240 ac) within NASA boundaries and 1,060 ha (2,620 ac) outside NASA boundaries. Wetland losses within NASA's boundaries accounted for 32% of the wetland impacts in the total study area during this timeframe. The amount of wetland loss attributable to NASA within the total study area appears large; however, it is important to note that during that time period, NASA was one of the largest developments within the study area and a majority of the remaining portions of the study area remained undeveloped.

As wetlands are lost over the study area, the overall function and total value of those wetlands will decrease. **Table 5.4-3** provides the total functional value for each of the 10 wetland functions and the percent change in value over time for the years 1938 and 2025 determined using the method described in Section 1.3.4 of **Appendix H.** The year 2025 is the temporal extent of this study since there are no known proposed projects at WFF beyond this timeframe.

**Table 5.4-3** provides data for the entire study area; however, since the Proposed Action would not affect the streamflow maintenance function, this function was removed from the analysis. The 2025 functional value was calculated with and without the Proposed Action to determine how much of the change in functional value is attributable to the Proposed Action. The change in functional value attributable to the Proposed Action would be minimal and range from 0.03% (fish and shellfish/waterbird habitat) to 0.05% (conservation of biodiversity).

In determining whether the cumulative impact would potentially be significant, it is important to discuss the regulatory requirements in place to offset wetland impacts through avoidance and minimization measures. Unavoidable impacts to wetlands within the NASA boundaries since promulgation of the 1972 CWA (which established the basic structure for Section 404 permits) and EO 11990, have been minimized to the greatest extent possible. As discussed, 382 ha (944 ac) of wetlands within NASA's boundaries were impacted between 1938 and 1974. Of these impacts, 258 ha (923 ac), were associated with wetland dredge and fill actions taken at Wallops Island from 1939 through 1966, primarily attributed to construction of the Wallops Island Causeway. No mitigation was performed for these wetland impacts since the regulatory authority did not exist to protect wetlands during this timeframe.

Since implementation of permit requirements and methodology for delineating wetlands (USACE 1987), 103 ha (255 ac) of wetlands have been or are planned to be impacted at WFF through other actions (1988 through present [2017]). Additionally, every 3 to 7 years, the No Action Alternative of recurring beach renourishment will temporarily impact the same area of approximately 60 ha (150 ac) of marine subtidal and intertidal unconsolidated bottoms. In accordance with the CWA and EO 11990, NASA has and would secure the proper permits through the USACE, VMRC, VDEQ, and Accomack County. The additional impact of up to 5 ha (12 ac) in wetlands from implementation of the Proposed Action would be avoided and minimized to the greatest extent possible. Any impacts that could not be avoided would be permitted through the USACE, VMRC, VDEQ, and Accomack County to ensure no net loss of wetlands.

Therefore, while unavoidable adverse impacts to wetlands would occur through implementation of the Proposed Action and have occurred cumulatively over time at WFF, no net loss of wetlands has occurred since 1988 due to the existence of regulations which require unavoidable impacts to be mitigated. Moreover, while the appropriate mitigation is determined at the time of permitting, it is often the case that the ratio of wetlands created to wetlands loss is greater than 1:1. Secondly it is also important to note that there is still a significant amount of existing high value wetlands. Therefore, the Proposed Action would not contribute a significant cumulative impact to wetlands.

| Table 5.4-3. Change in Total Functional Scores for Each Wetland Function in the Study Area | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Wetland Functions** | **Surface Water Detention** | **Coastal Storm Surge Detention** | **Streamflow Maintenance *** | **Nutrient Transfor mation** | **Sediment & Particulate Retention** | **Shoreline Stabilization** | **Fish & Shellfish Habitat** | **Waterbird Habitat** | **Other Wildlife Habitat** | **Conservation of Biodiversity** |
| ***Change in the 10 Functions and Values With the Proposed Action*** | | | | | | | | | | |
| **1938 Functional Score** | 64,041.54 | 62,901.47 | na | 62,879.51 | 63,089.37 | 62,376.47 | 54,747.90 | 58,292.35 | 59,087 | 35,247 |
| **2025 Functional Score** | 60,765.94 | 60,396.37 | na | 60,074.91 | 60,319.77 | 60,185.37 | 53,394.30 | 56,854.75 | 56,808 | 33,725 |
| **Change in Function and Value (%)** | -5.11 | -3.98 | na | -4.46 | -4.39 | -3.51 | -2.47 | -2.47 | -3.86 | -4.32 |
| ***Change in the 10 Functions and Values Without Proposed Action*** | | | | | | | | | | |
| **Change in Function and Value (%)** | -5.08 | -3.94 | na | -4.42 | -4.35 | -3.47 | -2.44 | -2.43 | -3.82 | -4.27 |
| **Change in Functional Score Attributable to Proposed Action (%)** | -0.04 | -0.04 | na | -0.04 | -0.04 | -0.04 | -0.03 | -0.03 | -0.03 | -0.05 |

Note: *The function of stream flow maintenance is not affected by the Proposed Action and was not included in this analysis.
Legend: na = not applicable.

## 5.4.5 TERRESTRIAL WILDLIFE

### 5.4.5.1 Description of Geographic Study Area and Temporal Extent

The geographic study area for this CEA includes the Main Base, Mainland, and Wallops Island. The temporal extent is limited to the 20-year planning horizon of this PEIS but focuses on the period between 2019 through 2025, as there are currently no known projects after 2025.

### 5.4.5.2 Relevant Past, Present, and Future Actions

Past, present, or future installation actions may impact terrestrial wildlife. The relevant past actions may include construction of the North Wallops Island UAS airstrip, WFF main entrance reconfiguration, alternative energy project, expansion of the WFF Launch Range, and the WRP. The present and future actions relevant to this analysis include construction and demolition projects under the Proposed Action that include replacement of the Causeway Bridge, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pier 0-D. Other relevant actions include the federal maintenance dredging of the navigation channel in Bogues Bay (approximately every 10 years); federal maintenance dredging of Chincoteague Inlet just north of Wallops Island (on a near annual basis); SRIPP renourishment at Wallops Island (every 3 to 7 years, as needed to maintain an elevated beach); construction and operation of the North Wallops Island UAS airstrip; launches of orbital and suborbital LVs, expansion of the space program to include larger LVs and the introduction of RLVs; Navy operations (i.e., DoD SM-3, EMRG operations, and AN / SPY-6 radar testing in the Navy Assets area on Wallops Island); Navy RDT&E within the VACAPES Range Complex; and the U.S. Air Force Instrumentation Tower, as well as Navy FCLP at the Main Base runways and implementation of the WFF *Phragmites Control Plan*.

### 5.4.5.3 Cumulative Effects Analysis

This CEA will focus on the potential for cumulative effects associated with habitat loss, noise, and predation.

#### 5.4.5.3.1 Habitat Loss

Habitat loss for terrestrial wildlife would be associated with all past, present, and future projects that occur at WFF that require some type of construction. This would include all construction projects that impact natural, unmaintained vegetation at the facility. Some habitat loss would be permanent due to the construction of new facilities; the habitat losses would be additive in nature.

As part of constructing the North Wallops Island UAS airstrip, approximately 3.3 ha (8.1 ac) of upland vegetated areas (characterized as mature pine with mixed hardwoods) on the northern portion of Wallops Island were cleared; the main entrance project removed 1.4 ha (3.5 ac) of trees; and the expansion of the WFF Launch Range would affect up to 0.4 ha (1.1 ac) of trees. Moreover, construction of the North Wallops Island UAS Airstrip affected up to approximately 0.9 ha (2.3 ac) of wetlands; the expansion of the WFF Launch Range would affect up to 1.7 ha (4.1 ac) of wetlands; and the WRP would affect up to 0.4 ha (1.0 ac) of wetlands. These vegetated areas represent a permanent loss of potential habitat for terrestrial wildlife at WFF.

The U.S. Air Force Instrumentation Tower project on Wallops Island would also impact vegetation and terrestrial wildlife. The tower footprint itself is rather small, but the guy wires would extend out approximately 150 m (500 ft) in three directions and would require periodic mowing of vegetation under the wires near their anchor points. The 2017 EA for the Proposed Construction and Operation of

Instrumentation Tower on Wallops Island (U.S. Air Force 2017) did not do an in-depth analysis of vegetation or terrestrial wildlife impacts. However, it did conclude that vegetation removal would only be at the base of the tower, at the anchor points for the guy wires, for a gravel access road to the base of the tower, and for a pre-fabricated structure near the tower base. This would permanently remove some native habitat and some maintained grassy areas on Wallops Island. Impacts from construction would be minor and temporary disturbance to terrestrial wildlife. The Air Force EA (2017) does document the potential for bird collisions with guy wires, as well as mitigations and requirement monitoring to document and reduce the potential impacts to avian species.

While SRIPP would eventually replace lost beach habitat for beach foragers, during the beach renourishment phase, dredging and placement of sand along the beachfront would essentially "reset" the infaunal recovery that is taking place at the project site following the initial fill cycle. This would cause a temporary adverse impact to foraging wildlife, especially birds that would have to utilize another area for of the beach for foraging.

A relatively small amount of vegetation and wetlands would be disturbed from implementation of the institutional support projects under the Proposed Action and other construction projects at WFF. Although the majority of institutional support projects on the Main Base and Mainland/Wallops Island would occur in previously disturbed areas or maintained areas with anthropogenic vegetation, the small permanent loss of natural habitat from construction would impact less mobile species that are not able to leave the area. As discussed above in the CEA for wetland impacts, approximately 0.03% of waterbird and other wildlife and 0.05% of the conservation biology function of wetlands would be lost on WFF due to implementation of the Proposed Action. These functional losses would represent a minor amount of cumulative terrestrial wildlife habitat loss.

WFF developed a *Phragmites Control Plan* that includes aerial and hand herbicide applications, controlled burning, mowing, and controls to prevent vehicles from spreading *Phragmites* seeds and rhizomes (NASA 2014). Implementation of WFF's *Phragmites Control Plan* could offer some beneficial impacts to terrestrial wildlife, particularly to bird species that utilize native marshes, by removing the invasive species in favor of native vegetation and restoring native habitats.

No adverse long-term cumulative effects to populations of affected species is anticipated from loss of habitat from implementing construction projects under the Proposed Action since these species are abundant in surrounding areas, would rapidly repopulate suitable portions of the affected area once construction has ceased, and construction projects would likely be separated in time and space. Once design specifics are known, additional analysis would be needed to fully assess the cumulative effects the Causeway Bridge Replacement project would have on tidal wetland habitat. The occasional maintenance dredging of Bogues Bay would replace subaqueous conditions with an intertidal habitat that would be valuable for avian foraging activities (USACE 2003).

5.4.5.3.2 Noise

**Institutional Support Projects**

Noise impacts on terrestrial animals can include changing habitat use and activity patterns, increasing stress response, decreasing immune response, reducing reproductive success, increasing predation risks, degrading conspecific communications, and damaging hearing (Pater et al. 2009). However, animals tend to be at little risk from hearing loss because they are seldom close enough to the source to be affected (Larkin 1996). All construction activity has the potential to temporarily impact terrestrial wildlife though general disturbance and noise. Terrestrial wildlife residing in habitat on the periphery of the construction sites may be temporarily disturbed or displaced by construction-related noise. However, it is assumed that any noise generated from construction activities would be temporary over the course of the individual projects and would not result in a cumulative disturbance to wildlife. WFF is an active facility and wildlife would be habituated to the general human activity at the facility.

Federal maintenance dredging of the navigation channel occasionally (approximately every 10 years) occurs in Bogues Bay and federal maintenance dredging of Chincoteague Inlet (just north of Wallops Island) occurs on a near annual basis. If dredging were occurring near land, terrestrial wildlife could be startled, but would likely habituate to the dredging noise and activity. Activities from SRIPP could also elicit a startle or flee response, which would interrupt foraging and nesting activities. Effects would be most pronounced during the spring and summer months, when nesting would occur. Refer to Section 5.3.2.1, NASA Activities, SRIPP.

**<u>Operational Missions and Activities</u>**

The Expanded Space Program under the Proposed Action has the potential to result in an incremental cumulative effect when added to existing sounding rockets, drones, EMRG actions, and AFTT activities that occur in the VACAPES Range Complex. In addition, the Navy conducts military readiness training and research, development, testing, and evaluation activities within the VACAPES Range Complex; however, the Navy did not define temporal restrictions and it is anticipated testing and training could occur year round with no seasonality of all or any activities.

In general, given its distance from the launch facilities on South Wallops Island, North Wallops Island is not measurably affected by noise from most range activity with the exception of the future UAS overflights from the North Wallops Island UAS Airstrip and the potential for sonic booms from horizontal or vertical RTLS (BRRC 2017). This operational buffer has been applied historically at the South Wallops Island UAS airstrip and was established for the future use of the North Wallops Island UAS airstrip to reduce potential startle effects and bird strikes. Noise from actions on mid- and South Wallops Island (e.g., EMRG, rocket launches) combined with new shorebird habitat from the SRIPP, have the potential to impact shorebirds, and it is anticipated that birds present will flush from the area either during pre-firing or pre-launch activities or during the launch activity.

Cumulative effects on nesting shorebirds could also occur from motorized uses on the Wallops Island beach. If unmanaged, motorized vehicle use on beaches can be a threat to beach nesting birds due to the potential for disturbance or mortality of adults, nests, and fledglings. Site-specific measures, particularly the relocation of recreational activities to areas without nesting activity, could mitigate any potential effects. Additionally, as vehicular use of the Wallops Island beach is relatively low, and is limited to WFF employees (who receive protected species awareness training), as well as those of other organizations with a mission or research need for use of the beach, these effects are not expected to be substantial. NASA would enforce at least a 300 m (1,000 ft) buffer from identified protected shorebird nests to reduce the potential for impacts.

5.4.5.3.3 Predation

One of the greatest threats to nesting shorebirds is predation. To reduce the risks of predation to nesting shorebirds and sea turtles on the Wallops Island beach, WFF employs biologists from USDA Animal and Plant Health Inspection Service Wildlife Services who routinely perform predator removal.

Despite potential adverse cumulative effects on beach nesting and foraging waterbirds, at a time when the availability of elevated beach nesting habitat is declining, the SRIPP would return several miles of the beach that are currently intertidal to supratidal, which would be more suitable for nesting. Coupled with long-term active monitoring of nesting activities and predator control, the combined effect would likely be a net benefit on beach-reliant species.

Given the temporary and intermittent nature of proposed construction and operational activities that terrestrial wildlife are currently exposed to, as well as general operational activities, and the likely separation in implementation time frames, there is little potential for cumulative effects to resident terrestrial wildlife or migratory bird populations from the Proposed Action in combination with other past, present, and likely foreseeable actions.

### 5.4.6 Special-Status Species

#### 5.4.6.1 Description of Geographic Study Area and Temporal Extent

The geographic study area for this CEA includes the Main Base, Wallops Island and Atlantic Ocean. The temporal extent is limited to the 20-year planning horizon of this PEIS but focuses on the period between 2019 through 2025, as there are currently no known projects after 2025. Please note that special-status marine mammals are not discussed in this section; refer to Section 5.4.7 for a discussion of cumulative effects related to special-status marine mammals.

#### 5.4.6.2 Relevant Past, Present, and Future Actions

The relevant past actions include the initial Causeway Bridge and boat basin construction and federal navigation projects. The present and future actions relevant to this analysis include construction and demolition projects under the Proposed Action that include replacement of the Causeway Bridge, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pier 0-D). Other relevant actions include the federal maintenance dredging of the navigation channel in Bogues Bay (approximately every 10 years); federal maintenance dredging of Chincoteague Inlet just north of Wallops Island (on a near annual basis); SRIPP renourishment at Wallops Island (every 3 to 7 years, as needed to maintain an elevated beach); construction and operation of the North Wallops Island UAS airstrip; launches of orbital and suborbital LV, expansion of the space program to include larger LVs and the introduction of RLVs; U.S. Navy operations (i.e., DoD SM-3, EMRG operations, and AN / SPY-6 radar testing in the Navy Assets area on Wallops Island); U.S. Navy RDT&E within the VACAPES Range Complex; and the U.S. Air Force Instrumentation Tower on Wallops Island.

#### 5.4.6.3 Cumulative Effects Analysis

This CEA will focus on the potential for cumulative effects associated with habitat loss, noise, and predation. In anticipation of potential cumulative effects from actions addressed in this CEA, WFF entered into Section 7 of the ESA consultation with USFWS. In 2016, USFWS offered its BO to WFF including an Incidental Take Statement based upon NASA's fulfillment of specific terms and conditions (USFWS 2016).

##### 5.4.6.3.1 Habitat Loss

Construction and demolition activities at the Main Base would have the potential to impact the northern long-eared bat. While no suitable habitat exists for this species, WFF would conduct tree removal outside of the northern long-eared bat roosting period in the June 1 to July 31 timeframe to reduce any potential impacts to the species. Should NASA deem it necessary to remove trees of 3 inches diameter at breast height or greater between June 1 and July 31, it will either:

1. Conduct a bat emergence survey (1 surveyor per 10 trees) 1 to 2 days prior to the scheduled tree removal and report results to USFWS; or
2. Conduct a presence/absence survey of the affected area, employing a qualified bat surveyor and report results to USFWS.

As part of the consultation for the SRIPP PEIS, NMFS concurred that the project may affect but is not likely to jeopardize the continued existence of the loggerhead and Kemp's ridley sea turtles and is not likely to adversely affect leatherback or green sea turtles. In addition, USFWS concurred the SRIPP action may affect but is not likely to jeopardize the continued existence of the piping plover; green, leatherback, and loggerhead sea turtles; or seabeach amaranth (NASA 2010).

As part of the North Wallops Island UAS Airstrip EA, NASA determined there would be no effect to nesting loggerhead sea turtles and the project may affect but is not likely to adversely affect piping plovers (NASA 2012b). The USFWS concurred with NASA's determination of "no effect" to protected species from the proposed UAS construction activities since the activities would be "limited to areas outside habitat that supports the listed species." USFWS concurred with NASA's determination of "no effect" to the Federally listed seabeach amaranth and NASA's determination of "may affect, but is not likely to adversely affect" piping plovers with the addition of avoidance and monitoring measures agreed to by NASA WFF and USFWS (NASA 2012b). The USFWS also determined that a BGEPA permit would not be required since the Proposed Action would not occur within known eagle concentration areas and the project would employ a 200 m (660 ft) encroachment buffer surrounding the active nest within which no construction activities would occur (NASA 2012b). NASA is currently in the process of obtaining a permit to remove this nest (Miller 2017). The U.S. Air Force Instrumentation Tower project on Wallops Island has been determined to "may affect, but unlikely to adversely affect" piping plover and red knots at WFF (USFWS 2017). The instrumentation tower is planned to have bird diverters installed on the guy wires, as well as being equipped with lighting that would reduce impacts to local and migrating birds, to include special-status species that may utilize the Wallops Island area during migrations (U.S. Air Force 2017).

5.4.6.3.2 Noise

**Institutional Support Projects**

With the exception of replacement of the Causeway Bridge, maintenance dredging, SRIPP, North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D at the south end of Wallops Island, the other institutional support projects under the Proposed Action would not affect special-status species. Replacement of the Causeway Bridge and maintenance dredging projects have the potential to adversely impact Atlantic sturgeon and sea turtles from in-water noise. In addition, dredging and construction activities associated with Launch Pad 0-C, Launch Pier 0-D, and the North Wallops Island Deep-water Port and Operations Area; maintenance dredging and beach disposal; and SRIPP has the potential to affect piping plover and nesting loggerhead sea turtles. Operation of heavy equipment on the Wallops Island beach during SRIPP, Launch Pad 0-C, and Launch Pier 0-D construction would again compact the beach, which could cause the affected area to be less suitable for sea turtle nesting. The placement of additional fill would also steepen the beach profile, which could lead to scarping in areas. The time of year that the renourishment and construction would be conducted would dictate the likelihood of impacts, with fall/winter activities providing the greatest amount of time for profile equilibration prior to the following nesting season. Activities occurring during the spring or summer months would present the greatest potential for effects, however the extent of the affected area would be less than that affected by the initial beach SRIPP project. In summary, despite potential adverse cumulative effects on sea turtles and plovers, at a time when the availability of elevated beach nesting habitat is declining, the proposed SRIPP would return several miles of the beach that are currently intertidal to supratidal, which would be more suitable for nesting, therefore providing a net benefit to these beach nesting species.

**Operational Missions and Activities**

Operational activities under the Proposed Action associated with Launch Pad 0-C, Launch Pier 0-D, and all rocket launches could also potentially affect piping plovers, red knots, and sea turtles. EMRG and AFTT activities may affect piping plovers, Atlantic sturgeon or green, hawksbill, Kemp's ridley, loggerhead, or leatherback sea turtles**.** A letter of authorization for AFTT activities was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b). WFF would continue beach surveys in accordance with the *Protected Species Monitoring Plan* and would continue to adhere to the terms and conditions of the Incidental Take Statement pursuant to the 2016 Revised BO (USFWS 2016b). The WFF Environmental Office would coordinate with the Range and Mission Management Office and USFWS regarding the located species (NASA 2011c). Under the Proposed Action, the launching and landing of the larger orbital vehicles would have similar impacts to special-status species as orbital vehicles currently launched from WFF. This would include impacts from noise, vibration, general disturbance from operational activities, as well as the potential for mortality of special-status species if too near a launch pad during a launch event.

With regard to sea turtles and piping plover, continued recreational and motorized uses of the beach could inadvertently disturb nesting females, crush eggs within the nest, or crush, entrap, or disturb hatchlings attempting to leave the nest. However, with the continued implementation of the protected species monitoring program on the Wallops Island beach, it is expected that nests would be identified shortly after establishment and marked with signage. Site-specific measures, for both species including relocation of recreational activities, shielding nests from artificial light (for sea turtles), or establishment of travel corridors between the nest and ocean (for sea turtles) could further mitigate any potential effects. Additionally, as vehicular use of the Wallops beach is relatively low, and is limited to WFF employees (who receive protected species awareness training), as well as those of other organizations with a mission or research need for use of the beach, these effects are not expected to be substantial.

5.4.6.3.3 Predation

Perhaps the greatest risk to sea turtle success is the predation of eggs and young by mammals, birds, and ghost crabs which may eliminate up to 100 percent of the nests and any hatchlings that emerge on beaches where predation is not managed (National Research Council 1990). WFF employs biologists from USDA Animal and Plant Health Inspection Services who routinely perform predator removal. As such, it is expected that the effects of predation are already mitigated to the greatest extent practicable.

In summary, while incremental cumulative effects to piping plovers, foraging sea turtles, nesting loggerhead sea turtles, and Atlantic sturgeon are possible due to occurrence of activities within the same geographic area, no significant cumulative impacts are anticipated. Site-specific NEPA documentation would be conducted prior to commencement of Causeway Bridge construction once construction details are known. In addition, dredging activities associated with maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and SRIPP would be conducted in accordance with NMFS guidelines to minimize impacts to the Atlantic sturgeon and sea turtles foraging in the area. Beneficial reuse of dredge material removed during maintenance of the Maintained Barge Route would be performed to avoid sea turtle and piping plover nesting areas. Beneficial nesting and foraging habitat for piping plover and nesting habitat for sea turtles would be created during continued implementation of the SRIPP. WFF would continue to implement the *Protected Species Monitoring Plan* and to adhere to the terms and conditions of the Incidental Take Statement pursuant to the 2016 Revised BO for all operational and institutional support activities and for proposed and ongoing operations and shoreline restoration (USFWS 2016).

### 5.4.7 MARINE MAMMALS AND FISH

#### 5.4.7.1 Description of Geographic Study Area and Temporal Extent

The study area considered in the cumulative analysis includes portions of the Atlantic Ocean adjacent to Wallops Island and within 22.2 km (12.0 nm) of the shore. In accordance with Presidential Proclamation 5928, impacts on ocean areas that lie within 22.2 km [12.0 nm] of land are considered territorial sea of the U.S. and thus subject to analysis under NEPA. The temporal extent is limited to the 20-year planning horizon of this PEIS but focuses on the period between 2019 through 2025, as there are currently no known projects after 2025.

#### 5.4.7.2 Relevant Past, Present, and Future Actions

The relevant past actions include the initial Causeway Bridge and boat basin construction and federal navigation projects. Present and future actions under the Proposed Action (i.e., development of the North Wallops Island Deep-water Port and Operations Area and construction of Launch Pier 0-D); federal maintenance dredging of the navigation channel in Bogues Bay (approximately every 10 years); federal maintenance dredging of Chincoteague Inlet just north of Wallops Island (on a near annual basis); SRIPP renourishment at Wallops Island (every 3 to 7 years, as needed to maintain an elevated beach); and expansion of the space program to include larger LVs and the introduction of RLVs; and Navy operations that include DoD SM-3 and EMRG operations in the Navy Assets area on Wallops Island and Navy RDT&E within the VACAPES Range Complex.

#### 5.4.7.3 Cumulative Effects Analysis

This CEA will focus on the potential for cumulative effects associated with habitat loss and noise. The launching and landing of the larger orbital LVs would have similar impacts to marine species and EFH as orbital LVs currently launched from WFF.

5.4.7.3.1 Habitat Loss

As part of the consultation for the SRIPP PEIS, NMFS concurred that the action would not likely adversely affect right, humpback, or fin whales (NMFS 2009). In addition, there would be direct site-specific adverse effects on EFH within 1) the dredged area due to removal of benthic habitat and changes in shoal bathymetry and 2) the fill placement area due to burial of existing benthic habitat; there may be indirect adverse effects on inshore EFH due to propagation of the invasive species, *Phragmites*. However, the impacts would not be significant within a regional context. Although biological recovery at the borrow area would be prolonged, the effects would only persist for several seasons following disturbance and would not extend beyond the area that was affected by the initial fill cycle. When considered within the larger context of the inner continental shelf offshore of Virginia and Maryland, nearby shoals such as Blackfish Bank, Chincoteague Shoals, and other unnamed shoals in the area would provide alternate foraging and refuge grounds (**Figure 5.4-2**). There would also be minor direct impacts to fisheries outside the dredging and fill footprints due to turbidity as a result of the dredging and fill placement operations and indirect impacts from loss of habitat by additional *Phragmites* induced alteration of the ecology and function of the area. NASA is committed to reducing the spread of this invasive species and would implement its *Phragmites Control Plan* (NASA 2014) in consultation with USACE, VMRC, and VDCR to control propagation of *Phragmites* in these areas.

5.4.7.3.2 Noise

**<u>Institutional Support Projects</u>**

Cumulative effects to bottlenose dolphins are likely to result from pile driving during the Causeway Bridge construction and all projects requiring dredging. However, specific project details on the Causeway Bridge remain unknown, and additional NEPA documentation would occur and authorization from NMFS would be obtained prior to project commencement.

**<u>Operational Missions and Activities</u>**

Cumulative effects to bottlenose dolphins are likely to result rocket launches, LFIC RTLS, and AFTT activities. Implementing the operational missions and activities under the Proposed Action may also result in the cumulative effect on marine mammals when combined with EMRG and AFTT events; however, not enough project information is known to adequately characterize impacts. Additional NEPA documentation would occur in the future and, if needed, authorization from NMFS and/or USFWS would be obtained prior to project commencement.

AFTT activities may affect, but are not likely to adversely affect the North Atlantic right, humpback, sei, and sperm whales or Florida manatees. A letter of authorization for AFTT activities was issued to the Navy from NMFS on November 13, 2018 (U.S. Navy 2018b). In addition, the Navy determined only explosives on or near the bottom and military expended materials have any significant potential to impact marine habitats as a substrate for biological communities. The impact area for underwater explosions and military expended materials were all much less than one percent of the total area of documented soft bottom or hard bottom in their respective training or testing areas. Such a low percentage of bottom habitat impacted suggests no significant impact on marine substrates and associated biogenic habitats from either individual stressors or combined stressors. Furthermore, the combined impact area of acoustic impulsive stressors, physical disturbances, and strike stressors proposed for training and testing events would have no significant impact on the ability of soft shores, soft bottoms, hard shores, hard bottoms, or artificial substrates to serve their function as habitat.

Based on the best available information at this time, no significant cumulative effects to EFH or marine mammals are anticipated from implementation of the institutional support projects and operational missions and activities. Additional NEPA analysis would be conducted for the Causeway Bridge project and maintenance dredging. NASA would secure the required permits and complete the required consultation prior to initiating activities associated with the Causeway Bridge project, maintenance dredging, and LFIC RTLS. At that time, cumulative effects would be further assessed.

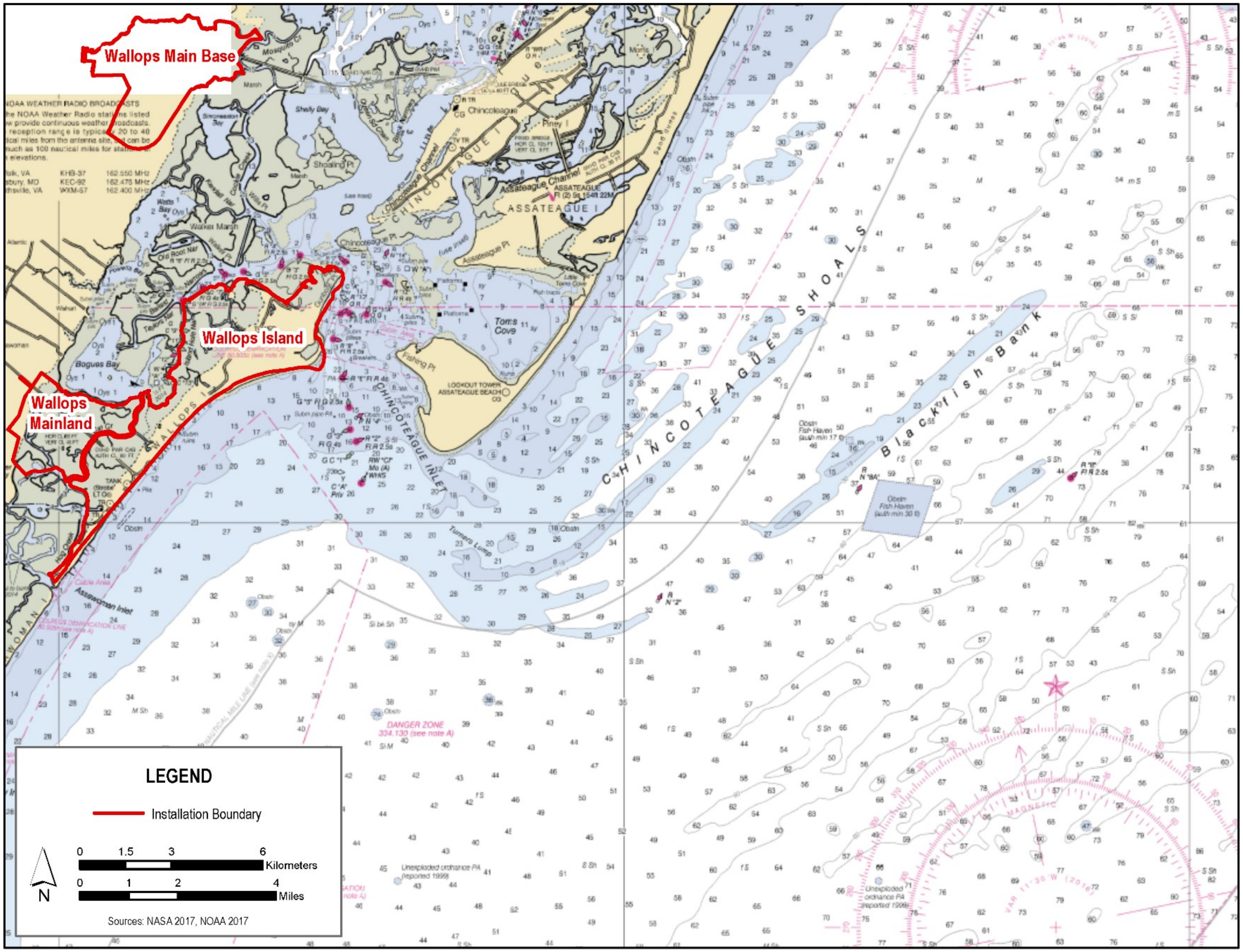


**Figure 5.4-2. Shoals in the Vicinity of Wallops Flight Facility**

# 6.0 OTHER CONSIDERATIONS

### 6.1.1 UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

NEPA requires a description of any significant impacts resulting from implementation of a proposed action, including those that can be mitigated to a less than significant level. Avoidance, minimization, or mitigation of adverse effects to natural, cultural, and other environmental resources were integrated into the Proposed Action to the greatest extent possible and practicable; however, all impacts may not be completely avoided and/or mitigated. Section 4.1 describes NASA's proposed mitigation measures, by resource category, for implementing the Proposed Action. These mitigation measures also include measures implemented by NASA on an ongoing basis as part of BMPs, compliance with permit requirements, and adherence to various management plans previously mentioned in the environmental consequences sections of this PEIS.

### 6.1.2 RELATIONSHIP BETWEEN SHORT-TERM USE OF MAN'S ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

NEPA requires analyzing the relationship between a project's short-term impacts on the environment and the effects those impacts may have on the maintenance and enhancement of the long-term productivity of the affected environment. Impacts that narrow the range of beneficial uses of the environment are of particular concern. Choosing one option may reduce future flexibility in pursuing other options or committing a resource to a certain use may eliminate the possibility for other uses of that resource.

As discussed in this chapter, implementation of the Proposed Action would result in both short- and long-term environmental effects. The Proposed Action would, irreversibly, dedicate parcels of land, equipment, and other resources to a particular use during an extended period of time. These resources would not be available for other productive uses throughout the useful life of the proposed facilities and infrastructure. However, these impacts are considered negligible, as the facilities and geographic areas associated with the Proposed Action are designated for and have historically accommodated the types of uses proposed. The Proposed Action is consistent with the 2008 WFF Facility Master Plan for development of the facility. Implementation of the Proposed Action is not expected to result in the types of impacts that would reduce environmental productivity, affect biodiversity, permanently narrow the range of beneficial uses of the environment, or pose long-term risks to human safety or the general welfare of the public.

## 6.2 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

NEPA requires that environmental analyses include identification of any irreversible and irretrievable commitments of resources that would be involved if the Proposed Action is implemented. Irreversible and irretrievable resource commitments are related to the use of non-renewable resources and the effects this use could have on future generations. Irreversible effects primarily result from the use or destruction of a specific resource (e.g., energy and minerals) that cannot be replaced within a reasonable time frame. Irretrievable resource commitments involve the loss in value of an affected resource that cannot be restored as a result of the action (e.g., extinction of a special-status species or the disturbance of a cultural resource).

EO 13834, *Efficient Federal Operations (May 2018)*, set goals for Federal agencies in areas such as energy efficiency, renewable energy, toxic waste management and disposal, recycling, sustainable buildings, electronics stewardship, and water conservation. Energy typically associated with construction activities would be expended and irretrievably lost under the Proposed Action; however, the majority of the institutional projects are designed to replace existing buildings. All infrastructure upgrades would comply with EO 13834 and NPR 8820.2D, *Design and Construction of Facilities*, NPR 8500.1C, *NASA Environmental Management*, and NPR 8570.1A, *NASA Energy Management Program*; therefore, any potential increase in utility demand from new construction could be counteracted through the use of energy and resource efficient, green building methods. Fossil fuels used during transportation of construction materials (e.g., fill, concrete/asphalt, and mobilization of equipment to the site) and the operation of construction equipment would constitute an irretrievable commitment of fuel resources. Energy would also be expended and irretrievably lost during operational missions and activities, resulting in an irretrievable commitment of fuel resources as well (e.g., fuel for planes, rockets, personnel usage). However, the current utility infrastructure utilization is under capacity and any increased demand associated with the proposed operational missions and activities could be accommodated. This energy use would not have an adverse impact on the continued availability of these resources and is not anticipated to be excessive in terms of region wide usage. Furthermore, compliance with the requirements set forth in EO 13834 would minimize any irreversible or irretrievable effects to multiple non-renewable and renewable resources.

On August 1, 2016, the CEQ issued final guidance on the consideration of GHG emissions and climate change in NEPA review (CEQ 2016). The guidance clarified that NEPA review requires federal agencies to consider the effects of GHG emissions and climate change when evaluating Proposed Actions: "Analyzing a proposed action's GHG emissions and the effects of climate change relevant to a proposed action—particularly how climate change may change an action's environmental effects—can provide useful information to decision makers and the public."

The guidance also emphasized that agency analyses should be commensurate with projected GHG emissions and climate impacts, and should employ appropriate quantitative or qualitative analytical methods to ensure useful information is available to inform the public and the decision-making process in distinguishing between alternatives and mitigations (CEQ 2016). Implementation of the Proposed Action has the potential to incrementally increase global emissions of GHG (as shown in **Table 3.2-5**). The overall emissions do not exceed the comparative threshold. As such, the Proposed Action does not represent a net incremental addition to the global greenhouse gases and global climate change problem.

# 7.0 REFERENCES

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# 8.0 AGENCIES AND PERSONS CONSULTED

| Agencies and Persons Consulted | | | |
|---|---|---|---|
| **Agency** | **Sent a Scoping Letter** | **Expressed Interest at Scoping Meeting** | **Sent a Notice/Copy of Draft PEIS** |
| **FEDERAL AGENCIES** | | | |
| Bureau of Ocean Energy Management | | | X |
| CEQ, Office of NEPA Oversight | X | | X |
| EPA, Office of Environmental Programs | X | | X |
| FAA, Headquarters, Washington D.C | | X | X |
| FAA, Operations Support Group | X | | X |
| FAA, Office of Commercial Space Transportation | | | X |
| NMFS, Protected Resources Division | X | | X |
| NMFS, Habitat Conservation Division | X | | X |
| NOAA, WCDAS | X | X | X |
| NOAA/NESDIS Headquarters, Facilities Management Branch | X | X | X |
| NPS, AINS | X | X | X |
| U.S. Air Force SMC/ENC | | | X |
| USACE, Norfolk District Office | | | X |
| U.S. Coast Guard | | | X |
| U.S. Department of Interior, Office of Environmental Policy and Compliance | X | | X |
| USFWS, CNWR | X | | X |
| USFWS, Northeast Regional Office | X | | X |
| USFWS, R5 - Northeast Region | | | |
| USFWS, Ecological Services, Virginia Field Office | X | | X |
| U.S. Navy, SCSC | | X | X |
| U.S. Navy Fleet Forces Command | | | X |
| U.S. Navy, NAVAIR Command | | | X |
| **STATE AGENCIES** | | | |
| VDCR, Department of Natural Heritage | X | | X |
| VDEQ, Tidewater Regional Office | X | | X |
| VDEQ, Office of Environmental Impact Review | X | | X |
| VDGIF, Wildlife Diversity Division | X | | X |
| VDHR, Office of Review and Compliance | X | | X |
| VIMS, Center for Coastal Resources Management | X | | X |
| VIMS, Eastern Shore Laboratory | X | | X |
| VMRC | | X | X |
| VMRC, Habitat Management Division | X | | X |
| **LOCAL GOVERNMENT** | | | |
| Accomack County | | | X |
| Accomack County Wetlands Board | X | X | X |
| Accomack County Planning and Community Development | | | X |

| Agencies and Persons Consulted (cont.) | | | |
|---|---|---|---|
| **Agency** | **Sent a Scoping Letter** | **Expressed Interest at Scoping Meeting** | **Sent a Notice/Copy of Draft PEIS** |
| Accomack-Northampton Planning District Commission | X | | X |
| Northampton County | X | | X |
| Somerset County | | | X |
| Town of Chincoteague | X | | X |
| Wicomico County | X | | X |
| Worcester County | | | X |
| **OTHER ORGANIZATIONS AND INDIVIDUALS** | | | |
| Akin Gump Strauss Hauer &Feld | | X | X |
| Anheuser-Busch Coastal Research Center | X | | X |
| Assateague Coastal Trust | X | | X |
| Formerly - BaySys Technologies, Inc. | X | | X |
| Chincoteague Bay Field Station (Formerly - Marine Science Consortium) | X | | X |
| Chincoteague Chamber of Commerce | X | | X |
| Citizens for a Better Eastern Shore | X | | X |
| Delmarva Low-Impact Tourism Experiences | X | | X |
| Eastern Shore Defense Alliance | X | | X |
| Eastern Shore of Virginia Chamber of Commerce | X | | X |
| Eastern Shore of Virginia Tourism Commission | X | | X |
| Economic Development Commission Of Florida's Space Coast | X | | X |
| Hampton Roads Military and Federal Facilities Alliance | X | X | X |
| HDR Environmental, Operations, and Construction, Inc. | X | | X |
| Maryland Coastal Bays Program | X | | X |
| Mid-Atlantic Regional Spaceport | X | | X |
| Resource Management Associates | | X | X |
| S.M. Stoller Corporation | X | | X |
| Space Florida | X | | X |
| TNC | X | X | X |
| Trails End Campground | X | | X |
| Virginia Eastern ShoreKeeper | X | | X |
| Private Citizens | | X | X |
| **ELECTED OFFICALS** | | | |
| United States House of Representatives | X | | X |
| United States Senate | X | | X |
| Virginia House of Delegates | X | | X |
| Virginia Senate | X | | X |
| Accomack County Board of Supervisors | X | | X |
| Somerset County Board of Commissioners | X | | X |
| Town of Chincoteague | X | | X |
| Wicomico County Council | | | X |
| Worcester County Board of Supervisors | | | X |

# 9.0 PREPARERS AND CONTRIBUTORS

| NAME | AREA OF RESPONSIBILITY | EDUCATION AND EXPERIENCE |
|---|---|---|
| **NASA WFF** | | |
| Bonsteel, Michael | Environmental Scientist<br>(LJT and Associates, Inc.) | M.S. Ecology, B.S. Biology<br>Years of Experience: 10 |
| Bundick, Joshua | Document Review | B.A. Environmental Sciences<br>Years of Experience: 15 |
| Miller, Shari | Project Manager | B.S. Chemistry, B.S. Biology<br>Years of Experience: 26 |
| Mitchell, Joel | Natural Resources Program Manager | M.S. Environmental Management<br>Years of Experience: 20 |
| Ward, Charles | Environmental Scientist<br>(LJT and Associates, Inc.) | B.S. Agriculture/Animal Science<br>Years of Experience: 22 |
| **Cardno GS, Inc.** | | |
| Albee, Lewis "Bud" | Program Director | M.S. Limnology, B.A. Biology<br>Years of Experience: 27 |
| Anderson, Stephen | Hazardous Materials, Toxic Substances, and Hazardous Waste; Health and Safety; Land Use; Land Resources | B.A. Environmental Science<br>Years of Experience: 9 |
| Banwart, Dana | Project Director<br>Quality Assurance/Quality Control | B.S. Biology<br>Years of Experience: 19 |
| Bartlett, Matt | Deputy Project Manager<br>Transportation; Infrastructure and Utilities | B.S. Environmental Policy and Planning<br>Years of Experience: 15 |
| Ferguson, Emily | Visual Resources and Recreation | B.A. Public and Urban Affairs<br>Years of Experience: 11 |
| Doan, Cathy | Airspace Management | M.A. Human Resources, B.A. English<br>Years of Experience: 23 |
| Hamilton, Lesley | Air Quality | B.S. Environmental Engineering, B.S. Biology<br>Years of Experience: 30 |
| Harrison, Michael | Biological Resources; Noise | M.S. Environmental Sciences, B.S. Biology<br>Years of Experience: 14 |
| Hoffman, Chareé | Project Manager | B.S. Biology<br>Years of Experience: 19 |
| Lortie, Joanne | Socioeconomics; Environmental Justice | B.A. Economics, M.A. Economics<br>Years of Experience: 26 |
| Lowenthal, John | Water Resources | M.S. Biology/Plant Ecology, B.S. Biology<br>Years of Experience: 31 |
| Mertz, Edie | Graphics | A.A. General Education<br>Years of Experience: 29 |
| Nicoletti, Jeremy | Geographic Information Systems, Mapping and Analysis | B.S. Geology<br>Years of Experience: 7 |
| Simpson, Sharon | Production Coordinator | A.S. Science<br>Years of Experience: 19 |
| Spaulding, Richard | Biological Resources | M.S. Wildlife and Fisheries Science, B.S. Biology<br>Years of Experience: 34 |
| Thursby, Lori | Cultural Resources | M.S. Architectural History,<br>B.S. Environmental Design in Architecture<br>Years of Experience: 22 |
| **Jones Edmunds & Associates, Inc.** | | |
| Berry, Stephen | Subconsultant | B.S. Environmental Engineering, B.S. Ecology/Chemistry<br>Years of Experience: 37 |

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# APPENDIX A
# NASA WFF SITE-WIDE ENVIRONMENTAL CHECKLIST

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## NASA GSFC Wallops Flight Facility

### Site-wide Programmatic Environmental Impact Statement
### Environmental Checklist

PROJECT NAME: ______________________________________PROJECT START DATE: _________________
PROJECT CONTACT: _________________ TELEPHONE: _______________________ MAILSTOP: __________

***Instructions:*** *This checklist is to be completed for proposed NASA actions at Wallops Flight Facility (WFF) to determine if the action is covered by the NASA WFF Site-wide Programmatic Environmental Impact Statement (PEIS). If the action is covered by the Site-wide PEIS (as determined by this checklist) a Record of Environmental Consideration (REC) will be prepared documenting the determination, and no further NEPA documentation will be required. If the checklist indicates the need for additional analysis or that the action is not adequately covered under the Site-wide PEIS, then a REC will be prepared that includes sufficient documentation of the additional analysis to support a determination of no significant impact. An Environmental Assessment (EA) or Environmental Impact Statement (EIS) will be completed if substantial additional analysis is required to determine direct, indirect, or cumulative impacts.*

*This Environmental Checklist and the Site-wide PEIS are only applicable to NASA WFF actions and customer actions that use NASA-owned facilities at WFF.*

**SECTION I. PROJECT ELIGIBILITY FOR COVERAGE UNDER THE SITE-WIDE PEIS**
**PROJECT DESCRIPTION:** ______________________________________________________________________

______________________________________________________________________________________________

______________________________________________________________________________________________

**PROJECT OWNER AND LOCATION:** _______________________________________________________________

______________________________________________________________________________________________

**Is the project listed in Site-wide PEIS Table 3.0-2 as requiring additional NEPA review? Yes ____ No ____**

| **If the proposed project includes any of the following actions, it may require additional analysis or further NEPA review.** | | | | | | |
|---|---|---|---|---|---|---|
| ***Construction*** | ***Routine/Recurring Activities and Maintenance*** | ***Research and Education/ Payloads*** | ***Airfield/ Aircraft*** | ***Rockets Operations*** | ***Balloons*** | ***Unmanned Aerial Systems*** |
| Construction not listed in PEIS Tables 2.5-1 or 2.5-2, or listed in Table 3.0-2 as requiring additional review | New fabrication, fueling, fuel storage, or payload processing facilities | Electromagnetic radiation, biological agents, or chemical releases greater those listed in PEIS Table 2.4-9 | Alteration of airspace or runways, or exceedance of 61,000 annual airfield operations (cumulative) | Over 18 orbital, 60 sub-orbital, 30 drones, or 20 projectiles per year, or > Castor 1200 or Atlas V launch vehicle | Larger than 1,000,000 $m^3$ (40,000,000 cf) or with a payload larger than 4,000 kgs (8,000 lbs) | Aerial: exceed 3,900 sorties or louder than Viking 300; Land/Aquatic: exceed Theseus vehicle specifications |

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# APPENDIX B
# COOPERATING AGENCY CORRESPONDENCE

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| DOCUMENT NUMBER | DATE | FROM | TO |
|---|---|---|---|
| 001 | April 26, 2011 | NASA | Federal Aviation Administration (FAA) Office of Commercial Space Transportation (CST) |
| 002 | October 13, 2011 | FAA CST | NASA |
| 003 | April 26, 2011 | NASA | FAA |
| 004 | April 29, 2011 | FAA Air Traffic Organization | NASA |
| 005 | July 31, 2017 | NASA | Department of Transportation (DOT) Federal Highway Administration (FHWA) |
| 006 | March 13, 2018 | DOT FHWA | NASA |
| 007 | April 12, 2018 | DOT FHWA | NASA |
| 008 | April 26, 2011 | NASA | National Oceanic and Atmospheric Administration (NOAA) |
| 009 | July 25, 2011 | NOAA | NASA |
| 010 | April 26, 2011 | NASA | U.S. Army Corps of Engineers (USACE) |
| 011 | May 05, 2011 | USACE | NASA |
| 012 | April 26, 2011 | NASA | U.S. Coast Guard |
| 013 | April 26, 2011 | U.S. Coast Guard | NASA |
| 014 | July 7, 2011 | NASA | U.S. Environmental Protection Agency (EPA) |
| 015 | July 27, 2011 | EPA | NASA |
| 016 | June 1, 2011 | NASA | U.S. Fish and Wildlife Service (USFWS) |
| 017 | July 28, 2011 | USFWS | NASA |
| 018 | June 3, 2011 | NASA | U.S. Navy Atlantic Test Range |
| 019 | June 17, 2011 | U.S. Navy Atlantic Test Range | NASA |
| 020 | April 26, 2011 | NASA | U.S. Navy Surface Combat Systems Center (SCSC) |
| 021 | May 16, 2011 | U.S. Navy SCSC | NASA |
| 022 | October 26, 2011 | NASA | U.S. Navy Fleet Forces Command |
| 023 | November 18, 2011 | U.S. Navy Fleet Forces Command | NASA |
| 024 | February 25, 2013 | NASA | U.S. Air Force AFSPC SMC/ENC |
| 025 | February 22, 2013 | U.S. Air Force AFSPC SMC/ENC | NASA |
| 026 | January 04, 2013 | NASA | Virginia Commercial Spaceflight Authority |
| 027 | January 25, 2017 | Virginia Commercial Spaceflight Authority | NASA |
| 028 | August 07, 2017 | NASA | Cooperating Agencies |
| 029 | April 19, 2018 | FAA | USFWS |

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National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

Mr. Michael McElligott
Manager, Space Systems Development Division
Office of Commercial Space Transportation
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Dear Mr. McElligott:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the Federal Aviation Administration has regulatory authority for licensing new or modified commercial launch pads, vehicles, and space craft at WFF; we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

**Silbert, Shari A. (WFF-200.C)[EGG, Inc. (WICC)]**

**From:** Daniel.Czelusniak@faa.gov
**Sent:** Thursday, October 13, 2011 2:48 PM
**To:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**Subject:** Re: Wallops PEIS CA status

Hey Shari,

Sorry for the delay..I just returned from New Mexico. I'm not in the office to try to find if we ever sent a formal response. For the record, the FAA/AST accepts NASA's request for FAA/AST to be a cooperating agency on the PEIS.

Daniel A. Czelusniak
Environmental Program Lead
Federal Aviation Administration
Commercial Space Transportation
800 Independence Ave., SW, Suite 331
Washington, DC 20591
[redacted]

From: "Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]" <shari.a.silbert@nasa.gov>
To: Daniel Czelusniak/AWA/FAA@FAA
Date: 10/12/2011 03:15 PM
Subject: Wallops PEIS CA status

---

Hey, Dan.

I'm trying to close some gaps in the Admin Record. Do you know if the FAA-AST Cooperating Agency acceptance for the Wallops PEIS was ever finalized? Can I get a copy or can you send me an email stating that you accept?

Thanks so much!

*Shari A. Silbert*
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

Mr. Dennis E. Roberts
Director, Airspace Services
Mission Support Services
Federal Aviation Administration
800 Independence Ave, SW
Washington, DC 20591

Dear Mr. Roberts:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the Federal Aviation Administration has regulatory authority for airspace surrounding WFF; we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

U.S. Department
of Transportation
**Federal Aviation
Administration**

APR 2 9 2011

Ms. Carolyn Turner
Associate Chief
Medical and Environmental Management Division
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337-5099

Dear Ms. Turner:

Thank you for your letter requesting the Federal Aviation Administration participate as a cooperating agency in the environmental impact statement (EIS) for NASA's continued operations at the Wallops Flight Facility.

Because the proposal may include the establishment or modification to special use airspace (SUA), the FAA is pleased to participate in the EIS process in accordance with the National Environmental Policy Act of 1969 as amended, and its implementing regulations.

Modification of the SUA resides under the jurisdiction of the Eastern Service Center, Operations Support Group, Atlanta, Georgia. The Eastern Service Center will be the primary focal point for matters related to both airspace and environmental matters. Mr. Mark Ward is the Manager of the Operations Support Group. FAA Order 7400.2, Chapter 32 indicates the airspace and environmental processes should be conducted in tandem as much as possible; however, they are separate processes. Approval of either the aeronautical process or the environmental process does not automatically indicate approval of the entire proposal. I have attached Appendix 2, 3, and 4 of FAA Order 7400.2 for additional details.

A copy of the incoming correspondence and this response is being forwarded to Mr. Ward of the Eastern Service Center, Operations Support Group. Mr. Ward can be contacted at (404) 305-5571 for further processing of your proposal.

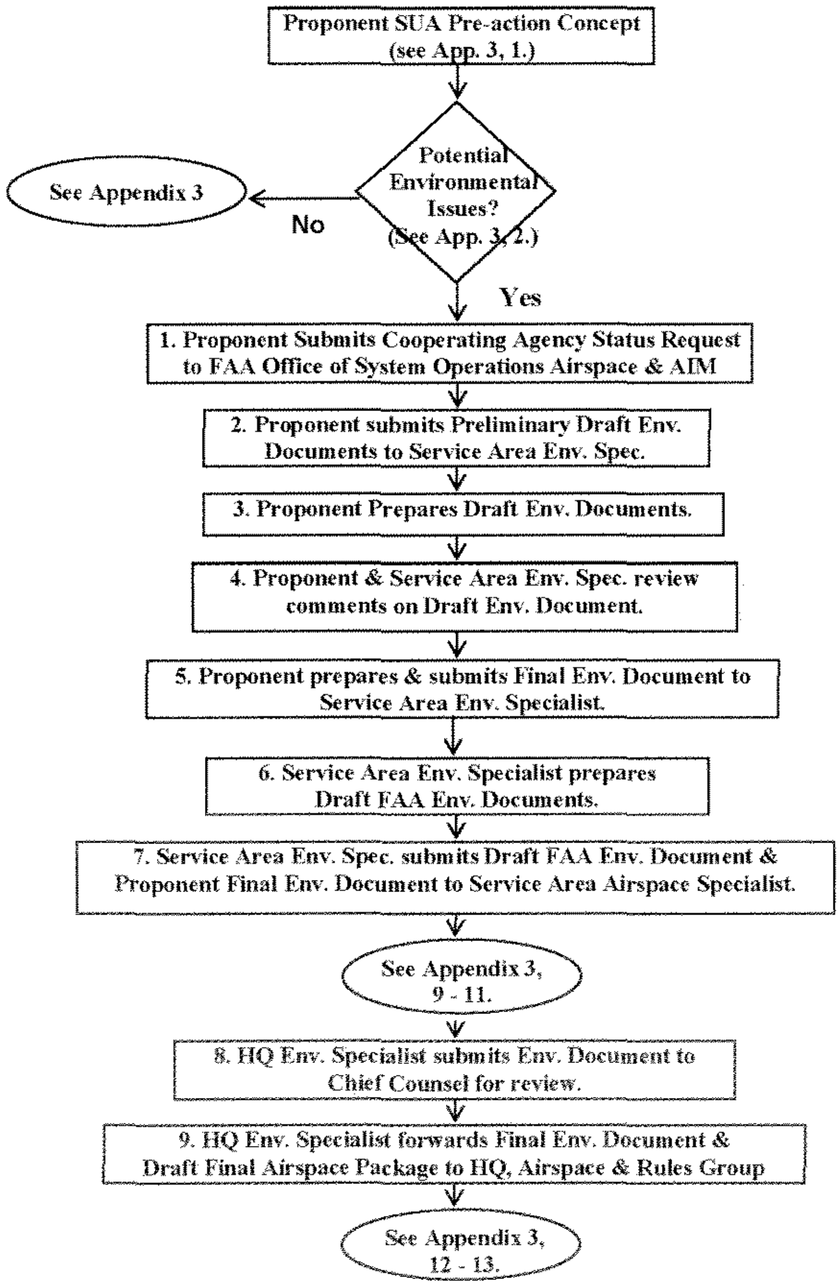
Sincerely,

Dennis E. Roberts
Director, Airspace Services
Air Traffic Organization

3 Enclosures

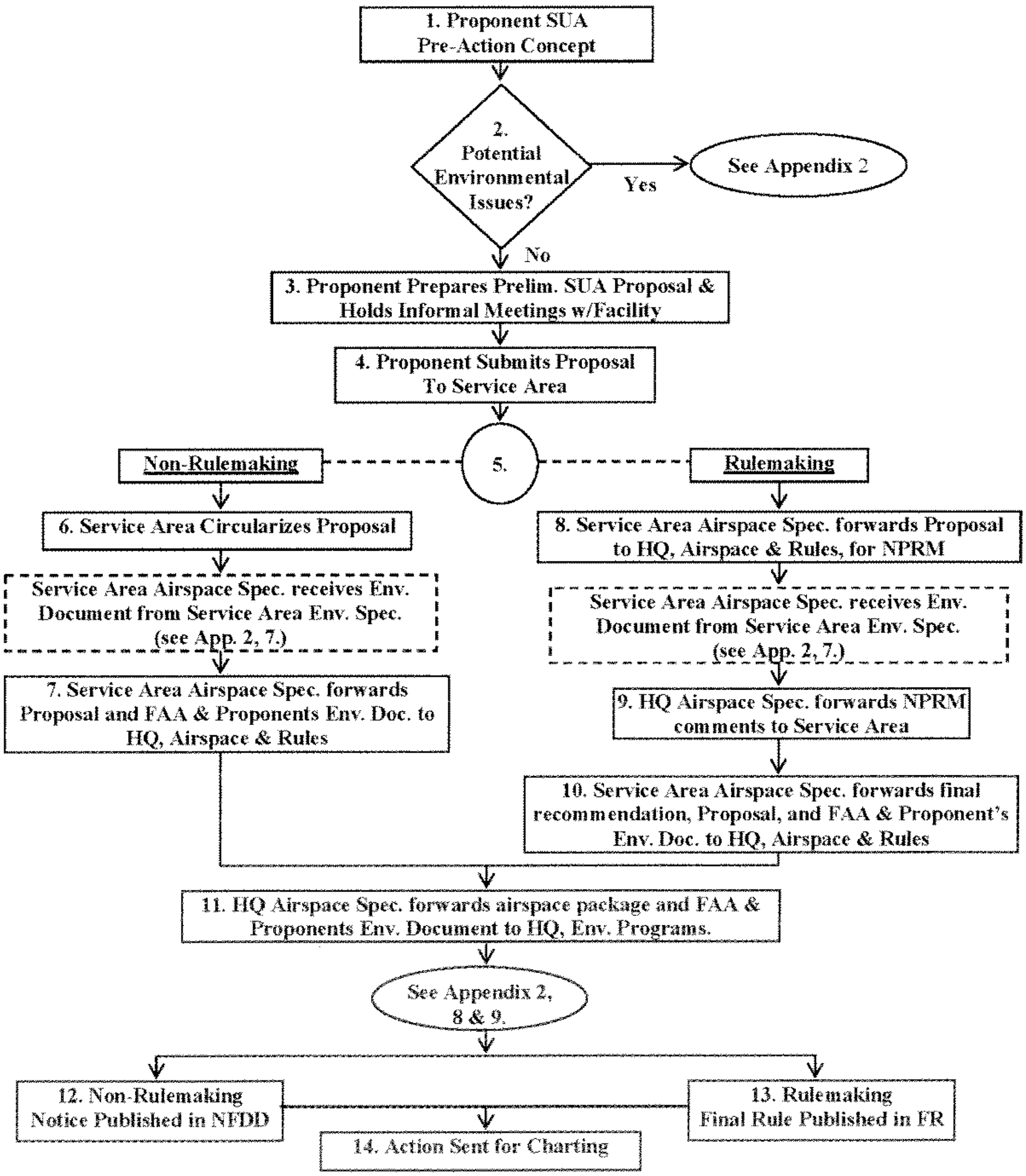
# Appendix 2. Procedures for Processing SUA Actions Environmental Process Flow Chart

(This Appendix is for use with Appendix 4 and the numbers correlate to the numbers in the Environmental column of that table.)



# Appendix 3. Procedures for Processing SUA Actions Aeronautical Process Flow Chart

(This Appendix is for use with Appendix 4 and the numbers correlate to the numbers in the Aeronautical column of that table.)



# Appendix 4. FAA Procedures for Processing SUA Actions Aeronautical and Environmental Summary Table

(The aeronautical and environmental processes may not always occur in parallel.)
(This Appendix is for use with Appendix 2 and Appendix 3, and the numbers correlate to numbers on those charts.)

(See note below.)

| AERONAUTICAL | ENVIRONMENTAL |
|---|---|
| 1. Proponent shall present to the Facility a Pre-draft concept (i.e., new/ revisions to SUA needed or required). | 1. Proponent shall discuss with the Service Area, at the earliest time, the potential for environmental impacts associated with the proposal. |
| | 2. If there is the potential for environmental impacts, Proponent shall make a request to the FAA for a Cooperating Agency (CA) status when Proponent decides to initiate the environmental process. Proponent shall forward the request to the Director of the Mission Support, Airspace Services. The Director will transmit the request to the Airspace Management Group who prepares and forwards the response to Proponent. The Airspace Management Group will send a courtesy copy of the response to the responsible Service Area. The Service Area environmental specialist works as the FAA point of contact throughout the process in development of any required environmental documentation. |
| | 3. Proponent submits a Preliminary Draft EA or EIS to the Service Area environmental specialist.<br><br>The Service Area environmental specialist shall provide comments, in consultation with the airspace specialist and the Airspace Management Group, back to Proponent. |

| | |
|---|---|
| 2. Proponent forwards the aeronautical proposal to the FAA Service Area for review and processing by the airspace specialist. | 4. Proponent prepares a Draft EA or EIS with a 45-day public comment period. As the FAA CA point of contact, the Service Area environmental specialist reviews the associated draft environmental documentation to ensure that the Proponent addressed adequately all environmental concerns submitted on the Preliminary Draft. If required, the Service Area environmental specialist forwards the draft environmental documentation to the Airspace Management Group for review and comment by the headquarters environmental specialist and the Office of Chief Counsel. |
| 3. The Service Area airspace specialist, in accordance with this order, determines the type of airspace action(s) necessary, either Non-Rulemaking or Rulemaking. FAA Service Area and Proponent determine if informal Airspace Meetings are required. | |
| **For Non-Rulemaking:** | |
| 4. The Service Area airspace specialist sends out a circularization with a 45-day public comment period. The Service Area airspace specialist reviews and prepares, in consultation with the Proponent, responses to the aeronautical comments from the study and circularization in accordance with Chapter 21 of this order. | 5. The Proponent reviews comments received on their Draft EA/FONSI or EIS and prepares their responses to the comments, in consultation with the FAA and other cooperating agencies, if necessary, and in accordance with Chapter 32 of this order. |
| | 6. Proponent prepares and submits their Final EA/FONSI or EIS/ROD to the Service Area environmental specialist. |
| | 7. The Service Area environmental specialist prepares a Draft FAA FONSI/ROD or Draft FAA Adoption Document/ROD. |
| | 8. The Service Area environmental specialist submits the Draft FAA FONSI/ROD or Draft FAA Adoption Document/ROD and the Proponent's Final EA/FONSI or EIS/ROD to the Service Area airspace specialist for inclusion with the airspace proposal package. |
| 5. The Service Area airspace specialist then sends the completed package containing the aeronautical proposal, response to comments, Proponent's Final EA/FONSI, and the Draft FAA FONSI/ROD to the Headquarters Airspace Regulations and ATC Procedures Group with their recommendation. | |

| **For Rulemaking:** | |
|---|---|
| 6. The Service Area airspace specialist sends the proposal to the Airspace Regulations and ATC Procedures Group who prepares a Notice of Proposed Rulemaking (NPRM). The Headquarters Airspace Regulations and ATC Procedures Group submits the NPRM for publication in the Federal Register with a 45-day comment period in accordance with Chapter 2 of this order. | |
| 7. The Headquarters airspace specialist sends comments received on the NPRM to the Service Area airspace specialist for resolution. | |
| 8. The Service Area airspace specialist then sends the completed package containing the response to comments, final service area recommendation, the proposal, Proponent's Final EA/FONSI or EIS/ROD, and the Draft FAA FONSI/ROD or Draft FAA Adoption Document/ROD to the Headquarters Airspace Regulations and ATC Procedures Group for preparation of the Final Rule. | |
| 9. The Headquarters airspace specialist forwards the draft final rule package or draft non-rulemaking case summary (NRCS) with all supporting documentation to the Headquarters Airspace Management Group for review (after all aeronautical comments have been resolved). | 9. The Headquarters environmental specialist reviews the package for environmental technical accuracy; then submits the environmental documentation to the Office of the Chief Counsel, Airports and Environmental Law Division, for legal sufficiency review (having collaborated throughout the process). |
| | 10. The Chief Counsel's environmental attorney's comments are incorporated into the final FAA environmental decision and signed by Headquarters Airspace Management Group Manager.<br><br>The package is then returned to the Headquarters Airspace Regulations and ATC Procedures Group. |
| 10. For Non-rulemaking:<br>The non-rulemaking action is published in the National Flight Data Digest (NFDD).<br><br>11. For Rulemaking:<br>The Final Rule is published in the Federal Register. The Final Rule will contain a reference to the decision rendered and location of documentation for the associated environmental process. | |

Consult the following documents throughout the process for further information:

- Council on Environmental Quality Regulations for Implementing the National Environmental Policy Act (NEPA), 40 CFR Parts 1500–1508
- FAA Order 1050.1E, "Environmental Impacts: Policies and Procedures"
- FAA Order 7400.2, "Procedures for Handling Airspace Matters," Part 5
- FAA Order 7400.2, Chapter 32, "Environmental Matters" and the associated appendixes (for specific SUA environmental direction)

**NOTE:** The time periods below are for a non-controversial aeronautical proposal and its associated environmental process. The time periods are for FAA review/processing only. Times for proponent and/or environmental contract support processing must be added.

ENVIRONMENTAL: The estimated time of completion for EA processing is 12 to 18 months or, for EIS processing, 18 to 36 months.

AERONAUTICAL (Non-Rulemaking): A minimum 4 months is required from submission of the Formal Airspace Proposal by the Proponent to the Service Area through completion of the circularization process. Additionally, a minimum of 6 months is required from submission of the Formal Airspace Proposal by the Service Area to Headquarters through completion of the charting process.

AERONAUTICAL (Rulemaking): A minimum 6 weeks for Service Area processing, and a minimum of 9 months to complete rulemaking once the formal package is received at Headquarters.

**From:** Miller, Shari A. (WFF-2500)
**To:** "Rajashree.Mooney@dot.gov"
**Cc:** Saecker, John R. (WFF-2280)
**Subject:** NASA Wallops Flight Facility Cooperating Agency Request
**Date:** Monday, July 31, 2017 11:07:00 AM
**Attachments:** WSW PEIS MOU NASA 11 signed.pdf

---

Good morning, Ms. Mooney.

My name is Shari Miller and I'm the Environmental Planning Lead for National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF). I'm currently working with John Saecker in our Facilities Management Branch regarding the proposed Wallops Island Causeway Bridge project. WFF is including this action as part of a broader 20-year master planning effort and requests your agency's participation as a Cooperating Agency in the preparation of a Programmatic Environmental Impact Statement (PEIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that a PEIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare a PEIS to satisfy the NEPA obligations of all federal and state partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the Federal Highway Administration has specialized expertise in replacing the causeway bridge to Wallops Island, we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would anticipate our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A copy of our current Memorandum of Understanding detailing Lead and Cooperating Agency expectations is attached for your review. We are anticipating releasing our first Cooperating Agency internal draft this September and would appreciate an environmental planning point of contact.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact me at (757) 824-2327 or at Shari.A.Miller@nasa.gov.

*Shari A. Miller*
Environmental Planning Lead

**From:** Kimberley, Ryan (FHWA)
**To:** Miller, Shari A. (WFF-2500); Mooney, Rajashree (FHWA)
**Cc:** Saecker, John R. (WFF-2280); Rose, Kevin (FHWA)
**Subject:** RE: NEPA coordination for Wallops Island Causeway Bridge
**Date:** Tuesday, March 13, 2018 3:59:07 PM

Hello Shari,

Yes, FHWA would like to accept your invitation to participate in the Wallops Island EIS as a cooperating agency. We look forward to working with you on this.

Thank you very much,
Ryan

**From:** Miller, Shari A. (WFF-2500) [mailto:shari.a.miller@nasa.gov]
**Sent:** Tuesday, March 13, 2018 10:24 AM
**To:** Kimberley, Ryan (FHWA) <ryan.kimberley@dot.gov>; Mooney, Rajashree (FHWA) <Rajashree.Mooney@dot.gov>
**Cc:** Saecker, John R. (WFF-2280) <john.r.saecker@nasa.gov>
**Subject:** RE: NEPA coordination for Wallops Island Causeway Bridge

Good morning, Ryan & Raju,

We are getting closer to releasing the draft of the Wallops Site-wide Programmatic Environmental Impact Statement (PEIS) for public review. At the moment, based upon input from Raju back in July/August of 2017, the document does not include FHWA as a Cooperating Agency (CA). Following Ryan's review of the PEIS, and before it goes public, I'd like to re-invite FHWA as a CA. Please let me know if your agency accepts this invitation and I'll add you to our list in the document.

Thank you.

*Shari A. Miller*
Environmental Planning Lead
NASA Wallops Flight Facility
Wallops Island, VA 23337
(757) 824-2327
Shari.A.Miller@nasa.gov
SIPRnet: Shari.Miller@nss.sgov.gov
http://sites.wff.nasa.gov/code250/

*"After the laws of physics, everything else is opinion." – Neil deGrasse Tyson*

**From:** Kimberley, Ryan (FHWA) [mailto:ryan.kimberley@dot.gov]
**Sent:** Tuesday, November 21, 2017 1:53 PM
**To:** Miller, Shari A. (WFF-2500) <shari.a.miller@nasa.gov>

**From:** Mooney, Rajashree (FHWA)
**To:** Miller, Shari A. (WFF-2500)
**Cc:** Rose, Kevin (FHWA); Kimberley, Ryan (FHWA); Bell, Holly (FHWA); Saecker, John R. (WFF-2280)
**Subject:** NEPA coordination for Wallops Island Causeway Bridge
**Date:** Thursday, April 12, 2018 4:12:26 PM

Hi Shari:

We have identified funding for our Ryan's time to participate in the PEIS. Please include EFLHD as a cooperating agency in the MOU.

Thanks,

Raju

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

Mr. A. John Gironda, III
Environmental Compliance and Safety Project Manager
NESDIS Management Operations & Analysis Division
National Oceanic and Atmospheric Administration
1335 E. West Highway, Suite 7415
Silver Spring, MD 20910

Dear Mr. Gironda:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service has permanent facilities and missions at WFF; we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA,
AND INFORMATION SERVICE

RECEIVED
AUG 1 2011

JUL 25 2011

Ms. Carolyn Turner
National Aeronautics and Space Administration
Goddard Space Flight Center Wallops Flight Facility
Code 250 Building F-160
Wallops Island, VA 23337

Dear Ms. Turner,

Thank you for your invitation to participate as a Cooperating Agency in developing the Wallops Site-Wide Environmental Impact Statement (EIS) to be prepared for the National Aeronautics and Space Administration (NASA) Wallops Flight Facility (WFF). On behalf of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) I am happy to accept your invitation.

NESDIS shares your desire of planning for future actions and missions, and certainly support your effort to comply with National Environmental Protection Act (NEPA) responsibilities. We understand and accept our role to provide support to your effort in the form of technical expertise, document reviews, and active participation throughout the NEPA process. We accept this commitment with the understanding we will meet to discuss in more detail the manner of our coordination. NESDIS understands that our commitment does not represent an obligation for financial support.

During the process the NESDIS representatives will be Mr. Doug Crawford and Mr. A John Gironda III. Their contact information is listed below. You may contact directly to coordinate times and availability:

Mr. Doug Crawford
Wallops Command Data Acquisition Station:
Station Manager
35663 Chincoteague Road
Wallops, VA 23337
Van.D.Crawford@noaa.gov
[redacted]

Mr. A John Gironda III, P.E.
NESDIS
Environmental Compliance Program Manager
1335 East West Highway, Suite 7415
Silver Spring, MD 20910
John.Gironda@noaa.gov
[redacted]

We appreciate the opportunity to participate in this effort, and look forward to working with you on the development of the environmental package for the WFF.

Sincerely,

Paul E. Pegnato
Facilities Team Lead
National Environmental Satellite, Data
and Information Service

cc:
Doug Crawford, NOAA/NESDIS, WCDAS Station Manager
Keith Amburgey, NOAA/NESDIS Office of Satellite and Product Operations
Steve Kokkinakis, NOAA Office of Program Planning and Integration

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

Ms. Kimberly A. Prisco-Baggett
Chief, Eastern Virginia Regulatory Section
Norfolk District
U.S. Army Corps of Engineers
803 Front Street
Norfolk, VA 23510

Dear Ms. Prisco-Bagget:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the U.S. Army Corps of Engineers possess both regulatory authority and specialized expertise pertaining to the proposed action, we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

**From:** Smith, Marshall (Tucker) T NAO
**To:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**Cc:** Gibson, Steven W NAO
**Subject:** RE: Cooperating Agency Request (UNCLASSIFIED)
**Date:** Thursday, May 05, 2011 7:18:00 AM

---

Classification: UNCLASSIFIED
Caveats: NONE

Ms. Silbert,

This is in response to your letter requesting the USACE Norfolk District's Regulatory Branch to participate as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at Wallops Flight Facility (WFF).

I will be drafting an official response to be signed by our Regulatory Chief that will detail our acceptance as cooperating agency for this effort.

Just wanted to let you know what was going on.

v/r

Tucker Smith
Environmental Scientist
Regulatory Branch
U.S. Army Corps of Engineers, Norfolk District
803 Front Street
Norfolk, VA  23510

[redacted]
tucker.smith@usace.army.mil

-----Original Message-----
From: Baggett, Kimberly A NAO
Sent: Monday, May 02, 2011 12:46 PM
To: Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
Cc: Smith, Marshall (Tucker) T NAO; Gibson, Steven W NAO
Subject: RE: Cooperating Agency Request (UNCLASSIFIED)

Classification:  UNCLASSIFIED
Caveats: NONE

Classification: UNCLASSIFIED
Caveats: NONE

Mr. Tucker Smith will be the Project Manager handling this request.

He will respond to your request shortly.

Thanks.
Respectfully,

- Kim
Kimberly A. Prisco-Baggett
Chief, Eastern Virginia Regulatory Section Norfolk District Corps of Engineers "2010 - THE BEST PLACE TO WORK IN HAMPTON ROADS"
803 Front Street
Norfolk, VA 23510
[redacted]

Experience is not what happens to a man; it is what a man does with what happens to him. - Aldous Huxley

-----Original Message-----
From: Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)] [mailto:shari.a.silbert@nasa.gov]
Sent: Tuesday, April 26, 2011 2:09 PM
To: Baggett, Kimberly A NAO
Cc: Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020); Gibson, Steven W NAO
Subject: Cooperating Agency Request

Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division:

Ms. Prisco-Baggett,

NASA is initiating the preparation of an Environmental Impact Statement (EIS) for its continued operations at Wallops Flight Facility in Wallops Island, Virginia. It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

Letters have been sent to each agency with an electronic cc attached, requesting your agreement to participate in this EIS process as a Cooperating Agency. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept our request.

______________
Shari A. Silbert

URS Corporation

Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

LT Marcus Merriman
Chincoteague Group
U.S. Coast Guard
3823 Main Street
Chincoteague, VA 23336

Dear LT Merriman:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the U.S. Coast Guard, Chincoteague Group has permanent facilities at WFF, we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

## Simpson, Sharon E.

| | |
|---|---|
| **From:** | Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)] <shari.a.silbert@nasa.gov> |
| **Sent:** | Tuesday, April 26, 2011 4:05 PM |
| **To:** | Marcus.R.Merriman@uscg.mil |
| **Cc:** | Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Norwood, Tina (HQ-LD020) |
| **Subject:** | RE: Cooperating Agency Request |

Thank you, Lieutenant. We look forward to working with you.

*Shari A. Silbert*
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

Please visit our website at WFF Environmental Office
*"The contents of this message do not reflect any position of the National Aeronautics and Space Administration or Goddard Space Flight Center."*

-----Original Message-----
From: Marcus.R.Merriman@uscg.mil [mailto:Marcus.R.Merriman@uscg.mil]
Sent: Tuesday, April 26, 2011 3:40 PM
To: Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
Subject: RE: Cooperating Agency Request

Ms. Silbert,
We will participate; keep my information as your point of contact.

Thanks!

LT Marc Merriman
Supervisor
USCG SFO Eastern Shore
[redacted]

-----Original Message-----
From: shari.a.silbert@nasa.gov [mailto:shari.a.silbert@nasa.gov]
Sent: Tuesday, April 26, 2011 2:10 PM
To: Merriman, Marcus LT
Cc: Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020)
Subject: Cooperating Agency Request

Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division:

LT Merriman,

NASA is initiating the preparation of an Environmental Impact Statement (EIS) for its continued operations at Wallops Flight Facility in Wallops Island, Virginia. It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

Letters have been sent to each agency with an electronic cc attached, requesting your agreement to participate in this EIS process as a Cooperating Agency. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept our request.

___________________

Shari A. Silbert

URS Corporation

Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

Please visit our website at WFF Environmental Office
<http://sites.wff.nasa.gov/code250/>

"The contents of this message do not reflect any position of the National Aeronautics and Space Administration or Goddard Space Flight Center."

**Silbert, Shari A. (WFF-200.C)[EGG, Inc. (WICC)]**

**To:** 'Lapp.Jeffrey@epamail.epa.gov'; Rudnick.Barbara@epamail.epa.gov; Alaina DeGeorgio
**Cc:** Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020)
**Subject:** Cooperating Agency Request

*Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division*:

Thank you again for your responses to the scoping request for the Site-wide Programmatic Environmental Impact Statement (PEIS) for the Wallops Flight Facility in Wallops Island, Virginia. It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

NASA is requesting your agreement to participate in this PEIS process as a Cooperating Agency. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process.

We will be holding a kick-off meeting for the Site-wide PEIS at 9:00a.m. Wednesday August 3, 2011, prior to the Agency and Public Scoping Meetings (an Outlook invitation will follow this message). Your participation is greatly appreciated.

*Shari A. Silbert*
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

Please visit our website at WFF Environmental Office
*"The contents of this message do not reflect any position of the National Aeronautics and Space Administration or Goddard Space Flight Center."*

**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
**REGION III**
**1650 Arch Street**
**Philadelphia, Pennsylvania 19103-2029**

27 JUL 2011

Shari Silbert
Manager, Site-wide PEIS
NASA Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

Dear Ms. Silbert,

The U.S. Environmental Protection Agency (EPA) has received your letter dated July 7, 2011 regarding the Site-wide Programmatic Environmental Impact Statement (PEIS) for the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) located at Wallops Island, Virginia.

EPA is very interested to learn more about the proposed PEIS and participate along with other federal and state resource agencies at the agency scoping meeting on August 3, 2011. My staff plans to attend this agency scoping meeting. EPA is still interested in touring the WFF facilities at a future date to get a better understanding of the ongoing activities at WFF and of the barrier island resource where the facility is located. Please advise if this activity can be coordinated. We feel that it will aid in our discussions at the scoping meeting and benefit our review of projects at WFF.

EPA would like to offer our expertise on the National Environmental Policy Act (NEPA) and the Clean Water Act Section 404, which EPA jointly administers with the Army Corps of Engineers, to NASA as a cooperating agency for this project. In EPA's experience, we have found that early agency participation in project planning facilitates the NEPA process and results in a more beneficial environmental outcome. We encourage NASA to work with EPA along with the many cooperating agencies on this project.

EPA is pleased by and supports the interagency approach of assessing impacts and coordinated planning for NASA WFF's Site-wide PEIS. We look forward to working with you on this project. If you have any questions or would like to further coordinate the upcoming agency scoping meeting, please contact Alaina DeGeorgio of my staff at 215-814-2741 or Barbara Rudnick, NEPA Team Leader, at 215-814-3322.

Sincerely,

Jeffrey D. Lapp
Associate Director,
Office of Environmental Programs

cc. Robert Cole, USACE

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

June 1, 2011

Reply to Attn of: 250.W

Mr. Louis Hinds
Manager
Chincoteague National Wildlife Refuge
U.S. Fish and Wildlife Service
P.O. Box 62
Chincoteague, VA 23336

Dear Mr. Hinds:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

The U.S. Fish and Wildlife Service (USFWS) currently collaborates with WFF in managing protected species on our barrier island. Both WFF and the Chincoteague National Wildlife Refuge (CNWR) desire to enhance this level of cooperation by partnering on Goals 1 through 5 of the CNWR's Comprehensive Conservation Plan (coastal habitats, managed wetlands, upland habitats, southern barrier islands unit, and partnerships). Additionally, as the USFWS possess both regulatory authority and specialized expertise pertaining to the proposed action; we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

## Silbert, Shari A. (WFF-200.C)[EGG, Inc. (WICC)]

**From:** Louis_Hinds@fws.gov
**Sent:** Thursday, July 28, 2011 12:36 PM
**To:** Massey, Caroline R. (WFF-2000)
**Cc:** Turner, Carolyn (WFF-2500); Hoffman, Charee; CONNELL, EDWARD (GSFC-2500); Bundick, Joshua A. (WFF-2500); Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**Subject:** RE: Cooperating Agency Request

Okay, just got clearance from Solicitor and Regional Office, so, sign the FWS up as a Cooperating Agency.

Lou Hinds
Refuge Manager - Chincoteague NWR Complex
(Chincoteague NWR & Eastern Shore of VA NWR)
PO Box 62
Chincoteague, VA. 23336
[redacted]

"If I were to try to read, much less answer, all the attacks made on me,
this shop might as well be closed for any business. I do the very best
I know how - the very best I can; and I mean to keep doing so until the end.
If the end brings me out all right, what is said against me won't amount to anything.
If the end brings me out wrong, ten thousand angels swearing I was right would make no
difference" Abraham Lincoln

**"Massey, Caroline R. (WFF-2000)" <caroline.r.massey@nasa.gov>**

07/27/2011 12:47 PM

To "Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]" <shari.a.silbert@nasa.gov>, "Louis_Hinds@fws.gov" <Louis_Hinds@fws.gov>
cc "Turner, Carolyn (WFF-2500)" <carolyn.turner-1@nasa.gov>, "Bundick, Joshua A. (WFF-2500)" <joshua.a.bundick@nasa.gov>, "Hoffman, Charee" <CDHoffman@tecinc.com>, "CONNELL, EDWARD (GSFC-2500)" <edward.a.connell@nasa.gov>
Subject RE: Cooperating Agency Request

[redacted]

[redacted]

[redacted]

**From:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**Sent:** Wednesday, July 27, 2011 11:21 AM
**To:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]; Louis_Hinds@fws.gov
**Cc:** Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500)
**Subject:** Cooperating Agency Request

Hi, Lou.

Great talking to you this morning! Welcome home. Per our conversation, I'm resending our request to have

USFWS as a cooperating agency on our Site-wide PEIS. Please see the original request below.

---

Shari A. Silbert
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

Please visit our website at WFF Environmental Office
*"The contents of this message do not reflect any position of the National Aeronautics and Space Administration or Goddard Space Flight Center."*

**From:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**Sent:** Friday, June 03, 2011 12:36 PM
**To:** 'Louis_Hinds@fws.gov'
**Cc:** Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); 'Hoffman, Charee'; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020)
**Subject:**

*Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division*:

Mr. Hinds,

NASA is initiating the preparation of an Programmatic Environmental Impact Statement (EIS) for its continued operations at Wallops Flight Facility in Wallops Island, Virginia. It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

Letters have been sent to each agency with an electronic cc attached, requesting your agreement to participate in this EIS process as a Cooperating Agency. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept our request.

---

Shari A. Silbert
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

Please visit our website at WFF Environmental Office
*"The contents of this message do not reflect any position of the National Aeronautics and Space Administration or Goddard Space Flight Center."*

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

June 3, 2011

Reply to Attn of: 250.W

Mr. Greg Gillingham
Associate Director
Atlantic Test Range
23012 Cedar Point Road
Building 2118
Patuxent River, MD 20670-1183

Dear Mr. Gillingham:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the U.S. Navy Naval Air Systems Command has permanent missions at WFF and desires to increase those missions with programs such as the Broad Area Maritime Surveillance (BAMS) and Field Carrier Landing Practice (FCLP); we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Caroline Massey
Assistant Director, Management Operations Directorate

| | |
|---|---|
| **From:** | Jarboe, Christopher CIV ATR, 5.2.2.F |
| **To:** | Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)] |
| **Cc:** | Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020); Gillingham, Greg J CIV Atlantic Test Range, 2118 1 209 |
| **Subject:** | RE: Cooperating Agency Request |
| **Date:** | Friday, June 17, 2011 11:41:55 AM |

I look forward to supporting this effort and working with you on the EIS.

v/r

Chris

-----Original Message-----
From: Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)] [mailto:shari.a.silbert@nasa.gov]
Sent: Wednesday, June 15, 2011 13:56
To: Jarboe, Christopher CIV ATR, 5.2.2.F
Cc: Turner, Carolyn (WFF-2500); Bundick, Joshua A. (WFF-2500); Hoffman, Charee; Caroline Massey R,; CONNELL, EDWARD (GSFC-2500); Norwood, Tina (HQ-LD020); Gillingham, Greg J CIV Atlantic Test Range, 2118 1 209
Subject: Cooperating Agency Request

Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division:

Chris,

Greg Gillingham stated that you would be our contact in this effort. NASA is initiating the preparation of an Environmental Impact Statement (EIS) for its continued operations at Wallops Flight Facility in Wallops Island, Virginia. It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

Letters have been sent to each agency with an electronic cc attached, requesting your agreement to participate in this EIS process as a Cooperating Agency. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. I am currently drafting a Memorandum of Understanding for all Cooperating Agencies to this effort and will forward it to you for review ASAP.

Shari A. Silbert

URS Corporation

Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

April 26, 2011

Reply to Attn of: 250.W

LCDR Timothy Mead
Executive Officer
Surface Combat Systems Center
U.S. Navy
30 Battle Group Way
Wallops Island, VA 23337

Dear LCDR Mead:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of an Environmental Impact Statement (EIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that an EIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare an EIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the U.S. Navy, Surface Combat Systems Center has permanent facilities and missions at WFF; we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A more detailed list of Cooperating Agency expectations will be provided if you accept this request.

If you have any questions or require additional information regarding the Wallops Site-Wide EIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

| | |
|---|---|
| **From:** | Mead, Timothy J LCDR SCSC, XO |
| **To:** | Turner, Carolyn (WFF-2500) |
| **Cc:** | Massey, Caroline R. (WFF-2000); CONNELL, EDWARD (GSFC-2500); Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]; Bundick, Joshua A. (WFF-2500); Ailes, Marilyn CIV SCSC, X31 |
| **Subject:** | RE: SCSC / WFF Site-wide EIS |
| **Date:** | Monday, May 16, 2011 11:06:05 AM |

Good morning Carolyn,
We are in full support of participating in the preparation of the EIS.
IRT your last question, SCSC can speak for numbers 4, 6 and 7. Recommend you contact NAVAIR and see if they have one rep for the remaining groups or if they want to designate one from Pax and one from Norfolk.
Also, IRT to your last question, you have Dahlgren as the rep for number 6, Electromagnetic Railgun. Has Dahlgren contacted you or any NASA reps directly regarding Electromagnetic Railgun? If I am not mistaking, we have been kind of spearheading this effort with NASA.
Ms. Marilyn Ailes will be our rep.
If you have any questions, as always, please feel free to ask.
V/R,
Tim

-----Original Message-----
From: Turner, Carolyn (WFF-2500) [mailto:carolyn.turner-1@nasa.gov]
Sent: Friday, May 13, 2011 13:35
To: Mead, Timothy J LCDR SCSC, XO
Cc: Caroline Massey R,; CONNELL, EDWARD (GSFC-2500); Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]; Bundick, Joshua A. (WFF-2500)
Subject: SCSC / WFF Site-wide EIS

Hi LCDR Mead,

As to your question regarding Cooperating Agency (CA) expectations during the preparation of the Wallops Site-wide EIS, NASA would be the Lead Agency for this action and would coordinate with and fund the contractor preparing the EIS, coordinate with all Cooperating Agencies, interface with regulators, etc. We would expect the Navy to provide the following:

• Provide a point of contact for this project.

• Fund your employee travel (if any), labor hours, and other direct costs in support of the EIS.

• Provide NASA with relevant documentation to assist in the characterization of baseline conditions as well as the potential environmental consequences of the proposed action and its reasonable alternatives (e.g., recent NEPA documents, agency authored environmental reports and data, and scientific publications).

• Participate in regularly scheduled and ad-hoc meetings with NASA and its contractor as the EIS is prepared. It is expected that attendance at such meetings shall not exceed eight hours per month.

• Attend public meetings to represent their respective agency's interests. One scoping meeting and one draft release meeting are currently planned at the Wallops Visitor Center.

• Review versions of the Preliminary Draft and Preliminary Final EIS and provide consolidated written responses. Notify the other parties immediately if this is not possible.

NASA is considering drafting a Memorandum of Understanding to further clarify all CA roles and responsibilities.

Additionally, we are seeking to capture the following Navy-sponsored programs that our Range Office and WFF Senior Management have indicated may come here to Wallops. I'm not sure if there is one Navy POC that could serve each of these groups ? Could you recommend either an overall POC, NavAir and NavSea POCs, or whom you think would be the most appropriate person for each program listed below? Some of these programs may already have the appropriate NEPA analysis or may require additional studies to be part of our analysis.

Action Navy Sponsor:
1. DOD - FCLP (C-2/E-2),Norfolk
2. DOD - F-35: Joint Strike Fighter, PAX River
3. DOD - F-22: Raptor, PAX River
4. DOD - SM-3 SCSC (WFF)
5. BAMS PAX River
6. Electromagnetic Railgun, Dalghren
7. High Energy Laser Systems , SCSC

I would be happy to meet and discuss if you would like.

Thank you, Carolyn Turner

-----Original Message-----
From: Mead, Timothy J LCDR SCSC, XO [mailto:timothy.mead@navy.mil]
Sent: Wednesday, May 11, 2011 4:54 PM
To: Turner, Carolyn (WFF-2500)
Cc: Massey, Caroline R. (WFF-2000); Crawford, Bonnie H. (WFF-2500); CONNELL, EDWARD (GSFC-2500); Ailes, Marilyn CIV SCSC, X31; Hoffken, William P. (WFF-011.0)[NAVY (SURFACE COMBAT SYSTEM CENTER WALLOPS ISLAND)]; Talbot, Patrick H. (WFF-011.0)[NAVY (SURFACE COMBAT SYSTEM CENTER WALLOPS ISLAND)]
Subject: [redacted]

Carolyn,

Good afternoon to you as well. [redacted]
On a different note, I received letter regarding the EIS in the mail and will be in touch with you shortly. I want to brief Marilyn on it first and then answer you officially. There is one line that has me a little apprehensive. "A more detailed list of Cooperating Agency expectations will be provided if you accept this request". I would kind of like to know those expectations prior to committing. Thanks Carolyn.
V/R,
Tim

[redacted]

[redacted]

[redacted]

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
**Wallops Flight Facility**
**Wallops Island, VA 23337**

October 26, 2011

Reply to Attn of: 250.W

Mr. J.W. Murphy
Deputy Chief of Staff for Shore and Environmental Readiness
U.S. Navy Fleet Forces Command
1562 Mitscher Avenue, Suite 250
Norfolk, VA 23551-2487

Dear Mr. Murphy:

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) requests your agency's participation as a Cooperating Agency in the preparation of a Programmatic Environmental Impact Statement (PEIS) for its continued operations at WFF. Due to the level of projected actions and missions of NASA and its partners at WFF, we have decided that a PEIS is the most appropriate level of National Environmental Policy Act (NEPA) documentation.

It is NASA's desire to prepare a PEIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess both regulatory authority and specialized expertise pertaining to the proposed action. Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

As the U.S. Navy Fleet Forces Command has permanent missions at WFF and desires to increase those missions with programs such as the Field Carrier Landing Practice (FCLP); we feel that your agency would be a valuable member of our project team. As Lead Agency, NASA would assume primary responsibility for project management and document preparation; we would expect our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process. A Draft Memorandum of Understanding is enclosed.

If you have any questions or require additional information regarding the Wallops Site-Wide PEIS, please contact Ms. Shari Silbert at (757) 824-2327 or at Shari.A.Silbert@nasa.gov.

Sincerely,

Carolyn Turner
Associate Chief, Medical and Environmental Management Division

**DEPARTMENT OF THE NAVY**
COMMANDER
U.S. FLEET FORCES COMMAND
1562 MITSCHER AVE, SUITE 250
NORFOLK, VA 23551-2487

5090
Ser N46/041
November 18, 2011

Ms. Carolyn Turner
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337

Dear Ms. Turner:

I am writing in response to the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility letter of October 26, 2011, requesting Commander, U.S. Fleet Forces Command (USFF) serve as a cooperating agency in the preparation of a Programmatic Environmental Impact Statement (PEIS) for continued operations at Wallops Flight Facility. USFF will participate as a cooperating agency for your project, however, we desire to review and edit the draft Memorandum of Understanding to ensure a clear understanding of the requirements.

As provided in the USFF media statement of October 20, 2011, and as discussed with your staff, the Department of the Navy (Navy) is preparing an Environmental Assessment (EA) to study the effects of using the Emporia-Greensville Regional Airport and/or the NASA Wallops Flight Facility to conduct E-2/C-2 turbo prop aircraft Field Carrier Landing Practice (FCLP) operations. NASA personnel have special expertise that can ensure all of the potential environmental effects on your installation and under your jurisdiction are properly evaluated. Therefore, in accordance with 40 Code of Federal Regulations Part 1501.6, and the Council on Environmental Quality Cooperating Agency guidance issued on January 30, 2002, the Navy will forward a similar request that NASA serve as a cooperating agency for the Navy EA.

As the Navy's goal is to complete the environmental analysis for the proposed action by February 2013, the Navy will provide the EA to NASA to include in the PEIS by reference. We also request that the Navy action be discussed within the cumulative impacts section.

5090
Ser N46/041
November 18, 2011

NASA and Navy cooperation is vitally important to the forthcoming National Environmental Policy Act (NEPA) efforts by both parties, and will help ensure that both efforts contain the environmental information necessary to make informed and timely decisions. My point of contact for this issue is Ms. Patsy Kerr, (757) 836-6336 or e-mail: patricia.kerr@navy.mil.

Sincerely,

J. W. MURPHY
Deputy Chief of Staff
for Shore and Environmental
Readiness

Copy to: NAVFAC LANT

**From:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**To:** "HUYNH, THOMAS T GG-14 USAF AFSPC SMC/ENC"
**Cc:** HASHAD, ADEL A GG-13 USAF AFSPC SMC/ENC; Kriz, Joseph; Turner, Carolyn (WFF-2500); Massey, Caroline R. (WFF-2000); Bundick, Joshua A. (WFF-2500) (joshua.a.bundick@nasa.gov)
**Subject:** RE: Site-wide PEIS & Minotaur I
**Date:** Monday, February 25, 2013 10:47:00 AM
**Attachments:** WSW PEIS MOU FINAL.pdf
WSW PEIS MOU rev 6.docx

---

*Sent on behalf of Ms. Carolyn Turner, Associate Chief, Medical and Environmental Management Division*:

Good morning, Tom.

Thank you for your interest in NASA's Site-wide Programmatic Environmental Impact Statement (PEIS) for the Wallops Flight Facility in Wallops Island, Virginia.  It is NASA's desire to prepare an PEIS to satisfy the NEPA obligations of all federal partners with permanent facilities or missions at WFF or those that possess either regulatory authority or specialized expertise pertaining to the proposed action.  Such a strategy would allow for easier document adoption, avoid duplication, and greatly streamline the NEPA process for all action agencies involved.

NASA is pleased to have the USAF/SMC participate in this PEIS process as a Cooperating Agency. As Lead Agency, NASA assumes primary responsibility for project management and document preparation; we would anticipate our Cooperating Agencies to provide technical expertise, document review, and occasional meeting attendance throughout the NEPA process.  Attached is the current fully executed Memorandum of Understanding between NASA and the current Cooperating Agencies on this effort.  Also attached is an MS Word version adding AF/SMC.  Please review the MOU and add the information for the person signing as well as for the Working Level and Management Level Points of Contact (yellow highlights). Once signed, please return the document to the following address:

NASA Wallops Flight Facility
Attn:  Ms. Carolyn Turner
34200 Fulton Street
Wallops Island, VA 23337

If you have any comments or questions, please contact Ms. Shari Silbert at 757.824.2327 or Shari.A.Silbert@nasa.gov.

Thank you.

---

*Shari A. Silbert*
URS Corporation

Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

*The fate of man rests on 3 pillars - the pursuit of justice, the practice of compassion, and a sense of humility.*



-----Original Message-----
From: HUYNH, THOMAS T GG-14 USAF AFSPC SMC/ENC [mailto:thomas.huynh@us.af.mil] 025
Sent: Friday, February 22, 2013 4:42 PM
To: Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
Cc: HASHAD, ADEL A GG-13 USAF AFSPC SMC/ENC; Kriz, Joseph
Subject: Site-wide PEIS & Minotaur I

Shari,

Joe Kriz is relaying a message for me to send you an e-mail to indicate our desire to be a cooperating agency on your new Wallops Flight Facility Site-wide PEIS. As you may have already known, the AF/SMC is scheduled to launch ORS-3 and LADEE missions from Wallops this year and potential new missions scheduled in the near future. As a cooperating agency, SMC can provide input to the PEIS to make it a more effective NEPA document. Our involvement could help improve the document's overall quality and accuracy, particularly for the analyses involving activities related to USAF missions.

The benefit for AF/SMC is that we could make direct use of your PEIS in support of USAF missions without having to prepare additional NEPAs. Mr.
Hashad is my NEPA program lead and Mr. Kriz is my NEPA support contractor.
Adel or Joe will contact you soon to discuss the draft PEIS and the potential collaboration effort.

v/r
Tom Huynh

**From:** Silbert, Shari A. (WFF-200.C)[EG&G, Inc. (WICC)]
**To:** "Dale.Nash@vaspace.org"
**Cc:** Bundick, Joshua A. (WFF-2500) (joshua.a.bundick@nasa.gov); Turner, Carolyn (WFF-2500); Massey, Caroline R. (WFF-2000)
**Subject:** WFF Site-wide PEIS MOU
**Date:** Friday, January 04, 2013 3:30:00 PM
**Attachments:** WSW PEIS MOU_FINAL.pdf

Dale,

It was good to meet you before the holidays. As we discussed in Jay Pittman's office, the WFF Environmental Office is preparing a master-planning document, the Site-wide Programmatic Environmental Impact Statement to assess the potential impacts of foreseeable actions at or from Wallops on the surrounding environment and the public. There are currently 10 Federal agencies cooperating with NASA on this effort. A Cooperating Agency is typically a Federal agency, and sometimes a State entity, that has either jurisdictional oversight or special expertise in the proposed action. As an Authority of the Commonwealth with special expertise, we would like to invite the Virginia Commercial Space Flight Authority to formally participate in this effort as a Cooperating Agency. Attached is the current Memorandum of Understanding between the CAs. If the VCSFA consents to participate, we will amend this MOU.

Thank you and please let me know if you have any questions or concerns.

*Shari A. Silbert*
URS Corporation
Environmental Scientist
NASA Wallops Flight Facility
Wallops Island, VA 23337
ph (757) 824-2327
fx (757) 824-1819
Shari.A.Silbert@nasa.gov

*The fate of man rests on 3 pillars - the pursuit of justice, the practice of compassion, and a sense of humility.*

**From:** Daryl Moore
**To:** Miller, Shari A. (WFF-2500)
**Cc:** Nash, Dale K. (WFF-013.0)[VIRGINIA COMMERCIAL SPACE FLT]
**Subject:** RE: Update on the WFF Site-wide PEIS status
**Date:** Wednesday, January 25, 2017 1:36:48 PM

Shari,

Dale accepts the participation of VCSFA as a Cooperating Agency for the PEIS.

Daryl

**From:** Miller, Shari A. (WFF-2500) [mailto:shari.a.miller@nasa.gov]
**Sent:** Monday, January 23, 2017 8:22 AM
**To:** Daryl Moore <daryl.moore@vaspace.org>
**Subject:** RE: Update on the WFF Site-wide PEIS status

Daryl,

Can you confirm with Dale that VCSFA will accept to participate as a Cooperating Agency for the PEIS? Can the Authority accept the terms of the MOU? If so, I will add VSCFA to the MOU and send a signature page for Dale.

Thanks!

*Shari A. Miller*
Environmental Planning Lead
NASA Wallops Flight Facility
Wallops Island, VA 23337
(757) 824-2327
Shari.A.Miller@nasa.gov
http://sites.wff.nasa.gov/code250/

*"A single act of kindness throws out roots in all directions, and the roots spring up and make new trees."* - Amelia Earhart

**From:** Daryl Moore [mailto:daryl.moore@vaspace.org]
**Sent:** Monday, January 23, 2017 7:31 AM
**To:** Miller, Shari A. (WFF-2500) <shari.a.miller@nasa.gov>
**Subject:** FW: Update on the WFF Site-wide PEIS status

Good morning Shari,

I noticed Virginia Commercial Space Flight Authority is not listed on the MOU. Dale Nash is listed as the point of contact.

**From:** Miller, Shari A. (WFF-2500)
**To:** Rudnick, Barbara; McCurdy, Alaina; Daniel.Czelusniak@faa.gov; Jarboe, Christopher CIV ATR, 5.2.2.F; Kerr, Patricia k CIV USFF, N46 (patricia.kerr@navy.mil); John Gironda - NOAA Federal; Nash, Dale K. (WFF-013.0)[Virginia Commercial Space Flight Authority]; Kriz, Joseph; Sloan, Kevin; Hooks, Michael S CTR SCSC, T-Solutions; Sean Mulligan; John.Vinyard@faa.gov; Lisa.Favors@faa.gov; Stacey.Zee@faa.gov; Anderson, Melanie L CIV ATR, 5.2.2.F; Ryon, Debra R. (WFF-011.0)[NAVY (SURFACE COMBAT SYSTEM CENTER WALLOPS ISLAND)]; Johnson, Rose M CIV SEA 04, SEA 04RE; Charles.S.Bryant@noaa.gov; James Deck - NOAA Federal; peter.r.kube@usace.army.mil; jecely.torres_ramos@us.af.mil; Joshua.j.zirbes@uscg.mil
**Cc:** Massey, Caroline R. (WFF-2000); Hymer, Daniel C. (GSFC-1400); Norwood, Tina (HQ-LD020); Meyer, T J (WFF-2500); Charee Hoffman; Ward, Charles S. (WFF-200.C)[LJT AND ASSOCIATES, INC.]; CONNELL, EDWARD (GSFC-2500); Rubilotta, Raymond J. (GSFC-2000)
**Subject:** Update on the NASA WFF Site-wide PEIS status
**Date:** Monday, August 07, 2017 9:42:49 AM

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All,

In an effort to streamline the NEPA obligations of all federal and Commonwealth partners with permanent facilities or missions at the National Aeronautics and Space Administration's (NASA's) Wallops Flight Facility (WFF) or those that possess either regulatory authority or specialized expertise pertaining to the proposed action, WFF previously initiated (2011) the preparation of a Site-wide Programmatic Environmental Impact Statement (PEIS). Such a strategy would allow for easier document adoption, avoid duplication, and greatly simplify the NEPA process for all action agencies involved.

As you may recall, NASA had anticipated releasing a public draft in the Spring of 2014. However, the Agency initiated a review of the methodology and input data that was used during the development of the Alternatives and decided to await the results of the review as they had the potential to inform the Alternatives to be analyzed in the PEIS. This process and vetting took longer than we anticipated.

WFF is pleased to announce that, based on the results of the review, we are proceeding with revisions to the current version of PEIS. As such, we are reaching out to inform you that we anticipate releasing a Cooperating Agency preliminary draft PEIS next month, September 2017 for your 60-day review and comments. Please let me know if your point of contact for this effort has changed.

Thank you all, again, for your participation in this process.

*Shari A. Miller*
Environmental Planning Lead
NASA Wallops Flight Facility
Wallops Island, VA 23337
(757) 824-2327
Shari.A.Miller@nasa.gov
SIPRnet: Shari.Miller@nss.sgov.gov
http://sites.wff.nasa.gov/code250/

U.S. Department of Transportation
**Federal Aviation Administration**

Office of Commercial Space Transportation

800 Independence Ave., SW.
Washington, DC 20591

APR 19 2018

Mr. Bob Leffel
Deputy Refuge Manager
Chincoteague National Wildlife Refuge
PO Box 62
Chincoteague, VA 23336

Dear Mr. Leffel:

The Federal Aviation Administration (FAA) is participating as a cooperating agency in the preparation of the National Aeronautics and Space Administration's (NASA's) Programmatic Environmental Impact Statement (PEIS) for new construction and demolition projects and new operational missions and activities at NASA Goddard Space Flight Center's Wallops Flight Facility (WFF). The U.S. Fish and Wildlife Service (USFWS) is also participating as a cooperating agency. The FAA is a cooperating agency because of its role in issuing licenses for operation of commercial space launch sites and commercial launch vehicles. The Virginia Commercial Space Flight Authority (Virginia Space) holds and maintains an active FAA launch site operator license to operate Launch Complex 0 (Pads 0-A and 0-B) at WFF as a commercial space launch site (referred to as the Mid-Atlantic Regional Spaceport). The proposed action analyzed in the PEIS includes, among other activities, proposed commercial rocket launches at Launch Complex 0, as well as construction of two new launch pads at Launch Complex 0: Pad 0-C and Launch Pier 0-D.

After NASA publishes the final PEIS, the FAA may decide to adopt the PEIS (in whole or in part) or reference the analysis in the PEIS in its own environmental document if the FAA 1) receives a license application from Virginia Space to modify its site license to include Pad 0-C and/or Launch Pier 0-D, and/or 2) receives a license application for commercial launch operations at Launch Complex 0. Unlike NASA, the FAA is subject to Section 4(f) of the U.S. Department of Transportation Act of 1966 (49 U.S.C. § 303). Section 4(f) applies only to agencies within the Department of Transportation. Section 4(f) protects significant publicly owned parks, recreational areas, wildlife and waterfowl refuges, and public and private historic sites. Section 4(f) provides that the Secretary of Transportation may approve a transportation program or project requiring the *use* of publicly owned land of a public park, recreation area, or wildlife or waterfowl refuge of national, state, or local significance, or land of an historic site of national, state, or local significance, only if there is no feasible and prudent alternative to using that land and the project includes all possible planning to minimize harm resulting from the use.

There are two types of uses: physical use and constructive use. A physical use would occur if the action involved an actual physical taking of a 4(f) property through purchase of land or a permanent easement, physical occupation of a portion or all of the property, or alteration of structures or facilities on the property. Constructive use occurs when the impacts of a project on a 4(f) property are so severe that the activities, features, or attributes that qualify the property for protection under Section 4(f) are substantially impaired. Substantial impairment occurs only when the protected activities, features, or attributes of the 4(f) property that contribute to its significance or enjoyment are substantially diminished. This means the value of the 4(f) property, in terms of its prior significance and enjoyment, is substantially reduced or lost.

The PEIS analyzes potential impacts of rocket launches at Launch Complex 0 on 4(f) properties, including the Chincoteague National Wildlife Refuge (CNWR). The PEIS states the proposed action would not result in a physical or constructive use of any 4(f) properties, including CNWR. Closures of the southern end of CNWR could be required for launch operations from Pad 0-C or Launch Pier 0-D. Additionally, USFWS overland access to adjacent Assawoman Island (also part of CNWR) could be restricted during pre-launch and launch day operations. NASA has an established agreement with USFWS for such closures and coordinates with USFWS personnel during mission planning to ensure closures do not adversely affect CNWR activities. The value of CNWR in terms of its significance and enjoyment is not substantially impaired due to launch activities at WFF. Instead, the northern area of CNWR has become a popular observation location for viewing launches. Therefore, the FAA finds that rocket launches occurring at Launch Complex 0, including the proposed Pad 0-C and Launch Pier 0-D, would not result in a use of Section 4(f) properties, including CNWR.

Because the FAA finds there would be no physical use or constructive use associated with the FAA action of 1) modifying Virginia Space's site license to include Pad 0-C and/or Launch Pier 0-D or 2) issuing launch licenses for commercial space launches at Launch Complex 0, there is no requirement to engage in consultation with 4(f) property officials with jurisdiction or make a 4(f) determination (e.g., reach a *de minimis* determination or conduct a 4(f) evaluation).[1] However, the FAA is interested in obtaining USFWS input on the analysis described in the PEIS and summarized in this letter. If your office has no objection to the FAA's Section 4(f) finding described in the PEIS and summarized in this letter, please provide written concurrence. A signature placeholder is located below to facilitate this request. If you have any questions or concerns, please contact Mr. Daniel Czelusniak at (202) 267-5924 or via e-mail at Daniel.Czelusniak@faa.gov.

Sincerely,

Daniel Murray
Manager, Space Transportation Development Division

I hereby concur with the FAA that commercial space launch operations at Launch Complex 0 at WFF, as proposed in NASA's WFF Site-Wide PEIS, would not result in a use of Section 4(f) properties under the jurisdiction of the USFWS, including CNWR.

ROBERT LEFFEL Digitally signed by ROBERT LEFFEL Date: 2018.04.23 13:01:28 -04'00'

Mr. Bob Leffel

04/23/2018

Date

[1] Refer to the Federal Highway Administration's Section 4(f) Policy Paper (codified at 23 CFR Part 774), which the FAA uses as guidance. https://www.environment.fhwa.dot.gov/legislation/section4f/4fpolicy.aspx.

# APPENDIX C
# SCOPING SUMMARY REPORT (CONDENSED)

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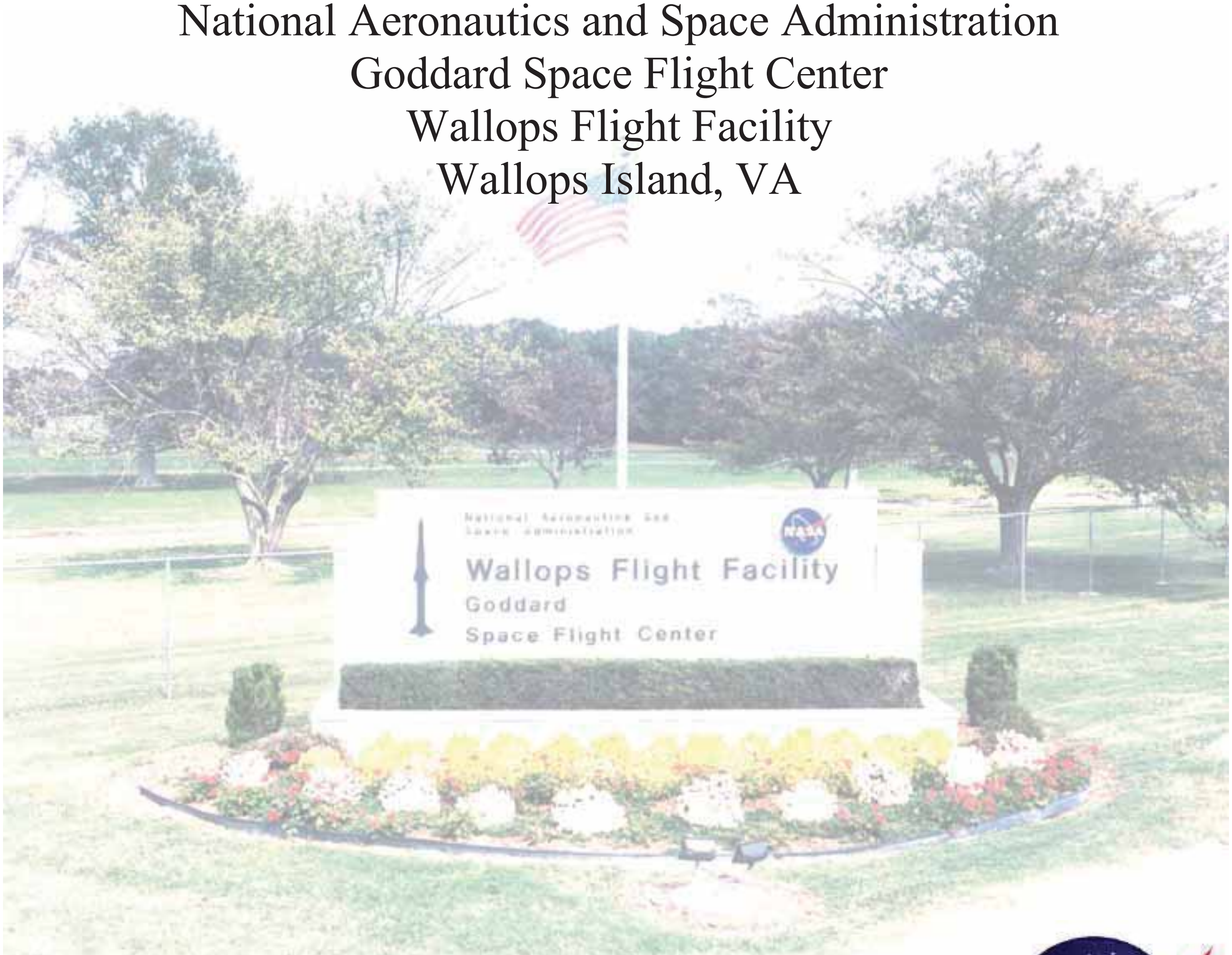
*Scoping Summary Report*

# NASA WFF SITE-WIDE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

Prepared for
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA




October 2011

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## 1.0 INTRODUCTION

Scoping is an important aspect of the National Environmental Policy Act (NEPA) process, which states that "There shall be an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to the proposed action." Scoping not only informs the public about the proposed action and alternatives but identifies the issues and concerns that are of particular interest to the affected populace. This scoping summary report presents an analysis of issues and concerns raised during the official public scoping period of July 11, 2011 to September 2, 2011 for the NASA WFF Site-wide Programmatic Environmental Impact Statement (PEIS).

This summary report:

- provides an outline of the scoping process;
- describes the scoping meeting format and schedule;
- summarizes comments received during the scoping period; and
- identifies the major issues and concerns derived from scoping meetings, comment sheets, and letters.

## 2.0 SCOPING PROCESS

Scoping provides opportunities for government and regulatory agencies, interest groups, and the general public to learn about the proposal and alternatives, identify alternative approaches to meet the need, and provide input that is then used to assist resource specialists in data collection and resource analysis for the Draft PEIS.

In a letter dated April 26, 2011, NASA formally invited six cooperating agencies to be part of the NEPA process for this proposal: Federal Aviation Administration (FAA) Office of Commercial Space Transportation; FAA Air Traffic Organization Office; National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS); Department of the Navy Naval Sea Systems Command; Department of the Army Corps of Engineers; and United States Coast Guard (USCG). The United States Fish and Wildlife Service and Department of the Navy Naval Air Systems Command were also invited to be cooperating agencies in letters dated June 1 and June 3, 2011, respectively. Appendix A provides an example of the cooperating agency coordination letter and acceptance letters received by NASA.

On July 7, 2011, coordination letters were sent to federal, state, and local governments and regulatory agencies; elected officials; and various interest groups. The coordination letters outlined the proposal and provided details for a dedicated regulatory agency scoping meeting and a public scoping meeting later the same day. Examples of the regulatory agency and public coordination letters are provided in Appendix B. Official public notification of the NASA proposal began with the publication of the Notice of Intent

(NOI) on July 11, 2011 in the *Federal Register* (Appendix C). On July 29, 2011, NASA issued a press release that outlined the proposal, provided details for the public scoping meeting, and solicited public input on the proposal (Appendix C). The public, regulatory agencies and NASA employees were also invited to provide comments on the Site-wide PEIS website at http://sites.wff.nasa.gov/code250/site-wide_eis.html.

Advertisements were placed a week before the meetings in the following newspapers: *Eastern Shore News* (27 July)*, The Daily Times* (27 July)*, and Chincoteague Beacon* (28 July) describing the proposal and alternatives (Appendix D). The advertisement provided the time, date, and location of the meeting. The public was invited to comment on the NASA proposal prior to as well as at the scoping meeting. In addition to the newspaper advertisements, an email was sent to all NASA WFF employees on August 3, 2011 provided the meeting information and invited NASA employees to comment on the proposal (Appendix D).

## 3.0 SCOPING MEETING FORMAT

The two scoping meetings were conducted on August 3, 2011 - one for the regulatory agencies and one for the general public - in an "open house" format to create a comfortable atmosphere where attendees could interact directly with NASA personnel. Attendees were welcomed at the entrance by NASA representatives. Attendees were asked to sign in, provided a factsheet, and directed to the first of five poster displays. Copies of the factsheet and comment sheet are found in Appendix E. Displays were designed to describe the Proposed Action, present the purpose and need for the Proposed Action, and enhance public understanding of the NEPA process while emphasizing the public's role in shaping the proposal. Copies of the displays are also found in Appendix E.

Immediately following the general information portion of both meetings, NASA gave a thorough presentation that provided attendees with additional information in the following areas:

- Mission Overview – A general look at the overall NASA mission and a more detailed look at the WFF mission and the different ways in which WFF carries out that mission.
- Institutional Overview – A look at location and condition of current WFF facilities on the Main Base, Mainland and Wallops Island, and the long term vision for these facilities that will allow WFF to continue to carry out its mission in the future.
- PEIS Overview – A introduction to the NEPA process and an explanation of how the PEIS relates to the 2005 Site-Wide EA and the WFF Master Plan Update, as well as a general schedule of major milestones and tentative focus areas. The PEIS Overview also provided additional information on WFF; it outlined the Proposed Action/Alternatives, and listed the cooperating agencies.

- Public Comment – A chance for meeting attendees to provide NASA with verbal comments on the Site-wide PEIS. See Section 5.0 for a summary of comments made during the scoping meeting comment period. A stenotype reporter recorded verbal comments which are provided via transcript in Appendix F.

NASA provided the public with three venues for commenting during the scoping period. Attendees could submit written comments they brought with them to the scoping meeting, complete a comment form provided by NASA at the meeting, or send their comments at anytime during the scoping period to Ms. Shari Silbert, NASA WFF Site-wide PEIS Project Manager. NASA representatives from WFF, as well as contractor support from TEC Inc. provided a range of expertise at the public meeting to answer any questions attendees may have had.

## 4.0 SCOPING MEETING SCHEDULE

In the afternoon of August 3, 2011, a scoping meeting was held with applicable regulatory agency representatives to discuss the proposal and consult with them regarding their concerns. That evening, NASA held a public scoping meeting at the NASA Visitor Center on Wallops Island, central to areas that could potentially be affected by the Proposed Action and communities that have expressed concerns with the proposed NASA action. The schedule and location of each meeting is provided below.

| Schedule of Meetings and Attendance | | |
|---|---|---|
| ***City/Town*** | ***Date and Time*** | ***Location*** |
| Wallops Island | Regulatory Agency Scoping Meeting<br>Wednesday, August 3; 1:00 to 3:00 p.m. | NASA Visitor Center |
| Wallops Island | Public Scoping Meeting<br>Wednesday, August 3; 6:00 to 8:00 p.m. | NASA Visitor Center |

## 5.0 SUMMARY OF COMMENTS AND CONCERNS

A summary of all comments and concerns raised during the scoping period is provided below.

| Comment Topic | No. of Comments |
|---|---|
| Impacts to wildlife/listed species | 6 |
| Sea level rise/barrier island dynamics | 6 |
| Assawoman Island “land swap” | 4 |
| Commercial/human space flight | 4 |
| Causeway bridge replacement | 2 |
| Impacts to water quality/wetlands | 2 |
| Maintenance dredging | 2 |
| More explanation/information needed in PEIS | 2 |
| Alternative 2 | 1 |
| Coastal Zone Management Act/Federal Consistency Determination | 1 |
| Encroachment | 1 |

| Comment Topic | No. of Comments |
|---|---|
| Invasive species | 1 |
| Noise | 1 |
| Positive/supportive comment | 1 |
| Restricted airspace | 1 |
| Socioeconomic impacts | 1 |
| Unmanned Aerial Systems test range | 1 |
| Wastewater treatment issues | 1 |

During the official scoping period, the NASA received 16 comment letters. A summary of related concerns is located below in the order in which they were received. Complete comment letters can be found in Appendix B:

- Virginia Department of Environmental Quality (DEQ) – DEQ's Office of Environmental Review will coordinate Virginia's review of the PEIS and comment to NASA on behalf of the Commonwealth. Under the Coastal Zone Management Act, NASA must provide a Federal Consistency Determination (FCD) which includes an analysis of the proposed activities in light of the foreseeable policies of the Virginia Coastal Zone Management Program and a commitment to comply with the enforceable policies. DEQ recommends that the FCD be provided with the PEIS and that 60 days be allowed for review. DEQ requests 4 printed copies of the document and either 14 CD's or one electronic copy available for download at a NASA website.
- NOAA, National Marine Fisheries Service (NMFS) – Due to shallow water depths and near shore location of the proposed project areas, impacts to listed species of whales are unlikely. Any future in-water work that is necessary for the growth and/or repair of WFF has the potential to impact sea turtles and the PEIS should consider al direct and indirect impacts on sea turtles. The PEIS should also highlight any mitigation measures to reduce the affects to listed species.
- U.S. Environmental Protection Agency (EPA) – EPA is interested in touring the WFF facility as it will benefit future EPA review of projects at WFF. EPA offers its expertise on NEPA and the Clean Water Act Section 404, and encourages NASA to work with cooperating agencies on this project.
- Virginia Department of Game and Inland Fisheries (DGIF) – DGIF provided a table of listed species for consideration in the EIS and recommends further coordination as the project scope evolves and more site-specific information becomes available.
- U.S. National Park Service – No comment/input at this time.
- Resource Management Associates – Phragmities on Wallops Island is widespread and further expanding with recent construction activities. To limit the spread of Phragmities and its impacts to the Eastern Shore seaside tidal wetlands, NASA should begin an intensive effort to limit the spread of this highly invasive species by requiring advanced treatment and follow-up treatment prior to construction activities.
- Virginia Department of Historic Resources – No comment/input at this time.

- Virginia Commercial Space Flight Authority (VCSFA) – VCSFA owns and operated the Mid-Atlantic Regional Spaceport and is committed to playing a large role in human spaceflight. VSFCA is also interested in the enlargement of the restricted airspace, building a larger launch pad and support facilities (Pad-Sea/C), the replacement of the causeway bridge, maintenance dredging between the Barge Dock and the Main Base that was highlighted in the Notice of Intent.
- Hampton Roads Military and Federal Facilities Alliance (HRMFFA) – HRMFFA fully supports NASAs expand operations at WFF. NASA should consider, as an element of both alternatives, development of an Atlantic Unmanned Aircraft Systems (UAS) Test Range at WFF.
- Space Florida – The potential development of launch infrastructure for orbital human spaceflight at WFF is duplicative and competes with infrastructure already in place in the State of Florida. Development of a duplicate site also goes against the NASA Authorization Act of 2011, which clearly states: "*It is the sense of Congress that NASA needs to rescope, and as appropriate down-size, to fit current and future missions and expected funding levels.*"
- Economic Development Commission of Florida's Space Coast – Some of the potential alternatives detailed in the PEIS scoping materials constitute a direct threat to the economic well-being of the people of the Space Coast, and to the fiscal health of the U.S. population, in general. The results of this effort to expand the capability of manned space launches to the International Space Station from Virginia are 'undesirable' to the people of Florida, both as taxpayers paying for redundant infrastructure and as a workforce struggling to maintain thousands of jobs.
- The Nature Conservancy (TNC) – The location of infrastructure and facilities on Wallops Island is vulnerable to sea level rise and barrier island subsidence. TNC recommends that NASA include an alternative that evaluates the costs and benefits of locating new infrastructure off of Wallops Island and strategically relocating existing infrastructure to more secure and protected locations within Accomack County. This alternative should also evaluate the costs and benefits associated with locating certain critical launch infrastructure in the coastal bay and NASA-owned salt marsh west of Wallops Island. TNC is also opposed to a "land swap" with USFWS for access to Assawoman Island and has concerns about the impacts to water quality due to increased operations/expanded capabilities at WFF.
- Accomack County Economic Development Authority – The Economic Development Authority supports Alternative 2 as outlined in the NOI. In particular, commercial manned space flight will spur economic development in Accomack County without adversely affecting the environment.
- Virginia Department of Conservation and Recreation, Division of Natural Heritage (DCR) – DCR notes that there are several natural heritage resources located within the project area: Wallops Island Seeps and Little Mosquito Creek Conservation Sites on Wallops Main Base, Wallops Island Causeway Marshes Conservation Site on Wallops Mainland, and North Wallops Island and Assawoman Island Conservation Sites on or near Wallops Island. The biodiversity significance ranking of these sites rages from B4 (moderate significance) to B2 (very high significance) based on the statewide importance of these sites for native biological diversity. DCR recommends that

NASA undertake ecological surveys of Assawoman Island, the Main Base, and Wallops Mainland so that planning could consider, to the maximum extent practicable, the protection of natural heritage communities.

- Public comment – The past 50 years have shown an 8 inch increase in sea level in the mid-Atlantic region. Based on this information, a 1 meter sea level rise for the project area is not out of the question in the near future. Why would NASA want to spend hundreds of millions to billions of dollars on facilities that are most certainly in mortal peril insofar as climate driven sea level rise is concerned? Why doesn't NASA use facilities at Andrews AFB or at the White Sands Range in New Mexico that are immune to this type of potential natural disaster?
- U.S. Fish and Wildlife Service (USFWS) – USFWS is particularly interested in several of the proposed projects under Alternative 1: the causeway bridge replacement, maintenance dredging, and installation of 2 permanent rocket launchers. Under Alternative 2, USFWS is interested in the Assawoman Island land swap, since it could potentially align with one of the alternatives being presented in the Comprehensive Conservation Plan (CCP) for the Chincoteague and Wallops Island National Wildlife refuges but is opposed to development of the north end of Assawoman Island. USFWS is concerned about the impacts to wildlife (beach nesting shorebirds in particular) from this proposal and suggests 2 alternatives for WFF to consider: develop and implement mobile launch technology for rocket launched or develop a small launch pad on the mainland for launching sounding rockets. USFWS would also like NASA to consider the resource management activities (e.g., species monitoring, habitat management) as part of the list of "Institutional Project Support." WFF should develop an additional alternative focused on accomplishing its mission while contributing to the conservation value of the area. This could include relocating infrastructure inland whenever possible to reduce sea level rise risks to mission-critical infrastructure; acquiring lands to better buffer WFF from sensitive natural resource areas as well as reducing potential safety and security concerns; developing cooperative resource management approaches that would facilitate conservation, public use of the resources in the area, and the NASA mission; and planned responsible development in the area that would help support and protect the NASA mission and local economy.

The attendance for each of the scoping meetings is provided below. Appendix F provides copies of the scoping meeting sign-in sheets.

| **Scoping Meeting Attendance** | |
|---|---|
| Regulatory Agency Scoping Meeting | 17 |
| Public Scoping Meeting | 19 |

Concerns raised during the regulatory agency scoping meeting include:

- Socioeconomic impacts, as opposed to socioeconomic benefits, to Accomack County resulting from the proposed action and action alternatives.
- Commonwealth of Virginia owned land west of Wallops Island that will need clearly defined boundaries before any land swap can take place under Alternative 2.
- VMRC maintains a GIS database of existing oyster leases that will be helpful in determining impacts.
- VIMS maintains a database for permitted wetlands impacts that will be useful when analyzing cumulative impacts.
- The proposed Atlantic Town Center Wastewater Facility to address wastewater treatment issues in the Towns of Atlantic and Chincoteague, as well as other surrounding areas, may fall within the approach to Runway 220 and NASA needs to make sure that appropriate county officials know that this is not acceptable. A conditional use permit was originally approved by the Accomack County Planning Department; however, the permit is currently under review following a recommendation by the Accomack County Director of Zoning stating that "the developers conditional use permit application should not be accepted or processed" based on current county zoning regulations.
- Need to consider impacts to wildlife due to potential operations on Assawoman Island.
- Noise analysis should be included under the Health and Safety analysis in the EIS.
- NASA should consider the possibility of restricting sounding rocket launches to times when piping plovers and other protected species are not in the area.
- The impacts of sea level rise and global climate change on operations at WFF and Accomack County as a whole needs to be evaluated.

Concerns raised during the public scoping meeting are located below. An official transcript can be found in Appendix F.

- The effects of sea level rise on areas surrounding NASA WFF needs to be considered.
- NASA needs to consider the dynamics of barrier islands and the impacts these dynamics may have on Wallops Island and surrounding barrier islands. It was recommended that the project team study *The Beaches are Moving: The Drowning of America's Shoreline* by Dr. Orrin H. Pilkey. Dr. Pilkey is also giving (gave) a lecture on Barrier Islands on September 9, 2011 at the Barrier Islands Center in Machipongo, VA.
- Encroachment issues that the Accomack County Board of Supervisors is facing and how they might impact operations and airspace at WFF should be included. It was also mentioned that NASA has need to do a better job of vocalizing their needs to the Board of Supervisors and commenting on County actions in order to protect their interests.
- Does WFF see an increase in the demand for wastewater treatment in the 20-year plan?

- How does WFF plan on addressing stormwater runoff issues as facilities are consolidated at WFF and hard surfaces are moved or altered?

## 6.0 CONCLUSION

The scoping part of the proposed NASA Site-wide environmental impact analysis process was completed successfully. The public was given ample notification of the proposal and scoping process and given opportunities to comment through various means. Meetings were held in a location that afforded the agencies and public access to information on the proposal as well as the time and opportunity to express any concerns or issues with the Proposed Action. Additionally, NASA has provided a project website that the public and agencies can access to obtain publically released documents.

# APPENDIX D
# WALLOPS FLIGHT FACILITY LAUNCH VEHICLE NOISE STUDIES

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Blue Ridge Research and Consulting, LLC

*Technical Report*

# Launch Noise Study for the Wallops Flight Facility Programmatic Environmental Impact Statement

***August 31, 2015***

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## Acronyms and Abbreviations

The following acronyms and abbreviations are used in the report:

| | |
|---|---|
| AEE | Office of Environment and Energy |
| AFCEE | Air Force Center for Engineering and Environment |
| AST | Office of Commercial Space Transportation |
| BRRC | Blue Ridge Research and Consulting, LLC |
| dB | decibel |
| dBA | A-weighted decibel level |
| DI | directivity indices |
| DOD | Department of Defense |
| DSM-1 | Distributed Source Method 1 |
| ELV | Expendable Launch Vehicle |
| FAA | Federal Aviation Administration |
| ft | foot/feet |
| Kg | kilogram |
| lbf | pound force |
| lbm | pound mass |
| LFIC | Liquid Fueled Intermediate Class |
| LFMC | Liquid Fueled Medium Class |
| $L_{A,max}$ | maximum A-weighted OASPL in decibels |
| $L_{max}$ | maximum unweighted OASPL in decibels |
| $L_{pk}$ | peak sound pressure level in decibels |
| LMLV | Lockheed Martin Launch Vehicle |
| LV | Launch Vehicle |
| NASA | National Aeronautics and Space Administration |
| N | newton |
| NEPA | National Environmental Policy Act |
| NIHL | noise-induced hearing loss |
| NIOSH | National Institute for Occupational Safety and Health |
| nm | Nautical miles |
| OASPL | overall sound pressure level in decibels |
| OSHA | Occupational Safety and Health Administration |
| PEIS | Programmatic Environmental Impact Statement |
| $P_k$ | peak pressure |
| psf | pounds per square foot |
| psi | pounds per square inch |
| RUMBLE | The Launch Vehicle Acoustic Simulation Model |
| RSRM | reusable solid rocket motor |
| S.L. | sea level |
| sec | second |
| SEL | Sound Exposure Level in decibels |
| SFHC | Solid Fueled Heavy Class |
| SFMC | Solid Fueled Medium Class |
| µPa | micropascal |
| WFF | Wallop Flight Facility |

# 1 Introduction

This report documents the noise study on rocket launch operations at the National Aeronautics and Space Administration's (NASA) Wallops Flight Facility (WFF) in Accomack County, Virginia. This study supports the analysis for WFF's Site-wide Programmatic Environmental Impact Statement (PEIS) for proposed future actions. Even though a number of launch vehicles could be flown from WFF in the future, this noise study examines four nominal launch vehicles representing the current baseline and, considering future mission growth, the largest orbital vehicles (in terms of thrust) that would be launched from WFF. The representative vehicles for WFF's current baseline are the Antares 200 Series (Antares 200) and Lockheed Martin Launch Vehicle (LMLV) III. Representative larger vehicles that could be launched in the future include a Liquid Fueled Intermediate Class Expendable Launch Vehicle (LFIC ELV) and Solid Fueled Heavy Class Expendable Launch Vehicle (SFHC ELV).

WFF consists of three separate parcels of land, as shown in Figure 1: the Main Base, the Mainland, and Wallops Island. The Mainland and Wallops Island are located side by side and the Main Base is approximately 7 miles northwest of the Island launch site. The focus of this noise study is specific to operations occurring at Wallops Island on Pad 0-A, Pad 0-B, and a future Pad 0-C.

This noise study describes the launch noise and sonic booms expected to be generated by the projected operations described within the PEIS. Section 2 summarizes the noise metrics discussed throughout this report; Section 3 describes the general methodology of the rocket launch noise and sonic boom noise models; Section 4 describes the acoustical modeling input parameters for WFF; and Section 5 presents the noise modeling results. A summary is provided in Section 6 to document the notable findings of this noise study.


**Figure 1. Left, Wallops Flight Facility boundaries. Right, photo of an Orbital ATK Inc. Antares rocket launching from Wallops Flight Facility (photo credit NASA).**

# 2 Noise Metrics and Criteria

## 2.1 Noise Metrics

Any unwanted sound that interferes with normal activities or the natural environment can be defined as noise. Noise sources can be continuous (constant) or transient (short-duration) and contain a wide range of frequency (pitch) content. Determining the character and level of sound aids in predicting the way it is perceived. Both launch noise and sonic booms are classified as transient noise events.

A decibel (dB) is a ratio that compares the sound pressure of a sound source of interest (e.g., the rocket launch) to a reference pressure (the quietest sound humans can hear, 20 µPa [micropascal]). A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or halving) of the sound's loudness. In the community, "it is unlikely that the average listener would be able to correctly identify at a better than chance level the louder of two other-wise similar… events which differed in maximum sound level by < 3 dB" (Fayh and Thompson, 2015). Standard weighting filters help to shape the levels in reference to how they are perceived. An "A-weighting" filter approximates the frequency response of human hearing, adjusting low and high frequencies to match the sensitivity of human hearing. For this reason, the A-weighted decibel level (dBA) is commonly used to assess community noise. However, if the structural response is of importance to the analysis, a "flat-weighted" (unweighted) level is more appropriate.

Noise metrics are used to describe the noise event and to identify any potential impacts to receptors within the environment. These metrics are based on the nature of the event and who or what is affected by the sound. Individual time-varying noise events have two main characteristics: a sound level that changes throughout the event and a period of time the event is heard. The overall sound pressure level (OASPL) provides a measure of the sound level at any given time and the maximum OASPL ($L_{max}$) indicates the highest level achieved over the duration of the event. Sound Exposure Level (SEL) represents both the magnitude of a sound and its duration. SEL provides a measure of the cumulative noise exposure of the entire acoustical event, but it does not directly represent the sound level heard at any given time. Mathematically, it represents the sound level of a constant sound that would generate the same acoustical energy in one second as the actual time-varying noise event. For sound generated by rocket launches, which last more than one second, the SEL is greater than the $L_{max}$ because an individual launch can last for minutes and the $L_{max}$ occurs instantaneously. Sonic boom noise levels are described in units of peak overpressure in pounds per square foot (psf). Noise contour maps of these metrics are comprised of lines of equal noise level or exposure, and they serve as visual aids for assessing the impact of noise on a community.

The Day-Night Average Sound Level (DNL) is a cumulative noise metric that accounts for the SEL of all noise events in a 24-hour period. Typically, DNL values are expressed as the level over a 24-hour annual average day. In order to account for increased human sensitivity to noise at night, a 10 dB penalty is applied to nighttime events (occurring between the hours of 10:00 p.m. and 7:00 a.m.). DNL is based on long-term cumulative noise exposure and has been found to correlate well with adverse community impacts for regularly occurring events including aircraft, rail, and road noise (Schultz, 1978;

Finegold, et al., 1994). Noise studies used in the development of the DNL metric did not include rocket noise, which are historically irregularly occurring events. Thus, it is acknowledged that the suitability of DNL for infrequent rocket noise and sonic boom events is uncertain. The analysis in the current study is on a single event basis and does not include DNL.

## 2.2 Noise Criteria

Noise criteria have been developed to protect the public health and welfare of the surrounding communities. This report includes the analysis of maximum A-weighted and unweighted OASPL, as they relate to hearing conservation and structural damage criteria, respectively. In addition, sonic booms impacts are evaluated on a single-event basis in regards to hearing conservation and structural damage criteria.

### 2.2.1 Hearing Conservation

#### *Rocket Noise*

U.S. government agencies have provided guidelines on permissible noise exposure limits. These documented guidelines are in place to protect human hearing from long-term continuous daily exposures to high noise levels and aid in the prevention of noise-induced hearing loss (NIHL). Three federal agencies have set upper limits on non-impulsive noise levels including the Occupational Safety and Health Administration (OSHA) (OSHA, 2008), Department of Defense (DOD) Occupational Hearing Conservation Program (Department of Defense, 2010), and the National Institute for Occupational Safety and Health (NIOSH). The most conservative of these limits has been set by OSHA at 115 dBA for an allowable exposure duration of 15 minutes, which is far greater than would be experienced during a rocket launch. Therefore, an $L_{max}$ of 115 dBA is used as the best available, conservative threshold to identify potential locations where hearing protection should be considered for a rocket launch.

#### *Sonic Boom*

A sonic boom is the sound associated with the shock waves created by a vehicle traveling through the air faster than the speed of sound. Multiple federal government agencies have provided guidelines on permissible noise exposure limits on impulsive noise such as a sonic boom. These documented guidelines are in place to protect one's hearing from exposures to high noise levels and aid in the prevention of NIHL. In terms of upper limits on impulsive or impact noise levels, NIOSH (NIOSH, 1998) and OSHA (OSHA, 2008) have stated that levels should not exceed 140 dB peak sound pressure level, which equates to a sonic boom level of approximately 4 psf.[1]

[1] The peak pressure of a sonic boom, $P_k$ (psf), can be converted to the peak sound pressure level in decibels ($L_{pk}$) by the mathematical relationship of: $L_{pk} = 127.6 + 20 \log_{10} P_k$

### 2.2.2 Structural Damage

#### *Rocket Noise*

Typically, the most sensitive components of a structure to launch noise are windows, and infrequently, the plastered walls and ceilings. The potential for damage to a structure is unique to the material of each element and its respective boundary conditions, the condition of the structure, and the incident sound. Due to these complexities, a number of generalized damage criteria have been proposed based on findings from anecdotal evidence, theoretical modeling, and rocket testing.

Regier published both observations on the response of building structures to noise and the development of a theoretical modeling technique to study the effects of intense low-frequency noise on structures (Regier, et al., 1962). He documented, "glass breakage and loosening of ceiling tile and fixtures" had occurred at a building near a large blowdown wind tunnel, which had similar frequency spectra to that of a Saturn rocket. At this building, sound-pressure levels up to 142 dB had been measured. As a result of the limited empirical data available, Regier developed a criterion for building damage based on theory for the response of a single-degree of freedom system to random loads. He proposed a 130 dB octave-band sound-pressure level threshold for well-maintained walls and windows. However, he noted that levels in this range will likely "cause some damage in highly stressed elements or poorly installed windows." Similarly, a report from the National Research Council on the "Guidelines for Preparing Environmental Impact Statements on Noise" (Committee on Hearing, 1977) states that one may conservatively consider all sound lasting more than one second with levels exceeding 130 dB (unweighted) as potentially damaging to structures.

A NASA technical memo found a relationship between structural damage claims and overall sound pressure level, where "the probability of structural damage [was] proportional to the intensity of the low frequency sound" (Guest and Slone, 1972). This relationship estimated that one damage *claim* in 100 households exposed is expected at an average continuous level of 120 dB, and one in 1,000 households at 111 dB. The study was based on community responses to the 45 ground tests of the first and second stages of the Saturn V rocket system conducted in Southern Mississippi over a period of five years. The sound levels used to develop the criteria were mean modeled sound levels. It is important to highlight the difference between the static ground tests in which the probability of structural damage is based on and the launch events of concern for this noise analysis. The ground tests occurred for durations much greater than the exposure duration expected for the proposed launch events. Additionally, during ground tests, the engine/motor remains in one position which results in longer exposure duration to continuous levels as opposed to the transient noise occurring from the moving vehicle during a launch event.

Notwithstanding the aforementioned differences between the Saturn V ground test conditions and the ELV launches from WFF, Guest and Slone's (1972) damage claim criteria represent the best available dataset regarding structural damage resulting from rocket noise. Thus, $L_{max}$ values of 120 dB and 111 dB are used in this report as a conservative threshold for potential risk of structural damage claims.

### *Sonic Boom*

Sonic booms are also commonly associated with structural damage. Most damage claims are for brittle objects, such as glass and plaster. Table 1 summarizes the threshold of damage that may be expected at various overpressures (Haber, et al., April 1989). A large degree of variability exists in damage experience, and much damage depends on the pre-existing condition of a structure. Breakage data for glass, for example, spans a range of two to three orders of magnitude at a given overpressure. The probability of a window breaking at 1 psf ranges from one in a billion (Sutherland, 1990) to one in a million (Hershey, et al., 1976). These damage rates are associated with a combination of boom load and glass condition. At 10 psf, the probability of breakage is between one in 100 and one in 1,000. Laboratory tests involving glass (White, 1972) have shown that properly installed window glass will not break at overpressures below 10 psf, even when subjected to repeated booms. However, in the real world, glass is not always in a pristine condition.

Damage to plaster occurs at similar ranges to glass damage. Plaster has a compounding issue in that it will often crack due to shrinkage while curing or from stresses as a structure settles, even in the absence of outside loads. Sonic boom damage to plaster often occurs when internal stresses are high from these factors. In general, for well-maintained structures, the threshold for damage from sonic booms is 2 psf (Haber, et al., 1989), below which damage is unlikely.

**Table 1. Possible damage to structures from sonic booms (Haber, et al., 1989)**

| Sonic Boom Overpressure Nominal (psf) | Type of Damage | Item Affected |
|---|---|---|
| 0.5 - 2 | Plaster | Fine cracks; extension of existing cracks; more in ceilings; over doorframes; between some plasterboards. |
| | Glass | Rarely shattered; either partial or extension of existing. |
| | Roof | Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole. |
| | Damage to outside walls | Existing cracks in stucco extended. |
| | Bric-a-brac | Those carefully balanced or on edges can fall; fine glass, such as large goblets, can fall and break. |
| | Other | Dust falls in chimneys. |
| 2 - 4 | Glass, plaster, roofs, ceilings | Failures show that would have been difficult to forecast in terms of their existing localized condition. Nominally in good condition. |
| 4 - 10 | Glass | Regular failures within a population of well-installed glass; industrial as well as domestic greenhouses. |
| | Plaster | Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured, or very old plaster. |
| | Roofs | High probability rate of failure in nominally good state, slurry-wash; some chance of failures in tiles on modern roofs; light roofs (bungalow) or large area can move bodily. |
| | Walls (out) | Old, free standing, in fairly good condition can collapse. |
| | Walls (in) | Inside ("party") walls known to move at 10 psf. |
| Greater than 10 | Glass | Some good glass will fail regularly to sonic booms from the same direction. Glass with existing faults could shatter and fly. Large window frames move. |
| | Plaster | Most plaster affected. |
| | Ceilings | Plasterboards displaced by nail popping. |
| | Roofs | Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gale-end and will-plate cracks; domestic chimneys dislodged if not in good condition. |
| | Walls | Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage. |
| | Bric-a-brac | Some nominally secure items can fall; e.g., large pictures, especially if fixed to party walls. |

# 3 Acoustic Modeling Methodology

Launch vehicle propulsion systems, such as solid rocket motors and liquid-propellant rocket engines, generate high amplitude, broadband noise. The majority of the noise is created by the rocket plume, or jet exhaust, interacting with the atmosphere along the entire plume, and combustion noise of the propellants. Although rocket noise radiates in all directions, it is highly directive, meaning that a significant portion of the source's acoustic power is concentrated in a specific direction.

In addition to the rocket noise, a launch vehicle creates sonic booms during supersonic flight. The potential for the boom to intercept the ground depends on the trajectory and speed of the vehicle as well as the atmospheric profile. The sonic boom is shaped by the physical characteristics of the vehicle and the atmospheric conditions through which it propagates. These factors affect the perception of a sonic boom. The noise is perceived as a deep double boom, with most of its energy concentrated in the low frequency range. Although sonic booms generally last less than one second, their potential for impact may be considerable.

## 3.1 Far-Field Launch Noise Modeling

The Launch Vehicle Acoustic Simulation Model (RUMBLE), developed by Blue Ridge Research and Consulting, LLC (BRRC), is the noise model used to predict the launch vehicle noise associated with the proposed operations from the WFF launch range. The noise model utilizes user inputs describing the facility, vehicle, engines/motors, and operations in conjunction with model databases to predict noise exposure to the communities surrounding launch sites. The model produces both overall and spectral sound pressure level time-history signatures at each receiver location. The core components of the model are visualized in Figure 2 and described in the following sub sections.

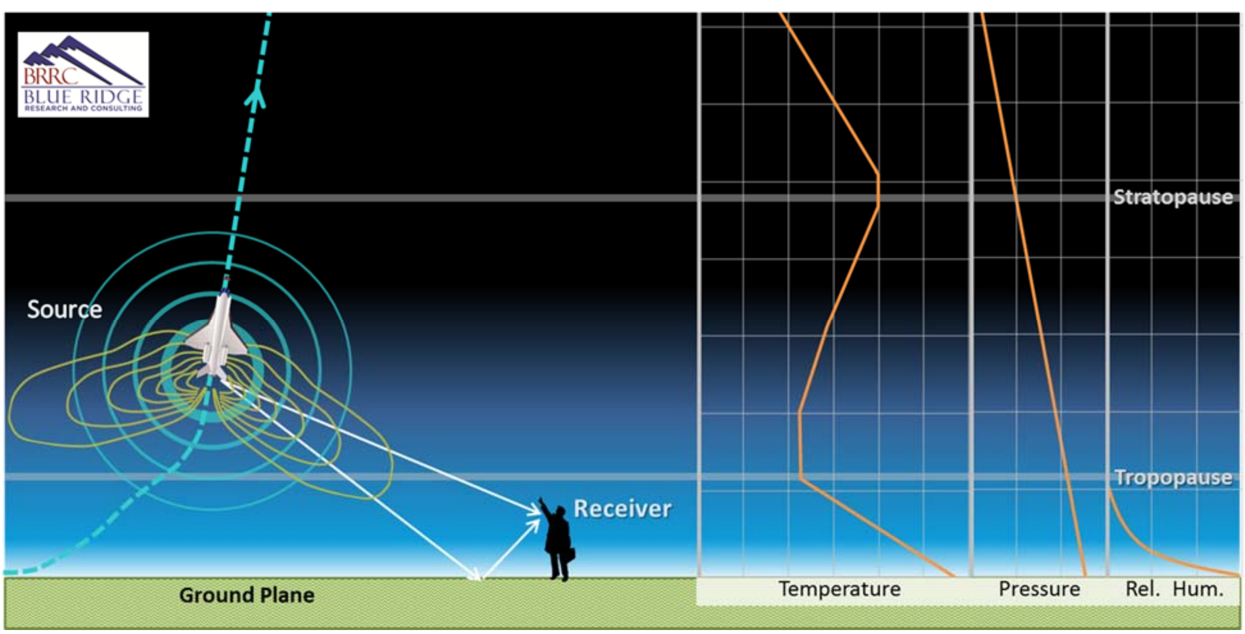


**Figure 2. Conceptual overview of rocket noise prediction model methodology.**

### 3.1.1 Source

The rocket noise source definition considers the acoustic power of the rocket, forward flight effects, directivity, and the Doppler effect.

#### *Acoustic Power*

Eldred's Distributed Source Method 1 (DSM-1) (Eldred, 1971) is utilized for the source characterization. The DSM-1 model determines the launch vehicle's total sound power based on its total thrust, exhaust-velocity and the engine/motor's acoustic efficiency. BRRC's recent validation of the DSM-1 model showed very good agreement between full-scale rocket noise measurements and the empirical source curves (James, et al., 2014). The acoustic efficiency of the rocket engine/motor specifies the percentage of the mechanical power converted into acoustic power. The acoustic efficiency of the rocket engine/motor was modeled using Guest's variable acoustic efficiency (Guest, 1964). Typical acoustic efficiency values range from 0.2% to 1.0% (Eldred, 1971). In the far-field, distributed sources are modeled as a compact source located at the nozzle exit with an equivalent total sound power and range of frequencies. Therefore, launch vehicle propulsion systems with multiple tightly clustered equivalent engines can be modeled as a single engine with an effective exit diameter and total thrust (Eldred, 1971). Additional boosters or cores (that are not considered to be tightly clustered) are handled by summing the noise contribution from each booster/core.

The presence of a launch pad flame duct relocates and redirects the primary noise source from the nozzle exit to the duct exit when the rocket is close to the pad (Panda, et al., 2013). The presence of the flame duct is modeled during the initial launch sequence when the rocket is close to the pad. The source is located at the duct exit and the direction of the plume is assumed to be equivalent to the heading of the flame duct exit.

#### *Forward Flight Effect*

A jet in forward flight radiates less noise than the same jet in a static environment. A standard method to quantify this effect reduces overall sound levels as a function of the relative velocity between the jet and the outside airflow (Viswanathan, et al., 2011; Saxena, et al., 2012; Buckley, et al., 1983; Buckley, et al., 1984). This outside airflow travels in the same direction as the rocket exhaust. At the onset of a launch, the rocket exhaust travels at far greater speeds than the ambient airflow. As the differential between the forward flight velocity and exhaust velocity decreases, jet mixing is reduced, which reduces the corresponding noise emission. Notably, the maximum OASPLs are normally generated before the vehicle reaches sonic velocity. Thus, the modeled noise reduction is capped at a forward flight velocity of Mach1.

#### *Directivity*

Rocket noise is highly directive, meaning the acoustic power is concentrated in specific directions and the sound pressure observed will depend on the angle from the source to the receiver. NASA's Constellation Program has made significant improvements in determining launch vehicle directivity of the reusable solid rocket motor (RSRM) (Haynes, et al., 2009). The RSRM directivity indices (DI) incorporate a larger range of frequencies and angles then previously available data. Subsequently improvements were made to the formulation of the RSRM DI (James, et al., 2014) accounting for the spatial extent and downstream origin of the rocket noise source. These updated DI are used for this analysis.

### *Doppler Effect*

The Doppler effect is defined as the change in frequency of a wave for an observer moving relative to its source. During a rocket launch, an observer on the ground will hear a downward shift in the frequency of the sound as the distance from the source to receiver increases. The perceived frequency is related to the actual frequency by the speed of the source and receiver and the speed of the waves in the medium. The received frequency is higher (compared to the emitted frequency) during the approach, it is identical at the instant of passing by, and it is lower during the recession. The relative changes in frequency can be explained as follows: when the source of the waves is moving toward the observer, each successive wave crest is emitted from a position closer to the observer than the previous wave. Therefore, each wave takes slightly less time to reach the observer than the previous wave, and the time between the arrivals of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are travelling, the distance between successive wave fronts is reduced such that the waves "bunch together". Conversely, if the source of waves is moving away from the observer, then each wave is emitted from a position farther from the observer than the previous wave; the arrival time between successive waves is increased, reducing the frequency. Likewise, the distance between successive wave fronts increases, so the waves "spread out." Figure 3 illustrates this spreading effect for an observer in a series of images, where a) the source is stationary, b) the source is moving less than the speed of sound, c) the source is moving at the speed of sound, and d) the source is moving faster than the speed of sound. As the frequency is shifted lower, the A-Weighting filtering on the spectrum results in a decreased A-weighted sound level. For unweighted overall sound levels, the Doppler effect does not change the levels since all frequencies are accounted for equally.

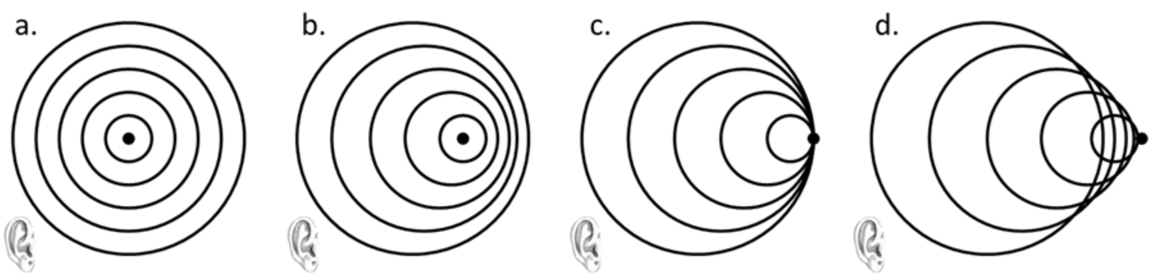


**Figure 3. Effect of expanding wavefronts (decrease in frequency) that an observer would notice for higher relative speeds of the rocket relative to the observer for: a) stationary source b) source velocity < speed of sound c) source velocity = speed of sound d) source velocity > speed of sound**

### 3.1.2 Propagation

The sound propagation from the source to receiver considers the ray path, atmospheric absorption, nonlinear propagation, and ground interference.

### *Ray Path*

The model assumes a straight line between the source and receiver to determine propagation effects. For straight rays, sound levels decrease as the sound wave propagates away from a source uniformly in all directions. The launch noise model components are calculated based on the specific source (launch vehicle trajectory point) to receiver geometry (grid point). The position of the launch vehicle, described by the trajectory, is often provided in the angular geodetic coordinates of latitude and longitude, defined relative to a reference system (e.g., World Geodetic System 1984 [WGS84]) that approximates the Earth's surface by an ellipsoid. The receiver grid is described in geodetic latitude and longitude, referenced to the same reference system as the trajectory data. Maintaining the same reference system ensures greater accuracy in source to receiver geometry calculations

### *Atmospheric Absorption*

Atmospheric absorption is a measure of the sound attenuation from the excitation of vibration modes of air molecules. Atmospheric absorption is a function of temperature, pressure and relative humidity of the air. Figure 2 shows an example atmospheric profile. The atmospheric absorption is calculated using formulas found in ANSI standard S1.26-1995 (R2004). The result is a sound-attenuation coefficient, which is a function of frequency, atmospheric conditions, and distance from the source. The amount of absorption depends on the parameters of the atmospheric layer and the distance that the sound travels through the layer. The total sound attenuation is the sum of the absorption experienced from each atmospheric layer.

### *Nonlinear Propagation*

Nonlinear propagation effects can result in distortions of high-amplitude sound waves (McInerny, et al., 2007) as they travel through the medium. These nonlinear effects are counter to the effect of atmospheric absorption (McInerny, et al., 2005; Pernet, et al., 1971). However, recent research shows that nonlinear propagation effects change the perception of the received sound (Gee, et al., 2007; Ffowcs, et al., 1975) , but the standard acoustical metrics are not strongly influenced by nonlinear effects (Gee, et al., 2008; Gee, et al., 2006). The overall effects of nonlinear propagation on high-amplitude sound signatures and their perception is an on-going area of research.

### *Ground Interference*

The calculated results of the sound propagation using DSM-1 provide a free-field sound level (i.e., no adjacent reflecting surface) at the receiver. However, sound propagation near the ground is most accurately modeled as the combination of a direct wave (source to receiver) and a reflected wave (source to ground to receiver) shown in Figure 2. The ground will reflect sound energy back toward the receiver and interfere both constructively and destructively with the direct wave. Additionally, the ground may attenuate the sound energy causing the reflected wave to propagate a smaller portion of energy to the receiver. RUMBLE accounts for the attenuation of sound by the ground (Chessel, 1977; Embleton, et al., 1983) when estimating the received noise. A receiver height of 5 feet is assumed along with a homogeneous grass ground surface. It should be noted that noise levels directly above a water surface may see an increase of up to 3 dB because of the acoustical hardness of the water surface. To account for the random fluctuations of wind and temperature on the direct and reflected wave, the effect of atmospheric turbulence is also included (Chessel, 1977; Daigle, 1979).

### 3.1.3 Receiver

Combining the source and propagation components, the received noise is estimated. The basic received noise is modeled as overall and spectral level time histories. This approach enables a range of noise metrics relevant to environmental noise analysis to be calculated and prepared as output.

### 3.1.4 Validation

BRRC has performed comparisons of data predicted using RUMBLE to measured data from three Antares 100 series rocket launches from Pad 0-A at Wallops Launch Range. Figure 4 and Figure 5 present examples of comparative results for various distances from the launch pad. The model-predicted SEL and Maximum OASPL (both A-weighted) values agree very well to actual measurements of the launch event over distances ranging from less than 0.6 miles to 4.1 miles. Figure 5 shows a comparison of the modeled and measured OASPL time histories for distances of 0.6, 1.2, 2.5, and 4.1 miles from the launch site. The modeled time histories match the level, shape, and duration of the levels recorded during the three measured launches: ORB-D1 (Launch 1), ORB-1 (Launch 2), and ORB-2 (Launch 3).

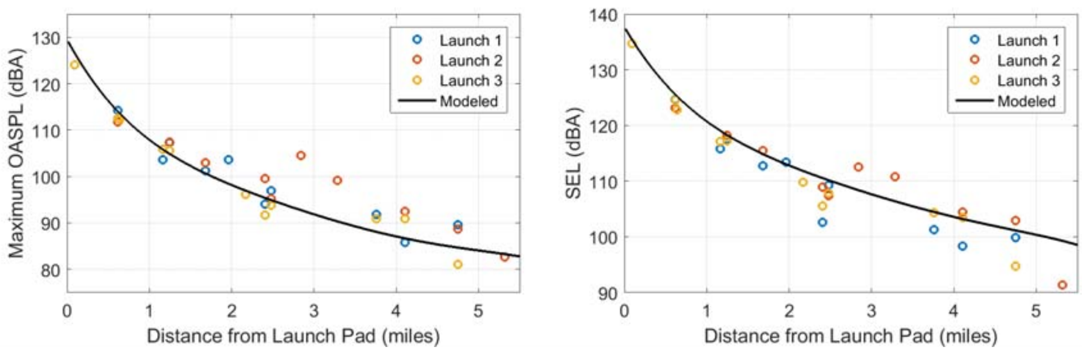


**Figure 4. Measured versus predicted launch vehicle noise exposure levels. (Left) SEL values at set distances from the launch pad. (Right) Maximum OASPL at set distances from the launch pad.**

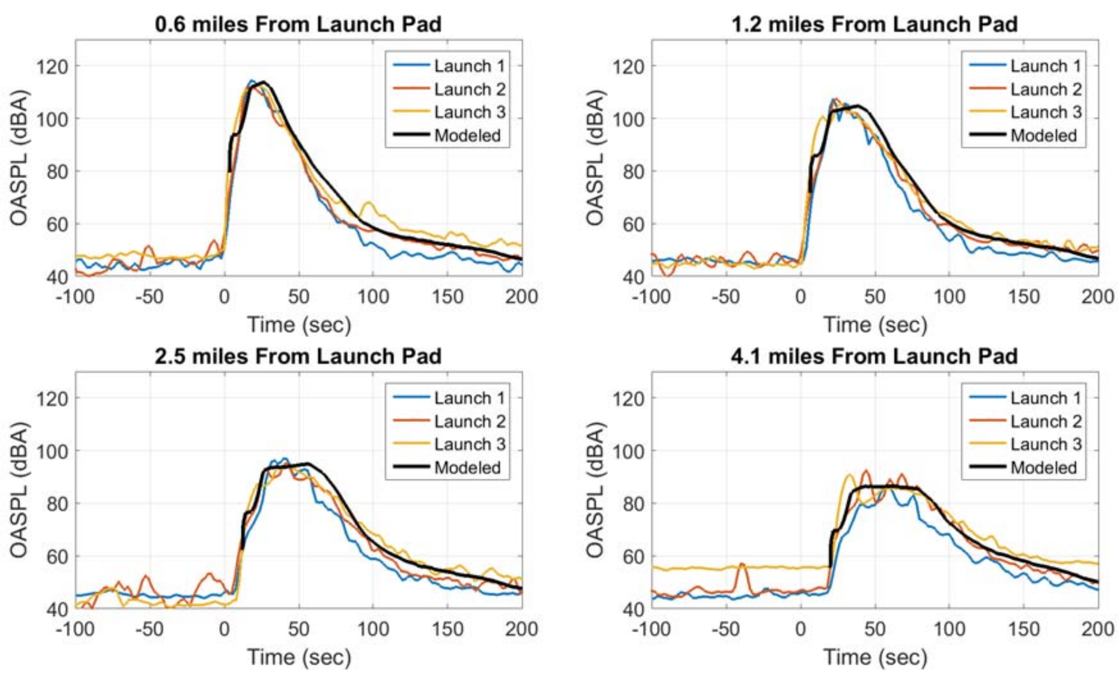


**Figure 5. Measured versus predicted launch vehicle noise time histories.**

## 3.2 Sonic Boom Modeling

When an aircraft moves through the air, it pushes the air out of its way. At subsonic speeds, the displaced air forms a pressure wave that disperses rapidly. At supersonic speeds, the aircraft is moving too quickly for the wave to disperse, so it remains as a coherent wave. This wave is a sonic boom. When heard at ground level, a sonic boom consists of two shock waves (one associated with the forward part of the aircraft, the other with the rear part) of approximately equal strength and (for fighter aircraft) separated by 100 to 200 milliseconds. For rockets, the separation can be extended because of the volume of the plume. Thus, their waveform durations can be as large as one second. When plotted, this pair of shock waves and the expanding flow between them has the appearance of a capital letter “N,” so a sonic boom pressure wave is usually called an “N-wave.” An N-wave has a characteristic "bang-bang" sound that can be startling. Figure 6 shows the generation and evolution of a sonic boom N-wave under the aircraft. Figure 7 shows the sonic boom pattern for an aircraft in steady, level supersonic flight. The boom forms a cone that is said to sweep out a “carpet” under the flight track. The boom levels vary along the lateral extent of the “carpet” with the highest levels directly underneath the flight track and decreasing as the lateral distance increases to the cut-off edge of the “carpet.” When the vehicle is maneuvering, the sonic boom energy can be focused in highly localized areas on the ground. This focusing will cause the N-wave boom to be amplified and transformed into a U-wave.

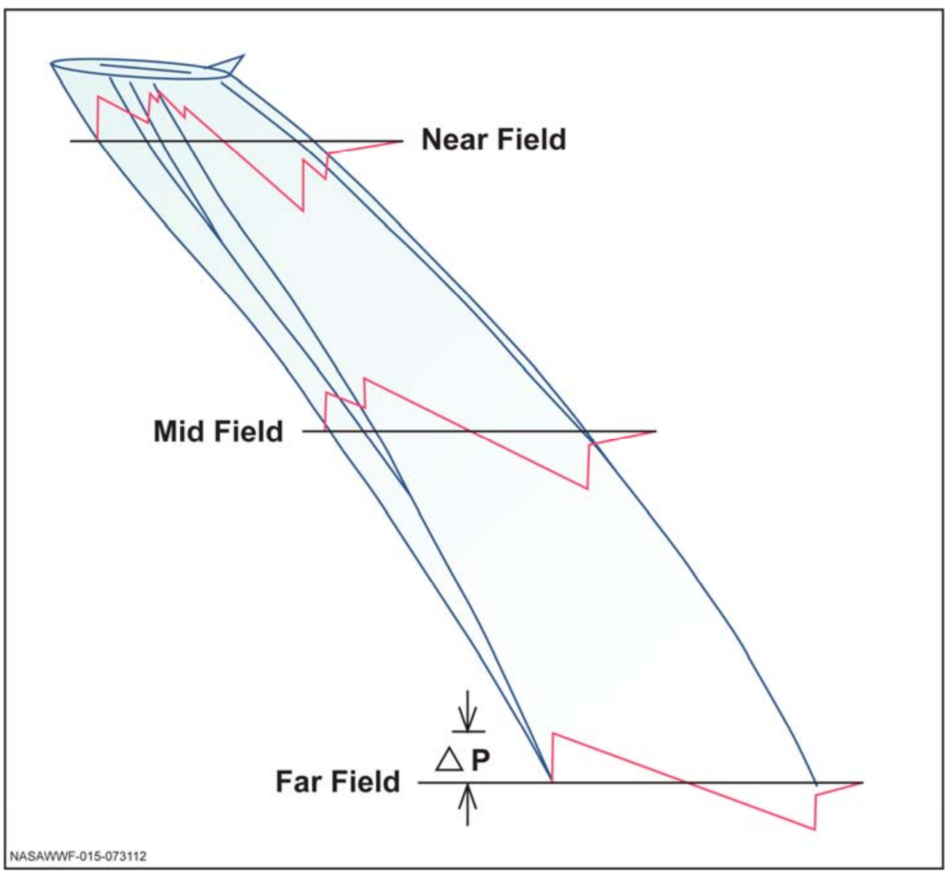


**Figure 6. Sonic boom generation and evolution to N-wave (Carlson, 1967)**

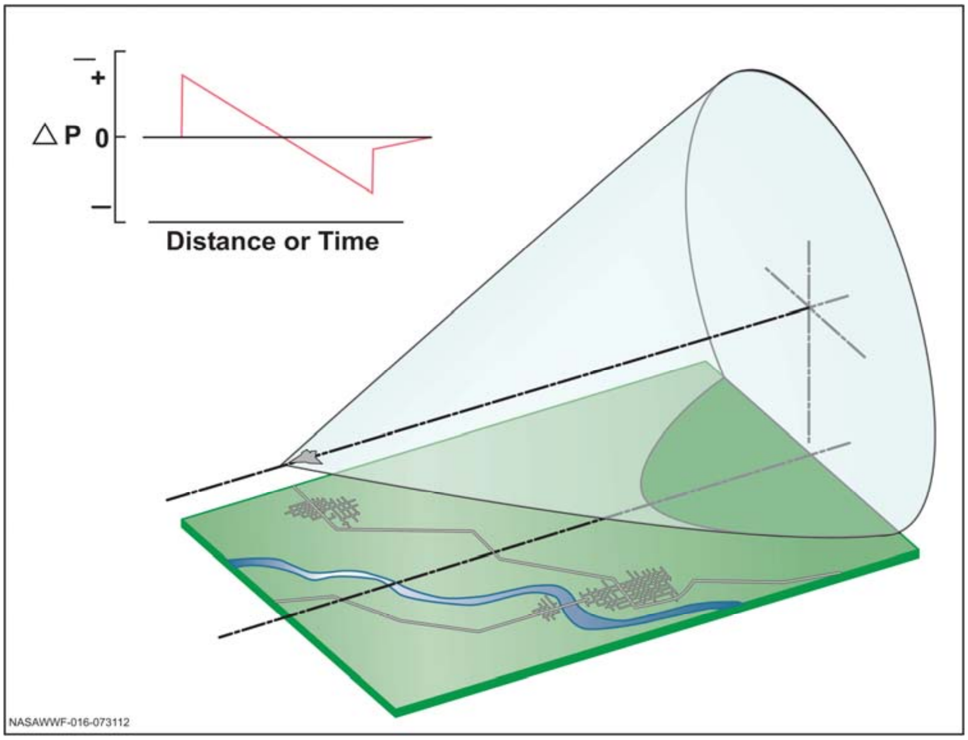


**Figure 7. Sonic boom carpet in steady flight (Plotkin, et al., 1990)**

The complete ground pattern of a sonic boom depends on the size, weight, shape, speed, and trajectory of the vehicle. Since aircraft fly supersonically with relatively low horizontal angles, the boom is directed toward the ground. However, for rocket trajectories, the boom is directed laterally until the rocket rotates significantly away from vertical, as shown in Figure 8. This difference causes a sonic boom from a rocket to propagate much further downrange compared to aircraft sonic booms. This extended propagation usually results in relatively lower sonic boom levels from rocket launches. For aircraft, the front and rear shock are generally the same magnitude. However, for a rocket the plume provides a smooth decrease in the vehicle volume, which diminishes the strength of the rear shock. During reentry of a rocket body, the vehicle can also generate sonic boom on the ground as the body descends back toward the earth. The sonic booms are somewhat reduced as the vehicle is decelerating. For this case, the propagation is direct toward the ground, so the boom is concentrated around the impact site. Figure 9 shows the sonic boom intercepting the ground for a reentering sounding rocket.

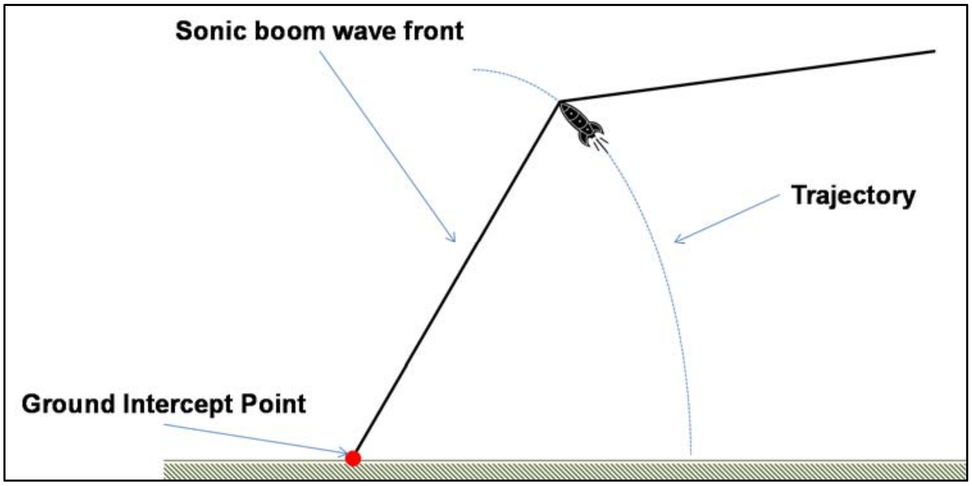


**Figure 8. Sonic boom propagation for rocket launch**

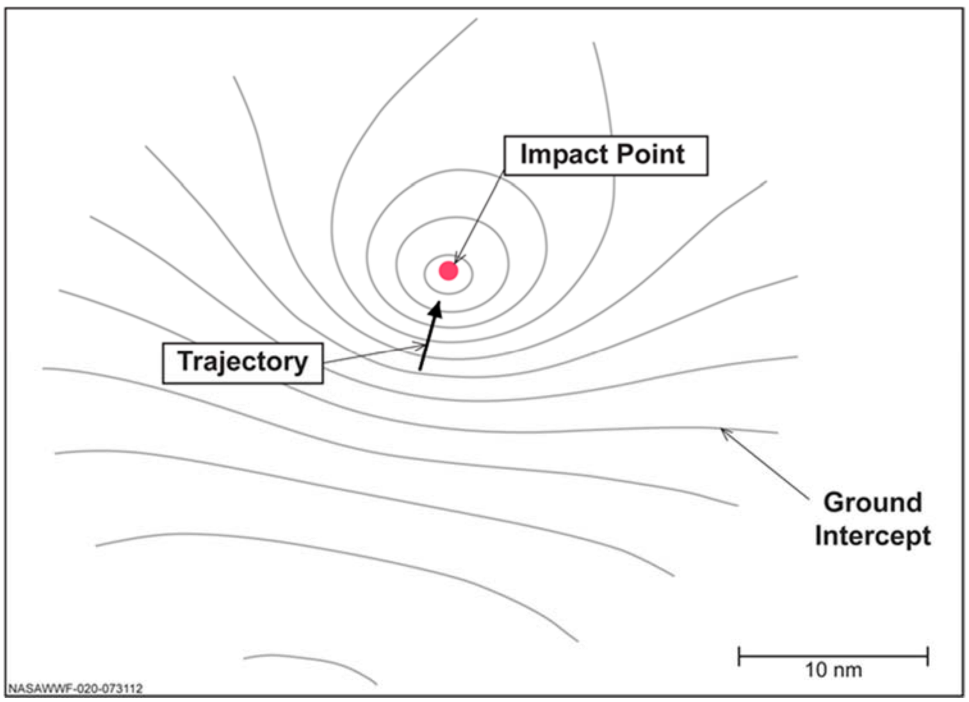


**Figure 9. Sonic boom ground intercepts for reentry of a sounding rocket**

The single-event prediction model, PCBoom4 (Plotkin, 1996; Plotkin, 1989; Plotkin, et al., 2002), is used to predict the sonic boom footprint. PCBoom4 calculates the magnitude and location of sonic boom overpressures on the ground from supersonic flight. Several inputs are required to calculate the sonic boom impact, including the vehicle model, the trajectory path, the atmospheric conditions and the ground surface height. Predicted sonic boom footprints are generally presented as contours of constant peak overpressure.

# 4 Wallops Island Launch Range

## 4.1 Launch Range Description

WFF is the NASA's principal facility for management and implementation of suborbital research programs. WFF supports missions for suborbital and orbital rocket vehicles. The launch range on Wallops Island currently includes seven launch pads, three blockhouses for launch control, and assembly buildings that support the preparation and launching of suborbital and orbital launch systems. The current modeling effort considers launches from three WFF launch pads, two of which are existing launch pads: Launch Pad 0-A (Pad 0-A) and Launch Pad 0-B (Pad 0-B). The third site, Launch Pad 0-C (Pad 0-C), is a future launch site that could support launches of SFHC ELV; its location is estimated for planning purposes. Although Pad 0-B is an existing launch site, plans could include updating its design to support launches of SFHC ELV's. All three launch pads, shown in Figure 10, are located within WFF facility boundaries, specifically within the southern portion of Wallops Island, south of Causeway Road and east of Bypass Rd. Table 2 includes the longitude, latitude, and altitude above ground level (AGL) of the three modeled launch pads at WFF. Table 3 presents the associated flame duct parameters corresponding to the three launch pads.


Figure 10. WFF launch range

**Table 2. Launch pad locations at the WFF launch range**

| Launch Pad | Latitude | Longitude | Altitude | Associated Launch Vehicles |
|---|---|---|---|---|
| Pad 0-A | 37.833864° | -75.487683° | 17 ft AGL | Antares 200 and LFIC ELV |
| Pad 0-B | 37.831200° | -75.491300° | 28 ft AGL | LMLV III and SFHC ELV |
| Pad 0-C* | 37.827284° | -75.494435° | 28 ft AGL | SFHC ELV |

**Pad-0C location is estimated at the UAS runway northern pad for planning purposes.*

**Table 3. Launch pad flame duct locations and geometry at the WFF launch range**

| Launch Pad | Flame Duct Exit | | | Flame Duct Geometry | | | | |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Centerline Height | Top Height | Bottom Lip Height | Length | Heading* | Exit Angle* |
| Pad 0-A | 37.833722° | -75.487579° | 11.2 ft | 20.9 ft | 1.4 ft | 59.5 ft | ~150° | ~9.85° |
| Pad 0-B | 37.831196° | -75.491251° | 13.2 ft | 25.4 ft | 1.1 ft | 14.1 ft | ~95° | ~0° |
| Pad 0-C | 37.827280° | -75.494386° | 13.2 ft | 25.4 ft | 1.1 ft | 14.1 ft | ~95° | ~0° |

**Heading is measured relative to True North and Exit Angle is measured relative to the Horizon*
***Pad 0-B and Pad 0-C flame duct parameters are estimated for modeling purposes*

The launch noise model utilizes an atmospheric profile, which describes the variation of temperature, pressure and relative humidity with respect to the altitude. Site-specific and standard atmospheric data sources, detailed in Table 4, were used to create a composite atmospheric profile for altitudes up to 66 miles. Figure 11 shows the composite atmospheric profile temperature, relative humidity, and pressure profile.

**Table 4. Source of atmospheric profile data**

| Altitude Range | Source | Parameters |
|---|---|---|
| 0 – 18 miles | WFF Climatology Summary 1963-2010 | Temperature, Pressure and Relative Humidity |
| 19 – 56 miles | NASA Technical Memo 4511 | Temperature and Pressure |
| 57 – 66 miles | "Handbook of Astronautical Engineering" (McGraw-Hill 1961) | Temperature and Pressure |

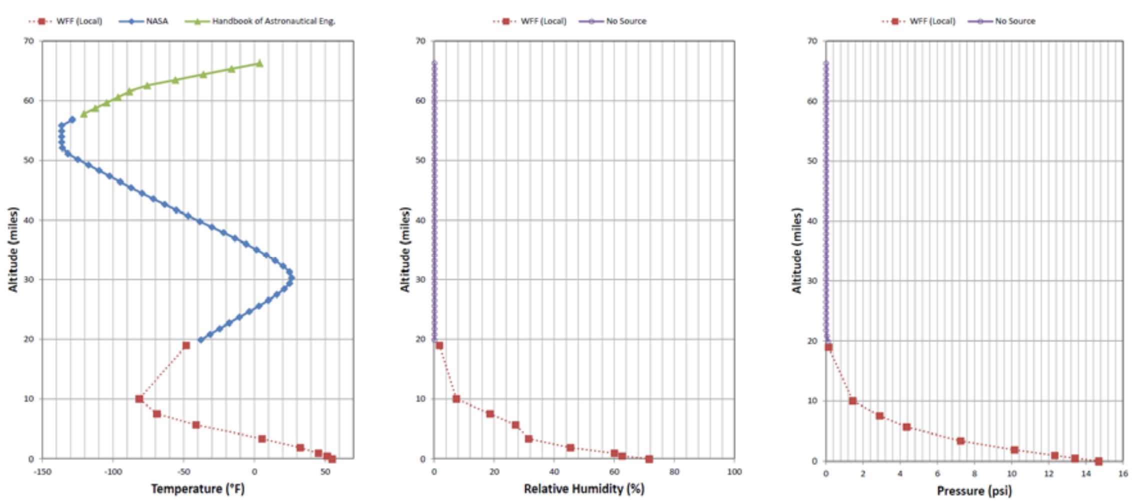


**Figure 11. Atmospheric temperature, relative humidity, and pressure profiles (Note, above 20 miles, the relative humidity and pressure are assumed to asymptote to zero)**

## 4.2 Vehicle and Engine Modeling Parameters

This noise study considers the operations of four representative launch vehicles, the current baseline: Antares 200 and LMLV III; and proposed future growth to an LFIC ELV and an SFHC ELV. The RUMBLE model requires specific vehicle/engine input parameters to determine the noise exposure resulting from the proposed operations of the four representative launch vehicles. Table 5 and Table 6 present the launch vehicle parameters utilized in the acoustic modeling.

**Table 5. Vehicle parameters used in acoustic modeling**

| Reference Name/Acronym | Antares 200 (Baseline) | LMLV III (Baseline) | LFIC ELV (Proposed) | SFHC ELV (Proposed) |
|---|---|---|---|---|
| Launch Vehicle Class | Liquid Fueled Medium Class (LFMC) | Solid Fueled Medium Class (SFMC) | Liquid Fueled Intermediate Class (LFIC) | Solid Fueled Heavy Class (SFHC) |
| Representative Vehicle | **Antares 200 Series** | **Lockheed Martin Launch Vehicle (LMLV)/Athena III** | **SpaceX Falcon 9** | **ATK Castor-1200 based vehicle** |
| Length | 133 ft | 92.50 ft | 224.4 ft | N/A (no assoc. vehicle) |

**Table 6. Vehicle parameters used in acoustic modeling**

| Reference Name/Acronym | Antares 200 (Baseline) | LMLV III (Baseline) | LFIC ELV (Proposed) | SFHC ELV (Proposed) |
|---|---|---|---|---|
| First Stage Engine/Motor | **RD-181** | **CASTOR 120** | **Merlin** | **CASTOR 1200** |
| Number of Engines/Motors | 2 | 1 | 9 | 1 |
| Propellant | LO2/RP (liquid) | TP H1246 (solid) | LO2/RP (liquid) | TP H1148 Type VIII (solid) |
| Single Engine/Motor Nozzle Exit Diameter | 56.3 in | 59.7 in | 33.8 in | 149.6 in |
| Exhaust Velocity | 10,141 ft/s | 8,202 ft/s | 9,500 ft/s | 8,301 ft/s |
| Single Engine/Motor Thrust (Sea Level) | 432,104 lbf (100% Thrust) | 325,972 lbf (Burn time average) | 147,000 lbf | 2,250,000 lbf (Burn time average) |
| Booster Engine/Motor | | **CASTOR IVA** | | |
| Number of Booster Engines/Motors | | 8 | | |
| Propellant | | HTPB (solid) | | |
| Single Booster Engine/Motor Nozzle Exit Diameter | | 32.15 in | | |
| Exhaust Velocity | | 8,202 ft/s | | |
| Single Booster Engine/Motor Thrust (Sea Level) | | 112,019 lbf | | |
| Modeled Effective Diameter | **79.6 in** | **108.7 in** | **100.4 in** | **149.6 in** |
| Modeled Combined Total Thrust | **864,208 lbf** | **1,267,082 lbf** | **1,323,000 lbf** | **2,250,000 lbf** |

## 4.3 Flight Trajectory Modeling

Launch trajectories departing from WFF's Wallops Island launch range are unique to each particular mission and the environmental conditions. However, all launches are conducted to the east over the Atlantic Ocean. For the purposes of this study, the noise model utilizes a nominal Antares 200 series launch trajectory to model noise emissions from the four representative launch vehicles. Figure 12 shows the nominal launch trajectory, with its ground path displayed within the inset map. The nominal launch trajectory, provided by WFF personnel, originates from Pad 0-A. The Pad 0-A launch trajectory is translated to Pad 0-B and Pad 0-C to model launches departing from these two launch sites. The translation process involves determining the distance and direction of each launch trajectory point in relation to Pad 0-A, then moves each launch trajectory point to an equivalent distance and direction in relation to the new pad location. The time-varying thrust profile for each vehicle was based on the Antares 200 series trajectory, normalized on a thrust basis.

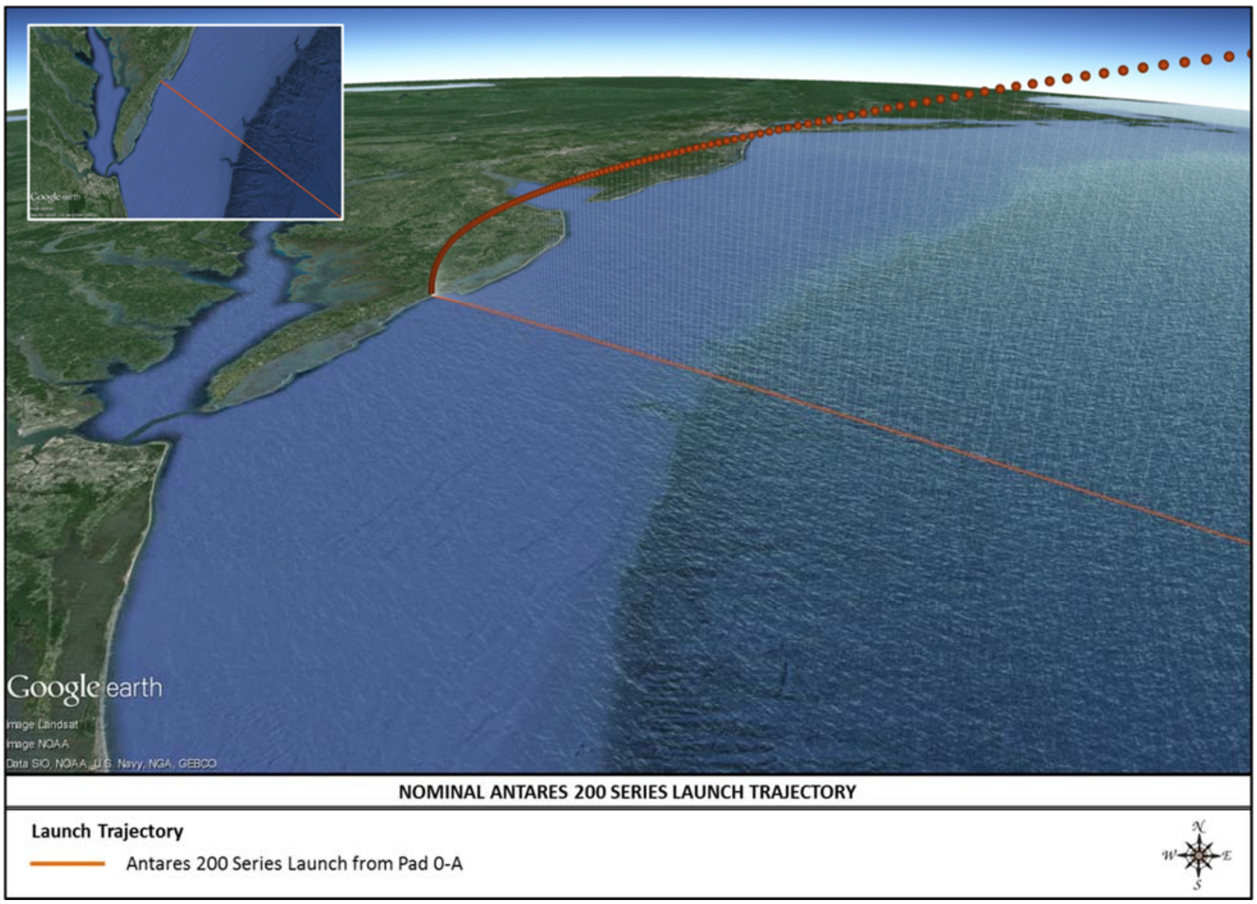


**Figure 12. Nominal Antares 200 series trajectory launching from Pad 0-A**

# 5 Results

The following sections present results of the noise study concerning the baseline and proposed future rocket launch operations at Wallops Island. Sections 5.1, 5.2 and 5.3, respectively, present the results of the launch noise impact, specific point analysis, and sonic boom analysis.

## 5.1 Launch Noise Analysis

### 5.1.1 Maximum A-weighted OASPL

The OASPL provides a measure of the sound level at any given time, while the maximum A-weighted OASPL ($L_{A,max}$) indicates the maximum OASPL achieved over the duration of the event. OSHA has set an upper limit noise level of 115 dBA for fifteen minutes as a guideline to protect human hearing from long-term continuous daily exposures to high noise levels and aid in the prevention of noise-induced hearing loss. As summarized in Table 7, the $L_{A,max}$ generated by a single launch event exceeds 115 dBA within a distance of approximately 0.6 miles from the launch pad for all four vehicles. The $L_{A,max}$ is a combination of a number of factors including the individual engines' thrust, acoustic efficiencies, exit velocity, effective diameter, and A-weighting. Note, the differences in these parameters, in some cases, can result in a larger $L_{A,max}$ associated with a vehicle with a smaller total thrust. Figure 13, Figure 14, and Figure 15 present the $L_{A,max}$ contours within the range of 85 to 115 dBA for vehicles launched from Pad 0-A, Pad 0-B, and Pad 0-C, respectively. Although the 115 dBA contours lie partially outside WFF boundaries, these areas do not include any residences as they are mainly over the ocean or the bay between Wallops Island and the mainland.

**Table 7. Approximate distance (miles) from launch site for hearing conservation criteria.**

| Launch Vehicle | Antares 200 | LMLV III | LFIC ELV | SFHC ELV |
|---|---|---|---|---|
| 115 dBA Hearing Conservation Criteria | 0.6 mi | 0.6 mi | 0.6 mi | 0.6 mi |

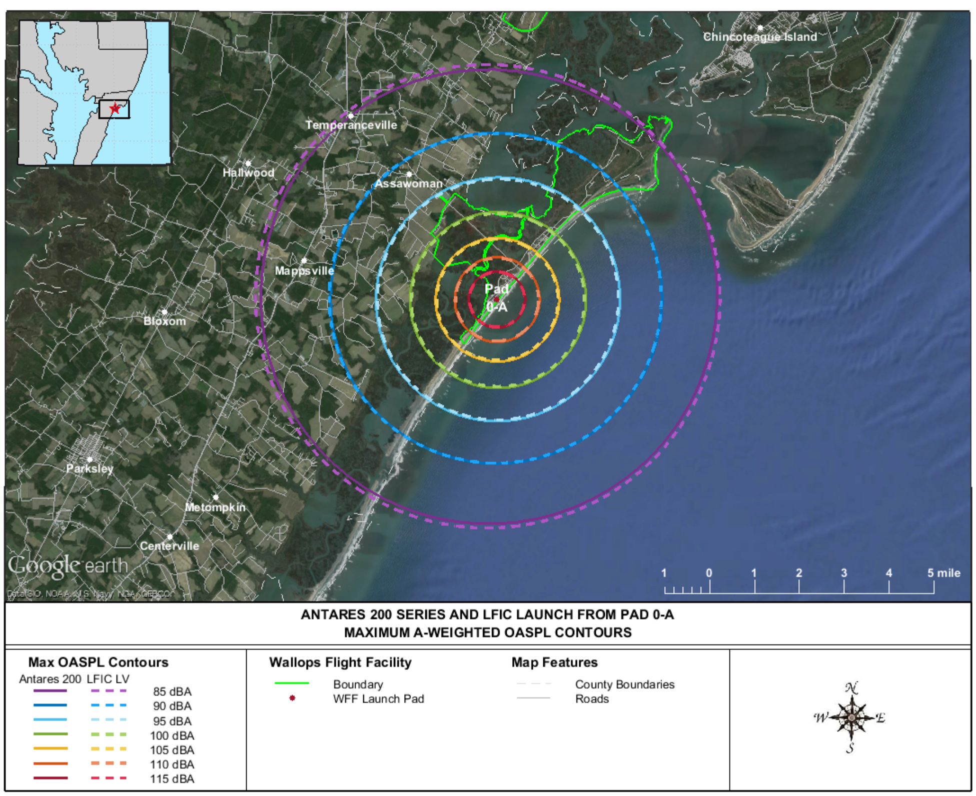


**Figure 13. Maximum A-weighted OASPL ($L_{A,max}$) contours for vehicles launching from Pad 0-A**

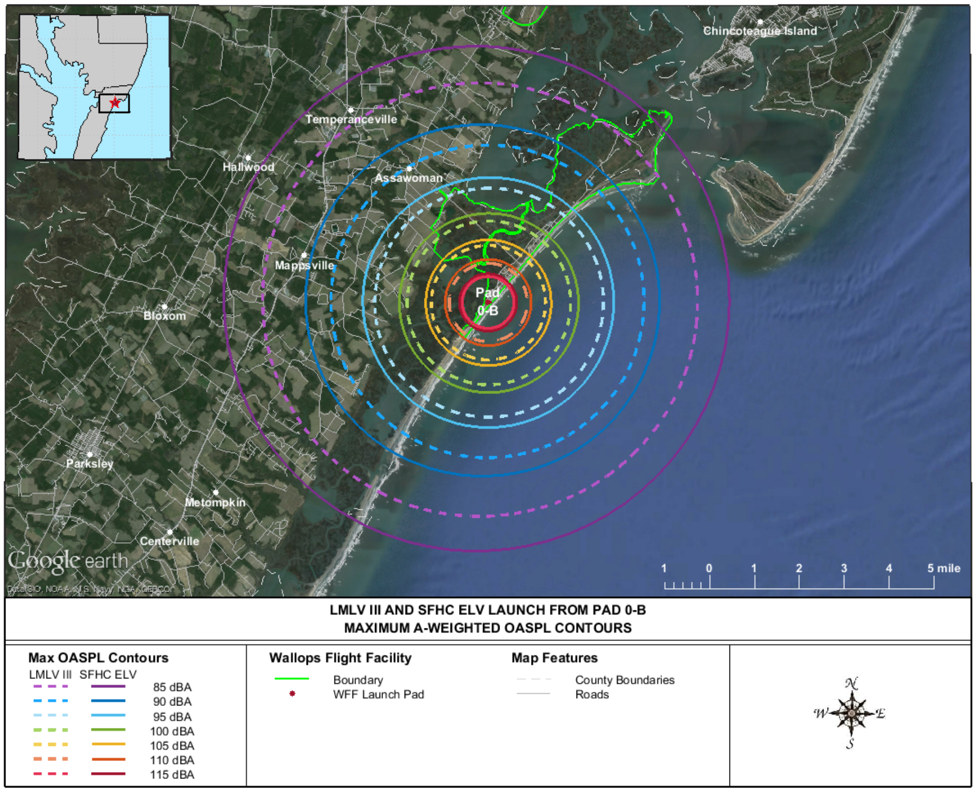


**Figure 14. Maximum A-weighted OASPL ($L_{A,max}$) contours for vehicles launching from Pad 0-B**

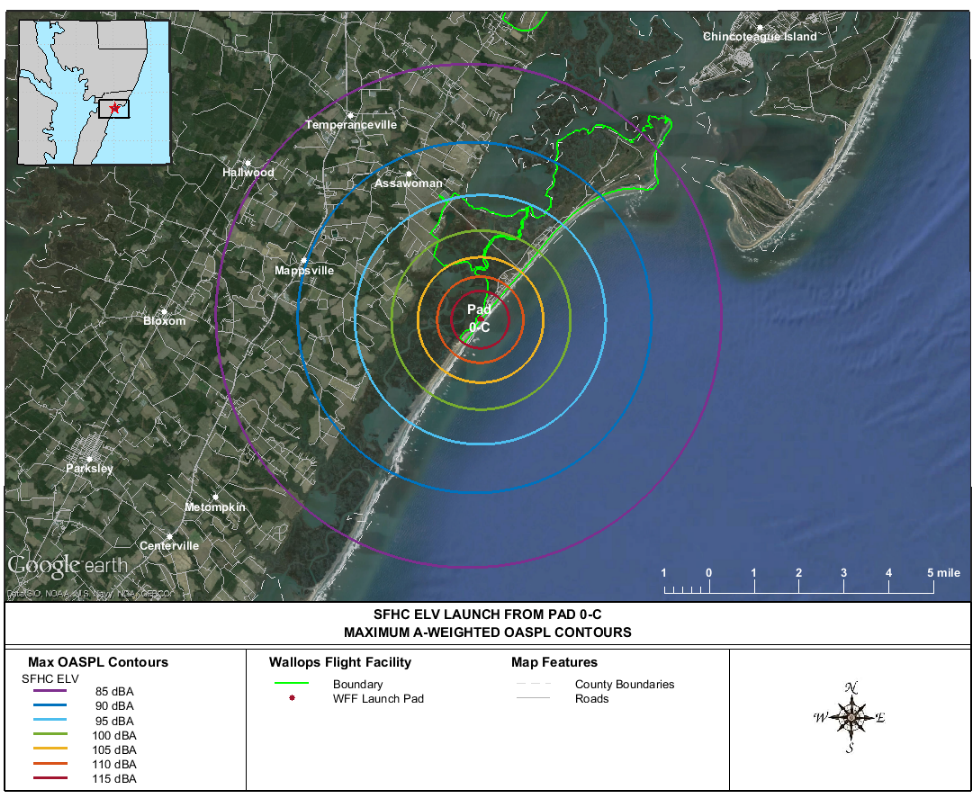


**Figure 15. Maximum A-weighted OASPL ($L_{A,max}$) contours for vehicles launching from Pad 0-C**

### 5.1.2 Maximum Unweighted OASPL

The OASPL provides a measure of the sound level at any given time, while the $L_{max}$ indicates the maximum OASPL achieved over the duration of the event. To assess the potential risk to structural damage claims, the 111 dB and 120 dB contours are presented in Figure 16, Figure 17, and Figure 18 for vehicles launched from Pad 0-A, Pad 0-B and Pad 0-C respectively. The potential for structural damage claims is approximately one damage claim per 1,000 households exposed at 111 dB and one in 100 households at 120 dB. The 120 dB contour extends approximately 2.0 to 3.6 miles from the WFF launch pads, depending on the launch vehicle. Table 8 summarizes the approximate distances within which 111 dB and 120 dB are exceeded. The 120 dB contours include population in the region east of U.S. Route 13. The 111 dB contours extends approximately 5.1 to 8.8 miles from the WFF launch pads, depending on the launch vehicle. The 111 dB contours include populations in the regions of Chincoteague Island and Oak Hall to the north, Jenkins Bridge to the west, and Centerville to the south.

**Table 8. Distance (miles) from launch site for structural damage claim criteria.**

| Launch Vehicle | Antares 200 | LMLV III | LFIC ELV | SFHC ELV |
|---|---|---|---|---|
| 111 dB Structural Damage Claim Criteria | 5.1 mi | 5.4 mi | 6.1 mi | 8.8 mi |
| 120 dB Structural Damage Claim Criteria | 2.0 mi | 2.1 mi | 2.4 mi | 3.6 mi |

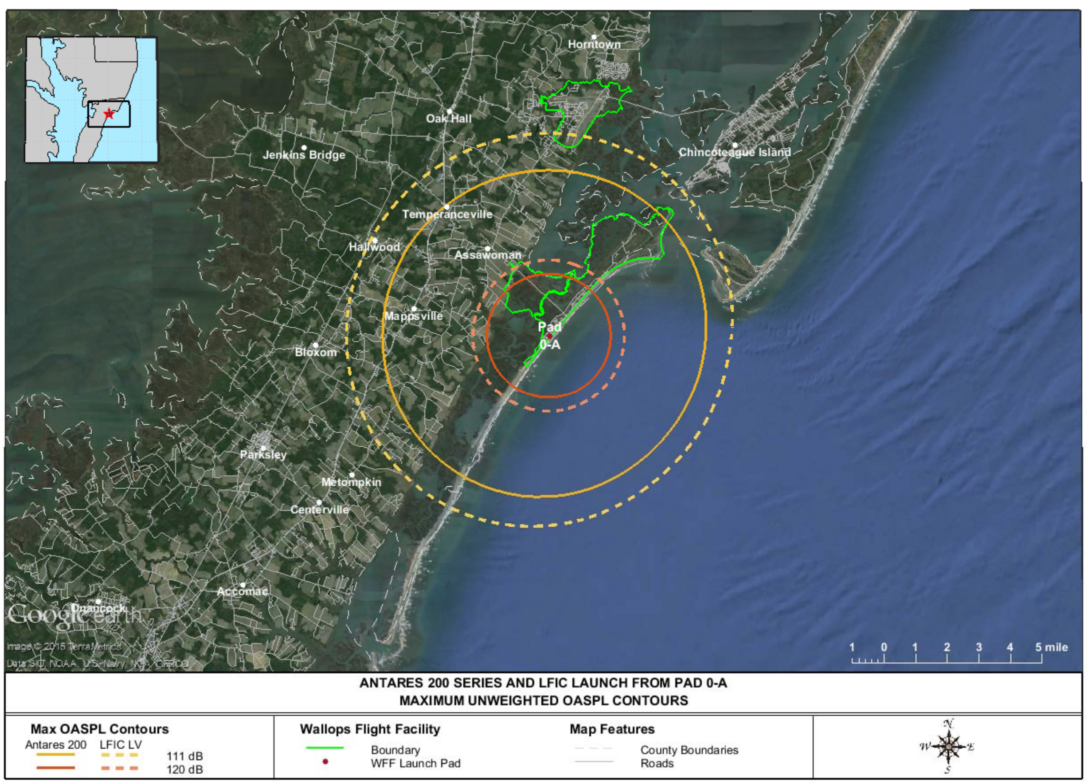


**Figure 16. Maximum unweighted OASPL ($L_{max}$) contours for vehicles launched from Pad 0-A**

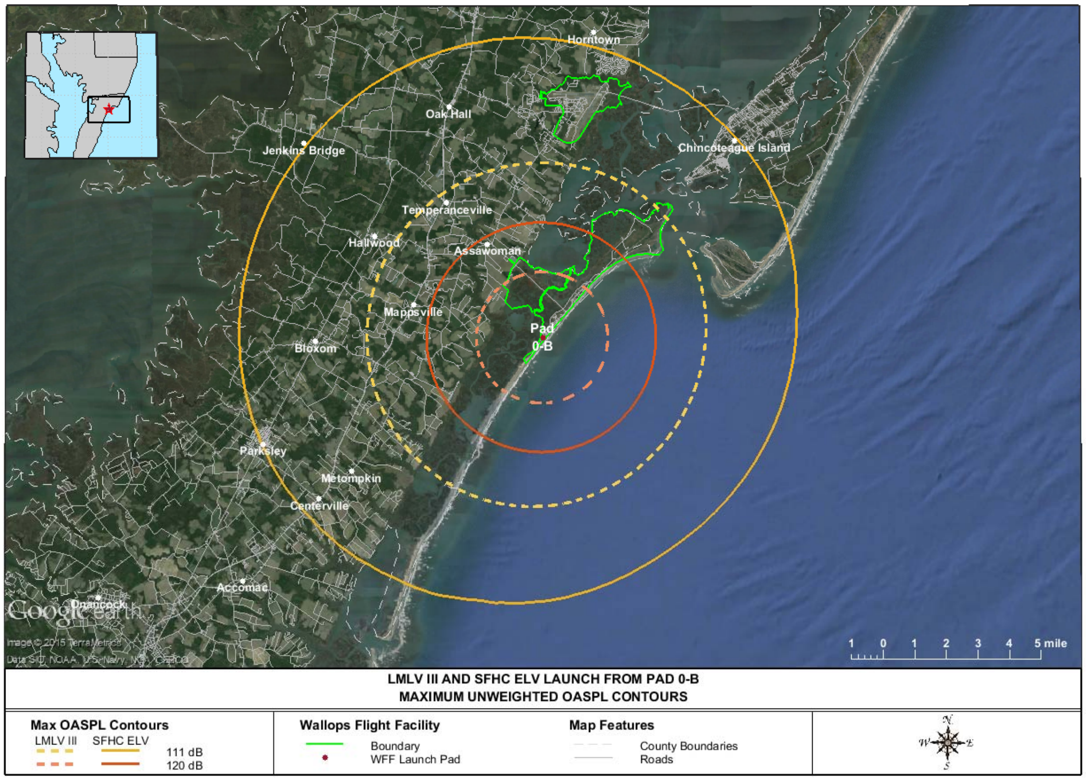


**Figure 17. Maximum unweighted OASPL ($L_{max}$) contours for vehicles launched from Pad 0-B**

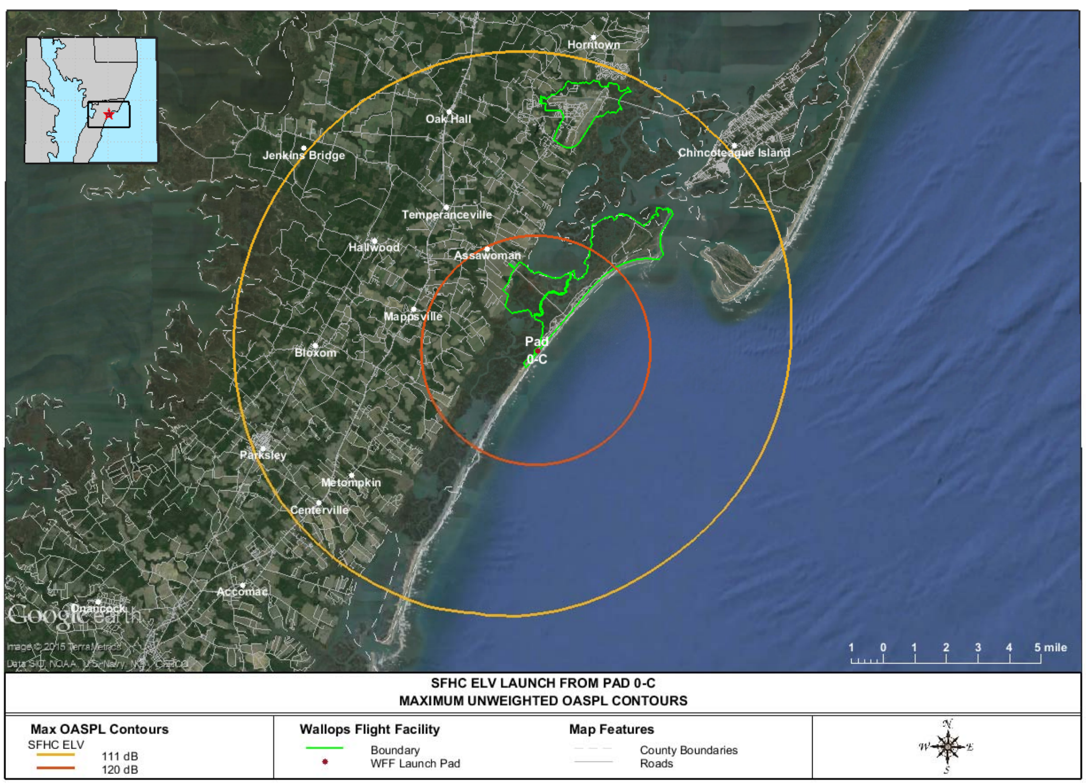


**Figure 18. Maximum unweighted OASPL ($L_{max}$) contours for vehicles launched from Pad 0-C**

### 5.1.3 A-weighted SEL

SEL represents both the magnitude of a sound and its duration. SEL provides a measure of the cumulative noise exposure of the entire acoustic event, but it does not directly represent the sound level heard at any given time. Mathematically, it represents the sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound generated by rocket launches, which last more than one second, the SEL is greater than the $L_{max}$ because an individual launch can last for minutes and the $L_{max}$ occurs instantaneously. Figure 19, Figure 20 and Figure 21 depict the A-weighted SEL contours for vehicles launched from Pad 0-A, Pad 0-B, and Pad 0-C respectively. Currently, there are no reported guidelines for SEL in reference to launch vehicle noise.

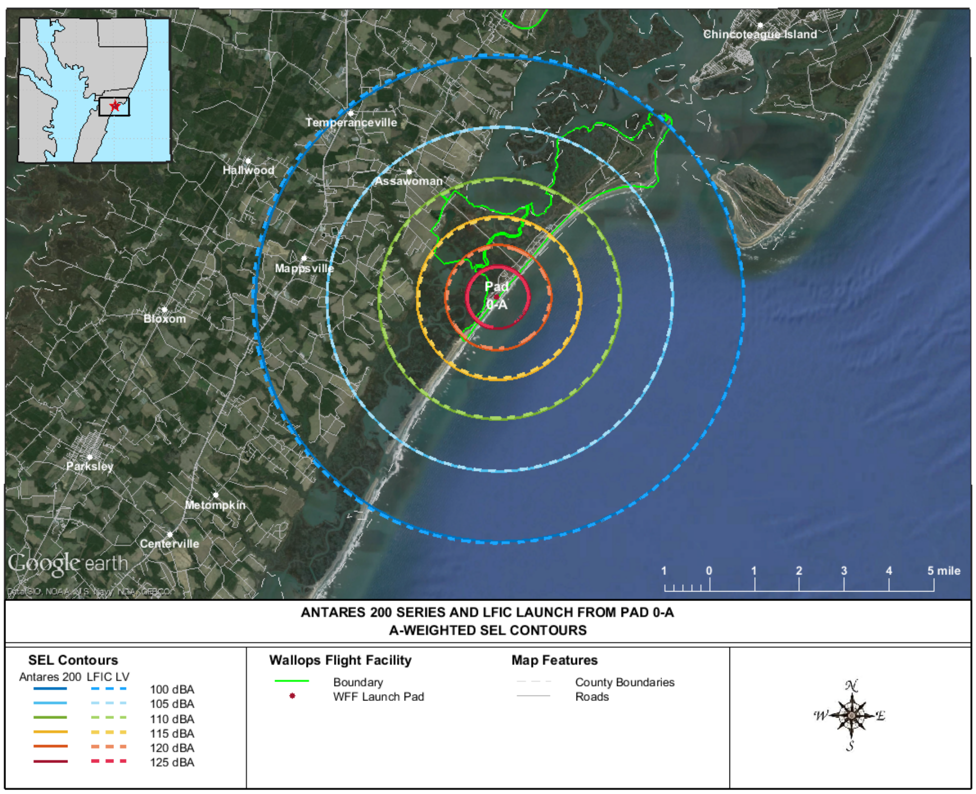


Figure 19. A-weighted SEL contours for vehicles launched from Pad 0-A

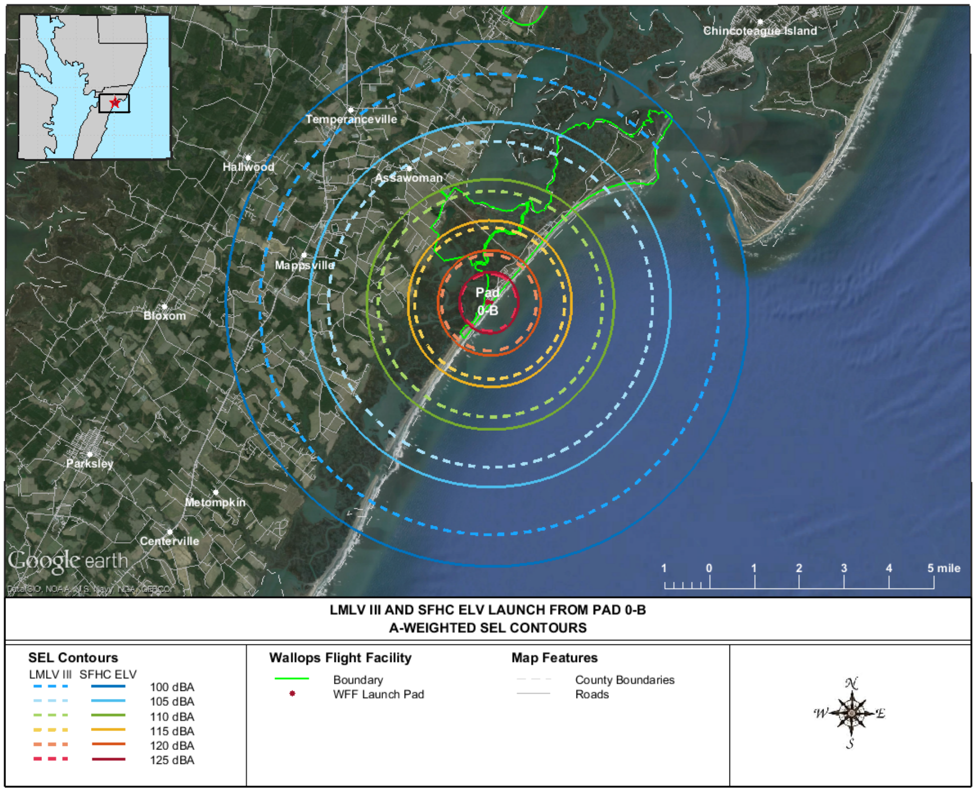


**Figure 20. A-weighted SEL contours for vehicles launched from Pad 0-B**

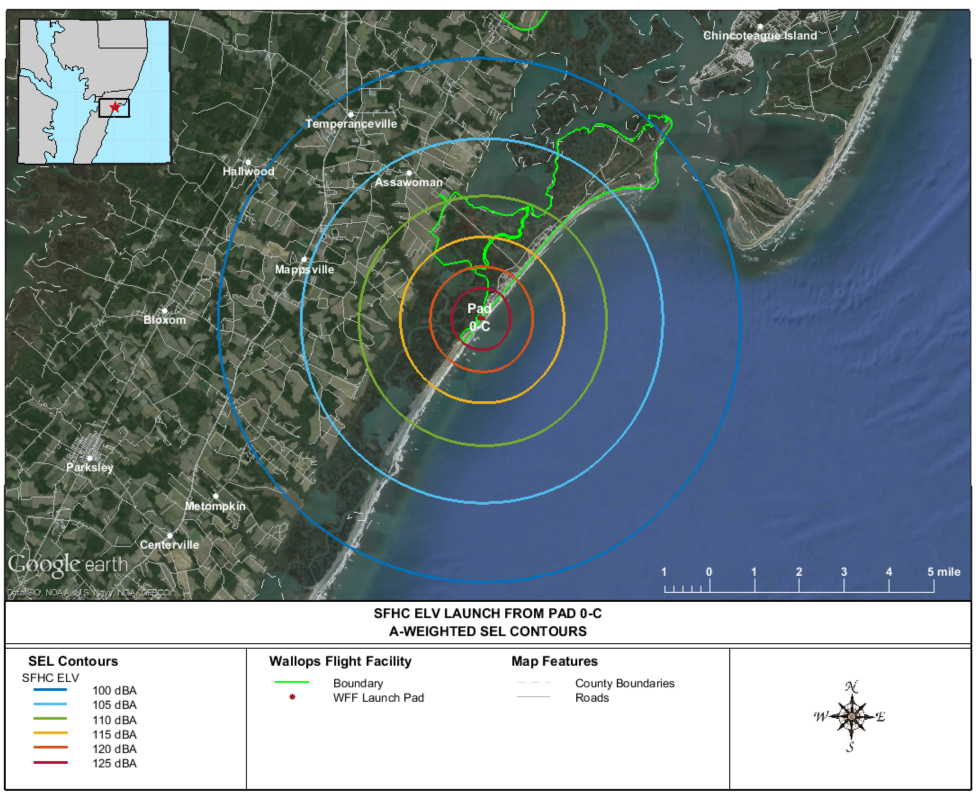


**Figure 21. A-weighted SEL contours for vehicles launched from Pad 0-C**

## 5.2 Specific Point Analysis at Nearest Residence

To provide more detail on potential community impacts when comparing the baseline to proposed future actions, the nearest residence location was modeled as a specific point of interest. The nearest residence, shown in Figure 22, is located approximately 1.7 to 1.9 miles west of the launch pads at a latitude and longitude of 37.838404° N and -75.522186° W. Figure 23 and Figure 24 present A-weighted and unweighted OASPL time histories, respectively, corresponding to the nearest residence. Although the launch event begins at time zero, it takes approximately 8 to 9 seconds for launch noise to propagate from the launch pads to the nearest residence. The time at which the maximum level occurs depends on the thrust profile, peak directivity angle, and distance between the source and the receiver. Maximum A-weighted OASPL at the nearest residence is less than the 115 dBA upper limit noise level associated with protecting human hearing. However, the maximum unweighted OASPL at the nearest residence exceeds 120 dB, indicating that, based on Guest and Slone (1972), the probability of a noise induced damage claim is greater than one in 100 for a launch event.


**Figure 22. Location of the nearest residence shown in relation to the WFF launch pads**

The maximum A-weighted OASPL, maximum unweighted OASPL, A-weighted SEL and Time Above an OASPL of 66 dBA at the nearest residence are presented in Table 9. Time above is a supplemental metric associated with speech interference measured in sentence intelligibility percentage. A sentence intelligibility of 95% usually permits reliable communication because of the redundancy in normal conversation. Levels must remain below 66 dBA to maintain a speech intelligibility of 95% for two people standing outside approximately 3 ft (1 m) apart (U.S. EPA, November 1978). For launches at WFF, levels may exceed 66 dBA at the nearest residence for a period of up to 80 seconds per launch.

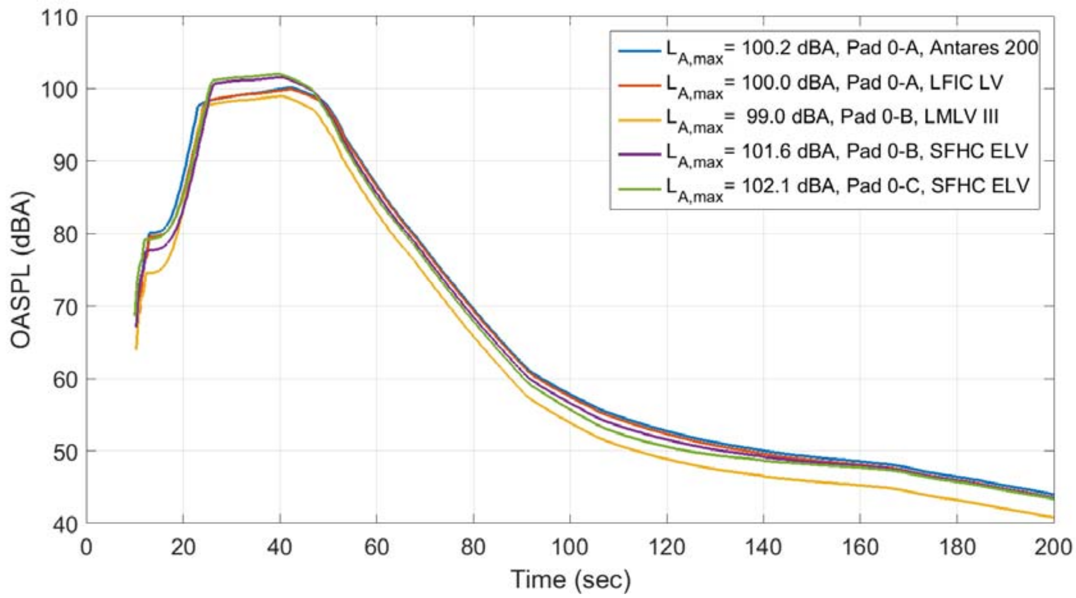


**Figure 23. A-weighted OASPL time history at nearest residence**

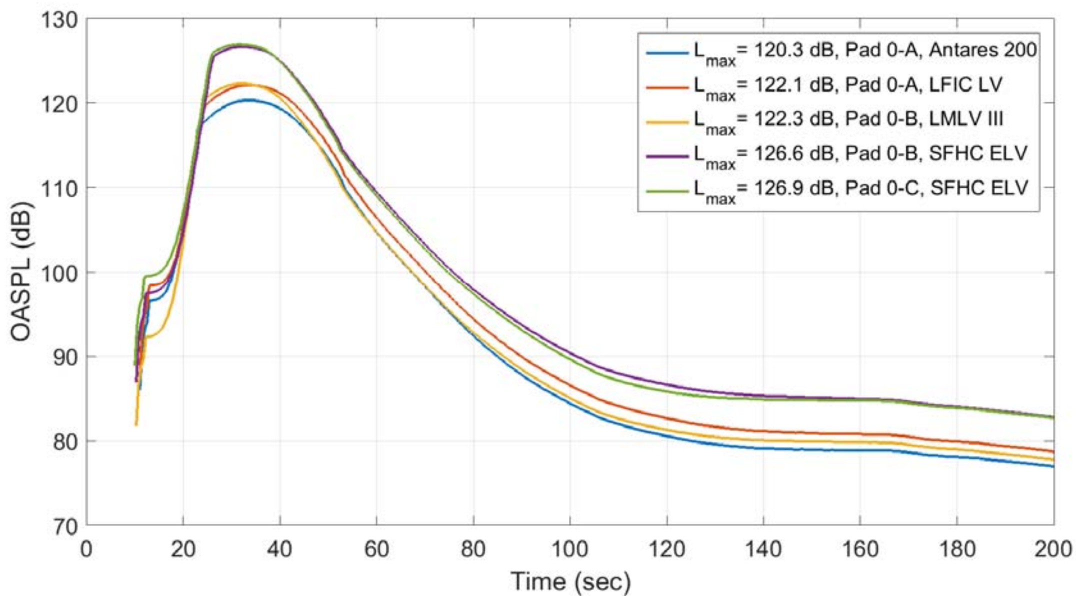


**Figure 24. Unweighted OASPL time history at nearest residence**

**Table 9. Nearest residence noise analysis results**

| | Antares 200 Pad 0-A | LFIC ELV Pad 0-A | LMLV III Pad 0-B | SFHC ELV Pad 0-B | SFHC ELV Pad 0-C |
|---|---|---|---|---|---|
| **Lmax (dB)** | 120 | 122 | 122 | 127 | 127 |
| **Lmax (dBA)** | 100 | 100 | 100 | 102 | 102 |
| **SEL (dBA)** | 114 | 114 | 114 | 115 | 115 |
| **Time Above (66 dBA)** | < 80 sec | < 80 sec | < 80 sec | < 80 sec | < 80 sec |

## 5.3 Sonic Boom Noise Analysis

Launches of the four representative launch vehicles from WFF would produce sonic booms during the vehicles' ascent. However, the resulting sonic booms would be directed southeasterly out over the ocean in the direction of the launch azimuth. Note that the presence and/or location of sonic boom regions will be highly dependent on the actual trajectory and atmospheric conditions at the time of flight. The nominal Antares 200 series launch trajectory would generate sonic booms that impact the ocean surface approximately 30 miles from the coast making them inaudible on the mainland. Therefore, with respect to human health and safety or structural damage, noise impacts due to sonic booms are not expected. Thus a quantitative analysis was not performed. However, to provide perspective, modeled sonic booms from ELVs at other launch sites ranged from 3.0 and 5.25 psf (FAA, April 2013), for a liquid-fueled medium class launch vehicle and liquid-fueled heavy class launch vehicle, respectively. A sonic boom due to the overflight of a Titan IV from Vandenberg AFB was measured at a number of locations in the Channel Islands, 30 to 40 miles from the launch pad (Downing and Plotkin, 1996). The over pressures recorded at these locations were less than 2.4 psf, with the exception one site which recorded an 8.4 psf focused sonic boom. Note, a vehicle's observed sonic boom peak overpressure is highly dependent on the vehicle trajectory and atmospheric conditions at the time of flight.

# 6 Summary

This noise study was performed to support the NASA WFF Site-wide PEIS for baseline and proposed future actions at WFF in Accomack County, Virginia. This noise study examines four nominal launch vehicles representing the largest orbital thrust vehicles currently and proposed to be launched from WFF: the two baseline vehicles Antares 200 Series and LMLV III, and the two future vehicles LFIC ELV and SFHC ELV.

To assess the impact of rocket noise with respect to hearing conservation, $L_{A,max}$ contours are presented. OSHA has set an upper limit noise level of 115 dBA for a fifteen minute exposure as a guideline to protect human hearing from long-term continuous daily exposures to high noise levels and to aid in the prevention of NIHL. Although the 115 dBA contours lie partially outside WFF boundaries, these areas do not include any residences as they are mainly over the ocean or the bay between Wallops Island and the mainland.

To assess the potential impact of rocket noise with respect to structural damage claims, $L_{max}$ contours are provided. A NASA technical memo written by Guest and Slone (April 1972) estimated that one damage claim is expected in 1,000 households exposed at an average continuous level of 111 dB, and one in 100 households at 120 dB. The 120 dB contours include populations in the region east of U.S. Route 13. The 111 dB contours extends approximately 5.2 to 9.7 miles from the WFF launch pads, depending on the launch vehicle. The 111 dB contours include populations in the regions of Chincoteague Island and Oak Hall to the north, Jenkins Bridge to the west, and Centerville to the south.

As an additional supplemental metric, A-weighted SEL noise contours were provided to assess the impact of the entire launch event beyond the maximum noise level provided by the OASPL noise contours. Currently, there are no reported guidelines for limiting SEL in reference to launch vehicle noise.

To help further assess community impact as a result of the proposed future launches, the nearest residence location was modeled as a specific point of interest. $L_{A,max}$ at the nearest residence is less than the 115 dBA upper limit noise level associated with protecting human hearing. The maximum unweighted OASPL at the nearest residence exceeds 120 dB, indicating that, per Guest and Slone (1972), the potential for damage claims is greater than one in 100 for a launch event. For launches at WFF, noise levels at the nearest residence may exceed 66 dBA, and sentence intelligibility may decrease below 95%, for a period of up to 80 seconds per launch.

The potential for sonic boom impacts as a result of launches of the representative launch vehicles was qualitatively assessed and discussed. For vehicles launching from Wallops Island, little impact is expected since the launch trajectories are in a primarily southeasterly direction, which is out over the water. This direction precludes any structural damage since the booms will intercept the ocean. The nominal Antares 200 series launch trajectory would generate sonic booms that impact the ocean surface approximately 30 miles from the coast making them inaudible on the mainland. Therefore, with respect to human health and safety or structural damage, noise impacts due to sonic booms are not expected.

In the community, the smallest change in average noise level between two events that can likely be detected by the average listener is about 3 dB (Fayh and Thompson, 2015). At the nearest residence, the modeled proposed future mission growth is projected to increase the maximum sound pressure level up to 2 dBA, per launch, relative to the baseline, which will likely be difficult for people to detect.

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Blue Ridge Research and Consulting, LLC

*Technical Report*

# Return to Launch Site Noise Study for the Wallops Flight Facility Programmatic Environmental Impact Statement

***March 24, 2016 – FINAL (Revised June 27, 2017)***

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# Table of Contents



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## Acronyms and Abbreviations

The following acronyms and abbreviations are used in the report:

| | |
|---|---|
| BRRC | Blue Ridge Research and Consulting, LLC |
| dB | decibel |
| dBA | A-weighted decibel level |
| LFIC | Liquid Fueled Intermediate Class |
| $L_{A,max}$ | maximum A-weighted OASPL in decibels |
| $L_{max}$ | maximum unweighted OASPL in decibels |
| LV | Launch Vehicle |
| NASA | National Aeronautics and Space Administration |
| NIHL | noise-induced hearing loss |
| OASPL | overall sound pressure level in decibels |
| OSHA | Occupational Safety and Health Administration |
| PEIS | Programmatic Environmental Impact Statement |
| psf | pounds per square foot |
| RTLS | Return to launch site |
| RUMBLE | The Launch Vehicle Acoustic Simulation Model |
| sec | second |
| SEL | Sound Exposure Level in decibels |
| WFF | Wallop Flight Facility |

# 1 Introduction

This report documents the results of a noise study conducted to evaluate potential noise impacts of return to launch site (RTLS) operations at the National Aeronautics and Space Administration's (NASA) Wallops Flight Facility (WFF) in Accomack County, Virginia. The analysis was performed in support of the WFF's Site-wide Programmatic Environmental Impact Statement (PEIS) for proposed future actions. This study examined the potential for impacts from a notational RTLS operation of a representative Liquid Fueled Intermediate Class Launch Vehicle (LFIC LV) to a notional WFF landing site located at Pad 0-C. The analysis employed the same noise metrics, impact criteria, acoustic modeling methodology, and input parameters documented in the previous noise analysis performed for launch operations at WFF titled "Launch Noise Study for the Wallops Flight Facility Programmatic Environmental Impact Statement" [1]. Section 2 provides a brief summary of the essential input parameters. Section 3 presents the noise modeling results, and a summary is provided in Section 4 to document the notable findings of this noise study.

# 2 Wallops Launch Range

## 2.1 Launch Range Description

WFF is the NASA's principal facility for management and implementation of suborbital research programs. WFF supports missions for suborbital and orbital rocket vehicles. The launch range on Wallops Island currently includes seven launch pads, three blockhouses for launch control, and assembly buildings that support the preparation and launching of suborbital and orbital launch systems [1]. This modeling effort considers RTLS operations to a notional WFF landing site located at Pad 0-C, shown in Figure 1. The Pad 0-C landing site is modeled to provide a conservative evaluation of the potential noise impacts, as landings on off-shore landing platforms will generate less noise impacts to people and/or structures.


**Figure 1. WFF launch range**

## 2.2 Vehicle and Engine Modeling Parameters

This noise study considered the RTLS operations of a representative LFIC LV. The Launch Vehicle Acoustic Simulation Model (RUMBLE) model requires specific vehicle/engine input parameters to determine the noise exposure resulting from the proposed RTLS operations. Table 1 presents the launch vehicle and engine parameters utilized in the acoustic modeling.

**Table 1. Vehicle and engine parameters used in acoustic modeling**

| Reference Name/Acronym | LFIC LV |
|---|---|
| Launch Vehicle Class | Liquid Fueled Intermediate Class (LFIC) |
| Length | 224.4 ft |
| Number of Engines/Motors | 1 |
| Propellant | LO2/RP (liquid) |
| Single Engine/Motor Nozzle Exit Diameter | 33.8 in |
| Exhaust Velocity | 9,500 ft/s |
| Single Engine/Motor Thrust (Sea Level) | 147,000 lbf |
| Landing Pad | Notional Pad 0-C<br>N 37.827284°, W -75.494435° |

## 2.3 Flight Trajectory Modeling

Launch trajectories departing from WFF's Wallops Island launch range and associated landing trajectories are unique to each particular mission and the environmental conditions. However, all launches and landing operations are conducted to and from the east over the Atlantic Ocean, respectively. The propulsion noise modeling assumes a landing trajectory that returns along the same flight path as the representative nominal Antares 200 series launch trajectory with a southeasterly heading, since a detailed landing trajectory was not available. Recent LFIC LV landings have included two engine relights [2]. The first engine relight typically happens upon reentering the atmosphere, where the vehicle's altitude is too high to generate significant noise at ground level. The second relight occurs during the final portion of the landing operation, and its durations is approximately 35 seconds [3]. The landing propulsion noise is evaluated for this second relight of the LFIC LV's landing operation. Accurate analysis of the resultant sonic boom generated by this landing operations requires a more detailed kinematic trajectory that is not available for WFF at this time. Thus, the sonic boom analysis for this operation is based on a previous study of a similar vehicle and RTLS operation [4].

# 3 Results

The following sections present results of the noise study concerning the proposed LFIC LV RTLS rocket operations at Wallops Island. Sections 3.1 and 3.2, respectively, present the results of the propulsion noise impact and sonic boom discussion.

## 3.1 Propulsion Noise Analysis

RUMBLE, developed by Blue Ridge Research and Consulting, LLC (BRRC), was used to predict the propulsion noise associated with the proposed WFF LFIC LV RTLS operations. It should be noted that noise levels may be 3 dB louder over water surfaces compared to levels over ground surfaces which is assumed in the modeling.

### 3.1.1 Maximum A-weighted OASPL

The A-weighted Overall Sound Pressure Level (OASPL) provides a measure of the sound level relative to human hearing at any given time, while the maximum A-weighted OASPL ($L_{A,max}$) indicates the maximum A-weighted OASPL occurring during the duration of the event. OSHA has set an upper limit noise level of 115 dBA for fifteen minutes as a guideline to protect human hearing from long-term continuous daily exposures to high noise levels. This limit aids in the prevention of noise-induced hearing loss [5]. The $L_{A,max}$ generated by a single LFIC LV RTLS event exceeds 115 dBA within a distance of approximately 0.4 miles from the landing site. Figure 2 presents the $L_{A,max}$ contours within the range of 85 to 115 dBA. Although the 115 dBA contour extends partially outside WFF boundaries, these areas are mainly over the ocean or the bays between coast and the mainland and they do not include any residences.

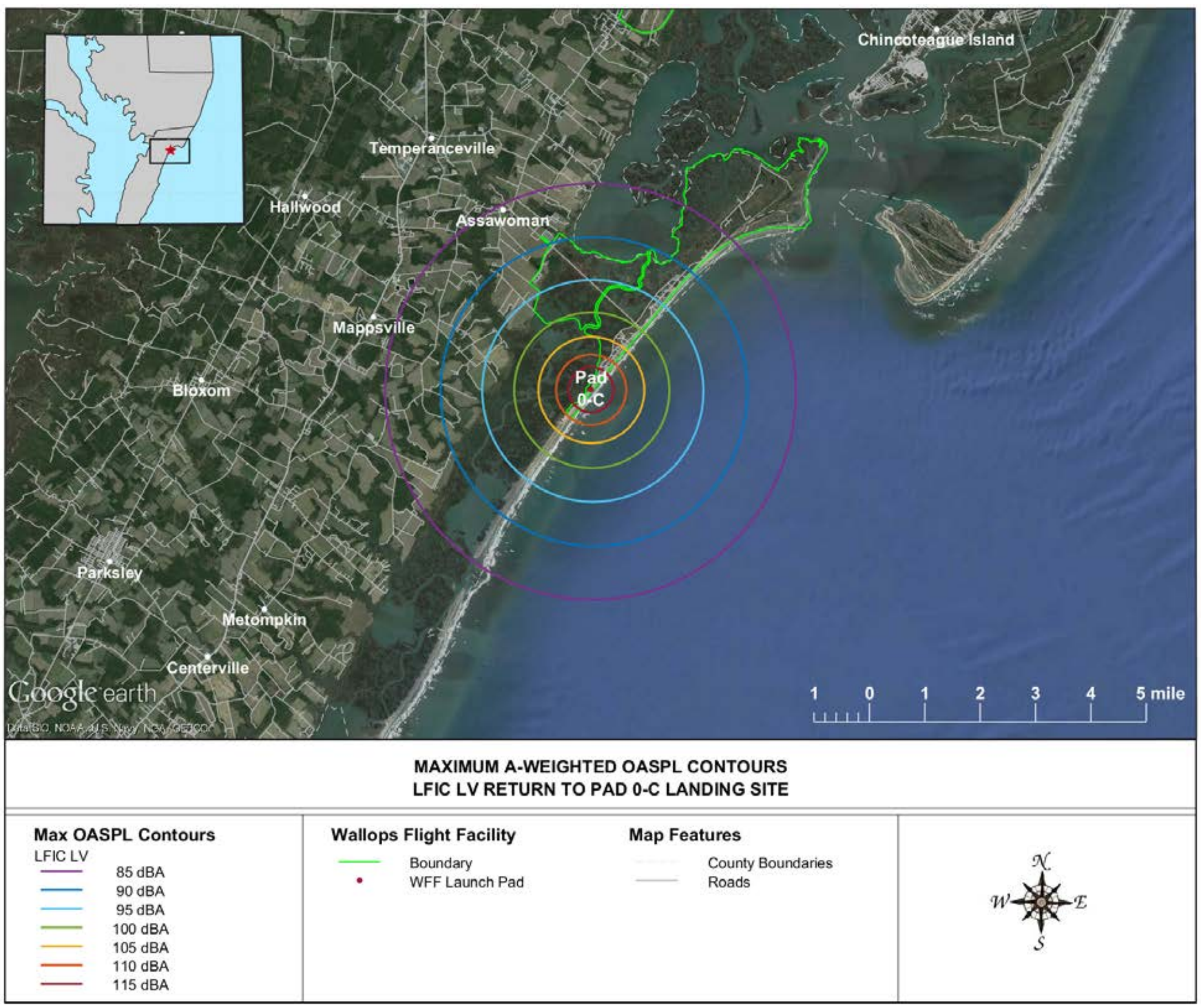


**Figure 2. Maximum A-weighted OASPL ($L_{A,max}$) contours for a LFIC LV return to the Pad 0-C landing site**

### 3.1.2 Maximum Unweighted OASPL

The OASPL provides a measure of the sound level at any given time, while the $L_{max}$ indicates the maximum OASPL occurring during the duration of the event. OASPL of 111dB and 120dB are utilized to assess the potential risk of structural damage claims [6]. The 111 dB and 120 dB contours are presented in Figure 3. The potential for structural damage claims is approximately one damage claim per 1,000 households exposed at 111 dB and one in 100 households at 120 dB. The 120 dB and 111 dB contours extend approximately 0.6 to 1.6 miles from the landing site. Although the 111 dB and 120 dB contours extend outside WFF boundaries, these areas do not include any residential structures.

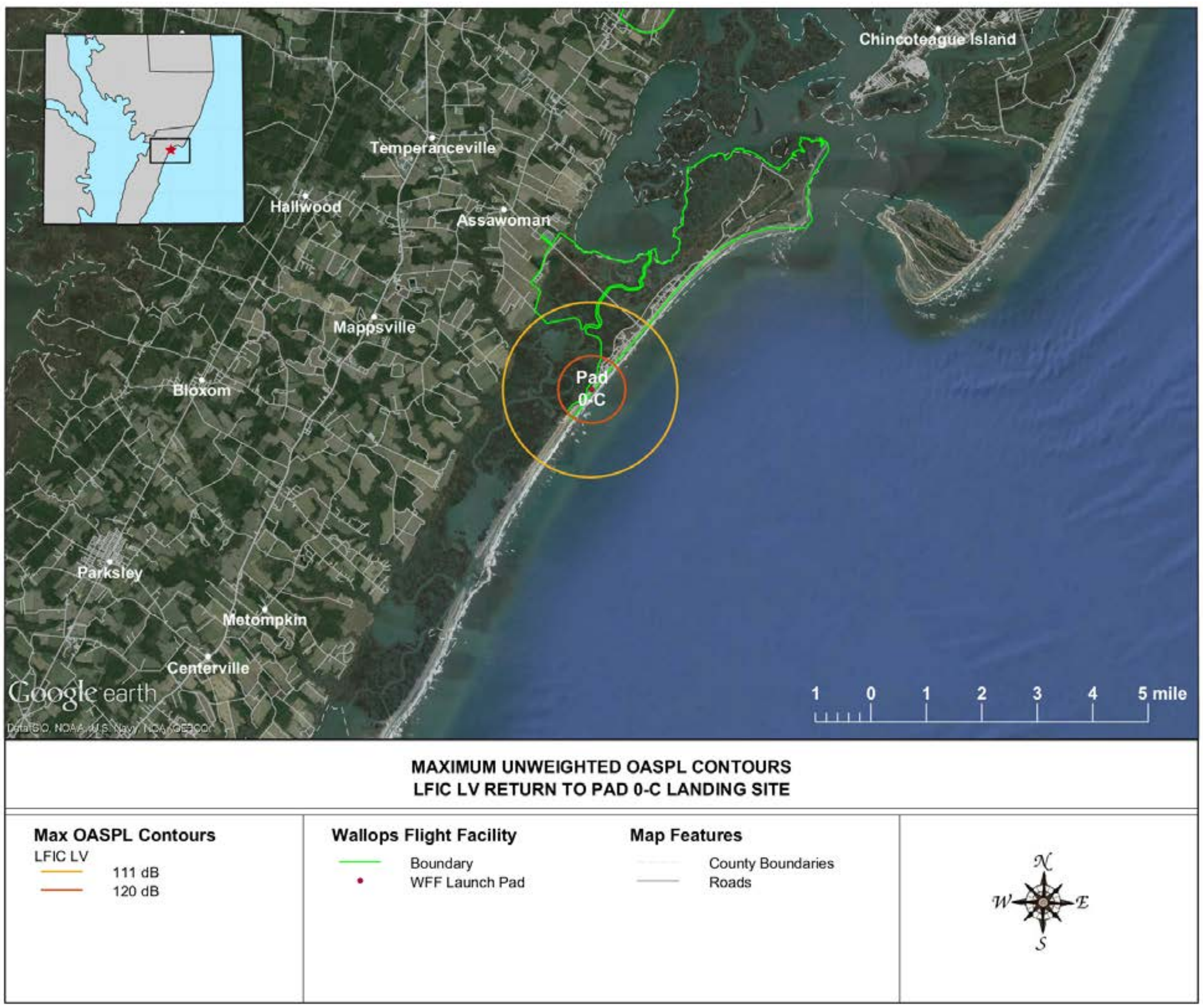


**Figure 3. Maximum unweighted OASPL ($L_{max}$) contours for a LFIC LV return to the Pad 0-C landing site**

### 3.1.3 A-weighted Sound Exposure level (SEL)

SEL represents the cumulative noise exposure of a transient noise event and includes both its magnitude and its duration. However, it does not directly represent the sound level heard at any given time. Mathematically, it represents the sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound generated by rocket operations, which last more than one second, the SEL is greater than the $L_{max}$ because an individual event can last for minutes and the $L_{max}$ occurs instantaneously. Figure 4 depicts the A-weighted SEL contours for a single LFIC LV RTLS event. Currently, no reported guidelines have been established for SEL in reference to launch vehicle noise.

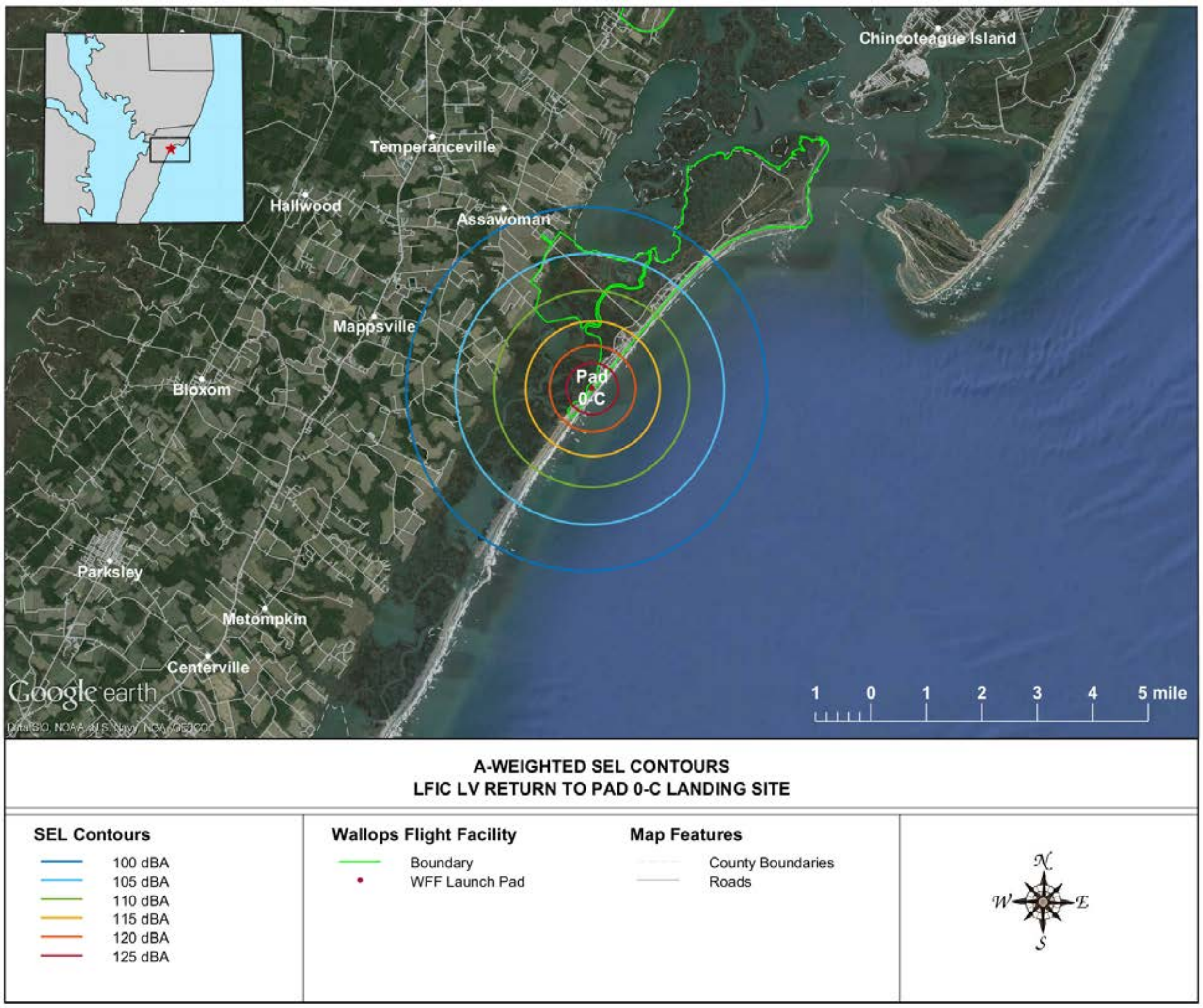


**Figure 4. A-weighted SEL contours for a LFIC LV return to the Pad 0-C landing site**

## 3.2 Sonic Boom Discussion

A sonic boom is the sound associated with the shock waves created by a vehicle traveling through the air faster than the speed of sound. NIOSH [7] and OSHA [8] have stated that sound pressure levels should not exceed 140 dB peak, which equates to a sonic boom level of approximately 4 psf.‡

Sonic booms are also commonly associated with structural damage. Most damage claims are for brittle objects, such as glass and plaster. In general, for well-maintained structures, the threshold for damage produced by sonic booms is 2 psf, below which damage is unlikely [9]. At levels between 2 and 4 psf, failures begin to show for structures that appear to be in nominally good condition that would have been difficult to forecast based on their existing localized condition [9]. As levels rise above 4 psf, the probability and significance of the potential for structural damage increases.

However, a large degree of variability exists in damage experience, and much of the damage depends on the pre-existing condition of a structure. Breakage data for glass, for example, spans a range of two to three orders of magnitude at a given overpressure. The probability of a window breaking at 1 psf ranges from one in a billion [10] to one in a million [11]. These damage rates are associated with a combination of boom load and glass condition. At 10 psf, the probability of breakage is between one in 100 and one in 1,000. Laboratory tests involving glass [12] have shown that properly installed window glass will not break at overpressures below 10 psf, even when subjected to repeated booms. However, in the real world, glass is not always in pristine condition.

RTLS operations of a LFIC LV landing at WFF would generate sonic booms when the vehicle is supersonic during descent. The observed sonic boom peak overpressure is highly dependent on the vehicle trajectory and atmospheric conditions at the time of flight. A detailed LFIC LV landing trajectory accurately representing the vehicle's supersonic descent to WFF was unavailable, therefore the following discussion is in general terms. For a notional RTLS operation returning from a southeasterly direction toward WFF, a majority of the sonic boom would occur over the Atlantic Ocean. The sonic boom overpressure levels near the landing site will reach a maximum of 6 psf, decreasing with distance from the landing site and approaching a level of 0.5 psf at 20 miles. The levels approach 2 psf at 6 miles from the landing site, near the communities of Atlantic to the north, Macedonia to the west, and Gargatha to the southwest. The majority of land area exposed to levels greater than 4 psf is within WFF boundaries but may include land east of Route 679 within 2 miles of the landing site. Note, that these levels and relative locations are representative of a nominal landing trajectory returning from a southeasterly direction. The potential impacts may differ based on actual mission trajectories and atmospheric conditions.

Given that the expected sonic boom overpressure levels are greater than 2 psf for communities within 6 miles of the landing site, there is a potential for structural damage as a result of a LFIC LV RTLS operation [9, 10, 11, 12]. Additionally, there is a potential for hearing damage (to humans) within 2 miles of the landing site, where sonic boom overpressure levels may be greater than the ~4 psf impulsive hearing conservation noise criteria [5, 13].

‡ The peak pressure of a sonic boom, $P_k$ (psf), can be converted to the peak sound pressure level in decibels ($L_{pk}$) by the mathematical relationship of: $L_{pk} = 127.6 + 20 \log_{10} P_k$

# 4 Summary

This noise study was performed to support the NASA WFF's Site-wide PEIS for proposed future actions. inclusion of RTLS rocket operations at WFF in Accomack County, Virginia. This study examines the potential for impacts from a notational RTLS operation of a representative LFIC LV to a notional WFF landing site located at Pad 0-C. The Pad 0-C landing site is modeled to provide a conservative evaluation of the potential noise impacts, as landings on off-shore landing platforms will generate less noise and sonic boom exposures to people and/or structures. This conservative evaluation found that the propulsion noise impacts generated by the proposed landing operation are less than those experienced from any of the launch operations analyzed for the WFF PEIS.

To assess the impact of rocket noise with respect to hearing conservation, $L_{A,max}$ contours are presented. OSHA has set an upper limit noise level of 115 dBA for a fifteen-minute exposure as a guideline to protect human hearing from long-term continuous daily exposures to high noise levels and to aid in the prevention of NIHL [5]. Although the 115 dBA contour extends partially outside WFF boundaries, these areas are mainly over the ocean or the bays between the coast and the mainland and they do not include any residences.

To assess the potential impact of rocket noise with respect to structural damage claims, $L_{max}$ contours are provided. A NASA technical memo written by Guest and Slone [6] estimated that one damage claim is expected in 1,000 households exposed at an average continuous level of 111 dB, and one in 100 households at 120 dB. Although the 111 dB and 120 dB contours lie partially outside WFF boundaries, these areas do not include any residential structures.

As an additional supplemental metric, A-weighted SEL noise contours were provided to assess the impact of the entire launch event beyond the maximum noise level provided by the OASPL noise contours. Currently, no reported guidelines have been established for limiting SEL in reference to launch vehicle noise.

Given that the expected sonic boom overpressure levels are greater than 2 psf for communities within 6 miles of the landing site, there is potential for structural damage as a result of a LFIC LV RTLS operation [9, 10, 11, 12]. The levels approach 2 psf at 6 miles from the landing site, near the communities of Atlantic to the north, Macedonia to the west, and Gargatha to the southwest. The majority of land area exposed to levels greater than 4 psf is within WFF boundaries but may include land east of Route 679 within 2 miles of the landing site. Additionally, there is potential for hearing damage (to humans) within 2 miles of the landing site, where sonic boom overpressure levels may be greater than the ~4 psf impulsive hearing conservation noise criteria [5, 13].

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# APPENDIX E
# NOISE TABLES

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Table E-1 was generated from the Federal Highway Administration (FHWA) Road Construction Noise Handbook (2006) and represents accepted noise levels produced from a range of typical road construction equipment. These values were developed to be used for the estimation of noise impacts from construction activities related to the building of roads. The values described below are only for in-air noise levels. These values are used in the database associated with the FHWA's Road Construction Noise Model; free software that assists in the estimation of noise impacts from roadway construction. The values below were used in developing the in-air noise impacts for construction of the Causeway Bridge presented in Section 3.1, Noise.

**Table E-1. In-Air Construction-Related Noise Emissions**

| Equipment Description | Actual Measured $L_{max}$ at 50 feet (dBA) |
|---|---|
| Flat Bed Truck | 74 |
| Welder/Torch | 74 |
| Man Lift | 75 |
| Dump Truck | 76 |
| Paver | 77 |
| Backhoe | 78 |
| Compressor (air) | 78 |
| Slurry Plant | 78 |
| Concrete Mixer Truck | 79 |
| Drill Rig Truck | 79 |
| Front End Loader | 79 |
| Rivet Buster/Chipping Gun | 79 |
| Ventilation Fan | 79 |
| Drum Mixer | 80 |
| Roller | 80 |
| Slurry Trenching Machine | 80 |
| Vibratory Concrete Mixer | 80 |
| Concrete Pump Truck | 81 |
| Crane | 81 |
| Excavator | 81 |
| Generator | 81 |
| Pumps | 81 |
| Dozer | 82 |
| Horizontal Boring Hydraulic Jack | 82 |
| Vacuum Street Sweeper | 82 |
| Boring Jack Power Unit | 83 |
| Compactor (ground) | 83 |
| Gradall | 83 |
| Warning Horn | 83 |
| Auger Drill Rig | 84 |
| Chain Saw | 84 |
| Scraper | 84 |
| Pneumatic Tools | 85 |
| Vacuum Excavator | 85 |
| Vibrating Hopper | 87 |
| Jackhammer | 89 |
| Concrete Saw | 90 |

| Table E-1. In-Air Construction-Related Noise Emissions (cont.) | |
|---|---|
| **Equipment Description** | **Actual Measured $L_{max}$ at 50 feet (dBA)** |
| Mounted Impact Hammer (hoe ram) | 90 |
| Sheers (on backhoe) | 96 |
| Impact Pile Driver | 101 |
| Vibratory Pile Driver | 101 |

***Source***: FHWA 2006.

Table E-2 below was developed using methods outlined by the Washington State Department of Transportation's Biological Assessment Advanced Training Manual (2015). The method involves choosing the three noisiest pieces of construction equipment that would be used for construction and using a series of mathematical equations for noise addition, attenuation, and transmission loss, yields a series of distances and noise levels at those distances. Table E-2 was developed to estimate airborne construction noise and the potential for disturbance from general construction projects at the WFF Main Base, Wallops Mainland, and Wallops Island, in Section 3.1, Noise.

| Table E-2. Noise Attenuation Table for Typical Construction | | | |
|---|---|---|---|
| **Distance (m/ft)** | **Equipment Noise Level (dBA)** | **Traffic Noise Level (dBA)** | **Ambient Noise Level (dBA)** |
| 0 | 102 | 30 | 55 |
| 15 (50) | 94.5 | 55.5 | 55 |
| 30 (100) | 87 | 51 | 55 |
| 60 (200) | 79.5 | 46.5 | 55 |
| 120 (400) | 72 | 42 | 55 |
| 240 (800) | 64.5 | 37.5 | 55 |
| 480 (1,600) | 57 | 33 | 55 |
| 960 (3,200) | 49.5 | 28.5 | 55 |

***Source***: Generated using Washington State Department of Transportation (WSDOT) 2015 methodology.

Table E-3 provides a summary of unattenuated sound pressure levels for marine pile driving. The data presented in Table E-3 characterize actual measurements of underwater sound pressure levels from various types of piles and pile driving equipment. These values are used to assist in the estimation of underwater noise impacts and the distances to which underwater noise thresholds will be reached or exceeded. The values were used in conjunction with the National Oceanic and Atmospheric Administration's Underwater Noise Calculator that uses an equation for transmission loss (attenuation) for underwater sounds. The results of this are discussed in Section 3.11, Marine Mammals and Fish.

| Table E-3. Summary of Unattenuated Sound Pressures for Marine Pile Driving | | | | | |
|---|---|---|---|---|---|
| **Type of Pile** | **Relative Water Depth (m)** | **Hammer Type** | **Root Mean Square (dB)** | **Peak Pressure (dB)** | **Sound Exposure Level (dB)** |
| **Concrete Piles** | | | | | |
| 16-inch Square | 10 | Steam-powered | 173 at 10 m | 184 at 10 m | NA |
| 24-inch Square | 3-4 | Diesel Impact | 173 at 10 m;<br>165 at 20 m | 185 at 10 m;<br>178 at 20 m | NA |
| 24-inch Octagonal | 10-15 | Diesel Impact | 176 at 10 m;<br>163 at 100 m | 188 at 10 m;<br>174 at 100 m | 166 at 10 m;<br>152 at 100 m |
| 24-inch Octagonal | 7-8 | Diesel Impact | 173 at 10 m | 185 at 10 m | 163 at 10 m |
| 24-inch Octagonal | 8 | Diesel Impact | 174 at 10 m | 184 at 10 m | 165 at 10 m |
| 24-inch Octagonal | 4 | Diesel Impact | 172 at 10 m;<br>170 at 20 m | 185 at 10 m;<br>180 at 20 m | NA |
| **Steel H Pile** | | | | | |
| 10-inch | 2 | Diesel Impact | 175 at 10 m;<br>160 at 20 m | 190 at 10 m;<br>170 at 20 m | NA |
| 10-inch | 2 | Vibratory Hammer | 147 at 10 m;<br>137 at 20 m | 161 at 10 m;<br>152 at 20 m | NA |
| 12-inch | 5 | Diesel Impact | 156 at 70 m;<br>158 at 90 m | 168 at 70 m;<br>170 at 90 m | NA |
| 15-inch | 2-3 | Diesel Impact | 180 at 10 m | 195 at 10 m | 170 at 10 m |
| **Steel Pipe** | | | | | |
| 12-inch | 1-2 | Diesel Impact | 165 at 10 m;<br>156 at 20 m | 177 at 10 m;<br>170 at 10 m | 152 at 10 m |
| 14-inch | >15 | Diesel Impact | 180 at 20 m;<br>180 at 30m;<br>178 at 40 m;<br>175 at 50 m;<br>159 at 195 m | 196 at 20 m;<br>190 at 30m;<br>191 at 40 m;<br>189 at 50 m;<br>172 at 195 m | 170 at 20 m;<br>NA at 30m;<br>165 at 40 m;<br>NA at 50 m;<br>NA at 195 m |
| 24-inch | 5 | Diesel Impact | 189 at 10 m;<br>178 at 50 m | 203 at 10 m;<br>191 at 50 m | 178 at 10 m; 167 at 50 m |
| 30-inch | 4-5 | Diesel Impact | 190 at 10 m;<br>185 at 20 m;<br>181 at 30 m;<br>178 at 40 m;<br>169 at 60 m | 205 at 10 m;<br>200 at 20 m;<br>199 at 30 m;<br>194 at 40 m;<br>195 at 60 m | NA at 10 m;<br>NA at 20 m;<br>170 at 30 m;<br>NA at 40 m;<br>NA at 60 m |
| 36-inch | 10 | Diesel Impact | 193 at 10 m;<br>182 at 50 m | 210 at 10 m;<br>198 at 50 m | 183 at 10 m;<br>NA at 50 m |

| Table E-3. Summary of Unattenuated Sound Pressures for Marine Pile Driving (cont.) | | | | | |
|---|---|---|---|---|---|
| **Type of Pile** | **Relative Water Depth (m)** | **Hammer Type** | **Root Mean Square (dB)** | **Peak Pressure (dB)** | **Sound Exposure Level (dB)** |
| **Cast-in-Steel Shell Pipe** | | | | | |
| 36-inch | 10 | Diesel Impact | 193 at 10 m; 182 at 50 m | 210 at 10 m; 198 at 50 m | 183 at 10 m; NA at 50 m |
| 48-inch | 2 | Diesel Impact | 195 at 10 m; 190 at 20 m; 185 at 45 m; 175 at 65 m | 205 at 10 m; 202 at 20 m; 195 at 45 m; 185 at 65 m | 185 at 10 m; 180 at 20 m; 175 at 45 m; NA at 65 m |
| 66-inch | 4 | Diesel Impact | 202 at 4 m; 195 at 10 m; 189 at 20 m; 185 at 30 m; 180 at 40 m; 169 at 60 m; 170 at 80 m | 219 at 4 m; 210 at 10 m; 205 at 20 m; 203 at 30 m; 198 at 40 m; 187 at 60 m; 187 at 80 m | NA at 4 m; NA at 10 m; NA at 20 m; 173 at 30 m; NA at 40 m; 158 at 60 m; NA at 80 m |
| 96-inch | 8-12 | Hydraulic Impact | 197 at 25 m; 200 at 50 m; 186-192 at 100m; 175 at 400 m | 213 at 25 m; 23 at 50 m; 197-204 at 100m; 186 at 400 m | 188 at 25 m; 187 at 50 m; 174-180 at 100 m; 165 at 400 m |

***Source***: CalTrans 2015.

Table E-4 shows a summary of the number of strikes required to drive in various types of piles used in pile supported structures. Also shown is the typical number of piles that can be driven in one work day. This data was used in conjunction with the data provided in Table E-3 to develop the distances to underwater noise threshold guidance for marine mammals, as presented in Section 3.11, Marine Mammals and Fish. The number of pile strikes per day and total number of piles driven per day are necessary to determine how many daily pile strikes would occur, which is then used to develop a cumulative underwater noise value that can be used to estimate underwater noise impacts to marine mammals and fish.

| Table E-4. Summary of Typical Strike Data | | | |
|---|---|---|---|
| **Pile Type, Size, and Shape** | **Typical Use** | **Typical Installation Duration** | **Typical Strikes per Pile** |
| Concrete, 24-inch Hexagon | Wharf Construction Projects | 1 to 5 Piles per Day | 580 |
| Thin Steel H, Small | Temporary Construction Projects | 6 Piles per Day | 550 |
| Steel Pipe, 40-inch Diameter | Permanent Construction Projects | 1 to 5 Piles per Day | 600 |
| Cast-in-Steel Shell (CISS) Pipe, 30-inch Diameter | Permanent Construction Projects | 2 to 4 Piles per Day | 1,600 to 2,400 |
| Cast-in-Steel Shell (CISS) Pipe, 96-inch Diameter | Permanent Construction Projects | 1 to 3 Piles per Day | 7,000 |

***Source***: CalTrans 2015.

**References:**

CalTrans. 2015. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. November.

Federal Highway Administration (FHWA). 2006. Construction Noise Handbook, Appendix A FHWA Roadway Construction Noise Model User's Guide, A-1. http://www.fhwa.dot.gov/environment/noise/construction_noise/rcnm/index.cfm.

Washington State Department of Transportation (WSDOT). 2015. Biological Assessment Preparation Advanced Training Manual Version 02-2015. February. https://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm#manual.

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# APPENDIX F
# AIR QUALITY CALCULATIONS

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**TAB A. EMISSIONS SUMMARY**

**Table 1. Construction for Proposed Action: Institutional Support Projects**

| YEAR | Area | VOC T/yr | CO T/yr | NOx T/yr | SO2 T/yr | PM10 T/yr | PM2.5 T/yr | CO2e MT/yr |
|---|---|---|---|---|---|---|---|---|
| TBD | Main Base Construction | 1.01 | 4.85 | 14.62 | 0.20 | 14.54 | 2.14 | 1,291 |
| | Mainland and Island | 0.12 | 0.54 | 1.60 | 0.02 | 6.70 | 0.74 | 140 |
| | **TBD Construction Total** | **1.13** | **5.39** | **16.22** | **0.22** | **21.24** | **2.88** | **1,431** |
| TBD | Main Base Demo | 0.11 | 0.73 | 1.28 | 0.03 | 13.34 | 1.43 | 157 |
| | Mainland and Island | 0.01 | 0.10 | 0.15 | 0.00 | 0.27 | 0.04 | 19 |
| | **TBD Demo Total** | **0.12** | **0.83** | **1.42** | **0.03** | **13.61** | **1.47** | **176** |
| 2019 | Main Base | 0.02 | 0.13 | 0.21 | 0.00 | 0.12 | 0.03 | 25 |
| | Mainland and Island | 0.47 | 2.92 | 11.30 | 1.73 | 0.37 | 0.35 | 2,518 |
| | **2019 Total** | **0.49** | **3.05** | **11.50** | **1.73** | **0.49** | **0.38** | **2543** |
| 2020 | Main Base | 0.07 | 0.37 | 1.05 | 0.02 | 0.11 | 0.06 | 94 |
| | Mainland and Island | 0.48 | 3.03 | 11.48 | 1.73 | 0.88 | 0.42 | 2,540 |
| | **2020 Total** | **0.56** | **3.39** | **12.53** | **1.75** | **0.99** | **0.48** | **2,634** |
| 2021 | Mainland and Island | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| 2022 | Main Base | 0.01 | 0.09 | 0.13 | 0.00 | 0.98 | 0.11 | 17 |
| | Mainland and Island | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| | **2022 Total** | **0.48** | **2.99** | **11.41** | **1.73** | **1.34** | **0.46** | **2,532** |
| 2023 | Mainland and Island | **0.78** | **5.15** | **21.04** | **2.14** | **0.72** | **0.69** | **3,148** |

**Table 2. Potential Annual Operations for Proposed Action**

| Year | Activity | VOC T/yr | CO T/yr | NOx T/yr | $SO_2$ T/yr | $PM_{10}$ T/yr | $PM_{2.5}$ T/yr | CO2e MT/yr |
|---|---|---|---|---|---|---|---|---|
| 2019-2025 | 3-MW Generators | 1.43 | 12.50 | 2.39 | ND | 0.36 | 0.36 | 2,350 |
| 2019-2025 | new launch envelope | 0.00 | 68.13 | 7.20 | ND | 152.19 | 152.19 | 5,253 |
| 2019-2025 | Annual UAS Operations | 0.35 | 2.20 | 2.37 | 0.19 | 0.09 | 0.09 | 101.25 |
| | **2019 – 2025 Annual Total** | **1.78** | **82.83** | **11.96** | **0.19** | **152.64** | **152.64** | **7,704** |

**Table 3. Comparison of Current Envelope Launch Vehicle (Antares + LMLV-3) Emissions to Proposed Envelope Launch Vehicle (LSLB + Falcon 9) Emissions**

| Launch Vehicle | CO T/yr | NOx T/yr | (PM) T/yr | HCL T/yr | CO2 MT/yr |
|---|---|---|---|---|---|
| current envelope | 184.1 | 0.0 | 153.6 | 125 | 646 |
| new envelope | 68.1 | 7.2 | 154.6 | 107.0 | 5,253 |
| **Change:** | **-116.0** | **7.2** | **1.0** | **-18.1** | **4,607** |

Table 4. Comparison of Total Operational Emissions for UAS and Launch Vehicles

| UAV + Launch Operations | CO T/yr | NOx T/yr | CO2 MT/yr |
|---|---|---|---|
| current envelopes | 184.3 | 0.4 | 655 |
| new envelopes | 70.3 | 9.6 | 5,354 |
| **Change:** | **-114.0** | **9.2** | **4,699** |

**TAB B. CONSTRUCTION EMISSIONS - PROPOSED ACTION INSTITUTIONAL SUPPORT PROJECTS**

**Basic Conversions**

| | |
|---|---|
| 453.59 | grams per pound |
| 43,560 | Conversion from Acre to SF |
| 0.03704 | Cubic feet to Cubic Yards |
| 0.1111 | Square Feet to Square Yards |
| 1.4 | tons/CY for Gravel |
| 80,000 | lbs/Truck Load for Delivery |
| 1.66 | CY for each CY of asphalt/concrete demo |
| 0.50 | asphalt thickness for demolition |
| 0.50 | asphalt thickness for pavement |
| 2000 | pounds per ton |
| 145 | $lb/ft^3$ density of Hot Mix Asphalt |
| 0.67 | asphalt thickness for pavement on runways |

**TBD CONSTRUCTION**

**Table 1. Clearing - TBD**

2.0 Acres Vehicle Trips = 11

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Dozer | 24 | 145 | 0.58 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 535.69 |
| Loader w/ integral Backhoe | 24 | 87 | 0.21 | 1.43 | 7.35 | 6.35 | 0.15 | 1.06 | 1.03 | 691.66 |
| Small backhoe | 24 | 55 | 0.21 | 1.43 | 7.35 | 6.35 | 0.15 | 1.06 | 1.03 | 691.66 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck | 11 | 230 | 16 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

**Annual Emissions**

| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 1.64 | 6.17 | 18.20 | 0.50 | 1.29 | 1.25 | 2,336 |
| | 1.36 | 6.96 | 6.01 | 0.14 | 1.01 | 0.98 | 655 |
| | 0.86 | 4.40 | 3.80 | 0.09 | 0.64 | 0.62 | 414 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 0.30 | 1.54 | 7.02 | 0.00 | 0.30 | 0.29 | 605 |
| **Subtotal (lbs):** | **4** | **19** | **35** | **1** | **3** | **3** | **4,011** |
| **Clearing Grand Total in Tons** | **0.00** | **0.01** | **0.02** | **0.00** | **0.00** | **0.00** | |
| **Clearing Grand Total in Metric Tons** | | | | | | | **2** |

Vehicle Trips = 11

**Table 2. Site Work - TBD**

| | | | |
|---|---|---|---|
| Site Prep - Excavate/Fill (CY) | 50,858 CY | | |
| Trenching (LF) | 2,500 LF | Assume 3' deep,1 ' wide | |
| Grading (SY) | 26,944 SY | Assume compact 0.5 feet (0.166 yards) | 4,473 CY compacted |

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavator | 170 | 243 | 0.59 | 0.34 | 1.21 | 4.03 | 0.12 | 0.22 | 0.22 | 536 |
| Skid Steer Loader | 203 | 160 | 0.23 | 0.38 | 1.47 | 4.34 | 0.12 | 0.31 | 0.30 | 536 |
| Dozer (Rubber Tired) | 184 | 145 | 0.59 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 536 |
| Compactor | 21 | 103 | 0.58 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 536 |
| Grader | 10 | 285 | 0.58 | 0.34 | 1.21 | 4.07 | 0.12 | 0.23 | 0.22 | 536 |
| Backhoe/Loader | 4 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 536 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Excavator | 18.43 | 64.80 | 215.92 | 6.18 | 11.94 | 11.58 | 28,709.57 |
| Skid Steer Loader | 6.33 | 24.26 | 71.60 | 1.90 | 5.04 | 4.89 | 8,840.99 |
| Dozer (Rubber Tired) | 13.09 | 49.15 | 145.05 | 4.00 | 10.29 | 9.98 | 18,617.45 |
| Compactor | 1.08 | 4.28 | 12.45 | 0.31 | 0.87 | 0.84 | 1,460.81 |
| Grader | 1.20 | 4.21 | 14.19 | 0.40 | 0.79 | 0.76 | 1,868.27 |
| Backhoe/loader | 0.16 | 0.57 | 1.92 | 0.05 | 0.11 | 0.10 | 242.52 |

| On-road Equipment | Hours | MPH | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | PM10 lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 170 | 5 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dump Truck | 1.29 | 6.82 | 30.57 | 0.02 | 1.28 | 1.24 | 2,915 |
| ***Subtotal in lb:*** | **42** | **154** | **492** | **13** | **30** | **29** | **62,654** |
| **Site Prep Grand Total in Tons** | **0.02** | **0.08** | **0.25** | **0.01** | **0.02** | **0.01** | |
| **Site Prep Grand Total in Metric Tons** | | | | | | | **28** |

Vehicle Trips = 92

**Table 3. RBR Demo - TBD**

71,040 SF — 3,552 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | Emission Factors: VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator | 592 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 592 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 592 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |

| | Annual Emissions: VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Hydraulic excavator | 15.16 | 170.21 | 177.51 | 7.53 | 26.69 | 25.88 | 39,433.37 |
| Wheel Loader w/ integral Backhoe | 27.86 | 160.03 | 131.14 | 3.69 | 24.78 | 24.04 | 18,092.25 |
| Wheel mounted air compressor | 9.90 | 53.16 | 132.37 | 4.07 | 8.75 | 8.49 | 20,231.58 |
| ***Subtotal (lbs):*** | 52.93 | 383.40 | 441.02 | 15.29 | 60.21 | 58.41 | 77757.20 |

| On-road Equipment | Hours of Operation | Engine HP | Speed (mph) | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck (12 CY Capacity) | 326 | 230 | 27 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |

| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dump Truck (12 CY Capacity) | 13.39 | 70.79 | 317.49 | 0.16 | 13.24 | 12.83 | 30,266 |
| ***Subtotal (lbs):*** | 66.32 | 454.19 | 758.51 | 15.45 | 73.46 | 71.24 | 108,023.23 |
| **Building Demo Grand Total in Tons** | **0.033** | **0.227** | **0.379** | **0.008** | **0.037** | **0.036** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **49.00** |

Vehicle Trips = 278

**Table 4. Demo Asphalt Concrete RBR - TBD**

72,604 SF 2,232 CY

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Off-road Equipment** | **Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Crawler Dozer w/attachments | 263 | 125 | 0.58 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 535.79 |
| Air Compressor | 263 | 49 | 0.59 | 0.33 | 2.54 | 4.53 | 0.13 | 0.54 | 0.53 | 595.16 |
| Excavator | 61 | 380 | 0.59 | 0.31 | 2.50 | 4.51 | 0.13 | 0.55 | 0.54 | 595.21 |
| | | | | **Annual Emissions** | | | | | | |
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Crawler Dozer w/attachments | 14.48 | 50.84 | 171.82 | 4.85 | 9.52 | 9.23 | 22562.78 |
| | | | Wheel mounted air compressor | 5.50 | 42.68 | 76.02 | 2.15 | 9.10 | 8.83 | 9994.14 |
| | | | Excavator | 9.34 | 74.67 | 134.78 | 3.83 | 16.51 | 16.01 | 17800.11 |

| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **On-road Equipment** | **Hours of Operation** | **Engine HP** | **Speed (mph)** | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile |
| Dump Truck | 205 | 230 | 27 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Dump Truck | 8.42 | 44.51 | 199.65 | 0.10 | 8.33 | 8.07 | 19,032 |
| | | | **Subtotal (lbs):** | **38** | **213** | **582** | **11** | **43** | **42** | **69,389** |
| | | | **Asphalt Demo Grand Total in Tons** | **0.02** | **0.11** | **0.29** | **0.01** | **0.02** | **0.02** | |
| | | | **Asphalt Demo Grand Total in Metric Tons** | | | | | | | **31** |

Vehicle Trips = 92

**Table 5. Building Construction**

120,000 SF Foundation
120,000 SF Total

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | PM10 | PM2.5 | $CO_2$ |
| **Off-road Equipment** | **Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Crane | 600 | 330 | 0.58 | 0.25 | 1.22 | 5.26 | 0.11 | 0.21 | 0.20 | 530 |
| Concrete Truck | 600 | 300 | 0.43 | 0.19 | 1.45 | 4.32 | 0.12 | 0.21 | 0.20 | 536 |
| Diesel Generator | 480 | 40 | 0.43 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536 |
| Telehandler | 1,200 | 99 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Scissors Lift | 960 | 83 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Skid Steer Loader | 600 | 67 | 0.59 | 1.69 | 7.97 | 6.70 | 0.15 | 1.19 | 1.15 | 691 |
| Pile Driver | 6,188 | 260 | 0.43 | 0.46 | 1.55 | 5.90 | 0.11 | 0.31 | 0.30 | 530 |
| All Terrain Forklift | 24 | 84 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| | | | | **Annual Emissions** | | | | | | |
| | | | | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Crane | 62.21 | 308.75 | 1331.67 | 28.88 | 52.59 | 51.01 | 134,261 |
| | | | Concrete Truck | 32.01 | 248.20 | 737.28 | 19.68 | 35.85 | 34.77 | 91,507 |
| | | | Diesel Generator | 4.78 | 25.64 | 63.85 | 1.96 | 4.22 | 4.09 | 9,760 |
| | | | Telehandler | 78.74 | 608.80 | 761.66 | 19.76 | 80.53 | 78.11 | 91,884 |
| | | | Scissors Lift | 52.81 | 408.32 | 510.85 | 13.26 | 54.01 | 52.39 | 61,627 |
| | | | Skid Steer Loader | 88.49 | 416.63 | 350.23 | 7.77 | 62.18 | 60.31 | 36,125 |
| | | | Pile Driver | 707.73 | 2366.77 | 9001.43 | 173.76 | 478.69 | 464.33 | 807,780 |
| | | | All Terrain Forklift | 1.34 | 10.33 | 12.93 | 0.34 | 1.37 | 1.33 | 1,559 |

| | | | | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **On-road Equipment** | **Hours of Operation** | **Engine HP** | **Speed (mph)** | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile |
| Delivery Truck | 2,880 | 265 | 45 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Delivery Truck | 197.16 | 1042.24 | 4674.68 | 2.34 | 194.98 | 188.93 | 445,635 |
| | | | ***Subtotal (lbs):*** | **1225** | **5436** | **17445** | **268** | **964** | **935** | **1680139** |
| | | | **Building Construction Grand Total in Tons** | **0.61** | **2.72** | **8.72** | **0.13** | **0.48** | **0.47** | |
| | | | **Building Construction Grand Total in Metric Tons** | | | | | | | **762** |

Vehicle Trips = 1664

**Table 6. Gravel Work - TBD**

23,389 CY | 1,671 trips | 147,017 total miles

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Dozer | 234 | 185 | 0.59 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 536 |
| Wheel Loader for Spreading | 292 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 536 |
| Compactor | 645 | 103 | 0.43 | 0.36 | 1.34 | 4.45 | 0.12 | 0.26 | 0.25 | 536 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dozer | 19.35 | 67.95 | 229.64 | 6.49 | 12.72 | 12.34 | 30155.48 |
| Wheel Loader for Spreading | 11.54 | 41.30 | 140.06 | 3.81 | 7.90 | 7.66 | 17726.03 |
| Compactor | 22.65 | 84.32 | 280.39 | 7.26 | 16.19 | 15.71 | 33743.76 |

| On-road Equipment | Miles | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 147,017 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dump Truck | 223.66 | 1182.30 | 5302.90 | 2.65 | 221.18 | 214.31 | 505,523 |
| ***Subtotal (lbs):*** | **277** | **1,376** | **5,953** | **20** | **258** | **250** | **587,148** |
| **Gravel Work Grand Total in Tons** | **0.14** | **0.69** | **2.98** | **0.01** | **0.13** | **0.13** | |
| **Gravel Work Grand Total in Metric Tons** | | | | | | | **266** |

Vehicle Trips = 183

**Table 7. Concrete Work - TBD**

Foundation Work 17,778 CY
Sidewalks, etc. 74 CY
Total 17,852 CY

Note: Assume all excavated soil is accounted for in Excavate/Fill and Trenching

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Concrete Mixer | 940 | 3.5 | 0.43 | 0.69 | 3.04 | 6.17 | 0.13 | 0.54 | 0.52 | 588 |
| Concrete Truck | 850 | 300 | 0.43 | 0.38 | 1.75 | 6.18 | 0.11 | 0.27 | 0.26 | 530 |

| | Annual Emissions VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Concrete Mixer | 2.14 | 9.49 | 19.25 | 0.39 | 1.69 | 1.64 | 1,834.95 |
| Concrete Truck | 91.77 | 422.06 | 1,494.69 | 27.56 | 64.96 | 63.01 | 128,109.75 |
| ***Subtotal (lbs):*** | **94** | **432** | **1,514** | **28** | **67** | **65** | **129,945** |
| **Concrete Work Grand Total in Tons** | **0.05** | **0.22** | **0.76** | **0.01** | **0.03** | **0.03** | |
| **Concrete Work Grand Total in Metric Tons** | | | | | | | **59** |

Vehicle Trips = 280

**Table 8. Paving - TBD**

Pavement - Surface Area 12,000 SF | 222 CY
Paving - HMA 4,000 CF

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | SO2 g/hp-hr | PM g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Grader | 37 | 145 | 0.59 | 0.38 | 1.41 | 4.16 | 0.12 | 0.30 | 0.29 | 536 |
| Roller | 55 | 401 | 0.59 | 0.34 | 2.46 | 5.53 | 0.12 | 0.34 | 0.33 | 536 |
| Paving Machine | 74 | 164 | 0.59 | 0.38 | 1.44 | 4.25 | 0.12 | 0.30 | 0.29 | 536 |
| Asphalt Curbing Machine | 7 | 130 | 0.59 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 536 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Grader | 2.61 | 9.79 | 28.84 | 0.80 | 2.05 | 1.99 | 3,713.03 |
| Roller | 9.81 | 70.81 | 159.14 | 3.31 | 9.74 | 9.45 | 15,405.71 |
| Paving Machine | 5.96 | 22.62 | 66.67 | 1.81 | 4.70 | 4.56 | 8,398.95 |
| Asphalt Curbing Machine | 0.49 | 1.95 | 5.67 | 0.14 | 0.40 | 0.38 | 665.71 |

| On-road Equipment | Hours of Operation | Engine HP | Productivity based Speed (miles/hour) | VOC lb/mile | CO lb/mile | NOx lb/mile | SO2 lb/mile | PM lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 44 | 230 | 17 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| Water Truck | 1 | 230 | 10 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | | | Dump Truck | 1.15 | 6.06 | 27.19 | 0.01 | 1.13 | 1.10 | 2,592 |
| | | | Water Truck | 0.02 | 0.09 | 0.42 | 0.00 | 0.02 | 0.02 | 40 |

| Hot Mix Asphalt (HMA) | Volume of HMA ($ft^3$) | Weight of HMA (tons) | VOC lb/ton of asphalt | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|---|---|---|
| Standard Hot Mix Asphalt | 4,000 | 0 | 0.04 | 0.00 | - | - | - | - | - | - |
| | | | ***Subtotal (lbs):*** | **20** | **111** | **288** | **6** | **18** | **17** | **30,815** |
| | | | **Paving Grand Total in Tons** | **0.01** | **0.06** | **0.14** | **0.00** | **0.01** | **0.01** | |
| | | | **Paving Grand Total in Metric Tons** | | | | | | | **14** |

Vehicle Trips = 7

**Table 9. Runway Construction**

| | | | |
|---|---|---|---|
| Concrete Surface | 187,500 SF | 4.3 acres | |
| | 20,831 SY | 1.83 yards thick | |

| [1]Off-road Equipment | [2]Cumulative Hours of Operation | [3]Engine HP | [4]Load Factor | [6,7]Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Grader (CAT 120M2 or similar) | 29 | 150 | 0.61 | 1.06 | 3.52 | 8.24 | 0.06 | 0.47 | 0.47 | 568 |
| Steel drum roller/soil compactor | 290 | 401 | 0.56 | 0.70 | 3.18 | 7.20 | 0.05 | 0.28 | 0.28 | 568 |
| Paving/Concrete Machine | 290 | 164 | 0.53 | 1.14 | 3.71 | 8.87 | 0.49 | 0.49 | 0.49 | 568 |
| Curbing Machine | 14 | 130 | 0.59 | 1.14 | 3.71 | 8.87 | 0.49 | 0.49 | 0.49 | 568 |
| Cement and Motar Mixer 1 | 290 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Cement and Motar Mixer 2 | 290 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Cement and Motar Mixer 3 | 290 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Tractor/Loader/Backhoe | 290 | 75 | 0.55 | 1.50 | 4.22 | 8.33 | 0.06 | 0.80 | 0.80 | 568 |
| **[1]On-road Equipment** | **[2]Cumulative Hours of Operation** | **[3]Engine HP** | **[5]Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **SO2** lb/mile | **PM10** lb/mile | **PM2.5** lb/mile | **CO2** lb/mile |
| Cement Truck | 290 | 230 | 20 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| Water Truck/Oil truck | 29 | 230 | 10 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |

| | Annual Emissions VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 6.21 | 20.58 | 48.15 | 0.33 | 2.74 | 2.74 | 3,321.35 |
| | 99.97 | 456.55 | 1,032.14 | 7.17 | 40.45 | 40.45 | 81,512.80 |
| | 63.01 | 205.70 | 492.61 | 27.43 | 27.43 | 27.43 | 31,551.00 |
| | 2.78 | 9.08 | 21.73 | 1.21 | 1.21 | 1.21 | 1,392.06 |
| | 2.96 | 8.51 | 17.42 | 0.21 | 1.12 | 1.12 | 1,829.46 |
| | 2.96 | 8.51 | 17.42 | 0.21 | 1.12 | 1.12 | 1,829.46 |
| | 2.96 | 8.51 | 17.42 | 0.21 | 1.12 | 1.12 | 1,829.46 |
| | 39.50 | 111.19 | 219.34 | 1.58 | 21.13 | 21.13 | 14,973.30 |
| | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | 8.82 | 46.60 | 209.01 | 0.10 | 8.72 | 8.45 | 19,924 |
| | 0.44 | 2.33 | 10.45 | 0.01 | 0.44 | 0.42 | 996 |
| **Runway Construction Grand Total in Tons** | **0.11** | **0.44** | **1.04** | **0.02** | **0.05** | **0.05** | |
| **Runway Construction Grand Total in Metric Tons** | | | | | | | **72** |

Vehicle Trips = 278

**TBD - DEMO**

**Table 10. Demo Site Work - TBD**

| | | |
|---|---|---|
| Site Prep - Excavate/Fill (CY) | 33,692 | CY |
| Trenching (LF) | 0 | LF |
| Grading (SY) | 7,590 | SY |

Assume compact 0.5 feet (0.166 yards) 1,260 CY compacted

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavator | 112 | 243 | 0.59 | 0.34 | 1.21 | 4.03 | 0.12 | 0.22 | 0.22 | 536 |
| Skid Steer Loader | 135 | 160 | 0.23 | 0.38 | 1.47 | 4.34 | 0.12 | 0.31 | 0.30 | 536 |
| Dozer (Rubber Tired) | 122 | 145 | 0.59 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 536 |
| Compactor | 6 | 103 | 0.58 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 536 |
| Grader | 3 | 285 | 0.58 | 0.34 | 1.21 | 4.07 | 0.12 | 0.23 | 0.22 | 536 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Excavator | 12.21 | 42.92 | 143.04 | 4.09 | 7.91 | 7.67 | 19,019.29 |
| Skid Steer Loader | 4.19 | 16.07 | 47.44 | 1.26 | 3.34 | 3.24 | 5,856.91 |
| Dozer (Rubber Tired) | 8.67 | 32.56 | 96.09 | 2.65 | 6.81 | 6.61 | 12,333.54 |
| Compactor | 0.30 | 1.21 | 3.51 | 0.09 | 0.25 | 0.24 | 411.50 |
| Grader | 0.34 | 1.19 | 4.00 | 0.11 | 0.22 | 0.21 | 526.27 |

| On-road Equipment | Hours | MPH | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | PM10 lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 112 | 5 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dump Truck | 0.85 | 4.52 | 20.25 | 0.01 | 0.84 | 0.82 | 1,931 |
| ***Subtotal in lb:*** | **27** | **98** | **314** | **8** | **19** | **19** | **40,078** |
| **Site Prep Grand Total in Tons** | **0.01** | **0.05** | **0.16** | **0.00** | **0.01** | **0.01** | |
| **Site Prep Grand Total in Metric Tons** | | | | | | | **18** |

Vehicle Trips = 59

**Table 11. Demo Bldgs - TBD**

153,102 SF 7,655 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator | 1,276 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 1,276 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 1,276 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |

| | Annual Emissions VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Hydraulic excavator | 32.68 | 366.84 | 382.56 | 16.22 | 57.51 | 55.79 | 84,984.91 |
| Wheel Loader w/ integral Backhoe | 60.05 | 344.89 | 282.62 | 7.96 | 53.40 | 51.80 | 38,991.55 |
| Wheel mounted air compressor | 21.35 | 114.56 | 285.28 | 8.78 | 18.86 | 18.29 | 43,602.12 |
| ***Subtotal (lbs):*** | 114.08 | 826.29 | 950.46 | 32.96 | 129.77 | 125.88 | 167578.58 |

| On-road Equipment | Hours of Operation | Engine HP | Speed (mph) | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck (12 CY Capacity) | 702 | 230 | 27 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |

| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Dump Truck (12 CY Capacity) | 28.84 | 152.43 | 683.67 | 0.34 | 28.52 | 27.63 | 65,174 |
| ***Subtotal (lbs):*** | 142.91 | 978.72 | 1,634.13 | 33.30 | 158.29 | 153.51 | 232,752.68 |
| **Building Demo Grand Total in Tons** | **0.071** | **0.489** | **0.817** | **0.017** | **0.079** | **0.077** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **105.57** |

Vehicle Trips = 598

**Table 12. Demo Asphalt Concrete - TBD**

15,358 SF 472 CY

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Off-road Equipment** | **Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Crawler Dozer w/attachments | 263 | 125 | 0.58 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 535.79 |
| Air Compressor | 263 | 49 | 0.59 | 0.33 | 2.54 | 4.53 | 0.13 | 0.54 | 0.53 | 595.16 |
| Excavator | 61 | 380 | 0.59 | 0.31 | 2.50 | 4.51 | 0.13 | 0.55 | 0.54 | 595.21 |
| | | | | Annual Emissions | | | | | | |
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Crawler Dozer w/attachments | 14.48 | 50.84 | 171.82 | 4.85 | 9.52 | 9.23 | 22562.78 |
| | | | Wheel mounted air compressor | 5.50 | 42.68 | 76.02 | 2.15 | 9.10 | 8.83 | 9994.14 |
| | | | Excavator | 9.34 | 74.67 | 134.78 | 3.83 | 16.51 | 16.01 | 17800.11 |

| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **On-road Equipment** | **Hours of Operation** | **Engine HP** | **Speed (mph)** | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile | lb/mile |
| Dump Truck | 205 | 230 | 27 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Dump Truck | 8.42 | 44.51 | 199.65 | 0.10 | 8.33 | 8.07 | 19,032 |
| | | | **Subtotal (lbs):** | **38** | **213** | **582** | **11** | **43** | **42** | **69,389** |
| | | | **Asphalt Demo Grand Total in Tons** | **0.02** | **0.11** | **0.29** | **0.01** | **0.02** | **0.02** | |
| | | | **Asphalt Demo Grand Total in Metric Tons** | | | | | | | **31** |

Vehicle Trips = 92

## 2019

**Table 13. Building Demo - 2019**

153,102 SF 7,655 Estimated CY of debris based on 20 SF/CY

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Off-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Hydraulic excavator with breakers and jackhammer bits | 287 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 287 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 287 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck (12 CY Capacity) | 158 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | | | | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | | 7.36 | 82.59 | 86.13 | 3.65 | 12.95 | 12.56 | 19,134 |
| | | | | 13.52 | 77.65 | 63.63 | 1.79 | 12.02 | 11.66 | 8,779 |
| | | | | 4.81 | 25.79 | 64.23 | 1.98 | 4.25 | 4.12 | 9,817 |
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | | 7.15 | 36.97 | 169.00 | 0.08 | 7.29 | 7.08 | 14,575 |
| | | | **Subtotal (lbs):** | **33** | **223** | **383** | **7** | **37** | **35** | **52,306** |
| | | | **Building Demo Grand Total in Tons** | **0.016** | **0.112** | **0.192** | **0.004** | **0.018** | **0.018** | |
| | | | **Building Demo Grand Total in Metric Tons** | | | | | | | **23.73** |

Vehicle Trips = 135

**Table 14. Demo Asphalt and Concrete- 2019**

15,358 SF 94 CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Crawler Dozer w/attachments | 11 | 125 | 0.58 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 535.79 |
| Air Compressor | 11 | 49 | 0.59 | 0.33 | 2.54 | 4.53 | 0.13 | 0.54 | 0.53 | 595.16 |
| Excavator | 3 | 380 | 0.59 | 0.31 | 2.50 | 4.51 | 0.13 | 0.55 | 0.54 | 595.21 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck | 9 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 0.60 | 2.12 | 7.17 | 0.20 | 0.40 | 0.39 | 942 |
| | 0.23 | 1.78 | 3.17 | 0.09 | 0.38 | 0.37 | 417 |
| | 0.39 | 3.14 | 5.67 | 0.16 | 0.69 | 0.67 | 748 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 0.41 | 2.11 | 9.63 | 0.00 | 0.42 | 0.40 | 830 |
| **Subtotal (lbs):** | **2** | **9** | **26** | **0** | **2** | **2** | **2,938** |
| **Asphalt Demo Grand Total in Tons** | **0.00** | **0.00** | **0.01** | **0.00** | **0.00** | **0.00** | |
| **Asphalt Demo Grand Total in Metric Tons** | | | | | | | **1** |

Vehicle Trips = 4

## 2020

**Table 15. Building Demo - 2020**

12,000 SF | 600 Estimated CY of debris based on 20 SF/CY

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Off-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Hydraulic excavator with breakers and jackhammer bits | 100 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 100 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 100 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
| Dump Truck (12 CY Capacity) | 55 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 2.56 | 28.75 | 29.98 | 1.27 | 4.51 | 4.37 | 6,661 |
| | 4.71 | 27.03 | 22.15 | 0.62 | 4.19 | 4.06 | 3,056 |
| | 1.67 | 8.98 | 22.36 | 0.69 | 1.48 | 1.43 | 3,417 |
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 2.49 | 12.87 | 58.83 | 0.03 | 2.54 | 2.46 | 5,074 |
| **Subtotal (lbs):** | **11** | **78** | **133** | **3** | **13** | **12** | **18,208** |
| **Building Demo Grand Total in Tons** | **0.006** | **0.039** | **0.067** | **0.001** | **0.006** | **0.006** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **8.26** |

Vehicle Trips = 47

**Table 16. Building Construction-2020**

12,000 SF Foundation
12,000 SF Total

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VOC | CO | NOx | $SO_2$ | PM10 | PM2.5 | $CO_2$ |
| **Off-road Equipment** | **Hours of Operation** | **Engine HP** | **Load Factor** | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr | g/hp-hr |
| Crane | 60 | 330 | 0.58 | 0.25 | 1.22 | 5.26 | 0.11 | 0.21 | 0.20 | 530 |
| Concrete Truck | 60 | 300 | 0.43 | 0.19 | 1.45 | 4.32 | 0.12 | 0.21 | 0.20 | 536 |
| Diesel Generator | 48 | 40 | 0.43 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536 |
| Telehandler | 120 | 99 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Scissors Lift | 96 | 83 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Skid Steer Loader | 60 | 67 | 0.59 | 1.69 | 7.97 | 6.70 | 0.15 | 1.19 | 1.15 | 691 |
| Pile Driver | 619 | 260 | 0.43 | 0.46 | 1.55 | 5.90 | 0.11 | 0.31 | 0.30 | 530 |
| All Terrain Forklift | 2 | 84 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| Crane | 6.22 | 30.88 | 133.17 | 2.89 | 5.26 | 5.10 | 13426.11 |
| Concrete Truck | 3.20 | 24.82 | 73.73 | 1.97 | 3.58 | 3.48 | 9150.71 |
| Diesel Generator | 0.48 | 2.56 | 6.39 | 0.20 | 0.42 | 0.41 | 975.95 |
| Telehandler | 7.87 | 60.88 | 76.17 | 1.98 | 8.05 | 7.81 | 9188.40 |
| Scissors Lift | 5.28 | 40.83 | 51.09 | 1.33 | 5.40 | 5.24 | 6162.72 |
| Skid Steer Loader | 8.85 | 41.66 | 35.02 | 0.78 | 6.22 | 6.03 | 3612.54 |
| Pile Driver | 70.77 | 236.68 | 900.14 | 17.38 | 47.87 | 46.43 | 80778.00 |
| All Terrain Forklift | 0.13 | 1.03 | 1.29 | 0.03 | 0.14 | 0.13 | 155.92 |

| On-road Equipment | Hours of Operation | Engine HP | Speed (mph) | VOC lb/mile | CO lb/mile | NOx lb/mile | SO2 lb/mile | PM lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Delivery Truck | 288 | 265 | 45 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Delivery Truck | 19.72 | 104.22 | 467.47 | 0.23 | 19.50 | 18.89 | 44,563 |
| | | | ***Subtotal (lbs):*** | **123** | **544** | **1744** | **27** | **96** | **94** | **168014** |
| | | | **Building Construction Grand Total in Tons** | **0.06** | **0.27** | **0.87** | **0.01** | **0.05** | **0.05** | |
| | | | **Building Construction Grand Total in Metric Tons** | | | | | | | **76** |

Vehicle Trips = 166

**Table 17. Gravel Work-2020**

244 CY 17 trips 1,534 total miles

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Dozer | 2 | 185 | 0.59 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 536 |
| Wheel Loader for Spreading | 3 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 536 |
| Compactor | 7 | 103 | 0.43 | 0.36 | 1.34 | 4.45 | 0.12 | 0.26 | 0.25 | 536 |
| | | | | VOC | CO | NOx | SO2 | PM10 | PM2.5 | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Dozer | 0.17 | 0.58 | 1.96 | 0.06 | 0.11 | 0.11 | 257.86 |
| | | | Wheel Loader for Spreading | 0.12 | 0.42 | 1.44 | 0.04 | 0.08 | 0.08 | 181.89 |
| | | | Compactor | 0.25 | 0.92 | 3.04 | 0.08 | 0.18 | 0.17 | 366.18 |

| On-road Equipment | Miles | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 1,534 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | VOC | CO | NOx | SO2 | PM10 | PM2.5 | $CO_2$ |
| | | | lb | lb | lb | lb | lb | lb | lb |
| | | Dump Truck | 2.33 | 12.33 | 55.32 | 0.03 | 2.31 | 2.24 | 5,274 |
| | | ***Subtotal (lbs):*** | **3** | **14** | **62** | **0** | **3** | **3** | **6,080** |
| | | **Gravel Work Grand Total in Tons** | **0.00** | **0.01** | **0.03** | **0.00** | **0.00** | **0.00** | |
| | | **Gravel Work Grand Total in Metric Tons** | | | | | | | **3** |

Vehicle Trips = 2

**Table 18. Concrete Work - 2020**

Foundation Work 1,778 CY
Sidewalks, etc. 7 CY
Total 1,785 CY

Note: Assume all excavated soil is accounted for in Excavate/Fill and Trenching

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Off-road Equipment** | **Hours of Operation** | **Engine HP** | **Load Factor** | **VOC** g/hp-hr | **CO** g/hp-hr | **NOx** g/hp-hr | $SO_2$ g/hp-hr | **PM10** g/hp-hr | **PM2.5** g/hp-hr | $CO_2$ g/hp-hr |
| Concrete Mixer | 94 | 3.5 | 0.43 | 0.69 | 3.04 | 6.17 | 0.13 | 0.54 | 0.52 | 588 |
| Concrete Truck | 85 | 300 | 0.43 | 0.38 | 1.75 | 6.18 | 0.11 | 0.27 | 0.26 | 530 |
| | | | | Annual Emissions | | | | | | |
| | | | | VOC | CO | NOx | SO2 | PM | PM2.5 | $CO_2$ |
| | | | | lb | lb | lb | lb | lb | lb | lb |
| | | | Concrete Mixer | 0.21 | 0.95 | 1.92 | 0.04 | 0.17 | 0.16 | 183.48 |
| | | | Concrete Truck | 9.18 | 42.20 | 149.45 | 2.76 | 6.50 | 6.30 | 12,809.54 |
| | | | ***Subtotal (lbs):*** | **9** | **43** | **151** | **3** | **7** | **6** | **12,993** |
| | | | **Concrete Work Grand Total in Tons** | **0.00** | **0.02** | **0.08** | **0.00** | **0.00** | **0.00** | |
| | | | **Concrete Work Grand Total in Metric Tons** | | | | | | | **6** |

Vehicle Trips = 28

## 2022

**Table 19. Building Demo - 2022**

22,337 SF — 1,117 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator with breakers and jackhammer bits | 186 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 186 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 186 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC lb/mile** | **CO lb/mile** | **NOx lb/mile** | **$SO_2$ lb/mile** | **$PM_{10}$ lb/mile** | **$PM_{2.5}$ lb/mile** | **$CO_2$ lb/mile** |
| Dump Truck (12 CY Capacity) | 102 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

**Annual Emissions**

| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 4.76 | 53.48 | 55.77 | 2.37 | 8.38 | 8.13 | 12,390 |
| | 8.75 | 50.28 | 41.20 | 1.16 | 7.79 | 7.55 | 5,684 |
| | 3.11 | 16.70 | 41.59 | 1.28 | 2.75 | 2.67 | 6,357 |
| | **VOC lb** | **CO lb** | **NOx lb** | **$SO_2$ lb** | **$PM_{10}$ lb** | **$PM_{2.5}$ lb** | **$CO_2$ lb** |
| | 4.62 | 23.87 | 109.10 | 0.05 | 4.70 | 4.57 | 9,409 |
| **Subtotal (lbs):** | **21** | **144** | **248** | **5** | **24** | **23** | **33,840** |
| **Building Demo Grand Total in Tons** | **0.011** | **0.072** | **0.124** | **0.002** | **0.012** | **0.011** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **15.35** |

Vehicle Trips = 87

**Table 20. Demo Asphalt and Concrete- 2022**

2,234 SF — 69 CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| D-6K Crawler Dozer with attachments | 8 | 125 | 0.58 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 535.79 |
| Wheel mounted air compressor | 8 | 49 | 0.59 | 0.33 | 2.54 | 4.53 | 0.13 | 0.54 | 0.53 | 595.16 |
| Pneumatic Paving Breaker and jackhammer on excavator (CAT 345D L or similar) | 2 | 380 | 0.59 | 0.31 | 2.50 | 4.51 | 0.13 | 0.55 | 0.54 | 595.21 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC lb/mile** | **CO lb/mile** | **NOx lb/mile** | **$SO_2$ lb/mile** | **$PM_{10}$ lb/mile** | **$PM_{2.5}$ lb/mile** | **$CO_2$ lb/mile** |
| Dump Truck | 6 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

**Annual Emissions**

| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 0.44 | 1.54 | 5.22 | 0.15 | 0.29 | 0.28 | 685 |
| | 0.17 | 1.30 | 2.31 | 0.07 | 0.28 | 0.27 | 303 |
| | 0.31 | 2.47 | 4.46 | 0.13 | 0.55 | 0.53 | 588 |
| | **VOC lb** | **CO lb** | **NOx lb** | **$SO_2$ lb** | **$PM_{10}$ lb** | **$PM_{2.5}$ lb** | **$CO_2$ lb** |
| | 0.27 | 1.40 | 6.42 | 0.00 | 0.28 | 0.27 | 553 |
| **Subtotal (lbs):** | **1** | **7** | **18** | **0** | **1** | **1** | **2,130** |
| **Asphalt Demo Grand Total in Tons** | **0.00** | **0.00** | **0.01** | **0.00** | **0.00** | **0.00** | |
| **Asphalt Demo Grand Total in Metric Tons** | | | | | | | **1** |

Vehicle Trips = 3

**Table 21. Fugitive Dust**

| Year | $PM_{10}$ tons/acre/mo | acres | days of disturbance | $PM_{10}$ Total (tons) | $PM_{2.5}/PM_{10}$ Ratio | $PM_{2.5}$ Total (tons) |
|---|---|---|---|---|---|---|
| TBD - Construction | 0.42 | 7.28 | 90 | 13.8 | 0.1 | 1.4 |
| TBD - Demo | 0.42 | 3.5 | 180 | 13.2 | 0.1 | 1.3 |
| 2019 | 0.42 | 0.2 | 30 | 0.1 | 0.1 | 0.0 |
| 2020 | 0.42 | 0.3 | 9 | 0.1 | 0.1 | 0.0 |
| 2022 | 0.42 | 0.5 | 90 | 1.0 | 0.1 | 0.1 |

**Table 22. Annual Construction Worker POVs - 2019 - TBD**

| Year | Vehicle Trips | mile/trip | VOCs lb/mi | CO lb/mi | NOx lb/mi | $SO_2$ lb/mi | $PM_{10}$ lb/mi | $PM_{2.5}$ lb/mi | $CO_2$ g/mi | $CH_4$ g/mi | $N_2O$ g/mi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TBD - Construction | 2,885 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| TBD - Demo | 749 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| 2019 | 138 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| 2020 | 243 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| 2022 | 90 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |

| VOCs ton/year | CO ton/year | NOx ton/year | $SO_2$ ton/year | $PM_{10}$ ton/year | $PM_{2.5}$ ton/year | $CO_2e$ metric ton/year |
|---|---|---|---|---|---|---|
| 0.011 | 0.319 | 0.044 | 0.000 | 0.002 | 0.002 | 6.5 |
| 0.003 | 0.083 | 0.011 | 0.000 | 0.000 | 0.000 | 1.7 |
| 0.001 | 0.015 | 0.002 | 0.000 | 0.000 | 0.000 | 0.3 |
| 0.001 | 0.027 | 0.004 | 0.000 | 0.000 | 0.000 | 0.5 |
| 0.000 | 0.010 | 0.001 | 0.000 | 0.000 | 0.000 | 0.2 |

**Table 23. Wallops Main Base Area Construction Summary**

| YEAR | VOC T/yr | CO T/yr | NOx T/yr | $SO_2$ T/yr | $PM_{10}$ T/yr | $PM_{2.5}$ T/yr | $CO_2$ MT/yr |
|---|---|---|---|---|---|---|---|
| TBD - Construction | 1.01 | 4.85 | 14.62 | 0.20 | 14.54 | 2.14 | 1,291 |
| TBD - Demo | 0.11 | 0.73 | 1.28 | 0.03 | 13.34 | 1.43 | 157 |
| 2019 | 0.02 | 0.13 | 0.21 | 0.00 | 0.12 | 0.03 | 25 |
| 2020 | 0.07 | 0.37 | 1.05 | 0.02 | 0.11 | 0.06 | 94 |
| 2022 | 0.01 | 0.09 | 0.13 | 0.00 | 0.98 | 0.11 | 17 |

**TAB C. CONSTRUCTION EMISSIONS - CONTROL CENTER AREA**

**Basic Conversions**

| | |
|---|---|
| 453.59 | grams per pound |
| 43,560 | Conversion from Acre to SF |
| 0.03704 | Cubic feet to Cubic Yards |
| 0.1111 | Square Feet to Square Yards |
| 1.4 | tons/CY for Gravel |
| 80,000 | lbs/Truck Load for Delivery |
| 1.66 | CY for each CY of asphalt/concrete demo |
| 0.333333333 | asphalt thickness for demolition |
| 0.333333333 | asphalt thickness for pavement |
| 2000 | pounds per ton |
| 145 | lb/ft$^3$ density of Hot Mix Asphalt |
| 0.666666667 | asphalt thickness for pavement on runways |

**TBD Construction**

**Table 1. Clearing - TBD**

3.5 Acres

Vehicle Trips = 19

| | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
| Dozer | 41 | 145 | 0.58 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 535.69 |
| Loader w/ integral Backhoe | 41 | 87 | 0.21 | 1.43 | 7.35 | 6.35 | 0.15 | 1.06 | 1.03 | 691.66 |
| Small backhoe | 41 | 55 | 0.21 | 1.43 | 7.35 | 6.35 | 0.15 | 1.06 | 1.03 | 691.66 |
| On-road Equipment | Cumulative Hours of Operation | Engine HP | Productivity based Speed (miles/hour) | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
| Dump Truck | 19 | 230 | 16 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
| | 2.86 | 10.75 | 31.73 | 0.88 | 2.25 | 2.18 | 4,072.21 |
| | 2.36 | 12.14 | 10.48 | 0.25 | 1.76 | 1.70 | 1,142.23 |
| | 1.49 | 7.67 | 6.63 | 0.16 | 1.11 | 1.08 | 722.10 |
| | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
| | 0.51 | 2.64 | 12.08 | 0.01 | 0.52 | 0.51 | 1,042 |
| **Subtotal (lbs):** | **7** | **33** | **61** | **1** | **6** | **5** | **6,979** |
| **Clearing Grand Total in Tons** | **0.00** | **0.02** | **0.03** | **0.00** | **0.00** | **0.00** | |
| **Clearing Grand Total in Metric Tons** | | | | | | | **3** |

Vehicle Trips = 19

**Table 2. Site Prep**

| | | |
|---|---|---|
| Site Prep - Excavate/Fill (CY) | 14,442 | CY |
| Trenching (LF) | 3,300 | LF |
| Grading (SY) | 32,263 | SY |

Assume 3' deep,1 ' wide

Assume compact 0.5 feet (0.166 yards) 5,356 CY compacted

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavator | 48 | 243 | 0.59 | 0.34 | 1.21 | 4.03 | 0.12 | 0.22 | 0.22 | 536 |
| Skid Steer Loader | 58 | 160 | 0.23 | 0.38 | 1.47 | 4.34 | 0.12 | 0.31 | 0.30 | 536 |
| Dozer (Rubber Tired) | 52 | 145 | 0.59 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 536 |
| Compactor | 25 | 103 | 0.58 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 536 |
| Grader | 11 | 285 | 0.58 | 0.34 | 1.21 | 4.07 | 0.12 | 0.23 | 0.22 | 536 |
| Backhoe/Loader | 5 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 536 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| Excavator | 5.23 | 18.40 | 61.31 | 1.75 | 3.39 | 3.29 | 8,152.57 |
| Skid Steer Loader | 1.80 | 6.89 | 20.33 | 0.54 | 1.43 | 1.39 | 2,510.55 |
| Dozer (Rubber Tired) | 3.72 | 13.96 | 41.19 | 1.14 | 2.92 | 2.83 | 5,286.74 |
| Compactor | 1.29 | 5.13 | 14.91 | 0.38 | 1.04 | 1.01 | 1,749.16 |
| Grader | 1.44 | 5.04 | 16.99 | 0.48 | 0.94 | 0.91 | 2,237.05 |
| Backhoe/loader | 0.21 | 0.74 | 2.51 | 0.07 | 0.14 | 0.14 | 317.59 |

| On-road Equipment | Hours | MPH | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | PM10 lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 48 | 5 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | | | Dump Truck | 0.37 | 1.94 | 8.68 | 0.00 | 0.36 | 0.35 | 828 |
| | | | ***Subtotal in lb:*** | **14** | **52** | **166** | **4** | **10** | **10** | **21,081** |
| | | | **Site Prep Grand Total in Tons** | **0.01** | **0.03** | **0.08** | **0.00** | **0.01** | **0.00** | |
| | | | **Site Prep Grand Total in Metric Tons** | | | | | | | **10** |

Vehicle Trips = 31

**Table 3. Building Construction**

12,000 SF Foundation
12,000 SF Total

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Emission Factors** | | | | | | |
| Crane | 60 | 330 | 0.58 | 0.25 | 1.22 | 5.26 | 0.11 | 0.21 | 0.20 | 530 |
| Concrete Truck | 60 | 300 | 0.43 | 0.19 | 1.45 | 4.32 | 0.12 | 0.21 | 0.20 | 536 |
| Diesel Generator | 48 | 40 | 0.43 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536 |
| Telehandler | 120 | 99 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Scissors Lift | 96 | 83 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| Skid Steer Loader | 60 | 67 | 0.59 | 1.69 | 7.97 | 6.70 | 0.15 | 1.19 | 1.15 | 691 |
| Pile Driver | 619 | 260 | 0.43 | 0.46 | 1.55 | 5.90 | 0.11 | 0.31 | 0.30 | 530 |
| All Terrain Forklift | 2 | 84 | 0.59 | 0.51 | 3.94 | 4.93 | 0.13 | 0.52 | 0.51 | 595 |
| | | | | **Annual Emissions** | | | | | | |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | | | Crane | 6.22 | 30.88 | 133.17 | 2.89 | 5.26 | 5.10 | 13426.11 |
| | | | Concrete Truck | 3.20 | 24.82 | 73.73 | 1.97 | 3.58 | 3.48 | 9150.71 |
| | | | Diesel Generator | 0.48 | 2.56 | 6.39 | 0.20 | 0.42 | 0.41 | 975.95 |
| | | | Telehandler | 7.87 | 60.88 | 76.17 | 1.98 | 8.05 | 7.81 | 9188.40 |
| | | | Scissors Lift | 5.28 | 40.83 | 51.09 | 1.33 | 5.40 | 5.24 | 6162.72 |
| | | | Skid Steer Loader | 8.85 | 41.66 | 35.02 | 0.78 | 6.22 | 6.03 | 3612.54 |
| | | | Pile Driver | 70.77 | 236.68 | 900.14 | 17.38 | 47.87 | 46.43 | 80778.00 |
| | | | All Terrain Forklift | 0.13 | 1.03 | 1.29 | 0.03 | 0.14 | 0.13 | 155.92 |

| On-road Equipment | Hours of Operation | Engine HP | Speed (mph) | VOC lb/mile | CO lb/mile | NOx lb/mile | SO2 lb/mile | PM lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Delivery Truck | 288 | 265 | 45 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | | | Delivery Truck | 19.72 | 104.22 | 467.47 | 0.23 | 19.50 | 18.89 | 44,563 |
| | | | ***Subtotal (lbs):*** | **123** | **544** | **1744** | **27** | **96** | **94** | **168014** |
| | | | **Building Construction Grand Total in Tons** | **0.06** | **0.27** | **0.87** | **0.01** | **0.05** | **0.05** | |
| | | | **Building Construction Grand Total in Metric Tons** | | | | | | | **76** |

Vehicle Trips = 166

**Table 4. Gravel Work**

2,761 CY     197 trips     17,355 total miles

| Off-road Equipment | Hours | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Dozer | 28 | 185 | 0.59 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 536 |
| Wheel Loader for Spreading | 35 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 536 |
| Compactor | 76 | 103 | 0.43 | 0.36 | 1.34 | 4.45 | 0.12 | 0.26 | 0.25 | 536 |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM10** lb | **PM2.5** lb | **$CO_2$** lb |
| | | | Dozer | 2.28 | 8.02 | 27.11 | 0.77 | 1.50 | 1.46 | 3559.76 |
| | | | Wheel Loader for Spreading | 1.36 | 4.88 | 16.53 | 0.45 | 0.93 | 0.90 | 2092.50 |
| | | | Compactor | 2.67 | 9.95 | 33.10 | 0.86 | 1.91 | 1.85 | 3983.35 |

| On-road Equipment | Miles | Engine HP | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 17,355 | 230 | 0.0015 | 0.0080 | 0.0361 | 0.0000 | 0.0015 | 0.0015 | 3.4385 |
| | | | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | $CO_2$ lb |
| Dump Truck | | | 26.40 | 139.57 | 625.99 | 0.31 | 26.11 | 25.30 | 59,675 |
| ***Subtotal (lbs):*** | | | **33** | **162** | **703** | **2** | **30** | **30** | **69,311** |
| **Gravel Work Grand Total in Tons** | | | **0.02** | **0.08** | **0.35** | **0.00** | **0.02** | **0.01** | |
| **Gravel Work Grand Total in Metric Tons** | | | | | | | | | **31** |

Vehicle Trips = 22

**Table 5. Concrete Work**

Concrete Surface SF
4,690 SY 1.83 yards thick

| [1]Off-road Equipment | [2]Cumulative Hours of Operation | [3]Engine HP | [4]Load Factor | [6,7]Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Grader (CAT 120M2 or similar) | 7 | 150 | 0.61 | 1.06 | 3.52 | 8.24 | 0.06 | 0.47 | 0.47 | 568 |
| Steel drum roller/soil compactor | 65 | 401 | 0.56 | 0.70 | 3.18 | 7.20 | 0.05 | 0.28 | 0.28 | 568 |
| Paving/Concrete Machine | 65 | 164 | 0.53 | 1.14 | 3.71 | 8.87 | 0.49 | 0.49 | 0.49 | 568 |
| Curbing Machine | 3 | 130 | 0.59 | 1.14 | 3.71 | 8.87 | 0.49 | 0.49 | 0.49 | 568 |
| Cement and Motar Mixer 1 | 65 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Cement and Motar Mixer 2 | 65 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Cement and Motar Mixer 3 | 65 | 9 | 0.56 | 0.92 | 2.64 | 5.41 | 0.07 | 0.35 | 0.35 | 568 |
| Tractor/Loader/Backhoe | 65 | 75 | 0.55 | 1.50 | 4.22 | 8.33 | 0.06 | 0.80 | 0.80 | 568 |
| **[1]On-road Equipment** | **[2]Cumulative Hours of Operation** | **[3]Engine HP** | **[5]Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **SO2** lb/mile | **PM10** lb/mile | **PM2.5** lb/mile | **CO2** lb/mile |
| Cement Truck | 65 | 230 | 20 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| Water Truck/Oil truck | 7 | 230 | 10 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |

| | Annual Emissions VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 1.40 | 4.63 | 10.84 | 0.08 | 0.62 | 0.62 | 747.78 |
| | 22.51 | 102.79 | 232.38 | 1.61 | 9.11 | 9.11 | 18,352.00 |
| | 14.19 | 46.31 | 110.91 | 6.17 | 6.17 | 6.17 | 7,103.47 |
| | 0.63 | 2.04 | 4.89 | 0.27 | 0.27 | 0.27 | 313.41 |
| | 0.67 | 1.91 | 3.92 | 0.05 | 0.25 | 0.25 | 411.89 |
| | 0.67 | 1.91 | 3.92 | 0.05 | 0.25 | 0.25 | 411.89 |
| | 0.67 | 1.91 | 3.92 | 0.05 | 0.25 | 0.25 | 411.89 |
| | 8.89 | 25.03 | 49.38 | 0.36 | 4.76 | 4.76 | 3,371.13 |
| | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| | 1.98 | 10.49 | 47.06 | 0.02 | 1.96 | 1.90 | 4,486 |
| | 0.10 | 0.52 | 2.35 | 0.00 | 0.10 | 0.10 | 224 |
| **Runway Construction Grand Total in Tons** | **0.03** | **0.10** | **0.23** | **0.00** | **0.01** | **0.01** | |
| **Runway Construction Grand Total in Metric Tons** | | | | | | | **16** |

Vehicle Trips = 63

**Table 6. Paving**

Pavement - Surface Area 2,400 SF 30 CY
Paving - HMA 800 CF

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | SO2 g/hp-hr | PM g/hp-hr | PM2.5 g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Grader | 7 | 145 | 0.59 | 0.38 | 1.41 | 4.16 | 0.12 | 0.30 | 0.29 | 536 |
| Roller | 11 | 401 | 0.59 | 0.34 | 2.46 | 5.53 | 0.12 | 0.34 | 0.33 | 536 |
| Paving Machine | 15 | 164 | 0.59 | 0.38 | 1.44 | 4.25 | 0.12 | 0.30 | 0.29 | 536 |
| Asphalt Curbing Machine | 1 | 130 | 0.59 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 536 |
| | | | | **VOC** lb | **CO** lb | **NOx** lb | **SO2** lb | **PM** lb | **PM2.5** lb | **$CO_2$** lb |
| Grader | | | | 0.50 | 1.86 | 5.49 | 0.15 | 0.39 | 0.38 | 707.24 |
| Roller | | | | 1.96 | 14.13 | 31.76 | 0.66 | 1.94 | 1.88 | 3,074.15 |
| Paving Machine | | | | 1.22 | 4.62 | 13.61 | 0.37 | 0.96 | 0.93 | 1,714.07 |
| Asphalt Curbing Machine | | | | 0.07 | 0.27 | 0.77 | 0.02 | 0.05 | 0.05 | 90.57 |

| On-road Equipment | Hours of Operation | Engine HP | Productivity based Speed (miles/hour) | VOC lb/mile | CO lb/mile | NOx lb/mile | SO2 lb/mile | PM lb/mile | PM2.5 lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 6 | 230 | 17 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| Water Truck | 0 | 230 | 10 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| | | | | VOC lb | CO lb | NOx lb | SO2 lb | PM lb | PM2.5 lb | $CO_2$ lb |
| | | | Dump Truck | 0.16 | 0.82 | 3.68 | 0.00 | 0.15 | 0.15 | 351 |
| | | | Water Truck | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |

| Hot Mix Asphalt (HMA) | Volume of HMA ($ft^3$) | Weight of HMA (tons) | VOC lb/ton of asphalt | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|---|---|---|
| Standard Hot Mix Asphalt | 800 | 58 | 0.04 | 2.32 | - | - | - | - | - | - |
| | | | ***Subtotal (lbs):*** | **6** | **22** | **55** | **1** | **4** | **3** | **5,937** |
| | | | **Paving Grand Total in Tons** | **0.00** | **0.01** | **0.03** | **0.00** | **0.00** | **0.00** | |
| | | | **Paving Grand Total in Metric Tons** | | | | | | | **3** |

Vehicle Trips = 1

**TBD Demo**

**Table 7. Building Demo - TBD**

27,094 SF — 1,355 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator | 226 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 226 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 226 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| | | | | **Annual Emissions** | | | | | | |
| | | | | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
| | | | Hydraulic excavator | 5.79 | 64.98 | 67.76 | 2.87 | 10.19 | 9.88 | 15,053.96 |
| | | | Wheel Loader w/ integral Backhoe | 10.64 | 61.09 | 50.06 | 1.41 | 9.46 | 9.18 | 6,906.84 |
| | | | Wheel mounted air compressor | 3.78 | 20.29 | 50.53 | 1.55 | 3.34 | 3.24 | 7,723.54 |
| | | | ***Subtotal (lbs):*** | 20.21 | 146.37 | 168.36 | 5.84 | 22.99 | 22.30 | 29684.33 |

| On-road Equipment | Hours of Operation | Engine HP | Speed (mph) | VOC lb/mile | CO lb/mile | NOx lb/mile | $SO_2$ lb/mile | $PM_{10}$ lb/mile | $PM_{2.5}$ lb/mile | $CO_2$ lb/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 124 | 230 | 27 | 0.001521 | 0.008042 | 0.036070 | 1.80E-05 | 0.001504 | 0.001458 | 3.438541 |
| | | | | VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
| | | | Dump Truck (12 CY Capacity) | 5.09 | 26.92 | 120.76 | 0.06 | 5.04 | 4.88 | 11,512 |
| | | | ***Subtotal (lbs):*** | 25.30 | 173.29 | 289.12 | 5.90 | 28.02 | 27.18 | 41,196.57 |
| | | | **Building Demo Grand Total in Tons** | **0.013** | **0.087** | **0.145** | **0.003** | **0.014** | **0.014** | |
| | | | **Building Demo Grand Total in Metric Tons** | | | | | | | **18.69** |

Vehicle Trips = 106

**2019**

**Table 8. Building Demo - 2019**

3,705 SF — 185 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator with breakers and jackhammer bits | 31 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 31 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 31 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck | 17 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 0.79 | 8.88 | 9.26 | 0.39 | 1.39 | 1.35 | 2,057 |
| | 1.45 | 8.35 | 6.84 | 0.19 | 1.29 | 1.25 | 944 |
| | 0.52 | 2.77 | 6.90 | 0.21 | 0.46 | 0.44 | 1,055 |
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 0.77 | 3.98 | 18.18 | 0.01 | 0.78 | 0.76 | 1,568 |
| **Subtotal (lbs):** | 4 | 24 | 41 | 1 | 4 | 4 | 5,624 |
| **Building Demo Grand Total in Tons** | **0.002** | **0.012** | **0.021** | **0.000** | **0.002** | **0.002** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **2.55** |

Vehicle Trips = 10

**2020**

**Table 9. Building Demo - 2020**

36,106 SF 1,805 Estimated CY of debris based on 20 SF/CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydraulic excavator with breakers and jackhammer bits | 301 | 86 | 0.59 | 0.23 | 2.57 | 2.68 | 0.11 | 0.40 | 0.39 | 595.46 |
| Wheel Loader w/ integral Backhoe | 301 | 87 | 0.23 | 1.07 | 6.13 | 5.02 | 0.14 | 0.95 | 0.92 | 692.77 |
| Wheel mounted air compressor | 301 | 49 | 0.59 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck | 165 | 230 | 27 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 7.71 | 86.54 | 90.25 | 3.83 | 13.57 | 13.16 | 20,050 |
| | 14.17 | 81.37 | 66.68 | 1.88 | 12.60 | 12.22 | 9,199 |
| | 5.04 | 27.03 | 67.30 | 2.07 | 4.45 | 4.32 | 10,287 |
| | VOC | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| | lb | lb | lb | lb | lb | lb | lb |
| | 7.47 | 38.61 | 176.49 | 0.08 | 7.61 | 7.39 | 15,221 |
| **Subtotal (lbs):** | 34 | 234 | 401 | 8 | 38 | 37 | 54,756 |
| **Building Demo Grand Total in Tons** | **0.017** | **0.117** | **0.200** | **0.004** | **0.019** | **0.019** | |
| **Building Demo Grand Total in Metric Tons** | | | | | | | **24.84** |

Vehicle Trips = 94

**Table 10. Fugitive Dust**

| Year | $PM_{10}$ tons/acre/mo | acres | days of disturbance | $PM_{10}$ Total (tons) | $PM_{2.5}/PM_{10}$ Ratio | $PM_{2.5}$ Total (tons) |
|---|---|---|---|---|---|---|
| TBD - Construction | 0.42 | 3.5 | 90 | 6.6 | 0.1 | 0.7 |
| TBD - Demo | 0.42 | 0.6 | 20 | 0.3 | 0.1 | 0.0 |
| 2019 | 0.42 | 0.1 | 5 | 0.0 | 0.1 | 0.0 |
| 2020 | 0.42 | 0.8 | 30 | 0.5 | 0.1 | 0.1 |

**Table 11. Annual Construction Worker POVs - 2019 - TBD**

| Year | Vehicle Trips | mile/trip | VOCs lb/mi | CO lb/mi | NOx lb/mi | $SO_2$ lb/mi | $PM_{10}$ lb/mi | $PM_{2.5}$ lb/mi | $CO_2$ g/mi | $CH_4$ g/mi | $N_2O$ g/mi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TBD - Construction | 302 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| TBD - Demo | 106 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| 2019 | 10 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |
| 2020 | 94 | 6 | 0.00129 | 0.03681 | 0.00510 | 0.00001 | 0.00021 | 0.00019 | 364.00 | 0.031 | 0.032 |

| VOCs ton/year | CO ton/year | NOx ton/year | $SO_2$ ton/year | $PM_{10}$ ton/year | $PM_{2.5}$ ton/year | $CO_2e$ metric ton/year |
|---|---|---|---|---|---|---|
| 0.001 | 0.033 | 0.005 | 0.000 | 0.000 | 0.000 | 0.7 |
| 0.000 | 0.012 | 0.002 | 0.000 | 0.000 | 0.000 | 0.2 |
| 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.0 |
| 0.000 | 0.010 | 0.001 | 0.000 | 0.000 | 0.000 | 0.2 |

**Table 12. Wallops Mainland and Island Area Construction Summary**

| YEAR | VOC<br>T/yr | CO<br>T/yr | NOx<br>T/yr | $SO_2$<br>T/yr | $PM_{10}$<br>T/yr | $PM_{2.5}$<br>T/yr | $CO_2$<br>MT/yr |
|---|---|---|---|---|---|---|---|
| TBD - Construction | 0.12 | 0.54 | 1.60 | 0.02 | 6.70 | 0.74 | 140 |
| TBD - Demo | 0.01 | 0.10 | 0.15 | 0.00 | 0.27 | 0.04 | 19 |
| 2019 | 0.00 | 0.01 | 0.02 | 0.00 | 0.01 | 0.00 | 3 |
| 2020 | 0.02 | 0.12 | 0.20 | 0.00 | 0.52 | 0.07 | 25 |

**TAB D. CONSTRUCTION EMISSIONS - Dredging and Bridge Construction**

**Basic Conversions**

| | |
|---|---|
| 453.59 | grams per pound |
| 43,560 | Conversion from Acre to SF |
| 0.03704 | Cubic feet to Cubic Yards |
| 0.1111 | Square Feet to Square Yards |
| 1.4 | tons/CY for Gravel |
| 80,000 | lbs/Truck Load for Delivery |
| 1.66 | CY for each CY of asphalt/concrete demo |
| 0.333333333 | asphalt thickness for demolition |
| 0.333333333 | asphalt thickness for pavement |
| 2000 | pounds per ton |
| 145 | lb/ft$^3$ density of Hot Mix Asphalt |
| 0.666666667 | asphalt thickness for pavement on runways |

**Dredging**

**Table 1. Mechanical Dredge 2019-2023**

500,000 CY

| | | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Off-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/hp-hr | **CO** g/hp-hr | **NOx** g/hp-hr | **$SO_2$** g/hp-hr | **$PM_{10}$** g/hp-hr | **$PM_{2.5}$** g/hp-hr | **$CO_2$** g/hp-hr |
| Mechanical Dredge- main | 1,529 | 1,800 | 1,342 | 0.40 | 0.52 | 1.92 | 7.41 | 0.11 | 0.32 | 0.31 | 529.46 |
| Mechanical Dredge- auxiliary | 1,529 | 200 | 149 | 0.30 | 0.46 | 1.55 | 5.90 | 0.11 | 0.31 | 0.30 | 529.64 |
| **Marine Vessel Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/kw-hr | **CO** g/kw-hr | **NOx** g/kw-hr | **$SO_2$** g/kw-hr | **$PM_{10}$** g/kw-hr | **$PM_{2.5}$** g/kw-hr | **$CO_2$** g/kw-hr |
| Tender Boat - main | 1,529 | 300 | 224 | 0.40 | 0.27 | 1.5 | 10 | 0.63 | 0.3 | 0.291 | 758.85 |
| Tender Boat- auxiliary | 1,529 | 35 | 26 | 0.40 | 0.27 | 2 | 11 | 0.63 | 0.9 | 0.873 | 758.85 |
| Survey Vessel | 510 | 100 | 75 | 0.40 | 0.27 | 1.7 | 10 | 0.63 | 0.4 | 0.388 | 758.85 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 1,268.98 | 4,662.79 | 17,975.90 | 276.42 | 782.01 | 758.55 | 1,285,061 |
| | 93.86 | 313.87 | 1,193.73 | 23.04 | 63.48 | 61.58 | 107,124 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 81.45 | 452.48 | 3,016.51 | 190.04 | 90.50 | 87.78 | 228,908 |
| | 9.50 | 70.39 | 387.12 | 22.17 | 31.67 | 30.72 | 26,706 |
| | 9.05 | 56.98 | 335.17 | 21.12 | 13.41 | 13.00 | 25,434 |
| **Subtotal (lbs):** | **1,463** | **5,557** | **22,908** | **533** | **981** | **952** | **1,673,233** |
| **Dredging Total in Tons** | **0.73** | **2.78** | **11.45** | **0.27** | **0.49** | **0.48** | |
| **Dredging Total in Metric Tons** | | | | | | | **759** |

**Table 2. Materials Handling post dredge 2019-2023**

500,000 CY

| | | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Off-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/hp-hr | **CO** g/hp-hr | **NOx** g/hp-hr | **$SO_2$** g/hp-hr | **$PM_{10}$** g/hp-hr | **$PM_{2.5}$** g/hp-hr | **$CO_2$** g/hp-hr |
| Loader w/ integral Backhoe | 2,500 | 87 | 65 | 0.21 | 1.43 | 7.35 | 6.35 | 0.15 | 1.06 | 1.03 | 691.66 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck | 8,929 | 230 | 16 | | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 144.18 | 740.10 | 639.30 | 14.98 | 107.06 | 103.85 | 69,648 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 240.28 | 1,242.19 | 5,678.63 | 2.64 | 244.84 | 237.76 | 489,735 |
| **Subtotal (lbs):** | **384** | **1,982** | **6,318** | **18** | **352** | **342** | **559,383** |
| **Materials Handling Total in Tons** | **0.19** | **0.99** | **3.16** | **0.01** | **0.18** | **0.17** | |
| **Materials Handling Total in Metric Tons** | | | | | | | **254** |

**Table 3. Annual Emissions from Dredging**

| YEAR | VOC T/yr | CO T/yr | NOx T/yr | $SO_2$ T/yr | $PM_{10}$ T/yr | $PM_{2.5}$ T/yr | $CO_2$ MT/yr |
|---|---|---|---|---|---|---|---|
| Annually | 0.18 | 0.75 | 2.92 | 0.06 | 0.13 | 0.13 | 203 |

**Bridge**

**Table 4. Site Prep - Excavate/Fill - Trenching - Grading - 2019-2022**

| | | | | | | |
|---|---|---|---|---|---|---|
| Site Prep - Excavate/Fill (CY) | 12,963 CY | Assume 100% hauled in or out | 12,963 CY hauled | | | |
| Trenching (LF) | 0 LF | Assume 2 ft deep trench, 2 feet wide | 0 CY | Assume 100% hauled in or out | 0 CY hauled | |
| Grading (SY) | 1,556 SF | Convert | 173 SY | Assume compact 0.5 feet (0.166 yards) | 29 CY compacted | |

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|
| Backhoe Excavator | 43 | 243 | 0.59 | 0.34 | 1.21 | 4.03 | 0.12 | 0.22 | 0.22 | 535.79 |
| Skid Steer Loader | 52 | 160 | 0.23 | 0.38 | 1.47 | 4.34 | 0.12 | 0.31 | 0.30 | 535.67 |
| Dozer | 47 | 145 | 0.59 | 0.38 | 1.41 | 4.17 | 0.12 | 0.30 | 0.29 | 535.69 |
| Scraper Hauler Excavator | 47 | 365 | 0.58 | 0.38 | 1.42 | 4.19 | 0.12 | 0.30 | 0.29 | 535.69 |
| Compactor | 15 | 103 | 0.58 | 0.40 | 1.57 | 4.57 | 0.12 | 0.32 | 0.31 | 535.63 |
| Grader | 6 | 285 | 0.58 | 0.34 | 1.21 | 4.07 | 0.12 | 0.23 | 0.22 | 535.79 |
| Trenching with backhoe loader | 3 | 87 | 0.59 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 535.77 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Dump Truck (12 CY capacity) | 926 | 230 | 16 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |
| Delivery Truck | 4 | 365 | 45 | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 4.70 | 16.52 | 55.03 | 1.57 | 3.04 | 2.95 | 7,318 |
| | 1.61 | 6.18 | 18.25 | 0.48 | 1.28 | 1.25 | 2,253 |
| | 3.34 | 12.53 | 36.97 | 1.02 | 2.62 | 2.54 | 4,745 |
| | 8.27 | 31.11 | 91.78 | 2.53 | 6.50 | 6.30 | 11,742 |
| | 0.80 | 3.18 | 9.23 | 0.23 | 0.65 | 0.63 | 1,083 |
| | 0.76 | 2.67 | 8.99 | 0.25 | 0.50 | 0.48 | 1,183 |
| | 0.12 | 0.42 | 1.42 | 0.04 | 0.08 | 0.08 | 180 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 24.92 | 128.82 | 588.90 | 0.27 | 25.39 | 24.66 | 50,787 |
| | 0.26 | 1.35 | 6.18 | 0.00 | 0.27 | 0.26 | 533 |
| **Subtotal (lbs):** | **45** | **203** | **817** | **6** | **40** | **39** | **79,825** |
| **Site Prep Grand Total in Tons** | **0.02** | **0.10** | **0.41** | **0.00** | **0.02** | **0.02** | |
| **Site Prep Grand Total in Metric Tons** | | | | | | | **36** |

Vehicle Trips (per year) 6

**Table 5. Construct bridge base (Cofferdams, Piers)**

1400 Feet of Bridge 4466 CY Concete

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Engine KW | Load Factor | Emission Factors VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | $SO_2$ g/hp-hr | $PM_{10}$ g/hp-hr | $PM_{2.5}$ g/hp-hr | $CO_2$ g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Crane | 2240 | 330 | 246 | 0.21 | 0.25 | 1.22 | 5.26 | 0.11 | 0.21 | 0.20 | 530.30 |
| Backhoe/loader | 622 | 98 | 73 | 0.21 | 0.35 | 1.25 | 4.23 | 0.12 | 0.24 | 0.23 | 535.77 |
| Small generator | 2489 | 10 | 7 | 0.43 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| Concrete Truck | 213 | 300 | 224 | 0.43 | 0.19 | 1.45 | 4.32 | 0.12 | 0.21 | 0.20 | 536.26 |
| Pile Driver | 2,240 | 260 | 194 | 0.43 | 0.46 | 1.55 | 5.90 | 0.11 | 0.31 | 0.30 | 529.64 |
| **Marine Vessel Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/kw-hr | **CO** g/kw-hr | **NOx** g/kw-hr | **$SO_2$** g/kw-hr | **$PM_{10}$** g/kw-hr | **$PM_{2.5}$** g/kw-hr | **$CO_2$** g/kw-hr |
| Tugboat - main | 2,240 | 2,000 | 1491 | 0.6 | 0.27 | 2.50 | 13.00 | 0.63 | 0.30 | 0.29 | 722.10 |
| Tugboat - auxiliary | 2,240 | 200 | 149 | 0.4 | 0.27 | 1.50 | 10.00 | 0.63 | 0.40 | 0.39 | 758.85 |
| Work Boat | 2,240 | 200 | 149 | 0.4 | 0.27 | 1.50 | 10.00 | 0.63 | 0.40 | 0.39 | 758.85 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Delivery truck | 388 | 180 | 40 | | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions VOC lb | CO lb | NOx lb | $SO_2$ lb | $PM_{10}$ lb | $PM_{2.5}$ lb | $CO_2$ lb |
|---|---|---|---|---|---|---|---|
| | 84.09 | 417.35 | 1,800.06 | 39.04 | 71.09 | 68.96 | 181,484 |
| | 9.84 | 35.24 | 119.50 | 3.25 | 6.74 | 6.54 | 15,124 |
| | 6.19 | 33.24 | 82.77 | 2.55 | 5.47 | 5.31 | 12,651 |
| | 11.36 | 88.11 | 261.73 | 6.99 | 12.73 | 12.34 | 32,485 |
| | 256.20 | 856.78 | 3,258.54 | 62.90 | 173.29 | 168.09 | 292,419 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 1,193.15 | 11,047.65 | 57,447.79 | 2,784.01 | 1,325.72 | 1,286 | 3,191,004 |
| | 79.54 | 441.91 | 2,946.04 | 185.60 | 117.84 | 114 | 223,560 |
| | 79.54 | 441.91 | 2,946.04 | 185.60 | 117.84 | 114 | 223,560 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 25.78 | 133.26 | 609.18 | 0.28 | 26.27 | 25.51 | 52,537 |
| **Subtotal (lbs):** | **1,746** | **13,495** | **69,472** | **3,270** | **1,857** | **1,801** | **4,224,824** |
| **Bridge Construction Total in Tons** | **0.87** | **6.75** | **34.74** | **1.64** | **0.93** | **0.90** | |
| **Bridge Construction Total in Metric Tons** | | | | | | | **1916** |

Vehicle Trips (per year) 378

**Table 6. Construct superstructure, final roadway approaches (concrete)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 26 Prestress Bridge Section | | Approaches | 40,000 | SF | | | | |
| Pavement - Surface Area | 40,000 SF | | | 494 CY | | | | | | | |

| | | | | | Emission Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Off-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/hp-hr | **CO** g/hp-hr | **NOx** g/hp-hr | **$SO_2$** g/hp-hr | **$PM_{10}$** g/hp-hr | **$PM_{2.5}$** g/hp-hr | **$CO_2$** g/hp-hr |
| Crane | 416 | 170 | 127 | 0.21 | 0.25 | 1.22 | 5.26 | 0.11 | 0.21 | 0.20 | 530.30 |
| Grader | 184 | 150 | 112 | 0.59 | 1.06 | 3.52 | 8.24 | 0.06 | 0.47 | 0.47 | 568.30 |
| Roller | 184 | 30 | 22 | 0.59 | 0.70 | 3.18 | 7.20 | 0.05 | 0.28 | 0.28 | 568.30 |
| Paving/Concrete Machine | 245 | 164 | 122 | 0.53 | 1.14 | 3.71 | 8.87 | 0.49 | 0.49 | 0.49 | 568.30 |
| Small diesel engines | 245 | 25 | 19 | 0.43 | 0.26 | 1.41 | 3.51 | 0.11 | 0.23 | 0.22 | 536.20 |
| Concrete Truck | 155 | 300 | 224 | 0.43 | 0.19 | 1.45 | 4.32 | 0.12 | 0.21 | 0.20 | 536.26 |
| **Marine Vessel Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/kw-hr | **CO** g/kw-hr | **NOx** g/kw-hr | **$SO_2$** g/kw-hr | **$PM_{10}$** g/kw-hr | **$PM_{2.5}$** g/kw-hr | **$CO_2$** g/kw-hr |
| Tugboat - main | 416 | 2,000 | 1491 | 0.6 | 0.27 | 2.5 | 13 | 0.63 | 0.3 | 0.29 | 722.10 |
| Tugboat - auxiliary | 416 | 200 | 149 | 0.4 | 0.27 | 1.5 | 10 | 0.63 | 0.4 | 0.39 | 758.85 |
| Work Boat | 416 | 200 | 149 | 0.4 | 0.27 | 1.5 | 10 | 0.63 | 0.4 | 0.39 | 758.85 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **$SO_2$** lb/mile | **$PM_{10}$** lb/mile | **$PM_{2.5}$** lb/mile | **$CO_2$** lb/mile |
| Delivery truck | 150 | 180 | 40 | | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | Annual Emissions | | | | | | |
|---|---|---|---|---|---|---|---|
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 8.04 | 39.93 | 172.21 | 3.73 | 6.80 | 6.60 | 17,363 |
| | 38.07 | 126.27 | 295.34 | 2.04 | 16.81 | 16.81 | 20,374 |
| | 5.00 | 22.82 | 51.60 | 0.36 | 2.02 | 2.02 | 4,075 |
| | 53.29 | 173.94 | 416.57 | 23.19 | 23.19 | 23.19 | 26,681 |
| | 1.52 | 8.18 | 20.37 | 0.63 | 1.35 | 1.31 | 3,113 |
| | 8.28 | 64.21 | 190.73 | 5.09 | 9.27 | 8.99 | 23,672 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 221.58 | 2,051.71 | 10,668.87 | 517.03 | 246.20 | 239 | 592,615 |
| | 14.77 | 82.07 | 547.12 | 34.47 | 21.88 | 21 | 41,518 |
| | 14.77 | 82.07 | 547.12 | 34.47 | 21.88 | 21 | 41,518 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 9.97 | 51.52 | 235.52 | 0.11 | 10.15 | 9.86 | 20,312 |
| **Subtotal (lbs):** | **375** | **2,703** | **13,145** | **621** | **360** | **350** | **791,242** |
| **Superstructure Construction Total in Tons** | **0.19** | **1.35** | **6.57** | **0.31** | **0.18** | **0.18** | |
| **Superstructure Construction Total in Metric Tons** | | | | | | | **359** |

Vehicle Trips (per year) 70

**Table 7. Demo Asphalt/Concrete- 2023**

20,000 CY

| Off-road Equipment | Cumulative Hours of Operation | Engine HP | Enging KW | Load Factor | VOC g/hp-hr | CO g/hp-hr | NOx g/hp-hr | SO2 g/hp-hr | PM10 g/hp-hr | PM2.5 g/hp-hr | CO2 g/hp-hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Emission Factors | | | | | | |
| D-6K Crawler Dozer with attachments | 2,125 | 125 | 93 | 0.58 | 0.34 | 1.21 | 4.08 | 0.12 | 0.23 | 0.22 | 535.79 |
| Wheel mounted air compressor | 2,125 | 49 | 37 | 0.59 | 0.33 | 2.54 | 4.53 | 0.13 | 0.54 | 0.53 | 595.16 |
| excavator (CAT 345D L or similar) | 445 | 380 | 283 | 0.59 | 0.31 | 2.50 | 4.51 | 0.13 | 0.55 | 0.54 | 595.21 |
| **Marine Vessel Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Engine KW** | **Load Factor** | **VOC** g/kw-hr | **CO** g/kw-hr | **NOx** g/kw-hr | **$SO_2$** g/kw-hr | **$PM_{10}$** g/kw-hr | **$PM_{2.5}$** g/kw-hr | **$CO_2$** g/kw-hr |
| Tugboat - main | 523 | 2,000 | 1491 | 0.6 | 0.27 | 2.5 | 13 | 0.63 | 0.3 | 0.29 | 722.10 |
| Tugboat - auxiliary | 523 | 200 | 149 | 0.4 | 0.27 | 1.5 | 10 | 0.63 | 0.4 | 0.39 | 758.85 |
| Work Boat | 523 | 200 | 149 | 0.4 | 0.27 | 1.5 | 10 | 0.63 | 0.4 | 0.39 | 758.85 |
| **On-road Equipment** | **Cumulative Hours of Operation** | **Engine HP** | **Productivity based Speed (miles/hour)** | | **VOC** lb/mile | **CO** lb/mile | **NOx** lb/mile | **SO2** lb/mile | **PM10** lb/mile | **PM2.5** lb/mile | **CO2** lb/mile |
| Dump Truck | 1,650 | 230 | 27 | | 0.00166 | 0.00858 | 0.03922 | 0.00002 | 0.00169 | 0.00164 | 3.38 |

| | VOC lb | CO lb | NOx lb | SO2 lb | PM10 lb | PM2.5 lb | CO2 lb |
|---|---|---|---|---|---|---|---|
| | Annual Emissions | | | | | | |
| | 116.73 | 410.00 | 1385.57 | 39.14 | 76.77 | 74.47 | 181,947 |
| | 44.38 | 344.13 | 613.06 | 17.34 | 73.39 | 71.19 | 80,593 |
| | 68.64 | 548.82 | 990.58 | 28.14 | 121.31 | 117.67 | 130,827 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 278.31 | 2,576.98 | 13,400.29 | 649.40 | 309.24 | 300 | 744,335 |
| | 18.55 | 103.08 | 687.19 | 43.29 | 27.49 | 27 | 52,148 |
| | 18.55 | 103.08 | 687.19 | 43.29 | 27.49 | 27 | 52,148 |
| | **VOC** lb | **CO** lb | **NOx** lb | **$SO_2$** lb | **$PM_{10}$** lb | **$PM_{2.5}$** lb | **$CO_2$** lb |
| | 74.68 | 386.06 | 1,764.88 | 0.82 | 76.09 | 73.89 | 152,206 |
| **Subtotal (lbs):** | **619.84** | **4472.15** | **19528.78** | **821.42** | **711.78** | **690.51** | **1,394,203** |
| **Demo Asphalt/Concrete Total in Tons** | **0.31** | **2.24** | **9.76** | **0.41** | **0.36** | **0.35** | |
| **Demo Asphalt/Concrete Total in Metric Tons** | | | | | | | **632** |

Vehicle Trips (per year) 163

**Table 9. Bridge POV 2019- 2023**

| Year | Vehicle Trips | mile/trip | **VOCs** lb/mi | **CO** lb/mi | **NOx** lb/mi | **$SO_2$** lb/mi | **$PM_{10}$** lb/mi | **$PM_{2.5}$** lb/mi | **$CO_2$** g/mi | **$CH_4$** g/mi | **$N_2O$** g/mi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Any year 2019 - 2023 | 617 | 6 | 0.00128593 | 0.03681076 | 0.00509876 | 0.00001339 | 0.00020844 | 0.00019220 | 364.00 | 0.031 | 0.032 |
| | | | **VOCs** ton/year | **CO** ton/year | **NOx** ton/year | **$SO_2$** ton/year | **$PM_{10}$** ton/year | **$PM_{2.5}$** ton/year | **$CO_2e$** metric ton/year | | |
| | | | 2.38E-03 | 6.81E-02 | 9.43E-03 | 2.48E-05 | 3.86E-04 | 3.55E-04 | 1 | | |

**Table 10. Wallops Causeway Bridge Totals**

| YEAR | **VOC** T/yr | **CO** T/yr | **NOx** T/yr | **$SO_2$** T/yr | **$PM_{10}$** T/yr | **$PM_{2.5}$** T/yr | **$CO_2$** MT/yr |
|---|---|---|---|---|---|---|---|
| 2019 | 0.28 | 2.16 | 8.35 | 1.67 | 0.23 | 0.22 | 2,313 |
| 2020 | 0.28 | 2.16 | 8.35 | 1.67 | 0.23 | 0.22 | 2,313 |
| 2021 | 0.28 | 2.16 | 8.35 | 1.67 | 0.23 | 0.22 | 2,313 |
| 2022 | 0.28 | 2.16 | 8.35 | 1.67 | 0.23 | 0.22 | 2,313 |
| 2023 | 0.59 | 4.39 | 18.12 | 2.08 | 0.58 | 0.56 | 2,945 |

**Table 11. Causeway, Bridge and Dredging Totals**

| YEAR | **VOC** T/yr | **CO** T/yr | **NOx** T/yr | **$SO_2$** T/yr | **$PM_{10}$** T/yr | **$PM_{2.5}$** T/yr | **$CO_2$** MT/yr |
|---|---|---|---|---|---|---|---|
| 2019 | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| 2020 | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| 2021 | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| 2022 | 0.47 | 2.91 | 11.28 | 1.73 | 0.36 | 0.35 | 2,515 |
| 2023 | 0.78 | 5.15 | 21.04 | 2.14 | 0.72 | 0.69 | 3,148 |

| Project Name | Building Number | Type (Renov or Const) | Year | FootPrint (AC) | Clearing (AC) | Grading (sf) | Demo Bldgs (SF) | Demo asphalt/ concrete (SF) | Site Prep - Excavate/Fill (CY) | Trenching (LF) | Building Construction - Total Size (sf) | Building Construction foundation footprint (sf) | # Stories | Paving - Surface area (SF) | Pavement type, vehicle or aircraft | Paving - HMA (CF) | Sidewalks (sf) | Gravel Work (CY) | Concrete Work - sidewalks, etc (CY) | Concrete Work - foundation (CY) | Runway Construction (Concrete and Asphalt) (SF) | Concrete Pilings Required | Building Square Footage (original for Renovation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Main Base** | | | | | | | | | | | | | | | | | | | | | | | |
| Commercial Space Terminal | N/A | New | TBD | 0.80 | - | 35,000 | | | 1,296 | - | 35,000 | 35,000 | 1 | 3,500 | | 1,167 | 1,750 | 745 | 22 | 5,185 | | | |
| Runway 04/22 Extension | N/A | New | TBD | 4.30 | - | 187,500 | | | 20,833 | 2,500 | - | - | - | | Aircraft | | | 20,833 | | | 187,500 | | |
| Sounding Rocket Program Facility | E-107 | New | TBD | 0.46 | 0.25 | 20,000 | 6,040 | 604 | 1,329 | - | 20,000 | 20,000 | 1 | 2,000 | Vehicle | 667 | 1,000 | 426 | 12 | 2,963 | - | - | |
| Range and Project Management Facility | N/A | RBR | TBD | 1.72 | 1.72 | - | 65,000 | 72,000 | 27,400 | - | 65,000 | 65,000 | 1 | 6,500 | Vehicle | 2,167 | 3,250 | 1,384 | 40 | 9,630 | - | - | |
| **Totals TBD** | | | | **7.28** | **2.0** | **242,500** | **71,040** | **72,604** | **50,858** | **2,500** | **120,000** | **120,000** | **-** | **12,000** | **-** | **4,000** | **6,000** | **23,389** | **74** | **17,778** | **187,500** | **-** | |
| Packing and Crating Facility | D-049 | Demo | TBD | 0.08 | - | - | 3,200 | 320 | 704 | - | - | - | - | - | - | - | - | - | - | - | - | | |
| ATC Tower | A-001 | Demo | TBD | 0.10 | - | 4,232 | 4,232 | 423 | 931 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Source Evaluation Board Building | A-131 | Demo | TBD | 0.02 | - | 882 | 882 | 88 | 194 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Air Support | C-015 | Demo | TBD | 0.12 | - | 5,097 | 5,097 | 510 | 1,121 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Groundwater Remediation Facility | E-010 | Demo | TBD | 0.09 | - | 3,909 | 3,909 | 391 | 860 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Management Education Center | E-104 | Demo | TBD | 0.80 | - | 35,000 | 35,000 | 3,500 | 7,700 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Reproduction Facility | F-001 | Demo | TBD | 0.14 | - | 5,940 | 5,940 | 594 | 1,307 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Telecommunications Facility | F-002 | Demo | TBD | 0.15 | - | 6,495 | 6,495 | 650 | 1,429 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Visitors Center | J-017 | Demo | TBD | 0.09 | - | 3,728 | 3,728 | 373 | 820 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Garage | H-030 | Demo | TBD | 0.05 | - | 2,068 | 2,068 | 207 | 455 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| Empty Drum Storage | F-014 | Demo | TBD | 0.02 | - | 960 | 960 | 96 | 211 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| WFF Administration | F-006 | Demo | TBD | 0.34 | - | - | 14,613 | 1,461 | 3,215 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| Compressed Air Distribution Facility | F-021 | Demo | TBD | - | - | - | 110 | 11 | 24 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Rain Simulator Shelter | F-162 | Demo | TBD | 0.06 | - | - | 2,500 | 250 | 550 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Supply Warehouse | F-019 | Demo | TBD | 0.51 | - | - | 22,400 | 2,240 | 4,928 | - | - | - | - | - | - | - | - | - | - | - | | | |
| Optical Lab | D-101 | Demo | TBD | 0.05 | - | - | 2,100 | 210 | 462 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| Post Office | E-007 | Demo | TBD | 0.18 | - | - | 7,902 | 790 | 1,738 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Credit Union | N-133 | Demo | TBD | 0.03 | - | - | 1,446 | 192 | 328 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| Cafeteria/Photo Lab/Gift Shop | E-002 | Demo | TBD | 0.70 | - | - | 30,520 | 3,052 | 6,714 | - | - | - | 1 | - | - | - | - | - | - | - | | | |
| **Totals TBD** | | | | **3.52** | | **68,311** | **153,102** | **15,358** | **33,692** | **0** | **0** | **0** | **-** | **0** | **-** | **0** | **0** | **0** | **0** | **0** | **0** | **-** | **0** |
| Central Heating Plant | D-008 | Demo | 2019 | 0.16 | - | 0 | 7,137 | 714 | 1,570 | | | | | | | | | | | | | | |
| **Totals 2019** | | | | **0.16** | **-** | **7,137** | **7,137** | **714** | **71** | | | | | | | | | | | | | | |
| Consolidated Laboratories | N/A | RBR | 2020 | 0.28 | | 12000 | 12000 | 1,200 | | | 12,000 | 12,000 | 1 | 600 | Vehicle | | 600 | 244 | 7 | 1,778 | | | |
| **Totals 2020** | | | | **0.28** | **-** | **12,000** | **12,000** | **1,200** | | **-** | **12,000** | **12,000** | **1** | **600** | **Vehicle** | | **600** | **244** | **7** | **1,778** | **-** | **-** | **-** |
| Health/Quality Verification Lab | F-160 | Demo | 2022 | 0.51 | | | 22,337 | 2,234 | 4,914 | | | | | | | | | | | | | | |
| **Totals 2022** | | | | **0.51** | | **-** | **22,337** | **2,234** | **4,914** | **-** | | | **-** | | **-** | | | | | | **-** | **-** | **-** |

| Project Name | Building Number | Type (Renov or Const) | Year | FootPrint (AC) | Clearing (AC) | Grading (sy) | Demo Bldgs (SF) | Demo asphalt/ concrete (SF) | Site Prep - Excavate/Fill (CY) | Trenching (LF) | Building Construction - Total Size (sf) | Building Construction foundation footprint (sf) | # Stories | Paving - Surface area (SF) | Pavement type, vehicle or aircraft | Paving - HMA (CF) | Sidewalks (sf) | Gravel Work (CY) | Concrete Work - sidewalks, etc (CY) | Concrete Work - foundation (CY) | Runway Construction (Concrete and Asphalt) (CY) | Concrete Pilings Required | Building Square Footage (original for Renovation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mainland and Wallops Island** | | | | | | | | | | | | | | | | | | | | | | | |
| ELV Launch Pad 0-C | | Infrastructure - New | TBD | 3.18 | 3.18 | 15,389 | - | - | 6,840 | 500 | | | 1 | | | - | - | 0 | - | | 0 | 10 | |
| DoD SM-3 Vertical Launch System Pad | | New | TBD | 0.00 | 0.00 | 12 | - | - | 47 | 500 | | | | - | | - | | 5 | - | | 23 | 4 | |
| ESSM Launch System Pad and Blockhouse | | New | TBD | | | 2,222 | - | - | 6,667 | 500 | - | - | - | - | | - | | 2,222 | - | | 4,444 | | |
| Radar and Computer Facility (AEGIS) | | New | TBD | 0.34 | 0.34 | 14,640 | - | - | 889 | 1,800 | 12,000 | 12,000 | 1 | 2,400 | Vehicle | 800 | 240 | 533 | 3 | 222 | - | - | |
| **Totals TBD** | | | | **3.52** | **3.5** | **32,263** | | | **14,442** | **3,300** | **12,000** | **12,000** | **-** | **2,400** | **-** | **800** | **240** | **2,761** | **3** | **222** | **4,468** | **-** | |
| Block House 3 | | Demo | TBD | 0.48 | | | 20872 | | | | | | | | | | | | | | | | |
| Terminal Cubicle | | Demo | TBD | 0.00 | | | 97 | | | | | | | | | | | | | | | | |
| Cable Terminal | | Demo | TBD | 0.01 | | | 541 | | | | | | | | | | | | | | | | |
| Fuel Storage Magazine | | Demo | TBD | 0.04 | | | 1681 | | | | | | | | | | | | | | | | |
| Island Radar Control Building | | Demo | TBD | 0.08 | | | 3503 | | | | | | | | | | | | | | | | |
| Camera Stand | | Demo | TBD | 0.01 | | | 400 | | | | | | | | | | | | | | | | |
| **Totals TBD** | | | | **0.6** | | | **27,094** | | | | | | | | **-** | | | | | | | **-** | |
| AN FSP Radar | Y-055 | Demo | 2019 | 0.08 | - | - | 3,510 | | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Sewer Ejector Station | Y-061 | Demo | 2019 | 0.00 | - | - | 195 | | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| **Totals 2019** | | | | **0.09** | **-** | **-** | **3,705** | | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| Former Coast Guard Station | | Demo | 2020 | 0.10 | | | 4,140 | | | | | | | | | | | | | | | | |
| Rocket Motor Storage Facility | | Demo | 2020 | 0.19 | | | 8,200 | | | | | | | | | | | | | | | | |
| Fire Department Support Building | | Demo | 2020 | 0.02 | | | 1,024 | | | | | | | | | | | | | | | | |
| Paint Shop | | Demo | 2020 | 0.06 | | | 2,410 | | | | | | | | | | | | | | | | |
| Paint Shop Storage | | Demo | 2020 | 0.01 | | | 422 | | | | | | | | | | | | | | | | |
| Electrical Storage Building | | Demo | 2020 | 0.02 | | | 1,000 | | | | | | | | | | | | | | | | |
| NSEC Performance Test Building | | Demo | 2020 | 0.27 | | | 11,617 | | | | | | | | | | | | | | | | |
| Block House 1 | | Demo | 2020 | 0.08 | | | 3,300 | | | | | | | | | | | | | | | | |
| Movable Launch Shelter Building | | Demo | 2020 | 0.04 | | | 1,890 | | | | | | | | | | | | | | | | |
| Launch Control Building | | Demo | 2020 | 0.01 | | | 240 | | | | | | | | | | | | | | | | |
| Rocket Flight Hardware Storage | Y-050 | Demo | 2020 | 0.02 | - | - | 955 | | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Fire Pump House | X-091 | Demo | 2020 | 0.01 | - | - | 235 | | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | |
| Relocation of Radar 3 (Relocated to Mainland) | | Relocation | 2020 | 0.01 | - | | 625 | | - | - | 625 | 625 | 1 | - | - | - | - | 12 | - | 93 | - | - | - |
| Storm Drainage Pump | Y-046 | Demo | 2020 | 0.00 | - | - | 48 | | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | |
| **Totals 2020** | | | | **0.83** | **-** | **0** | **36,106** | **0** | **-** | **-** | **625** | **625** | **-** | **-** | **-** | **-** | **-** | **12** | **-** | **93** | **-** | **-** | **-** |

| Project Name | Building Number | Type (Renov or Const) | Year | FootPrint (AC) | Clearing (AC) | Grading (sf) | Demo Bldgs (SF) | Demo asphalt/ concrete (CY) | Site Prep - Excavate/Fill (CY) | Trenching (LF) | Building Construction - Total Size (sf) | Building Construction foundation footprint (sf) | # Stories | Paving - Surface area (SF) | Pavement type, vehicle or aircraft | Paving - HMA (CF) | Sidewalks (sf) | Gravel Work (CY) | Concrete Work - sidewalks, etc (CY) | Concrete Work - foundation (CY) | Runway Construction (Concrete and Asphalt) (SF) | Concrete Pilings Required | Dredging (CY) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Causeway** | | | | | | | | | | | | | | | | | | | | | | | |
| Causeway Bridge | | | 2019-2023 | 0.30 | - | 14,000 | - | - | 12,963 | | - | - | - | 70,000 | Vehicle - Concrete | - | - | - | - | - | - | Yes | |
| Causeway Bridge Demolition | | | 2023 | | - | - | - | 20,000 | - | - | - | - | - | - | - | - | - | - | - | - | - | no | |
| Dredging | | | 2019-2023 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 500,000 |

20,000 tons construction debris
20,000 CY
based on 2000 lb/cy

## TAB F. OPERATIONAL EMISSIONS

**Table 1. [1]Antares Launch Exhaust Emissions**

| | | | | | |
|---|---|---|---|---|---|
| Burn Rate: | 2,414 lbm/sec | Fuel (RP-1): | 142,735 x 1 = | | 142,735 lbm |
| Time to 10,000 ft | 45 sec | Oxidizer (LOX): | 390,779 x 1 = | | 390,779 lbm |
| Time to 3,000 feet | 13.50 sec | | | Sum: | 533,514 lbm |

| Compound | Mole Fractions | Molecular Weight | Weight (g/gmole) | Weight Fraction | Total Mass (lbm) | Per-launch Mass (tons) | 6 launches per year total (tons) | Below 3000 ft AGL Mixing Height (tons) | Total in Metric Tons |
|---|---|---|---|---|---|---|---|---|---|
| CO | 0.23932 | 28.01000 | 6.7033532 | 0.254385863 | 135,718 | 67.86 | 407.16 | **24.87** | **22.19** |
| CO2 | 0.26632 | 44.01000 | 11.7207432 | 0.44479103 | 237,302 | 118.65 | **711.91** | | **646** |
| H | 0.00144 | 1.00800 | 0.00145152 | 5.50838E-05 | 29 | 0.01 | 0.09 | | |
| H2 | 0.07231 | 0.32204 | 0.023286712 | 0.000883709 | 471 | 0.24 | 1.41 | | |
| H2O | 0.41938 | 18.01500 | 7.5551307 | 0.286710007 | 152,964 | 76.48 | 458.89 | | |
| O | 0.00002 | 15.99900 | 0.00031998 | 1.21429E-05 | 6 | 0.00 | 0.02 | | |
| OH | 0.00118 | 17.00700 | 0.02006826 | 0.000761571 | 406 | 0.20 | 1.22 | | |
| O2 | 0.00004 | 31.9988 | 0.001279952 | 4.8573E-05 | 26 | 0.01 | 0.08 | | |
| SUM: | 0.99999 | | 26.35112 | 1.00000 | 533,514 | 266.76 | 1,600.54 | | |

Source: Evaluation of Taurus II Static Test Firing and Normal Launch Rocket Plume Emissions, ACTA 2009

| Current Envelope | | | | | |
|---|---|---|---|---|---|
| | **CO** | **CO2** | **NOx** | **PM** | **HCl** |
| Antares | 24.87 | 646 | | | |
| LMLV-3 | 159 | | | 154 | 125 |
| **Total** | **184** | **646** | **0** | **154** | **125** |
| New Envelope | | | | | |
| Castor 1200 Beast | 68.13 | 92.87 | | 154.56 | 107.03 |
| Falcon 9 | | 5,160 | 7.2 | | |
| **Total** | **68** | **5,253** | **7** | **155** | **107** |
| **Net change** | **-116.0** | **4,607.4** | **7.2** | **1.0** | **-18.1** |

**Table 2. LMLV-3 Launch Exhaust Emissions[1]**

| | | | | |
|---|---|---|---|---|
| Burn Rate 1 for Castor IV: | 4,436 lb/sec | Fuel (NH4ClO4 in HTPB): | | 293,479 lb total |
| | for 60 sec | Total fuel burned in 60 sec: | | 88,720 lb |
| Burn Rate 2 for Castor IV: | 1,367 lb/sec | Burn duration: | 80 sec | |
| | for 20 sec | Total fuel burned in 20 sec: | | 27,340 lb |
| Time to 3,000 feet | 20 sec | Total fuel burned in 80 sec: | | 116,060 lb |

| Compound | Below 3000 ft AGL Mixing Height (lbs) | Below 3000 ft AGL Mixing Height (tons) | Total for 12 Launches | Total in Metric Tons |
|---|---|---|---|---|
| Al2O3 | 25,596 | 13 | 154 | 139 |
| CO | 26,544 | 13 | 159 | 144 |
| HCl | 20,856 | 10 | 125 | 114 |

[1]Data from Environmental Assessment for Range Operations Expansion at the NASA Goddard Space Flight Center. 1997.

**Table 3. Total Existing Launch Envelope Emissions**

| | Al2O3 | HCl | CO | CO2 |
|---|---|---|---|---|
| Total in Tons | 154 | 125 | 184 | 712 |
| Total in Metric Tons | 139 | 114 | 167 | 646 |

Note: CO2 is also emitted from solid rocket fuel combustion, but at much lower concentrations - around an order of magnitude lower compared to Al2O3 and HCl (ATK-EELV Program 1996). This would amount to less than 10 tons for the entire fuel-burning trajectory in 12 launches.

**Table 4. Large Space Launch Booster Emissions - with Castor 1200 solid rocket motors - 12 launches annually**

1,114,115 lb mass of the TP-1148 propellent per motor

| Chemical | ACTA Weight Fraction[1] | Approx. lbs per launch | Approx. tons per launch (metric tons for CO2) | 12 launches annually T/yr except CO2 (MT/yr) |
|---|---|---|---|---|
| $Al_2O_3$ | 0.16797 | 187,138 | 12.68 | 152.19 |
| CO | 0.07519 | 83,770 | 5.68 | 68.13 |
| $CO_2$ | 0.11299 | 125,884 | 7.74 | 92.87 |
| Cl | 0.00052 | 579 | 0.04 | 0.47 |
| HCl | 0.11813 | 131,610 | 8.92 | 107.03 |
| H | 0.00001 | 11 | 0.00 | 0.01 |
| OH | 0.00007 | 78 | 0.01 | 0.06 |
| $H_2$ | 0.00333 | 3,710 | 0.25 | 3.02 |
| $H_2O$ | 0.12725 | 141,771 | 9.61 | 115.30 |
| NO | 0.00001 | 11 | 0.00 | 0.01 |
| $N_2$ | 0.38621 | 430,282 | 29.16 | 349.93 |
| $FeCl_2$ | 0.00261 | 2,908 | 0.20 | 2.36 |

| | | |
|---|---|---|
| Castor 1200 burn time = | | 132.8 s |
| Time to reach 10,000 FT AGL = | | 20 s |
| Time to reach 3,000 FT AGL = | | 18 s |
| | 13.55% | of total time |

[1]ACTA 2012. Evaluation of Toxic Emissions for a Large Solid Propellent Launch Vehicle at Wallops Flight Facility, Table 5-1, page 35.

**Table 5. Falcon 9 Launch Emissions - 6 Launches Annually Including RTLS**

| Launch Vehicle | Max # launches/yr | RP-1 Use gal/launch | RP-1 MMBtu/gal | [1]NOx Tons/launch | NOx Annual Tons | [2]CO2 EF (kg/gal) | CO2 Metric Tons |
|---|---|---|---|---|---|---|---|
| Falcon 9 | 6 | 35,000 | 0.135 | 1.2 | 7.2 | 9.76 | 2,050 |

[1] From Table 4.5-1 of Environmental Assessment for the Operation and Launch of the Falcon 1 and Falcon 9 Space Vehicles at CCAFS, FL 2007

[2] From Environmental Assessment Falcon 9 and Falcon 9 Heavy Launch Vehicle Programs from SLC-4E, Vandenberg AFB 2011.

| Vehicle | Max # RTLS/yr | Vertical Landing sec | [1]CO2 Exhaust lb/sec | Total CO2 exhaust MT/yr |
|---|---|---|---|---|
| Falcon 9 - RTLS | 6 | 17 | 1,121 | 3,111 |

[1] From Table 4.5-1 of Environmental Assessment for the Operation and Launch of the Falcon 1 and Falcon 9 Space Vehicles at CCAFS, FL 2007

**Table 6. Generator Operations**

Wallops Island

Two 3 -MW Caterpillar 175 emergency power generator — Meets EPA Interim Tier 4 emission requirements

| | | Emission Factors | | | | | | Emissions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours/yr | Fuel Flow Rate L/Hr @ 100% | [1]g/kW-hr VOCs | [1]g/kW-hr CO | [1]g/kW-hr NOx | [1]g/kW-hr PM10 | [1]g/kW-hr PM2.5 | [2]kg/l CO2 | **T/yr VOCs** | **T/yr CO** | **T/yr NOx** | **T/yr PM10** | **T/yr PM2.5** | **MT/yr CO2** |
| 360 | 807 | 0.4 | 3.5 | 0.67 | 0.1 | 0.1 | 2.70 | **0.952** | **8.334** | **1.595** | **0.238** | **0.238** | **1,567** |

[1]USEPA Interim Tier 4 emission standards.

[2]Federal GHG Accounting and Reporting Guidance Technical Document, Appendix D, Table D-2. 2010.

Main Base

One 3 -MW Caterpillar 175 emergency power generator

| | | Emission Factors | | | | | | Emissions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours/yr | Fuel Flow Rate L/Hr @ 60% | [1]g/kW-hr VOCs | [1]g/kW-hr CO | [1]g/kW-hr NOx | [1]g/kW-hr PM10 | [1]g/kW-hr PM2.5 | [2]kg/l CO2 | **T/yr VOCs** | **T/yr CO** | **T/yr NOx** | **T/yr PM10** | **T/yr PM2.5** | **MT/yr CO2** |
| 144 | 484 | 0.4 | 3.5 | 0.67 | 0.1 | 0.1 | 2.70 | **0.476** | **4.167** | **0.798** | **0.119** | **0.119** | **783** |

[1]USEPA Interim Tier 4 emission standards.

[2]Federal GHG Accounting and Reporting Guidance Technical Document, Appendix D, Table D-2. 2010.

UAS

**Table 1. Operation of Viking UAS**

| Model | HP | annual # flights | flight time (hr) | BSFC lb/hp-hr | VOC lb/hp-hr | CO lb/hp-hr | NOx lb/hp-hr | PM lb/hp-hr | CO2 g/hp-hr | VOC Tons | CO Tons | NOx Tons | PM Tons | CO2 Metric Tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Viking 300 | 25 | 1,950 | 11 | 0.408 | 0.000966 | 0.004764 | 0.0097884 | 0.000588 | 188 | 0.11 | 0.52 | 1.07 | 0.06 | 101 |

**Table 2. Operation of MQ-4C**

Engine is Rolls-Royce/Allison AE3007H

| Number Type of Operation | Number of Operations per Year | Power Setting | Fuel Flowrate (lb/hr) | Time in Mode | Total Fuel Used | Emission Factor (lb/1000 lb) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | VOCs | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | CO2 |
| Taxi/Idle-out | 1,950 | Idle | 427.65 | 0.1083 | 46.33 | 2.39 | 17.31 | 3.82 | 1.2 | 0.15 | 0.14 | 3.1 |
| Takeoff | 1,950 | Military | 3021.05 | 0.0067 | 20.14 | 0.26 | 0.83 | 20.5 | 1.2 | 0.27 | 0.24 | 3.1 |
| Climbout | 1,950 | Intermediate | 2531.72 | 0.0083 | 21.10 | 0.26 | 0.83 | 17.43 | 1.2 | 0.24 | 0.22 | 3.1 |
| Approach | 1,950 | Approach | 946.85 | 0.0267 | 25.25 | 0.61 | 3.27 | 7.77 | 1.2 | 0.22 | 0.2 | 3.1 |
| Taxi/Idle-In | 1,950 | Idle | 427.65 | 0.1083 | 46.33 | 2.39 | 17.31 | 3.82 | 1.2 | 0.15 | 0.14 | 3.1 |
| | | | | | | Total Emission in pounds | | | | | | |
| | | | | | | VOCs | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | CO2 |
| | | | | | | 215.9 | 1,563.8 | 345.1 | 108.4 | 13.6 | 12.6 | 280 |
| | | | | | | 10.2 | 32.6 | 805.1 | 47.1 | 10.6 | 9.4 | 122 |
| | | | | | | 10.7 | 34.1 | 717.1 | 49.4 | 9.9 | 9.1 | 128 |
| | | | | | | 30.0 | 161.0 | 382.6 | 59.1 | 10.8 | 9.8 | 153 |
| | | | | | | 215.9 | 1,563.8 | 345.1 | 108.4 | 13.6 | 12.6 | 280 |
| | | | | | **Annual emissions (tons/year)** | **0.24** | **1.68** | **1.30** | **0.19** | **0.03** | **0.03** | |
| | | | | | **Annual Emission (metric ton/year)** | | | | | | | **0.44** |

**Table 3. Net Change Based on Total Representative Annual UAS Operations**

| Operations | VOCs | CO | NOx | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | CO2 |
|---|---|---|---|---|---|---|---|
| Original Envelope | 0.03 | 0.2 | 0.4 | NA | 0.05 | 0.05 | 9.6 |
| New Envelope | 0.35 | 2.20 | 2.37 | 0.19 | 0.09 | 0.09 | 101 |
| **Net Change** | **0.32** | **2.00** | **1.97** | **NA** | **0.04** | **0.04** | **91.7** |

Report No. 09-640/5-01

# Evaluation of Taurus II Static Test Firing and Normal Launch Rocket Plume Emissions

Subcontract No.
Prime Contract No.
Task No. *5*

Prepared by

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March 18, 2009

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# 1. INTRODUCTION

The Taurus II launch vehicle is being designed and built by Orbital Sciences Corporation with the objective of launching missions from Wallops Flight Facility (WFF) to service the International Space Station. This report presents the findings of rocket exhaust plume emission and atmospheric dispersion analyses performed for the Taurus II first stage using a large archive of WFF weather balloon soundings. The report also explains the development of input data, describes the basic features of the modeling tools and identifies the assumptions made to support the analyses.

The Taurus II first stage uses liquid propellants commonly found in other modern U.S. built rockets. The first stage fuel is a refined form of kerosene known as RP-1 and the oxidizer is liquid oxygen (LOX). Although these propellants are burned in a fuel rich mixture the exhaust products can be considered environmentally friendly compared to solid propellant exhaust. The use of RP-1/LOX also avoids handling and spill toxic hazards associated with liquid hypergolic propellants. Consequently, the primary chemical exhaust constituent of concern from a toxicity standpoint is carbon monoxide (CO). The hazard associated with exposure to CO can be associated with several industry standard exposure criteria. Since rocket emissions from static test firings or rocket launches are relatively short duration events that only occur a few times a year over the course of the program, short duration or emergency exposure standards are more appropriate than long duration exposure standards designed for work place environments. One such emergency exposure standard is the National Institute for Occupational Safety and Health (NIOSH) definition of the Immediately Dangerous to Life or Health (IDLH) exposure threshold for an airborne chemical. The IDLH is intended to be used in conjunction with workers wearing respirators in contaminated areas, such that if the respirator fails the person could escape the contaminated area without being incapacitated given a maximum exposure of 30 minutes. Perhaps a more appropriate set of exposure guidelines are the Acute Exposure Guideline Levels (AEGLs) that are supported by the EPA. The development of Acute Exposure Guideline Levels (AEGLs) is a collaborative effort of the public and private sectors worldwide. AEGLs are intended to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. The National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances (AEGL Committee) is involved in developing these guidelines to help both national and local authorities, as well as private companies, deal with emergencies involving spills, or other catastrophic exposures. The recommended interim AEGLs for carbon monoxide are listed in Table 1-1.

**Table 1-1: Interim Acute Exposure Guideline Levels (AEGLs) for Carbon Monoxide.**

| AEGL Level | 10 min Exposure [ppm] | 30 min Exposure [ppm] | 60 min Exposure [ppm] | 4 hr Exposure [ppm] |
|---|---|---|---|---|
| AEGL 1 | NR | NR | NR | NR |
| AEGL 2 | 420 | 150 | 83 | 33 |
| AEGL 3 | 1700 | 600 | 330 | 150 |

NR = No exposure level recommended due to insufficient or inconclusive data.

Definitions of the AEGL levels are as follows:

**AEGL-1** is the airborne concentration, expressed as parts per million or milligrams per cubic meter (ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

**AEGL-2** is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

**AEGL-3** is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The time duration that a receptor is exposed to a rocket exhaust plume emission depends upon the cloud transport wind speed and the size of the cloud. The cloud or plume grows in size as it transports downwind. Typical exposure durations are estimated to be in the 10 to 30 minute range but may approach one hour under very light wind conditions.

The report authors do not have toxicological expertise regarding hazardous CO thresholds for flora and fauna that may be of environmental concern. The selection of the most appropriate exposure level to apply to exposed flora and fauna is left to the judgment of others. It is however noted here that the vast majority of emission scenarios evaluated in this study predict far field maximum ground level CO concentrations below 10 parts per million (ppm), which is quite benign relative to all published human hazardous thresholds.

There are two emission scenarios of concern for the Taurus II environmental assessment:

1. Static test firing of the first stage while the stacked vehicle is held stationary on the launch pad. In this scenario the two first stage engines are both ignited and are run through a 52 second thrust profile that ramps the engines up to full performance (112.9%) and back down. Exhaust from the rocket engine nozzles is directed downward into a flame trench and deflected through the flame duct such that the exhaust gases are diverted away from the launch vehicle and nearby facilities. The exhaust plume exits the flame duct at supersonic velocity and the flow is approximately parallel to and slightly above the ground.

2. Normal launch of the Taurus II vehicle. In this scenario a fully configured launch vehicle with payload is ignited on the launch pad at time T-0. The vehicle is held on the pad for approximately 2 seconds as the first stage engines build thrust and then hold-downs are released allowing the vehicle to begin ascent to orbit. During ascent the vehicle velocity steadily increases resulting in a time and altitude varying exhaust product emission rate. Initially the rocket engine exhaust is largely directed into and through the flame duct. As the vehicle lifts off from the pad and clears the launch tower, a portion of the exhaust plume impinges on the pad structure and is directed radially around the launch pad stand. The portion of the rocket plume that interacts with the launch pad and flame trench is referred to as the “ground cloud”. As the vehicle climbs to several hundred feet above the pad, the rocket plume reaches a point where the gases no longer interact with the ground surface and the exhaust plume is referred to as the “contrail cloud”.

The concepts of the ground and contrail clouds are illustrated in Figure 1-1 using a Titan IV launch from Cape Canaveral as an example. For atmospheric dispersion analyses of rocket emissions that could affect receptors on the ground, it has been standard practice at the Federal Ranges (Cape Canaveral and Vandenberg Air Force Base) to simulate the emissions from the ascending launch vehicle from the ground to a vehicle altitude of approximately 3000 meters. The operational toxic dispersion analysis tool used by the Federal Ranges for launch support and public risk assessment is Version 7.13 of the Rocket Exhaust Effluent Diffusion Model (REEDM). This same computer program was used to perform the dispersion analyses for the Taurus II emission scenarios. The features of REEDM pertinent to this study are discussed in the next section.

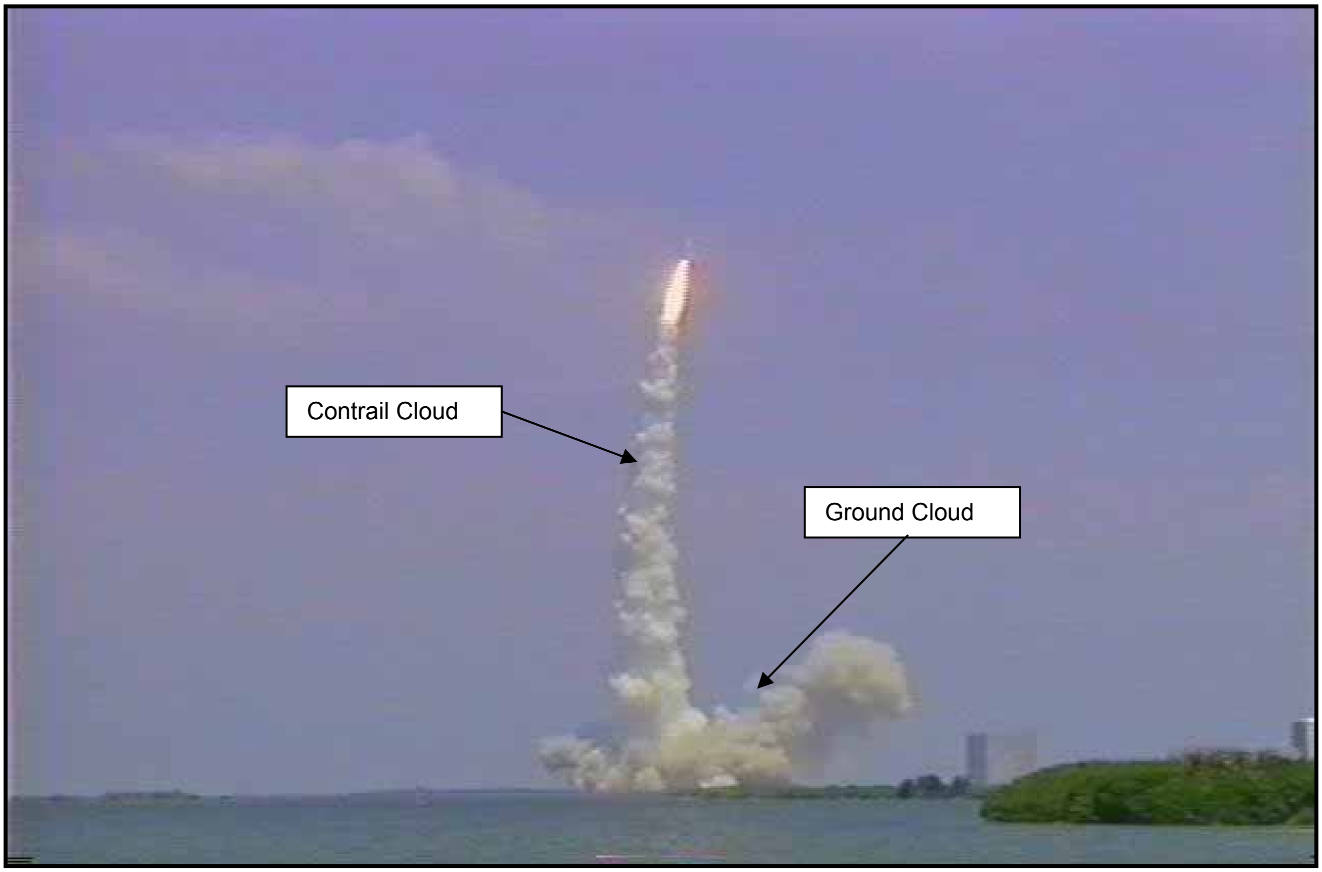


**Figure 1-1. Illustration of the Ground Cloud and Contrail Cloud Portions of a Titan IV Rocket Emission Plume Associated With Normal Vehicle Launch.**

## 2. THE ROCKET EXHAUST EFFLUENT DISPERSION MODEL (REEDM)

REEDM is a toxic dispersion model specifically tailored to address the large buoyant source clouds generated by rocket launches, test firings and catastrophic launch vehicle explosions. Under ongoing Air Force support, REEDM evolved from the NASA Multi-Layer Diffusion Model, which was written initially to evaluate environmental effects associated with the Space Shuttle, and has been generalized to handle a wide variety of launch vehicle types and propellant combinations. REEDM falls in the category of "Gaussian puff" atmospheric dispersion models in that the initial mass distribution of toxic materials within the cloud at the time the cloud reaches thermal stabilization height in the atmosphere is assumed to be normally distributed. By making the Gaussian mass distribution assumption, the differential equation defining mass diffusion can be solved in closed form using exponential functions and may be readily implemented in a fast running computer program. Gaussian puff models are still widely used by the EPA for environmental and permitting studies, by Homeland Security and the Defense Threat Reduction Agency for assessment of chemical, biological and radiological materials, and by the petrochemical industry for accidental releases of industrial chemicals.

REEDM processing of an emission event can be partitioned into the following basic steps:

1. Acquire and process vehicle related data from an input vehicle database file.

2. Acquire and process meteorological data, which in this study is a combination of archived weather balloon soundings used in conjunction with an internal REEDM climatological turbulence algorithm.

3. Acquire the chemical composition and thermodynamic properties of the rocket exhaust emissions and define the initial size, shape, location and heat content of the exhaust cloud (herein referred to as the "source term" or "source cloud"). REEDM has an internal propellant equilibrium combustion model that is used to compute these terms for vehicle catastrophic failure modes but for normal launch and static test firing scenarios this data is calculated external to REEDM and placed in the vehicle database file read by REEDM.

4. Iteratively calculate the buoyant cloud rise rate and cloud growth rate to achieve a converged estimate of the cloud stabilization height above ground, size and downwind position. The cloud rise equations evaluate both cloud thermodynamic state as well as the local atmospheric stability, which is defined by the potential temperature lapse rate.

5. Partition the stabilized cloud into disks and mark whether or not part of the stabilized cloud is above a capping atmospheric temperature inversion. Inversions (or other sufficiently stable air masses) act as a barrier to gaseous mixing and are treated in REEDM as reflective boundaries.

6. Transport the cloud disks downwind and grow the disk size using climatologic model estimates of atmospheric turbulence intensity. Turbulence intensity is a function of wind speed and solar radiation intensity. Turbulence varies with time of day and cloud cover conditions because these influence the solar radiation intensity.

7. Calculate concentrations at ground receptor points and determine the plume or cloud track "centerline" that defines the peak concentration as a function of downwind distance. Concentration at any given receptor point is computed as the sum of exposure contributions from each cloud disk. Concentration is solved using the closed form Gaussian dispersion equation and accounts for the effect of ground and capping inversion reflections.

8. Report concentration centerline values in table format as a function of distance from the source origin (e.g. launch pad)

There are other features and submodels of REEDM that are more fully described in the REEDM technical description manual and will not be reviewed in this report.

There are several important assumptions made in REEDM that have a bearing on this Environmental Assessment study. REEDM was designed to primarily predict hazard conditions downwind from the stabilized exhaust cloud. REEDM does not directly calculate or report cloud concentrations during the buoyant cloud rise phase, however, advanced model users can extract sufficient pertinent cloud data from internal calculations to derive concentration estimates during the cloud rise phase manually. One assumption that REEDM makes about the nature and behavior of a rocket exhaust cloud is that it can be initially defined as a single cloud entity that grows and moves but remains as a single cloud during the formation and cloud rise phases. A consequence of this assumption is that once the cloud lifts off the ground during the buoyant cloud rise phase, there will be no predicted cloud chemical concentration on the ground immediately below the cloud. Ground level concentrations will be predicted to remain at zero ppm until the some of the elevated cloud material is eventually brought back down to ground level by mixing due to atmospheric turbulence. This concept is illustrated in Figure 2-1 and it is noted that REEDM is designed to report concentrations downwind from the stabilized cloud position. The region downwind from the stabilized exhaust cloud is referred to as the "far field". It is also noted here that the most concentrated part of these rocket exhaust clouds remains at an altitude well above the ground level. REEDM is not able to model stochastic uncertainty in the source cloud and atmospheric flow such that if a gust of wind, small turbulence eddy or nuance of the launch pad flame duct structure causes a small portion of the main exhaust cloud to detach from the main cloud, the model will not correctly predict the transport, dispersion or concentration contribution from the detached cloud material. Likewise if there are strong atmospheric updrafts or down drafts, such as associated with development of thunderstorm cells or towering cumulus clouds, REEDM will not correctly model strong vertical displacements of the entire exhaust cloud or strong shearing forces that may completely breakup the cloud under such conditions (these are not favorable conditions for launch either and a planned launch would never be conducted with strong thunderstorm and cloud development activity in the launch area).

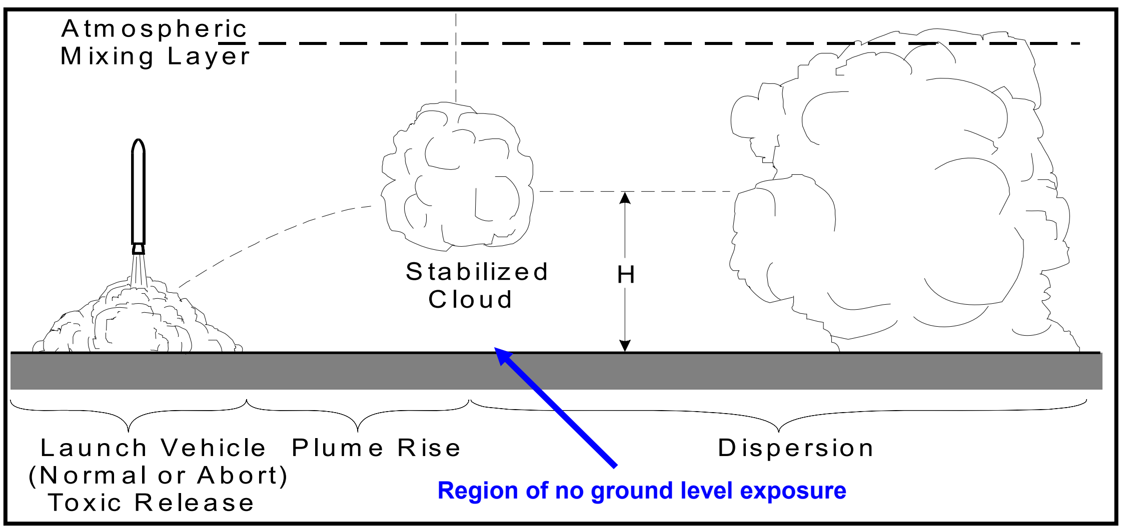


**Figure 2-1. Conceptual Illustration of Rocket Exhaust Source Cloud Formation, Cloud Rise and Cloud Atmospheric Dispersion.**

REEDM is also somewhat constrained by the Gaussian assumptions inherent in the model that require a single average transport wind speed and direction. The portion of the atmosphere selected for averaging the transport winds has been improved over the years of operational use at the Air Force ranges. Old versions of REEDM averaged the winds over the entire boundary layer, which in the absence of a capping inversion, was treated as being 3000 meters deep. The modern version of REEDM now selects the appropriate atmospheric layer based on the stabilization height of the cloud, the top of the cloud and the location of the reflective boundary layers. Comparison of REEDM predicted rocket exhaust cloud transport direction and speed with Doppler weather radar tracks of rocket exhaust clouds has indicated that the modern version of REEDM performs very satisfactorily in predicting the correct average cloud transport direction and speed. The "multi-layer" aspect of REEDM is still retained from its early development and refers to the partitioning of the stabilized rocket exhaust cloud into "disks" of cloud material assigned to meteorological levels at different altitudes. The altitude bands are typically 20 to 50 meters in depth. REEDM models the initial formation of a rocket exhaust cloud as either an ellipsoid or a sphere and predicts the buoyant could rise of the source as a single cloud entity. Once the cloud is predicted to have achieved a condition of thermal stability in the atmosphere, the cloud is partitioned into disks. The placement of each disk relative to the source origin (e.g. the launch pad) is determined based on the rise time of the cloud through a sequence of meteorological layers that are defined using the measurement levels obtained from a mandatory weather balloon input data file. Each meteorological layer may have a unique wind speed and direction that displaces the cloud disk in the down wind direction. The initial placement of cloud disks that are associated with the lower portion of the overall source cloud are not influenced by winds above their stabilized altitude level whereas disks near the top of the stabilized cloud will be displaced by the winds all the way from the ground level to the disk stabilization altitude. Thus the vertical stack of cloud disks can be displaced relative to each other due to the influence of wind speed and direction shears. The concept of the stabilized cloud partition into disks is illustrated in Figure 2-2.

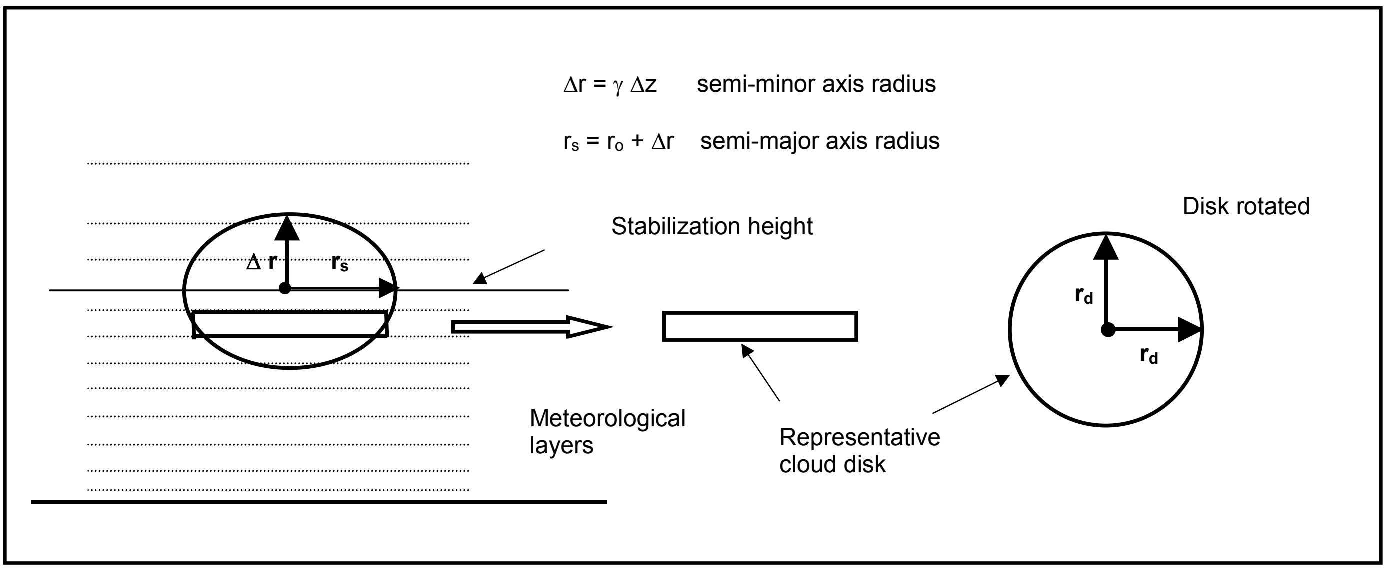


**Figure 2-2. Illustration of REEDM Partitioning a Stabilized Cloud into Disks.**

Once the cloud disks positions are initialized, future downwind transport applies the same average atmospheric boundary layer transport wind speed and direction to each cloud disk as illustrated in Figure 2-3.

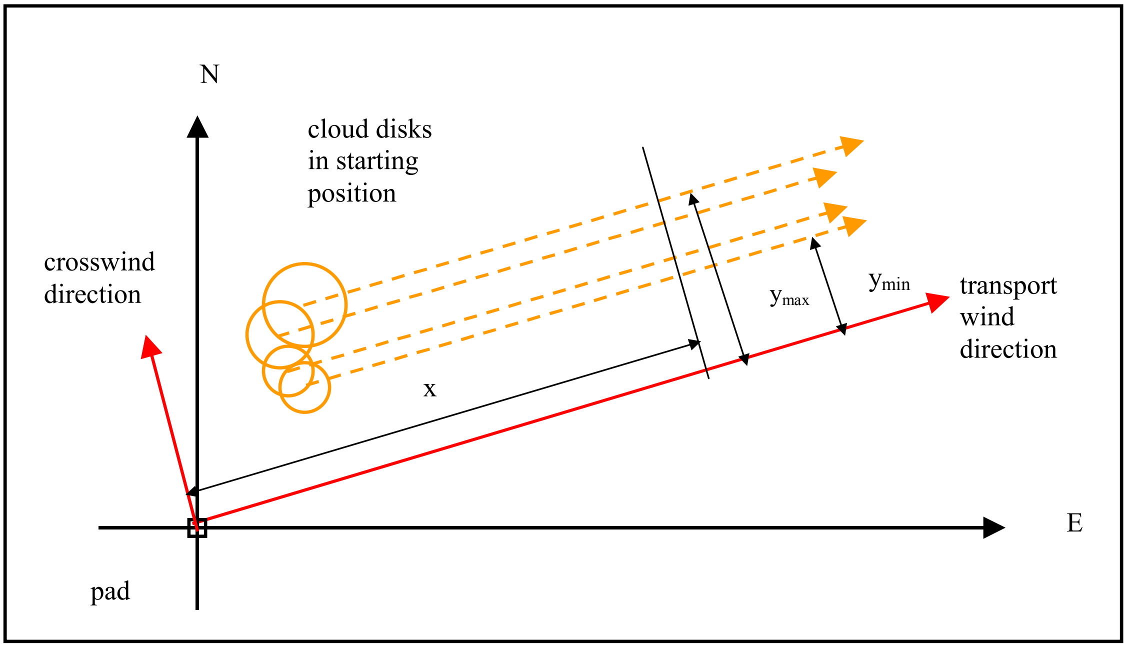


**Figure 2-3. Illustration of Straight Line Transport of Stabilized Exhaust Cloud Disks Using Average Mixing Layer Wind Speed and Direction.**

The assumption of straight-line transport used in REEDM during the cloud transport and dispersion phase ignores the possibility of complex wind fields that might arise in mountainous terrain or that could evolve during passage of a seabreeze front or synoptic scale weather front. It is recommended that the assumption of uniform winds be limited to plume transport distances of less that 20 kilometers. As will be shown in the analysis results section, REEDM predicted typical ranges of 5 to 10 kilometers from the launch pad to the location of the maximum far field ground level CO concentration point, thus the assumption of straight line transport should not be a problem.

In both Taurus II scenarios the exhaust emissions from the rocket combustion are at several thousand degrees Kelvin and are highly buoyant. The high temperature of these exhaust emissions causes the plume to be less dense than the surrounding atmosphere and buoyancy forces acting on the cloud cause it to lift off the ground and accelerate vertically. As the buoyant cloud rises, it entrains ambient air and grows in size while also cooling. In this initial cloud rise phase, the growth of the cloud volume is due primarily to internal velocity gradients and mixing induced by large temperature gradients within the cloud itself. Even though the cloud is entraining air and cooling by virtue of mixing hot combustion gases with cooler ambient air, the net thermal buoyancy in the cloud is conserved and the cloud will continue to rise until it either reaches a stable layer in the atmosphere or the cloud vertical velocity becomes slow enough to be damped by viscous forces. REEDM applies the following solution of Newton's second law of motion to a buoyant cloud in the atmosphere to iteratively predict cloud stabilization height:

$$z(t) = \left[ \frac{3F_m}{u\gamma^2\sqrt{s}} \sin\left(t\sqrt{s}\right) + \frac{3F_c}{u\gamma^2 s}\left(1 - \cos\left(t\sqrt{s}\right)\right) + \left(\frac{r_o}{\gamma}\right)^3 \right]^{1/3} - \frac{r_o}{\gamma}$$

where:

s = atmospheric stability parameter = $\dfrac{g}{\theta_a} \dfrac{\Delta\theta_a}{\Delta Z}$ [sec$^{-2}$]

g = gravitational acceleration constant = 9.81 [m/sec$^2$]

$\theta_a$ = potential temperature of ambient air [K]

$F_m$ = $r_o^2 w_o u$ = initial vertical momentum [m$^4$/sec$^2$]

u = mean ambient wind speed [m/sec]

$w_o$ = initial vertical velocity [m/sec] (typically = 0.0)

$r_o$ = initial plume cross-sectional radius [m]

$F_c$ = initial buoyancy = $\dfrac{g\,\dot{q}}{\pi\,\rho_c\,C_p\,T_a}$ [m$^4$/s$^3$]

$C_p$ = specific heat of exhaust cloud gases [cal/kg K]

$\gamma$ = air entrainment coefficient (dimensionless)

z = plume height at time t [m]

$\dot{q}$ = initial plume heat flux [cal/sec]

$T_a$ = ambient air temperature [K]

$\rho_c$ = density of exhaust cloud gases [kg/m$^3$]

A critical parameter in the cloud rise equation is the rate of ambient air entrainment that is defined by the dimensionless air entrainment coefficient, γ. Cloud growth as a function of altitude is assumed to be linearly proportional and the air entrainment coefficient defines the constant of proportionality. REEDM's cloud rise equations have been compared with observations and measurements of Titan rocket ground clouds and a best-fit empirical cloud rise air entrainment coefficient has been derived from the test data, a sample of which is illustrated in Figure 2-4.

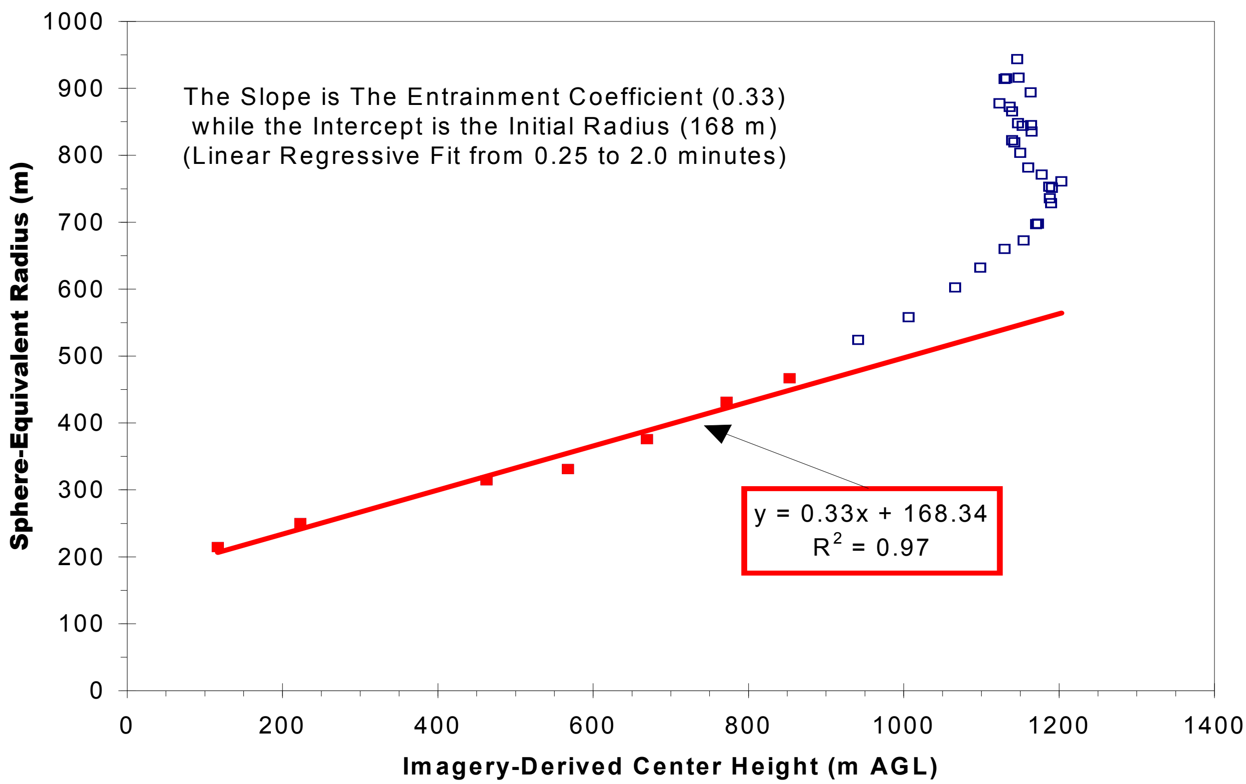


**Figure 2-4. Observed Cloud Growth Versus Height for Titan IV A-17 Mission.**

The Taurus II buoyant source clouds are predicted to rise from 500 to 1300 meters above the ground depending on atmospheric lapse rate conditions.

## 3. TAURUS II DATA DEVELOPMENT

Proper specification of vehicle characterization input data is critical to the overall toxic dispersion analysis problem. While many vehicle input parameters are straightforward and readily verifiable (e.g. types and amounts of propellants loaded on the vehicle), other parameters inherently involve greater uncertainty and are not readily verifiable (e.g. amount of ambient air entrained into the rocket plume at the flame duct inlet). In this report section the vehicle input data values used in the REEDM Taurus II normal launch and static test firing scenario analyses are itemized and explained. Input parameters that entail significant uncertainty were treated in a conservative fashion in the sense that choices were made to favor overestimating rather than underestimating the toxic chemical concentrations being evaluated for the Environmental Assessment study. Information pertaining to the vehicle propellant loads, burn rates and expected nominal launch flight trajectory were provided by WFF NASA or Orbital Sciences personnel and converted by ACTA into REEDM database format.

### 3.1 Normal Launch Vehicle Data

The following data items represent the vehicle data needed to characterize the normal launch scenario and are presented in the REEDM database format.

```
#05.00                       VEHICLE DATA SECTION
   VEHICLE TYPE = 4, NAME =     TAURUS-II,
   TIME HEIGHT COEFFICIENTS A,B,C =     0.967700,     0.471980,       2.2000,
#05.01 NORMAL LAUNCH ENGINE DATA FOR STAGES IGNITED AT LIFT-OFF:
   NUMBER OF IGNITED SRB'S           =   0,
   SOLID FUEL MASS              (LBM) =   0.0000000,
   SOLID FUEL BURN RATE       (LBM/S) =   0.0000000,
   LIQUID FUEL MASS             (LBM) =  142735.000,
   LIQUID FUEL BURN RATE      (LBM/S) =   645.90000,
   LIQUID OXIDIZER MASS         (LBM) =  390779.000,
   LIQUID OXIDIZER BURN RATE (LBM/S) =   1768.2000,
   AIR ENTRAINMENT RATE IN GROUND CLOUD       (LBM/S) =   0.0000000,
   TOTAL DELUGE WATER ENTRAINED IN GROUND CLOUD (LBM) =   0.0000000,
   AIR ENTRAINMENT RATE IN ROCKET CONTRAIL    (LBM/S) =   0.0000000,
   VEHICLE HEIGHT TO WHICH PLUME CONTRIBUTES TO GROUND CLOUD (FT) = 525,
   GROUND CLOUD INITIAL AVERAGE TEMPERATURE         (F) =  3487,
   GROUND CLOUD INITIAL HEAT CONTENT          (BTU/LBM) =  3475,
   INITIAL VERTICAL VELOCITY OF GROUND CLOUD     (FT/S) =   0.0,
   INITIAL RADIUS OF GROUND CLOUD                  (FT) = 160.0,
   INITIAL HEIGHT OF GROUND CLOUD                  (FT) =   0.0,
   INITIAL X DISPLACEMENT OF GROUND CLOUD FROM PAD (FT) =   0.0,
   INITIAL Y DISPLACEMENT OF GROUND CLOUD FROM PAD (FT) =   0.0,
   PLUME CONTRAIL INITIAL AVERAGE TEMPERATURE       (F) =  3487,
   PLUME CONTRAIL INITIAL HEAT CONTENT        (BTU/LBM) =  3475,
#05.02 NORMAL LAUNCH EXHAUST PRODUCT DATA:
 CHEMICAL NAME     MOL. WT.   MASS FRAC. GAS   MASS FRAC. COND  HAZARDOUS
 GROUND CLOUD:
   CO2             44.011        0.44824          0.00000           Y
   CO              28.011        0.25637          0.00000           Y
   H2O             18.015        0.28893          0.00000           N
```

```
  H2              2.016       0.00557         0.00000         N
  OH             17.007       0.00077         0.00000         N
  H               1.008       0.00006         0.00000         N
  O2             31.999       0.00005         0.00000         N
  O              15.999       0.00001         0.00000         N
  END
CONTRAIL:
  CO2            44.011       0.44824         0.00000         Y
  CO             28.011       0.25637         0.00000         Y
  H2O            18.015       0.28893         0.00000         N
  H2              2.016       0.00557         0.00000         N
  OH             17.007       0.00077         0.00000         N
  H               1.008       0.00006         0.00000         N
  O2             31.999       0.00005         0.00000         N
  O              15.999       0.00001         0.00000         N
  END
```

REEDM does not utilize the launch vehicle trajectory directly; instead a power law fit to the height of the vehicle above ground as a function of time is derived from the trajectory data. The fit achieved with the derived power law time-height coefficients is demonstrated in Figure 3-1

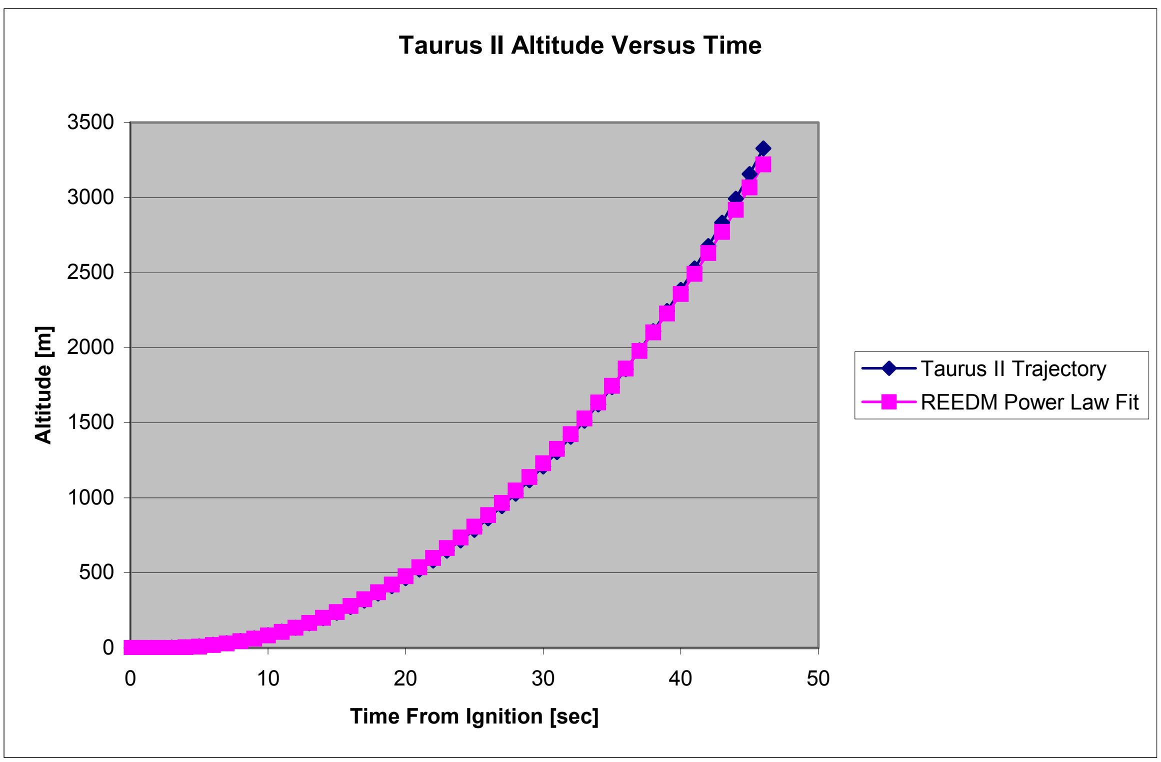


**Figure 3-1. Plot of Vendor Taurus II Nominal Trajectory Compared with ACTA Derived Power Law Fit Used in REEDM.**

REEDM allows for several chemical additions that may be included in the propellant exhaust of the normal launch ground cloud and the normal launch contrail cloud. In addition to specifying the nominal burn rates of the RP-1 fuel and the LOX oxidizer, the user may optionally consider adding deluge or sound suppression water and entrained ambient air. For these two items the REEDM database serves only as a source of documentation for the assumptions applied in deriving the chemical compositions of the exhaust specified in section #05.02 of the database. It is noted here that “air entrainment” as specified in this section represents the user assumption about the amount of air, if any, added as a ***reactant*** in the propellant combustion calculations. This “air entrainment” definition is not to be confused with the “air entrainment” process that takes place during the cloud rise calculations. REEDM assumes that all chemical combustion reactions are completed before the cloud rise process takes place and REEDM therefore does not attempt to recompute chemical composition and additional heat release during the cloud rise computations.

The REEDM database provides the chemical composition of the normal ground and contrail clouds. A mass fraction is assigned to each constituent and the total exhaust mass in the source cloud is multiplied by this fraction to determine the total mass of each chemical in the exhaust cloud. The molecular weight of each species is used to convert the concentration from mass per unit volume [e.g.mg/$m^3$] to parts per million. For this study ACTA computed the chemical composition of the Taurus II stage 1 RP-1/LOX exhaust using the NASA Lewis chemical equilibrium combustion model. The ACTA version of the NASA combustion model was modified slightly to output thermodynamic properties of the exhaust mixture that were needed to initialize the REEDM cloud rise equations. ACTA’s combustion results for the Taurus II first stage agreed within 2% for the major constituents (CO, $CO_2$, $H_2O$) compared with similar data provided by Orbital Sciences 0 as shown in Table 3-1. ACTA ran the NASA combustion model in “rocket” analysis mode using an oxidizer to fuel ratio of 2.7 and a combustion chamber pressure of 2194 PSIA. The Orbital analysis appears to have been conducted with a newer version of the NASA equilibrium combustion model and was executed with a slightly different nozzle to throat area ratio than the ACTA model. The supporting thermodynamic databases between the two versions of the combustion models may also differ slightly. ACTA considers the small chemical composition differences to have insignificant effect on the analysis results and conclusions of this study.

**Table 3-1. Comparison of ACTA and Orbital Taurus II Stage-1 Combustion Model Nozzle Exit Results.**

| Chemical | ACTA Mole Fraction | Orbital Mole Fraction | Ratio ACTA/Orbital |
|---|---|---|---|
| $CO_2$ | 0.26632 | 0.27071 | 0.984 |
| CO | 0.23932 | 0.23532 | 1.017 |
| $H_2O$ | 0.41938 | 0.41627 | 1.007 |
| $H_2$ | 0.07231 | 0.07650 | 0.945 |
| OH | 0.00118 | 0.00048 | 2.458 |
| H | 0.00144 | 0.00072 | 2.000 |
| $O_2$ | 0.00004 | 0.00001 | 4.000 |
| O | 0.00002 | 0.00000 | -- |

Both ACTA and Orbital ran combustion for only RP-1 and LOX and the chemical compositions listed in Table 3-1 do not consider the shift in chemical equilibrium that takes place if ambient air or water are added to the nozzle exit exhaust mixture.

## 3.2 Static Test Firing Vehicle Data

The REEDM database also includes a data section used to define the parameters that characterize a static test firing scenario. The data developed for the Taurus II stage-1 static test firing is listed as follows:

```
#05.20 TEST FIRING ENGINE DATA:
   SOLID FUEL MASS                           (LBM) = 123552.,
   SOLID FUEL BURN RATE                    (LBM/S) =   2376.,
   AIR ENTRAINMENT RATE IN CLOUD           (LBM/S) =       0,
   TOTAL DELUGE WATER ENTRAINED IN CLOUD     (LBM) =       0,
   CLOUD INITIAL AVERAGE TEMPERATURE           (F) =    3487,
   CLOUD INITIAL HEAT CONTENT            (BTU/LBM) =    3475,
   INITIAL VERTICAL VELOCITY OF CLOUD       (FT/S) =     0.0,
   INITIAL RADIUS OF CLOUD                    (FT) =   151.1,
   INITIAL HEIGHT OF CLOUD                    (FT) =     0.0,
   INITIAL X DISPLACEMENT OF CLOUD FROM STAND (FT) =     0.0,
   INITIAL Y DISPLACEMENT OF CLOUD FROM STAND (FT) =     0.0,
#05.21 TEST FIRING PLUME CHEMISTRY  DATA:
 CHEMICAL NAME      MOL. WT.   MASS FRAC. GAS   MASS FRAC. COND  HAZARDOUS
   CO2               44.011        0.44824          0.00000          Y
   CO                28.011        0.25637          0.00000          Y
   H2O               18.015        0.28893          0.00000          N
   H2                 2.016        0.00557          0.00000          N
   OH                17.007        0.00077          0.00000          N
   H                  1.008        0.00006          0.00000          N
   O2                31.999        0.00005          0.00000          N
   O                 15.999        0.00001          0.00000          N
   END
```

The REEDM static test firing scenario was originally developed for burns of solid propellant motors and the nomenclature used in the database is outdated and somewhat misleading. In the case of the Taurus II first stage test firing the line items identified as "solid fuel mass" and "solid fuel burn rate" are set to represent the total quantity of RP-1 + LOX and the average burn rate of the RP-1 + LOX mixture consumed during a 52 second static burn. The chemical composition of the static test firing exhaust is set the same as the normal launch ground cloud. As with the normal launch scenario, the effects of plume afterburning and deluge water injection are ignored.

## 3.3 Conservative Assumptions Applied In Data Development

The REEDM atmospheric dispersion model has been used operationally by the Air Force to make range safety launch decisions since 1989. During that time vehicle databases have been developed for many vehicles (e.g. Space Shuttle, Titan II, Titan III, Titan IV, Delta II, Delta III, Delta IV, Atlas II, Atlas III, Atlas V, Taurus, TaurusXL, Taurus Lite, Minotaur, Peacekeeper, Minuteman II, Minuteman III, Athena, Lance, Scud, ATK-ALV-1). As noted at the beginning of this section, some vehicle data is easily obtained and verified, such as the stage propellant types, quantities and burn rates. Other model input parameters required by REEDM are based on derived values obtained from mathematical and physical models, empirical measurement data or engineering judgment from the vehicle designer or range safety experts.

An example of a derived value is the selection of how much pad deluge water to include with the rocket engine exhaust when defining the normal launch cloud heat content, mass and chemical composition. A typical pad deluge system is comprised of a series of pressure fed sprayers and sprinkers that wet the launch pad, the launch service tower and the flame duct. The deluge system is typically turned on several seconds before the rocket motors are ignited and continues until the rocket has ascended above the launch tower and the plume no longer impinges on the ground. As the vehicle ascends, the rocket plume interaction with the pad structures is time varying, such that the gas flow velocity ranges from supersonic to subsonic and involves multiple shock fronts, reflected shocks, deflected flow from the pad surface, partial flow ducting through the flame trench and plume temperatures that range from 300 to 3000 K. A simple energy balance between the amount of heat available in the plume and the amount of water released in the deluge system may suggest that there is ample energy to vaporize all of the deluge water, but actual observation of launches indicates that residual deluge water is often collected in a concrete containment basin designed to collect residual deluge water. Likewise the initial ignition impulse often blows standing water out of the flame trench or away from the pad and depositing it as droplets before they can be fully mixed with the combustion gases and vaporized. Some parts of the launch plume during vehicle liftoff may become saturated with water vapor and other portions may remain relatively “dry”. Thus the task of selecting a specific deluge water inclusion amount for the REEDM database and setting the associated chemical and thermodynamic data for the exhaust products is challenging and typically not estimated by the launch agency or vehicle developer. This type of flow problem is extremely complex and would require advanced computational fluid dynamics analysis that is extremely costly and also constrained by modeling assumptions. Consequently, these types of detailed analyses are rarely performed or conducted only for limited specific design purposes.

Other examples of highly uncertain processes are the mixing of propellants from ruptured tanks in a vehicle explosion, and the fragmentation of a solid rocket motor propellant grain in the event of a case rupture. These latter events are related to vehicle failures that are not considered in this study, however, they illustrate the problem routinely faced by the launch community when attempting to set up REEDM database entries to model these scenarios. Historically the range safety community has taken a conservative approach in setting these uncertain database entries. The vast majority of vehicles characterized in the REEDM database ignore deluge water contributions (a notable exception being Shuttle). One reason for ignoring the deluge water effect is that it is known that water vapor and water droplets scrub hydrogen chloride ( a common solid propellant toxic exhaust product) from the launch plume but the degree of the effect is difficult to quantify and verify, therefore ignoring this removal mechanism favors maximizing the downwind ground level concentrations of HCl at receptor sites of concern that must be protected.

The same philosophy of erring in favor of overestimating rather than underestimating potential emission hazards has been applied in this study of the Taurus II carbon monoxide emissions. There are two main factors to which conservative assumptions have been applied in this study; 1) ambient air entrainment and its effect on plume afterburning chemistry, and 2), deluge water injection into the plume. Both of these factors are discussed in further detail in the following paragraphs with an explanation for why it is believed that the REEDM modeling assumptions applied in this study are in fact conservative.

It is recognized that the Taurus II, like most rocket engines, is designed to run somewhat fuel rich for efficiency reasons and that the exhaust products will contain compounds (mainly CO and OH) that are not fully oxidized. Entrainment of ambient air into the superheated gases exiting from the rocket nozzle will allow for further oxidation in the plume, a process referred to as plume afterburning. The rate of air entrainment into the plume and the amount of additional oxidation that occurs in the plume downstream from the nozzle exit plane requires sophisticated computation fluid dynamic (CFD) solutions of the plume flow as it decelerates through multiple shock front to subsonic velocity that are beyond the design capabilities and run time requirements of REEDM. In this study ACTA has ignored the effect of air entrainment on the combustion products and heat content of the normal launch ground cloud and contrail cloud emissions. Ignoring air entrainment and after burning is assumed to be conservative for this study in that the ground level CO concentration predictions will err on the side of overestimating rather than underestimating the concentration for the following two reasons:

1. Ignoring ambient air entrainment in the combustion calculations will favor production of CO rather than $CO_2$ and CO is the more toxic species.

2. Ignoring ambient air afterburning reduces the total amount of heat released by the combustion process, which in turn leads to a lower stabilized cloud height prediction. Ground level concentrations of cloud chemicals vary approximately with the inverse cube of the stabilization height (e.g. doubling the cloud stabilization height reduces the ground concentrations by about a factor of 8, other factors being constant). Lower stabilization height therefore favors higher ground level CO predictions.

A deluge water system is planned for the Taurus II launch pad and serves to cool pad structures exposed to rocket engine exhaust as well as to suppress acoustic vibrations during motor ignition. An objective of the deluge water system design is to inject water into the plume just downstream of the nozzle exit plane at a rate of 2 lbm of water for every lbm of rocket propellant exhaust. Water is expected to chemically react with the high temperature rocket engine exhaust gases, which are fuel rich. In this situation water acts as an oxidizer and gives up oxygen to convert CO to $CO_2$ in the plume while simultaneously releasing hydrogen gas. The reaction between high temperature CO and $H_2O$ is referred to as the "water-gas shift" reaction. ACTA evaluated the effect of 2:1 water to rocket exhaust mixing on the plume chemistry immediately downstream of the nozzle exit plane by running the NASA Lewis chemical equilibrium combustion model 0, 0 using the RP-1/LOX nozzle exit products as high temperature reactants at 2193 K mixed with liquid water at 298 K. The input reactant information entered into the combustion model is listed below:

**NASA Lewis Combustion Model Input Reactants for RP-1/LOX Exhaust Products and Deluge Water Mixture.**

```
THERMO
TRAN
REACTANTS
C 1.     O 2.0                            63.111  -69368.  G 2193.  F
C 1.     O 1.0                            36.096  -11178.  G 2193.  F
H 2.                                       0.784   14240.  G 2193.  F
H 1.                                       0.008   61472.  G 2193.  F
H 2.     O 1.0                            87.345  -68267.  L  298.  O
H 2.     O 1.0                            12.619  -37989.  G 2193.  O
O 2.                                       0.002   15877.  G 2193.  O
O 1.     H 1.0                             9.631   23759.  G 2193.  O
```

```
NAMELISTS
 &inpt2 kase=1,hp=t,p=1.000,of=t,mix=3.2239,siunit=t &end
```

The predicted combustion products and thermodynamic state properties for the exhaust plume + water mixture are listed below. Post combustion products are highlighted. Note that the plume is cooled from 2193 K to 856 K, but remains unsaturated. The predicted amount of CO in the exhaust has dropped from 25.6% to 0.3%, a reduction factor of approximately 100. $CO_2$ concentration is predicted to decrease from 44.8% to 27.9%. The total amount of $CO_2$ produced has actually increased but the percentage relative to the total exhaust mixture mass has decreased.

**NASA Lewis Combustion Model Output Products for RP-1/LOX Exhaust and Deluge Water Mixture.**

```
0                  O/F=   3.2239     PERCENT FUEL=   23.6748     EQUIVALENCE RATIO= 1.0383     PHI=
2.0181
0THERMODYNAMIC PROPERTIES

 P, MPA            0.10132
 T, DEG K           856.32
 RHO, KG/CU M    2.9654-1
 H, KJ/KG         -11095.9
 U, KJ/KG         -11437.6
 G, KJ/KG         -20674.8
 S, KJ/(KG)(K)     11.1861

 M, MOL WT          20.837
 (DLV/DLP)T       -1.00000
 (DLV/DLT)P         1.0000
 CP, KJ/(KG)(K)     1.9758
 GAMMA (S)          1.2531
 SON VEL,M/SEC       654.3
   trace =    0.000000000000000E+000
   npt   =             1
 total product molecular wt. (including condensed sp) = 20.837

0MOLE FRACTIONS

   oxidizer mass fraction =    0.7632520
   fuel mass fraction     =    0.2367480
  C O            -69368.0    44.010  F    0.6311
  C O            -11178.0    28.010  F    0.3610
  H               14240.0     2.016  F    0.0078
  H               61472.0     1.008  F    0.0001
  H O            -68267.0    18.015  O    0.7970
  H O            -37989.0    18.015  O    0.1151
  O               15877.0    31.999  O    0.0000
  O H             23759.0    17.007  O    0.0879

   oxfl =     3.22390007972717
   temperature =     856.317902340247
   Total reactant enthalpy [cal/g] =    -2651.987

   INJECTOR CONDITIONS
```

| chemical | mole frac | mole wt | wt kg | wt frac | hval cal/gmole | hf298 cal/gmole | heat cal | heat@stag cal | hstag cal/gmole |
|---|---|---|---|---|---|---|---|---|---|
| H2O | 0.82599 | 18.015 | 14.88037 | 0.71412 | -52929.2 | -57754.7 | 3985.8 | 3985.8 | -52929.2 |
| CO2 | 0.13216 | 44.010 | 5.81651 | 0.27914 | -87837.4 | -93983.8 | 812.3 | 812.3 | -87837.4 |
| H2 | 0.03969 | 2.016 | 0.08002 | 0.00384 | 3910.7 | 0.6 | 155.2 | 155.2 | 3910.7 |
| CO | 0.00215 | 28.010 | 0.06027 | 0.00289 | -22342.6 | -26398.0 | 8.7 | 8.7 | -22342.6 |

```
  total kg products (per kgmole) =     20.83716
```

```
total heat of form. of prod. [cal/gmole] =   -60182.82
enthalpy of prod. at plume T [cal/gmole]=   -55220.72
heat content of prod. @ plume T & V [cal/gmole] =    4962.093
heat content of prod. @ plume T & V [cal/g] =    238.1358
total weight fractions of products =   0.9999962
total mole fractions of products =   0.9999994
gas velocity [m/sec] =   0.0000000E+00
stagnation enthalpy of prod. [cal/gmole]=   -55220.72
heat content of prod. @ stag T & V = 0 [cal/gmole] =    4962.093
heat content of prod. @ stag T & V = 0  [cal/g] =    238.1358
total heat of form. of reac. [cal/g] =   -2651.987
heat of combustion [cal/g] =    236.2465
```

The addition of deluge water has another effect in that it may reduce the net heat content of the cloud in proportion to the amount of liquid deluge water that is converted to gaseous phase and does not chemically react with other plume constituents. The amount of liquid water that is vaporized and then does not re-condense during the cloud rise phase reduces the cloud buoyancy. The effects of deluge water on the plume chemistry and plume rise where ignored in this study, in part because the normal launch plume has a time varying interaction with the deluge system and transitions from a high water injection condition to an essentially dry plume. Ignoring deluge or sound suppression water injection into the plume is expected to be conservative in that it should lead to model predictions that overestimate the downwind ground level CO concentrations. The reduction of in-cloud CO is expected to far outweigh the reduction in cloud stabilization height due to loss of thermal buoyancy.

# 4. ANALYSIS OF EMISSION SCENARIOS

The REEDM Taurus II database was used in conjunction with a large set of archived WFF weather balloon soundings to predict downwind concentrations of carbon monoxide and to achieve some statistical perspective of the potential toxic hazard corridors associated with normal launch and static test firing scenarios.

## 4.1 Meteorological Data Preparation

Gaseous dispersion of rocket exhaust clouds is extremely dependent upon the meteorological conditions at the time the source cloud is generated. The presence or absence of temperature inversions, the temperature lapse rate, wind speed and direction, wind shears and atmospheric turbulence are important factors that influence the cloud rise and rate of dispersion of the source cloud. Meteorological conditions that are adverse from a toxic chemical dispersion perspective are light winds with little wind speed or wind direction variation over the first several thousand feet of the atmosphere coupled with a capping temperature inversion just above the top of the stabilized source cloud. An additional adverse factor is suppression of atmospheric turbulence, as occurs at night or under cloudy or marine stratus and fog conditions.

ACTA acquired and ran REEDM analyses for 6432 meteorological cases based on actual weather balloon measurements made at Wallops Flight Facility between 2000 and 2008. The raw weather balloon data was not in a format usable by REEDM and needed to be preprocessed to reduce the number of measurement levels from several thousand to approximately one hundred, to quality control check the raw data, and to output the data in REEDM compatible format. A computer program written by ACTA and delivered to WFF for operational use in 2007 was used to perform the raw data file conversions. A critical part of the conversion process is to test for, and capture, inflection points where temperature, wind speed, wind direction or relative humidity reach minimum or maximum values and change slope as a function of altitude. An example of the weather profile testing algorithm capabilities is illustrated in Figure 4-1, which is contrived test data with positive, negative and infinite slopes and multiple inflection points. The resulting converted files were sorted into daytime and nighttime sets for each month of the year. Data was classified as "daytime" if the balloon release time was between 0600 and 1900 Eastern Standard Time.

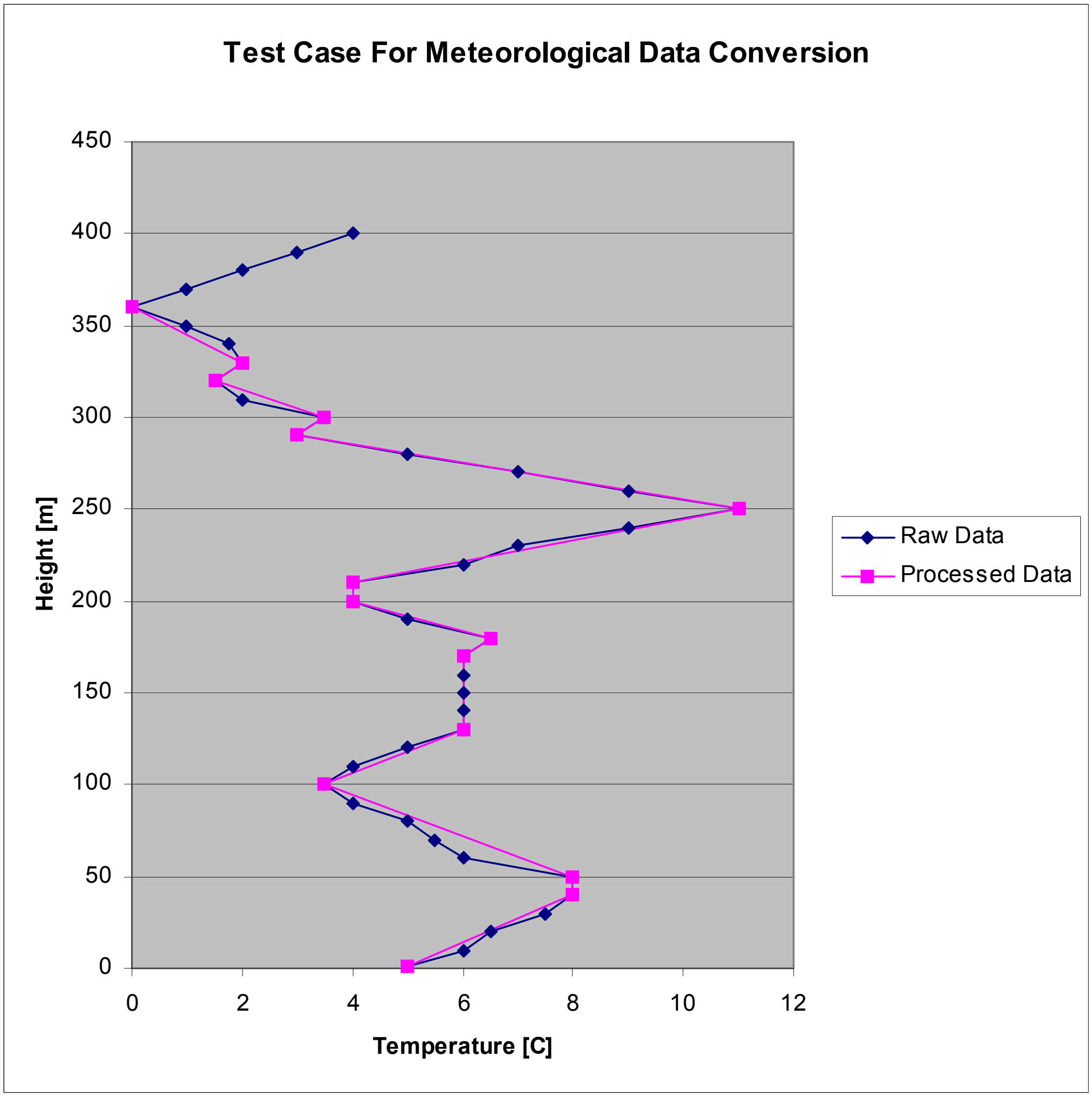


**Figure 4-1. Illustration of Testing a Raw Data Profile to Capture Slope Inflection Points that Define Minimum and Maximum Values and Measure Inversions and Shear Effects.**

## 4.2 REEDM Far Field Results For Taurus II Normal Launch Scenario

ACTA executed REEDM in batch processing mode to cycle through all archived meteorological cases and to extract key information to a summary table. Typically REEDM generates an output file for a single weather case that consists of 10 to 20 pages of information on the run setup, intermediate calculated value and tables of concentration versus downwind distance. When processing thousands of cases, saving the standard REEDM output file for each run results in an overwhelming amount of output data. ACTA developed a special batch version of REEDM for the Air Force that has been used over the years to execute thousands of scenarios and condense the REEDM output for all runs into a summary table containing the following critical analysis parameters:

1. Chemical being tracked in REEDM analysis.
2. Concentration threshold used to calculate concentration isopleth beginning and end distances.
3. Meteorological input file name.
4. Zulu time of balloon release.
5. REEDM computed mixing boundary depth.
6. REEDM predicted cloud stabilization height.
7. REEDM predicted average wind speed used to transport exhaust cloud.
8. REEDM predicted average wind direction used to transport exhaust cloud.
9. REEDM predicted maximum ground level concentration.
10. REEDM predicted distance from exhaust cloud source to location of maximum concentration.
11. REEDM predicted bearing from exhaust cloud source to location of maximum concentration.
12. REEDM predicted nearest distance from exhaust cloud source to the location where the ground concentration centerline first exceeds the user defined concentration threshold.
13. REEDM predicted farthest distance from exhaust cloud source to the location where the ground concentration centerline last exceeds the user defined concentration threshold.
14. REEDM predicted bearing from exhaust cloud source to location where the ground concentration centerline last exceeds the user defined concentration threshold.
15. REEDM derived average wind speed shear in the lower planetary boundary layer.
16. REEDM derived average wind direction shear in the lower planetary boundary layer.

17. REEDM derived average horizontal (azimuthal) turbulence intensity in the lower planetary boundary layer.

18. REEDM derived average vertical (elevation) turbulence intensity in the lower planetary boundary layer.

19. REEDM derived average wind speed shear in the region above the planetary boundary layer.

20. REEDM derived average wind direction shear in the region above the planetary boundary layer.

21. REEDM derived average horizontal (azimuthal) turbulence intensity in the region above the planetary boundary layer.

22. REEDM derived average vertical (elevation) turbulence intensity in the region above the planetary boundary layer.

The above list of parameters is provided for REEDM predictions of both peak instantaneous concentration and time weighted average (TWA) concentration. In the runs performed for this study a 1-hour averaging time was used to compute time weighted average concentrations. A fairly short averaging time is appropriate for rocket exhaust cloud exposures because the source cloud typically passes over a receptor with a time scale of tens of minutes rather than hours. The REEDM summary tables from the monthly batch runs were further condensed to identify the meteorological case that produced the highest peak concentration and record the range and bearing from the source location (WFF Taurus II launch Pad-0A). Table 4-1 presents the maximum far field CO peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Taurus II with subsequent dispersion of the normal launch ground and contrail clouds. The far field exposure is REEDM's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak CO concentrations ranged from 3 to 8 ppm with the maximum concentration predicted to occur from 5000 to 16000 meters downwind from the launch site. These values represent the maximum concentrations predicted over a sample set of 4704 WFF balloon soundings. Table 4-2 lists the maximum predicted far field 1-hour TWA concentrations of CO for daytime normal launch scenarios. The maximum TWA concentrations are all predicted to be less than 1 ppm. Table 4-3 and Table 4-4 show the REEDM predicted maximum peak and maximum TWA CO far field concentrations for 1728 nighttime cases for Taurus II normal launch scenarios. As with the daytime cases, the peak instantaneous CO concentrations are less than 10 ppm and the peak TWA CO concentrations are less than 1 ppm.

**Table 4-1: Taurus II Normal Launch CO Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 344 | 4.7 | 8000 | 73 |
| February | 364 | 4.9 | 8000 | 158 |
| March | 397 | 5.1 | 7000 | 285 |
| April | 383 | 6.1 | 8000 | 249 |
| May | 398 | 7.9 | 7000 | 245 |
| June | 392 | 4.3 | 6000 | 258 |
| July | 416 | 5.4 | 5000 | 285 |
| August | 408 | 6.0 | 8000 | 226 |
| September | 413 | 4.7 | 9000 | 22 |
| October | 435 | 2.9 | 16000 | 240 |
| November | 382 | 4.0 | 11000 | 205 |
| December | 372 | 6.4 | 6000 | 83 |

**Table 4-2. Taurus II Normal Launch CO TWA Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 344 | 0.22 | 7000 | 259 |
| February | 364 | 0.17 | 3000 | 23 |
| March | 397 | 0.19 | 11000 | 315 |
| April | 383 | 0.23 | 7000 | 228 |
| May | 398 | 0.34 | 11000 | 300 |
| June | 392 | 0.32 | 4000 | 51 |
| July | 416 | 0.32 | 7000 | 274 |
| August | 408 | 0.21 | 6000 | 133 |
| September | 413 | 0.18 | 7000 | 305 |
| October | 435 | 0.24 | 13000 | 108 |
| November | 382 | 0.20 | 28000 | 120 |
| December | 372 | 0.17 | 15000 | 127 |

**Table 4-3: Taurus II Normal Launch CO Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 93 | 5.5 | 8000 | 74 |
| February | 157 | 4.0 | 10000 | 74 |
| March | 162 | 3.7 | 10000 | 176 |
| April | 156 | 6.3 | 9000 | 226 |
| May | 158 | 6.2 | 11000 | 242 |
| June | 152 | 4.4 | 7000 | 114 |
| July | 153 | 4.4 | 8000 | 113 |
| August | 162 | 3.4 | 10000 | 82 |
| September | 163 | 2.7 | 9000 | 356 |
| October | 119 | 2.7 | 18000 | 259 |
| November | 125 | 3.8 | 9000 | 91 |
| December | 128 | 6.0 | 7000 | 149 |

**Table 4-4. Taurus II Normal Launch CO TWA Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 93 | 0.08 | 9000 | 74 |
| February | 157 | .09 | 24000 | 77 |
| March | 162 | 0.10 | 13000 | 230 |
| April | 156 | 0.60 | 7000 | 46 |
| May | 158 | 0.17 | 16000 | 120 |
| June | 152 | 0.24 | 7000 | 210 |
| July | 153 | 0.15 | 14000 | 34 |
| August | 162 | 0.20 | 12000 | 223 |
| September | 163 | 0.16 | 12000 | 226 |
| October | 119 | 0.08 | 28000 | 59 |
| November | 125 | 0.20 | 7000 | 202 |
| December | 128 | 0.17 | 21000 | 146 |

The REEDM predicted CO concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 4-5 and it is noted that approximately 81% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level CO concentrations of less than 1 ppm.

**Table 4-5. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide Concentrations For Daytime Taurus II Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 3805 | 0.809 |
| 1 - 2 | 644 | 0.137 |
| 2 - 3 | 174 | 0.037 |
| 3 - 4 | 54 | 0.011 |
| 4 - 5 | 14 | 0.003 |
| 5 - 6 | 9 | 0.002 |
| 6 - 7 | 3 | 0.001 |
| 7 - 8 | 1 | 0.0002 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 0 | 0.0000 |

The REEDM predicted CO 1-hour time weighted average concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field TWA concentration probability. This information is provided in Table 4-6 and it is noted that approximately 88% of all daytime meteorological cases resulted in REEDM maximum 1-hour TWA ground level CO concentrations of less than 0.04 ppm. The fact that the TWA concentration is much less than the peak instantaneous concentration is consistent with the short cloud passage time.

The REEDM predicted cloud transport directions were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 4-7 indicates the predicted Taurus II normal launch plume direction probability of occurrence observed across the 4704 daytime balloon soundings. It is noted that for the daytime launch scenarios transport of the exhaust plume to the East is favored. The transport direction reflects the average airflow over a depth of approximately 1000 meters, hence the windrose observed for elevated rocket exhaust clouds may differ significantly from a windrose derived from a surface wind tower.

**Table 4-6. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide TWA Concentrations For Daytime Taurus II Normal Launch Scenarios.**

| 1-Hour TWA Concentration Bin | Count | Probability |
|---|---|---|
| 0.00 – 0.02 | 1933 | 0.411 |
| 0.02 – 0.04 | 1464 | 0.311 |
| 0.04 - 0.06 | 735 | 0.156 |
| 0.06 - 0.08 | 285 | 0.061 |
| 0.08 - 0.10 | 126 | 0.027 |
| 0.10 - 0.12 | 66 | 0.014 |
| 0.12 - 0.14 | 35 | 0.007 |
| 0.14 - 0.16 | 18 | 0.004 |
| 0.16 - 0.18 | 17 | 0.004 |
| 0.18 – 0.20 | 10 | 0.002 |
| 0.20 – 0.22 | 3 | 0.001 |
| 0.22 – 0.24 | 3 | 0.001 |
| 0.24 – 0.26 | 2 | 0.0004 |
| 0.26 – 0.28 | 2 | 0.0004 |
| 0.28 – 0.30 | 2 | 0.0004 |
| 0.30 – 0.32 | 0 | 0.0000 |
| 0.32 – 0.34 | 2 | 0.0004 |
| 0.34 – 0.36 | 1 | 0.0002 |
| 0.36 – 0.38 | 0 | 0.0000 |
| 0.38 -0.40 | 0 | 0.0000 |

**Table 4-7. REEDM Predicted Exhaust Cloud Transport Directions For Daytime Taurus II Normal Launch Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 363 | 0.077 |
| 22.5 – 67.5 (NE) | 830 | 0.176 |
| 67.5 – 112.5 (E) | 801 | 0.170 |
| 112.5 – 157.5 (SE) | 976 | 0.207 |
| 157.5 – 202.5 (S) | 515 | 0.109 |
| 202.5 – 247.5 (SW) | 453 | 0.096 |
| 247.5 – 292.5 (W) | 326 | 0.069 |
| 292.5 – 337.5 (NW) | 440 | 0.094 |

Similar summary tables for the 1728 nighttime Taurus II normal launch simulations were compiled. Table 4-8 shows that the peak CO instantaneous concentration predictions for nighttime conditions continues with a high probability that the maximum far field concentration will be less than 1 ppm.

**Table 4-8. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide Concentrations For Nighttime Taurus II Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1390 | 0.804 |
| 1 - 2 | 237 | 0.137 |
| 2 - 3 | 67 | 0.039 |
| 3 - 4 | 23 | 0.013 |
| 4 - 5 | 7 | 0.004 |
| 5 - 6 | 2 | 0.0012 |
| 6 - 7 | 2 | 0.0012 |
| 7 - 8 | 0 | 0.0000 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 0 | 0.0000 |

The REEDM predicted CO 1-hour time weighted average concentrations for all nighttime meteorological cases is provided in Table 4-9 and it is noted that approximately 73% of all nighttime meteorological cases resulted in REEDM maximum 1-hour TWA ground level CO concentrations of less than 0.04 ppm.

Table 4-10 indicates the predicted Taurus II normal launch plume direction probability of occurrence observed across the 1728 nighttime balloon soundings. It is noted that for nighttime launch scenarios transport of the exhaust plume to the East is still favored as it was during the daytime.

**Table 4-9. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide TWA Concentrations For Nighttime Taurus II Normal Launch Scenarios.**

| 1-Hour TWA Concentration Bin | Count | Probability |
|---|---|---|
| 0.00 – 0.02 | 817 | 0.473 |
| 0.02 – 0.04 | 449 | 0.260 |
| 0.04 - 0.06 | 264 | 0.153 |
| 0.06 - 0.08 | 114 | 0.066 |
| 0.08 - 0.10 | 52 | 0.030 |
| 0.10 - 0.12 | 12 | 0.007 |
| 0.12 - 0.14 | 6 | 0.0035 |
| 0.14 - 0.16 | 4 | 0.0023 |
| 0.16 - 0.18 | 5 | 0.0029 |
| 0.18 – 0.20 | 0 | 0.0000 |
| 0.20 – 0.22 | 3 | 0.0017 |
| 0.22 – 0.24 | 0 | 0.0000 |
| 0.24 – 0.26 | 0 | 0.0000 |
| 0.26 – 0.28 | 0 | 0.0000 |
| 0.28 – 0.30 | 0 | 0.0000 |
| 0.30 – 0.32 | 0 | 0.0000 |
| 0.32 – 0.34 | 0 | 0.0000 |
| 0.34 – 0.36 | 0 | 0.0000 |
| 0.36 – 0.38 | 0 | 0.0000 |
| 0.38 -0.40 | 0 | 0.0000 |

**Table 4-10. REEDM Predicted Exhaust Cloud Transport Directions For Nighttime Taurus II Normal Launch Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 61 | 0.035 |
| 22.5 – 67.5 (NE) | 315 | 0.182 |
| 67.5 – 112.5 (E) | 296 | 0.171 |
| 112.5 – 157.5 (SE) | 369 | 0.214 |
| 157.5 – 202.5 (S) | 231 | 0.134 |
| 202.5 – 247.5 (SW) | 215 | 0.124 |
| 247.5 – 292.5 (W) | 106 | 0.061 |
| 292.5 – 337.5 (NW) | 135 | 0.078 |

## 4.3 REEDM Far Field Results For The Taurus II Static Test Firing Scenario

REEDM was executed in batch mode using the same archived WFF meteorological soundings to evaluate the formation, transport and ground level concentration of CO from Taurus II static test firings on the launch stand. Table 4-11 presents the maximum peak instantaneous CO concentration predicted for the static test firing. It is noted that in general the static test firing is predicted to produce higher ground level CO concentrations than the normal launch scenario.

**Table 4-11: Taurus II Static Test Firing CO Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 344 | 10.8 | 6000 | 53 |
| February | 364 | 15.5 | 6000 | 31 |
| March | 397 | 18.9 | 6000 | 34 |
| April | 383 | 13.5 | 6000 | 33 |
| May | 398 | 11.6 | 7000 | 16 |
| June | 392 | 6.1 | 8000 | 21 |
| July | 416 | 5.2 | 7000 | 75 |
| August | 408 | 5.2 | 11000 | 25 |
| September | 413 | 9.2 | 8000 | 249 |
| October | 435 | 5.9 | 6000 | 58 |
| November | 382 | 11.8 | 6000 | 92 |
| December | 372 | 13.6 | 8000 | 37 |

Table 4-12 lists the predicted daytime CO TWA concentrations for the Taurus II static test firing scenarios. The TWA concentrations are somewhat higher than the corresponding values predicted for the normal launch scenario, but the overall expectation is that the 1-hour TWA CO concentrations will be less than 1 ppm. Table 4-13 and Table 4-14 show the maximum predicted CO instantaneous and 1-hour TWA concentrations for the nighttime static test firing conditions.

**Table 4-12. Taurus II Static Test Firing CO TWA Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 344 | 0.20 | 7000 | 53 |
| February | 364 | 0.27 | 8000 | 70 |
| March | 397 | 0.26 | 5000 | 46 |
| April | 383 | 0.23 | 9000 | 20 |
| May | 398 | 0.25 | 11000 | 251 |
| June | 392 | 0.16 | 5000 | 61 |
| July | 416 | 0.18 | 4000 | 181 |
| August | 408 | 0.14 | 14000 | 136 |
| September | 413 | 0.15 | 7000 | 241 |
| October | 435 | 0.17 | 14000 | 221 |
| November | 382 | 0.23 | 6000 | 92 |
| December | 372 | 0.25 | 9000 | 37 |

**Table 4-13: Taurus II Static Test Firing CO Ceiling Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 93 | 12.3 | 6000 | 100 |
| February | 157 | 8.7 | 7000 | 8 |
| March | 162 | 11.4 | 6000 | 40 |
| April | 156 | 13.7 | 5000 | 58 |
| May | 158 | 7.2 | 6000 | 80 |
| June | 152 | 5.9 | 6000 | 113 |
| July | 153 | 4.2 | 8000 | 83 |
| August | 162 | 4.7 | 9000 | 82 |
| September | 163 | 4.6 | 13000 | 72 |
| October | 119 | 6.1 | 8000 | 59 |
| November | 125 | 6.9 | 8000 | 92 |
| December | 128 | 13.6 | 8000 | 37 |

**Table 4-14. Taurus II Static Test Firing CO TWA Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak CO Concentration [ppm] | Distance to Peak CO Concentration [m] | Bearing to Peak CO Concentration [deg] |
|---|---|---|---|---|
| January | 93 | 0.22 | 7000 | 100 |
| February | 157 | 0.24 | 16000 | 42 |
| March | 162 | 0.21 | 11000 | 29 |
| April | 156 | 0.28 | 7000 | 58 |
| May | 158 | 0.23 | 13000 | 100 |
| June | 152 | 0.15 | 7000 | 113 |
| July | 153 | 0.11 | 18000 | 83 |
| August | 162 | 0.12 | 10000 | 79 |
| September | 163 | 0.30 | 12000 | 226 |
| October | 119 | 0.13 | 12000 | 152 |
| November | 125 | 0.18 | 11000 | 66 |
| December | 128 | 0.25 | 9000 | 37 |

Histograms of REEDM predicted CO concentrations for Taurus II static test firings for all daytime meteorological cases were generated in a similar fashion to the normal launch scenario. Table 4-15 presents the maximum predicted CO concentrations and it is noted that approximately 76% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level CO concentrations of less than 1 ppm. The static test firing scenarios exhibited a trend toward somewhat higher concentrations than predicted for the normal launch.

**Table 4-15. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide Concentrations For Daytime Taurus II Static Test Firing Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 3568 | 0.759 |
| 1 - 2 | 632 | 0.134 |
| 2 - 3 | 195 | 0.041 |
| 3 - 4 | 125 | 0.027 |
| 4 - 5 | 51 | 0.011 |
| 5 - 6 | 48 | 0.010 |
| 6 - 7 | 21 | 0.004 |
| 7 - 8 | 18 | 0.004 |
| 8 - 9 | 14 | 0.003 |
| 9 + | 12 | 0.003 |

Table 4-16 presents the REEDM predicted CO 1-hour time weighted average concentrations for all daytime meteorological cases processed for the Taurus II static test firing scenario. It is noted that approximately 60% of all daytime meteorological cases resulted in REEDM maximum 1-hour TWA ground level CO concentrations of less than 0.04 ppm.

The REEDM predicted cloud transport directions were also aggregated into bins for the static test firing scenario. Table 4-17 indicates the predicted Taurus II static test firing plume direction probability of occurrence observed across the 4704 daytime balloon soundings. It is noted that for the daytime launch scenarios transport of the exhaust plume to the East is favored.

**Table 4-16. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide TWA Concentrations For Daytime Taurus II Static Test Firing Scenarios.**

| 1-Hour TWA Concentration Bin | Count | Probability |
|---|---|---|
| 0.00 – 0.02 | 1468 | 0.312 |
| 0.02 – 0.04 | 1372 | 0.292 |
| 0.04 - 0.06 | 863 | 0.183 |
| 0.06 - 0.08 | 446 | 0.095 |
| 0.08 - 0.10 | 230 | 0.049 |
| 0.10 - 0.12 | 138 | 0.029 |
| 0.12 - 0.14 | 74 | 0.016 |
| 0.14 - 0.16 | 40 | 0.009 |
| 0.16 - 0.18 | 29 | 0.006 |
| 0.18 – 0.20 | 17 | 0.004 |
| 0.20 – 0.22 | 15 | 0.003 |
| 0.22 – 0.24 | 6 | 0.0012 |
| 0.24 – 0.26 | 3 | 0.0006 |
| 0.26 – 0.28 | 2 | 0.0004 |
| 0.28 – 0.30 | 0 | 0.0000 |
| 0.30 – 0.32 | 0 | 0.0000 |
| 0.32 – 0.34 | 0 | 0.0000 |
| 0.34 – 0.36 | 0 | 0.0000 |
| 0.36 – 0.38 | 0 | 0.0000 |
| 0.38 -0.40 | 0 | 0.0000 |

**Table 4-17. REEDM Predicted Exhaust Cloud Transport Directions For Daytime Taurus II Static Test Firing Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 397 | 0.084 |
| 22.5 – 67.5 (NE) | 832 | 0.177 |
| 67.5 – 112.5 (E) | 838 | 0.178 |
| 112.5 – 157.5 (SE) | 955 | 0.203 |
| 157.5 – 202.5 (S) | 489 | 0.104 |
| 202.5 – 247.5 (SW) | 440 | 0.094 |
| 247.5 – 292.5 (W) | 316 | 0.067 |
| 292.5 – 337.5 (NW) | 437 | 0.093 |

Similar summary tables for the 1728 nighttime Taurus II static test firing simulations were compiled. Table 4-18 shows that the peak CO instantaneous concentration predictions for nighttime conditions continues with a high probability that the maximum far field concentration will be less than 1 ppm.

**Table 4-18. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide Concentrations For Nighttime Taurus II Static Test Firing Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1231 | 0.712 |
| 1 - 2 | 279 | 0.161 |
| 2 - 3 | 99 | 0.057 |
| 3 - 4 | 42 | 0.024 |
| 4 - 5 | 33 | 0.019 |
| 5 - 6 | 15 | 0.009 |
| 6 - 7 | 9 | 0.005 |
| 7 - 8 | 9 | 0.005 |
| 8 - 9 | 3 | 0.002 |
| 9 + | 3 | 0.002 |

The REEDM static test firing predicted CO 1-hour time weighted average concentrations for all nighttime meteorological cases is provided in Table 4-19 and it is noted that approximately 59% of all nighttime meteorological cases resulted in REEDM maximum 1-hour TWA ground level

CO concentrations of less than 0.04 ppm. Static test firing TWA CO concentrations trend higher than those observed in the normal launch simulations.

Table 4-20 indicates the predicted Taurus II static test firing plume direction probability of occurrence observed across the 1728 nighttime balloon soundings. It is noted that for nighttime launch scenarios transport of the exhaust plume to the East is still favored as it was during the daytime.

**Table 4-19. REEDM Predicted Maximum Far Field Ground Level Carbon Monoxide TWA Concentrations For Nighttime Taurus II Static Test Firing Scenarios.**

| 1-Hour TWA Concentration Bin | Count | Probability |
|---|---|---|
| 0.00 – 0.02 | 605 | 0.350 |
| 0.02 – 0.04 | 407 | 0.236 |
| 0.04 - 0.06 | 293 | 0.170 |
| 0.06 - 0.08 | 197 | 0.114 |
| 0.08 - 0.10 | 84 | 0.049 |
| 0.10 - 0.12 | 58 | 0.034 |
| 0.12 - 0.14 | 31 | 0.018 |
| 0.14 - 0.16 | 9 | 0.005 |
| 0.16 - 0.18 | 19 | 0.011 |
| 0.18 – 0.20 | 11 | 0.006 |
| 0.20 – 0.22 | 7 | 0.004 |
| 0.22 – 0.24 | 3 | 0.002 |
| 0.24 – 0.26 | 2 | 0.001 |
| 0.26 – 0.28 | 0 | 0.000 |
| 0.28 – 0.30 | 1 | 0.001 |
| 0.30 – 0.32 | 1 | 0.001 |
| 0.32 – 0.34 | 0 | 0.0000 |
| 0.34 – 0.36 | 0 | 0.0000 |
| 0.36 – 0.38 | 0 | 0.0000 |
| 0.38 -0.40 | 0 | 0.0000 |

**Table 4-20. REEDM Predicted Exhaust Cloud Transport Directions For Nighttime Taurus II Static Test Firing Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 72 | 0.042 |
| 22.5 – 67.5 (NE) | 321 | 0.186 |
| 67.5 – 112.5 (E) | 306 | 0.177 |
| 112.5 – 157.5 (SE) | 378 | 0.219 |
| 157.5 – 202.5 (S) | 221 | 0.128 |
| 202.5 – 247.5 (SW) | 207 | 0.120 |
| 247.5 – 292.5 (W) | 92 | 0.053 |
| 292.5 – 337.5 (NW) | 131 | 0.076 |

## 4.4 REEDM Near Field Results For Taurus II Normal Launch Scenario

In REEDM terminology the "near field" is defined as the geographical region near the launch pad where the rocket exhaust cloud source is formed and undergoes vertical cloud rise due to buoyancy effects. REEDM is not specifically designed to predict cloud concentrations in this region because the area is typically evacuated during launches due to high risk from debris, blast, fire and toxics hazards. Emissions in this region are of interest for environmental considerations however; therefore ACTA modified the output of REEDM to report intermediate calculations of the exhaust cloud size, position and temperature during the cloud rise phase. Using information about the size and location of the exhaust cloud coupled with the known quantity of exhaust products emitted and the mass fractions of the exhaust chemical constituents allows an estimate to be made of chemical concentrations inside the cloud in the near field. When performing far field calculations, REEDM assumes that the mass distribution of exhaust products in the expanded and diluted exhaust cloud is Gaussian. In the near field, as the source cloud is initially formed, the exhaust products may be more uniformly distributed. ACTA computed in-cloud concentrations in the near field assuming both uniform and Gaussian mass distributions. For the Gaussian distribution the maximum concentration occurs at the cloud centroid and the edge of the cloud is defined as the point where the concentration is 10% of the centroid maximum values. This assumption defines the cloud radius as 2.14 standard deviations.

The size and shape of the near field ground level carbon monoxide concentration pattern depends upon several factors:

1. The dynamics of the exhaust flow emitted from the Taurus II Pad-0A flame duct.

2. The effects of thermal buoyancy that lifts the plume off the ground and imparts vertical acceleration to the hot plume gases.

3. The effect of local wind speed and direction after the jet momentum has dissipated and the plume is beginning to lift off the ground.

The jet dynamics of the high speed exhaust plume venting from the flame duct are largely independent of the weather conditions and are determined by the design of the flame duct and concrete ramp structure at the exit of the duct. These design features were still in development and evaluation at the time of this study. The vertical rise rate of the buoyant cloud after the jet dynamics have dampened are computed by REEDM and were used to estimate the vertical and horizontal cloud displacement from a point where the exhaust plume is assumed to become buoyancy dominated. For normal launches, only a portion of the main engine exhaust vents through the flame duct and some of the ground cloud forms around the launch pad. A detailed computational fluid dynamics flow analysis of the plume interaction with the flame duct and the launch pad surface is not available, however, based on photographs and video of other launch vehicle normal launch ground clouds, it is estimated that the center of the Taurus II normal launch ground cloud will be displaced about 100 meters from the vehicle liftoff position in the direction of the flame duct exit.

REEDM calculations for the near field normal launch cloud rise were processed for 6427 meteorological cases and summarized by month as shown in Table 4-21. REEDM approximates the Taurus II normal launch ground cloud as a sphere the radius of which grows linearly during the buoyant cloud rise phase according to the following relationship:

$$r(z) = r_0 + \gamma \Delta z$$

| | | | |
|---|---|---|---|
| where: | $r(z)$ | = | cloud radius at height z [m] |
| | $r_o$ | = | initial cloud radius [m] = 48.8 [m] (160 ft) |
| | $\gamma$ | = | air entrainment coefficient = 0.36 |
| | $\Delta z$ | = | height of cloud centroid above the ground [m] |

Based on the forgoing relationship, the spherical cloud will just touch the ground surface when the cloud centroid lifts to approximately 76 meters above the ground. This is also referred to in this report as the "cloud liftoff" point. Beyond this point the downwind ground CO concentration is assumed to be zero until the ground concentrations once again start to occur in the far field due to downward mixing from the stabilized normal launch cloud. The maximum distance from the point where the flame duct horizontal flow dynamics are dampened (REEDM initialization point) to the point where the wind driven normal launch plume lifts off the ground is estimated to be 144 meters. Average distance from the REEDM initialization point to the point of cloud liftoff is estimated to be about 25 meters. These distances are influenced by the initial amount of cloud "exhaust" materials as well as the air entrainment rate assumption. If deluge water injection and combustion air are added to the initial exhaust mass, then the initial cloud radius will be larger and the downwind distance to the liftoff point will be somewhat longer. Given uncertainties in the plume mass entrainment and other modeling assumptions, the maximum travel distance to Taurus II normal launch ground cloud liftoff is estimated at about 200 meters. Thus a circle with a radius of 200 meters centered 100 meters downstream from the flame duct exit would approximately define the region within which a toxic exposure to CO might occur under high surface wind conditions. The average potential toxic exposure zone is expected to be much smaller and is associated with moderate to light surface winds. Maximum ground level CO concentrations inside the near field toxic hazard zone could exceed 7000 ppm.

**Table 4-21. Taurus II Normal Launch Near Field CO Concentration Summary.**

| Month | Number of Weather Cases | Ground CO Concentration at Cloud Liftoff Uniform Distribution [ppm] | Ground CO Concentration at Cloud Liftoff Gaussian Distribution [ppm] | Maximum Distance to Cloud Liftoff [m] | Average Distance to Cloud Liftoff [m] |
|---|---|---|---|---|---|
| January | 435 | 7530 | 1980 | 78 | 22 |
| February | 521 | 7420 | 1950 | 86 | 23 |
| March | 559 | 7190 | 1890 | 99 | 25 |
| April | 538 | 8440 | 2220 | 93 | 25 |
| May | 556 | 7250 | 1910 | 86 | 23 |
| June | 544 | 7140 | 1880 | 55 | 21 |
| July | 569 | 6650 | 1750 | 62 | 20 |
| August | 570 | 7790 | 2050 | 61 | 18 |
| September | 576 | 7190 | 1890 | 144 | 21 |
| October | 554 | 7330 | 1930 | 98 | 19 |
| November | 507 | 7870 | 2070 | 101 | 20 |
| December | 498 | 8280 | 2180 | 76 | 22 |

An example of near field concentration calculations for a normal launch plume with a May meteorological case that produced a low cloud rise is listed below. As the ground cloud rises REEDM assumes it intersects and combines with the contrail cloud above it and the total amount of exhaust mass in the rising cloud continues to increase until the ground cloud stops rising at the stabilization altitude. As previously defined, when the predicted ground cloud radius just equals the height of the ground cloud centroid above the ground, the exhaust cloud is just at the point of lifting off the ground. In Table 4-22 this occurs as the cloud rises through the 8th meteorological layer where the top of the layer is 89.9 meters above the ground and the cloud radius is predicted to be 80.8 meters. At this point the cloud is predicted to have moved 20.6 meters in the downwind direction, has an average temperature of 329.5 Kelvin (133 F) and has an uniform CO concentration of 7615 ppm. As the cloud continues to move downwind it rises further above the ground and only flying birds or tall trees would be exposed to the concentrated cloud exhaust chemicals. This sample normal launch cloud is predicted to stabilize at 440 meters above the ground approximately 200 meters downwind from the initial source formation point and has a predicted radius of 206.9 meters. The bottom of the exhaust cloud would be approximately 233 meters above the ground. The centroid concentration, assuming the mass distribution has transitioned to Gaussian, is predicted to be 3881 ppm with the concentration at the edge of the cloud equal to 388 ppm (10% of the peak centroid concentration).

**Table 4-22. Sample Near Field Taurus II Normal Launch Exhaust Cloud Concentration Estimates For a May WFF Meteorological Case.**

```
     initial cloud radius          [m] =    48.76800
     initial cloud height          [m] =   0.0000000E+00
     initial cloud rise velocity [m/s] =   0.0000000E+00
```

| met layer | cloud height [m] | cloud radius [m] | cloud volume [m**3] | exhaust mass [g] | downwind dist [m] | rise time [sec] | cloud temp [K] | uniform conc [ppm] | Gaussian conc [ppm] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.0 | 52.4 | .60123E+06 | .17505E+08 | 2.3 | 1.295 | 590.5 | 6516. | 17152. |
| 2 | 20.6 | 55.8 | .72845E+06 | .23196E+08 | 5.8 | 0.632 | 498.6 | 7127. | 18760. |
| 3 | 30.2 | 59.3 | .87234E+06 | .30021E+08 | 8.0 | 0.580 | 443.6 | 7703. | 20275. |
| 4 | 39.8 | 62.7 | .10341E+07 | .37721E+08 | 10.1 | 0.573 | 407.6 | 8164. | 21489. |
| 5 | 49.4 | 66.2 | .12148E+07 | .46158E+08 | 12.2 | 0.584 | 382.5 | 8504. | 22384. |
| 6 | 59.3 | 69.8 | .14221E+07 | .55242E+08 | 14.4 | 0.622 | 363.7 | 8694. | 22884. |
| 7 | 69.2 | 73.3 | .16517E+07 | .64928E+08 | 16.7 | 0.647 | 349.6 | 8798. | 23158. |
| 8 | 89.9 | 80.8 | .22091E+07 | .75165E+08 | 20.6 | 1.451 | 329.5 | 7615. | 20044. |
| 9 | 108.5 | 87.5 | .28051E+07 | .86432E+08 | 26.0 | 1.423 | 317.9 | 6896. | 18152. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 126.5 | 94.0 | .34754E+07 | .98520E+08 | 31.5 | 1.490 | 310.0 | 6345. | 16701. |
| 11 | 144.5 | 100.4 | .42446E+07 | .11134E+09 | 37.3 | 1.605 | 304.2 | 5871. | 15453. |
| 12 | 176.0 | 111.8 | .58536E+07 | .12482E+09 | 46.4 | 3.091 | 297.9 | 4773. | 12563. |
| 13 | 207.6 | 123.2 | .78254E+07 | .13940E+09 | 59.1 | 3.425 | 294.1 | 3987. | 10494. |
| 14 | 222.5 | 128.5 | .88963E+07 | .15495E+09 | 69.4 | 1.734 | 292.7 | 3898. | 10261. |
| 15 | 240.2 | 134.9 | .10285E+08 | .17095E+09 | 77.2 | 2.141 | 291.2 | 3720. | 9792. |
| 16 | 295.4 | 154.8 | .15530E+08 | .18744E+09 | 96.9 | 7.536 | 288.8 | 2701. | 7111. |
| 17 | 339.9 | 170.8 | .20869E+08 | .20538E+09 | 127.3 | 7.224 | 287.6 | 2203. | 5798. |
| 18 | 386.5 | 187.6 | .27649E+08 | .22438E+09 | 158.3 | 9.055 | 286.9 | 1816. | 4781. |
| 19 | 440.1 | 206.9 | .37099E+08 | .24441E+09 | 198.2 | 14.517 | 286.9 | 1475. | 3881. |

## 4.5 REEDM Near Field Results For Taurus II Static Test Firing Scenario

REEDM calculations for the near field static test firing cloud rise were processed for 6427 meteorological cases and summarized by month as shown in Table 4-23. REEDM approximates the Taurus II static test firing cloud as a sphere the radius of which grows linearly during the buoyant cloud rise phase according to the following relationship:

$$r(z) = r_0 + \gamma \Delta z$$

where:

- $r(z)$ = cloud radius at height z [m]
- $r_o$ = initial cloud radius [m] = 46.05 [m] (151 ft)
- $\gamma$ = air entrainment coefficient = 0.5
- $\Delta z$ = height of cloud centroid above the ground [m]

Based on the forgoing relationship, the spherical cloud will just touch the ground surface when the cloud centroid lifts to approximately 91 meters above the ground. The initial cloud radius is calculated using the ideal gas law and the principle of mass conservation applied to the engine RP-1 and LOX propellant consumed in the test firing. Inclusion of deluge water and combustion air injected beyond the nozzle exit plane would increase the cloud exhaust mass and therefore would also increase the estimated initial cloud radius.

**Table 4-23. Taurus II Static Test Firing Near Field CO Concentration Summary.**

| Month | Number of Weather Cases | Ground CO Concentration at Cloud Liftoff Uniform Distribution [ppm] | Ground CO Concentration at Cloud Liftoff Gaussian Distribution [ppm] | Maximum Distance to Cloud Liftoff [m] | Cloud Transport Bearing Associated With Max Cloud Liftoff [deg] | Average Distance to Cloud Liftoff [m] |
|---|---|---|---|---|---|---|
| January | 435 | 3990 | 1050 | 212 | 181 | 36 |
| February | 521 | 3980 | 1050 | 249 | 298 | 40 |
| March | 559 | 4010 | 1055 | 299 | 269 | 43 |
| April | 538 | 3960 | 1040 | 271 | 316 | 43 |
| May | 556 | 4050 | 1065 | 259 | 302 | 38 |
| June | 544 | 3980 | 1050 | 126 | 328 | 33 |
| July | 569 | 4020 | 1060 | 161 | 101 | 31 |
| August | 570 | 4020 | 1060 | 143 | 333 | 27 |
| September | 576 | 3970 | 1040 | 557* | 298 | 36 |
| October | 554 | 3960 | 1040 | 296 | 309 | 30 |
| November | 507 | 4050 | 1065 | 307 | 310 | 33 |
| December | 498 | 4020 | 1060 | 211 | 283 | 36 |

* September case with 557-meter downwind distance was under storm conditions with 60 knot surface winds, an unlikely weather condition for conducting a test firing.

Given uncertainties in the static test firing plume mass entrainment and other modeling assumptions, the maximum travel distance to Taurus II static test firing cloud liftoff is estimated at about 350 meters. Thus a circle with a radius of 350 meters centered 200 meters downstream from the flame duct exit would approximately define the region within which a toxic exposure to CO might occur under high surface wind conditions. The average potential toxic exposure zone is expected to be much smaller and is associated with moderate to light surface winds. Maximum ground level CO concentrations inside the near field static test firing toxic hazard zone could exceed 4000 ppm.

## 5. CONCLUSIONS

A conservative analysis approach has been applied to estimate carbon monoxide concentrations associated with Taurus II normal launch and static test firing scenarios. The analysis is deemed to be conservative in the sense that certain modeling assumptions, such as discounting the effect of uncertain processes such as the plume chemical alterations due to deluge water injection and plume afterburning with ambient air, favor predicting higher carbon monoxide concentrations than are expected to actually occur. The study also evaluated maximum chemical concentrations predicted using a set of over 6000 historical Wallops Flight Facility weather balloon soundings. Thus reasonable worst-case weather conditions should have inherently been captured in the study. The Taurus II first stage propellants are the hydrocarbon based fuel RP-1 and liquid oxygen (LOX). Under design combustion conditions the oxidizer to fuel burn ratio is approximately 2.7, which represents a somewhat fuel rich mixture. The main combustion byproduct of concern is carbon monoxide, which is estimated to comprise approximately 25.6 percent of the exhaust mixture by mass at the rocket nozzle exit. The other main combustion byproducts are carbon dioxide and water vapor. Rocket emissions from both the a normal vehicle launch and a static test firing on the launch pad are extremely hot and therefore less dense than surrounding ambient air and are accelerated vertically due to buoyancy forces that act on the exhaust cloud gases. The effect of buoyancy is to loft the exhaust clouds above the ground to a point of neutral stability in the atmosphere at altitudes ranging from 400 to 1300 meters above the ground. From the stabilization altitude, exhaust cloud materials eventually mix back down to the ground due to atmospheric turbulence, unless the entire cloud is predicted to rise above a capping thermal inversion. The geographic region near the launch pad where the source cloud forms and begins its thermal rise process is referred to as the "near field". Ground level CO concentrations in the near field region are estimate to be in the 4000 to 20000 ppm range, however the downwind transport distance before the cloud lifts off the ground is predicted to be relatively short—on the order of several hundred meters or less. The geographic region where the stabilized and neutrally buoyant cloud material mixes back to the ground is referred to as the "far field". REEDM predicts that the peak instantaneous CO concentrations in the far field region are typically less than 1 ppm but have the potential to reach as high as 20 ppm. One-hour time weighted average CO concentrations are estimated to be very low, typically less than 0.04 ppm, and these low TWA values are due to the short cloud passage time over a receptor location (e.g. minutes rather than hours). The far field CO concentration levels are well below published emergency exposure guidelines for humans and are considered to be benign to people, flora and fauna. Near field CO concentrations may reach hazardous levels that exceed the AEGL-3 10-minute exposure threshold or the IDLH exposure threshold. Given the proximity of the near field exposed region to the plume point of origin, other hazards, such as radiant heat transfer or direct exposure to the high temperature exhaust gas mixture, may be more severe than the hazard from CO chemical concentration exposure.

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# Evaluation of Toxic Emissions for a Large Solid Propellant Launch Vehicle at Wallops Flight Facility

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# 1. EXECUTIVE SUMMARY

This study investigated potential toxic hazards associated with normal launch and catastrophic vehicle failure scenarios for a large space launch booster that utilizes four successively smaller solid propellant stages. The vehicle design was based on a concept vehicle proposed by Alliant Techsystems Inc. (ATK) that is comprised of Castor solid rocket motors designed and built by ATK. These motors are closely related to the motor segments used on the Space Shuttle solid rocket boosters. The first stage of this vehicle is designated as the Castor 1200 and contains just over 1.1 million pounds of solid propellant that is a mixture of ammonium perchlorate (AP), aluminum powder and a rubbery polybutadiene acrylic acid acrylonitrile (PBAN) binder. When burned, this propellant generates exhaust that is about 20% by mass toxic hydrogen chloride gas. The aluminum powder, which is part of the fuel component in the propellant, is oxidized during combustion to aluminum oxide and generates small particulates of solid $Al_2O_3$ in the rocket engine plume after the plume expands and cools. For the purposes of this study a set of default particle size and mass distribution assumptions contained in the Rocket Exhaust Effluent Diffusion Model (REEDM) were applied to the Castor 1200 motor. These default assumptions have been applied by Air Force range safety analysts in the past to evaluate emissions from the large solid rocket boosters on the Space shuttle and Titan vehicles. The entire mass distribution of $Al_2O_3$ in assigned to size bins that are all under 10 microns in size and fall within pollution and health standards that pertain to the "$PM_{10}$" classification. Approximately 70% of the $Al_2O_3$ particulate mass falls in a smaller "$PM_5$" category that is also defined as "respirable dust" with average sizes of 5 microns or less. In addition to chemical releases associated with the solid propellant, this study considered potential releases of hypergolic nitrogen tetroxide ($N_2O_4$) oxidizer and monomethyl hydrazine fuel (MMH) ($CH_3(NH)NH_2$) from a representative generic spacecraft that would be a payload on the candidate launch vehicle. When released to the atmosphere $N_2O_4$ readily dissociates to $NO_2$, therefore concentrations for the oxidizer are evaluated as $NO_2$. Both $NO_2$ and MMH are highly toxic and have human health effect thresholds in the 2 to 20 part per million range.

New launch vehicles have a high probability of failure due to the complexity of the launch system and the inability to fully test vehicle integration and flight performance at the manufacturing facility. Catastrophic loss of the entire launch vehicle is the most common result of a launch system failure. The Federal Aviation Administration (FAA) office of commercial space transport has established guidelines that assign probable launch vehicle failure rates to new launch vehicles that are based on historical performance of similar vehicles. New launch vehicles under the FAA binomial failure probability allocation have mission failure probabilities on the 3rd flight ranging from 0.276 to 0.724 with a median of 0.5. In other words, there is historical supporting evidence that the statistical probability of a launch failure is as high as 72.4% for a new launch vehicle on a third flight attempt with prior failures. For this reason, it is prudent to consider the environmental effect of launch vehicle failures as well as normal launch successes. The chemical emissions that result from a catastrophic launch vehicle failure are invariably more severe than the emissions from the normal launch, in part because 100% of the launch vehicle propellants are released simultaneously in a vehicle breakup and in part because rupture of liquid propellant tanks leads to inefficient mixing and only partial combustion of the hypergolic propellants.

To assess formation of the launch vehicle emissions and the subsequent cloud rise and atmosphere transport and dispersion, two recognized range safety computer programs were employed for this study. The Rocket Exhaust Effluent Diffusion Model (REEDM) was used to simulate HCl and $AL_2O_3$ releases associated with the normal launch scenarios. REEDM supports calculations that account for gravitational settling of $Al_2O_3$ particulates. The Launch Area Toxic Risk Analysis 3-Dimensional (LATRA3D) program was used to simulate releases from launch vehicle catastrophic failures and liquid propellant spills. Explosion of the pressurized Castor 1200 during first stage flight from 0 to 20 seconds into flight was evaluated to assess the formation of toxic plumes from the explosion and the burning propellant fragments that result as the motor breaks up. This is referred to as the "conflagration" scenario. It was assumed that the payload containing 1000 pound of MMH and 1640 pound of nitrogen tetroxide would be ejected from a Castor 1200 explosion and fall back to the ground intact resulting in either a liquid propellant explosion and fire (called the "deflagration" scenario) or rupture the propellant tanks and spill the liquid propellants without initiating a fire or explosion (called the "evaporating pool" scenario).

Each of these release scenarios were evaluated by running REEDM or LATRA3D for 6430 archived meteorological weather balloon soundings obtained from the Wallops Flight Facility. Approximately 102,000 computer simulations were generated for the combination of release scenarios and weather cases. Toxic dispersion predictions from these runs were post processed to summarize general characteristics, trends and to identify bounding worst case hazard conditions expressed in terms of maximum expected ground level concentrations and maximum downwind distances to the endpoint of a concentration threshold or to the maximum predicted concentration location. Except for the evaporating pool scenarios, the sources are initially buoyant and rise hundreds to thousands of feet into the atmosphere and then gradually mix back down to the ground level. Elevated sources typically exhibit a "clear" zone near the source where the buoyant cloud passes overhead and there is no detectable concentration at the ground. As the cloud material mixes back to the ground, the ground level concentration starts to increase, reaches a maximum and then decreases due to continued dilution as the expanding cloud moves further downwind. We summarize here the general observations and findings from the large set of simulations.

**Normal Launch Scenario:**

The normal launch scenario releases HCl and $Al_2O_3$ and is deemed by the author to constitute relatively benign toxic hazards (at ground level) with following characteristics:

| | |
|---|---|
| Peak HCl concentrations: | 2 to 5 ppm |
| Maximum downwind distance to peak concentration: | 11000 to 19000 meters |
| Concentration probabilities: | 63% of cases < 1 ppm |
| Duration of exposure: | < 60 minutes |

| | |
|---|---|
| Peak $Al_2O_3$ $PM_5$ concentrations: | 2 to 6 $mg/m^3$ |
| Maximum downwind distance to peak concentration: | 10000 to 33000 meters |
| Concentration probabilities: | 67% of cases < 1 $mg/m^3$ |
| Duration of exposure: | < 90 minutes |

**Conflagration Scenario for Failures over the First 20 Seconds of Flight:**

The conflagration scenario releases HCl and $Al_2O_3$ and results in significantly higher ground level concentrations than the normal launch scenario. The magnitude of ground level HCl concentrations vary depending on the launch vehicle failure time. The worst case for the candidate launch vehicle appears to be for a failure at about 4 seconds into flight. The following general characteristics are noted:

**For HCl:**

| | |
|---|---|
| T-0 failure peak HCl concentrations: | 18 to 65 ppm |
| Maximum downwind distance to peak concentration: | 1000 to 6000 meters |
| Concentration probabilities: | 79% of cases < 10 ppm |
| Duration of exposure: | < 60 minutes |

| | |
|---|---|
| T+4 failure peak HCl concentrations: | 31 to 315 ppm |
| Maximum downwind distance to peak concentration: | 40 to 2300 meters |
| Concentration probabilities: | 72% of cases < 10 ppm |
| Duration of exposure: | < 60 minutes |

| | |
|---|---|
| T+8 failure peak HCl concentrations: | 30 to 120 ppm |
| Maximum downwind distance to peak concentration: | 90 to 5400 meters |
| Concentration probabilities: | 76% of cases < 10 ppm |

| | |
|---|---|
| Duration of exposure: | < 60 minutes |
| T+12 failure peak HCl concentrations: | 18 to 118 ppm |
| Maximum downwind distance to peak concentration: | 90 to 3500 meters |
| Concentration probabilities: | 79% of cases < 10 ppm |
| Duration of exposure: | < 60 minutes |
| T+16 failure peak HCl concentrations: | 19 to 153 ppm |
| Maximum downwind distance to peak concentration: | 330 to 2700 meters |
| Concentration probabilities: | 82% of cases < 10 ppm |
| Duration of exposure: | < 60 minutes |
| T+20 failure peak HCl concentrations: | 14 to 153 ppm |
| Maximum downwind distance to peak concentration: | 980 to 3000 meters |
| Concentration probabilities: | 87% of cases < 10 ppm |
| Duration of exposure: | < 60 minutes |

**For $Al_2O_3$:**

| | |
|---|---|
| T-0 failure peak $Al_2O_3$ concentrations: | 5 to 18 $mg/m^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 7000 to 18000 meters |
| Concentration probabilities: | 2.8% of cases >5 $mg/m^3$ $PM_5$ |
| Duration of exposure: | < 60 minutes |
| T+4 failure peak $Al_2O_3$ concentrations: | 7 to 30 $mg/m^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 5000 to 18000 meters |
| Concentration probabilities: | 6.7% of cases >5 $mg/m^3$ $PM_5$ |
| Duration of exposure: | < 60 minutes |
| T+8 failure peak $Al_2O_3$ concentrations: | 15 to 423 $mg/m^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 1000 to 8000 meters |
| Concentration probabilities: | 21.4% of cases >5 $mg/m^3$ $PM_5$ |
| Duration of exposure: | < 60 minutes |
| T+12 failure peak $Al_2O_3$ concentrations: | 33 to 1000 $mg/m^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 1000 to 5000 meters |
| Concentration probabilities: | 40.2% of cases >5 $mg/m^3$ $PM_5$ |

| | |
|---|---|
| Duration of exposure: | < 60 minutes |

| | |
|---|---|
| T+16 failure peak $Al_2O_3$ concentrations: | 55 to 765 mg/m$^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 1000 to 3000 meters |
| Concentration probabilities: | 52.5% of cases >5 mg/m$^3$ $PM_5$ |
| Duration of exposure: | < 60 minutes |

| | |
|---|---|
| T+20 failure peak $Al_2O_3$ concentrations: | 79 to 550 mg/m$^3$ $PM_{10}$ |
| Maximum downwind distance to peak concentration: | 1000 to 7000 meters |
| Concentration probabilities: | 60.2% of cases >5 mg/m$^3$ $PM_5$ |
| Duration of exposure: | < 60 minutes |

**Payload Hypergol Deflagration Scenario:**

The payload deflagration scenario releases $NO_2$ and MMH as constituents in an instantaneous fireball. These are present because of incomplete mixing and incomplete combustion of fuel and oxidizer. The following general characteristics are noted:

| | |
|---|---|
| Peak $NO_2$ concentrations: | 7 to 42 ppm |
| Maximum downwind distance to peak concentration: | 500 to 2100 meters |
| Maximum 0.5 ppm hazard distance: | 9000 meters |
| Concentration probabilities: | 5.4% of cases >10 ppm |
| Duration of exposure: | < 30 minutes |

| | |
|---|---|
| Peak MMH concentrations: | 0.8 to 4.6 ppm |
| Maximum downwind distance to peak concentration: | 500 to 2100 meters |
| Maximum 0.5 ppm hazard distance: | 5000 meters |
| Concentration probabilities: | 0.7% of cases >2 ppm |
| Duration of exposure: | < 30 minutes |

**Payload Hypergol Pool Evaporation Scenario:**

The payload pool evaporation scenario releases $NO_2$ and MMH as single constituents in separate evaporating pools that are assumed to have no chemical interaction. Extremely high concentrations occur right at the evaporating pool. Exposure to these concentrations for even a short duration could be lethal to humans and animals.

The 5 ppm hazard zone distances reported here contain within their borders much higher concentrations nearer to the source. The 5 ppm hazard zone could be considered a containment area or distance within which moderate health effects (or worse) in people are expected. The following general characteristics are noted:

| | |
|---|---|
| Peak $NO_2$ concentrations: | 10000 to 50000 ppm |
| Maximum downwind distance to peak concentration: | -- not meaningful (at pool) -- |
| Maximum 5.0 ppm hazard distance: | 800 to 2500 meters |
| Concentration probabilities: | 100% of cases >10 ppm |
| Duration of exposure: | < 20 minutes |
| | |
| Peak MMH concentrations: | 200 to 5000 ppm |
| Maximum downwind distance to peak concentration: | -- not meaningful (at pool) -- |
| Maximum 5.0 ppm hazard distance: | 100 to 280 meters |
| Concentration probabilities: | 100% of cases >10 ppm |
| Duration of exposure: | < 120 minutes |

How best to interpret and use these toxic hazard assessment is left to the judgment of range planner and NASA policy directives. The Air Force ranges employ detailed risk mitigation procedures for launch vehicles and missions that have potential for exposing workers or the general public to planned or accidental releases. Mitigations include holding a launch until meteorological conditions are favorable, moving people out of potential toxic hazard corridors and sheltering in place in approved shelters. While these types of policies can be applied to people, they cannot all be applied to sensitive flora and fauna that may be present at the launch facility.

## 2. INTRODUCTION AND BACKGROUND

In recent years Wallops Flight Facility (WFF) has expanded launch vehicle operations to include increasingly larger launch vehicles such as the Minotaur 1. Planned future missions anticipate launches of the Orbital Sciences Corporation Antares vehicle and the Minotaur 4 and 5. This report evaluates atmospheric dispersion of chemical emissions resulting from the launch of a hypothetical large solid rocket booster that might be launched from Wallops Flight Facility at some point in the future. These findings are intended to supplement a broader range programmatic Environmental Impact Study (EIS) being conducted by CardnoTec Inc. to assess impacts at WFF related to infrastructure development for, and launch of, a large solid rocket booster. Traditionally the Air Force and NASA have supported mission planning and day of launch hazard assessments for the launch of large vehicles from Cape Canaveral and Vandenberg Air Force Base. Recognized launch hazards can be categorized into the following classes that affect the larger launch area:

1. Inert Debris Impact Hazards
2. Explosive Debris Impact and Air Blast Overpressure Hazards
3. Distant Focused Overpressure Hazards
4. Toxic Emission Hazards

In general these hazards are associated with catastrophic failure of the launch vehicle or range safety command destruct of a vehicle exhibiting errant flight behavior. Debris hazards can affect a long flight corridor extending thousands of miles downrange. In the case of an orbital launch from WFF, the debris hazard region can include Europe or Africa. Depending on the type of first stage propellants used, toxic emission hazards may also be associated with normal (successful) launch of the vehicle.

Additional hazards that affect a more limited area near the launch pad are:

1. Acoustic Energy and Ignition Over Pressure (IOP) Hazards
2. Thermal Energy Hazards

The scope of this study is restricted to evaluation of toxic hazard emissions from both normal launch and early flight failures (e.g. the first 20 seconds of flight) that can deposit large quantities of chemicals in the convective boundary layer of the atmosphere. The convective boundary layer is generally that region of the atmosphere that is affected by surface heating and terrain topography. The boundary layer thickness varies with a diurnal cycle and is also affected by synoptic scale weather patterns (e.g. frontal systems). In this study the wind, temperature, humidity and pressure profiles in the lower 10,000 feet of the atmosphere are used to define the region of interest for chemical release and subsequent downwind transport and dispersion. Chemical concentrations of vaporized propellants or propellant combustion products at ground level are predicted as a measure of hazard potential.

Although dozens of rocket propellant types have been developed and tested over the years, the current inventory of large rockets manufactured in the United States employ a relatively few combinations of propellant types, which are:

1. Liquid stages using RP-1 fuel + liquid oxygen
2. Liquid stages using liquid hydrogen fuel + liquid oxygen
3. Liquid stages using hydrazine based fuel + nitrogen tetroxide oxidizer
4. Solid propellant stages using aluminum metal and organic binder fuel + ammonium perchlorate oxidizer.

A previous WFF Environmental Assessment (EA) study [1] was performed to evaluate chemical emissions from static test firing and normal launch of the Taurus II (Antares) launch vehicle. The Antares vehicle is representative of the first class of vehicles that use RP-1 (refined rocket propellant grade kerosene) and liquid oxygen (LOX). Although these propellants are burned in a fuel rich mixture the exhaust products can be considered environmentally friendly compared to solid propellant exhaust. The use of RP-1/LOX also avoids handling and spill toxic hazards associated with liquid hypergolic propellants. Consequently, the primary chemical exhaust constituent of concern for RP-1/LOX combustion from a toxicity standpoint is carbon monoxide (CO). The vehicle configuration evaluated in this study was assumed to be a four stage vehicle with each stage using solid propellant. A payload (e.g. satellite) was assumed to contain relatively small quantities of commonly used liquid hypergolic monomethylhdrazine (MMH) ($CH_3(NH)NH_2$) fuel and liquid hypergolic nitrogen tetroxide ($N_2O_4$) oxidizer. The last U.S. launch vehicle to use large quantities of hypergols in the main propulsion stages was the Titan IV, which is no longer in production. Many Russian and Chinese launch vehicles still use hypergolic propellants, but these are unlikely to be used at WFF. All of the commonly used hypergolic fuel and oxidizer chemicals are highly toxic. Since the candidate vehicle did not employ RP-1 + LOX or the cryogenic combination of liquid hydrogen + LOX, no further consideration is given to these common propellant combinations.

## 3. REPRESENTATIVE LAUNCH VEHICLE CHARACTERISTICS

The launch vehicle selected for this analysis is based on a design concept proposed by ATK [2]. The proposed launch vehicle has not yet been built but the stages are based on motors or motor segments used on other existing launch vehicles. ATK provide sufficiently detailed motor ballistics and propellant data for ACTA to develop database parameters needed by the toxic dispersion models used in this analysis. The first stage of the proposed launch vehicle is designated by ATK as a Castor 1200, which is a 4-segment motor built from slightly modified motor segments used on the now retired Space Shuttle Reusable Solid Rocket Motor (RSRM) design. The solid propellant formulation is designated as TP H1148 Type VIII (RSRMV) by ATK. This formulation is very similar to that used in the Shuttle RSRM segments differing primarily in the amount of iron oxide, a minor constituent that is used to control the burn rate of the propellant. The major constituents of TP-1148 on a percent by weight basis are:

| | |
|---|---|
| Ammonium Perchlorate (AP) | 69.7% |
| Aluminum | 16.0% |
| PBAN binder and curatives | 14.3% |

PBAN (polybutadiene acrylonitrile) copolymer is a viscous organic binder used to mix the aluminum powder, AP crystals and curing agents together into a propellant slurry that is poured into castings and cured to form a rubbery solid propellant grain inside the motor. Motor propellant castings are typically cylindrical in shape with a center bore where the casting mandrel is removed. The propellant castings have a star pattern to increase the burning surface area during the early stage of the propellant burn. The burn rate of solid propellant is pressure dependent, a factor that will be significant to this analysis because in the catastrophic failure scenario analyses the solid propellant motor is assumed to break up into many pieces with the propellant burning at atmospheric pressure (14.7 PSIA). Normal motor burn has an internal pressure around 900 PSIA with a substantially higher burn rate. This study used the following atmospheric burn rate provided by Thiokol for Shuttle SRB TP-1148 propellant that is also used by the Air Force to predict toxic dispersion from catastrophic failures of Shuttle SRBs:

Burn rate at 14.7 PSIA = 0.065 in/sec

At normal Castor 1200 operating pressure, ATK indicated that the average burn rate of the solid propellant is about 0.347 in/sec. Figure 3-1 illustrates the general design and dimensions of the Castor 1200 motor.

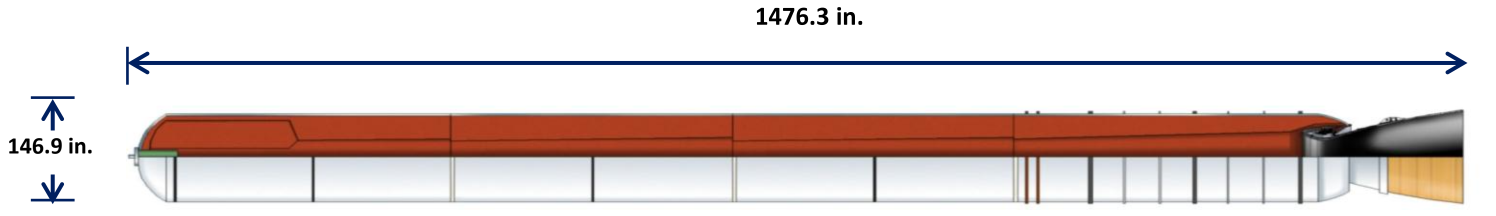


**Figure 3-1. Motor Dimensions of the Castor 1200 First Stage.**

The Castor 1200 motor contains 1,114,155 pounds of solid propellant and has a burn time of approximately 132.8 seconds.

During a nominal launch event the first stage motor is ignited with a starter cartridge and a flame front develops on the interior surface of the propellant grain. Hot combustion gases build up pressure within a few tenths of a second to approximately 870 pounds per square inch (PSIA). The combustion temperature inside the motor chamber is approximately 3400 Kelvin. The hot gases flow out of the combustion chamber through the rocket nozzle and exit the nozzle at supersonic flow at about Mach 3 giving the motor the thrust that lifts the vehicle from the pad and accelerates the vehicle as it ascends. The mass flux exiting the nozzle is somewhat time dependent and is a function of the burn rate and pressure inside the solid rocket motor.

Large launch vehicles are designed to carry a payload into orbit around the Earth. The first stage typically contains the largest percentage of the total vehicle propellant load and gets the vehicle to a position high above the dense part of the atmosphere and well downrange from the launch pad. The Ares-1X test vehicle launched from Cape Canaveral in October 2009 used a first stage very similar in design to the Castor 1200 motor. At burn out of the Ares-1x first stage the vehicle was approximately at 24.5 miles altitude, 41 miles down range and traveling at almost 5000 feet per second. At first stage separation, even if the second stage failed to ignite, the upper stage and payload would have sufficient velocity to carry the upper stage assembly 142 miles downrange. In the event that the vehicle guidance system had a gross azimuth failure, a large launch vehicle like the Castor 1200 or the Ares-1X launched from WFF could thrust an upper stage assembly (with explosive rocket motors) in an unintended direction with an impact in the Washington DC or Baltimore area. To prevent this type of consequence from errant flight failure conditions, the range tracks the launch vehicle with ground radars and monitors telemetry signals sent to the ground tracking station from the vehicle. If the vehicle deviates from the intended downrange "safe" flight corridor, the Range Safety Office (RSO) sends command destruct signals to the launch vehicle. The launch vehicle stages contain linear shaped explosive charges that destroy the launch vehicle and terminate thrust such that the debris still falls within a “safe” area. In the event of a command destruct action during early first stage flight, the Castor 1200 motor is shattered into hundreds of burning propellant fragments that fall to the ground in the launch area. Sudden release of the high pressure combustion gases inside the first stage solid rocket motor imparts additional “explosion induced” velocities to the propellant fragments. The net velocity of each fragment is the sum of the vehicle velocity at the explosion time plus a randomly oriented explosion induced component. In general the propellant fragments will impact in approximately a circular debris field surrounding the launch pad as the vehicle first begins its vertical ascent. As the vehicle climbs above the launch tower the guidance system initiates a pitch program that starts moving the vehicle downrange and gradually the resulting ground debris impact patterns also shift downrange and grow larger in diameter. In the event of a first stage explosive failure, the upper stage will experience a lesser degree of breakup and because the upper stage motors are unpressurized and are massive, they will only receive a small explosion induced velocity from the energetic gas expansion of the first stage.

The vehicle design evaluated for catastrophic aborts in this study was assigned the stage characteristics presented in Table 3-1. Castor information was provided courtesy of ATK. The payload designation was selected by ACTA based on typical propellant quantities and an oxidizer to fuel ratio of 1.64 used on payloads previously launched on Delta and Atlas launch vehicles.

**Table 3-1: Castor 1200 Vehicle Stage Characteristics.**

| Stage | Stage Name | Propellant Type | Propellant Mass [lbm] | Motor Length [in] | Motor Diameter [in] |
|---|---|---|---|---|---|
| Stage 1 | Castor 1200 | TP-1148 | 1,114,115 | 1476 | 146.9 |
| Stage 2 | Castor 120 | TP-1148 | 107,466 | 354.5 | 93.1 |
| Stage 3 | Castor 30B | TP-1148 | 28,278 | 164.5 | 92.1 |
| Stage 4 | Castor 20 | TP-1148 | 17,790 | 146.7 | 92.1 |
| Payload | --- | MMH + $N_2O_4$ | 1,000 MMH<br>1,640 $N_2O_4$ | --- | --- |

Given the early stage of the Castor 1200 vehicle design development, ATK did not yet have a representative nominal trajectory (position and velocity of the vehicle as a function of time). Based on technical discussions between ACTA and ATK, it was agreed that use of the Ares-1X nominal trajectory would be an adequate representation of the early stage 1 flight profile of a Castor 1200 launch vehicle. A plot of the first 40 seconds of the Ares-1X flight profile is illustrated in Figure 3-2. As will be presented later, abort analyses considered only the first 20 seconds of flight and normal launch considered approximately the first 28 seconds of flight to a vehicle altitude of 10,000 feet. Normal launch chemical emissions consider only the portion of propellant burned from stage 1 during ascent to 10,000 feet. Catastrophic abort of the launch vehicle applies a conservative assumption that all 4 stages of the launch vehicle will have their solid propellant contents burned to depletion in the lower atmosphere. The upper stages are assumed to be non-burning during free fall from the breakup altitude but are ignited at ground impact by the impact energy.

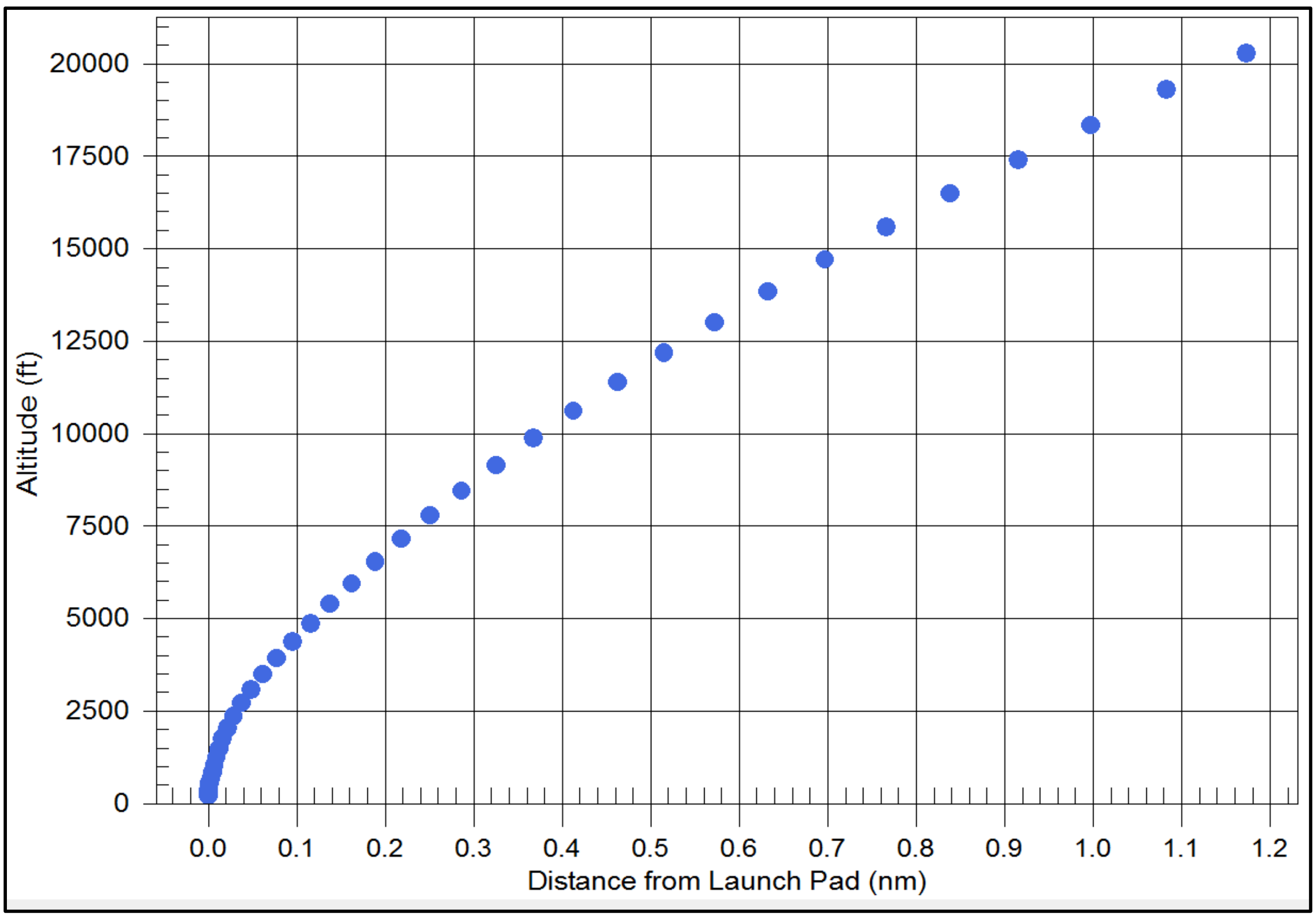


**Figure 3-2. The Ares-1X Nominal Trajectory Flight Profile that was Applied to the Castor 1200 Vehicle Configuration.**

## 4. TOXICITY THRESHOLDS FOR HAZARDOUS CHEMICALS

Regarding human toxicity, the chemicals of concern in the combustion products produced by burning TP-1148 propellant are hydrogen chloride gas (HCl) and aluminum oxide ($Al_2O_3$) particulates. HCl is a highly reactive gas that readily forms hydrochloric acid when it contacts water (this includes human lung, eye and skin tissues). Human response to high concentrations of HCl gas is prompt irritation with symptoms of coughing, choking, watering eyes, burning sensation and mucus membrane response. This prompt response characteristic correlates with toxic thresholds that are defined in terms of peak ceiling concentration values rather than accumulated dosage. (Lead poisoning would be an example of a toxic chemical exposure with delayed health response that is based on total dosage rather than time varying peak concentrations). The aluminum metal used in most solid propellant formulations is first melted and then oxidized to molten $Al_2O_3$ in the combustion chamber of the motor. The molten $Al_2O_3$ is entrained in the gas stream exiting through the throat of the nozzle and the mixture of liquid droplets and gas is accelerated to supersonic flow exiting the nozzle. As the jet exiting the nozzle expands and cools, the aluminum oxide solidifies into particulates of varying sizes. The exhaust flow is a complex two-phase flow with a slip velocity between the particles and the gas. Particles of differing sizes can agglomerate in the plume jet. Microscopic examination of $Al_2O_3$ particles that settled out from the Space Shuttle solid rocket motors indicated that many of the particles were actually hollow spheres. Particulate matter is a potential health hazard to humans and the following definitions give an idea of how the hazard varies with the size of the particles.

> Total inhalable dust = The fraction of airborne particles that enters the nose and mouth during normal breathing. Generally considered as particles 100 microns and smaller.
>
> Thoracic dust = The fraction of dust approximately 10 microns and less and will pass the nose and throat region and enter the lungs.
>
> Respirable dust = The fraction of dust particles approximately 5 microns or less that can enter the gas exchange regions of the lungs. This region of the lungs is beyond the cilia and mucous clearance regions and these particles are more likely to be retained in the lung tissue.

Real particulates are not necessarily spheres with a definable diameter; consequently particulate material size is defined in terms of "aerodynamic diameter" where:

> Aerodynamic Diameter = The diameter of a unit-density sphere having the same terminal settling velocity as the particle in question.

Toxicologists define two general categories of particulates that are of interest in lung disease:

Coarse particles (PM10) = Particles ranging in size from 2.5 to 10 microns in diameter.

Fine particles (PM2.5) = Particles under 2.5 microns in size.

- Ultra-fine particles (PM0.1) are a subset of fine particles and are drawing some attention as a unique category.

The particulate sizes emitted by solid rocket motors are at least partially dependent on the throat and nozzle size and is not well characterized by mathematical calculations. Measurements of particle sizes drawn from plume gas flow samples is often required to estimate the range of particle sizes and the distribution of the total $Al_2O_3$ mass among the size "bins". Such data is not available for the Castor 1200 motor. Consequently this study used the default particle size categories and mass distribution set in the Air Force Rocket Exhaust Effluent Diffusion Model (REEDM) that has been applied to other large solid rocket motors on the Titan launch vehicle and the Space Shuttle. The REEDM $Al_2O_3$ characteristics are presented in Table 4-1.

**Table 4-1. REEDM Default $Al_2O_3$ Particulate Data.**

| Category | Diameter [microns] | Settling Velocity [m/sec] | Mass Fraction |
|---|---|---|---|
| 1 | 0.95 | 0.0001 | 0.04 |
| 2 | 1.95 | 0.0003 | 0.14 |
| 3 | 2.95 | 0.0006 | 0.19 |
| 4 | 3.95 | 0.0010 | 0.18 |
| 5 | 4.95 | 0.0014 | 0.15 |
| 6 | 5.95 | 0.0019 | 0.11 |
| 7 | 6.95 | 0.0025 | 0.08 |
| 8 | 7.95 | 0.0032 | 0.05 |
| 9 | 8.95 | 0.0040 | 0.03 |
| 10 | 9.95 | 0.0049 | 0.02 |

It is noteworthy that the settling velocities for these small particle sizes are small, which means that the suspended particulate matter essential travels with the gas cloud and can result in simultaneous exposure of receptors to both HCl gas and small $Al_2O_3$ respirable particles. The 9.95 micron particle size has a settling velocity of 0.0049 meters per second. During the first 30 minutes of downwind transport, these largest particles will settle only about 9 meters relative to a neutral density gas. The propellant exhaust cloud itself rises under the influence of thermal buoyancy to a stabilization height that is dependent on the prevailing temperature profile in the atmosphere but is typically in the range of several hundred meters to a thousand meters. At stabilization, the exhaust cloud has dimensions of hundreds of meters and continues to grow in size during downwind transport due to wind shears and atmospheric turbulence. Thus a 9 meter settling distance represents only a small percentage of the overall cloud size and the particulate concentration will disperse approximately at the same rate as the gaseous material.

The hazard associated with exposure to HCl can be associated with several industry standard exposure criteria. Since emissions from rocket launches are relatively short duration events that only occur a few times a year over the course of the program, short duration or emergency exposure standards are more appropriate than long duration exposure standards designed for work place environments. One such emergency exposure standard is the National Institute for Occupational Safety and Health (NIOSH) definition of the Immediately Dangerous to Life or Health (IDLH) exposure threshold for an airborne chemical. The IDLH is intended to be used in conjunction with workers wearing respirators in contaminated areas, such that if the respirator fails the person could escape the contaminated area without being incapacitated given a maximum exposure of 30 minutes. Perhaps a more appropriate set of exposure guidelines are the Acute Exposure Guideline Levels (AEGLs) that are supported by the EPA. The development of AEGLs is a collaborative effort of the public and private sectors worldwide. AEGLs are intended to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. The National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances (AEGL Committee) is involved in developing these guidelines to help both national and local authorities, as well as private companies, deal with emergencies involving spills, or other catastrophic exposures. The recommended final AEGLs for HCl are listed in Table 4-2.

**Table 4-2: Final Acute Exposure Guideline Levels (AEGLs) for Hydrogen Chloride.**

| AEGL Level | 10 min Exposure [ppm] | 30 min Exposure [ppm] | 60 min Exposure [ppm] | 4 hr. Exposure [ppm] |
|---|---|---|---|---|
| AEGL 1 | 1.8 | 1.8 | 1.8 | 1.8 |
| AEGL 2 | 100 | 43 | 22 | 11 |
| AEGL 3 | 620 | 210 | 100 | 26 |

Definitions of the AEGL levels are as follows:

**AEGL-1** is the airborne concentration, expressed as parts per million or milligrams per cubic meter (ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

**AEGL-2** is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

**AEGL-3** is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The time duration that a receptor is exposed to a rocket exhaust plume emission depends upon the cloud transport wind speed and the size of the cloud. The cloud or plume grows in size as it transports downwind. Typical exposure durations are estimated to be in the 10 to 30 minute range but may approach one hour under very light wind conditions.

The payload hypergolic propellants are quite toxic and pose an airborne hazard when released to the atmosphere as the consequence of a vehicle failure. In this study the payload propellants considered were MMH and $N_2O_4$. Hydrazine is sometimes used on payloads as a monopropellant where the liquid propellant is reacted in an exothermic catalytic process to produce a hot gas that provides thrust to maneuver the payload. The recommended final AEGLs for MMH are listed in Table 4-3.

**Table 4-3: Final Acute Exposure Guideline Levels (AEGLs) for Methyl Hydrazine (MMH).**

| AEGL Level | 10 min Exposure [ppm] | 30 min Exposure [ppm] | 60 min Exposure [ppm] | 4 hr. Exposure [ppm] |
|---|---|---|---|---|
| AEGL 1 | NR | NR | NR | NR |
| AEGL 2 | 5.3 | 1.8 | 0.9 | 0.23 |
| AEGL 3 | 16 | 5.5 | 2.7 | 0.68 |

Numeric values for AEGL-1 are not recommended, because (1) studies suggest that notable toxic effects may occur at or below the odor threshold or other modes of sensory detection, (2) an inadequate margin of safety exists between the derived AEGL-1 and the AEGL-2, or (3) the derived AEGL-1 is greater than the AEGL-2. The absence of an AEGL-1 does not imply that exposure below the AEGL-2 is without any adverse effects.
Abbreviations: NR, not recommended; ppm, parts per million

The recommended final AEGLs for Hydrazine are listed in Table 4-4.

**Table 4-4: Final Acute Exposure Guideline Levels (AEGLs) for Hydrazine ($N_2H_4$).**

| AEGL Level | 10 min Exposure [ppm] | 30 min Exposure [ppm] | 60 min Exposure [ppm] | 4 hr. Exposure [ppm] |
|---|---|---|---|---|
| AEGL 1 | 0.1 | 0.1 | 0.1 | 0.1 |
| AEGL 2 | 23 | 16 | 13 | 3.1 |
| AEGL 3 | 64 | 45 | 35 | 8.9 |

The hypergolic oxidizer nitrogen tetroxide ($N_2O_4$) boils at 70.1 F and when released to the atmosphere the molecule readily dissociates into two molecules of nitrogen dioxide ($NO_2$), which effectively doubles the ppm concentration of $NO_2$ relative to $N_2O_4$. The recommended final AEGLs for nitrogen dioxide are listed in Table 4-5. The AEGLs for nitrogen tetroxide are exactly ½ of the values listed in Table 4-5.

**Table 4-5: Final Acute Exposure Guideline Levels (AEGLs) for Nitrogen Dioxide ($NO_2$).**

| AEGL Level | 10 min Exposure [ppm] | 30 min Exposure [ppm] | 60 min Exposure [ppm] | 4 hr. Exposure [ppm] |
|---|---|---|---|---|
| AEGL 1 | 0.5 | 0.5 | 0.5 | 0.5 |
| AEGL 2 | 20 | 15 | 12 | 8.2 |
| AEGL 3 | 34 | 25 | 20 | 14 |

AEGL thresholds have not been established for $Al_2O_3$. The Environmental Protection Agency (EPA) has defined National Ambient Air Quality Standards (NAAQS) for 24-hour ("short term") and annual $PM_{10}$ and $PM_{2.5}$ exposures in the 2006 71 FR 61144. The 24-hour NAAQS 2006 standards are:

2006 (PM2.5) 35 $\mu g/m^3$ 98th percentile averaged over 3 years

2006 (PM10) 150 $\mu g/m^3$ not more than once per year over a 3 year period

The NAAQS are intended primarily to address pollution sources that tend to be area wide and which can be exacerbated under adverse meteorological conditions ("pollution episodes"). It is unclear how meaningful the 24-hour exposure standards are to rocket emissions which are from a mobile transient source with exposure durations generally less than 1 hour and perhaps as short as 10 to 20 minutes. The Occupational Safety and Health Administration (OSHA) have also published standards for certain particulates that are codified in CFR Part 29 1910.1000 subpart Z "Toxic and Hazardous Substances". OSHA standards are geared toward protecting workers from excessive exposure during an 8-hour work day and 40-hour work week environment. The nearest applicable OSHA standards for $Al_2O_3$ are for "emery" (CAS 12415-34-8) and "Particulates Not Otherwise Regulated" (PNOR). PNOR values apply to "Inert or Nuisance Dust" and the recommended threshold OSHA standards for both are:

– 15 $mg/m^3$ total dust (8-hour time weighted average concentration)

– 5 $mg/m^3$ respirable dust (8-hour time weighted average concentration)

It is unclear how applicable the OSHA standards are to emissions from rocket launches that may only occur several times a year and that produce transient short term exposures in toxic corridors that vary with prevailing wind speed and wind direction.

The American Industrial Hygiene Association has published recommended Emergency Response Planning Guidelines (ERPGs), which have very similar definitions to AEGLs. ERPGs cover a wide range of chemicals but no ERPG standards are defined for $Al_2O_3$ or emery.

The National Institute for Occupational Safety and Health (NIOSH) derives authority from Occupational Health and Safety Act (OSHA 1970) and Federal Mine Safety and Health Act (MSHA 1977). OSHA and MSHA have responsibility to promulgate and enforce legal standards. NIOSH develops and periodically revises recommended exposure limits (RELs) for hazardous substances or conditions in the workplace. NIOSH publishes the "Pocket Guide to Chemical Hazards" ref. http://www.cdc.gov/NIOSH/NPG/. Several NIOSH standards are:

– IDLH = Immediately Dangerous to Life and Health

– REL = 10-hour TWA for 40-hour workweek

– STEL = 15 minute TWA not to be exceeded anytime during workday.

The 2007 NIOSH Pocket Guide has the following guideline standards and comments pertaining to $Al_2O_3$ ($\alpha$-Alumina) particulates:

– IDLH – not defined

– Respirator requirements - Not Available

– OSHA PEL = 8-hour TWA 15 $mg/m^3$ total dust, 5 $mg/m^3$ respirable dust

– NIOSH REL = No recommendation, however, NIOSH review of OSHA PEL supporting literature was criticized as being insufficient to justify selection of PEL thresholds.

The American Conference of Governmental Industrial Hygienists (ACGIH) provides guidance in the form of Threshold Limit Values (TLVs). ACGIH Threshold Limit Values are defined as follows:

– Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) are determinations made by a voluntary body of independent knowledgeable individuals. They represent the opinion of the scientific community that has reviewed the data described in the *Documentation*, that exposure at or below the level of the TLV® or BEI® does not create an unreasonable risk of disease or injury.

- TLVs® and BEIs® are not standards. They are guidelines designed for use by industrial hygienists in making decisions regarding safe levels of exposure to various chemical substances and physical agents found in the workplace. In using these guidelines, industrial hygienists are cautioned that the TLVs® and BEIs® are only one of multiple factors to be considered in evaluating specific workplace situations and conditions.

  Source: http://www.acgih.org/TLV/

The ACGIH recommended exposure threshold for $Al_2O_3$ is: 10 $mg/m^3$ 8-hour TWA

- Ref. 2001 New Jersey Dept. of Health and Senior Services, Hazardous Substance Fact Sheet

The bio-environmental organization at the NASA Kennedy Space Center launch complex prefers to use ACGIH recommendations when AEGLs are not available.

The Subcommittee on Consequence Assessment and Protective Actions (SCAPA) supports the Department of Energy/National Nuclear Security Administration. SCAPA developed standards called Temporary Emergency Exposure Limits (TEELs) through their Chemical Exposures Working Group. TEELs are recommended by SCAPA when ERPGs or AEGLs are not defined. The TEEL threshold descriptions are virtually identical to the ERPGs. The formal TEEL definitions are:

- **TEEL-3** = The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

- **TEEL-2** = The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

- **TEEL-1** = The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

- **TEEL-0** = The threshold concentration below which most people will experience no appreciable risk of health effects.

The National Oceanic and Atmospheric Administration (NOAA) provide the following explanation of TEELs:

– TEELs estimate the concentrations at which most people will begin to experience health effects if they are exposed to a toxic chemical for a given duration.

– Sensitive members of the public--such as old, sick, or very young people--are not covered by these guidelines and they may experience adverse effects at concentrations below the TEEL values.

– TEELs are used in similar situations as the 60-minute AEGLs and ERPGs. However, in situations where the concentration varies over time, the TEEL developers recommend using a conservative 15-minute time-weighted average concentration. A chemical may have up to four TEEL values, each of which corresponds to a specific tier of health effects.

– Source: http://response.restoration.noaa.gov/

SCAPA uses the various guidelines and thresholds to define "Protective Action Criteria" (PACs), which are equivalent to the TEEL threshold definitions.

– Used by DOE facilities for emergency planning purposes.

– Intended to approximate ERPGs.

– AEGLs and ERPGs evaluated more rigorously but limited to several hundred chemicals.

– SCAPA PACs available for over 3000 chemicals.

PAC thresholds for $Al_2O_3$ are:

– TEEL-0 1.5 mg/m$^3$

– PAC-1 1.5 mg/m$^3$

– PAC-2 15 mg/m$^3$

– PAC-3 25 mg/m$^3$

Although no AEGLs have been published for $Al_2O_3$ particulates, the review of multiple guidelines published by various agencies suggests that a reasonable exposure standard for $Al_2O_3$ falls somewhere in the 1 to 25 $mg/m^3$ concentration range. This report provides information on concentration versus distance predictions for $Al_2O_3$ that allow for evaluation of toxic hazard corridor size and probability of occurrence over a range of possible threshold values that may be deemed by various parties to be applicable to an EIS assessment. Co-authors of this EIS have suggested that 5 $mg/m^3$ of respirable particulates (those particles 5 microns or less in size) is a suitable threshold for EIS evaluation.

The report authors do not have toxicological expertise regarding hazardous HCl, $Al_2O_3$, $NO_2$ or MMH thresholds for flora and fauna that may be of environmental concern. The selection of the most appropriate exposure level to apply to exposed flora and fauna is left to the judgment of others. We note that human toxicity and adverse health response data are often based on studies of laboratory mice, rats, and rhesus monkeys and that this type of data may be quite applicable to mammalian species. We also note that HCl and $NO_2$ are both reactive chemicals that form strong acids with water. They pose a short term acute hazard but do not persist long in the environment. We also know of one anecdotal event that occurred in Colorado at a rocket manufacturer processing facility. An accidental spill of $N_2O_4$ left a visible trail of vegetation damage along the plume path for several weeks after the release event. The following spring the same plume path was visible as a corridor with lusher green vegetation. The judgment of the propulsion chemists at that facility was that the $NO_2$ and $HNO_3$ resulting from the release entered the nitrification cycle and acted as a fertilizer the following spring.

## 5. COMPUTER MODELS AND EMISSION SCENARIOS

This study considered four hazardous chemical species (HCl, $Al_2O_3$, MMH and $NO_2$) and four launch vehicle emission scenarios. The emission scenarios are:

1. Normal launch
2. Catastrophic failure resulting in scattered burning propellant fragments (Conflagration)
3. Catastrophic failure leading to intact payload impact and hypergols fireball (Deflagration)
4. Catastrophic failure leading to intact payload impact with spill of liquid hypergols (Cold Spill)

ACTA elected to use two different Range Safety toxic dispersion models to simulate this combination of release scenarios and chemical types. The Rocket Exhaust Effluent Diffusion Model was used to simulate the normal launch scenario for both HCl and $Al_2O_3$. REEDM was also used to model $Al_2O_3$ dispersion for the conflagration scenario. The Launch Area Toxic Risk Analysis 3-Dimensional (LATRA3D) computer program was used to simulate HCl dispersion from the conflagration scenario and the hypergol releases for both the deflagration and cold spill scenarios. Both models are used by the Air Force, NASA, the Army and the FAA to perform toxic dispersion assessments for launch vehicles launched from Federal and commercial ranges.

### 5.1 Castor 1200 Normal Launch Emission Scenario

In this scenario a fully configured launch vehicle with payload is ignited on the launch pad at time T-0. The vehicle may be secured to the launch pad by hold down bolts as the first stage motor builds thrust after which the hold-downs are released allowing the vehicle to begin ascent to orbit. During ascent the vehicle velocity steadily increases resulting in a time and altitude varying exhaust product emission rate. Initially the rocket engine exhaust is largely directed into and through a flame duct. As the vehicle lifts off from the pad and clears the launch tower, a portion of the exhaust plume impinges on the pad structure and is directed radially around the launch pad stand. The portion of the rocket plume that interacts with the launch pad and flame trench is referred to as the "ground cloud". As the vehicle climbs to several hundred feet above the pad, the rocket plume reaches a point where the gases no longer interact with the ground surface and the exhaust plume is referred to as the "contrail cloud".

The concepts of the ground and contrail clouds are illustrated in Figure 5-1 using the Ares-1X launch from Cape Canaveral as an example. The Ares-1X first stage is very similar to the Castor

1200 first stage. For atmospheric dispersion analyses of rocket emissions that could affect receptors on the ground, it has been standard practice at the Federal Ranges (Cape Canaveral and Vandenberg Air Force Base) to simulate the emissions from the ascending launch vehicle from the ground to a vehicle altitude of approximately 3000 meters. The operational toxic dispersion analysis tool used by the Federal Ranges for launch support and public risk assessment has been Version 7.13 of the Rocket Exhaust Effluent Diffusion Model (REEDM). Most of the Ranges are now transitioning from REEDM to LATRA3D as the operational support tool. ACTA used REEDM Version 7.13 to simulate the normal launch emission scenario because REEDM includes a sub model to handle gravitational deposition of $Al_2O_3$ particulates that LATRA3D does not have. In order to maintain a consistent set of modeling assumptions and source cloud formation algorithms, REEDM was also used to predict HCl dispersion and downwind concentrations for the normal launch scenario. The features of REEDM pertinent to this study are discussed in the next section.

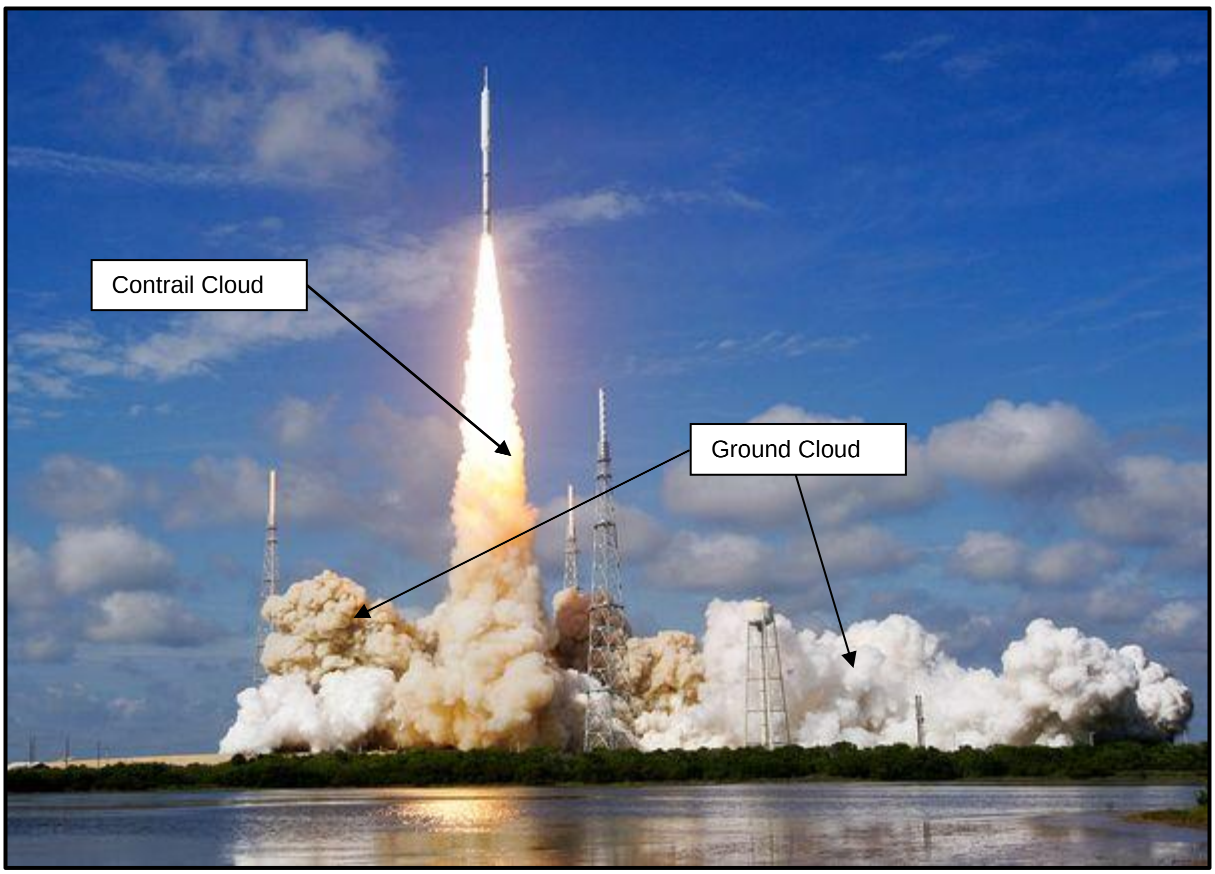


**Figure 5-1. Illustration of the Ground Cloud and Contrail Cloud Portions of the Ares-1X Rocket Emission Plume Associated With Normal Vehicle Launch.**

## 5.2 The Rocket Exhaust Effluent Dispersion Model (REEDM)

REEDM is a toxic dispersion model specifically tailored to address the large buoyant source clouds produced by rocket launches, test firings and catastrophic launch vehicle explosions. Under ongoing Air Force support, REEDM evolved from the NASA Multi-Layer Diffusion Model, which was written initially to evaluate environmental effects associated with the Space Shuttle, and has been generalized to handle a wide variety of launch vehicle types and propellant combinations. REEDM falls in the category of "Gaussian puff" atmospheric dispersion models in that the initial mass distribution of toxic materials within the cloud at the time the cloud reaches thermal stabilization height in the atmosphere is assumed to be normally distributed. By making the Gaussian mass distribution assumption, the differential equation defining mass diffusion can be solved in closed form using exponential functions and may be readily implemented in a fast running computer program. Gaussian puff models are still widely used by the EPA for environmental and permitting studies, by Homeland Security and the Defense Threat Reduction Agency for assessment of chemical, biological and radiological materials, and by the petrochemical industry for accidental releases of industrial chemicals.

REEDM processing of an emission event can be partitioned into the following basic steps:

1. Acquire and process vehicle related data from an input vehicle database file.

2. Acquire and process meteorological data, which in this study is a combination of archived weather balloon soundings used in conjunction with an internal REEDM climatological turbulence algorithm.

3. Acquire the chemical composition and thermodynamic properties of the rocket exhaust emissions and define the initial size, shape, location and heat content of the exhaust cloud (herein referred to as the "source term" or "source cloud"). REEDM has an internal propellant equilibrium combustion model that is used to compute these terms for vehicle catastrophic failure modes but for normal launch and static test firing scenarios this data is calculated external to REEDM and placed in the vehicle database file read by REEDM.

4. Iteratively calculate the buoyant cloud rise rate and cloud growth rate to achieve a converged estimate of the cloud stabilization height above ground, size and downwind position. The cloud rise equations evaluate both cloud thermodynamic state as well as the local atmospheric stability, which is defined by the potential temperature lapse rate.

5. Partition the stabilized cloud into disks and mark whether or not part of the stabilized cloud is above a capping atmospheric temperature inversion. Inversions (or other sufficiently stable air masses) act as a barrier to gaseous mixing and are treated in REEDM as reflective boundaries. Aluminum oxide particulates however are assumed to settle through a stable meteorological layer and are not reflected at the gaseous reflection boundary.

6. Transport the cloud disks downwind and grow the disk size using climatologic model estimates of atmospheric turbulence intensity. Turbulence intensity is a function of wind speed and solar radiation intensity. Turbulence varies with time of day and cloud cover conditions because these influence the solar radiation intensity. Particulate matter and gases are assumed to disperse at the same rate albeit the particulate matter is allowed to settle toward the ground.

7. Calculate concentrations at ground receptor points and determine the plume or cloud track "centerline" that defines the peak concentration as a function of downwind distance. Concentration at any given receptor point is computed as the sum of exposure contributions from each cloud disk. Concentration is solved using the closed form Gaussian dispersion equation and accounts for the effect of ground and capping inversion reflections.

8. Report concentration centerline values in table format as a function of distance from the source origin (e.g. launch pad)

There are other features and sub models of REEDM that are more fully described in the REEDM technical description manual [3] and will not be reviewed in this report.

There are several important assumptions made in REEDM that have a bearing on this Environmental Impact Study. REEDM was designed to primarily predict hazard conditions downwind from the stabilized exhaust cloud. REEDM does not directly calculate or report cloud concentrations during the buoyant cloud rise phase, however, advanced model users can extract sufficient pertinent cloud data from internal calculations to derive concentration estimates during the cloud rise phase manually. One assumption that REEDM makes about the nature and behavior of a rocket exhaust cloud is that it can be initially defined as a single cloud entity that grows and moves but remains as a single cloud during the formation and cloud rise phases. A consequence of this assumption is that once the cloud lifts off the ground during the buoyant cloud rise phase, there will be no predicted cloud chemical concentration on the ground immediately below the cloud. Ground level concentrations will be predicted to remain at zero ppm until the some of the elevated cloud material is eventually brought back down to ground level by mixing due to atmospheric turbulence. This concept is illustrated in Figure 5-2 and it is noted that REEDM is designed to report concentrations downwind from the stabilized cloud position. The region downwind from the stabilized exhaust cloud is referred to as the "far field". It is also noted here that the most concentrated part of these rocket exhaust clouds remains at an altitude well above the ground level. REEDM is not able to model stochastic uncertainty in the source cloud and atmospheric flow such that if a gust of wind, small turbulence eddy or nuance of the launch pad flame duct structure causes a small portion of the main exhaust cloud to detach from the main cloud, the model will not correctly predict the transport, dispersion or concentration contribution from the detached cloud material. Likewise if there are strong atmospheric updrafts or down drafts, such as associated with development of thunderstorm cells or towering cumulus clouds, REEDM will not correctly model strong vertical displacements of the entire exhaust cloud or strong shearing forces that may completely breakup the cloud under such conditions (these are not favorable conditions for launch either and a planned launch would never be conducted with strong thunderstorm and cloud development activity in the launch area).

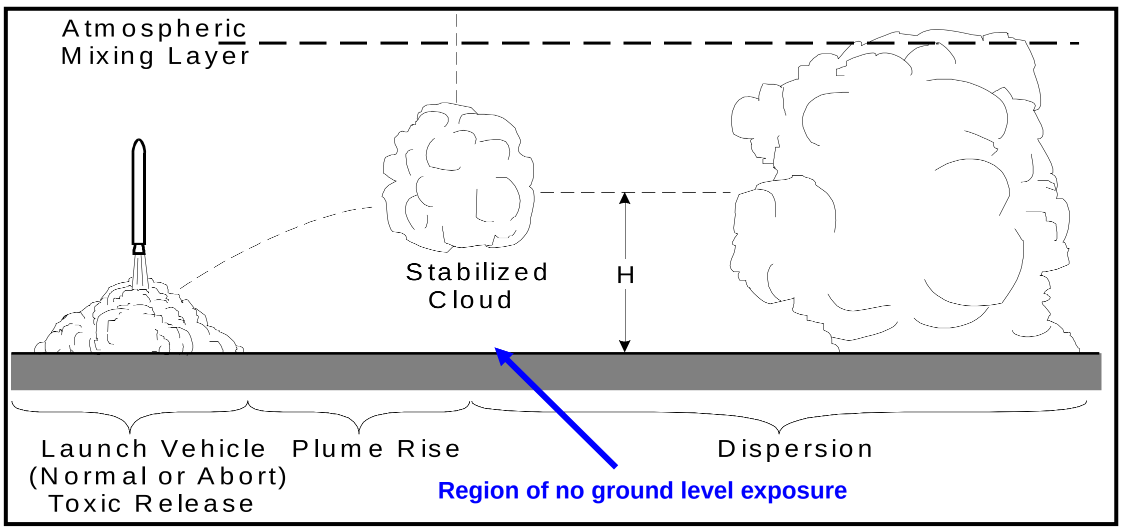


**Figure 5-2. Conceptual Illustration of Rocket Exhaust Source Cloud Formation, Cloud Rise and Cloud Atmospheric Dispersion.**

REEDM is also somewhat constrained by the Gaussian assumptions inherent in the model that require a single average transport wind speed and direction. The portion of the atmosphere selected for averaging the transport winds has been improved over the years of operational use at the Air Force ranges. Old versions of REEDM averaged the winds over the entire boundary layer, which in the absence of a capping inversion, was treated as being 3000 meters deep. The modern version of REEDM now selects the appropriate atmospheric layer based on the stabilization height of the cloud, the top of the cloud and the location of the reflective boundary layers. Comparison of REEDM predicted rocket exhaust cloud transport direction and speed with Doppler weather radar tracks of rocket exhaust clouds has indicated that the modern version of REEDM performs very satisfactorily in predicting the correct average cloud transport direction and speed. The "multi-layer" aspect of REEDM is still retained from its early development and refers to the partitioning of the stabilized rocket exhaust cloud into "disks" of cloud material assigned to meteorological levels at different altitudes. The altitude bands are typically 20 to 50 meters in depth. REEDM models the initial formation of a rocket exhaust cloud as either an ellipsoid or a sphere and predicts the buoyant could rise of the source as a single cloud entity. Once the cloud is predicted to have achieved a condition of thermal stability in the atmosphere, the cloud is partitioned into disks. The placement of each disk relative to the source origin (e.g. the launch pad) is determined based on the rise time of the cloud through a sequence of meteorological layers that are defined using the measurement levels obtained from a mandatory weather balloon input data file. Each meteorological layer may have a unique wind speed and direction that displaces the cloud disk in the down wind direction. The initial placement of cloud disks that are associated with the lower portion of the overall source cloud are not influenced by winds above their stabilized altitude level whereas disks near the top of the stabilized cloud will be displaced by the winds all the way from the ground level to the disk stabilization altitude. Thus the vertical stack of cloud disks can be displaced relative to each other due to the influence of wind speed and direction shears. The concept of the stabilized cloud partition into disks is illustrated in Figure 5-3.

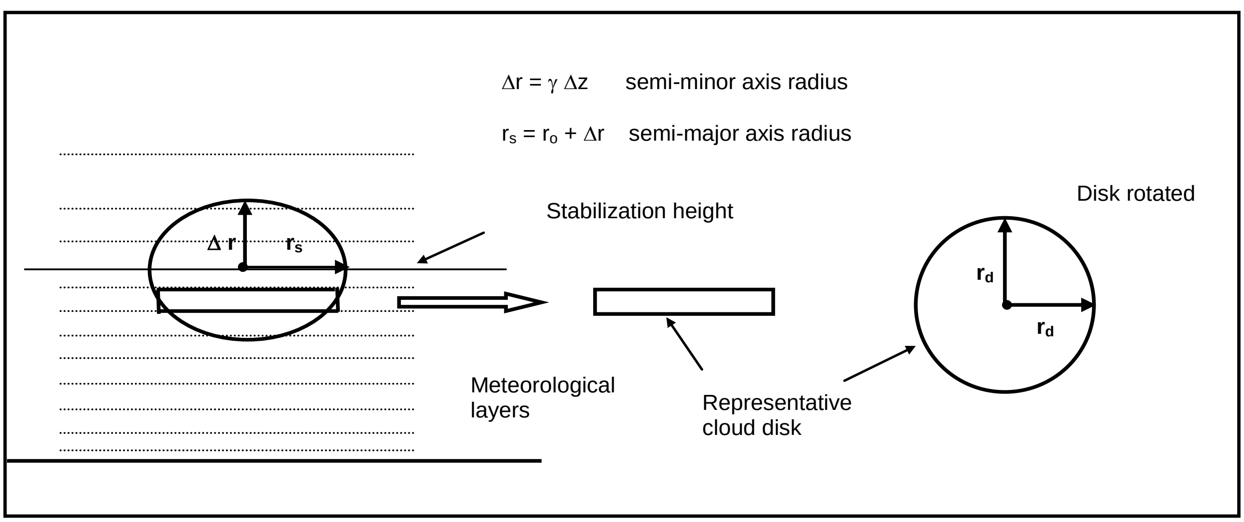


**Figure 5-3. Illustration of REEDM Partitioning a Stabilized Cloud into Disks.**

Once the cloud disks positions are initialized, future downwind transport applies the same average atmospheric boundary layer transport wind speed and direction to each cloud disk as illustrated in Figure 5-4.

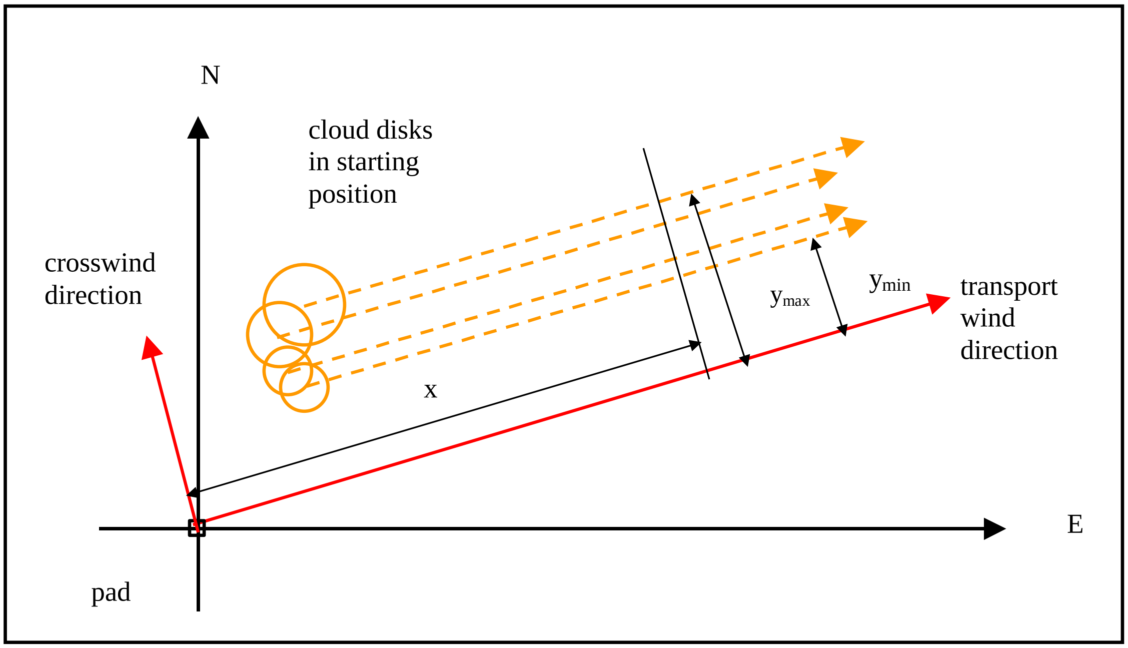


**Figure 5-4. Illustration of Straight Line Transport of Stabilized Exhaust Cloud Disks Using Average Mixing Layer Wind Speed and Direction.**

The assumption of straight-line transport used in REEDM during the cloud transport and dispersion phase ignores the possibility of complex wind fields that might arise in mountainous terrain or that could evolve during passage of a seabreeze front or synoptic scale weather front. It is recommended that the assumption of uniform winds be limited to plume transport distances of less than 20 kilometers. As will be shown in the analysis results section, REEDM predicted typical ranges of 10 to 20 kilometers from the launch pad to the location of the maximum far field ground level HCl concentration point, thus the assumption of straight line transport should not be a problem.

In the Castor 1200 normal launch scenario the exhaust emissions from the rocket combustion are at several thousand degrees Kelvin and are highly buoyant. The high temperature of these exhaust emissions causes the plume to be less dense than the surrounding atmosphere and buoyancy forces acting on the cloud cause it to lift off the ground and accelerate vertically. As the buoyant cloud rises, it entrains ambient air and grows in size while also cooling. In this initial cloud rise phase, the growth of the cloud volume is due primarily to internal velocity gradients and mixing induced by large temperature gradients within the cloud itself. Even though the cloud is entraining air and cooling by virtue of mixing hot combustion gases with cooler ambient air, the net thermal buoyancy in the cloud is conserved and the cloud will continue to rise until it either reaches a stable layer in the atmosphere or the cloud vertical velocity becomes slow enough to be damped by viscous forces. REEDM applies the following solution of Newton's second law of motion to a buoyant cloud in the atmosphere to iteratively predict cloud stabilization height:

$$z(t)=\left[\frac{3F_m}{u\gamma^2\sqrt{s}}\sin\left(t\sqrt{s}\right)+\frac{3F_c}{u\gamma^2 s}\left(1-\cos\left(t\sqrt{s}\right)\right)+\left(\frac{r_o}{\gamma}\right)^3\right]^{1/3}-\frac{r_o}{\gamma}$$

where:

s = atmospheric stability parameter = $\dfrac{g}{\theta_a}\dfrac{\Delta\theta_a}{\Delta Z}$ [$sec^{-2}$]

g = gravitational acceleration constant = 9.81 [$m/sec^2$]

$\theta_a$ = potential temperature of ambient air [K]

$F_m$ = $r_o^2 w_o u$ = initial vertical momentum [$m^4/sec^2$]

u = mean ambient wind speed [m/sec]

$w_o$ = initial vertical velocity [m/sec] (typically = 0.0)

$r_o$ = initial plume cross-sectional radius [m]

$F_c$ = initial buoyancy = $\dfrac{g\,\dot{q}}{\pi\,\rho_c\,C_p\,T_a}$ [$m^4/s^3$]

$C_p$ = specific heat of exhaust cloud gases [cal/kg K]

= air entrainment coefficient (dimensionless)

z = plume height at time t [m]

$\dot{q}$ = initial plume heat flux [cal/sec]

$T_a$ = ambient air temperature [K]

$\rho_c$ = density of exhaust cloud gases [$kg/m^3$]

A critical parameter in the cloud rise equation is the rate of ambient air entrainment that is defined by the dimensionless air entrainment coefficient, $\gamma$. Cloud growth as a function of altitude is assumed to be linearly proportional and the air entrainment coefficient defines the constant of proportionality. REEDM's cloud rise equations have been compared with observations and measurements of Titan rocket ground clouds and a best-fit empirical cloud rise air entrainment coefficient has been derived from the test data, a sample of which is illustrated in Figure 5-5.

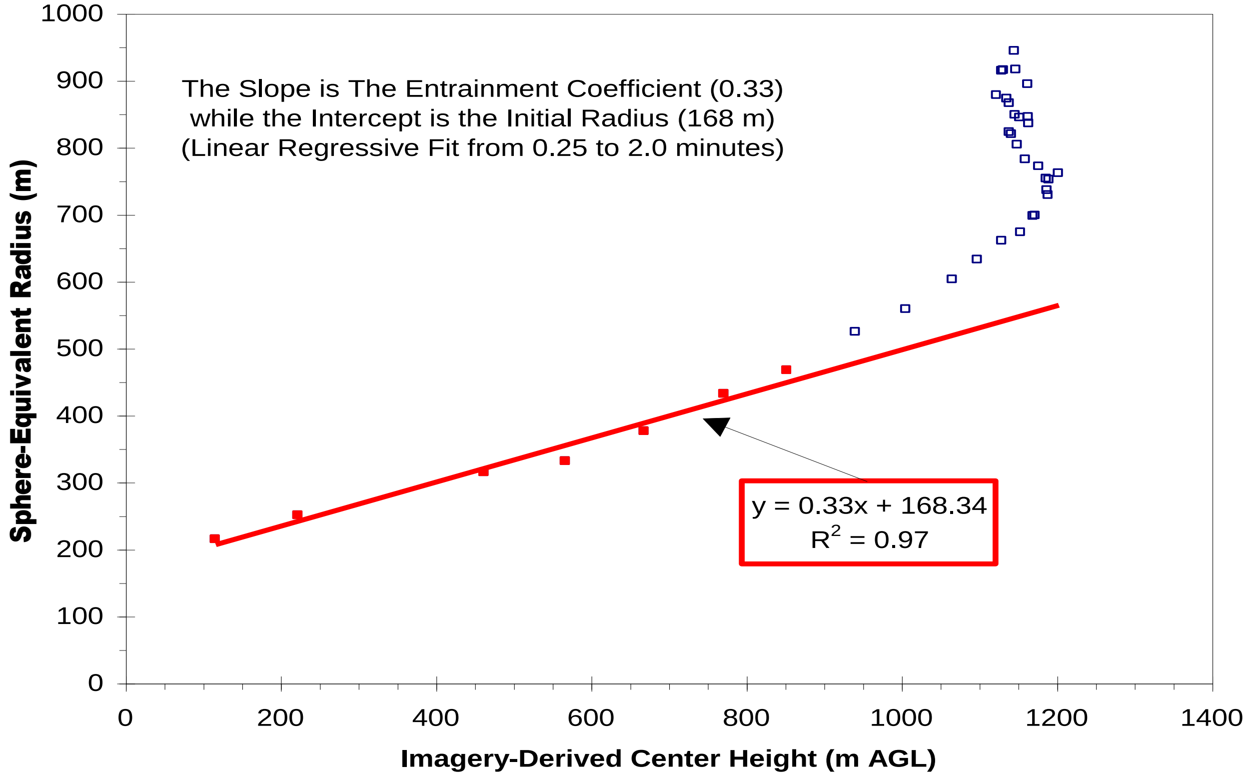


**Figure 5-5. Observed Cloud Growth Versus Height for Titan IV A-17 Mission.**

The Castor 1200 buoyant source clouds are predicted to rise from 500 to 1300 meters above the ground depending on atmospheric lapse rate conditions.

### 5.3 Castor 1200 Normal Launch Data Development

Proper specification of vehicle characterization input data is critical to the overall toxic dispersion analysis problem. While many vehicle input parameters are straightforward and readily verifiable (e.g. types and amounts of propellants loaded on the vehicle), other parameters inherently involve greater uncertainty and are not readily verifiable (e.g. amount of ambient air entrained into the rocket plume at the flame duct inlet). In this report section the vehicle input data values used in the REEDM Castor 1200 normal launch scenario analyses are itemized and explained. Input parameters that entail significant uncertainty were treated in a conservative fashion in the sense that choices were made to favor overestimating rather than underestimating the toxic chemical concentrations being evaluated for the Environmental Impact Study. Information pertaining to the vehicle propellant loads and burn rates were provided by ATK personnel whereas the expected nominal launch flight trajectory was based on the Ares-1X nominal trajectory provided by NASA to the 45$^{th}$ Space Wing and converted by ACTA into REEDM database format.

### 5.4 Castor 1200 Normal Launch REEDM Vehicle Data

The following data items represent the vehicle data needed to characterize the normal launch scenario and are presented in the REEDM database format.

```
#05.00                       VEHICLE DATA SECTION
   VEHICLE TYPE = 4, NAME =  CASTOR1200  ,
   TIME HEIGHT COEFFICIENTS A,B,C =     0.74678 ,     0.45406 ,       0.0000,
#05.01 NORMAL LAUNCH ENGINE DATA FOR STAGES IGNITED AT LIFT-OFF:
   NUMBER OF IGNITED SRB'S           =   1,
   SOLID FUEL MASS             (LBM) =   1.11416E6,
   SOLID FUEL BURN RATE      (LBM/S) =   1.0940E4 ,          avg over first 20 sec
   LIQUID FUEL MASS            (LBM) =   0.0000000,
   LIQUID FUEL BURN RATE     (LBM/S) =   0.0000000,
   LIQUID OXIDIZER MASS        (LBM) =   0.0000000,
   LIQUID OXIDIZER BURN RATE (LBM/S) =   0.0000000,
   AIR ENTRAINMENT RATE IN GROUND CLOUD    (LBM/S) =   8752.0000,80% of propellant burn
rate
   TOTAL DELUGE WATER ENTRAINED IN GROUND CLOUD (LBM) =   0.0000000,
   AIR ENTRAINMENT RATE IN ROCKET CONTRAIL    (LBM/S) =   8752.0000,
   VEHICLE HEIGHT TO WHICH PLUME CONTRIBUTES TO GROUND CLOUD (FT) = 525,   ares1x values
   GROUND CLOUD INITIAL AVERAGE TEMPERATURE         (F) =  3100,
   GROUND CLOUD INITIAL HEAT CONTENT           (BTU/LBM) =  2169,
   INITIAL VERTICAL VELOCITY OF GROUND CLOUD      (FT/S) =   0.0,
   INITIAL RADIUS OF GROUND CLOUD                  (FT) = 150.0,
   INITIAL HEIGHT OF GROUND CLOUD                  (FT) =   0.0,
   INITIAL X DISPLACEMENT OF GROUND CLOUD FROM PAD (FT) =   0.0,
   INITIAL Y DISPLACEMENT OF GROUND CLOUD FROM PAD (FT) =   0.0,
   PLUME CONTRAIL INITIAL AVERAGE TEMPERATURE       (F) =  3100,
   PLUME CONTRAIL INITIAL HEAT CONTENT         (BTU/LBM) =  2169,
#05.02 NORMAL LAUNCH EXHAUST PRODUCT DATA:
 CHEMICAL NAME       MOL. WT.    MASS FRAC. GAS    MASS FRAC. COND   HAZARDOUS    ares1x
values
 GROUND CLOUD:
   HCL              36.460       0.11865          0.00000          Y
```

```
   CO2              44.010          0.11299          0.00000          Y
   CO               28.010          0.07519          0.00000          Y
   AL2O3           101.960          0.16797          0.00000          Y
   END
 CONTRAIL:
   HCL              36.460          0.11865          0.00000          Y
   CO2              44.010          0.11299          0.00000          Y
   CO               28.010          0.07519          0.00000          Y
   AL2O3           101.960          0.16797          0.00000          Y
   END
```

REEDM does not utilize the launch vehicle trajectory directly; instead a power law fit to the height of the vehicle above ground as a function of time is derived from the trajectory data. The fit achieved with the derived power law time-height coefficients is demonstrated in Figure 5-6

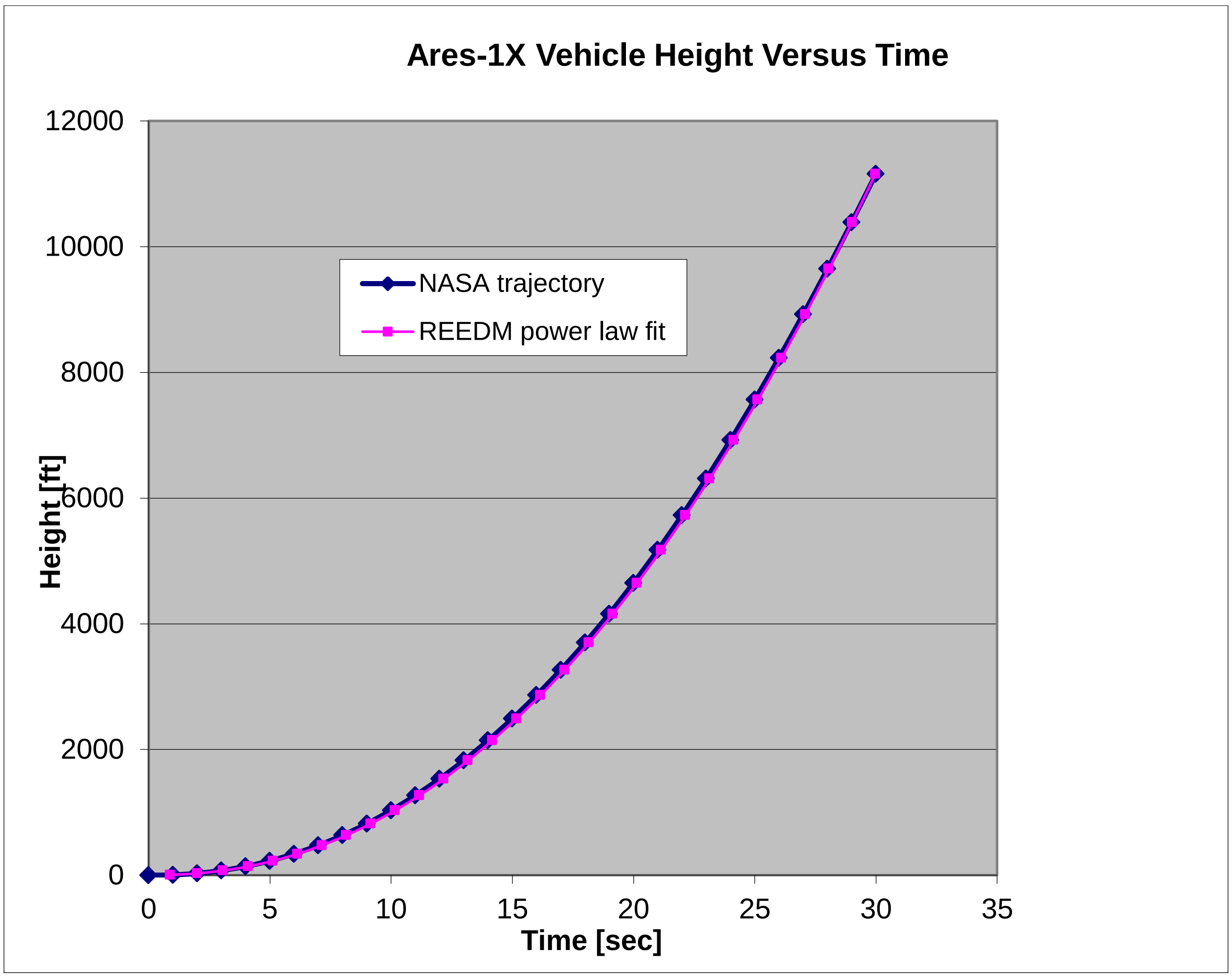


**Figure 5-6. Plot of NASA Ares-1X Nominal Trajectory Compared with ACTA Derived Power Law Fit Used in REEDM.**

REEDM allows for several chemical additions that may be included in the propellant exhaust of the normal launch ground cloud and the normal launch contrail cloud. In addition to specifying the nominal burn rates of the TP-1148 propellant, the user may optionally consider adding deluge or sound suppression water and entrained ambient air. For these two items the REEDM database serves only as a source of documentation for the assumptions applied in deriving the chemical compositions of the exhaust specified in section #05.02 of the database. It is noted here that "air entrainment" as specified in this section represents the user assumption about the amount of air, if any, added as a ***reactant*** in the propellant combustion calculations. This "air entrainment" definition is not to be confused with the "air entrainment" process that takes place during the cloud rise calculations. REEDM assumes that all chemical combustion reactions are completed before the cloud rise process takes place and REEDM therefore does not attempt to recompute chemical composition and additional heat release during the cloud rise computations.

The REEDM database provides the chemical composition of the normal ground and contrail clouds. A mass fraction is assigned to each constituent and the total exhaust mass in the source cloud is multiplied by this fraction to determine the total mass of each chemical in the exhaust cloud. The molecular weight of each species is used to convert the concentration from mass per unit volume [e.g.mg/$m^3$] to parts per million. For this study ACTA computed the chemical composition of the TP-1148 solid propellant exhaust using the NASA Lewis chemical equilibrium combustion model. The ACTA version of the NASA combustion model was modified slightly to output thermodynamic properties of the exhaust mixture that were needed to initialize the REEDM cloud rise equations. ACTA's combustion results for TP-1148 combustion with 80% added air to account for plume afterburning are shown in Table 5-1 ACTA ran the NASA combustion model in "rocket" analysis mode using an oxidizer (AP + Air) to fuel (aluminum + PBAN) ratio of 4.9406 and a combustion chamber pressure of 909 PSIA. ATK was provided the combustion product data developed by ACTA for the Ares-1X TP-1148 and ATK offered no comment or alternative data. The TP-1148 combustion data used by ACTA for the Shuttle RSRM (and later for the Ares-1X) was reviewed by Thiokol in the 1999 time frame and minor adjustments to the propellant formulation were made at that time giving ACTA combustion product results nearly identical to the Thiokol values. ACTA and ATK concurred that the ACTA TP-1148 propellant formulation used in this study was sufficiently close to the revised TP-1148 formulation to be used in the Castor 1200 as to not require modification of the REEDM database.

**Table 5-1. Listing of ACTA Castor 1200 TP-1148 Propellant Combustion Products in the Normal Launch Exhaust Cloud Including Afterburning with Ambient Air.**

| Chemical | ACTA Weight Fraction |
|---|---|
| Ar | 0.00570 |
| $Al_2O_3$ | 0.16797 |
| CO | 0.07519 |
| $CO_2$ | 0.11299 |
| Cl | 0.00052 |
| HCl | 0.11813 |
| H | 0.00001 |
| OH | 0.00007 |
| $H_2$ | 0.00333 |
| $H_2O$ | 0.12725 |
| NO | 0.00001 |
| $N_2$ | 0.38621 |
| $FeCl_2$ | 0.00261 |

## 5.5 Conservative Assumptions Applied In Data Development

The REEDM atmospheric dispersion model has been used operationally by the Air Force to make range safety launch decisions since 1989. During that time vehicle databases have been developed for many vehicles (e.g. Space Shuttle, Titan II, Titan III, Titan IV, Delta II, Delta III, Delta IV, Atlas II, Atlas III, Atlas V, Taurus, TaurusXL, Taurus Lite, Minotaur, Peacekeeper, Minuteman II, Minuteman III, Athena, Lance, Scud, ATK-ALV-1). As noted at the beginning of this section, some vehicle data is easily obtained and verified, such as the stage propellant types, quantities and burn rates. Other model input parameters required by REEDM are based on derived values obtained from mathematical and physical models, empirical measurement data or engineering judgment from the vehicle designer or range safety experts.

An example of a derived value is the selection of how much pad deluge water to include with the rocket engine exhaust when defining the normal launch cloud heat content, mass and chemical composition. A typical pad deluge system is comprised of a series of pressure fed sprayers and sprinklers that wet the launch pad, the launch service tower and the flame duct. The deluge system is typically turned on several seconds before the rocket motors are ignited and continues until the rocket has ascended above the launch tower and the plume no longer impinges on the ground. As the vehicle ascends, the rocket plume interaction with the pad structures is time varying, such that the gas flow velocity ranges from supersonic to subsonic and involves multiple shock fronts, reflected shocks, deflected flow from the pad surface, partial flow ducting through the flame trench and plume temperatures that range from 300 to 3000 K. A simple energy balance between the amount of heat available in the plume and the amount of water released in the deluge system may suggest that there is ample energy to vaporize all of the deluge water, but actual observation of launches indicates that residual deluge water is often collected in a concrete containment basin designed to collect residual deluge water. Likewise the initial ignition impulse often blows standing water out of the flame trench or away from the pad and depositing it as droplets before they can be fully mixed with the combustion gases and vaporized. Some parts of the launch plume during vehicle liftoff may become saturated with water vapor and other portions may remain relatively "dry". Thus the task of selecting a specific deluge water inclusion amount for the REEDM database and setting the associated chemical and thermodynamic data for the exhaust products is challenging and typically not estimated by the launch agency or vehicle developer. This type of flow problem is extremely complex and would require advanced computational fluid dynamics analysis that is extremely costly and also constrained by modeling assumptions. Consequently, these types of detailed analyses are rarely performed or conducted only for limited specific design purposes.

For the purposes of this study, it was agreed with CardnoTec to ignore the effect of any deluge water on normal launch ground cloud chemistry since an actual launch system and pad design remains unknown at present.

### 5.6 Castor 1200 Conflagration $Al_2O_3$ Emission Scenario

In REEDM terminology a conflagration event is defined as the explosion of a pressurized solid rocket motor that shatters the solid propellant casting (the "grain") and ejects burning solid propellant fragments away from the center of explosion due to the sudden release of the pressurized combustion gases. This event may be initiated by a failure within the motor that leads to over pressurization of the motor case, or, it may be deliberately initiated by activation of shaped explosive charges placed on the exterior of the motor as part of a range safety system. In the event that the launch vehicle exhibits an errant flight trajectory or erratic flight behavior, the Range Safety Officer sends a command destruct signal to destroy the vehicle before it can leave the approved "safe launch" corridor. Unlike the normal launch scenario, analysis of the conflagration event requires a series of abort simulations at time intervals along the nominal flight path. In this study failure times at 0, 4, 8, 2, 16 and 20 seconds were simulated. Given the complex interaction of fragment trajectories, scatter of impacting propellant fragments, buoyant cloud rise from scattered fragments and differing meteorological conditions, it is difficult to predetermine what failure time creates the worst case downwind toxic hazard corridor. Consequently a series of failure times are analyzed. The analysis procedure requires the following general steps:

1. Define the fragmentation of the pressurized solid rocket motor at the failure time.
2. Apply randomly sampled explosion induced velocities to the fragments and vector sum these with the vehicle velocity at the time of failure.
3. For each fragment perform a drag corrected ballistic trajectory computation.
4. Account for depletion of propellant mass and formation of combustion exhaust as each burning fragment falls to the ground (smaller fragments may burn up before impacting the ground).
5. Map the impact point, residual mass and dimensions of the propellant fragments that survive to ground impact. Determine the size of the impact region, which is typically referred to as a "debris footprint" and takes on the form of an ellipse that depends on fragment ballistic coefficients.
6. Account for exhaust plumes that emanate from ground burning propellant fragments until these fragments burn to depletion.

Figure 5-7 and Figure 5-8 illustrate a Delta II 7925 launch vehicle failure that would be modeled as a conflagration event. The first photo is take a fraction of a second after the initiating explosion and illustrates the large number of high velocity solid propellant fragments ejected for the center of the explosion. In this case the fragments came from 6 pressurized strap-on graphite epoxy motors rather than a single large solid rocket motor. The second photo is taken about 30 seconds after the explosion and shows the large exhaust cloud formed by the trails of exhaust created by the falling fragments. The second photo also shows the early stage of plumes forming from propellant burning on the ground. Figure 5-9 illustrated both a conflagration source and a deflagration source associated with explosion of a large Titan 34D-9 launch vehicle.

**Figure 5-7. High Velocity Burning Propellant Fragments from a Delta II 7925 Solid Rocket Motor Explosion 13 Seconds into Flight.**

**Figure 5-8. Trails of Toxic Exhaust From Burning Delta II 7925 Propellant Fragments that Fell to The Ground and Continue Burning.**


**Figure 5-9. Solid Propellant Conflagration Cloud (White) and Liquid Hypergol Deflagration Cloud (Red) Formed When the Titan 34D-9 Vehicle Exploded at Vandenberg AFB.**

REEDM is not designed to model burning propellant fragment trajectories directly and requires the conflagration source cloud to be defined in simplified terms based on calculations made external to the program. ACTA develops conflagration data for REEDM using the following procedure:

1. Define the pressurized motor dimensions including the length, weight and outer radius of the propellant grain.
2. Define the internal combustion chamber average radius as a function of time. The interior radius increases and the propellant web thickness decreases as propellant burns away.

3. Define the motor chamber pressure as a function of time.
4. Define the motor case material, thickness and density.
5. Define the vehicle altitude as a function of time.
6. Define the smallest expected solid propellant fragment size (typically a 2 inch cube).
7. Define the largest expected solid propellant fragment size (typically 6% of the total propellant weight at the time of failure).
8. Enter items 1 through 7 into the Air Force FRAG model to predict fragmentation of the entire motor as a function of time. FRAG assumes a log normal distribution of fragment sizes based on the upper and lower bound pieces the user assigns and applies a hydrodynamic algorithm to estimate fragment velocities induced by the rapidly expanding chamber gases. FRAG outputs fragment debris tables with 10 to 20 fragment size groups. Each group is allocated a shape factor, number of fragments, weight, average ballistic coefficient, maximum explosion induced velocity and dimensions.
9. Manually add upper stage unpressurized solid propellant motors to the fragment list.

A representative set of FRAG output data is presented in Table 5-2.

**Table 5-2. FRAG Generated Propellant Fragmentation Data for the Castor 1200 Motor Given a Failure at 12 Seconds into Flight.**

TIME = 12.0

| (Burning) Index | Type | Number | Area (in^2) | Weight (lbs) | Beta (psf) | High Vel (ft/sec) | Burn Flag | Length (in) | Arcseg (rad) | Rout (in) | Rin (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CAS | 1 | 13835.48 | 50620.97 | 1573 | 107 | 1 | 228.655 | 1.885 | 72.350 | 39.300 |
| 2 | CAS | 1 | 10903.91 | 38914.10 | 1535 | 107 | 1 | 175.775 | 1.885 | 72.350 | 39.300 |
| 3 | CAS | 1 | 9195.48 | 32091.67 | 1501 | 107 | 1 | 144.958 | 1.885 | 72.350 | 39.300 |
| 4 | CAS | 1 | 8048.66 | 27511.98 | 1470 | 107 | 1 | 124.272 | 1.885 | 72.350 | 39.300 |
| 5 | CAS | 1 | 7219.13 | 24199.36 | 1441 | 107 | 1 | 109.308 | 1.885 | 72.350 | 39.300 |
| 6 | CAS | 2 | 6327.46 | 20638.57 | 1402 | 107 | 1 | 93.224 | 1.885 | 72.350 | 39.300 |
| 7 | CAS | 3 | 5341.32 | 16700.58 | 1344 | 107 | 1 | 75.436 | 1.885 | 72.350 | 39.300 |
| 8 | CAS | 4 | 4477.74 | 13252.70 | 1273 | 107 | 1 | 66.592 | 1.694 | 72.350 | 39.300 |
| 9 | CAS | 7 | 3623.14 | 10041.96 | 1192 | 107 | 1 | 57.967 | 1.475 | 72.350 | 39.300 |
| 10 | CAS | 10 | 2857.81 | 7347.44 | 1105 | 107 | 1 | 49.584 | 1.262 | 72.350 | 39.300 |
| 11 | CAS | 14 | 2236.22 | 5296.82 | 1018 | 107 | 1 | 42.100 | 1.071 | 72.350 | 39.300 |
| 12 | CAS | 22 | 1716.58 | 3694.88 | 926 | 107 | 1 | 35.162 | 0.895 | 72.350 | 39.300 |
| 13 | CAS | 35 | 1274.29 | 2434.10 | 821 | 110 | 1 | 28.539 | 0.726 | 72.350 | 39.300 |
| 14 | Cube | 56 | 1231.96 | 1498.33 | 523 | 120 | 1 | 28.658 | 0.000 | 72.350 | 39.300 |
| 15 | Cube | 90 | 842.37 | 847.16 | 432 | 132 | 1 | 23.698 | 0.000 | 72.350 | 39.300 |
| 16 | Cube | 150 | 528.36 | 420.83 | 342 | 150 | 1 | 18.768 | 0.000 | 72.350 | 39.300 |
| 17 | Cube | 244 | 287.79 | 169.17 | 253 | 177 | 1 | 13.851 | 0.000 | 72.350 | 39.300 |
| 18 | Cube | 341 | 123.53 | 47.57 | 166 | 226 | 1 | 9.075 | 0.000 | 72.350 | 39.300 |
| 19 | Cube | 219 | 36.48 | 7.64 | 90 | 384 | 1 | 4.932 | 0.000 | 72.350 | 39.300 |
| 20 | Stg | 1 | 30025.00 | 107466.00 | 1244 | 10 | 3 | 322.500 | 6.282 | 44.940 | 10.000 |
| 21 | Stg | 1 | 10921.00 | 28278.00 | 897 | 15 | 3 | 75.130 | 6.282 | 44.170 | 8.300 |
| 22 | Stg | 1 | 8333.00 | 17790.00 | 773 | 20 | | 58.500 | 6.282 | 43.160 | 14.800 |

10. Define a nominal trajectory file and launch azimuth for the vehicle.
11. Define an Earth gravitational model and site file for the launch mission.

12. Define a set of "standard" ballistic coefficients, explosion induced velocities, and failure times.
13. Define a standard atmosphere density profile.
14. Enter items 10 through 13 into the Air Force DVDISP (Delta Velocity Dispersions) computer program and generate a set of "standard" debris impact ellipses as a function of failure time, ballistic coefficient and fragment velocity.
15. Define the burn rate of the propellant fragments at 1 atmosphere of pressure.
16. Enter item 15 and output files from the FRAG and DVDISP analyses into the Air Force PIMP (Propellant Impact) computer program and generate estimated average propellant impact footprint 2-sigma standard deviation ellipse size, mass of propellant surviving to ground impact, mass averaged burn time of fragments impacting the ground and distance of impact distribution centroid from the launch pad.
17. Set up the REEDM conflagration database entries using the PIMP output.

ACTA performed this sequence of steps to generate REEDM input data needed to simulate Castor 1200 conflagration events over the first 20 seconds of flight for a launch from Pad-OA at Wallops Flight Facility.

## 5.7 Castor 1200 Conflagration Abort REEDM Vehicle Data

The resulting REEDM conflagration Castor 1200 vehicle data entries are as follows:

```
#05.10 ON-PAD CONFLAGRATION PROPELLANT DATA:
   REACTANT#1 NAME AND MASS [LBM] =PBAN2 ,1.238e6,
   REACTANT#2 NAME AND MASS [LBM] =AIR   ,3.715e6,
   REACTANT#3 NAME AND MASS [LBM] =      ,0.0    ,
   REACTANT#4 NAME AND MASS [LBM] =      ,0.0    ,
   REACTANT#5 NAME AND MASS [LBM] =      ,0.0    ,
   REACTANT#6 NAME AND MASS [LBM] =      ,0.0    ,
   AVERAGE REACTANT BURN TIME (S)                =   287.4,
   INITIAL VERTICAL VELOCITY OF CLOUD (FT/S)     =     0.0,
   INITIAL RADIUS OF CLOUD (FT)                  =   285.0,
   INITIAL HEIGHT OF CLOUD (FT)                  =     0.0,
   INITIAL X DISPLACEMENT OF CLOUD FROM PAD (FT) =     0.0,
   INITIAL Y DISPLACEMENT OF CLOUD FROM PAD (FT) =     0.0,
   COMBUSTION PRESS FOR CONFLAGRATION BURN [ATM] =     1.0,
   COMBUSTION TEMP. FOR CONFLAGRATION BURN   [K] =     0.0,
#05.11 ELEVATED ABORT CONFLAGRATION PROPELLANT DATA:
   REACTANT#1 NAME AND MASS FRAC  =PBAN2 ,0.25000,
   REACTANT#2 NAME AND MASS FRAC  =AIR   ,0.75000,
   REACTANT#3 NAME AND MASS FRAC  =      ,0.00000,
   REACTANT#4 NAME AND MASS FRAC  =      ,0.00000,
   REACTANT#5 NAME AND MASS FRAC  =      ,0.00000,
```

```
   REACTANT#6 NAME AND MASS FRAC  =      ,0.00000,
   LAUNCH AZIMUTH (DEGREES)       = 115.0,
#05.12 ELEVATED ABORT CONFLAGRATION FAILURE AND IMPACT DATA:
   FAILURE TIMES (S)                 =   4.0,   8.0,  12.0,  16.0,  20.0,
   AVERAGE REACTANT BURN TIMES (S)   = 283.3, 275.0, 264.0, 257.3, 251.4,
   INITIAL RADIUS OF CLOUD (FT)      = 456.0, 868.0, 1305., 1653., 1902.,
   INITIAL HEIGHT OF CLOUD (FT)      =   0.0,   0.0,   0.0,   0.0,   0.0,
   INITIAL VERT. VEL. OF CLOUD (FT/S)=   0.0,   0.0,   0.0,   0.0,   0.0,
   TOTAL REACTANT MASS IN CLOUD (LBM)=4684644,4172240,3698396,3267396,2868540,
   DOWNRANGE  DISTANCE      (FT)     =    20.,   182.,   664.,  2214.,  4544.,
   DEVIATION FROM LAUNCH AZ (DEG)    =     0.,    -3.,    -2.,    -1.,     0.,
```

The REEDM conflagration database was set up specifically to run abort simulations at 4 second failure time intervals and predict downwind ground level $Al_2O_3$ concentrations and hazard corridor distances.

## 5.8 The Launch Area Toxic Risk Analysis 3-Dimensional (LATRA3D) Model

LATRA3D was developed by ACTA under Air Force sponsorship over the 2000 to 2008 time frame. During the late 1990's a peer review team evaluated REEDM and found that while the model physics and concepts were sound, the program was becoming outdated and was constrained in certain assumptions by software design that was developed for memory and processor speeds of 1980's computer hardware. LATRA3D was developed to address known deficiencies in REEDM, most notably the following items:

1. The use of excessive averaging of wind speed and direction in the mixing layer to drive stabilized exhaust cloud "disks" (see section 5.2).
2. Application of uniform propellant burn rate per unit area within a large propellant fragment impact ellipse footprint area leading to low heat flux and low stabilized cloud rise predictions.

For the purposes of this report, only a summary of several pertinent LATRA3D features will be summarized here. An extensive description of LATRA3D is documented in the Technical Description Manual [4]. In 2010 LATRA3D Version 2.4 was also submitted to a highly qualified scientific review team for Independent Verification and Validation (IV&V). The IV&V team drew the following conclusions:

1. ***"We conclude that the LATRA3D model meets the user's requirements. There are, however, a few improvements that could be made and some additional evaluations with field observations that could be carried out, as described in the remainder of this Executive Summary, and as explained in more detail in the body of the report."***

2. ***"We conclude from our scientific review that LATRA3D has no major technical flaws and its science is adequate for operational use at the launch sites."***

ACTA incorporated a number of the IV&V team recommended improvements in 2011 and LATRA3D analyses that were performed for this study used Version 3.0 with the IV&V enhancements.

LATRA3D differs from REEDM in that is defines a fully 3-dimensional wind field. If suitable meteorological measurements are provided, or mesoscale prognostic weather model output data is provided, LATRA3D will read and process the data to assign wind speed, wind direction and temperature at every grid node within a 3-D grid. The wind field grid set up for Wallops Flight Facility has horizontal grid spacing at one kilometer intervals and vertical spacing over the lower 3000 meters of the atmosphere set at measurement levels taken from mandatory weather balloon input data. There are typically about 80 vertical levels in a WFF archived weather balloon data file spanning this 3,000 meter region. LATRA3D requires as a minimum a single weather balloon input to run. When given a single balloon the horizontal domain is set with the same vertical profile at each node and the wind field becomes essentially 2-dimensional. This was the case for this study where approximately 6,430 archived weather balloons were used as inputs one at a time to run LATRA3D. Even with a single balloon sounding input, LATRA3D provides better resolution of the effects of wind speed and direction shears within the vertical profile than REEDM. LATRA3D accomplishes this by subdividing the normal launch and conflagration initial sources into many smaller Gaussian puffs and allows the local wind at the puff centroid altitude to transport the puff. As individual puffs grow due to atmospheric turbulence, LATRA3D invokes puff splitting criteria that are based on either maximum puff size or maximum amount of wind shear distortion. Puffs that are split to higher and lower altitudes are then driven by the unique measured wind conditions at the new puff centroid altitudes. REEDM averages the vertical winds over a vertical region between the top of the stabilized cloud and the ground surface and applies a single wind speed and single wind direction to all dispersing cloud disks.

The other major feature incorporated into LATRA3D is internal processing of solid propellant fragment trajectories and mapping of propellant combustion products generated by the fragments as they are ejected from the point of explosion to the point of ground impact. LATRA3D still requires a FRAG type analysis external to the code to define input data for propellant fragments versus time, but the external processes reflected in DVDISP and PIMP calculations are performed internally. Within LATRA3D the conflagration exhaust cloud is resolved into as many as 1000 volume "bins" encompassing the fragment trajectories and as many as 100 ground cells covering the ground impact region. In REEDM the ground impact region is defined as a single area with uniform burn rate of propellant and a single, extremely wide, "chimney" of propellant exhaust. Since LATRA3D maps the fragment impact points within the impact grid, it can model "hot spots" and "low density" regions of burning propellant. This results in more realistic simulation of the actual event depicted in Figure 5-8.

Figure 5-10 through Figure 5-13 illustrate how LATRA3D simulates various rocket emission sources with initial source Gaussian puffs that are allowed to move with local winds and split as puff growth occurs during downwind transport and dispersion.

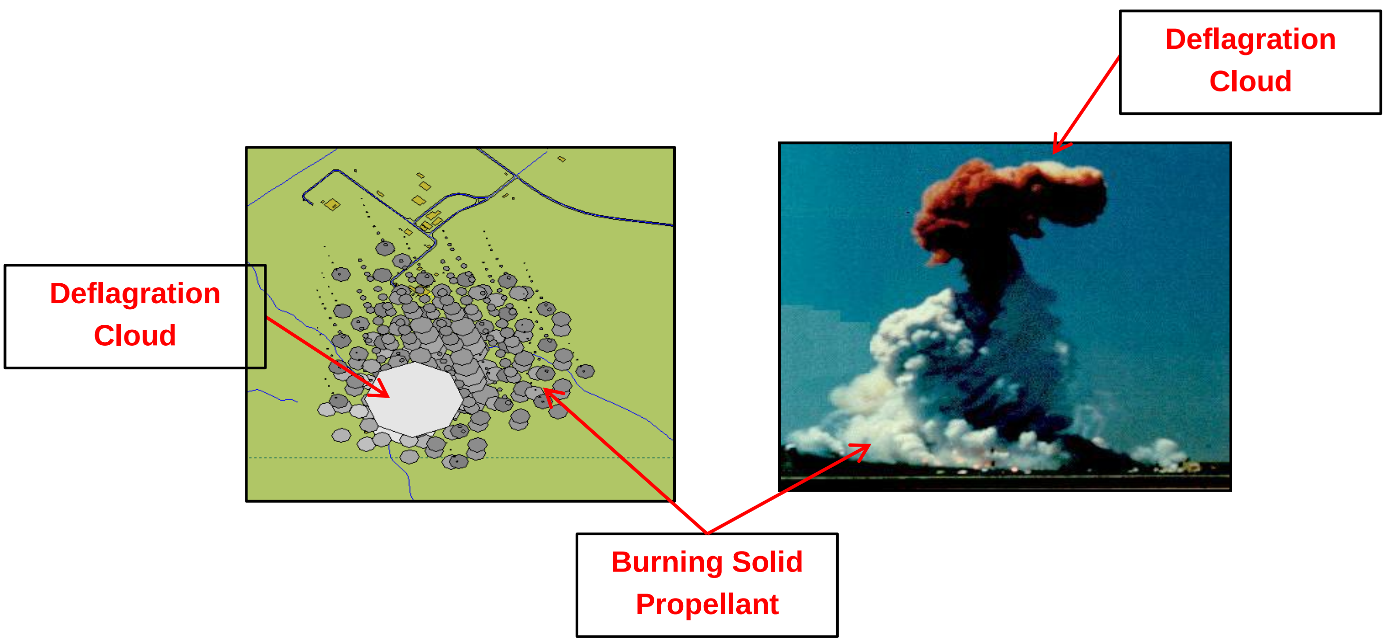


**Figure 5-10. LATRA3D Puffs Generated For an Atlas V 411 Vehicle Abort Simulation Compared with Titan 34D-9 Abort Photo – Both at 8-Second Failure Time.**

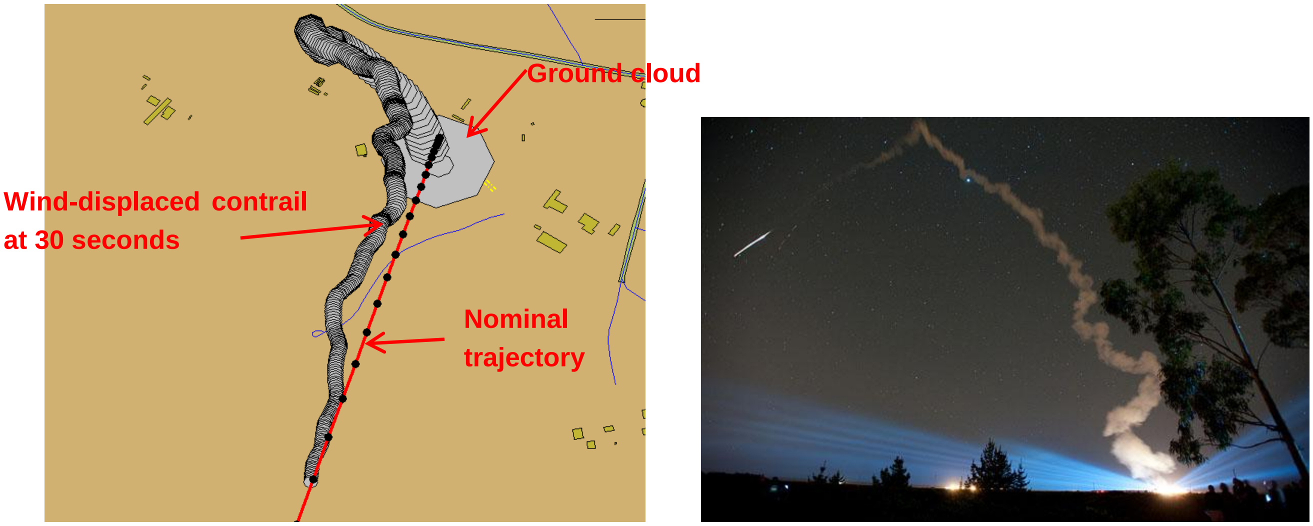


**Figure 5-11. Comparison of LATRA3D Normal Launch Plume Puffs for a Delta II Vehicle Versus Photo of a Delta II Normal Launch Plume.**

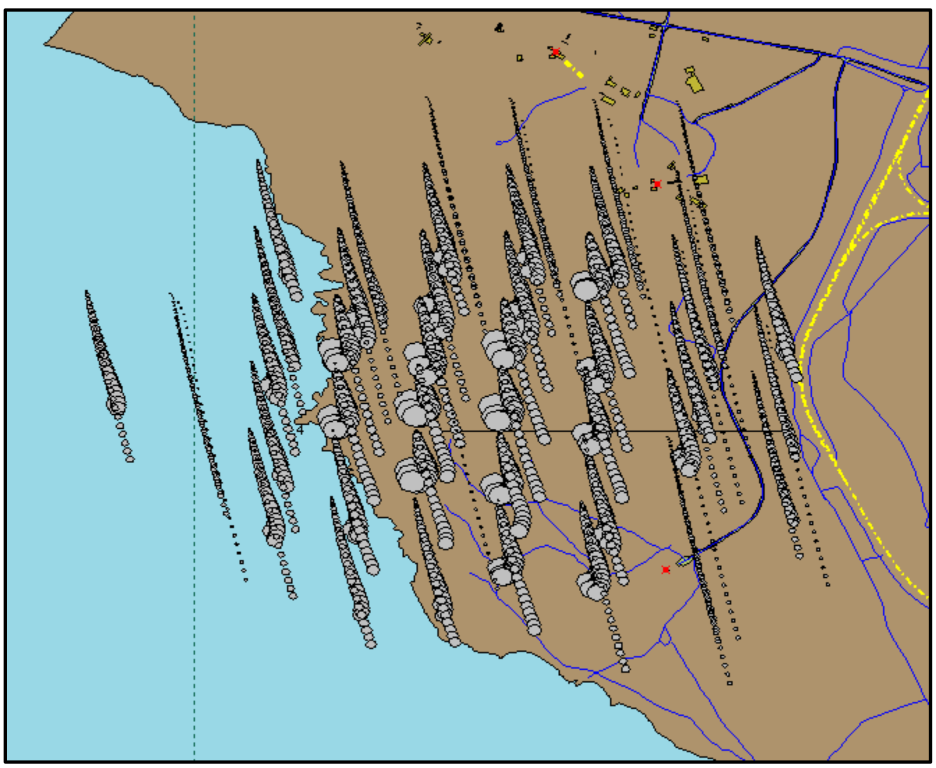

**Figure 5-12. Depiction of LATRA3D Solid Propellant Impacts and Source Puffs for a Late Flight Failure.**

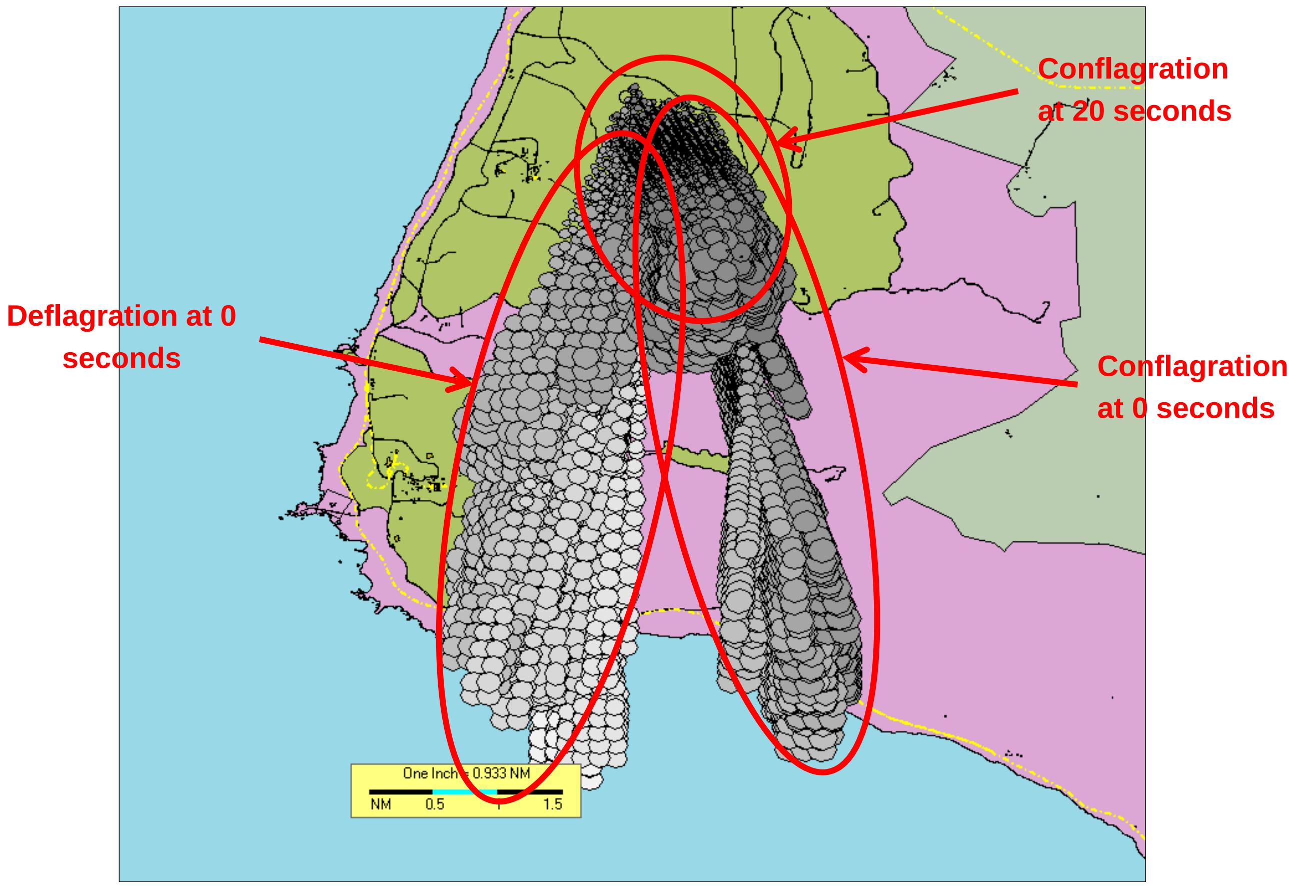


**Figure 5-13. Depiction of LATRA3D Ensemble of Source Puff Transport Directions for a Single Vehicle Launch with Simulations at Different Assumed Failure Times.**

## 5.9 Payload Deflagration MMH and $NO_2$ Emission Scenario

Actual early flight launch failures have demonstrated that the payload has a reasonable probability of surviving explosive breakup of the first stage during an early flight failure. In this scenario simulation it is assumed that the payload containing separate tanks of hypergolic fuel (MMH) and oxidizer ($N_2O_4$) impact the ground rupturing the propellant tanks and confining the propellants sufficiently to generate a mixing and partial combustion resulting in a small liquid propellant fireball (i.e. a deflagration source). This type of scenario has been routinely modeled at the Air Force ranges and ACTA applied the same deflagration propellant mixing assumptions in this study that are used for Air Force launch simulations. By definition, hypergols react upon contact of fuel and oxidizer without the need for an ignition source. For this reason, hypergol mixing tends to be somewhat self-limiting. As soon as a contact interface occurs the propellants react with each other generating hot expansion gases that tend to drive the unmixed portions of the propellants away from each other. Propulsion chemists studying launch vehicle abort conditions at Martin Marietta estimated that only about 20 to 25% of the hypergol mass reacts and the remainder is subject to thermal decomposition or vaporization reactions. It is the vaporized (unreacted) portion of the material that presents the toxic hazard because complete hypergol combustion produces benign combustion products.

In this study the following mixing conditions and reaction pathways were assigned to the payload LATRA3D deflagration scenario. LATRA3D permits three mixing scenarios to be defined for deflagration events. For this study, where a falling payload is assumed to impact the ground, the "column B: Confined by Ground Surface" mixing assumptions were applied as being more conservative that column C, which includes afterburning and further depletes MMH fuel.

```
DEFLAGRATION DATA:
   INITIAL VERTICAL VELOCITY OF CLOUD (FT/S)     =   0.0,
   INITIAL X DISPLACEMENT OF CLOUD FROM PAD (FT) =   0.0,
   INITIAL Y DISPLACEMENT OF CLOUD FROM PAD (FT) =   0.0,
   INITIAL Z DISPLACEMENT OF CLOUD FROM PAD (FT) =   0.0,
   COMBUSTION PRESS. FOR DEFLAGRATION BURN [ATM] =   1.0,
   COMBUSTION TEMP. FOR DEFLAGRATION BURN    [K] =   0.0,

DEFLAGRATION REACTANTS:
   NAME                TOTAL MASS [LBM]    IGNITION TIME [S]   BURN RATE [LBM/S]
   MMH                 1000                278.9               5.87
   N2O4                1640                278.9               22.14
   END


DEFLAGRATION EVENT MODES:
   column A scenario description: COMMAND DESTRUCT
   column B scenario description: CONFINED BY GROUND SURFACE
   column C scenario description: LOW VELOCITY IMPACT WITH AFTERBURNING
```

```
DEFLAGRATION, EXPLOSIVE REACTIONS (MAX 10):
    FUEL   OXIDIZER   FRACTION OF TOTAL FUEL      FRACTION OF TOTAL OXIDIZER
    NAME     NAME      A         B         C         A         B         C
   MMH       N2O4   0.0146    0.0013    0.0063    0.0222148 0.0019780 0.0095858
   END

DEFLAGRATION, SECONDARY FIREBALL BURNING MIXTURE (MAX 10):
  REACTANT               FRACTION OF TOTAL
   NAME                A         B         C
   MMH              0.2174    0.2277    0.2367
   N2O4             0.2174    0.2277    0.2367
   END

DEFLAGRATION, CLOUD CONTRIBUTIONS FROM SOLID PROPELLANT EXHAUST (MAX 5):
PROPELLANT               FRACTION OF TOTAL              AIR/PROP RATIO
   NAME                A         B         C         A         B         C
   END

DEFLAGRATION, PROPELLANT AFTERBURNING REACTIONS (MAX 10):
   FUEL                  FRACTION OF TOTAL              AIR/PROP RATIO
   NAME                A         B         C         A         B         C
   MMH              0.0000    0.0000    0.3785    0.0000    0.0000    7.531039
   END


DEFLAGRATION, PROPELLANT THERMAL DECOMPOSITION REACTIONS (MAX 10):
 CHEMICAL                FRACTION OF TOTAL
   NAME                A         B         C
   MMH              0.62976   0.63222   0.31037
   N2O4             0.7603852 0.770322  0.7537142
   END

DEFLAGRATION, PROPELLANT VAPORIZATION REACTIONS (MAX 10):
  LIQUID                 FRACTION OF TOTAL
   NAME                A         B         C
   MMH              0.13824   0.13878   0.06813
   END

DEFLAGRATION, FIREBALL REACTIONS INVOLVING PRODUCT SPECIES:
   FRACTION OF AVAILABLE N2O4 DECOMPOSED TO NO2            1.0000    1.0000    1.0000
   FRACTION OF AVAILABLE NO2 DECOMPOSED TO N2 AND O2       0.0000    0.0000    0.0000
   FRACTION OF AVAILABLE NO2 CONVERTED TO HNO3 GAS         0.0000    0.0000    0.0000
```

## 5.10 Payload Liquid Spill of MMH and $NO_2$ Emission Scenario

In this scenario simulation it is assumed that the payload containing separate tanks of hypergolic fuel (MMH) and oxidizer ($N_2O_4$) impact the ground rupturing the propellant tanks but the propellants are not sufficiently confined and no combustion of fuel and oxidizer takes place. Instead it is assumed that the propellant tanks rupture or feed and pressurization lines are severed and the liquid propellant spills out on to the ground resulting in an evaporating pool. LATRA3D has incorporated the pool evaporation algorithms of the Air Force Toxics (AFTOX) code and these algorithms are used for this scenario simulation. AFTOX is used operationally at Vandenberg AFB to simulate spills of hypergols associated with propellant transfers of other ground processing applications. AFTOX has also been used at Vandenberg to estimate toxic hazard corridors for potential impacts of large intact payloads flown on Titan launch vehicles. Like AFTOS, LATRA3D invokes the Vossler pool evaporation model for MMH and $N_2O_4$ spills. The Vossler evaporation model is the most sophisticated of three internal evaporation models and it has been tailored to evaluation of hypergols spills. This evaporation model performs a full energy transfer and mass balance calculation on the evaporating pool and uses ground heating, solar heating and wind convection to estimate the evaporation rate. It automatically recognizes $N_2O_4$ as a unique case and converts the evaporated gas to $NO_2$ rather than $N_2O_4$ vapor. Physical and chemical properties for the spilled commodities are acquired by LATRA3D from the AFTOX and Vossler chemical databases, which have been vetted by a 30$^{th}$ Space Wing IV&V team in the past.

# 6. METEOROLOGICAL DATA PREPARATION

Gaseous dispersion of rocket exhaust clouds is extremely dependent upon the meteorological conditions at the time the source cloud is generated. The presence or absence of temperature inversions, the temperature lapse rate, wind speed and direction, wind shears and atmospheric turbulence are important factors that influence the cloud rise and rate of dispersion of the source cloud. Meteorological conditions that are adverse from a toxic chemical dispersion perspective are light winds with little wind speed or wind direction variation over the first several thousand feet of the atmosphere coupled with a capping temperature inversion just above the top of the stabilized source cloud. An additional adverse factor is suppression of atmospheric turbulence, as occurs at night or under cloudy or marine stratus and fog conditions.

ACTA ran LATRA3D and REEDM analyses for this study using 6432 meteorological data sets based on actual weather balloon measurements made at Wallops Flight Facility between 2000 and 2008. This data was previously processed by ACTA to support the Taurus II Environmental Assessment and was converted to REEDM format at that time. The original raw weather balloon data was not in a format usable by REEDM and needed to be preprocessed to reduce the number of measurement levels from several thousand to approximately one hundred, to quality control check the raw data, and to output the data in REEDM compatible format. A computer program written by ACTA and delivered to WFF for operational use in 2007 was used to perform the raw data file conversions. A critical part of the conversion process was to test for, and capture, inflection points where temperature, wind speed, wind direction or relative humidity reach minimum or maximum values and change slope as a function of altitude. An example of the weather profile testing algorithm capabilities is illustrated in Figure 6-1, which is contrived test data with positive, negative and infinite slopes and multiple inflection points. The resulting converted files were sorted into daytime and nighttime sets for each month of the year. Data was classified as "daytime" if the balloon release time was between 0600 and 1900 Eastern Standard Time. The archived converted files generated in 2009 were recovered for this study and tested in LATRA3D to verify compatibility with LATRA3D processing. Two "bad" weather data sets were found and discarded leaving an archive of 6430 cases.

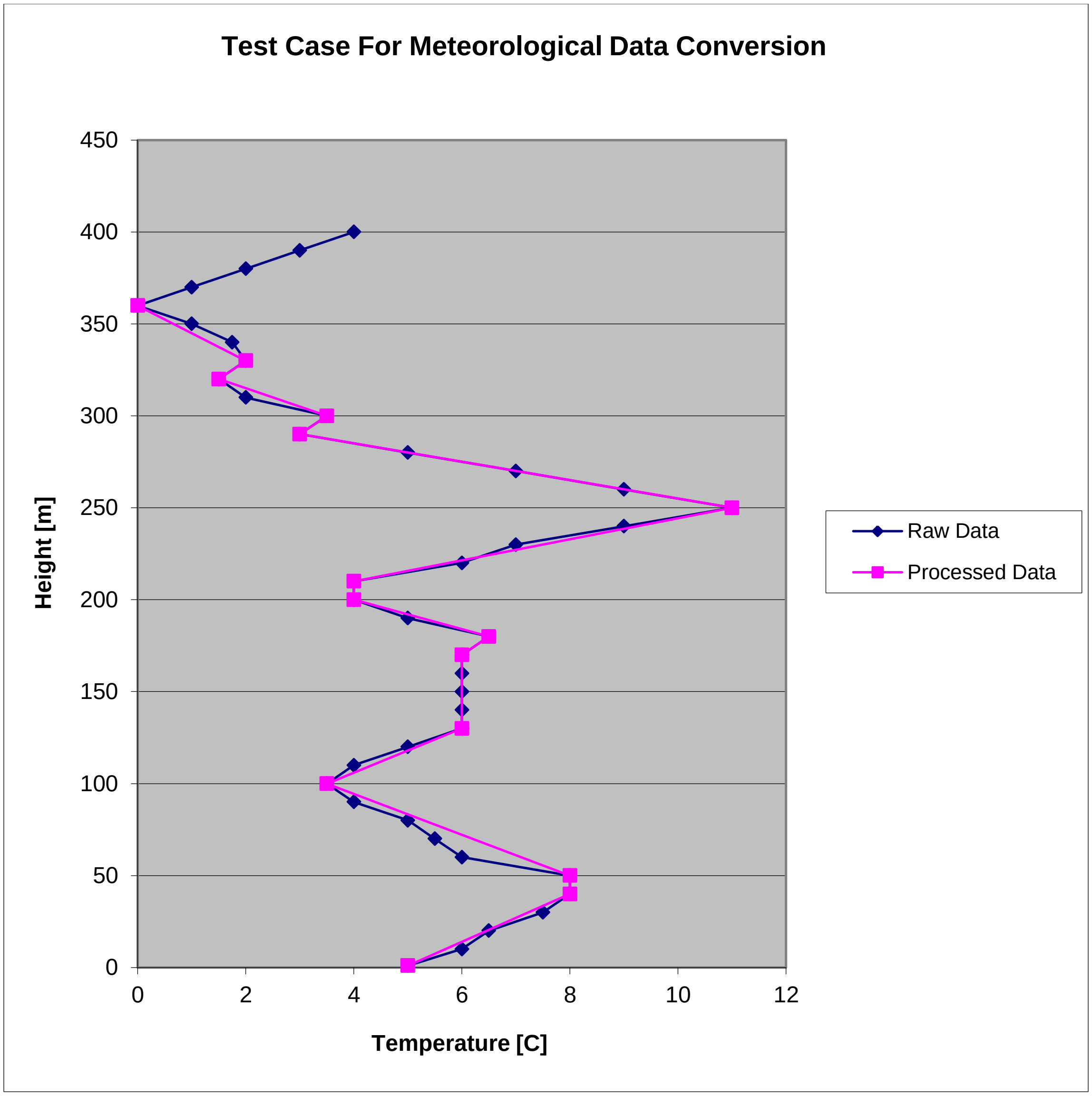


**Figure 6-1. Illustration of Testing a Raw Data Profile to Capture Slope Inflection Points that Define Minimum and Maximum Values and Measure Inversions and Shear Effects.**

## 6.1 REEDM Castor 1200 Normal Launch Scenario Setup

ACTA executed REEDM in batch processing mode to cycle through all archived meteorological cases and to extract key information to a summary table. Typically REEDM generates an output file for a single weather case that consists of 10 to 20 pages of information on the run setup, intermediate calculated values and tables of concentration versus downwind distance. Saving the standard REEDM output file for each run over thousands of simulations results in an overwhelming amount of output data. ACTA developed a special batch version of REEDM for the Air Force that has been used over the years to execute thousands of scenarios and condense the REEDM output for all runs into a summary table containing the following critical analysis parameters:

1. Chemical being tracked in REEDM analysis.
2. Concentration threshold used to calculate concentration isopleth beginning and end distances.
3. Meteorological input file name.
4. Zulu time of balloon release.
5. REEDM computed mixing boundary depth.
6. REEDM predicted cloud stabilization height.
7. REEDM predicted average wind speed used to transport exhaust cloud.
8. REEDM predicted average wind direction used to transport exhaust cloud.
9. REEDM predicted maximum ground level concentration.
10. REEDM predicted distance from exhaust cloud source to location of maximum concentration.
11. REEDM predicted bearing from exhaust cloud source to location of maximum concentration.
12. REEDM predicted nearest distance from exhaust cloud source to the location where the ground concentration centerline first exceeds the user defined concentration threshold.

13. REEDM predicted farthest distance from exhaust cloud source to the location where the ground concentration centerline last exceeds the user defined concentration threshold.

14. REEDM predicted bearing from exhaust cloud source to location where the ground concentration centerline last exceeds the user defined concentration threshold.

15. REEDM derived average wind speed shear in the lower planetary boundary layer.

16. REEDM derived average wind direction shear in the lower planetary boundary layer.

17. REEDM derived average horizontal (azimuthal) turbulence intensity in the lower planetary boundary layer.

18. REEDM derived average vertical (elevation) turbulence intensity in the lower planetary boundary layer.

19. REEDM derived average wind speed shear in the region above the planetary boundary layer.

20. REEDM derived average wind direction shear in the region above the planetary boundary layer.

21. REEDM derived average horizontal (azimuthal) turbulence intensity in the region above the planetary boundary layer.

22. REEDM derived average vertical (elevation) turbulence intensity in the region above the planetary boundary layer.

The above list of parameters is provided for REEDM predictions of both peak instantaneous concentration and time weighted average (TWA) concentration. In the runs performed for this study the time weighted average concentrations for HCl were not needed because the health response time is acute and toxicity thresholds call for comparison with model peak concentration predictions. In any event, if TWA concentration estimates are needed, a fairly short averaging time is appropriate for rocket exhaust cloud exposures because the source cloud typically passes over a receptor with a time scale of tens of minutes rather than hours. The REEDM summary tables from the monthly batch runs were further condensed to identify the meteorological case that produced the highest peak concentration and record the range and bearing from the source location (WFF Castor 1200 launch Pad-0A).

## 6.2 REEDM Far Field HCl Results for the Castor 1200 Normal Launch Scenario

Table 6-1 presents the maximum far field HCl peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the normal launch ground and contrail clouds. The far field exposure is REEDM's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 2 to 5 ppm with the maximum concentration predicted to occur from 11000 to 19000 meters downwind from the launch site. These values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-2 shows the REEDM predicted maximum peak HCl far field concentrations for 1751 nighttime cases for Castor 1200 vehicle normal launch scenarios. As with the daytime cases, the peak instantaneous HCl concentrations are less than 10 ppm.

**Table 6-1: Castor 1200 Normal Launch HCl Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 2.1 | 15000 | 80 |
| February | 363 | 2.4 | 12000 | 141 |
| March | 393 | 3.3 | 17000 | 241 |
| April | 382 | 2.3 | 19000 | 227 |
| May | 398 | 2.5 | 13000 | 231 |
| June | 391 | 2.7 | 16000 | 47 |
| July | 417 | 3.0 | 11000 | 87 |
| August | 410 | 2.0 | 14000 | 212 |
| September | 412 | 5.0 | 16000 | 257 |
| October | 429 | 2.0 | 15000 | 183 |
| November | 376 | 2.3 | 17000 | 201 |
| December | 367 | 3.3 | 13000 | 227 |

**Table 6-2: Castor 1200 Normal Launch HCl Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 2.9 | 12000 | 134 |
| February | 158 | 2.4 | 14000 | 227 |
| March | 165 | 2.5 | 16000 | 227 |
| April | 158 | 5.1 | 10000 | 207 |
| May | 159 | 2.2 | 27000 | 231 |
| June | 153 | 1.8 | 14000 | 308 |
| July | 153 | 2.3 | 13000 | 104 |
| August | 162 | 1.7 | 12000 | 74 |
| September | 163 | 2.9 | 11000 | 204 |
| October | 125 | 1.3 | 19000 | 168 |
| November | 129 | 2.1 | 14000 | 177 |
| December | 131 | 1.8 | 15000 | 135 |

The REEDM predicted HCl concentration data for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-3.

**Table 6-3. REEDM Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 2938 | 0.6279 |
| 1 - 2 | 280 | 0.0598 |
| 2 - 3 | 23 | 0.0049 |
| 3 - 4 | 3 | 0.0006 |
| 4 - 5 | 0 | 0.000 |
| 5 - 6 | 1 | 0.0002 |
| 6 - 7 | 0 | 0.0000 |
| 7 - 8 | 0 | 0.0000 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 0 | 0.0000 |

It is noted that approximately 63% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level HCl concentrations of less than 1 ppm. Approximately

31% (1434) of the daytime meteorological cases resulted in zero ground level HCl concentration predictions because the normal launch cloud was predicted to rise entirely above a capping inversion that defined the top of the mixed boundary layer. Thus a total of 93.4% of the daytime meteorological cases had very benign predictions of zero or less than 1 ppm ground level HCl concentration for the normal launch scenario.

The REEDM predicted cloud transport directions for the normal launch HCl dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-4 indicates the predicted Castor 1200 normal launch plume direction probability of occurrence observed across the 3245 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. It is noted that for the daytime launch scenarios transport of the exhaust plume to the East and Southeast are favored. This would tend to carry the toxic cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia. The transport direction reflects the average airflow over a depth of approximately 1000 meters, hence the windrose observed for elevated rocket exhaust clouds may differ significantly from a windrose derived from a surface wind tower.

**Table 6-4. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Normal Launch HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 178 | 0.055 |
| 22.5 – 67.5 (NE) | 497 | 0.153 |
| 67.5 – 112.5 (E) | 766 | 0.236 |
| 112.5 – 157.5 (SE) | 879 | 0.271 |
| 157.5 – 202.5 (S) | 361 | 0.111 |
| 202.5 – 247.5 (SW) | 264 | 0.081 |
| 247.5 – 292.5 (W) | 175 | 0.054 |
| 292.5 – 337.5 (NW) | 125 | 0.039 |

Similar summary tables for the 1751 nighttime Castor 1200 normal launch simulations were compiled. Table 6-5 shows that the peak HCl instantaneous concentration predictions for nighttime conditions continues with a high probability that the maximum far field concentration will be less than 1 ppm. Approximately 43% (748) of the nighttime meteorological cases resulted in zero ground level HCl concentration predictions because the normal launch cloud was predicted to rise entirely above a capping inversion that defined the top of the mixed boundary layer. Thus a total of 94.2% of the nighttime meteorological cases had very benign predictions of zero or less than 1 ppm ground level HCl concentration for the normal launch scenario.

**Table 6-5. REEDM Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 902 | 0.5151 |
| 1 - 2 | 90 | 0.0514 |
| 2 - 3 | 9 | 0.0051 |
| 3 - 4 | 0 | 0.0000 |
| 4 - 5 | 1 | 0.0006 |
| 5 - 6 | 1 | 0.0006 |
| 6 - 7 | 0 | 0.0000 |
| 7 - 8 | 0 | 0.0000 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 0 | 0.0000 |

Table 6-6 indicates the predicted Castor 1200 vehicle normal launch plume direction probability of occurrence observed across the 1003 nighttime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. It is noted that for nighttime launch scenarios transport of the exhaust plume to the East and Southeast are still favored as they were during the daytime.

**Table 6-6. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Normal Launch Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 54 | 0.035 |
| 22.5 – 67.5 (NE) | 128 | 0.182 |
| 67.5 – 112.5 (E) | 214 | 0.171 |
| 112.5 – 157.5 (SE) | 287 | 0.214 |
| 157.5 – 202.5 (S) | 115 | 0.134 |
| 202.5 – 247.5 (SW) | 101 | 0.124 |
| 247.5 – 292.5 (W) | 55 | 0.061 |
| 292.5 – 337.5 (NW) | 49 | 0.078 |

## 6.3 REEDM Far Field $Al_2O_3$ Results for the Castor 1200 Normal Launch Scenario

Table 6-7 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the normal launch ground and contrail clouds. The far field exposure is REEDM's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations ranged from 2 to 9 mg/m$^3$ with the maximum concentration predicted to occur from 10000 to 33000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-8 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle normal launch scenarios. As with the daytime cases, the peak instantaneous $Al_2O_3$ concentrations are less than 10 mg/m$^3$.

**Table 6-7: Castor 1200 Normal Launch $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 3.6 | 2.5 | 31000 | 40 |
| February | 363 | 3.7 | 2.6 | 33000 | 205 |
| March | 393 | 3.8 | 2.7 | 17000 | 241 |
| April | 382 | 9.1 | 6.4 | 10000 | 136 |
| May | 398 | 3.1 | 2.2 | 24000 | 238 |
| June | 391 | 2.6 | 1.8 | 21000 | 113 |
| July | 417 | 2.8 | 2.0 | 11000 | 83 |
| August | 410 | 2.1 | 1.5 | 13000 | 213 |
| September | 412 | 5.1 | 3.6 | 16000 | 255 |
| October | 429 | 3.4 | 2.4 | 22000 | 256 |
| November | 376 | 4.0 | 2.8 | 18000 | 197 |
| December | 367 | 3.1 | 2.2 | 13000 | 106 |

**Table 6-8: Castor 1200 Normal Launch $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 5.1 | 3.6 | 20000 | 183 |
| February | 158 | 3.4 | 2.4 | 20000 | 172 |
| March | 165 | 4.7 | 3.3 | 18000 | 227 |
| April | 158 | 5.0 | 3.5 | 11000 | 225 |
| May | 159 | 3.1 | 2.2 | 24000 | 77 |
| June | 153 | 2.5 | 1.8 | 27000 | 77 |
| July | 153 | 2.3 | 1.6 | 12000 | 111 |
| August | 162 | 1.7 | 1.2 | 11000 | 75 |
| September | 163 | 3.1 | 2.2 | 10000 | 202 |
| October | 125 | 2.8 | 2.0 | 26000 | 168 |
| November | 129 | 2.5 | 1.8 | 42000 | 165 |
| December | 131 | 3.9 | 2.7 | 29000 | 67 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-9.

**Table 6-9. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ Concentrations for Daytime Castor 1200 Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 4069 | 0.8696 |
| 1 - 2 | 485 | 0.1037 |
| 2 - 3 | 82 | 0.0175 |
| 3 - 4 | 20 | 0.0043 |
| 4 - 5 | 0 | 0.0000 |
| 5 - 6 | 1 | 0.0002 |
| 6 - 7 | 0 | 0.0000 |
| 7 - 8 | 0 | 0.0000 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 1 | 0.0002 |

It is noted that approximately 67% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 mg/m$^3$.

The REEDM predicted cloud transport directions for the normal launch $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-10 indicates the predicted Castor 1200 normal launch plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime launch scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored. This would tend to carry the toxic cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia. The transport direction reflects the average airflow over a depth of approximately 3000 meters, hence the windrose observed for these elevated rocket exhaust clouds may differ significantly from a windrose derived from a surface wind tower.

**Table 6-10. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Normal Launch $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 385 | 0.083 |
| 22.5 – 67.5 (NE) | 971 | 0.208 |
| 67.5 – 112.5 (E) | 957 | 0.205 |
| 112.5 – 157.5 (SE) | 1058 | 0.227 |
| 157.5 – 202.5 (S) | 489 | 0.105 |
| 202.5 – 247.5 (SW) | 386 | 0.083 |
| 247.5 – 292.5 (W) | 221 | 0.047 |
| 292.5 – 337.5 (NW) | 191 | 0.041 |

Similar summary tables for the 1751 nighttime Castor 1200 normal launch simulations were compiled. Table 6-11 shows that the peak $Al_2O_3$ $PM_{10}$ instantaneous concentration predictions for nighttime conditions continues with a high probability that the maximum far field concentration will be less than 1 mg/m$^3$.

**Table 6-11. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ Concentrations for Nighttime Castor 1200 Normal Launch Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1511 | 0.8629 |
| 1 - 2 | 186 | 0.1062 |
| 2 - 3 | 39 | 0.0223 |
| 3 - 4 | 7 | 0.0040 |
| 4 - 5 | 2 | 0.0011 |
| 5 - 6 | 2 | 0.0011 |
| 6 - 7 | 0 | 0.0000 |
| 7 - 8 | 0 | 0.0000 |
| 8 - 9 | 0 | 0.0000 |
| 9 - 10 | 0 | 0.0000 |

Table 6-12 indicates the predicted Castor 1200 vehicle normal launch plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime launch scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored as they were during the daytime.

**Table 6-12. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Normal Launch Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 110 | 0.0630 |
| 22.5 – 67.5 (NE) | 328 | 0.1877 |
| 67.5 – 112.5 (E) | 382 | 0.2187 |
| 112.5 – 157.5 (SE) | 420 | 0.2404 |
| 157.5 – 202.5 (S) | 209 | 0.1196 |
| 202.5 – 247.5 (SW) | 136 | 0.0779 |
| 247.5 – 292.5 (W) | 85 | 0.0487 |
| 292.5 – 337.5 (NW) | 77 | 0.0441 |

## 6.4 LATRA3D Far Field HCl Results for the Castor 1200 Conflagration Scenarios

Conflagration results are difficult to characterize with just a few parameters because the toxic hazard corridor varies with both the meteorological case and the assumed failure time. ACTA run LATRA3D HCl dispersion simulations for all 6430 archived weather balloon soundings for failure times set at 0, 4, 8, 12, 16 and 20 seconds (38,580 simulations). Results are present by day versus night, month and launch vehicle failure time.

### 6.4.1 T-0 Conflagration HCl Results

Table 6-13 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T-0 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 30 to 65 ppm with the maximum concentration predicted to occur from 1000 to 3400 meters downwind from the conflagration debris field source location. These values represent the maximum concentrations predicted over a sample set of 4655 WFF balloon soundings. Table 6-14 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T-0 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-15 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1749 nighttime cases for Castor 1200 vehicle T-0 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 18 to 58 ppm with the maximum concentration predicted to occur from 1000 to 6000 meters downwind from the conflagration debris field source location. Table 6-16 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T-0 conflagration scenarios.

**Table 6-13: Castor 1200 T-0 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 5.33E+01 | 2007 | 215 |
| February | 362 | 5.29E+01 | 2679 | 15 |
| March | 391 | 6.09E+01 | 1615 | 343 |
| April | 378 | 6.49E+01 | 1955 | 314 |
| May | 395 | 4.75E+01 | 2059 | 12 |
| June | 389 | 3.58E+01 | 1363 | 48 |
| July | 410 | 4.78E+01 | 2250 | 350 |
| August | 409 | 3.46E+01 | 1064 | 347 |
| September | 408 | 3.17E+01 | 3412 | 6 |
| October | 429 | 2.94E+01 | 2320 | 40 |
| November | 376 | 3.38E+01 | 2249 | 42 |
| December | 367 | 3.42E+01 | 3088 | 85 |

**Table 6-14: Castor 1200 T-0 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 280 | 1.00E+00 | 8606 | 78 |
| February | 284 | 1.00E+00 | 8332 | 350 |
| March | 279 | 1.00E+00 | 8156 | 11 |
| April | 252 | 1.00E+00 | 8011 | 19 |
| May | 267 | 1.00E+00 | 7854 | 298 |
| June | 272 | 1.00E+00 | 6397 | 218 |
| July | 266 | 1.00E+00 | 6004 | 31 |
| August | 295 | 1.00E+00 | 7613 | 242 |
| September | 295 | 1.00E+00 | 8898 | 339 |
| October | 369 | 1.00E+00 | 8127 | 241 |
| November | 338 | 1.00E+00 | 8479 | 27 |
| December | 322 | 1.00E+00 | 8391 | 81 |

**Table 6-15: Castor 1200 T-0 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 3.57E+01 | 2980 | 96 |
| February | 158 | 5.48E+01 | 2118 | 37 |
| March | 165 | 2.95E+01 | 2642 | 46 |
| April | 157 | 5.18E+01 | 2072 | 6 |
| May | 158 | 1.77E+01 | 2615 | 47 |
| June | 153 | 2.92E+01 | 1683 | 19 |
| July | 153 | 3.23E+01 | 1271 | 359 |
| August | 162 | 2.46E+01 | 1545 | 157 |
| September | 163 | 3.45E+01 | 5724 | 231 |
| October | 125 | 3.35E+01 | 3165 | 104 |
| November | 129 | 5.76E+01 | 2580 | 239 |
| December | 131 | 4.16E+01 | 2893 | 164 |

**Table 6-16: Castor 1200 T-0 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 280 | 1.00E+00 | 8606 | 78 |
| February | 284 | 1.00E+00 | 8332 | 350 |
| March | 279 | 1.00E+00 | 8156 | 11 |
| April | 252 | 1.00E+00 | 8011 | 19 |
| May | 267 | 1.00E+00 | 7854 | 298 |
| June | 272 | 1.00E+00 | 6397 | 218 |
| July | 266 | 1.00E+00 | 6004 | 31 |
| August | 295 | 1.00E+00 | 7613 | 242 |
| September | 295 | 1.00E+00 | 8898 | 339 |
| October | 369 | 1.00E+00 | 8127 | 241 |
| November | 338 | 1.00E+00 | 8479 | 27 |
| December | 322 | 1.00E+00 | 8391 | 81 |

The LATRA3D T-0 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-17.

**Table 6-17. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T-0 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1755 | 0.37701 |
| 2- 4 | 714 | 0.15338 |
| 4 - 6 | 533 | 0.11450 |
| 6 - 8 | 380 | 0.08163 |
| 8 - 10 | 293 | 0.06294 |
| 10 - 20 | 705 | 0.15145 |
| 20 - 30 | 188 | 0.04039 |
| 30 - 40 | 68 | 0.01461 |
| 40 - 50 | 14 | 0.00301 |
| 50 - 60 | 3 | 0.00064 |
| 60 – 70 | 2 | 0.00043 |
| 70 – 80 | 0 | 0.00000 |
| 80 – 90 | 0 | 0.00000 |
| 90 - 100 | 0 | 0.00000 |
| > 100 | 0 | 0.00000 |

It is noted that approximately 79% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 15% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range.

The LATRA3D predicted cloud transport directions for the T-0 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-18 indicates the predicted Castor 1200 T-0 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4655 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough approximation only. Recall that LATRA3D simulates a conflagration event with up to 1000 volume elements encompassing the fragment trajectory space and up to 100 grid cells on the ground for burning fragment plumes. A small plume on the edge of the grid that has a low cloud rise stabilization height can result in a LATRA3D predicted maximum concentration at a ground location relatively close to the small plume location (e.g. within several thousand meters). The "plume transport" direction reported in Table 6-18 is estimated as the bearing from the center of the debris field (i.e. not the offending small plume location) to the point of the maximum concentration location. When the maximum predicted concentration point is near the debris field and the debris field has a large radius, the computed "plume transport direction" can be off by many degrees. Geometrically these points form a triangle whereas a more accurate transport direction calculation would have the three points co-linear. In general, the transport direction to the peak concentration point is driven by the puffs with the lowest stabilization heights and the region of the atmosphere under consideration is probably the first 200 to 300 meters, rather than the deeper layer that drives the normal launch ground cloud transport direction. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-19 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-18. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T-0 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 759 | 0.16305 |
| 22.5 – 67.5 (NE) | 901 | 0.19356 |
| 67.5 – 112.5 (E) | 492 | 0.10569 |
| 112.5 – 157.5 (SE) | 691 | 0.14844 |
| 157.5 – 202.5 (S) | 507 | 0.10892 |
| 202.5 – 247.5 (SW) | 572 | 0.12288 |
| 247.5 – 292.5 (W) | 397 | 0.08528 |
| 292.5 – 337.5 (NW) | 336 | 0.07218 |

**Table 6-19. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T-0 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 559 | 0.15885 |
| 22.5 – 67.5 (NE) | 841 | 0.23899 |
| 67.5 – 112.5 (E) | 479 | 0.13612 |
| 112.5 – 157.5 (SE) | 517 | 0.14692 |
| 157.5 – 202.5 (S) | 379 | 0.10770 |
| 202.5 – 247.5 (SW) | 293 | 0.08326 |
| 247.5 – 292.5 (W) | 240 | 0.06820 |
| 292.5 – 337.5 (NW) | 211 | 0.05996 |

Similar summary tables for the 1751 nighttime Castor 1200 T-0 conflagration simulations were compiled. Table 6-20 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 82% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 15% of the nighttime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range.

**Table 6-20. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T-0 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 555 | 0.31732 |
| 2- 4 | 308 | 0.17610 |
| 4 - 6 | 268 | 0.15323 |
| 6 - 8 | 197 | 0.11264 |
| 8 - 10 | 102 | 0.05832 |
| 10 - 20 | 262 | 0.14980 |
| 20 - 30 | 41 | 0.02344 |
| 30 - 40 | 12 | 0.00686 |
| 40 - 50 | 1 | 0.00057 |
| 50 - 60 | 3 | 0.00172 |
| 60 – 70 | 0 | 0.00000 |
| 70 – 80 | 0 | 0.00000 |
| 80 – 90 | 0 | 0.00000 |
| 90 - 100 | 0 | 0.00000 |
| > 100 | 0 | 0.00000 |

Table 6-21 indicates the predicted Castor 1200 vehicle T-0 conflagration plume direction probability of occurrence observed across the 1749 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-22 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for nighttime launch scenarios transport of the exhaust plume is least favored for transport to the West, Northwest and North, which is similar but not identical to the estimated daytime transport directions.

**Table 6-21. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T-0 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 151 | 0.08634 |
| 22.5 – 67.5 (NE) | 339 | 0.19383 |
| 67.5 – 112.5 (E) | 214 | 0.12236 |
| 112.5 – 157.5 (SE) | 305 | 0.17439 |
| 157.5 – 202.5 (S) | 252 | 0.14408 |
| 202.5 – 247.5 (SW) | 271 | 0.15495 |
| 247.5 – 292.5 (W) | 124 | 0.07090 |
| 292.5 – 337.5 (NW) | 93 | 0.05317 |

**Table 6-22. LATRA3D Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T-0 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 109 | 0.07649 |
| 22.5 – 67.5 (NE) | 279 | 0.19579 |
| 67.5 – 112.5 (E) | 244 | 0.17123 |
| 112.5 – 157.5 (SE) | 220 | 0.15439 |
| 157.5 – 202.5 (S) | 227 | 0.15930 |
| 202.5 – 247.5 (SW) | 194 | 0.13614 |
| 247.5 – 292.5 (W) | 87 | 0.06105 |
| 292.5 – 337.5 (NW) | 65 | 0.04561 |

### 6.4.2 T+4 Conflagration HCl Results

Maximum predicted ground level HCl concentrations are higher and closer to the source for the T+4 second failure than for the "on-pad" T-0 conflagration failure time. This is due to greater scatter of the burning propellant fragments as the launch vehicle begins its ascent. The large scatter region reduces the net heat flux of burning propellant mass per unit area in the debris field. This leads to lower stabilization heights of the source puffs, which in turn equates to higher ground level concentrations. Ground level concentration is very sensitive to the stabilization heights of the puffs and varies approximately in proportion to the invers cube of the stabilization height (i.e. reducing the stabilization height by ½ increases the ground concentration by about a factor of 8).

Table 6-23 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T+4 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 46 to 315 ppm with the maximum concentration predicted to occur from 70 to 2300 meters downwind from the conflagration debris field source location. Concentrations above 100 ppm are generally associated with low puff stabilization heights for portions of the ground burning plumes that are in the debris impact regions. These high concentration points are either within the impact region or very close to it. The table values represent the maximum concentrations predicted over a sample set of 4662 WFF balloon soundings. Table 6-24 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T+4 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-25 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+4 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 31 to 213 ppm with the maximum concentration predicted to occur from 40 to 2400 meters downwind from the conflagration debris field source location. Table 6-26 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T+4 conflagration scenarios.

**Table 6-23: Castor 1200 T+4 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 3.15E+02 | 104 | 352 |
| February | 362 | 1.79E+02 | 73 | 47 |
| March | 389 | 1.49E+02 | 535 | 32 |
| April | 378 | 1.67E+02 | 176 | 89 |
| May | 396 | 1.65E+02 | 254 | 31 |
| June | 389 | 8.87E+01 | 133 | 358 |
| July | 414 | 4.62E+01 | 2308 | 350 |
| August | 410 | 4.59E+01 | 236 | 223 |
| September | 411 | 6.67E+01 | 202 | 240 |
| October | 429 | 1.27E+02 | 772 | 23 |
| November | 376 | 1.15E+02 | 260 | 136 |
| December | 367 | 1.07E+02 | 71 | 93 |

**Table 6-24: Castor 1200 T+4 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 280 | 1.00E+00 | 9567 | 24 |
| February | 292 | 1.00E+00 | 9673 | 306 |
| March | 297 | 1.00E+00 | 9431 | 346 |
| April | 282 | 1.00E+00 | 8307 | 330 |
| May | 319 | 1.00E+00 | 7976 | 297 |
| June | 308 | 1.00E+00 | 6036 | 218 |
| July | 306 | 1.00E+00 | 6144 | 31 |
| August | 319 | 1.00E+00 | 7698 | 242 |
| September | 302 | 1.00E+00 | 9141 | 339 |
| October | 385 | 1.00E+00 | 8261 | 240 |
| November | 342 | 1.00E+00 | 8907 | 55 |
| December | 329 | 1.00E+00 | 9476 | 95 |

**Table 6-25: Castor 1200 T+4 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 1.18E+02 | 229 | 57 |
| February | 158 | 2.13E+02 | 101 | 173 |
| March | 165 | 1.89E+02 | 283 | 56 |
| April | 158 | 1.30E+02 | 84 | 100 |
| May | 159 | 1.32E+02 | 40 | 129 |
| June | 153 | 5.56E+01 | 314 | 189 |
| July | 153 | 3.82E+01 | 2386 | 173 |
| August | 162 | 3.12E+01 | 1122 | 149 |
| September | 163 | 6.41E+01 | 280 | 159 |
| October | 125 | 1.54E+02 | 48 | 150 |
| November | 129 | 1.02E+02 | 149 | 196 |
| December | 131 | 7.76E+01 | 332 | 53 |

**Table 6-26: Castor 1200 T+4 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 70 | 1.00E+00 | 9273 | 59 |
| February | 134 | 1.00E+00 | 9761 | 126 |
| March | 140 | 1.00E+00 | 9645 | 318 |
| April | 135 | 1.00E+00 | 7639 | 332 |
| May | 140 | 1.00E+00 | 6486 | 29 |
| June | 141 | 1.00E+00 | 7626 | 44 |
| July | 143 | 1.00E+00 | 6273 | 359 |
| August | 155 | 1.00E+00 | 6466 | 52 |
| September | 149 | 1.00E+00 | 7375 | 229 |
| October | 123 | 1.00E+00 | 10366 | 127 |
| November | 118 | 1.00E+00 | 10585 | 182 |
| December | 113 | 1.00E+00 | 8617 | 42 |

The LATRA3D T+4 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-27.

**Table 6-27. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T+4 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1508 | 0.32347 |
| 2- 4 | 684 | 0.14672 |
| 4 - 6 | 490 | 0.10511 |
| 6 - 8 | 366 | 0.07851 |
| 8 - 10 | 283 | 0.06070 |
| 10 - 20 | 730 | 0.15659 |
| 20 - 30 | 269 | 0.05770 |
| 30 - 40 | 139 | 0.02982 |
| 40 - 50 | 69 | 0.01480 |
| 50 - 60 | 32 | 0.00686 |
| 60 – 70 | 15 | 0.00322 |
| 70 – 80 | 21 | 0.00450 |
| 80 – 90 | 15 | 0.00322 |
| 90 - 100 | 10 | 0.00215 |
| > 100 | 31 | 0.00665 |

It is noted that approximately 71.5% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 15.6% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 2.7% of the cases produced HCl ground concentration predictions above 50 ppm.

The LATRA3D predicted cloud transport directions for the T+4 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-28 indicates the predicted Castor 1200 T+4 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4662 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough

approximation only. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-29 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-28. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+4 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 791 | 0.16967 |
| 22.5 – 67.5 (NE) | 888 | 0.19048 |
| 67.5 – 112.5 (E) | 561 | 0.12033 |
| 112.5 – 157.5 (SE) | 612 | 0.13127 |
| 157.5 – 202.5 (S) | 524 | 0.11240 |
| 202.5 – 247.5 (SW) | 541 | 0.11604 |
| 247.5 – 292.5 (W) | 388 | 0.08323 |
| 292.5 – 337.5 (NW) | 357 | 0.07658 |

**Table 6-29. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+4 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 615 | 0.16352 |
| 22.5 – 67.5 (NE) | 863 | 0.22946 |
| 67.5 – 112.5 (E) | 498 | 0.13241 |
| 112.5 – 157.5 (SE) | 503 | 0.13374 |
| 157.5 – 202.5 (S) | 397 | 0.10556 |
| 202.5 – 247.5 (SW) | 367 | 0.09758 |
| 247.5 – 292.5 (W) | 277 | 0.07365 |
| 292.5 – 337.5 (NW) | 241 | 0.06408 |

Similar summary tables for the 1751 nighttime Castor 1200 T+4 conflagration simulations were compiled. Table 6-30 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 66% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 18.6% of the nighttime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 4.2% of the cases produced HCl ground concentration predictions above 50 ppm.

**Table 6-30. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T+4 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 372 | 0.21245 |
| 2- 4 | 243 | 0.13878 |
| 4 - 6 | 243 | 0.13878 |
| 6 - 8 | 179 | 0.10223 |
| 8 - 10 | 120 | 0.06853 |
| 10 - 20 | 326 | 0.18618 |
| 20 - 30 | 108 | 0.06168 |
| 30 - 40 | 54 | 0.03084 |
| 40 - 50 | 33 | 0.01885 |
| 50 - 60 | 26 | 0.01485 |
| 60 – 70 | 11 | 0.00628 |
| 70 – 80 | 8 | 0.00457 |
| 80 – 90 | 9 | 0.00514 |
| 90 - 100 | 5 | 0.00286 |
| > 100 | 14 | 0.00800 |

Table 6-31 indicates the predicted Castor 1200 vehicle T+4 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-32 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the nighttime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-31. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+4 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 145 | 0.08281 |
| 22.5 – 67.5 (NE) | 327 | 0.18675 |
| 67.5 – 112.5 (E) | 274 | 0.15648 |
| 112.5 – 157.5 (SE) | 278 | 0.15877 |
| 157.5 – 202.5 (S) | 267 | 0.15248 |
| 202.5 – 247.5 (SW) | 249 | 0.14220 |
| 247.5 – 292.5 (W) | 122 | 0.06967 |
| 292.5 – 337.5 (NW) | 89 | 0.05083 |

**Table 6-32. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+4 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 124 | 0.07944 |
| 22.5 – 67.5 (NE) | 308 | 0.19731 |
| 67.5 – 112.5 (E) | 266 | 0.17040 |
| 112.5 – 157.5 (SE) | 243 | 0.15567 |
| 157.5 – 202.5 (S) | 222 | 0.14222 |
| 202.5 – 247.5 (SW) | 207 | 0.13261 |
| 247.5 – 292.5 (W) | 108 | 0.06919 |
| 292.5 – 337.5 (NW) | 83 | 0.05317 |

### 6.4.3 T+8 Conflagration HCl Results

Maximum predicted ground level HCl concentrations are higher and closer to the source for the T+8 second failure are approximately comparable to the T+4 second conflagration failure time.

Table 6-33 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T+8 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 30 to 120 ppm with the maximum concentration predicted to occur from 200 to 3200 meters downwind from the conflagration debris field source location. Concentrations above 100 ppm are generally associated with low puff stabilization heights for portions of the ground burning plumes that are in the debris impact regions. These high concentration points are either within the impact region or very close to it. The table values represent the maximum concentrations predicted over a sample set of 4660 WFF balloon soundings. Table 6-34 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T+8 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-35 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1750 nighttime cases for Castor 1200 vehicle T+8 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 22 to 114 ppm with the maximum concentration predicted to occur from 90 to 5400 meters downwind from the conflagration debris field source location. Table 6-36 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T+8 conflagration scenarios.

**Table 6-33: Castor 1200 T+8 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 1.20E+02 | 218 | 14 |
| February | 361 | 1.07E+02 | 249 | 287 |
| March | 390 | 1.60E+02 | 586 | 27 |
| April | 378 | 8.90E+01 | 211 | 347 |
| May | 396 | 6.09E+01 | 2109 | 12 |
| June | 389 | 3.70E+01 | 1399 | 50 |
| July | 415 | 4.34E+01 | 2353 | 351 |
| August | 409 | 4.01E+01 | 2382 | 6 |
| September | 410 | 3.01E+01 | 3247 | 6 |
| October | 429 | 9.40E+01 | 647 | 25 |
| November | 376 | 5.24E+01 | 742 | 146 |
| December | 366 | 4.61E+01 | 1070 | 4 |

**Table 6-34: Castor 1200 T+8 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 276 | 1.00E+00 | 9283 | 24 |
| February | 286 | 1.00E+00 | 9586 | 60 |
| March | 291 | 1.00E+00 | 8514 | 346 |
| April | 287 | 1.00E+00 | 7912 | 19 |
| May | 315 | 1.00E+00 | 7779 | 297 |
| June | 308 | 1.00E+00 | 6046 | 17 |
| July | 298 | 1.00E+00 | 5698 | 30 |
| August | 310 | 1.00E+00 | 7534 | 341 |
| September | 297 | 1.00E+00 | 8981 | 338 |
| October | 383 | 1.00E+00 | 7882 | 242 |
| November | 344 | 1.00E+00 | 8147 | 54 |
| December | 324 | 1.00E+00 | 8641 | 70 |

**Table 6-35: Castor 1200 T+8 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 4.29E+01 | 2838 | 95 |
| February | 158 | 8.73E+01 | 279 | 33 |
| March | 164 | 1.14E+02 | 160 | 35 |
| April | 158 | 7.68E+01 | 2607 | 334 |
| May | 159 | 4.73E+01 | 92 | 40 |
| June | 153 | 2.99E+01 | 1654 | 20 |
| July | 153 | 3.11E+01 | 2321 | 172 |
| August | 162 | 2.79E+01 | 1631 | 157 |
| September | 163 | 2.16E+01 | 5382 | 232 |
| October | 125 | 4.73E+01 | 2584 | 34 |
| November | 129 | 5.59E+01 | 2622 | 238 |
| December | 131 | 5.27E+01 | 2915 | 165 |

**Table 6-36: Castor 1200 T+8 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 73 | 1.00E+00 | 8355 | 72 |
| February | 134 | 1.00E+00 | 10171 | 37 |
| March | 138 | 1.00E+00 | 9177 | 34 |
| April | 138 | 1.00E+00 | 7519 | 333 |
| May | 144 | 1.00E+00 | 6333 | 48 |
| June | 142 | 1.00E+00 | 7477 | 44 |
| July | 143 | 1.00E+00 | 6200 | 359 |
| August | 154 | 1.00E+00 | 6457 | 197 |
| September | 151 | 1.00E+00 | 7339 | 345 |
| October | 122 | 1.00E+00 | 7917 | 99 |
| November | 117 | 1.00E+00 | 7867 | 2 |
| December | 111 | 1.00E+00 | 8385 | 136 |

The LATRA3D T+8 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-37.

**Table 6-37. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T+8 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1668 | 0.35794 |
| 2- 4 | 800 | 0.17167 |
| 4 - 6 | 487 | 0.10451 |
| 6 - 8 | 349 | 0.07489 |
| 8 - 10 | 257 | 0.05515 |
| 10 - 20 | 662 | 0.14206 |
| 20 - 30 | 253 | 0.05429 |
| 30 - 40 | 98 | 0.02103 |
| 40 - 50 | 44 | 0.00944 |
| 50 - 60 | 21 | 0.00451 |
| 60 – 70 | 8 | 0.00172 |
| 70 – 80 | 6 | 0.00129 |
| 80 – 90 | 3 | 0.00064 |
| 90 - 100 | 1 | 0.00021 |
| > 100 | 3 | 0.00064 |

It is noted that approximately 76.4% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 14.2% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.9% of the cases produced HCl ground concentration predictions above 50 ppm.

The LATRA3D predicted cloud transport directions for the T+8 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-38 indicates the predicted Castor 1200 T+8 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4660 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough

approximation only. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-39 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-38. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+8 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 889 | 0.19077 |
| 22.5 – 67.5 (NE) | 817 | 0.17532 |
| 67.5 – 112.5 (E) | 455 | 0.09764 |
| 112.5 – 157.5 (SE) | 559 | 0.11996 |
| 157.5 – 202.5 (S) | 493 | 0.10579 |
| 202.5 – 247.5 (SW) | 586 | 0.12575 |
| 247.5 – 292.5 (W) | 472 | 0.10129 |
| 292.5 – 337.5 (NW) | 389 | 0.08348 |

**Table 6-39. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+8 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 635 | 0.17074 |
| 22.5 – 67.5 (NE) | 829 | 0.22291 |
| 67.5 – 112.5 (E) | 500 | 0.13444 |
| 112.5 – 157.5 (SE) | 463 | 0.12450 |
| 157.5 – 202.5 (S) | 407 | 0.10944 |
| 202.5 – 247.5 (SW) | 356 | 0.09572 |
| 247.5 – 292.5 (W) | 290 | 0.07798 |
| 292.5 – 337.5 (NW) | 239 | 0.06426 |

Similar summary tables for the 1750 nighttime Castor 1200 T+8 conflagration simulations were compiled. Table 6-40 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 76.2% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 15.8% of the nighttime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.8% of the cases produced HCl ground concentration predictions above 50 ppm.

**Table 6-40. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T+8 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 410 | 0.23429 |
| 2- 4 | 358 | 0.20457 |
| 4 - 6 | 261 | 0.14914 |
| 6 - 8 | 197 | 0.11257 |
| 8 - 10 | 107 | 0.06114 |
| 10 - 20 | 277 | 0.15829 |
| 20 - 30 | 78 | 0.04457 |
| 30 - 40 | 33 | 0.01886 |
| 40 - 50 | 15 | 0.00857 |
| 50 - 60 | 4 | 0.00229 |
| 60 – 70 | 2 | 0.00114 |
| 70 – 80 | 5 | 0.00286 |
| 80 – 90 | 1 | 0.00057 |
| 90 - 100 | 1 | 0.00057 |
| > 100 | 1 | 0.00057 |

Table 6-41 indicates the predicted Castor 1200 vehicle T+8 conflagration plume direction probability of occurrence observed across the 1750 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-42 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the nighttime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-41. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+8 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 180 | 0.10286 |
| 22.5 – 67.5 (NE) | 319 | 0.18229 |
| 67.5 – 112.5 (E) | 234 | 0.13371 |
| 112.5 – 157.5 (SE) | 247 | 0.14114 |
| 157.5 – 202.5 (S) | 245 | 0.14000 |
| 202.5 – 247.5 (SW) | 251 | 0.14343 |
| 247.5 – 292.5 (W) | 158 | 0.09029 |
| 292.5 – 337.5 (NW) | 116 | 0.06629 |

**Table 6-42. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+8 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 125 | 0.07977 |
| 22.5 – 67.5 (NE) | 314 | 0.20038 |
| 67.5 – 112.5 (E) | 264 | 0.16847 |
| 112.5 – 157.5 (SE) | 218 | 0.13912 |
| 157.5 – 202.5 (S) | 231 | 0.14742 |
| 202.5 – 247.5 (SW) | 215 | 0.13720 |
| 247.5 – 292.5 (W) | 121 | 0.07722 |
| 292.5 – 337.5 (NW) | 79 | 0.05041 |

### 6.4.4 T+12 Conflagration HCl Results

Maximum predicted ground level HCl concentrations for the T+12 second failure are approximately comparable to the T+8 second conflagration failure time.

Table 6-43 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T+12 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 26 to 118 ppm with the maximum concentration predicted to occur from 380 to 3500 meters downwind from the conflagration debris field source location. Concentrations above 100 ppm are generally associated with low puff stabilization heights for portions of the ground burning plumes that are in the debris impact regions. These high concentration points are either within the impact region or very close to it. The table values represent the maximum concentrations predicted over a sample set of 4663 WFF balloon soundings. Table 6-44 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T+12 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-45 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+12 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 18 to 112 ppm with the maximum concentration predicted to occur from 90 to 2800 meters downwind from the conflagration debris field source location. Table 6-46 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T+12 conflagration scenarios.

**Table 6-43: Castor 1200 T+12 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 1.18E+02 | 385 | 354 |
| February | 361 | 1.08E+02 | 587 | 292 |
| March | 392 | 1.44E+02 | 638 | 10 |
| April | 376 | 8.81E+01 | 528 | 351 |
| May | 395 | 5.76E+01 | 560 | 16 |
| June | 390 | 3.33E+01 | 1435 | 112 |
| July | 415 | 3.58E+01 | 2201 | 351 |
| August | 410 | 3.11E+01 | 2386 | 5 |
| September | 411 | 2.55E+01 | 3457 | 5 |
| October | 429 | 9.21E+01 | 662 | 8 |
| November | 376 | 5.24E+01 | 379 | 159 |
| December | 367 | 4.53E+01 | 886 | 80 |

**Table 6-44: Castor 1200 T+12 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 281 | 1.00E+00 | 9303 | 23 |
| February | 293 | 1.00E+00 | 9487 | 59 |
| March | 293 | 1.00E+00 | 8593 | 345 |
| April | 288 | 1.00E+00 | 7379 | 18 |
| May | 322 | 1.00E+00 | 7414 | 297 |
| June | 318 | 1.00E+00 | 5853 | 18 |
| July | 318 | 1.00E+00 | 5509 | 348 |
| August | 311 | 1.00E+00 | 7476 | 341 |
| September | 303 | 1.00E+00 | 8709 | 338 |
| October | 385 | 1.00E+00 | 7697 | 40 |
| November | 348 | 1.00E+00 | 8225 | 233 |
| December | 323 | 1.00E+00 | 8521 | 69 |

**Table 6-45: Castor 1200 T+12 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 4.33E+01 | 260 | 26 |
| February | 158 | 8.95E+01 | 312 | 353 |
| March | 165 | 1.12E+02 | 232 | 335 |
| April | 158 | 7.64E+01 | 113 | 318 |
| May | 159 | 4.57E+01 | 92 | 348 |
| June | 153 | 2.43E+01 | 1657 | 17 |
| July | 153 | 2.77E+01 | 2354 | 173 |
| August | 162 | 2.34E+01 | 2819 | 39 |
| September | 163 | 1.84E+01 | 1873 | 64 |
| October | 125 | 3.90E+01 | 2567 | 35 |
| November | 129 | 4.69E+01 | 2613 | 239 |
| December | 131 | 4.63E+01 | 952 | 51 |

**Table 6-46: Castor 1200 T+12 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 72 | 1.00E+00 | 8212 | 71 |
| February | 131 | 1.00E+00 | 10131 | 36 |
| March | 135 | 1.00E+00 | 9173 | 33 |
| April | 141 | 1.00E+00 | 7024 | 54 |
| May | 144 | 1.00E+00 | 6035 | 29 |
| June | 148 | 1.00E+00 | 7287 | 43 |
| July | 149 | 1.00E+00 | 6247 | 359 |
| August | 157 | 1.00E+00 | 6545 | 197 |
| September | 155 | 1.00E+00 | 7446 | 344 |
| October | 123 | 1.00E+00 | 7652 | 99 |
| November | 119 | 1.00E+00 | 7786 | 1 |
| December | 116 | 1.00E+00 | 8135 | 137 |

The LATRA3D T+12 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-47.

**Table 6-47. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T+12 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1628 | 0.34913 |
| 2- 4 | 911 | 0.19537 |
| 4 - 6 | 522 | 0.11195 |
| 6 - 8 | 371 | 0.07956 |
| 8 - 10 | 258 | 0.05533 |
| 10 - 20 | 611 | 0.13103 |
| 20 - 30 | 226 | 0.04847 |
| 30 - 40 | 69 | 0.01480 |
| 40 - 50 | 33 | 0.00708 |
| 50 - 60 | 16 | 0.00343 |
| 60 – 70 | 6 | 0.00129 |
| 70 – 80 | 5 | 0.00107 |
| 80 – 90 | 3 | 0.00064 |
| 90 - 100 | 1 | 0.00021 |
| > 100 | 3 | 0.00064 |

It is noted that approximately 79.1% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 13.1% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.7% of the cases produced HCl ground concentration predictions above 50 ppm.

The LATRA3D predicted cloud transport directions for the T+12 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-48 indicates the predicted Castor 1200 T+12 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4663 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough

approximation only. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-49 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West and Northwest.

**Table 6-48. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+12 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 961 | 0.20609 |
| 22.5 – 67.5 (NE) | 752 | 0.16127 |
| 67.5 – 112.5 (E) | 550 | 0.11795 |
| 112.5 – 157.5 (SE) | 427 | 0.09157 |
| 157.5 – 202.5 (S) | 462 | 0.09908 |
| 202.5 – 247.5 (SW) | 555 | 0.11902 |
| 247.5 – 292.5 (W) | 523 | 0.11216 |
| 292.5 – 337.5 (NW) | 433 | 0.09286 |

**Table 6-49. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+12 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 671 | 0.17737 |
| 22.5 – 67.5 (NE) | 806 | 0.21306 |
| 67.5 – 112.5 (E) | 542 | 0.14327 |
| 112.5 – 157.5 (SE) | 427 | 0.11287 |
| 157.5 – 202.5 (S) | 402 | 0.10626 |
| 202.5 – 247.5 (SW) | 348 | 0.09199 |
| 247.5 – 292.5 (W) | 328 | 0.08670 |
| 292.5 – 337.5 (NW) | 259 | 0.06846 |

Similar summary tables for the 1751 nighttime Castor 1200 T+12 conflagration simulations were compiled. Table 6-50Table 6-40 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 79% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 14% of the nighttime meteorological cases resulted in in LATRA3D

maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.7% of the cases produced HCl ground concentration predictions above 50 ppm.

**Table 6-50. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T+12 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 375 | 0.21416 |
| 2- 4 | 426 | 0.24329 |
| 4 - 6 | 273 | 0.15591 |
| 6 - 8 | 198 | 0.11308 |
| 8 - 10 | 111 | 0.06339 |
| 10 - 20 | 246 | 0.14049 |
| 20 - 30 | 73 | 0.04169 |
| 30 - 40 | 26 | 0.01485 |
| 40 - 50 | 11 | 0.00628 |
| 50 - 60 | 4 | 0.00228 |
| 60 – 70 | 1 | 0.00057 |
| 70 – 80 | 4 | 0.00228 |
| 80 – 90 | 2 | 0.00114 |
| 90 - 100 | 0 | 0.00000 |
| > 100 | 1 | 0.00057 |

Table 6-51 indicates the predicted Castor 1200 vehicle T+12 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-52 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the nighttime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the West.

**Table 6-51. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+12 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 209 | 0.11936 |
| 22.5 – 67.5 (NE) | 309 | 0.17647 |
| 67.5 – 112.5 (E) | 248 | 0.14163 |
| 112.5 – 157.5 (SE) | 198 | 0.11308 |
| 157.5 – 202.5 (S) | 205 | 0.11708 |
| 202.5 – 247.5 (SW) | 273 | 0.15591 |
| 247.5 – 292.5 (W) | 190 | 0.10851 |
| 292.5 – 337.5 (NW) | 119 | 0.06796 |

**Table 6-52. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+12 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 127 | 0.07987 |
| 22.5 – 67.5 (NE) | 316 | 0.19874 |
| 67.5 – 112.5 (E) | 271 | 0.17044 |
| 112.5 – 157.5 (SE) | 217 | 0.13648 |
| 157.5 – 202.5 (S) | 227 | 0.14277 |
| 202.5 – 247.5 (SW) | 214 | 0.13459 |
| 247.5 – 292.5 (W) | 137 | 0.08616 |
| 292.5 – 337.5 (NW) | 81 | 0.05094 |

### 6.4.5 T+16 Conflagration HCl Results

Maximum predicted ground level HCl concentrations for the T+16 second failure are approximately comparable to the T+12 second conflagration failure time.

Table 6-53 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T+16 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 20 to 153 ppm with the maximum concentration predicted to occur from 330 to 2200 meters downwind from the conflagration debris field source location. Concentrations above 100 ppm are generally associated with low puff stabilization heights for portions of the ground burning plumes that are in the debris impact regions. These high concentration points are either within the impact region or very close to it. The table values represent the maximum concentrations predicted over a sample set of 4669 WFF balloon soundings. Table 6-54 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T+16 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-55 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+16 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 19 to 115 ppm with the maximum concentration predicted to occur from 580 to 2700 meters downwind from the conflagration debris field source location. Table 6-56 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T+16 conflagration scenarios.

**Table 6-53: Castor 1200 T+16 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 1.20E+02 | 736 | 315 |
| February | 362 | 1.10E+02 | 944 | 293 |
| March | 391 | 1.53E+02 | 887 | 338 |
| April | 379 | 8.79E+01 | 831 | 306 |
| May | 396 | 5.49E+01 | 777 | 339 |
| June | 390 | 2.90E+01 | 2032 | 298 |
| July | 416 | 2.92E+01 | 2150 | 349 |
| August | 410 | 2.48E+01 | 1304 | 130 |
| September | 412 | 1.99E+01 | 2213 | 67 |
| October | 429 | 9.35E+01 | 940 | 340 |
| November | 376 | 4.82E+01 | 330 | 251 |
| December | 367 | 4.70E+01 | 578 | 46 |

**Table 6-54: Castor 1200 T+16 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 275 | 1.00E+00 | 9315 | 21 |
| February | 281 | 1.00E+00 | 9444 | 282 |
| March | 290 | 1.00E+00 | 8963 | 342 |
| April | 286 | 1.00E+00 | 7504 | 332 |
| May | 320 | 1.00E+00 | 7274 | 298 |
| June | 307 | 1.00E+00 | 5739 | 18 |
| July | 297 | 1.00E+00 | 5407 | 23 |
| August | 307 | 1.00E+00 | 7380 | 341 |
| September | 301 | 1.00E+00 | 8872 | 251 |
| October | 382 | 1.00E+00 | 7580 | 41 |
| November | 341 | 1.00E+00 | 8457 | 236 |
| December | 315 | 1.00E+00 | 8587 | 18 |

**Table 6-55: Castor 1200 T+16 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 4.32E+01 | 594 | 321 |
| February | 158 | 8.32E+01 | 686 | 317 |
| March | 165 | 1.15E+02 | 656 | 304 |
| April | 158 | 7.57E+01 | 582 | 302 |
| May | 159 | 4.71E+01 | 611 | 300 |
| June | 153 | 2.01E+01 | 2736 | 45 |
| July | 153 | 2.17E+01 | 2683 | 173 |
| August | 162 | 1.98E+01 | 1693 | 151 |
| September | 163 | 1.91E+01 | 881 | 225 |
| October | 125 | 3.31E+01 | 2549 | 36 |
| November | 129 | 3.84E+01 | 2604 | 239 |
| December | 131 | 4.40E+01 | 702 | 9 |

**Table 6-56: Castor 1200 T+16 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 71 | 1.00E+00 | 8100 | 39 |
| February | 134 | 1.00E+00 | 10040 | 34 |
| March | 139 | 1.00E+00 | 9159 | 28 |
| April | 135 | 1.00E+00 | 6952 | 78 |
| May | 142 | 1.00E+00 | 6302 | 251 |
| June | 145 | 1.00E+00 | 7068 | 308 |
| July | 147 | 1.00E+00 | 6341 | 360 |
| August | 155 | 1.00E+00 | 6386 | 196 |
| September | 155 | 1.00E+00 | 7803 | 341 |
| October | 121 | 1.00E+00 | 7540 | 100 |
| November | 121 | 1.00E+00 | 7633 | 1 |
| December | 113 | 1.00E+00 | 7889 | 137 |

The LATRA3D T+16 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-57.

**Table 6-57. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T+16 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1773 | 0.37974 |
| 2- 4 | 923 | 0.19769 |
| 4 - 6 | 525 | 0.11244 |
| 6 - 8 | 377 | 0.08075 |
| 8 - 10 | 245 | 0.05247 |
| 10 - 20 | 585 | 0.12529 |
| 20 - 30 | 147 | 0.03148 |
| 30 - 40 | 45 | 0.00964 |
| 40 - 50 | 18 | 0.00386 |
| 50 - 60 | 11 | 0.00236 |
| 60 – 70 | 8 | 0.00171 |
| 70 – 80 | 5 | 0.00107 |
| 80 – 90 | 3 | 0.00064 |
| 90 - 100 | 1 | 0.00021 |
| > 100 | 3 | 0.00064 |

It is noted that approximately 82.3% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 12.5% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.7% of the cases produced HCl ground concentration predictions above 50 ppm.

The LATRA3D predicted cloud transport directions for the T+16 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-58 indicates the predicted Castor 1200 T+16 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4669 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough

approximation only. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-59 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the North and Northeast is favored. Transport in other directions is approximately uniformly distributed.

**Table 6-58. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+16 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 896 | 0.19190 |
| 22.5 – 67.5 (NE) | 647 | 0.13857 |
| 67.5 – 112.5 (E) | 285 | 0.06104 |
| 112.5 – 157.5 (SE) | 360 | 0.07710 |
| 157.5 – 202.5 (S) | 558 | 0.11951 |
| 202.5 – 247.5 (SW) | 657 | 0.14072 |
| 247.5 – 292.5 (W) | 617 | 0.13215 |
| 292.5 – 337.5 (NW) | 649 | 0.13900 |

**Table 6-59. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+16 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 668 | 0.18044 |
| 22.5 – 67.5 (NE) | 751 | 0.20286 |
| 67.5 – 112.5 (E) | 354 | 0.09562 |
| 112.5 – 157.5 (SE) | 374 | 0.10103 |
| 157.5 – 202.5 (S) | 481 | 0.12993 |
| 202.5 – 247.5 (SW) | 334 | 0.09022 |
| 247.5 – 292.5 (W) | 338 | 0.09130 |
| 292.5 – 337.5 (NW) | 402 | 0.10859 |

Similar summary tables for the 1751 nighttime Castor 1200 T+16 conflagration simulations were compiled. Table 6-60Table 6-40 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 81.2% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 13.5% of the nighttime meteorological cases resulted in in LATRA3D

maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.5% of the cases produced HCl ground concentration predictions above 50 ppm.

**Table 6-60. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T+16 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 463 | 0.26442 |
| 2- 4 | 429 | 0.24500 |
| 4 - 6 | 251 | 0.14335 |
| 6 - 8 | 172 | 0.09823 |
| 8 - 10 | 107 | 0.06111 |
| 10 - 20 | 236 | 0.13478 |
| 20 - 30 | 51 | 0.02913 |
| 30 - 40 | 24 | 0.01371 |
| 40 - 50 | 9 | 0.00514 |
| 50 - 60 | 1 | 0.00057 |
| 60 – 70 | 1 | 0.00057 |
| 70 – 80 | 4 | 0.00228 |
| 80 – 90 | 1 | 0.00057 |
| 90 - 100 | 1 | 0.00057 |
| > 100 | 1 | 0.00057 |

Table 6-61 indicates the predicted Castor 1200 vehicle T+16 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-62 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the nighttime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is a lower probability for transport of the conflagration plumes to the Northwest.

**Table 6-61. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+16 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 209 | 0.11936 |
| 22.5 – 67.5 (NE) | 263 | 0.15020 |
| 67.5 – 112.5 (E) | 146 | 0.08338 |
| 112.5 – 157.5 (SE) | 167 | 0.09537 |
| 157.5 – 202.5 (S) | 230 | 0.13135 |
| 202.5 – 247.5 (SW) | 282 | 0.16105 |
| 247.5 – 292.5 (W) | 221 | 0.12621 |
| 292.5 – 337.5 (NW) | 233 | 0.13307 |

**Table 6-62. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+16 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 144 | 0.09125 |
| 22.5 – 67.5 (NE) | 300 | 0.19011 |
| 67.5 – 112.5 (E) | 221 | 0.14005 |
| 112.5 – 157.5 (SE) | 206 | 0.13054 |
| 157.5 – 202.5 (S) | 249 | 0.15779 |
| 202.5 – 247.5 (SW) | 205 | 0.12991 |
| 247.5 – 292.5 (W) | 142 | 0.08999 |
| 292.5 – 337.5 (NW) | 111 | 0.07034 |

### 6.4.6 T+20 Conflagration HCl Results

Maximum predicted ground level HCl concentrations for the T+20 second failure are approximately comparable to the T+16 second conflagration failure time.

Table 6-63 presents the maximum far field HCl peak instantaneous concentration predicted by LATRA3D for a simulated T+20 conflagration failure of a Castor 1200 vehicle with subsequent dispersion of the exhaust from burning fragments falling to the ground and from burning propellant fragments on the ground. The far field exposure is LATRA3D's prediction for concentrations at ground level downwind of the stabilized exhaust cloud. Far field peak HCl concentrations ranged from 15 to 153 ppm with the maximum concentration predicted to occur from 980 to 2300 meters downwind from the conflagration debris field source location. Concentrations above 100 ppm are generally associated with low puff stabilization heights for portions of the ground burning plumes that are in the debris impact regions. These high concentration points are either within the impact region or very close to it. The table values represent the maximum concentrations predicted over a sample set of 4668 WFF balloon soundings. Table 6-64 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the daytime T+20 conflagration scenarios. Hazard zones for higher concentration thresholds will always be shorter than the reported 1-ppm hazard zone length but due to non-linearity factors in the dispersion equations the hazard zone lengths for other threshold ppm values cannot be directly scaled from the 1-ppm hazard zone length.

Table 6-65 shows the LATRA3D predicted maximum peak HCl far field concentrations for 1749 nighttime cases for Castor 1200 vehicle T+20 conflagration scenario. Nighttime far field peak HCl concentrations ranged from 14 to 115 ppm with the maximum concentration predicted to occur from 1000 to 3000 meters downwind from the conflagration debris field source location. Table 6-66 provides information about the general size (length) and direction of a low threshold 1-ppm hazard zone for the nighttime T+20 conflagration scenarios.

**Table 6-63: Castor 1200 T+20 Conflagration HCl Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 1.16E+02 | 1429 | 303 |
| February | 363 | 1.07E+02 | 1680 | 294 |
| March | 392 | 1.53E+02 | 1447 | 319 |
| April | 379 | 8.67E+01 | 1508 | 302 |
| May | 395 | 5.82E+01 | 1399 | 320 |
| June | 390 | 2.63E+01 | 1250 | 299 |
| July | 414 | 1.83E+01 | 2258 | 347 |
| August | 410 | 1.84E+01 | 1609 | 282 |
| September | 412 | 1.50E+01 | 2271 | 66 |
| October | 429 | 9.07E+01 | 1482 | 321 |
| November | 376 | 4.79E+01 | 984 | 280 |
| December | 367 | 4.52E+01 | 1964 | 324 |

**Table 6-64: Castor 1200 T+20 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 268 | 1.00E+00 | 9379 | 16 |
| February | 278 | 1.00E+00 | 10142 | 282 |
| March | 283 | 1.00E+00 | 9428 | 339 |
| April | 274 | 1.00E+00 | 7394 | 335 |
| May | 310 | 1.00E+00 | 7225 | 298 |
| June | 292 | 1.00E+00 | 5928 | 348 |
| July | 279 | 1.00E+00 | 5576 | 359 |
| August | 296 | 1.00E+00 | 7194 | 340 |
| September | 282 | 1.00E+00 | 9363 | 254 |
| October | 371 | 1.00E+00 | 7661 | 263 |
| November | 336 | 1.00E+00 | 8848 | 240 |
| December | 311 | 1.00E+00 | 8674 | 13 |

**Table 6-65: Castor 1200 T+20 Conflagration HCl Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak HCl Concentration [ppm] | Distance to Peak HCl Concentration [m] | Bearing to Peak HCl Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 4.34E+01 | 1158 | 310 |
| February | 158 | 9.05E+01 | 1396 | 308 |
| March | 164 | 1.15E+02 | 1373 | 299 |
| April | 157 | 7.13E+01 | 1276 | 299 |
| May | 159 | 4.73E+01 | 1346 | 297 |
| June | 153 | 1.94E+01 | 1489 | 286 |
| July | 153 | 1.57E+01 | 2978 | 170 |
| August | 162 | 1.60E+01 | 1167 | 310 |
| September | 163 | 1.39E+01 | 1108 | 225 |
| October | 125 | 2.82E+01 | 1021 | 312 |
| November | 129 | 2.47E+01 | 1258 | 298 |
| December | 131 | 4.26E+01 | 1138 | 332 |

**Table 6-66: Castor 1200 T+20 Conflagration 1-ppm HCl Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | HCl Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 71 | 1.00E+00 | 7920 | 34 |
| February | 132 | 1.00E+00 | 9940 | 30 |
| March | 133 | 1.00E+00 | 9082 | 25 |
| April | 133 | 1.00E+00 | 7440 | 325 |
| May | 139 | 1.00E+00 | 6841 | 256 |
| June | 137 | 1.00E+00 | 7069 | 307 |
| July | 139 | 1.00E+00 | 5238 | 171 |
| August | 150 | 1.00E+00 | 6255 | 195 |
| September | 142 | 1.00E+00 | 7068 | 338 |
| October | 119 | 1.00E+00 | 7544 | 99 |
| November | 116 | 1.00E+00 | 7631 | 97 |
| December | 111 | 1.00E+00 | 7935 | 136 |

The LATRA3D T+20 conflagration predicted HCl concentrations for all daytime meteorological cases processed in the 8-year sample set were aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-67.

**Table 6-67. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Daytime Castor 1200 T+20 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1973 | 0.42266 |
| 2- 4 | 963 | 0.20630 |
| 4 - 6 | 511 | 0.10947 |
| 6 - 8 | 351 | 0.07519 |
| 8 - 10 | 244 | 0.05227 |
| 10 - 20 | 464 | 0.09940 |
| 20 - 30 | 75 | 0.01607 |
| 30 - 40 | 39 | 0.00835 |
| 40 - 50 | 17 | 0.00364 |
| 50 - 60 | 12 | 0.00257 |
| 60 – 70 | 7 | 0.00150 |
| 70 – 80 | 5 | 0.00107 |
| 80 – 90 | 3 | 0.00064 |
| 90 - 100 | 1 | 0.00021 |
| > 100 | 3 | 0.00064 |

It is noted that approximately 86.6% of all daytime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 10.0% of the daytime meteorological cases resulted in in LATRA3D maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.7% of the cases produced HCl ground concentration predictions above 50 ppm.

The LATRA3D predicted cloud transport directions for the T+20 conflagration HCl dispersion were aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). The transport direction for conflagration modes is defined relative to the center of the propellant impact debris field. Table 6-68 indicates the predicted Castor 1200 T+20 conflagration plume direction probability of occurrence for the direction to the maximum concentration point. The table is based on 4668 daytime balloon sounding cases that produced non-zero predicted ground level HCl concentrations. Estimation of plume direction using LATRA3D peak concentration for conflagration scenarios should be considered as a rough

approximation only. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-69 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the daytime launch scenarios transport of the conflagration exhaust plume to the North and Northeast is favored. Transport to the East and Southeast are least favored.

**Table 6-68. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+20 Conflagration HCl Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 745 | 0.15960 |
| 22.5 – 67.5 (NE) | 484 | 0.10368 |
| 67.5 – 112.5 (E) | 256 | 0.05484 |
| 112.5 – 157.5 (SE) | 303 | 0.06491 |
| 157.5 – 202.5 (S) | 290 | 0.06213 |
| 202.5 – 247.5 (SW) | 654 | 0.14010 |
| 247.5 – 292.5 (W) | 642 | 0.13753 |
| 292.5 – 337.5 (NW) | 1294 | 0.27721 |

**Table 6-69. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+20 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 691 | 0.19302 |
| 22.5 – 67.5 (NE) | 678 | 0.18939 |
| 67.5 – 112.5 (E) | 304 | 0.08492 |
| 112.5 – 157.5 (SE) | 292 | 0.08156 |
| 157.5 – 202.5 (S) | 283 | 0.07905 |
| 202.5 – 247.5 (SW) | 315 | 0.08799 |
| 247.5 – 292.5 (W) | 455 | 0.12709 |
| 292.5 – 337.5 (NW) | 562 | 0.15698 |

Similar summary tables for the 1749 nighttime Castor 1200 T+20 conflagration simulations were compiled. Table 6-70Table 6-40 shows the peak HCl instantaneous concentration predictions for nighttime conditions. It is noted that approximately 86% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level HCl concentrations of less than 10 ppm. Approximately 9.7% of the nighttime meteorological cases resulted in in LATRA3D

maximum peak instantaneous ground level HCl concentrations in the 10 to 20 ppm range. Approximately 0.5% of the cases produced HCl ground concentration predictions above 50 ppm.

**Table 6-70. LATRA3D Predicted Maximum Far Field Ground Level HCl Concentrations for Nighttime Castor 1200 T+20 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 585 | 0.33448 |
| 2- 4 | 413 | 0.23613 |
| 4 - 6 | 235 | 0.13436 |
| 6 - 8 | 169 | 0.09663 |
| 8 - 10 | 103 | 0.05889 |
| 10 - 20 | 169 | 0.09663 |
| 20 - 30 | 38 | 0.02173 |
| 30 - 40 | 20 | 0.01144 |
| 40 - 50 | 9 | 0.00515 |
| 50 - 60 | 0 | 0.00000 |
| 60 – 70 | 1 | 0.00057 |
| 70 – 80 | 4 | 0.00229 |
| 80 – 90 | 0 | 0.00000 |
| 90 - 100 | 2 | 0.00114 |
| > 100 | 1 | 0.00057 |

Table 6-71 indicates the predicted Castor 1200 vehicle T+20 conflagration plume direction probability of occurrence observed across the 1749 nighttime balloon sounding cases based on the direct to the maximum concentration point. The plume transport directions derived from the computed direction to the endpoint of the 1-ppm hazard zone listed in Table 6-72 provide a better estimate of expected plume transport directions over the ensemble of weather cases. It is noted that for the nighttime launch scenarios transport of the conflagration exhaust plume to the Northeast is favored. There is approximately equal probability for transport of the conflagration plumes in the other directions.

**Table 6-71. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+20 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 190 | 0.10863 |
| 22.5 – 67.5 (NE) | 191 | 0.10921 |
| 67.5 – 112.5 (E) | 91 | 0.05203 |
| 112.5 – 157.5 (SE) | 153 | 0.08748 |
| 157.5 – 202.5 (S) | 124 | 0.07090 |
| 202.5 – 247.5 (SW) | 306 | 0.17496 |
| 247.5 – 292.5 (W) | 243 | 0.13894 |
| 292.5 – 337.5 (NW) | 451 | 0.25786 |

**Table 6-72. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+20 Conflagration HCl Scenarios Using the 1-ppm Hazard Zone Endpoint.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 172 | 0.11301 |
| 22.5 – 67.5 (NE) | 274 | 0.18003 |
| 67.5 – 112.5 (E) | 182 | 0.11958 |
| 112.5 – 157.5 (SE) | 189 | 0.12418 |
| 157.5 – 202.5 (S) | 164 | 0.10775 |
| 202.5 – 247.5 (SW) | 191 | 0.12549 |
| 247.5 – 292.5 (W) | 179 | 0.11761 |
| 292.5 – 337.5 (NW) | 171 | 0.11235 |

### 6.4.7 T+0 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-73 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T-0 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 5 to 16 $mg/m^3$ with the maximum concentration predicted to occur from 7000 to 15000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings.

Table 6-74 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T-0 conflagration scenarios Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 5 to 18 $mg/m^3$ with the maximum concentration predicted to occur from 7000 to 18000 meters downwind from the launch site.

**Table 6-73: Castor 1200 T-0 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 1.26E+01 | 8.8 | 12000 | 10 |
| February | 363 | 1.51E+01 | 10.6 | 8000 | 30 |
| March | 393 | 1.64E+01 | 11.5 | 7000 | 32 |
| April | 382 | 1.36E+01 | 9.5 | 13000 | 9 |
| May | 398 | 1.10E+01 | 7.7 | 9000 | 15 |
| June | 391 | 6.64E+00 | 4.6 | 15000 | 83 |
| July | 417 | 6.70E+00 | 4.7 | 10000 | 76 |
| August | 410 | 4.84E+00 | 3.4 | 15000 | 25 |
| September | 412 | 7.20E+00 | 5.0 | 9000 | 241 |
| October | 429 | 6.29E+00 | 4.4 | 14000 | 196 |
| November | 376 | 1.23E+01 | 8.6 | 8000 | 92 |
| December | 367 | 1.34E+01 | 9.4 | 9000 | 107 |

**Table 6-74: Castor 1200 T-0 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 1.36E+01 | 9.5 | 8000 | 73 |
| February | 158 | 1.38E+01 | 9.7 | 15000 | 51 |
| March | 165 | 1.38E+01 | 9.7 | 12000 | 28 |
| April | 158 | 1.77E+01 | 12.4 | 7000 | 52 |
| May | 159 | 9.68E+00 | 6.8 | 13000 | 32 |
| June | 153 | 5.74E+00 | 4.0 | 8000 | 108 |
| July | 153 | 5.86E+00 | 4.1 | 17000 | 48 |
| August | 162 | 5.44E+00 | 3.8 | 11000 | 79 |
| September | 163 | 6.23E+00 | 4.4 | 17000 | 71 |
| October | 125 | 7.97E+00 | 5.6 | 17000 | 119 |
| November | 129 | 1.00E+01 | 7.0 | 18000 | 55 |
| December | 131 | 1.67E+01 | 11.7 | 10000 | 36 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-75.

**Table 6-75. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T-0 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 2467 | 0.52725 |
| 1 - 2 | 1099 | 0.23488 |
| 2 - 3 | 499 | 0.10665 |
| 3 - 4 | 225 | 0.04809 |
| 4 - 5 | 148 | 0.03163 |
| 5 - 6 | 73 | 0.01560 |
| 6 - 7 | 54 | 0.01154 |
| 7 - 8 | 35 | 0.00748 |
| 8 - 9 | 31 | 0.00663 |
| 9 - 10 | 12 | 0.00256 |
| > 10 | 36 | 0.00769 |

It is noted that approximately 52.7% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 2.4% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T-0 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-76 indicates the predicted Castor 1200 T-0 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T-0 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-76. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T-0 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 535 | 0.11434 |
| 22.5 – 67.5 (NE) | 890 | 0.19021 |
| 67.5 – 112.5 (E) | 812 | 0.17354 |
| 112.5 – 157.5 (SE) | 948 | 0.20261 |
| 157.5 – 202.5 (S) | 517 | 0.11049 |
| 202.5 – 247.5 (SW) | 436 | 0.09318 |
| 247.5 – 292.5 (W) | 309 | 0.06604 |
| 292.5 – 337.5 (NW) | 232 | 0.04958 |

Similar summary tables for the 1751 nighttime Castor 1200 T-0 conflagration simulations were compiled. Table 6-77 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 43.7% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 3.9% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

**Table 6-77. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T-0 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 765 | 0.43689 |
| 1 - 2 | 397 | 0.22673 |
| 2 - 3 | 253 | 0.14449 |
| 3 - 4 | 132 | 0.07539 |
| 4 - 5 | 63 | 0.03598 |
| 5 - 6 | 53 | 0.03027 |
| 6 - 7 | 20 | 0.01142 |
| 7 - 8 | 27 | 0.01542 |
| 8 - 9 | 16 | 0.00914 |
| 9 - 10 | 8 | 0.00457 |
| > 10 | 17 | 0.00971 |

Table 6-78 indicates the predicted Castor 1200 vehicle T-0 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime T-0 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored as they were during the daytime.

**Table 6-78. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T-0 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 123 | 0.07025 |
| 22.5 – 67.5 (NE) | 309 | 0.17647 |
| 67.5 – 112.5 (E) | 333 | 0.19018 |
| 112.5 – 157.5 (SE) | 370 | 0.21131 |
| 157.5 – 202.5 (S) | 238 | 0.13592 |
| 202.5 – 247.5 (SW) | 196 | 0.11194 |
| 247.5 – 292.5 (W) | 96 | 0.05483 |
| 292.5 – 337.5 (NW) | 86 | 0.04911 |

### 6.4.8 T+4 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-79 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T+4 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 7 to 30 $mg/m^3$ with the maximum concentration predicted to occur from 5000 to 13000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-80 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+4 conflagration scenarios. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 7 to 28 $mg/m^3$ with the maximum concentration predicted to occur from 5000 to 18000 meters downwind from the launch site.

**Table 6-79: Castor 1200 T+4 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 2.16E+01 | 15.1 | 9000 | 10 |
| February | 363 | 2.75E+01 | 19.3 | 5000 | 29 |
| March | 393 | 2.99E+01 | 20.9 | 5000 | 30 |
| April | 382 | 2.28E+01 | 16.0 | 9000 | 8 |
| May | 398 | 1.82E+01 | 12.7 | 11000 | 29 |
| June | 391 | 1.01E+01 | 7.1 | 8000 | 19 |
| July | 417 | 9.73E+00 | 6.8 | 13000 | 40 |
| August | 410 | 6.75E+00 | 4.7 | 13000 | 25 |
| September | 412 | 1.09E+01 | 7.6 | 7000 | 241 |
| October | 429 | 1.10E+01 | 7.7 | 7000 | 59 |
| November | 376 | 2.13E+01 | 14.9 | 6000 | 93 |
| December | 367 | 2.09E+01 | 14.6 | 6000 | 17 |

**Table 6-80: Castor 1200 T+4 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 2.23E+01 | 15.6 | 6000 | 96 |
| February | 158 | 2.40E+01 | 16.8 | 9000 | 50 |
| March | 165 | 1.88E+01 | 13.2 | 6000 | 32 |
| April | 158 | 2.73E+01 | 19.1 | 5000 | 50 |
| May | 159 | 1.57E+01 | 11.0 | 9000 | 32 |
| June | 153 | 8.08E+00 | 5.7 | 11000 | 155 |
| July | 153 | 8.13E+00 | 5.7 | 13000 | 48 |
| August | 162 | 6.99E+00 | 4.9 | 10000 | 79 |
| September | 163 | 1.06E+01 | 7.4 | 9000 | 225 |
| October | 125 | 1.22E+01 | 8.5 | 18000 | 84 |
| November | 129 | 1.49E+01 | 10.4 | 13000 | 54 |
| December | 131 | 2.83E+01 | 19.8 | 8000 | 36 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-81.

**Table 6-81. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T+4 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 2157 | 0.46100 |
| 1 - 2 | 1053 | 0.22505 |
| 2 - 3 | 539 | 0.11520 |
| 3 - 4 | 279 | 0.05963 |
| 4 - 5 | 176 | 0.03761 |
| 5 - 6 | 105 | 0.02244 |
| 6 - 7 | 78 | 0.01667 |
| 7 - 8 | 49 | 0.01047 |
| 8 - 9 | 53 | 0.01133 |
| 9 - 10 | 44 | 0.00940 |
| > 10 | 146 | 0.03120 |

It is noted that approximately 46.1% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 6.2% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T+4 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-82 indicates the predicted Castor 1200 T+4 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T+4 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-82. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+4 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 543 | 0.11605 |
| 22.5 – 67.5 (NE) | 873 | 0.18658 |
| 67.5 – 112.5 (E) | 800 | 0.17098 |
| 112.5 – 157.5 (SE) | 971 | 0.20752 |
| 157.5 – 202.5 (S) | 519 | 0.11092 |
| 202.5 – 247.5 (SW) | 434 | 0.09275 |
| 247.5 – 292.5 (W) | 302 | 0.06454 |
| 292.5 – 337.5 (NW) | 237 | 0.05065 |

Similar summary tables for the 1751 nighttime Castor 1200 T+4 conflagration simulations were compiled. Table 6-83 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 38% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 mg/m$^3$. Approximately 8.2% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 mg/m$^3$ or higher.

**Table 6-83. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T+4 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 666 | 0.38035 |
| 1 - 2 | 331 | 0.18903 |
| 2 - 3 | 252 | 0.14392 |
| 3 - 4 | 153 | 0.08738 |
| 4 - 5 | 98 | 0.05597 |
| 5 - 6 | 51 | 0.02913 |
| 6 - 7 | 56 | 0.03198 |
| 7 - 8 | 32 | 0.01828 |
| 8 - 9 | 19 | 0.01085 |
| 9 - 10 | 13 | 0.00742 |
| > 10 | 80 | 0.04569 |

Table 6-84 indicates the predicted Castor 1200 vehicle T+4 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime T+4 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored as they were during the daytime.

**Table 6-84. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+4 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 118 | 0.06739 |
| 22.5 – 67.5 (NE) | 317 | 0.18104 |
| 67.5 – 112.5 (E) | 324 | 0.18504 |
| 112.5 – 157.5 (SE) | 365 | 0.20845 |
| 157.5 – 202.5 (S) | 248 | 0.14163 |
| 202.5 – 247.5 (SW) | 200 | 0.11422 |
| 247.5 – 292.5 (W) | 94 | 0.05368 |
| 292.5 – 337.5 (NW) | 85 | 0.04854 |

### 6.4.9 T+8 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-85 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T+8 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 17 to 423 $mg/m^3$ with the maximum concentration predicted to occur from 1000 to 7000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-86 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+8 conflagration scenarios. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 15 to 84 $mg/m^3$ with the maximum concentration predicted to occur from 3000 to 8000 meters downwind from the launch site.

**Table 6-85: Castor 1200 T+8 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 6.97E+01 | 48.8 | 4000 | 214 |
| February | 363 | 9.64E+01 | 67.5 | 3000 | 26 |
| March | 393 | 2.29E+02 | 160.3 | 2000 | 26 |
| April | 382 | 9.05E+01 | 63.4 | 3000 | 16 |
| May | 398 | 7.26E+01 | 50.8 | 3000 | 38 |
| June | 391 | 2.32E+01 | 16.2 | 5000 | 71 |
| July | 417 | 3.19E+01 | 22.3 | 7000 | 38 |
| August | 410 | 1.66E+01 | 11.6 | 5000 | 63 |
| September | 412 | 1.70E+02 | 119.0 | 2000 | 242 |
| October | 429 | 4.23E+02 | 296.1 | 1000 | 17 |
| November | 376 | 4.52E+01 | 31.6 | 4000 | 94 |
| December | 367 | 6.05E+01 | 42.4 | 3000 | 5 |

**Table 6-86: Castor 1200 T+8 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 5.84E+01 | 40.9 | 4000 | 9 |
| February | 158 | 8.35E+01 | 58.5 | 3000 | 24 |
| March | 165 | 6.91E+01 | 48.4 | 3000 | 41 |
| April | 158 | 4.83E+01 | 33.8 | 3000 | 47 |
| May | 159 | 4.34E+01 | 30.4 | 5000 | 31 |
| June | 153 | 2.20E+01 | 15.4 | 8000 | 83 |
| July | 153 | 2.06E+01 | 14.4 | 8000 | 46 |
| August | 162 | 1.45E+01 | 10.2 | 6000 | 206 |
| September | 163 | 2.84E+01 | 19.9 | 4000 | 205 |
| October | 125 | 4.16E+01 | 29.1 | 7000 | 83 |
| November | 129 | 3.52E+01 | 24.6 | 7000 | 31 |
| December | 131 | 6.84E+01 | 47.9 | 4000 | 30 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-87.

**Table 6-87. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T+8 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1522 | 0.32528 |
| 1 - 2 | 834 | 0.17824 |
| 2 - 3 | 515 | 0.11007 |
| 3 - 4 | 342 | 0.07309 |
| 4 - 5 | 251 | 0.05364 |
| 5 - 6 | 192 | 0.04103 |
| 6 - 7 | 131 | 0.02800 |
| 7 - 8 | 98 | 0.02094 |
| 8 - 9 | 82 | 0.01753 |
| 9 - 10 | 69 | 0.01475 |
| > 10 | 643 | 0.13742 |

It is noted that approximately 32.5% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 19.1% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T+8 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-88 indicates the predicted Castor 1200 T+8 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T+8 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-88. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+8 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 555 | 0.11862 |
| 22.5 – 67.5 (NE) | 871 | 0.18615 |
| 67.5 – 112.5 (E) | 734 | 0.15687 |
| 112.5 – 157.5 (SE) | 974 | 0.20816 |
| 157.5 – 202.5 (S) | 524 | 0.11199 |
| 202.5 – 247.5 (SW) | 473 | 0.10109 |
| 247.5 – 292.5 (W) | 305 | 0.06518 |
| 292.5 – 337.5 (NW) | 243 | 0.05193 |

Similar summary tables for the 1751 nighttime Castor 1200 T+8 conflagration simulations were compiled. Table 6-89 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 23.5% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 27.7% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

**Table 6-89. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T+8 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 412 | 0.23529 |
| 1 - 2 | 242 | 0.13821 |
| 2 - 3 | 191 | 0.10908 |
| 3 - 4 | 121 | 0.06910 |
| 4 - 5 | 144 | 0.08224 |
| 5 - 6 | 92 | 0.05254 |
| 6 - 7 | 63 | 0.03598 |
| 7 - 8 | 67 | 0.03826 |
| 8 - 9 | 43 | 0.02456 |
| 9 - 10 | 35 | 0.01999 |
| > 10 | 341 | 0.19475 |

Table 6-90 indicates the predicted Castor 1200 vehicle T+8 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime T+8 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored as they were during the daytime.

**Table 6-90. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+8 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 129 | 0.07367 |
| 22.5 – 67.5 (NE) | 317 | 0.18104 |
| 67.5 – 112.5 (E) | 304 | 0.17362 |
| 112.5 – 157.5 (SE) | 359 | 0.20503 |
| 157.5 – 202.5 (S) | 231 | 0.13192 |
| 202.5 – 247.5 (SW) | 225 | 0.12850 |
| 247.5 – 292.5 (W) | 101 | 0.05768 |
| 292.5 – 337.5 (NW) | 85 | 0.04854 |

### 6.4.10 T+12 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-91 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T+12 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 33 to 1000 $mg/m^3$ with the maximum concentration predicted to occur from 1000 to 4000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-92 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+12 conflagration scenarios. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 42 to 249 $mg/m^3$ with the maximum concentration predicted to occur from 2000 to 5000 meters downwind from the launch site.

**Table 6-91: Castor 1200 T+12 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 3.04E+02 | 212.8 | 2000 | 17 |
| February | 363 | 1.61E+02 | 112.7 | 2000 | 32 |
| March | 393 | 2.78E+02 | 194.6 | 1000 | 24 |
| April | 382 | 2.14E+02 | 149.8 | 2000 | 35 |
| May | 398 | 1.88E+02 | 131.6 | 2000 | 43 |
| June | 391 | 8.68E+01 | 60.8 | 3000 | 13 |
| July | 417 | 6.56E+01 | 45.9 | 3000 | 23 |
| August | 410 | 3.26E+01 | 22.8 | 4000 | 34 |
| September | 412 | 1.82E+02 | 127.4 | 3000 | 242 |
| October | 429 | 1.01E+03 | 707.0 | 1000 | 15 |
| November | 376 | 1.37E+02 | 95.9 | 2000 | 132 |
| December | 367 | 1.58E+02 | 110.6 | 2000 | 27 |

**Table 6-92: Castor 1200 T+12 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 1.08E+02 | 75.6 | 5000 | 72 |
| February | 158 | 2.47E+02 | 172.9 | 2000 | 106 |
| March | 165 | 1.64E+02 | 114.8 | 2000 | 104 |
| April | 158 | 1.28E+02 | 89.6 | 3000 | 54 |
| May | 159 | 1.05E+02 | 73.5 | 2000 | 94 |
| June | 153 | 5.39E+01 | 37.7 | 3000 | 181 |
| July | 153 | 4.23E+01 | 29.6 | 4000 | 102 |
| August | 162 | 5.54E+01 | 38.8 | 3000 | 235 |
| September | 163 | 8.08E+01 | 56.6 | 2000 | 216 |
| October | 125 | 7.77E+01 | 54.4 | 3000 | 84 |
| November | 129 | 1.11E+02 | 77.7 | 3000 | 166 |
| December | 131 | 2.49E+02 | 174.3 | 3000 | 25 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-93.

**Table 6-93. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T+12 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1038 | 0.22184 |
| 1 - 2 | 677 | 0.14469 |
| 2 - 3 | 426 | 0.09105 |
| 3 - 4 | 293 | 0.06262 |
| 4 - 5 | 214 | 0.04574 |
| 5 - 6 | 170 | 0.03633 |
| 6 - 7 | 164 | 0.03505 |
| 7 - 8 | 143 | 0.03056 |
| 8 - 9 | 119 | 0.02543 |
| 9 - 10 | 108 | 0.02308 |
| > 10 | 1327 | 0.28361 |

It is noted that approximately 22.2% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 36.3% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T+12 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-94 indicates the predicted Castor 1200 T+12 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T+12 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-94. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+12 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 620 | 0.13251 |
| 22.5 – 67.5 (NE) | 857 | 0.18316 |
| 67.5 – 112.5 (E) | 666 | 0.14234 |
| 112.5 – 157.5 (SE) | 954 | 0.20389 |
| 157.5 – 202.5 (S) | 527 | 0.11263 |
| 202.5 – 247.5 (SW) | 492 | 0.10515 |
| 247.5 – 292.5 (W) | 323 | 0.06903 |
| 292.5 – 337.5 (NW) | 240 | 0.05129 |

Similar summary tables for the 1751 nighttime Castor 1200 T+12 conflagration simulations were compiled. Table 6-95 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 14.4% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 mg/m$^3$. Approximately 50.8% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 mg/m$^3$ or higher.

**Table 6-95. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T+12 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 252 | 0.14392 |
| 1 - 2 | 159 | 0.09081 |
| 2 - 3 | 126 | 0.07196 |
| 3 - 4 | 105 | 0.05997 |
| 4 - 5 | 84 | 0.04797 |
| 5 - 6 | 73 | 0.04169 |
| 6 - 7 | 62 | 0.03541 |
| 7 - 8 | 67 | 0.03826 |
| 8 - 9 | 51 | 0.02913 |
| 9 - 10 | 46 | 0.02627 |
| > 10 | 726 | 0.41462 |

Table 6-96 indicates the predicted Castor 1200 vehicle T+12 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime T+12 conflagration scenarios transport of the exhaust plume to the Northeast, East and Southeast are favored as they were during the daytime.

**Table 6-96. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+12 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 129 | 0.07367 |
| 22.5 – 67.5 (NE) | 341 | 0.19475 |
| 67.5 – 112.5 (E) | 269 | 0.15363 |
| 112.5 – 157.5 (SE) | 339 | 0.19360 |
| 157.5 – 202.5 (S) | 242 | 0.13821 |
| 202.5 – 247.5 (SW) | 244 | 0.13935 |
| 247.5 – 292.5 (W) | 101 | 0.05768 |
| 292.5 – 337.5 (NW) | 86 | 0.04911 |

### 6.4.11 T+16 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-97 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T+16 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 64 to 765 $mg/m^3$ with the maximum concentration predicted to occur from 1000 to 3000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-98 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+16 conflagration scenarios. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 55 to 380 $mg/m^3$ with the maximum concentration predicted to occur from 1000 to 3000 meters downwind from the launch site.

**Table 6-97: Castor 1200 T+16 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 4.83E+02 | 338.1 | 1000 | 28 |
| February | 363 | 3.11E+02 | 217.7 | 1000 | 12 |
| March | 393 | 3.48E+02 | 243.6 | 1000 | 54 |
| April | 382 | 2.95E+02 | 206.5 | 1000 | 31 |
| May | 398 | 2.58E+02 | 180.6 | 1000 | 21 |
| June | 391 | 1.24E+02 | 86.8 | 3000 | 114 |
| July | 417 | 8.68E+01 | 60.8 | 2000 | 220 |
| August | 410 | 6.42E+01 | 44.9 | 2000 | 146 |
| September | 412 | 1.77E+02 | 123.9 | 3000 | 241 |
| October | 429 | 7.65E+02 | 535.5 | 1000 | 15 |
| November | 376 | 1.90E+02 | 133.0 | 1000 | 160 |
| December | 367 | 1.83E+02 | 128.1 | 2000 | 26 |

**Table 6-98: Castor 1200 T+16 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [mg/m$^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [mg/m$^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 2.99E+02 | 209.3 | 2000 | 356 |
| February | 158 | 3.81E+02 | 266.7 | 2000 | 105 |
| March | 165 | 3.51E+02 | 245.7 | 2000 | 30 |
| April | 158 | 2.24E+02 | 156.8 | 1000 | 48 |
| May | 159 | 1.67E+02 | 116.9 | 2000 | 93 |
| June | 153 | 8.32E+01 | 58.2 | 2000 | 55 |
| July | 153 | 5.49E+01 | 38.4 | 3000 | 100 |
| August | 162 | 9.27E+01 | 64.9 | 2000 | 228 |
| September | 163 | 1.75E+02 | 122.5 | 2000 | 224 |
| October | 125 | 2.22E+02 | 155.4 | 2000 | 176 |
| November | 129 | 3.49E+02 | 244.3 | 2000 | 161 |
| December | 131 | 2.99E+02 | 209.3 | 2000 | 56 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-99.

**Table 6-99. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T+16 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 735 | 0.15708 |
| 1 - 2 | 518 | 0.11071 |
| 2 - 3 | 375 | 0.08015 |
| 3 - 4 | 253 | 0.05407 |
| 4 - 5 | 231 | 0.04937 |
| 5 - 6 | 176 | 0.03761 |
| 6 - 7 | 142 | 0.03035 |
| 7 - 8 | 116 | 0.02479 |
| 8 - 9 | 131 | 0.02800 |
| 9 - 10 | 105 | 0.02244 |
| > 10 | 1897 | 0.40543 |

It is noted that approximately 15.7% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 48.1% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T+16 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-100 indicates the predicted Castor 1200 T+16 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T+16 conflagration scenarios transport of the exhaust plume to the Northeast and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-100. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+16 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 667 | 0.14255 |
| 22.5 – 67.5 (NE) | 864 | 0.18465 |
| 67.5 – 112.5 (E) | 601 | 0.12845 |
| 112.5 – 157.5 (SE) | 929 | 0.19855 |
| 157.5 – 202.5 (S) | 531 | 0.11349 |
| 202.5 – 247.5 (SW) | 515 | 0.11007 |
| 247.5 – 292.5 (W) | 331 | 0.07074 |
| 292.5 – 337.5 (NW) | 241 | 0.05151 |

Similar summary tables for the 1751 nighttime Castor 1200 T+16 conflagration simulations were compiled. Table 6-101 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 9% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 64.1% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

**Table 6-101. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T+16 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 157 | 0.08966 |
| 1 - 2 | 118 | 0.06739 |
| 2 - 3 | 94 | 0.05368 |
| 3 - 4 | 71 | 0.04055 |
| 4 - 5 | 76 | 0.04340 |
| 5 - 6 | 56 | 0.03198 |
| 6 - 7 | 56 | 0.03198 |
| 7 - 8 | 54 | 0.03084 |
| 8 - 9 | 57 | 0.03255 |
| 9 - 10 | 37 | 0.02113 |
| > 10 | 975 | 0.55682 |

Table 6-102 indicates the predicted Castor 1200 vehicle T+16 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for nighttime T+16 conflagration scenarios transport of the exhaust plume to the Northeast and Southeast are favored.

**Table 6-102. REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+16 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 131 | 0.07481 |
| 22.5 – 67.5 (NE) | 348 | 0.19874 |
| 67.5 – 112.5 (E) | 262 | 0.14963 |
| 112.5 – 157.5 (SE) | 328 | 0.18732 |
| 157.5 – 202.5 (S) | 249 | 0.14220 |
| 202.5 – 247.5 (SW) | 241 | 0.13764 |
| 247.5 – 292.5 (W) | 108 | 0.06168 |
| 292.5 – 337.5 (NW) | 84 | 0.04797 |

### 6.4.12 T+20 Conflagration $Al_2O_3$ Results

REEDM was used to estimate the aluminum oxide dispersion because it includes settling velocity deposition algorithms for airborne transport of particulates that LATRA3D does not contain.

Table 6-103 presents the maximum far field $Al_2O_3$ peak instantaneous concentration predicted by REEDM for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent dispersion of the aluminum oxide particulates in the T+20 conflagration cloud. The far field exposure is REEDM's prediction for concentrations at ground level downwind from the stabilized exhaust cloud. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for daytime weather cases ranged from 130 to 550 mg/$m^3$ with the maximum concentration predicted to occur from 1000 to 7000 meters downwind from the launch site. Respirable dust is primarily under 5 microns in size. The default mass distribution among particle size categories used in the REEDM analysis places about 70% of the dispersed $Al_2O_3$ mass in the particle size bins 5 microns and less. The table values represent the maximum concentrations predicted over a sample set of 4679 WFF balloon soundings. Table 6-104 shows the REEDM predicted maximum peak $Al_2O_3$ far field concentrations for 1751 nighttime cases for Castor 1200 vehicle T+20 conflagration scenarios. Far field peak $Al_2O_3$ $PM_{10}$ concentrations for nighttime weather cases ranged from 79 to 520 mg/$m^3$ with the maximum concentration predicted to occur from 1000 to 2000 meters downwind from the launch site.

**Table 6-103: Castor 1200 T+20 Conflagration $Al_2O_3$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [$mg/m^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [$mg/m^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 341 | 4.79E+02 | 335.3 | 1000 | 10 |
| February | 363 | 4.54E+02 | 317.8 | 1000 | 8 |
| March | 393 | 3.39E+02 | 237.3 | 1000 | 53 |
| April | 382 | 3.51E+02 | 245.7 | 1000 | 30 |
| May | 398 | 3.31E+02 | 231.7 | 1000 | 19 |
| June | 391 | 1.51E+02 | 105.7 | 3000 | 114 |
| July | 417 | 1.31E+02 | 91.7 | 1000 | 216 |
| August | 410 | 1.55E+02 | 108.5 | 1000 | 145 |
| September | 412 | 2.45E+02 | 171.5 | 7000 | 242 |
| October | 429 | 5.46E+02 | 382.2 | 1000 | 298 |
| November | 376 | 2.77E+02 | 193.9 | 2000 | 99 |
| December | 367 | 2.44E+02 | 170.8 | 2000 | 71 |

**Table 6-104: Castor 1200 T+20 Conflagration $Al_2O_3$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $Al_2O_3$ $PM_{10}$ Concentration [$mg/m^3$] | Peak $Al_2O_3$ $PM_5$ Respirable Dust Concentration [$mg/m^3$] | Distance to Peak $Al_2O_3$ Concentration [m] | Bearing to Peak $Al_2O_3$ Concentration [deg] |
|---|---|---|---|---|---|
| January | 95 | 2.97E+02 | 207.9 | 2000 | 356 |
| February | 158 | 3.29E+02 | 230.3 | 1000 | 105 |
| March | 165 | 5.17E+02 | 361.9 | 1000 | 22 |
| April | 158 | 4.57E+02 | 319.9 | 1000 | 29 |
| May | 159 | 1.91E+02 | 133.7 | 2000 | 94 |
| June | 153 | 9.14E+01 | 64.0 | 2000 | 53 |
| July | 153 | 7.89E+01 | 55.2 | 2000 | 68 |
| August | 162 | 1.01E+02 | 70.7 | 2000 | 224 |
| September | 163 | 2.79E+02 | 195.3 | 2000 | 145 |
| October | 125 | 3.86E+02 | 270.2 | 1000 | 81 |
| November | 129 | 2.83E+02 | 198.1 | 2000 | 160 |
| December | 131 | 3.21E+02 | 224.7 | 1000 | 228 |

The REEDM predicted $Al_2O_3$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-105.

**Table 6-105. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Daytime Castor 1200 T+20 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 580 | 0.12401 |
| 1 - 2 | 421 | 0.09001 |
| 2 - 3 | 327 | 0.06992 |
| 3 - 4 | 241 | 0.05153 |
| 4 - 5 | 196 | 0.04191 |
| 5 - 6 | 171 | 0.03656 |
| 6 - 7 | 133 | 0.02844 |
| 7 - 8 | 119 | 0.02544 |
| 8 - 9 | 109 | 0.02331 |
| 9 - 10 | 110 | 0.02352 |
| > 10 | 2270 | 0.48535 |

It is noted that approximately 12.4% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 $mg/m^3$. Approximately 55.7% of all daytime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 $mg/m^3$ or higher.

The REEDM predicted cloud transport directions for the T+20 conflagration $Al_2O_3$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-106 indicates the predicted Castor 1200 T+20 conflagration plume direction probability of occurrence observed across the 4679 daytime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations. It is noted that for the daytime T+20 conflagration scenarios transport of the exhaust plume to the Northeast and Southeast are favored. This would tend to carry the particulate cloud in an offshore direction for the launch pads located on the WFF barrier island on the Atlantic coastline of Virginia.

**Table 6-106. REEDM Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 T+20 Conflagration $Al_2O_3$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 704 | 0.15052 |
| 22.5 – 67.5 (NE) | 851 | 0.18195 |
| 67.5 – 112.5 (E) | 588 | 0.12572 |
| 112.5 – 157.5 (SE) | 906 | 0.19371 |
| 157.5 – 202.5 (S) | 524 | 0.11204 |
| 202.5 – 247.5 (SW) | 520 | 0.11118 |
| 247.5 – 292.5 (W) | 340 | 0.07270 |
| 292.5 – 337.5 (NW) | 244 | 0.05217 |

Similar summary tables for the 1751 nighttime Castor 1200 T+20 conflagration simulations were compiled. Table 6-101 shows the $Al_2O_3$ $PM_{10}$ concentration histogram results. Approximately 5.6% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_{10}$ concentrations of less than 1 mg/m$^3$. Approximately 72.2% of all nighttime meteorological cases resulted in REEDM maximum peak instantaneous ground level $Al_2O_3$ $PM_5$ (respirable dust) concentrations of 5 mg/m$^3$ or higher.

**Table 6-107. REEDM Predicted Maximum Far Field Ground Level $Al_2O_3$ $PM_{10}$ Concentrations for Nighttime Castor 1200 T+20 Conflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 99 | 0.05654 |
| 1 - 2 | 94 | 0.05368 |
| 2 - 3 | 76 | 0.04340 |
| 3 - 4 | 61 | 0.03484 |
| 4 - 5 | 49 | 0.02798 |
| 5 - 6 | 63 | 0.03598 |
| 6 - 7 | 44 | 0.02513 |
| 7 - 8 | 42 | 0.02399 |
| 8 - 9 | 44 | 0.02513 |
| 9 - 10 | 47 | 0.02684 |
| > 10 | 1132 | 0.64649 |

Table 6-108 indicates the predicted Castor 1200 vehicle T+20 conflagration plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases that produced non-zero predicted ground level $Al_2O_3$ concentrations.  It is noted that for nighttime T+20 conflagration scenarios transport of the exhaust plume to the Northeast and Southeast are favored.

**Table 6-108.  REEDM Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 T+20 Conflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 135 | 0.07710 |
| 22.5 – 67.5 (NE) | 344 | 0.19646 |
| 67.5 – 112.5 (E) | 262 | 0.14963 |
| 112.5 – 157.5 (SE) | 321 | 0.18332 |
| 157.5 – 202.5 (S) | 258 | 0.14734 |
| 202.5 – 247.5 (SW) | 237 | 0.13535 |
| 247.5 – 292.5 (W) | 111 | 0.06339 |
| 292.5 – 337.5 (NW) | 83 | 0.04740 |

### 6.4.13 Payload Deflagration $NO_2$ Results

LATRA3D was used to estimate the chemical reactions, heat of combustion, buoyancy, cloud rise and dispersion of a liquid propellant fireball that could occur when a payload assembly impacts the ground after a launch vehicle failure. For the purposes of this study, two hypergolic propellants that are commonly used on satellites were assumed for a generic payload. The propellants are MMH fuel and nitrogen tetroxide oxidizer. Standard mixing and reaction pathway assumptions used by the Air Force range safety organizations were applied in this study such that approximately 23% of the $N_2O_4$ oxidizer reacts and 77% is vaporized. The vaporized portion produces the toxic airborne chemical $NO_2$. Total mass of oxidizer in the payload is assumed to be 1640 pounds (a small to medium sized satellite). Dispersion of approximately 1263 pounds of $NO_2$ within a buoyant release is evaluated in this scenario. Since the payload is not depleting propellant and is assumed to remain as a single fragment during stage 1 flight there is no time dependency associated with the payload deflagration scenario.

Table 6-109 presents the maximum far field $NO_2$ peak instantaneous concentration predicted by LATRA3D for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent core vehicle breakup that leaves the payload assembly intact and ejected from the vehicle explosion center. Far field peak $NO_2$ concentrations for daytime weather cases ranged from 13 to 42 ppm with the maximum concentration predicted to occur from 500 to 1550 meters downwind from the launch site. The table values represent the maximum concentrations predicted over a sample set of 3732 WFF balloon soundings that resulted in non-zero surface concentrations. Table 6-110 shows the LATRA3D predicted maximum peak $NO_2$ far field concentrations for 1568 nighttime cases for payload deflagration scenarios the produced non-zero grid concentrations. Far field peak $NO_2$ concentrations for nighttime weather cases ranged from 7 to 26 ppm with the maximum concentration predicted to occur from 500 to 2100 meters downwind from the payload impact point near the launch site.

**Table 6-109: Castor 1200 Payload Deflagration $NO_2$ Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak $NO_2$ Concentration [ppm] | Distance to Peak $NO_2$ Concentration [m] | Bearing to Peak $NO_2$ Concentration [deg] |
|---|---|---|---|---|
| January | 247 | 4.19E+01 | 504 | 27 |
| February | 255 | 2.05E+01 | 1547 | 305 |
| March | 305 | 3.75E+01 | 506 | 27 |
| April | 345 | 2.73E+01 | 847 | 20 |
| May | 367 | 1.82E+01 | 1029 | 45 |
| June | 352 | 1.47E+01 | 696 | 7 |
| July | 383 | 1.51E+01 | 868 | 22 |
| August | 350 | 1.32E+01 | 1246 | 23 |
| September | 333 | 1.25E+01 | 664 | 200 |
| October | 313 | 1.42E+01 | 1062 | 37 |
| November | 245 | 2.05E+01 | 658 | 136 |
| December | 237 | 2.29E+01 | 712 | 32 |

**Table 6-110: Castor 1200 Payload Deflagration $NO_2$ Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak $NO_2$ Concentration [ppm] | Distance to Peak $NO_2$ Concentration [m] | Bearing to Peak $NO_2$ Concentration [deg] |
|---|---|---|---|---|
| January | 81 | 1.19E+01 | 2077 | 48 |
| February | 121 | 2.60E+01 | 809 | 112 |
| March | 133 | 1.92E+01 | 749 | 117 |
| April | 156 | 1.45E+01 | 734 | 48 |
| May | 158 | 1.66E+01 | 593 | 13 |
| June | 152 | 1.25E+01 | 614 | 156 |
| July | 152 | 7.12E+00 | 681 | 272 |
| August | 155 | 1.33E+01 | 681 | 240 |
| September | 155 | 2.10E+01 | 498 | 217 |
| October | 100 | 2.13E+01 | 1031 | 189 |
| November | 100 | 1.93E+01 | 849 | 172 |
| December | 105 | 1.79E+01 | 1110 | 33 |

The LATRA3D predicted $NO_2$ concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability.  This information is provided in Table 6-111

**Table 6-111.  LATRA3D Predicted Maximum Far Field Ground Level $NO_2$ Concentrations for Daytime Payload Deflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 1971 | 0.52814 |
| 2- 4 | 853 | 0.22856 |
| 4 - 6 | 374 | 0.10021 |
| 6 - 8 | 202 | 0.05413 |
| 8 - 10 | 130 | 0.03483 |
| 10 - 20 | 188 | 0.05038 |
| 20 - 30 | 12 | 0.00322 |
| 30 - 40 | 1 | 0.00027 |
| 40 - 50 | 1 | 0.00027 |
| 50 - 60 | 0 | 0.00000 |
| 60 – 70 | 0 | 0.00000 |
| 70 – 80 | 0 | 0.00000 |
| 80 – 90 | 0 | 0.00000 |
| 90 - 100 | 0 | 0.00000 |
| > 100 | 0 | 0.00000 |

It is noted that approximately 52.8% of the daytime meteorological cases with non-zero concentration resulted in LATRA3D maximum peak instantaneous ground level $NO_2$ concentrations of less than 2 ppm.  Approximately 5.4% of the cases resulted in LATRA3D maximum peak instantaneous ground level $NO_2$ concentrations of 10 ppm or higher.

Table 6-112 lists the maximum downwind distance from the source to the endpoint for a low $NO_2$ peak instantaneous concentration value of 0.5 ppm for the daytime weather cases.  This could be thought of as a containment distance beyond which negligible effects to $NO_2$ exposure occur. Maximum distances range from 5800 to 11000 meters from the source. Table 6-113 lists the maximum downwind distance from the source to the endpoint for a low $NO_2$ peak instantaneous concentration value of 0.5 ppm for the nighttime weather cases.  Maximum nighttime 0.5 ppm distances range from 6300 to 10000 meters from the source.

**Table 6-112: Castor 1200 Payload Deflagration 0.5 ppm $NO_2$ Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | $NO_2$ Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 187 | 5.00E-01 | 9621 | 221 |
| February | 185 | 5.00E-01 | 10710 | 308 |
| March | 228 | 5.00E-01 | 8205 | 224 |
| April | 282 | 5.00E-01 | 9906 | 330 |
| May | 304 | 5.00E-01 | 7522 | 223 |
| June | 303 | 5.00E-01 | 5858 | 329 |
| July | 304 | 5.00E-01 | 6368 | 258 |
| August | 280 | 5.00E-01 | 7900 | 44 |
| September | 223 | 5.00E-01 | 8983 | 338 |
| October | 259 | 5.00E-01 | 9854 | 27 |
| November | 202 | 5.00E-01 | 10702 | 55 |
| December | 192 | 5.00E-01 | 10026 | 39 |

**Table 6-113: Castor 1200 Payload Deflagration 0.5 ppm $NO_2$ Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | $NO_2$ Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 60 | 5.00E-01 | 8905 | 79 |
| February | 99 | 5.00E-01 | 9191 | 38 |
| March | 106 | 5.00E-01 | 9819 | 307 |
| April | 139 | 5.00E-01 | 6262 | 232 |
| May | 140 | 5.00E-01 | 6619 | 53 |
| June | 145 | 5.00E-01 | 6354 | 306 |
| July | 139 | 5.00E-01 | 6935 | 34 |
| August | 133 | 5.00E-01 | 6581 | 245 |
| September | 141 | 5.00E-01 | 7098 | 339 |
| October | 90 | 5.00E-01 | 7590 | 272 |
| November | 85 | 5.00E-01 | 9404 | 223 |
| December | 88 | 5.00E-01 | 10013 | 207 |

The LATRA3D predicted cloud transport directions for the payload deflagration $NO_2$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-115 indicates the predicted Castor 1200 payload deflagration cloud direction probability of occurrence observed across the 2949 daytime balloon sounding cases that produced predicted ground level $NO_2$ concentrations above 0.5 ppm. It is noted that for the daytime payload deflagration scenarios transport of the exhaust plume to the North and Northeast are favored.

**Table 6-114. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Payload Deflagration $NO_2$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 620 | 0.21024 |
| 22.5 – 67.5 (NE) | 705 | 0.23906 |
| 67.5 – 112.5 (E) | 306 | 0.10376 |
| 112.5 – 157.5 (SE) | 301 | 0.10207 |
| 157.5 – 202.5 (S) | 270 | 0.09156 |
| 202.5 – 247.5 (SW) | 344 | 0.11665 |
| 247.5 – 292.5 (W) | 231 | 0.07833 |
| 292.5 – 337.5 (NW) | 172 | 0.05832 |

Similar summary tables for the 1568 nighttime Castor 1200 payload deflagration simulations that produced non-zero concentrations were compiled. Although a total of 1751 meteorological cases were run, 183 cases had the predicted stabilized deflagration cloud completely above a mixing boundary, which results in a prediction of zero ground level concentrations. Table 6-115 shows the $NO_2$ concentration histogram results for the nighttime payload deflagration cases. Approximately 47.8% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level $NO_2$ concentrations of less than 2 ppm. Approximately 5.1% of the nighttime cases resulted in LATRA3D maximum peak instantaneous ground level $NO_2$ concentrations of 10 ppm or higher.

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**Table 6-115. LATRA3D Predicted Maximum Far Field Ground Level $NO_2$ Concentrations for Nighttime Payload Deflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 2 | 749 | 0.47768 |
| 2- 4 | 403 | 0.25702 |
| 4 - 6 | 178 | 0.11352 |
| 6 - 8 | 99 | 0.06314 |
| 8 - 10 | 59 | 0.03763 |
| 10 - 20 | 77 | 0.04911 |
| 20 - 30 | 3 | 0.00191 |
| 30 - 40 | 0 | 0.00000 |
| 40 - 50 | 0 | 0.00000 |
| 50 - 60 | 0 | 0.00000 |
| 60 – 70 | 0 | 0.00000 |
| 70 – 80 | 0 | 0.00000 |
| 80 – 90 | 0 | 0.00000 |
| 90 - 100 | 0 | 0.00000 |
| > 100 | 0 | 0.00000 |

Table 6-116 indicates the predicted Castor 1200 vehicle payload deflagration plume direction probability of occurrence observed across the 1365 nighttime balloon sounding cases that produced predicted ground level $NO_2$ concentrations above 0.5 ppm. It is noted that for nighttime payload deflagration scenarios transport of the exhaust plume to the Northeast is slightly favored.

**Table 6-116. LATRA3D Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Payload Deflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 108 | 0.07912 |
| 22.5 – 67.5 (NE) | 292 | 0.21392 |
| 67.5 – 112.5 (E) | 223 | 0.16337 |
| 112.5 – 157.5 (SE) | 199 | 0.14579 |
| 157.5 – 202.5 (S) | 175 | 0.12821 |
| 202.5 – 247.5 (SW) | 205 | 0.15018 |
| 247.5 – 292.5 (W) | 97 | 0.07106 |
| 292.5 – 337.5 (NW) | 66 | 0.04835 |

### 6.4.14 Payload Deflagration MMH Results

LATRA3D was used to estimate the chemical reactions, heat of combustion, buoyancy, cloud rise and dispersion of a liquid propellant fireball that could occur when a payload assembly impacts the ground after a launch vehicle failure. For the purposes of this study, two hypergolic propellants that are commonly used on satellites were assumed for a generic payload. The propellants are MMH fuel and nitrogen tetroxide oxidizer. Standard mixing and reaction pathway assumptions used by the Air Force range safety organizations were applied in this study such that approximately 23% of the MMH fuel reacts with oxidizer, 63.1% thermally decomposes and 13.9% is vaporized. The vaporized portion produces the toxic airborne chemical MMH. Total mass of fuel in the payload is assumed to be 1000 pounds (a small to medium sized satellite). Dispersion of approximately 139 pounds of MMH within a buoyant release is evaluated in this scenario. Since the payload is not depleting propellant and is assumed to remain as a single fragment during stage 1 flight there is no time dependency associated with the payload deflagration scenario.

Table 6-117 presents the maximum far field MMH peak instantaneous concentration predicted by LATRA3D for the hypothetical daytime launches of a Castor 1200 vehicle with subsequent core vehicle breakup that leaves the payload assembly intact and ejected from the vehicle explosion center. Far field peak MMH concentrations for daytime weather cases ranged from 1.4 to 4.6 ppm with the maximum concentration predicted to occur from 500 to 1550 meters downwind from the launch site. The table values represent the maximum concentrations predicted over a sample set of 3732 WFF balloon soundings that resulted in non-zero surface concentrations. Table 6-118 shows the LATRA3D predicted maximum peak MMH far field concentrations for 1568 nighttime cases for payload deflagration scenarios the produced non-zero grid concentrations. Far field peak MMH concentrations for nighttime weather cases ranged from 0.8 to 2.9 ppm with the maximum concentration predicted to occur from 500 to 2100 meters downwind from the payload impact point near the launch site.

**Table 6-117: Castor 1200 Payload Deflagration MMH Peak Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Peak MMH Concentration [ppm] | Distance to Peak MMH Concentration [m] | Bearing to Peak MMH Concentration [deg] |
|---|---|---|---|---|
| January | 247 | 4.60E+00 | 504 | 27 |
| February | 255 | 2.25E+00 | 1547 | 305 |
| March | 305 | 4.12E+00 | 506 | 27 |
| April | 345 | 3.00E+00 | 847 | 20 |
| May | 367 | 2.00E+00 | 1029 | 45 |
| June | 352 | 1.61E+00 | 696 | 7 |
| July | 383 | 1.66E+00 | 868 | 22 |
| August | 350 | 1.45E+00 | 1246 | 23 |
| September | 333 | 1.37E+00 | 664 | 200 |
| October | 313 | 1.56E+00 | 1062 | 37 |
| November | 245 | 2.25E+00 | 658 | 136 |
| December | 237 | 2.51E+00 | 712 | 32 |

**Table 6-118: Castor 1200 Payload Deflagration MMH Peak Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Peak MMH Concentration [ppm] | Distance to Peak MMH Concentration [m] | Bearing to Peak MMH Concentration [deg] |
|---|---|---|---|---|
| January | 81 | 1.31E+00 | 2077 | 48 |
| February | 121 | 2.86E+00 | 809 | 112 |
| March | 133 | 2.10E+00 | 749 | 117 |
| April | 156 | 1.59E+00 | 734 | 48 |
| May | 158 | 1.83E+00 | 593 | 13 |
| June | 152 | 1.38E+00 | 614 | 156 |
| July | 152 | 7.83E-01 | 681 | 272 |
| August | 155 | 1.46E+00 | 681 | 240 |
| September | 155 | 2.30E+00 | 498 | 217 |
| October | 100 | 2.34E+00 | 1031 | 189 |
| November | 100 | 2.12E+00 | 849 | 172 |
| December | 105 | 1.96E+00 | 1110 | 33 |

The LATRA3D predicted MMH concentrations for all daytime meteorological cases processed in the 8-year sample set was aggregated into bins to evaluate the peak far field concentration probability. This information is provided in Table 6-119

**Table 6-119. LATRA3D Predicted Maximum Far Field Ground Level MMH Concentrations for Daytime Payload Deflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 3479 | 0.93221 |
| 1 - 2 | 226 | 0.06056 |
| 2 - 3 | 23 | 0.00616 |
| 3 - 4 | 2 | 0.00054 |
| 4 - 5 | 2 | 0.00054 |
| 5 - 6 | 0 | 0.00000 |
| 6 - 7 | 0 | 0.00000 |
| 7 - 8 | 0 | 0.00000 |
| 8 - 9 | 0 | 0.00000 |
| 9 - 10 | 0 | 0.00000 |
| 10 - 11 | 0 | 0.00000 |
| 11 - 12 | 0 | 0.00000 |
| 12 - 13 | 0 | 0.00000 |
| 13 - 14 | 0 | 0.00000 |
| 14 - 15 | 0 | 0.00000 |

It is noted that approximately 93.2% of the daytime meteorological cases with non-zero concentration resulted in LATRA3D maximum peak instantaneous ground level MMH concentrations of less than 1 ppm. Approximately 0.7% of the cases resulted in LATRA3D maximum peak instantaneous ground level MMH concentrations of 2 ppm or higher (approximately the 30 minute AEGL 2 threshold).

Table 6-120 lists the maximum downwind distance from the source to the endpoint for a low MMH peak instantaneous concentration value of 0.5 ppm for the daytime weather cases. This could be thought of as a containment distance beyond which negligible effects to MMH exposure occur. Maximum distances range from 2000 to 5300 meters from the source for the daytime cases. Table 6-121 lists the maximum downwind distance from the source to the endpoint for a low MMH peak instantaneous concentration value of 0.5 ppm for the nighttime weather cases. Maximum nighttime 0.5 ppm distances range from 1900 to 4900 meters from the source.

**Table 6-120: Castor 1200 Payload Deflagration 0.5 ppm MMH Concentration Hazard Zone Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | MMH Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 67 | 5.00E-01 | 4454 | 61 |
| February | 61 | 5.00E-01 | 5285 | 307 |
| March | 87 | 5.00E-01 | 4135 | 115 |
| April | 104 | 5.00E-01 | 3114 | 48 |
| May | 86 | 5.00E-01 | 2401 | 29 |
| June | 70 | 5.00E-01 | 2130 | 18 |
| July | 49 | 5.00E-01 | 1980 | 38 |
| August | 52 | 5.00E-01 | 2499 | 20 |
| September | 26 | 5.00E-01 | 2390 | 4 |
| October | 39 | 5.00E-01 | 4021 | 88 |
| November | 79 | 5.00E-01 | 5330 | 55 |
| December | 53 | 5.00E-01 | 4836 | 39 |

**Table 6-121: Castor 1200 Payload Deflagration 0.5 ppm MMH Concentration Hazard Zone Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | MMH Hazard Zone Concentration [ppm] | Distance to End of Hazard Zone [m] | Bearing to End of Hazard Zone [deg] |
|---|---|---|---|---|
| January | 20 | 5.00E-01 | 4460 | 47 |
| February | 36 | 5.00E-01 | 4936 | 40 |
| March | 42 | 5.00E-01 | 4552 | 180 |
| April | 41 | 5.00E-01 | 2454 | 358 |
| May | 37 | 5.00E-01 | 2386 | 32 |
| June | 27 | 5.00E-01 | 1942 | 57 |
| July | 13 | 5.00E-01 | 1962 | 43 |
| August | 22 | 5.00E-01 | 1877 | 32 |
| September | 17 | 5.00E-01 | 2354 | 188 |
| October | 33 | 5.00E-01 | 2661 | 83 |
| November | 30 | 5.00E-01 | 4461 | 85 |
| December | 30 | 5.00E-01 | 4596 | 140 |

The LATRA3D predicted cloud transport directions for the payload deflagration MMH dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-122 indicates the predicted Castor 1200 payload deflagration cloud direction probability of occurrence observed across the 773 daytime balloon sounding cases that produced predicted ground level MMH concentrations above 0.5 ppm. It is noted that for the daytime payload deflagration scenarios transport of the exhaust plume to the North and Northeast are favored.

**Table 6-122. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Payload Deflagration MMH Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 221 | 0.28590 |
| 22.5 – 67.5 (NE) | 310 | 0.40103 |
| 67.5 – 112.5 (E) | 61 | 0.07891 |
| 112.5 – 157.5 (SE) | 30 | 0.03881 |
| 157.5 – 202.5 (S) | 57 | 0.07374 |
| 202.5 – 247.5 (SW) | 48 | 0.06210 |
| 247.5 – 292.5 (W) | 24 | 0.03105 |
| 292.5 – 337.5 (NW) | 22 | 0.02846 |

Similar summary tables for the 348 nighttime Castor 1200 payload deflagration simulations that produced non-zero concentrations were compiled. Although a total of 1751 meteorological cases were run, 183 cases had the predicted stabilized deflagration cloud completely above a mixing boundary, which results in a prediction of zero ground level concentrations. An additional 1220 cases had maximum ground concentrations below 0.5 ppm due to the small 139 pound mass quantity of the release. Table 6-123 shows the MMH concentration histogram results for the nighttime payload deflagration cases. Approximately 93.4% of all nighttime meteorological cases resulted in LATRA3D maximum peak instantaneous ground level MMH concentrations of less than 1 ppm. Approximately 0.4% of the cases resulted in LATRA3D maximum peak instantaneous ground level MMH concentrations of 2 ppm or higher (approximately the 30 minute AEGL 2 threshold).

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**Table 6-123. LATRA3D Predicted Maximum Far Field Ground Level MMH Concentrations for Nighttime Payload Deflagration Scenarios.**

| Concentration Bin | Count | Probability |
|---|---|---|
| 0 - 1 | 1465 | 0.93431 |
| 1 - 2 | 96 | 0.06122 |
| 2 - 3 | 7 | 0.00446 |
| 3 - 4 | 0 | 0.00000 |
| 4 - 5 | 0 | 0.00000 |
| 5 - 6 | 0 | 0.00000 |
| 6 - 7 | 0 | 0.00000 |
| 7 - 8 | 0 | 0.00000 |
| 8 - 9 | 0 | 0.00000 |
| 9 - 10 | 0 | 0.00000 |
| 10 - 11 | 0 | 0.00000 |
| 11 - 12 | 0 | 0.00000 |
| 12 - 13 | 0 | 0.00000 |
| 13 - 14 | 0 | 0.00000 |
| 14 - 15 | 0 | 0.00000 |

Table 6-124 indicates the predicted Castor 1200 vehicle payload deflagration plume direction probability of occurrence observed across the 348 nighttime balloon sounding cases that produced predicted ground level MMH concentrations above 0.5 ppm. It is noted that for nighttime payload deflagration scenarios transport of the exhaust plume to the Northeast is favored.

**Table 6-124. LATRA3D Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Payload Deflagration Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 33 | 0.09483 |
| 22.5 – 67.5 (NE) | 126 | 0.36207 |
| 67.5 – 112.5 (E) | 51 | 0.14655 |
| 112.5 – 157.5 (SE) | 26 | 0.07471 |
| 157.5 – 202.5 (S) | 40 | 0.11494 |
| 202.5 – 247.5 (SW) | 55 | 0.15805 |
| 247.5 – 292.5 (W) | 9 | 0.02586 |
| 292.5 – 337.5 (NW) | 8 | 0.02299 |

### 6.4.15 Payload Spill and Pool Evaporation $NO_2$ Results

LATRA3D was used to estimate the evaporation rate from a spill of $N_2O_4$ oxidizer assuming that payload impact ruptures the propellant tanks but does not lead to a fire or explosion. The evaporated oxidizer produces the toxic airborne chemical $NO_2$. The boiling point of $N_2O_4$ is 71 F so it is volatile and evaporates quickly. The total mass of oxidizer in the payload is assumed to be 1640 pounds (a small to medium sized satellite). Neutral buoyancy dispersion of all 1640 pounds of $NO_2$ is evaluated in this scenario. Since this is a neutral buoyancy release there is no “cloud rise” as with the sources that release combustion heat. The neutral buoyancy source forms at ground level where the concentrations of interest are being estimated. The pool evaporation scenarios can have very high concentrations right at the pool location and concentration decreases monotonically moving away from the pool in the downwind direction. For this reason, reporting statistics on the “maximum peak ground level concentration” is not very informative about the size of the toxic hazard corridor. Concentrations of $NO_2$ near the evaporating pool are estimated to be in the 10,000 to 50,000 ppm range, which is extremely hazardous to health. To give a better assessment of the downwind extent of a potential toxic hazard corridor, a threshold of 5 ppm of $NO_2$ was selected as a reference value. The 5-ppm hazard zone for $NO_2$ could be thought of as a region within which adverse effect would be low (or worst) but not negligible. Solar heating and ground temperature effects generally result in higher predicted evaporation rates during the day than at night, consequently the daytime hazard corridors are somewhat longer than the nighttime hazard corridors.

Table 6-125 presents the estimated 5-ppm maximum hazard corridor distances predicted over a sample set of 4678 WFF daytime balloon soundings. The predicted daytime 5-ppm $NO_2$ maximum hazard zone distances ranged from 1000 to 2500 meters downwind from the spill site. Table 6-126 presents the estimated 5-ppm maximum hazard corridor distances predicted over a sample set of 1751 WFF nighttime balloon soundings. The predicted nighttime 5-ppm $NO_2$ maximum hazard zone distances ranged from 800 to 1500 meters downwind from the spill site.

**Table 6-125: Castor 1200 Payload Pool Evaporation 5-ppm $NO_2$ Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Reference $NO_2$ Concentration [ppm] | Max Distance to Reference $NO_2$ Concentration [m] | Bearing to Reference $NO_2$ Concentration [deg] |
|---|---|---|---|---|
| January | 341 | 5.00E+00 | 1585 | 55 |
| February | 363 | 5.00E+00 | 1038 | 328 |
| March | 393 | 5.00E+00 | 2330 | 80 |
| April | 381 | 5.00E+00 | 1685 | 90 |
| May | 398 | 5.00E+00 | 1806 | 174 |
| June | 391 | 5.00E+00 | 1444 | 49 |
| July | 417 | 5.00E+00 | 1696 | 95 |
| August | 410 | 5.00E+00 | 1963 | 70 |
| September | 412 | 5.00E+00 | 1952 | 270 |
| October | 429 | 5.00E+00 | 1469 | 230 |
| November | 376 | 5.00E+00 | 2524 | 261 |
| December | 367 | 5.00E+00 | 1024 | 50 |

**Table 6-126: Castor 1200 Payload Pool Evaporation 5-ppm $NO_2$ Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Reference $NO_2$ Concentration [ppm] | Max Distance to Reference $NO_2$ Concentration [m] | Bearing to Reference $NO_2$ Concentration [deg] |
|---|---|---|---|---|
| January | 95 | 5.00E+00 | 900 | 111 |
| February | 158 | 5.00E+00 | 955 | 150 |
| March | 165 | 5.00E+00 | 1509 | 310 |
| April | 158 | 5.00E+00 | 827 | 54 |
| May | 159 | 5.00E+00 | 823 | 40 |
| June | 153 | 5.00E+00 | 823 | 184 |
| July | 153 | 5.00E+00 | 821 | 133 |
| August | 162 | 5.00E+00 | 885 | 35 |
| September | 163 | 5.00E+00 | 987 | 100 |
| October | 125 | 5.00E+00 | 977 | 90 |
| November | 129 | 5.00E+00 | 997 | 140 |
| December | 131 | 5.00E+00 | 963 | 70 |

The LATRA3D predicted cloud transport directions for the payload evaporating pool $NO_2$ dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-127 indicates the predicted Castor 1200 payload evaporating pool plume direction probability of occurrence observed across the 4678 daytime balloon sounding cases that produced predicted ground level $NO_2$ concentrations above 5 ppm. It is noted that for the daytime payload pool evaporation scenarios transport of the exhaust plume to the North is favored. This is a reflection of prevailing wind directions near the ground surface.

**Table 6-127. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Payload Pool Evaporation $NO_2$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 1020 | 0.21804 |
| 22.5 – 67.5 (NE) | 714 | 0.15263 |
| 67.5 – 112.5 (E) | 569 | 0.12163 |
| 112.5 – 157.5 (SE) | 686 | 0.14664 |
| 157.5 – 202.5 (S) | 560 | 0.11971 |
| 202.5 – 247.5 (SW) | 461 | 0.09855 |
| 247.5 – 292.5 (W) | 413 | 0.08829 |
| 292.5 – 337.5 (NW) | 255 | 0.05451 |

Table 6-128 indicates the predicted Castor 1200 vehicle payload pool evaporation plume direction probability of occurrence observed across the 1751 nighttime balloon sounding cases. It is noted that for nighttime payload pool evaporation scenarios transport of the exhaust plume toward a wide sector from the Northeast clockwise to the South is favored. This is a reflection of prevailing nighttime wind directions near the ground surface.

**Table 6-128. LATRA3D Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Payload Pool Evaporation $NO_2$ Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 174 | 0.09937 |
| 22.5 – 67.5 (NE) | 332 | 0.18961 |
| 67.5 – 112.5 (E) | 269 | 0.15363 |
| 112.5 – 157.5 (SE) | 311 | 0.17761 |
| 157.5 – 202.5 (S) | 298 | 0.17019 |
| 202.5 – 247.5 (SW) | 188 | 0.10737 |
| 247.5 – 292.5 (W) | 117 | 0.06682 |
| 292.5 – 337.5 (NW) | 62 | 0.03541 |

### 6.4.16 Payload Spill and Pool Evaporation MMH Results

LATRA3D was used to estimate the evaporation rate from a spill of MMH fuel assuming that payload impact ruptures the propellant tanks but does not lead to a fire or explosion. The evaporated oxidizer produces the toxic airborne chemical MMH. The boiling point of MMH is 188.6 F and it has low saturation pressure and therefore evaporates slowly. The total mass of fuel in the payload is assumed to be 1000 pounds (a small to medium sized satellite). Neutral buoyancy dispersion of all 1000 pounds of MMH is evaluated in this scenario. Since this is a neutral buoyancy release there is no “cloud rise” as with the sources that release combustion heat. The neutral buoyancy source forms at ground level where the concentrations of interest are being estimated. The pool evaporation scenarios can have very high concentrations right at the pool location and concentration decreases monotonically moving away from the pool in the downwind direction. For this reason, reporting statistics on the “maximum peak ground level concentration” is not very informative about the size of the toxic hazard corridor. Concentrations of MMH near the evaporating pool are estimated to be in the 200 to 5,000 ppm range, which is extremely hazardous to health. To give a better assessment of the downwind extent of a potential toxic hazard corridor, a threshold of 5 ppm of MMH was selected as a reference value. The 5-ppm hazard zone for MMH could be thought of as a region within which adverse effect would be low (or worst) but not negligible. Solar heating and ground temperature effects generally result in higher predicted evaporation rates during the day than at night, consequently the daytime hazard corridors are somewhat longer than the nighttime hazard corridors.

Table 6-129 presents the estimated 5-ppm hazard corridor distances predicted over a sample set of 4546 WFF daytime balloon soundings that had MMH concentrations above 5-ppm in the LATRA3D calculation grid (132 cases had very short hazard zones that did not reach the first downwind row in LATRA3D concentration grid node array). The predicted daytime 5-ppm MMH maximum hazard zone distances ranged from 170 to 280 meters downwind from the spill site. Table 6-130 presents the estimated 5-ppm hazard corridor distances predicted over a sample set of 1669 WFF nighttime balloon soundings that had MMH concentrations above 5-ppm in the LATRA3D calculation grid (82 cases had very short hazard zones that did not reach the first downwind row in LATRA3D concentration grid node array). The predicted nighttime 5-ppm MMH maximum hazard zone distances ranged from 100 to 240 meters downwind from the spill site.

**Table 6-129: Castor 1200 Payload Pool Evaporation 5-ppm MMH Concentration Summary – Daytime Meteorology.**

| Month | Number of Weather Cases | Reference MMH Concentration [ppm] | Max Distance to Reference MMH Concentration [m] | Bearing to Reference MMH Concentration [deg] |
|---|---|---|---|---|
| January | 309 | 5.00E+00 | 207 | 55 |
| February | 336 | 5.00E+00 | 169 | 190 |
| March | 380 | 5.00E+00 | 195 | 285 |
| April | 367 | 5.00E+00 | 225 | 55 |
| May | 396 | 5.00E+00 | 257 | 50 |
| June | 391 | 5.00E+00 | 264 | 60 |
| July | 417 | 5.00E+00 | 266 | 90 |
| August | 409 | 5.00E+00 | 276 | 50 |
| September | 411 | 5.00E+00 | 260 | 310 |
| October | 424 | 5.00E+00 | 219 | 230 |
| November | 365 | 5.00E+00 | 204 | 261 |
| December | 341 | 5.00E+00 | 169 | 176 |

**Table 6-130: Castor 1200 Payload Pool Evaporation 5-ppm MMH Concentration Summary – Nighttime Meteorology.**

| Month | Number of Weather Cases | Reference MMH Concentration [ppm] | Max Distance to Reference MMH Concentration [m] | Bearing to Reference MMH Concentration [deg] |
|---|---|---|---|---|
| January | 81 | 5.00E+00 | 104 | 40 |
| February | 141 | 5.00E+00 | 115 | 150 |
| March | 144 | 5.00E+00 | 148 | 310 |
| April | 156 | 5.00E+00 | 186 | 100 |
| May | 159 | 5.00E+00 | 217 | 30 |
| June | 153 | 5.00E+00 | 229 | 157 |
| July | 152 | 5.00E+00 | 237 | 133 |
| August | 162 | 5.00E+00 | 222 | 50 |
| September | 161 | 5.00E+00 | 197 | 71 |
| October | 125 | 5.00E+00 | 146 | 270 |
| November | 122 | 5.00E+00 | 141 | 112 |
| December | 113 | 5.00E+00 | 108 | 50 |

The LATRA3D predicted cloud transport directions for the payload evaporating pool MMH dispersion were also aggregated into bins representing 45-degree arc corridors around the compass (i.e. N, NE, E, SE, S, SW, W, NW). Table 6-131 indicates the predicted Castor 1200 payload evaporating pool plume direction probability of occurrence observed across the 4546 daytime balloon sounding cases that produced predicted ground level MMH concentrations above 5 ppm. It is noted that for the daytime payload pool evaporation scenarios transport of the exhaust plume to the North is favored. This is a reflection of prevailing wind directions near the ground surface.

**Table 6-131. LATRA3D Predicted Exhaust Cloud Transport Directions for Daytime Castor 1200 Payload Pool Evaporation MMH Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 997 | 0.21931 |
| 22.5 – 67.5 (NE) | 704 | 0.15486 |
| 67.5 – 112.5 (E) | 558 | 0.12275 |
| 112.5 – 157.5 (SE) | 658 | 0.14474 |
| 157.5 – 202.5 (S) | 538 | 0.11835 |
| 202.5 – 247.5 (SW) | 433 | 0.09525 |
| 247.5 – 292.5 (W) | 404 | 0.08887 |
| 292.5 – 337.5 (NW) | 254 | 0.05587 |

Table 6-132 indicates the predicted Castor 1200 vehicle payload pool evaporation plume direction probability of occurrence observed across the 1669 nighttime balloon sounding cases. It is noted that for nighttime payload pool evaporation scenarios transport of the exhaust plume toward a wide sector from the Northeast clockwise to the South is favored. This is a reflection of prevailing nighttime wind directions near the ground surface.

**Table 6-132. LATRA3D Predicted Exhaust Cloud Transport Directions for Nighttime Castor 1200 Payload Pool Evaporation MMH Scenarios.**

| Plume Transport Direction Bin | Count | Probability |
|---|---|---|
| 337.5 – 22.5 (N) | 168 | 0.10066 |
| 22.5 – 67.5 (NE) | 325 | 0.19473 |
| 67.5 – 112.5 (E) | 266 | 0.15938 |
| 112.5 – 157.5 (SE) | 286 | 0.17136 |
| 157.5 – 202.5 (S) | 287 | 0.17196 |
| 202.5 – 247.5 (SW) | 166 | 0.09946 |
| 247.5 – 292.5 (W) | 111 | 0.06651 |
| 292.5 – 337.5 (NW) | 60 | 0.03595 |

# 7. CONCLUSIONS

Approximately 102,000 REEDM and LATRA3D computer simulations have been executed to assess peak ground level concentrations for HCl, $AL_2O_3$, $NO_2$ and MMH chemicals that are released either as part of normal launch propellant combustion or from catastrophic breakup of a Castor 1200 based launch vehicle and payload. Tables of maximum predicted ground level concentration values are provide for each chemical release scenario and are parsed into daytime versus nighttime weather cases for each month of the year. Some minor trends can be seen in the monthly data that reflect seasonal weather effects. These are not deemed overly significant. Some diurnal effects are also observed between day and night. Toxic transport and dispersion and the formation of the convective boundary layer are very weather dependent. At night stable air layers can form near the ground and these cases can present the most adverse conditions for rocket emissions leading to high ground level concentrations if toxic plume material gets trapped in the surface stable layer.

Not surprisingly, the normal launch scenario generates relatively benign toxic results due to the limited amount of propellant that is burned while the vehicle is ascending through the atmospheric boundary layer (e.g. lower 10,000 feet of the atmosphere). The vehicle catastrophic solid propellant "conflagration" and liquid propellant "deflagration" modes generate some cases where ground level concentrations are high enough to pose a toxic hazard to humans (and presumably other animals). Many of the conflagration and deflagration cases result in low or zero ground level concentrations, however, there are a large enough percentage of cases with higher concentration predictions that can be used to estimate reasonable bounding conditions both in terms of expected maximum exposure concentrations and maximum hazard distances from the source (e.g. launch pad). Readers are referred to the Executive Summary of this document for a more concise summary of the peak concentrations and maximum hazard zone distances.

# 8. REFERENCES


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[5] Hanna, Steven R., David G. Strimaitis, and Jeffrey Weil, *IV&V of LATRA3D Software*, Report No. P122-4, Hanna Consultants, Kennebunkport, ME 04046, March 28, 2010.

[6] Gordon, Sanford and Bonnie J. McBride, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions, Rocket Performance, Incident and Reflected Shocks, and Chapman-Jouguet Detonations", Interim Revision NASA SP-273, Lewis Research Center, Cleveland OH, March 1976.

[7] Gordon, Sanford and Bonnie J. McBride, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions and Applications, I. Analysis", NASA Reference Publication 1311, Lewis Research Center, Cleveland OH, October 1994.

Appendix A

Representative Sample Toxic Hazard Corridors and Concentration Isopleths for Castor 1200 Release Scenarios

## A. Case 1 - Castor 1200 Worst Case Normal Launch HCl Isopleths

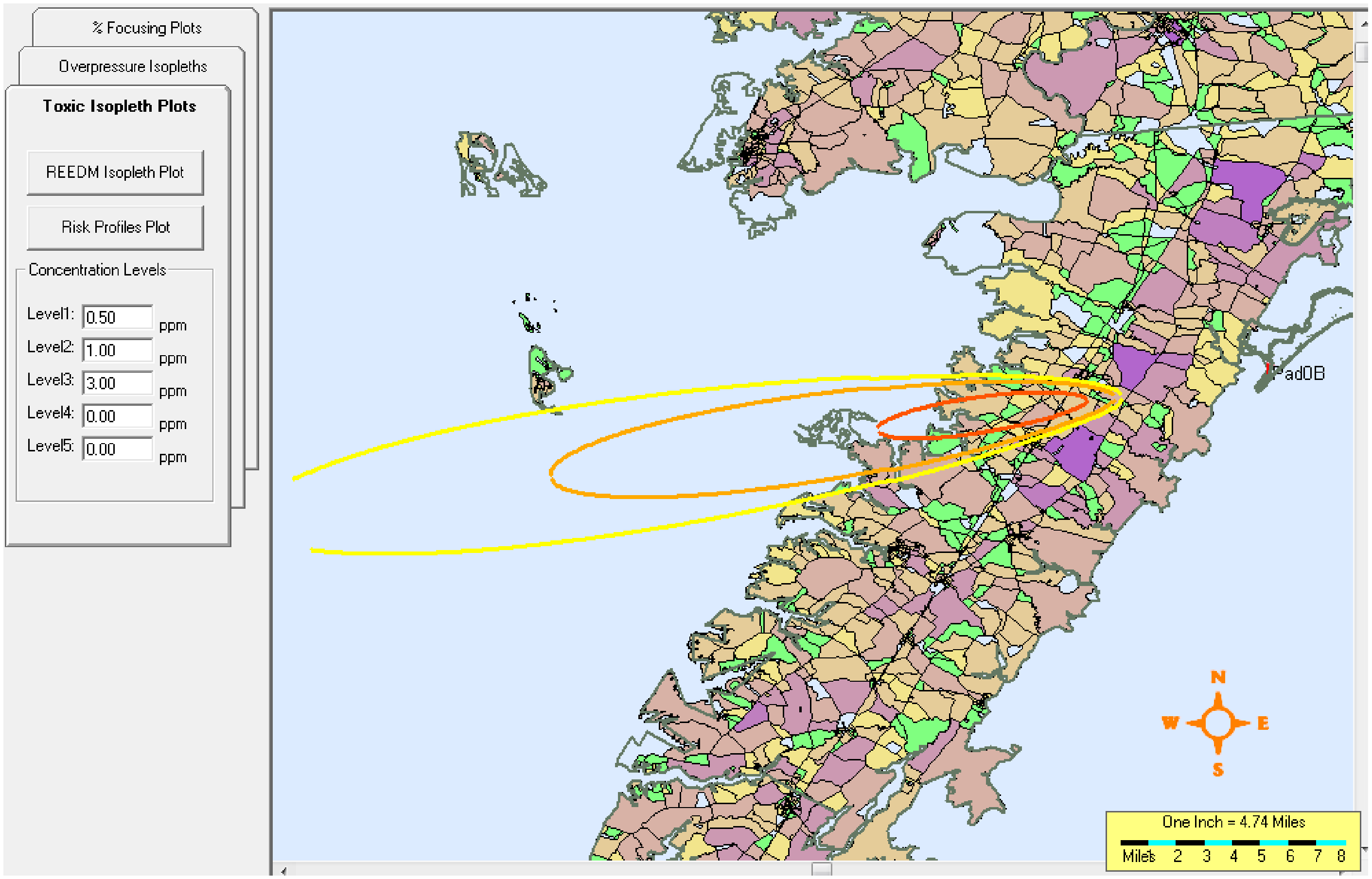


**Figure A - 1. Worst Case Hydrogen Chloride Concentration Contours for the Normal Launch of a Castor 1200 from Wallops Flight Facility.**

Case 1 Discussion

This example plots the 0.5, 1 and 3 ppm ground level HCl isopleths for the meteorological case that generated the worst case peak HCl concentration prediction of 5.03 ppm out of the 6430 cases evaluated. The analysis code used here was REEDM. The normal launch ground cloud centroid was predicted to stabilize at an altitude of 1138 meters above the ground with the bottom of the cloud positioned 733 meters above the ground. REEDM assigned a mixing layer boundary at 1473 meters, effectively trapping the majority of the ground cloud beneath a reflective upper boundary set at 1473 meters. In this case the winds carry the exhaust cloud inland from the WFF launch site along a bearing of 256 degrees.

The surface concentrations of HCl from a normal launch result from emissions of the rocket first stage during lift-off and ascent. The largest portion of exhaust mass is injected into the ground cloud, which is that portion of the nozzle exit flow that interacts with the launch pad structure and ground surface. The ground cloud could potentially interact with deluge water injected into the motor exhaust flame trench and onto the pad structures. In this study any effect of deluge water has been ignored as that amount of deluge water (if any) is as yet undefined. The composition of the gases leaving the Castor 1200 nozzle exit plane is about 20% hydrogen chloride gas by mass. As the rocket ascends away from the launch pad it accelerates and begins to pitch in the downrange direction leaving a contrail of exhaust gases behind the vehicle. The contrail cloud is also considered when performing HCl normal launch dispersion analyses. In this study a launch azimuth of 115 degrees was applied, but the toxic dispersion model for normal launch emissions is relatively insensitive to launch azimuth since the early phase of liftoff has the vehicle climbing nearly vertically above the launch pad and with only a small downrange velocity component after pitch is initiated.

Both the ground cloud and the contrail cloud are buoyant and rise from the launch site to the stabilization altitude of 1138 meters. Atmospheric turbulence eventually mixes the cloud material back down to the ground level. This is predicted to occur about 8000 meters downwind from the launch site (Pad-OA). The maximum predicted ground level concentration is 5.03 ppm, occurring at 16,000 meters downwind. REEDM HCl concentration versus distance predictions for this case are presented in Table A - 1. Note that the predicted cloud passage time is only a few minutes over any given receptor location.

**Table A - 1. REEDM Predicted HCl Concentration Versus Distance for the Normal Launch Worst Case.**

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0
DOWNWIND FROM A CASTOR1200 NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 1472.8 METERS

| RANGE FROM PAD (METERS) | BEARING FROM PAD (DEGREES) | PEAK CONCEN-TRATION (PPM) | CLOUD ARRIVAL TIME (MIN) | CLOUD DEPARTURE TIME (MIN) | |
|---|---|---|---|---|---|
| 8000.0000 | 254.7636 | 0.0017 | 1.8522 | 4.1909 | |
| 9000.9307 | 255.3932 | 0.2098 | 2.3474 | 4.6904 | |
| 10000.1982 | 255.8563 | 1.0785 | 2.8402 | 5.1889 | |
| 11000.0000 | 256.2197 | 2.2862 | 3.3322 | 5.6877 | |
| 12000.1621 | 256.5155 | 3.4056 | 3.8236 | 6.1867 | |
| 13000.3672 | 256.6477 | 4.2454 | 4.3145 | 6.6861 | |
| 14000.2334 | 256.5479 | 4.7665 | 4.8050 | 7.1857 | |
| 15000.6660 | 256.7570 | 5.0076 | 5.2953 | 7.6856 | |
| **16000.5518** | **256.6931** | **5.0327** | **5.7854** | **8.1858** | **←peak concentration** |
| 17000.4551 | 256.6367 | 4.9075 | 6.2754 | 8.6862 | |
| 18000.3730 | 256.5865 | 4.6908 | 6.7652 | 9.1868 | |
| 19000.3047 | 256.5416 | 4.4262 | 7.2549 | 9.6877 | |
| 20000.2461 | 256.5012 | 4.1442 | 7.7446 | 10.1888 | |
| 21000.1953 | 256.4647 | 3.8642 | 8.2342 | 10.6902 | |
| 22000.1543 | 256.4315 | 3.5972 | 8.7237 | 11.1917 | |
| 23000.4570 | 256.4012 | 3.3487 | 9.2127 | 11.6929 | |
| 24000.0898 | 256.3733 | 3.1197 | 9.7027 | 12.1953 | |
| 25000.9570 | 256.7185 | 2.9114 | 10.1921 | 12.6974 | |
| 26000.9199 | 256.6992 | 2.7215 | 10.6815 | 13.1997 | |
| 27000.8867 | 256.6814 | 2.5484 | 11.1709 | 13.7021 | |
| 28000.8535 | 256.6648 | 2.3905 | 11.6602 | 14.2047 | |
| 29000.8242 | 256.6494 | 2.2462 | 12.1495 | 14.7074 | |
| 30000.7969 | 256.6350 | 2.1139 | 12.6389 | 15.2102 | |
| 31000.7715 | 256.6215 | 1.9925 | 13.1282 | 15.7132 | |
| 32000.7480 | 256.6089 | 1.8808 | 13.6175 | 16.2163 | |
| 33000.7266 | 256.5970 | 1.7779 | 14.1067 | 16.7195 | |
| 34000.7031 | 256.5858 | 1.6827 | 14.5960 | 17.2229 | |
| 35000.6836 | 256.5753 | 1.5947 | 15.0853 | 17.7263 | |
| 36000.6641 | 256.5653 | 1.5131 | 15.5745 | 18.2299 | |
| 37000.6484 | 256.5559 | 1.4373 | 16.0638 | 18.7335 | |
| 38000.6289 | 256.5470 | 1.3668 | 16.5530 | 19.2372 | |
| 39000.6133 | 256.5386 | 1.3012 | 17.0422 | 19.7410 | |
| 40000.5977 | 256.5305 | 1.2400 | 17.5315 | 20.2449 | |
| 41000.5820 | 256.5229 | 1.1828 | 18.0207 | 20.7488 | |
| 42000.5703 | 256.5156 | 1.1293 | 18.5099 | 21.2529 | |

| | | | | |
|---|---|---|---|---|
| 43000.5547 | 256.5087 | 1.0792 | 18.9991 | 21.7570 |
| 44000.5430 | 256.5020 | 1.0323 | 19.4883 | 22.2611 |
| 45000.5312 | 256.4957 | 0.9882 | 19.9775 | 22.7654 |
| 46000.5195 | 256.4897 | 0.9468 | 20.4667 | 23.2696 |
| 47000.5078 | 256.4839 | 0.9078 | 20.9559 | 23.7740 |
| 48000.5000 | 256.4783 | 0.8711 | 21.4451 | 24.2784 |
| 49000.4883 | 256.4730 | 0.8365 | 21.9343 | 24.7828 |
| 50000.4766 | 256.4679 | 0.8038 | 22.4235 | 25.2873 |
| 51000.4688 | 256.4630 | 0.7730 | 22.9127 | 25.7918 |
| 52000.4609 | 256.4582 | 0.7438 | 23.4019 | 26.2964 |
| 53000.4531 | 256.4537 | 0.7162 | 23.8911 | 26.8010 |
| 54000.4414 | 256.4493 | 0.6900 | 24.3803 | 27.3057 |
| 55000.4336 | 256.4451 | 0.6653 | 24.8695 | 27.8104 |
| 56000.4258 | 256.4410 | 0.6417 | 25.3586 | 28.3151 |
| 57000.4180 | 256.4371 | 0.6194 | 25.8478 | 28.8199 |
| 58000.4141 | 256.4333 | 0.5982 | 26.3370 | 29.3247 |
| 59000.4062 | 256.4296 | 0.5780 | 26.8262 | 29.8295 |
| 60000.3984 | 256.4261 | 0.5588 | 27.3153 | 30.3343 |

| | RANGE | BEARING |
|---|---|---|
| 5.033 IS THE MAXIMUM PEAK CONCENTRATION | 16000.6 | 256.7 |

## A. Case 2 - Castor 1200 Worst Case Normal Launch $Al_2O_3$ Isopleths

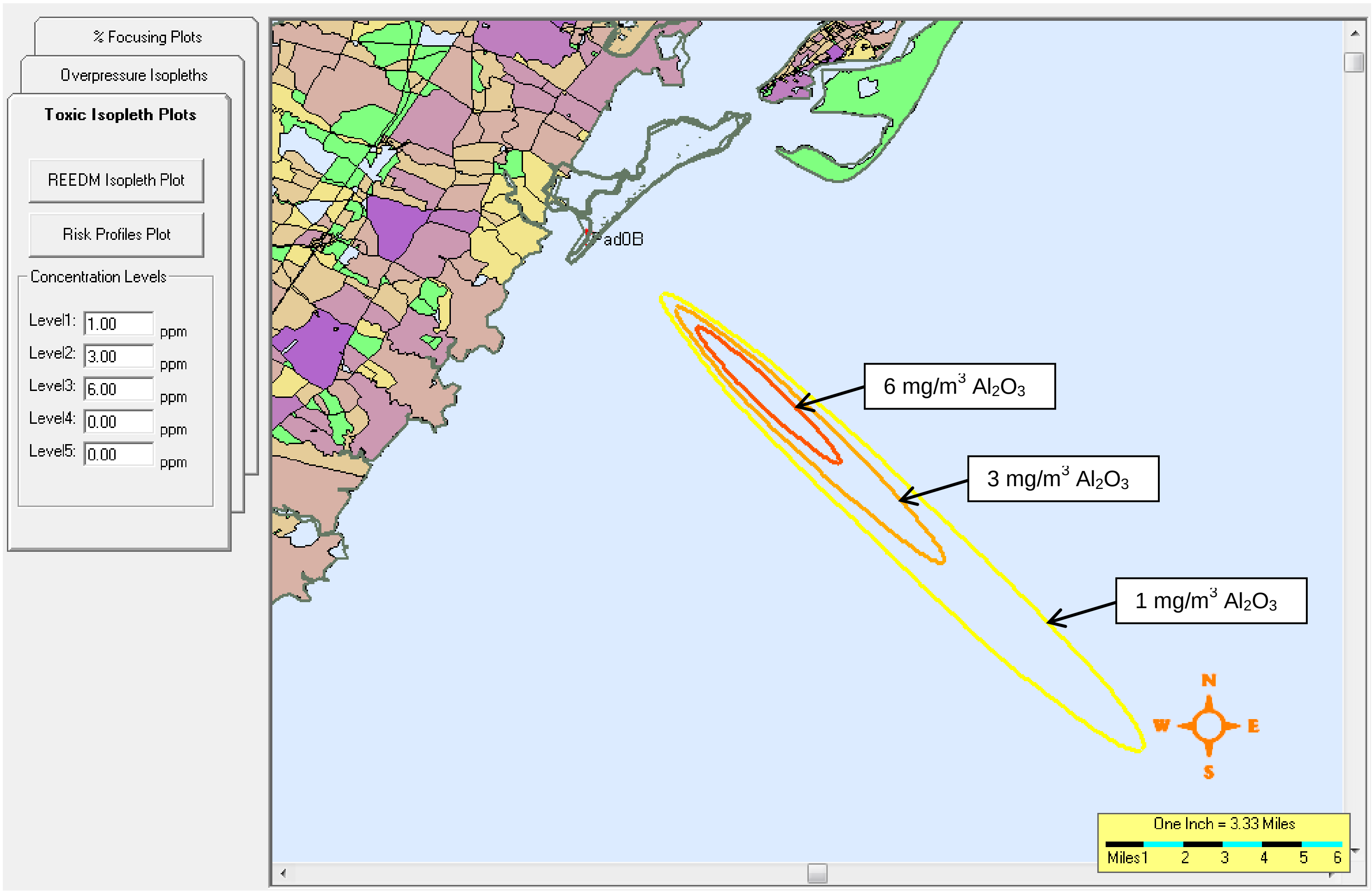


**Figure A - 2. Worst Case Aluminum Oxide Particulate Concentration Contours for the Normal Launch of a Castor 1200 from Wallops Flight Facility.**

Case 2 Discussion – Normal Launch $AL_2O_3$

This example plots the 1, 3 and 6 $mg/m^3$ ground level $AL_2O_3$ isopleths for the meteorological case that generated the worst case peak $AL_2O_3$ concentration prediction of 9.07 $mg/m^3$ out of the 6430 cases evaluated. The analysis code used here was REEDM. The normal launch ground cloud centroid was predicted to stabilize at an altitude of 642 meters above the ground with the bottom of the cloud positioned 419 meters above the ground. REEDM assigned a mixing layer boundary at 314 meters. Although the ground cloud is placed entirely above the mixing boundary layer, the boundary layer is deemed to only prevent gaseous transport across the boundary. Particulate $AL_2O_3$ is allowed by REEDM to pass through the gaseous boundary due to the influence of gravitational settling. The meteorological profile has light wind speeds and very little wind direction shear, which keeps the cloud from spreading out in the horizontal plane. In this case the winds carry the exhaust cloud offshore from the WFF launch site along a bearing of 136 degrees.

The surface concentrations of $AL_2O_3$ from a normal launch result from emissions of the rocket first stage during lift-off and ascent. The largest portion of exhaust mass is injected into the ground cloud, which is that portion of the nozzle exit flow that interacts with the launch pad structure and ground surface. The ground cloud could potentially interact with deluge water injected into the motor exhaust flame trench and onto the pad structures. In this study any effect of deluge water has been ignored as that amount of deluge water (if any) is as yet undefined. The composition of the gases leaving the Castor 1200 nozzle exit plane is about 28% aluminum oxide by mass. As the rocket ascends away from the launch pad it accelerates and begins to pitch in the downrange direction leaving a contrail of exhaust gases behind the vehicle. The contrail cloud up to an altitude of 3000 meters is also considered when performing $AL_2O_3$ normal launch dispersion analyses. In this study a launch azimuth of 115 degrees was applied, but the toxic dispersion model for normal launch emissions is relatively insensitive to launch azimuth since the early phase of liftoff has the vehicle climbing nearly vertically above the launch pad and with only a small downrange velocity component after pitch is initiated.

Both the ground cloud and the contrail cloud are buoyant and rise from the launch site to the stabilization altitude of 642 meters. Atmospheric turbulence eventually mixes the cloud material back down to the ground level. This is predicted to occur about 3000 meters downwind from the launch site (Pad-OA). The maximum predicted ground level concentration is 9.07 $mg/m^3$, occurring at 10,000 meters downwind. REEDM $AL_2O_3$ concentration versus distance predictions for this case are presented in Table A - 2. Note that the predicted cloud passage time is only about 10 minutes at the peak concentration point increasing to about 60 minutes at 60,000 meters downwind.

**Table A - 2. REEDM Predicted $AL_2O_3$ Concentration Versus Distance for the Normal Launch Worst Case.**

```
----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) =  0.00000E+00 **

CONCENTRATION OF AL2O3 AT A HEIGHT OF 0.0
DOWNWIND FROM A CASTOR1200 NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 3007.5 METERS
```

| RANGE FROM PAD (METERS) | BEARING FROM PAD (DEGREES) | PEAK CONCEN-TRATION (MILLI G/ M**3) | CLOUD ARRIVAL TIME (MIN) | CLOUD DEPARTURE TIME (MIN) | |
|---|---|---|---|---|---|
| 3000.0000 | 134.8997 | 0.0289 | 4.3376 | 5.5857 | |
| 4000.0000 | 134.6230 | 0.8472 | 5.9502 | 7.8461 | |
| 5000.0000 | 134.7638 | 2.9236 | 7.2351 | 10.1874 | |
| 6000.0000 | 135.0241 | 5.1650 | 8.4533 | 12.5314 | |
| 7000.0000 | 135.2521 | 6.9702 | 9.4184 | 14.8774 | |
| 8000.0000 | 135.5624 | 8.2030 | 10.3896 | 17.2228 | |
| 9000.0000 | 135.7263 | 8.8792 | 11.4859 | 19.5704 | |
| **10000.0000** | **135.8717** | **9.0713** | **12.7690** | **21.9184** | **←Peak Concentration** |
| 11000.0000 | 135.9805 | 8.8977 | 14.0460 | 24.2716 | |
| 12000.0000 | 136.0801 | 8.4809 | 15.3269 | 26.6205 | |
| 13000.0000 | 136.1547 | 7.9256 | 16.6062 | 28.9703 | |
| 14000.0000 | 136.0536 | 7.3082 | 17.8848 | 31.3204 | |
| 15000.0000 | 136.1093 | 6.6816 | 19.1629 | 33.6706 | |
| 16000.0000 | 136.1581 | 6.0747 | 20.4404 | 36.0210 | |
| 17000.0000 | 136.1705 | 5.5043 | 21.7165 | 38.3728 | |
| 18000.0000 | 136.2082 | 4.9800 | 22.9933 | 40.7235 | |
| 19000.0000 | 136.2424 | 4.5034 | 24.2698 | 43.0742 | |
| 20000.0000 | 136.2727 | 4.0737 | 25.5460 | 45.4251 | |
| 21000.0000 | 136.3005 | 3.6884 | 26.8151 | 47.7843 | |
| 22000.0000 | 136.3254 | 3.3439 | 28.0906 | 50.1357 | |
| 23000.0000 | 136.3482 | 3.0364 | 29.3660 | 52.4871 | |
| 24000.0000 | 136.3687 | 2.7620 | 30.6413 | 54.8386 | |
| 25000.0000 | 136.3879 | 2.5172 | 31.9164 | 57.1901 | |
| 26000.0000 | 136.4056 | 2.2985 | 33.1915 | 59.5416 | |
| 27000.0000 | 136.4219 | 2.1030 | 34.4664 | 61.8932 | |
| 28000.0000 | 136.4367 | 1.9279 | 35.7412 | 64.2448 | |
| 29000.0000 | 136.4509 | 1.7709 | 37.0160 | 66.5964 | |
| 30000.0000 | 136.4642 | 1.6298 | 38.2906 | 68.9481 | |
| 31000.0000 | 136.3198 | 1.5029 | 39.5653 | 71.2997 | |
| 32000.0000 | 136.3311 | 1.3885 | 40.8398 | 73.6514 | |
| 33000.0000 | 136.3423 | 1.2852 | 42.1143 | 76.0031 | |
| 34000.0000 | 136.3523 | 1.1917 | 43.3888 | 78.3548 | |
| 35000.0000 | 136.3622 | 1.1070 | 44.6632 | 80.7065 | |
| 36000.0000 | 136.3716 | 1.0301 | 45.9376 | 83.0582 | |

| | | | | |
|---|---|---|---|---|
| 37000.0000 | 136.3799 | 0.9601 | 47.2119 | 85.4100 |
| 38000.0000 | 136.3884 | 0.8964 | 48.4862 | 87.7617 |
| 39000.0000 | 136.3959 | 0.8383 | 49.7604 | 90.1135 |
| 40000.0000 | 136.4035 | 0.7853 | 51.0347 | 92.4652 |
| 41000.0000 | 136.4103 | 0.7367 | 52.3089 | 94.8170 |
| 42000.0000 | 136.4172 | 0.6922 | 53.5831 | 97.1687 |
| 43000.0000 | 136.4233 | 0.6514 | 54.8572 | 99.5205 |
| 44000.0000 | 136.4296 | 0.6139 | 56.1314 | 101.8723 |
| 45000.0000 | 136.4352 | 0.5794 | 57.4054 | 104.2241 |
| 46000.0000 | 136.4406 | 0.5477 | 58.6795 | 106.5759 |
| 47000.0000 | 136.4461 | 0.5184 | 59.9536 | 108.9277 |
| 48000.0000 | 136.4510 | 0.4913 | 61.2128 | 111.2985 |
| 49000.0000 | 136.4561 | 0.4662 | 62.4866 | 113.6507 |
| 50000.0000 | 136.4606 | 0.4430 | 63.7603 | 116.0030 |
| 51000.0000 | 136.4653 | 0.4214 | 65.0341 | 118.3552 |
| 52000.0000 | 136.4695 | 0.4014 | 66.3078 | 120.7074 |
| 53000.0000 | 136.4735 | 0.3828 | 67.5815 | 123.0597 |
| 54000.0000 | 136.4775 | 0.3654 | 68.8551 | 125.4119 |
| 55000.0000 | 136.4814 | 0.3492 | 70.1288 | 127.7642 |
| 56000.0000 | 136.4853 | 0.3340 | 71.4025 | 130.1164 |
| 57000.0000 | 136.4884 | 0.3199 | 72.6761 | 132.4687 |
| 58000.0000 | 136.4921 | 0.3066 | 73.9498 | 134.8209 |
| 59000.0000 | 136.4956 | 0.2941 | 75.2235 | 137.1731 |
| 60000.0000 | 136.4990 | 0.2824 | 76.4971 | 139.5254 |

| | RANGE | BEARING |
|---|---|---|
| 9.071 IS THE MAXIMUM PEAK CONCENTRATION | 10000.0 | 135.9 |

## A. Case 3 - Castor 1200 Worst Case Conflagration Abort Mode $Al_2O_3$ Isopleths

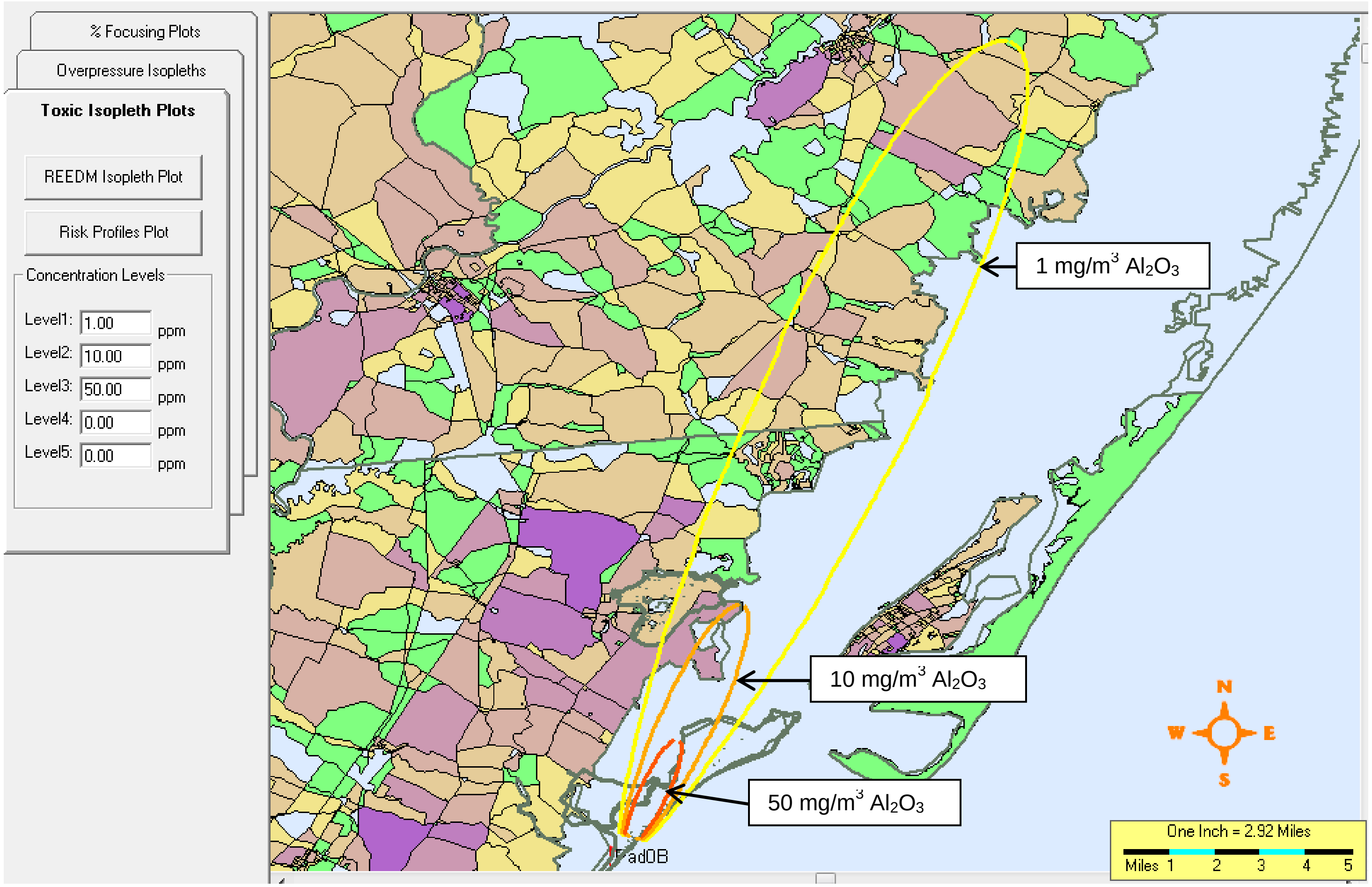


**Figure A - 3. Worst Case Aluminum Oxide Particulate Concentration Contours for a Castor 1200 Conflagration Failure at T+8 Seconds from Wallops Flight Facility.**

Case 3 Discussion – Conflagration Abort Mode $AL_2O_3$

This example plots the 1, 10 and 50 mg/$m^3$ ground level $AL_2O_3$ isopleths for the meteorological case that generated the worst case peak $AL_2O_3$ concentration prediction of 423 mg/$m^3$ given a T+8 second failure time evaluated over 6430 meteorological cases. The analysis code used here was REEDM. The conflagration cloud centroid was predicted to stabilize at an altitude of 48 meters above the ground with the bottom of the cloud contacting the ground. REEDM assigned a mixing layer boundary at 1457 meters. The conflagration cloud stabilized at a low altitude because of the presence of a strong nocturnal stable layer over the lower 130 meters of the atmosphere. The meteorological profile has moderately high wind speeds with very little wind direction shear in the cloud region, which keeps the cloud from spreading out in the horizontal plane. In this case the winds carry the exhaust cloud offshore from the WFF launch site along a bearing of 17 degrees.

The surface concentrations of $AL_2O_3$ from a conflagration event result from emissions of the solid propellant fragments burning on the ground. The failure at 8 seconds in to flight destroys the Castor 1200 generating an estimated 1221 fragments (including the 3 upper stages) with a propellant weight of just over 1.2 million pounds. Explosion induced velocities range from 10 to 243 feet/second. The debris impact area is approximately circular with an estimated radius of 265 meters centered approximately 55 meters downrange of the launch pad. The estimated burn time of the residual propellant burning on the ground is 275 seconds.

The maximum predicted ground level concentration is 423 mg/$m^3$ of $Al_2O_3$, occurring at 1,000 meters downwind. REEDM $AL_2O_3$ concentration versus distance predictions for this case are presented in Table A - 3. There are actually two parts to this table, one for liquid phase $Al_2O_3$ (L) and one for solid alpha phase $Al_2O_3$ (A). The liquid phase is identified by the REEDM internal combustion model as a product of the conflagration burn conditions at adiabatic flame temperature, but this liquid phase will be converted to solid phase as the buoyant plume rises and cools. ACTA summed the two phase concentrations to estimate downwind airborne $Al_2O_3$ particulate concentrations. Note that the predicted cloud passage time is only few minutes near the source at the peak concentration point and increases to about 16 minutes at 30,000 meters downwind. Even though the wind speed is assumed constant, the cloud passage time increases in the downwind direction because the cloud continues to expand horizontally and vertically as it moves downwind.

**Table A - 3. REEDM Predicted $AL_2O_3$ Concentration Versus Distance the Worst Case T+8 Second Castor 1200 Conflagration Failure.**

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF AL2O3(L) AT A HEIGHT OF 0.0
DOWNWIND FROM A CASTOR1200 CONFLAGRATION LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 3016.6 METERS

| RANGE FROM PAD (METERS) | BEARING FROM PAD (DEGREES) | PEAK CONCEN-TRATION (MILLI G/ M**3) | CLOUD ARRIVAL TIME (MIN) | CLOUD DEPARTURE TIME (MIN) | |
|---|---|---|---|---|---|
| **1000.0000** | **16.7844** | **395.5367** | **0.0000** | **3.9721** | **←Peak Concentration** |
| 2000.0000 | 17.1377 | 346.9832 | 0.0000 | 5.3218 | |
| 3000.0000 | 16.7326 | 167.7236 | 0.4792 | 6.6781 | |
| 4000.0000 | 17.1734 | 96.5501 | 1.5084 | 8.0393 | |
| 5000.0000 | 16.8524 | 62.2361 | 2.5346 | 9.4005 | |
| 6000.0000 | 16.8235 | 43.2066 | 3.5564 | 10.7704 | |
| 7000.0000 | 17.1176 | 31.6245 | 4.5734 | 12.1523 | |
| 8000.0000 | 16.9226 | 24.0447 | 5.5908 | 13.5247 | |
| 9000.0000 | 17.0983 | 18.8346 | 6.6037 | 14.9107 | |
| 10000.0000 | 16.8340 | 15.0932 | 7.6150 | 16.2986 | |
| 11000.0000 | 16.9551 | 12.3443 | 8.6289 | 17.6716 | |
| 12000.0000 | 17.0559 | 10.2545 | 9.6381 | 19.0613 | |
| 13000.0000 | 17.1411 | 8.6349 | 10.6465 | 20.4520 | |
| 14000.0000 | 17.2142 | 7.3604 | 11.6540 | 21.8435 | |
| 15000.0000 | 16.8835 | 6.3489 | 12.6661 | 23.2135 | |
| 16000.0000 | 16.9404 | 5.5365 | 13.6729 | 24.6052 | |
| 17000.0000 | 16.9906 | 4.8765 | 14.6793 | 25.9973 | |
| 18000.0000 | 17.0352 | 4.3354 | 15.6852 | 27.3899 | |
| 19000.0000 | 17.0750 | 3.8877 | 16.6909 | 28.7829 | |
| 20000.0000 | 17.1109 | 3.5137 | 17.6962 | 30.1762 | |
| 21000.0000 | 17.1433 | 3.1979 | 18.7013 | 31.5698 | |
| 22000.0000 | 17.1728 | 2.9284 | 19.7061 | 32.9637 | |
| 23000.0000 | 17.1997 | 2.6960 | 20.7108 | 34.3578 | |
| 24000.0000 | 17.2244 | 2.4935 | 21.7153 | 35.7521 | |
| 25000.0000 | 16.8630 | 2.3157 | 22.7196 | 37.1465 | |
| 26000.0000 | 16.8845 | 2.1583 | 23.7325 | 38.5034 | |
| 27000.0000 | 16.9045 | 2.0175 | 24.7369 | 39.8968 | |
| 28000.0000 | 16.9230 | 1.8906 | 25.7413 | 41.2904 | |
| 29000.0000 | 16.9402 | 1.7754 | 26.7455 | 42.6840 | |
| 30000.0000 | 16.9562 | 1.6705 | 27.7497 | 44.0778 | |

| | RANGE | BEARING |
|---|---|---|
| 395.537 IS THE MAXIMUM PEAK CONCENTRATION | 1000.0 | 16.8 |

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF AL2O3(A) AT A HEIGHT OF 0.0
DOWNWIND FROM A CASTOR1200 CONFLAGRATION LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 3016.6 METERS

| RANGE FROM PAD (METERS) | BEARING FROM PAD (DEGREES) | PEAK CONCEN-TRATION (MILLI G/ M**3) | CLOUD ARRIVAL TIME (MIN) | CLOUD DEPARTURE TIME (MIN) | |
|---|---|---|---|---|---|
| **1000.0000** | **16.7844** | **27.6024** | **0.0000** | **3.9721** | **←Peak Concentration** |
| 2000.0000 | 17.1377 | 24.2141 | 0.0000 | 5.3218 | |
| 3000.0000 | 16.7326 | 11.7045 | 0.4792 | 6.6781 | |
| 4000.0000 | 17.1734 | 6.7377 | 1.5084 | 8.0393 | |
| 5000.0000 | 16.8524 | 4.3431 | 2.5346 | 9.4005 | |
| 6000.0000 | 16.8235 | 3.0152 | 3.5564 | 10.7704 | |
| 7000.0000 | 17.1176 | 2.2069 | 4.5734 | 12.1523 | |
| 8000.0000 | 16.9226 | 1.6780 | 5.5908 | 13.5247 | |
| 9000.0000 | 17.0983 | 1.3144 | 6.6037 | 14.9107 | |
| 10000.0000 | 16.8340 | 1.0533 | 7.6150 | 16.2986 | |
| 11000.0000 | 16.9551 | 0.8614 | 8.6289 | 17.6716 | |
| 12000.0000 | 17.0559 | 0.7156 | 9.6381 | 19.0613 | |
| 13000.0000 | 17.1411 | 0.6026 | 10.6465 | 20.4520 | |
| 14000.0000 | 17.2142 | 0.5136 | 11.6540 | 21.8435 | |
| 15000.0000 | 16.8835 | 0.4431 | 12.6661 | 23.2135 | |
| 16000.0000 | 16.9404 | 0.3864 | 13.6729 | 24.6052 | |
| 17000.0000 | 16.9906 | 0.3403 | 14.6793 | 25.9973 | |
| 18000.0000 | 17.0352 | 0.3025 | 15.6852 | 27.3899 | |
| 19000.0000 | 17.0750 | 0.2713 | 16.6909 | 28.7829 | |
| 20000.0000 | 17.1109 | 0.2452 | 17.6962 | 30.1762 | |
| 21000.0000 | 17.1433 | 0.2232 | 18.7013 | 31.5698 | |
| 22000.0000 | 17.1728 | 0.2044 | 19.7061 | 32.9637 | |
| 23000.0000 | 17.1997 | 0.1881 | 20.7108 | 34.3578 | |
| 24000.0000 | 17.2244 | 0.1740 | 21.7153 | 35.7521 | |
| 25000.0000 | 16.8630 | 0.1616 | 22.7196 | 37.1465 | |
| 26000.0000 | 16.8845 | 0.1506 | 23.7325 | 38.5034 | |
| 27000.0000 | 16.9045 | 0.1408 | 24.7369 | 39.8968 | |
| 28000.0000 | 16.9230 | 0.1319 | 25.7413 | 41.2904 | |
| 29000.0000 | 16.9402 | 0.1239 | 26.7455 | 42.6840 | |
| 30000.0000 | 16.9562 | 0.1166 | 27.7497 | 44.0778 | |

| | RANGE | BEARING |
|---|---|---|
| 27.602 IS THE MAXIMUM PEAK CONCENTRATION | 1000.0 | 16.8 |

## A. Case 4 - Castor 1200 Long 1-ppm HCl Isopleth for Conflagration Abort at T+8 Seconds

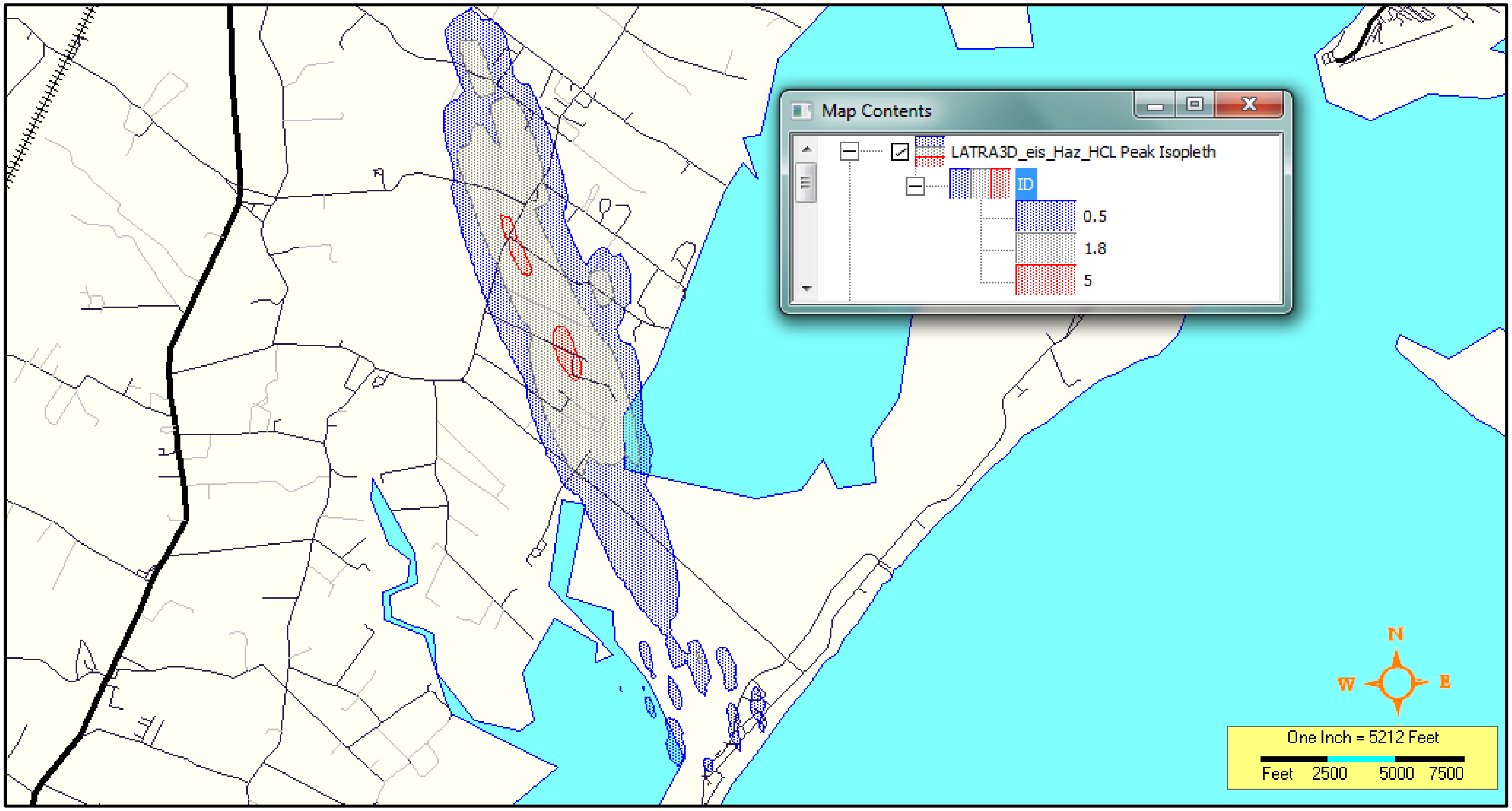


**Figure A - 4. HCl Concentration Contours for a Castor 1200 Conflagration Failure at T+8 Seconds for the Case Yielding a Long 1-ppm HCl Hazard Zone from Wallops Flight Facility.**

Case 4 Discussion – Conflagration Abort Mode HCl

This example plots the 0.5 1.8 (AEGL-1) and 5 ppm ground level HCl isopleths for the meteorological case that generated the longest downwind distance HCl 1 ppm isopleth that extended 8930 meters downwind. The peak HCl concentration level predicted for this case was 6.1 ppm at a range of 5013 meters and a bearing of 337 degrees. The maximum HCl peak concentration over all 6430 meteorological cases evaluated for a T+8 second failure time was 120 ppm but the peak concentration occurred much closer to the source. The analysis code used here was LATRA3D.

The surface concentrations of HCl from a conflagration event result from emissions from a combination of the normal launch emissions to the failure time (e.g. 8 seconds), emissions from the falling solid propellant fragments, and emissions from the solid propellant fragments burning on the ground. The failure at 8 seconds into flight destroys the Castor 1200 generating an estimated 1221 fragments (including the 3 upper stages) with a propellant weight of just over 1.2 million pounds. Explosion induced velocities range from 10 to 243 feet/second. The debris impact area is approximately circular with an estimated radius of 265 meters centered approximately 55 meters downrange of the launch pad. The estimated burn time of the residual propellant burning on the ground is 275 seconds.

The maximum predicted ground level concentration is 6.1 ppm of HCl, occurring at 5013 meters downwind. LATRA3D HCl concentration versus distance predictions for this case are presented in Table A-4. Note that the predicted cloud passage time is about 29 minutes.

**Table A - 4. LATRA3D Predicted HCl Concentration Versus Distance for a Case with a Long 1-ppm Concentration Isopleth Given a T+8 Second Castor 1200 Conflagration Failure.**

```
EXPOSURE GRID DEFINITION:
   UTM ZONE:      17.0
   UTM COORDS OF MIN X,Y (M):  980825.4 4210017.5
   SPACING BETWEEN NODES (M):      80.0      80.0
   NUMBER OF X,Y GRID NODES:        122        28
   X AXIS ORIENTATION WRT EAST (DEG):    -68.5
   EXPOSURE CALCULATION HEIGHT (M):        0.0
   TWA CONC AVERAGING PERIOD (SEC):     3600.0
   UTM COORDS OF PAD X,Y (M):  985200.3 4201711.5

 NUMBER OF SPECIES INCLUDED IN EXPOSURE CALCS:  1
 ORDER OF SPECIES:    HCL
```

MAXIMUM CROSSWIND CONCENTRATION LOCATIONS

| ALONG WIND NODE | RANGE | BEAR | CONC | PUFF TIME (MIN) ARR | DEP |
|---|---|---|---|---|---|
| 119 | 366. | 217. | 4.08E-01 | 3 | 5 |
| 118 | 332. | 229. | 1.39E-01 | 3 | 5 |
| 117 | 30. | 146. | 3.92E-01 | 6 | 7 |
| 116 | 239. | 261. | 7.71E-01 | 7 | 7 |
| 115 | 212. | 30. | 7.28E-01 | 4 | 6 |
| 114 | 269. | 17. | 8.96E-01 | 4 | 6 |
| 113 | 335. | 8. | 1.36E+00 | 4 | 7 |
| 112 | 666. | 282. | 1.39E+00 | 4 | 7 |
| 111 | 663. | 26. | 1.24E+00 | 5 | 7 |
| 110 | 720. | 21. | 1.33E+00 | 7 | 8 |
| 109 | 773. | 301. | 1.30E+00 | 3 | 9 |
| 108 | 837. | 304. | 8.82E-01 | 3 | 9 |
| 107 | 774. | 333. | 6.95E-01 | 8 | 14 |
| 106 | 911. | 360. | 1.20E+00 | 4 | 15 |
| 105 | 982. | 320. | 1.25E+00 | 9 | 12 |
| 104 | 1011. | 339. | 1.10E+00 | 8 | 17 |
| 103 | 1094. | 343. | 1.28E+00 | 3 | 19 |
| 102 | 1174. | 343. | 1.70E+00 | 4 | 20 |
| 101 | 1254. | 343. | 2.36E+00 | 4 | 21 |
| 100 | 1334. | 342. | 1.71E+00 | 5 | 22 |
| 99 | 1419. | 332. | 1.40E+00 | 5 | 21 |
| 98 | 1499. | 333. | 9.94E-01 | 5 | 22 |
| 97 | 1641. | 322. | 7.38E-01 | 8 | 16 |
| 96 | 1659. | 344. | 7.14E-01 | 10 | 26 |
| 95 | 1739. | 344. | 7.46E-01 | 11 | 27 |
| 94 | 1828. | 346. | 7.85E-01 | 11 | 28 |
| 93 | 1907. | 346. | 8.21E-01 | 12 | 29 |
| 92 | 1986. | 346. | 8.61E-01 | 12 | 29 |
| 91 | 2066. | 345. | 8.98E-01 | 13 | 29 |
| 90 | 2145. | 345. | 9.32E-01 | 13 | 29 |
| 89 | 2225. | 345. | 9.61E-01 | 14 | 29 |
| 88 | 2292. | 337. | 1.04E+00 | 14 | 29 |
| 87 | 2372. | 337. | 1.11E+00 | 14 | 29 |
| 86 | 2452. | 337. | 1.21E+00 | 14 | 30 |
| 85 | 2532. | 337. | 1.30E+00 | 15 | 31 |
| 84 | 2612. | 337. | 1.37E+00 | 15 | 32 |
| 83 | 2692. | 337. | 1.43E+00 | 16 | 33 |
| 82 | 2772. | 337. | 1.49E+00 | 16 | 34 |
| 81 | 2852. | 337. | 1.56E+00 | 17 | 35 |
| 80 | 2932. | 337. | 1.64E+00 | 17 | 36 |
| 79 | 3012. | 337. | 1.63E+00 | 18 | 36 |
| 78 | 3092. | 337. | 1.73E+00 | 18 | 37 |
| 77 | 3175. | 336. | 1.78E+00 | 19 | 38 |
| 76 | 3254. | 336. | 1.59E+00 | 19 | 38 |
| 75 | 3334. | 336. | 1.65E+00 | 20 | 39 |
| 74 | 3414. | 336. | 1.68E+00 | 20 | 40 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 73 | 3495. | 341. | 1.85E+00 | 22 | 45 | |
| 72 | 3575. | 341. | 2.33E+00 | 23 | 46 | |
| 71 | 3655. | 341. | 2.70E+00 | 23 | 47 | |
| 70 | 3735. | 341. | 2.83E+00 | 24 | 48 | |
| 69 | 3811. | 339. | 3.22E+00 | 24 | 49 | |
| 68 | 3891. | 339. | 3.55E+00 | 24 | 50 | |
| 67 | 3972. | 337. | 3.98E+00 | 24 | 47 | |
| 66 | 4051. | 338. | 4.09E+00 | 25 | 48 | |
| 65 | 4131. | 338. | 4.30E+00 | 25 | 48 | |
| 64 | 4211. | 338. | 4.69E+00 | 25 | 49 | |
| 63 | 4291. | 338. | 4.70E+00 | 26 | 51 | |
| 62 | 4371. | 338. | 4.83E+00 | 26 | 52 | |
| 61 | 4451. | 338. | 4.77E+00 | 27 | 54 | |
| 60 | 4531. | 338. | 4.78E+00 | 27 | 55 | |
| 59 | 4611. | 338. | 4.82E+00 | 28 | 55 | |
| 58 | 4693. | 337. | 4.95E+00 | 28 | 56 | |
| 57 | 4773. | 337. | 5.44E+00 | 29 | 57 | |
| 56 | 4853. | 337. | 5.77E+00 | 29 | 58 | |
| 55 | 4933. | 337. | 6.04E+00 | 30 | 58 | |
| **54** | **5013.** | **337.** | **6.14E+00** | **30** | **59** | **← Peak Concentration Point** |
| 53 | 5093. | 337. | 6.02E+00 | 31 | 60 | |
| 52 | 5173. | 337. | 5.76E+00 | 31 | 60 | |
| 51 | 5253. | 337. | 5.62E+00 | 32 | 61 | |
| 50 | 5333. | 337. | 5.11E+00 | 33 | 62 | |
| 49 | 5413. | 337. | 4.73E+00 | 33 | 62 | |
| 48 | 5493. | 337. | 4.46E+00 | 34 | 63 | |
| 47 | 5573. | 337. | 4.23E+00 | 39 | 64 | |
| 46 | 5653. | 337. | 3.82E+00 | 40 | 64 | |
| 45 | 5736. | 336. | 3.93E+00 | 40 | 64 | |
| 44 | 5816. | 336. | 4.23E+00 | 40 | 64 | |
| 43 | 5895. | 336. | 4.47E+00 | 40 | 64 | |
| 42 | 5975. | 336. | 4.80E+00 | 40 | 64 | |
| 41 | 6055. | 336. | 5.17E+00 | 41 | 65 | |
| 40 | 6135. | 336. | 5.28E+00 | 41 | 66 | |
| 39 | 6215. | 336. | 5.27E+00 | 42 | 66 | |
| 38 | 6299. | 336. | 5.19E+00 | 42 | 67 | |
| 37 | 6379. | 336. | 5.30E+00 | 42 | 67 | |
| 36 | 6458. | 336. | 5.13E+00 | 43 | 68 | |
| 35 | 6538. | 336. | 5.23E+00 | 43 | 68 | |
| 34 | 6618. | 336. | 5.23E+00 | 44 | 71 | |
| 33 | 6698. | 336. | 5.11E+00 | 44 | 72 | |
| 32 | 6778. | 336. | 5.00E+00 | 45 | 72 | |
| 31 | 6858. | 336. | 4.79E+00 | 45 | 73 | |
| 30 | 6938. | 336. | 4.55E+00 | 46 | 74 | |
| 29 | 7018. | 336. | 4.19E+00 | 46 | 75 | |
| 28 | 7098. | 336. | 3.93E+00 | 47 | 75 | |
| 27 | 7178. | 336. | 3.64E+00 | 48 | 76 | |
| 26 | 7251. | 339. | 3.23E+00 | 55 | 87 | |
| 25 | 7331. | 339. | 3.33E+00 | 56 | 88 | |
| 24 | 7411. | 339. | 3.37E+00 | 57 | 89 | |
| 23 | 7491. | 339. | 3.38E+00 | 58 | 89 | |
| 22 | 7573. | 340. | 3.42E+00 | 60 | 90 | |
| 21 | 7653. | 340. | 3.63E+00 | 61 | 90 | |

| | | | | | |
|---|---|---|---|---|---|
| 20 | 7733. | 340. | 3.41E+00 | 65 | 90 |
| 19 | 7811. | 339. | 3.24E+00 | 65 | 90 |
| 18 | 7891. | 339. | 2.89E+00 | 66 | 90 |
| 17 | 7971. | 339. | 2.36E+00 | 66 | 90 |
| 16 | 8055. | 340. | 1.29E+00 | 69 | 90 |
| 15 | 8131. | 339. | 2.25E+00 | 68 | 92 |
| 14 | 8211. | 339. | 2.69E+00 | 69 | 92 |
| 13 | 8291. | 339. | 2.82E+00 | 69 | 93 |
| 12 | 8371. | 339. | 2.67E+00 | 71 | 93 |
| 11 | 8451. | 339. | 2.62E+00 | 71 | 94 |
| 10 | 8531. | 338. | 2.57E+00 | 72 | 94 |
| 9 | 8611. | 338. | 2.53E+00 | 72 | 95 |
| 8 | 8691. | 338. | 2.36E+00 | 74 | 95 |
| 7 | 8771. | 338. | 1.85E+00 | 74 | 95 |
| 6 | 8851. | 338. | 1.61E+00 | 74 | 95 |
| 5 | 8931. | 338. | 9.85E-01 | 74 | 95 |
| 4 | 9012. | 340. | 7.04E-01 | 85 | 89 |
| 3 | 9092. | 340. | 5.14E-01 | 85 | 89 |
| 2 | 9171. | 339. | 2.78E-01 | 86 | 89 |
| 1 | 9259. | 336. | 1.03E-01 | 75 | 78 |
| 0 | 9339. | 336. | 9.97E-02 | 76 | 78 |

MAXIMUM HCL CONC 6.14E+00 AT RANGE 5013. M, BEARING 337. DEG
PUFF ARRIVAL AT 30, DEPARTURE AT 59 MIN

**A. Case 5 - Castor 1200 Worst Case Payload Deflagration Abort Mode $NO_2$ and MMH Isopleths**

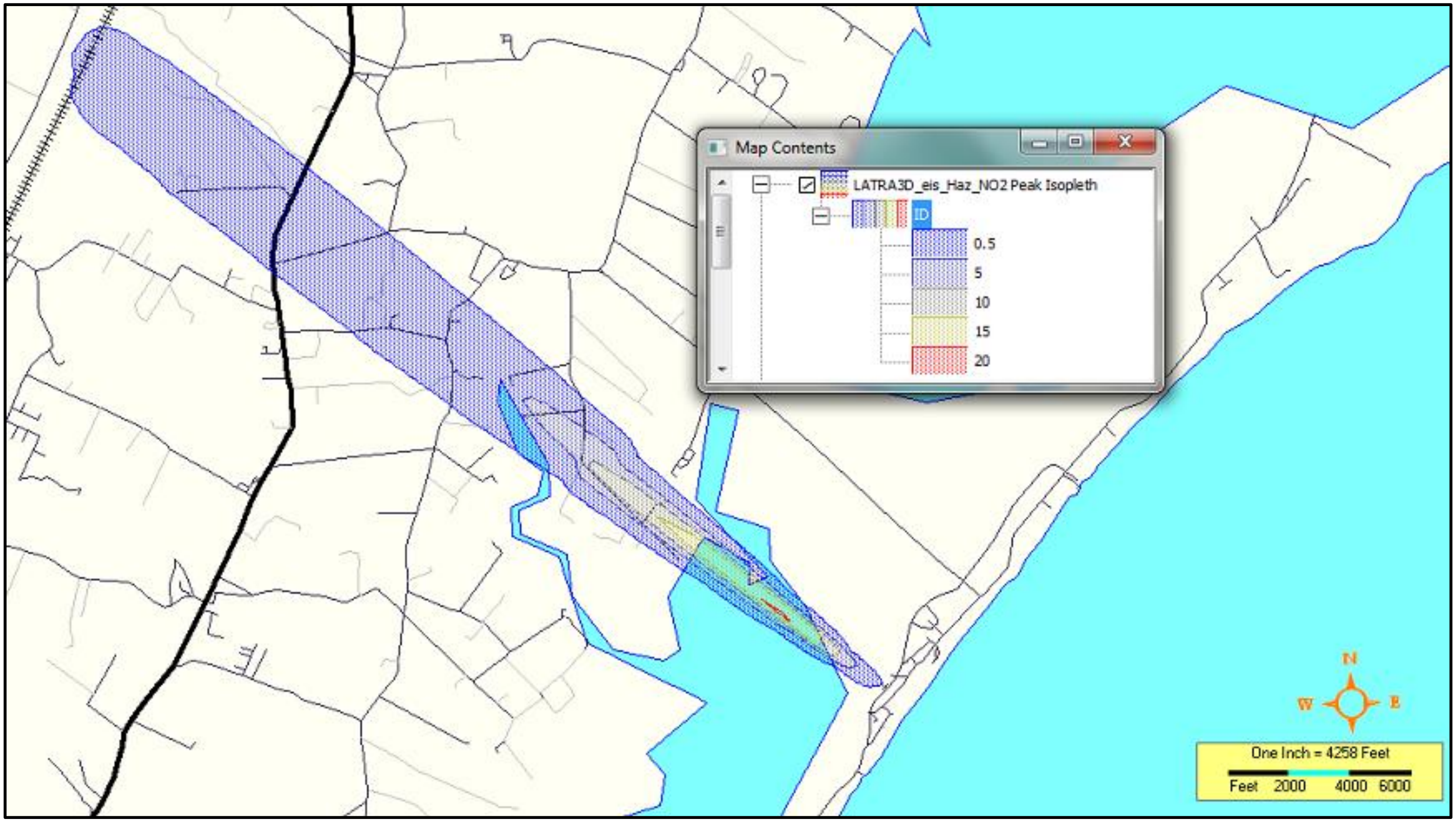


**Figure A - 5. $NO_2$ Concentration Contours for a Castor 1200 Payload Deflagration Failure for a Case Yielding a Long 0.5-ppm $NO_2$ Hazard Zone from Wallops Flight Facility.**

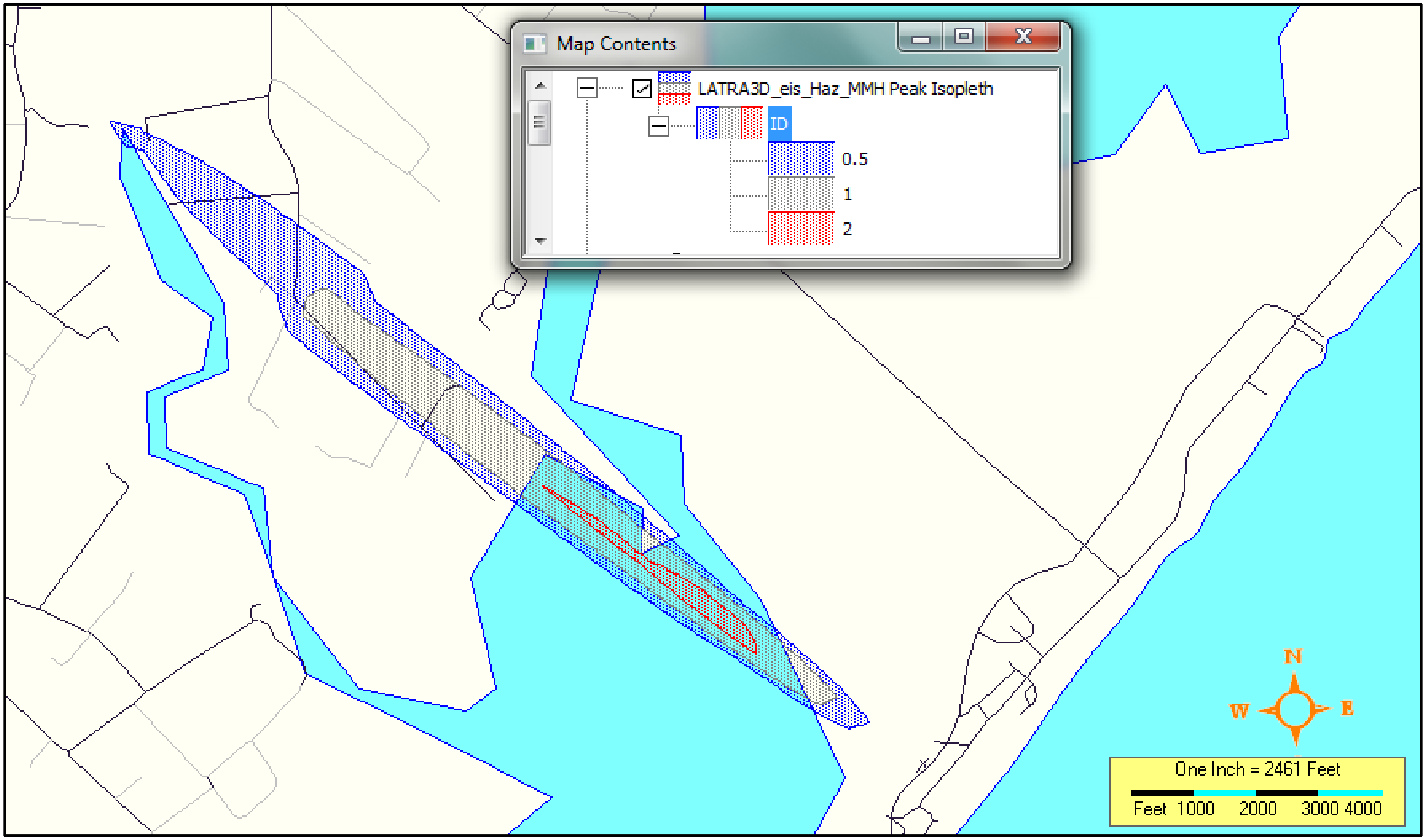


**Figure A - 6. MMH Concentration Contours for a Castor 1200 Payload Deflagration Failure for a Case Yielding a Long 0.5-ppm MMH Hazard Zone from Wallops Flight Facility.**

Case 5 Discussion – Payload Deflagration Abort Mode Producing $NO_2$ and MMH.

This example plots the 0.5 5, 10 15 and 20 ppm ground level $NO_2$ isopleths for the meteorological case that generated the longest downwind distance $NO_2$ 0.5 ppm isopleth that extended 10700 meters downwind. The peak $NO_2$ concentration level predicted for this case was 20.5 ppm at a range of 1547 meters and a bearing of 305 degrees. The maximum $NO_2$ peak concentration over all 6430 meteorological cases evaluated for the payload deflagration failure mode was 41.9 ppm. The case presented here represents approximately a 99$^{th}$ percentile case with regard to peak $NO_2$ concentration. The analysis code used here was LATRA3D. The deflagration cloud is assumed to form when an intact payload ejected for a breakup of the launch vehicle impacts the ground rupturing the Hygergol tanks resulting in propellant mixing and a propellant fireball.

The same event deflagration event produces residual unreacted vapor phase MMH that is assumed to travel downwind in conjunction with the $NO_2$ cloud. The peak MMH concentration for this case is predicted to be 2.25 ppm located at the same point of maximum concentration as the $NO_2$ cloud (1547 meters downwind on a bearing of 305 degrees).

LATRA3D $NO_2$ and MMH concentrations versus distance predictions for this case are presented in Table A-5. Note that the predicted cloud passage time is short, only about 3 minutes, due to the small size of the deflagration cloud.

**Table A - 5. LATRA3D Predicted $NO_2$ and MMH Concentrations Versus Distance for a Case with a Long 0.5-ppm $NO_2$ Concentration Isopleth Given a Payload Deflagration Failure.**

```
EXPOSURE GRID DEFINITION:
   UTM ZONE:      17.0
   UTM COORDS OF MIN X,Y (M):  975876.4 4207721.0
   SPACING BETWEEN NODES (M):      80.0      80.0
   NUMBER OF X,Y GRID NODES:        139        21
   X AXIS ORIENTATION WRT EAST (DEG):    -36.8
   EXPOSURE CALCULATION HEIGHT (M):        0.0
   TWA CONC AVERAGING PERIOD (SEC):       90.0
   UTM COORDS OF PAD X,Y (M):  985200.3 4201711.5

 NUMBER OF SPECIES INCLUDED IN EXPOSURE CALCS:  2
 ORDER OF SPECIES:    MMH       NO2
```

MAXIMUM CROSSWIND CONCENTRATION LOCATIONS

| ALONG WIND NODE | RANGE | BEAR | CONC | PUFF TIME (MIN) ARR | DEP | RANGE | BEAR | CONC | ARR | DEP | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 137 | 110. | 323. | 9.49E-03 | 1 | 1 | 110. | 323. | 8.65E-02 | 1 | 1 | |
| 136 | 189. | 316. | 2.71E-02 | 1 | 2 | 189. | 316. | 2.47E-01 | 1 | 2 | |
| 135 | 268. | 313. | 7.25E-02 | 1 | 2 | 268. | 313. | 6.61E-01 | 1 | 2 | |
| 134 | 347. | 312. | 1.55E-01 | 2 | 3 | 347. | 312. | 1.41E+00 | 2 | 3 | |
| 133 | 427. | 311. | 2.79E-01 | 2 | 4 | 427. | 311. | 2.54E+00 | 2 | 4 | |
| 132 | 507. | 310. | 4.43E-01 | 2 | 4 | 507. | 310. | 4.03E+00 | 2 | 4 | |
| 131 | 587. | 310. | 6.36E-01 | 3 | 5 | 587. | 310. | 5.80E+00 | 3 | 5 | |
| 130 | 667. | 309. | 8.47E-01 | 3 | 5 | 667. | 309. | 7.72E+00 | 3 | 5 | |
| 129 | 747. | 309. | 1.06E+00 | 4 | 6 | 747. | 309. | 9.67E+00 | 4 | 6 | |
| 128 | 827. | 309. | 1.27E+00 | 4 | 6 | 827. | 309. | 1.16E+01 | 4 | 6 | |
| 127 | 907. | 309. | 1.46E+00 | 4 | 7 | 907. | 309. | 1.33E+01 | 4 | 7 | |
| 126 | 987. | 309. | 1.62E+00 | 5 | 7 | 987. | 309. | 1.48E+01 | 5 | 7 | |
| 125 | 1067. | 304. | 1.81E+00 | 5 | 8 | 1067. | 304. | 1.65E+01 | 5 | 8 | |
| 124 | 1147. | 304. | 1.96E+00 | 6 | 9 | 1147. | 304. | 1.79E+01 | 6 | 9 | |
| 123 | 1227. | 304. | 2.08E+00 | 6 | 9 | 1227. | 304. | 1.89E+01 | 6 | 9 | |
| 122 | 1307. | 305. | 2.17E+00 | 7 | 10 | 1307. | 305. | 1.97E+01 | 7 | 10 | |
| 121 | 1387. | 305. | 2.22E+00 | 7 | 10 | 1387. | 305. | 2.02E+01 | 7 | 10 | |
| 120 | 1467. | 305. | 2.25E+00 | 7 | 11 | 1467. | 305. | 2.05E+01 | 7 | 11 | |
| **119** | **1547.** | **305.** | **2.25E+00** | **8** | **11** | **1547.** | **305.** | **2.05E+01** | **8** | **11** | **←Peak Conc.** |
| 118 | 1627. | 305. | 2.24E+00 | 8 | 12 | 1627. | 305. | 2.04E+01 | 8 | 12 | |
| 117 | 1707. | 305. | 2.21E+00 | 9 | 12 | 1707. | 305. | 2.01E+01 | 9 | 12 | |
| 116 | 1787. | 305. | 2.17E+00 | 9 | 13 | 1787. | 305. | 1.98E+01 | 9 | 13 | |
| 115 | 1867. | 305. | 2.12E+00 | 10 | 13 | 1867. | 305. | 1.93E+01 | 10 | 13 | |
| 114 | 1947. | 305. | 2.11E+00 | 10 | 14 | 1947. | 305. | 1.92E+01 | 10 | 14 | |
| 113 | 2027. | 305. | 2.13E+00 | 10 | 15 | 2027. | 305. | 1.93E+01 | 10 | 15 | |
| 112 | 2107. | 305. | 2.13E+00 | 11 | 15 | 2107. | 305. | 1.94E+01 | 11 | 15 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 2187. | 305. | 2.12E+00 | 11 | 16 | 2187. | 305. | 1.93E+01 | 11 | 16 |
| 110 | 2267. | 306. | 2.10E+00 | 12 | 16 | 2267. | 306. | 1.91E+01 | 12 | 16 |
| 109 | 2347. | 306. | 2.08E+00 | 12 | 17 | 2347. | 306. | 1.89E+01 | 12 | 17 |
| 108 | 2427. | 306. | 2.04E+00 | 13 | 17 | 2427. | 306. | 1.86E+01 | 13 | 17 |
| 107 | 2507. | 306. | 2.00E+00 | 13 | 18 | 2507. | 306. | 1.82E+01 | 13 | 18 |
| 106 | 2587. | 306. | 1.96E+00 | 13 | 18 | 2587. | 306. | 1.78E+01 | 13 | 18 |
| 105 | 2667. | 306. | 1.91E+00 | 14 | 19 | 2667. | 306. | 1.74E+01 | 14 | 19 |
| 104 | 2747. | 306. | 1.86E+00 | 14 | 19 | 2747. | 306. | 1.69E+01 | 14 | 19 |
| 103 | 2827. | 306. | 1.81E+00 | 15 | 20 | 2827. | 306. | 1.65E+01 | 15 | 20 |
| 102 | 2907. | 306. | 1.76E+00 | 15 | 20 | 2907. | 306. | 1.60E+01 | 15 | 20 |
| 101 | 2987. | 306. | 1.71E+00 | 16 | 21 | 2987. | 306. | 1.55E+01 | 16 | 21 |
| 100 | 3067. | 306. | 1.66E+00 | 16 | 21 | 3067. | 306. | 1.51E+01 | 16 | 21 |
| 99 | 3147. | 306. | 1.61E+00 | 16 | 22 | 3147. | 306. | 1.46E+01 | 16 | 22 |
| 98 | 3227. | 306. | 1.56E+00 | 17 | 22 | 3227. | 306. | 1.42E+01 | 17 | 22 |
| 97 | 3307. | 306. | 1.51E+00 | 17 | 23 | 3307. | 306. | 1.37E+01 | 17 | 23 |
| 96 | 3387. | 306. | 1.46E+00 | 18 | 24 | 3387. | 306. | 1.33E+01 | 18 | 24 |
| 95 | 3467. | 306. | 1.42E+00 | 18 | 25 | 3467. | 306. | 1.29E+01 | 18 | 25 |
| 94 | 3547. | 306. | 1.37E+00 | 19 | 25 | 3547. | 306. | 1.25E+01 | 19 | 25 |
| 93 | 3626. | 306. | 1.33E+00 | 19 | 26 | 3626. | 306. | 1.21E+01 | 19 | 26 |
| 92 | 3706. | 306. | 1.29E+00 | 20 | 26 | 3706. | 306. | 1.17E+01 | 20 | 26 |
| 91 | 3786. | 306. | 1.25E+00 | 20 | 27 | 3786. | 306. | 1.13E+01 | 20 | 27 |
| 90 | 3866. | 306. | 1.22E+00 | 20 | 27 | 3866. | 306. | 1.10E+01 | 20 | 27 |
| 89 | 3946. | 306. | 1.19E+00 | 21 | 28 | 3946. | 306. | 1.08E+01 | 21 | 28 |
| 88 | 4026. | 307. | 8.95E-01 | 21 | 29 | 4026. | 307. | 8.11E+00 | 21 | 29 |
| 87 | 4106. | 307. | 8.53E-01 | 22 | 29 | 4106. | 307. | 7.74E+00 | 22 | 29 |
| 86 | 4186. | 307. | 8.14E-01 | 22 | 30 | 4186. | 307. | 7.38E+00 | 22 | 30 |
| 85 | 4266. | 307. | 7.77E-01 | 23 | 30 | 4266. | 307. | 7.04E+00 | 23 | 30 |
| 84 | 4346. | 307. | 7.44E-01 | 23 | 31 | 4346. | 307. | 6.75E+00 | 23 | 31 |
| 83 | 4426. | 307. | 7.12E-01 | 24 | 31 | 4426. | 307. | 6.45E+00 | 24 | 31 |
| 82 | 4506. | 307. | 6.81E-01 | 24 | 32 | 4506. | 307. | 6.17E+00 | 24 | 32 |
| 81 | 4586. | 307. | 6.52E-01 | 24 | 32 | 4586. | 307. | 5.91E+00 | 24 | 32 |
| 80 | 4666. | 307. | 6.25E-01 | 25 | 33 | 4666. | 307. | 5.66E+00 | 25 | 33 |
| 79 | 4746. | 307. | 5.99E-01 | 25 | 33 | 4746. | 307. | 5.43E+00 | 25 | 33 |
| 78 | 4826. | 307. | 5.75E-01 | 25 | 34 | 4826. | 307. | 5.21E+00 | 25 | 34 |
| 77 | 4906. | 307. | 5.52E-01 | 26 | 35 | 4906. | 307. | 5.00E+00 | 26 | 35 |
| 76 | 4986. | 307. | 5.30E-01 | 26 | 35 | 4986. | 307. | 4.80E+00 | 26 | 35 |
| 75 | 5066. | 307. | 5.08E-01 | 27 | 36 | 5066. | 307. | 4.60E+00 | 27 | 36 |
| 74 | 5146. | 307. | 5.26E-01 | 27 | 36 | 5146. | 307. | 4.76E+00 | 27 | 36 |
| 73 | 5226. | 307. | 5.11E-01 | 28 | 37 | 5226. | 307. | 4.63E+00 | 28 | 37 |
| 72 | 5306. | 307. | 4.96E-01 | 28 | 37 | 5306. | 307. | 4.49E+00 | 28 | 37 |
| 71 | 5386. | 307. | 4.82E-01 | 28 | 38 | 5386. | 307. | 4.36E+00 | 28 | 38 |
| 70 | 5466. | 307. | 4.69E-01 | 29 | 38 | 5466. | 307. | 4.24E+00 | 29 | 38 |
| 69 | 5546. | 307. | 4.56E-01 | 29 | 39 | 5546. | 307. | 4.12E+00 | 29 | 39 |
| 68 | 5626. | 307. | 4.43E-01 | 30 | 39 | 5626. | 307. | 4.01E+00 | 30 | 39 |
| 67 | 5706. | 307. | 4.31E-01 | 30 | 40 | 5706. | 307. | 3.90E+00 | 30 | 40 |
| 66 | 5786. | 307. | 4.21E-01 | 31 | 40 | 5786. | 307. | 3.81E+00 | 31 | 40 |
| 65 | 5866. | 307. | 4.13E-01 | 31 | 41 | 5866. | 307. | 3.73E+00 | 31 | 41 |
| 64 | 5946. | 307. | 4.04E-01 | 32 | 41 | 5946. | 307. | 3.66E+00 | 32 | 41 |
| 63 | 6026. | 307. | 3.96E-01 | 32 | 42 | 6026. | 307. | 3.58E+00 | 32 | 42 |
| 62 | 6106. | 306. | 3.90E-01 | 33 | 42 | 6106. | 306. | 3.53E+00 | 33 | 42 |
| 61 | 6186. | 306. | 3.85E-01 | 33 | 43 | 6186. | 306. | 3.48E+00 | 33 | 43 |
| 60 | 6266. | 306. | 3.79E-01 | 33 | 43 | 6266. | 306. | 3.43E+00 | 33 | 43 |
| 59 | 6346. | 307. | 3.79E-01 | 34 | 44 | 6346. | 307. | 3.43E+00 | 34 | 44 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 58 | 6426. | 307. | 3.86E-01 | 34 | 44 | 6426. | 307. | 3.49E+00 | 34 | 44 |
| 57 | 6506. | 307. | 3.78E-01 | 35 | 45 | 6506. | 307. | 3.42E+00 | 35 | 45 |
| 56 | 6586. | 307. | 3.70E-01 | 35 | 45 | 6586. | 307. | 3.35E+00 | 35 | 45 |
| 55 | 6666. | 307. | 3.63E-01 | 36 | 46 | 6666. | 307. | 3.28E+00 | 36 | 46 |
| 54 | 6746. | 306. | 3.56E-01 | 36 | 46 | 6746. | 306. | 3.21E+00 | 36 | 46 |
| 53 | 6826. | 306. | 3.49E-01 | 37 | 47 | 6826. | 306. | 3.15E+00 | 37 | 47 |
| 52 | 6906. | 306. | 3.42E-01 | 37 | 47 | 6906. | 306. | 3.09E+00 | 37 | 47 |
| 51 | 6986. | 306. | 3.37E-01 | 37 | 48 | 6986. | 306. | 3.05E+00 | 37 | 48 |
| 50 | 7066. | 306. | 3.31E-01 | 38 | 48 | 7066. | 306. | 2.99E+00 | 38 | 48 |
| 49 | 7146. | 306. | 3.25E-01 | 39 | 49 | 7146. | 306. | 2.93E+00 | 39 | 49 |
| 48 | 7226. | 306. | 3.18E-01 | 39 | 49 | 7226. | 306. | 2.88E+00 | 39 | 49 |
| 47 | 7306. | 306. | 3.12E-01 | 40 | 50 | 7306. | 306. | 2.82E+00 | 40 | 50 |
| 46 | 7386. | 306. | 3.06E-01 | 40 | 50 | 7386. | 306. | 2.77E+00 | 40 | 50 |
| 45 | 7466. | 306. | 3.00E-01 | 40 | 51 | 7466. | 306. | 2.71E+00 | 40 | 51 |
| 44 | 7546. | 306. | 2.94E-01 | 41 | 51 | 7546. | 306. | 2.66E+00 | 41 | 51 |
| 43 | 7626. | 307. | 2.91E-01 | 41 | 52 | 7626. | 307. | 2.62E+00 | 41 | 52 |
| 42 | 7706. | 306. | 2.88E-01 | 42 | 52 | 7706. | 306. | 2.60E+00 | 42 | 52 |
| 41 | 7786. | 306. | 2.83E-01 | 42 | 53 | 7786. | 306. | 2.55E+00 | 42 | 53 |
| 40 | 7866. | 306. | 2.78E-01 | 42 | 53 | 7866. | 306. | 2.50E+00 | 42 | 53 |
| 39 | 7946. | 306. | 2.72E-01 | 43 | 54 | 7946. | 306. | 2.46E+00 | 43 | 54 |
| 38 | 8026. | 306. | 2.67E-01 | 43 | 54 | 8026. | 306. | 2.41E+00 | 43 | 54 |
| 37 | 8106. | 306. | 2.62E-01 | 44 | 55 | 8106. | 306. | 2.36E+00 | 44 | 55 |
| 36 | 8186. | 306. | 2.57E-01 | 44 | 55 | 8186. | 306. | 2.32E+00 | 44 | 55 |
| 35 | 8266. | 307. | 2.52E-01 | 45 | 56 | 8266. | 307. | 2.27E+00 | 45 | 56 |
| 34 | 8346. | 307. | 2.47E-01 | 45 | 56 | 8346. | 307. | 2.23E+00 | 45 | 56 |
| 33 | 8426. | 307. | 2.44E-01 | 46 | 57 | 8426. | 307. | 2.20E+00 | 46 | 57 |
| 32 | 8506. | 306. | 2.43E-01 | 46 | 57 | 8506. | 306. | 2.19E+00 | 46 | 57 |
| 31 | 8586. | 306. | 2.39E-01 | 47 | 58 | 8586. | 306. | 2.15E+00 | 47 | 58 |
| 30 | 8666. | 306. | 2.35E-01 | 47 | 58 | 8666. | 306. | 2.12E+00 | 47 | 58 |
| 29 | 8746. | 306. | 2.31E-01 | 48 | 59 | 8746. | 306. | 2.08E+00 | 48 | 59 |
| 28 | 8826. | 306. | 2.27E-01 | 48 | 59 | 8826. | 306. | 2.05E+00 | 48 | 59 |
| 27 | 8906. | 306. | 2.25E-01 | 49 | 60 | 8906. | 306. | 2.03E+00 | 49 | 60 |
| 26 | 8986. | 307. | 2.20E-01 | 49 | 60 | 8986. | 307. | 1.98E+00 | 49 | 60 |
| 25 | 9066. | 307. | 2.17E-01 | 50 | 61 | 9066. | 307. | 1.95E+00 | 50 | 61 |
| 24 | 9146. | 306. | 2.14E-01 | 50 | 61 | 9146. | 306. | 1.93E+00 | 50 | 61 |
| 23 | 9226. | 306. | 2.12E-01 | 51 | 61 | 9226. | 306. | 1.91E+00 | 51 | 61 |
| 22 | 9306. | 306. | 2.09E-01 | 51 | 62 | 9306. | 306. | 1.88E+00 | 51 | 62 |
| 21 | 9386. | 306. | 2.05E-01 | 51 | 62 | 9386. | 306. | 1.84E+00 | 51 | 62 |
| 20 | 9466. | 306. | 2.01E-01 | 52 | 63 | 9466. | 306. | 1.81E+00 | 52 | 63 |
| 19 | 9546. | 306. | 1.97E-01 | 52 | 63 | 9546. | 306. | 1.77E+00 | 52 | 63 |
| 18 | 9626. | 306. | 1.93E-01 | 53 | 64 | 9626. | 306. | 1.74E+00 | 53 | 64 |
| 17 | 9706. | 306. | 1.93E-01 | 53 | 64 | 9706. | 306. | 1.74E+00 | 53 | 64 |
| 16 | 9786. | 306. | 1.96E-01 | 54 | 65 | 9786. | 306. | 1.76E+00 | 54 | 65 |
| 15 | 9866. | 306. | 1.98E-01 | 54 | 65 | 9866. | 306. | 1.78E+00 | 54 | 65 |
| 14 | 9946. | 306. | 1.93E-01 | 55 | 65 | 9946. | 306. | 1.73E+00 | 55 | 65 |
| 13 | 10026. | 306. | 1.86E-01 | 55 | 66 | 10026. | 306. | 1.67E+00 | 55 | 66 |
| 12 | 10106. | 307. | 1.74E-01 | 56 | 66 | 10106. | 307. | 1.57E+00 | 56 | 66 |
| 11 | 10186. | 307. | 1.64E-01 | 56 | 67 | 10186. | 307. | 1.48E+00 | 56 | 67 |
| 10 | 10266. | 307. | 1.47E-01 | 57 | 67 | 10266. | 307. | 1.32E+00 | 57 | 67 |
| 9 | 10346. | 307. | 1.22E-01 | 57 | 67 | 10346. | 307. | 1.10E+00 | 57 | 67 |
| 8 | 10426. | 307. | 1.10E-01 | 58 | 67 | 10426. | 307. | 9.89E-01 | 58 | 67 |
| 7 | 10507. | 307. | 9.84E-02 | 59 | 67 | 10507. | 307. | 8.85E-01 | 59 | 67 |
| 6 | 10587. | 307. | 8.52E-02 | 59 | 67 | 10587. | 307. | 7.66E-01 | 59 | 67 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 10667. | 307. | 6.43E-02 | 60 | 67 | 10667. | 307. | 5.78E-01 | 60 | 67 |
| 4 | 10748. | 308. | 4.80E-02 | 60 | 67 | 10748. | 308. | 4.32E-01 | 60 | 67 |
| 3 | 10828. | 308. | 3.25E-02 | 61 | 67 | 10828. | 308. | 2.92E-01 | 61 | 67 |
| 2 | 10908. | 308. | 1.85E-02 | 62 | 67 | 10908. | 308. | 1.66E-01 | 62 | 67 |
| 1 | 10989. | 308. | 1.28E-02 | 65 | 67 | 10989. | 308. | 1.15E-01 | 65 | 67 |

MAXIMUM MMH CONC 2.25E+00 AT RANGE 1547. M, BEARING 305. DEG
PUFF ARRIVAL AT 8, DEPARTURE AT 11 MIN

MAXIMUM NO2 CONC 2.05E+01 AT RANGE 1547. M, BEARING 305. DEG
PUFF ARRIVAL AT 8, DEPARTURE AT 11 MIN

## A. Case 6 - Castor 1200 Worst Case Payload Deflagration Abort Mode $NO_2$ and MMH Isopleths

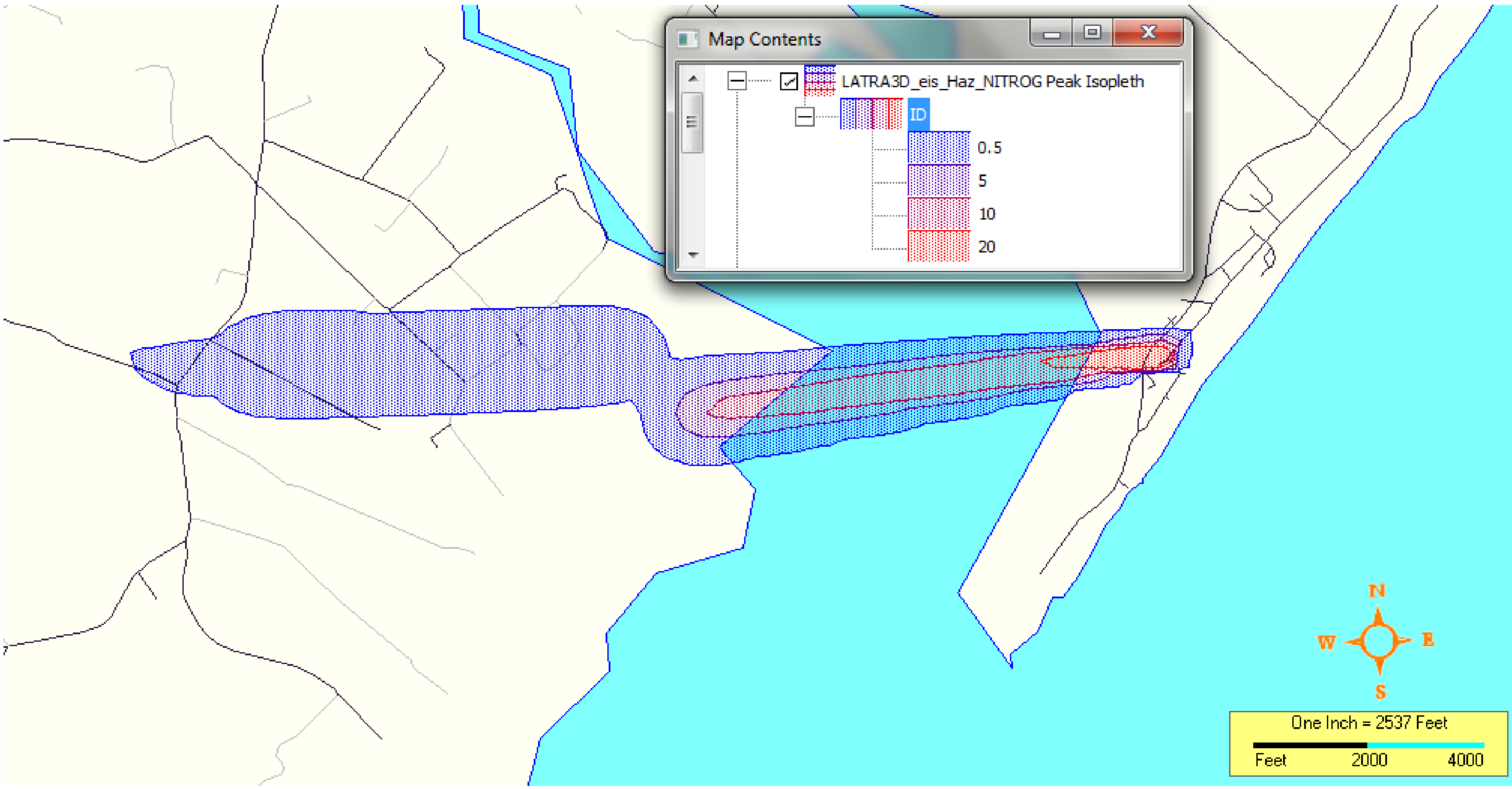


**Figure A - 7. $NO_2$ Concentration Contours for a Castor 1200 Payload Pool Evaporation Scenario for a Case Yielding a Long 0.5-ppm $NO_2$ Hazard Zone from Wallops Flight Facility.**

Case 6 Discussion – Payload Pool Evaporation Mode Producing $NO_2$.

This example plots the 0.5 5, 10 and 20 ppm ground level $NO_2$ isopleths for the meteorological case that generated the longest downwind distance $NO_2$ 5 ppm isopleth that extended 2800 meters downwind. The peak $NO_2$ concentration level predicted for this case was 62.7 ppm at a range of 257 meters and a bearing of 255 degrees. The maximum $NO_2$ peak concentration near the evaporating pool should be much higher (in the hundreds of ppm range). In this run LATRA3D was set up with an 80 meter by 80 meter concentration grid spacing input. The original source puffs formed at the evaporating pool are small; on the order of 5 meters diameter. The 80 meter grid spacing is too coarse to accurately capture the high concentrations in the source puffs. At 10 meter by 10 meter grid would have been better for the pool evaporation scenario, but this highly resolved grid would have created thousands of grid point calculations far downwind where the puffs have grown large and would have negatively impacted the computer run time to process all 6430 cases. The analysis code used here was LATRA3D. The evaporating pool is assumed to form when an intact payload ejected for a breakup of the launch vehicle impacts the ground rupturing the hygergol tanks causing them to spill their contents but without generating a fire or explosion.

The same event payload impact event produces an evaporating pool of MMH that is assumed to travel downwind in conjunction with the $NO_2$ plume, at least initially. The downwind distance of the MMH corridor is approximately $1/10^{th}$ as long as the $NO_2$ corridor due to the slow evaporation rate of MMH compared to $N_2O_4$.

LATRA3D $NO_2$ concentration versus distance predictions for this case are presented in Table A-6. Note that the predicted cloud passage time on the order of 45 minutes, due primarily to the time required to evaporate the entire pool.

**Table A - 6. LATRA3D Predicted $NO_2$ Concentration Versus Distance for a Case with the Longest 5-ppm $NO_2$ Concentration Isopleth Given a Payload Pool Evaporation Scenario.**

```
EXPOSURE GRID DEFINITION:
   UTM ZONE:      17.0
   UTM COORDS OF MIN X,Y (M):  979462.5 4200892.0
   SPACING BETWEEN NODES (M):      80.0      80.0
   NUMBER OF X,Y GRID NODES:          74        12
   X AXIS ORIENTATION WRT EAST (DEG):      2.9
   EXPOSURE CALCULATION HEIGHT (M):        0.0
   TWA CONC AVERAGING PERIOD (SEC):       90.0
   UTM COORDS OF PAD X,Y (M):  985200.3 4201711.5

 NUMBER OF SPECIES INCLUDED IN EXPOSURE CALCS:  1
 ORDER OF SPECIES:    NITROG
```

MAXIMUM CROSSWIND CONCENTRATION LOCATIONS

| ALONG WIND NODE | RANGE | BEAR | CONC | PUFF TIME (MIN) ARR | DEP |
|---|---|---|---|---|---|
| 71 | 96. | 284. | 6.05E+00 | 1 | 45 |
| 70 | 179. | 250. | 4.25E+01 | 2 | 47 |
| 69 | 257. | 255. | 6.27E+01 | 3 | 49 |
| 68 | 336. | 258. | 5.83E+01 | 4 | 50 |
| 67 | 415. | 260. | 4.89E+01 | 5 | 52 |
| 66 | 494. | 261. | 4.02E+01 | 6 | 53 |
| 65 | 574. | 262. | 3.33E+01 | 7 | 55 |
| 64 | 654. | 263. | 2.79E+01 | 8 | 56 |
| 63 | 733. | 263. | 2.37E+01 | 10 | 58 |
| 62 | 813. | 263. | 2.04E+01 | 11 | 59 |
| 61 | 901. | 259. | 1.91E+01 | 12 | 61 |
| 60 | 980. | 259. | 1.96E+01 | 13 | 63 |
| 59 | 1060. | 260. | 1.96E+01 | 14 | 64 |
| 58 | 1139. | 260. | 1.93E+01 | 16 | 65 |
| 57 | 1219. | 261. | 1.86E+01 | 17 | 67 |
| 56 | 1298. | 261. | 1.78E+01 | 18 | 68 |
| 55 | 1378. | 262. | 1.68E+01 | 19 | 70 |
| 54 | 1458. | 262. | 1.58E+01 | 20 | 71 |
| 53 | 1537. | 262. | 1.48E+01 | 22 | 73 |
| 52 | 1625. | 260. | 1.40E+01 | 23 | 74 |
| 51 | 1705. | 260. | 1.43E+01 | 24 | 76 |
| 50 | 1784. | 260. | 1.43E+01 | 25 | 77 |
| 49 | 1864. | 261. | 1.42E+01 | 27 | 79 |
| 48 | 1943. | 261. | 1.40E+01 | 28 | 80 |
| 47 | 2023. | 261. | 1.36E+01 | 29 | 81 |
| 46 | 2102. | 261. | 1.32E+01 | 30 | 83 |
| 45 | 2182. | 262. | 1.27E+01 | 32 | 84 |
| 44 | 2262. | 262. | 1.21E+01 | 33 | 86 |
| 43 | 2341. | 262. | 1.16E+01 | 34 | 87 |
| 42 | 2429. | 260. | 1.15E+01 | 35 | 89 |
| 41 | 2509. | 260. | 1.14E+01 | 37 | 89 |
| 40 | 2588. | 261. | 1.10E+01 | 38 | 89 |
| 39 | 2668. | 261. | 9.75E+00 | 39 | 89 |
| 38 | 2747. | 261. | 7.45E+00 | 40 | 89 |
| 37 | 2827. | 261. | 4.54E+00 | 42 | 89 |
| 36 | 2906. | 261. | 2.06E+00 | 43 | 89 |
| 35 | 2972. | 268. | 1.99E+00 | 47 | 94 |
| 34 | 3052. | 268. | 3.26E+00 | 47 | 95 |
| 33 | 3132. | 268. | 4.23E+00 | 47 | 97 |
| 32 | 3212. | 268. | 4.67E+00 | 47 | 98 |
| 31 | 3292. | 268. | 4.76E+00 | 47 | 99 |
| 30 | 3372. | 268. | 4.68E+00 | 47 | 101 |
| 29 | 3452. | 268. | 4.58E+00 | 48 | 102 |
| 28 | 3532. | 268. | 4.48E+00 | 50 | 103 |
| 27 | 3612. | 268. | 4.37E+00 | 51 | 104 |

| | | | | | |
|---|---|---|---|---|---|
| 26 | 3692. | 268. | 4.27E+00 | 52 | 106 |
| 25 | 3772. | 268. | 4.18E+00 | 53 | 107 |
| 24 | 3852. | 268. | 4.07E+00 | 54 | 108 |
| 23 | 3932. | 268. | 3.97E+00 | 56 | 110 |
| 22 | 4012. | 268. | 3.87E+00 | 57 | 111 |
| 21 | 4092. | 268. | 3.78E+00 | 58 | 112 |
| 20 | 4172. | 268. | 3.69E+00 | 59 | 114 |
| 19 | 4252. | 266. | 3.60E+00 | 61 | 115 |
| 18 | 4332. | 266. | 3.56E+00 | 62 | 116 |
| 17 | 4412. | 266. | 3.51E+00 | 63 | 118 |
| 16 | 4492. | 267. | 3.56E+00 | 64 | 119 |
| 15 | 4572. | 267. | 3.65E+00 | 65 | 120 |
| 14 | 4652. | 267. | 3.72E+00 | 67 | 121 |
| 13 | 4732. | 267. | 3.72E+00 | 68 | 122 |
| 12 | 4812. | 267. | 3.57E+00 | 69 | 122 |
| 11 | 4892. | 267. | 3.28E+00 | 70 | 124 |
| 10 | 4972. | 267. | 3.00E+00 | 71 | 125 |
| 9 | 5052. | 267. | 2.57E+00 | 73 | 126 |
| 8 | 5132. | 267. | 2.16E+00 | 74 | 127 |
| 7 | 5212. | 267. | 1.79E+00 | 75 | 128 |
| 6 | 5292. | 267. | 1.23E+00 | 79 | 129 |
| 5 | 5372. | 267. | 1.19E+00 | 79 | 130 |
| 4 | 5452. | 267. | 1.04E+00 | 80 | 131 |
| 3 | 5533. | 268. | 8.02E-01 | 81 | 131 |
| 2 | 5613. | 268. | 7.02E-01 | 82 | 132 |
| 1 | 5693. | 268. | 5.64E-01 | 83 | 132 |
| 0 | 5773. | 268. | 4.09E-01 | 84 | 132 |

MAXIMUM NITROG CONC 6.27E+01 AT RANGE 257. M, BEARING 255. DEG
PUFF ARRIVAL AT 3, DEPARTURE AT 49 MIN

# APPENDIX G
# FEDERAL CONSISTENCY DETERMINATION

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# FEDERAL CONSISTENCY DETERMINATION FOR THE SITE-WIDE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**
**GODDARD SPACE FLIGHT CENTER**
**WALLOPS FLIGHT FACILITY**
**WALLOPS ISLAND, VA 23337**

## Introduction

The National Aeronautics and Space Administration (NASA) has prepared a Programmatic Environmental Impact Statement (PEIS) to evaluate the potential environmental impacts from proposed Site-wide projects at NASA's Goddard Space Flight Center Wallops Flight Facility (WFF), Wallops Island, Virginia. The Site-wide PEIS was prepared in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S. Code 4321-4347), the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 Code of Federal Regulations [CFR] 1500-1508), NASA's regulations for implementing NEPA (14 CFR Subpart 1216.3), and the *NASA Procedural Requirements (NPR) for Implementing NEPA* and *Executive Order (EO) 12114* (NPR 8580.1).

This document provides the Commonwealth of Virginia with NASA's Consistency Determination under Coastal Zone Management Act Section 307(c)(1) and Title 15 CFR Part 930, Subpart C, for implementation of the Proposed Action analyzed in the NASA WFF Site-wide PEIS. The information in this Consistency Determination is provided pursuant to 15 CFR Section 930.39.

NASA requested the cooperation of multiple tenant and partner agencies in the preparation of the Site-wide PEIS. The Federal Aviation Administration, National Oceanic and Atmospheric Administration's National Environmental Satellite Data Information Service, United States (U.S.) Army Corps of Engineers (Norfolk District), U.S. Coast Guard, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service (USFWS), U.S. Navy Fleet Forces Command, U.S. Navy Naval Sea Systems Command, U. S. Navy Naval Air Systems Command, U.S. Air Force's Space Command/Space and Missile Systems Center, Federal Highway Administration, and the Virginia Commercial Space Flight Authority served as Cooperating Agencies in preparing the Site-wide PEIS and this Consistency Determination, because they possess regulatory authority or specialized expertise pertaining to the Proposed Action. The PEIS is being developed to fulfill each Federal agency's obligations under NEPA and the Coastal Zone Management Act (CZMA). NASA, as the WFF property owner and project proponent, is the Lead Agency and responsible for ensuring overall compliance with applicable environmental statutes, including NEPA and the CZMA.

The Site-wide PEIS encompasses a 20-year planning horizon. The Proposed Action considered the impacts of a number of current and proposed institutional support projects ranging from routine and recurring activities, new construction, demolition, and renovation throughout the installation to include construction of a Commercial Space Terminal, the replacement of the Causeway Bridge, maintenance dredging between the boat docks at the Main Base and Wallops Island, and development of a deep-water port and operations area on North Wallops Island. .Several of the institutional support projects would directly correlate with new operational missions and activities including the construction and operation of Launch Pad 0-C and Launch Pier 0-D to accommodate larger LVs, smaller launch pads to accommodate Department of Defense (DoD) initiatives, and construction of a Commercial Space Terminal and extension of Runway 04/22 for horizontal launch and landing vehicles in support of the Expanded Space Program. In addition to current operations, the Proposed Action also considered several new operational missions and activities including introduction and expansion of existing DoD programs such as the standard missile rocket (SM-3) and Directed Energy, a new weapons system proposal currently under development comprised of a high energy laser or high power microwave; future opportunities within the Expanded Space Program involving the potential for either horizontal or vertical launch and landing including the ability to return to the launch site of intermediate and heavy class launch vehicles capable of delivering supplies to the International Space Station; and consideration of commercial human spaceflight missions from WFF.

**Effects to Resources**

NASA has determined that implementing the Site-wide PEIS would affect resources of Virginia in the following manner:

***Noise*** – Construction and transportation activities have the potential to generate temporary increases in noise levels from heavy equipment operations. Temporary localized impacts to marine mammals would occur during Causeway Bridge replacement, barge route maintenance dredging, and dredging for development of the North Wallops Island Deep-water Port and Operations Area; no adverse impacts are anticipated. Noise levels generated during the launch or return of a liquid fueled intermediate class (LFIC) launch vehicle/reusable launch vehicle (LV/RLV) or launch of a solid-fueled heavy class (SFHC) LV would affect a larger land area than current launch activities; however, there would be no increase in the number of occupied structures or estimated populations affected. The potential for a sonic boom during an LV launch or horizontal landing exists; however, no significant noise impacts would be anticipated. No more than 6 LFIC LV/RLVs or 12 SFHC LVs would be authorized in a rolling 12-month period.

***Air Quality*** – Emissions from construction equipment, barge activities (dredging and transport), and new and expanded operational missions and activities are not anticipated to cause long-term adverse impacts on air quality; annual emissions of criteria pollutants would not exceed the 227 metric tons (250 tons) per year comparative threshold and would not result in significant impacts. Operational missions and activities have the potential to incrementally contribute to global levels of greenhouse gases; however, total emissions are anticipated to be insignificant in terms of global levels.

***Hazardous Materials, Toxic Substances, and Hazardous Waste*** – Increased operational missions and activities could result in slight increases of hazardous materials, toxic substances and hazardous waste; however, no adverse impacts would be anticipated since the types of hazardous materials, toxic substances, and hazardous waste would be similar to those used or generated during existing operations at WFF. All hazardous materials, toxic substances and hazardous waste would be managed in accordance with current and standard procedures.

***Health and Safety –*** Established protocols and protective measures to ensure the health and safety of NASA personnel, contractors, civilians, and the general public would continue for institutional support projects and expanded operational missions and activities. These include adhering to established safety protocols; activation of launch site hazard arcs; issuance of Notice-to-Airmen and Notice to Mariners; activation of Restricted Area Airspace R-6604; U.S. Navy scheduling procedures to prevent potential impacts to personal, commercial, and DoD ships and aircraft; and temporary road closures during LV launches and landings.

***Water Resources*** – NASA has determined that no long-term significant impacts to water resources from either institutional support projects or operational missions and activities would be anticipated. Several projects have the potential to impact wetlands: the Causeway Bridge replacement, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D. Up to 2 hectares (5 acres) of tidal wetlands could be disturbed from construction of the new Causeway Bridge. Temporary impacts to wetlands could occur during maintenance dredging by the placement of the dredge pipe crossing wetlands along the route from the dredge to the upland disposal areas. Development of the North Wallops Island Deep-water Port and Operations Area has the potential to disturb tidal and non-tidal wetlands. Pad 0-C construction could impact up to 2 hectares (5 acres) of wetlands; Launch Pier 0-D (creekside) could impact tidal wetlands. All wetland impacts would be avoided to the greatest extent practicable during the design and permitting phase. If potential unavoidable wetland impacts are identified, NASA would implement wetland mitigation to ensure no net loss of wetlands. Additionally, site specific Stormwater Pollution Prevention Plans may be prepared and implemented to further reduce potential impacts from these and other institutional support projects. Wallops Island is located entirely within the 100-year and 500-year floodplains; there is no practicable alternative to avoid development within the floodplain. The functionality of the floodplain on Wallops Island, provided both by the wetlands on the island and the area of the island itself, would not be reduced under the Site-wide proposal.

***Land Use and Land Resources –*** Construction projects would fall within compatible land uses. An increase in the noise and affected land areas associated with the Expanded Space Program would not require a change in land use within WFF boundaries since the launch vehicles would be operated in areas designated for such operations. An increase in noise and affected land areas surrounding WFF would also occur; however, the LV noise at sensitive receptors would not exceed OSHA noise standards that could result in land use changes. USFWS concurs with the determination that the Proposed Action would not be considered a physical or constructive use of surrounding Department of Transportation 4(f) properties. Land resources would be affected by construction activities and from LV exhaust plume; the impact would be limited to a small area adjacent to the launch pad resulting in no long-term or adverse impact.

***Vegetation*** – Ground disturbance on the Main Base would not result in adverse impacts to vegetation; however, ground disturbance on the Mainland and Wallops Island may increase the spread of *Phragmites australis*. NASA has developed various management plans, including a Phragmites Control

Plan, which would be implemented in these areas reducing the potential spread. Tidal wetland vegetation would be affected from the replacement of the Causeway Bridge, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D (creekside); final design plans would avoid tidal wetland vegetation to the extent practicable. Adverse impacts to vegetation from the larger LVs proposed, would likely occur; however the launch events would be infrequent with impacts likely confined to an area adjacent to the launch pad. No long-term adverse impacts would be anticipated from new or expanded operational missions and activities on Wallops Island.

***Terrestrial Wildlife, Special-Status Species and Marine Mammals and Fish*** – The majority of construction-related projects would not adversely impact wildlife species but the noise, vibration and turbidity generated during the Causeway Bridge replacement, barge route maintenance dredging and dredging for development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pier 0-D (oceanside) may adversely impact marine mammals and fish. However, no-long term impacts would be expected. Land based species would generally be disturbed through noise, vibration, and if near enough, mortality from heat due to rocket fuel combustion generated during LFIC LV and SFHC LV launches; marine mammals and fish would unlikely be affected. NASA consulted with the USFWS regarding potential impacts of Wallops Island's Antares and ongoing and proposed operations on special-status species. These consultations concluded that the ongoing and expanded orbital rocket program at WFF and other ongoing operations and use of the facility, as proposed, may affect, but are not likely to adversely affect the Northern long-eared bat, roseate tern, green sea turtle, leatherback sea turtle, or seabeach amaranth. Additionally, the consultations determined that the proposed and ongoing operations are not likely to jeopardize the continued existence of the piping plover, red knot or loggerhead sea turtle, and is not likely to destroy or adversely modify designated critical habitat. Although, the LFIC LV and SFHC LV are both larger launch vehicles than the Antares, launching of these larger vehicles would have similar impacts to special-status species and marine mammals and fish as vehicles currently launched from WFF.

***Airspace Management –*** NASA's restricted airspace (R-6604 A-E) is comprised of five independent airspace units that may be activated individually or together, as needed, to safely segregate civilian air traffic from the flight testing of unproven and experimental aerial systems, including unmanned aerial systems (UAS) and LVs. NASA would activate only the airspace needed for operations associated with UAS, LVs, and U.S. Navy SM-3 and Directed Energy operations. When not in use, the entire R-6604 airspace unit would be available for all users.

***Transportation*** – NASA would coordinate with Accomack County, the Virginia State Police, and the Virginia Department of Transportation Accomack Residency Office when it is anticipated that an LFIC LV/RLV, SFHC LV, or horizontal launch and landing event has the potential to impact the level of service on area roads; however, the overall impact to the level of service would be short-term and not significant. No adverse impact to rail would be expected. NASA would coordinate with the U.S. Coast Guard and issue Notices to Mariners when it is anticipated that a launch or landing event or in-water construction for the Causeway Bridge replacement, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pier 0-D (oceanside) has the potential to impact water vessel traffic.

***Infrastructure and Utilities –*** The current utility infrastructure has sufficient capacity. All new construction would adhere to the use of energy and resource efficient green building standards so that any spikes in demand generated during construction activities would be short-term and not adverse. Operational activities would also generate short-term spikes in demand but it is anticipated that no adverse impacts would occur.

***Socioeconomics and Environmental Justice*** – Short-term beneficial impacts to the local economy would be expected during construction periods with longer term positive impacts anticipated from revenues generated during launch events. Long-term positive impacts are anticipated from the increase in personnel required to support new operational missions and activities, especially the Expanded Space Program. Disproportionate impacts to minority or low-income populations or children from institutional support projects or operational missions and activities would not be anticipated.

***Visual Resources and Recreation –*** Institutional support projects and operational missions and activities would be similar in nature to those already occurring at WFF; negligible impacts to visual resources would be anticipated. Minor short-term impacts to boaters and fishermen during the Causeway Bridge replacement project, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and launch events would be expected.

***Cultural Resources*** – With the exception of the Runway 04/22 extension, no archaeological (below ground or underwater) resources or above-ground historic properties are known to be present within any of the construction project areas. During consultation for the WFF Programmatic Agreement, the Virginia State Historic Preservation Officer concurred with NASA's determination that based upon the distance between the launch range and historic properties, WFF operations would have no impact on historic resources. NASA would continue to implement the WFF Programmatic Agreement and would consult with the Virginia Department of Historic Resources prior to extending Runway 04/22. Likewise, in the event that previously unrecorded historic properties are discovered during project activities, NASA would immediately stop work in the area and contact the Virginia Department of Historic Resources.

***Cumulative Impacts*** – The resources that have been identified as having the potential to experience minor short-term adverse impacts by the cumulative effects of the Proposed Action include **noise** from the Expanded Space Program combined with the U.S. Navy's proposed Electromagnetic Railgun operations and Atlantic Fleet Forces training and testing activities; **air quality** from construction projects on the Main Base, Mainland and Island and new and expanded operational missions and activities; **water resources** from turbidity and erosion during WFF construction activities and from development in Accomack County; and **wetlands** and **terrestrial wildlife** during construction activities. No significant cumulative effects to **special-status species** and **marine mammals and fish** are anticipated with implementation of mitigation and monitoring measures. No cumulative impacts are anticipated on other resources.

**Consistency Determination**

The Virginia Coastal Resources Management Program contains the following applicable enforceable policies:

- **Fisheries Management**. Administered by Virginia Marine Resources Commission (VMRC) and the Virginia Department of Game and Inland Fisheries (VDGIF), this program stresses the conservation and enhancement of shellfish and finfish resources and the promotion of commercial and recreational fisheries.

  The State Tributyltin (TBT) Regulatory Program is also part of the Fisheries Management program. The TBT program monitors boating activities and boat painting activities to ensure compliance with TBT regulations promulgated pursuant to the amendment. The VMRC, VDGIF, and Virginia Department of Agriculture and Consumer Services share enforcement responsibilities.
- **Subaqueous Lands Management.** Administered by VMRC, this program establishes conditions for granting permits to use state-owned bottomlands.
- **Wetlands Management.** Administered by VMRC, Virginia Department of Environmental Quality (VDEQ), and the Accomack County Wetland Board, the wetlands management program preserves and protects both tidal and non-tidal wetlands.
- **Dunes and Beaches Management.** Administered by VMRC and the Accomack County Wetland Board, the purpose of this program is to prevent the destruction and/or alteration of primary dunes.
- **Non-point Source Water Pollution Control.** Administered by the Virginia Department of Environmental Quality, the Virginia Erosion and Sediment Control Law is intended to minimize soil erosion and to decrease inputs of chemical nutrients and sediments to the Chesapeake Bay, its tributaries, and other rivers and waters of the Commonwealth.
- **Point Source Water Pollution Control.** Administered by the State Water Control Board, the Virginia Pollution Discharge Elimination System and Virginia Pollution Abatement permit programs regulate point source discharges to Virginia's waterways.
- **Shoreline Sanitation.** Administered by the Virginia Department of Health, this program regulates the installation of septic tanks to protect public health and the environment.
- **Point Source Air Pollution Control.** Administered by the State Air Pollution Control Board, this program implements the Federal Clean Air Act through a legally enforceable State Implementation Plan.
- **Coastal Lands Management.** Administered by VDEQ's Office of Ecology and the Chesapeake Bay Local Assistance Department, the Chesapeake Bay Preservation Act guides land development in coastal areas to protect the Chesapeake Bay and its tributaries.

Based upon the following information, data, and analysis, NASA finds that the proposed new institutional support projects and proposed new operational missions and activities evaluated under the Site-wide PEIS are consistent to the maximum extent practicable with the enforceable policies of the Virginia Coastal Resources Management Program. The table below summarizes NASA's analysis supporting this determination.

| Virginia Policy | Consistent? | Analysis |
|---|---|---|
| Fisheries Management | Yes | There would be short-term site-specific adverse effects on fish habitat and increased levels of turbidity during the Causeway Bridge construction, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D. The Proposed Action would not violate the provisions outlined in Code of Virginia § 28.2-200 through 28.2-713 and Code of Virginia § 29.1-100 through 29.1-570. |
| Subaqueous Lands Management | Yes | Public and private oyster beds occur along portions of the maintained barge route and in the area for development of the North Wallops Island Deep-water Port and Operations Area and the Launch Pad 0-C. Dredging and construction in these areas, along with the Causeway Bridge Replacement and Launch Pier 0-D projects, would result in increased turbidity during operations. NASA would obtain any necessary permits required prior to implementing these actions. |
| Wetlands Management | Yes | Up to 4 hectares (10 acres) of tidal wetlands would be disturbed during the Causeway Bridge construction, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D.Any necessary VDEQ, VMRC, and Accomack County Wetland Board permits would be obtained by NASA prior to implementing the action. |
| Dunes and Beaches Management | Yes | None of the activities under the Proposed Action would impact primary dunes. |
| Non-point Source Water Pollution Control | Yes | Activities under the Proposed Action have the potential to increase non-point source runoff to the Virginia waters and the Atlantic Ocean. NASA would implement appropriate best management practices to avoid these impacts. |
| Point Source Water Pollution Control | Yes | Construction of Launch Pad 0-C or Launch Pier 0-D could create new point sources for water pollution. These source would be added to NASA VPDES permit for WFF and all permitted controls would be implemented. |
| Shoreline Sanitation | Yes | The Proposed Action would not involve the construction of septic tanks. |
| Point Source Air Pollution Control | Yes | The Proposed Action would not create any new point sources for air pollution. Institutional support projects and operational missions and activities would contribute to the annual air emissions inventory; however, the emissions generated would not violate Federal or Virginia air quality standards. |
| Coastal Lands Management | Yes | The Proposed Action would not include land development activities that would impact the Chesapeake Bay or its tributaries. Moreover, although Accomack County has adopted the Chesapeake Bay Preservation Act restrictions for its seaside riparian areas, WFF is specifically excluded from this overlay area. |

Pursuant to 15 CFR section 930.41, the Virginia Coastal Resources Management Program has 60 days from the receipt of this letter in which to concur with or object to this Consistency Determination, or to request an extension under 15 CFR Section 930.41(b). Virginia's concurrence will be presumed if its response is not received by NASA on the 60th day from receipt of this determination. The

Commonwealth's response should be sent to:

Shari A. Miller
Lead, Environmental Planning
NASA Wallops Flight Facility
Wallops Island, VA 23337
(757) 824-2327
Shari.A.Miller@nasa.gov

# Appendix H
# White Paper: A Report on the Historical Impacts and Protection of Wetlands at NASA Wallops Flight Facility

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*WHITE PAPER*

# A Report on the Historical Impacts and Protection of Wetlands at NASA Wallops Flight Facility

National Aeronautics and Space Administration
Goddard Space Flight Center's Wallops Flight Facility
Wallops Island, VA 23337

**August 2017**

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ac | acres |
| EPA | Environmental Protection Agency |
| GIS | Geographic Information System |
| ha | hectares |
| HUC | Hydrologic Unit Codes |
| NASA | National Aeronautics and Space Administration |
| NRCS | Natural Resource Conservation Service |
| NWI | National Wetland Inventory |
| PEIS | Programmatic Environmental Impact Statement |
| U.S. | United States |
| USDA | U.S. Department of Agriculture |
| VIMS | Virginia Institute of Marine Science |
| WETCAT | non-tidal wetland assessment |
| WFF | Wallops Flight Facility |
| W-PAWF | Watershed-based Preliminary Assessment of Wetland Functions |

# 1.0 INTRODUCTION AND METHODS

## 1.1 INTRODUCTION

An extensive analysis of historical impacts to wetlands at the National Aeronautics and Space Administration (NASA) Wallops Flight Facility (WFF) and surrounding areas was performed in support of the Site-wide Programmatic Environmental Impact Statement (PEIS). The geographic boundary of the analysis is the two 12-digit Hydrologic Unit Codes (HUCs) (020403030504 and 020403040101) that encompass the Wallops Main Base, Mainland, and Wallops Island, as well as adjacent areas (**Figure 1)**. The study area totals 20,539 hectares (ha) (50,753 acres [ac]). To fully analyze the impact development has had on wetland size and functional value, the temporal extent of the study was defined as 1938 through 2025. The first period beginning in 1938 establishes the timeframe in which the NASA site was relatively undisturbed with the exception of agricultural fields, the Wallops Coast Guard Life Saving Station, and a hunt club. The year 2025 was chosen to encompass all proposed projects evaluated in the Site-wide PEIS.

Initially, the cumulative impacts analysis planned to use wetland permit data from the United States Army Corps of Engineers and the Virginia Marine Resources Commission to calculate the permitted wetland losses since the inception of the Clean Water Act in 1972. However, it was determined that this data was incomplete or not in a format that could be used for this analysis.

## 1.2 OBJECTIVES

The overall objective of the historical wetland impacts analysis was to compare the changes in the extent and function of wetlands over time. This objective was accomplished using the following steps:

1) Determine the historical extent of wetlands within the two 12-digit HUC study area.
2) Determine the historical wetland impacts within NASA boundaries and outside NASA boundaries.
3) Assign a functional value to:
    a) historically impacted wetlands,
    b) current wetlands, and
    c) cumulatively proposed to be impacted wetlands.
4) Evaluate the change in total functional value from 1938 to 2025 attributable to the Proposed Action evaluated in the Site-wide PEIS.

## 1.3 METHODS

Methods used to accomplish the objectives are described in the following sections.

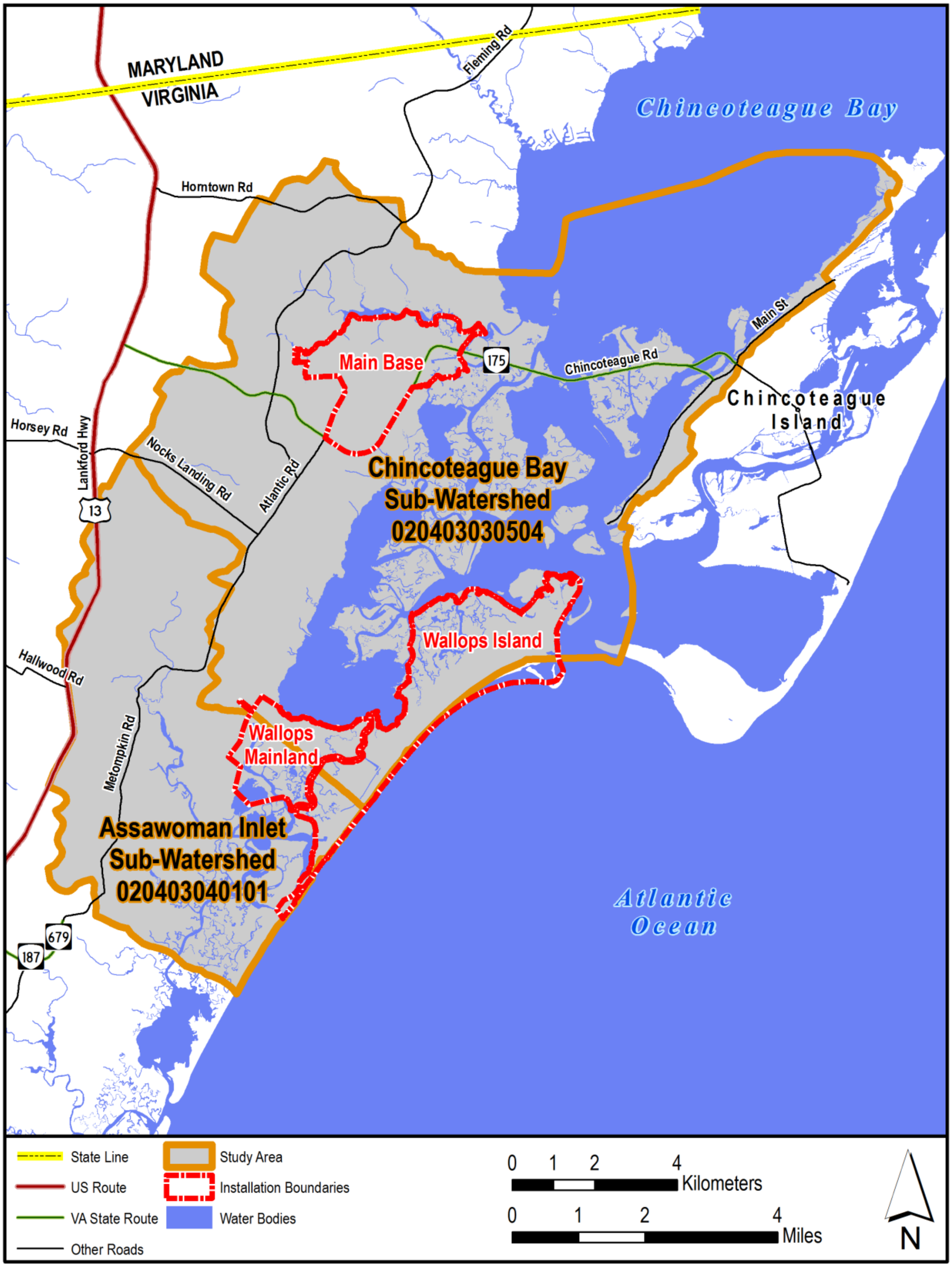


**Figure 1. Cumulative Wetlands Study Area**

### 1.3.1 Determining the Historic Wetland Extent

National Wetlands Inventory (NWI) data was combined with Natural Resource Conservation Service (NRCS) soils data and historic aerial photographs to determine the extent of wetlands within the study area. The 1920 NRCS soils survey was compared against the 1997 NRCS soils survey (United States Department of Agriculture [USDA] 1997) and it was determined that there were approximately 25% fewer acres of hydric soils in the 1920 soils survey, primarily due to the mapping conventions of the time (Stevens 1920). Therefore, the 1997 limit of hydric soils was considered the historic extent of wetlands.

### 1.3.2 Determining Historic Wetland Impacts

Historic aerial photography was used to calculate the wetland losses over time. A review of the historic aerial photography identified "areas of disturbance" compared to the 1997 historic hydric soils limit. These areas of disturbance were classified as: dredge area, fill area, impervious area, or miscellaneous disturbance. All aerial photographs were ortho-rectified and digitized to develop polygons for these areas of disturbance (i.e., loss of wetlands) using Geographic Information System (GIS) software. The wetland loss by wetland type was calculated for each year that photography was available.

Based on the availability of photography, the wetland losses were divided into two categories, 1) losses within the NASA boundaries, and 2) losses outside of the NASA boundaries within the remainder of the study area. Within the NASA boundaries, historic aerial photographs were available for the years 1938, 1949, 1957, 1963, 1966, 1974, 1979, 1988, 1994, and 2010 (Environmental Protection Agency [EPA] 1996, EPA 2004, and U.S. Army Corps of Engineers [USACE] 2000). Historic aerial photography for areas outside of the NASA boundaries was only available for the years 1938 and 1974.

### 1.3.3 Assigning Functional Values to Wetlands

A landscape level wetland assessment approach called Watershed-based Preliminary Assessment of Wetland Functions (W-PAWF) was employed to assign a functional value to wetlands. W-PAWF applies general knowledge about wetland function to emphasize wetlands of potential significance for numerous functions in a given study area (Tiner 2005). The new non-tidal wetland assessment procedure (WETCAT) currently underway at the Virginia Institute of Marine Science (VIMS) was considered for this analysis. However, it was determined that VIMS did not have any study sites within the geographic extent of this study area, and the methodology VIMS employed to evaluate the various non-tidal wetland areas used a suite of functions and values that differed enough from those used in the W-PAWF study that the datasets were not comparable. Therefore, the W-PAWF approach was used in this analysis. An overview of this approach is described below.

First, wetlands were classified according to criteria established by Tiner (2011) that includes landscape, landform, water flow path, and water body type. Habitats that were disturbed and no longer classified as wetlands were classified based on the closest adjacent wetland type, which, in this case, were all estuarine wetlands. All inland hydric soils (palustrine) were classified as palustrine forested wetlands following Tiner's methodology (2003).

Following Tiner's wetlands classification (Tiner 2003), the wetlands were then assigned a numerical quantity: low (0), moderate (1) and high (2) using W-PAWF for 10 wetland functions (**Table 1**). The maximum value a wetland could score was 20. However, the wetlands within NASA boundaries could only score a maximum value of 18 due to the fact that there are no streams within the NASA boundaries and Streamflow Maintenance for all wetlands would have a score of 0.

| Table 1. Assigning Functional Values to Wetlands | | | | |
|---|---|---|---|---|
| | | Value | | |
| **Function** | **Importance to Wetland** | ***Low*** | ***Moderate*** | ***High*** |
| Surface water detention | Reduces downstream flooding and lowers flood heights, both of which aid in minimizing property damage and personal injury from such events. | 0 | 1 | 2 |
| Coastal storm surge detention | Estuarine and freshwater tidal wetlands are important areas for temporary storage of tidal waters brought into estuaries by storms (e.g., Nor'easters, tropical storms, and hurricanes). | 0 | 1 | 2 |
| Streamflow maintenance | Many wetlands are sources of groundwater discharge and some may be in a position to sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life in streams. | 0 | 1 | 2 |
| Nutrient transformation | All wetlands recycle nutrients but those having a fluctuating water table are best able to recycle nitrogen and other nutrients. Vegetation slows the flow of water causing deposition of mineral and organic particles with adsorbed nutrients (nitrogen and phosphorus). Microbial action in the soil is the driving force behind chemical transformations in wetlands. Microbes need a food source (i.e., organic matter) to survive, so wetlands with high amounts of organic matter should have an abundance of microflora to perform the nutrient cycling function. | 0 | 1 | 2 |
| Retention of sediment and other particulates | Supports water quality maintenance by capturing sediments with nutrients or heavy metals (especially downstream of urban areas). Estuarine and floodplain wetlands plus streamside and lakeshore fringe and basin wetlands including in-stream ponds are likely to trap and retain sediments and particulates at significant levels. Terrene through-flow basins should function similarly. Vegetated wetlands will likely favor sedimentation over non-vegetated wetlands and are therefore rated higher. | 0 | 1 | 2 |
| Shoreline stabilization | Vegetation stabilizes the soil or substrate and diminishes wave action, thereby reducing shoreline erosion potential. | 0 | 1 | 2 |
| Provision of fish and shellfish habitat | Vegetated tidal and permanently flooded non tidal wetlands provide nursery, feeding and refuge habitat. | 0 | 1 | 2 |
| Provision of waterfowl and waterbird habitat | Wetlands designated as important for waterfowl (e.g., ducks, geese, mergansers, and loons) and waterbirds (e.g., wading birds, shorebirds, rails, marsh wrens, and red-winged blackbirds) are generally those used for nesting, reproduction, or feeding. The emphasis is on the wetter wetlands and ones that are frequently flooded for long periods. | 0 | 1 | 2 |
| Provision of other wildlife habitat | Wetlands provide habitat and conditions that provide significant habitat for other vertebrate wildlife (mainly reptiles and amphibians, interior forest birds, and mammals). | 0 | 1 | 2 |
| Conservation of biodiversity | The term "biodiversity" is used to identify wetlands that may contribute to the preservation of an assemblage of wetlands that encompass the natural diversity of wetlands in a given watershed. Four types of wetlands may be identified: 1) certain wetland types that appear to be scarce or relatively uncommon in the watershed, 2) individual wetlands that possess several different cover types (i.e., naturally diverse wetland complexes), 3) complexes of large wetlands, and 4) regionally unique or uncommon wetland types. | 0 | 1 | 2 |
| | | | **Maximum Possible Total Value** | **20** |

#### 1.3.4 Evaluating Change in Functional Value from 1938 to 2025

To assess the change in the 10 functions from 1938 to 2025, the wetland losses by habitat type in 1938 and 2025 were multiplied by the value for each function (0, 1 or 2) to generate a "functional unit total" for each time period following the methodology in Fizzell 2007. The functional totals for each year were compared to calculate a percent change in the function over time. The percent change over time was calculated with and without the Proposed Action to determine the change in functional value attributable to the Proposed Action addressed in the Site-wide PEIS.

# 2.0 RESULTS

In accordance with the objectives identified in Section 1.2 and the methods described in Section 1.3, the results of the historical analysis are presented in the following sections.

## 2.1 Functional Value of Current Wetlands in the Study Area

Based on the analysis of wetlands identified on the U.S. Fish and Wildlife Service (USFWS) 1998 NWI mapping (assumed as the current extent of wetlands), the majority of the wetlands present in the study area are estuarine intertidal and sub-tidal areas with a functional value of 17, classifying them as high value in 8 out of 10 functions. The next most common habitat is palustrine forested with a functional value of 14. **Table 2** provides a summary of the wetlands currently present in the study area with their functional value total.

**Table 2. Summary of Wetland Areas Based on 1998 NWI Data**

| Cowardin Classification | Habitat | Functional Value | Hectares/Acres |
|---|---|---|---|
| E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 4,513/11,151 |
| E2AB | Estuarine Intertidal Aquatic Bed | 11 | 1/3 |
| E2EM | Estuarine Intertidal Emergent | 17 | 4,233/10,461 |
| E2FO | Estuarine Intertidal Forested | 15 | 14/35 |
| E2RF | Estuarine Intertidal Reef | 14 | 21/52 |
| E2SS | Estuarine Intertidal Scrub-Shrub | 17 | 55/136 |
| E2US | Estuarine Intertidal Unconsolidated Shore | 17 | 1,875/4,633 |
| M1UB | Marine Subtidal Unconsolidated Bottom | 7 | 87/214 |
| M2US | Marine Intertidal Unconsolidated Shore | 7 | 47/117 |
| PAB | Palustrine Aquatic Bed | 13 | 2/4 |
| PEM | Palustrine Emergent | 14 | 286/709 |
| PFO | Palustrine Forested | 14 | 968/2,394 |
| PSS | Palustrine Scrub-Shrub | 14 | 211/522 |
| PUB | Palustrine Unconsolidated Bottom | 9 | 74/183 |
| PUS | Palustrine Unconsolidated Shore | 9 | 22/54 |
| | | **TOTAL** | **12,409/30,668** |
| ***Source***: USFWS 1998. | | | |

## 2.2 Functional Value of Historical and Cumulative Wetland Impacts

### 2.2.1 Within NASA Boundaries

The results of the aerial photography review and calculation of historical wetland loss within the NASA boundaries for each year that photography was available are presented in **Table 3**. Also provided is the potential loss of wetlands associated with the Proposed Action addressed in the Site-wide PEIS and the cumulative loss of wetlands for past, present, and reasonably foreseeable future projects within NASA boundaries identified in the Site-wide PEIS.

The functional value for each wetland type established using Tiner methodology is provided in **Table 3.** It should be noted that the total area for each time period may not add up exactly due to rounding and conversion to metric. It should also be noted that the wetlands within NASA boundaries could only score a maximum value of 18 due to the fact that there are no streams within the NASA boundaries and Streamflow Maintenance for all wetlands would have a score of 0.

Including pre-NASA development (1938), 2014 UAS airstrip construction and shoreline renourishment activities of the No Action Alternative, and the Proposed Action, an approximate total of 550 ha (1,355 ac) of wetlands would be cumulatively impacted within the NASA boundaries. A total of 70% of the impacts (383 ha [946 ac]) that occurred on WFF happened between 1938 and 1974. The primary causes for historical wetland impacts within the NASA boundaries included development of the WFF buildings, runways, launch pads, infrastructure, and dredging the access channels. Additionally, every 3 to 5 years, the No Action Alternative of recurring beach renourishment will temporarily impact the same area of approximately 60 ha (150 ac) of marine subtidal and intertidal unconsolidated bottoms.

**Table 3. Historical Wetland Impacts Within NASA Boundaries in Hectares/Acres[1]**

| Year | Cowardin Classification | Habitat | Functional Value | Hectares/Acres |
|---|---|---|---|---|
| **1938** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 0.4/1 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 14/34 |
| | PEM | Palustrine Emergent | 14 | 0.2/0.4 |
| | PFO | Palustrine Forested | 14 | 1/2 |
| | PSS | Palustrine Scrub Shrub | 14 | 1/2 |
| | | | **TOTAL (ha/ac)** | **16/39** |
| **1949** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 5/13 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 11/27 |
| | E2SS | Estuarine Intertidal Scrub Shrub | 17 | 0.4/1 |
| | E2US | Estuarine Intertidal Unconsolidated Shore | 17 | 1/2 |
| | PEM | Palustrine Emergent | 14 | 1/2 |
| | PFO | Palustrine Forested | 14 | 3/7 |
| | PSS | Palustrine Scrub Shrub | 14 | 15/37 |
| | | | **TOTAL (ha/ac)** | **36/88** |
| **1957** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 2/6 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 22/55 |
| | PEM | Palustrine Emergent | 14 | 9/22 |
| | PFO | Palustrine Forested | 14 | 5/13 |
| | PSS | Palustrine Scrub Shrub | 14 | 9/23 |
| | PUB | Palustrine Unconsolidated Bottom | 9 | 0.4/1 |
| | | | **TOTAL (ha/ac)** | **49/120** |

| Table 3. Historical Wetland Impacts Within NASA Boundaries in Hectares/Acres[1] (cont.) | | | | |
|---|---|---|---|---|
| **Year** | **Cowardin Classification** | **Habitat** | **Functional Value** | **Hectares/Acres** |
| **1963** | E2EM | Estuarine Intertidal Emergent | 17 | 1/2 |
| | PEM | Palustrine Emergent | 14 | 2/4 |
| | PFO | Palustrine Forested | 14 | 4/11 |
| | | | **TOTAL (ha/ac)** | **7/17** |
| **1966** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 20/49 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 52/129 |
| | E2US | Estuarine Unconsolidated Shore | 17 | 29/72 |
| | E2SS | Estuarine intertidal Scrub Shrub | 17 | 0.4/1 |
| | PEM | Palustrine Emergent | 14 | 42/103 |
| | PFO | Palustrine Forested | 14 | 0.4/1 |
| | PSS | Palustrine Scrub Shrub | 14 | 105/260 |
| | PUB | Palustrine Unconsolidated Bottom | 9 | 0.8/2 |
| | PUS | Palustrine Unconsolidated Shore | 14 | 17/43 |
| | | | **TOTAL (ha/ac)** | **267/659** |
| **1974** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 3/8 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 2/5 |
| | E2US | Estuarine Unconsolidated Shore | 17 | 0.4/1 |
| | PEM | Palustrine Emergent | 14 | 0.01/0.03 |
| | PFO | Palustrine Forested | 14 | 0.8/2 |
| | PSS | Palustrine Scrub Shrub | 14 | 2/5 |
| | | | **TOTAL (ha/ac)** | **8.5/21** |
| **1979** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 0.01/0.03 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 0.1/0.3 |
| | E2SS | Estuarine Intertidal Scrub Shrub | 17 | 0.02/0.04 |
| | PEM | Palustrine Emergent | 14 | 0.01/0.03 |
| | PSS | Palustrine Scrub Shrub | 14 | 1/3 |
| | PUB | Palustrine Unconsolidated Bottom | 9 | 0.001/0.002 |
| | | | **TOTAL (ha/ac)** | **1/3** |

| Table 3. Historical Wetland Impacts Within NASA Boundaries in Hectares/Acres[1] (cont.) | | | | |
|---|---|---|---|---|
| **Year** | **Cowardin Classification** | **Habitat** | **Functional Value** | **Hectares/Acres** |
| **1988** | E2EM | Estuarine Intertidal Emergent | 17 | 2/5 |
| | PAB | Palustrine Aquatic Bed | 14 | 0.2/0.5 |
| | PEM | Palustrine Emergent | 14 | 0.4/1 |
| | PFO | Palustrine Forested | 14 | 0.1/0.3 |
| | PSS | Palustrine Scrub Shrub | 14 | 4/11 |
| | PUB | Palustrine Unconsolidated Bottom | 9 | 2/4 |
| | | | **TOTAL (ha/ac)** | **9/22** |
| **1994** | E2EM | Estuarine Intertidal Emergent | 17 | 0.04/0.1 |
| | PEM | Palustrine Emergent | 14 | 0.4/1 |
| | PFO | Palustrine Forested | 14 | 0.4/1 |
| | PSS | Palustrine Scrub Shrub | 14 | 0.4/1 |
| | | | **TOTAL (ha/ac)** | **1/3** |
| **2012** | M1UB | Marine Subtidal Unconsolidated Bottom | 6 | 85/211 |
| | M2US | Marine Intertidal Unconsolidated Shore | 9 | 7/17 |
| | | | **TOTAL (ha/ac)** | **92/228** |
| **No Action Alternative[2]** | PEM | Palustrine Emergent | 14 | 1/2 |
| | PSS | Palustrine Scrub Shrub | 14 | 0.06/0.15 |
| | M1UB | Marine Subtidal Unconsolidated Bottom | 6 | 20/50 |
| | M2US | Marine Intertidal Unconsolidated Shore | 9 | 36/90 |
| | | | **TOTAL (ha/ac)** | 57/142 |
| **Proposed Action[3]** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 1/2 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 2/5 |
| | E2US | Estuarine Unconsolidated Shore | 17 | 0.4/1 |
| | PEM | Palustrine Emergent | 14 | 2/4 |
| | | | **TOTAL (ha/ac)** | **5/12** |
| **Cumulative Total by Habitat Type[4]** | E1UB | Estuarine Subtidal Unconsolidated Bottom | 17 | 32/79 |
| | E2EM | Estuarine Intertidal Emergent | 17 | 106/262 |
| | E2SS | Estuarine Intertidal Scrub Shrub | 17 | 0.8/2 |
| | E2US | Estuarine intertidal Unconsolidated Shore | 17 | 31/76 |
| | M1UB | Marine Subtidal Unconsolidated Bottom | 6 | 106/261 |

| Table 3. Historical Wetland Impacts Within NASA Boundaries in Hectares/Acres[1] (cont.) | | | | |
|---|---|---|---|---|
| Year | Cowardin Classification | Habitat | Functional Value | Hectares/Acres |
| | M2US | Marine Intertidal Unconsolidated Shore | 9 | 43/107 |
| | PAB | Palustrine Aquatic Bed | 13 | 0.2/0.4 |
| | PEM | Palustrine Emergent | 14 | 56/139 |
| | PFO | Palustrine Forested Palustrine Forested | 14 | 15/37 |
| | PSS | Palustrine Scrub Shrub | 14 | 139/342 |
| | PUB | Palustrine Unconsolidated Bottom | 9 | 3/7 |
| | PUS | Palustrine Unconsolidated Shore | 14 | 17/43 |
| | | | **CUMULATIVE TOTAL (ha/ac)** | **549/1,357** |

***Notes**:* [1] Totals may not add up exactly due to rounding and conversion.
[2] No Action Alternative impacts based upon 2014 UAS Airstrip construction and beach renourishment.
[3] Future impacts are based on the upper end of the range of impacts presented in the Site-wide PEIS, Section 3.5.2.2.
[4] Includes historical impacts for all years photography was available and the Proposed Action.

### 2.2.2 Outside NASA Boundaries

**Table 4** provides the results of the aerial photography review and calculation for historical wetland loss outside of NASA boundaries (photography was only available for the years 1938 and 1974). This table also includes the functional value established using Tiner's methodology. There was a difference in the coverage of the aerial photographs between the two analysis years (1938 and 1974). The majority of the difference was within estuarine areas; however, there were gaps of inland areas, as well. In 1938, 1,007 ha (2,488 ac) of the hydric soils within the aerial photography coverage area were identified as converted to agricultural fields. The conversion of wetlands (i.e., hydric soils) to agricultural use amounts to a 12.0% loss of wetlands. In 1974, 1,060 ha (2,620 ac) of the hydric soils within the aerial photography coverage area were identified as agricultural areas totaling a 12.6% loss of wetlands. Wetlands impacts after 1974 are unknown, but were assumed to be minor in nature; these impacts were not confirmed due to the lack of available USACE permit data that would quantify the permitted impacts from 1974 to present.

| Table 4. Historic Wetland Impacts Outside of NASA Boundaries in Hectares/Acres | | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Study Area Size[1] | Average Hydric Soils | Aerial Photo Coverage[2] | Wetland Loss[3] | Cowardin Classification | Habitat | Functions and Values Total |
| 1938 | 20,539 ha<br>50,753 ac | 8,363 ha<br>20,665 ac | 14,608 ha<br>36,097 ac | 1,007 ha<br>2,488 ac | PFO | Palustine Forested | 9 |
| 1974 | 20,539 ha<br>50,753 ac | 8,363 ha<br>20,665 ac | 17,013 ha<br>42,040 ac | 1,060 ha<br>2,620 ac | PFO | Palustine Forested | 9 |

***Notes**:* [1] Includes both HUC Codes, minus NASA property.
[2] Aerial Photo Coverage did not include the entire Study Area.
[3] Wetland loss is calculated by determining the area converted to agriculture compared to the 1997 hydric soils historic wetlands extent. Conversion to agriculture is the assumed wetland loss.

### 2.2.3 Total Study Area Comparison

Historical total wetland losses across the entire study area from 1938 to present (2012) totaled 1,555 ha (3,842 ac); 495 ha (1,222 ac) within NASA boundaries and 1,060 ha (2,620 ac) outside NASA boundaries.

Wetland losses within NASA's boundaries accounted for 32% of the wetland impacts in the total study area during this timeframe. The amount of historical wetland loss attributable to NASA within the total study area appears large; however, it is important to note that during that time period, NASA was one of the largest developments within the study area and a majority of the remaining portions of the study area remained undeveloped.

### 2.3 Evaluation of Change in Functional Value Over Time

As wetlands are lost over the study area, the overall function and total value of those wetlands will decrease. **Table 5** provides the total functional value for each of the 10 wetland functions and the percent change in value over time for the years 1938 and 2025 determined using the method described in Section 1.3.4. The year 2025 is the temporal extent of this study since there are no known proposed projects at WFF beyond this timeframe. **Table 5** provides data for the entire study area; however, since the Proposed Action would not affect the Streamflow Maintenance function, this function was removed from the analysis. The 2025 functional value was calculated with and without the Proposed Action to determine how much of the change in functional value is attributable to the Proposed Action. The change in functional value attributable to the Proposed Action would be minimal and range from 0.03% (fish and shellfish/waterbird habitat) to 0.05% (conservation of biodiversity).

**Table 5. Total Functional Scores for Each Wetland Function**

| Wetland Functions | Surface Water Detention | Coastal Storm Surge Detention | Streamflow Maintenance * | Nutrient Transformation | Sediment & Particulate Retention | Shoreline Stabilization | Fish & Shellfish Habitat | Waterbird Habitat | Other Wildlife Habitat | Conservation of Biodiversity |
|---|---|---|---|---|---|---|---|---|---|---|
| **Change in the 10 Functions and Values With the Proposed Action** | | | | | | | | | | |
| **1938 Functional Score** | 64,042 | 62,901 | 387 | 62,880 | 63,089 | 62,376 | 54,748 | 58,292 | 59,087 | 35,247 |
| **2025 Functional Score** | 60,766 | 60,396 | 8 | 60,075 | 60,320 | 60,185 | 53,394 | 56,855 | 56,808 | 33,725 |
| **Change in Function and Value (%)** | -5.11 | -3.98 | -97.85 | -4.46 | -4.39 | -3.51 | -2.47 | -2.47 | -3.86 | -4.32 |
| **Change in the 10 Functions and Values Without Proposed Action** | | | | | | | | | | |
| **Change in Function and Value (%)** | -5.08 | -3.94 | NA | -4.42 | -4.35 | -3.47 | -2.44 | -2.43 | -3.82 | -4.27 |
| **Change in Functional Score Attributable to Proposed Action (%)** | -0.04 | -0.04 | NA | -0.04 | -0.04 | -0.04 | -0.03 | -0.03 | -0.03 | -0.05 |

***Note***: * The function of stream flow maintenance is not affected by the Proposed Action and was not included in this analysis.

# 3.0 CONCLUSIONS

In determining whether the historical and cumulative impacts to wetlands would potentially be significant, it is important to discuss the regulatory requirements in place to offset wetland impacts through avoidance and minimization measures. Unavoidable impacts to wetlands within the NASA boundaries since promulgation of the 1972 CWA (which established the basic structure for Section 404 permits) and Executive Order 11990 have been minimized to the greatest extent possible. As shown in **Table 3**, 383 ha (946 ac) of wetlands within NASA's boundaries were impacted between 1938 and 1974. Of these impacts, 258 ha (923 ac) were associated with wetland dredge and fill actions taken at Wallops Island from 1939 through 1966, primarily attributed to construction of the Wallops Island Causeway. No mitigation was performed for these wetland impacts since the regulatory authority did not exist to protect wetlands during this timeframe.

Since implementation of permit requirements and methodology for delineating wetlands (USACE 1987), 103 ha (255 ac) of wetlands have been or are planned to be impacted at WFF through other actions (1988 through present [2014]). Additionally, every 3 to 5 years, the No Action Alternative of recurring beach renourishment will temporarily impact the same area of approximately 60 ha (150 ac) of marine subtidal and intertidal unconsolidated bottoms. In accordance with the CWA and EO 11990, NASA has secured the proper permits through the USACE, Virginia Marine Resources Commission, Virginia Department of Environmental Quality, and Accomack County. The additional impact of up to 5 ha (12 ac) of wetlands from implementation of the Proposed Action addressed in the Site-wide PEIS would be avoided and minimized to the greatest extent possible. Any impacts that could not be avoided would be permitted through the USACE, Virginia Marine Resources Commission, Virginia Department of Environmental Quality, and Accomack County to ensure no net loss of wetlands.

Therefore, while unavoidable adverse impacts to wetlands would occur through implementation of the Proposed Action and have occurred cumulatively over time at WFF, no net loss of wetlands has occurred since 1988 due to the existence of regulations which require unavoidable impacts to be mitigated. Moreover, while the appropriate mitigation is determined at the time of permitting, it is often the case that the ratio of wetlands created to wetlands lost is greater than 1:1.

As shown in **Table 2**, there are currently 12,409 ha (30,668 ac) of wetlands throughout the entire study area, the majority of which have a functional value of 17. The Proposed Action has the potential to impact approximately 0.04% of the total wetlands within the study area. The cumulative loss in wetland functional value based on the methodology used by Tiner and Fizzell demonstrate a functional score loss of no more than 5.11% across all functions evaluated since 1938 (including the Proposed Action). The Proposed Action contributes 0.03 to 0.05% (depending on the function being evaluated) of this loss. Therefore, the Proposed Action would not contribute a significant cumulative impact to wetlands.

# 4.0 REFERENCES


Environmental Protection Agency (EPA). 1996. Aerial Photographic and NASA Wallops Flight Facility Wallops Island, Virginia. EPA Region 3.

EPA. 2004. Aerial Photographic Analysis of NASA Wallops Flight Facility Site. Linden, Virginia: Giles, Kenneth W. and Donley E. Kisner.

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# APPENDIX I
# PUBLIC COMMENT PERIOD SUMMARY

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## 1.0 INTRODUCTION

This document provides a summary of the public comment period for the NASA Wallops Flight Facility (WFF) Draft Site-wide Programmatic Environmental Impact Statement (PEIS). The public notices, public meeting materials, and public comments are provided in the attached appendices.

## 2.0 PUBLIC COMMENT PERIOD

The Draft Site-wide PEIS was available for comment during the 45-day public comment period that ran from May 4 to June 18, 2018. Virginia Department of Environmental Quality (VDEQ) is provided a 60-day Coastal Zone Management Act (CZMA) review; VDEQ's CZMA comment period ended July 3, 2018.

### 2.1 Notice of Availability

The Notice of Availability (NOA) was published on May 4, 2018 in the *Federal Register* (**Appendix A**). The NOA notified the public and government entities of the draft PEIS availability, identified where copies of the draft PEIS could be reviewed, and provided information on how to electronically review the draft PEIS and submit comments to NASA WFF. The NOA provided the duration of the 45-day comment period, and announced the date and time of the public meeting held at the NASA Wallops Flight Facility Visitor Center. A NOA was also published in four area newspapers: *Eastern Shore News, Chincoteague Beacon, Eastern Shore Post,* and *The Daily Times* (**Appendix A**).

In addition to the *Federal Register* and area newspaper notices, emails were sent to NASA WFF employees, tenants and partners that provided meeting information and invited comments on the findings in the Draft Site-wide PEIS. A project website has been established and maintained at https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.

### 2.2 Public Meeting

Public meetings are an important aspect of the environmental impact analysis process. A public meeting was held at the NASA Wallops Flight Facility Visitor Center on May 23, 2018 from 6:00 to 8:00 p.m. The meeting was in an in an "open house" format to create a comfortable atmosphere where attendees could interact directly with NASA personnel. Attendees were welcomed at the entrance by NASA representatives. Attendees were asked to sign in, provided a factsheet, and directed to a poster display. Posters were designed to describe the Proposed Action, present the purpose and need for the Proposed Action, provide an overview of several institutional support projects and operational missions and activities, and briefly describe the roles of the cooperating agencies in many of these proposals. Copies of the posters, factsheet, sign-in sheet, and comment sheet are found in **Appendix B**.

NASA provided the public with multiple venues for commenting during the public meeting. Attendees could complete a comment form and give it to a NASA representative at the meeting; mail, email, or fax comments; or provide oral comments to the stenographer present at the meeting. One member of the public attended the public meeting. No written or oral comments were submitted during the public meeting. Ms. Shari Miller provided the stenographer with a statement for the record that no oral public comments were given. The public meeting transcript is located in **Appendix C**.

## 2.3 Public Comments

NASA received nine comment documents containing approximately 60 comments during the 45-day public comment period. All comments received were considered to determine whether corrections, clarifications, or other revisions were required before publishing the Final Site-wide PEIS. **Appendix C** provides the comment documents that were received during the public comment period and NASA's responses to those comments.

| Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Public, Agency or Organization** | **Commenter** |
| 001 | Private Citizen | BK1492 |
| 002 | Somerset County | Ralph Taylor |
| 003 | U.S. Army Corps of Engineers | Brian Denson |
| 004 | Environmental Protection Agency | Barbara Rudnick |
| 005 | Virginia Marine Resources Commission | Randal Owen |
| 006 | U.S. Navy Surface Combat Systems Center | Michael Hooks |
| 007 | National Environmental Satellite Data Information Service | John Gironda |
| 008 | National Oceanic and Atmospheric Administration | Keith Hanson; Brian Hopper |
| 009 | Virginia Department of Environmental Quality | Bettina Rayfield; John Fisher |

**PUBLIC NOTICES**

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**ADDRESSES:** The public meeting will be held in Room N–3437 A–B, U.S. Department of Labor, 200 Constitution Avenue NW, Washington, DC 20210.

*Written Comments:* Submit written comments to the OSHA Docket Office, Docket No. OSHA–2018–0005, Room N–3653, U.S. Department of Labor, 200 Constitution Avenue, NW, Washington, DC 20210; telephone (202) 693–2350. You may submit materials, including attachments, electronically at *http://www.regulations.gov* which is the Federal eRulemaking Portal. Follow the on-line instructions for submissions. All comments should be identified with Docket No. OSHA–2018–0005.

*Registration To Attend and/or To Participate in the Meeting:* If you wish to attend the public meeting, make an oral presentation at the meeting, or participate in the meeting via telephone, you must register using this link *https://www.eventbrite.com/e/occupational-safety-and-health-administration-stakeholder-meeting-registration-45311347460* by close of business on May 29, 2018. Participants may speak and pass out written materials, but there will not be an opportunity to give an electronic presentation. Actual times provided for presentation will depend on the number of requests, but no more than 10 minutes per participant. There is no fee to register for the public meeting. Registration on the day of the public meeting will be permitted on a space-available basis beginning at 12 p.m. ET. After reviewing the presentation requests, participants will be contacted prior to the meeting with an approximate time the participants' presentation is scheduled to begin.

**FOR FURTHER INFORMATION CONTACT:**

*For press inquiries:* Mr. Frank Meilinger, Director, OSHA Office of Communications, U.S. Department of Labor; telephone (202) 693–1999; email *meilinger.francis2@dol.gov.*

*For general information:* Mr. Anthony Rosa, Deputy Director, OSHA Directorate of Whistleblower Protection Programs, U.S. Department of Labor; telephone (202) 693–2199; email *osha.dwpp@dol.gov.*

**SUPPLEMENTARY INFORMATION:**

## Scope of Meeting

OSHA is interested in obtaining information from the public on key issues facing the agency's whistleblower program. This meeting will be the first in a series of meetings requesting public input on this program. For this meeting, OSHA is focusing on issues relating to whistleblower protection in the railroad and trucking industries. In particular, the agency invites input on the following:

1. How can OSHA deliver better whistleblower customer service?
2. What kind of assistance can OSHA provide to help explain the whistleblower laws it enforces?

## Request for Comments

Regardless of attendance at the public meeting, interested persons may submit written or electronic comments (see **ADDRESSES**). Submit a single copy of electronic comments or two paper copies of any mailed comments, except that individuals may submit one paper copy. Please indicate which industry (railroad or trucking) your comments are intended to address. To permit time for interested persons to submit data, information, or views on the issues in the ''Scope of Meeting'' section of this notice, submit comments by June 5, 2018. Please include Docket No. OSHA–2018–0005. Comments received may be seen in the U.S. Department of Labor, OSHA Docket Office, (see **ADDRESSES**), between 10:00 a.m. and 3:00 p.m. ET, Monday through Friday.

## Access to the Public Record

Electronic copies of this **Federal Register** notice are available at *http://www.regulations.gov.* This notice, as well as news releases and other relevant information, also are available on the Directorate of Whistleblower Protection Programs' web page at: *http://www.whistleblowers.gov.*

## Authority and Signature

Loren Sweatt, Deputy Assistant Secretary for Occupational Safety and Health, authorized the preparation of this notice under the authority granted by Secretary's Order 01–2012 (Jan. 18, 2012), 77 FR 3912 (Jan. 25, 2012); 29 U.S.C. 660(c); 49 U.S.C. 31105; 49 U.S.C. 20109, and 6 U.S.C. 1142.

Signed at Washington, DC on April 30, 2018.

**Loren Sweatt,**

*Deputy Assistant Secretary of Labor for Occupational Safety and Health.*

[FR Doc. 2018–09456 Filed 5–3–18; 8:45 am]

BILLING CODE 4510–26–P

# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

**[Notice (18–039)]**

## National Environmental Policy Act; Wallops Flight Facility; Site-Wide

**AGENCY:** National Aeronautics and Space Administration (NASA).

**ACTION:** Notice of availability of the Draft Site-wide Programmatic Environmental Impact Statement (PEIS) for improvement of infrastructure and services at Wallops Flight Facility (WFF), Accomack County, Virginia.

**SUMMARY:** Pursuant to the National Environmental Policy Act (NEPA), as amended, the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA, and NASA's NEPA policy and procedures, NASA has prepared a Draft PEIS for the improvement of infrastructure and services at WFF. The Federal Aviation Administration's Air Traffic Organization (FAA–ATO) and Office of Commercial Space Transportation (FAA–AST); the Federal Highway Administration (FHWA); the National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service (NOAA–NESDIS); the U.S. Army Corps of Engineers (USACE); the U.S. Coast Guard; the U.S. Fish and Wildlife Service (USFWS); the U.S. Navy, Naval Sea Systems Command (NAVSEA); the U.S. Navy, Naval Air Systems Command (NAVAIR); U.S. Navy, U.S. Fleet Forces Command; the U.S. Environmental Protection Agency (EPA); the U.S. Air Force Space Command/Space and Missile Systems Center; and Virginia Commercial Space Flight Authority (Virginia Space) have served as Cooperating Agencies in preparing the Draft PEIS as they either have permanent facilities or missions at WFF or possess regulatory authority or specialized expertise pertaining to the Proposed Action.

The purpose of this notice is to apprise interested agencies, organizations, tribal governments, and individuals of the availability of the Draft PEIS and to invite comments on the document. In partnership with its Cooperating Agencies, NASA will hold a public meeting as part of the Draft PEIS review process. The meeting location and date is provided under **SUPPLEMENTARY INFORMATION** below.

**DATES:** Interested parties are invited to submit comments on environmental issues and concerns, preferably in writing, no later than forty-five (45) days following the publication of the EPA's Notice of Availability of the Draft PEIS in the **Federal Register**. Once known, this date will be posted on the project website at: *https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.*

**ADDRESSES:** Comments submitted by mail should be addressed to Shari Miller, Site-wide PEIS, NASA Goddard Space Flight Center's Wallops Flight Facility, Mailstop: 250.W, Wallops Island, Virginia 23337. Comments may be submitted via email to *Shari.A.Miller@nasa.gov.*

The Draft PEIS may be reviewed at the following locations:

(a) Chincoteague Island Library, Chincoteague, Virginia, 23336 (757) 336–3460
(b) NASA Wallops Visitor Center, Wallops Island, Virginia, 23337 (757) 824–1344
(c) Eastern Shore Public Library, Accomac, Virginia, 23301 (757) 787–3400
(d) Northampton Free Library, Nassawadox, Virginia, 23413 (757) 414–0010

A limited number of hard copies of the Draft PEIS are available, on a first request basis, by contacting the NASA point of contact listed under **FOR FURTHER INFORMATION CONTACT**. The Draft PEIS is available on the internet in Adobe® portable document format at *https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.* The **Federal Register** Notice of Intent to prepare the Draft PEIS, issued on July 11, 2011, is also available on the internet at the same website address.

**FOR FURTHER INFORMATION CONTACT:** Shari Miller, Site-wide PEIS, NASA Goddard Space Flight Center's Wallops Flight Facility, Mailstop: 250.W, Wallops Island, Virginia 23337; telephone (757) 824–2327; email: *Shari.A.Miller@nasa.gov.* A toll-free telephone number, (800) 521–3415, is also available for persons outside the local calling area. When using the toll-free number, please follow the menu options and enter the ''pound sign (#)'' followed by extension number ''2327.'' Additional information about NASA's WFF may be found on the internet at *http://www.nasa.gov/centers/wallops/home/index.html.* Information regarding the NEPA process for this proposal and supporting documents (as available) are located at *https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.*

**SUPPLEMENTARY INFORMATION:** WFF is a NASA Goddard Space Flight Center field installation located in northern Accomack County on the Eastern Shore of Virginia. The facility consists of three distinct landmasses—the Main Base, Wallops Mainland, and Wallops Island. WFF operates the oldest active launch range in the continental U.S. and the only range completely under NASA management. For over 70 years, WFF has flown thousands of research vehicles in the quest for information on the characteristics of airplanes, rockets, and spacecraft, and to increase the knowledge of the Earth's upper atmosphere and the near space environment. The flight programs and projects conducted by WFF range from small sounding and suborbital rockets, unmanned scientific balloons, unmanned aerial systems, manned aircraft, and orbital spacecraft to next-generation launch vehicles and small- and medium-classed launch vehicles. In keeping with the principles, goals, and guidelines of the 2010 National Space Policy, as updated by the 2013 U.S. National Space Transportation Policy and the 2017 Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, NASA is proposing to improve its service capability at WFF to support a growing mission base in the areas of civil, defense, and academic aerospace. One guiding principle of the National Space Policy is for Federal agencies to facilitate the commercial space industry. The Mid-Atlantic Regional Spaceport, a commercial launch site on Wallops Island, is a real-world example of WFF's commitment to making commercial access to space a reality. Accordingly, it is expected that a commercial presence at WFF will continue to expand in the coming years.

The National Space Policy also instructs Federal agencies to improve their partnerships through cooperation, collaboration, information sharing, and/or alignment of common pursuits with each other. WFF supports aeronautical research, and science, technology, engineering, and math (STEM) education programs by providing other NASA centers and other U.S. government agencies access to resources such as special use (*i.e.,* controlled/restricted) airspace, runways, and launch pads. WFF regularly facilitates a wide array of U.S. Department of Defense (DoD) research, development, testing, and evaluation; training missions, including target and missile launches; and aircraft pilot training. Similar to its forecasted commercial growth at WFF, NASA also expects an increase in DoD presence at WFF in the foreseeable future.

Finally, the National Space Policy directs NASA to fulfill various key civil space roles regarding space science, exploration, and discovery; a number of which have been priorities at WFF for decades. NASA's need to ensure continued growth while preserving the ability to safely conduct its historical baseline of services is a key component of facilitating future projects and new missions at WFF.

**Related Environmental Documents**

In January 2005, NASA issued a Final Site-Wide Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for its operations and institutional support at WFF. Since then, substantial growth has occurred and NASA, and its Cooperating Agencies, have prepared multiple supplemental NEPA documents including the 2008 EA/FONSI for the Wallops Research Park; the 2009 EA/FONSI for the Expansion of the Wallops Flight Facility Launch Range; the 2010 PEIS/Record of Decision for the Shoreline Restoration and Infrastructure Protection Program; the 2011 EA/FONSI for the Alternative Energy Project; the 2011 EA/FONSI for the Main Entrance Reconfiguration; the 2011 NOAA–NESDIS EA/FONSI for Electrical and Operational Upgrade, Space Addition, and Geostationary Operational Environmental Satellite Installation; the 2012 EA/FONSI for the North Wallops Island Unmanned Aerial Systems Airstrip Project; the U.S. Fleet Force Command's 2013 EA/FONSI for E–2/C–2 Field Carrier Landing Practice at WFF; the Navy's 2014 EA/FONSI for the Testing of Hypervelocity Projectiles and an Electromagnetic Railgun; the 2015 Supplemental EA/FONSI for Antares 200 Configuration Expendable Launch Vehicle at WFF; the 2016 EA/FONSI for Establishment of Restricted Area Airspace R–6604 C/D/E; the Navy's 2017 EA/FONSI for and the Installation and Operation of Air and Missile Defense Radar AN/SPY-6; and the 2017 U.S. Air Force's EA/FONSI for the Instrumentation Tower on Wallops Island.

**Need for Preparing a PEIS**

Since the 2005 WFF Site-wide EA, WFF, NOAA–NESDIS, and the Navy have updated their Master Plans; which propose new facilities and numerous infrastructure improvements to enable a growing mission base. Additionally, during reviews of the post-2005 Site-wide EA NEPA documents, resource agencies have expressed concerns regarding cumulative environmental effects and a desire for NASA to consider all reasonably foreseeable future projects at WFF in a consolidated NEPA document. NASA determined that preparing a single Site-wide PEIS not only would assist in its decision-making process for future mission growth at WFF but also address concerns regarding cumulative environmental effects. Therefore, the Site-wide PEIS considers all reasonably foreseeable future actions at WFF; those proposed by NASA along with those proposed by its tenants and partners.

**Cooperating Agency Actions**

The Site-wide PEIS will serve as a decision-making tool not only for NASA but also for its Cooperating Agencies. Given the potential for their undertaking actions related to NASA's actions, each of these agencies has been involved closely in NASA's NEPA process.

**Alternatives**

The PEIS evaluates the environmental consequences of a range of reasonable alternatives that meet NASA's need to ensure continued growth at WFF while also preserving the ability to safely conduct its historical baseline of services. The planning horizon for actions in the PEIS is 20 years.

Currently under consideration are the Proposed Action and a No Action alternative. The Proposed Action would support a number of facility projects ranging from new construction, demolition, and renovation; the replacement of the Wallops causeway bridge; maintenance dredging between the boat docks at the Main Base and Wallops Island; development of a deep-water port and operations area on North Wallops Island; construction and operation of an additional medium to heavy class launch site; the introduction of new NASA and DoD programs at WFF; the expansion of the launch vehicle services with liquid-fueled intermediate class and solid fueled heavy class launch vehicles; and the consideration of commercial human spaceflight missions and the return of launch vehicles to the launch site. Under the No Action Alternative, WFF and its partners would continue the existing operations and programs previously discussed in the 2005 Site-Wide EA and the subsequent NEPA documents identified under *Related Environmental Documents.*

**Public Meeting**

NASA and its Cooperating Agencies will hold a public meeting to discuss WFF's proposed actions and to solicit comments on the Draft PEIS. The public meeting will be held at the WFF Visitor Center on May 23, 2018, from 6 p.m. to 8 p.m.

NASA anticipates that the public will be most interested in the potential environmental impacts of each alternative on protected and special-status species, wetlands, noise, and socioeconomics.

In developing its Final PEIS, NASA will consider all comments received; comments received and responses to comments will be included in the Final PEIS. In conclusion, written public input on environmental issues and concerns associated with the improvement of infrastructure and services at WFF is hereby requested.

**Cheryl E. Parker,**

*Federal Register Liaison.*

[FR Doc. 2018–09469 Filed 5–3–18; 8:45 am]

BILLING CODE 7510–13–P

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## NATIONAL SCIENCE FOUNDATION

### Proposal Review Panel for Computing and Communication Foundations; Notice of Meeting

In accordance with the Federal Advisory Committee Act (Pub., L. 92–463, as amended), the National Science Foundation (NSF) announces the following meeting:

*Name and Committee Code:* Proposal Review Panel for Computing and Communication Foundations—Science and Technology Centers—Integrative Partnerships Site Visit (#1192)

*Date and Time:* May 21, 2018; 7:00 p.m.–8:30 p.m.; May 22, 2018; 8:00 a.m.–8:00 p.m.; May 23, 2018; 8:00 a.m.–4:00 p.m.

*Place:* McGovern Institute for Brain Research, Massachusetts Institute of Technology (MIT), 43 Vassar St., Cambridge, MA 02139.

*Type of Meeting:* Part-Open.

*Contact Person:* Phillip Regalia, National Science Foundation, 2415 Eisenhower Avenue, Room W10207, Alexandria, VA 22314; Telephone: (703) 292–8910.

*Purpose of Meeting:* Site visit to assess the progress of the STC Award: 1231216 ''A Center for Brains, Minds and Machines: The Science and the Technology of Intelligence'', and to provide advice and recommendations concerning further NSF support for the Center.

*Agenda: MIT Renewal Review Site Visit*

**Monday, May 21, 2018**

7:00 p.m. to 8:30 p.m.: Closed
Site Team and NSF Staff meet to discuss site visit materials, review process and charge

**Tuesday, May 22, 2018**

8:00 a.m. to 8:00 p.m.: Open
Presentations by Awardee Institution, faculty staff and students, to Site Team and NSF Staff; Discussions, question and answer sessions

**Wednesday, May 23, 2018**

8:00 a.m.–4:00 p.m.: Closed
Complete written site visit report with preliminary recommendations.

*Reason for Closing:* The work being reviewed during closed portions of the site review will include information of a proprietary or confidential nature, including technical information; financial data, such as salaries; and personal information concerning individuals associated with the project. These matters are exempt under 5 U.S.C. 552b(c), (4) and (6) of the Government in the Sunshine Act.

Dated: May 1, 2018.

**Crystal Robinson,**

*Committee Management Officer.*

[FR Doc. 2018–09479 Filed 5–3–18; 8:45 am]

BILLING CODE 7555–01–P

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## NATIONAL SCIENCE FOUNDATION

### Committee on Equal Opportunities in Science and Engineering; Notice of Meeting

In accordance with the Federal Advisory Committee Act (Pub. L. 92–463, as amended), the National Science Foundation (NSF) announces the following meeting:

*Name and Committee Code:* Committee on Equal Opportunities in Science and Engineering (CEOSE) Advisory Committee Meeting (#1173).

*Date and Time:* May 30, 2018 1:00 p.m.–5:30 p.m.; May 31, 2018 8:30 a.m.–3:30 p.m.

*Place:* National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA 22314. To help facilitate your entry into the building, please contact Una Alford (*ualford@nsf.gov* or 703–292–7111) on or prior to May 29, 2018.

*Type of Meeting:* Open.

*Contact Person:* Dr. Bernice Anderson, Senior Advisor and CEOSE Executive Secretary, Office of Integrative Activities (OIA), National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA 22314. Contact Information: 703–292–8040/*banderso@nsf.gov.*

*Minutes:* Meeting minutes and other information may be obtained from the CEOSE Executive Secretary at the above address or the website at *http://www.nsf.gov/od/oia/activities/ceose/index.jsp.*

*Purpose of Meeting:* To study data, programs, policies, and other information pertinent to the National Science Foundation and to provide advice and recommendations concerning broadening participation in science and engineering.

*Agenda:*

- Opening Statement and Chair Report by the CEOSE Chair
- NSF Executive Liaison Report
- Discussion: Responses to the 2015–2016 CEOSE Biennial Report: NSF and Higher Education

# Top Va. education official talks school safety

**Carol Vaughn**
Salisbury Daily Times
USA TODAY NETWORK - DELMARVA

**Virginia Secretary of Education Atif Qarni speaks during a stop at Eastern Shore Community College in Melfa.** STAFF PHOTO BY CAROL VAUGHN

Virginia Secretary of Education Atif Qarni was on the Eastern Shore of Virginia on Wednesday as part of a statewide listening tour.

Gov. Ralph Northam appointed the 40-year-old former civics, economics, U.S. history and math teacher at Beville Middle School in Prince William County, who immigrated from Pakistan at age 10 with his family.

He is the first of 19 Virginia secretaries of education to be appointed "right out of the classroom," Qarni said.

"There are a lot of teacher friends of mine who I talk to on a daily basis, and they are really counting on us to make a lot of changes — positive changes," he said.

Qarni, in addition to a question-and-answer session at Eastern Shore Community College, made stops at Kiptopeke Elementary School and Nandua High School and also was scheduled to attend a PTA meeting on the Shore.

Qarni said the listening tour is an important part of the Northam administration's strategy as it works on setting priorities for the next biennial budget.

"It's really important that we go and talk to different communities, and talk about what things are being done well and what challenges we are facing — and then after that, our office will produce a very comprehensive report and take that to the governor, saying these are our recommendations," he said.

Virginia's community colleges will play an important role, in particular in the area of workforce development, Qarni said.

Among a dozen questions Qarni fielded from college students, faculty and administrators in the hour-long session were queries about school safety, teacher shortages, standardized testing and dual enrollment.

Qarni said multiple actions are being taken at the state level to address concerns about school safety — including roundtables being convened by Secretary of Public Safety and Health Brian Moran; Secretary of Health Dr. Daniel Carey leading discussions about mental health issues; and the General Assembly's creation of a commission to study the problem.

"So there are a lot of folks working in different silos. Right now, what our goal will be from an education perspective, is to try to get everybody to communicate better," Qarni said.

"One thing we don't want is that education perspective missing — it's a big piece of it," he said.

Qarni said in his view, there needs to be a focus on devoting additional resources to school counselors, in addition to the emphasis on providing more school resource offices and on improving security of school buildings.

"We have significant issues with the ratio of school counselors to students, and also, school counselors are doing a lot more things outside of actually working with children," he said.

Qarni also spoke about the teacher shortage problem in Virginia and efforts to develop a statewide plan to address it.

"We just ran the numbers. There are currently 935 positions where a long-term substitute is in the position which should be fully certified," he said, noting that number is slightly lower than last year.

Special education is the biggest area with a shortage, with about 250 teaching positions unfilled.

Additionally, there has been a rise in teacher shortages at the elementary school level, Qarni said.

"Salary — how to really wrap our head around increasing salaries — is a significant issue," he said, adding, "It's probably the most challenging thing as far as the teacher shortage is concerned."

Additional related concerns include working conditions for teachers, which are affected by things like class size and older buildings in some regions.

"It can't be a one size fits all approach. There are some broad challenges that apply to everyone, but then there are very specific things," Qarni said, adding, "One thing that we don't want to do is try to have unfunded state mandates."

"From our perspective, we are going to have a statewide plan — it definitely will have a fund attached to it," he said.

Among state initiatives that will be announced during Teacher Appreciation Week in May are several provisions to help teachers, including legislation that increases the time allowed for teachers to get recertification from five to 10 years and an extension of the provisional license term from three to five years, Qarni said.

*On Twitter @cvvaughnESN*
*443-260-3314*

**In this 2017 file photo, a man looks at a map showing where the Eastern Shore of Virginia Broadband Authority has fiber laid on the Eastern Shore, at a town hall meeting at Eastern Shore Community College in Melfa.**
STAFF FILE PHOTO BY CAROL VAUGHN

# Broadband

Continued from Page 1A

brand, using a combination of wireless technologies, including television white spaces, to celebrate the release said.

"DNG and Microsoft share a commitment to establishing quality broadband solutions for rural America," said Bob Nichols, chief executive officer of DNG.

"Our partnership reflects a shared vision that focuses on an effective plan to align stakeholders, technology and resources for a sustainable path to address the digital divide," he said.

Virginia and Maryland officials commented on the need to close the rural broadband gap.

"As a native of the Eastern Shore, I am thrilled that Microsoft is taking action to bring new broadband connectivity to communities that need it," Gov. Ralph Northam said, adding, "This new effort, in addition to ongoing efforts in state government, will help bridge the digital divide.

"Connecting rural communities will help create jobs, grow our economy and improve our quality of life. I am happy to celebrate this positive step forward as we work to make our commonwealth work better for all Virginians, no matter who you are or where you live."

Maryland Gov. Larry Hogan said, "Reliable access to high-speed internet is critical for Maryland's small businesses, families and students to thrive in our 21st century economy. We are working diligently to eliminate the rural broadband gap and ensure that all Marylanders have the opportunity to access trusted, cost-effective broadband solutions."

*On Twitter @cvvaughnESN*
*443-260-3314*

# Ponies

Continued from Page 1A

Also Sunday, the fire company said the Saltwater cowboys responded to a report of three ponies stuck in the mud.

"Upon arriving the cowboys found one pony deceased and two more having difficulty. The two were transported to the carnival grounds and the vet was called," the fire company said in the Facebook post.

"The vet arrived, gave each pony two IV bags of fluid, wrapped each pony with blankets where they will be monitored for a lil while to see how they are doing but as of this writing, they seem to be doing very well."

The fire company identified the two rescued ponies as Surf Queen and Randy.

It said the dead pony, named Wild Island Orchid, was given a proper burial. The mare was 24 years old, Cole said.

"Thank you to those who reported these issues that allowed us to get there quickly, the Facebook post said.

**Wild Island Orchid, a 24-year-old Chincoteague pony, was found deceased by the Chincoteague Saltwater Cowboys in late April 2018.** DSC PHOTOGRAPHY IMAGE



**In this Nov. 12, 2017, file photo, an Orbital ATK Antares rocket launched from the Wallops Flight Facility.** NASA IMAGE

# Commercial resupply launch set for Wallops

**Jeremy Cox** Salisbury Daily Times | USA TODAY NETWORK - DELMARVA

NASA and a private contractor plan to light up the predawn sky over the Eastern Shore of Virginia next month with the launch of a commercial resupply rocket.

Dulles, Virginia,-based Orbital ATK will deliver supplies and science experiments to the International Space Station for the ninth time.

The Antares rocket's takeoff is scheduled for 5:04 a.m. Sunday, May 20. NASA didn't immediately provide launch-viewing information, but the flights are typically visible from much of the Mid-Atlantic and along the East Coast from New Hampshire to South Carolina.

The last Orbital launch at Wallops soared into space Nov. 12. Its Cygnus payload carried 7,400 pounds of cargo to the space station.

The flight was delayed nearly 24 hours after a small airplane wandered into the restricted area moments in the final minutes of countdown.

NASA's contract with Orbital was initially valued at $1.9 billion. It is one of two aerospace companies, along with Elon Musk's SpaceX, that ferry supplies to the orbiting outpost.

SpaceX conducts its flights at Cape Canaveral in Florida.

# Cape Charles Man Convicted of Child Sex Crimes To Be Sentenced Next Week

*By Linda Cicoira*

Lenny Rock Kenner, the 39-year-old Cape Charles man who was convicted of sex crimes with a six-year-old girl last spring, will be sentenced in Northampton Circuit Court next week. A jury recommended life plus seven years in prison and a fine of $200.

He was brought before Judge W. Revell Lewis III and given the mandatory term of five years in prison Monday for possessing a firearm after being convicted of a felon. That offense occurred in October 2015. It is unclear from the record what the previous felony was.

The incidents with the girl happened in 2014 and include convictions for object penetration of a child under 13, which carries a mandatory sentence of life in prison; aggravated sexual battery, which the jury recommended a term of five years and the fine; and custodial sexual abuse, for which the jury said he should serve two years. The girl was living at Kenner's home when the incidents occurred.

Kenner is being held in Eastern Shore Regional Jail, which is connected to the courthouse. Testimony at the trial showed Kenner served as a father figure to the victim and several other adolescents and teenagers including his own children.

Thirty-eight counts of possession of child pornography, listed as occurring in November 2015, were not prosecuted. Court records state those charges were not pursued "for tactical reasons in accordance with the discretion exercised by the commonwealth's attorney." The document was signed by Commonwealth's Attorney Beverly Leatherbury, defense lawyer Garrett Dunham, and Lewis last summer. Records stated 36 of the images were found on the desktop computer in the defendant's bedroom. The girl said he showed her sex videos.

A victim impact statement was filed in the court and made by the girl's mother. "This will affect her for the rest of her life," the woman wrote. "She had a part of her soul taken. She takes four baths plus a day with changing (of) all of her clothes. She also refuses to be in any room alone. I will also live with the challenges my daughter faces and nothing can ever heal her," the mother continued. "She receives … services five days a week even at school and will continue to receive any help she needs. Before this happened … she loved to laugh and smile and almost nothing made her mad. Now she thinks everything is her fault and feels like no one likes her."

# New Program for Finding At-Risk Wanderers

A program designed to find and rescue people who are at risk from wandering away from their loved ones, including those with Alzheimer's, autism, Down syndrome, and dementia, was initiated locally this week, according to Accomack Sheriff Todd Godwin.

The law enforcement agency joined forces with Project Lifesaver International, a leader in electronic search and rescue programs. Training includes teaching public safety officials how to use the equipment and how to gain the trust of and communicate with those in need. Training for caregivers will also be available, which Godwin said is "essential to a successful rescue."

Participants will wear, on their wrist or ankle, a radio transmitter that is comparable in size to a watch. The transmitter constantly emits a signal that can be tracked even in dense woods, a marsh, a concrete garage, or in a steel building.

The program allows rescues to be made in about 30 minutes, Godwin said. "Additionally, we have access to air support services, should it become necessary. The Accomack County Sheriff's Office (ACSO) … is constantly working toward developing public policy and effective law enforcement response to help save lives and bring loved ones home," he said.

To enroll, call coordinator, Capt. Todd Wessells of ACSO, at 757-787-1131.

## SALISBURY FIVE-DAY FORECAST

| TODAY | SATURDAY | SUNDAY | MONDAY | TUESDAY |
|---|---|---|---|---|
| HIGH 89° LOW 65° | HIGH 76° LOW 58° | HIGH 71° LOW 51° | HIGH 69° LOW 45° | HIGH 69° LOW 44° |
| Partly sunny | Not as warm with a few showers | Cloudy with brief showers | Partly sunny and nice | Mostly sunny and nice |

## SALISBURY TODAY

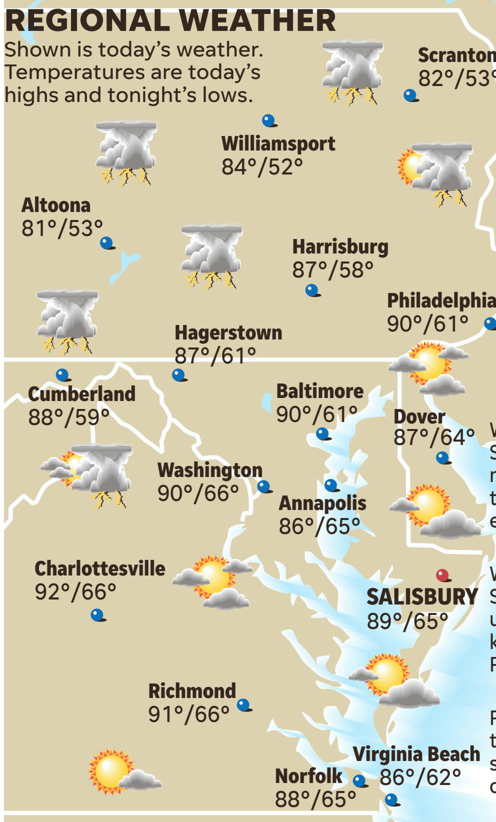
Partly sunny and breezy today with the temperature tying the record from 2001. Increasing clouds tonight.

## OCEAN CITY TODAY

Partly sunny and pleasantly warm today. Clear early tonight, then increasing clouds. Rather cloudy Saturday with a couple of showers.

## REGIONAL WEATHER

Shown is today's weather. Temperatures are today's highs and tonight's lows.




## REGIONAL FORECASTS

**Chesapeake Bay**
Wind S 7-14 knots today. Seas 3-5 feet. Visibility 5 miles. Wind SW 7-14 knots tonight. Seas 3-6 feet. Thickening clouds.

**Chincoteague**
Wind SSW 8-16 knots today. Seas 3-6 feet. Visibility unrestricted. Wind SSW 8-16 knots tonight. Seas 4-7 feet. Partly cloudy.

**Rehoboth Beach**
Partly sunny and very warm today. A shower or thunderstorm in the area tonight. A couple of showers Saturday.

## REGIONAL CITIES

| City | Today Hi | Lo | W | Saturday Hi | Lo | W |
|---|---|---|---|---|---|---|
| Annapolis | 86 | 65 | pc | 72 | 59 | sh |
| Baltimore | 90 | 61 | pc | 73 | 56 | sh |
| Cambridge | 86 | 64 | pc | 74 | 59 | sh |
| Charlottesville | 92 | 66 | pc | 74 | 58 | sh |
| Crisfield | 80 | 65 | pc | 71 | 59 | t |
| Cumberland | 88 | 59 | c | 73 | 56 | sh |
| Danville | 87 | 61 | pc | 77 | 58 | pc |
| Dover | 87 | 64 | pc | 72 | 57 | sh |
| Frederick | 90 | 61 | pc | 73 | 58 | sh |
| Fredericksburg | 91 | 65 | pc | 76 | 60 | sh |
| Gettysburg | 86 | 59 | pc | 72 | 55 | sh |
| Hagerstown | 87 | 61 | c | 71 | 57 | sh |
| Martinsburg | 89 | 61 | c | 72 | 57 | sh |
| Norfolk | 88 | 65 | s | 76 | 61 | pc |
| Ocean City | 75 | 62 | pc | 67 | 57 | sh |
| Pittsburgh | 76 | 50 | t | 73 | 53 | pc |
| Rehoboth Beach | 83 | 63 | pc | 71 | 59 | sh |
| Richmond | 91 | 66 | pc | 77 | 60 | t |
| Virginia Beach | 86 | 62 | s | 79 | 62 | pc |
| Washington, DC | 90 | 66 | pc | 75 | 60 | sh |
| Wheaton | 91 | 65 | pc | 74 | 59 | sh |
| Williamsburg | 90 | 67 | s | 79 | 62 | pc |
| Wilmington, DE | 88 | 60 | pc | 74 | 57 | sh |

## MARINE FORECAST

**Tangier Sound**
Partly sunny today. Wind S 7-14 knots. Seas 3-5 feet. Visibility 5 miles. Showers Saturday. Wind E 6-12 knots. Seas 1-3 feet.

**Pocomoke Sound**
Partly sunny today. Wind S 8-16 knots. Seas 4-7 feet. Visibility 5 miles. Showers Saturday. Wind N 4-8 knots. Seas 2-4 feet.

**Chesapeake Bay from Choptank River to Hooper Straits**
Clouds and sun today. Wind SSW 7-14 knots. Seas 2-4 feet. Visibility 5 miles. Showers Saturday. Wind N 4-8 knots becoming S. Seas 1-2 feet.

**Cape Henlopen**
Partly sunny today. Wind S 8-16 knots. Seas 4-8 feet. Visibility 5 miles. Showers Saturday. Wind NE 4-8 knots. Seas 3-6 feet.

**Ocean City**
Clouds and sun today; unhealthy air quality for sensitive groups. Wind SSW 10-20 knots. Visibility 5 miles. Seas 4-8 feet. Water temp 54.

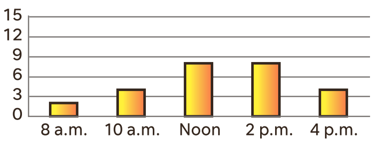
## ALMANAC

Salisbury through 4 p.m. Thursday

| | |
|---|---|
| **Temperature:** | |
| Thursday's high/low | 85°/62° |
| Normal high/low | 73°/51° |
| **Precipitation:** | |
| 24 hrs ending 4 p.m. Thu. | 0.00" |
| Month to date | 0.00" |
| Normal month to date | 0.29" |
| Year to date | 11.60" |
| Normal year to date | 15.15" |
| Last year to date | 11.23" |

## UV INDEX TODAY

The higher the **AccuWeather UV Index™** number the greater the need for eye and skin protection. **0-2**, Low; **3-5**, Moderate; **6-7**, High; **8-10**, Very High; **11+**, Extreme




## SUN AND MOON

| | |
|---|---|
| Sunrise today | 6:02 a.m. |
| Sunset tonight | 7:56 p.m. |
| Moonrise today | none |
| Moonset today | 9:28 a.m. |
| Total daylight | 13 hrs. 54 min. |
| Daylight gain | 1 min. |

| Last | New | First | Full |
|---|---|---|---|
| May 7 | May 15 | May 21 | May 29 |

## THE SKY

Source: Longway Planetarium

Tonight and tomorrow morning is the peak of the Aquariid meteor shower, but the bright moon will make the shower tougher to enjoy.

## TIDE INFORMATION

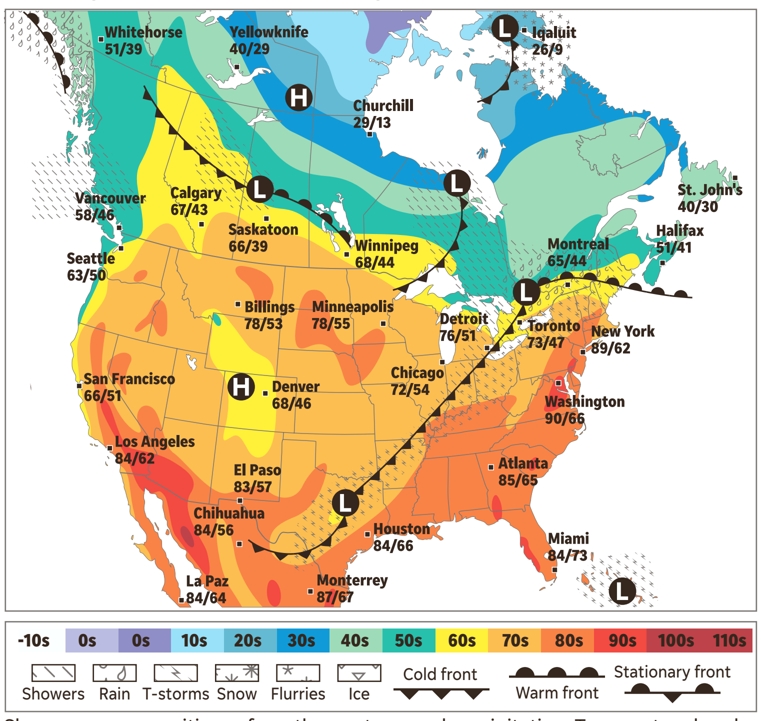
**Today's High/Low Tides**

| | High a.m. | High p.m. | Low a.m. | Low p.m. |
|---|---|---|---|---|
| **Salisbury (Port of Salisbury)** | 6:55 | 7:20 | 12:37 | 1:22 |
| **Ocean CIty (Inlet)** | 11:18 | 11:39 | 5:25 | 5:19 |
| **Chincoteague Channel (south end)** | 11:55 | --- | 5:44 | 5:38 |
| **Crisfield (Somer's Cove)** | 4:24 | 4:49 | 11:03 | 11:00 |
| **Nanticoke (Roaring Point)** | 5:34 | 5:59 | --- | 12:33 |
| **Cambridge (Long Wharf)** | 7:42 | 8:13 | 1:02 | 3:06 |

## AG FORECAST

Partly sunny and breezy today with the temperature tying the record from 2001. Winds SW 10-20 mph. Expect 8-12 hours of sunshine with average relative humidity 45% and excellent drying conditions. Increasing clouds tonight. Winds SW 6-12 mph. Average humidity 65%.

## NATIONAL WEATHER TODAY




Shown are noon positions of weather systems and precipitation. Temperature bands are highs for the day. Forecast high/low temperatures are given for selected cities.

## NATIONAL SUMMARY

Gusty winds and thunderstorms will rattle the eastern Great Lakes states today as warmth continues to span the mid-Atlantic and Southeast. Flooding downpours and gusty thunderstorms will target Texas, while most of the Plains welcome a quieter day. Meanwhile, dry and warmer weather will encompass much of the West.

## NATIONAL CITIES

| City | Today Hi | Lo | W | Saturday Hi | Lo | W |
|---|---|---|---|---|---|---|
| Atlanta | 85 | 65 | s | 82 | 61 | pc |
| Atlantic City | 87 | 64 | pc | 74 | 56 | sh |
| Boston | 78 | 58 | c | 74 | 55 | s |
| Charleston, SC | 84 | 63 | s | 85 | 67 | pc |
| Charleston, WV | 82 | 58 | t | 71 | 54 | r |
| Cincinnati | 77 | 55 | t | 73 | 52 | c |
| Columbia, SC | 90 | 63 | s | 88 | 65 | pc |
| Dallas | 71 | 58 | sh | 83 | 59 | pc |
| Denver | 68 | 46 | s | 75 | 46 | pc |
| Des Moines | 76 | 54 | pc | 83 | 57 | s |
| Honolulu | 83 | 70 | r | 83 | 72 | sh |
| Houston | 84 | 66 | c | 81 | 63 | c |
| Indianapolis | 75 | 54 | sh | 77 | 55 | s |
| Jacksonville | 85 | 60 | s | 84 | 64 | pc |
| Kansas City | 77 | 53 | s | 83 | 56 | s |
| Las Vegas | 87 | 68 | s | 93 | 71 | pc |
| Los Angeles | 84 | 62 | s | 87 | 61 | pc |
| Louisville | 81 | 62 | t | 75 | 57 | sh |
| Memphis | 80 | 63 | c | 75 | 58 | t |
| Miami | 84 | 73 | pc | 84 | 75 | sh |
| Minneapolis | 78 | 55 | pc | 81 | 50 | pc |
| Nashville | 83 | 64 | c | 72 | 56 | t |
| New Orleans | 85 | 68 | pc | 84 | 67 | c |
| New York | 89 | 62 | pc | 74 | 60 | pc |
| Oklahoma City | 74 | 52 | pc | 82 | 55 | s |
| Philadelphia | 90 | 61 | pc | 74 | 58 | sh |
| Phoenix | 94 | 70 | s | 102 | 77 | s |
| Portland, OR | 69 | 52 | c | 75 | 57 | pc |
| Raleigh | 87 | 62 | s | 83 | 63 | pc |
| St. Louis | 77 | 58 | c | 81 | 60 | s |
| San Francisco | 66 | 51 | pc | 65 | 53 | c |
| Seattle | 63 | 50 | c | 69 | 54 | pc |

**Weather (W):** **s**-sunny, **pc**-partly cloudy, **c**-cloudy, **sh**-showers, **t**-thunderstorms, **r**-rain, **sf**-snow flurries, **sn**-snow, **i**-ice.

## WORLD CITIES

| City | Today Hi | Lo | W | Saturday Hi | Lo | W |
|---|---|---|---|---|---|---|
| Athens | 80 | 66 | t | 80 | 65 | t |
| Bangkok | 91 | 79 | t | 91 | 79 | t |
| Beijing | 81 | 57 | s | 82 | 63 | c |
| Berlin | 65 | 40 | s | 67 | 45 | s |
| Buenos Aires | 68 | 60 | c | 69 | 64 | r |
| Cairo | 102 | 69 | pc | 93 | 71 | pc |
| Copenhagen | 57 | 44 | pc | 61 | 47 | pc |
| Dublin | 65 | 49 | pc | 66 | 45 | pc |
| Frankfurt | 69 | 49 | s | 74 | 49 | s |
| Hong Kong | 81 | 74 | pc | 84 | 77 | c |
| Jerusalem | 87 | 65 | c | 81 | 63 | s |
| London | 66 | 49 | pc | 71 | 47 | pc |
| Madrid | 71 | 49 | s | 73 | 54 | pc |
| Mexico City | 78 | 60 | pc | 75 | 55 | pc |
| Montreal | 65 | 44 | r | 66 | 51 | pc |
| Moscow | 72 | 55 | s | 76 | 50 | pc |
| Nassau | 83 | 75 | t | 86 | 77 | pc |
| Paris | 68 | 48 | s | 75 | 53 | s |
| Sao Goncalo | 86 | 71 | s | 86 | 70 | pc |
| Rome | 70 | 56 | t | 70 | 54 | t |
| Tokyo | 73 | 57 | pc | 77 | 58 | s |
| Toronto | 73 | 47 | c | 73 | 51 | pc |

Forecasts and graphics provided by **AccuWeather, Inc.** ©2018

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**PUBLIC MEETING MATERIALS**

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# Welcome

## TO THE
## WALLOPS FLIGHT FACILITY
## PUBLIC INFORMATION MEETING
## FOR THE DRAFT SITE-WIDE PROGRAMMATIC
## ENVIRONMENTAL IMPACT STATEMENT (PEIS)

NASA Wallops Flight Facility is hosting a public information meeting this evening.

Participants at tonight's open-house meeting will have the opportunity to view a poster presentation of many of the projects and activities proposed at the facility.

Participants are invited to provide comments on the findings presented in the Draft PEIS. A court reporter will take your oral comments or you may give your written comments to a WFF representative this evening. You may also mail, email or fax your comments.

# NASA WALLOPS FLIGHT FACILITY


WFF is located in the northeastern portion of Accomack County, Virginia, on the Delmarva Peninsula. The facility is comprised of the Main Base, Wallops Mainland, and Wallops Island.

Components of the Proposed Action would occur at all three main areas of WFF.

# SITE-WIDE PEIS

## PURPOSE AND NEED

The **PURPOSE** of the Proposed Action is to meet strategic management goals developed by Goddard Space Flight Center WFF and to increase WFF's ability to support a growing mission base in the areas of commercial, defense, civil, and academic aerospace research.

The **NEED** for the proposed action is to:

- Support the growing U.S. focus on the commercial space industry
- Create more frequent partnership opportunities with defense agencies
- Continue the NASA role in academia, civil space science, exploration, and discovery
- Safely increase WFF's operational frequency on Wallops Island, and
- Replace aging infrastructure by renewing, sustaining, and consolidating WFF facilities.

The Site-Wide PEIS evaluated the most reasonably foreseeable actions at WFF within a 20-year planning horizon

## PROPOSED ACTION

The **Proposed Action** would implement numerous institutional support projects (i.e., construction, demolition and renovation) and new or expanded operational missions and activities.

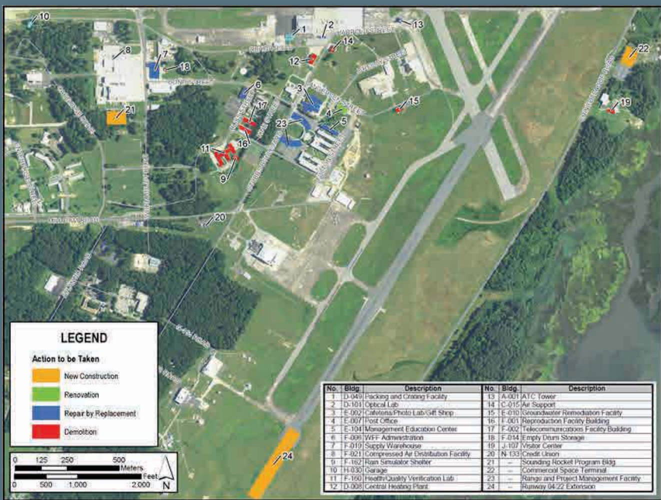
Under the **No Action Alternative,** the level of activity at WFF would remain at present levels. The No Action Alternative serves as the baseline against which the impacts of the Proposed Action are compared.

The actions considered within this document are at various stages of conceptual maturity.

In some cases, the level of discussion may be such that the environmental consequences can be adequately considered and an informed decision made, therefore eliminating the need for additional NEPA documentation.

For others, only high level, cursory treatment can be given thereby warranting more focused analysis in the future once plans become more certain.

# INSTITUTIONAL SUPPORT PROJECTS WFF




**Main Base Construction, Demolition, and RBR Locations – WFF projects**

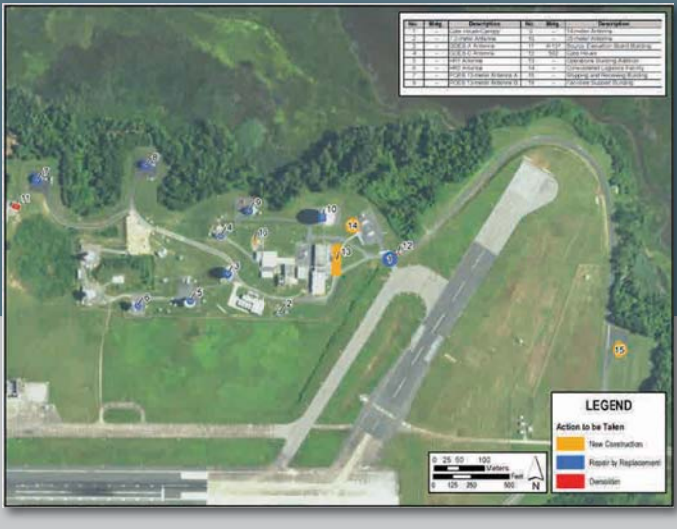
**A Commercial Space Terminal** may be located on the east side of the WFF airfield. The terminal may include lodging, dining areas, and training facilities such as pools, classroom space, mission specific training equipment, and other required facilities.

**Runway 04/22** would be lengthened to add an additional 1,250 ft to the runway surface. This extension would accommodate horizontal launch and landing vehicles at the Main Base.

**Causeway Bridge**
The 1960's era bridge is at the end of its design life. A new causeway bridge would be constructed parallel to the existing structure prior to its removal.

The entire barge route between the Main Base and Wallops Island boat basins would be dredged to remove long-term sedimentation of the non-Federal channel. The route would be dredged to the depth needed to support barge transfer of cargo too large for overland transport.


**Main Base Construction, Demolition, and RBR Locations – NOAA Projects**




**Refer to Site-wide PEIS Section 2.5.1 for the complete list and descriptions of institutional support projects proposed at WFF**

# INSTITUTIONAL SUPPORT PROJECTS MARS


### Launch Vehicle Pad 0-C (Notional)

Launch activity on Wallops Island is anticipated to increase. A new launch vehicle launch pad is being considered at the south end of Wallops Island to support the preparation of concurrent launch activities.


### Launch Vehicle Pier 0-D (Notional)

To provide additional launch capability, a launch vehicle launch pier is being introduced for consideration.

Two notional locations are presented. An LV launch pad at either location would include a pile-supported pad access ramp, launch pad, and deluge system/flame deflector over water.


### North Wallops Island Deep-water Port and Operations Area

A deep-water port and operations area is being considered for the north end of Wallops Island. This project would support barge access and berthing for offloading large launch vehicle components and related equipment. Three notional pathways are being considered.

**Refer to Site-wide PEIS Section 2.5.1 for the complete list and descriptions of institutional support projects proposed at WFF**

# OPERATIONAL MISSIONS AND ACTIVITIES EXPANDED SPACE PROGRAM

NASA is considering larger intermediate- and heavy-class LVs and intermediate-class return to launch site (RTLS) reusable LVs at WFF. Up to 6 liquid-fueled intermediate class (LFIC) LV launches/LFIC RTLS landings and 12 solid-fueled heavy class (SFHC) LV launches per year are being considered for distribution among launch Pads 0-A, 0-B, 0-C (proposed), or Launch Pier 0-D (proposed).


### Falcon 9

Developed by SpaceX, the Falcon 9 is considered a fully reusable **vertical launch and landing** LV due to its ability to return its first stage via soft landing back to Earth.

**New Shepard vertical launch and landing vehicle**


**Examples of Wallops Flight Facility Approved Orbital Launch Vehicles**


### Horizontal launch and landing

**LVs** like Generation Orbit could launch from extended Runway 04/22 while LVs like SpaceShip Two/WhiteKnight Two could launch and land from extended Runway 04/22.

### Commercial Human Spaceflight Missions

Steps are being taken to develop a U.S. commercial crew transportation capability with the goal of achieving safe, reliable and cost-effective access to and from the International Space Station and in Low Earth Orbit from WFF.

**Refer to Site-wide PEIS Section 2.5.2 for the complete list and descriptions of operational missions and activities proposed at WFF**

# ENVELOPE CONCEPT AND NEPA TRIGGER

## The Envelope Concept

The **envelope concept** is applied at WFF since missions at the facility are constantly evolving and, while the basic outline of a project may be known during the NEPA analysis, its details often have not been finalized.

A range or "envelope" of activities has been identified for each type of operation conducted at WFF; the scenario with the greatest potential for environmental impacts is presented.

## NEPA Trigger

The envelope concept facilitates the environmental analysis documentation process by providing a threshold below which, if not exceeded, further in-depth NEPA analysis is not needed.

**Baseline and Proposed Envelopes**

| *Activity* | *Baseline (No Action)* | *Change (Proposed Actions)* |
|---|---|---|
| ***Institutional Support Projects*** | | |
| Construction and Demolition | Existing construction design projects analyzed in previous NEPA documentation. | All new construction, demolition, and RBR projects proposed including Causeway Bridge replacement, development of North Wallops Island Deep-water Port and Operations Area, and Launch Pad 0-C and Launch Pier 0-D. |
| ***Routine/Recurring Activities*** | | |
| Fabrications | Existing fabrication processes/existing facilities. | No change. |
| Maintenance and Improvements | Existing maintenance and improvement activities. | Maintenance dredging. |
| Payload Processing Facilities | Existing payload processing activities. | No change. |
| Transportation Infrastructure | Existing transportation infrastructure. | Causeway Bridge replacement; maintenance dredging; North Wallops Island Deep-water Port and Operations Area. |
| Utility Infrastructure | Existing utility infrastructure. | No change. |
| Safety and Security | Existing WFF fire prevention and protection programs. | No change. |
| Storage | Existing storage activities. | Hybrid fuels; greater capacity for liquid fuel for LFIC LV. |
| ***Operational Missions and Activities*** | | |
| Scientific Research Programs and Education Programs | Existing payload envelopes established for radio frequencies, lasers, radioactive materials, biological agents, and chemical releases. | No change. |
| Airfield | Existing FAA designated airspace and runways. | No change. |
| Main Base Piloted and Unmanned Aircraft | Approximately 61,000 annual airfield operations. | No change in annual operations. |
| North Wallops Island UAS Operations | 1,040 sorties per year. Limited night operations. The Viking 300 is the noise envelope; the Viking 400 is the vehicle size envelope. | • Increase to 3,900 sorties per year.<br>• Increase in night operations.<br>• Vehicle size is limited to runway allowance.<br>• Addition of rotorcraft and vertical take-off and landing craft. |
| Orbital Rockets | 18 orbital rocket launches per year (6 from Launch Pad 0-A; 12 from Pad 0-B). Antares is the envelope liquid-fueled LV to be launched from Launch Pad 0-A; Athena III is the envelope solid-fueled LV to be launched from Pad 0-B. | • 18 orbital rocket launches per year distributed among launch pads 0-A, 0-B, 0-C and Launch Pier 0-D.<br>• LFIC is the envelope liquid-fueled LV to be launched; and landed (RTLS); limit of 6 LFIC LV launches/RTLS landings per year<br>• SFHC is the envelope solid-fueled LV to be launched. Limit of 12 SFHC LV launches per year.<br>• Horizontal launch and landing from Main Base Runway 04/22.<br>• Commercial human spaceflight. |
| Sounding Rockets / Suborbital Rockets | 60 launches per year. The four-stage Black Brant XII is the envelope sounding rocket. Includes 5 launches per year of Minotaur III, the envelope suborbital vehicle. | No change. |
| Drone Targets and Missiles | 30 drone target flights per year. The AQM-37 is the envelope drone target. | No change. |
| Fuel Types | Existing solid and liquid fuels evaluated in previous NEPA documentation. | Hybrid fuels; larger quantities of liquid fuels. |
| Static Fire Testing | Occurs at Launch Pad 0-A, Pad 2, and F-010. Propellant throughput governed by the 2010 MARS Regional Spaceport Air State Operating Permit and the 2010 Wallops Island State Operating Permit. The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year. | No change. |
| OB Area | The maximum amount of propellant from combined open-burns and static fire testing events is 30 metric tons (33.5 tons) for double-base fuel and 35 metric tons (38.3 tons) for composite fuel per year. | No change. |
| Projectile Testing | Testing cannot exceed 20 test missions per year. Powder and/or electromagnetically-propelled projectiles via electromagnetic railgun (EMRG) cannot exceed 250 combined firings per year. | Addition of Directed Energy. |
| Payloads | Multiple envelopes established in previous NEPA documentation. | No change in existing payloads. |
| Tracking and Data Systems | Data and tracking systems established in previous NEPA documentation. | Addition of Sonic Detection and Ranging. |
| Balloons | Balloons cannot be larger than 1,000,000 $m^3$ (40,000,000 $ft^3$); payloads cannot weigh more than 4,000 kgs (8,000 lbs) per flight. Meteorological balloons launched cannot exceed 886 per year. | No change. |
| AUVs/ASVs | The Theseus, International Submarine Engineering Limited's AUV is the envelope vehicle. | No change. |

**For both institutional support and operational components, use of an environmental checklist is the procedure by which a proposed project is reviewed to see if that project triggers additional NEPA analysis or falls within the envelope.**

# ENVIRONMENTAL IMPACT ANALYSIS PROCESS

The National Environmental Policy Act guides the environmental impact analysis.

Accomplished thus far:

- Notice of Intent
- Scoping Comment Period
- Preparation of Draft PEIS
- Notice of Availability of Draft PEIS
- Public Review Period/ Public Meeting - 45 Days
- Preparation of Final PEIS
- Notice of Availability of Final PEIS
- Waiting Period—30 Days
- Record of Decision

## *ENVIRONMENTAL IMPACT STATEMENT*

The NASA WFF Site-wide PEIS analyzed the potential effects of the proposed action alternatives on the following resources:

***Noise***
***Air Quality***
*Hazardous Materials/Toxic Substances/Hazardous Waste*
*Health and Safety*
***Water Resources***
*Land Use*
*Land Resources*
*Vegetation*
***Terrestrial Wildlife***
***Special-Status Species***
***Marine Mammals and Fish***
*Airspace Management*
*Transportation*
*Infrastructure and Utilities*
*Socioeconomics*
*Environmental Justice*
*Visual Resources and Recreation*
*Cultural Resources*

The measureable effects of past, present, and reasonable foreseeable future actions were analyzed on the resources in bold. The NASA WFF Site-wide PEIS includes a detailed wetlands cumulative effects analysis.

***Your involvement and input are essential to the environmental impact analysis process.***

# COOPERATING AGENCIES AND THEIR ROLES IN THE DEVELOPMENT OF THE SITE-WIDE PEIS:

**Federal Aviation Administration** – Responsible for issuing licenses for operation of commercial space launch sites and commercial launch vehicles.

**Federal Highway Administration** – As a division of the Department of Transportation is responsible for undertaking design and oversight of the construction of the new Causeway Bridge and approach road.

**National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service (NOAA-NESDIS)** –Wallops Command and Data Acquisition Station is a permanent tenant on the Main Base and may undertake additional operations or improvements to its existing infrastructure.

**Department of the Army, Corps of Engineers (USACE)** – Responsible for issuing permits for proposed activities that have the potential for dredging or placement of fill in waters of the U.S.; also involved in design and oversight of WFF's Shoreline Restoration and Infrastructure Protection Program.

**United States Coast Guard** – Responsible for undertaking additional operations or improvements to its existing infrastructure, would issue a permit for the Causeway Bridge reconstruction, and assumes Captain of the Port Authority for clearing the launch range during operations.

**U.S. Environmental Protection Agency (EPA)** – Responsible for has overseeing permits related to components of the Proposed Action that have the potential for dredging or placement of fill in waters of the U.S.; under Section 309 of the Clean Air Act, EPA has an obligation to review and comment on all Federal EISs.

**U.S. Fish and Wildlife Service (USFWS)** – Responsible for issuing incidental take statements and providing management of special-status species; partners with NASA on mutually beneficial projects related to the Chincoteague National Wildlife Refuge.

**U.S. Navy, Naval Air Systems Command (NAVAIR)** – Responsible for increasing existing research, development, test, and evaluation mission tempos and new missions.

**U.S. Navy, Naval Sea Systems Command (NAVSEA)** – Responsible for undertaking additional operations, improvements to infrastructure, and target launches at the Surface Command System Center, and providing oversight of the Virginia Capes Operating Area offshore of WFF.

**U.S. Navy, U.S. Fleet Forces Command** – Responsible for conducting pilot proficiency training missions at the Main Base airfield and Navy personnel training ship-board in the VACAPES OPAREA. WFF often supplies range services and target launches during these training exercises.

**U.S. Air Force Space Command/Space and Missile Systems Center (AFSPC/SMC)** – Responsible for increasing test and evaluation missions and increasing interest in using the Wallops launch range for further missions.

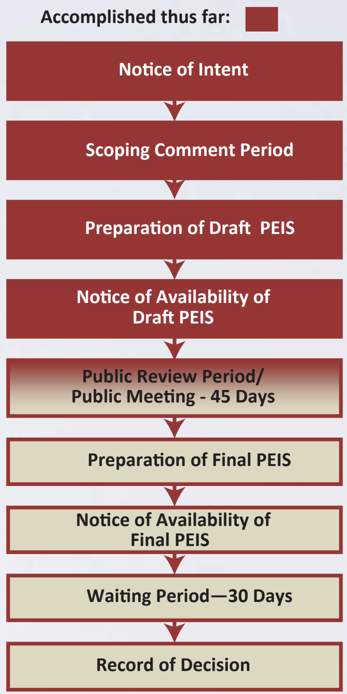
**Virginia Commercial Space Flight Authority (Virginia Space)** – In partnership with NASA WFF has expanded the development and operation of the Mid-Atlantic Regional Spaceport.

## *The National Environment Policy Act*

The National Environmental Policy Act (NEPA) establishes a framework for considering the scope of environmental issues and concerns early in the federal decision making process. Public involvement is an essential part of the process. Through involving the public and completing detailed environmental analysis,the NEPA process helps the decision-maker arrive at the best possible informed decision.

NASA sought input and suggestions from the public on proposed activities to be addressed in the Site-wide PEIS. Following an extensive data collection and research effort during the scoping period, the type and extent of impacts was identified and potential effects of proposed projects on resources was analyzed.

The Draft Site-wide PEIS has been made available for public view. WFF is seeking public comments on the analysis and findings presented in the Draft Site-wide PEIS during the 45-day public comment period. Oral comments will be accepted at the public meeting; written comments will be accepted throughout the public comment period. Responses to relevant comments on the Draft Site-wide PEIS and supplemental, modified, or improved analysis based on comments received, will be included in the preparation of the Final Site-wide PEIS.




## *How Can You Be Involved?*

Your involvement in the decision-making process is important to NASA. There are many ways to submit comments on the Draft Site-wide PEIS:

1. Fill out a comment form at the public meeting and give it to a NASA representative
2. Visit the project website: https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis
3. Mail, email, or fax your comments:

Shari Miller
NASA Wallops Flight Facility
Mailstop: 250. W
Wallops Island, VA 23337
Shari.A.Miller@nasa.gov
Fax (757) 824-1819

To ensure consideration in the Final Site-wide PEIS, please provide your comments no later than June 18, 2018

FACT SHEET

MAY 2018

# Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Wallops Flight Facility (WFF) is preparing a Site-wide Programmatic Environmental Impact Statement (PEIS). The Draft PEIS provides an impact assessment of the institutional support and operational missions and activities at WFF required to support existing and future program missions.

## *Why did WFF Need to Prepare a Site-wide PEIS?*

For over 70 years, WFF has launched thousands of research vehicles in the quest for information on the flight characteristics of airplanes, launch vehicles, and spacecraft, and to increase the knowledge of the Earth's upper atmosphere and the near space environment. The flight programs and projects conducted by WFF range from small sounding and suborbital rockets, unmanned scientific balloons, unmanned aerial systems, manned aircraft, and orbital spacecraft to include to next-generation launch vehicles and small- and medium-classed launch vehicles.

In keeping with the principles, goals and guidelines of the 2010 National Space Policy, as updated by the 2013 U.S. National Space Transportation Policy and the 2017 Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, WFF not only fulfills its own mission, but also provides unique services to NASA, the Department of Defense (DoD), academia, and the fast growing commercial space industry. WFF regularly provides launch support either directly or through the Mid-Atlantic Regional Spaceport on Wallops Island.

In January 2005, NASA issued a Final Site-wide Environmental Assessment and Finding of No Significant Impact for activities at WFF. However, since then substantial growth has occurred and NASA, and its Cooperating Agencies have prepared multiple supplemental National Environmental Policy Act (NEPA) documents. The Site-wide PEIS considers all reasonably foreseeable future actions proposed by NASA WFF and those proposed by its tenants and partners.

## *What is the Proposed Action?*

The Site-wide PEIS evaluated the potential environmental impacts from institutional support projects and operational missions and activities under the Proposed Action that would meet NASA's need to ensure continued growth at WFF while also preserving the ability to safely conduct its historical baseline of operations. The PEIS evaluated the Proposed Action and No Action Alternative. Under the No Action Alternative, the level of activity at WFF would remain at present levels and within existing envelopes.

**The Proposed Action would support at WFF:**

- A number of facility projects ranging from new construction, demolition, and renovation identified in the WFF Facility Master Plan
- Replacement of the Causeway Bridge
- Maintenance dredging between the boat docks at the Main Base and Wallops Island
- A North Wallops Island deep-water port and operations area
- Additional launch vehicle launch sites
- New NASA and DoD programs
- Expansion of the launch vehicle program with liquid-fueled intermediate class and solid-fueled heavy class launch vehicles
- Consideration of commercial human spaceflight missions
- Return of launch vehicles to the launch site
- Extension of Runway 04/22 to 10,000 linear feet

Causeway Bridge

## *Cooperating Agencies*

NASA, as the lead agency for preparation of the Site-wide PEIS, requested the cooperation of several tenant and partner agencies. A cooperating agency is a government agency which has jurisdiction by law or special expertise regarding the environmental impact of a proposal.

The following federal and state agencies agreed to be cooperating agencies on the Site-Wide PEIS:

- Federal Aviation Administration
- Federal Highway Administration
- National Oceanic and Atmospheric Administration National Environmental Satellite Data Information Service
- United States (U.S.) Army Corps of Engineers
- U.S. Coast Guard
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Navy, Naval Air Systems Command
- U.S. Navy, Naval Sea Systems Command
- U.S. Navy, U.S. Fleet Forces Command
- U.S. Air Force, Space Command/Space and Missile Systems Center
- Virginia Commercial Spaceflight Authority

## *Summary of Impacts*

The Site-wide PEIS impact analysis focused on the resources potentially affected by implementing institutional support projects and operational missions and activities under the Proposed Action. The proposals considered in the Site-wide PEIS are at various stages of conceptual maturity; future tiered NEPA documents may be prepared for specific actions related to the Site-wide PEIS. Impacts under the No Action Alternative would remain as analyzed in previous NEPA documents. Below is a summary of impacts for a few of the proposals evaluated in the Site-wide PEIS.

### Replacement of the Causeway Bridge

The Causeway Bridge is over 50 years old and is showing accelerated signs of deterioration. Vehicular traffic on the bridge, the size of transport trucks, and the frequency of "super-loads" crossing the bridge has increased significantly in the last decade. A new bridge would be constructed parallel to the existing bridge. Construction of the new Causeway Bridge would be anticipated to occur from 2019-2023; dismantling and removal of the old bridge may begin in 2023 and take approximately 9 months to complete. Because design plans are not currently available, site-specific NEPA analysis would be required prior to implementing this action. The following impacts would likely be experienced:

- Temporary increase in noise levels during the construction and demolition phases.
- Tidal wetlands and associated vegetation could be disturbed; the amount of disturbance would depend on the final bridge design.
- Marine special-status species, marine mammals, and Essential Fish Habitat may be affected; impacts would be dependent on final design.

### Maintenance Dredging between the Boat Docks

Long-term sedimentation of the barge route from the Main Base Visitor Center to the North Wallops Island boat basin dictates the need for maintenance dredging to support the transfer of cargo that is too large for overland transport. The entire barge route would be dredged. The dredged material is expected to be unsuitable for re-use or placement on nearby beaches; upland placement of the dredged material is to be determined in the future. As project planning and design details become more developed, further NEPA analysis would be required in the future to fully evaluate the potential impacts that may include: temporary increase in noise levels during active dredging; short-term adverse impacts to water quality; and impacts to marine special-status species, marine mammals, and Essential Fish Habitat. In addition, waterway closures may be needed during active dredging resulting in short-term impact to boaters and fishermen.

Long-term impacts to tidal and non-tidal wetlands and vegetation impacts would be anticipated and would be mitigated accordingly.

### Expanded Space Program

WFF has a unique opportunity to provide its services to the commercial launch industry upon which NASA, civil, defense, and academic customers are more frequently relying. The Expanded Space Program at WFF includes the potential for:

- Launch vehicle (LV) launches distributed among Launch Pads 0-A, 0-B, 0-C (proposed), or Launch Pier 0-D (proposed);
- Up to 6 liquid-fueled intermediate class (LFIC) launch LVs and return to launch site (RTLS) landings;
- Up to 12 solid fueled heavy class (SFHC) LVs;
- Horizontal launch and landing LVs from Main Base extended Runway 04/22; and
- Consideration of commercial human spaceflight missions.

The type of impacts that would be likely include the potential for: an increase in LV noise, sonic booms from horizontal landing LVs, temporary impacts to terrestrial wildlife and special-status species, and temporary road and waterway closures.

Each of the activities under the Expanded Space Program are in the planning stage; further NEPA analysis may be required in the future to fully evaluate the potential impacts.

### North Wallops Island Deep-water Port and Operations Area

A deep-water port on the north end of Wallops Island would provide barge access and berthing to offload large LV components and related equipment. Three potential pathways are being considered.

As project planning and design details become more developed, further NEPA analysis for all three port pathways would be required and may involve: characterization of the materials to be dredged during any construction dredging; hydrodynamic modeling to assess the effects of any proposed new channel creation (Port Paths 2 and 3); assessment of proposed dredged material upland placement alternatives once the dredge volumes and expected maintenance volumes are predicted; and other potential impacts such as water quality, tidal and nontidal wetlands and vegetation impacts, and impacts to Essential Fish Habitat and special-status species.

# Public Meeting
# Wallops Flight Facility
# Draft Site-wide Programmatic Environmental Impact Statement (PEIS)

**Location:** Wallops Flight Facility Visitor Center

**Date:** May 23, 2018

| Name | Affiliation | Address | Would you like a CD or Paper Copy of the Final PEIS? |
|---|---|---|---|
| | | | |
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| | | | |

**Public Meeting**
**Wallops Flight Facility**
**Draft Site-wide Programmatic Environmental Impact Statement**

# COMMENT SHEET

Thank you for providing your comments on the NASA's Wallops Flight Facility (WFF) Site-wide Programmatic Environmental Impact Statement (PEIS). Please provide us with your comments on the Draft PEIS no later than June 18, 2018. Comments may be submitted at the meeting or mailed to the address below.

____________________________________________

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*Over for more space →*

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***Please Print***

Name: ____________________________________________

Address: ____________________________________________

Do you wish to be sent a copy of the Final Site-wide PEIS? Yes No

If yes, please indicate whether you would prefer: CD Paper Copy

Please give this form to one of the NASA WFF representatives tonight.
You may also mail, email, or fax your comments.

**Shari Miller**
**NASA Wallops Flight Facility**
**Mailstop: 250. W**
**Wallops Island, VA 23337**
**Shari.A.Miller@nasa.gov**
**FAX (757) 824-1819**

**PUBLIC MEETING TRANSCRIPT**

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NASA WALLOPS FLIGHT FACILITY

DRAFT SITE-WIDE PROGRAMMATIC ENVIRONMENTAL

IMPACT STATEMENT

PUBLIC MEETING

WALLOPS FLIGHT FACILITY VISITOR CENTER

MAY 23, 2018

COURT REPORTER: DANA M. PON

SHARI MILLER: All right. So we're going on the record. It's now 8:08 p.m. NASA Wallops Flight Facility held an open public meeting from 6:00 to 8:00 p.m. on Wednesday, May 23rd to take comments on the Site-wide Programmatic Environmental Impact Statement. One person from the public showed up to our meeting, and no one left comments.

(The dictation into the record concluded at 8:08 p.m.)

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COURT REPORTER'S CERTIFICATE

COMMONWEALTH OF VIRGINIA:
CITY OF VIRGINIA BEACH:

I, Dana M. Pon, Notary Public in and for the above county and state, do hereby certify that the foregoing testimony was taken before me at the time and place herein-before set forth; that thereupon the foregoing testimony was later reduced by computer transcription; and I certify that this is a true and correct transcript of my stenographic notes so taken to the best of my ability.

I further certify that I am not of counsel to any party, nor interested in the event of this cause.

Given under my hand this 6th day of June, 2018.

My commission expires September 30, 2018.

Dana M. Pon, Court Reporter
Notary Registration Number 320348

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# COMMENT RESPONSES

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| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 001 | 1 | Comment noted. |
| 001 | 2 | Sections 1.3, 1.4, 2.2, 2.7, 3.5.1.9, and 3.5.2.2.1 of the PEIS provide detailed discussions for the approach taken to expand and develop the launch range with consideration of sea-level rise. |
| 002 | 1 | Comment noted. See Section 3.15.2.2. |
| 003 | 1 | As the land owner, NASA is authorized to construct new infrastructure and facilities only within the boundary of the installation.<br><br>The following statement has been added to the end of Section 2.1: "*As such, this PEIS analyzes institutional and operational missions that could occur within NASA WFF's property, managed airspace, and water resources. Although, as discussed in Section 3.0 Affected Environment and Environmental Consequences, impacts of these actions may occur offsite, no offsite actions are proposed or analyzed in this PEIS.*"<br><br>The following statement has been added to Table ES-1, Table 2.6-2, and Section 4.1.5: "*As required by the 404(b)(1) guidelines, only the Least Environmentally Damaging Practicable Alternative (LEDPA) can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable.*"<br><br>The following paragraphs have been incorporated into Section 3.5.2: "*New infrastructure and facilities to support mission requirements on Wallops Island would be sited within previously disturbed areas, to the extent practicable. To reduce potential environmental impacts, BMPs and avoidance and minimization measures, as described for resource areas in Chapter 3, Affected Environment and Environmental Consequences and in Chapter 4, Mitigation and Monitoring would be incorporated and implemented, to the maximum extent practicable under the Proposed Action. As required by the 404(b)(1) guidelines, only the LEDPA can be authorized through the permit process. To be the LEDPA, an alternative must result in the least impact to aquatic resources while being practicable.*<br><br>*The in-water projects (i.e., Causeway Bridge replacement, barge route maintenance dredging, and North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D) described under the Proposed Action are analyzed as programmatic actions in that they are in various stages of conceptual maturity with varying levels of detail for discussion. Information for these projects is provided in as much detail as is currently available. As project planning and design details become more developed, further NEPA analysis will occur, along with all relevant consultation and permitting, prior to construction.*" |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 003 | 2 | Comment noted. As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction. |
| 004 | 1 | Comment noted. |
| 004 | 2 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction. |
| 004 | 3 | Comment noted. The following bullets have been added to Section 2.5.1.2, Maintenance Dredging:<br>• *assessment of proposed construction staging and/or stockpile areas*<br>• *assessment of each proposed dredging method* |
| 004 | 4 | As project planning and design details become more developed, further NEPA analysis of alternative upland dredge material placement sites will occur. |
| 004 | 5 | If thin layer application were an acceptable means of reuse, WFF would consult with the natural resource agencies (e.g., EPA and USACE); further NEPA analysis will be prepared that would describe the potential environmental impacts of this method of reuse. |
| 004 | 6 | As project planning for the proposed North Wallops Island Deep-water Port and Operations Area become more developed, further NEPA analysis will be prepared that would describe potential environmental impacts of alternatives.<br><br>The following bullets have been added to Section 2.5.1.2, North Wallops Island Deep-water Port and Operations Area:<br>• *assessment of proposed construction staging and/or stockpile areas*<br>• *assessment of each proposed dredging method*<br>• *assessment of any ancillary facilities and/or roads which may be required for each alternative* |
| 004 | 7 | As project planning and design details for LV Launch Pad 0-C become more developed, further NEPA analysis will be prepared to fully evaluate the potential environmental impacts.<br><br>PEIS Section 4.1.5 describes NASA's proposed mitigation measures to water resources for implementing water-related projects. These mitigation measures also include measures implemented by NASA to avoid and minimize impacts to the extent practicable on an ongoing basis as part of BMPs and agreed upon approaches with appropriate agencies, compliance with permit requirements, and adherence to various management plans mentioned in the Environmental Consequences sections in Chapter 3 of the PEIS. |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 004 | 8 | Section 3.5.1.4 has been modified with the following clarifying statement: *"Perfluorooctane sulfonate/perfluorooctanoic acid (PFOS/PFOA), chemicals associated with firefighting foams, have been detected in the Columbia aquifer on the Main Base, including the FFTA. The extent of the PFOS/PFOA plume is currently unknown. NASA has developed a work plan to conduct a facility-wide investigation to better understand the extent of the plume."* |
| 004 | 9 | Section 3.5.1.4 of the PEIS states four of the Town of Chincoteague water supply wells are constructed to withdraw water from one of the Yorktown aquifers; water quality in the underlying Yorktown aquifer has not been affected by contamination due to the presence of an aquitard, the geologic layer that prevents groundwater movement from the Columbia aquifer downward into the Yorktown aquifer. |
| 004 | 10 | In the event of a chemical or petroleum discharge into the stormwater system during construction, demolition, or RBR projects, NASA would implement stormwater sampling and analysis prior to releasing the stormwater. |
| 004 | 11 | Comment noted. |
| 004 | 12 | As project planning and design details for the replacement of the Causeway Bridge become more developed, further NEPA analysis will be prepared to fully evaluate the potential impacts.<br>The following bullet has been added to Section 2.5.1.2, Causeway Bridge Replacement:<br>• *assessment of proposed construction staging and/or stockpile areas* |
| 004 | 13 | As project planning and design details become more developed, further NEPA analysis will be prepared to fully evaluate the potential environmental impacts of alternative material transfer sites. |
| 004 | 14 | The following paragraph found in Section 3.10.2.2.1 of the PEIS has been rephrased:<br>"*There is the potential for disturbance to wetland habitat at the Mainland and Wallops Island under the Proposed Action (refer to Figure 2.5-4 and Figure 2.5-5 in Chapter 2 for specific locations of institutional support projects at the Mainland and Wallops Island). The permanent loss of natural habitat from new construction under the Proposed Action at the Mainland and Wallops Island would be* ***approximately 5.0 ha (12.0 ac)****, as currently planned.* ***Of this total, an estimated 2.0 ha (5.0 ac) would be wetlands.*** *If the removal of wetland habitat were required, this would cause species in the area to be permanently displaced once the wetland is cleared and filled.* |
| 004 | 15 | The following statement has been added to Section 4.1.5, "*WFF is in the process of developing a wetland management plan. The plan would include avoidance measures and appropriate wetland mitigations to ensure no net loss of wetlands and would consider the potential impacts to protected species and high functional value wetlands. As the plan progresses, WFF would consult with EPA, USACE, and USFWS.*" |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 005 | 1 | As details of the maintenance dredging project becomes more developed, further NEPA analysis will be prepared to fully evaluate the potential environmental impacts prior to the issuance of permits or project initiation.<br><br>Private oyster leases and public shellfish grounds have been included in the bulleted list of additional analyses that may be required for the Causeway Bridge replacement, maintenance dredging, North Wallops Island Deep-water Port and Operations Area, and Launch Pier 0-D projects described in Section 2.5.1.2 of the PEIS. |
| 005 | 2 | Comment noted. |
| 005 | 3 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction. |
| 005 | 4 | As project planning and design details become more developed, further NEPA analysis for the Causeway Bridge replacement, maintenance dredging, North Wallops Island Deep-water Port and Operations Area, Launch Pad 0-C and Launch Pier 0-D projects will be prepared. Site-specific EFH assessments may be required along with consultation with NMFS to quantify any potential impacts to EFH from the listed projects. |
| 06 | | No response or action required. |
| 07 | | No response or action required. |
| 08 | 1 | As project planning and design details become more developed, further NEPA analysis for the Causeway Bridge replacement, barge route maintenance dredging, North Wallops Island Deep-water Port and Operations Area, Launch Pad 0-C and Launch Pier 0-D projects will be prepared. Site-specific EFH assessments may be required along with consultation with NMFS to quantify any potential impacts to EFH from the listed projects. |
| 08 | 2 | See Response #1. |
| 08 | 3 | See Response #1. |
| 08 | 4 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction.<br><br>The following text has been added to Section 4.1.5: "*For work that may increase vessel traffic, restrictions may be placed on the number of trips taken by each vessel and shallow draft vessels may be used.*" A new bullet has been added to Section 4.1.8 and Section 4.1.9: *"Restrictions may be placed on the number of trips taken by each vessel and shallow draft vessels may be selected for water-related projects."* |
| 08 | 5 | Comment noted. |
| 09 | 1 | Comment noted. Section 3.5.2.2.1, Coastal Zone has been updated to reflect VDEQ's concurrence. |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 09 | 2 | Comment noted. Section 1.8.2 of the Final PEIS describes VDEQ's FCD public participation. |
| 09 | 3 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction. NASA would comply with the CZMA federal consistency regulations. Should any of the proposed actions change substantially from the descriptions described in the Draft PEIS and FCD, NASA will consult again with agencies as appropriate. |
| 09 | 4 | Comment noted. |
| 09 | 5 | Comment noted. |
| 09 | 6 | The list of recommended practices has been included as bullets in Section 4.1.5. |
| 09 | 7 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction.<br><br>The FCD (Appendix G) in the Final PEIS has been amended to include the Causeway Bridge Replacement and Launch Pier 0-D projects under Subaqueous Lands Management. |
| 09 | 8 | As project planning and design details become more developed, further NEPA analysis for the Causeway Bridge replacement, barge route maintenance dredging, North Wallops Island Deep-water Port and Operations Area, Launch Pad 0-C and Launch Pier 0-D projects will be prepared. Site-specific EFH assessments may be required along with consultation with NMFS and VMRC to quantify any potential impacts to EFH from the listed projects. |
| 09 | 9 | NASA would develop site-specific erosion and sediment control plans for projects that have the potential to cause soil erosion. The site-specific plans would implement BMPs that are outlined in the facility's SWPPP and Erosion and Sediment Control Plan. |
| 09 | 10 | Section 4.1.2 has been amended to add the suggested dust suppression techniques. |
| 09 | 11 | Comment noted. |
| 09 | 12 | Comment noted. |
| 09 | 13 | Comment noted. |
| 09 | 14 | Comment noted. |
| 09 | 15 | Comment noted. |
| 09 | 16 | Comment noted. |
| 09 | 17 | Comment noted. |
| 09 | 18 | Comment noted. |
| 09 | 19 | Comment noted. |
| 09 | 20 | Comment noted. |
| 09 | 21 | Comment noted. |
| 09 | 22 | Comment noted. |
| 09 | 23 | The VDCR-DNH recommendation has been added as a bullet to Section 4.1.8. |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 09 | 24 | Comment noted. |
| 09 | 25 | The recommendation has been added as a bullet to Section 4.1.8. |
| 09 | 26 | As project planning and design details become more developed, further NEPA analysis of projects identified in Table 3.0-2 of the PEIS will occur, along with all relevant consultation and permitting, prior to construction. NASA would consult again with agencies as appropriate. |
| 09 | 27 | The recommendation has been added as a bullet to Section 4.1.8. |
| 09 | 28 | The recommendation has been added as a bullet to Section 4.1.8. |
| 09 | 29 | The recommendation has been added as a bullet to Section 4.1.8. |
| 09 | 30 | Comment noted. |
| 09 | 31 | Sections 3.9.1, 3.10.1.3, and 3.10.1.3.3 of the Final PEIS have been updated. |
| 09 | 32 | While no shorebird colonies have been found on Wallops Island, WFF will continue to monitor for them. If shorebird colonies become established, consultation with USFWS and VDGIF would occur. WFF will continue to implement its Protected Species Monitoring Plan. |
| 09 | 33 | Comment noted. Refer to PEIS sections 4.1.8 and 4.1.9. |
| 09 | 34 | Comment noted. |
| 09 | 35 | Comment noted. |
| 09 | 36 | Comment noted. |
| 09 | 37 | Comment noted. |
| 09 | 38 | Comment noted. |
| 09 | 39 | The following statement has been added to Section 4.1.5: "*WFF is in the process of developing a wetland management plan. The plan would include avoidance measures and appropriate wetland mitigations to ensure no net loss of wetlands and would consider the potential impacts to protected species and high functional value wetlands. As the plan progresses, WFF would consult with EPA, USACE, and USFWS*." |
| 09 | 40 | Suggested practices that had not been listed or discussed in Section 4.1.5 of the Draft PEIS have been added as bullets to Section 4.1.5 in the Final PEIS. |
| 09 | 41 | Comment noted. |
| 09 | 42 | Comment noted. |
| 09 | 43 | Comment noted. |
| 09 | 44 | Comment noted. |
| 09 | 45 | Comment noted. |
| 09 | 46 | Comment noted. |
| 09 | 47 | Comment noted. |
| 09 | 48 | Comment noted. |
| 09 | 49 | Comment noted. |
| 09 | 50 | Comment noted. |
| 09 | 51 | Comment noted. |
| 09 | 52 | Comment noted. |
| 09 | 52 | Comment noted. |

| Responses to Comments Received on the Draft Site-wide PEIS | | |
|---|---|---|
| **Comment Document** | **Comment Number** | **Response** |
| 09 | 53 | Comment noted. |
| 09 | 54 | Comment noted. |
| 09 | 55 | Comment noted. |
| 09 | 56 | Comment noted. |
| 09 | 57 | Comment noted. |
| 09 | 58 | Comment noted. |
| 09 | 59 | Comment noted. |
| 09 | 60 | Comment noted. |

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# COMMENT LETTERS

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**From:** Miller, Shari A. (WFF-2500)
**To:** Charee Hoffman
**Subject:** Fwd: PUBLIC comment ON FEDERAL REGISTER
**Date:** Friday, May 04, 2018 11:16:15 PM

---

Shari Miller
Environmental Planning Lead
NASA WFF

Begin forwarded message:

> **From:** o <bk1492@aol.com>
> **Date:** May 4, 2018 at 11:11:04 AM EDT
> **To:** <SHARI.A.MILLER@NASA.GOV>, <AMERICANVOICES@MAIL.HOUSE.GOV>, <INFO@TAXPAYER.NET>, <MEDIA@CAGW.ORG>, <HUMANELINES@HSUS.ORG>, <INFO@PETA.ORG>, <INFO@IDAUSA.ORG>, <INFO@COK.NET> **Subject:** **Fwd: PUBLIC comment ON FEDERAL REGISTER**
>
> I OPPOSE THIS EXPANSION AT WALLOPS ISLAND. THE NEGATIVE EFFECTS ON WILDLIFE, MARINE LIFE, PEOPLE, WATER USE, ETC ARE MAJOR AND THIS IS A DELICATE SITUATION, ESPECIALY WITH 1
> RISING SEA LEVELS. THIS IS NOT A SUITABLE SITE FOR EXPANSION. IT COULD BE AND WILL BE COVERED BY WATER IN A SHORT TIME. THIS PLAN IS TOTALLY WASTEFUL. THE SPENDING 2
> IS UNJUSTIFIED. THIS COMMETN IS FOR THE PUBLIC RECORD. HOW CAN YOU NOT PAY ATTENTION THE CLIMATE AND RISING SEA WATERS. B KER.
> BK1492@AOL.COM
>
> Federal Register Volume 83, Number 87 (Friday, May 4, 2018)]
> [Notices]
> [Pages 19839-19841]
> From the Federal Register Online via the Government Publishing Office [www.gpo.gov]
> [FR Doc No: 2018-09469]
>
> =======================================================================
>
> -----------------------------------------------------------------------
>
> NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
>
> [Notice (18-039)]
>
> National Environmental Policy Act; Wallops Flight Facility; Site-
> Wide

AGENCY: National Aeronautics and Space Administration (NASA).

ACTION: Notice of availability of the Draft Site-wide Programmatic Environmental Impact Statement (PEIS) for improvement of infrastructure and services at Wallops Flight Facility (WFF), Accomack County, Virginia.

-----------------------------------------------------------------------

SUMMARY: Pursuant to the National Environmental Policy Act (NEPA), as amended, the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA, and NASA's NEPA policy and procedures, NASA has prepared a Draft PEIS for the improvement of infrastructure and services at WFF. The Federal Aviation Administration's Air Traffic Organization (FAA-ATO) and Office of Commercial Space Transportation (FAA-AST); the Federal Highway Administration (FHWA); the National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service (NOAA-NESDIS); the U.S. Army Corps of Engineers (USACE); the U.S. Coast Guard; the U.S. Fish and Wildlife Service (USFWS); the U.S. Navy, Naval Sea Systems Command (NAVSEA); the U.S. Navy, Naval Air Systems Command (NAVAIR); U.S. Navy, U.S. Fleet Forces Command; the U.S. Environmental Protection Agency (EPA); the U.S. Air Force Space Command/Space and Missile Systems Center; and Virginia Commercial Space Flight Authority (Virginia Space) have served as Cooperating Agencies in preparing the Draft PEIS as they either have permanent facilities or missions at WFF or possess regulatory authority or specialized expertise pertaining to the Proposed Action.

The purpose of this notice is to apprise interested agencies, organizations, tribal governments, and individuals of the availability of the Draft PEIS and to invite comments on the document. In partnership with its Cooperating Agencies, NASA will hold a public meeting as part of the Draft PEIS review process. The meeting location and date is provided under SUPPLEMENTARY INFORMATION below.

DATES: Interested parties are invited to submit comments on environmental issues and concerns, preferably in writing, no later than forty-five (45) days following the publication of the EPA's Notice of Availability of the Draft PEIS in the Federal Register. Once known, this date will be posted on the project website at: https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.

ADDRESSES: Comments submitted by mail should be addressed to Shari Miller, Site-wide PEIS, NASA Goddard Space Flight Center's Wallops Flight Facility, Mailstop: 250.W, Wallops Island, Virginia 23337. Comments may



be submitted via email to Shari.A.Miller@nasa.gov.

The Draft PEIS may be reviewed at the following locations:

(a) Chincoteague Island Library, Chincoteague, Virginia, 23336 (757) 336-3460
(b) NASA Wallops Visitor Center, Wallops Island, Virginia, 23337 (757) 824-1344

(c) Eastern Shore Public Library, Accomac, Virginia, 23301 (757) 787-3400
(d) Northampton Free Library, Nassawadox, Virginia, 23413 (757) 414-0010

A limited number of hard copies of the Draft PEIS are available, on a first request basis, by contacting the NASA point of contact listed under FOR FURTHER INFORMATION CONTACT. The Draft PEIS is available on the internet in Adobe[supreg] portable document format at https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis. The Federal Register Notice of Intent to prepare the Draft PEIS, issued on July 11, 2011, is also available on the internet at the same website address.

FOR FURTHER INFORMATION CONTACT: Shari Miller, Site-wide PEIS, NASA Goddard Space Flight Center's Wallops Flight Facility, Mailstop: 250.W, Wallops Island, Virginia 23337; telephone (757) 824-2327; email: Shari.A.Miller@nasa.gov. A toll-free telephone number, (800) 521-3415, is also available for persons outside the local calling area. When using the toll-free number, please follow the menu options and enter the ``pound sign (#)'' followed by extension number ``2327.''
Additional information about NASA's WFF may be found on the internet at http://www.nasa.gov/centers/wallops/home/index.html. Information regarding the NEPA process for this proposal and supporting documents (as available) are located at https://code200-external.gsfc.nasa.gov/250-wff/site-wide_eis.

SUPPLEMENTARY INFORMATION: WFF is a NASA Goddard Space Flight Center field installation located in northern Accomack County on the Eastern Shore of Virginia. The facility consists of three distinct landmasses--the Main Base, Wallops Mainland, and Wallops Island. WFF operates the oldest active launch range in the continental U.S. and the only range completely under NASA management. For over 70 years, WFF has flown thousands of research vehicles in the quest for information on the characteristics of airplanes, rockets, and spacecraft, and to increase the knowledge of the Earth's upper atmosphere and the near space environment. The flight programs and projects conducted by WFF range from small sounding and suborbital rockets, unmanned scientific balloons, unmanned aerial systems, manned aircraft, and orbital spacecraft to next-generation launch vehicles and small- and medium-classed launch vehicles. In keeping with the principles, goals, and guidelines of the 2010 National Space Policy, as updated by the 2013 U.S. National Space Transportation Policy and the 2017 Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, NASA is proposing to improve its service capability at WFF to support a growing mission base in the areas of civil, defense, and academic aerospace. One guiding principle of the National Space Policy is for Federal agencies to facilitate the commercial space industry. The Mid-Atlantic Regional Spaceport, a commercial launch site on Wallops Island, is a real-world example of WFF's commitment to making commercial access to space a reality. Accordingly, it is expected that a commercial presence at WFF will continue to expand in the coming years.

The National Space Policy also instructs Federal agencies to improve their partnerships through cooperation, collaboration, information sharing, and/or alignment of common pursuits with each other. WFF supports aeronautical research, and science, technology, engineering, and math (STEM) education programs by providing other NASA centers and other U.S. government agencies access to resources such as special use (i.e., controlled/restricted) airspace, runways, and launch pads. WFF regularly facilitates a wide array of U.S. Department of Defense (DoD) research, development, testing, and evaluation; training missions, including target and missile launches; and aircraft pilot training. Similar to its forecasted commercial growth at WFF, NASA also expects an increase in DoD presence at WFF in the foreseeable future.

Finally, the National Space Policy directs NASA to fulfill various key civil space roles regarding space science, exploration, and discovery; a number of which have been priorities at WFF for decades. NASA's need to ensure continued growth while preserving the ability to safely conduct its historical baseline of services is a key component of facilitating future projects and new missions at WFF.

Related Environmental Documents

In January 2005, NASA issued a Final Site-Wide Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for its operations and institutional support at WFF. Since then, substantial growth has occurred and NASA, and its Cooperating Agencies, have prepared multiple supplemental NEPA documents including the 2008 EA/ FONSI for the Wallops Research Park; the 2009 EA/FONSI for the Expansion of the Wallops Flight Facility Launch Range; the 2010 PEIS/ Record of Decision for the Shoreline Restoration and Infrastructure Protection Program; the 2011 EA/FONSI for the Alternative Energy Project; the 2011 EA/FONSI for the Main Entrance Reconfiguration; the 2011 NOAA-NESDIS EA/FONSI for Electrical and Operational Upgrade, Space Addition, and Geostationary Operational Environmental Satellite Installation; the 2012 EA/FONSI for the North Wallops Island Unmanned Aerial Systems Airstrip Project; the U.S. Fleet Force Command's 2013 EA/FONSI for E-2/C-2 Field Carrier Landing Practice at WFF; the Navy's 2014 EA/FONSI for the Testing of Hypervelocity Projectiles and an Electromagnetic Railgun; the 2015 Supplemental EA/FONSI for Antares 200 Configuration Expendable Launch Vehicle at WFF; the 2016 EA/FONSI for Establishment of Restricted Area Airspace R-6604 C/D/E; the Navy's 2017 EA/FONSI for and the Installation and Operation of Air and Missile Defense Radar AN/SPY[hyphen]6; and the 2017 U.S. Air Force's EA/FONSI for the Instrumentation Tower on Wallops Island.

Need for Preparing a PEIS

Since the 2005 WFF Site-wide EA, WFF, NOAA-NESDIS, and the Navy have updated their Master Plans; which propose new facilities and numerous infrastructure improvements to enable a growing mission base. Additionally, during reviews of the post-2005 Site-wide EA NEPA documents, resource agencies have expressed concerns regarding cumulative environmental effects and a desire for NASA to consider all reasonably foreseeable future projects at WFF in a consolidated NEPA document. NASA determined that preparing a single Site-wide PEIS not only would assist in its decision-making process for future mission growth at WFF but also address concerns regarding cumulative environmental effects. Therefore, the Site-wide PEIS considers all reasonably foreseeable future actions at WFF; those proposed by NASA along with those proposed by its tenants and partners.

Cooperating Agency Actions

The Site-wide PEIS will serve as a decision-making tool not only for NASA

[[Page 19841]]

but also for its Cooperating Agencies. Given the potential for their undertaking actions related to NASA's actions, each of these agencies has been involved closely in NASA's NEPA process.

Alternatives

The PEIS evaluates the environmental consequences of a range of reasonable alternatives that meet NASA's need to ensure continued growth at WFF while also preserving the ability to safely conduct its historical baseline of services. The planning horizon for actions in the PEIS is 20 years.

Currently under consideration are the Proposed Action and a No Action alternative. The Proposed Action would support a number of facility projects ranging from new construction, demolition, and renovation; the replacement of the Wallops causeway bridge; maintenance dredging between the boat docks at the Main Base and Wallops Island; development of a deep-water port and operations area on North Wallops Island; construction and operation of an additional medium to heavy class launch site; the introduction of new NASA and DoD programs at WFF; the expansion of the launch vehicle services with liquid-fueled intermediate class and solid fueled heavy class launch vehicles; and the consideration of commercial human spaceflight missions and the return of launch vehicles to the launch site. Under the No Action Alternative, WFF and its partners would continue the existing operations and programs previously discussed in the 2005 Site-Wide EA and the subsequent NEPA documents identified under Related Environmental Documents.

Public Meeting

NASA and its Cooperating Agencies will hold a public meeting to discuss WFF's proposed actions and to solicit comments on the Draft PEIS. The public meeting will be held at the WFF Visitor Center on May 23, 2018, from 6 p.m. to 8 p.m.

NASA anticipates that the public will be most interested in the potential environmental impacts of each alternative on protected and special-status species, wetlands, noise, and socioeconomics.

In developing its Final PEIS, NASA will consider all comments received; comments received and responses to comments will be included in the Final PEIS. In conclusion, written public input on environmental issues and concerns associated with the improvement of infrastructure and services at WFF is hereby requested.

Cheryl E. Parker,
Federal Register Liaison.
[FR Doc. 2018-09469 Filed 5-3-18; 8:45 am]
BILLING CODE 7510-13-P

| | |
|---|---|
| **From:** | Lory Ebron |
| **To:** | Miller, Shari A. (WFF-2500) |
| **Cc:** | Doug Taylor |
| **Subject:** | Comment Letter-Somerset County |
| **Date:** | Monday, June 04, 2018 3:53:22 PM |
| **Attachments:** | image001.png<br>Comment Somerset Cty PEIS.pdf |

Ms. Miller,

Thank you for the opportunity to provide a comment regarding the Draft Site-wide Programmatic Environmental Impact Statement. Attached is a scanned copy of our letter. The original letter will be mailed to your attention.

Regards,

**Lory Ebron**
Executive Aide **| Commissioners Office**
**Somerset County Government**
11916 Somerset Avenue Room 111
Princess Anne, MD 21853
www.somersetmd.us
lebron@somersetmd.us
**Voice:** (410) 651-0320 **| Fax:** (410) 651-0366

**COMMISSIONERS FOR SOMERSET COUNTY**
11916 SOMERSET AVENUE, ROOM 111
PR[NCESS ANNE, MARYLAND 21853
TELEPHONE 410-651-0320, FAX 410-651-0366

**COMMISSIONERS**
RANDY LAIRD, PRESIDENT
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REX SIMPKINS
JERRY S. BOSTON

**COUNTY ADMINISTRATOR-CLERK**
RALPH D. TAYLOR

COUNTY A rroRNEY
KIRK G. SIMPKINS

June 4, 2018

NASA Wallops Flight Facility
Draft Site-wide PEIS - Shari Miller
Mailstop: 250.W
Wallops Island, VA 23337

Re: Draft Site-wide PEIS

Dear Ms. Miller:

The Somerset County Commissioners appreciate the opportunity to comment on the Draft Site-wide Programmatic Environmental Impact Statement (Site-wide PEIS) for the NASA Wallops Flight Facility. Considering the proximity of this facility to Somerset County a majority of the environmental aspects assessed will have no direct impact.

Somerset County looks at potential growth at the NASA Wallops Flight Facility as a
benefit. An increase in residential, commercial and industrial development could occur as the
number of jobs increase. Some of this potential development could actually occur in Somerset 1
County. Support of the nation's space, defense and energy needs is extremely important to its
citizens as well as visitors. For this reason, the Somerset County Commissioners continue to
support the critical role that the NASA Wallops Flight Facility plays.

Sincerely,

Ralph D. Taylor
County Administrator/Clerk

**DEPARTMENT OF THE ARMY**
**US ARMY CORPS OF ENGINEERS**
**NORFOLK DISTRICT**
**FORT NORFOLK**
**803 FRONT STREET**
**NORFOLK VA 23510-1011**

June 14, 2018

Eastern Virginia Regulatory Section
NAO-2017-1941

Shari Miller
Environmental Planning Lead
NASA Wallops Flight Facility
Wallops Island, VA 23337

Dear Ms. Miller:

This letter provides the comments of the Norfolk District Corps of Engineers (USACE) in response to the NASA Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement Preliminary Draft for which USACE is a cooperating agency.

Our comments on the Preliminary Draft Environmental Impact Statement are given in relation to specific topics as follows:

**Offsite Alternatives**: This alternative is not addressed in the PDEIS. Provide a
statement on why all listed projects need to take place within the facility boundary and
how staying within the boundaries will contribute to your preferred alternative(s) 1
becoming the least environmentally damaging practicable alternative (LEDPA). Only the
LEDPA can receive a Department of the Army permit.

Due to this PDEIS being site wide and not for one individual project, the information
within is at too broad a level to comment on each individual project. Those projects
impacting waters and/or wetlands regulated by USACE under Section 404 of the Clean 2
Water Act (33 U.S.C. 1344) and/or Section 10 of the Rivers and Harbors Act (33 U.S.C.
403) will require additional NEPA documentation.

As part of our public interest review and in accordance with the Clean Water Act Section 404(b)(1) Guidelines, the Corps must evaluate all alternatives that avoid impacts to waters of the U.S. In addition to wetland and waters impacts, we must also consider public interest review factors such as land use, floodplain hazards and values, water supply and conservation, energy, water quality, safety, cost, economics, threatened and endangered species, historic and cultural resources, and environmental justice. In addition, navigation and potential effects to USACE Civil Works projects will be a primary consideration during permit review.

If you have any questions and/or concerns about these comments, please contact me via email at brian.c.denson@usace.army.mil or via telephone at (757) 201-7792.

Sincerely,

Brian Denson
Environmental Scientist,
Eastern Virginia
Regulatory Section

**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
**REGION III**
**1650 Arch Street**
**Philadelphia, Pennsylvania 19103-2029**

IJUN 1 B 2018

Ms. Shari A. Miller
NASA Wallops Flight Facility
34200 Fulton Street
Building F-160/Room CI65
Wallops Island, Virginia 23337

RE: Draft Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement, Wallops Island, Virginia (May 2018); CEQ 20180073

Dear Ms. Miller:

In accordance with the National Environmental Policy Act (NEPA), Section 309 of the Clean Air Act, and the Council on Environmental Quality (CEQ) regulations, 40 CFR Parts 1500-1508, the U.S. Environmental Protection Agency (EPA) has reviewed the Draft Wallops Flight Facility (WFF) Site-wide Programmatic Environmental Impact Statement (PEIS). The Draft PEIS has been prepared by the National Aeronautics and Space Administration (NASA) to evaluate the environmental effects of implementing proposed projects that would support existing and future NASA goals and objectives.

NASA is proposing to implement a suite of new construction and demolition projects and new operational missions and activities that are needed to ensure continued growth at NASA Goddard Space Flight Center's Wallops Flight Facility while also preserving the ability to safely conduct its historical baseline of operations. As a Programmatic NEPA document, this PEIS is broad in scope and will be followed by a series of site-specific NEPA documents, as appropriate. This Site-wide PEIS addresses the most reasonably foreseeable actions at WFF withjn a 20-year planning horizon, both proposed by NASA as well as its on-site tenant and partner agencies. The PEIS identifies a number of projects ranging from new construction, demolition, and renovation throughout the installation including several new mission activities which, together, comprise the Proposed Action. The PEIS also identifies a No-Action alternative. The impacts from the various activities considered in the PEIS under the Proposed Action vary from project to project and in some cases, may warrant additional, more focused analysis in the future as projects achieve conceptual maturity. The PETS included responses to comments on earlier drafts of the document provided by EPA through our role as a cooperating agency for the WFF Site-wide PEIS.

As a way of evaluating NEPA projects and providing recommendations to the lead agency, EPA has developed a set of criteria for rating Draft Environmental Impact Statements. Based on this rating system, EPA has rated the Draft PEIS for the project as Environmental Concerns 1 (EC- I). This rating 1
means that our review identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the Proposed Action or application of

mitigation measures that can reduce the environmental impact. We understand that a Preliminary EIS
may lack speci fie information based on the nature of the document and uncertainties of potential future
actions; the information in the document is commensurate with the Programmatic study. We expect that
further NEPA studies on relevant projects will include sufficient information to fully assess 2
environmental impacts. Our rating is based on the impacts to high quality wetlands both from the
Proposed Action (12 acres of high quality wetland impacts) and the No-Action Alternative (142 acres of
high quality wetland impacts). The area in which WFF is sited contains an abundance of important
wetland resources, such that a loss in habitat and function of the resources is virtually inherent in any
activity that may encroach on previously undeveloped land. The importance of these resources are
exhibited by the area's status as an Audubon Barrier Island Lagoon System Important Bird Area,
UNESCO Biosphere Reserve, and Western Hemisphere Shorebird Reserve Site. These designations
highlight the importance of this area to migratory and non-migratory birds, marine habitat restoration,
and coastal resilience. The wetlands present in this area not only perform functions critical to human
health, but also provide habitat for wildlife such as Birds of Conservation Concern which have been
known to use these resources at WFF. Our review did identify some recommendations for
environmental protection that we recommend be addressed prior to implementing the individual
projects; technical comments can be found in the enclosure. A copy of our rating system can be found
at:
https://www.epa.gov/nepa/environmental-impact-statcment-rnting-system-criLeria

We appreciate NASA's efforts to consider and actively engage EPA in the development of the study and for the opportunity to contribute under our NEPA and Clean Water Act authorities. For any questions or assistance EPA can provide, please contact Aaron Blair of the NEPA review team at (215) 814-2748.

Sincerely,

Barbara Rudnick
NEPA Team Leader

Enclosure (I)

**Enclosure - WFF Draft PEIS**
**Technical Comments**
**EPA Region III**

Please find below specific technical comments, referenced by chapter. We would be pleased to discuss the recommendations at your convenience:

**2-40:** Future NEPA analyses regarding maintenance dredging should include an analysis of each 3
dredging method prior to selecting a method and dredged material placement site.

**2-42:** Any temporary or permanent confined disposal facility to hold and dewater dredged materials
from the barge basins and/or entrance channels should not be sited within a wetland. If nearby a 4
wetland, the proper erosion and sedimentation controls should be implemented. In addition, EPA and 5
U.S. Army Corps of Engineers should be consulted should dredged material planned to be used in a thin
layer application.

**2-43:** As the North Wallops Island Deep-water Port and Operations Area is in very early stages of
development, we suggest further NEPA study include analysis of all possible alternatives including 6
environmental impacts from dredging and any ancillary facilities, as well as roads which may
accompany a particular alternative.

**2-46:** Since little is known about proposal LV Launch Pad 0-C in its early stage of development, the
potential to convert a large area of pervious surface to impervious, impacts to wetlands, water quality,
birds of conservation concern, and aquatic species, we suggest further NEPA analysis beyond the PEIS. 7
Since unavoidable impacts to wetland vegetation would be likely, we suggest early planning for
mitigation of these wetland loses. EPA staff can be available to assist with mitigation planning.

**3-68:** The EIS states that the extent of the per- and polyfluoroalkyl substances (PFAS) plume is
currently unknown but that NASA has successfully completed active remediation of the contamination
plume. These statements appear somewhat contradictory and it would be helpful if the current condition
were clarified in the NEPA report. We recommend the Final PEIS and studies for forthcoming activities 8
clearly state the status of the investigation of contamination. It is recommended that the potential
groundwater, surface water or soil contamination be considered in any work plan or project design. We
understand monitoring is in place, however, we suggest the plume extent of PFAS be considered in
order to confirm that any future construction in the area will not influence the plume or facilitate its
movement. Although the Town of Chincoteague wells located in the Columbia aquifer are no longer 9
used for potable water, it would be helpful to state status of other drinking water supply.

**3-82:** The PEIS states that the Stormwater Pollution Prevention Plan (SWPPP) would identify all
stormwater discharges at the site including "actual and potential sources of stormwater contamination". 10
Please state if NASA will be monitoring stormwater for specific contaminants.

**3-82:** In order to comply with Section 438 of the Energy Independence and Security Act of 2007, EPA
recommends consideration of Low Impact Development (LID) and green infrastructure technologies 11
such as vegetative buffers and biofiltration when constructing facilities identified in the Proposed
Action.

**3-82:** Any construction staging sites or stockpile areas associate with the Causeway Bridge Replacement should not be located in a wetlands or waterbody. 12

**3-87:** We recommend Material Transfer Sites be located in previously disturbed areas not adjacent to wetlands and proper best management practices (BMPs) implemented, as material that has yet to be de-watered could cause a sediment influx into wetlands or other ecologically sensitive areas nearby. 13

**3-152:** This section of the PEIS states that the permanent loss of natural habitat from new construction under the Proposed Action at the Mainland and Wallops Island would be less than 0.4 ha (1.0ac). However, the proposed Launch Pad 0-C alone would impact at least 5 acres of wetlands, which are natural habitat. Wetland habitat should be considered 'natural habitat' and in the case of Launch Pad 0-C, impacts would be permanent. This would reduce the habitat of not only Special-Status Species, but also Birds of Conservation Concern which rely on marshland habitat. If impacts to wetlands were to occur, mitigation outside of the immediately impacted area may not commensurately benefit the species which are affected by the habitat loss, as mitigation opportunities on the island may be limited. For these reasons, we recommend wetland impacts be avoided and minimized. 14

**WHITE PAPER - A Report on the Historical Impacts and Protection of Wetlands at NASA Wallops Flight Facility:** Many of the wetlands that will be impacted by the Proposed Action are of very high functional value according to the criteria established by Tiner (2011). The majority of impacted wetlands scoring 17 (18 is the highest value possible within NASA boundaries). We recommend that the Final PEIS discuss how NASA plans to use the results of the wetland functional assessment in their decision-making process when choosing sites for projects identified in the Proposed Action and for evaluation of mitigation opportunities and planning for potential impact of the Proposed Action. We recommend this assessment be used in developing avoidance measures, specifically for those areas which scored particularly high on the wetland assessment. We recommend consulting with U.S. Fish & Wildlife Service to determine how impacts to these areas may effect migratory and non-migratory birds including Birds of Conservation Concern. 15

COMMONWEALTH of VIRGINIA

Marine Resources Commission
2600 Washington Avenue
Third Floor
Newport News, Virginia 23607

Matthew J. Strickler
Secretary of Natural Resources

John M.R. Bull
Commissioner

June 18, 2018

NASA Wallops Flight Facility
Attn: Shari Miller
Mailstop: 250.W
Wallops Island, VA 23337

Re: Draft Site-wide PEIS
Wallops Flight Facility

Dear Ms. Miller:

This will respond to the request for comments regarding the Wallops Flight Facility Site-wide draft Programmatic Environmental Impact Statement prepared by NASA. Specifically the applicant has proposed new construction and updates to the NASA Goddard Space Flight Center's Wallops Flight Facility in Accomack County, Virginia that encompasses a 20-year planning horizon. We reviewed your submittal information and found that several pieces of the proposal have the potential to impact tidal wetlands, State marshlands, State subaqueous lands, in addition to both shellfish and finfish resources.

Please be advised that the dredging associated with the proposed barge route may impact 1
private oyster leases as well as public shellfish grounds (Baylor). Placement of any dredge
material on State-owned submerged lands or tidal wetlands will require a permit from the
Commission or local wetlands board. Likewise, permits may be required for the Causeway 2
Bridge replacement, development of the North Wallops Island Deep-water Port and Operations
Area, and construction of Launch Pad 0-C, and Launch Pier 0-D.

Pursuant to §28.2-1200 et seq of the Code of Virginia, the Commission has jurisdiction over any encroachment in, on, or over the beds of the bays, ocean, rivers, streams, or creeks, which are the property of the Commonwealth. If any portion of the project involves any encroachments channelward of the mean low water line a permit may be required from our
agency. Any jurisdictional impacts to state-owned submerged lands, tidal wetlands and/or coastal 3
primary sand dunes and beaches will be reviewed by VMRC and the Accomack County Wetlands Board during the Joint Permit Application process pursuant to §28.2-1200 et seq, §28.2-1300 et seq and §28.2-1400 et seq of the Code of Virginia.

At this time, the Commission cannot provide extensive comments as details of the project are not finalized. When the true scope of the project is determined, the Commission would like both the project and final analysis to focus on avoiding or minimizing impacts to tidal wetlands, submerged aquatic vegetation (SAV), hard clam, oyster, blue crab, and summer flounder, in
addition to any other species of ecological or economic importance to the Commonwealth. The 4
Virginia seaside is an important habitat fostering growth and development of larval and juvenile species that drive recruitment to the Commonwealth's recreational and commercial tidal fisheries each year. The Commission welcomes the opportunity to provide further comments once the planning process is complete.

Should you have any questions, please do not hesitate to contact me. Thank you for the opportunity to comment.

Sincerely,

Randal D. Owen

Randal D. Owen
Deputy Chief, Habitat Management

RDO/lra
HM

| | |
|---|---|
| **From:** | Hooks, Michael S. (WFF-011.0)[T-SOLUTIONS, INC.] |
| **To:** | Miller, Shari A. (WFF-2500) |
| **Cc:** | Haag, John CIV SCSC, TD15 |
| **Subject:** | Additional comments RE: Draft NASA WFF Site-wide PEIS |
| **Date:** | Wednesday, June 06, 2018 2:54:04 PM |

Shari,

I've reviewed the WFF PEIS and the only comments I have are "great job" and "excellent work!"

v/r

Mike
Michael Hooks, CHMM CSP
Environmental Specialist
T-Solutions, Inc.
Surface Combat Systems Center
Bldg Q-29, Public Works Department
30 Battle Group Way
Wallops Island, VA 23337
[redacted]
☎ 757-824-7705
Fax: 757-854-2730

-----Original Message-----
From: Haag, John CIV SCSC, TD15
Sent: Wednesday, June 06, 2018 12:48 PM
To: Hooks, Michael S CTR SCSC, T-Solutions
Subject: FW: Draft NASA WFF Site-wide PEIS

We have provided input and are good with this, right?

Thanks,

John Haag
Public Works Officer
Wallops Island VA
(W) 757-824-7700
(C) 757-894-4745

-----Original Message-----
From: Miller, Shari A. (WFF-2500) [mailto:shari.a miller@nasa.gov]
Sent: Wednesday, June 06, 2018 12:43 PM
To: [redacted] Haag, John CIV SCSC, TD15 [redacted]

**From:** Miller, Shari A. (WFF-2500)
**To:** Charee Hoffman
**Subject:** Draft NASA WFF Site-wide PEIS--NOAA and NESDIS Review Comments
**Date:** Wednesday, June 27, 2018 4:02:30 PM
**Attachments:** NOAA Review Comments for NASA Wallops Flight Facility--Draft PEIS 2018 0622.pdf

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**From:** John Gironda - NOAA Federal [mailto:john.gironda@noaa.gov]
**Sent:** Wednesday, June 27, 2018 3:46 PM
**To:** Miller, Shari A. (WFF-2500) <shari.a.miller@nasa.gov>
**Subject:** Re: Draft NASA WFF Site-wide PEIS--NOAA and NESDIS Review Comments

Hi Shari,

NESDIS HQ and Wallops Command Data Acquisition Station have no further comments to the subject PEIS.

NOAA National Marine Fisheries Service (NMFS) offices do have comments, and these are included in the attached PDF. We and NMFS thank you for the extra time you were able to offer us.

For issues related to the NMFS document, POCs are listed in the NMFS document.

b/r

-- John
A John Gironda III, P.E.
NESDIS Office of the CFO/CAO
Facility Management Branch
1335 E. West Hwy, Suite 7407
Silver Spring, MD 20910
301-713-9208
"*The general principles on which the fathers achieved independence were the general principles of Christianity*." President John Adams, June 1813

On Tue, Jun 5, 2018 at 9:13 AM, Miller, Shari A. (WFF-2500) <shari.a.miller@nasa.gov> wrote:

> John,
>
> As VDEQ has a total of 60 days for CZMA review, we can extend another 15 days until July 3rd. Does that give NMFS enough time?
>
> *Shari A. Miller*
> Environmental Planning Lead
> NASA Wallops Flight Facility
> Wallops Island, VA 23337
> (757) 824-2327
> Shari.A.Miller@nasa.gov

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

**RE: Comments on NASA Draft Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement**

NOAA's National Marine Fisheries Service (NMFS) Greater Atlantic Regional Fisheries Office's (GARFO) Habitat Conservation Division (HCD) and Protected Resources Division (PRD) have reviewed the information provided in the draft site-wide Programmatic Environmental Impact Statement (PEIS) for the Goddard Space Flight Center's Wallops Flight Facility (WFF) on Wallops Island in Accomack County, Virginia. The National Aeronautics and Space Administration (NASA) is proposing to implement a suite of new construction and demolition projects and new operational missions and activities at WFF to support a growing mission base while preserving NASA's ability to safely conduct its historical baseline operations. The PEIS addresses the most reasonably foreseeable actions at WFF within a 20-year planning horizon. As the nation's federal trustee for the conservation and management of marine, estuarine, and diadromous fishery resources, we offer you the following comments pursuant to the authorities of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), Fish and Wildlife Coordination Act and the Endangered Species Act.

**Magnuson Stevens Fishery Conservation and Management Act (MSA)**

The Atlantic Ocean, Shelly Bay, Chincoteague Bay, Inlet, and Channel and its tributaries, and the surrounding coastal bays, creeks, and marshes have been designated essential fish habitat (EFH) for a variety of life stages of fish managed by the New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), South Atlantic Fishery Management Council (SAFMC), and NMFS because these areas provide feeding, resting, nursery, and staging habitat for a variety of commercially, recreationally, and ecologically important species. Species for which EFH has been designated in the area of the proposed project include, but are not limited to, Atlantic butterfish (*Peprilus triacanthus*), bluefish (*Pomatomus saltatrix*), black sea bass (*Centropristis striata*), scup (*Stenotomus chrysops*), summer flounder (*Paralichthys dentatus*), windowpane flounder (*Scophthalmus aquosus*), clearnose skate (*Raja eglanteria*), and winter skate (*Leucoraja ocellata*). The project area is also designated EFH for several Atlantic highly migratory species (tuna, swordfish, billfish, small and large coastal sharks, and pelagic sharks) including, but not limited to, sandbar 1
shark (*Carcharhinus plumbeus*), smoothhound shark complex (Atlantic stock), albacore tuna (*Thunnus alalunga*) and sand tiger shark (*Carcharias taurus*). The sand tiger shark has been listed as a Species of Concern by NOAA. The goal of listing a species as a Species of Concern is to promote proactive conservation efforts for these species in order to preclude the need to list them in the future. Furthermore, coastal inlets are designated as EFH for Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*Scomberomorus cavalla*), and cobia (*Rachycentron canadum*).

The MSA requires federal agencies, such as NASA, to consult with us on any action or proposed action authorized, funded, or undertaken, by such agency that may adversely affect EFH identified under the MSA. This process is guided by the requirements of our EFH regulation at 50 CFR 600.905, which mandates the preparation of EFH assessments and generally outlines each agency's obligations in the consultation process. The level of detail in an EFH assessment should be commensurate with the complexity and magnitude of the potential adverse effects of the action. 1 (cont.)

Essential fish habitat is defined as, "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." For the purpose of interpreting the definition of EFH:

- "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate;
- "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities;
- "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem;
- "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

The EFH final rule published in the Federal Register on January 17, 2002 defines an adverse effect as: "any impact which reduces the quality and/or quantity of EFH." The rule further states that:

> An adverse effect may include direct or indirect physical, chemical or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat and other ecosystems components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from action occurring within EFH or outside EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

The EFH final rule also states that the loss of prey may be an adverse effect on EFH and managed species. As a result, actions that reduce the availability of prey species, either through direct harm or capture, or through adverse impacts to the prey species' habitat may also be considered adverse effects on EFH.

Our EFH regulations also allow federal agencies to incorporate an EFH assessment into documents prepared for other purposes including National Environmental Policy Act (NEPA) documents provided certain conditions are met. If an EFH assessment is contained in another document, it must be clearly identified as an EFH assessment and include all of the following mandatory elements including: (i) a description of the action, (ii) and analysis of the potential adverse effects of the action on EFH and the managed species, (iii) the federal agency's conclusions regarding the effects of the action on EFH, and (iv) proposed mitigation, if applicable. If appropriate, the assessment should also contain additional information, including: (i) the results of an on-site inspection to evaluate the habitat and the site specific effects of the project, (ii) the views of recognized experts on the habitat or species that may be affected, (iii) a review of pertinent literature and related information, (iv) an analysis of alternatives to the action. Such analysis should include alternatives that could avoid or minimize adverse effects on EFH, and (v) other relevant information.

By letter date May 3, 2018, NASA indicated that additional future NEPA documentation and consultation with NMFS HCD would be required once information was known for various projects at WFF, including (1) the causeway bridge, (2) maintenance dredging between the boat docks at the Main Base and Wallops Island, and (3) development of a deep-water port and operations area on the north end of Wallops Island. NASA indicated that consultation with NMFS HCD will commence on these projects once sufficient details of the proposed activities are available to conduct EFH analyses. We concur that the above-listed projects will require 2
future EFH consultation. However, other actions including, but not limited to, work at the LV Launch Pad O-C complex, LV Launch Pier O-D, any dredging, placement of fill in the aquatic environment, or other activities that may adversely affect EFH, federally managed species, or their prey, will also require consultation with us once sufficient details become available on those actions. NMFS HCD staff area available to work with NASA in determining which proposed actions will require additional EFH consultation.

EFH assessments should be prepared for all actions that may adversely affect EFH, federally managed species and their prey, and should address the direct, indirect, individual, and cumulative effects of project elements. To fully evaluate proposed actions at WFF, information regarding the location, type, frequency, magnitude, and duration of impacts will be necessary as well as biological information characterizing the distribution, abundance, biomass, production and diversity of fish and invertebrates. Fishery-independent and -dependent surveys will be useful for evaluating project effects. Furthermore, thorough analyses of alternatives, avoidance and minimization measures, and proposed mitigation will be required to fully evaluate each proposed project. NMFS HCD staff is available to assist NASA in determining the level of detail needed for the EFH assessments for the individual projects planned at WFF as project specific details become available.

For a listing of EFH and further information useful for EFH assessments, please see our website at: http://www.greateratlantic.fisheries.noaa.gov/habitat. The website also contains information on descriptions of EFH for each species, guidance on the EFH consultation process including EFH assessments, and information relevant to our other mandates. Furthermore, a number of Fisheries Management Plans and amendments to those plans (e.g., June 2009 Amendment 1 to 3
the Consolidated Highly Migratory Species (HMS) Fisheries Management Plan) address non-fishing activities, and provide a number of general EFH conservation recommendations, which can be included as avoidance and minimization measures.

**Fish and Wildlife Coordination Act (FWCA)**

The Fish and Wildlife Coordination Act (FWCA), as amended in 1964, requires that all federal agencies consult with us when proposed actions might result in modifications to a natural stream or body of water. Federal agencies must consider effects that these projects would have on fish and wildlife and must also provide for improvement of these resources. Under this authority, we work to protect, conserve and enhance species and habitats for a wide range of aquatic resources such as shellfish, diadromous species, and other commercially and recreationally importance species that are not managed by the federal fishery management councils.

The waters and wetlands in and around the WFF also serve as important habitat for many NOAA trust resources that are considered under our FWCA authorities including both state and federally managed species and their forage including Atlantic butterfish, Atlantic sea herring (*Clupea harengus*), bluefish, black sea bass, striped bass (*Morone saxatilis*), blue crab (*Callinectes sapidus*), Atlantic menhaden (*Brevoortia tyrannus*), bay anchovies (*Anchoa mitchilli*) and other assorted baitfishes and shrimps (e.g., *Neomysis Americana*, *Mysidopsis bigelow*). Shellfish and crustaceans such as Atlantic bay scallop (*Aequipecten irradians*), quahogs or hard clams (*Mercenaria mercenaria*), Eastern oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*) and horseshoe crab (*Limulus Polyphemus*) can also be found within the project area.

The area is also important habitat for anadromous species such as alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), and striped bass. In addition to their commercial and recreational importance, many of these species are also ecologically important. Because landing statistics and the number of fish observed on annual spawning runs indicate a drastic decline in alewife and blueback herring populations throughout much of their range since the mid-1960s, river herring have been designated as Species of Concern by NOAA. 3 (cont.)

The 2012 river herring benchmark stock assessment found that of the 52 stocks of alewife and blueback herring assessed, 23 were depleted relative to historic levels, one was increasing, and the status of 28 stocks could not be determined because the time-series of available data was too short. The "depleted" determination was used instead of "overfished" and "overfishing" to indicate factors besides fishing have contributed to the decline, including habitat loss, habitat degradation and modification, and climate change. Increases in turbidity due to the resuspension of sediments into the water column during dredging and construction activities can degrade water quality, lower dissolved oxygen levels, and potentially release chemical contaminants bound to the fine-grained estuarine/marine sediments.

**General Comments Applicable to our MSA and FWCA Authorities**

Generally, we recommend projects at WFF are designed to affect the minimum amount of aquatic habitat necessary to accomplish a projects purpose. Activities that may adversely affect fishery habitat should be avoided when less environmentally harmful alternatives are available. For example, projects should avoid filling aquatic habitats, avoid temporary fills for construction purposes, and use only clean fill when filling is necessary. In many locations, permanent fill can be avoided or minimized by using upland areas, bridging areas, and using elevated permanent structures. Bridges and other elevated structures should be designed to avoid and minimize shading to marsh vegetation and other aquatic vegetation and algae. Additionally, new dredging should be avoided if other alternatives are practicable.

NMFS HCD looks forward to continued coordination with NASA as individual projects at WFF are developed. If you have any questions or need additional information on EFH or other NOAA trust resources, please do not hesitate to contact Keith Hanson in our Annapolis, MD field office at keith.hanson@noaa.gov or (410) 573-4559.

**Endangered Species Act**
The following endangered or threatened species under our jurisdiction may be present in the project area:

*Atlantic Sturgeon*
Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) are present in coastal waters along the coast of Virginia as well as in and around Chesapeake Bay and its tributaries. The New York Bight, Chesapeake Bay, South Atlantic, and Carolina distinct population segments (DPS) of Atlantic sturgeon are endangered; the Gulf of Maine DPS is threatened. Adult and subadult Atlantic sturgeon from any of these DPSs could occur in the proposed project area. As young remain in their natal river/estuary until approximately age 2, and early life stages are not tolerant of saline waters; therefore, no egg, larvae, or juvenile Atlantic sturgeon will occur in the area.

*Sea Turtles*
Four species of federally threatened or endangered sea turtles under our jurisdiction can be found seasonally in the coastal waters of Virginia from late April – mid November of each year. The threatened Northwest Atlantic Ocean DPS of loggerhead (*Caretta caretta*), the endangered Kemp's ridley (*Lepidochelys kempii*), and the endangered leatherback (*Dermochelys coriacea*) sea turtles may be present along the Virginia coast. NMFS published the final listing of eleven Green sea turtle (*Chelonia mydas*) DPS on April 6, 2016. Eight DPSs were listed as threatened and three as endangered. The DPS found in U.S. Atlantic waters, the North Atlantic DPS, is listed as threatened. Due to the inability to distinguish between these populations away from the nesting beach, green sea turtles are considered endangered wherever they occur in U.S. waters.

Juvenile and adult turtles of all species of sea turtles may occur seasonally along Virginia shores though leatherback turtles would normally be found offshore in deeper waters. There are no established nesting beaches in Virginia and eggs and hatchlings will not be present within the proposed project area.

*Cetaceans (Whales)*
Five species of endangered large whales occur seasonally off the Mid-Atlantic coast of the U.S.: North Atlantic right whale (*Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), sperm whale (*Physeter macrocephalus*), and blue whale (*Balaenoptera musculus*).

However, of these five species, only two, the right and fin whales, are likely to occur closer to the Virginia shore in shallower waters. Sperm, blue, and sei whales are typically found in waters further offshore. Right whales are most likely to occur along the Virginia coast during seasonal migrations between November and April and fin whales are most likely to occur during seasonal migrations between October and January.

As project plans develop, we recommend you consider the following project best management practices and avoidance/minimization measures for all of the proposed project's activities that might affect sea turtles, sturgeon, and whales: 4

- For activities that increase levels of suspended sediment, consider the use of silt management and/or soil erosion best practices (i.e., silt curtains and / or cofferdams).

- For work that will increase vessel traffic within the project area, consider restricting the number of trips taken by each vessel and selecting shallow draft vessels. 4 (cont.)

- For any impacts to habitat or conditions that temporarily render affected water bodies unsuitable for the above-mentioned species, consider the use of timing restrictions for in-water work.

For additional guidance on the section 7 consultation process, technical resources and species information, please visit our website at: https://greateratlantic.fisheries.noaa.gov/protected/section7/index.html .

NASA will be responsible for determining whether the proposed action may affect listed species. If you determine that the proposed action may affect a listed species, you should submit your determination of effects, along with justification and a request for concurrence to the attention of the Section 7 Coordinator, NMFS, Greater Atlantic Regional Fisheries Office, Protected Resources Division, 55 Great Republic Drive, Gloucester, MA 01930. We also have a specialized e-mail account to expedite the process of submitting a request for consultation to us at nmfs.gar.esa.section7@noaa.gov. We encourage you to electronically submit any consultation 5
requests directly to this e-mail account. After reviewing this information, we would then be able to conduct a consultation under section 7 of the ESA. If you have any questions regarding ESA or the section 7 consultation process, please contact Brian D. Hopper (410-573-4592; brian.d.hopper@noaa.gov).

cc: NMFS GARFO HCD – Greene, Hanson
NMFS GARFO PRD – Hopper, Murray Brown

# COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
*Street address:* 1111 East Main Street, Richmond, Virginia 23219
*Mailing address:* P.O. Box 1105, Richmond, Virginia23218
www.deq.virginia.gov

Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482

July 2, 2018

NASA Wallops Flight Facility
Site-wide PEIS
C/o: Ms. Shari Miller
Mailstop: 250.W
Wallops Island, Virginia 23337

RE: Draft Site-wide Programmatic Environmental Impact Statement and Federal Consistency Determination, Wallops Flight Facility, Accomack County, (DEQ 18-073F).

Dear Ms. Miller:

The Commonwealth of Virginia has completed its review of the above-referenced proposal. The Department of Environmental Quality is responsible for coordinating Virginia's review of federal environmental documents submitted under the National Environmental Policy Act (NEPA) and responding to appropriate federal officials on behalf of the Commonwealth. DEQ is also responsible for coordinating Virginia's review of federal consistency documents submitted pursuant to the Coastal Zone Management Act (CZMA) and providing the state's response. This is in response to the May 2018 Draft Programmatic Environmental Impact Statement (DPEIS) and Federal Consistency Determination (FCD) (received May 3, 2018) submitted by the National Aeronautics and Space Administration for the proposed action. The following agencies participated in the review of this proposal:

Department of Environmental Quality
Department of Game and Inland Fisheries
Department of Conservation and Recreation
Department of Health
Virginia Marine Resources Commission

In addition, the Department of Agriculture and Consumer Services, Department of Historic Resources, Department of Mines, Minerals, and Energy, Department of Aviation, Accomack County, and the Accomack-Northampton Planning District Commission were invited to comment on the proposal.

## PROJECT DESCRIPTION

The National Aeronautics and Space Administration (NASA) proposes a number of site-wide improvements at the Wallops Flight Facility (WFF) in Accomack County, Virginia. WFF consists of three distinct landmasses:

- Main Base;
- Wallops Mainland; and
- Wallops Island.

NASA proposes to improve its service capability at WFF to support a growing mission base in the areas of civil, defense, and academic aerospace. The proposed action would support a number of facility projects to include:

- new construction, demolition, and renovation;
- the replacement of the Wallops causeway bridge;
- maintenance dredging between the boat docks at the Main Base and Wallops Island;
- development of a deep-water port and operations area on North Wallops Island;
- construction and operation of an additional medium to heavy class launch site;
- the introduction of new NASA and Department of Defense programs at WFF;
- the expansion of the launch vehicle services with liquid-fueled intermediate class and solid fueled heavy class launch vehicles; and
- the consideration of commercial human spaceflight missions and the return of launch vehicles to the launch site.

The planning horizon for the action is 20 years.

## CZMA FEDERAL CONSISTENCY CONCURRENCE

The DPEIS includes a Federal Consistency Determination (FCD) (Appendix G) that includes an analysis of the consistency of the proposed programmatic improvements on the enforceable policies of the CZM Program. Based on our review of the FCD and the comments submitted by agencies administering the enforceable policies of the CZM Program, DEQ concurs that the programmatic activities as currently described are 1
consistent to the maximum extent practicable with the enforceable policies of the CZM Program, provided all applicable permits and approvals are obtained as described below. In addition, in accordance with 15 CFR §930.39(c), DEQ recommends that NASA consider the impacts of the improvements on the advisory policies of the Virginia CZM Program found at https://www.deq.virginia.gov/Programs/EnvironmentalImpactReview/FederalConsistencyReviews.aspx#advisory.

**Federal Consistency Public Participation**

In accordance with Title 15, Code of Federal Regulations (CFR), §930.2, the public was invited to participate in the review of the FCD submitted for the proposal. Public notice of this proposed action was published in OEIR's Program Newsletter and on the DEQ 2
website from May 11, 2018 through June 21, 2018. No public comments were received in response to the notice.

**Supplemental Coordination**

Pursuant to 15 CFR, Part 930, Subpart C, §930.46(a), NASA must submit supplemental information to DEQ for review and approval for the site-wide improvement projects that will affect any coastal uses or resources substantially different than described in the PEIS and FCD. Substantially different coastal effects include:

- substantial changes in the proposed activity that are relevant to Virginia CZM Program enforceable policies;
- significant new circumstances or information relevant to the proposed activity and the proposed activity's effect on any coastal use or resources; 3
- substantial changes that are made to the activity affecting enforceable policies and/or coastal uses or resources.

Accordingly, as detailed construction plans are developed and the site-specific environmental impacts of each project are identified, a project-specific Federal Consistency Determination must be submitted to DEQ for review and concurrence in accordance with the CZMA federal consistency regulations (15 CFR, Part 930, Subpart C, §930.30 *et seq.*) .

Other state approvals which may apply to project activities are not included in this concurrence. Therefore, NASA must ensure that site-wide improvement activities are 4
implemented in accordance with all applicable federal, state, and local laws and regulations.

**NEPA CONCLUSION**

Provided activities are performed in accordance with the recommendations which follow in the Environmental Impacts and Mitigation section of this report, the proposal described in the DPEIS is unlikely to have significant effects on ambient air quality, water quality, wetlands, important farmland, wildlife resources, forest resources, historic resources, and solid and hazardous wastes. It is unlikely to adversely affect species of animals, plants or insects listed by state agencies as rare, threatened, or endangered.

## ENVIRONMENTAL IMPACTS AND MITIGATION

**1. Surface Waters and Wetlands**. According to the DPEIS (pages 4-2 and 4-3), NASA would comply with required federal, state and local laws and regulations for impacts to surface waters and wetlands anticipated from proposed construction activities.

**1(a) Agency Jurisdiction.**

***(i) Virginia Marine Resources Commission.***

The Virginia Marine Resources Commission (VMRC) regulates encroachments on tidal wetlands pursuant to Virginia Code §28.2-1200 through 1400.

***(ii) Department of Environmental Quality***

The State Water Control Board promulgates Virginia's water regulations covering a variety of permits to include the Virginia Pollutant Discharge Elimination System Permit regulating point source discharges to surface waters, Virginia Pollution Abatement Permit regulating sewage sludge, storage and land application of biosolids, industrial wastes (sludge and wastewater), municipal wastewater, and animal wastes, the Surface and Groundwater Withdrawal Permit, and the Virginia Water Protection (VWP) Permit regulating impacts to streams, wetlands, and other surface waters. The VWP permit is a state permit which governs wetlands, surface water, and surface water withdrawals and impoundments. It also serves as §401 certification of the federal Clean Water Act §404 permits for dredge and fill activities in waters of the U.S. The VWP Permit Program is under the Office of Wetlands and Stream Protection, within the DEQ Division of Water Permitting. In addition to central office staff that review and issue VWP permits for transportation and water withdrawal projects, the six DEQ regional offices perform permit application reviews and issue permits for the covered activities:

- Clean Water Act, §401;
- Section 404(b)(i) Guidelines Mitigation Memorandum of Agreement (2/90);
- State Water Control Law, Virginia Code section 62.1-44.15:20 *et seq*.; and
- State Water Control *Regulations*, 9 VAC 25-210-10.

**1(b) Agency Findings.**

***(i) Virginia Marine Resources Commission***

VMRC finds that it appears that some of the activities will require authorization from the agency and/or the Accomack County Wetlands Board based on information provided in the DPEIS. The Causeway Bridge replacement, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D all have elements that will require permits.

### *(ii) Department of Environmental Quality*

The VWP Permit program at the DEQ Tidewater Regional Office (TRO) finds that projects involving impacts to surface waters, including wetlands, may require a VWP permit. In addition, the VPDES program at DEQ-TRO finds that WFF is currently covered under an individual VPDES permit (VA0024457).

**1(c) Requirements.**

### *(i) Virginia Marine Resources Commission*

NASA must submit a Joint Permit Application (JPA) to VMRC, which serves as the
clearinghouse for permits issued by VMRC, DEQ, U.S. Army Corps of Engineers, and 5
local wetlands boards, for projects that are anticipated to impact jurisdictional surface
waters and wetlands.

### *(ii) Department of Environmental Quality*

Upon receipt of a JPA for proposed surface water impacts, DEQ VWP Permit staff will review the proposed project in accordance with program regulations and current guidance. In addition, future activities at WFF may require updates or changes to its VPDES permit. Construction may require mapping changes for the facility as required by the Stormwater Pollution Prevention Plan (SWPPP).

**1(d) Recommendations.** In general, the DEQ VWP Permit program recommends that stream and wetland impacts be avoided to the maximum extent practicable. To minimize unavoidable impacts to wetlands and waterways, DEQ recommends the following practices:

- Operate machinery and construction vehicles outside of stream-beds and wetlands; use synthetic mats when in-stream work is unavoidable.
- Preserve the top 12 inches of trench material removed from wetlands for use as wetland seed and root-stock in the excavated area.
- Erosion and sedimentation controls should be designed in accordance with the
  most current edition of the Virginia Erosion and Sediment Control Handbook. 6
  These controls should be in place prior to clearing and grading, and maintained in good working order to minimize impacts to State waters. The controls should remain in place until the area is stabilized.
- Place heavy equipment, located in temporarily impacted wetland areas, on mats, geotextile fabric, or use other suitable measures to minimize soil disturbance, to the maximum extent practicable.
- Restore all temporarily disturbed wetland areas to pre-construction conditions and plant or seed with appropriate wetlands vegetation in accordance with the cover type (emergent, scrub-shrub, or forested). The applicant should take all appropriate measures to promote revegetation of these areas. Stabilization and

restoration efforts should occur immediately after the temporary disturbance of each wetland area instead of waiting until the entire project has been completed.

- Place all materials which are temporarily stockpiled in wetlands, designated for use for the immediate stabilization of wetlands, on mats, geotextile fabric in order to prevent entry in State waters. These materials should be managed in a manner that prevents leachates from entering state waters and must be entirely removed within thirty days following completion of that construction activity. The disturbed areas should be returned to their original contours, stabilized within thirty days following removal of the stockpile, and restored to the original vegetated state. 6 (cont.)
- All non-impacted surface waters within the project or right-of-way limits that are within 50 feet of any clearing, grading, or filling activities should be clearly flagged or marked for the life of the construction activity within that area. The project proponent should notify all contractors that these marked areas are surface waters where no activities are to occur.
- Measures should be employed to prevent spills of fuels or lubricants into state waters.

**2. State Subaqueous Lands.** The DPEIS does not discuss potential project impacts to state subaqueous lands. However, the Federal Consistency Determination (PEIS, Appendix G, page G-9) states that dredging and construction at the North Wallops Island Deep-water Port and Operations Area, and Launch Pad 0-C, would require permits prior to implementing these actions.

**2(a) Agency Jurisdiction.** The Virginia Marine Resources Commission regulates encroachments in, on or over state-owned subaqueous beds as well as tidal wetlands pursuant to Virginia Code §28.2-1200 through 1400. For nontidal waterways, VMRC states that it has been the policy of the Habitat Management Division to exert jurisdiction only over the beds of perennial streams where the upstream drainage area is 5 square miles or greater. The beds of such waterways are considered public below the ordinary high water line. 7

**2(b) Agency Findings.** VMRC finds that the Causeway Bridge replacement, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D, all have elements that will require subaqueous lands permits from VMRC.

**2(c) Requirements.** NASA must submit a JPA to VMRC for projects that are anticipated to impact state subaqueous lands.

**3. Fish and Shellfish Resources.** According to the DPEIS (page 3-178), dredging impacts to essential fish habitat (EFH), fish, and shellfish could occur from direct entrainment (fish being captured by the dredge bucket), increased turbidity and subsequent sedimentation, direct habitat loss, and disturbance from noise and in-water 8 activity. Impacts to fish and shellfish would depend on the season during which the dredging occurred and the life stages of organisms that occupy the project area.

**3(a) Agency Jurisdiction.** The Virginia Marine Resources Commission is charged with the management and regulation of marine resources. The Fisheries Management Division carries out current and long-term state policies effecting saltwater fisheries, both recreational and commercial, in Virginia's tidal waters. The Division's goal is to provide the maximum benefit and long-term use of the Commonwealth's finfish and shellfish resources through conservation and enhancement. The Commission's management programs are authorized or mandated under state and federal law. 8 (cont.)

**3(b) Agency Findings.** VMRC notes that the DPEIS (Appendix G) states that dredging may affect existing oyster ground leases and wild shellfish along the barge route. Also, the driving of pilings and dredging may adversely impact marine mammals and fisheries.

**3(c) Requirement.** NASA must coordinate with VMRC on projects that are anticipated to impact fish and shellfish resources.

**4. Erosion and Sediment Control and Stormwater Management.** According to the PEIS (page 4-4), site specific erosion and sediment control plans would be developed and utilized to ensure that soil erosion during construction is minimal. These plans would implement best management practices (BMPs) that are outlined in the facility's Stormwater Pollution Prevention Plan (SWPPP) and Erosion and Sediment Control Plan. These BMPs could include using silt fencing; soil stabilization blankets; and matting construction entrances, material laydown areas, and around areas of land disturbance during construction. Bare soils would be vegetated after construction to reduce erosion and stormwater runoff velocities.

**4(a) Agency Jurisdiction.** The DEQ Office of Stormwater Management (OSWM) administers the following laws and regulations governing construction activities:

- Virginia Erosion and Sediment Control (ECS) Law (§ 62.1-44.15:51 *et seq.*) and *Regulations* (9 VAC 25-840);
- Virginia Stormwater Management Act (§ 62.1-44.15:24 *et seq.*);
- *Virginia Stormwater Management Program* (*VSMP*) *Regulation* (9 VAC 25-870); and
- 2014 General Virginia Pollutant Discharge Elimination System (VPDES) Permit for Discharges of Stormwater from Construction Activities (9 VAC 25-880).

In addition, DEQ is responsible for the Virginia Stormwater Management Program (VSMP) General Permit for Stormwater Discharges from Construction Activities related to Municipal Separate Storm Sewer Systems (MS4s) and construction activities for the control of stormwater discharges from MS4s and land disturbing activities under the Virginia Stormwater Management Program (9 VAC 25-890-40).

**4(b) Requirements.** DEQ-OSWM did not respond to DEQ's request for comments. However, based on previous responses to similar projects, regulatory guidance for the control of non-point source pollution is presented below.

***(i) Erosion and Sediment Control and Stormwater Management Plans***

NASA and its authorized agents conducting regulated land-disturbing activities on private and public lands in the state must comply with the *Virginia Erosion and Sediment Control Law and Regulations* (*VESCL&R*) and *Virginia Stormwater Management Law and Regulations* (*VSWML&R*), including coverage under the general permit for stormwater discharge from construction activities, and other applicable federal nonpoint source pollution mandates (e.g. Clean Water Act-Section 313, federal consistency under the Coastal Zone Management Act). Clearing and grading activities, installation of staging areas, parking lots, roads, buildings, utilities, borrow areas, soil stockpiles, and related land-disturbing activities that result in the total land disturbance of equal to or greater than 10,000 square feet would be regulated by *VESCL&R*. Accordingly, the applicant must prepare and implement an erosion and sediment control (ESC) plan to ensure compliance with state law and regulations. The ESC plan 9
is submitted to DEQ-TRO, the review authority for federal projects, for review for compliance. The applicant is ultimately responsible for achieving project compliance through oversight of on-site contractors, regular field inspection, prompt action against non-compliant sites, and other mechanisms consistent with agency policy. [Reference: VESCL 62.1-44.15 *et seq*.]

***(ii) Virginia Stormwater Management Program General Permit for Stormwater Discharges from Construction Activities (VAR10)***

The operator or owner of a construction project involving land-disturbing activities equal to 1 acre is required to register for coverage under the General Permit for Discharges of Stormwater from Construction Activities and develop a project-specific SWPPP. The SWPPP must be prepared prior to submission of the registration statement for coverage under the general permit and the SWPPP must address water quality and quantity in accordance with the *VSMP Permit Regulations*. General information and registration forms for the General Permit are available on DEQ's website at http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/VSMPPermits/ConstructionGeneralPermit.aspx. [Reference: Virginia Stormwater Management *Act* 62.1-44.15 *et seq*.] *VSMP Permit Regulations* 9 VAC 25-870-10 *et seq*.].

**5. Air Emissions**. According to the DPEIS (page 4-2), construction activities related to institutional support projects have the potential to impact air quality due to increased emissions from construction equipment and fugitive particle emissions. During construction activities, BMPs would be implemented in order to mitigate all construction-related emissions and may include engine idling limitations, lower speed limits, traffic rerouting, and dust suppression techniques.

**5(a) Agency Jurisdiction.** The DEQ Air Division, on behalf of the State Air Pollution Control Board, is responsible for developing regulations that implement Virginia's Air Pollution Control Law (Virginia Code §10.1-1300 *et seq.*). DEQ is charged with carrying out mandates of the state law and related regulations as well as Virginia's federal obligations under the Clean Air Act as amended in 1990. The objective is to protect and enhance public health and quality of life through control and mitigation of air pollution. The division ensures the safety and quality of air in Virginia by monitoring and analyzing air quality data, regulating sources of air pollution, and working with local, state and federal agencies to plan and implement strategies to protect Virginia's air quality. The appropriate DEQ regional office is directly responsible for the issuance of necessary permits to construct and operate all stationary sources in the region as well as monitoring emissions from these sources for compliance.

The Air Division regulates emissions of air pollutants from industries and facilities and implements programs designed to ensure that Virginia meets national air quality standards. The most common regulations associated with major State projects are:

- Open burning: 9 VAC 5-130 *et seq.*
- Fugitive dust control: 9 VAC 5-50-60 *et seq.*
- Permits for fuel-burning equipment: 9 VAC 5-80-1100 *et seq.*

**5(b) Agency Findings.** According to the DEQ Air Division, the project site is located in a designated ozone attainment area.

**5(c) Recommendation.** The DEQ recommends that NASA take all reasonable precautions to limit emissions of oxides of nitrogen ($NO_x$) and volatile organic compounds (VOCs), principally by controlling or limiting the burning of fossil fuels.

**5(d) Requirements.**

***(i) Fugitive Dust***

During construction, fugitive dust must be kept to a minimum by using control methods 10
outlined in 9 VAC 5-50-60 *et seq.* of the *Regulations for the Control and Abatement of Air Pollution*. These precautions include, but are not limited to, the following:

- Use, where possible, of water or chemicals for dust control;
- Installation and use of hoods, fans, and fabric filters to enclose and vent the handling of dusty materials;
- Covering of open equipment for conveying materials; and
- Prompt removal of spilled or tracked dirt or other materials from paved streets and removal of dried sediments resulting from soil erosion.

### *(ii) Open Burning*

Should the project change to include the open-burning of construction or demolition material, or use of special incineration devices, this activity must meet the requirements 11
under 9 VAC 5-130 *et seq.* of the *Regulations* for open burning, and may require a permit. The *Regulations* provide for, but do not require, the local adoption of a model ordinance concerning open burning. The applicant should contact Accomack County fire officials to determine what local requirements, if any, exist.

### *(iii) Fuel Burning Equipment*

The installation of fuel burning equipment (e.g. boilers and generators), may require permitting from DEQ prior to beginning construction of the facility (9 VAC 5-80, Article 6, 12
Permits for New and Modified Sources). The applicant should contact DEQ-TRO for guidance on whether this provision applies.

For additional information regarding air comments, contact the DEQ Office of Air Data Analysis, Kotur Narasimhan at (804) 698-4415.

**6. Chesapeake Bay Preservation Areas.** The DPEIS does not discuss potential project impacts to Chesapeake Bay Preservation Areas. However, the Federal Consistency Determination (PEIS, Appendix G, page G-9) states that the Proposed Action would not include land development activities that would impact the Chesapeake Bay or its tributaries. In addition, although Accomack County has adopted the Chesapeake Bay Preservation Act restrictions for its seaside riparian areas, WFF is specifically excluded from this overlay area.

**6(a) Agency Jurisdiction.** The DEQ Office of Local Government Programs (OLGP) administers the Chesapeake Bay Preservation Act (Virginia Code §62.1-44.15:67 *et seq.*) and *Chesapeake Bay Preservation Area Designation and Management Regulations* (9 VAC 25-830-10 *et seq.*). Each Tidewater locality must adopt a program based on the Bay Act and *Regulations*. The Act and *Regulations* recognize local government responsibility for land use decisions and are designed to establish a framework for compliance without dictating precisely what local programs must look like. Local governments have flexibility to develop water quality preservation programs that reflect unique local characteristics and embody other community goals. Such flexibility also facilitates innovative and creative approaches in achieving program objectives. The regulations address nonpoint source pollution by identifying and protecting certain lands called Chesapeake Bay Preservation Areas. The regulations use a resource-based approach that recognizes differences between various land forms and treats them differently.

**6(b) Agency Findings.** DEQ-OLGP finds that proposed activities are located in the Atlantic Ocean watershed and is outside of the Chesapeake Bay watershed. 13
Therefore, there are no applicable requirements under the *Chesapeake Bay*

*Preservation Area Designation and Management Regulations.* 13 (cont.)

For additional information, contact DEQ-OLGP, Rachel Hamm at (804) 698-4128.

**7. Solid and Hazardous Wastes and Hazardous Materials**. According to the DPEIS (page 4-2), the WFF Integrated Contingency Plan (ICP), developed by NASA to meet the requirements of 40 CFR Part 112 (Oil Pollution Prevention and Response), 40 CFR Part 265 Subparts C and D (Hazardous Waste Contingency Plan), and 9 VAC 25-91-10 (Oil Discharge Contingency Plan), serves as the facility's primary guidance document for the prevention and management of oil, hazardous material, and hazardous waste releases. For those projects involving hazardous materials, toxic substances, and hazardous waste, the ICP outlines procedures for dealing with hazardous materials and hazardous waste and would be implemented in all aspects of the Proposed Action in order to mitigate potential impacts from hazardous materials and hazardous waste.

**7(a) Agency Jurisdiction.** On behalf of the Virginia Waste Management Board, the DEQ Division of Land Protection and Revitalization (DEQ-DLPR) is responsible for carrying out the mandates of the Virginia Waste Management Act (Virginia Code §10.1-1400 *et seq.*), as well as meeting Virginia's federal obligations under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response Compensation Liability Act (CERCLA), commonly known as Superfund. DEQ-DLPR also administers laws and regulations on behalf of the State Water Control Board governing Petroleum Storage Tanks (Virginia Code §62.1-44.34:8 *et seq.*), including Aboveground Storage Tanks (9 VAC 25-91 *et seq.*) and Underground Storage Tanks (9 VAC 25-580 *et seq.* and 9 VAC 25-580-370 *et seq.*), also known as 'Virginia Tank Regulations', and § 62.1-44.34:14 *et seq.* which covers oil spills.

*Virginia:*

- Virginia Waste Management Act, Virginia Code § 10.1-1400 *et seq.*
- *Virginia Solid Waste Management Regulations*, 9 VAC 20-81 (9 VAC 20-81-620 applies to asbestos-containing materials)
- *Virginia Hazardous Waste Management Regulations*, 9 VAC 20-60 (9 VAC 20-60-261 applies to lead-based paints)
- *Virginia Regulations for the Transportation of Hazardous Materials*, 9 VAC 20-110.

*Federal:*

- Resource Conservation and Recovery Act, 42 U.S. Code sections 6901 *et seq.*
- U.S. Department of Transportation *Rules for Transportation of Hazardous Materials*, 49 *Code of Federal Regulations*, Part 107
- Applicable rules contained in Title 40, *Code of Federal Regulations.*

**7(b) Agency Findings.** DLPR staff conducted a search (2,000-foot radius) of solid and hazardous waste databases (including petroleum releases) to identify waste sites in close proximity to the project corridor. The search identified 32 sites in proximity to the project corridor which might impact the project. 14
In addition, two waste sites of possible concern were located in the zip code of the project area. See DLPR detailed comments attached for additional information.

**7(c) Agency Recommendations.**

***(i) Hazardous Waste Sites***

Additional information on identified RCRA and CERCLA hazardous waste sites can be accessed from Environmental Protection Agency (EPA) websites at:

- https://www3.epa.gov/enviro/,
- https://rcrainfopreprod.epa.gov/rcrainfoweb/action/main-menu/view, and
- https://www.epa.gov/superfund

***(ii) Petroleum Release Sites***

Additional information on identified petroleum release sites may be obtained by accessing DEQ's Pollution Complaint (PC) cases (see attached memo). It is recommended that the Airport evaluated these files to establish the exact location, 15
nature and extent of the petroleum releases and their potentials to impact the proposed project. Contact the Tanks Program at DEQ-TRO, (757) 518-2115, for further information about the PC cases.

***(iii) Pollution Prevention***

DEQ encourages all construction projects and facilities to implement pollution prevention principles, including the reduction, reuse, and recycling of all solid wastes 16
generated. All generation of hazardous wastes should be minimized and handled appropriately.

**7(d) Requirements.**

***(i) Solid and Hazardous Waste Management***

Any soil, sediment or groundwater that is suspected of contamination or wastes that are generated must be tested and disposed of in accordance with applicable federal, state, and local laws and regulations. All construction waste must be characterized in accordance with the *Virginia Hazardous Waste Management Regulations* prior to 17
management at an appropriate facility.

***(ii) Petroleum Contamination***

If evidence of a petroleum release is discovered during construction, it must be reported
to DEQ-TRO in accordance with Virginia Code § 62.1-44.34.8 through 9 and 9 VAC 25- 18
580-10 *et seq*. Petroleum-contaminated soils and groundwater that is generated during
project implementation must be characterized and disposed of properly.

***(iii) Petroleum Storage Tanks***

The removal, relocation or closure of any regulated petroleum storage tanks, either an
aboveground storage tank (AST) or an underground storage tank (UST), must be
conducted in accordance with the requirements of the Virginia Tank Regulations 9 VAC 19
25-91-10 *et seq*. (AST) and/or 9 VAC 25-580-10 *et seq*. (UST). Documentation must
be submitted DEQ-TRO.

The installation and operation of regulated petroleum ASTs or USTs must be
conducted in accordance with 9 VAC 25-91-10 *et seq*. and/or 9 VAC 25-580-10 *et seq*. 20

The installation and use of ASTs with a capacity of greater than 660 gallons for temporary fuel storage (>120 days) during construction must follow the requirements in 9 VAC 25-91-10 *et seq*.

For additional information, contact DEQ-DLPR, Katy Dacey at (804) 698-4274.

**8. Natural Heritage Resources**. According to the DPEIS (page 3-150), the Department of Conservation and Recreation Division of Natural Heritage has identified five Conservation Sites at WFF, including North Wallops Island and North Assawoman/South Wallops Island on Wallops Island; Little Mosquito Creek and Wallops Main Base Airfield Swale on the Main Base; and Wallops Island Causeway Marshes on the Mainland and west side of central Wallops Island. The two Conservation Sites most likely affected by the actions are the 1,600 acre Wallops Island Causeway Marshes, and the approximately 100 acre North Assawoman/South Wallops Island site.

**8(a) Agency Jurisdiction.**

***(i)*** The Virginia Department of Conservation and Recreation's (DCR) Division of Natural Heritage (DNH)

DNH's mission is conserving Virginia's biodiversity through inventory, protection and stewardship. The Virginia Natural Area Preserves Act (Virginia Code §10.1-209 through 217), authorizes DCR to maintain a statewide database for conservation planning and project review, protect land for the conservation of biodiversity, and protect and ecologically manage the natural heritage resources of Virginia (the habitats of rare, threatened and endangered species, significant natural communities, geologic sites, and other natural features).

*(ii)* The Virginia Department of Agriculture and Consumer Services (VDACS)

The Endangered Plant and Insect Species Act of 1979 (Virginia Code Chapter 39 §3.1-1020 through 1030) authorizes VDACS to conserve, protect and manage endangered and threatened species of plants and insects. Under a Memorandum of Agreement established between VDACS and the DCR, DCR represents VDACS in comments regarding potential impacts on state-listed threatened and endangered plant and insect species.

**8(b) Agency Findings.**

***(i) Conservation Sites***

According to DCR-DNH, the following Conservation Sites are located within the project sites: North Wallops Island, Little Mosquito Creek, Wallops Island Seeps, Wallops Island Causeway Marshes, and Assawoman Island. Conservation sites are tools for representing key areas of the landscape that warrant further review for possible 21
conservation action because of the natural heritage resources and habitat they support. See Table 1 (attached) for a list of natural heritage resources that are associated with these conservation sites. Many of the proposed projects have the potential to impact these natural heritage resources.

***(ii) State Natural Area Preserves***

DCR files do not indicate the presence of any State Natural Area Preserves under the 22
agency's jurisdiction in the project vicinity.

**8(c) Recommendations.** DCR-DNH recommends the following:

- Coordinate with DCR-DNH as specific projects are planned, to determine if 23
  surveys are needed and potential impacts to natural heritage resources.
- Enter into a data license agreement with DCR-DNH, similar to a 2010 agreement, so that WFF can incorporate quarterly updates of natural heritage 24
  information into their facility planning process.
- Coordinate with the U.S. Fish and Wildlife Service (USFWS) and the Virginia Department of Game and Inland Fisheries, to ensure compliance with protected species legislation due to the legal status of some of the species associated with 25
  the conservation sites.
- Contact DCR-DNH to secure updated information on natural heritage resources if the scope of the proposal changes and/or six months has passed before it is 26
  implemented. New and updated information is continually added to the Biotics Data System.

**9. Wildlife Resources and Protected Species**. According to the DPEIS (page 4-4), NASA is considering the adoption of a variety of mitigation strategies for the protection of special status species, included but not limited to: the installation of "turtle friendly" lighting and shielding; time-of-day and seasonal restrictions of activities; adherence to dredging guidelines set forth by the National Marine Fisheries Service (NMFS) and Virginia; beach surveys in accordance with the WFF Protected Species Monitoring Plan; observance of a 660-foot buffer around bald eagle nest sites and coordination with USFWS; and conducting surveys and restrict tree removal activities between June 1 to July 31 to reduce impacts to the Northern long-eared bat.

**9(a) Agency Jurisdiction.** The Virginia Department of Game and Inland Fisheries (DGIF), as the Commonwealth's wildlife and freshwater fish management agency, exercises enforcement and regulatory jurisdiction over wildlife and freshwater fish, including state- or federally-listed endangered or threatened species, but excluding listed insects (Virginia Code, Title 29.1). DGIF is a consulting agency under the U.S. Fish and Wildlife Coordination Act (16 U.S. Code §661 *et seq.*) and provides environmental analysis of projects or permit applications coordinated through DEQ and several other state and federal agencies. DGIF determines likely impacts upon fish and wildlife resources and habitat, and recommends appropriate measures to avoid, reduce or compensate for those impacts. For more information, see the DGIF website at *www.dgif.virginia.gov*.

**9(b) Agency Findings.** DGIF is concerned that sites such as Wallops, located along the Atlantic Ocean, are prone to significant shoreline and other habitat changes, changes that are likely to increase in scope in the coming decades. As sands shift and habitats migrate over this extended period of time, wildlife, including listed species, may not be provided the protection required.

DGIF documents the following listed and/or tiered wildlife from Wallops Mainland, Wallops Island, and nearby environs:

***(i) Listed Species***

- Federal-listed Endangered and state-listed Endangered leatherback sea turtle
- Federal-listed Endangered Kemp's Ridley sea turtle
- Federal-listed Threatened and state-listed Threatened loggerhead sea turtle
- Federal-listed Threatened green turtle
- Federal-listed Threatened red knot
- Federal-listed Threatened piping plover
- State-listed Endangered Wilson's plover
- State-listed Threatened peregrine falcon
- State-listed Threatened gull-billed tern

### *(ii) Wildlife Action Plan Species of Greatest Conservation Need*

- Northern diamond-backed terrapins (Tier IIa)
- Glossy ibis (Tier Ia)
- Snowy egrets (Tier IIa)
- Little blue herons (Tier IIa)
- Black skimmers (Tier IIa)
- Common terns (Tier IIa)

DGIF documents a number of waterbird colonies, many containing one or more of the avian species listed above, from Wallops Island and associated islands, including nearby the barge route that is proposed for dredging. In addition, a number of bald eagle nests have been documented from this area over the years. Finally, sea turtles are known from the installation, breeding on the beaches that form the eastern boundary of the facility. See www.bewildvirginia.org for more information on species of greatest conservation need.

## 9(c) Recommendations.

### *(i) Coordination and Documentation*

- Coordinate with DGIF, USFWS and NMFS on projects proposed to impact undisturbed ground and wildlife habitats, and/or projects that build upwards impacting migratory flyways and foraging spaces for birds and bats. 27
- Conduct biological monitoring on site each year, in close coordination with DGIF, NMFS, and the USFWS, to ensure that effective monitoring protocols are followed and that participants are appropriately permitted to perform the work, if necessary. 28
- Develop updated maps of documented species and the habitats that support them each year, and provide these maps to WFF management and staff so that planning around protection of documented wildlife species and resources can occur. 29
- Adhere to the protective/mitigation measures contained within the DPEIS. 30
- Update the DPEIS to reflect that Upland sandpipers are no longer listed as threatened in Virginia. 31

### *(ii) Protection of Resources Under State Jurisdiction*

DGIF offers the following recommendations for the protection of resources under its jurisdiction, in addition to recommendations in the DPEIS, as development plans for the installation move forward.

### Waterbird Colonies and Beach Nesting Birds

- Monitor shorebird/waterbird colonies and nest sites on Wallops Mainland and 32

Wallops Island each breeding season and map documented colonies and nest sites.

- Conduct no significant land development or timbering activities within 0.5-mile of
  a documented colony/nest site from March 15 through August 31 of any year, or 32 (cont.)
  when the last brood fledges as determined by monitoring activities.
- Maintain plants or enhance undisturbed a naturally vegetated buffer of at least 500 feet around any documented waterbird colonies (not beach nest sites). This provides the colony with a line-of-sight and habitat buffer, providing nesting activity protection as well as habitat protection to ensure suitability for future nesting seasons.

**Sea Turtles**

- Monitor beach habitats each nesting season to determine the location of any
  nesting sea turtles on installation grounds. Once identified, the beach should be
  excluded from activity until monitoring has confirmed the last nest has hatched. 33
- Suspend work on beaches known to have supported nesting from May 1-November 15, if surveys cannot be performed during any given year.
- Suspend dredging by hydraulic hopper in nearby waters from April 1 through November 30 of any year.
- Coordinate with the USFWS and NMFS regarding the protection of sea turtles.

**Peregrine Falcons**

- Avoid significant human activity within 600 feet of a nest/nest box during the 34
  nesting season from February 15 through July 15 of any year.
- Coordinate with DGIF regarding any proposed modification of natural habitats and/or man-made structures currently supporting the species.

**Sea Mammals**

- Adhere to the mitigation measures included within the DPEIS and coordinate 35
  with NMFS and USFWS regarding protection of sea mammals.

**Bats**

- Adhere to the mitigation measures in the DPEIS, including adherence to a time-
  of-year restriction on tree clearing from June 1-July 31 of any year, to protect
  northern long eared bats. 36
- Coordinate with DGIF and USFWS regarding tree clearing on site, particularly if NASA cannot adhere to the time-of-year restriction.
- Consider impacts upon foraging and migrating bats associated with projects resulting in flyway impediments.

**Bald Eagles**

- Adhere to the mitigation measures included within the DPEIS, including maintenance of an undisturbed buffer around the nest site and continued nest monitoring. 37

***(iii) General Protection of Wildlife Resources***

DGIF offers the following comments about development activities, to minimize overall impacts to wildlife and natural resources

- Avoid and minimize impacts to undisturbed forest, wetlands, and streams to the fullest extent practicable. Avoidance and minimization may include relocating stream channels as opposed to filling or channelizing, as well as using, and incorporating into the development plan, a natural stream channel design and wooded buffers. 38
- Maintain undisturbed naturally vegetated buffers of at least 100 feet in width around all onsite wetlands and on both sides of all perennial and intermittent streams.
- Maintain wooded lots to the fullest extent possible.
- Avoid the mitigation of wetland impacts through the construction of stormwater management ponds or the creation of instream stormwater management ponds. 39
- Conduct any in-stream activities during low or no-flow conditions.
- Use non-erodible cofferdams or turbidity curtains to isolate the construction area.
- Block no more than 50% of the streamflow at any given time.
- Stockpile excavated material in a manner that prevents reentry into the stream. 40
- Restore original streambed and streambank contours.
- Revegetate barren areas with native vegetation.
- Implement strict erosion and sediment control measures.
- Install concrete "in the dry," whether using the Tremie method, grout bags, or wet concrete, to ensure the concrete has hardened and cured prior to contact with open water.
- Construct stream crossings via clear-span bridges to avoid future maintenance costs associated with culverts and the loss of riparian and aquatic habitat. However, if this is not possible, countersink culverts below the streambed at least 6 inches or use bottomless culverts to allow passage of aquatic organisms.
- Install floodplain culverts to carry bankfull discharges. 41
- Design stormwater controls to replicate and maintain the hydrographic condition of the site prior to the change in landscape. This may include utilizing bioretention areas and minimizing the use of curb and gutter in favor of grassed swales. Bioretention areas (i.e. rain gardens) and grass swales are components of Low Impact Development (LID). Bioretention areas are designed to capture stormwater runoff as close to the source as possible and allow it to slowly infiltrate into the surrounding soil. They benefit natural resources by filtering pollutants and decreasing downstream runoff volumes.

- Adhere to a time-of-year restriction protective of resident and migratory songbird nesting from March 15 through August 15 of any year for all tree removal and ground clearing. 42
- Adhere to erosion and sediment controls during ground disturbance. 43

**10. Public Water Supply.** According to the DPEIS (page 3-198), WFF receives all of its potable water from groundwater supply wells located within the boundaries of the installation. The document does not indicate that water resources would be adversely impacted by the proposal.

**10(a) Agency Jurisdiction.** The Virginia Department of Health (VDH) Office of Drinking Water (ODW) reviews projects for the potential to impact public drinking water sources (groundwater wells, springs and surface water intakes). VDH administers both federal and state laws governing waterworks operation. 44

**10(b) Agency Findings.** VDH-ODW concludes that there are no apparent impacts to public drinking water sources due to this project.

For additional information, contact VDH-ODW, Arlene Fields Warren at (804) 864-7781.

**11. Aviation Impacts**. According to the DPEIS (page 3-191), the Runway 04/22 extension would prevent use of the airspace surrounding the Main Base for a limited time. No institutional support projects would extend into the airspace or clear zone around the Main Base airfield or into the runway approach zone. Therefore, no aspect of implementing any or all of the institutional support projects would affect or have a significant impact on airspace management.

**11(a) Agency Jurisdiction**. The Virginia Department of Aviation (DoAv) is a state agency that plans for the development of the state aviation system; promotes aviation; grants aircraft and airports licenses; and provides financial and technical assistance to cities, towns, counties and other governmental subdivisions for the planning, development, construction and operation of airports, and other aviation facilities. 45

**11(b) Agency Findings.** DoAv staff does not indicate any concern with the proposal.

**11(c) Requirements.** Due to the proximity of future development to the airfield, a 7460 form must be submitted to the Federal Aviation Administration (FAA) for every project to be constructed within 20,000 linear feet of the airfield or that will require a structure, either permanent or temporary, having a height of 200 feet above ground level.

For additional information, contact DoAv, Scott Denny at (804) 236-3638.

## REGULATORY AND COORDINATION NEEDS

**1. Water Quality and Wetlands.** Surface water and wetland impacts associated with improvement activities may require a VWP Permit issued by the DEQ-TRO pursuant to Virginia Code §62.1-44.15:20. Tidal wetland impacts will require review from VMRC and/or Accomack County Wetlands Board. This requires the submission of a JPA which initiates the review process used by DEQ, VMRC, Corps, and local wetland boards. In addition, NASA must coordinate with DEQ-TRO regarding modifications to its existing VPDES individual permit (VA0024457) as a result of project activities. 46
Contact VMRC, George Badger at (757) 414-0710 or george.badger@mrc.virginia.gov, for information and coordination on tidal wetland impacts and the JPA process. For additional information and coordination involving VWP permitting, contact DEQ-TRO, Bert Parolari at (757) 518-2166 or bert.parolari@deq.virginia.gov. For additional information regarding VPDES program requirements, contact DEQ-TRO, Deanna Austin at (757) 518-2008 or deanna.austin@deq.virginia.gov.

**2. Subaqueous Lands Impacts.** Pursuant to Virginia Code §28.2-1200 through 1400, 47
NASA must obtain a permit from VMRC for anticipated impacts to state subaqueous lands. This requires the submission of a JPA to VMRC. For additional information and coordination, contact VMRC, George Badger at (757) 414-0710 or george.badger@mrc.virginia.gov.

**3. Fish and Shellfish Resources.** Contact VMRC, George Badger at (757) 414-0710 or george.badger@mrc.virginia.gov, to address potential project impacts on state 48
fisheries and shellfish resources as a result of proposed improvement activities.

**4. Nonpoint Source Pollution.**

**4(a) Erosion and Sediment Control and Stormwater Management Plans.** NASA must ensure that it is in compliance with Virginia's Erosion and Sediment Control Law (Virginia Code § 62.1-44.15:61) and *Regulations* (9 VAC 25-840-30 *et seq.*) and Stormwater Management Law (Virginia Code § 62.1-44.15:31) and *Regulations* (9 VAC 25-870-210 *et seq.*) as administered by DEQ. Land-disturbing activities equal to or 49
greater than 10,000 square feet would be regulated by VESCL&R and VSWML&R. NASA is encouraged to contact DEQ-TRO, Janet Weyland at (757) 518-2151, for assistance with developing or implementing ESC and SWM plans to ensure project conformance.

**4(b) Virginia Stormwater Management Program General Permit for Stormwater Discharges from Construction Activities (VAR10).** For projects involving land-disturbing activities of equal to or greater than one acre , NASA is required to develop a project-specific stormwater pollution prevention plan and apply for registration coverage under the Virginia Stormwater Management Program General Permit for Discharges of 50
Stormwater from Construction Activities (9 VAC 25-870-10 *et seq.*). Specific questions regarding the Stormwater Management Program requirements should be directed to

DEQ, Holly Sepety at (804) 698-4039.

**5. Air Emissions.** Proposed site-wide improvements may be subject to air quality
regulations administered by the Department of Environmental Quality. The following
sections of Virginia Administrative Code are applicable: 51

- fugitive dust and emissions control (9 VAC 5-50-60 *et seq.*);
- open burning restrictions (9 VAC 5-130); and
- fuel-burning equipment (9 VAC 5-80, Article 6, Permits for New and Modified Sources).

For additional information and coordination contact DEQ-TRO, Laura Corl at (757) 518-2178 or laura.corl@deq.virginia.gov. Also, contact Accomack County fire officials for information on any local requirements pertaining to open burning.

**5. Waste Management.** All solid waste, hazardous waste, and hazardous materials
must be managed in accordance with all applicable federal, state, and local
environmental regulations. For additional information concerning location and
availability of suitable waste management facilities in the project area or if free product, 52
discolored soils, or other evidence of contaminated soils are encountered, contact
DEQ-TRO, Sean Priest at (757) 518-2141 or jonathan.priest@deq.virginia.gov.

**5(a) Asbestos-Containing Material.** The owner or operator of a demolition activity,
prior to the commencement of the activity, is responsible to thoroughly inspect affected
structures for the presence of asbestos, including Category I and Category II nonfriable
asbestos containing material (ACM). Upon classification as friable or non-friable, all
waste ACM shall be disposed of in accordance with the Virginia Solid Waste 53
Management Regulations (9 VAC 20-80-640), and transported in accordance with the
Virginia regulations governing Transportation of Hazardous Materials (9 VAC 20-110-10
et seq.). Contact the DEQ-TRO, Lisa Silvia at (757) 518-2175 and the Department of
Labor and Industry, Doug Wiggins (540) 562-3580 ext. 131 for additional information.

**5(b) Lead-Based Paint.** This project must comply with the U.S. Department of Labor,
Occupational Safety and Health Administration (OSHA) regulations, and with the 54
Virginia Lead-Based Paint Activities Rules and Regulations. For additional information
regarding these requirements contact the Department of Professional and Occupational
Regulation at (804) 367-8500.

**5(c) Petroleum Contamination.** In accordance with Virginia Code §§ 62.1-44.34.8
through 9 and 9 VAC 25-580-10 *et seq.*, site activities involving excavation or 55
disturbance of petroleum contaminated soils and or groundwater must be reported to
DEQ-TRO, Tom Madigan at (757) 518-2115.

**5(d) Petroleum Storage Tank Compliance and Inspection.** The installation and use
of an AST of greater than 660 gallons for temporary fuel storage of more than 120 days 56

must comply with the requirements in 9 VAC 25-91-10 *et seq*. Contact DEQ-TRO, Tom Madigan at (757) 518-2115 for additional details. 56 (cont.)

**6. Natural Heritage Resources.** Coordinate with DCR-DNH, Rene Hypes at (804) 371-2708, on the following:

- natural heritage surveys for specific improvements projects;
- a data license agreement for quarterly updates of natural heritage information; and 57
- updated information on natural heritage resources as the scopes of improvement projects are developed, if project changes occur, and/or six months passes before a project is implemented.

**7. Wildlife Resources and Protected Species**. Coordinate with DGIF, Amy Ewing at (804) 367-2211, regarding the following recommendations:

- impacts to undisturbed ground and wildlife habitats, and/or projects that build upwards impacting migratory flyways and foraging spaces for birds and bats. 58
- annual biological monitoring on site each year to ensure that effective monitoring protocols are followed and that participants are appropriately permitted to perform the work; and
- updated maps of documented species and the habitats that support them.

**8. Aviation Impacts.** Submit a 7460 form to the FAA, Susan Stafford at (304) 252-6216, x130, for projects within 20,000 linear feet of the airfield or that will require a permanent or temporary structure having a height of 200 feet above ground level. 59

**9. Historic and Archaeological Resources**. In accordance with Section 106 of the *National Historic Preservation Act*, as amended, and its implementing regulation 36 CFR 800, NASA must continue to coordinate with DHR with respect to potential project impacts to historic and archaeological resources. For additional information and coordination, contact DHR, Roger Kirchen at (804) 482-6091. 60

Thank you for the opportunity to review the Draft Site-wide Programmatic Environmental Impact Statement and Federal Consistency Determination at the Wallops Flight Facility in Accomack County. Detailed comments of reviewing agencies are attached for your review. Please contact me at (804) 698-4204 or John Fisher at (804) 698-4339 for clarification of these comments.

Sincerely,

Bettina Rayfield, Program Manager
Environmental Impact Review and Long-Range Priorities

Enclosures

Ec: Amy Ewing, DGIF
Robbie Rhur, DCR
Arlene Fields Warren, VDH
George Badger, VMRC
Roger Kirchen, DHR
Scott Denny, DoAv
Keith Tignor, VDACS
David Spears, DMME
Steven Miner, Accomack County
Elaine Meil, Accomack-Northampton PDC
Shari Miller, NASA

DEPARTMENT OF ENVIRONMENTAL QUALITY
TIDEWATER REGIONAL OFFICE
ENVIRONMENTAL IMPACT REVIEW COMMENTS

June 7, 2018

**PROJECT NUMBER: 18-073F**

**PROJECT TITLE:** Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

As Requested, TRO staff has reviewed the supplied information and has the following comments:

**Petroleum Storage Tank Cleanups:**
DEQ records indicate that there are several current and closed pollution compliant cases associated with this facility. The closed cases have been closed based on limited risk to the environment. Any future site activities involving excavation or disturbance of formerly petroleum contaminated soils and or groundwater or disturbance within a current pollution petroleum contaminated area should be reported to the DEQ Tidewater Regional Office (TRO). Contact Mr. Tom Madigan (757) 518-2115.

See #54

**Petroleum Storage Tank Compliance/Inspections:**
The removal, relocation or closure of any regulated petroleum storage tanks – aboveground storage tank (AST); underground storage tank (UST) must be conducted in accordance with the requirements of the Virginia Tank Regulations 9 VAC 25-91-10 et seq (AST) and / or 9 VAC 25-580-10 et seq (UST). Documentation and / or questions should be submitted to Tom Madigan – DEQ Tidewater Regional Office – 5636 Southern Blvd., Virginia Beach, VA 23462. Phone (757) 518-2115. Installation and operation of any regulated petroleum storage tank(s) either AST or UST must also be conducted in accordance with the Virginia Regulations 9 VAC 25-91-10 et seq and / or 9 VAC 25-580-10 et seq. Please contact Tom Madigan (757) 518-2115 for additional details. The installation and use of an AST (>660 gallons) for temporary fuel storage (>120 days) during the project must follow the requirements in 9 VAC 25-91-10 et. seq. Please contact Tom Madigan of the DEQ Tidewater Regional Office (757) 518-2115 for additional details.

See #19

**DEPARTMENT OF ENVIRONMENTAL QUALITY**
**TIDEWATER REGIONAL OFFICE**
**ENVIRONMENTAL IMPACT REVIEW COMMENTS**

**June 7, 2018**

**PROJECT NUMBER: 18-073F**

**PROJECT TITLE:** Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

**Virginia Water Protection Permit Program (VWPP):**
As described in the information provided, several of the institutional support projects will impact surface waters. These projects include the replacement of the existing Causeway Bridge, proposed maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C and Launch Pier 0-D. Projects involving impacts to surface waters, including wetlands, may require a VWP permit. Provided that the applicant submits a Joint Permit Application for any impacts to surface waters, receives authorization from our program, and adheres to the conditions of that authorization, the project will be consistent with the VWP program.

See #7 and #50

**Air Permit Program :**
The following air regulations of the Virginia Administrative Code may be applicable: 9VAC5-50-60 *et seq.* which addresses the abatement of visible emissions and fugitive dust emissions, and 9VAC5-80-1100 *et seq.* which regulates the permitting of new stationary sources of air emissions. For additional information, contact Laura Corl, DEQ-TRO at (757) 518-2178 or laura.corl@deq.virginia.gov.

See #10 and #12

**Water Permit Program :**
The facility is covered under an individual VPDES permit (VA0024457). Changes to the facility may require updates or changes to the VPDES permit. Construction activity may require mapping changes for the facility as required by the SWPPP. For additional information, please contact Deanna Austin at 757-518-2008 or deanna.austin@deq.virginia.gov

See #46

**Waste Permit Program :**
All construction, demolition and debris waste including excess soil must be characterized in accordance with the Virginia Hazardous Waste Management Regulations prior to management at an appropriate facility. For additional information, contact Sean Priest, DEQ-TRO at (757) 518-2141 or jonathan.priest@deq.virginia.gov.

See #52

**Storm Water Program:**
No comments.

See #9

DEPARTMENT OF ENVIRONMENTAL QUALITY
TIDEWATER REGIONAL OFFICE
ENVIRONMENTAL IMPACT REVIEW COMMENTS

June 7, 2018

**PROJECT NUMBER: 18-073F**

**PROJECT TITLE:** Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

The staff from the Tidewater Regional Office thanks you for the opportunity to provide comments.

Sincerely,

Cindy L. Robinson

Cindy Robinson
Environmental Specialist II
5636 Southern Blvd.
VA Beach, VA 23462
(757) 518-2167
Cindy.Robinson@deq.virginia.gov

# *COMMONWEALTH of VIRGINIA*

*Marine Resources Commission*
*2600 Washington Avenue*
*Third Floor*
*Newport News, Virginia 23607*

May 30, 2018

Mr. John E. Fisher
c/o Department. Of Environmental Quality
Office of the Environmental Impact Review
1111 East Main Street
Richmond, Virginia 23219

Re: DEQ #18-073F
"Wallops Flight Facility Site-wide PEIS"

Dear Mr. Fisher:

You have inquired regarding Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement that encompasses a 20-year planning horizon. Several projects have the potential to impact wetlands, State marshlands or State subaqueous lands.

The Marine Resources Commission requires a permit for any activities that encroach upon or over, or take use of materials from the beds of the bays, ocean, rivers and streams, or creeks, which are the property of the Commonwealth.

Based upon my review of the documents, it appear that some of the activities will require authorization from the Marine Resources Commission and/or the Accomack County Wetlands Board. The Causeway Bridge replacement, barge route maintenance dredging, development of the North Wallops Island Deep-water Port and Operations Area, and construction of Launch Pad 0-C, and Launch Pier 0-D all have elements that will require permits. In addition, as stated in appendix G of the PEIS the dredging may affect existing oyster ground leases and wild shellfish along the barge route. Also, the driving of pilings and dredging may adversely impact marine mammals and fisheries.

See #5, #8, and #46-48

If I may be of further assistance, please do not hesitate to contact me at (757) 414-0710.

Sincerely,

George H. Badger, III
Environmental Engineer

COMMONWEALTH of VIRGINIA

*DEPARTMENT OF ENVIRONMENTAL QUALITY*

*Street address:* 1111 East Main Street, Suite 1400, Richmond, VA 23219
*Mailing address:* P.O. Box 1105, Richmond, Virginia 23218
www.deq.virginia.gov

Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482


# MEMORANDUM

**TO:** John Fisher, DEQ Office of Environmental Impact Review

**FROM:** Rachel Hamm, DEQ Principal Environmental Planner

**DATE:** March 15, 2018

**SUBJECT:** DEQ #18-073F: Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement– Accomack County

We have reviewed the Federal Consistency Certification submittal for the proposed project and offer the following comments regarding consistency with the provisions of the Chesapeake Bay Preservation Area Designation and Management Regulations.

The proposed project is located in the Atlantic Ocean watershed and is outside of the Chesapeake Bay watershed; thus there are no comments or requirements under the Chesapeake Bay Preservation Area Designation and Management Regulations.

See #1 and #13

# DEPARTMENT OF ENVIRONMENTAL QUALITY
## DIVISION OF AIR PROGRAM COORDINATION

## ENVIRONMENTAL REVIEW COMMENTS APPLICABLE TO AIR QUALITY

TO: John E. Fisher DEQ - OEIR PROJECT NUMBER: DEQ #18-073F

PROJECT TYPE: ☐ STATE EA / EIR **X FEDERAL EA / EIS** ☐ SCC

X CONSISTENCY DETERMINATION

PROJECT TITLE: Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement

PROJECT SPONSOR: National Aeronautics and Space Administration

PROJECT LOCATION: X OZONE ATTAINMENT AREA

REGULATORY REQUIREMENTSMAY BE APPLICABLE TO: ☐ CONSTRUCTION ☐ OPERATION

STATE AIR POLLUTION CONTROL BOARD REGULATIONS THAT MAY APPLY:

1. ☐ 9 VAC 5-40-5200 C & 9 VAC 5-40-5220 E – STAGE I
2. ☐ 9 VAC 5-45-760 et seq. – Asphalt Paving operations
3. **X 9 VAC 5-130 et seq. – Open Burning**
4. **X 9 VAC 5-50-60 et seq. Fugitive Dust Emissions**
5. ☐ 9 VAC 5-50-130 et seq. - Odorous Emissions; Applicable to____________________
6. ☐ 9 VAC 5-60-300 et seq. – Standards of Performance for Toxic Pollutants
7. ☐ 9 VAC 5-50-400 Subpart_____, Standards of Performance for New Stationary Sources, designates standards of performance for the______________________________
8. ☐ 9 VAC 5-80-1100 et seq. of the regulations – Permits for Stationary Sources
9. ☐ 9 VAC 5-80-1605 et seq. Of the regulations – Major or Modified Sources located in PSD areas. This rule may be applicable to the ______________________________
10. ☐ 9 VAC 5-80-2000 et seq. of the regulations – New and modified sources located in non-attainment areas
11. ☐ 9 VAC 5-80-800 et seq. Of the regulations – State Operating Permits. This rule may be applicable to __________________________________________________

See #10-12 and #51

COMMENTS SPECIFIC TO THE PROJECT:

**Above regulations are applicable during any construction activity.**

(Kotur S. Narasimhan)
Office of Air Data Analysis

DATE: May 22, 2018

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

**MEMORANDUM**

**TO:** John Fisher, DEQ/EIR Environmental Program Planner

**FROM:** Katy Dacey, Division of Land Protection & Revitalization Review Coordinator

**DATE:** May 18, 2018

**COPIES:** Sanjay Thirunagari, Division of Land Protection & Revitalization Review Manager; file

**SUBJECT:** Environmental Impact Review: EIR Project No 18-073F Wallops Flight Facility Site-Wide Programmatic Environmental Impact Statement, Accomack County, VA

The Division of Land Protection & Revitalization (DLPR) has completed its review of the draft May 2018 EIR for the Wallops Flight Facility Site-Wide Programmatic project located at NASA's Goddard Space Flight Center's Wallops Flight Facility on Route 175 in Wallops Island, VA 23337

Project Scope: 20 year, site-wide planning horizon activates to include new construction, demolition, renovation, institutional supports and operations throughout the flight facility and Wallops Island areas

Solid and hazardous waste issues were not addressed in the submittal. The submittal did not indicate that a search of Federal or State environmental databases was conducted. DLPR staff conducted a search (2000 mile radius) of solid and hazardous waste databases (including petroleum releases) to identify waste sites in close proximity to the project areas of the flight facility in addition to Wallops Island. DLPR search did identify thirty-two sites within the project areas, which might impact the project. Additionally, the two facilities within the project areas are waste sites that were found to be of possible concern. DLPR staff has reviewed the submittal and offers the following comments:

See #14-20

***Hazardous Waste/RCRA Facilities** – six in close proximity to project areas*

1. ***VAR00518829, Navy-Surface Combat Systems Centers Buildings R-2, R-30, R-20, 30 Battleground Way, Wallops Island, VA 23337, Small Quantity Generator (SQG)***

2. ***VAR00518837, Navy-Surface Combat Systems Centers Buildings V-10/20/21, V-3, V-24, Artist, 30 Battleground Way, Wallops Island, VA 23337, SQG***

3. ***VAR000509240, Wallops FUDS Program, NASA Wallops Flight Facility, Wallops Island, VA 23337. SQG***

4. ***VAR000518845, Mid-Atlantic Regional Spaceport, 34200 Fulton Street Launch Pads O-A and O-B, Wallops Island, VA 23337. SQG***

5. ***VA7800020888, NASA GSFC Wallops Flight Facility, 34200 Fulton Street and Main land, Wallops Island, VA 23337. Large Quantity Generator (LQG)***

6. ***VA8800010763, NASA GSFC Wallops Flight Facility, 34200 Fulton Street and Main base, Wallops Island, VA 23337. LQG***

***CERCLA Sites** – two were the facilities in the project areas*

1. ***VA800010763, NASA Wallops Flight Facility, Route 175, Wallops Island, VA 23337, Not on NPL.***

2. ***VAN000306905, Naval Aviation Ordnance Test Station, Route 175, Wallops Island, VA 23337, Not on NPL.***

The above information related to hazardous wastes, RCRA/CERCLA sites can be accessed from EPA's websites at https://www3.epa.gov/enviro/,

https://rcrainfopreprod.epa.gov/rcrainfoweb/action/main-menu/view and https://www.epa.gov/superfund

***Formerly Used Defense Sites (FUDS)** – none in close proximity to project areas*

***Solid Waste** – none in close proximity to project areas*

***Virginia Remediation Program (VRP)** – none in close proximity to project areas*

***Petroleum Releases** – twenty-six within the project areas*

1. ***PC#19920783, NASA Wallops Flight Facility Building D-1, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 10/29/1991. Status: Closed.***

2. ***PC#19921558, NASA Wallops Flight Facility Building M-1, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 03/06/1992. Status: Closed.***

3. ***PC#19962241, NASA Wallops Flight Facility New Fuel Farm, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 09/18/1995. Status: Closed.***

4. ***PC#19931193, NASA Wallops Flight Facility - NOAA, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 12/17/1992. Status: Closed.***

5. ***PC#19922027, NASA Wallops Flight Facility Site D8, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 05/01/1992. Status: Closed.***

6. ***PC#19930400, NASA Wallops Flight Facility D-102/103, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 02/18/1992. Status: Closed.***

7. ***PC#19992348, NASA Wallops Island Earth Station-Runway 10-28, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 03/08/1999. Status: Closed.***

8. ***PC#20155141, Former Navy A-7 Auxiliary Power Station, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 01/12/2015. Status: Closed.***

9. ***PC#19910470, NASA Wallops Island Flight Facility – Control Tower, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 09/24/1990. Status: Closed.***

10. ***PC#19920576, NASA Wallops Island Flight Facility – Visitor Center, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 10/02/1991. Status: Closed.***

11. ***PC#19992209, NASA Wallops Island Flight Facility – NOAA Facility, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 07/21/1998. Status: Closed.***

12. ***PC#19900039, NASA Wallops Island Flight Facility – Old Aviation Fuel Farm, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 07/11/1989. Status: Open.***

13. ***PC#19992282, NASA Wallops Island Flight Facility – Satan Radar Antenna, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 11/17/1998. Status: Closed.***

14. ***PC#20165134, NASA Wallops Island Flight Facility – Pipeline and Jet Fuel Receiving Area, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 01/07/2016. Status: Closed.***

15. ***PC#20135070, MARS Wallops Island – Pad O-A – Hurricane Sandy, Route 798, Wallops Island, VA 23337. Release Date: 01/14/2013. Status: Closed.***

16. ***PC#19952405, NASA Wallops Island Flight Facility – Building V10, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 05/03/1995. Status: Closed.***

17. ***PC#19922026, NASA Wallops Flight Facility Building X-75, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 06/02/1992. Status: Closed.***

18. ***PC#19930913, NASA Wallops Flight Facility Building X-5 & X-15, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 11/04/1992. Status: Closed.***

19. ***PC#20005119, NASA Wallops Flight Facility Building X-76, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 10/26/1999. Status: Closed.***

20. ***PC#20015044, NASA Wallops Flight Facility Building X-5, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 10/18/2000. Status: Closed.***

21. ***PC#19910363, NASA Wallops Island Flight Facility – Building Y-40, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 09/11/1990. Status: Closed.***

22. ***PC#20085052, NASA Wallops Flight Facility Power Plant Site 5, 12, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 12/04/2007. Status: Closed.***

23. ***PC#19910039, Z-65 and Y-30, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 07/09/1990. Status: Closed.***

24. ***PC#19910580, NASA Wallops Island Flight Facility – Building Y-30, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 07/09/1990. Status: Closed.***

25. ***PC#20015022, NASA Wallops Island Flight Facility – AST 448, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 08/31/2000. Status: Closed.***

26. ***PC#19922008, NASA Wallops Island Flight Facility – Site U-30, 34200 Fulton Street, Wallops Island, VA 23337. Release Date: 06/02/1992. Status: Closed.***

Please note that the DEQ's Pollution Complaint (PC) cases identified should be further evaluated by the project engineer or manager to establish the exact location, nature and extent of the petroleum release and the potential to impact the proposed project. Also, the project engineer or manager should contact the DEQ's Tidewater Regional Office at (757) 518-2175 (Tanks Program) for further information about the PC cases.

**PROJECT SPECIFIC COMMENTS**

None

**GENERAL COMMENTS**

**Soil, Sediment, Groundwater, and Waste Management**

Any soil, sediment or groundwater that is suspected of contamination or wastes that are generated must be tested and disposed of in accordance with applicable Federal, State, and local laws and regulations. Some of the applicable state laws and regulations are: Virginia Waste Management Act, Code of Virginia Section 10.1-1400 *et seq.*; Virginia Hazardous Waste Management Regulations (VHWMR) (9VAC 20-60); Virginia Solid Waste Management Regulations (VSWMR) (9VAC 20-81); Virginia Regulations for the Transportation of Hazardous Materials (9VAC 20-110). Some of the applicable Federal laws and regulations are: the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. Section 6901 *et seq.*, and the applicable regulations contained in Title 40 of the Code of Federal Regulations; and the U.S. Department of Transportation Rules for Transportation of Hazardous Materials, 49 CFR Part 107.

See #52

**Pollution Prevention – Reuse - Recycling**

Please note that DEQ encourages all construction projects and facilities to implement pollution prevention principles, including the reduction, reuse, and recycling of all solid wastes generated. All generation of hazardous wastes should be minimized and handled appropriately.

If you have any questions or need further information, please contact Katy Dacey at (804) 698-4274.

Matthew J. Strickler
*Secretary of Natural Resources*

Clyde E. Cristman
*Director*

Rochelle Altholz
*Deputy Director of Administration and Finance*

Russell W. Baxter
*Deputy Director of Dam Safety & Floodplain Management and Soil & Water Conservation*

Thomas L. Smith
*Deputy Director of Operations*

# COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION

**MEMORANDUM**

DATE: June 1, 2018

TO: John Fisher, DEQ

FROM: Roberta Rhur, Environmental Impact Review Coordinator

SUBJECT: DEQ 18-073F, Wallops Flight Facility Site-Wide PEIS

Division of Natural Heritage

The Department of Conservation and Recreations Division of Natural Heritage (DCR) has searched its Biotics Data System for occurrences of natural heritage resources from the area outlined on the submitted map of the Wallops Flight Facility Site (the Main Base, Wallops Mainland, and Wallops Island). Natural heritage resources are defined as the habitat of rare, threatened, or endangered plant and animal species, unique or exemplary natural communities, and significant geologic formations.

According to the information currently in our files, the following Conservation Sites are located within the project sites: North Wallops Island, Little Mosquito Creek, Wallops Island Seeps, Wallops Island Causeway Marshes, and Assawoman Island. See #21

Conservation sites are tools for representing key areas of the landscape that warrant further review for possible conservation action because of the natural heritage resources and habitat they support. Conservation sites are polygons built around one or more rare plant, animal, or natural community designed to include the element and, where possible, its associated habitat, and buffer or other adjacent land thought necessary for the element's conservation. Conservation sites are given a biodiversity significance ranking based on the rarity, quality, and number of element occurrences they contain; on a scale of 1-5, 1 being most significant.

A biodiversity significance rank (B-rank) is assigned to all Conservation Sites and SCUs to provide a simple indication of the significance of each site for the conservation of natural heritage resources. B-ranks range from 1-5:
B1 – Outstanding significance
B2 – Very high significance
B3 – High significance
B4 – Moderate significance
B5 – General Biodiversity significance

Three factors are evaluated to assign the B-rank: the rarity of the natural heritage resources occurring in the site, the quality of these natural heritage resource occurrences, and the number of these occurrences. Please see Table 1 (attached) for a list of natural heritage resources that are associated with these conservation sites. Many of the proposed projects have the potential to impact these natural heritage resources. DCR recommends further coordination with this office as specific projects are planned to determine if surveys are needed and potential impacts to natural heritage resources. See #23

DCR also recommends that the National Aeronautics and Space Administration (NASA) enter into a data license agreement with DCR similar to the 2010 agreement, so that the NASA-Wallops Flight Facility can incorporate quarterly updates of natural heritage information into their facility planning process. See #24 and #57

Due to the legal status of some of the species associated with the conservation sites, DCR recommends coordination with the US Fish and Wildlife Service (USFWS) and the Virginia Department of Game and Inland Fisheries (VDGIF), Virginia's regulatory authority for the management and protection of these species to ensure compliance with protected species legislation. See #25

Under a Memorandum of Agreement established between the Virginia Department of Agriculture and Consumer Services (VDACS) and DCR represents VDACS in comments regarding potential impacts on state-listed threatened and endangered plant and insect species.

There are no State Natural Area Preserves under DCR's jurisdiction in the project vicinity. See #22

New and updated information is continually added to Biotics. Please re-submit project information and map for an update on this natural heritage information if the scope of the project changes and/or six months has passed before it is utilized. See #26

The VDGIF maintains a database of wildlife locations, including threatened and endangered species, trout streams, and anadromous fish waters that may contain information not documented in this letter. Their database may be accessed from http://vafwis.org/fwis/ or contact Ernie Aschenbach at 804-367-2733 or Ernie.Aschenbach@dgif.virginia.gov.

The remaining DCR divisions have no comments regarding the scope of this project. Thank you for the opportunity to comment.

CC: Amy Ewing, VDGIF
Troy Andersen, USFWS

Table 1

| GROUP NAME | SCIENTIFIC NAME | COMMON NAME | GLOBAL BIODIVERSITY RANK | USFWS-SPECIES OF CONCERN | STATE BIODIVERSITY RANK | FEDERAL PROTECTION STATUS | STATE PROTECTION STATUS | ASSOCIATED CONSERVATION SITE NAME |
|---|---|---|---|---|---|---|---|---|
| Animal Assemblage | Bird Nesting Colony | | G5 | | SNR | | | ASSAWOMAN ISLAND |
| Invertebrate Animal | Papaipema araliae | Aralia Shoot Borer Moth | G3G4 | | S2S3 | | | NORTH WALLOPS ISLAND |
| Invertebrate Animal | Papaipema duovata | Seaside Goldenrod Stem Borer | G4 | | S1S3 | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Eleocharis rostellata - Spartina patens Tidal Herbaceous Vegetation | Tidal Oligohaline Marsh (Beaked Spikerush - Saltmeadow Cordgrass Estuarine Fringe Type) | G3 | | S1? | | | LITTLE MOSQUITO CREEK |
| Terrestrial Natural Community | Cladium mariscoides - Drosera intermedia - Rhynchospora alba Herbaceous Vegetation | Sea-Level Fen | G1 | | S1 | | | WALLOPS ISLAND SEEPS |
| Terrestrial Natural Community | (Morella pensylvanica) / Schizachyrium littorale Shrub Herbaceous Vegetation | Xeric Backdune Grassland | G2 | | S2 | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Morella cerifera - Baccharis halimifolia / Spartina patens Shrubland | Wax Myrtle Interdune Shrubland | G3G4 | | S2S3 | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Spartina patens - Fimbristylis (castanea, caroliniana) - Cyperus filicinus - Pluchea odorata - (Schoenoplectus pungens) Herbaceous Vegetation | Interdune Swale (Northern Mixed Grassland Type) | G1G2 | | S1? | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Prunus serotina / Smilax rotundifolia / Schizachyrium littorale Woodland | Black Cherry Xeric Dune Woodland | G1G2 | | S1 | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Spartina alterniflora - Distichlis spicata - (Spartina patens) Tidal Herbaceous Vegetation | Low Salt Marsh (Salt Panne Type) | GNR | | S3? | | | NORTH WALLOPS ISLAND |
| Terrestrial Natural Community | Alnus serrulata - Magnolia virginiana / Andropogon glomeratus - Eupatorium pilosum - Rhynchospora gracilenta - Xyris torta Shrub Herbaceous Vegetation | Coastal Plain / Outer Piedmont Seepage Bog | G1 | | S1 | | | WALLOPS ISLAND SEEPS |
| Terrestrial Natural Community | Interdune Swale / Pond | Interdune Swale / Pond | G2 | | S2 | | | NORTH WALLOPS ISLAND |
| Vascular Plant | Juncus pelocarpus | Brown-fruited Rush | G5 | | S2 | | | LITTLE MOSQUITO CREEK |
| Vascular Plant | Crocanthemum propinquum | Low Frostweed | G4 | | S1 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Eleocharis uniglumis | One-scale Spikerush | G5 | | S1 | | | ASSAWOMAN ISLAND |
| Vascular Plant | Juncus pelocarpus | Brown-fruited Rush | G5 | | S2 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Eriocaulon decangulare var. decangulare | Ten-angled pipewort | G5T5? | | S2 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Rhynchospora alba | Northern white beaksedge | G5 | | S2 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Eriocaulon decangulare var. decangulare | Ten-angled pipewort | G5T5? | | S2 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Erigeron vernus | White-top Fleabane | G5 | | S2 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Eupatorium maritimum | | G2? | SOC | S1 | | | NORTH WALLOPS ISLAND |
| Vascular Plant | Plantago maritima var. juncoides | Seaside Plantain | G5T5 | | S1 | | | NORTH WALLOPS ISLAND |
| Vascular Plant | Juncus megacephalus | Big-headed rush | G4G5 | | S2 | | | NORTH WALLOPS ISLAND |
| Vascular Plant | Euphorbia bombensis | Southern seaside spurge | G4G5 | | S2 | | | NORTH WALLOPS ISLAND |
| Vascular Plant | Rhynchospora oligantha | Feather-bristled beaksedge | G4 | | S1 | | | WALLOPS ISLAND SEEPS |
| Vascular Plant | Utricularia juncea | Southern Bladderwort | G5 | | S1 | | | WALLOPS ISLAND SEEPS |
| Vertebrate Animal | Charadrius wilsonia | Wilson's Plover | G5 | | S1B | | LE | ASSAWOMAN ISLAND |
| Vertebrate Animal | Charadrius melodus | Piping Plover | G3 | | S2B,S1N | LT | LT | NORTH WALLOPS ISLAND |
| Vertebrate Animal | Sternula antillarum | Least Tern | G4 | | S2B | | | ASSAWOMAN ISLAND |
| Vertebrate Animal | Charadrius melodus | Piping Plover | G3 | | S2B,S1N | LT | LT | ASSAWOMAN ISLAND |
| Vertebrate Animal | Rynchops niger | Black Skimmer | G5 | | S2B,S1N | | | ASSAWOMAN ISLAND |
| Vertebrate Animal | Circus hudsonius | Northern Harrier | G5 | | S1S2B,S3N | | | WALLOPS ISLAND CAUSEWAY MARSHES, NORTH WALLOPS ISLAND, ASSAWOMAN ISLAND |
| Vertebrate Animal | Caretta caretta | Loggerhead (Sea Turtle) | G3 | | S1B,S1N | LT | LT | NORTH WALLOPS ISLAND, ASSAWOMAN ISLAND, ASSATEAGUE ISLAND |
| Vertebrate Animal | Ammodramus caudacutus | Saltmarsh Sparrow | G4 | | S2B,S3N | | | WALLOPS ISLAND CAUSEWAY MARSHES |
| Vertebrate Animal | Ammodramus caudacutus | Saltmarsh Sparrow | G4 | | S2B,S3N | | | LITTLE MOSQUITO CREEK, WIRE NARROWS MARSH |
| Vertebrate Animal | Falco peregrinus | Peregrine Falcon | G4 | | S1B,S2N | | LT | NORTH WALLOPS ISLAND |

| CONSERVATION SITE | BIODIVERSITY RANK | TYPE |
|---|---|---|
| NORTH WALLOPS ISLAND | B2 | Conservation Site |
| LITTLE MOSQUITO CREEK | B3 | Conservation Site |
| WALLOPS ISLAND SEEPS | B2 | Conservation Site |
| WALLOPS ISLAND CAUSEWAY MARSHES | B4 | Conservation Site |
| ASSAWOMAN ISLAND | B3 | Conservation Site |

Commonwealth of Virginia

Fisher, John <john.fisher@deq.virginia.gov>

# ESSLog# 39160_18-073F_WallopsPEIS_DGIF_AME20180607

1 message

**Amy Ewing** <amy.ewing@dgif.virginia.gov> Thu, Jun 7, 2018 at 11:10 AM
To: John Fisher <john.fisher@deq.virginia.gov>
Cc: Ruth Boettcher <ruth.boettcher@dgif.virginia.gov>, Raymond Fernald <ray.fernald@dgif.virginia.gov>

John,

I apologize that these comments are a few days late, but we turned this around as quickly as we could, in response to this expedited review.

We have reviewed the Draft NASA Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement (draft PEIS). We understand the interest by NASA to develop this document, to cover projects currently in various stages of planning proposed to occur at their facilities over the next 20 years. However, we caution that sites such as Wallops, located along the Atlantic Ocean, are prone to significant shoreline and other habitat changes, changes likely to increase in scope in the coming decades. We are concerned that as sands shift and habitats migrate over this extended period of time, wildlife, including listed species, may not be provided the protection they deserve. We recommend that any projects proposed to impact previously undisturbed ground and/or suitable wildlife habitats, and/or projects that build upwards, impacting migratory flyways, and foraging spaces for birds and bats be closely reviewed by us and our conservation partners, namely the USFWS and NOAA Fisheries Service.

If it is decided that development of and adherence to a PEIS for Wallops is the best way forward, we offer the following information to inform the final PEIS:

We document the following listed, and/or tiered wildlife from Wallops Mainland, Wallops Island, and nearby environs:

**Listed species:**

Federal Endangered state Endangered leatherback sea turtles

Federal Endangered Kemp's Ridley sea turtles

Federal Threatened state Threatened loggerhead sea turtles

Federal Threatened green turtles

Federal Threatened red knots

Federal Threatened piping plovers

State Endangered Wilson's plovers

State Threatened peregrine falcons

State Threatened gull-billed terns

**Wildlife Action Plan Species of Greatest Conservation Need*:**

Northern diamond-backed terrapins (Tier IIa)

Glossy ibis (Tier Ia)

Snowy egrets (Tier IIa)

Little blue herons (Tier IIa)

Black skimmers (Tier IIa)

Common terns (Tier IIa)

We document a number of waterbird colonies, many containing one or more of the avian species listed above, from Wallops Island and associated islands, including nearby the barge route that is proposed for dredging. In addition, we have documented a number of bald eagle nests from this area over the years. As noted above and as stated in the draft PEIS, sea turtles are known from the installation, breeding on the beaches that form the eastern boundary of the facility. The most recently documented locations of these species, and others, appear to be accurately depicted in Table 3.10-2 of draft PEIS. We recommend that biological monitoring occur on site each year, in close coordination with VDGIF, NOAA Fisheries Services and the USFWS, ensuring that effective monitoring protocols are followed and that participants are appropriately permitted to perform the work, if necessary. We recommend that updated maps of documented species, and habitats that support them, be developed each year and provided to installation management and staff so that planning around protection of documented wildlife species and resources can occur. We support adherence to the protective/mitigation measures contained within the draft PEIS. We offer the below recommendations for protection of resources under our jurisdiction (in some instances, shared jurisdiction) and recommend inclusion of these recommendations in the PEIS, if not already included, and adherence to them as development plans for the installation move forward. We note that upland sandpipers are no longer listed threatened in Virginia and recommend that the draft PEIS be updated to reflect this change.

**Waterbird colonies and beach nesting birds**:

We recommend monitoring of shorebird/waterbird colonies and nest sites on Wallops Mainland and Wallops Island each breeding season and mapping of documented colonies and nest sites. To ensure protection of the colony and the species known to nest within it, we recommend no significant land development or timbering activities occur within 0.5 miles of a documented colony/nest site from March 15 through August 31 of any year, or when the last brood fledges as determined by monitoring activities. In addition, we recommend maintaining, planting or enhancing, an undisturbed naturally vegetated buffer of at least 500 ft around any documented waterbird colonies (not beach nest sites). This provides the colony with a line of sight and habitat buffer, providing nesting activity protection as well as habitat protection to ensure suitability for future nesting seasons. See #32

**Sea turtles:**

We recommend monitoring of beach habitats each nesting season to determine the location of any nesting sea turtles on installation grounds. Once identified, we recommend the beach be excluded from activity until monitoring has confirmed the last nest has hatched. If surveys cannot be performed during any given year, we recommend no work on beaches known ever to have supported nesting from May 1 – November 15. We recommend no hydraulic hopper dredging in nearby waters from April 1 through November 30 of any year. We recommend close coordination with the USFWS and NOAA Fisheries Service regarding protection of sea turtles. See #33

**Peregrine falcons:**

We recommend no significant human activity within 600 ft of the nest/nest box during the nesting season from February 15 through July 15 of any year. We recommend coordination with us regarding any proposed modification of natural habitats and/or man-made structures currently supporting the species. See #34

**Sea mammals:**

We recommend adherence to the mitigation measures included within the draft PEIS and close coordination with NOAA Fisheries Service and the USFWS regarding protection of these animals. See #35

**Bats:**

We recommend adherence to the mitigation measures included within the draft PEIS, including adherence to a time of year restriction (TOYR) on tree clearing from June 1 – July 31 of any year, to protect northern long eared bats. We recommend close coordination with us and the USFWS regarding tree clearing on site, particularly if NASA cannot adhere to the TOYR. We recommend consideration of impacts upon foraging and migrating bats associated with projects resulting in flyway impediments. See #36

**Bald eagles:**

We recommend adherence to the mitigation measures included within the draft PEIS, including maintenance of an undisturbed buffer around the nest site and continued nest monitoring. See #37

**To minimize overall impacts to wildlife and our natural resources, we offer the following comments about development activities:**

We recommend that the applicant avoid and minimize impacts to undisturbed forest, wetlands, and streams to the fullest extent practicable. Avoidance and minimization of impact may include relocating stream channels as opposed to filling or channelizing as well as using, and incorporating into the development plan, a natural stream channel design and wooded buffers. See #38 We recommend maintaining undisturbed naturally vegetated buffers of at least 100 feet in width around all on-site wetlands and on both sides of all perennial and intermittent streams. We recommend maintaining wooded lots to the fullest extent possible. We generally do not support proposals to mitigate wetland impacts through the construction of stormwater management ponds, nor do we support the creation of in-stream stormwater management ponds. See #39

We recommend conducting any in-stream activities during low or no-flow conditions, using non-erodible cofferdams or turbidity curtains to isolate the construction area, blocking no more than 50% of the streamflow at any given time, stockpiling excavated material in a manner that prevents reentry into the stream, restoring original streambed and streambank contours, revegetating barren areas with native vegetation, and implementing strict erosion and sediment control measures. To minimize harm to the aquatic environment and its residents resulting from use of the Tremie method to install concrete, installation of grout bags, and traditional pouring of concrete, we recommend that such activities occur only in the dry, allowing all concrete to harden and cure prior to contact with open water. Due to future maintenance costs associated with culverts, and the loss of riparian and aquatic habitat, we prefer stream crossings to be constructed via clear-span bridges. However, if this is not possible, we recommend countersinking any culverts below the streambed at least 6 inches, or the use of bottomless culverts, to allow passage of aquatic organisms. We also recommend the installation of floodplain culverts to carry bankfull discharges. See #40

We recommend that the stormwater controls for this project be designed to replicate and maintain the hydrographic condition of the site prior to the change in landscape. This should include, but not be limited to, utilizing bioretention areas, and minimizing the use of curb and gutter in favor of grassed swales. Bioretention areas (also called rain gardens) and grass swales are components of Low Impact Development (LID). They are designed to capture stormwater runoff as close to the source as possible and allow it to slowly infiltrate into the surrounding soil. They benefit natural resources by filtering pollutants and decreasing downstream runoff volumes. See #41

We recommend that all tree removal and ground clearing adhere to a time of year restriction protective of resident and migratory songbird nesting from March 15 through August 15 of any year. See #42

We recommend adherence to erosion and sediment controls during ground disturbance. See #43

This project is located within 2 miles of a documented occurrence of a state or federal threatened or endangered plant or insect species and/or other Natural Heritage coordination species. Therefore, we recommend coordination with VDCR-DNH regarding the protection of these resources. See #23-26

We defer a determination of consistency to MRC, as this site drains to marine waters.

**See www.bewildvirginia.org for more information.*

Thanks, Amy

**Amy Ewing**

*Environmental Services Biologist*

*Manager, Fish and Wildlife Information Services*

P 804.367.2211

A 7870 Villa Park Drive, P.O. Box 90778, Henrico, VA 23228-0778

**www.dgif.virginia.gov**

*CONSERVE. CONNECT. PROTECT.*

Commonwealth of Virginia

Fisher, John <john.fisher@deq.virginia.gov>

# Re: NEW PROJECT NASA WFF PEIS 18-073F

1 message

**Warren, Arlene** <arlene.warren@vdh.virginia.gov> Mon, Jun 4, 2018 at 4:11 PM
To: John Fisher <john.fisher@deq.virginia.gov>

**Project Name: Wallops Flight Facility Site-wide Programmatic Environmental Impact Statement**
**Project #: 18-073 F**
**UPC #: N/A**
**Location: Accomack County**

VDH – Office of Drinking Water has reviewed the above project. Below are our comments as they relate to proximity to **public drinking water sources** (groundwater wells, springs and surface water intakes). Potential impacts to public water distribution systems or sanitary sewage collection systems **must be verified by the local utility.**

There are no public groundwater wells within a 1 mile radius of the project site.

There are no surface water intakes located within a 5 mile radius of the project site. See #44

The project is not within the watershed of any public surface water intakes.

There are no apparent impacts to public drinking water sources due to this project.

- ***Comments from the Office of Radiological Health, Mr. Steve Harrison, Director were "I've reviewed the WFF-PEIS and have no concerns or comments related to ORH."***

The Virginia Department of Health – Office of Drinking Water appreciates the opportunity to provide comments. If you have any questions, please let me know.

# COMMONWEALTH of VIRGINIA

Mark K. Flynn
Director

*Department of Aviation*
*5702 Gulfstream Road*
*Richmond, Virginia 23250-2422*

V/TDD • (804) 236-3624
FAX • (804) 236-3635

June 27, 2018

Mr. John Fisher
Virginia Department of Environmental Quality
Office of Environmental Impact Review
1111 East Main Street, Suite 1400
Richmond, Virginia 23219

RE: Wallops Island Flight Facility Site Wide Programmatic Environmental Impact Statement, DEQ-#18-073F

Dear Mr. Fisher:

The Virginia Department of Aviation has reviewed the information package you provided for the Wallops Island Flight Facility Site Wide Programmatic Environmental Impact Statement. Due to the proximity of future development to the airfield, a 7460 form must be submitted to the Federal Aviation Administration for every project to be constructed within 20,000 linear feet of the airfield or will require a structure, either permanent or temporary, to have a height of 200' above ground level.

See #45

If you have any questions regarding this matter, please contact me at (804) 236-3638.

Sincerely,

S. Scott Denny
Senior Aviation Planner
Virginia Department of Aviation

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Prepared in cooperation with:

Site-wide Programmatic Environmental Impact Statement