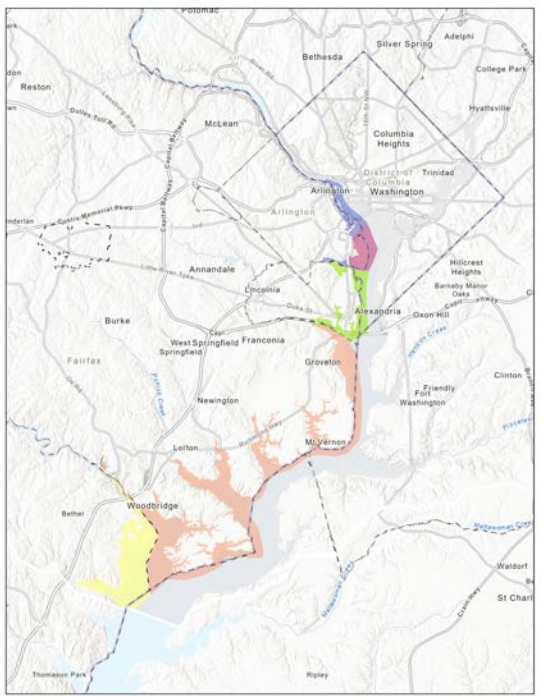
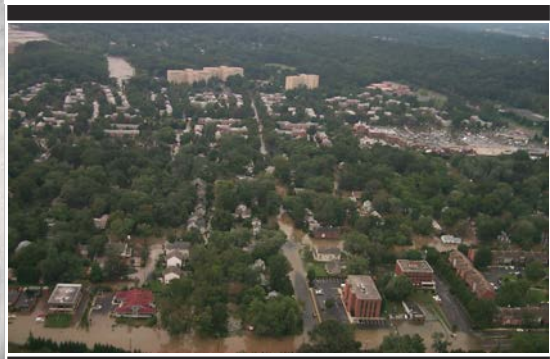
US Army Corps of Engineers®

Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study

Draft Integrated Feasibility Report & Environmental Assessment

May 2022





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Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study

Draft Integrated Feasibility Report and Environmental Assessment

U.S. Army Corps of Engineers
Baltimore District

May 2022

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Executive Summary

This Draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) documents the U.S. Army Corps of Engineers (USACE) feasibility study planning process for the Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study (DC Coastal Study) and compliance with the National Environmental Policy Act (NEPA) and other environmental laws as integrated into the planning process.

Following Hurricane Sandy in 2012, the USACE completed the North Atlantic Coast Comprehensive Study (NACCS), which identified nine high-risk areas on the Atlantic Coast that warranted further investigation of coastal storm risk management (CSRM) solutions. The Metropolitan Washington, District of Columbia (DC) region, which includes portions of Washington, D.C., Maryland, and Virginia, was identified as one of the nine high-risk areas recommended by NACCS for a follow-on feasibility study to investigate solutions to coastal flooding problems.

The North Atlantic Coast is vulnerable to the impacts of coastal flooding and the potential for future, more devastating events due to rising sea levels. The Metropolitan Washington D.C. region including Maryland and Northern Virginia support densely populated areas encompassing trillions of dollars of largely fixed public, private, and commercial investment. Coastal communities in this region must begin to consider long-term coastal storm risk.

The Metropolitan Washington, D.C. Feasibility Cost Share Agreement (FCSA) was signed by USACE and the Metropolitan Washington Council of Governments (MWCOG) on 18 July 2017. At that time, the jurisdictions contributing to the cost-sharing of the feasibility study included Washington, D.C.; Prince George's County, Maryland; Fairfax County, Virginia; the City of Alexandria, Virginia; Arlington County, Virginia; and the Metropolitan Washington Airports Authority (MWAA). In 2018, some of the jurisdictions including Washington, D.C. and Prince George's County, Maryland determined that their needs did not align with the proposed study and declined to participate. The study was therefore re-scoped to meet the needs of the remaining cost-share partners in Northern Virginia.

MWCOG is the non-federal sponsor (NFS) for the DC Coastal Study representing the following jurisdictions in Northern Virginia: Commonwealth of Virginia, Arlington County, Fairfax County, the City of Alexandria, Prince William County, and the MWAA. The study area encompasses the Northern Virginia jurisdictions within the Middle Potomac Watershed boundary, from Arlington County south to include a portion of Prince William County. An FCSA Amendment was signed on 7 April 2021.

The study authority is the resolution of the U.S. Senate Committee on Environment and Public Works, dated 23 May 2001. This draft IFR/EA would culminate in a Chief's Report on 1 March 2024 as an interim response to the study authority, since the authority remains

open for Washington, D.C., Maryland and/or Virginia to participate in future studies for their respective areas focusing on either CSRM or ecosystem restoration projects.

The purpose of the study is to evaluate the feasibility of Federal participation in the implementation of solutions to reduce long-term coastal flood risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources considering future climate and sea level change scenarios to support resilient communities in Northern Virginia within the Middle Potomac River watershed. Northern Virginia has been impacted by numerous major tropical and extratropical events, most notably the Chesapeake and Potomac Hurricane of 1933, Hurricane Agnes (1972), Hurricane Fran (1996), Nor'easter (1998), Hurricane Floyd (1999), Hurricane Isabel (2003), Hurricane Irene (2011), and Hurricane Sandy (2012). Hurricane Isabel in 2003 resulted in extreme water levels and caused millions of dollars of damage to residences, businesses, and critical infrastructure.

The Middle Potomac River watershed encompasses approximately 11,500 square miles, including a diverse landscape, with urban, rural, and natural areas in six different ecological regions and four states and the District of Columbia. The study area for the DC Coastal Study encompasses approximately 76 square miles and includes the Northern Virginia jurisdictions within the Middle Potomac watershed boundary, from Arlington County south to include a portion of Prince William County (Figure E-1). Within the study area, the Virginia side of the Potomac River contains approximately 135 miles of Potomac River shoreline. The study area is located in a densely populated urban setting that is primarily residential, but also includes commercial districts, industrial facilities, military installations, and transportation infrastructure as well as natural areas, green spaces, and historic properties. Notable features include the George Washington Memorial Parkway (GWMP) that runs along the west side of the Potomac River, the Ronald Reagan Washington National Airport (DCA) located in Arlington, Virginia, and the Dyke Marsh Wildlife Preserve (Dyke Marsh), a 380-acre tidal freshwater wetland located on the west bank of the Potomac River in Fairfax County, Virginia. The region's historic and cultural sites include the historic districts at Old Town Alexandria and the Town of Occoquan, George Washington's Mount Vernon Estate, and the GWMP. The Mount Vernon Trail is an important cultural and recreational resource with views of the Potomac River. The current population within the study area is approximately 155,000.

The Northern Virginia study area has experienced a marked increase in the number of days of "minor coastal flooding" over time, which will increase along with rising sea levels. Similarly, the water table below the study area will continue to rise, limiting the effectiveness of gravity drain potential post-storm. Subsidence will increase as soil deposited naturally, or by humans, compacts over time.

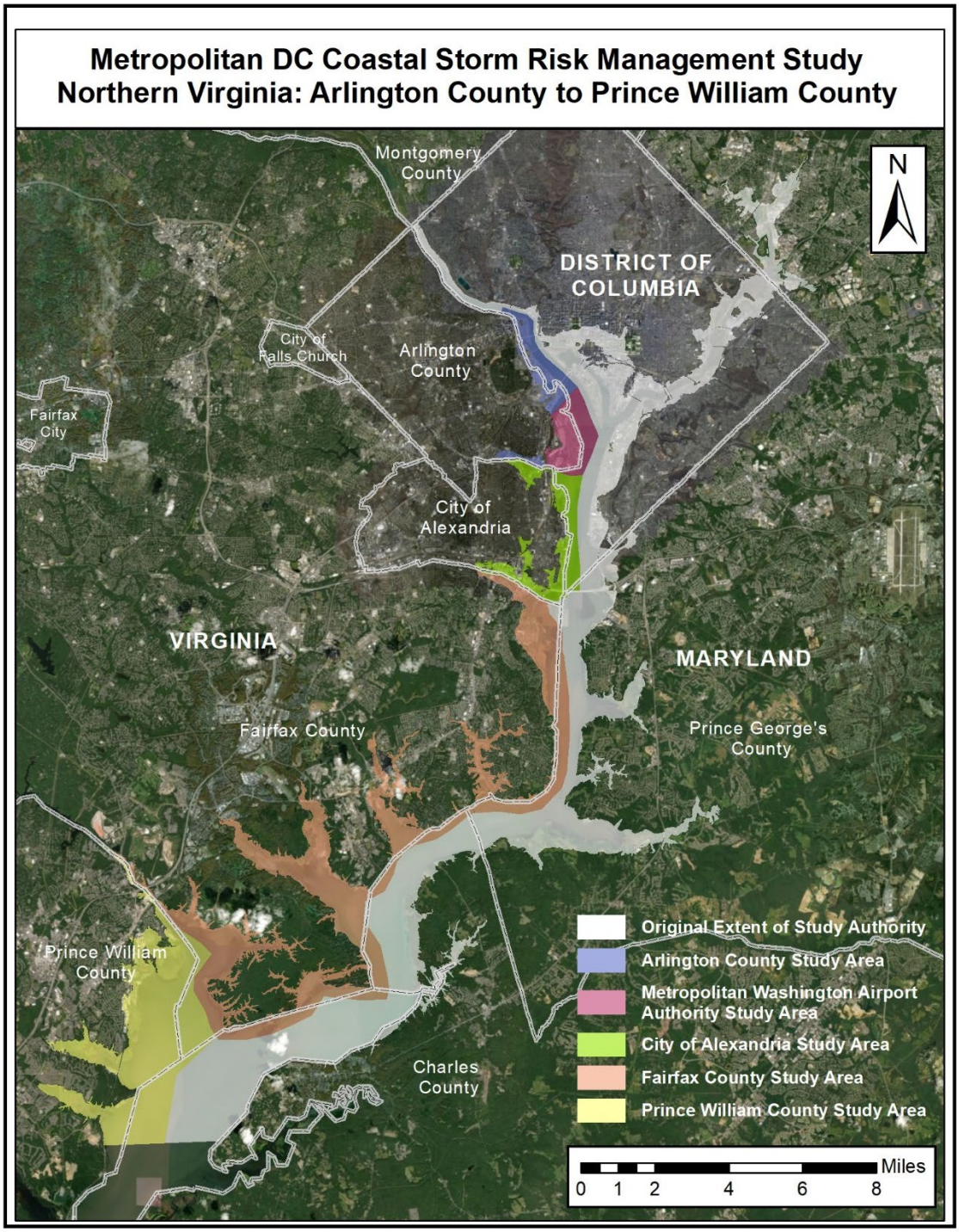

Figure E-1. Northern Virginia Study Area

The USACE low, intermediate, and high sea level change scenarios were evaluated for the without and with project condition, and with respect to determining tipping points/thresholds for impacts over the 50-year period of analysis and 100-year adaptation timeframe, and at multiple storm frequencies. National Oceanic and Atmospheric

Administration's (NOAA) Regional Rate at Washington D.C. tide gauge is 0.00997 feet/year.

The period of analysis for this study is 50-years per ER 1105-2-100 Planning Guidance Notebook. The planning horizon starts in baseline year 2031, when the project is anticipated to begin accruing flood risk management (FRM) benefits and ends in year 2080. Existing conditions reflect the conditions in place during the feasibility study through year 2024. Future without project (FWOP) conditions consider a range of activities from year 2021, the most recent year for which complete data was obtained, and projects that are planned to be implemented or are already underway that would be constructed in the absence of this project. Future with project (FWP) conditions are the conditions forecasted during the planning horizon, from years 2031 to 2080 with implementation of the recommended plan. The analysis is conducted using the fiscal year 2022 discount rate of 2.250 percent (October 2021 price level).

Plan formulation was conducted with a focus on achieving the federal objective of water and related land resources project planning, which is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders (EO), and other federal planning requirements. Plan formulation also considers the four system of accounts: NED, Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). The plan formulation process focuses on establishing alternatives considering non-structural and structural measures initially and then adds natural and nature-based features (NNBF) to the final array of alternatives as design considerations that will enhance the performance and effectiveness of structural measures included in those alternatives.

The development and screening of measures and formulation of alternatives went through several iterations starting with an initial array of 11 alternatives in addition to the no action plan. Due to study rescoping, cost effectiveness, economic, hydraulic and environmental considerations, these alternatives were screened to a final array of seven alternatives including two alternatives to address FRM to critical infrastructure, three levee and floodwall alternatives, a non-structural alternative, and an alternative combining various alternative plans, in addition to the no-action plan. Of these seven alternatives, three yielded positive net benefits. Alternative 8: Combination of the Arlington Water Pollution Control Plant (WPCP) Floodwall and Belle Haven Levee and Floodwall was identified as the NED Plan because it reasonably maximizes net benefits and is chosen as the Tentatively Selected Plan (TSP) in this report. The TSP has net benefits of $450,000 and a benefit-to-cost ratio (BCR) of 1.3. The total project cost for the TSP is $52.3 million.

The TSP consists of two project components at the Arlington WPCP and at Belle Haven (see Figures E-2 and E-3), a primarily residential neighborhood with some commercial

buildings. At the Arlington WPCP, a floodwall would be constructed along the left bank of Four Mile Run between Four Mile Run and the Arlington WPCP with a closure structure on the east side of the structure. The new floodwall would tie into the bank to the east just past South Eads Street. The floodwall would wrap around the Arlington WPCP to the west where the stop log closure structure is located along South Glebe Road.

At Belle Haven, a floodwall would be constructed just north of Belle Haven Road from Barrister Place to 10th Street with a closure structure at 10th Street and at the GWMP. Closure structures would also be constructed along Belle Haven Road and Belle View Boulevard. A floodwall would tie into the closure structure at 10th Street and run south along the west side of the GWMP, curving around Belle View Boulevard to 10th Street. The floodwall would then run west to East Wakefield Drive tying into both sides of a closure structure on Potomac Avenue. The floodwall would continue west to West Wakefield Drive and tie into a small portion of earthen levee ending at Westgrove Dog Park.

During the Pre-Construction Engineering and Design (PED) and construction phases, the project would be cost shared 65 percent Federal and 35 percent non-Federal. Lands, easements, rights-of-way, and relocations (LERRs) required for project construction must be provided by the non-Federal sponsor as part of the non-Federal construction cost share amount. The lands and damages real estate costs are estimated at $799,500 for the Arlington WPCP and $1,167,000 for the Belle Haven floodwall and levee.

The annualized operation and maintenance cost (O&M) for the TSP are estimated at $1,000 for the Arlington WPCP because the concrete floodwall requires minimal maintenance over the 50-year period of analysis. The closure structure would need to be deployed at minimum once per year which could incur some labor costs. The annualized O&M for the TSP are estimated at $16,000 for Belle Haven. The concrete floodwall would require minimal maintenance over the 50-year period of analysis. The earthen levee may require some maintenance after a storm event, but the majority of these O&M funds would be incurred for maintenance of the two pump stations and inspections of equipment.

It is estimated that the construction duration for the Arlington WPCP would be 18 months. There are no time-of-day restrictions and the cost estimate assumes 12 hour days. The construction duration for Belle Haven is four years. Belle Haven does not have any time-of-day restrictions and assumes 12 hour days. For both projects, materials would be brought in by land via by flat bed trucks, trailers and dump trucks.

PED is anticipated to take two years and was assumed to start in October 2024 and last through September 2026. Construction for the Arlington WPCP floodwall would likely start in 2026 and end in late 2027 or early 2028. Assuming a four-year construction window for Belle Haven, construction would likely start in 2026 and end in late 2030 or early 2031.

The non-Federal sponsor, MWCOG, and the local jurisdictions of Fairfax County and Arlington County support the TSP, Alternative 8: Combination of Arlington WPCP floodwall and Belle Haven levee and floodwall with pump stations. It is likely that Arlington County and Fairfax County would be the project sponsors and signatories for future agreements for design and construction.

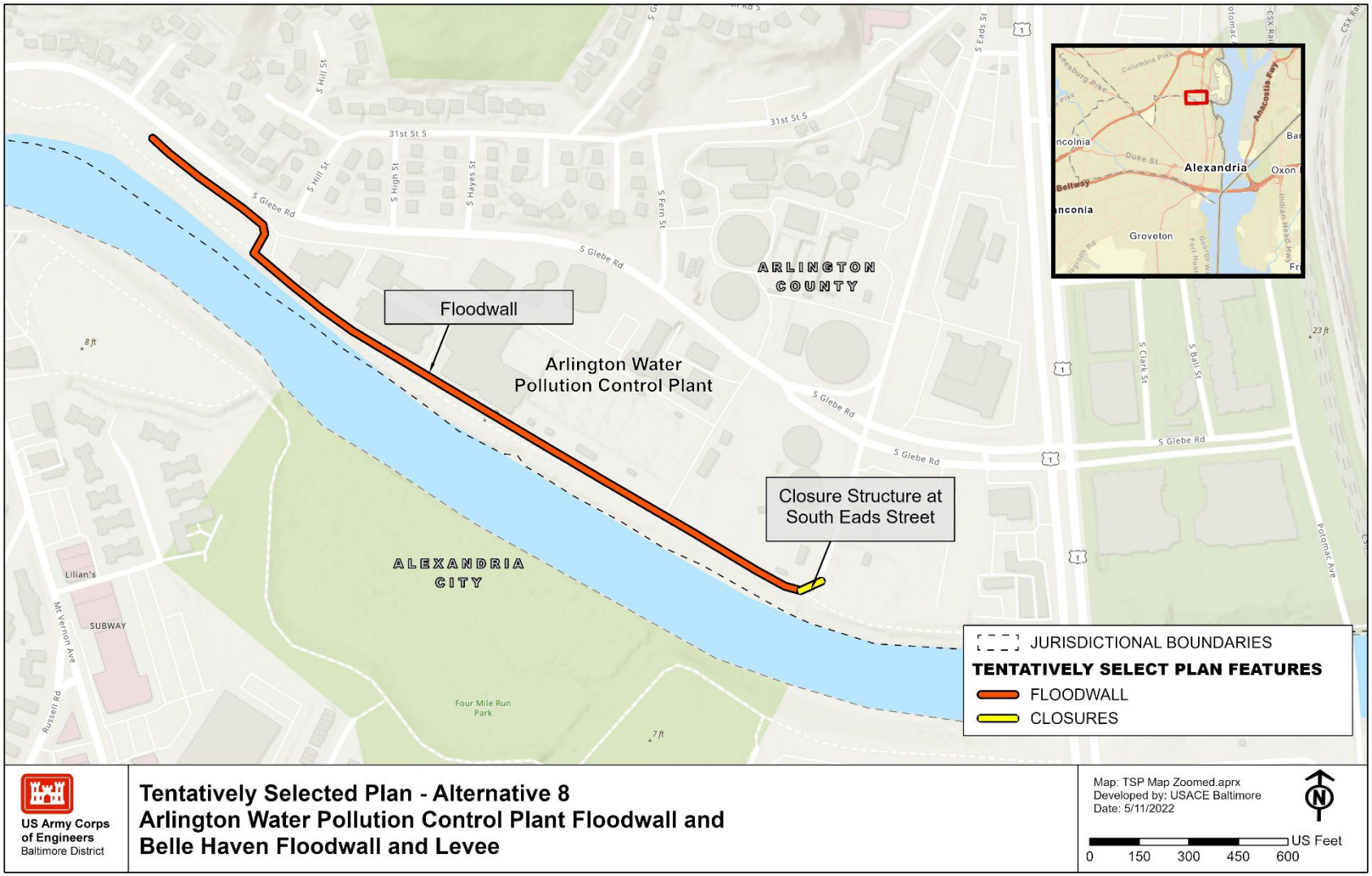

Figure E-2. Tentatively Select Plan – Combination Alternative 8: Arlington Water Pollution Control Plant Floodwall

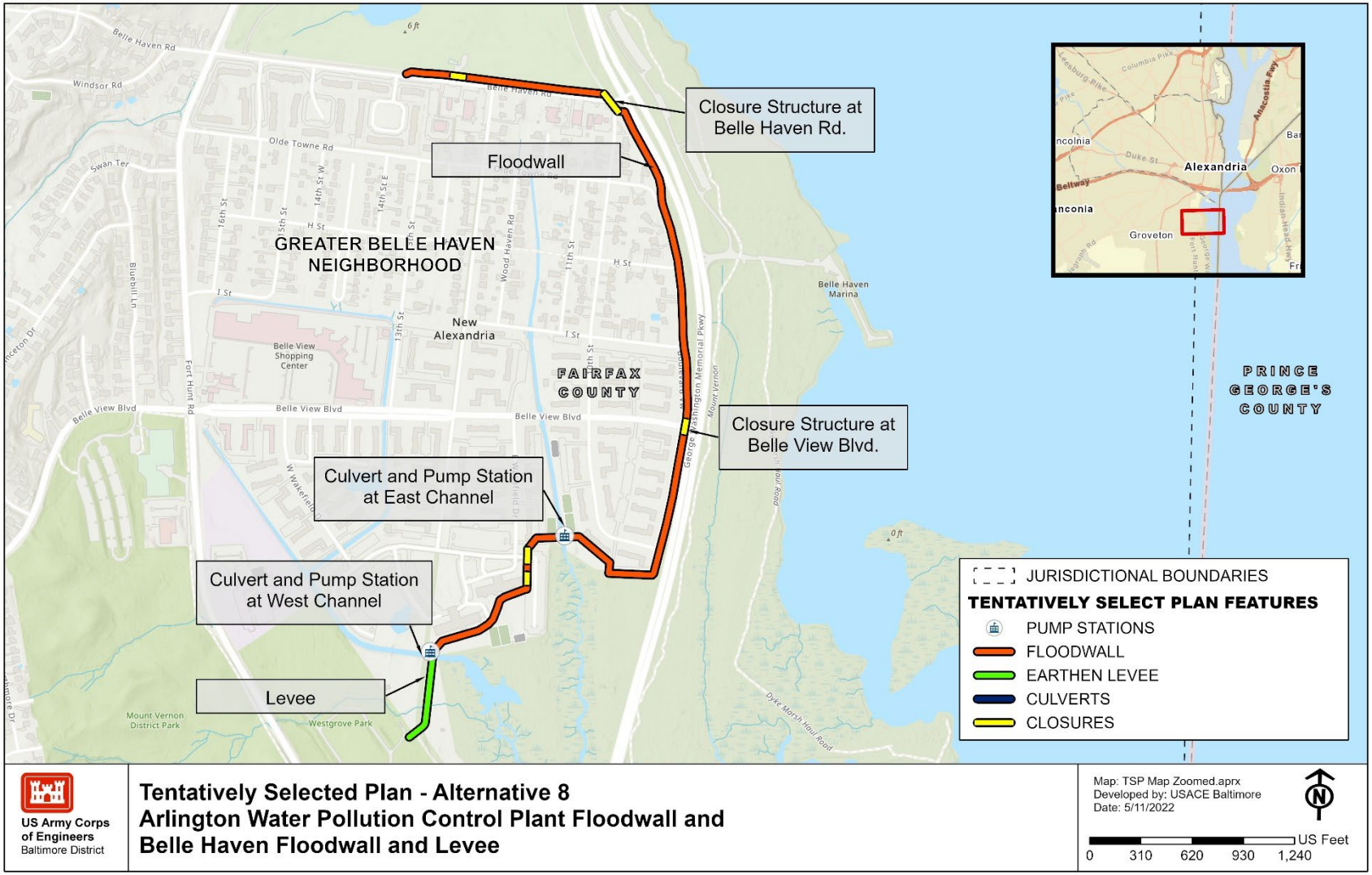

Figure E-3. Tentatively Select Plan – Combination Alternative 8: Belle Haven Floodwall and Levee

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Acronyms

AAEQ	Average Annual Equivalent Costs
ADM	Agency Decision Milestone
ADT	Average Daily Traffic
AEP	Annual Exceedance Probability
Alt	Alternative
AMM	Alternatives Milestone Meeting
APE	Area of Potential Effects
ASA(CW)	Assistant Secretary of the Army Civil Works
ASMFC	Atlantic States Marine Fisheries Commission
BCC	Birds of Conservation Concern
BCR	Benefit Cost Ratio
BH	Bulkhead
C-STORM	Coastal Storm Modeling System
CAP	Continuing Authorities Program
CBP	Chesapeake Bay Program
CDC	Centers for Disease Control
CENAB	U.S. Army Corps of Engineers, Baltimore District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CH_4	Methane
CO_2	Carbon Dioxide
CSRM	Coastal Storm Risk Management
CSX	CSX Corporation
CSVR	Content-to-Structure Value Ratios
CTLS	Cleanup target levels
CZMA	Coastal Zone Management Act
dB	Decibel
D.C.	District of Columbia
DCA	Ronald Reagan Washington National Airport

DC Coastal Study	Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study
DO	Dissolved Oxygen
DOEE	Department of Energy and Environment
DPS	Distinct Population Segment
DRAA13	Disaster Relief Appropriations Act of 2013
EA	Environmental Assessment
EAD	Equivalent Annual Damages
EDR	Environmental Data Resources
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice
EMAS	Engineered Material Arresting Systems
EO	Executive Order
EOP	U. S. Army Corps of Engineers Environmental Operating Principles
EPZ	Evacuation Planning Zone
EQ	Environmental Quality
ER	Engineer Regulation
ERDC	Engineering Research and Development Center
EMAS	Engineered Material Arresting Systems
ESA	Endangered Species Act
F	Fahrenheit
FAA	Federal Aviation Administration
FCSA	Feasibility Cost Share Agreement
FDM	Friends of Dyke Marsh
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FONSI	Finding of No Significant Impact
FRM	Flood Risk Management
FRMP	Flood Risk Management Program
ft	foot/feet
FWCA	Fish and Wildlife Coordination Act

FWOP	Future Without Project
FWP	Future With Project
G2CRM	Generation II Coastal Risk Model
GIS	Geographic Information System
GHG	Green House Gases
GWMP	George Washington Memorial Parkway
HTRW	Hazardous, Toxic and Radioactive Waste
I	Interstate
IDC	Interest During Construction
IFR/EA	Integrated Feasibility Report and Environmental Assessment
IPaC	Information for Planning and Consultation
IPCC	Intergovernmental Panel on Climate Change
IWR	Institute for Water Resources
LiDAR	Light Detection and Ranging
LOD	Limits of Disturbance
MA	Model Area
MDDNR	Maryland Department of Natural Resources
MIPR	Military Interdepartmental Purchase Request
MWAA	Metropolitan Washington Airport Authority
MWCOG	Metropolitan Washington Council of Governments
N_2O	Nitrogen oxides
N/A	Not Applicable
NAAQS	National Ambient Air Quality Standards
NACCS	North Atlantic Coastal Comprehensive Study
NAVD88	North Atlantic Vertical Datum of 1988
NCPC	National Capital Planning Commission
NED	National Economic Development
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NLEB	Northern Long-eared Bat
NMFS	National Marine Fisheries Service
NNC	National Nonstructural Committee
NNBF	Natural and Nature-Based Features

NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen oxides
NPL	National Priorities List
NPS	National Park Service
NRHP	National Register of Historic Places
NVRC	Northern Virginia Regional Commission
NS	Nonstructural
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
O&M	Operation and Maintenance
OMRR&R	Operation, Maintenance, Repair, Rehabilitation, and Replacement
OSE	Other Social Effects
P&G Criteria	Principles & Guidelines for Federal Investments in Water Resources
PA	Programmatic Agreement
PAR	Planning Aid Report
PB	Planning Bulletin
PCB	Polychlorinated Biphenyls
PDT	Project Delivery Team
PED	Pre-construction, Engineering, and Design
PGN	Planning Guidance Notebook
P.L.	Public Law
PPA	Project Partnership Agreement
Ppb	Parts Per Billion
PSE	Protective System Element
PV	Present Value
RCRA	Resource Conservation and Recovery Act
RED	Regional Economic Development
RECONS	Regional Economic System
ROM	Rough Order Magnitude
RSLC	Relative Sea Level Change
SAV	Submerged Aquatic Vegetation

S&I	Supervision and Inspection
SIP	State Implementation Plan
SIS	South Investigation Site
SHPO	State Historic Preservation Office
SLC	Sea Level Change
SLR	Sea Level Rise
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
SPGP	State Programmatic General Permit
sqft	Square Feet
TCDD	Tetrachlorodibenzo-p-dioxin
TMDL	Total Maximum Daily Load
TPC	Total Project Cost
TPCS	Total Project Cost Summary
TSP	Tentatively Selected Plan
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
U.S.C.	United States Code
USEPA	U.S. Environmental Protection Agency
USFWS	U. S. Fish and Wildlife Service
USGS	U. S. Geological Survey
V-CRIS	Virginia Cultural Resources Information System
VA	Virginia
VADCR	Virginia Department of Conservation and Recreation
VADEQ	Virginia Department of Environmental Quality
VAFWIS	Virginia Fish and Wildlife Information Search
VDHR	Virginia Department of Historic Resources
VIMS	Virginia Institute of Marine Science
VOCS	Volatile Organic Compounds
VOF	Virginia Outdoor Foundation
VRE	Virginia Rail Express
VRMC	Virginia Marine Resources Commission
WPCP	Water Pollution Control Plant
WRDA	Water Resources Development Act

WQC	Water Quality Certification
WSEL	Water Surface Elevation
YOY	Young-of-Year

1 Introduction

1.1 Introduction

This Draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) documents the U.S. Army Corps of Engineers (USACE) feasibility study planning process for the Metropolitan Washington District of Columbia (D.C.) Coastal Storm Risk Management Feasibility Study (DC Coastal Study) and compliance with the National Environmental Policy Act of 1969 (NEPA) and other environmental laws as integrated into the planning process. An EA has been prepared for this study because reasonably foreseeable effects to the human environment are not expected to be significant. Adverse environmental effects will be offset by mitigation. The sections of this report that satisfy the NEPA requirements are marked with an asterisk (*). [40 Code of Federal Regulations (CFR) 1501.5(c)]

The DC Coastal Study is being completed to determine whether the implementation of coastal storm risk management (CSRM) measures would reduce coastal flood risk to critical public and private infrastructure along the west bank of the Potomac River in Northern Virginia. Project costs and benefits associated with each alternative were compared to identify and recommend the best plan. The models used to forecast the future conditions and changes for the DC Coastal Study have been certified by the USACE.

The FCSA was signed by USACE and the Metropolitan Washington Council of Governments (MWCOG) on 18 July 2017. At that time, the jurisdictions contributing to the cost-share included Washington, D.C.; Prince George's County, Maryland; Fairfax County, Virginia; the City of Alexandria, Virginia; Arlington County, Virginia; and the Metropolitan Washington Airports Authority (MWAA). In 2018, some of the jurisdictions including Washington, D.C. and Prince George's County, Maryland determined that their needs did not align with the proposed study and declined to participate. The study was therefore re-scoped to meet the needs of the remaining cost-share partners in Northern Virginia.

MWCOG is the non-federal sponsor for the DC Coastal Study representing the following jurisdictions in Northern Virginia: Commonwealth of Virginia, Arlington County, Fairfax County, the City of Alexandria, Prince William County, and the MWAA. The study area encompasses the Northern Virginia jurisdictions within the Middle Potomac Watershed boundary, from Arlington County south to include a portion of Prince William County. An FCSA Amendment was signed on 07 April 2021.

The study authority is the resolution of the U.S. Senate Committee on Environment and Public Works, dated 23 May 2001. This draft IFR/EA would culminate in a Chief's Report on 1 March 2024 as an interim response to the study authority, since the authority remains

open for D.C., Maryland and/or Virginia to participate in future studies for their respective areas focusing on either CSRM or ecosystem restoration projects.

1.2 USACE Planning Process

The SMART (Specific, Measurable, Attainable, Risk Informed, Timely) planning process is used for conducting civil works feasibility studies for water resources development projects. The purpose of this process is to improve and streamline feasibility studies, reduce cost, and expedite completion of the study. The SMART planning process follows a 3x3x3 approach with the goal of completing the study in 3 years, for no more than $3 million dollars and with three levels of review.

Due to study delays and rescoping of the DC Coastal Study, the project delivery team (PDT) requested a 3x3x3 exemption for time and budget which was approved by the Assistant Secretary of the Army (ASA(CW)) on 05 February 2021. The study cost share also changed from 50 percent Federal and 50 percent non-Federal to 100 percent Federally funded under the Disaster Relief Appropriations Act of 2013 (DRAA13) Sandy Supplemental funds. The schedule approved under the 3x3x3 exemption established a signed Chief's Report date of 01 March 2024.

The feasibility study is broken into 4 segments: Scoping, Alternatives Evaluation and Analysis, Feasibility Analysis of Selected Plan and Washington Level Review (Figure 1-1). The Alternatives Milestone Meeting (AMM) was achieved on 22 November 2019. The DC Coastal Study has completed segment 2 with the confirmation of the Tentatively Selected Plan (TSP) at the milestone meeting held on 29 March 2022. The PDT is working on Segment 3 and the next milestone is the Agency Decision Milestone (ADM) scheduled for 01 November 2022.

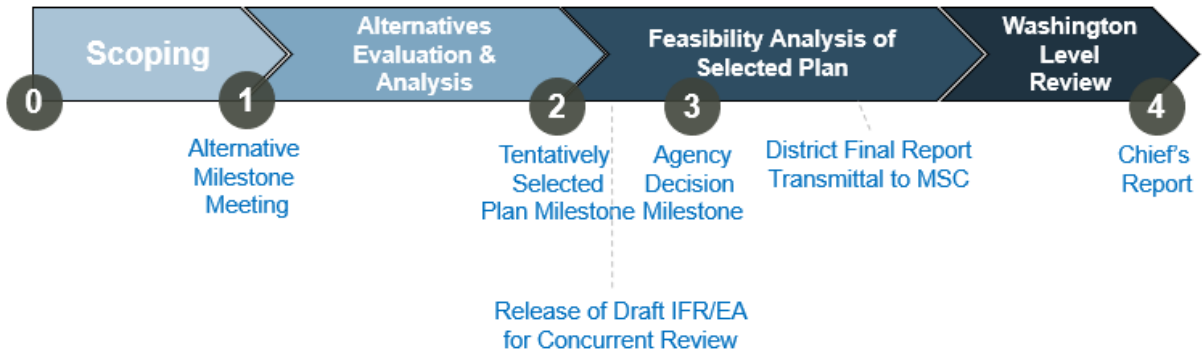

Figure 1-1. Feasibility Study Timeline

This IFR/EA was prepared in accordance with the Principles and Guidelines for Water and Land Related Resources Implementation Studies (P&G) and Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook (PGN) 22 April 2000 and follows the Final Feasibility Report Format and Content Guide 26 October 2021. To ensure sound decisions are made with respect to the development of alternatives, and with respect to plan selection, the plan formulation process requires a systematic and repeatable approach. This IFR/EA includes all NEPA sections for an EA, marked with an (*). This IFR/EA presents the CSRM problem to be addressed by the study, lays out the plan formulation process leading to the final array of alternatives, discusses the existing and future with and without project conditions, evaluates environmental effects and consequences of the alternatives, and explains the decision leading to the selection of the Tentatively Selected Plan (TSP).

1.3 Study Authority

The study authority is a resolution of the U.S. Senate Committee on Environment and Public Works, dated 23 May 2001:

> *"That the Secretary of the Army is requested to review the report of the Chief of Engineers on the Potomac River and Tributaries in Maryland, Virginia, and Pennsylvania published in House Document 343, ninety-first Congress, second session, and other pertinent reports, with a view to conducting a study, in cooperation with the States of Maryland and West Virginia, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia, their political subdivisions and agencies and instrumentalities thereof, other Federal agencies and entities, for improvements in the interest of the ecosystem restoration and protection, flood plain management, and other allied purposes for the middle Potomac River watershed."*

This study authority was identified by the Baltimore District Office of Counsel (memorandum dated 22 April 2014) as the most recent authority that includes the study area, with the ability to investigate solutions to coastal flooding problems leading to a USACE recommendation for implementation. Although the study authority also identifies ecosystem restoration, this study will focus solely on CSRM. This study is an interim response to the study authority.

1.4 Study Area (Planning Area)

The Middle Potomac River watershed encompasses approximately 11,500 square miles, including a diverse landscape, with urban, rural, and natural areas in six different eco-regions and four states and D.C. The study area for the DC Coastal study encompasses

approximately 76 square miles and includes the Northern Virginia jurisdictions within the Middle Potomac watershed boundary, from Arlington County south to include a portion of Prince William County (Figure 1-2). Within the study area, the Virginia side of the Potomac River contains approximately 135 miles of Potomac River shoreline. The current population within the study area is approximately 155,000.

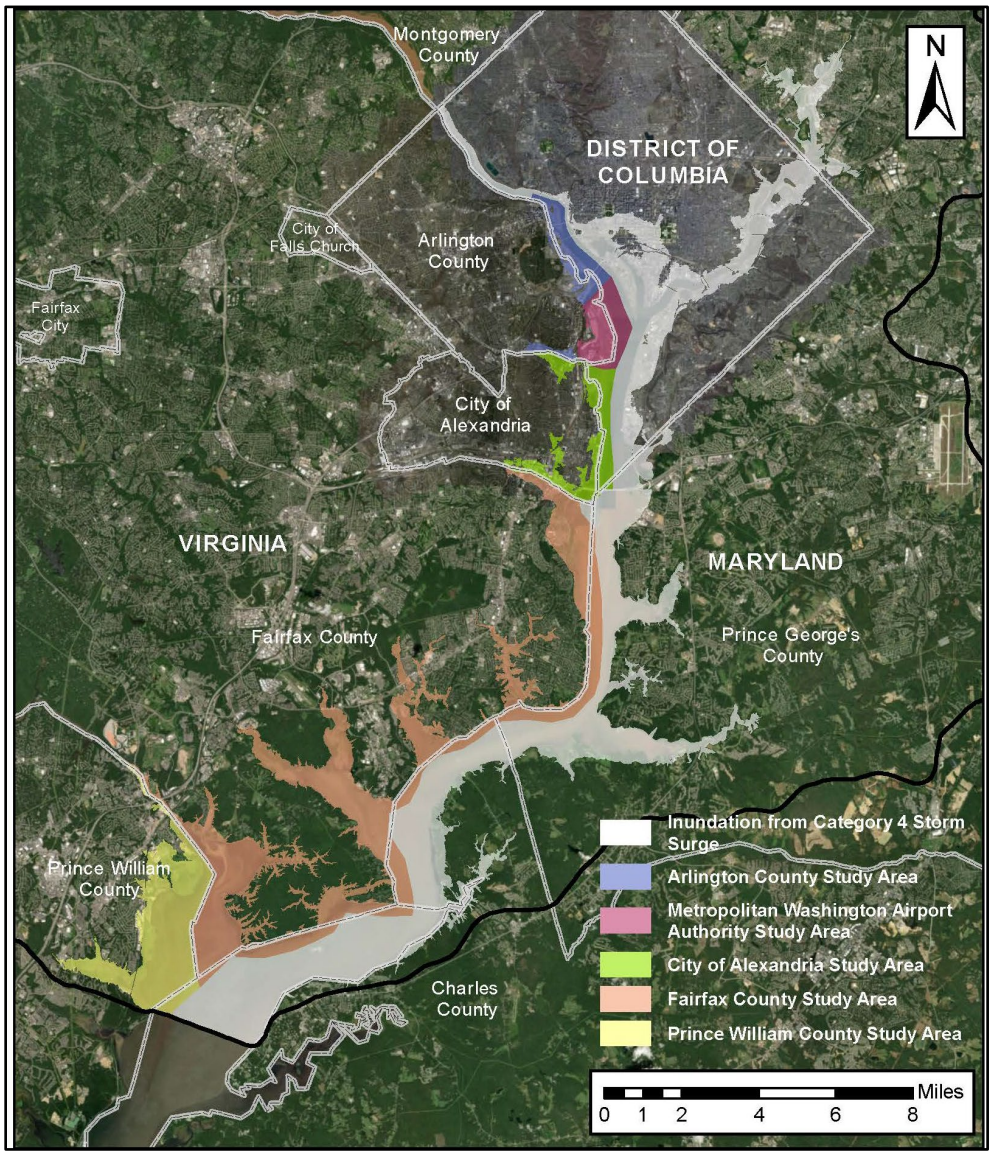

Figure 1-2. Study Area

1.5 Background and History

Following Hurricane Sandy in 2012, the USACE completed the North Atlantic Coast Comprehensive Study (NACCS), which identified nine high-risk areas on the Atlantic Coast that warranted further investigation of coastal FRM solutions. For a comprehensive

overview of NACCS, please refer to the NACCS Main Report, appendices, and associated study products at: https://www.nad.usace.army.mil/CompStudy/ (USACE, 2015).

The Metropolitan Washington, D.C. region, which includes portions of Washington, D.C., Maryland, and Virginia, was identified as one of the nine high-risk areas recommended by NACCS for a follow-on feasibility study to investigate solutions to coastal flooding problems.

1.6 Study Purpose and Need for Action*

The North Atlantic Coast is vulnerable to the impacts of coastal flooding and the potential for future, more devastating events due to rising sea levels. The NACCS identified the Washington, D.C., region including Northern Virginia, as an area at high risk to future coastal flooding problems. The Northern Virginia region supports densely populated areas encompassing trillions of dollars of largely fixed public, private, and commercial investment. Coastal communities in this region must begin to consider long-term coastal storm risk.

The purpose of the study is to evaluate the feasibility of Federal participation in the implementation of solutions to reduce long-term coastal flood risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources by considering future climate and sea level change scenarios to support resilient communities in Northern Virginia within the Middle Potomac River watershed.

The NAACS identified the Washington, D.C. region as an area at high risk to future coastal flooding problems. Northern Virginia has been impacted by numerous major tropical and extratropical events, most notably the Chesapeake and Potomac Hurricane of 1933, Hurricane Agnes (1972), Hurricane Fran (1996), Nor’easter (1998), Hurricane Floyd (1999), Hurricane Isabel (2003), Hurricane Irene (2011), and Hurricane Sandy (2012). Hurricane Isabel in 2003 resulted in extreme water levels and caused millions of dollars of damage to residences, businesses, and critical infrastructure in the study area. Coastal communities in this region must begin to consider long-term coastal storm risk.

1.7 Problems and Opportunities

The problems identified in the study area include concerns for life safety, economic damages, and critical infrastructure disruption resulting from storm surge inundation caused by coastal storms.

Problems within the study area include:

- Life safety: socially vulnerable populations may not be able to evacuate ahead of storm surge.
- Damage to residential, commercial, industrial, government, and aviation properties.
- Disruption to critical infrastructure and systems, including drinking water, wastewater, electric and gas transmission, communication services, and evacuation and transportation routes.
- Disruption to operations of the Federal Government, including national security.
- Damage to important cultural and historic properties.
- Developed shorelines with limited opportunity to minimize impacts to storm surge and wave attenuation or storage of floodwaters.
- Riverine flooding along the Potomac River and its tributaries exacerbates coastal flooding.

Opportunities exist in the study area to:

- Reduce vulnerability of coastal populations and properties to coastal storm impacts.
- Identify critical infrastructure vulnerabilities and improve resiliency of infrastructure to coastal storms.
- Increase public understanding of flood risk.
- Incorporate natural and nature-based features (NNBF) to reduce risk from storm surge inundation due to coastal storms and provide improved habitat.

1.8 Objectives and Constraints

The goal of the study is to support resilient communities by recommending actions to manage coastal storm risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources. All of the objectives listed below were evaluated over the 50-year period of analysis starting in 2031.

Objectives

- Reduce risk to human health and safety from coastal storm impacts in the study area.
- Reduce economic damages from coastal flooding in the study area to residential, commercial, industrial, and government buildings.
- Reduce disruption of critical infrastructure assets, services, and interdependent systems caused by coastal flooding in communities throughout the study area.

- Improve the resiliency of critical infrastructure in the study area to impacts from coastal storms.

Constraints

In consideration of the management of coastal storm risk, plans must avoid:

- Impacts to national security operations (e.g., Pentagon, Fort Belvoir).
- Exacerbating flooding in other portions of the study area or along the Potomac River in Maryland or D.C.

In consideration of the management of coastal storm risk, plans must minimize:

- Impacts to the operation of Ronald Reagan Washington National Airport (DCA).
- Impacts to the George Washington Memorial Parkway (GWMP) and other existing infrastructure.
- Impacts to historic properties, including the viewshed and character of historic structures and districts.

1.9 Study Scope

ER 1105-2-100, Planning Guidance Notebook (PGN) defines the contents of feasibility reports for CSRM. This IFR/EA documents the studies and coordination conducted to determine whether the Federal government should participate in CSRM in Northern Virginia. Studies of potential CSRM consider a wide range of alternatives and environmental consequences of those alternatives but focus mainly on coastal storm risk and flooding. Reducing the risk of inundation from coastal flooding is important in Northern Virginia because this area includes critical infrastructure and national security infrastructure that is important to the nation's capital and the region.

The study authority includes the Middle Potomac River watershed and tributaries. The study was scoped to include Northern Virginia within the Middle Potomac River watershed. This study will evaluate coastal storm inundation and damages within the tidally-influenced reach of the Potomac River and its tributaries. The study scope is to recommend a CSRM plan that would reduce coastal storm risk for Northern Virginia. The study will examine and evaluate structural, nonstructural, and NNBF measures to address coastal storm risk within the study area. Section 3 includes the plan formulation and evaluation of measures and alternatives.

1.10 Prior Studies and Reports

An extensive set of prior reports for this study area have been completed, including those produced by USACE and other agencies and jurisdictions. These primarily include reports produced for studies of known flooding problems in the region, including at Four Mile Run,

Cameron Run, Alexandria, and Belle Haven. The most recent studies relevant to the evaluation of CSRM within the study area are included below (Table 1-1).

Table 1-1. Existing Reports Relevant to the Study Area

Title	Author (Planning Unit)	Date
Washington, D.C. Flood Risk Management Project Limited Reevaluation Report	USACE	2018
Resilient Critical Infrastructure: A Roadmap for Northern Virginia	NVRC (Northern Virginia Regional Commission) and MWCOG	2018
Northern Virginia Hazard Mitigation Plan	Northern Virginia jurisdictions	2017
Preliminary Engineering for Flood Mitigation Implementation Project	Stantec Consulting (Old Town Alexandria)	2016
North Atlantic Coast Comprehensive Study	USACE	2015
Hurricane Surge Barrier Study for Washington, D.C.	CH2MHILL	2015
Cameron Run/Holmes Run Feasibility Study Summary Report	USACE (Cameron Run)	2014
Description and Comparison of Flood Risk Management Plans along and adjacent to the GWMP	USACE (Belle Haven)	2014
Final Dyke Marsh Wetland Restoration and Long-Term Management Plan/EIS	USACE (Belle Haven)	2014
Middle Potomac River Watershed Assessment	USACE	2014
Sustainable Shorelines and Community Management in Northern Virginia Phase III	NVRC*	2013
City of Alexandria Waterfront Small Area Plan	City of Alexandria (Old Town Alexandria)	2012
City of Alexandria, Potomac River Waterfront Flood Mitigation Study	URS Corporation (Old Town Alexandria)	2010
Huntington Flood Damage Reduction Study	USACE (Cameron Run)	2009
Flood Damage Reduction Analysis for Belle Haven Watershed, Fairfax County, VA	USACE (Belle Haven)	2008
Four Mile Run Watershed, Virginia, Section 905(b) Analysis	USACE (Four Mile Run)	2002
New Alexandria Flood Relief Feasibility Study	USACE (Belle Haven)	1980
Survey Report, Potomac River Streams Draining Alexandria Area (Cameron Run Basin)	USACE (Cameron Run)	1977
Cameron Run, City of Alexandria and Fairfax County, Virginia, Review Report on Flood Control	USACE (Cameron Run)	1971
Four Mile Run Chief of Engineer's Report	USACE (Four Mile Run)	1970
Four Mile Run, City of Alexandria & Arlington County, Virginia: Review Report on Flood Control	USACE (Four Mile Run)	1969
Hurricane Survey: Washington, D.C. Metropolitan Area	USACE	1963

2 Existing and Future Without Project Conditions (FWOP)*

This section describes the Existing Conditions, as well as a forecast of the FWOP Conditions, that together provide a basis for plan formulation discussed in Section 3. The Existing Conditions and the FWOP Conditions provide a description of the human environment, which is subdivided into the natural, physical, economic, and built environments. The Existing Conditions represent the Affected Environment for NEPA purposes. The Existing and FWOP Conditions serve as a baseline that are compared to the Future With Project (FWP) Condition to evaluate and compare the alternative plans. This comparison is integral to the selection of the TSP (Section 6).

2.1 Period of Analysis

The period of analysis for this study is 50-years per ER 1105-2-100 Planning Guidance Notebook. The planning horizon starts in baseline year 2031, when the project is anticipated to begin accruing FRM benefits and ends in year 2080. Existing conditions reflect the conditions in place during the feasibility study through year 2024. FWOP conditions consider a range of activities from year 2021, the most recent year for which complete data was obtained, and projects that are planned to be implemented or are already underway that would be constructed in the absence of this project. FWP Conditions are the conditions forecasted during the planning horizon, from years 2031 to 2080 with implementation of the TSP. The TSP will also be assessed for engineering and environmental performance out to 100 years from the baseline year to ensure coastal sustainability of the TSP and adaptation to sea level rise (SLR).

2.2 General Setting

The study area is located south and west of Washington, D.C. along the west side of the Potomac River in Northern Virginia. The study area is located in a densely populated urban setting that is primarily residential, but also includes commercial districts, industrial facilities, military installations, and transportation infrastructure as well as natural areas, green spaces, and historic properties. Notable features include the GWMP that runs along the west side of the Potomac River, the Reagan National Airport located in Arlington, Virginia, and the Dyke Marsh Wildlife Preserve (Dyke Marsh), a 380-acre tidal freshwater wetland located on the west bank of the Potomac River in Fairfax County, Virginia. The region’s historic and cultural sites include the historic districts at Old Town Alexandria and the Town of Occoquan, George Washington’s Mount Vernon Estate, and the GWMP. The Mount Vernon Trail is an important cultural and recreational resource. The general setting of the study area is not expected to change under the FWOP Condition.

2.3 Natural Environment*

2.3.1 Wetlands

2.3.1.1 Existing Condition

Wetlands historically lined the Potomac River, the Old Town Alexandria waterfront, Hunting Creek, and Cameron Run. Although most of these wetlands are gone, several large managed wetland areas still remain in the study area including Dyke Marsh, Mason Neck's Great Marsh, and the Occoquan Bay National Wildlife Refuge (NWR). The National Park Service (NPS) recently completed a project to stabilize portions of Dyke Marsh that were rapidly eroding. A breakwater and stone stills were constructed along the edge of the existing marsh to protect it from further erosion and to re-establish the marsh's ability to naturally regenerate (NPS, 2018).

Although the region is highly developed, small wetlands are scattered throughout the study area, many of which line the tributaries and creeks of the Potomac River. Wetlands in the study area include freshwater and palustrine forested, shrub, and emergent wetlands. Palustrine wetlands occur in tidal areas where the salinity due to ocean-derived salts is below 0.5 parts per thousand (Cowardin et al., 1979; Chesapeake Bay Program (CBP), 2019).

A wetland delineation was performed by USACE in July 2021 within areas adjacent to Four Mile Run in Arlington County and the City of Alexandria, as well as in Belle Haven, located in Fairfax County. All delineated wetlands were classified into systems and subsystems according to the *Classification of Wetlands and Deep-Water Habitats of the United States* (Cowardin et al., 1979). Various wetland types such as palustrine emergent, palustrine forested, and riverine systems were identified and delineated. Further details regarding the wetland delineation are located in the *Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study Wetland Delineation Report* (see Appendix G).

The City of Alexandria completed a Tidal Restoration Demonstration Project in 2016 to restore the shoreline and wetlands in the channelized portions of Four Mile Run from Mount Vernon Avenue to Route 1 (City of Alexandria, 2020). The City of Alexandria also completed the Windmill Hill Park and Living Shoreline Project in 2018, which involved replacing a dilapidated concrete bulkhead with a living shoreline at the Windmill Hill Park Waterfront (City of Alexandria, 2018).

The Reagan National Airport property is perched upon fill material that was placed along the west bank of the Potomac River in the late 1930s (MWAA, 2021). The airport property is a highly developed and landscaped environment with no natural/unmaintained areas (T. Wasaff, personal communication, January 6, 2022).

2.3.1.2 FWOP Condition

Wetlands located on managed conservation lands or lands protected under a conservation easement are expected to retain their natural and historic value in the future unless they are low-lying and threatened by SLR. A majority of the wetlands in the study area appear to be located on managed/protected conservation lands (VADCR, 2018). Wetlands in the study area that are not protected are threatened by pressures from future development.

SLR poses a threat to low-lying wetlands along the Potomac River and its tributaries (NPS, 2021). In addition to providing food and habitat for wildlife, water quality improvements, flood storage, and recreational opportunities, wetlands act as natural buffers that protect inland communities from flooding and erosion. Tidal gauges in the Chesapeake Bay indicate that SLR in the Bay is twice the average global rate of 2.8 millimeters per year (NPS, 2014). An NPS report that used data from the National Oceanic and Atmospheric Administration (NOAA) and the United Nations Intergovernmental Panel on Climate Change (IPCC) projected that shorelines in the NPS National Capital Region may experience the highest rate of SLR of all NPS regions in the next century. Wetlands must build up sediment to keep up with SLR. Low-lying wetlands along the Potomac River and its tributaries could become inundated with water if the rate of SLR outpaces the sediment build-up. A high rate of SLR may cause existing vegetation to change or disappear if continuously inundated with water (NPS, 2021).

2.3.2 Floodplains

2.3.2.1 Existing Condition

Natural floodplains provide flood risk reduction benefits by slowing runoff and storing flood water. Floodplains frequently contain wetlands and provide benefits to the natural environment including fish and wildlife habitat, natural erosion control, surface water quality maintenance, and groundwater recharge (USGS, 2016). Most of the existing regulatory floodplain (100-year floodplain) in the Potomac River (FEMA, 2021) located in Arlington County and the City of Alexandria is developed. Development in the floodplain has led to degradation and loss of natural floodplain functions as well as the habitat that the natural floodplain provides (USGS, 2016). Developed areas located in the floodplain include portions of the Pentagon parking areas, the GWMP, the Reagan National Airport, Old Town Alexandria, and highway infrastructure along Cameron Run. The Belle View/New Alexandria community in Fairfax County (Belle Haven) is also located in a floodplain. The most common flooding problem in this region is due to summer thunderstorms with high-intensity short duration rainfall. The tidal influence of the Potomac River, in conjunction with development in low-lying areas, as well as overtaxed

stormwater systems are contributing factors to flooding (City of Alexandria, Virginia, 2022a).

A majority of the floodplain in the southern part of the study area (Fairfax County south of Belle View and Prince William County) is undeveloped and natural. These natural floodplains are located in Dyke Marsh, Little Hunting Creek, Accotink and Pohick Bays, and in the Mason Neck NWR.

2.3.2.2 FWOP Condition

The floodplain is expected to move inland as sea level rises. Refer to Appendix B for maps of the 1 percent and 0.2 percent annual exceedance probability inundation areas for year 2031. These maps are available for the following locations in the study area: Reagan National Airport, Old Town Alexandria, Four Mile Run Park, Arlington Water Pollution Control Plant, and Belle Haven.

2.3.3 Submerged Aquatic Vegetation (SAV)

2.3.3.1 Existing Condition

Submerged aquatic vegetation (SAV) including hydrilla (*Hydrilla verticillata*), spiny naiad (*Najas minor*), coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera dubia*), wild celery (*Vallisneria americana*), and southern naiad (*Najas guadalupensis*) are found in the tidal portions of the study area. SAV is located along the western shoreline of the Potomac River, south of the airport at the entrance to Four Mile Run and Cameron Run, in Dyke Marsh, in Gunston Cove south of Fort Belvoir, and in Occoquan Bay. SAV is located in the main stem of the Potomac River (outside of the main navigation channel) from the airport to south of the Woodrow Wilson Bridge (VIMS, 2022a).

2.3.3.2 FWOP Condition

High-quality habitat conditions for SAV including shallow water with sufficient water quality/clarity, appropriate wave and current conditions, and healthy sediment are vital to sustain and increase SAV in the study area. Habitat conditions are impacted by additional factors including stressors associated with climate change. Because most of the shoreline in the study area is either modified/hardened or has steep shoreline elevations, SAV would not be able to migrate inland as water levels rise. Indirect impacts from localized water quality degradation resulting from activities such as shoreline alteration and sedimentation from changes in land use could also influence the health of SAV. The Chesapeake Bay Management Strategy for 2015 to 2025 outlines current efforts and gaps that influence the success of SAV recovery and restoration throughout the Chesapeake Bay Watershed (Chesapeake Bay Program, 2015).

2.3.4 Threatened and Endangered Species

2.3.4.1 Terrestrial and Freshwater Species

2.3.4.1.1 Existing Condition

Table 2-1 identifies species [under the jurisdiction of U.S. Fish and Wildlife Services (USFWS)] listed and proposed under Section 7 of the Endangered Species Act (ESA), as well as state-listed species, that have the potential to be present in the study area. This list was obtained from the following sources:

- Fish and Wildlife Planning Aid Report (PAR) prepared by the USFWS (dated January 2021) for this study (USFWS, 2021b) (see Appendix G)
- USFWS Information for Planning and Consultation (IPaC) species list dated March 10, 2022, from the Virginia Ecological Services Field Office (USFWS, 2021c) (see Appendix G)
- USFWS Environmental Conservation Online System (ECOS) (USFWS, 2022)
- Virginia Department of Wildlife Resources (formerly the Virginia Department of Game and Inland Fisheries) Fish and Wildlife Information Search (VaFWIS database) (VADWR, 2021a)

Each species was further assessed to determine if suitable habitat conditions are present in the study area to support each species (far right column in Table 2-1). These assessments are located in the *Section 7 of the Endangered Species Act No Effect Determination for Terrestrial and Freshwater Species, Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study* (see Appendix G). Based on these assessments, it is highly unlikely that most species shown in Table 2-1 would be present in the study area. Although uncommon, the state-listed peregrine falcon and the Henslow's sparrow have the potential to occur in the study area. It is likely that the monarch butterfly, a federal candidate species, could occur in the study area during its migration period from mid to late September. Although rare, the small whorled pogonia, a federal and state-listed plant, has the potential to occur in upland mixed hardwood forests in the study area.

Table 2-1. Listed and Proposed Freshwater and Terrestrial Species that have the Potential to be Present in the Study Area

SPECIES	GROUP	FEDERAL LISTING STATUS	STATE LISTING STATUS	PRESENCE IN THE STUDY AREA
Northern Long-eared Bat (*Myotis septentrionalis*)*	mammal	threatened	threatened	No known hibernaculum or maternity roosts
Little Brown Bat (*Myotis lucifugus*)*	mammal	under review	endangered	No known hibernaculum or maternity roosts
Tri-colored Bat (*Perimyotis subflavus*)*	mammal	under review	endangered	No known hibernaculum or maternity roosts
Eastern Black Rail (*Laterallus jamaicensis ssp. jamaicensis*)*	bird	threatened	not listed	Highly unlikely
Peregrine Falcon (*Falco peregrinus*)*	bird	not listed	threatened	Uncommon
Loggerhead Shrike (*Lanius ludovicianus*)*	bird	not listed	threatened	Highly unlikely
Migrant loggerhead Shrike (*Lanius ludovicianus migrans*)	bird	not listed	threatened	Highly unlikely
Henslow's Sparrow (*Centronyx henslowii*)*	bird	not listed	threatened	Uncommon
Dwarf Wedgemussel (*Alasmidonta heterodon*)*	mollusk	endangered	not listed	Highly unlikely
Yellow Lance (*Elliptio lanceolata*)*	mollusk	threatened***	threatened	Highly unlikely
Brook Floater (*Alasmidonta varicose*)**	mollusk	not listed	endangered	Highly unlikely
Monarch Butterfly (*Danaus plexippus*)*	insect	candidate	not listed	Likely from mid to late Sept
Appalachian Grizzled-skipper (*Pyrgus wyandot*)*	insect	not listed	threatened	Highly unlikely
Wood Turtle (*Glyptemys insculpta*)*	reptile	under review	threatened	Highly unlikely
Small Whorled Pogonia (*Isotria medeoloides*)	plant	threatened	endangered	Rare, but could occur in upland mixed hardwood forests

*Species identified in the Virginia Wildlife Action Plan and on-the-ground management strategies/actions exist and can be feasibly implemented for these species.
**Species identified in the Virginia Wildlife Action Plan and on-the-ground actions or research needs have been identified but cannot feasibly be implemented at this time.
***Listed as threatened by the USFWS but not included in the IPaC species list generated for the study area.

2.3.4.1.2 FWOP Condition

Habitats in low-lying areas may be degraded or lost from inundation due to SLR. Future development in the region could reduce the availability of suitable habitat for threatened and endangered species.

2.3.4.2 Marine and Anadromous Species

2.3.4.2.1 Existing Condition

Table 2-2 identifies species [under the jurisdiction of NOAA Fisheries] listed under Section 7 of the ESA that are known to occur in tidal waters of the study area. This list was obtained from the Greater Atlantic Region ESA Section 7 Mapper and text descriptions located in the mapper (NOAA, 2021a). Based on the mapper, various life stages of the endangered Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and the endangered shortnose sturgeon (*Acipenser brevirostrum*) have been known to occur at certain times of the year in the following locations in the study area: Potomac River, Cameron Run, Little Hunting Creek, Dogue Creek, Gunston Cove, Pohick Bay, Accotink Bay, Occoquan Bay, Belmont Bay, and the Occoquan River. The Potomac River is also designated as critical habitat for the endangered Chesapeake Bay distinct population segment (DPS) of the Atlantic sturgeon.

Table 2-2. Listed Marine and Anadromous Species that are Known to Occur in the Study Area

SPECIES	GROUP	FEDERAL LISTING STATUS	STATE LISTING STATUS	PRESENCE IN THE STUDY AREA		CRITICAL HABITAT
				LIFE STAGE	TIME OF YEAR	
Atlantic Sturgeon *(Acipenser oxyrinchus oxyrinchus)*	fish	All five distinct population segments (DPS) are listed as either threatened or endangered	endangered	Eggs and yolk-sac larvae	Mar 15 to Nov 30	yes – Chesapeake Bay DPS
				Post yolk-sac larvae (migrating and foraging)	Mar 15 to July 15; Aug 1 to Jan 31	
				Young-of-year (YOY) (migrating and foraging)	Jan 1 to Dec 31	
				Juvenile (migrating and foraging)	Jan 1 to Dec 31	
				Subadult (migrating and foraging)	Mar 15 to Nov 30	
				Adult (spawning)	Mar 15 to May 15; Aug 1 to Nov 30	
				Adult (migrating and foraging)	Mar 15 to Nov 30	

Table 2-2. Cont'd. Listed Marine and Anadromous Species that are known to Occur in the Study Area

SPECIES	GROUP	FEDERAL LISTING STATUS	STATE LISTING STATUS	PRESENCE IN THE STUDY AREA		CRITICAL HABITAT
				LIFE STAGE	TIME OF YEAR	
Shortnose Sturgeon ***(Acipenser brevirostrum)***	fish	endangered	endangered	Post yolk-sac larvae	Mar 15 to June 30	no
				YOY (migrating and foraging)	Jan 1 to Dec 31	
				Juvenile (migrating and foraging)	Jan 1 to Dec 31	
				Adult (migrating and foraging)	Jan 1 to Dec 31	

2.3.4.2.2 FWOP Condition

Conservation and management strategies have been developed by NOAA Fisheries for the Atlantic sturgeon and the shortnose sturgeon. Recovery of Atlantic sturgeon and shortnose sturgeon populations would take partnerships between state and federal agencies, the scientific community, and the public.

2.3.5 Essential Fish Habitat

2.3.5.1 Existing Condition

The Essential Fish Habitat (EFH) Mapper was used to identify species that may have EFH in the study area. The EFH Mapper identified the little skate (*Leucoraja erinacea*) (adult), winter skate (*Leucoraja ocellata*) (adult), clearnose skate (*Raja eglanteria*) (juvenile, adult), Atlantic herring (*Clupea harengus*) (juvenile, adult), red hake (*Urophycis chuss*) (eggs, larvae, juvenile, adult), windowpane flounder (*Scophthalmus aquosus*) (juvenile), bluefish (*Pomatomus saltatrix*) (juvenile, adult), and the summer flounder (*Paralichthys dentatus*) (juvenile, adult) as having potential EFH in the study area (NOAA, 2021b). EFH source documents were used to determine if suitable habitat conditions are present in the study area to support these species (Packer et al., 2003a, 2003b, 2003c; Reid et al., 1999; Steimle et al., 1999; Chang et al., 1999; Fahay et al., 1999; Packer et al., 1999). Due to unsuitable habitat conditions (low salinity in this portion of the Potomac River (0 to 0.5 parts per thousand (CBP, 2019)), it was determined that the study area does not provide EFH for these species. Since there is no EFH in the study area, the FWOP condition and environmental consequences (Section 4) are not evaluated for EFH.

2.3.6 Anadromous Fish

2.3.6.1 Existing Condition

Anadromous fish are fish that migrate from saltwater to freshwater to spawn. Anadromous fish spend the majority of their life at sea and only enter freshwater in the late winter/spring to spawn. Anadromous fish that may be present in the tidal waters of the study area during the spawning period and the specific spawning time for each species are shown in Table 2-3. Information on anadromous fish was obtained from the Maryland Department of Natural Resources (MDDNR) because the State of Maryland owns the Potomac River in the location of the study area up to the mean low water line (MDDNR, n.d.-a and n.d.-b).

Table 2-3. Anadromous Fish Species that may be Present in the Study Area

Species	Spawning Time
Alewife Herring (*Alosa pseudoharengus*)	late February through April
Blueback Herring (*Alosa aestivalis*)	late March through mid-May
American Shad (*Alosa sapidissima*)	mid-April through early June
White Perch (*Morone americana*)	April through June
Striped Bass *(Morone saxatilis*)	April, May, and early June
Atlantic Sturgeon (*Acipenser oxyrinchus*)	May or June

2.3.6.2 FWOP Condition

Ongoing efforts by the MDDNR and the Chesapeake Bay Program's Fish Passage Workgroup to improve fish passage in the region, as well as the State of Maryland fishing regulations can support the restoration of anadromous fish populations in the region (MD DNR, n.d.-c; CBP, 2022; eRegulations, n.d.).

2.3.7 Migratory Birds

2.3.7.1 Existing Condition

An IPaC search generated 25 species of migratory birds that may be present in the study area, 23 of which are considered Birds of Conservation Concern (BCC). A BCC designation can be assigned for any of the following reasons: documented or apparent population declines; small or restricted populations; dependence on restricted or vulnerable habitats; or overabundant to the point of causing ecological and economic damage. Birds are given the BCC designation within certain Bird Conservation Regions. The study area falls within the New England/Mid-Atlantic Coasts Bird Conservation Region (USFWS, 2021b).

To determine the known presence of the 25 migratory birds in the study area, eBird was searched for observations made at Gravelly Point (Reagan National Airport), Dyke Marsh, and Four Mile Run Park from 2000 to 2020 (The Cornell Lab of Ornithology, n.d.). The Friends of Dyke Marsh bird list was also used as it contains best available data for the area in the form of a 40-year-long compiled list of 296 species seen at Dyke Marsh (Friends of Dyke Marsh, 2021). Table 2-4 lists the 25 bird species generated by IPaC, identifies whether a species is designated as a BCC, known presence at the three locations in the study area with observation data (Gravelly Point, Dyke Marsh, and Four Mile Run Park), and the breeding season. A more detailed description of each migratory bird species is located in the PAR (Appendix G).

Table 2-4. Migratory Bird species with Known Presence in the Study Area

SPECIES	BIRD OF CONSERVATION CONCERN	PRESENCE IN STUDY AREA	BREEDING SEASON
Bald Eagle (*Haliaeetus leucocephalus*)	No	All	Oct. 15 to Aug. 31
Black-billed Cuckoo (*Coccyzus erythropthalmus*)**	Yes	All	May 15 to Oct. 10
Bobolink (*Dolichonyx oryzivorus*)	Yes	All	May 20 to July 31
Canada Warbler (*Cardellina canadensis*)**	Yes	All	May 20 to Aug. 10
Cerulean Warbler (*Dendroica cerulea*)*	Yes	Gravelly Point, Four Mile Run	Apr. 29 to July 20
Dunlin (*Calidris alpina arcticola*)*	Yes	All	Breeds elsewhere
Eastern Whip-poor-will (*Antrostomus vociferus*)*	Yes	All	May 1 to Aug. 20
Golden Eagle (*Aquila chrysaetos*)*	No	Gravelly Point, Four Mile Run	Breeds elsewhere
Golden-winged Warbler (*Vermivora chrysoptera*)*	Yes	Four Mile Run	May 1 to July 20
Hudsonian Godwit (*Limosa haemastica*)	Yes	Belle Haven	Breeds elsewhere
Kentucky Warbler (*Oporornis formosus*)*	Yes	All	Apr. 20 to Aug. 20
Least Tern (*Sterna antillarum*)*	Yes	All	Apr. 20 to Sep. 10
Lesser Yellowlegs (*Tringa flavipes*)	Yes	All	Breeds elsewhere
Prairie Warbler (*Dendroica discolor*)	Yes	All	May 1 to July 31

Table 2-4. Cont. Migratory Bird Species with Known Presence in the Study Area

SPECIES	BIRD OF CONSERVATION CONCERN	PRESENCE IN STUDY AREA	BREEDING SEASON
Prothonotary Warbler (*Prothonotary warbler*)	Yes	All	Apr. 1 to July 31
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	Yes	All	May 10 to Sep. 10
Red-throated Loon (*Gavia stellata*)*	Yes	All	Breeds elsewhere
Ruddy Turnstone (*Arenaria interpres morinella*)	Yes	All	Breeds elsewhere
Rusty Blackbird (*Euphagus carolinus*)**	Yes	All	Breeds elsewhere
Semipalmated Sandpiper (*Calidris pusilla*)	Yes	All	Breeds elsewhere
Short-billed Dowitcher (*Limnodromus griseus*)*	Yes	All	Breeds elsewhere
Snowy Owl (*Bubo scandiacus*)	Yes	Gravelly Point, Four Mile Run	Breeds elsewhere
Whimbrel (*Numenius phaeopus*)*	Yes	All	Breeds elsewhere
Willet (*Tringa semipalmata*)*	Yes	All	Apr. 20 to Aug. 5
Wood Thrush (*Hylocichla mustelina*)**	Yes	All	May 10 to Aug. 31

*Species identified in the Virginia Wildlife Action Plan and on-the-ground management strategies/actions exist and can be feasibly implemented for these species.
**Species identified in the Virginia Wildlife Action Plan and on-the-ground actions or research needs have been identified but cannot feasibly be implemented at this time.

2.3.7.2 FWOP Condition

Habitats in low-lying areas may be degraded or lost to inundation due to SLR. Future development in the region could reduce the availability of suitable habitat for migratory birds.

2.4 Physical Environment*

2.4.1 Waterways and Hydrology

2.4.1.1 Existing Condition

Waterways within the study area include the Potomac River and tributaries of the Potomac River including Four Mile Run, Cameron Run, Little Hunting Creek, Dogue Creek, Gunston Cove, and Belmont Bay. Smaller streams also drain into the Potomac River and its tributaries. Location maps and descriptions of the waterways in Four Mile Run Park and Belle Haven can be found in the following reports located in Appendix G: *Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study Wetland Delineation Report* (USACE, 2021) and the *Final Flood Damage Reduction Analysis for Belle Haven Watershed, Fairfax County, Virginia* (USACE, 2008).

The study area is located in the Middle Potomac River watershed. Normal flow conditions in streams and wadeable rivers in the watershed are considered to be similar to those found in heavily forested watersheds. Although the study area is not heavily forested today, prior to European settlement, the region was historically covered with mature forests consisting of oak, cedar, and chestnut. Over the last three centuries, normal flow conditions have been directly altered due to impoundments, withdrawals, and discharges, and indirectly through alterations in the landscape (USACE et al., 2014).

2.4.1.2 FWOP Condition

Future hydrology in the study area depends on changes in land and water use in the Middle Potomac River watershed. The extent of impervious surfaces and urbanization, stormwater management practices, losses/gains of wetlands and floodplains, and the quantity of water withdrawals relative to discharges all effect the future hydrology of the watershed. The *Middle Potomac River Watershed Assessment: Potomac River Sustainable Flow and Water Resources Analysis* discusses the alteration in hydrology and water flows in the Middle Potomac River watershed under future scenarios (USACE, 2008).

USACE modeled the water surface elevations (WSEL) under the FWOP condition up to the year 2075. The modeled WSELs were adjusted for anticipated changes due to SLR for another 5 years through year 2080. Further information on the WSEL modeling and a

qualitative description of climate change impacts to inland hydrology in the study area is provided in Appendix B.

Stream erosion and stream sedimentation are accelerated due to concentrated points of stormwater runoff. To mitigate some of these affects, Arlington County, Fairfax County, and the City of Alexandria have identified opportunities for both structural and non-structural improvement projects such as stream restoration, stormwater facility retrofits, community education and stewardship, streamside buffer enhancements, and installation of green stormwater infrastructure (Arlington County, 2014; Fairfax County, 2011; City of Alexandria, 2021).

2.4.2 Historic Climate and Precipitation

2.4.2.1 Existing Condition

The D.C. and Commonwealth of Virginia climate is changing. The region has warmed by more than two degrees Fahrenheit (F) in the last century, hot days and heavy rainstorms are more frequent, and the tidal Potomac is rising about one inch every eight years. In the coming decades, changing climate is likely to increase tidal flooding, cause more heavy rainstorms and sewer overflows, and increased risks to human health.

Warming rates on the northeast continental shelf have been higher than experienced in other ocean regions, and climate projections indicate that warming in this region will continue to exceed rates expected in other ocean regions. Since 1950, there has been no notable trend in the total annual number of extremely hot days (maximum temperature above 100°F) in D.C. However, from 2010 to 2014, D.C. averaged 12 very warm nights (nighttime minimum temperature greater than 75°F) per year compared to the 1950 to 2009 average of three very warm nights per year. NOAA reported that temperatures have risen approximately 1.5°F in the Commonwealth of Virginia since the beginning of the 20th century. The 1930s and 1950s were very warm, followed by a period of generally below average temperatures during the 1960s through early 1980s. More information on historic climate and precipitation can be found in Appendix B.

Although the 5-year average highest number of very hot days (maximum temperature above 95°F) and corresponding number of very warm nights (minimum temperature above 75°F) occurred in the early 1930s, gradual warming has occurred since the early 1990s. Average annual temperatures during the 21st century (2000 to 2014) have exceeded the previous highs of the 1930s. A winter warming trend is reflected in the below average number of very cold nights (minimum temperature below 0°F) since 1990.

2.4.3 Water Quality

2.4.3.1 Existing Condition

Potomac River Water Quality in Metropolitan Washington, an MWCOG Report, provides a broad overview of water quality conditions in the Potomac River, particularly the portion that flows through Metropolitan Washington. The Potomac River estuary is the focus of the report and where the study area is located (MWCOG, 2019).

Water quality in the Potomac River estuary is affected by three major water pollution inputs: wastewater treatment plant discharges into the river; stormwater runoff and other non-point discharges from urban development; and water flowing from the non-tidal portion of the river into the Potomac River estuary, which is heavily impacted by agriculture. Local governments and water utilities in the region are making progress in reducing the amount of nutrients discharged from wastewater treatment plants. Nitrogen and phosphorus (which in excess contribute to water quality problems) contained in the discharge from wastewater treatment plants has declined since the 1980s. There has also been some progress in achieving reductions from other nutrient sources (MWCOG, 2019).

Water quality data collected from the Potomac River estuary and the Chesapeake Bay since 1985 provides a picture of mixed progress in improvement of water quality in the region. For three of the Chesapeake Bay total maximum daily load (TMDL) major water quality standards – dissolved oxygen (DO), water clarity, and chlorophyll-a, data show that in some areas of the Potomac River estuary water quality is improving and in other areas it is degrading. In some areas of the estuary, water quality meets the current standards set by Maryland, Virginia, and D.C., and in other areas it does not. However, signs of improvement in overall DO levels indicates that efforts to improve water quality are having an impact (MWCOG, 2019).

Four Mile Run flows through residential areas and urban corridors in south and western Arlington County (Arlington County Virginia, 2022). Four Mile Run is impaired for fecal coliform bacteria and PCB contamination (polychlorinated biphenyls – a highly toxic industrial compound) in fish tissue (Northern Virginia Regional Commission, n.d.-a). Major sources of identifiable bacteria in Four Mile Run are urban wildlife (waterfowl and raccoons), humans, and dogs. A TMDL for fecal coliform bacteria has been developed for Four Mile Run and a management strategy for controlling anthropogenic sources of bacteria to the waterway has been created (Arlington County Virginia, 2022). A TMDL for PCB contamination in fish tissue has not yet been developed (Northern Virginia Regional Commission, n.d.-a). Arlington County is currently conducting a Watershed Retrofit Study to add stormwater facilities to areas that currently do not have them. Stormwater facilities help slow down and filter stormwater runoff before it flows into streams (Arlington County Virginia, 2022).

2.4.3.2 FWOP Condition

Research is ongoing to determine to what extent nutrient and sediment concentrations must decline to achieve water quality standards. This is challenging because it is not a simple linear relationship between which amount of pollutant reduction leads to a certain amount of water quality improvement. Climate change would also have a major effect on water quality. Wastewater treatment plants in the region have implemented the most up-to-date technology to reduce nutrients in wastewater (MWCOG, 2019). Reaching long-term water quality goals would depend on efforts to reduce nutrients and sediments from point sources including industry and non-point sources including agriculture and urban development. Technology to reduce nutrients in wastewater at wastewater treatment plants should continue to evolve.

2.4.4 Air Quality

2.4.4.1 Existing Condition

The Washington, DC-MD-VA region (air quality region that covers the entire study area) is designated by the U.S. Environmental Protection Agency (USEPA) as a marginal nonattainment area for the 8-hour ozone pollutant (2015 standard). Nonattainment means that an area is not meeting the National Ambient Air Quality Standards (NAAQS) set by the USEPA (USEPA, 2022a). The 8-hour ozone pollutant 2015 standard is 70 parts per billion (ppb) over an 8-hour period . The “marginal” designation classifies the region as being within 11 ppb of the standard. The region is an urban environment with little industry; therefore, air quality issues are primarily due to vehicle emissions and air pollution transferred from other states. The region recently attained the former 2008 8-hour ozone NAAQS of 75 ppb and is currently under maintenance to ensure the region stays below the standard (MWCOG, 2018). The region is in attainment for all other air quality parameters. USEPA announced in October 2021 it will reconsider the 2020 decision to retain the 2015 air quality standards for ground-level ozone based on the existing scientific record. USEPA is targeting the end of 2023 to complete this reconsideration (USEPA, 2021a).

The USEPA Environmental Justice (EJ) Screen provides tools to analyze a community’s exposure to air pollutants (USEPA, 2022b). Figure 2-1 shows Northern Virginia’s exposure to ozone as compared to the rest of the United States. Figure 2-1 shows that the areas depicted in orange are in the 80th national percentile, meaning that ozone levels are equal to or at a higher percentage in this area than where 80 percent of the population lives. The areas depicted in yellow are in the 70th percentile and the areas depicted in white are in the 60th percentile. Therefore, communities closer to Washington D.C. have a higher exposure to ozone than communities farther away from the city center.

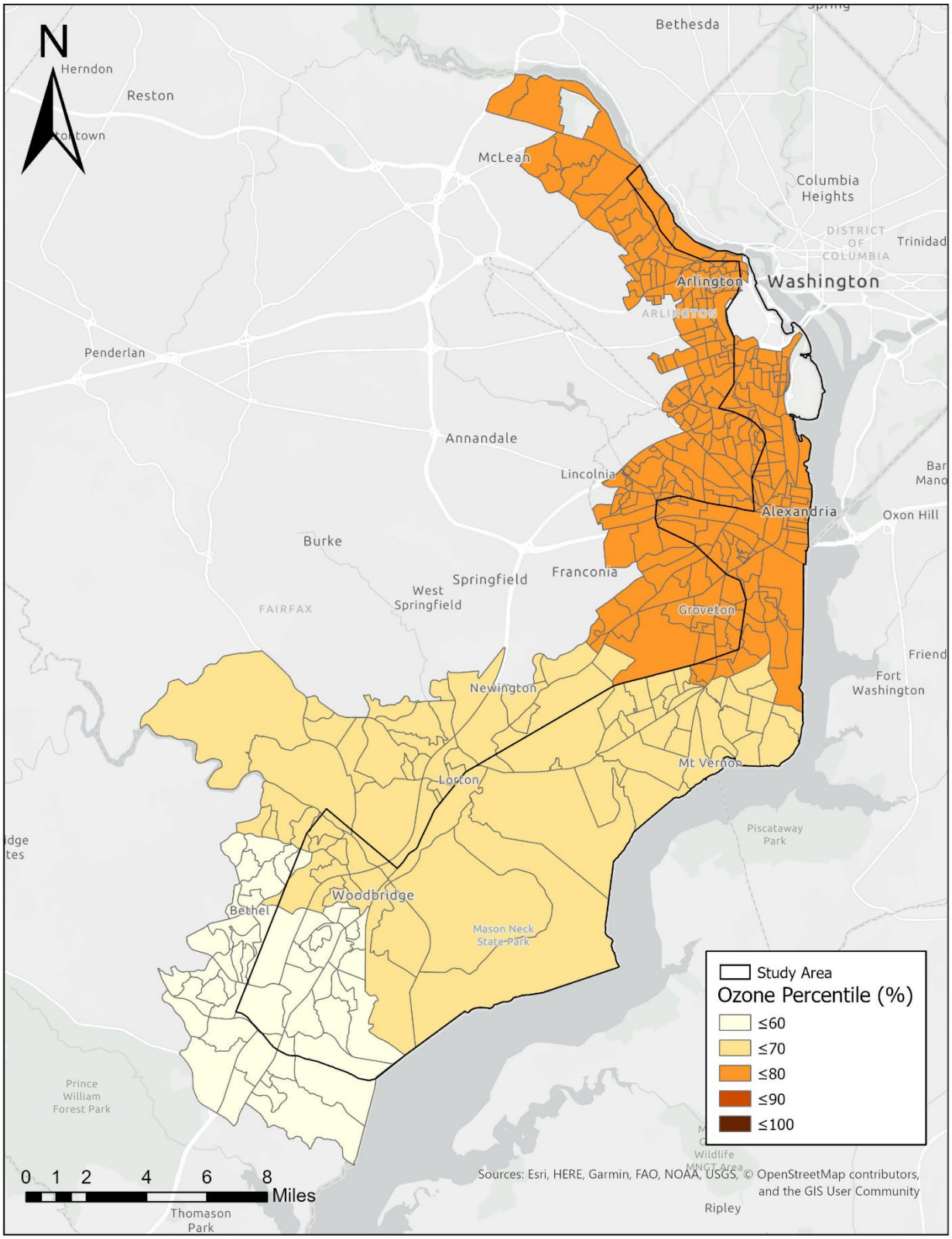

Figure 2-1. Ozone Exposure in Percentiles for the Study Area (USEPA, 2022b)

Virginia's State Implementation Plan (SIP) demonstrates how the state's air pollution will be reduced to levels at or below the NAAQS. Elements of the SIP are developed in conjunction with local governments and planning organizations to meet local air quality needs (VADEQ, 2021a). The MWCOG through the Metropolitan Washington Air Quality Committee, coordinates air quality planning in the region (MWCOG, 2021a).

2.4.4.2 FWOP Condition

The MWCOG published a report that identifies air quality measures that could be put into place to reduce ozone levels in the region, and prioritized these measures based on emission reductions or costs (MWCOG, 2018). Ground-level ozone is not emitted directly into the air by specific pollution sources, but rather is created by a chemical reaction between precursor pollutants such as NOx. MWCOG estimated that if the region implemented all of the high priority measures identified in the report, regional NOx emissions would be reduced by at least 30 tons per day (tpd), leading to further improvement in ozone levels. Based on this estimate, a reduction of 30 tpd of NOx can lead to a 4 to 7 ppb reduction in ozone levels. The USEPA-designated current design value (the air quality status of a given location relative to the level of the NAAQS) for ozone is 72 ppb, and a reduction of 4 ppb can reduce it to 68 ppb, below the current NAAQS (70 ppb). Implementation of high and medium priority measures could reduce the number of ozone exceedance days significantly. However, these measures would have to be implemented regionwide to get the projected benefits (MWCOG, 2018).

2.4.5 Greenhouse Gases

2.4.5.1 Existing Condition

The MWCOG's *Community-Wide Greenhouse Gas Emissions Inventory Summary* for the region shows that greenhouse gas (GHG) emissions decreased by 13 percent between 2005 and 2018. In 2018, energy consumption (residential and commercial) accounted for 52 percent of GHG emissions, and transportation and mobile sources accounted for 40 percent (MWCOG, 2021b).

2.4.5.2 FWOP Condition

In 2020, MWCOG and its member jurisdictions set a new interim GHG emissions reduction goal of 50 percent below 2005 levels by year 2030 and continues to work toward this goal (MWCOG, 2021b).

2.4.6 Hazardous, Toxic, and Radioactive Waste (HTRW)

2.4.6.1 Existing Condition

There are no USEPA Superfund sites (serious hazardous waste sites on the National Priorities List (NPL)) or Brownfield properties (expansion, redevelopment, or reuse of a property that may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant) located in the study area. However, there are several Superfund Non-NPL sites and several cleanup sites throughout the study area (USEPA, 2021b).

USACE conducted an investigation of environmental records to determine the presence of HTRW at Reagan National Airport, the Arlington Water Pollution Control Plant, Four Mile Run Park, Belle Haven, and nearby properties. The USACE HTRW Reports are located in Appendix G.

Reagan National Airport

The investigation revealed that there have been a significant number of spills and leaks of hazardous substances on airport property, as well as nearby properties. The south side of the airport was historically used as a landfill from the 1950s to the late 1970s. Areas along the south and southeastern portion of the airport were also used for fire training and solvent disposal. The *Remedial Investigation Summary Report, Ronald Reagan Washington National Airport (DCA) South Investigation Site (SIS)* (Booz Allen Hamilton, July 2020) documented numerous chemical contaminants in soil and groundwater samples on the south side of the airport that exceeded Virginia Department of Environmental Quality (VADEQ) cleanup target levels (CTLs) (Booz Allen Hamilton, 2020). The vast majority of the samples exceeding CTLs exceeded commercial/industrial CTLs. Some of the more common chemical contaminants that exceeded CTLs included arsenic, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), naphthalene, 2-methylnaphthalene, benzo(a) anthracene, benzo(a)pyrene, biphenyl, and dibenzofuran. Many of these chemicals are either constituents of petroleum products (jet fuels, heating oil, deicing fluids, fuel oil) or they are products of combustion of petroleum.

Arlington Water Pollution Control Plant

The investigation revealed that the Arlington Water Pollution Control Plant (WPCP) is located on the site of an old landfill. The Arlington WPCP is considered a small quantity waste generator with underground storage tanks on site. All underground storage tanks are expected to be replaced with above-ground tanks in the near future. There are several documented chemical spill incidents, including spills containing petroleum products, associated with the Arlington WPCP. Groundwater, soil, and sediment could be contaminated with petroleum products and/or chemicals from these spills. Chemical spills from nearby properties could also have contaminated the groundwater in this area (EDR, 2020a).

Four Mile Run Park

The investigation revealed approximately 30 potential contaminated sites on nearby properties. The nearby sites, which include several former and current gas stations and dry cleaners, are located along Mount Vernon Avenue. Former gas stations and dry cleaners are frequently a source of groundwater and soil contamination. Gas stations historically used single-wall steel tanks that often leaked, causing contamination. Several former and existing gas stations are located in close proximity to Four Mile Run Park. Chemical spills from these nearby properties could have contaminated the groundwater and soils in Four Mile Run Park (EDR, 2020a).

Belle Haven

The investigation revealed eight sources of potential groundwater, soil, and sediment contamination in Belle Haven. These include two gas stations, a wastewater pumping station, a commercial user of chlorinated solvents, a heating oil tank for a single residence and one for a multi-unit building, a dry cleaner, and a former wastewater treatment plant (EDR, 2020b).

2.4.6.2 FWOP Condition

The MWAA is in consultation with VADEQ regarding the next steps toward further delineation of contamination in the SIS area. Additional risk evaluations would be performed by the Federal Aviation Administration (FAA) once the delineation efforts by MWAA are completed.

Future development that would require subsurface excavation at the Arlington WPCP, Four Mile Run Park, and Belle Haven may warrant further investigations of the soils to determine the extent of contamination in these areas.

2.4.7 Cultural Resources

2.4.7.1 Existing Condition

This section describes existing cultural resources within the project's area of potential effects (APE).

Cultural resources are locations of human activity, use, or occupation. They can be defined by expressions of human culture and history in the physical environment such as prehistoric or historic archaeological sites, buildings, structures, objects, districts, and sacred sites, among others. Cultural resources may also include natural features, plants, and animals that are deemed important or significant to a group or community. It is important to note that historic properties, as defined by 36 CFR Part 800, the implementing regulations of Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended, are cultural resources that are eligible for or listed in the National

Register of Historic Places (NRHP). Additionally, to be considered a historic property, the resource must possess at least one of the following significance criteria:

- Association with events that have made a substantial contribution to the broad patterns of our history; or,
- Association with the lives of persons substantial in our past; or,
- Embodiment of the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a substantial or distinguishable entity whose components may lack individual distinction; or,
- Have yielded, or may be likely to yield, information important in prehistory or history.

A historic property must also possess enough integrity to portray its significance. A resource that retains integrity will embody several, and usually most, of the seven aspects of integrity:

- Location is the place where the historic property was constructed or the place where the historic event occurred.
- Design is the combination of elements that create the form, plan, space, structure, and style of a property.
- Setting is the physical environment of a historic property.
- Materials are the physical elements that were combined or deposited during a particular period of time and in a particular pattern or configuration to form a historic property.
- Workmanship is the physical evidence of the crafts of a particular culture or people during a given period in prehistory or history.
- Feeling is a property's expression of aesthetic or historic sense of a particular period of time.
- Association is the direct link between an important historic event or person and a historic property.

Section 106 of the NHPA requires consultation with the State Historic Preservation Office (SHPO), federally recognized Native American tribes, and other interested consulting parties for proposed federal actions that may affect historic properties. The Virginia Department of Historic Resources (VDHR) is designated as the SHPO for Virginia. USACE initiated Section 106 consultation with the SHPO via letter dated October 21, 2021. USACE initiated Section 106 consultation via letters dated March 10, 2022, with the Commission of Fine Arts, National Capital Planning Commission, NPS, Arlington County, City of Alexandria, Fairfax County, Catawba Indian Nation, Chickahominy Indian Tribe, Chickahominy Tribe Eastern Division, Delaware Nation, Monacan Indian Nation,

Nansemond Indian Nation, Pamunkey Indian Tribe, Rappahannock Indian Tribe, and Upper Mattaponi Tribe.

As part of Section 106 consultation, a preliminary APE was defined to identify any potential historic properties that could be affected by the proposed project alternatives. The preliminary APE includes those areas where direct impacts are proposed and areas within which the undertaking may directly or indirectly cause alterations in the character or use of historic properties, including visual effects. For this project the preliminary direct APE includes construction areas of proposed levees, floodwalls, pump stations, and any associated staging areas. The preliminary indirect APE includes the viewsheds of any nearby historic properties.

The potential for historic properties within the direct and indirect APEs was assessed using the Virginia Cultural Resources Information System (V-CRIS). Information gathered from V-CRIS included files pertaining to previously mapped archaeological and architectural/above-ground resources within 0.5 miles of the APE.

Archaeological and Architectural/Above-Ground Resources

USACE used V-CRIS to gather existing information on previously identified archaeological resources, and previously identified architectural/above-ground resources within 0.5 miles of the APE associated with structural measures. This information is presented in Tables 2-5 through 2-8, and only resources noted as potentially eligible for, eligible for, or listed in the NRHP are featured below.

Forty-three historic properties are located within 0.5 miles of the project alternatives, consisting of archaeological sites, individual properties, and historic districts; however, many individual resources or resources contributing to historic districts remain unevaluated for the NRHP. Factoring in unevaluated resources, the total number of resources within 0.5 miles of the project alternatives expands to 1,240. Of the 43 historic properties within 0.5 miles, 7 are within, or in the immediate vicinity of, the currently proposed alternative alignments.

Table 2-5. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 4b (Reagan National Airport)

VDHR ID	Resource Name	NRHP Eligibility
44AR0018	(Not Applicable) N/A	Eligible
029-0228-0131	Mount Vernon Trail	Potentially Eligible
029-0218	GWMP	Listed
000-0045	Washington National Airport Terminal and South Hangar Line	Listed
500-0001	Richmond, Fredericksburg and Potomac Railroad, Richmond, Fredericksburg, and Potomac Railroad Historic District	Eligible
000-0041	Abingdon Ruins	Eligible
000-9706	Aurora Highlands Historic District	Listed

Table 2-6. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 4c (Arlington Water Pollution Control Plant) and Alternative 5a (Arlandria Four Mile Run)

VDHR ID	Resource Name	NRHP Eligibility
000-0045	Washington National Airport Terminal and South Hangar Line	Listed
000-9706	Aurora Highlands Historic District	Listed
029-0218	GWMP	Listed
100-0136	Town of Potomac Historic District	Listed
100-5021	Lynhaven Historic District	Eligible
500-0001	Richmond, Fredericksburg and Potomac Railroad, Richmond, Fredericksburg, and Potomac Railroad Historic District	Eligible

Table 2-7. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 5b1 (Old Town Alexandria)

VDHR ID	Resource Name	NRHP Eligibility
44AX0004	Alexandria Canal and Tidelock	Listed
44AX0048	Lee-Fendell House	Listed
029-0218	GWMP	Listed
100-0002	Old Dominion Bank	Listed
100-0004	Bank of Alexandria	Listed
100-0010	Carlyle House Historic Park	Listed
100-0012	Christ Church	Listed
100-0022	Fairfax-Moore House	Listed
100-0024	Lee-Fendell House	Listed
100-0029	Gadsby's Tavern	Listed
100-0063	Alexandria Post Office	Eligible
100-0082	Potts-Fitzhugh House	Listed
100-0090	Lloyd House	Listed
100-0091	The Lyceum	Listed
100-0098	Old Presbyterian Meeting House	Listed
100-0099	Alexandria Canal Tide Lock	Listed
100-0104	St. Paul's Episcopal Church	Listed
100-0106	Stabler-Leadbeater Apothecary Shop	Listed
100-0121	Alexandria Historic District	Listed
100-0121-1004	Alexandria Library	Eligible
100-0121-1006	Gunston Hall Apartments	Potentially Eligible
100-0121-1529	Swann-Daingerfield House	Listed
100-0126	Alexandria City Hall and Market House	Listed
100-0133	Uptown/Parker-Gray Historic District	Listed
100-0167	Jones Point Army Reserve Center (Building 6001)	Eligible
100-0168	Jones Point Army Reserve Center (Building 6002)	Eligible
100-0284	Appomattox Statue	Listed
100-5015-0002	Beulah Baptist Church	Listed
100-5015-0003	Dr. Albert Johnson House	Listed
100-5015-0004	Moses Hepburn Rowhouses	Listed
100-5015-0005	Odd Fellows Hall	Listed
100-5015-0006	Roberts Chapel	Listed
100-5015-0007	George Lewis Seaton House	Listed

Table 2-8. Archaeological and architectural/above-ground resources within 0.5 miles of Alternative 5c (Belle Haven)

VDHR ID	Resource Name	NRHP Eligibility
029-0218	GWMP	Listed
029-0228-0131	Mount Vernon Trail	Potentially Eligible

2.4.7.2 FWOP Condition

Significant cultural resources would likely be affected by ongoing coastal flooding and SLR under this alternative. To preserve regional historic resources in the study area, Virginia Department of Conservation and Recreation (VADCR) recommends installation of highway markers to commemorate historic locations and events, placement of historic properties on the Virginia Landmarks Register or NRHP, and placement of historic preservation and open space easements. Conservation targets include 19th century dwellings and commercial buildings/districts, civil war resources, historic transportation routes and crossroads and significant prehistoric habitation sites (VADCR, 2018).

2.4.8 Aesthetics

2.4.8.1 Existing Condition

The study area is located in a densely populated urban setting that is primarily residential, but also includes commercial districts, some industrial facilities, and transportation infrastructure as well as natural areas, green spaces, and historic properties. The GWMP is registered as an All-American Road by the U.S. Department of Transportation – Federal Highway Administration. The GWMP is owned by NPS and its route is approximately 25 miles long, spanning from the interchange with the Capital Beltway (Interstate 495) to its terminus at George Washington's Mount Vernon Estate. There are no National Scenic Byways or Wild and Scenic Rivers in the study area. Northern Virginia offers an abundance of aesthetically pleasing landscapes ranging from industrial, natural, and historical. These areas include Washington D.C., Old Town Alexandria Historical District, Mount Vernon, Dyke Marsh, Mason Neck State Park, Occoquan Bay NWR, and many other areas along the Potomac River.

2.4.8.2 FWOP Condition

To keep pace with population growth in the region, major development projects that may affect the region's aesthetics are consistently being proposed in Northern Virginia including, but not limited to, transportation, water and utility, housing, and park projects as well as commercial developments. Each jurisdiction in the study area has a planning and zoning website that provides details on future development plans in that particular jurisdiction. Protected and managed lands and historic sites are expected to retain their

natural and historic value in the future. Due to its historical significance, the GWMP would preserve the scenery along the Potomac River.

2.4.9 Recreation

2.4.9.1 Existing Condition

Many parks, nature reserves, and historic venues exist within the study area. Recreation is a vital component of Northern Virginia's economy and provides the community with several opportunities to enjoy the area. Many of the outdoor resources are tourist destinations. The community may seek activities such as hiking, sight-seeing, birdwatching, sailing, fishing, crabbing, swimming, canoeing, kayaking, and biking among others. Table 2-9 highlights several parks and amenities located in the study area. This is not an exhaustive list of all recreational amenities in the study area.

Table 2-9. Recreation Amenities in the Study Area

Recreational Amenity	County/City
GWMP	Various counties
Washington Sailing Marina	Alexandria
Dangerfield Island	Alexandria
Jones Point Park	Alexandria
Four Mile Run Park	Alexandria
Mount Vernon Trail	Alexandria
Mount Vernon District Park	Fairfax
Dyke Marsh Wildlife Preserve	Fairfax
Fort Hunt Park	Fairfax
George Washington's Mount Vernon Estate	Fairfax
Fort Belvoir	Fairfax
Mason Neck State Park	Fairfax
Occoquan Bay NWR	Prince William
Leesylvania State Park	Prince William
Featherstone NWR	Prince William

The Virginia Department of Conservation and Recreation (VADCR) 2018 Virginia Outdoors Plan reported that visiting natural areas was the number one outdoor recreation activity, followed by walking for pleasure and visiting parks (VADCR, 2018). The outdoor

recreation economy contributes greatly to local county governments. Table 2-10 identifies the per-capita spending on parks and recreation for each jurisdiction in the study area.

Table 2-10. Per-capita Spending on Parks and Recreation for Jurisdictions in the Study Area

Per-capita Spending on Parks and Recreation	
Locality	**Dollars (per-capita)**
Arlington County	195.61
City of Alexandria	143.17
Fairfax County	80.28
Prince William County	75.17

Source: Virginia Auditor of Public Accounts, "Comparative Report on Local Government Revenues and Expenditures" 2019

2.4.9.2 FWOP Condition

Recommendations from the VADCR 2018 Virginia Outdoors Plan for future recreational opportunities in the study area include implementing the following:

- Four Mile Run Restoration Master Plan,
- NPS recommendations for the National Capital Region Paved Trail Plan,
- Updating the 1995 Potomac River Public Access Plan to improve public access to the tidal areas of the Potomac River and its tributaries in Northern Virginia for fishing, boating (motorized and non-motorized), swimming and beach use, and
- Implementing planned improvement and reconstruction at Occoquan Regional Park, a 400-acre park on the Occoquan River in Fairfax County (VADCR, 2018).

Refer to Section 2.4.7 for recommendations from VADCR to preserve historic resources in the study area.

2.4.10 Noise

2.4.10.1 Existing Condition

Northern Virginia residents are exposed to the sounds of a city, including noise from airports, cars, motorcycles, trains, police sirens, helicopters, commercial trucks, construction equipment, vessels, public transportation, and industrial/commercial activities. Noise loudness is measured in decibels (dB). In general, noise over 85 dB is harmful depending on how long a person is exposed to the sound. Normal conversation is about 60 dB (Centers for Disease Control (CDC), 2018).

Traffic is the single greatest contributor to background noise levels in urban areas (Earth Journalism Network, 2014). Heavy traffic is about 80 to 89 dB. Noise is associated with proximity to roads and public transportation and is higher among communities with mid-to-low incomes per capita (Huang et al. 2021).

The Bureau of Transportation Safety publishes the National Transportation Noise Map, showing approximate noise exposure. In the Northern Virginia study area, the highest noise exposures are within the takeoff and landing pathways of Reagan National Airport and along major interstates (Figure 2-2).

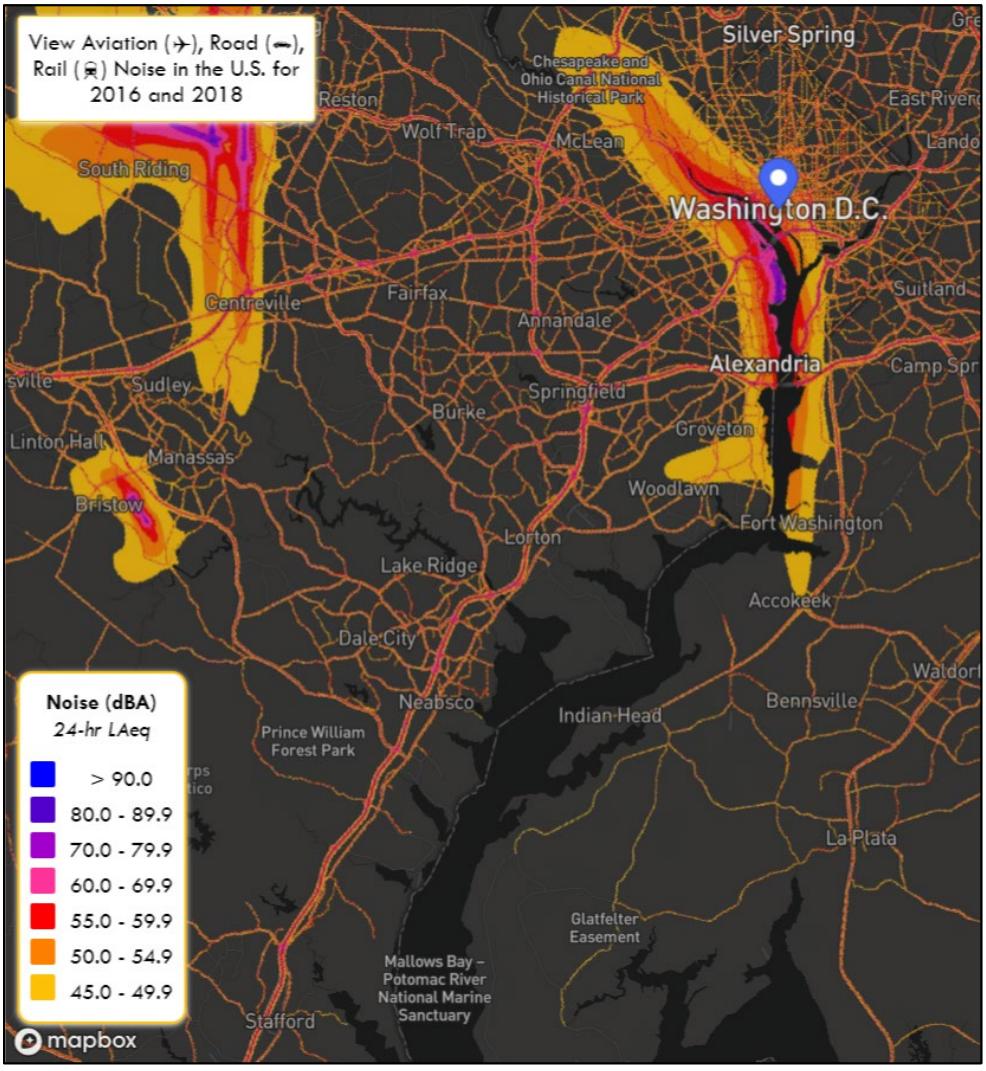

Figure 2-2. Noise Map of Northern Virginia and Washington D.C. from the Bureau of Transportation Safety

The Reagan National Airport Nighttime Noise Rule imposes noise restrictions for approach and takeoff from 10 p.m. to 6:59 a.m. Compliant aircraft must generate noise levels that are equal to or less than 85 dB on approach (measuring point starts 2,000

meters from the runway end) and 72 dB during takeoff (measuring point ends 6,500 meters from takeoff roll) (MWAA, n.d.).

Each jurisdiction in the study area has a noise ordinance that establishes noise limits for stationary noise sources. Based on these noise ordinances, the maximum continuous noise level allowed in residential areas during the daytime is 55 to 60 dB and 55 dB at night. The maximum continuous noise level allowed in commercial areas during the daytime is 60 dB and 65 dB at night. The maximum continuous noise level allowed in industrial areas during the daytime is 70 to 79 dB and 72 dB at night (Fairfax County, Virginia, 2021; City of Alexandria, Virginia, 2022b; Arlington County, Virginia, 2020; Prince William County, Virginia, 2021).

2.4.10.2 FWOP Condition

Construction and traffic noise would be expected to intensify in the study area as population and development increases.

2.4.11 Environmental Justice Communities

2.4.11.1 Existing Condition

The USEPA EJ Screen was used to identify 141 EJ census block groups within the study area using the following methods (USEPA, 2022b).

Census block groups located within one mile of the study area were included in the analysis. Census block groups identified for the analysis included 360 census block groups in Northern Virginia. EJ Screen 2021 data was used to identify block groups in the 80th percentile nationwide for percent low-income, minority, linguistically isolated, over age 64, and groups with less than a high school education.

For the purposes of this analysis, the following definitions and descriptions apply:

Underserved Community. The term “underserved communities” refers to communities that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life. For purpose of this analysis, a community with a disproportionate percentage of *any* of the following populations may be considered an underserved community:

- People-of-color population
- Low-income population
- Linguistically isolated population
- Population with less than high school education
- Population over age 64

People-of-Color Population. Refers to the proportion of individuals in a geographic area who are not non-Hispanic whites, as defined by the Census Bureau. 60 census block

groups within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent people-of-color population (Figure 2-3).

Low-Income Population. Refers to the proportion of individuals in a geographic area whose income is at or below 200% of the poverty line, as defined by the Census Bureau. 19 census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population that is at or below 200% of the federal poverty line (Figure 2-4). For a household of 4 people, the 200% of the federal poverty level is equal to $53,000.

Linguistically Isolated Population. Refers to the proportion of households in a geographic area in which no one over the age of 14 speaks English "very well," as defined by the Census Bureau. 79 census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population that is linguistically isolated (Figure 2-5).

Population with Less than High School Education. Refers to the proportion of individuals in a geographic area who are over age 25 and have not attained a high school diploma. 43 census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population over age 25 with less than a high school diploma (Figure 2-6).

Population over Age 64. Refers to the proportion of individuals in a geographic area who are age 64 or older. 38 census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population over age 64 (Figure 2-7).

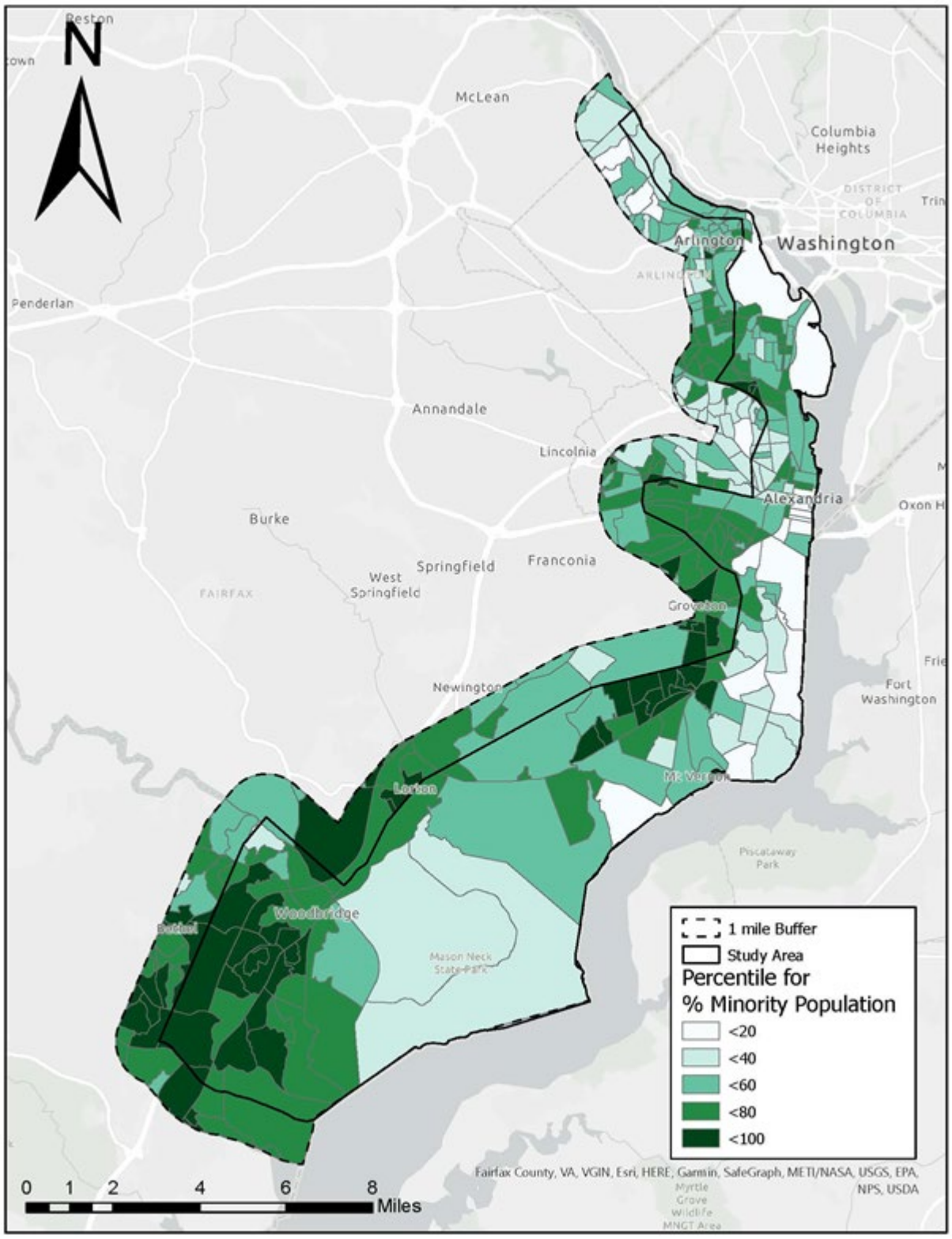

Figure 2-3. Census block groups in the study area and within a 1-mile buffer of the study area and the percent people of color population (percentile) in each census tract (USEPA, 2022b)

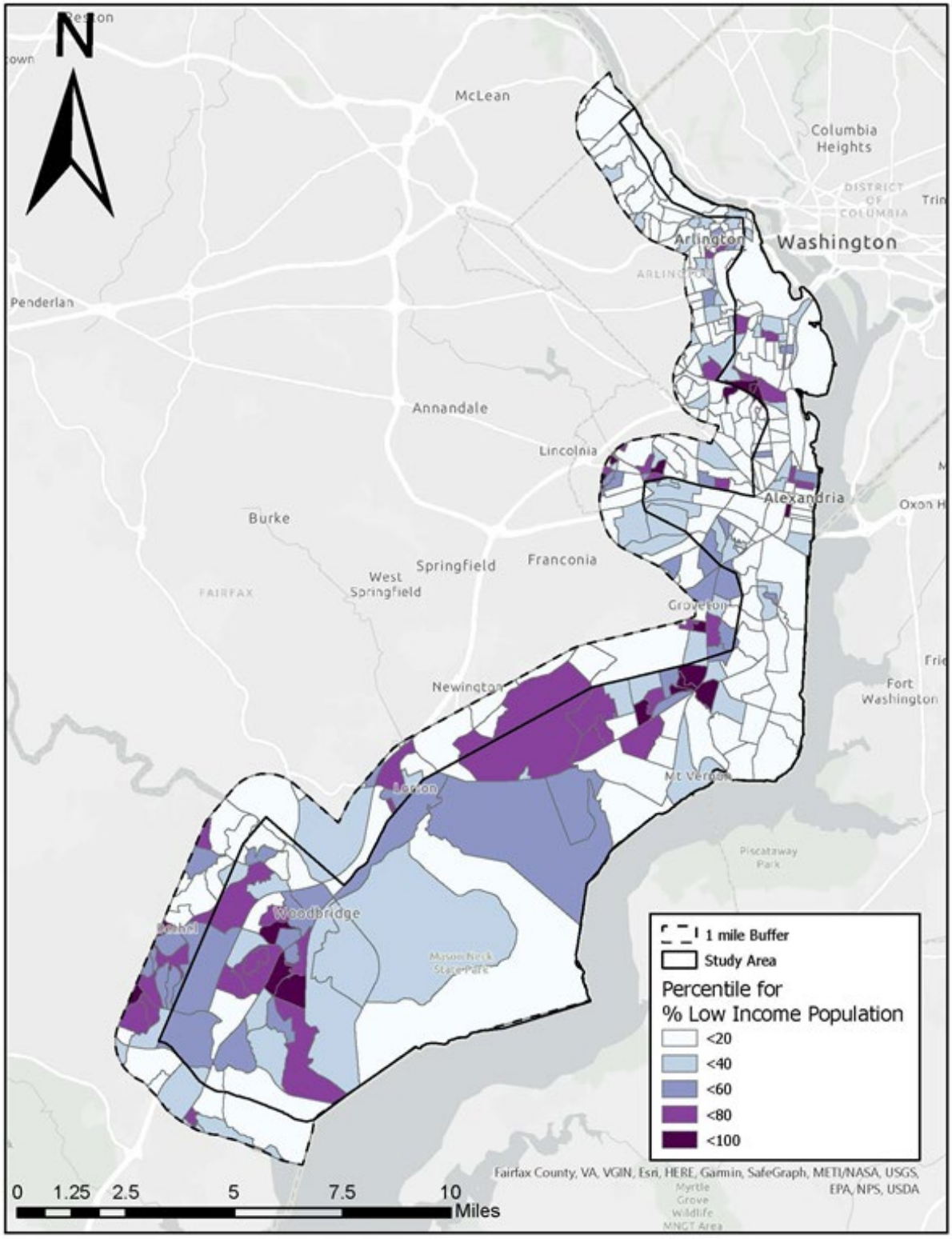

Figure 2-4. Census block groups in the study area and within a 1-mile buffer of the study area and the percent low-income population (percentile) in each census block (USEPA, 2022b)

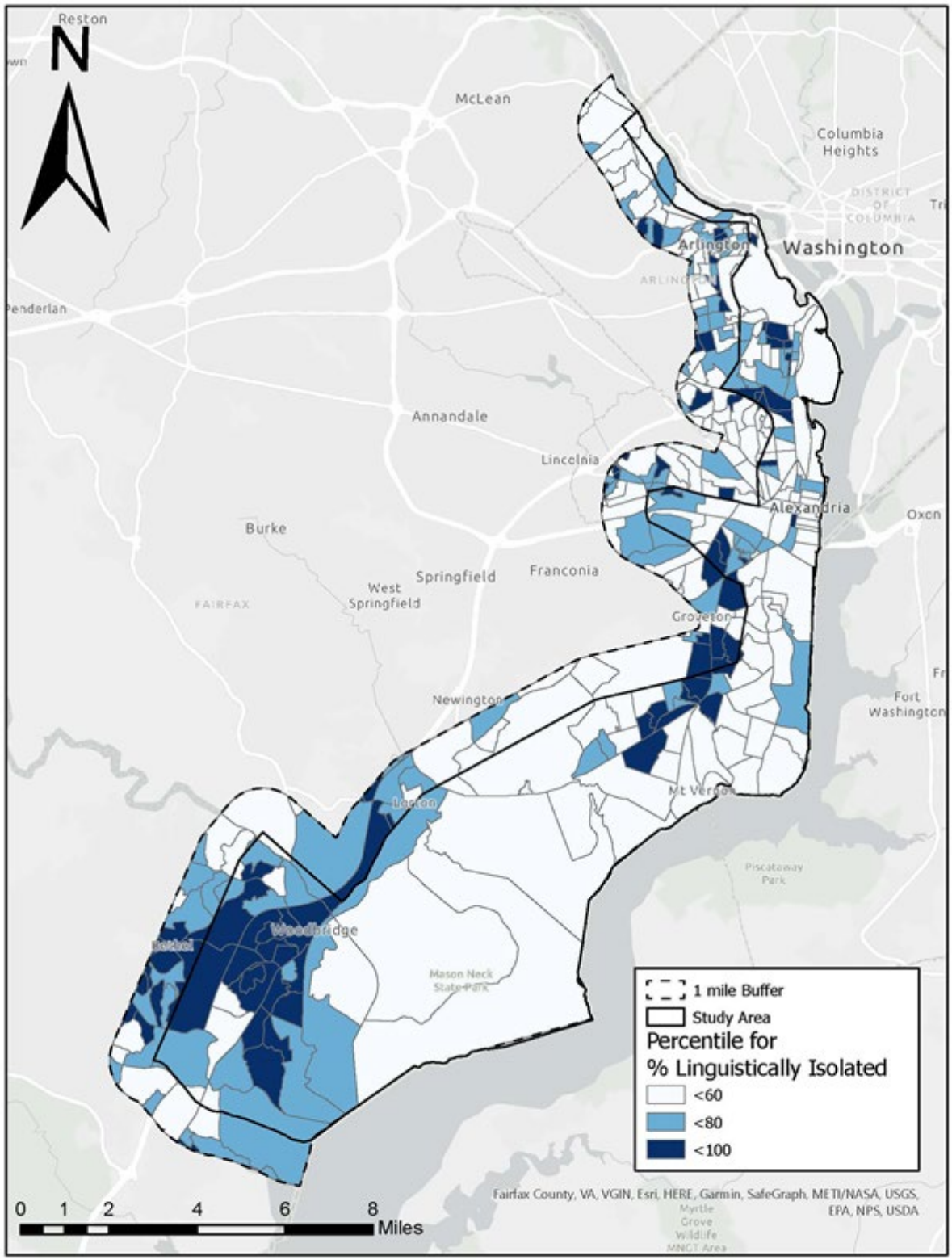

Figure 2-5. Census block groups in the study area and within a 1-mile buffer of the study area and the percent linguistically isolated population (percentile) in each census block (USEPA, 2022b)

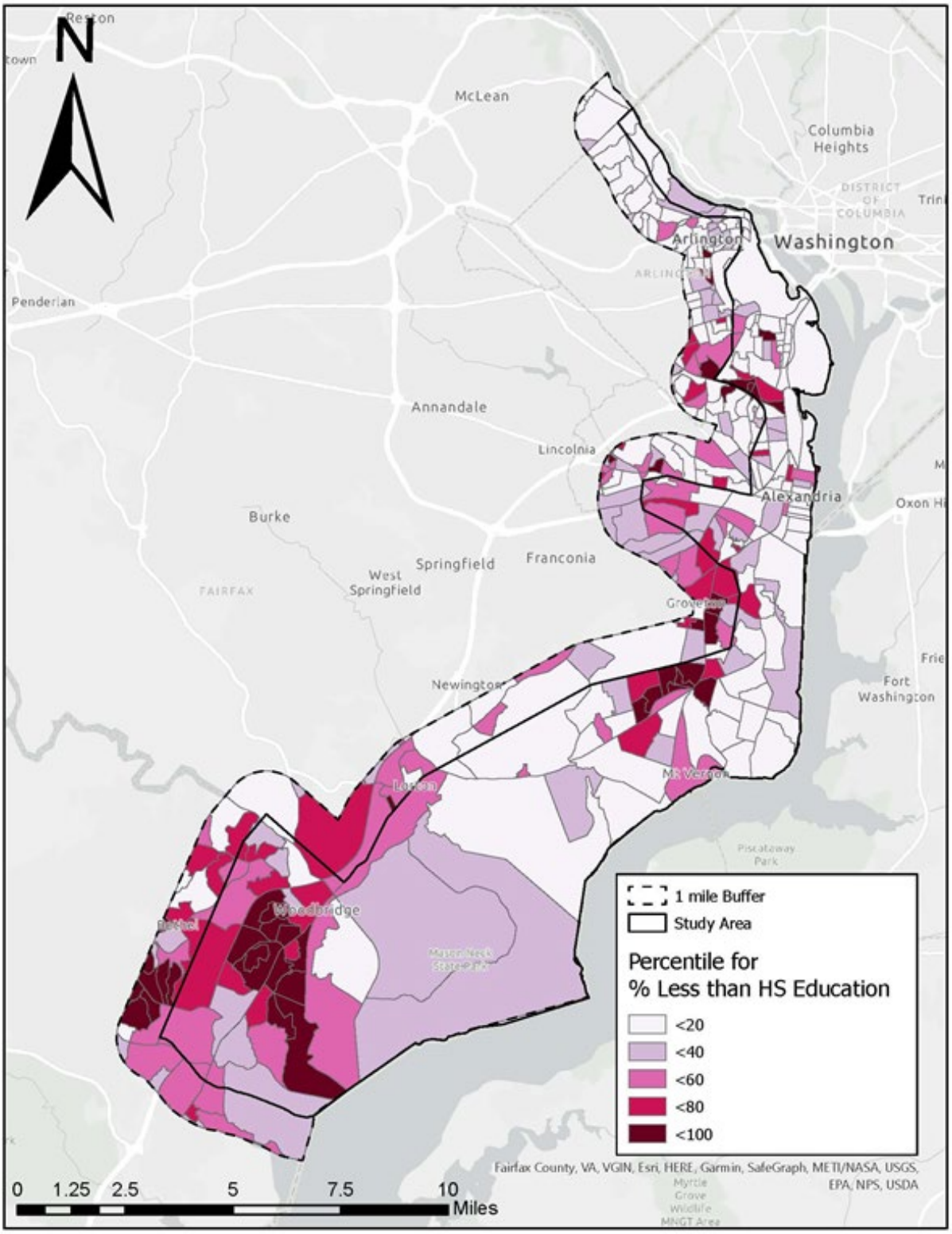

Figure 2-6. Census block groups in the study area and within a 1-mile buffer of the study area and the percent population with less than a high school education (percentile) in each census block (USEPA, 2022b)

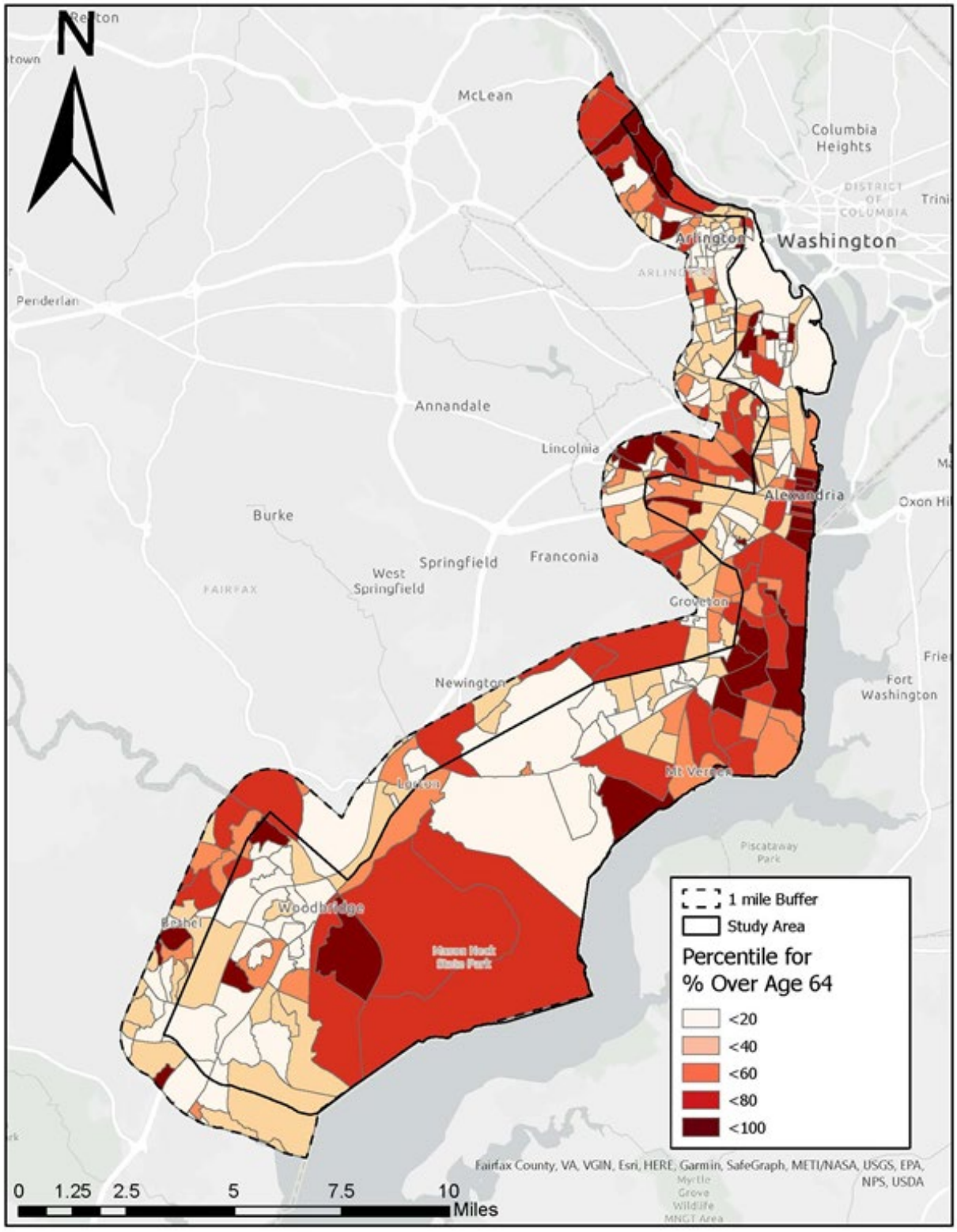

Figure 2-7. Census block groups in the study area and within a 1-mile buffer of the study area and the percent population over age 64 (percentile) in each census block (USEPA, 2022b)

These 141 EJ census block groups meeting one or more of the demographic indicators include 28 block groups in Arlington County, 43 block groups in Fairfax County, 41 block groups in Prince William County, and 29 block groups in the City of Alexandria. The census tracts are listed and grouped by jurisdiction in Table 2-11 below.

Table 2-11. Environmental Justice Census Tracts in the DC Coastal Study Area

	Tract	Block Group
Arlington (51-013)	1003	1
	1003	4
	1004	1
	1004	2
	1006	1
	1006	2
	1007	1
	1007	2
	1016.02	1
	1016.02	2
	1017.02	1
	1017.03	2
	1018.02	4
	1018.03	3
	1024	1
	1026	1
	1027.02	2
	1029.02	1
	1031	2
	1032	4
	1034.02	1
	1035.01	1
	1035.01	2
	1035.02	1
	1035.02	2
	1035.03	2
	1036.02	2
	1037	1
Fairfax (51-059)	4151	2
	4152	2
	4153	1
	4154.01	1

	Tract	Block Group
Fairfax *cont.*	4154.01	2
	4154.01	3
	4154.02	1
	4154.02	2
	4155	1
	4155	3
	4155	4
	4156	2
	4160	2
	4161	2
	4203	3
	4205.01	1
	4205.03	3
	4206	1
	4206	2
	4208	1
	4208	2
	4214	1
	4214	3
	4214	4
	4215	1
	4215	2
	4215	3
	4216	1
	4216	2
	4216	3
	4217.01	1
	4217.01	2
	4217.02	1
	4217.02	2
	4218	1
	4218	2

	Tract	Block Group
Fairfax *cont.*	4221.01	3
	4221.02	2
	4221.02	3
	4221.02	4
	4222.02	1
	4222.02	2
	4222.02	3
Prince William (51-153)	9001	1
	9002.01	1
	9002.02	1
	9002.02	2
	9002.02	3
	9002.03	1
	9002.03	2
	9003	3
	9004.03	1
	9004.03	2
	9004.03	4
	9004.04	1
	9004.04	2
	9004.04	3
	9004.09	1
	9004.09	2
	9004.09	3
	9004.1	1
	9004.1	2
	9005.01	1
	9005.01	2
	9005.01	3
	9005.01	4
	9006	1
	9006	2

	Tract	Block Group
Prince William *cont.*	9006	3
	9006	4
	9007.01	1
	9007.01	2
	9007.02	1
	9007.02	2
	9007.02	3
	9008.02	2
	9008.02	3
	9010.08	1
	9010.08	2
	9010.12	1
	9012.08	1
	9012.08	2
	9012.09	1
	9012.09	2
City of Alexandria (51-510)	2002.02	1
	2003.02	1
	2003.02	2
	2003.02	3
	2003.03	2
	2003.03	3
	2003.03	4
	2004.05	2
	2005	1
	2005	3
	2006	3
	2006	4
	2007.03	3
	2008.02	2
	2011	1
	2012.03	1

	Tract	Block Group
City of Alexandria *cont.*	2012.03	2
	2012.03	3
	2012.03	4
	2012.04	1
	2014	3
	2015	1
	2018.01	4
	2018.02	1
	2018.02	2
	2019	1
	2020.01	2
	2020.02	1
	2020.02	2

Each of the five demographic indicators are averaged for all 141 EJ census block communities and all census blocks in the study area plus 1-mile buffer in Table 2-12 below:

Table 2-12. Average Percent of Population for Demographic Indicators in EJ Communities and the Study Area Plus 1-mile Buffer

Demographic Indicator	Percent of Population	
	EJ Blocks	Study Area
People-of-color	60.0%	45.0%
Low Income	26.6%	16.9%
Less than HS Education	14.3%	7.9%
Linguistically Isolated	10.3%	5.2%
Over Age 64	12.9%	11.8%

Traffic Noise

The EJ communities experience some of the most persistent heavy traffic in Virginia due to their proximity to major roadways including Interstates (I) 95, 395, 495, and Routes 1 and 50. According to studies by TRIP, a National Transportation Research Nonprofit, Northern Virginia roadway users spend up to 102 hours a year in traffic congestion (TRIP, 2020).

Figure 2-8 shows the census tracts in Northern Virginia proximity to traffic with the EJ communities outlined in yellow. Many of the EJ census tracts have borders formed by I-95, I-495, and Route 1 and are therefore located in the highest percentiles of traffic proximity. Portions of the EJ communities located adjacent to major interstates are likely affected by higher-than-average noise levels.

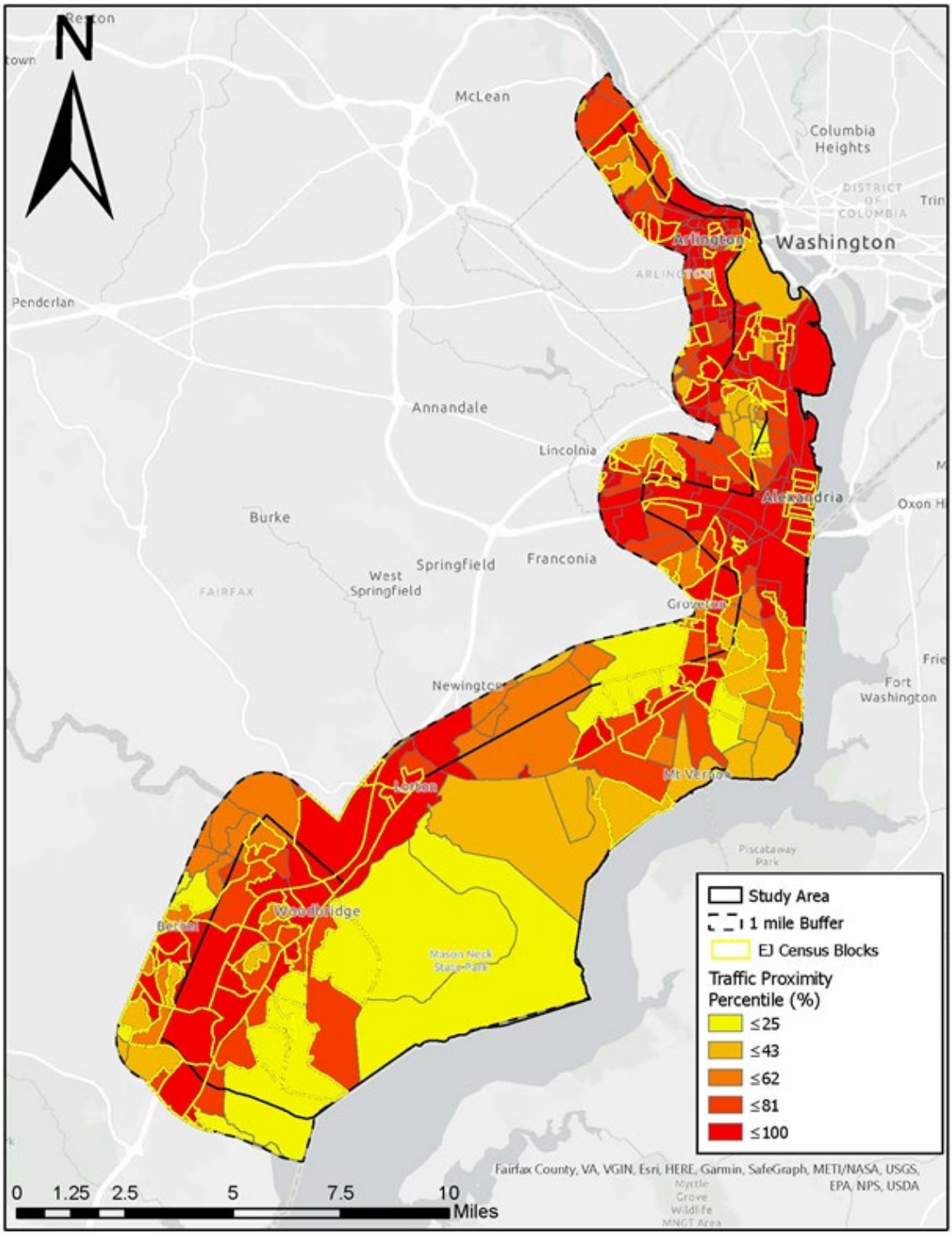

Figure 2-8. Environmental Justice census block groups proximity to traffic (USEPA, 2022b)

Air Quality

As discussed in Section 2.4.3, the study area is designated a marginal nonattainment area for the 8-hour ozone pollutant, based on the 2015 standard, with the NAAQS. Figure 2-9 below shows the EJ communities' and their exposure to ozone in percentiles. In general, EJ communities located closer to Washington D.C. have a higher exposure to ozone than EJ communities located farther away from the city center.

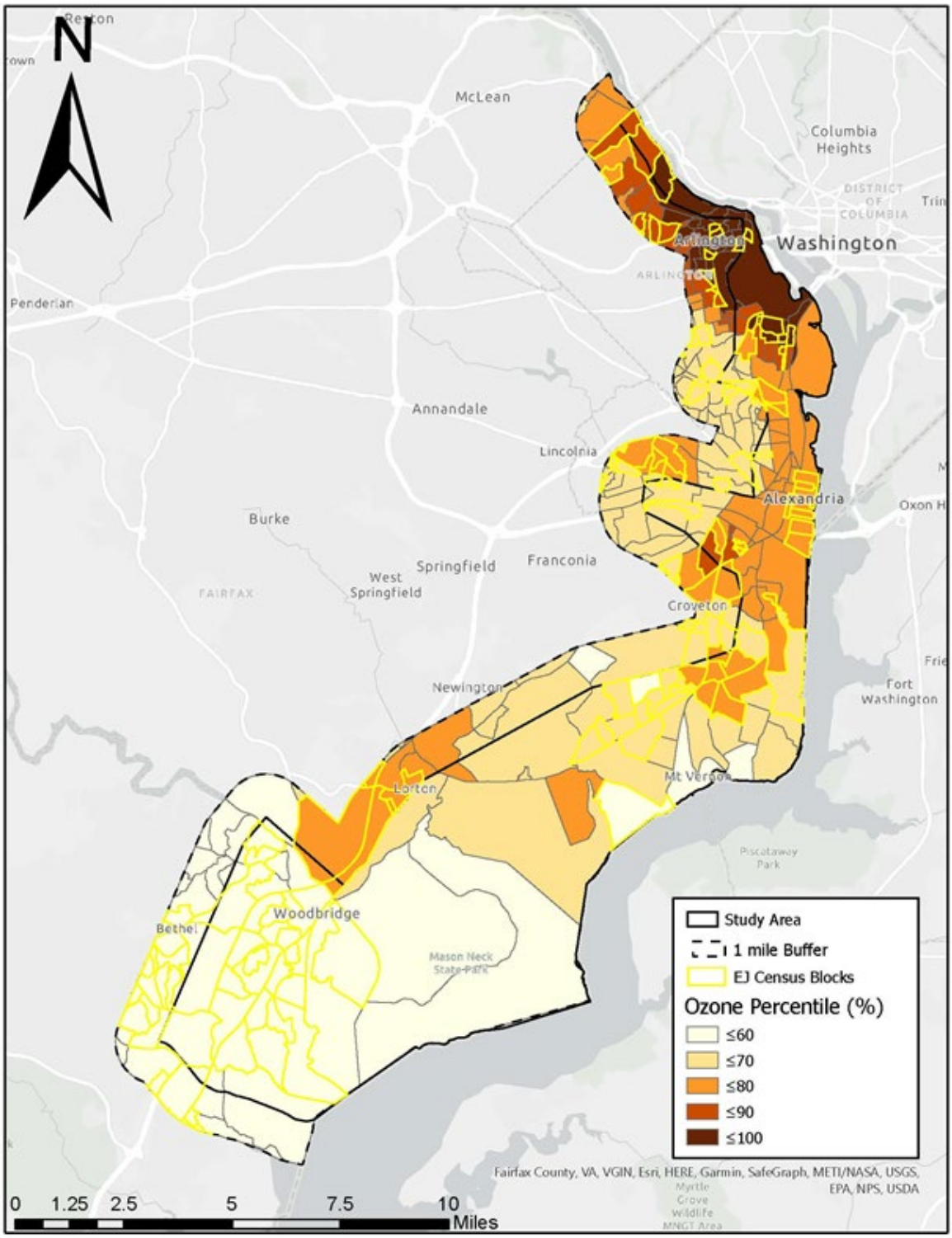

Figure 2-9. Environmental Justice census block groups and their exposure to ozone (USEPA, 2022b)

Hazardous Waste

As described in Section 2.4.5, there are no USEPA Superfund sites or Brownfield properties located in the study area. However, there are several Superfund Non-NPL sites and several cleanup sites throughout the study area (USEPA, 2021b). Figure 2-10 shows the EJ communities' and their proximity to hazardous waste treatment, storage, and disposal facilities. In general, EJ communities located closer to Washington D.C. have a higher exposure to hazardous waste facilities.

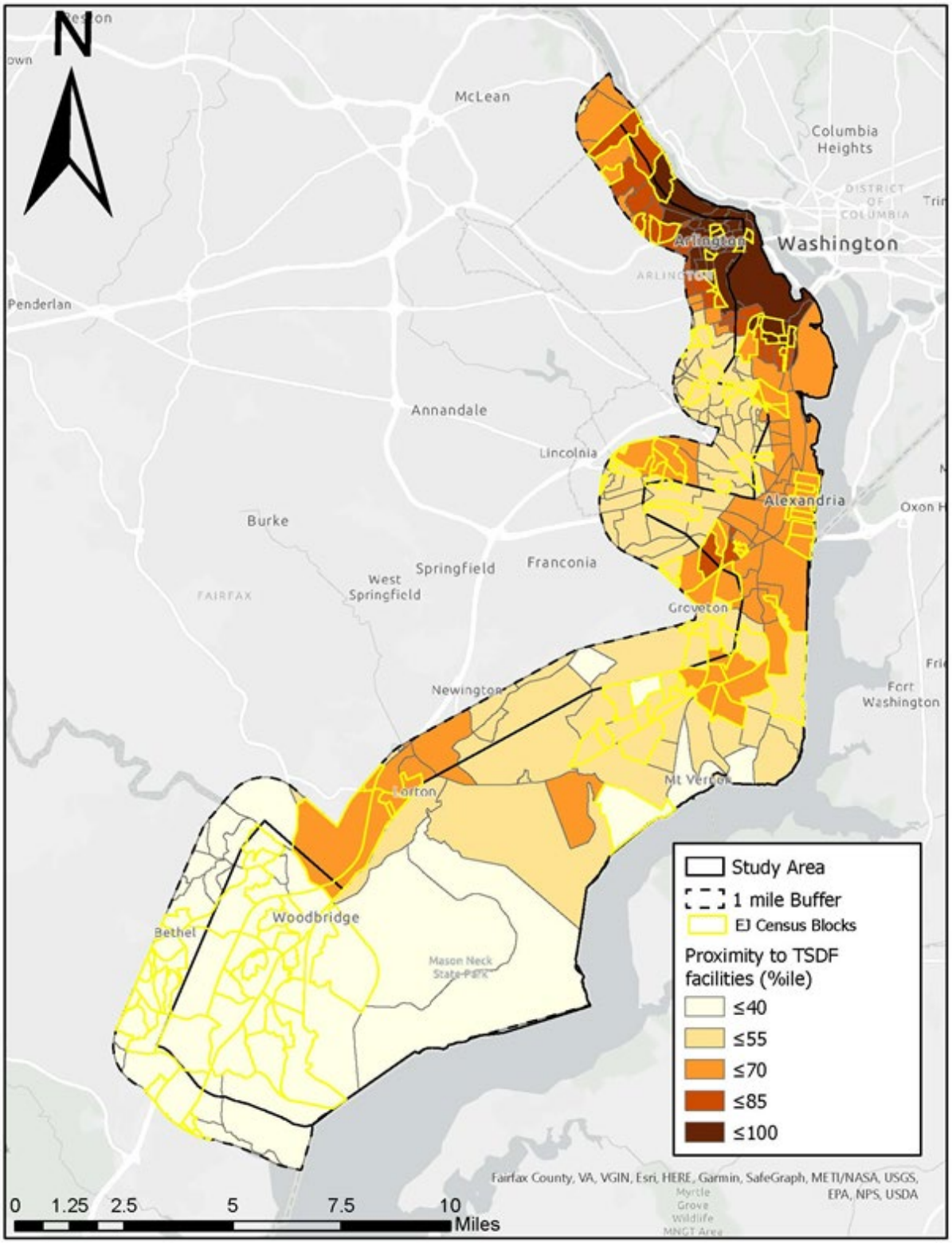

Figure 2-10. Environmental justice census block groups and their exposure to hazardous waste treatment, storage, and disposal facilities (USEPA, 2022b).

In summary, EJ census blocks that have a higher exposure to traffic noise, air pollution, and hazardous waste facilities are the census tracts located in Arlington County, as well several tracts located in the City of Alexandria and Fairfax County. A summary of average percentiles for traffic exposure, ozone levels, and proximity to hazardous waste facilities for EJ census blocks and all census blocks in the study area plus one mile buffer can be found in Table 2-13 below:

Table 2-13. Average Percentiles for Analyzed Environmental Indicators in the EJ Census Blocks and the Study Area Plus 1-mile Buffer

Environmental Indicator	Percentile	
	EJ Blocks	Study Area
Traffic Proximity	74.6	73.6
Hazardous Waste	49.7	54.6
Ozone	46.6	49.6

2.4.11.2 FWOP Condition

There are many ongoing efforts to promote fair and equitable treatment of all communities throughout Northern Virginia. Some examples of ongoing efforts in Northern Virginia are listed below. This list does not include all ongoing efforts in this region.

- *Virginia Department of Environmental Quality Environmental Justice Initiative* https://www.deq.virginia.gov/home/showpublisheddocument/1813/637425424131330000 (VADEQ, 2020)
- *Visualize 2045 Environmental Justice Analysis* – Long-term transportation plan for the National Capital Region. The report includes an examination on the accessibility and travel time to jobs, educational institutions, and hospitals for identified Equity Emphasis Areas compared to the rest of the region from the present time to 2045. https://www.mwcog.org/transportation/plans/visualize-2045/ (MWCOG, 2022)
- *Northern Virginia Regional Commission Diversity Equity Inclusion Roadmap* https://www.novaregion.org/1539/Diversity-Equity-Inclusion-DEI-Roadmap (Northern Virginia Regional Commission, n.d.-b)

2.5 Built Environment

The Northern Virginia study area is characterized by riverine and coastal storm risk along the Potomac River and two major tributaries with historic flooding concerns at Cameron

Run and Four Mile Run. Over the years, FRM infrastructure has been constructed by USACE and others at the following locations:

Four Mile Run Levee & Floodwall – This is a USACE project that was authorized in 1970 to a capacity 18,080 cubic feet per second (cfs) and constructed in 1984. The project consists of four levee and floodwall systems along Four Mile Run from just east of the I-395 bridge to Mount Vernon Avenue and includes 11,000 feet (ft) of channel improvement in Four Mile Run, 1,300 ft of earthen levee with an additional 300 ft along Long Branch, and 4,700 ft of concrete floodwall with an additional 500 ft along Long Branch. The height of the levee and floodwall varies along the length.

Huntington Levee – In 2019, Fairfax County constructed a levee along Cameron Run, in front of Huntington Park. The levee has length of 2,900 ft and provides protection from a 0.1% annual exceedance probability (AEP) event with approximately 95% confidence level.

Belle Haven/New Alexandria Tide Gates – Existing non-federal FRM infrastructure in this area includes a pump station at the northeast corner of the Belle View Shopping Center along 13th Street and a tide gate along a small channel where it crosses I Street between Potomac Avenue and 10th Street. The I Street Tide Gate protects the residential area upstream of I Street when the tide is above 4 ft in elevation (NGVD29). When the tide elevation is greater than 4 ft, the tide gate closes and will stay closed as long as the downstream water surface elevation is above 4 ft (USACE 2008). The pump station at 13th Street pumps storm water runoff from a drainage basin upstream into a drainage channel where it can flow by gravity to the Potomac River.

Reagan National Airport, Levee Road – An existing levee was built around the outer edge of the airport during airport construction.

In addition to existing FRM infrastructure, many projects are being carried in the study area between present day and the baseline year for this year in 2031 and are considered as part of the FWOP condition. Notable projects being constructed in coastal or riverine areas are described in this section.

Alexandria Waterfront Flood Mitigation Project – URS Corporation completed the Potomac River Waterfront Flood Mitigation Study in 2010 for the City of Alexandria. The study recommended FRM measures along the waterfront including elevating core areas between Duke and Queen Street up to 6 ft in North Atlantic Vertical Datum of 1988 (NAVD88) elevation, which represent a 10% AEP. The project is expected to be constructed in phases between 2021 and 2023.

Long Bridge Project – A partnership between Virginia Department of Rail and Public Transportation, the District Department of Transportation, and the Federal Railroad Administration, the Long Bridge Project aims to improve the heavy rail corridor between Arlington Virginia and Washington D.C. The project has recommended construction of a

new two-track bridge upstream of the existing Long Bridge and retaining Long Bridge to allow for four-track crossing along the Potomac River. A Final Environmental Impact Statement (EIS) was completed in August of 2020. Construction of the project is expected to be completed in 2028.

Potomac Yard Metrorail Station – The Potomac Yard Metrorail Station is a new planned metro station along the Blue and Yellow Lines located between Ronald Reagan National Airport (DCA) and the Braddock Road Station with access to the Potomac Greens/Yard neighborhoods in the City of Alexandria. The $370 million project is currently under construction and will be completed in 2022.

George Washington Memorial Parkway Renovation – The GWMP is initiating a $161 million major renovation project to address road deterioration and the need for major stormwater upgrades along the Parkway. The project is anticipated to be constructed from 2023 to 2025.

2.6 Economic Environment

2.6.1 Existing Conditions

2.6.1.1 Economic Modeling Description

The Generation II Coastal Risk Management (G2CRM) model is used to estimate economic damages from coastal storm impacts in this study. G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). Monte Carlo Simulation (MCS) is a method for representing uncertainty by making repeated runs (iterations) of a deterministic simulation, varying the values of the uncertain input variables according to probability distributions. A triangular distribution is a three-parameter statistical distribution (minimum value, most likely value, maximum value) used throughout G2CRM to characterize uncertainty for inputs in the model. This allows for incorporation of time-dependent and stochastic event-dependent behaviors such as sea level change, tide, and structure raising and removal. The model is based upon driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas (modeled areas) of different types that may interact hydraulically and may be defended by coastal defense elements that serve to shield the areas and the assets they contain from storm damage. Within the specific terminology of G2CRM, the important modeled components are:

- *Driving forces* - storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models.
- *Assets* – spatially located entities that can be affected by storms. Damage to structure and contents is determined using damage functions. For structures,

population data at individual structures allows for characterization of loss of life for storm events.

- *Modeled areas* - areas of various types (coastal upland, unprotected area) that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area.
- *Protective system elements* - the infrastructure that defines the coastal boundary be it a coastal defense system that protects the modeled areas from flooding (levees, pumps, closure structures, etc.), or a locally developed coastal boundary comprised of bulkheads and/or seawalls.

The model deals with the engineering and economic interactions of these elements as storms occur during the life cycle, areas are inundated, protective systems fail, and assets are damaged, and lives are lost. A simplified representation of hydraulics and water flow is used. Modeled areas currently include unprotected areas and coastal uplands defended by a seawall or bulkhead. Protective system elements are limited to bulkheads/seawalls.

2.6.1.2 Assets

A total of 6,419 residential and nonresidential structures were included in the inventory and used to develop the economic results. The following table presents a summary of these assets.

Table 2-14. Residential and Commercial Assets used in G2CRM

Jurisdiction	Assets Count
Arlington County	233
City of Alexandria	2,932
Fairfax County	2,624
Prince William County	630
Total	6,419

Privately owned vehicles in the study area, assets at the Arlington Water Pollution Control Plant, infrastructure at the Reagan National Airport, and debris clean-up synthetic assets were added to the inventory after the AMM. The infrastructure at the Reagan National Airport includes buildings and three Engineered Material Arresting Systems (EMAS). The space available at three large parking lots at the Reagan National Airport were used to evaluate the number private vehicles that may be impacted.

A total of 18,639 structures including residential and nonresidential buildings, privately owned vehicles, and debris clean-up assets were used to develop the inventory in this

economic analysis. See Figure 2-11 for asset distribution in the study area. More information on the economic analysis and methods are detailed in Appendix E.

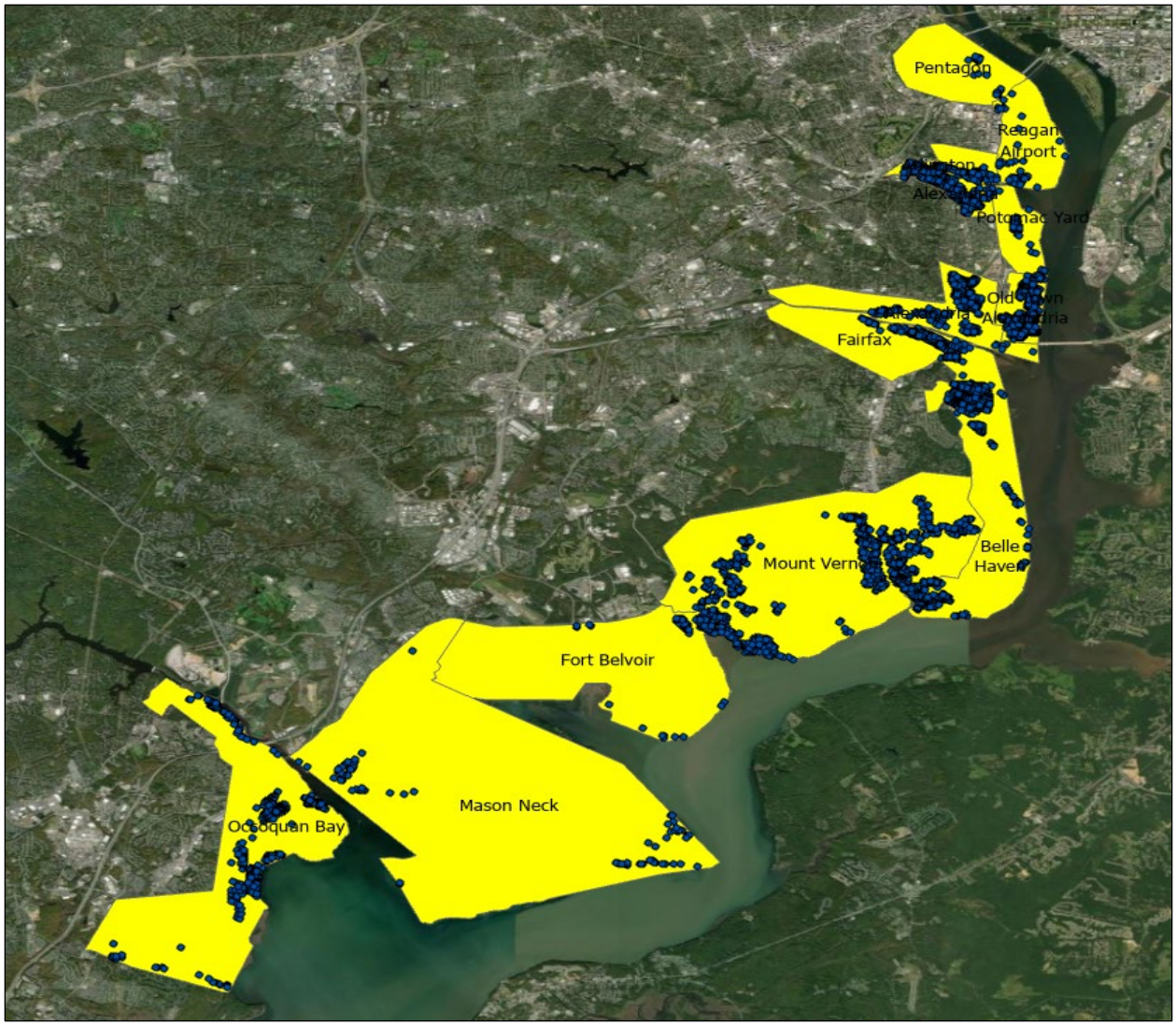

Figure 2-11. Location of Assets by Model Areas

The Northern Virginia study area structure inventory, as modeled, contains 18,639 structures (Figure 2-11). Out of residential and nonresidential structures, the occupancy types most found were single Family Residential, High Rise, and Residential Vehicles. Figure 2-12 shows the proportion of each occupancy type in the Northern Virginia area.

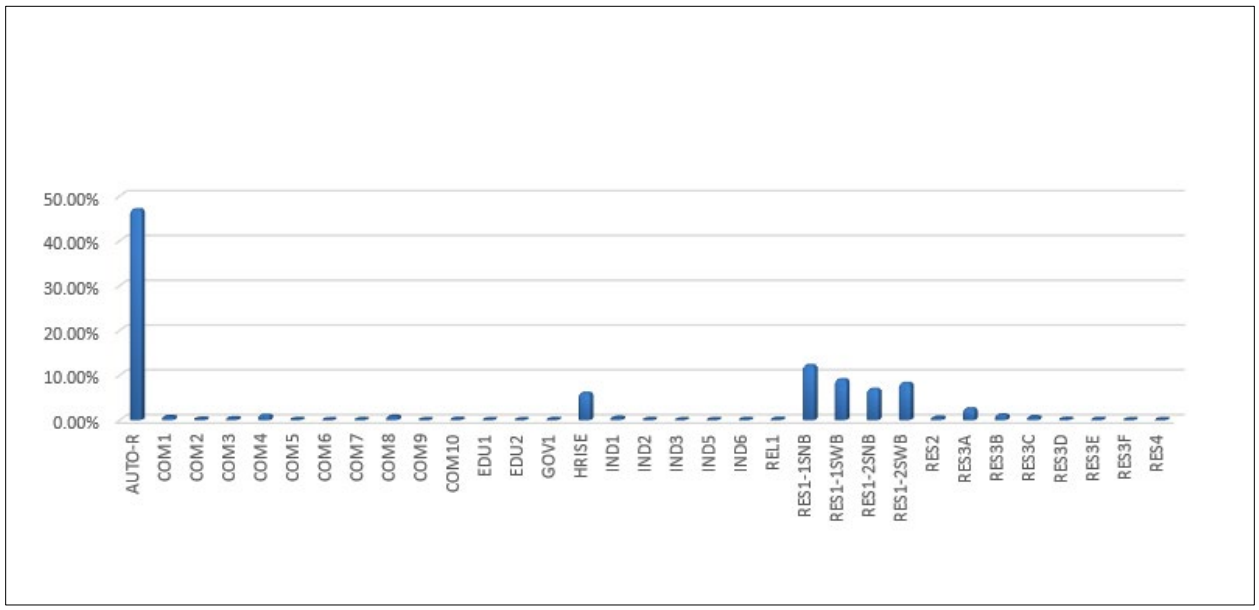

Figure 2-12. Proportion of Occupancy Types in the Northern Virginia Study Area

2.6.1.2.1 Residential and Non-residential Content-to-Structure Value Ratios

Content-to-Structure Value Ratios (CSVRs) used in this feasibility study were obtained from the North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk, Physical Depth Damage Function Summary Report (2015) and the Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013 (Institute for Water Resources, 2013). As shown in Table 2-15, a CSVR was computed for each residential and non-residential structure in the study as a percentage of the total depreciated replacement value. A triangular distribution was used to estimate error.

Table 2-15. Content-to-Structure Value Ratios (CSVRs)

Category	Occupancy Type	Occupancy Description	Min	Most Likely CSVR %	Max	Source
Commercial	COM1	Retail	37%	45%	53%	2013 Prototype 12
	COM2	Wholesale	31%	37%	43%	NACCS, Prototype 2
	COM3	Personal & Repair Services	56%	66%	74%	2013 Prototype 13
	COM4	Prof/Tech Services	14%	18%	24%	NACCS, Prototype 2
	COM5	Bank	14%	18%	24%	2013 Prototype 7
	COM6	Hospital	35%	44%	50%	2013 Prototype 6
	COM7	Medical Office	53%	60%	66%	2013 Prototype 5
	COM8	Entertainment/Recreation	20%	25%	31%	2013 Prototype 19
	COM9	Theatre	14%	18%	24%	NACCS, Prototype 2
	COM10	Garage	31%	37%	44%	NACCS, Prototype 3
	HRISE	Urban High-Rise	14%	18%	24%	NACCS, Prototype 4A
Public	EDU1	school	5%	7%	9%	2013 Prototype 21
	EDU2	College/University	5%	7%	9%	2013 Prototype 21
	GOV1	Government Services	14%	18%	24%	NACCS, Prototype 2
	GOV2	Emergency response	60%	70%	75%	2013 Prototype 18
	REL1	Church	5%	7%	11%	2013 Prototype 20
Industrial	IND1	Heavy industrial	32%	38%	44%	2013 Prototype 14
	IND2	Light industrial	32%	38%	44%	2013 Prototype 14
	IND3	Food/Drug/Chem	14%	18%	24%	NACCS, Prototype 2
	IND5	High Technology	14%	18%	24%	NACCS, Prototype 2
	IND6	Construction	32%	38%	44%	2013 Prototype 14
Residential	RES1-1SNB	Res 1, 1 Story no Basement	25%	50%	75%	NACCS, Prototype 5A
	RES1-1SWB	Res 1, 1 Story w/ Basement	25%	50%	75%	NACCS, Prototype 5A
	RES1-2SNB	Res 1, 2 Story no Basement	25%	50%	75%	NACCS, Prototype 5B
	RES1-2SWB	Res 1, 2 Story w/ Basement	25%	50%	75%	NACCS, Prototype 5B
	RES2	Mobile home	68%	142%	209%	M&S Res Valuation Sce
	RES3A	Multi-Family housing 2 units	8%	10%	14%	NACCS, Prototype 1A-1
	RES3B	Multi-Family housing 3-4 units	8%	10%	14%	NACCS, Prototype 1A-3
	RES3C	Multi-Family housing 5-10 units	8%	10%	14%	NACCS, Prototype 1A-3
	RES3D	Multi-Family housing 10-19 units	8%	10%	14%	NACCS, Prototype 1A-3
	RES3E	Multi-Family housing 20-50 units	8%	10%	14%	NACCS, Prototype 1A-3
	RES3F	Multi-Family housing 50 plus units	8%	10%	14%	NACCS, Prototype 1A-3
	RES4	Average Hotel, & Motel	20%	26%	33%	2013 Prototype 4

(1) 2013 – Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation, Revised 2013
(2) NACCS – NACCS Physical Depth Damage Functions Summary Report

2.6.1.2.2 Summary of the inventory

The assets were categorized as residential or nonresidential which were further categorized into occupancy types. Table 2-16 displays the count and structure value by occupancy type.

Table 2-16. Structure Inventory by Occupancy Type

Occupancy Type	Description	Count	Structure Value	Content Value
AUTO-R	Auto/Residential	5,733	$110,202,000	$0
COM1	Average Retail	89	$127,319,000	$44,036,000
COM2	Average Wholesale	32	$103,947,000	$29,479,000
COM3	Average Personal & Repair Services	51	$82,889,000	$43,215,000
COM4	Average Professional/Technical Services	132	$221,310,000	$39,443,000
COM5	Bank	13	$16,393,000	$2,376,000
COM6	Hospital	1	$1,467,000	$732,000
COM7	Average Medical Office	9	$21,194,000	$12,787,000
COM8	Average Entertainment/Recreation	102	$255,665,000	$35,617,000
COM9	Average Theatre	1	$16,214,000	$4,021,000
COM10	Garage	28	$25,897,000	$6,548,000
EDU1	Average School	7	$31,239,000	$6,769,000
EDU2	Average college/university	1	$3,091,000	$311,000
GOV1	Average Government Services	14	$87,477,000	$4,229,000
HRISE	Average Urban High-Rise, More Than 4 Floors	741	$3,096,378,000	$1,807,624,000
IND1	Average Heavy Industrial	66	$1,485,563,000	$3,331,000
IND2	Average Light Industrial	10	$7,073,000	$2,162,000
IND3	Average Food/Drugs/Chemicals	3	$507,000	$49,000
IND5	Average High Technology	3	$15,060,000	$0
IND6	Average Construction	16	$31,544,000	$9,139,000
REL1	Church	24	$43,431,000	$2,841,000
RES1-1SNB	Single Family Residential, 1 Story, No Basement	1,494	$348,670,000	$146,919,000
RES1-1SWB	Single Family Residential, 1 Story, With Basement	1,106	$285,803,000	$134,078,000
RES1-2SNB	Single Family Residential, 2 Story, No Basement	848	$233,300,000	$100,644,000
RES1-2SWB	Single Family Residential, 2 Story, With Basement	1,009	$241,645,000	$115,367,000
RES2	Mobile home	67	$2,590,000	$969,000
RES3A	Multi-Family housing 2 units	319	$71,586,000	$33,341,000
RES3B	Multi-Family housing 3-4 units	139	$37,151,000	$18,369,000
RES3C	Multi-Family housing 5-10 units	83	$34,106,000	$15,752,000
RES3D	Multi-Family housing 10-19 units	23	$40,673,000	$16,178,000
RES3E	Multi-Family housing 20-50 units	16	$38,309,000	$16,506,000
RES3F	Multi-Family housing 50 plus units	2	$11,755,000	$5,877,000
RES4	Average Hotel, & Motel	4	$31,330,000	$8,146,000
Total		12,186	$7,160,778,000	$2,666,855,000

The total number of debris clean-up assets in the inventory is 6,453 with a dollar amount of $97,503,000.

2.6.1.3 Model Areas

Model areas (MA) are established to represent the various geographic parts of the study area that have uniform flood elevations. A storm event is processed to determine the peak stage in each defined MA, and it is this peak stage that is used to estimate consequences to assets within the MA. Therefore, MA boundaries tend to correspond to the drainage divides separating local-scale watersheds. Considerable professional judgment was used in defining MA boundaries including accounting for natural or built topological features (e.g., a ridge, highway, or railway line). Dividing the study area into model areas facilitates evaluation of flood damages by breaking the study area down into several areas having some common features. Analyzing them separately also speeds up the economic modeling process. The study area consists of 22 model areas. The 22 model areas (MA) are MA1: Four Mile Run Arlington East - Protected, MA2: Four Mile Run Arlington West - Protected, MA3: Four Mile Run Alexandria East - Protected, MA4: Four Mile Run Alexandria West - Protected, MA5: Cameron Run Protected Huntington Levee, MA6: Pentagon Unprotected, MA7: Reagan National Airport - Proposed Bulkhead, MA8: Four Mile Run Arlington - Proposed Bulkhead, MA9: Potomac Yard Unprotected, MA10: Old Town Alexandria - Proposed Bulkhead, MA11: Cameron Run Alexandria - Unprotected, MA12: Belle Haven - Proposed Bulkhead, MA13: Mount Vernon - Unprotected, MA14: Fort Belvoir - Unprotected, MA15: Mason Neck - Unprotected, MA16: Occoquan Bay - Unprotected, MA17: Four Mile Run Alexandria - Proposed Bulkhead, MA18: Cameron Run Fairfax - Unprotected, MA19: Fort Hunt - Unprotected, MA20: Old Town Alexandria - Unprotected, MA21: Reagan National Airport - Unprotected, MA22: Four Mile Run Arlington - Unprotected. These model areas are spatial areas defined by polygons as shown in Figure 2-13.

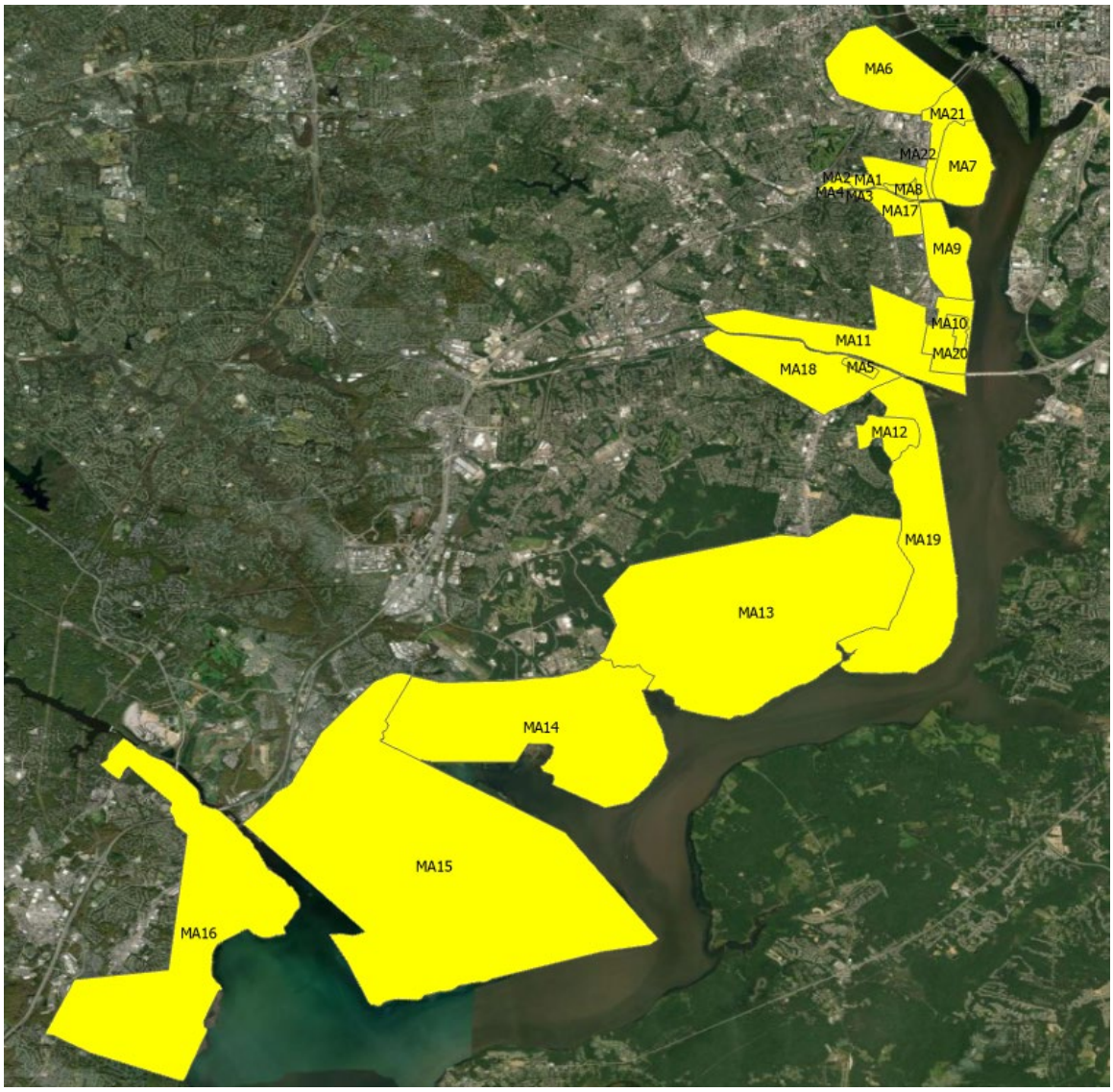

Figure 2-13. Model Area Boundaries and their Description

There are two types of model areas: unprotected MAs and upland MAs. An unprotected MA is a polygon boundary within Generation II Coastal Risk Model (G2CRM) that contains assets and derives associated stage from the total water level (i.e., storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, without any mediation by a protective system element (PSE). An upland MA is a polygonal boundary within G2CRM that contains assets and derives associated stage from the total water level (i.e., storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, as mediated by a PSE such as a bulkhead/seawall or flood barrier that must be overtopped before water appears in the MA. It also has an associated volume-stage relationship to account for filling behind the bulkhead/seawall or flood barrier during the initial stages of overtopping.

Moreover, it is important to note that some MAs have been protected by PSEs that exist in the Northern Virginia study area. Therefore, having each MA be a component of an upland MA in the existing and FWOP condition was a modeling strategy used in order to model the future with project condition. The Northern Virginia CSRM project team designed PSEs to protect MAs 7, 8, 10, 12, and 17. There are existing PSEs in the MAs 1, 2, 3, 4, and 5. A 6-ft wall is currently in construction in MA10, Old Town Alexandria. Table 2-17 shows the type of model area in the future with project conditions.

Table 2-17. Model Area Types

MA	MA Description and Type	MA Type for Modeling
MA1	Four Mile Run Arlington East - Protected	Upland
MA2	Four Mile Run Arlington West - Protected	Upland
MA3	Four Mile Run Alexandria East - Protected	Upland
MA4	Four Mile Run Alexandria West - Protected	Upland
MA5	Cameron Run Huntington Levee - Protected	Upland
MA6	Pentagon - Unprotected	Upland
MA7	Reagan National Airport – Proposed Bulkhead	Upland
MA8	Four Mile Run Arlington – Proposed Bulkhead	Upland
MA9	Potomac Yard - Unprotected	Upland
MA10	Old Town Alexandria – Proposed	Upland
MA11	Cameron Run Alexandria - Unprotected	Upland
MA12	Belle Haven – Protected – Proposed Bulkhead	Upland
MA13	Mount Vernon - Unprotected	Upland
MA14	Fort Belvoir - Unprotected	Upland
MA15	Mason Neck - Unprotected	Upland
MA16	Occoquan Bay - Unprotected	Upland
MA17	Four Mile Run Alexandria – Proposed Bulkhead	Upland
MA18	Cameron Fairfax Unprotected	Upland
MA19	Fort Hunt - Unprotected	Upland
MA20	Old Town Alexandria - Unprotected	Upland
MA21	Reagan National Airport - Unprotected	Upland
MA22	Four Mile Run Arlington - Unprotected	Upland

2.6.1.4 Protective System Elements (PSE)

Flood hazard manifested at the storm location is mediated by the PSE such as bulkhead/seawall or flood barrier. The PSE prevents transmission of the flood hazard into the MA until the flood hazard exceeds the top elevation of the bulkhead/seawall or flood barrier. When the flood hazard exceeds the bulkhead/seawall or flood barrier top elevation the flood hazard is instantaneously transmitted into the MA unmediated by the bulkhead/seawall or flood barrier.

PSEs are defined in G2CRM to capture the effect of built flood FRM infrastructure (i.e., what in G2CRM is categorized as a bulkhead/seawall or a flood barrier). Figures 2-14 and 2-15 show the protected MAs with bulkhead for the future with project conditions in the study area.

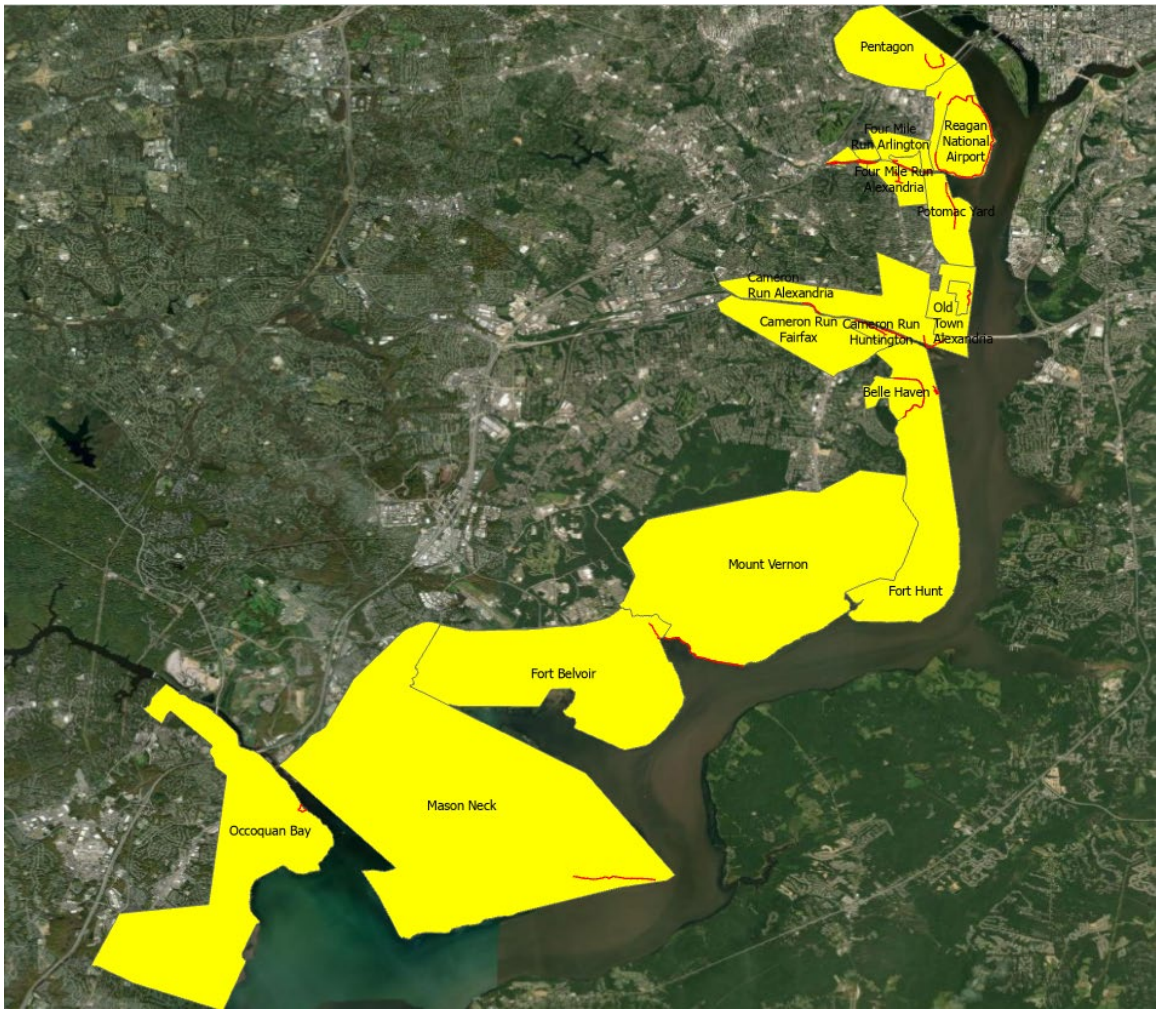

Figure 2-14. Unprotected and Protected MAs with Bulkheads

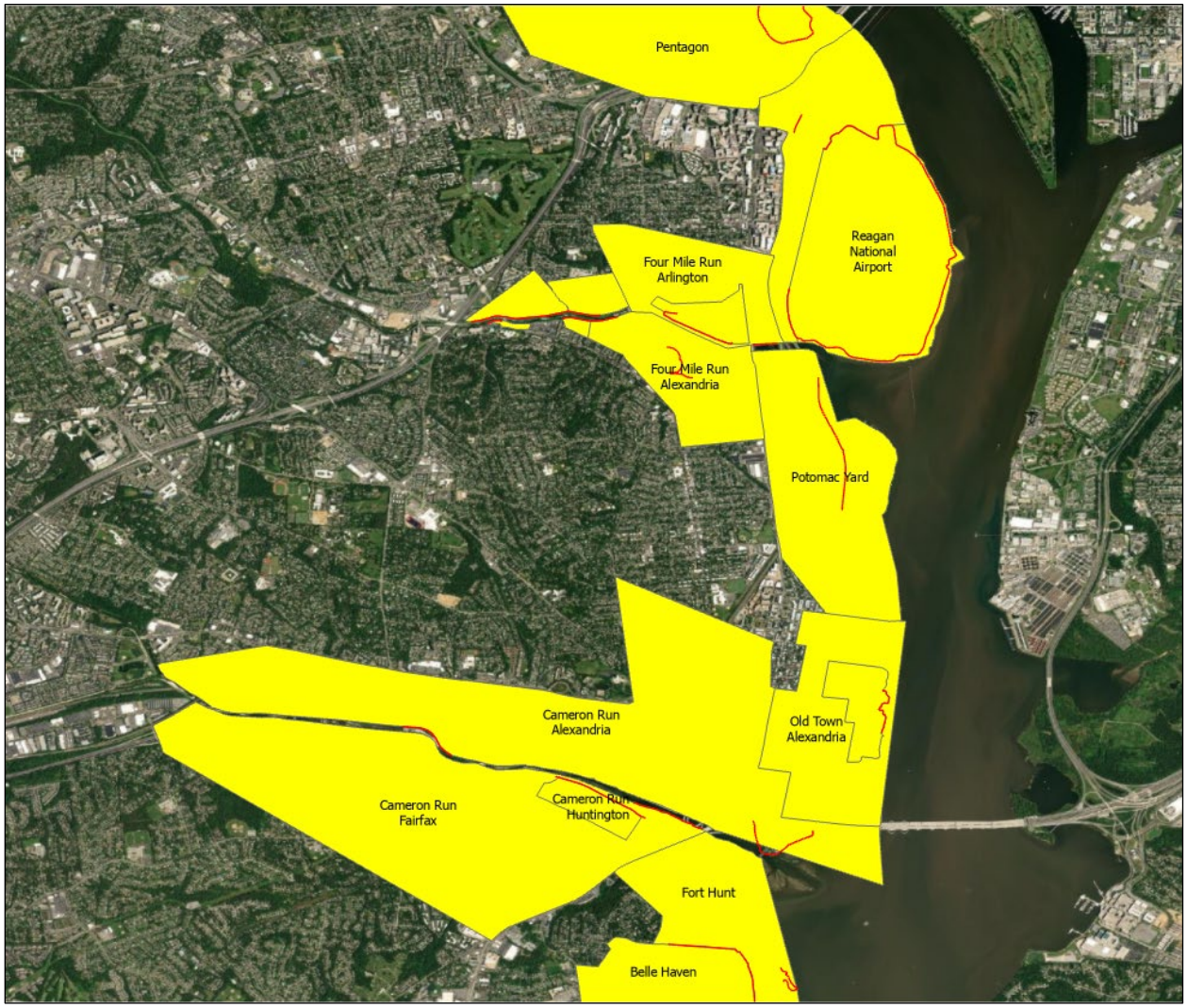

Figure 2-15. Unprotected and Protected MAs with Bulkheads – Partial view

The top elevation is specified at the approximate existing ground elevation within the MA for both the existing and future without condition simulation, in G2CRM. In this way, the bulkhead/seawall or the flood barrier does not influence the existing condition consequences of the flood hazard. For the future with project condition the bulkhead/seawall or the flood barrier top-elevation is raised in the alternative file and its influence is captured.

2.6.1.5 Volume Stage Functions

Volume-stage functions also called stage-volume functions are associated with an upland MA. For the study area, the volume-stage functions were derived from the digital terrain model (the same used to determine ground elevation of structures) developed from Post-Sandy Light Detection and Ranging (LiDAR) collected by USGS (U.S. Geological Survey) and published in 2014. Volume-stage functions describe the relationship between the

volume contained in the model area and the associated stage (water depths) for each MA. Stage-volume functions have been developed for each of 22 MAs. Water level within the MAs is computed by first estimating the volume of water passing over the PSEs and then using the stage-volume relationship to determine water level within the MAs. Once the storage area in the MAs is filled, the flood hazard is transmitted into the MAs unmediated by the bulkhead/seawall or the flood barrier.

2.6.1.5 Evacuation Planning Zones (EPZ)

Communities in the Northern Virginia area are vulnerable to flooding. In addition to the approximately 2 million people living in the four jurisdictions, thousands of people working in the Washington D.C. Metropolitan area commute in the study area on a daily basis. During storm surge events, the ability of first responders to reach the location of need and the ability of individuals to reach medical facilities can be limited or cut off entirely.

Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, many low-income communities, and communities of color are often disproportionately affected by, and less resilient to, the health impacts of climate change. Lessons from numerous coastal storm events have made it clear that if the elderly, functionally impaired persons, and/or low-income residents wish to evacuate from areas at risk from a pending coastal storm, they are unable to evacuate due to their physical or socioeconomic condition. Flooding in urban areas can cause serious health and safety problems for the affected population. The most obvious threat to health and safety is the danger of drowning in flood waters. When people attempt to drive through flood waters, their vehicles can be swept away in as little as two ft of water.

An evacuation planning zone (EPZ) is a spatial area, defined by a polygon boundary that is used within loss of life calculations in G2CRM to determine the population remaining in structures during a storm (i.e., population that did not evacuate). Therefore, in G2CRM, each Asset is assigned to an MA which is then assigned to an EPZ and then modeled in G2RM for potential life loss given a storm event.

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. In order for life loss calculations to be made, the maximum stage in the modeled area has to be greater than the foundation height plus the ground height.

Loss of life calculations are separated out by age categorization with under 65 being one category and 65 and older being the second category. They are also categorized during daytime and nighttime. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, although safe does not imply that there is no life loss, and chance would have the highest expected

life loss. G2CRM model was used to compute loss of life since the Northern Virginia study area does not present substantial life threatening from flooding.

2.6.2 Existing Condition Modeling Results

The assets assigned to each MA and EPZ were modeled in G2CRM using 58 tropical storms simulated in the Coastal Storm Modeling System (C-STORM) modeling suite. The C-STORM results provide annual exceedance probabilities for various storm frequencies along with a distribution of water surface levels based on the 95 percent confidence interval. G2CRM used the economic (e.g., Assets) and engineering inputs (e.g., Storms) to generate expected present value (PV) damages for each structure throughout the life cycle (i.e., the period of analysis). The possible occurrences of each economic (i.e., triangular distribution) and engineering (i.e., relative probabilities) variables were derived through the use of Monte Carlo simulation and a total of 100 iterations were executed by the model for this analysis. Every iteration represents expected PV damages for the period of analysis and cumulative damages of assets converged at about 100 iterations.

The sum of all damages for each life cycle were divided by the number of iterations to yield the expected PV damages for that modeled simulation. A mean and standard deviation were automatically calculated for the PV damages for each MA.

2.6.3 Economic FWOP

The FWOP condition and forecast assumptions based on the existing condition were critical to the planning process since they provide the baseline for the subsequent evaluation and comparison phases. The following discussion includes projections about the future of the Northern Virginia study area if the federal government or local interests do not address the problems identified in this study.

2.6.3.1 Background

The Northern Virginia study area has experienced a marked increase in the number of days of “minor coastal flooding” over time, which will increase along with rising sea levels. Similarly, the water table below the study area will continue to rise, limiting the effectiveness of gravity drain potential post-storm. Subsidence will increase as soil deposited naturally, or by humans, compacts over time.

The USACE low, intermediate, and high sea level change scenarios were evaluated for the without and with project condition, and with respect to determining tipping points/thresholds for impacts over the 50-year period of analysis and 100-year adaptation timeframe, and at multiple storm frequencies. NOAA’s Regional Rate for the Washington D.C. region is an average of 0.00997 ft/year. As per EC 1165-2-212, regional sea level change is an increase or decrease in the mean level of the ocean’s surface over a specific

region. Regional sea-level change does not include local geologic effects, such as subsidence or tectonic movement. The low scenario is the historic sea level change trend specific to the Washington DC tidal gauge.

Sea level is projected to rise as shown in Table 2-18 and Figure 2-16, based on the records at the NOAA gauge 8594900 at Washington D.C., the closest to the Northern Virginia area.

Table 2-18. Sea Level Change Projection

Year	Low	Intermediate	High
2030	**0.55**	**0.69**	**1.12**
2080	**1.06**	**1.75**	**3.93**
2130	**1.58**	**3.27**	**8.64**

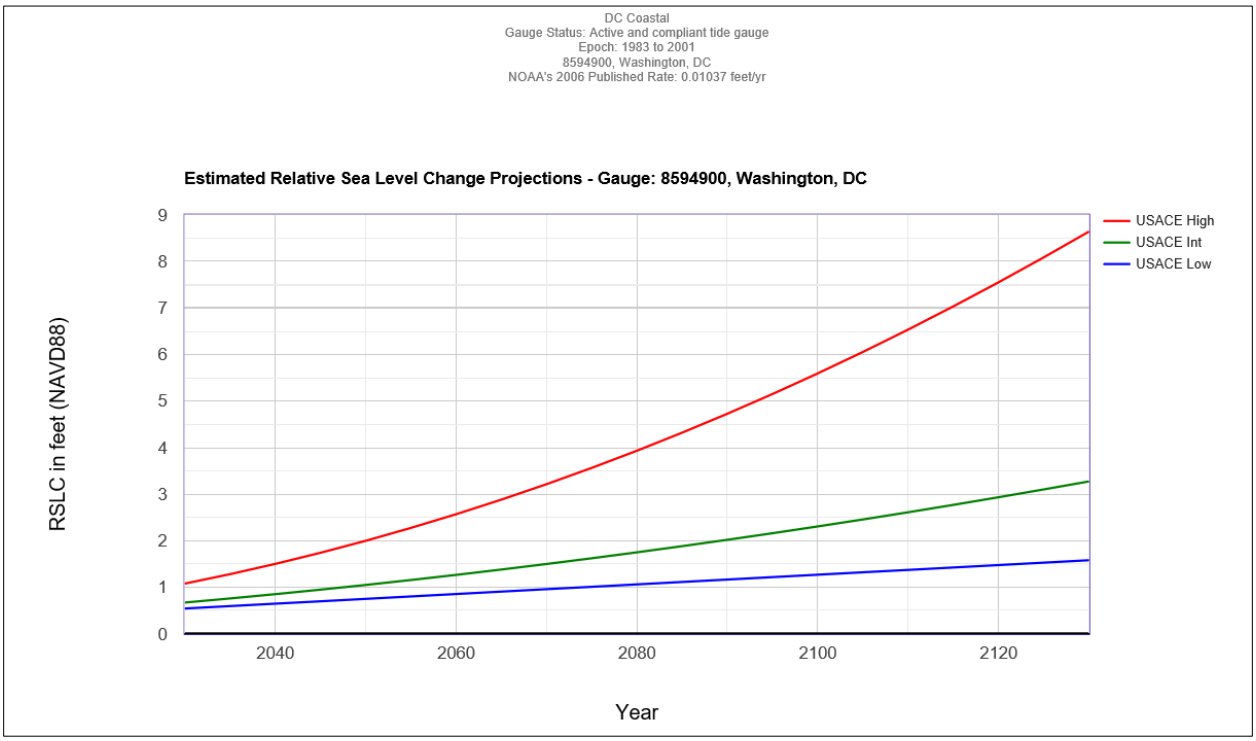

Figure 2-16. Sea Level Change

To address the flooding problems in the region, flood mitigation infrastructure is currently being designed and constructed in Northern Virginia. A six-foot (ft) floodwall addressing a 10 percent AEP is currently in the design phase for the City of Alexandria's waterfront.

Approximately, half of the floodwall is already in place. The construction of the second half is scheduled to start in 2023. The feasibility study will evaluate the performance of existing infrastructures with respect to storm risk, including FRM structures at Four Mile Run and the Cameron Run Huntington Levee. The FWOP condition analysis will consist of a comparison of WSELs to top of existing FRM infrastructure based on future condition surge scenarios.

Many agencies and organizations are making their own plans for adaptation to a potential disaster. But individual facilities, no matter how protected from disaster, still rely on regional utilities for energy, water, communications, and transportation that should be protected. Even regional utilities are interdependent; water pumping stations rely on electricity to function.

2.6.3.2 FWOP Modeling Results

The years 2031-2080 were selected to represent the FWOP condition. No additional development within the study area is anticipated to be at risk since it is assumed that no new development would be subject to future flood risk during the period of analysis. However, a combination of both wealth and complementary effects are likely to contribute to growth in the value of the assets at risk in the study area. The same structures in the Northern Virginia area will continue to be affected by the flooding from coastal storms and suffer increasing losses each year. The following Table 2-19 and Figure 2-17 display the expected PV. In addition, Table 2-19 shows the equivalent annual damages (EAD) for the study area by model areas for the without project conditions by MA. Belle Haven MA in Fairfax County yields the most damages of structures in the study area followed by Old Town Alexandria and Occoquan Bay (Prince William County) MA.

Table 2-19. FWOP Condition Expected Annual Damages by MA

Model Area	Present Value Damages	Equivalent Annual Damages
MA1: Four Mile Run Protected Arlington East	$0	$0
MA2: Four Mile Run Protected Arlington West	$0	$0
MA3: Four Mile Run Protected Alexandria East	$1,615,000	$54,000
MA4: Four Mile Run Protected Alexandria West	$0	$0
MA5: Cameron Run Protected Huntington Levee	$0	$0
MA6: Pentagon Unprotected	$53,000	$2,000
MA7: Reagan National Airport Proposed Bulkhead	$2,278,000	$76,000
MA8: Four Mile Run Arlington Proposed Bulkhead	$5,954,000	$200,000
MA9: Potomac Yard Unprotected	$3,583,000	$120,000
MA10: Old Town Alexandria Proposed Bulkhead	$59,900,000	$2,008,000
MA11: Cameron Run Alexandria Unprotected	$6,102,000	$205,000
MA12: Belle Haven Proposed Bulkhead	$77,625,000	$2,602,000
MA13: Mount Vernon Unprotected	$28,293,000	$948,000
MA14: Fort Belvoir Unprotected	$1,122,000	$38,000
MA15: Mason Neck Unprotected	$9,494,000	$318,000
MA16: Occoquan Bay Unprotected	$46,603,000	$1,562,000
MA17: Four Mile Run Alexandria Proposed Bulkhead	$3,686,000	$124,000
MA18: Cameron Run Fairfax Unprotected	$859,000	$29,000
MA19: Fort Hunt Unprotected	$16,271,000	$545,000
MA20: Old Town Alexandria Unprotected	$15,648,000	$524,000
MA21: Reagan National Airport Unprotected	$20,211,000	$677,000
MA22: Four Mile Run Arlington Unprotected	$34,073,000	$1,142,000
Total	$333,370,000	$11,174,000

G2CRM used Monte Carlo simulation to derive the expected PV damages with 100 iterations completed. The sum of all damages for each life cycle were divided by the number of iterations to yield the expected PV damages for that modeled simulation. A mean and standard deviation were automatically calculated for the PV damages for each MA to account for uncertainty. These PV damages for each MA were summed to derive the study area expected PV damages.

The forecasted SLR in the future, without a project in place, resulted in higher expected average PV damages. The total future “without project” PV damages are approximately $333 million or about $11 million EAD. The forecast of the FWOP condition reflects the conditions expected during the period of analysis (2031-2080) and provides the basis from which alternative plans are evaluated, compared, and selected since a portion of the

flood damages would be prevented (i.e., flood damages reduced) with a federal project in place.

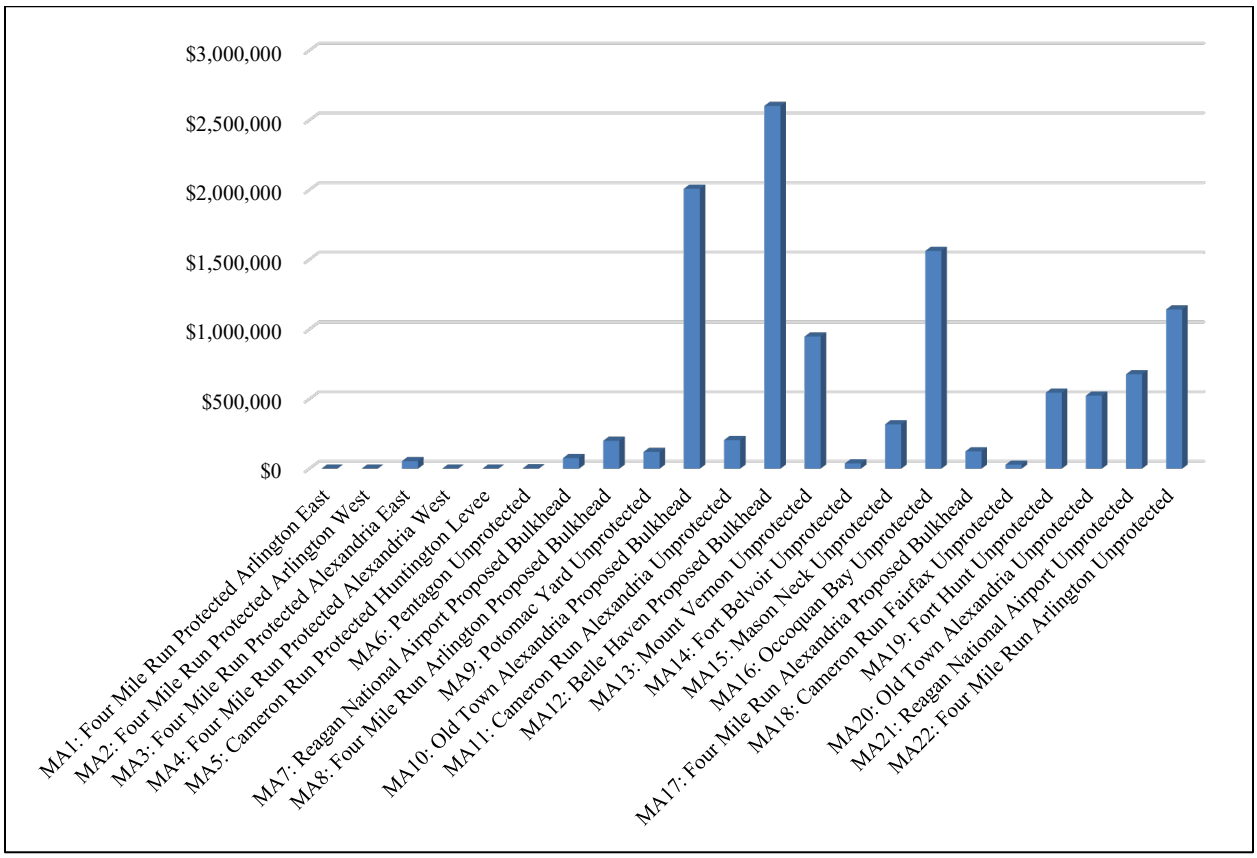

Figure 2-17. FWOP Condition Expected Annual Damages by MA.

3 Plan Formulation and Evaluation*

3.1 Plan Formulation and Evaluation

Plan formulation has been conducted with a focus on achieving the federal objective of water and related land resources project planning, which is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements. Plan formulation also considers the four economic accounts: NED, Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). The plan formulation process focuses on establishing alternatives with non-structural and structural measures initially and then adds natural and nature-based features (NNBF) to the final array of alternatives as design considerations that will enhance the performance and effectiveness of structural measures included in those alternatives.

Structural CSRM measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. This includes gates, levees, and flood walls (permanent and deployable) that are implemented to protect people and property.

Nonstructural CSRM measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the probability of flooding. Relocation, home elevation and floodproofing are examples of nonstructural measures. NNBF CSRM measures work with or restore natural processes with the aim of wave attenuation and storm surge inundation.

3.2 Planning Framework

The planning strategy for formulating alternatives is summarized in Figure 3-1. Section 3 describes the planning units, measures screening, and several iterations of alternative plan formulation culminating in the final array of alternatives which would be further evaluated and compared to determine the TSP. A rough order magnitude (ROM) cost was developed for each of the alternatives for the AMM. G2CRM is the FRM certified model used to analyze the inundation damages. The analysis is conducted using the fiscal year 2022 discount rate of 2.250 percent (October 2021 price level). The base year is 2031.

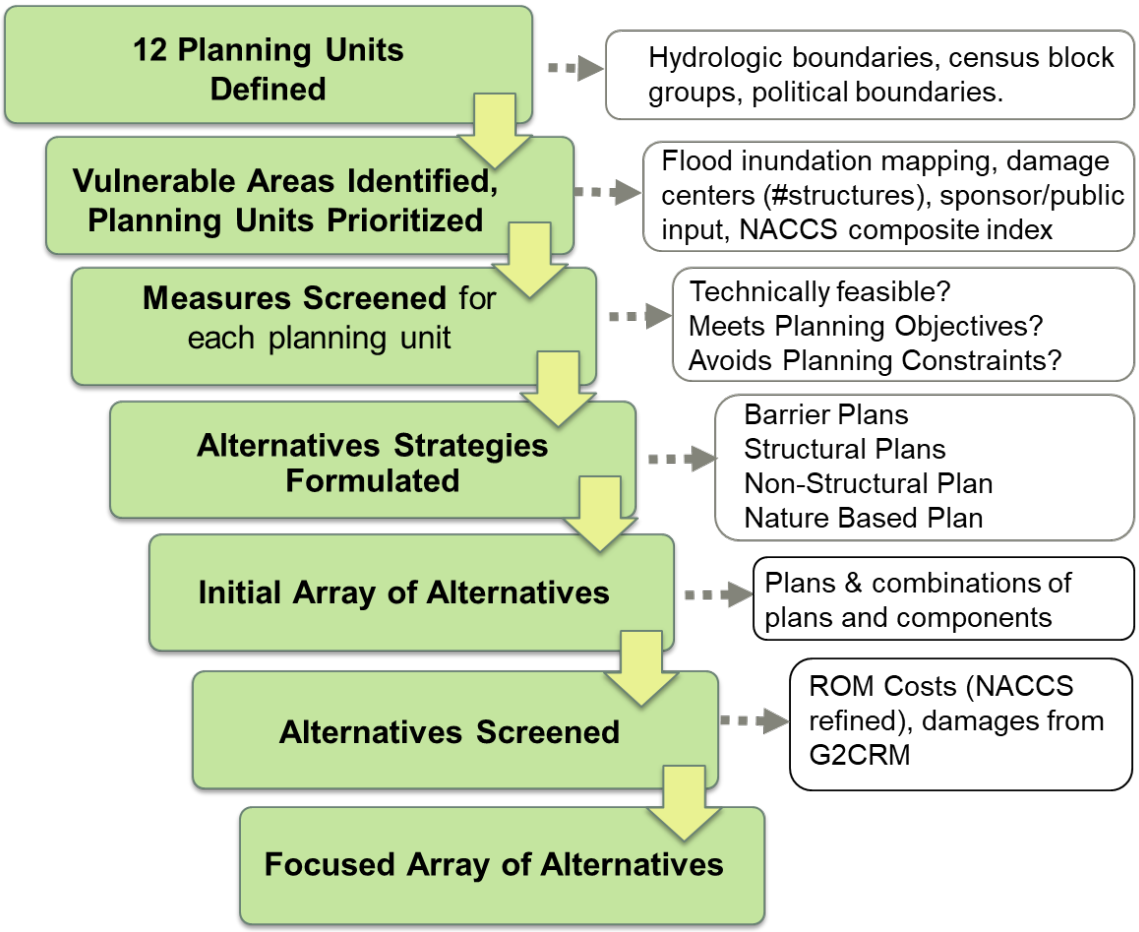

Figure 3-1. Plan Formulation Strategy for Developing Alternatives

3.3 Planning Unit Descriptions

The below descriptions of the planning units describe general vulnerabilities based on the flood inundation mapping conducted early in the study. A vulnerability assessment was conducted between January- April 2022 and the results are discussed in Section 3.6

Potomac Overlook

This planning unit includes the northern end of Arlington County along the Potomac River, from Arlingwood to the Francis Scott Key Bridge. The shoreline along this area is narrow and characterized by NACCS as man-made structures (exposed). The lowest elevation areas are toward the south end of the planning unit near the Francis Scott Key Bridge and the GWMP along the Potomac River. In this area, for the existing and FWOP condition, the GWMP and ramps to the bridge were evaluated. It was determined that no structures were at risk in this area.

Pentagon

The Pentagon planning unit extends from the Francis Scott Key Bridge in Arlington County to the I-395 Bridge across the Potomac. Major infrastructure in this unit includes the Pentagon, Arlington National Cemetery, Arlington and Pentagon Metro stations, and Pentagon parking lots. For existing and FWOP conditions, for the 1 percent AEP, only the shoreline along the Potomac is inundated which includes inundation of the GWMP and the interchanges at the I-395 Bridge. Similar impacts are evident for the FWOP scenarios. For the 0.2 percent AEP, parking lots north of the Pentagon and a few support buildings would also be inundated. Impacts from inundation are evident at the 1 percent AEP to locations within the jurisdiction of Washington, D.C., including Columbia Island Marina, Lady Bird Johnson Park, Lyndon Johnson Memorial Grove, and areas and structures across the Potomac River.

Reagan National Airport

This planning unit extends from just south of the Pentagon from I-395 to Four Mile Run. Within the planning unit, major infrastructure includes the Long Bridge Railroad CSX Corporation (CSX) tracks, used by Virginia Railway Express passenger service, the GWMP, and Ronald Reagan National Airport.

For existing conditions, inundation for the 1 percent AEP would impact the northern shoreline of the planning unit near the I-395 Bridge, including portions of the GWMP, and the coastline around Gravely Point. No structures would be inundated. The southern portion of Reagan National Airport would be inundated along the coastline, impacting portions of Levee Road, runways, and parking lots. With projected SLR (intermediate scenario), extensive inundation of the runways and parking lots is present, as well as impacts to structures and equipment, such as fuel storage tanks, the TSA Systems Integration Facility, navigation, and electrical equipment. The GWMP is also affected at the south end of Reagan National Airport with intermediate SLR. The CSX railroad and metro along the western border of Reagan National Airport is largely elevated and not impacted by inundation. Reagan National Airport borders Four Mile Run on its south side.

Inundation for the 0.2 percent AEP for FWOP conditions with sea level change would result in extensive impacts to Reagan National Airport, including the majority of runways and parking lots, and the locations of the fuel tanks. With SLR, in addition to parking lots and runways, the National Aeronautic Association Building, the entire area surrounding the terminal, parts of the terminal, and Thomas Avenue and adjacent roads are affected.

Four Mile Run

Four Mile Run is a tributary that flows into the Potomac River, just south of Reagan National Airport. This planning unit includes the area adjacent to Four Mile Run, which is in Arlington County to the north and Fairfax County to the south. As previously described in Section 2.5, an existing USACE levee extends from the Route 1 Bridge to Mount

Vernon Avenue along both sides of the river. In recent years, ecosystem improvements, including wetland restoration and living shoreline construction as well as pedestrian trails has occurred in and adjacent to Four Mile Run from Mount Vernon Avenue to Route 1.

For existing conditions for the 1 percent AEP, on the south side of Four Mile Run, Four Mile Park and adjacent housing to the south and west is inundated. For FWOP conditions with sea level change, flooding affects streets south of Four Mile Run Park around Mark Drive, as well as roads and structures (shopping center) east of Mt Vernon Avenue along Bruce Street and west of Mount Vernon Avenue along Four Mile Road. On the Arlington County side of Four Mile Run, with SLR, the Arlington Water Pollution Control Plant between Four Mile Run and South Glebe Road is largely inundated.

For the 0.2 percent AEP, existing and FWOP, inundation in Four Mile Run Park is even more extensive, extending further south and west, and also affecting the Arlington side of the river. Flooding on the north side of the river would impact the area between I-395 and the Arlington Water Pollution Control Plant.

Potomac Yards

The Potomac Yards planning unit extends along the Potomac River from south of Reagan National Airport and Four Mile Run to the north end of Old Town Alexandria at Montgomery Street. Inundation for the 1 percent AEP is similar for existing and FWOP conditions. Inundation would affect the GWMP, which runs the length of this unit along the Potomac River. In addition, Daingerfield Island (owned by the NPS) is inundated, which includes a marina and sailing club, as well as some other structures along Marina Drive. With SLR, there could be potential impacts to the Potomac Yards Metro Station, which is currently under construction, although it is anticipated that this station will be sufficiently elevated. Similar impacts with more extensive inundation of Daingerfield Island are evident for the 0.2 percent AEP, with or without SLR.

Alexandria Old Town

The Alexandria Old Town planning unit extends along the Potomac River from Montgomery Street near Tide Lock Park south to the mouth of Cameron Run, just south of the I-495 Capital Beltway Bridge across the Potomac. For the 1 percent AEP at the existing condition, there would be impacts to almost the entire length of the Potomac River waterfront. At the north end, Rivergate City Park and Oronoco Bay Park are inundated, including the Dee Campbell Rowing Center. Moving southward, Founders Park and structures south of Founders Park, including marinas, commercial, and residential structures are inundated to Jones Point Park. Impacts are similar, but extend slightly more inland, for the FWOP condition. With inundation for the 0.2 percent AEP, waterfront inundation is extensive, with flooding occurring in some inland neighborhoods, including along North Royal Street from Jones Point Park north to Gibbon Street. Inundated structures include numerous residences and historic buildings.

In 2009, the City of Alexandria began development of the Alexandria Waterfront Small Area Plan, which was approved by the City Council in 2012. In 2014, 15-30 percent design contracts were generated and approved by the City Council. The flood mitigation project is planned to address flooding from the Potomac River within a "core" area, extending along the waterfront from Duke to Queen Street. The city evaluated several mitigation plans, but the preferred option is to construct a structural bulkhead that would act to mitigate flooding up to six ft NAVD88), with a 10 percent AEP. A promenade would be constructed along the walkway with landscaping, park (green) space, and other amenities. The existing storm sewer would be rehabilitated, and pump stations would be added to address flooding from stormwater runoff. The height of the bulkhead was selected based on years of public input, as a way to mitigate flooding, but still allow residents to be connected to the river.

Cameron Run

This planning unit includes Cameron Run in Fairfax County, located south of Alexandria and north of Belle Haven. The Cameron Run shoreline is classified as vegetated, low banks. In NACCS, this area was flagged for risk due to the relatively high population and infrastructure present and because the area is vulnerable to both inland flooding and coastal flooding from the Potomac River; however, Fairfax County completed the construction of a levee to protect this area, including single family residences south of Huntington Park.

Flood inundation for the 1 percent AEP for existing and FWOP conditions would affect the area south of Cameron Run at the Old Richmond Highway/Capital Beltway intersection, as well as the area around the interchanges on the north side of Cameron Run. Capital Beltway interchanges on the north side of Cameron Run east of Telegraph Road are also impacted. Impacts for the 0.2 percent AEP are similar.

Belle Haven

This planning unit extends from Cameron Run along the Potomac River south toward Mount Vernon. Two subdivisions, New Alexandria and Belle Haven, experienced severe flooding from storm surge during Hurricane Isabel in 2003 are located within this unit. Over 200 structures were damaged in this area during Hurricane Isabel. For the 1 percent AEP, inundation would be widespread from the north end of the Belle Haven Country Club (golf course), southward to Wake Forest Drive, encompassing the subdivisions of Belle View and New Alexandria. New Alexandria is in the northern section of the Belle Haven watershed above I-Street and contains mostly single-family houses. Belle View contains condominiums, the Belle View shopping center, and the River Towers high-rise apartment complex, all of which would be inundated for the 1 percent AEP existing and FWOP condition, with similar impacts for the 0.2 percent AEP.

Under the authority provided by Section 206 of the 1960 Flood Control Act (PL 86-645), as amended, the Corps of Engineers can provide the full range of technical services and planning guidance that is needed to support effective flood plain management. In 2008 and 2014, USACE evaluated several alternatives through Flood Plain Management Services, including a levee/floodwall around the entire area to 12 ft, a levee/floodwall around New Alexandria, flood proofing in New Alexandria, and flood proofing in Belle View with a ring wall around the shopping center. USACE recommended a combination levee/floodwall around the entire area as the most cost-effective solution. The reports and recommendation were provided to the sponsor, but a project was not implemented due to community opposition to the project. The Belle View Reports can be found in Appendix G.

Shoreline type in this area is a mix of wetlands (sheltered), man-made structures (exposed), and beaches. Dyke Marsh Wildlife Preserve and Hog Island (and adjacent houses) are within the area that would be inundated by a coastal storm. Additionally, the GWMP runs the entire length of this planning unit along the Potomac River, and several sections, including adjacent to the Belle Haven/New Alexandria communities, would be inundated under existing or FWOP conditions.

Mount Vernon

The Mount Vernon planning unit encompasses the area from Little Hunting Creek to Dogue Creek. Inundation for the 1 percent AEP and 0.2 percent AEP for existing and FWOP conditions are very similar, and would affect the upstream reaches of Hunting Creek, which would include impacts mostly to wetlands and marinas. Gardens on the Mount Vernon Estate are impacted. Waterfront property along Dogue Creek, including the community of Yacht Haven, which includes boat docks and single-family houses would be impacted, as well as houses along Burke Drive.

Fort Belvoir

This planning unit includes the Fort Belvoir military installation in between Dogue Creek and the wetlands west of Fort Belvoir. For existing and FWOP condition (1 percent and 0.2 percent AEP) inundation of the military base includes the upstream end of Dogue Creek, including Fort Belvoir Marina and streets and base housing behind the marina. Wetlands to the west of Fort Belvoir are inundated, but with no impact to structures. Most docks/houses affected are along River Road.

Mason Neck

This planning unit extends from Pohick Creek adjacent to Ft. Belvoir to Belmont Bay. This area was identified in NACCS because of a wastewater treatment plant is at a high elevation and is not impacted. Docks or houses along the coastline may be impacted, but mostly the area is wetland with narrow beach, and includes the Mason Neck Wildlife Refuge. Inundation affects the coastline along the Occoquan River near Colchester,

which mainly impacts marinas, boat docks/houses, or boat yards. Impacts are similar for existing and FWOP condition (1 percent AEP and 0.2 percent AEP).

Occoquan Bay

This planning unit extends from the Occoquan River to Neabsco Creek. The 1 percent AEP inundation affects large portions of the Occoquan NWR, and the marina at Belmont Bay Harbor would be inundated, as well as the land behind the Belmont Town Center. South of the NWR, structures between the Potomac River and Marumsco Creek (Bayside Park), south into the Featherstone Shores development would be inundated as well as the Featherstone NWR. With the 0.2 percent AEP inundation, additional area is inundated up the various tributaries, with some impacts to the commercial development near Featherstone NWR and the existing railroad lines. The H.L. Mooney Advanced Water Reclamation Facility sits on high ground and is not impacted by coastal inundation.

For each planning unit, a standard list of CSRM measures was evaluated and screened, including those identified for certain areas in NACCS.

3.4 Management Measures

Management measures were evaluated and screened using the feasibility study's planning objectives (Table 3-1).

Plan formulation is the process of building alternative plans that meet planning objectives and avoid planning constraints. Alternatives are a set of one or more management measures functioning together to address one or more planning objectives. A management measure is a feature or activity that can be implemented at a specific geographic location to address one or more planning objectives. A feature is a "structural" element that requires construction or assembly on-site whereas an activity is defined as a "nonstructural" action.

The non-structural and structural management measures were developed during the Public Scoping Meeting held in Virginia on 11 September 2019 (Table 3-2). For each focus area a standard list of coastal storm risk measures were screened, including those identified for certain areas in the North Atlantic Coastal Comprehensive Study (NACCS). Measures were also screened to ensure they avoided the planning constraints.

These measures were investigated to identify means in which they could be combined to improve resiliency from coastal storm risk in Northern Virginia. The combined measures formed the initial array of alternatives described in the next section.

Table 3-1. Measures retained (X) for each planning unit

PLANNING UNITS	**Structural**	Storm Surge Barrier - Regional	Tide Gates	Shoreline Stabilization (Seawall, revetment, bulkheads)	Beach Fill Stabilization - Breakwaters*	Beach Fill Stabilization - Groins*	Floodwall (levee, dike, berm)	Deployable Floodwall	Drainage Improvements (Pump Station, Culvert/Drain, Water storage/retention/restore natural storage)	Channel Improvements (deepening/widening)	Shoal Removal/Dredging	**Non-Structural**	Structure Elevation	Acquisition/Relocation	Flood Proofing	Enhanced Warning Systems	**Natural/Nature Based****	Living Shoreline	Wetland Restoration	Reefs	Submerged Aquatic Vegetation	Beach restoration (dune)	**Policy/Programmatic**
Potomac Overlook		X					X									X							X
Pentagon		X					X									X							X
Reagan National Airport		X					X		X				X		X	X							X
Four Mile Run		X					X	X	X				X	X	X	X							X
Potomac Yards		X					X						X	X	X	X							X
Alexandria Old Town		X					X	X	X				X	X	X	X		X	X				X
Cameron Run		X					X	X	X				X	X	X	X							X
Belle Haven		X					X	X	X				X	X	X	X		X	X		X		X
Mount Vernon		X											X	X	X	X							X
Fort Belvoir		X					X						X	X	X	X							X
Mason Neck		X											X	X	X	X							X
Occoquan Bay		X											X	X	X	X							X

*Provides level of protection only when in combination with beach dune

**NNBF will not provide meet planning objectives on their own, but are considered for optimization of other alternatives.

Table 3-2. Management Measures Screened with Study Objectives

	Study Objectives			
	Reduce risk to human health and safety	Reduce economic damages	Reduce disruption of critical infrastructure	Improve resiliency of critical infrastructure
Measure Name	Do the following non-structural considerations meet the study objectives? (Yes/No)			
Storm surge barrier	Yes	Yes	Yes	Yes
Tide gates	Yes	No	Yes	Yes
Seawall, bulkheads	Yes	Yes	Yes	Yes
Groins, breakwaters	No	No	No	No
Floodwalls and levees	Yes	Yes	Yes	Yes
Deployable floodwalls	Yes	Yes	Yes	Yes
Drainage improvements	Yes	Yes	Yes	Yes
Channel improvements	No	No	No	No
Shoal removal/dredging	No	No	No	No
Flood-proofing	Yes	Yes	Yes	Yes
Building elevation	Yes	Yes	Yes	Yes
Acquisition & relocation	Yes	Yes	Yes	Yes
Enhanced warning systems	Yes	No	No	Yes
Living shoreline	Yes	No	No	Yes
Wetland restoration	No	No	No	Yes
Reefs	No	No	No	No
Submerged aquatic vegetation	No	No	No	No
Beach restoration (dunes)	No	No	No	Yes

The management measures that meet all four of the study objectives are storm surge barriers, seawall/bulkhead, deployable floodwalls, floodwalls and levees, drainage improvements, floodproofing, building elevation, and relocation/acquisition. It was determined that concrete I-wall or T-wall when compared to a seawall or bulkhead were found to be best suited for the areas analyzed. Inundation from three flood scenarios: 5 percent, 2 percent, and 1 percent AEP did not result in a high enough water level to warrant relocation/acquisition of any structures. Therefore, relocation/acquisition was not further evaluated and instead the non-structural plan focused on floodproofing and building elevation.

3.5 Vulnerability Assessment

To evaluate vulnerability and risk to populations and structures within the planning units, flood inundation mapping was performed for the 1 percent (100-year event) and 0.2 percent (500-year event) AEP for the existing condition (2020) and for the FWOP condition with relative sea level change (RSLC) using the USACE intermediate RSLC curve of 1.75 ft for 2080.

A vulnerability assessment conducted by USACE Engineering Research and Development Center (ERDC) evaluated the vulnerability of lifeline infrastructure, including electricity, drinking water, wastewater, natural gas, transportation, and other services. ERDC modeled the water levels generated by coastal storms for selected return periods ranging from 1 to 1000 years. Sea-level rise will increase the extent and depth of flooding caused by storms of a given return period. Using sea-level in 2020 as a baseline, sea-level change was projected for low, medium, and high rates of change and evaluated in years 2030, 2080, and 2130. ERDC simulated water surface elevations and the extent of flooding for each year and rate of change in sea level. The PDT used these results to estimate inundation depths by comparing water surface elevations to digital elevation models to calculate water depths at regular grid points in the study area. The vulnerability assessment focused on seven SLR scenarios (Table 3-3).

Table 3-4. Mapping of Sea Level Rise Scenarios to MWDC CSRM Sea Level Rise Scenarios

Scenario	Change in Sea Level (feet)	Corresponding MWDC CSRM Sea Level Rise Scenario	
		Year	Rate of Sea Level Change
1	0	2020	Intermediate
2	0.67	2030	Intermediate
3	1.08	2030	High
4	1.75	2080	Intermediate
5	3.27	2130	Intermediate
6	3.93	2080	High
7	8.64	2130	High

Coastal storm impacts to infrastructure systems were assessed for selected transportation and utility systems. Impacts were assessed for the following transportation systems: Reagan National Airport, Washington Metro (Metro), CSX freight and Virginia Rail Express (VRE) commuter rail systems, and road transportation. Impacts were assessed for the following utility systems: drinking water treatment, wastewater treatment and natural gas.

Runways are essential components of the infrastructure system at any airport. Staff at Reagan National Airport indicated that regulations would prohibit the use of any runway if any portion were inundated. At Reagan National Airport, runways are among the first

infrastructure components to be flooded. For Reagan National Airport, inundation between 1.75 ft and 3.27 ft of SLR could increase the probability that air travel would be disrupted with runway 4-22 likely being inundated by up to 2.2 ft of water under the base condition (0 ft of SLR) during a 1 percent AEP storm. Figure 3-2 shows inundation from the 1 percent AEP across four SLR scenarios.

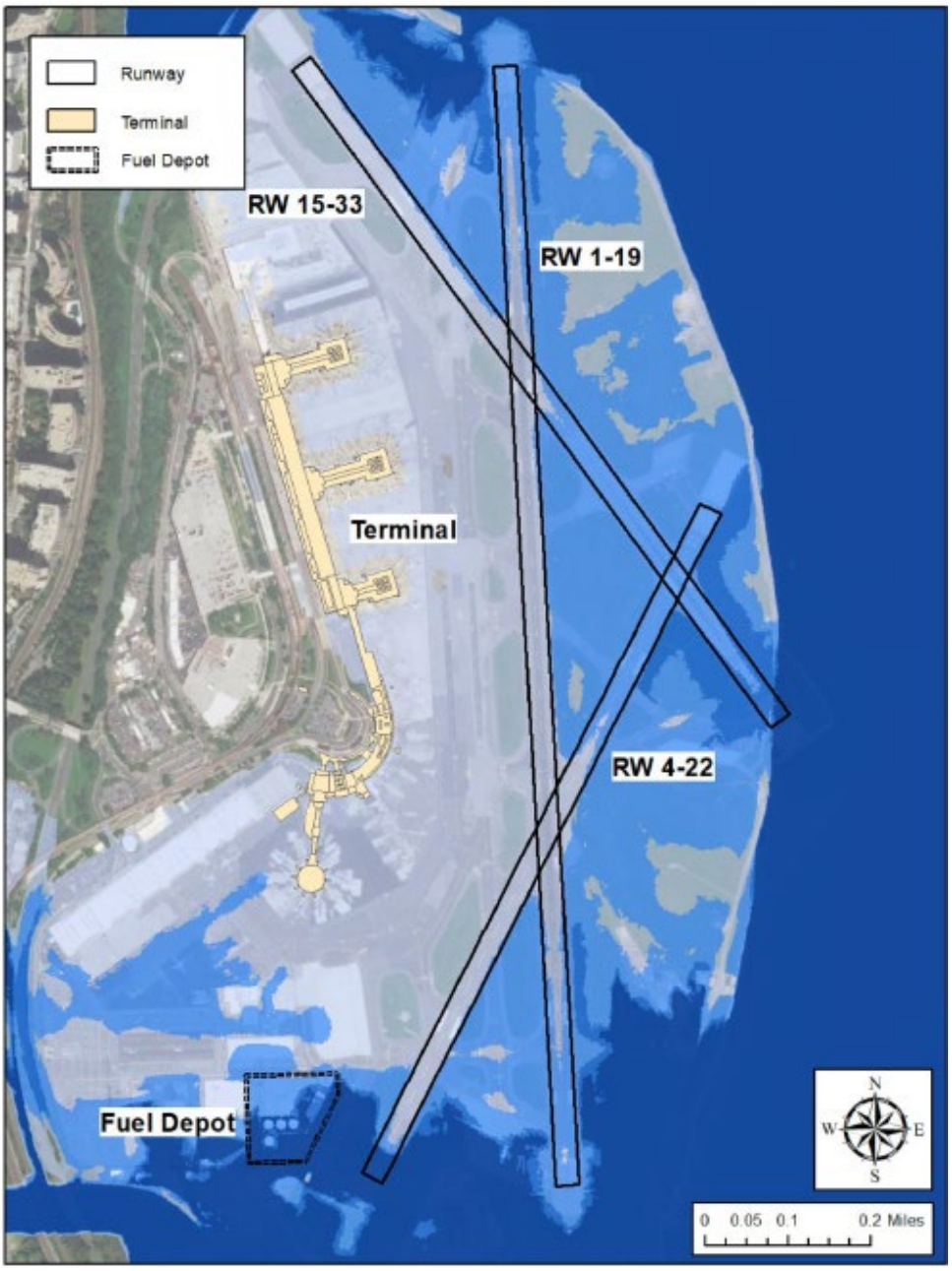

Figure 3-2. Reagan National Airport Runways, 1 percent AEP Inundation Under Various Sea Level Change Scenarios

Note: Inundation of Reagan National Airport runways given a 1 percent AEP coastal storm for four SLR scenarios. Areas of dark blue represent inundation given a 1 percent AEP coastal storm under existing sea level and successively lighter shades represent 1.08 ft, 3.27 ft and 8.64 ft, respectively.

The Washington Metro Orange and Silver Lines were found to have minimal flood impacts across all seven SLR scenarios and coastal storm scenarios. Under the 1 percent AEP coastal storm scenario, the Blue and Yellow Lines did not see inundation until the 8.64 ft SLR scenario (Figure 3-3). Under the 0.1 percent AEP (1000-year) coastal storm scenario, inundation started at 3.23 ft of SLR.

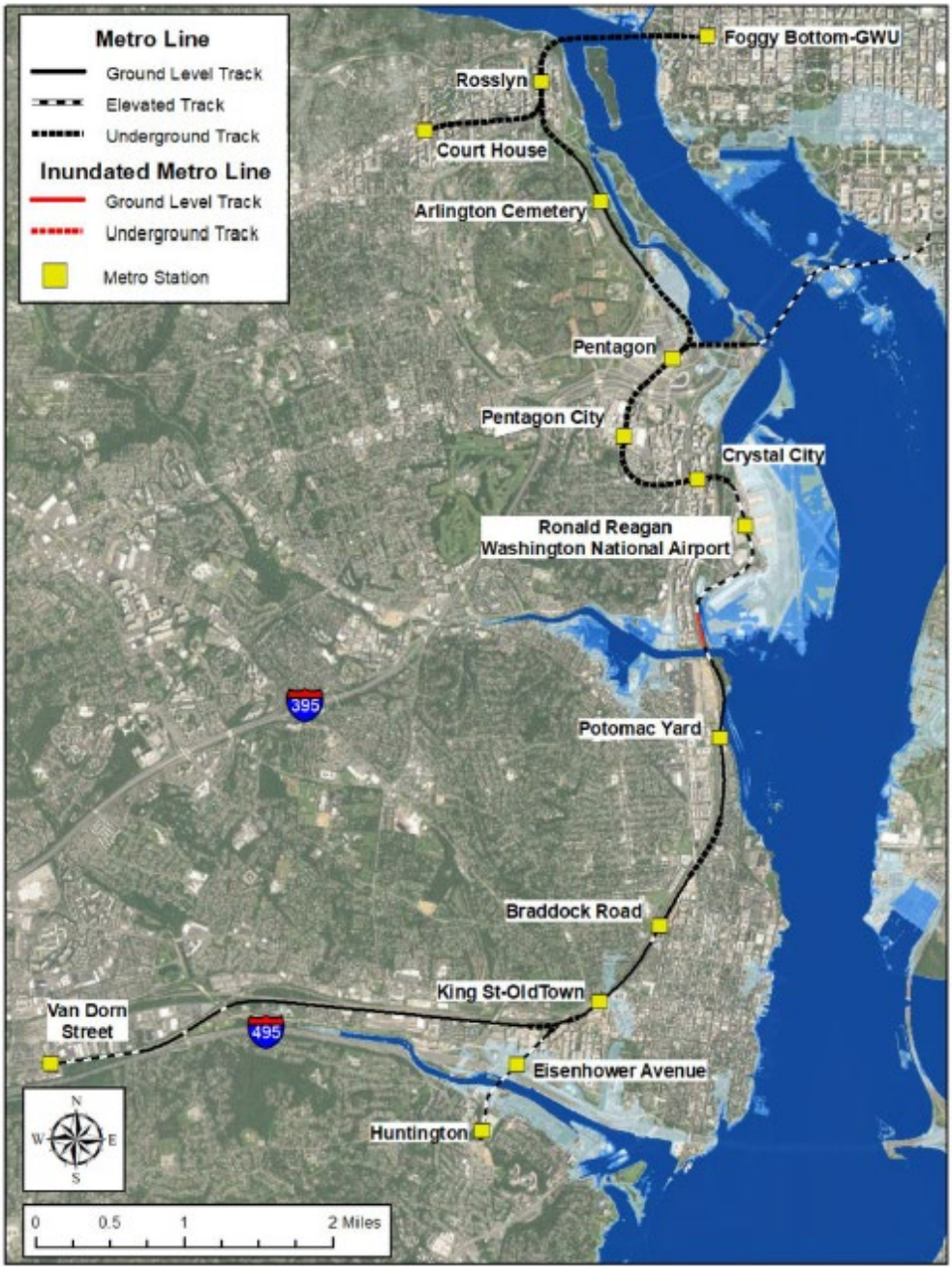

Figure 3-3. Washington Metro Blue and Yellow Lines, 1 percent AEP Inundation
Note: Metro railroad track inundation caused by a 1 percent AEP coastal storm under four SLR scenarios.

Commercial railways in the study area are operated by CSX Transportation and VRE. CSX Transportation is a Class 1 freight railroad that operates east of the Mississippi River. VRE is

a publicly owned corporation that operates commuter rail service in Virginia on tracks owned by CSX Transportation and Norfolk Southern Railroad. There are two rail segments that are potentially inundated during coastal storm events. The first is a roughly one-half mile segment of rail between Long Bridge Park and Roaches Run, just north of Crystal City. This segment is potentially flooded given a 0.1 percent AEP (1000-year) storm and 8.64 ft of SLR. The second is a three-mile segment of track just north of Rippon Station and adjacent to Occoquan Bay. This section of track is susceptible to flooding under a 1 percent AEP (100-year) storm with 8.64 ft of SLR, and 0.1 percent AEP (1000-year) storm with 3.23 ft of SLR. Figure 3-4 shows the 1 percent AEP coastal storm inundation between Woodbridge Station and Rippon Station.

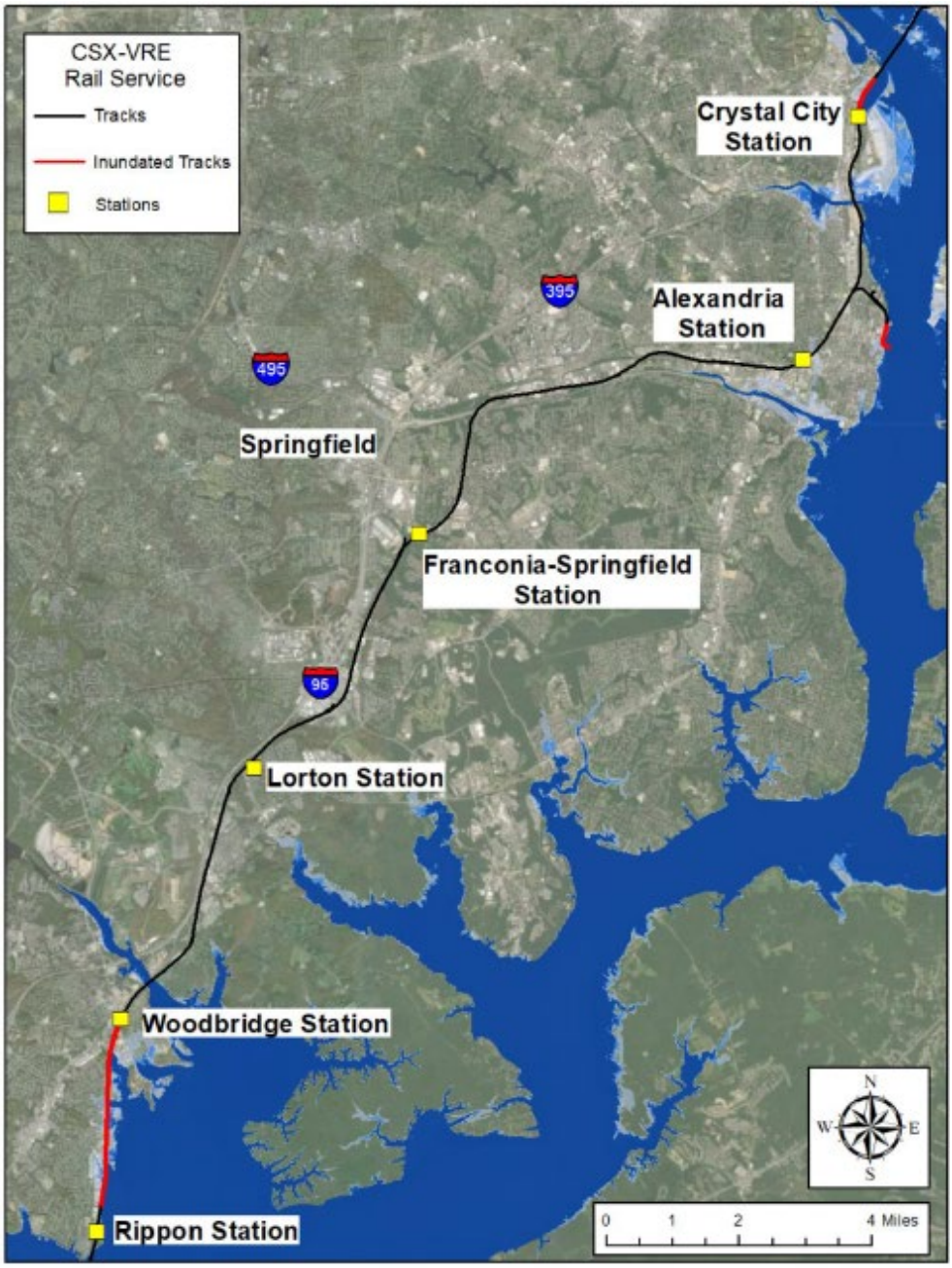

Figure 3-4. CSX Freight and VRE, 1 percent AEP Inundation

Note: Potentially inundated segments of CSX rail lines are shown in red. Areas of inundation are shown for a 1 percent AEP coastal storm given existing sea levels and three SLR scenarios (3.23 ft and 8.64 ft).

Potomac River floods have the potential to impact road transportation by reducing traffic capacity in the study area. In this study, traffic impacts within the planning area are quantified in terms of the percent reduction in traffic flow caused by inundation of road segments. The number of inundated road segments will increase as the extent of flooding increases with the intensity coastal storms and SLR. Inundation of road segments with higher average daily traffic (ADT) will have greater impact on overall traffic capacity in the

planning area. Therefore, in terms of describing the potential impacts of flooding on traffic capacity, it is not sufficient to describe the number of roads inundated. The network analysis developed in this study accounts for differences in average daily traffic flow to assess the overall impact of flooding on traffic capacity in the planning area. Inundation of road networks for each planning area included in the final array of alternatives was evaluated for four SLR scenarios (0.0 ft, 1.08 ft, 3.27 ft, 8.64 ft) for the 1 percent AEP and 0.1 percent AEP coastal storm scenarios (Figures 3-5 to 3-9).

Significant reductions in traffic capacity are attributed to the inundation of road segments along the GWMP. The GWMP is a high traffic corridor with an estimated ADT of 62,000 vehicles per day. Given a 1 percent AEP coastal storm, segments of the GWMP along Roaches Run and underneath I-395 are inundated, as are the access ramps that provide access to and from I-395 (Exit 10). The Richmond Highway follows US-1 to I-395 and continues north of I-395 along Route VA-110, on the east side of the Pentagon. Sections of VA-110 would be inundated during a 1 percent AEP coastal storm given more than 3.93 ft of SLR.

Although not a high traffic area, Four Mile Run and Arlandria are shown here because they are prone to flooding and have been considered for CSRM measures in this study. The bridge over Four Mile Run that carries Mount Vernon Avenue has an ADT of 12,000 vehicles per day. Although the bridge itself is marked in red, suggesting that some portion of the road segment would be flooded by a 1 percent AEP coastal storm with existing sea levels, this is not the case. The bridge would span the width of Four Mile Run. However, portions of Mount Vernon Road south of the bridge would be inundated by a 1 percent AEP coastal storm with 1.08 ft of SLR and impede access.

Given larger increases in sea level, low lying segments of the I-95/I-495 (the Capital Beltway) corridor along Cameron Run south of Old Town Alexandria are vulnerable to flooding. This route has ADT of 154,000 vehicles per day and, if inundated, these road segments would account for a large fraction of reductions in traffic capacity. Low lying segments of the Capital Beltway would become inundated given a 1 percent AEP storm and 8.64 ft of SLR or a 0.1 percent AEP storm with at least 3.93 ft of SLR. Also of interest is the extensive flooding of US-1 east of Huntington. This problem is more immediate, with inundation potentially occurring given a 1 percent AEP storm and existing sea levels. For comparison, Route US-1 has an ADT of 48,000 vehicles per day.

Old Town Alexandria and Belle Haven would not contribute significantly to reductions in traffic capacity, but both of these areas have been considered for CSRM measures in this study and were therefore evaluated. Routes of note in the Belle Haven neighborhood are SC-1510 (Belle Haven Boulevard), which has an ADT of 8,100 vehicles per day, and SC-632 (Belle Haven Road), which has an ADT of 7,100 vehicles per day. Both of these routes feed the GWMP and are significant contributors to reductions in traffic capacity under all coastal storm and SLR scenarios.

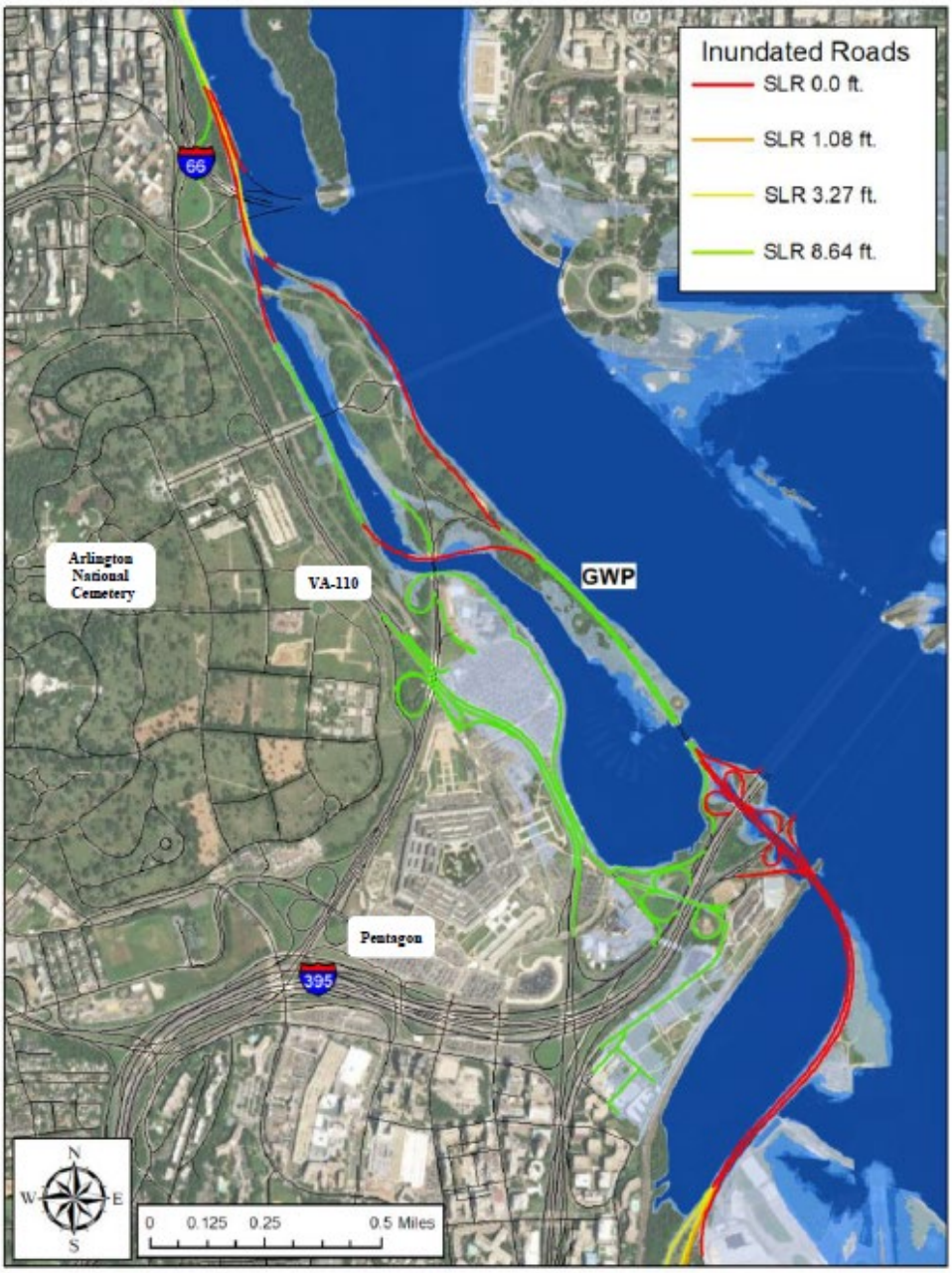

Figure 3-5. GWMP between Reagan National Airport and Key Bridge, 1 percent AEP Inundation

Note: Road inundation caused by a 1 percent AEP coastal storm under four SLR scenarios. The State of Virginia road network used in this assessment terminated at the Potomac River. None of the bridges crossing the Potomac River are inundated.

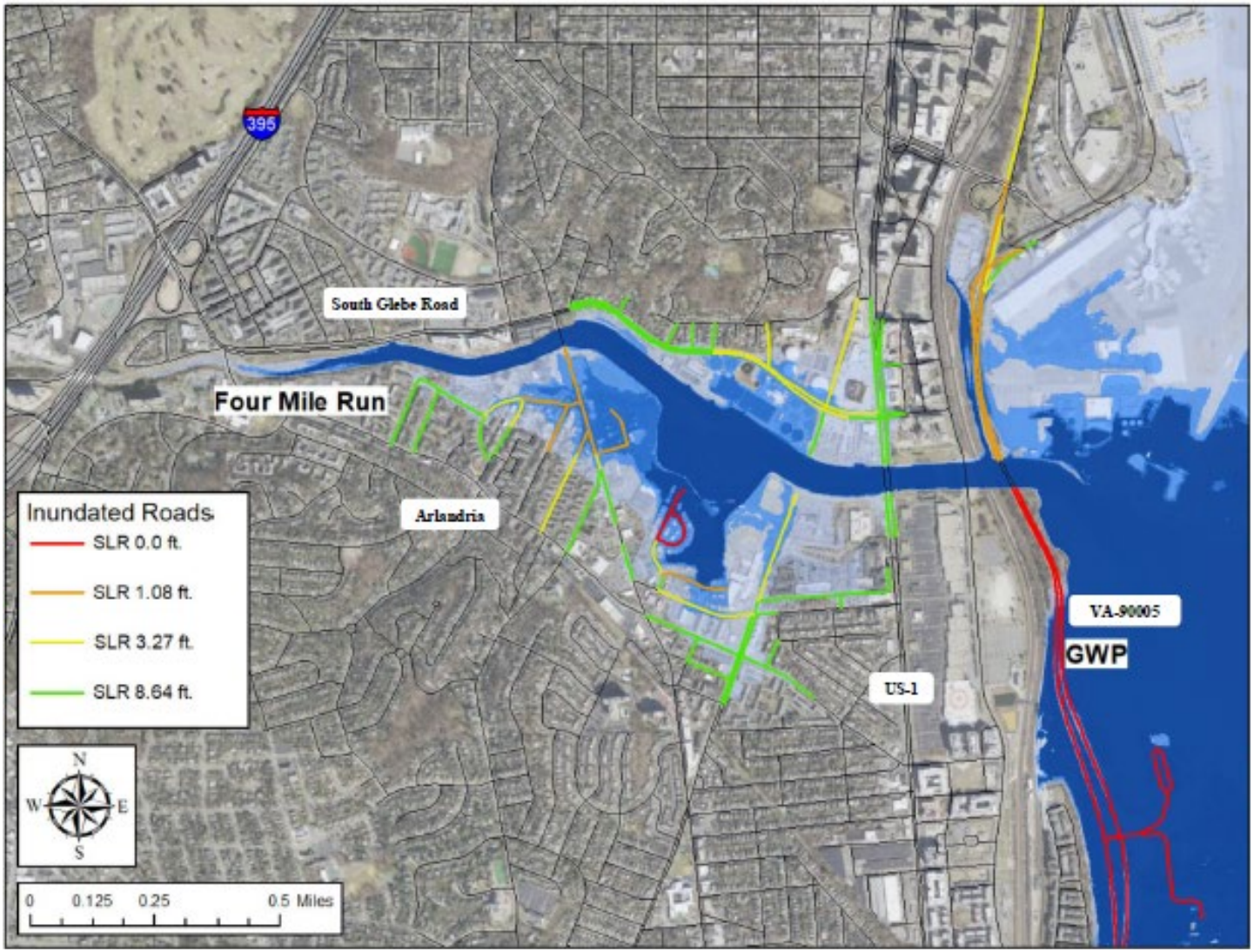

Figure 3-6. Four Mile Run and Arlandria, 1 percent AEP Inundation

Note: Road inundation caused by a 1 percent AEP coastal storm under four SLR scenarios.

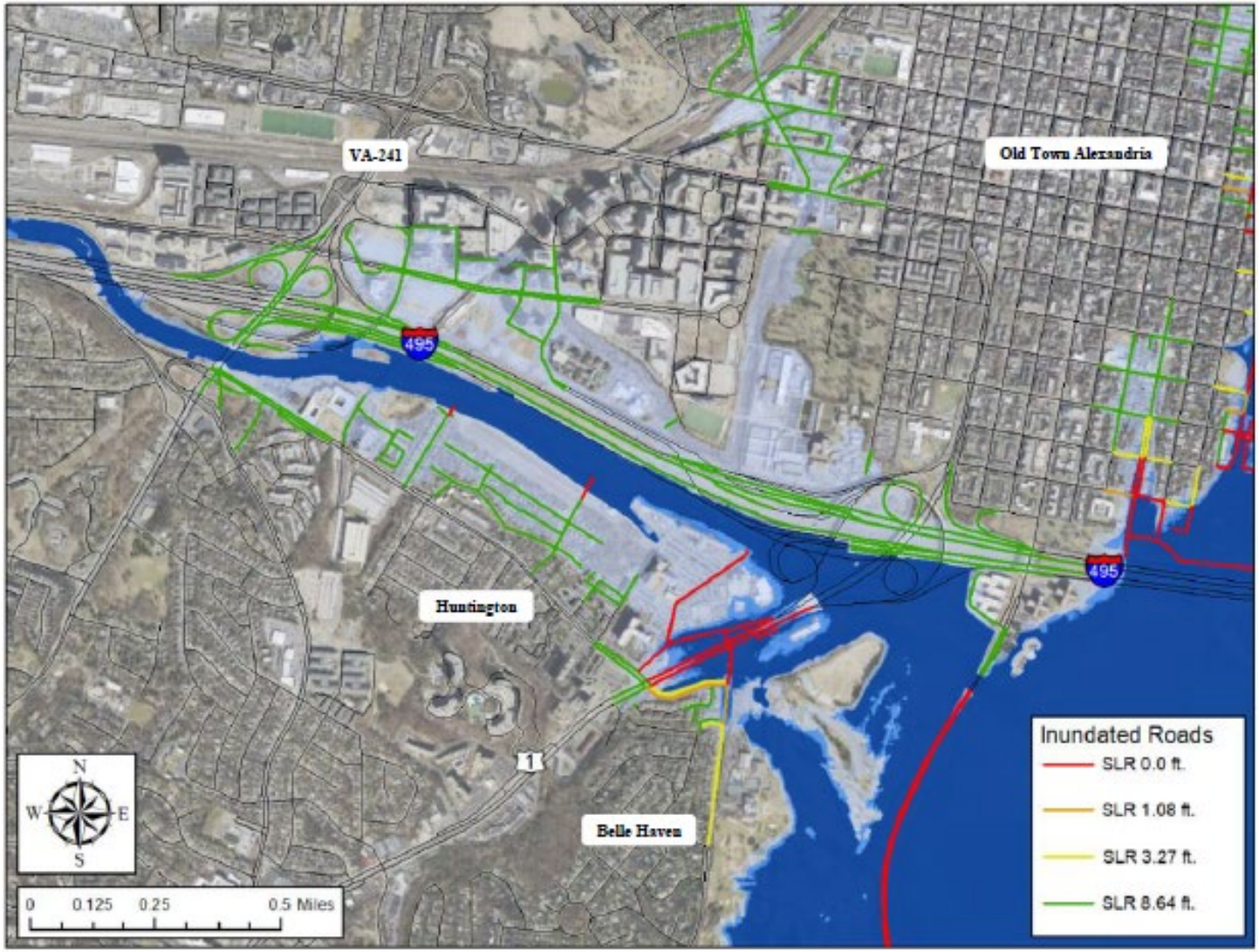

Figure 3-7. I-95/I-495 Corridor between Telegraph Road (VA-241) and the Potomac River, 1 percent AEP Inundation

Note: Road inundation caused by a 1 percent AEP coastal storm under four SLR scenarios.

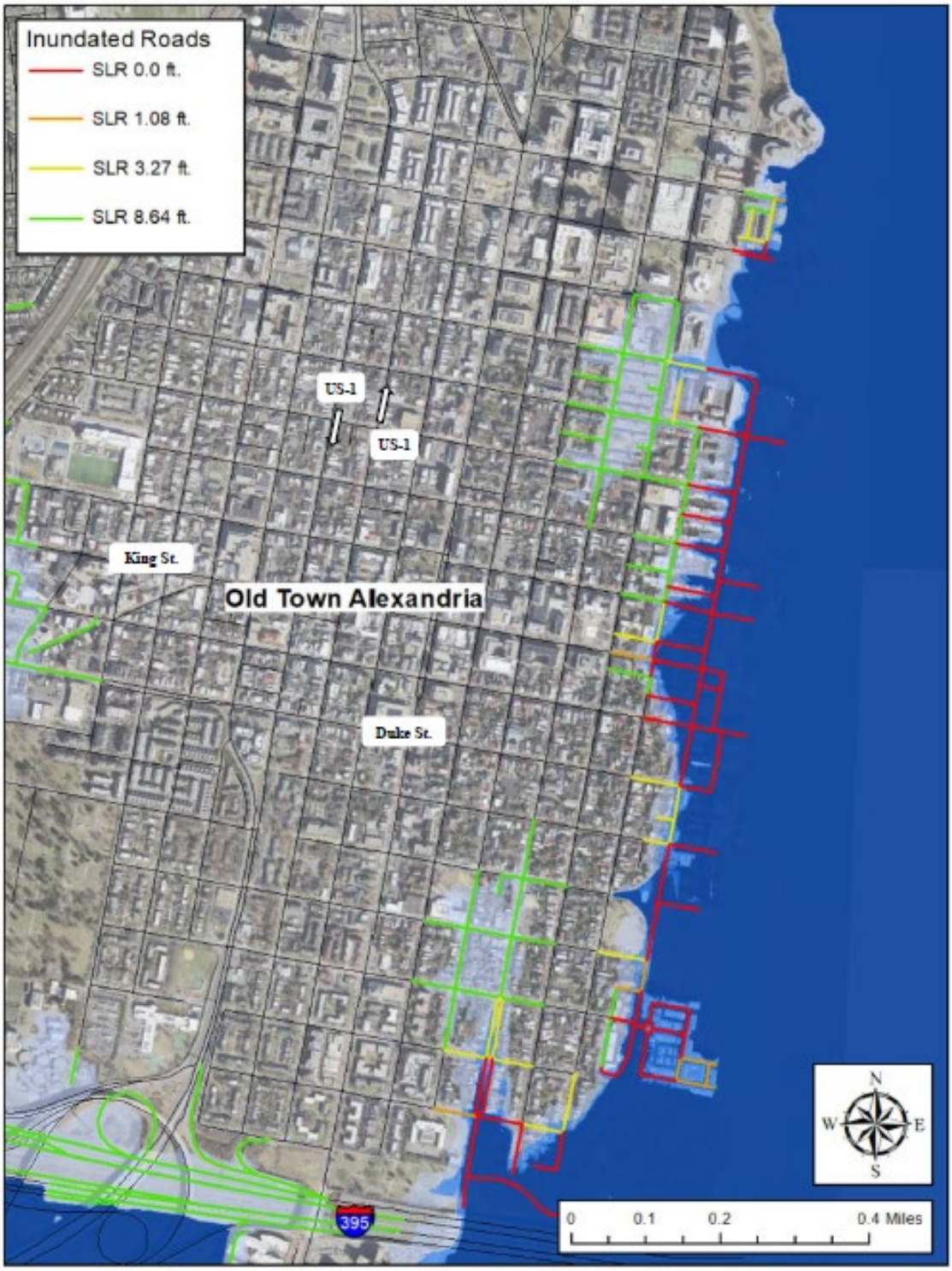

Figure 3-8. Old Town Alexandria, 1 percent AEP Inundation

Note: Road inundation caused by a 1 percent AEP coastal storm under four SLR scenarios.

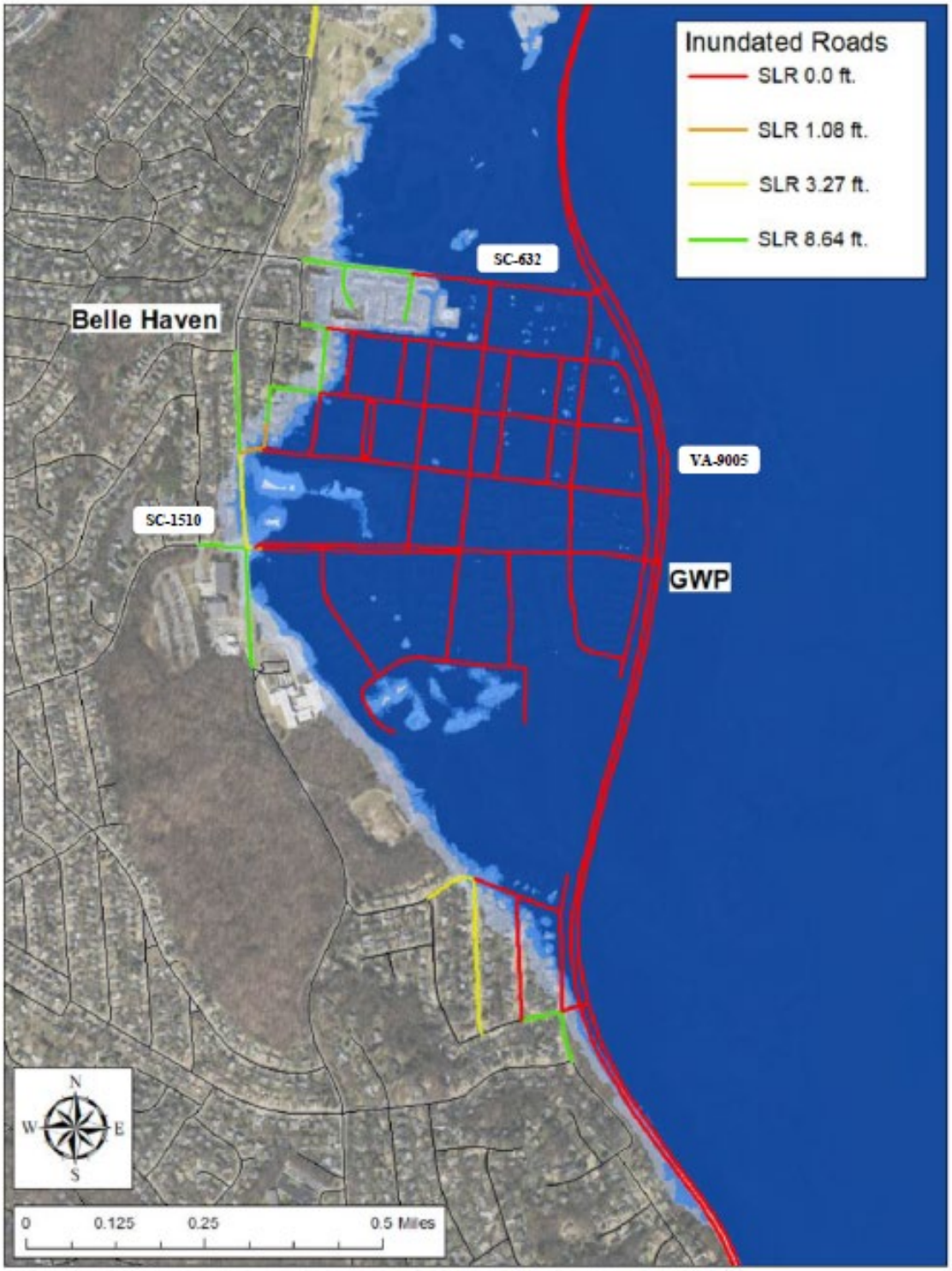

Figure 3-9. Belle Haven, 1 percent AEP Inundation

Note: Road inundation caused by a 1 percent AEP coastal storm under four SLR scenarios.

The Vulnerability Assessment is attached to Appendix B.

3.6 Array of Alternatives

From the compiled table of management measures, the team formulated "lines of defense", representing alternative plans, based on logical groupings of measures and planning units. Lines of defense are shown in Table 3-5 and include two surge barrier plans, two structural plans, and a non-structural plan.

A structural alternative was also generated for Fort Belvoir; however, since Fort Belvoir is owned by the Department of the Army, the alternative is presented here but not carried forward. Per ER 1105-2-100, military funds, not civil works funds, must be used for protection of Department of Army lands.

Table 3-5. Lines of Defense

Line of Defense	Strategy	Area
Comprehensive Coastal Surge Barrier Plan	Construction of a **storm surge barrier** across the Potomac downstream of the study area, at the Route 301 bridge.	Virginia, Washington, D.C., and Maryland upstream of the barrier.
Upper Coastal Surge Barrier Plan	Construction of a **storm surge barrier** across the Potomac near Fort Hunt to reduce risk to upstream areas, **with non-structural measures** outside barrier.	Virginia, Washington, D.C., and Maryland protected upstream of Fort Hunt. Non-structural measures downstream of barrier.
Floodwall/Levee Plan	Reduce risk to property and infrastructure through **structural** features (levees and floodwalls)	Four Mile Run, Belle Haven, Alexandria.
Critical Infrastructure Plan	Reduce risk to critical infrastructure through structural features (levees and floodwalls)	GWMP, Reagan National Airport, Arlington Water Pollution Control Plant
Non-Structural Plan	Application of **non-structural** measures to reduce damages and increase resilience to coastal communities.	Entire Study Area
Natural Areas Plan* ***for optimization of above plans, not stand alone**	Repair or prevent future damages by expansion/restoration of **natural features**, such as living shorelines and wetlands	Focus on Alexandria, Belle Haven and south (Mount Vernon, Fort Belvoir, Mason Neck, Occoquan Bay)

The following sections show the iterative planning process starting with the initial array of the alternatives developed for the AMM in November 2019 through the final array of alternatives evaluated and compared for the TSP Milestone in March 2022. Each section

builds upon the former with additional details added to alternative plan descriptions, applied screening criteria, revisions to alternative alignments, limits of disturbance (LOD) and change in measure type (i.e. floodwall extent changed to earthen levee etc.).

3.6.1 Initial Array of Alternatives

The Initial Array of Alternatives are shown in Table 3-6, which consists of the plans within the lines of defense, as well as the separable components of the plans and combinations of plans/components. The descriptions below are the initial array of alternatives formulated for the AMM in November 2019.

Table 3-6. Initial Array of Alternatives

Alt.	Description
1	**No Action**
2	**Comprehensive Coastal Surge Barrier**
3	**Upper Coastal Surge Barrier**
4	**Critical Infrastructure Plan (GWMP, Reagan, Arlington WPCP)**
4a	GWMP
4b	Reagan National Airport
4c	Arlington WPCP
5	**Floodwall/Levee Plan (Four Mile Run, Alexandria, Belle Haven)**
5a	Four Mile Run Floodwall
5b	Alexandria Floodwall
5c	Belle Haven Levee & Floodwall
6	**Non-Structural Plan (entire study area or components)**
7	**Alts 3 and 6 (Upper Coastal Barrier + Nonstructural downstream)**
8	**Combinations of 4, 5, 6**

Additionally, structural measures were formulated for initial design and evaluation considering one elevation based on water surface elevations in the coastal storm modeling updated as part of this study. For critical infrastructure assets in Alternative 4, the PDT used the 0.2 percent AEP water surface elevation to inform the design elevation of the structural measure due to the potential for substantial regional impacts resulting

from disruption to critical infrastructure assets. For residential/commercial areas in Alternative 4, the initial design elevation was developed using the 1 percent AEP water surface elevation because it represents a likely condition based on storm impacts experienced during Hurricane Isabel in 2003. The top of elevation considered for CSRM structures are detailed in Table 3-3.

Table 3-3. Top of Elevation of CSRM Structures by Project Area.

Project Area	NACCS ID/ Virtual ID	Top of Elevation of CSRM Structures ft NAVD88
Reagan National Airport	5984/3	14.3
Arlington WPCP	5984/3	14.3
Old Town Alexandria	14608/7	13.2
Four Mile Run	5984/3	13.9
Belle Haven	14731/9	13.0

Alternatives 2, 3, & 7: Surge Barrier Plans

These alternatives include the surge barrier plans (Figures 3-10 and 3-11). The Comprehensive Barrier alternative (Alternative 2) includes a location downstream of the study area, which encompasses the entire study area, additional area downstream of the study area, as well as areas upstream of the barrier in Maryland and Washington, D.C. The Upper Coastal Barrier alternative (Alternative 3) would be located within the study area upstream of Mt Vernon. Both of these locations were cited as the most suitable locations given the width of the Potomac River and technical feasibility, and the Upper Coastal location was also identified as a potential location for a barrier in the 1963 Washington, D.C. Hurricane Survey (CH2MHill, 2015).

Alternative 4: Critical Infrastructure Plan and Components

Alternative 4 (Figure 3-12) is the Critical Infrastructure Plan, which includes the most vulnerable structural infrastructure in the study area. This includes roads and building structures (fire stations, police stations, hospitals, treatment plants, airport, etc.) but excludes lifeline infrastructure (e.g., electricity, drinking water, wastewater, etc.,) networks that were evaluated by ERDC prior to TSP. The subcomponents of this alternative include GWMP at 3 locations, Reagan National Airport, and the Arlington Water Pollution Control Plant.

Alternative 5: Floodwall/Levee Plan

The Floodwall/Levee Alternatives (Figure 3-13) are focused on reducing risk to damage centers (neighborhoods and commercial) using structural measures. The subcomponents of this alternative include Four Mile Run, Alexandria waterfront, and Belle Haven.

Alternative 6: Non-structural Plan

Figure 3-14 shows the focus or concentrated areas for nonstructural measures (flood proofing, elevation, acquisition, relocation). The nonstructural alternative was formulated based on site and flooding characteristics using a Geographic Information System (GIS) analysis, which identified structures appropriate for certain nonstructural measures. The PDT evaluated elevation, flood proofing and acquisition based on flood depth.

Alternative 8: Combinations of Alternatives 4, 5, and 6

Alterative 8 would consist of a combination of alternatives or components of alternatives depending on which are viable. These could include combinations of components of the critical infrastructure alternative, floodwall levee alternative, and non-structural measure where areas are unprotected by structures.

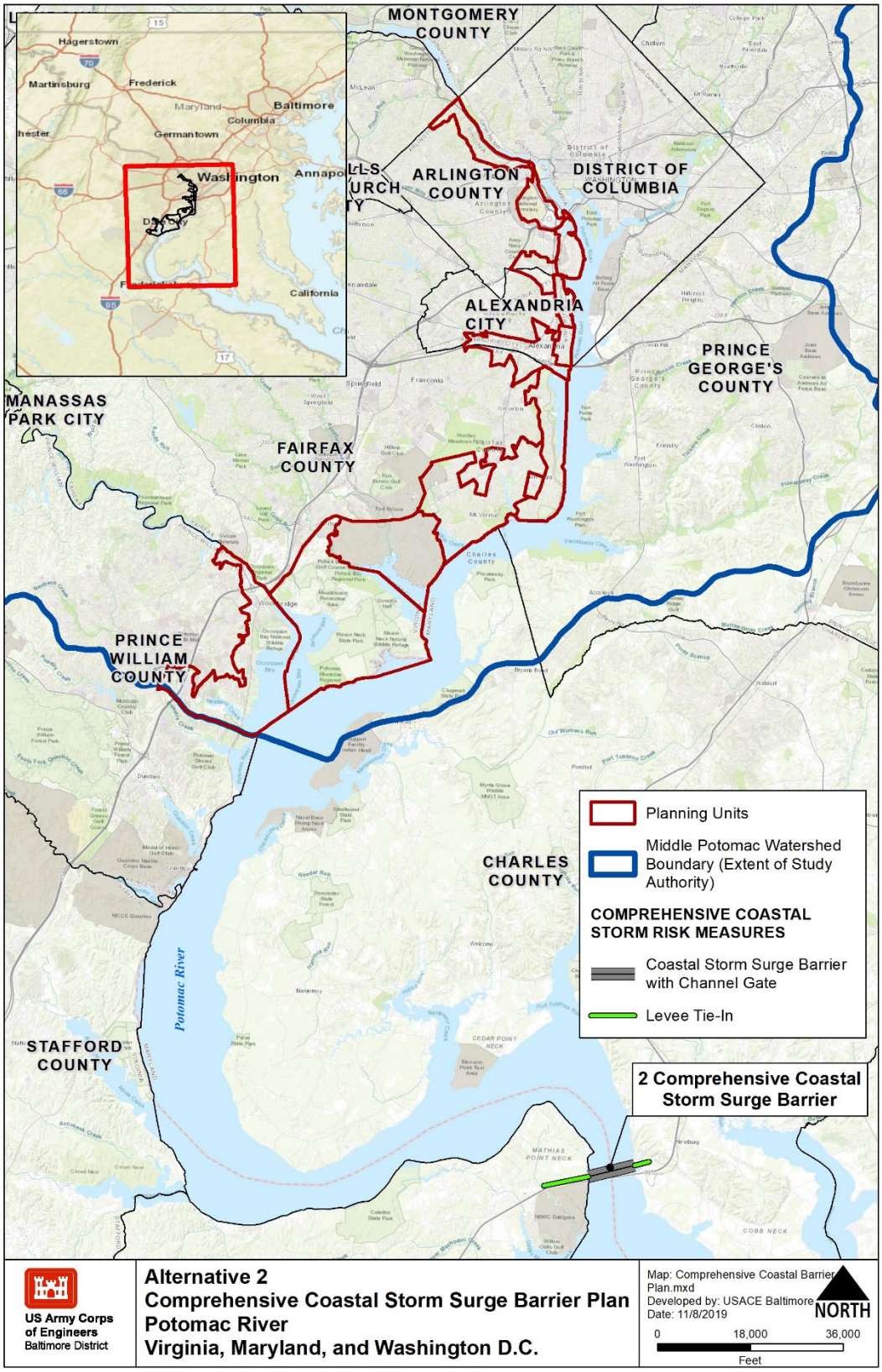

Figure 3-10. Alternative 2 – Comprehensive Coastal (downstream) Surge Barrier

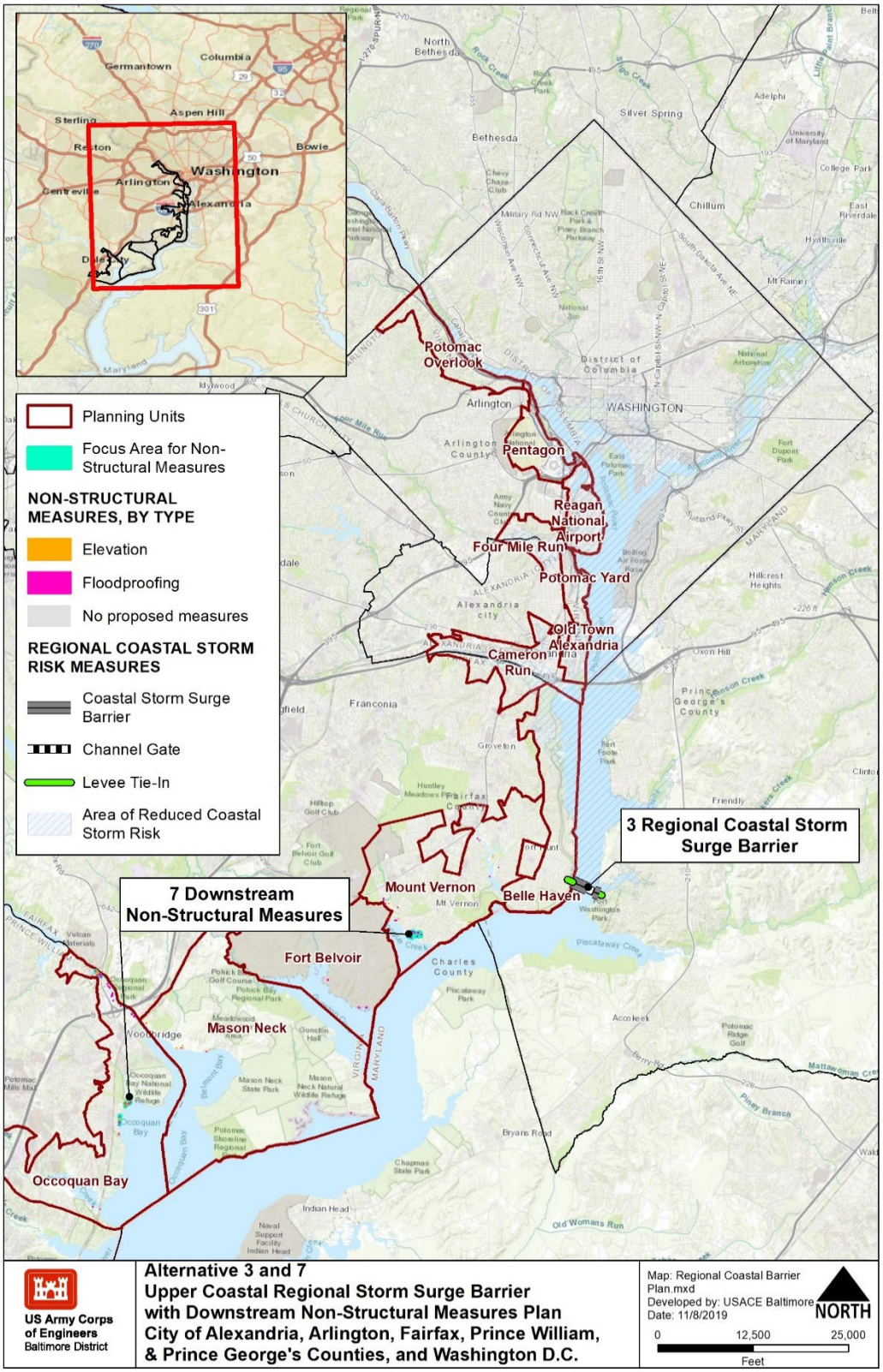

Figure 3-11. Alternative 3 – Upper Coastal (regional - upstream) Surge Barrier with Non-structural Measures Downstream (Alternative 7)

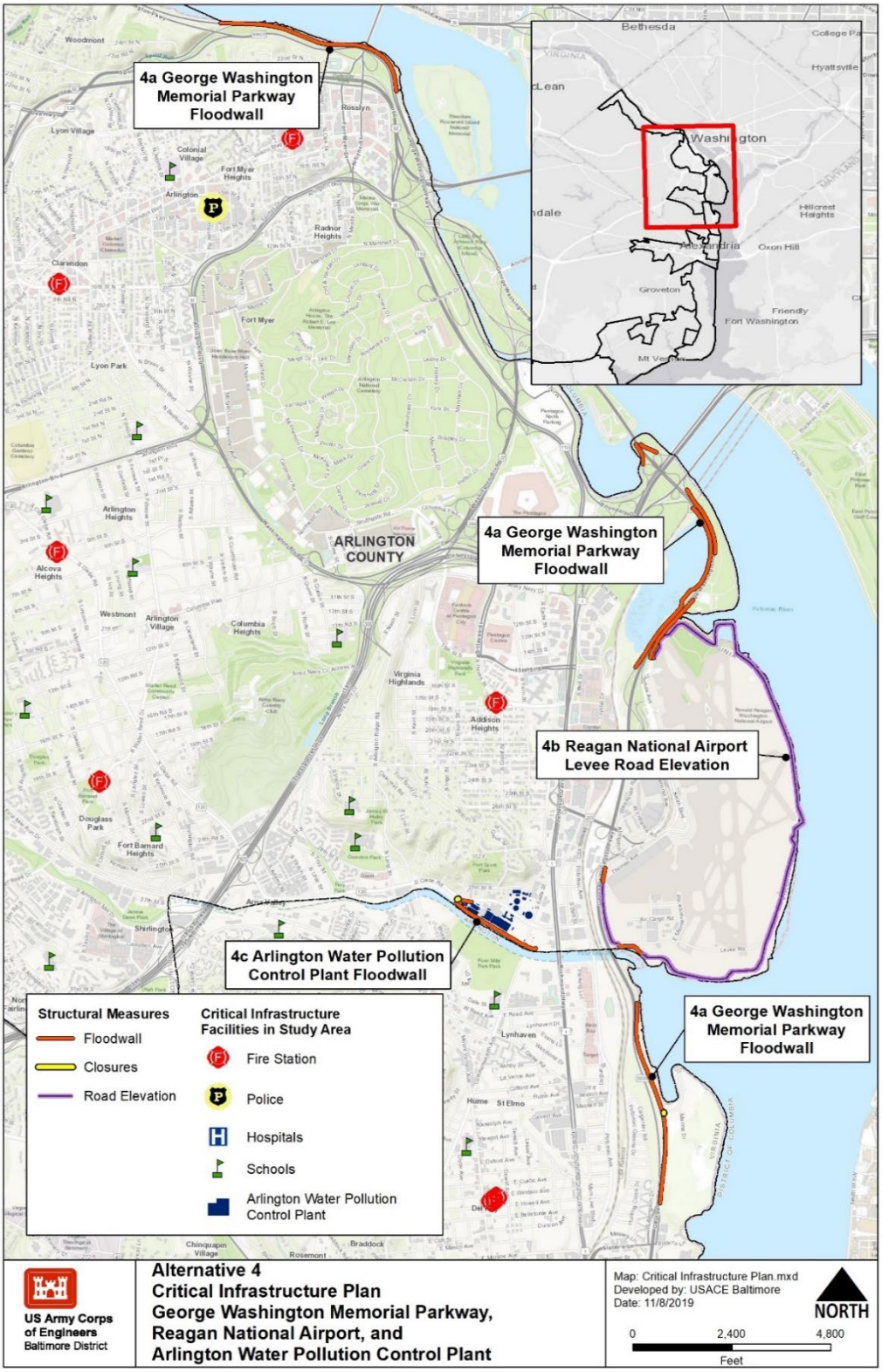

Figure 3-12. Alternative 4 – Critical Infrastructure Plan

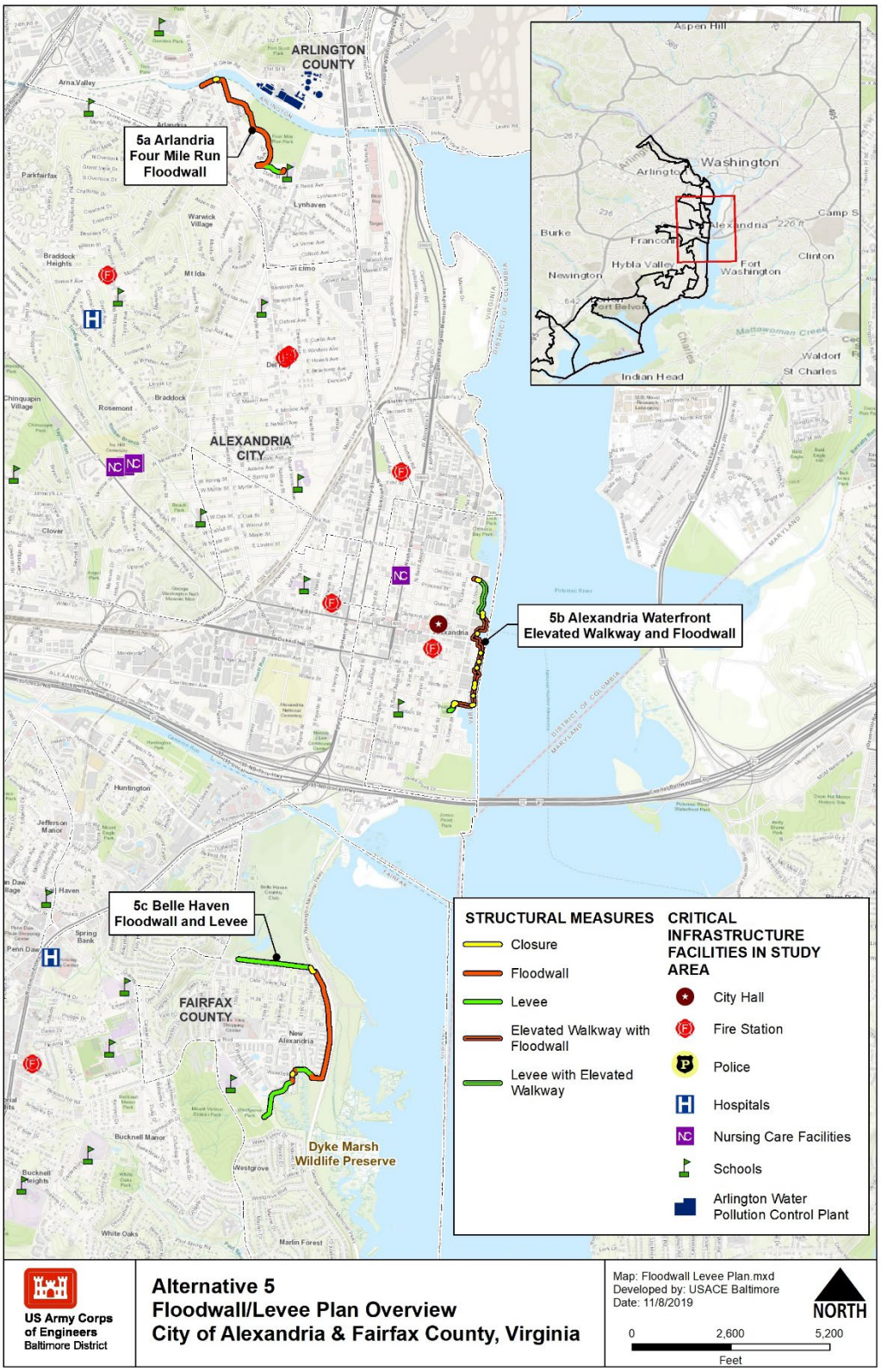

Figure 3-13. Alternative 5 – Floodwall/Levee Plan

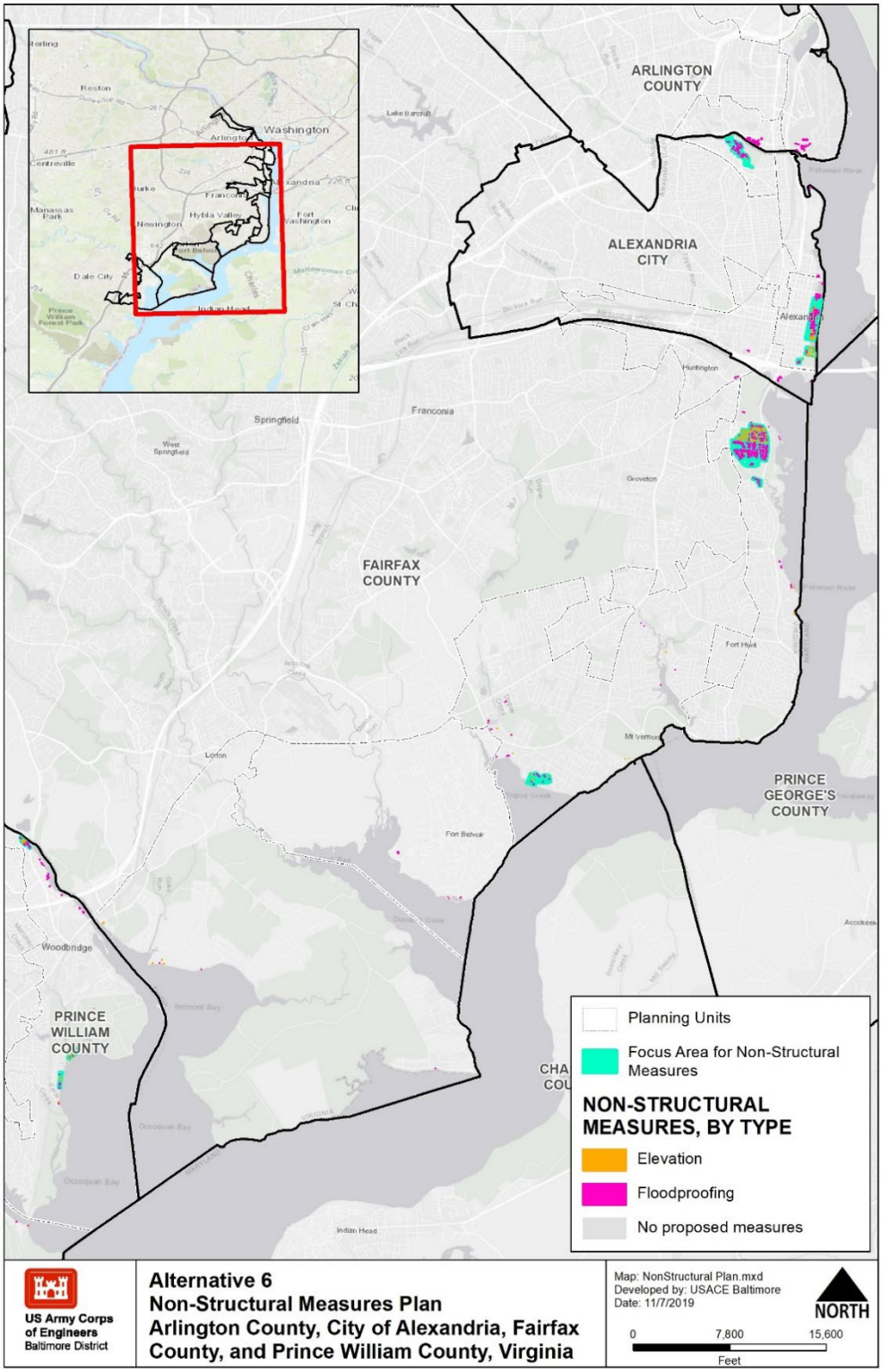

Figure 3-14. Alternative 6 – Non-structural Plan

3.6.2 Focused Array of Alternatives

In November 2019, the following focused array of alternatives were confirmed by USACE higher authority and as stated above, Alternatives 2, 3, 4a, and 7 were not carried forward into the final array of alternatives (Table 3-7).

Table 3-7. Focused Array of Alternatives

Alt.	Description	Screen/Retain
1	**No Action**	Retain
2	**Comprehensive Coastal Surge Barrier**	Screen
3	**Upper Coastal Surge Barrier**	Screen
4	**Critical Infrastructure Plan (GWMP, Reagan, Arlington WPCP)**	
4a	GWMP Floodwall	Screen
4b	Reagan National Airport Levee and Floodwall	Retain
4c	Arlington WPCP Floodwall	Retain
5	**Floodwall/Levee Plan (Four Mile Run, Alexandria, Belle Haven)**	
5a	Four Mile Run Floodwall	Retain
5b	Alexandria Floodwall	Screen
5c	Belle Haven Levee & Floodwall	Retain
6	**Non-Structural Plan (entire study area or components)**	Retain
7	Alts 3 and 6 (Upper Coastal Barrier + Nonstructural downstream)	Screen
8	Combinations of 4, 5, and 6	Retain

Alternatives 2, 3, & 7: Surge Barrier Plans

The cost for the Comprehensive Coastal Barrier (Alternative 2) was estimated by the consultant (CH2MHill, 2015) for rising sector gates (16) spanning a 4,000 ft wide channel, with a 4,400 ft earth/rock levee barrier. Base capital costs for the barrier and gate were $7.4 billion. Given the magnitude of the total cost estimated for this alternative, this alternative was immediately screened out from consideration.

The Upper Coastal Storm Surge Barrier (Alternative 3) was estimated by the consultant for radial gates with a 1,000 ft wide channel, and 2,800 ft of an earth/rock levee barrier. The base capital costs for the Upper Coastal Storm Surge Barrier were estimated to be $600 million for the barrier and gate. Following the alternative milestone meeting, the PDT

coordinated removal of storm surge barriers from further consideration in the study with USACE higher authorities. Consideration of barriers would have resulted in a substantial increase in the project scope (budget), by expanding the study area to include Maryland and Washington D.C., in addition to Northern Virginia. Additionally, the following preliminary considerations indicate that the barrier would not be acceptable to resource agencies or local jurisdictions including:

- Hydraulic constraints - riverine discharge, induced flooding impacts on either side of the barrier
- Cultural resource constraints - impacts to the George Washington Memorial Parkway and other cultural resources
- Environmental - water quality impacts, impacts to endangered species (e.g., Atlantic Sturgeon) and other anadromous fish

As discussed in Section 1.1, the study was descoped to include just the Northern Virginia area and based on this change in scope and the preliminary considerations listed, USACE removed surge barriers from further consideration.

Alternative 4: Critical Infrastructure Plan and Components

Reagan National Airport and Arlington WPCP are the most viable components of the Critical Infrastructure Plan. Coordination with the NPS led to the elimination of the floodwall/levee measures along the GWMP dropping Alternative 4a from consideration. During agency coordination meetings, NPS has voiced that they are very concerned with any impact to the parkway, which includes anything that detracts from the character or viewshed of the road and its' historic integrity. This includes changes to views of the river, disconnection from the natural landscape, alterations of other views, impact to the historical character of the road itself, impacts from induced flooding to trails or other NPS resources, and other cultural resource impacts. NPS has been negotiating with the Federal Highway Administration (FHWA) over a 7-inch raising of the wall along the parkway, and therefore there is little viability for a floodwall that would be significantly higher than what is currently under negotiation.

Alternative 5: Floodwall/Levee Plan

Four Mile Run

Although initial damages ($5.6 million maximum damages from G2CRM) do not support the cost of this alternative ($14 million), it was retained since damage estimates were cursory and there is significant public and sponsor interest in this alternative. Upon meeting with the City of Alexandria, it was clear that community acceptance of a floodwall through Four Mile Run Park would be difficult to obtain. It was suggested that a levee, rather than a floodwall, would allow community access to the park and amenities and would be more palatable. Alignment of levee on the west end at Mount Vernon Avenue

will be challenging. After this meeting, alignments were adjusted based on stakeholder input and observations during the site visit.

Alexandria

The City of Alexandria is moving forward with a Waterfront Mitigation Plan to address nuisance flooding, including building a six ft bulkhead along their "core" waterfront area, from Duke Street to Queen Street. In 2021, $120 million in funding was approved for this project with planned implementation expected by 2025-2026. The City of Alexandria conducted extensive public outreach as part of their Waterfront Mitigation Plan development and following public feedback, it was determined that six ft was the maximum height that is acceptable by the community. Additionally, new construction along the waterfront has elevation requirements above the base flood elevation and a majority of new development sits well above the planned six ft bulkhead along the waterfront. Therefore, the City's plan can reasonably be considered as part of future conditions.

Consideration was also given to the incorporation of a living shoreline along the Alexandria waterfront, which could extend from Founder's Park at Queen Street to the north end of Rivergate City Park (at Montgomery Street). However, if USACE will not be implementing flood protection along the waterfront, the project could not justify this feature through NED benefits, as no storm damage reduction would occur. Benefits would need to be justified as NER benefits.

Belle Haven

The Greater Belle Haven neighborhood was built in easily accessible flat, low-lying areas between the 1920s and 1960s, long before floodplain regulations were effectively implemented in the country. In 2010, USACE completed a technical study to examine solutions to flooding problems in Fairfax County at the Greater Belle Haven neighborhood. The study identified structural solutions including several floodwall and levee plans with positive net benefits. However, these plans did not move forward because of community opposition to viewshed impacts at the time. Based on preliminary analysis using coastal storm inundation, a floodwall and levee plan based on the 2010 USACE study would be effective at reducing flood risk in this community and was retained for consideration in the study. The team has continued coordination with Fairfax County and NPS on this proposed measure as part of this study.

The potential for additional restoration at Dyke Marsh was discussed during the 2019 public scoping meeting. During implementation of current USACE/NPS Dyke Marsh Project there was conflict with State of Virginia natural resource agencies, especially related to impacts to SAV. NPS and the public are in favor of additional restoration; however, this may be implausible due to the state's reluctance for further SAV impact.

Further information is required to understand how much marsh restoration would mitigate storm impact and restoration was not retained as a measure

Alternative 6: Non-structural Plan

A preliminary non-structural plan developed was developed for the AMM with a low level of detail. The plan did not include costs as unit costs developed for NACCS were not appropriate for the study area as vastly underestimated costs for large commercial buildings. Additional analysis was recommended following the AMM to evaluate focus areas in the nonstructural plan using the 1 percent, 2 percent and 5 percent AEP storm inundation mapping developed for the study.

ROM costs were developed for the Initial Array of Alternatives and are shown in Table 3-8.

Table 3-8. Rough Order of Magnitude Costs for the Initial Array of Structural Alternatives

Alternative Number	Description	Total Cost	Average Annual Cost
2	**Comprehensive Coastal Storm Surge Barrier**	**$9,000,000,000**	**$333,368,000**
3	**Upper Coastal Storm Surge Barrier**	**$600,000,000**	**$22,225,000**
4	**Critical Infrastructure Plan (GWMP, Reagan, Arlington WPCP)**	**$82,863,000**	**$3,069,000**
4a	GWMP Floodwall	$55,349,000	$2,050,000
4b	Reagan National Airport Levee and Floodwall	$19,547,000	$724,000
4c	Arlington WPCP Floodwall	$7,968,000	$295,000
5	**Floodwall/Levee Plan (Four Mile Run, Alexandria, Belle Haven)**	**$63,476,000**	**$2,351,000**
5a	Four Mile Run Floodwall	$14,368,000	$532,000
5b	Alexandria Floodwall	$24,045,000	$891,000
5c	Belle Haven Levee & Floodwall	$25,063,000	$928,000

3.6.3 Final Array of Alternatives

The Final Array of Alternatives are shown in Table 3-9.

Table 3-9. Final Array of Alternatives

Alternative Number	Description
1	**No Action**
4	**Critical Infrastructure Plan (Reagan, Arlington WPCP)**
4b	Reagan National Airport Levee and Floodwall
4c	Arlington WPCP Floodwall
5	**Floodwall/Levee Plan (Four Mile Run, Belle Haven)**
5a	Four Mile Run Levee & Floodwall
5b1	Alexandria Deployable Floodwall
5c	Belle Haven Levee & Floodwall
6	**Non-Structural Plan (entire study area or components)**
8	**Combinations of 4, 5, 6**

During the 22 June 2021 In-Progress Review, the PDT was asked by USACE higher authority to show a ROM analysis for Alternative 5b: Alexandria Floodwall to determine if there were benefits that could be gained above the 10-year level of performance covered by the existing project to justify a plan. A ROM cost was prepared to determine whether a temporary deployable structure should be evaluated for the City of Alexandria. In coordination with the City of Alexandria, concerns were again raised that constructing a permanent floodwall along the waterfront would have a negative effect on viewshed and aesthetics and would not maintain the community's connectedness to the river. Instead, the PDT decided to evaluate a deployable floodwall option that followed a similar footprint to the original alternative and could be implemented in conjunction with the ongoing bulkhead raising that the City of Alexandria is currently undertaking. This plan was named Alternative 5b1 to distinguish it from the permanent floodwall alternative evaluated previously.

The PDT decided to conduct additional analysis on this alternative and consulted with Floodbreak, a firm that specializes in deployable floodwall and sidewalk technology, to develop cost estimates for stop log closures and a manual deployable floodwall to address the 50-year and 100-year level of performance for the project. During the 16 February 2022 USACE higher authority meeting to discuss these results, it was determined that a deployable floodwall alternative would be evaluated for the City of Alexandria. As mentioned earlier, a structural alternative was removed from consideration

because it did not avoid the planning constraint of impacting viewshed and historic structures and the City of Alexandria was moving forward with a 6 ft NAVD88 bulkhead from Duke to Queen Street which is included in the FWOP condition. For the deployable floodwall analysis, the per unit cost for stop log closures was used to develop ROM cost to present these results during a 22 February 2022 In-Progress Review Pre-TSP Meeting. The cost for a stop log closure deployable floodwall was estimated at $25 million. After coordination with the City of Alexandria, Floodbreak, and risk discussion with the engineers on the PDT, it was determined that manually deployed panels would be a more suitable material in this area, so a revised cost estimate was provided to account for the change in material type. It could take days to deploy 4,200 linear ft of stop log closures which is a risk depending on how much advance warning there is, and there is potential failure of weak points due to changes in flow or operational errors, increasing the incremental risk for life loss.

Floodbreak provided a cost per unit for the deployable floodwall using panels which yielded a $157 million project cost and a 0.23 BCR. Raw materials alone were $68 million, which was substantially above an economically justified project based on modeled damages because the alternative is only accruing benefits above the 6 ft NAVD88 bulkhead in the FWOP condition. The decision was made during an USACE higher authority Meeting on 22 March 2022 to remove from consideration Alternative 5b1 as part of the TSP. USACE will continue to coordinate with the City of Alexandria as the local mitigation plan for the 6 ft NAVD88 bulkhead is implemented.

Alternative 4: Critical Infrastructure Plan and Components

Alternatives 4b, Reagan National Airport (Figure 3-15) and 4c: Arlington Water Pollution Control Plant (Figure 3-16) are components of the Critical Infrastructure Plan, which includes the most vulnerable critical infrastructure in the study area. This includes roads and buildings (fire stations, police stations, hospitals, treatment plants, airports).

Alternative 4b proposes raising the perimeter road of Reagan National Airport to be an earthen levee topped with heavy duty pavement. In two areas where there is limited land available to raise the road (along the water's edge south of the airport and along the GWMP), a floodwall would be constructed in lieu of an earthen levee. Stop log closures would be used at the end of the runways to avoid impacts to airport operations. Repairs would be made to sidewalks and asphalt within the project footprint once construction is completed. The construction period would be broken into 3 phases, spanning 6 years.

Alternative 4c proposes constructing a floodwall along the left bank of Four Mile Run between Four Mile Run and the Arlington WPCP with a closure structure on the east side of the structure. The new floodwall would tie into the bank to the east just past South Eads Street. The floodwall would wrap around the Arlington WPCP to the west where the stop

log closure structure would be located along South Glebe Road. The construction period would take approximately 18 months.

Figure 3-15. Alternative 4B - Reagan National Airport

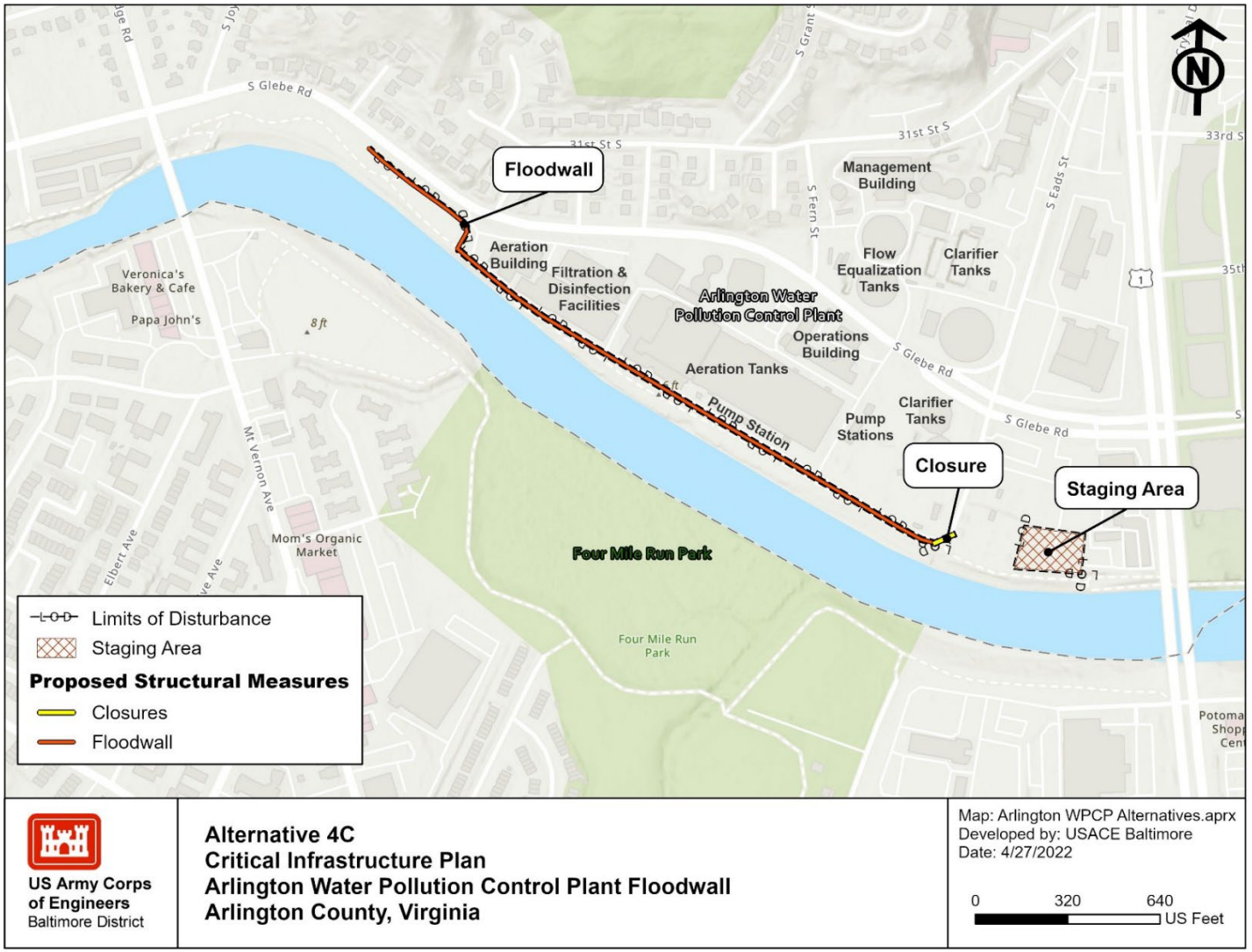

Figure 3-16. Alternative 4C - Arlington Water Pollution Control Plant

Alternative 5: Floodwall/Levee Plan

The Floodwall/Levee Alternatives (Figure 3-17 to Figure 3-19) are focused on reducing flood risk to areas of relative high flood risk including neighborhoods and commercial areas using structural measures. The subcomponents of this alternative include Alternative 5a: Four Mile Run Levee & Floodwall, Alternative 5b1: Alexandria Deployable Floodwall and Alternative 5c: Belle Haven Levee & Floodwall.

Alternative 5a proposes constructing a levee along the riverside of Four Mile Run Park Trail from Mount Vernon Avenue to Commonwealth Avenue. Two flap gates would be located along the levee at Sunnyside Stream and the stream just west of Four Mile Run softball field. The new levee would tie into the existing Four Mile Run Floodwall with two portions of floodwall on either side of Mount Vernon Avenue and a closure structure along Mount Vernon Avenue. The construction period would be broken into 2 phases, spanning 3 years.

Alternative 5b1 proposes a deployable floodwall composed of floating panels from Queen Street south to Wilkes Street along the waterfront and tying back to the 9.5-ft contour line at both the north and south extents. These floodgates would be manually deployed prior to a storm or high tide event by the City of Alexandria. Stop log structures were also evaluated for this area and were removed from consideration due to the time and risk associated with deploying approximately 4200 linear ft of closure structures and potential failure of weak points due to changes in flow or operational errors.

Alternative 5c proposes constructing a floodwall just north of Belle Haven Road from Barrister Place to 10th Street with a closure structure at 10th Street and the GWMP. Closure structures would also be constructed along Belle Haven Road and Belle View Blvd. A floodwall would tie into the closure structure at 10th Street and run south along the west side of the GWMP, curving around Boulevard View to 10th Street. The floodwall would then run west to East Wakefield Drive tying into both sides of a closure structure on Potomac Avenue. The floodwall would continue west to West Wakefield Drive and tie into a small portion of earthen levee ending at Westgrove Dog Park. The construction period would be broken into 2 phases, spanning 4 years.

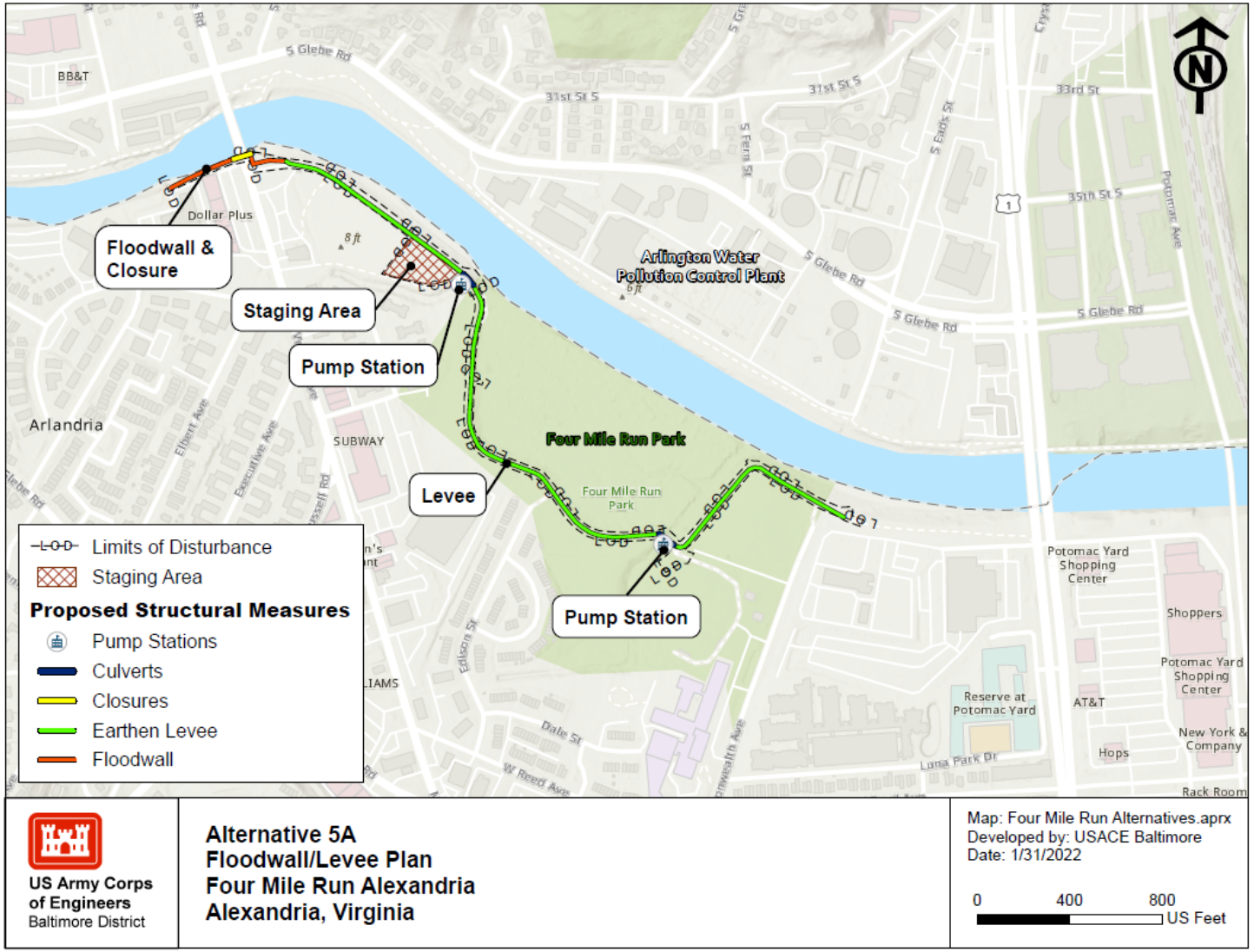

Figure 3-17. Alternative 5A - Four Mile Run

Figure 3-18. Alternative 5b1: Alexandria Deployable Floodwall.

Figure 3-19. Alternative 5C - Belle Haven

Alternative 6: Non-structural Plan

Figures 3-20 through 3-22 show the areas evaluated for nonstructural measures in the study area, which primarily consists of concentrations of structures impacted by coastal flooding identified as appropriate for non-structural measures. Alternative 6 includes evaluation of these three areas for flood proofing and building elevation. This alternative was formulated based on neighborhood, building, and flooding characteristics using a GIS analysis, which identified structures appropriate for certain nonstructural measures. The 5 percent, 2 percent and 1 percent AEP events were considered. The non-structural plan included several clusters of structures throughout the study area, but the areas selected for further evaluation across the three flood scenarios were Old Town Alexandria, Belle Haven, and Occoquan Bay.

Figure 3-20. Nonstructural Measures Cluster in the Old Town Alexandria Waterfront Neighborhood in the City of Alexandria

Figure 3-21. Nonstructural Measures Cluster in the Belle Haven Neighborhood in Fairfax County

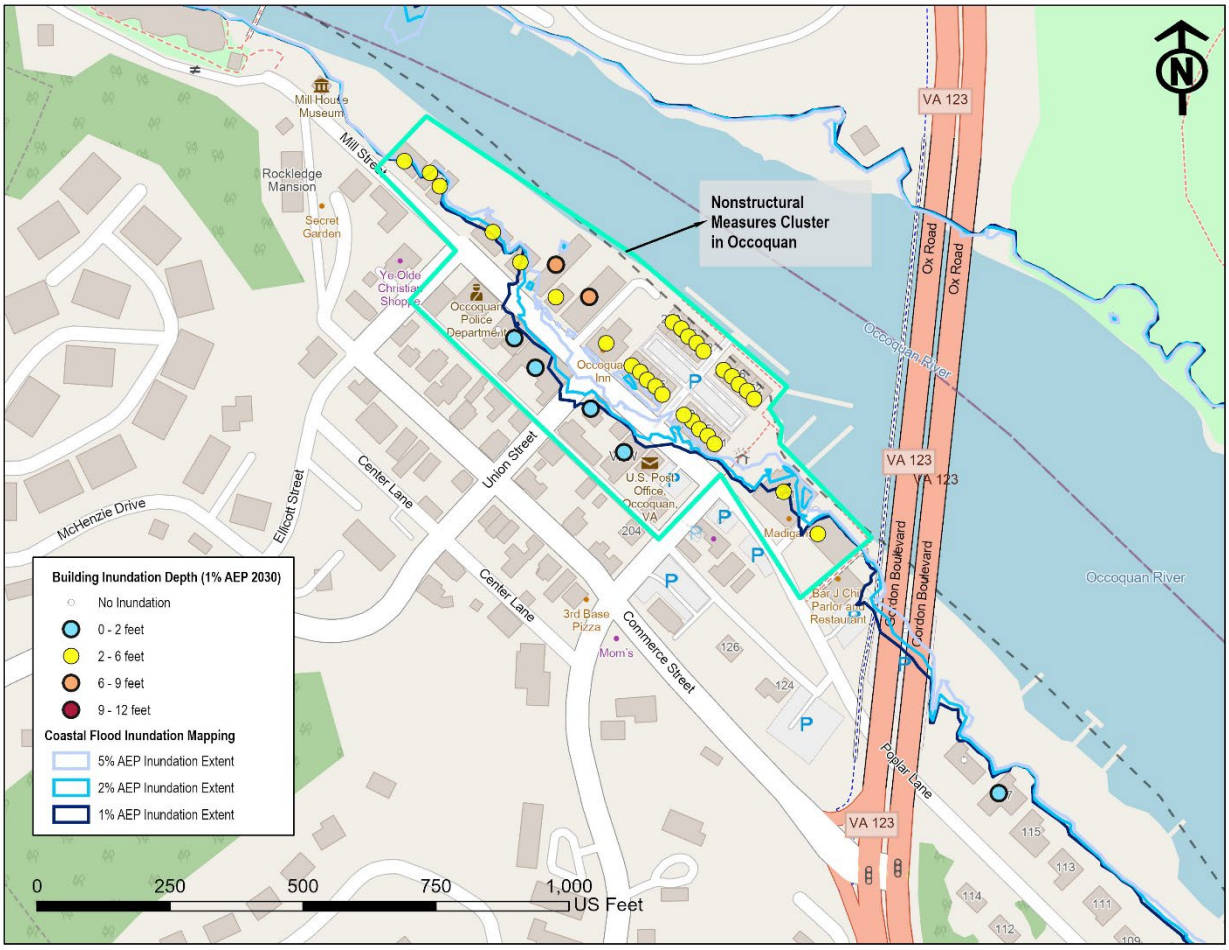

Figure 3-22. Nonstructural Measures Cluster in the Town of Occoquan in Prince William County

Alternative 8: Combination of Alternatives 4, 5, and 6

Alterative 8 may include a combination of Alternatives 4, 5 and 6 or components of these alternatives depending on which are viable based on the economic analysis. These may include, but are not limited to combinations of levee, floodwall (permanent and deployable), closure structures, flap gates, and nonstructural solutions (flood proofing and elevation). Alternative 8 will be a combination of all alternative plan components with positive net benefits based on the economic analysis.

3.7 Plan Evaluation

The Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies dated 10 March 1983 established the P&G criteria used to evaluate water resources projects pursuant to the Water Resources Planning Act of 1965 (Public Law 89-8). The PDT used the P&G Criteria to evaluate the

initial array of alternatives while additional engineering information was developed by various disciplines to inform decision-making. The P&G criteria are described below.

1. **Completeness** is the extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects, including any necessary actions by others. It does not necessarily mean that alternative actions need to be large in scope or scale.

2. **Effectiveness** is the extent to which an alternative alleviates the specified problems and achieves the specified opportunities.

3. **Efficiency** is the extent to which an alternative alleviates the specified problems and realizes the specified opportunities at the least cost.

4. **Acceptability** is the viability and appropriateness of an alternative from the perspective of the Nation's general public and consistency with existing Federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency.

The results of this initial P&G evaluation are detailed in Table 3-10. No alternatives were screened during the P&G evaluation.

Table 3-10. P&G Criteria Evaluation of Array of Alternatives

Alternative	Completeness	Effectiveness	Efficiency	Acceptability
Alternative 1 – No Action	Yes	No	Yes	Yes
Alternative 4b - Reagan National Airport Levee and Floodwall	Yes	Yes	Yes	Yes
Alternative 4c – Arlington WPCP Floodwall	Yes	Yes	Yes	Yes
Alternative 5a – Four Mile Run Levee & Floodwall	Yes	Yes	Yes	Yes
Alternative 5c – Belle Haven Levee and Floodwall	Yes	Yes	Yes	Yes
Alternative 6 – Nonstructural Plan	Yes	Yes	Yes	Yes
Alternative 8 – Combination Alternative	Yes	Yes	Yes	Yes

4 Environmental Effects and Consequences*

This section describes the environmental effects and consequences for the final array of alternatives (Alternatives 4b, 4c, 5a, 5b1, and 5c) on each resource topic discussed in Section 2.3, Natural Environment and Section 2.4, Physical Environment. The effects of the No-Action Alternative (Alternative 1) are the same as FWOP Condition. The FWOP condition is evaluated for each resource topic in Chapters 2.3 and 2.4 above and is not repeated in this section. Table 4-2 located at the end of this section provides a summary of environmental effects for the final array of alternatives including the No-Action Alternative.

4.1 Natural Environment

4.1.1 Wetlands

The wetland delineation boundaries shown in Figures 4-1, 4-2, and 4-3 were obtained from the wetland delineation conducted by USACE in July 2021. The *Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study Wetland Delineation Report* (USACE, 2021) is located in Appendix G. The wetland delineation report shows preliminary LODs (the outermost boundary of the area planned to be disturbed by construction) that were approximate boundaries at the time that the delineation was conducted. Since that time, the locations of the LODs have been refined as shown in Figures 4-1, 4-2, and 4-3.

4b Reagan National Airport Levee and Floodwall

The structural measures proposed at Reagan National Airport would have no effect on wetlands.

4c Arlington Water Pollution Control Plant Floodwall

As shown in Figure 4-1, existing wetlands that run along the north side of Four Mile Run adjacent to the Arlington WPCP are located outside of the footprint of the proposed floodwall, the proposed LOD, and the proposed staging area. The wetlands are located at the bottom of the bank adjacent to the shoreline of Four Mile Run. The floodwall would be constructed at the top of the bank. Therefore, the structural measures proposed at the Arlington WPCP would have no direct effects on wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

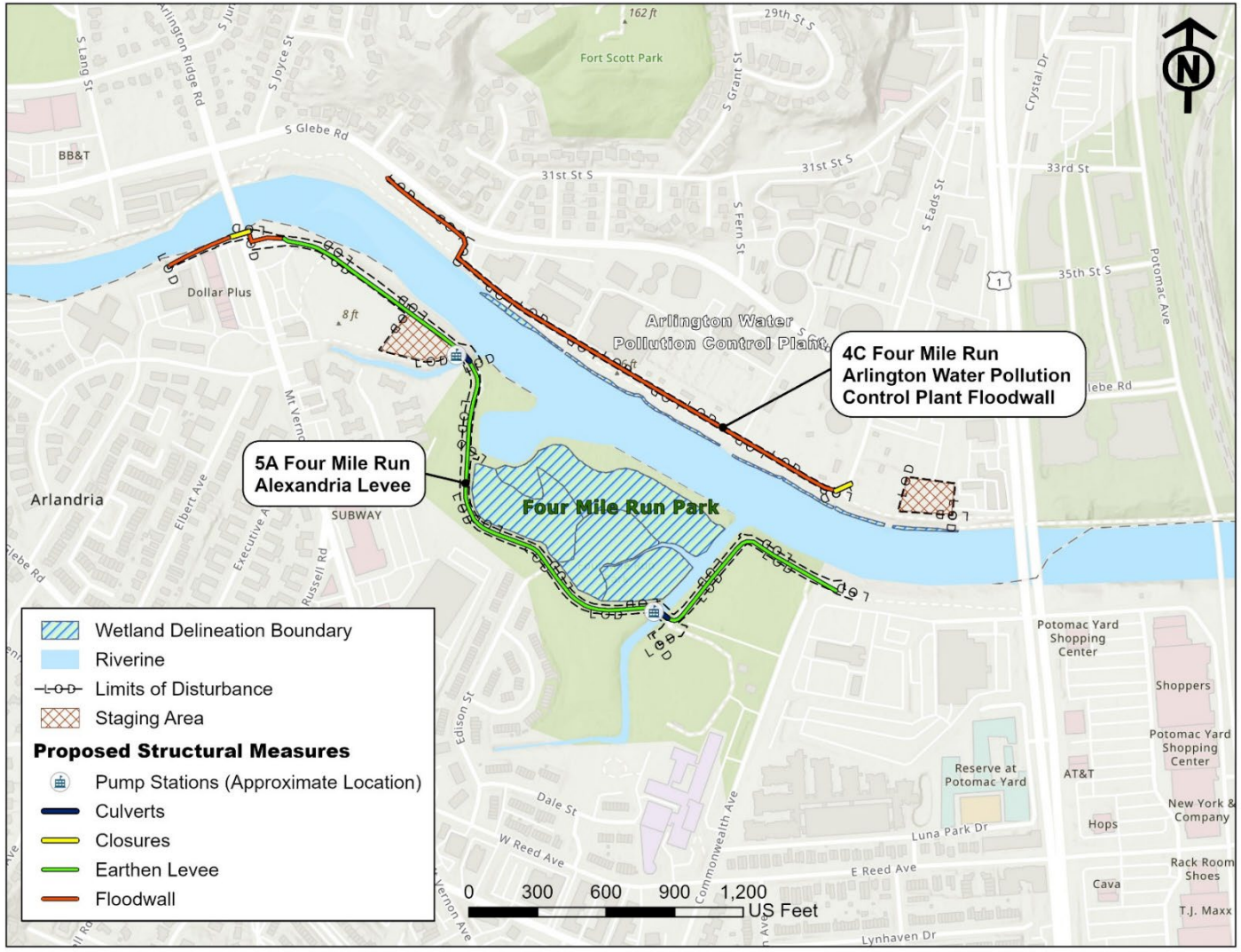

Figure 4-1. Proposed Structural Measures and Limits of Disturbance for Alternatives 4c and 5a and the Location of Wetlands and Riverine Systems at Four Mile Run

5a Four Mile Run Levee and Floodwall

As shown in Figure 4-2, existing wetlands that run along the south side of Four Mile Run in Four Mile Run Park are located outside of the footprint of the proposed levee and floodwall, the proposed LOD, and the proposed staging area. The proposed levee would be constructed in the footprint of the existing elevated walking path. Although the exact locations of the two proposed pump stations and associated generators and parking areas are not known at this time, these features would be located within the LOD outside of wetlands. Therefore, the structural measures proposed at Four Mile Run Park would have no direct effects on wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

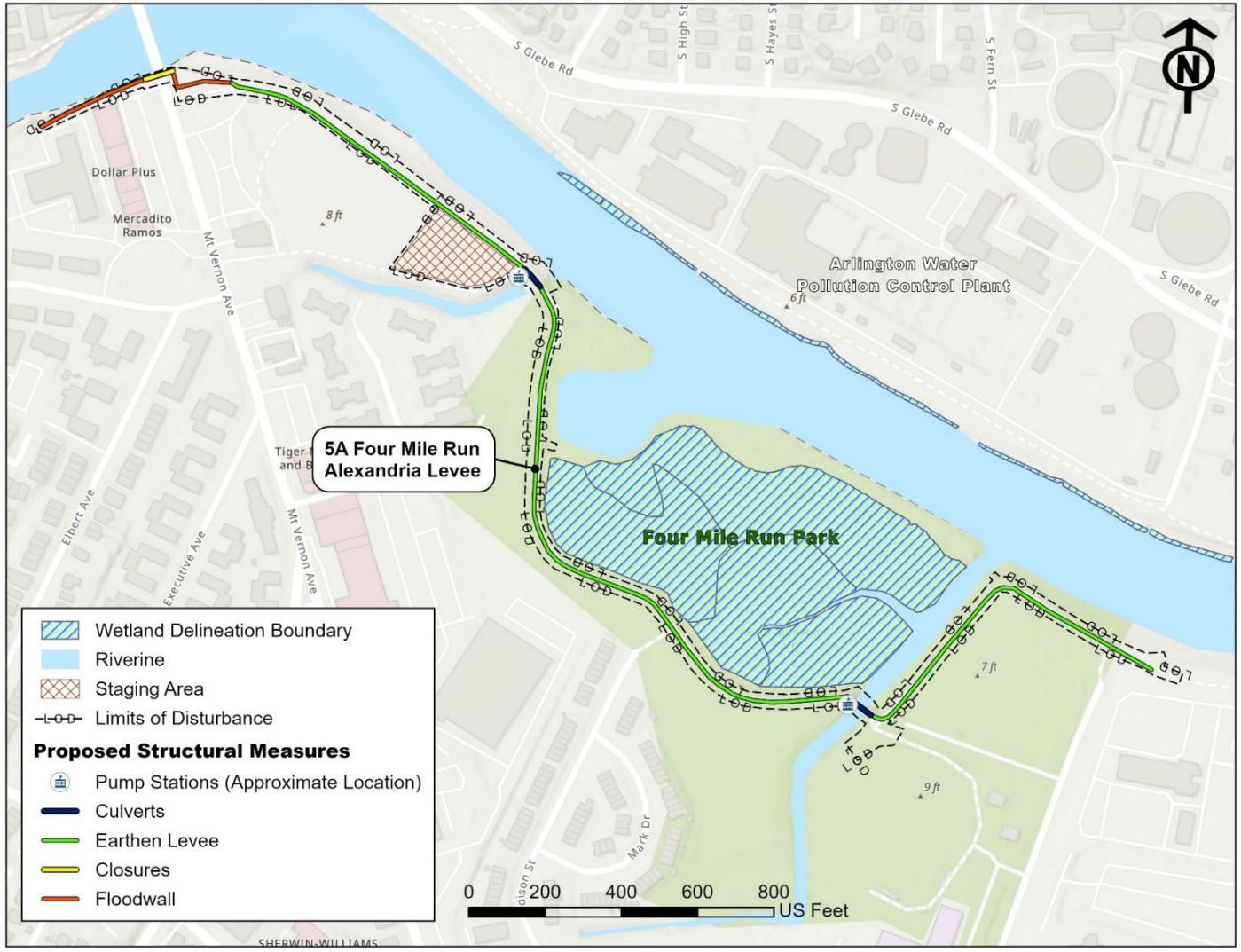

Figure 4-2. Proposed Structural Measures and Limits of Disturbance for Alternative 5a and the Location of Wetlands and Riverine Systems at Four Mile Run

5b1 City of Alexandria Deployable Floodwall

The only wetlands located near the construction footprint are located along the Windmill Hill Waterfront at the south end of the proposed floodwall. The recently completed Windmill Hill Park living shoreline project is located outside of the footprint of the proposed deployable floodwall, the proposed LOD, and the proposed staging area. Therefore, construction of the deployable floodwall along the City of Alexandria waterfront would have no direct effects to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

5c Belle Haven Levee and Floodwall

As shown in Figure 4-3, the existing wetlands south of Belle Haven are located outside of the footprint of the proposed levee and floodwall, the proposed LOD, and the proposed staging area. Although the exact locations of the two pump stations and associated generators and parking areas are not known at this time, these features would be located within the LOD outside of wetlands. Therefore, the structural measures proposed at Belle Haven would have no direct effects to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

During a flood event, the presence of the floodwall/levee would reduce the effective volume of available floodplain to coastal floodwaters. Therefore, these waters would be forced to stage higher within the remaining areas (including the wetlands located between the levee/floodwall and the Potomac River) than they otherwise would without the floodwall/levee. The relative increase in inundation depth is dependent upon the specific storm event, but the additional elevation (i.e., inundation depth) is not expected to be substantial. The potential change in inundation depth would only occur during storm events and is not expected to affect the health, character, or integrity of the wetlands. USACE is planning to model the FWP condition to assess the potential for induced flooding. As a result of this modeling, more specificity on the inundation depth in the wetlands under the FWP condition will be included in the final IFR/EA.

Discharge from the pump stations may result in minor impacts to the wetlands located between the proposed floodwall and the Potomac River. During normal water flows, including when a local storm is occurring within the Belle Haven Watershed, water would be able to pass through the drainage pipes of the floodwall with energy dissipaters placed at the pipe outlets to prevent high velocities. It is only during times of extreme flooding due to a coastal event or a massive storm occurring within the entire Potomac River watershed that the pump stations would be utilized. During these scenarios, the water level of the Potomac River would be so high that it would reach the riverside of the floodwall, which would result in the closure of the flap and sluice gates of the floodwall's drainage pipes. During this scenario, flow from the Belle Haven East and West Channels would be conveyed to the Potomac River via the pump stations. However, because the

riverside of the floodwall would be inundated with floodwaters, there will be little to no disturbance of the wetlands (scouring and erosion) as the outflow would discharge into floodwaters.

Flap gates would be installed at the ends of the culverts at the proposed culvert crossings. Flap gates are mounted by hinges at the top of the culvert pipe and open and close in response to water pressure. Flap gates allow the free flow of water through the culvert pipe during normal water flows. During a high-water event, when the depth of water is greater on the riverside of the floodwall, the flap will close automatically to prevent back flow. When the water level goes down, the gate will automatically open to allow discharge through the culverts. The flap gate would most likely only remain closed for up to 48 hours after a storm. This would allow a small amount of sediment to build up on the back side of the flap gate. This sediment would be released when the flap gate opens and may be carried into wetlands following a storm event. This would only occur a few times a year during a storm event. The amount of sediment released from the flap gate would be minimal in comparison to the turbidity and sedimentation generated by storm surge from the Potomac River. Therefore, effects to wetlands from sediment being released from the flag gates would be minor and temporary.

6 Non-Structural Plan

Implementation of the non-structural plan would have no effect on wetlands.

Figure 4-3. Proposed Structural Measures and Limits of Disturbance for Alternative 5c and the Location of Wetlands and Riverine Systems

Note: The hatched area labeled as “Wetland Delineation Boundary” only delineates the north side of the wetlands closest to the proposed LOD. Wetlands extend to the south beyond the southern boundary delineated by USACE in July 2021.

4.1.2 Floodplains

Implementation of the proposed structural alternatives (Alternatives 4b, 4c, 5a, 5b1 and 5c) would reduce the effective volume of available floodplain to coastal floodwaters during a storm event. However, there is no natural floodplain in the footprint of the structural measures or landward of the proposed structures that would be affected. Therefore, although the structural measures would reduce the effective volume of available floodplain for floodwaters, the structural measures would not affect any natural floodplains. Section 4.1.1 describes the effects from construction of the floodwall at Belle Haven on the natural floodplain located between the proposed floodwall and the Potomac River. Implementation of the non-structural plan (Alternative 6) would have no effect on floodplains.

4.1.3 Submerged Aquatic Vegetation (SAV)

4b Reagan National Airport Levee and Floodwall

As shown in Figure 4-4, SAV may be present (as of 2018) in the shallow waters of the Potomac River surrounding the Reagan National Airport (VIMS, 2022a). Barges may be required to support construction of portions of the levee and floodwall at the airport. Two barges may need to stage in the water at the south end of Runway 33 for up to one year during construction. During this time, the river bottom would experience an increased amount of shading in the footprint of the barges. As a result of shading, the existing SAV may experience a decrease in cover during the time the barges are in place. A typical crane barge used in USACE construction projects is approximately 150 ft long by 50 ft wide (USACE, 2012). Therefore, construction of the levee and floodwall at the Reagan National Airport may result in approximately 15,000 square ft (sqft) of temporary, indirect impacts to SAV for a period of up to one year dependent on the exact staging location. The SAV is expected to recover naturally once the barges are removed.

Implementation of Alternatives 4c, 5a, 5b1, 5c, and 6 would have no effect on SAV.

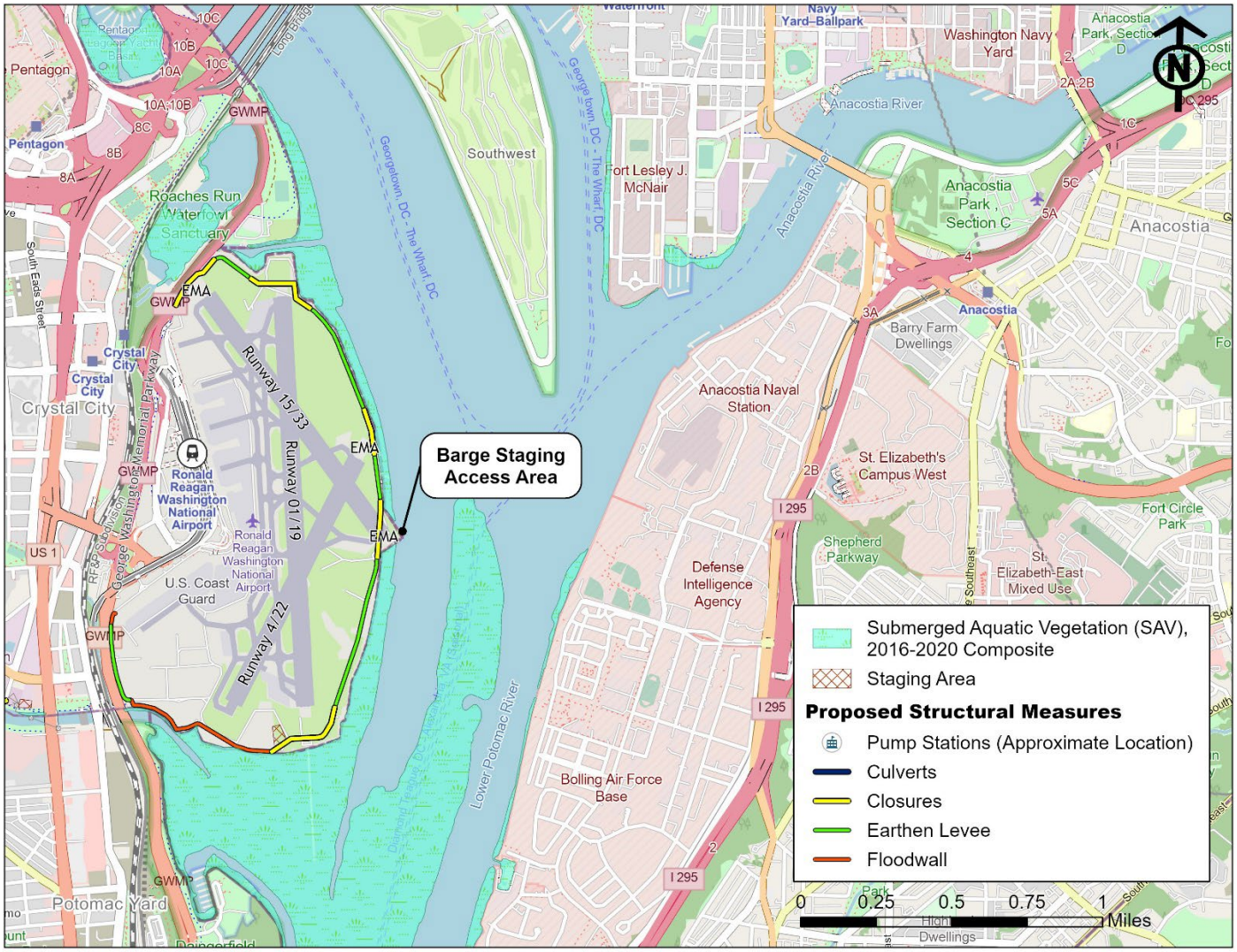

Figure 4-4. Submerged Aquatic Vegetation in the Vicinity of the Reagan National Airport and the Approximate Location of the Barge Staging Area

4.1.4 Threatened and Endangered Species

4.1.4.1 Terrestrial and Freshwater Species

The final array of alternatives would have no effect on federal and state-listed threatened and endangered species due to the lack of suitable habitat conditions and/or the lack of documented observances in the locations where the effects are likely to occur.

The proposed alternatives would have no effect on northern long-eared bat (NLEB) hibernaculum or maternity roosts. The USFWS PAR (Appendix G) states: “while the proposed alternatives may affect the NLEB if any tree clearing occurs, any take that may occur as a result is not prohibited under the ESA 4(d) rule adopted for this species at 50

CFR §17.40(o) and satisfies Service responsibilities for this Action under ESA Section 7(a)(2)" (USFWS, 2021b). As recommended in the PAR, USACE will resubmit the information for the NLEB required in the USFWS *Key to the Northern Long-Eared Bat 4(d) Rule for Federal Actions that May Affect Northern Long-Eared Bats* into the USFWS IPaC prior to construction (USFWS, 2016).

It is likely that the monarch butterfly, an ESA candidate species, would be present in the locations of the proposed alternatives during the monarch's migration season (mid to late September). Construction would not directly affect the monarch butterfly and would not affect the monarch's specific host plant, milkweed.

Refer to the document: *Section 7 of the Endangered Species Act No Effect Determination for Terrestrial and Freshwater Species, Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study* located in Appendix G for an evaluation of potential effects to each threatened and endangered species identified in Table 2-1.

4.1.4.2 Marine and Anadromous Species

4b Reagan National Airport Levee and Floodwall

The temporary staging of barges to construct the floodwall and levee at Reagan National Airport would have an insignificant effect on the Atlantic sturgeon and Atlantic sturgeon critical habitat. While shortnose sturgeon might occur as transients in the study area, their presence is so unlikely that proposed effects to shortnose sturgeon from this alternative are discountable.

Temporary Habitat Modification from Barges Shading SAV

Effects to listed species can be caused by disturbance to the river bottom that reduces the availability of prey species or alters the composition of forage. As described in Section 4.1.3, two barges may need to stage in the water at the south end of Runway 33 for up to one year during construction. During this time, the river bottom would experience an increased amount of shading in the footprint of the barges (approximately 15,000 sqft). As a result of shading, the existing SAV may experience a decrease in cover during the time the barges are in place.

There is not a strong linkage between Atlantic sturgeon and SAV. SAV may be encountered by these species, but SAV does not appear to be an important factor in the life histories of these species (Atlantic State Marine Fisheries Commission (ASMFC), 1997). It is likely that Atlantic sturgeon would be concentrated in the deeper waters of the navigation channel. As such, any effects to Atlantic sturgeon or critical habitat from the temporary loss of SAV would be too small to be meaningfully measured or detected. As a result, the effect of this alternative due to a temporary loss of SAV would be insignificant.

Vessel Strikes
Atlantic sturgeon can be struck by boats or by the blades of boats' propellers. They are struck and killed by large commercial vessels as well as smaller vessels such as recreational vessels. Two tugs would be used to move two barges to and from the staging areas. This would only involve the tugs taking two trips to and from the staging areas to drop off and pick up the barges. An increase in vessel traffic in the study area due to the project vessels would only occur over two days (one year apart). Construction equipment would operate from the barges. The barges would not be used to transport construction materials, so multiple barge trips are not expected. Any risk of a strike caused by the project vessels is so small that it cannot be meaningfully measured or detected. As a result, the effect of this alternative on the risk of a vessel strike would be insignificant.

Noise
Noise generated from equipment operating on the barges may affect fish behavior. Fish use sound to hunt for prey, avoid predators, and for social interaction. High intensity sounds can permanently damage fish hearing (Nightingale and Simenstad, 2001). Noise from equipment operating on the barge is not expected to generate continuous high intensity sound in the water. No work would occur in the water. Sounds would be generated primarily by a construction equipment operating on the barge(s). The noise would be temporary (intermittently at night for a period of up to one year). Fish would most likely avoid the area if bothered by noise levels. The effects of noise generated from equipment operating on the barge to Atlantic sturgeon is so small that it cannot be meaningfully measured or detected. As a result, the effect of this alternative due to construction noise would be insignificant.

Implementation of Alternatives 4c, 5a, 5b1, 5c and 6 would have no effect on the Atlantic sturgeon, Atlantic sturgeon critical habitat, or the shortnose sturgeon because the species are not present where the effects are likely to occur.

4.1.5 Anadromous Fish

4b Reagan National Airport Levee and Floodwall
Staging of barges in the water adjacent to the southeast end of Runway 33 at Reagan National Airport may result in temporary indirect effects to anadromous fish due to the temporary loss of SAV within and adjacent to the footprint of the barges and noise generated by equipment operating on the barges.

As described in Section 4.1.3, existing SAV may experience a decrease in cover during the time the barges are in place. SAV provides food and refuge to anadromous fish that are migrating to and from spawning areas. SAV also provides nursery habitat to young fish, specifically the striped bass, an anadromous fish that can be found in the study area (VIMS, 2022b). The loss of SAV would be temporary. SAV is expected to recover naturally

once the barges are removed. Anadromous fish would need to utilize other SAV beds in the area while the affected SAV is recovering. Therefore, effects to anadromous fish from the loss of SAV in the footprint of the barges would be temporary and minor.

As described in Section 4.1.4.2, noise generated from equipment operating on the barges may affect fish behavior. Noise from equipment operating on the barge is not expected to generate continuous high intensity sound in the water. No work would occur in the water. Sounds would be generated primarily by a crane unloading construction materials from the barge onto land. The noise would be temporary (intermittently at night for a period of up to one year). Fish would most likely avoid the area if bothered by noise levels. Therefore, effects to anadromous fish from construction noise would be temporary and minor.

5a Four Mile Run Levee and Floodwall, 5c Belle Haven Levee and Floodwall
Limitations in habitat availability due to the size of the streams, lack of pools, and water quality problems constrains the diversity of the fish in the streams located in Four Mile Run Park and Belle Haven. Fish passage would not be obstructed due to construction of the levees/floodwalls in these locations. Culvert crossings are proposed in two streams in the location of the proposed Four Mile Run levee, and in two streams in the location of the proposed Belle Haven levee/floodwall. A culvert would be placed in the existing streams to allow water to freely pass through the levee/floodwall. Therefore, fish passage would not be obstructed at the proposed culvert crossings during normal water flows.

As discussed in Section 4.1.1 above, flap gates would be installed at the ends of the culverts at the proposed culvert crossings. During a high-water event, when the depth of water is greater on the riverside of the floodwall, the flap will close automatically to prevent back flow. Fish passage would be blocked when the flap gate is closed. The flap gate would most likely only remain closed for up to 48 hours during and after a storm. This would only occur a few times a year during a storm event. Therefore, effects to fish passage due to the closure of flag gates during storm events would be temporary.

Implementation of Alternatives 4c, 5b1, and 6 would not affect anadromous fish because anadromous fish are not present where the effects would likely occur.

4.1.6 Migratory Birds

4b Reagan National Airport Levee and Floodwall
Reagan National Airport is surrounded by water on three sides and is often inhabited by birds. To avoid serious damage to aircraft, the airport uses 12 bird cannons that either shoot “blanks” or a series of bird alarm calls (sounds birds make when predators are nearby) to scare birds away from runways. The cannons are used when birds are seen gathering close to runways. Since the airport actively tries to keep birds away from

runways, construction of the proposed levee and floodwall would not result in any additional adverse effects to migratory birds.

4c Arlington Water Pollution Control Plant Floodwall, 5a Four Mile Run Levee and Floodwall, 5b1 City of Alexandria Deployable Floodwall

Birds could experience temporary disturbance during construction. No breeding habitat is known to occur in or adjacent to the construction LODs. Therefore, construction of these alternatives may result in temporary, minor effects to migratory birds. No long-term effects are expected. Removal of trees (both live and dead trees) and saplings and shrubs would be avoided to the greatest extent practicable as recommended by the PAR.

5c Belle Haven Levee and Floodwall

Bald eagle nests are located approximately 0.08, 0.28, and 0.60 miles away from the proposed Belle Haven LOD. These nests were last checked and known to be occupied in 2018 (Center for Conservation Biology, 2020). To minimize adverse effects to nesting bald eagles during construction of the Belle Haven levee and floodwall, protective buffers would be adhered to in accordance with the National Bald Eagle Management Guidelines of 2007. If these buffers cannot be adhered to, USACE will contact the USFWS to determine if an eagle disturbance permit is necessary to be in compliance with the prohibitions under the Bald and Golden Eagle Protection Act. This coordination would be done during the Pre-Construction, Engineering, and Design (PED) Phase. Removal of trees (both live and dead trees) and saplings and shrubs would be avoided to the greatest extent practicable as recommended by the PAR.

Refer to the PAR in Appendix G for further information on the potential effects to each migratory bird species identified in Table 2-4.

6 Non-Structural Plan

Birds could experience temporary disturbance during construction. Construction activities associated with the non-structural plan, specifically elevating existing structures, may result in temporary, minor effects to migratory birds. No long-term effects are expected.

4.2 Physical Environment

4.2.1 Waterways and Hydrology

USACE modeled the WSELs under the FWOP condition up to year 2075. The modeled WSEL were adjusted for anticipated changes due to SLR for another 5 years through year 2080. This information was used to determine the level of performance for the proposed structural measures. Refer to Appendix A for a description of the level of performance for the structural measures. Project elements would be designed accordingly during the PED phase.

To understand the hydrology and evaluate the effects of induced flooding across the study area after the project is constructed, USACE is planning to model the WSELs under the future with project condition for Alternatives 4c and 5c. This information will be included in the Final Report.

4b Reagan National Airport Levee and Floodwall, 4c Arlington WPCP Floodwall, 5b1 City of Alexandria Deployable Floodwall, 6 Non-Structural Plan

These alternatives would not directly affect any waterways. Sediment may be carried into waterways during construction. This would be a minor effect that would only occur during the construction period. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into water during construction.

5a Four Mile Run Levee and Floodwall

Culvert crossings are proposed at two locations in Four Mile Run Park - the East Stream and the West Stream (named Sunnyside Stream) as shown in Figure 4-2. Pump stations are also proposed at these locations. However, the pump stations and associated generators and parking areas would be located in uplands outside of the streams.

East Stream

There is an existing approximately 58-ft-long by 10-ft-wide pedestrian bridge that crosses the East Stream with concrete bridge abutments in the location of the proposed culvert crossing (Figure 4-5). The stream is 58 ft wide in this location. The East Stream a perennial waterway that flows from west to east, changes directions, and then flows from south to north. A perennial stream has flowing water year-round during a typical year (Virginia Places, n.d.). The stream receives water from localized runoff, groundwater, and adjacent waterways. The stream originates from a culvert underneath Edison Street, flows east through a concrete channel, then turns north and eventually discharges into Four Mile Run. The substrate varies from concrete, to silt, sand, and mud. The stream banks are steep and vegetated and vary in height from 0.5 ft to approximately 4 ft.

The proposed culvert crossing would be roughly 58 ft wide and 45 ft long (rough estimate based on preliminary designs). Therefore, construction of the proposed culvert crossing would result in roughly 2,610 sqft of new permanent fill impacts, except in the footprint of the existing concrete bridge abutments. The temporary LOD would be 20 ft on each side of the proposed crossing. Therefore, construction of the culvert crossing in the East Stream would result in roughly 2,320 sqft of temporary impacts from construction of the crossing (40 ft x 58 ft).

Figure 4-5. Existing Bridge Crossing in the Location of the Proposed Culvert Crossing at the East Stream in Four Mile Run

West Stream

An existing culvert crossing and asphalt pedestrian path crosses the West Stream in the location of the proposed culvert crossing (Figure 4-6). The existing culvert crossing is 50 ft long and 42 ft wide and consists of fill on top of a concrete culvert. The West Stream is a perennial waterway that originates outside of the study area and flows from west to east. The West Stream receives hydrology from groundwater, localized runoff, and adjacent waterways. The substrate consists of silt, sand, small cobbles, and boulders. The stream banks are steep and vegetated and range in height from 3 ft to 5 ft. The West Stream discharges directly into Four Mile Run.

The proposed culvert crossing would be roughly 50 ft wide and 45 ft long (rough estimate based on preliminary designs). Therefore, construction of the proposed culvert crossing would result in roughly 2,250 sqft of permanent fill impacts. The LOD would be 20 ft on each side. Therefore, construction of the culvert crossing in the West Stream would result in roughly 2,000 sqft of temporary impacts from construction of the crossing (40 ft x 50 ft). However, the proposed culvert crossing would replace the existing crossing and therefore would only result in roughly 150 sqft of new permanent fill impacts (2,250 sqft minus 2,100 sqft).

Figure 4-6. Existing Culvert Crossing in the Location of the Proposed Culvert Crossing at the West Stream in Four Mile Run

In summary, construction of the proposed culvert crossings at Four Mile Run would result in roughly 4,320 sqft of temporary impacts during construction and roughly 2,760 sqft of new permanent fill impacts to the existing streams.

5c Belle Haven Levee and Floodwall

Culvert crossings are proposed in two streams in Belle Haven - the Belle Haven East Channel and the Belle Haven West Channel as shown in Figure 4-3. The Belle Haven waterway names are derived from the USACE document: *Final Flood Damage Reduction Analysis for Belle Haven Watershed, Fairfax County, Virginia* (USACE, 2008). Pump stations are also proposed at these locations. However, the pump stations and associated generators and parking areas would be located in uplands outside of the streams.

Belle Haven East Channel

The Belle Haven East Channel at the proposed crossing location is 30-ft wide. There are no existing crossings or bridges in this location (Figure 4-7). The East Channel is a perennial stream that originates outside of the study area, flows into the Belle Haven Tributary, which runs through Dyke Marsh, and eventually into the Potomac River. The

stream has been altered into a straight channel before it reaches Dyke Marsh. The stream receives hydrology through adjacent waterways, localized urban runoff, and groundwater. The stream banks are steep (3 to 4 ft high) and vegetated. A small amount of spadderdock (*Nuphar lutea*) was found growing in the stream during the May 2022 site visit. Riparian buffers consist of maintained lawns, tennis courts, and large trees.

The proposed culvert crossing would be roughly 30-ft wide and 45 ft long (rough estimate based on preliminary designs). Therefore, construction of the proposed culvert crossing would result in roughly 1,350 sqft of new permanent fill impacts to the stream. The LOD would be 20 ft on each side. Therefore, construction of the culvert crossing in the Belle Haven East Channel would result in roughly 1,200 sqft of temporary impacts from construction of the crossing (40 ft x 30 ft).

Figure 4-7. Location of a Proposed Culvert Crossing at the Belle Haven East Channel

Belle Haven West Channel

The Belle Haven West Channel at the proposed culvert crossing location is an approximately 20-ft-wide concrete-lined channel. The stream has established a naturalized stream cross-section with normal stream features (sedimentation, vegetation). There are no existing crossings or bridges in this location (Figure 4-8). The West Channel is a perennial stream that originates outside of the study area, flows into the Belle Haven Tributary, which flows through Dyke Marsh, and eventually into the Potomac River. The stream flows from north to south and is directed by a concrete channel before discharging into Dyke Marsh. The stream receives hydrology through adjacent waterways, localized urban runoff, and groundwater. The banks have a moderate slope (3 to 4 ft high) and are vegetated. A small amount of spadderdock (Nuphar lutea) and pickerel weed (Pontederia cordata) was found growing in the stream during the May 2022 site visit. Riparian buffers consist of maintained lawns, concrete walkways, and large trees.

The proposed culvert crossing would be roughly 20 ft wide by 45 ft wide (rough estimate based on preliminary designs). Therefore, construction of the proposed culvert crossing would result in roughly 900 sqft of permanent fill impacts to the stream. The LOD would be 20 ft on each side. Therefore, construction of the culvert crossing in the Belle Haven West Channel would result in roughly 800 sqft of temporary impacts (40 ft x 20 ft).

Figure 4-8. Location of the proposed culvert crossing at the Belle Haven West Channel

In summary, construction of the proposed culvert crossings at Belle Haven would result in roughly 2,000 sqft of temporary impacts in the East and West Channels, and roughly 2,250 sqft of new permanent fill impacts to the East Channel. A habitat evaluation of both streams was conducted in May 2022 using the Virginia Unified Stream Methodology (USACE, 2007). The descriptions of the streams above were used to inform the habitat evaluation scores. The habitat evaluation is located in Appendix G. This methodology was approved for use in this study by the National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) (approval located in Appendix G).

4.2.2 Water Quality

Construction would have a temporary and minor effect on water quality. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into waterways during construction.

As described in Section 4.1.1., a minimal amount of sediment would be released into the water from the flap gates following a storm event at the culvert crossings in Four Mile Run

and Belle Haven. This would only occur a few times a year during a storm event. The amount of sediment released from the flap gate would be minimal in comparison to the turbidity and sedimentation created by storm surge from the Potomac River. Therefore, effects to water quality from sediment being released from the flap gate would be temporary and minor.

4.2.3 Air Quality

The actions associated with Alternatives 4b, 4c, 5a, and 5c are exempt from the General Conformity Rules in Section 176c of the Clean Air Act. Ozone precursors, volatile organic compounds (VOCs) and NOx are below the USEPA threshold of 100 tons per year for all maintenance areas. All other annual emission totals and aggregated study emission totals for criteria pollutants are not anticipated to exceed all other USEPA de minimis thresholds; therefore, no mitigation measures are required. Refer to the *Air Conformity Assessment, District of Columbia Coastal Storm Risk Management Study* in Appendix G for more information. Alternatives 5b1 and 6 are not included in the Air Conformity Assessment. The proposed FRM measures would have no long-term effects on air quality.

4.2.4 Greenhouse Gases

In addition to criteria pollutants, emissions were also estimated for the GHG - carbon dioxide (CO_2). The primary GHG emitted from diesel-fueled equipment is CO_2. Although nitrous oxides (N_2O) and methane (CH_4) have significantly higher global warming potentials, they are emitted at significantly lower rates, resulting in minimal fractional increases in CO_2 equivalents when compared with CO_2 alone (USEPA, 2015). Table 4-1 shows the CO_2 emission totals (tons). Implementation of the alternatives are not anticipated to exceed 16,000 metric tons of CO_2. Alternatives 5b1 and 6 are not included in the GHG estimates.

Table 4-1. Carbon Dioxide Emissions Totals

	CO2 Emissions (tons)				Total Emissions (tons)
	Reagan	Arlington WPCP	Four Mile Run	Belle Haven	
2026	158	650	520	178	1,506
2027	634	2,606	2,065	708	6,012
2028	636	548	2,081	716	3,980
2029	692	-	1,201	704	2,597
2030	712	-	-	520	1,232
2031	604	-	-	-	604
2032	60	-	-	-	60
2033	0	-	-	-	0
Total	**3,496**	**3,803**	**5,867**	**2,826**	**15,992**

4.2.5 Hazardous, Toxic, and Radioactive Waste (HTRW)

4b Reagan National Airport Levee and Floodwall

MWAA plans to conduct further investigations in the future to determine the extent of contamination on the south side of the airport. Based on the current understanding of environmental contamination at Reagan National Airport, subsurface excavation would require the implementation of health and safety measures to protect construction workers and procedures for handling and off-site disposal of contaminated materials.

4c Arlington WPCP Floodwall

Due to the potential for groundwater contamination due to historic landfilling of the property and nearby chemical spills, there is a risk that contaminated groundwater would be encountered during construction of the floodwall. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.

5a Four Mile Run Levee and Floodwall

Due to the potential for groundwater contamination due to nearby chemical spills, there is a risk that contaminated groundwater would be encountered during construction of the levee/floodwall. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.

5b1 City of Alexandria Deployable Floodwall, 6 Non-Structural Plan

USACE HTRW Reports were not drafted for these alternatives. However, there are no known USEPA Superfund sites, Superfund Non-NPL sites, Brownfield properties, or other

cleanup sites in the locations of the Alexandria deployable floodwall or the non-structural plan (USEPA, 2021b).

5c Belle Haven Levee and Floodwall
There are eight potential sources of groundwater contamination in the vicinity of the construction site. A gas station located at 1201 Belle Haven Road poses the biggest threat due to its close proximity to the construction site and likelihood of groundwater contamination. The other sites may have contamination but are thought to be far enough from the construction site to not have an effect. Due to the potential for groundwater contamination from the nearby gas station, there is a risk that contaminated groundwater would be encountered during construction. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.

4.2.6 Cultural Resources

USACE evaluated the direct and indirect effects to cultural resources due to the proposed alternatives. This section describes the potential effects that could occur to cultural resources that are either eligible for or listed in the National Register of Historic Places (NRHP) by the proposed alternatives.

4b Reagan National Airport Levee and Floodwall
Perimeter road elevation, levee construction, and closure installation would not have an adverse effect on the NRHP-listed Washington National Airport Terminal and South Hangar Line since these project components would not significantly diminish the resource's integrity or alter its character-defining features in such a way as to have an adverse effect. The Mount Vernon Trail may be affected since the proposed LOD for portions of levee and floodwall construction fall within its boundaries.

4c Arlington WPCP Floodwall
Construction of floodwalls, closure structures, and associated staging areas at the Arlington WPCP is not likely to have an adverse effect on historic properties since this area is built-up and the proposed alternative would occur in previously disturbed areas. Additionally, the nearest historic properties are too distant for there to be adverse effects on viewsheds.

5a Four Mile Run Levee and Floodwall
Portions of Alternative 5a are proposed within site 44AX0207, an archaeological site that has not been evaluated for listing in the NRHP. Areas of proposed levee, floodwall, and staging area construction may need to be archaeologically surveyed to determine their effects to this resource.

5b1 City of Alexandria Deployable Floodwall
A deployable floodwall along the waterfront in Old Town Alexandria would have an effect on the Alexandria Historic District, although it is unclear at this point in time if the effect would be adverse since the floodwall would be temporary and final designs have not been produced.

5c Belle Haven Levee and Floodwall
The proposed floodwall and closure structures around Belle Haven may have a visual effect on the GWMP and Mount Vernon Trail since it would introduce a new visual element to these resources. Since the Belle Haven neighborhood has never been evaluated for the NRHP, it may need to be formally evaluated to determine how it may be affected by the proposed alternative. Additionally, archaeological surveys may be needed in locations of proposed levee construction.

6 Non-Structural Plan
Adverse effects to historic properties from implementation of Alternative 6 would be specific to the historic properties treated. Floodproofing or structural elevation of a building eligible for or listed in the NRHP or contributing to an NRHP eligible or listed historic district would require mitigation. Alternative 6 proposes non-structural alternatives to buildings within the Alexandria Historic District, Occoquan Historic District, and Belle Haven. Mitigation would be required for non-structural measures proposed for buildings within the Alexandria and Occoquan Historic Districts as they would present numerous potential adverse effects to each historic district. As mentioned previously, the Belle Haven neighborhood has not been evaluated for its eligibility for listing in the NRHP. Belle Haven would require a formal determination of eligibility, or, at a minimum, individual buildings proposed for non-structural measures would need to be evaluated for their eligibility for NRHP listing.

4.2.7 Aesthetics

4b Reagan National Airport Levee and Floodwall
The airport property is entirety developed with no natural areas. Construction of the levee/floodwall at Reagan National Airport would not affect the aesthetics of the airport.

4c Arlington WPCP Floodwall
The Arlington WPCP is located in a highly developed urban environment with a mix of residential and commercial properties. The Arlington WPCP is a commercial facility located on the north side of Four Mile Run across the water from Four Mile Run Park. An asphalt walking path, security fence, and overhead electric power lines suspended by towers are located between the Arlington WPCP and Four Mile Run. The floodwall may permanently affect the view from nearby recreational areas including the walking paths along both sides of Four Mile Run and the view from Four Mile Run Park. This impact would not be significant because the area is already highly developed.

5a Four Mile Run Levee and Floodwall

The Four Mile Run levee and floodwall would be located in Four Mile Run Park – a recreational area with an asphalt walking path, playground, tennis courts, and a dirt walking path that winds through natural areas in the park. Four Mile Run Park is located in a highly developed urban environment with a mix and of residential and commercial properties. The earthen levee would be constructed in the footprint of the existing asphalt walking path. The levee/floodwall may permanently affect the view from the recreational areas in Four Mile Run Park and some residential properties that currently have a view of Four Mile Run. The asphalt walking path would be constructed on top of the proposed levee, so the view from the walking path would not be obstructed.

5b1 City of Alexandria Deployable Floodwall

The deployable floodwall would temporarily obstruct the view of the Potomac River from the Old Town Alexandria waterfront. This impact would be temporary only while the floodwall was in place during storm events.

5c Belle Haven Levee and Floodwall

The proposed floodwall at Belle Haven may permanently obstruct the view of the natural areas located south of Belle Haven and the GWMP the residents of the Belle Haven community. The levee/floodwall would be approximately 6 to 7 ft high on average. This would obstruct the view from the lower floors of the River Towers Condominiums located adjacent to the proposed levee/floodwall, and the view from the community grounds and recreational areas. Figures 4-9 and 4-10 are renderings from a 2009 Fairfax County Flood Risk Management Study of a proposed floodwall at Belle Haven (USACE, 2009).

Figure 4-9. Rendering of a 6.5-ft-tall Floodwall Along the East Side of Boulevard View

Figure 4-10. Rendering of a 6.5-ft Floodwall South of the River View Condominiums Located at Boulevard View and 10th Street

6 Non-Structural Plan
The elevated structures may obstruct the view in some locations.

4.2.8 Recreation

4b Reagan National Airport Levee and Floodwall
Plane spotting is a popular recreational activity at Gravelly Point located immediately north of the airport. Construction of the levee/floodwall may affect the view of planes taxiing to and from the runways. View of planes landing and taking off would not be affected. Therefore, the proposed levee/floodwall at the Reagan National Airport may have a minor, permanent effect on recreation.

4c Arlington WPCP Floodwall
Users of the existing asphalt pedestrian path may be temporarily affected during construction of the floodwall at the Arlington WPCP. The portion of the existing path in between the Arlington WPCP and Four Mile Run may need to be removed or temporarily closed in order to construct the floodwall (a period of 18 months). This alternative would have no permeant effect on recreation.

5a Four Mile Run Levee and Floodwall
Users of the existing asphalt pedestrian path and other recreational amenities located near the proposed construction area would be temporarily affected during construction of the levee at Four Mile Run Park. Since the levee would be constructed in the footprint of the existing asphalt path, the path would be unavailable during the construction period (3 years). Access to the hiking trails, tennis courts, playgrounds and other recreational amenities may be temporarily closed during this time. This alternative would have no permanent effect on recreation.

5b1 City of Alexandria Deployable Floodwall
Users of the Alexandria waterfront would be temporarily affected during construction of the deployable floodwall. Portions of the waterfront and Windmill Hill Park (staging area) would be inaccessible during initial construction of the floodwall. Portions of the waterfront may also be inaccessible while the floodwall is deployed during a storm event. This alternative would have no permanent effect on recreation.

5c Belle Haven Levee and Floodwall
Recreation would be temporarily affected during construction of the levee/floodwall. Access to the tennis courts, walking paths, and other recreational amenities may be closed during construction (a period of 4 years). General enjoyment of the natural areas and waterways would be temporarily disrupted. Wildlife may avoid the area due to construction noise which may affect activities such as birdwatching. This disruption would temporarily affect the residents of the Belle Haven community. Two tennis courts adjacent to the Belle Haven East Channel are located in the footprint of the proposed

floodwall. These tennis courts would need to be relocated. Residents would be able to access the other tennis courts and other recreation amenities via openings in the floodwall. Closure structures would be installed in these openings during a flood event.

6 Non-Structural Plan
Implementation of the non-structural plan would have no effect on recreation.

4.2.9 Noise

4b Reagan National Airport Levee and Floodwall
Construction at the airport would occur over an eight-hour period at night and total construction time is anticipated to be six years. Typical equipment that would be used to construct the levee and floodwall includes mobile equipment such as dozers, dump trucks, and asphalt and concrete trucks. This type of equipment typically generates noise levels ranging from 70 to 80 db. A crane would also be used for a period of two years that would generate noise levels at an average of 81 dB (Federal Highway Administration, 2017). Noise levels generated by the construction equipment are not expected to exceed levels generated by approaching aircraft. According to the Reagan National Airport Nighttime Noise Rule, compliant aircraft must generate noise levels that are equal to or less than 85 dBA (MWAA, n.d.). However, aircraft landings and takeoffs typically do not occur between the hours of 12 a.m. and 5 a.m. (MWAA, 2020). Therefore, construction would generate noise levels not emitted by aircraft during these hours.

4c Arlington WPCP Floodwall
Construction at the Arlington WPCP would occur during the daytime and total construction time is anticipated to be 18 months. Typical equipment that would be used to construct the floodwall includes mobile equipment such as dozers, dump trucks, and asphalt and concrete trucks. This type of equipment typically generates noise levels ranging from 70 to 80 db. A crane would also be used for a period of 16 months that would generate noise levels at an average of 81 dB (Federal Highway Administration, 2017). Typical background noise levels in urban residential neighborhoods range from 45 to 55 dB depending on the time of day and location of the measurement. Noise levels generally increase in relation to the amount of commercial activity (King et al., 2012). Noise in the location of the Arlington WPCP may be higher than other urban residential areas due to the amount of surrounding commercial activity on Mount Vernon Avenue and Route 1 and aircraft noise at the nearby Reagan National Airport. Construction of the proposed floodwall would contribute to overall daytime noise in this area and may affect residents as well as users of nearby parks and trails, but the noise would not be significantly louder than the ambient daytime noise.

5a Four Mile Run Levee and Floodwall
Construction at Four Mile Run Park would occur during the daytime and total construction time is anticipated to be three years. Typical equipment that would be used to construct

the levee and floodwall includes mobile equipment such as dozers, dump trucks, and asphalt and concrete trucks. This type of equipment typically generates noise levels ranging from 70 to 80 db (Federal Highway Administration, 2017). Typical background noise levels in urban residential neighborhoods range from 45 to 55 dB depending on the time of day and location of the measurement. Noise levels generally increase in relation to the amount of commercial activity (King et al., 2012). Noise in the location of the Four Mile Run Park may be higher than other urban residential areas due to the amount of surrounding commercial activity on Mount Vernon Avenue and Route 1 and aircraft noise at the nearby Reagan National Airport. Construction of the proposed floodwall would contribute to overall daytime noise in this area and may adversely affect residents as well as users of nearby parks and trails, but the noise would not be significantly louder than the ambient daytime noise.

5b1 City of Alexandria Deployable Floodwall

Initial construction of the proposed deployable floodwall would contribute to overall daytime noise in this area and may affect residents, but the noise would not be significantly louder than the ambient daytime noise. Noise generated from approaching aircraft contributes to the ambient background noise in this area. Noise would also be generated during installation of the deployable floodwall prior to storm events.

5c Belle Haven Levee and Floodwall

Construction at Belle Haven would occur during the daytime and total construction time is anticipated to be four years. Typical equipment that would be used to construct the levee and floodwall includes mobile equipment such as dozers, dump trucks, and asphalt and concrete trucks. This type of equipment typically generates noise levels ranging from 70 to 80 db (Federal Highway Administration, 2017). Typical background noise levels in urban residential neighborhoods range from 45 to 55 dB depending on the time of day and location of the measurement. Noise levels generally increase in relation to the amount of commercial activity (King et al., 2012). Belle Haven is a residential community. A commercial center is located on the north side of the community. Traffic on the GWMP may generate noise in the portions of Belle Haven located along the parkway. Due to the close proximity of the proposed floodwall and levee to several of the condominium buildings in Belle Haven, construction of the proposed levee and floodwall would temporary adversely affect the residents of Belle Haven during the daytime. This adverse effect would not be significant because noise is not expected to exceed 80 dB (no noise would be generated by jack hammering or pile driving) and would be temporary during the period of construction.

Alt 6 Non-Structural Plan

Construction of the non-structural measures would generate noise during construction. Noise is not expected to be significant and would be temporary during the period of construction.

4.2.10 Environmental Justice Communities

Alternative 5a (Four Mile Run levee and floodwall) is the only alternative located in a census tract identified under Section 2.4.10 as an EJ community. Construction of the levee and floodwall in Four Mile Run Park would not disproportionately affect the EJ community. Air emissions and noise generated during construction would not significantly affect nearby communities. Further investigations would be needed to determine the presence of groundwater contamination in the footprint of the construction site. If contamination is present, appropriate protocols would be implemented to ensure the health and safety of construction workers and residents. The levee would obstruct the view of the wetlands and Four Mile Run for the nearby residents. Construction of the levee and floodwall would build this community's resilience to coastal flooding, particularly with the additional threats posed by climate change.

4.3 Summary of Effects

Table 4-2 summarizes the effects of the final array of alternatives. Effects highlighted in red are potential adverse effects and effects highlighted in green are potential beneficial effects.

Table 4-2. Summary of Potential Effects from the Final Array of Alternatives

Resource Topic	1 No-Action Alternative	4b Reagan National Airport Levee and Floodwall	4c Arlington Water Pollution Control Plant Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Non-Structural Plan
Wetlands	Wetlands located on managed lands expected to maintain natural and historic value. SLR threatens low-lying wetlands.	No effect.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction. Potential change in inundation depth is not expected to affect the health, character, or integrity of the wetlands. Discharge from the pump stations would result in minor impacts to wetlands.	No effect.
Floodplains	Expected to move inland as sea levels rise.	Reduction in the amount of floodplain for coastal floodwaters. No effect to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No effect to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No effect to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No effect to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No effect to natural floodplains. Minor impacts to the natural floodplain south of Belle Haven.	No effect.
Submerged Aquatic Vegetation	Potential effects from stressors associated with climate change.	**Up to 15,000 sqft of temporary, indirect impacts to SAV due to shading from the barges.**	No effect.	No effect.	No effect.	No effect.	No effect.
Threatened and Endangered Species	Habitats located in low-lying areas are threatened by SLR. Successful management strategies may help recover species.	No effect to terrestrial and freshwater species. Insignificant effect to Atlantic sturgeon and critical habitat and shortnose sturgeon.	No effect.	No effect.	No effect.	No effect.	No effect.
Anadromous Fish	Ongoing efforts by MDDNR and the Chesapeake Program to improve fish passage in the region, as well as fishing regulations can support the restoration of anadromous fish populations in this region.	Temporary and minor indirect effects to anadromous fish due to the temporary loss of SAV and noise generated by equipment operating on the barges during construction at the airport.	No effect.	No effect.	No effect.	No effect.	No effect.
Migratory Birds	Habitats located in low-lying areas may be degraded or lost to inundation due to SLR. Future development in the region could reduce the availability of suitable habitats for migratory birds.	No additional adverse effects to migratory birds outside of effects generated by the bird cannons.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction.	Temporary and minor indirect effects during construction. Protective buffers to minimize adverse effects to nesting bald eagles would be implemented at Belle Haven. A permit from USFWS would be obtained if these buffers could not be adhered to.	Temporary and minor indirect effects during construction.
Waterways and Hydrology	Future hydrology in the study area depends on changes in land and water use in the Middle Potomac River Watershed. Jurisdictions have identified opportunities to improve erosion and sedimentation in streams. USACE plans to model the FWP condition to determine the potential for induced flooding.	Temporary and minor effects during construction.	Temporary and minor effects during construction.	**Roughly 4,320 sqft of temporary impacts and roughly 2,760 sqft of new permanent fill impacts to waterways.**	Temporary and minor effects during construction.	**Roughly 2,000 sqft of temporary impacts and roughly 2,250 sqft of permanent fill impacts to streams. A conceptual mitigation plan for the permanent fill impacts has been developed.**	No effect.
Water Quality	Reaching long-term water quality goals would depend on efforts to	Temporary and minor indirect effects on water quality.	Temporary and minor indirect effects on water quality.	Temporary and minor indirect effects on water quality.	Temporary and minor indirect effects on water quality.	Temporary and minor indirect effects on water quality. Temporary	No effect.

Resource Topic	1 No-Action Alternative	4b Reagan National Airport Levee and Floodwall	4c Arlington Water Pollution Control Plant Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Non-Structural Plan
	reduce nutrients and sediments from both point and non-point sources.			Temporary and minor effects to water quality from sediment released from the flap gates following a storm event.		and minor effects to water quality from sediment released from the flap gates following a storm event.	
Air Quality	Implementation of priority air pollution reduction measures identified by MWCOG could reduce the number of ozone exceedance days significantly. These measures would have to be implemented regionwide to get the projected benefits.	Minor and temporary effects during construction, but below de minimis air quality levels.	Minor and temporary effects during construction, but below de minimis air quality levels.	Minor and temporary effects during construction, but below de minimis air quality levels.	Minor and temporary effects are expected during construction.	Minor and temporary effects during construction, but below de minimis air quality levels.	Minor and temporary effects are expected during construction.
Greenhouse Gases	MWCOG and its member jurisdictions set a new interim GHG emission reduction goal of 50 percent below 2005 levels by 2030 and continues to work toward these goals.	3,496 tons of CO_2 emissions during construction.	3,803 tons of CO_2 emissions during construction.	5,867 tons of CO_2 emissions during construction.	Not determined.	2,826 tons of CO2 emissions during construction.	Not determined.
Hazardous, Toxic, and Radioactive Waste	MWAA is in consultation with VADEQ regarding the next steps towards further delineation of contamination in the SIS area. Additional risk evaluations would be performed by the FAA once the delineation efforts by MWAA are completed. Future development that would require subsurface excavation at the Arlington WPCP, Four Mile Run Park, and Belle Haven may warrant further investigations of the soils to determine the extent of groundwater contamination in these areas.	**Potential adverse effects to human health. Environmental health and safety measures would be implemented to protect construction workers. Procedures for handling and off-site disposal of contaminated materials may also be required.**	**Potential adverse effects to human health. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	**Potential adverse effects to human health. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	No effect.	**Potential adverse effects to human health. Further investigations are needed to determine the presence of contamination in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	No effect.
Cultural Resources	Significant cultural resources would likely be affected by ongoing coastal flooding and SLR.	**Potential effects to the Mount Vernon Trail during construction.**	No effect.	**Potential permanent adverse effects to site 44AX0207, an archaeological site that has not been evaluated for listing in the NRHP. An archeological survey of the levee/floodwall and staging area would need to be conducted to determine effects to this site.**	No effect.	**Potential visual effects from the GWMP and Mount Vernon Trail of the proposed floodwall. Belle Haven neighborhood has never been evaluated for the NRHP; it may need to be formally evaluated to determine how it may be affected. Archaeological surveys may be needed in locations of proposed levee/floodwall construction.**	**Mitigation would be required for non-structural measures proposed for buildings within the Alexandria and Occoquan Historic Districts. Belle Haven would require a formal determination of NRHP eligibility, or, at a minimum, individual buildings proposed for non-structural measures would need to be evaluated for their eligibility for NRHP listing.**
Aesthetics	Major development projects may affect the region's aesthetics. Protected and managed lands	Not significant because these areas are already highly developed.	Not significant because these areas are already highly developed.	**View of Four Mile Run would be permanently obstructed.**	View may be obstructed during storm events.	**View of natural areas and the GWMP would be permanently obstructed.**	View obstructed by elevated structures in some locations.

Resource Topic	1 No-Action Alternative	4b Reagan National Airport Levee and Floodwall	4c Arlington Water Pollution Control Plant Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Non-Structural Plan
	and historic sites are expected to retain their natural and historic value in the future.						
Recreation	Future recreational opportunities in the study area are outlined in VADCR's 2018 Outdoors Plan.	Minor, permanent effect.	Temporary effects during construction.	Temporary effects during construction.	Temporary effects during construction.	Temporary effects during construction. **Permanent effects to recreation due to impacts to tennis courts adjacent to the Belle Haven East Channel.**	No effect.
Noise	Construction and traffic noise would be expected to intensify in the study area as population and development increases.	Noise levels generated by construction equipment are not expected to exceed levels generated by approaching aircraft.	Temporary effects during construction.	Temporary effects during construction.	Temporary effects during construction.	Temporary effects during construction.	Temporary effects during construction.
Environmental Justice Communities	There are many ongoing efforts to promote fair and equitable treatment of all communities throughout Northern Virginia.	No effect.	No effect.	**The levee and floodwall would build the EJ community's resilience to coastal flooding.**	No effect.	No effect.	No effect.

4.4 Mitigation, Monitoring, and Adaptive Management

Measures to avoid, minimize, mitigate, and compensate for environmental impacts from the final array of alternatives are described in Table 4-3. The table describes each measure that may be taken to avoid, minimize, mitigate, and compensate for impacts, the objective that it is intended to fulfill, the impact to which it applies, and the relevant statute for each requirement. Measures to address minor impacts to wetlands and waterways such as the use of sediment and erosion control measures are not included in Table 4-3.

Measures for impacts that are considered greater than “minor impacts” are shown in the table below including temporary impacts to SAV at the Reagan National Airport and temporary and permanent impacts to streams at Four Mile Run and Belle Haven.

Avoidance/minimize measures and a discussion of mitigation for the TSP located in Section 6.6. A draft conceptual mitigation plan is located in Appendix G.

Table 4-3. Summary of Mitigation Sequencing Actions

Alternative	Avoid	Minimize	Mitigate	Compensate
Alternative 1 – No Action	n/a	n/a	n/a	n/a
Alternative 4b – Reagan National Airport Levee and Floodwall	**Measure:** Stage barges in a location devoid of SAV. **Objective:** Avoid impacts to SAV. **Impact Addressed:** Prevents temporary loss of SAV. **Relevant Laws:** Clean Water Act (CWA), Fish and Wildlife Coordination Act (FWCA), Water Resources Development Act (WRDA)	**Measures:** Stage barges in a location with less dense SAV. Reduce the amount of time barges are staged. **Objective:** Minimize impacts to SAV. **Impact Addressed:** Reduces the amount of SAV temporarily lost/reduces the amount of time SAV is shaded. **Relevant Laws:** CWA, FWCA, WRDA	No mitigation proposed because the impact would be temporary.	No compensation proposed because the impact would be temporary.
Alternative 4c – Arlington WPCP Floodwall	n/a	n/a	n/a	n/a
Alternative 5a – Four Mile Run Levee and Floodwall	**Measure**: Route alignment so that it does not cross waterways. **Objective:** Avoid impacts to streams. **Impact Addressed:** Prevents loss of stream bed. **Relevant Laws:** CWA, FWCA, WRDA	**Measure:** Reduce the permanent footprint of the levee that crosses waterways. **Objective:** Minimize impact to stream beds. **Impact Addressed:** Reduces the amount of stream bed lost. **Relevant Laws:** CWA, FWCA, WRDA	No mitigation measures were identified.	**Measure:** Purchase credits from a mitigation bank or approved in-lieu fee program, or construct a mitigation project. **Objective:** Compensate for unavoidable impacts to stream bed. **Impact Addressed:** Replaces lost functions and values of the stream bed impacted by project construction. Relevant Laws: CWA, FWCA, WRDA
Alternative 5b1 – Alexandria Deployable Floodwall	n/a	n/a	n/a	n/a

Alternative	Avoid	Minimize	Mitigate	Compensate
Alternative 5c – Belle Haven Levee and Floodwall	**Measure**: Route alignment so that it does not cross waterways. **Objective:** Avoid impacts to streams. **Impact Addressed:** Prevents loss of stream bed. **Relevant Laws:** CWA, FWCA, WRDA	**Measure:** Reduce the permanent footprint of the floodwall that crosses waterways. **Objective:** Minimize impacts to stream bed. **Impact Addressed:** Reduces the amount of stream bed lost. **Relevant Laws:** CWA, FWCA, WRDA	No mitigation measures were identified.	**Measure:** Purchase credits from a mitigation bank or approved in-lieu fee program, or construct a mitigation project. **Objective:** Compensate for unavoidable impacts to stream bed. **Impact Addressed:** Replaces lost functions and values of the stream bed impacted by project construction. **Relevant Laws:** CWA, FWCA, WRDA
Alternative 6 – Non-Structural Plan	n/a	n/a	n/a	n/a

5 Plan Comparison and Selection

The following section outlines the with-project condition and benefits for the final array of alternatives, the four accounts evaluation and the plan comparison leading to the TSP decision. The future with project condition is the most likely condition expected to exist in the future if a specific project is undertaken. A full discussion on the with-project condition and benefits can be found in Appendix E.

5.1 With Project Condition

As stated previously, the top level of protection for the alternatives was used to determine the PV damages and average annual damages for each MA. Tables 5-1 and 5-2 summarize the damages expected to occur under the various FWP scenarios.

Table 5-1. Alternative 4 - Future With Project Conditions

Model Area	Present Value Damages	Average Annual Damages
(Alt-4b) MA7: Reagan National Airport	$367,000	$12,000
(Alt-4c) MA8: Four Mile Run Arlington	$626,000	$21,000
Total	$993,000	$33,000

When the project alternative future conditions were compared to the FWOP conditions, Alternative 4 reduced the mean PV damages in Reagan National Airport MA by 84 percent, Four Mile Run Arlington Water Pollution Control Plan MA by 89 percent, and by 88 percent for both combined MAs.

Table 5-2. Alternative 5 - Future With Project Conditions

Model Area	Present Value Damages	Average Annual Damages
(Alt-5b1) MA10: Old Town Alexandria	$12,878,000	$432,000
(Alt-5a) MA12: Belle Haven	$16,942,000	$568,000
(Alt-5c) MA17: Four Mile Run Alexandria	$605,000	$20,000
Total	$30,425,000	$1,020,000

When comparing the project alternative future conditions were compared to the FWOP conditions, Alternative 5 reduced the mean PV damages in Old Town Alexandria MA by 79 percent, Belle Haven MA by 78 percent, Four Mile Run Alexandria by 84 percent, and by 78 percent for the combined MAs.

The nonstructural solutions were evaluated for 5 percent, 2 percent, and 1 percent AEP in compliance with the National Nonstructural Committee (NNC) Best Practice Guide 2020-06, dated *15 November 2021,* focusing on the structure aggregation methods used in the formulation and evaluation of nonstructural alternatives. A 5 percent AEP event was used instead of a 25-year event because of the availability of hydraulic stage functions. Elevation and floodproofing techniques were the nonstructural measures used in this analysis. Based on G2CRM outputs, Old Town Alexandria, Belle Haven, and Occoquan Bay were chosen for further evaluation of nonstructural solutions. Table 5-3 shows the number of structures by nonstructural measure type for the 5 percent, 2 percent, and 1 percent AEP event.

Table 5-3. Nonstructural treatments per location and floodplain

Planning Units	Nonstructural Measures (1% AEP)		Nonstructural Measures (2% AEP)		Nonstructural Measures (5% AEP)	
	Elevation	Floodproofing	Elevation	Floodproofing	Elevation	Floodproofing
MA10&20 - Old Town Alexandria	0	201	0	180	0	113
MA12 - Belle Haven	168	217	149	193	120	116
MA16 - Occoquan Bay	25	35	23	35	19	31
Total	193	453	172	408	139	260

5.2 With Project Benefits

The difference in expected mean PV flood damages in the DC Coastal Study area between the FWOP condition and future with project condition represents the FRM benefits to the project. Therefore, these benefits represent damages reduced (NED) from coastal storm surge inundation with the combination of SLR for each alternative. However, ER 1105-2-100, the PGN, dictates that the calculation of net NED benefits for a plan is calculated in average annual equivalent terms. Therefore, the PV damages were converted to average annual damages and the costs were annualized using the FY22 discount rate of 2.25% and a 50-year period of analysis for the purpose of the comparison.

The equivalent annual benefits were compared to the average annual cost to develop net benefits and a BCR for each alternative. The net benefits for each alternative were computed by subtracting the average annual costs from the equivalent average annual benefits. BCR was calculated by dividing average benefits by average annual costs. Net benefits were used for identification of the NED plan in accordance with the Federal objective. The NED benefits for the Alternatives are summarized in Table 5-4 and Table 5-5 and are detailed in Appendix E.

Table 5-4. Economic Evaluation by Alternative

Alternatives	Total Cost	Average Annualized Costs	Average Annualized Benefits	Average Annualized Net Benefits	BCR
Alt 1 (No-Action)		.	.	.	.
Alt 4 (Reagan and WPCP)	$96,050,000	$3,219,000	$243,000	($2,976,000)	0.08
Alt 5 (Four Mile Run, Alexandria and Belle Haven)	$241,765,000	$8,103,000	$3,339,000	($4,764,000)	0.41
Alt 6 (Nonstructural 1% AEP)	$209,738,000	$7,030,000	$1,218,000	($5,812,000)	0.17
Alt 6 (Nonstructural 2% AEP)	$188,233,000	$6,309,000	$1,081,000	($5,228,000)	0.17
Alt 6 (Nonstructural 5% AEP)	$130,742,000	$4,382,000	$831,000	($3,551,000)	0.19
Alt 8 (Combination WPCP and Belle Haven)	$52,606,000	$1,763,000	$2,213,000	$450,000	1.3

Table 5-5. Economic Evaluation by Alternative Components

Alternative Description	Total Cost	Average Annual Cost	Average Annual Benefits	Average Annual Net Benefits	BCR
No Action		.	.	.	.
Structural Alternatives 4, 5 and 8					
Alt 4b: Reagan National Airport 0.2% AEP	$93,356,000	$3,129,000	$64,000	($3,065,000)	0.02
Alt 4c: Arlington WPCP 0.2% AEP	$2,694,000	$90,000	$179,000	$89,000	2.0
Alt 5a: Four Mile Run Levee & Floodwall 1% AEP	$35,243,000	$1,181,000	$104,000	($1,077,000)	0.09
Alt 5b1: Alexandria Deployable Floodwall 2% AEP	$157,214,000	$5,270,000	$1,201,000	($4,069,000)	0.23
Alt 5c: Belle Haven Levee & Floodwall 1% AEP	$49,912,000	$1,673,000	$2,034,000	$361,000	1.2
Alt 8: Combination (WPCP & Belle Haven) – NED Plan	**$52,606,000**	**$1,763,000**	**$2,213,000**	**$450,000**	**1.3**
Alternative 6: Nonstructural					
MA10 & MA20: Old Town Alexandria 1% AEP	$61,616,000	$2,065,000	$380,000	($1,685,000)	0.18
MA12: Belle Haven 1% AEP	$128,212,000	$4,297,000	$782,000	($3,515,000)	0.18
MA16: Occoquan Bay 1% AEP	$19,910,000	$667,000	$56,000	($611,000)	0.08
MA10 & MA20: Old Town Alexandria 2% AEP	$55,178,000	$1,849,000	$342,000	($1,507,000)	0.18
MA12: Belle Haven 2% AEP	$113,879,000	$3,817,000	$684,000	($3,133,000)	0.18
MA16: Occoquan Bay 2% AEP	$19,176,000	$643,000	$55,000	($588,000)	0.09
MA10 & MA20: Old Town Alexandria 5% AEP	$34,639,000	$1,161,000	$286,000	($875,000)	0.25
MA12: Belle Haven 5% AEP	$79,624,000	$2,669,000	$514,000	($2,155,000)	0.19
MA16: Occoquan Bay 5% AEP	$16,479,000	$552,000	$31,000	($521,000)	0.06

Alternatives were first compared by group to show net benefits for Alternatives 4, 5, 6 (at 5%, 2% and 1% AEP) and 8. Only Alternative 8 yielded positive net benefits of $450,000. When the final array of alternatives components (Alts 4b, 4c, 5a, 5b1, 5c, 6 - nine

components by location and AEP) and Alternative 8 were evaluated, Alternatives 4c, 5c and 8, as explained previously, yielded positive net benefits. Alternative 4c and 5c yielded positive net benefits of $89,000 and $361,000, respectively. It was determined that based on the highest positive net benefits along with other environmental and social factors, Alternative 8 is the NED Plan because it reasonably maximizes net benefits.

5.3 Four Accounts Evaluation

5.3.1 National Economic Development (NED)

In accordance with the Federal objective, the NED plan is defined as the cost-effective plan that maximizes net benefits. Table 5-6 summarizes the equivalent annual benefits, interest during construction (IDC), average annual costs, first cost, net benefits, and BCR for each alternative.

Table 5-6. Costs and Benefits Comparison of Alternatives

Plan Alternatives	First Cost	IDC	Investment Cost	Operations & Maintenance (O&M)	Total Cost	Average Annualized Costs	Average Annualized Benefits	Average Annualized Net Benefits	BCR
Alternative-1	.	.	.	.		.	.	.	.
Alt-4b	$86,535,000	$5,956,000	$92,491,000	$865,000	$93,356,000	$3,129,000	$64,000	($3,065,000)	0.0
Alt-4c	$2,626,000	$42,000	$2,668,000	$26,000	$2,694,000	$90,000	$179,000	$89,000	2.0
Alternative-4	$89,161,000	$5,998,000	$95,159,000	$892,000	$96,050,000	$3,219,000	$243,000	($2,976,000)	0.1
Alt-5a	$33,784,000	$1,121,000	$34,905,000	$338,000	$35,243,000	$1,181,000	$104,000	($1,077,000)	0.1
Alt-5b1	$152,651,000	$2,432,000	$155,083,000	$1,527,000	$156,610,000	$5,249,000	$1,201,000	($4,048,000)	0.2
Alt-5c	$48,162,000	$1,268,000	$49,430,000	$482,000	$49,912,000	$1,673,000	$2,034,000	$361,000	1.2
Alternative-5	$234,597,000	$4,821,000	$239,418,000	$2,346,000	$241,765,000	$8,103,000	$3,339,000	($4,764,000)	0.4
	$57,976,000	$3,640,000	$61,616,000	-	$61,616,000	$2,065,000	$380,000	($1,685,000)	0.2
	$120,639,000	$7,573,000	$128,212,000	-	$128,212,000	$4,297,000	$782,000	($3,515,000)	0.2
	$18,734,000	$1,176,000	$19,910,000	-	$19,910,000	$667,000	$56,000	($611,000)	0.1
Alternative-6 - NS_100YR	$197,349,000	$12,389,000	$209,738,000	-	$209,738,000	$7,030,000	$1,218,000	($5,812,000)	0.2
	$51,919,000	$3,259,000	$55,178,000	-	$55,178,000	$1,849,000	$342,000	($1,507,000)	0.2
	$107,152,000	$6,727,000	$113,879,000	-	$113,879,000	$3,817,000	$684,000	($3,133,000)	0.2
	$18,043,000	$1,133,000	$19,176,000	-	$19,176,000	$643,000	$55,000	($588,000)	0.1
Alternative- 6 - NS_50YR	$177,114,000	$11,119,000	$188,233,000	-	$188,233,000	$6,309,000	$1,081,000	($5,228,000)	0.2
	$32,593,000	$2,046,000	$34,639,000	-	$34,639,000	$1,161,000	$286,000	($875,000)	0.2
	$74,921,000	$4,703,000	$79,624,000	-	$79,624,000	$2,669,000	$514,000	($2,155,000)	0.2
	$15,506,000	$973,000	$16,479,000	-	$16,479,000	$552,000	$31,000	($521,000)	0.1
Alternative- 6 - NS_20YR	$123,020,000	$7,722,000	$130,742,000	-	$130,742,000	$4,382,000	$831,000	($3,551,000)	0.2

5.3.2 Regional Economic Development (RED)

The current certified Regional Economic System (RECONS) 2.0 model was used to develop Northern Virginia RED benefits. The RED effects of each alternative were examined. The total cost for each alternative was used to input into the RECONS model.

Of the total expenditures, 99 percent would be captured within the local study area. The remainder of the expenditures would be captured within the state or regional level. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product.

5.3.3 Environmental Quality (EQ)

Wetland information and GIS data were collected from various sources for identification of wetland areas within the study areas. USGS topographic quadrangles, U.S. Department of Agriculture (USDA) web soil surveys, Federal Emergency Management Agency (FEMA) floodplain mapping, and U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) were used to access SAV, soil types, historical resources, archeological sites, EJ community, and aesthetics were examined in the classification of alternatives. The environmental quality (EQ) account used qualitative assessment consistent with ecosystem environmental compliance guidance to assesses the impact of floodwall, levee, and nonstructural measures in the Northern Virginia study area.

5.3.4 Other Social Effects (OSE)

5.3.4.1 Life Loss

To identify risk to life safety, each alterative was evaluated for potential life loss calculations. G2CRM is capable of modeling life loss using a simplified life loss methodology (Appendix E). Since there is uncertainty in modeling life loss, the FWOP condition was modeled to serve as a baseline. Therefore, when compared to the future with project condition, any addition or reduction of life loss from the baseline would serve as a proxy in identifying impacts to life safety the alternatives might have. Table 5-7 presents the mean life loss estimates for each alternative in the study area over a 50-year period of analysis.

Table 5-7. Alternatives Life Loss

Alternative		Life Loss		
		Under 65	Over 65	Total
Alt-4b (MA7)	No Action	0.0	0.0	0.0
	Project	0.0	0.0	0.0
	Incremental Life Loss	0.0	0.0	0.0
Alt-4c (MA8)	No Action	0.0	0.0	0.0
	Project	0.0	0.0	0.0
	Incremental Life Loss	0.0	0.0	0.0
Alt-5a (MA17)	No Action	0.0	0.1	0.1
	Project	0.0	0.0	0.0
	Incremental Life Loss	0.0	-0.1	-0.1
Alt-5b1 (MA10)	No Action	0.1	2.0	2.1
	Project	0.0	1.8	1.8
	Incremental Life Loss	-0.1	-0.3	-0.3
Alt-5c (MA12)	No Action	0.4	3.5	3.9
	Project	0.0	0.4	0.5
	Incremental Life Loss	-0.3	-3.1	-3.4
Alt-6 (NS_100YR) (MA10,12,16,20)	No Action	0.6	6.5	7.1
	Project	0.6	5.5	6.1
	Incremental Life Loss	0.0	-1.0	-1.0
Alt-6 (NS_50YR) (MA10,12,16,20)	No Action	0.6	6.5	7.1
	Project	0.6	5.7	6.3
	Incremental Life Loss	0.0	-0.8	-0.8
Alt-6 (NS_20YR) (MA10,12,16,20)	No Action	0.6	6.5	7.1
	Project	0.6	5.8	6.4
	Incremental Life Loss	0.0	-0.7	-0.7

As part of the OSE analysis, it was important to learn the risk to the individuals impacted during a flood event. In addition, vulnerable populations such as the elderly were considered. Therefore, during the G2CRM modeling the vertical evacuation (i.e. ability to reach higher ground via stairs, ladder etc.) of vulnerable groups was considered. Life loss calculations are separated out by two ages. One category is people under 65 years and the second category is people over 65. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, although safe does not imply that there is no life loss. Chance would have the highest expected life loss.

Each type of structure has an associated storm surge lethality. The surge over the foundation height is the minimum for a lethality zone (safe, compromised, chance). These surges over foundation heights are age-specific. There is one surge height for under 65 years and another surge height for people aged 65 years and older.

The model cycles through every active structure during each storm. For each structure, the model defaults the lethality function to safe and checks for the maximum lethality function such that the modeled area stage is greater than the sum of the first flood elevation of the structure and the lethality function's surge above the foundation. This will be checked separately for under and over 65, as these two age groups can have different lethality functions depending on the age-specific surge above foundation for that occupancy type.

Uncertainty is factored in the life loss modeling. The results of the modeling should be viewed as more qualitative as opposed to a quantitative assessment of life loss even though the results are stated in numerical values. This result should be used in terms of order of magnitude compared to the baseline, No Action or the FWOP and when comparing between alternatives.

As shown in Table 5-7, the implementation of each alternative would lower or show no increase in the overall life safety risk in the Northern Virginia study area when compared to the FWOP condition.

5.3.4.2 Health and Safety

The health and safety of people living in the community within the project area were considered for the with-project condition in each alternative. Structural and nonstructural measures would protect the health and safety of residents from the direct impact of coastal storms by keeping flood waters away from property and eliminating future damages. Preliminary costs and benefits for providing FRM measures for critical infrastructure and other structures were developed for each alternative as part of this study. The PDT will continue to investigate the inclusion of critical infrastructure protection and the nonstructural measures in the communities that would most likely need additional

support before, during, and after coastal flooding events. Protection for these vulnerable areas will be proposed in the recommended plan.

5.3.5 Summary of the Four Accounts

As discussed previously, the NED analysis was developed using G2CRM. Alternatives 4c and 5c yielded positive net benefits. Per ER 1105-2-100, the PGN, dictates that the calculation of net NED benefits for a plan is calculated in average annual equivalent costs (AAEQ). Therefore, the PV damages were converted to average annual damages and the costs were annualized using the FY22 discount rate of 2.25% and a 50-year period of analysis for the purpose of the comparison.

The RED account was analyzed using the RECONS model. The estimated expenditures for each alternative were used to capture the direct and indirect impacts within the local, state, and regional economy. Because RECONS uses the expenditures to forecast future jobs and value added to the economy, the higher the cost of the project the greater the number of jobs and greater value added to the economy. The direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product for each alternative.

The EQ account assessed the impacts of each alternative on plant and animal species, cultural resources, and air quality in the study area as well as other environmental attributes. In accordance with ecosystem and environmental compliance guidance the alternatives were compared using ranking scale.

The OSE account was estimated using the G2CRM model. Each structure has an associated with-storm surge lethality. The vulnerable group, the elderly over 65 years old was considered separately from the population under 65 years old to assess life loss risk to individuals impacted during a flood event. The Summary of the Four Accounts is detailed in Table 5-8.

Table 5-8. Comprehensive Benefits Evaluation of Alternative Plans

Plan Alternatives	Alternative Area Description	NED	RED		OSE	EQ	
		Nets Benefits	US Jobs	Value Added	Incremental Life Loss	Effects	Impact
Alt-4b	BH7: Reagan National Airport Proposed Bulkhead	($3,065,000)	1491	$166,890,000	0.0	Approximately 15,000 sqft of temporary impacts to SAV, Contaminated soils, Mount Vernon Trail Historic Resource	Moderate
Alt-4c	BH8: Four Mile Run Arlington WPCP Proposed Bulkhead	$89,000	43	$4,816,000	0.0	Potential Contaminated Soils	Minor
Alt-5a	BH17: Four Mile Run Alexandria Proposed Bulkhead	($1,077,000)	562	$63,003,000	-0.1	Approximately 2,750 sqft of permanent stream impacts, Potential contaminated soils, Archeological site, Aesthetics, Beneficial to EJ community	Moderate
Alt-5b1	BH10: Old Town Alexandria Proposed Bulkhead	($4,048,000)	2496	$279,967,000	-0.3	During Construction	Minor
Alt-5c	BH12: Belle Haven Proposed Bulkhead	$361,000	795	$89,227,000	-3.4	Approximately 2,520 sqft of permanent stream impacts, Potential contaminated soils, Viewshed from historic resources, Aesthetics	Moderate
Alt-6 NS_100YR	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($5,812,000)	3,342	$374,946,000	-1.0	Alexandria and Occoquan Historic Districts	Minor
Alt-6 NS_50YR	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($5,228,000)	2,999	$336,499,000	-0.8	Alexandria and Occoquan Historic Districts	Minor
Alt- 6 - NS_20YR	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($3,551,000)	2,084	$233,724,000	-0.7	Alexandria and Occoquan Historic Districts	Minor

5.4 Plan Comparison

All alternatives including the no action plan were compared against each other with an emphasis on outputs and effects that would influence the decision-making process for identifying the TSP. These alternatives were evaluated against the without project condition using G2CRM to determine damages to contents and structures. The array of alternatives was further screened to ensure they meet the study objectives: improve resiliency from coastal flood risk, reduce risk to human health and safety, reduce economic damages, and reduce disruption of critical infrastructure assets, services, and interdependent-systems caused by coastal flooding in communities throughout the study area. There are six alternatives in addition to the no-action alternative that were compared and evaluated against the objectives and P&G criteria.

The four P&G criteria were used to screen alternatives against the study objectives (low, medium or high) (Table 5-9).

Table 5-9. Alternatives Screened with Study Objectives and P&G Criteria.

Alts	Study Objectives																							
	Reduce risk to human health and safety												Reduce economic damages											
	National Evaluation Criteria																							
	Accept.			Complete.			Effective.			Efficien.			Accept.			Complete.			Effective.			Efficien.		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
NA			X			X			X			X			X			X			X			X
4b	X			X					X		X		X			X					X			X
4c	X			X			X			X			X			X			X			X			
5a	X			X					X			X		X			X					X			X
5b1		X		X				X		X			X				X					X		X	
5c	X			X				X			X			X			X		X					X	
NS		X			X			X			X		X			X						X			X

Alts	Study Objectives																							
	Reduce disruption of critical infrastructure												Improve resiliency of critical infrastructure											
	National Evaluation Criteria																							
	Accept.			Complete.			Effective.			Efficien.			Accept.			Complete.			Effective.			Efficien.		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
NA			X			X			X			X			X			X			X			X
4b	X			X					X		X			X		X					X		X	
4c	X			X			X			X			X			X			X			X		
5a			X			X			X			X			X			X			X			X
5b1			X			X			X			X			X			X			X			X
5c			X			X			X			X			X			X			X			X
NS		X			X				X			X		X			X				X			X

The no-action plan does not address the study objectives but does provide a basis for comparing the final array of alternatives. The final array of alternatives does address the four study objectives and the problem of coastal storm damage in Northern Virginia. Alternative 4b is less cost effective, more labor intensive with the extensive series of stop log closures and less efficient at reducing economic damages and risk to human health and safety than 4c which includes a permanent floodwall with limited maintenance. Alternatives 5a, 5b1 and 5c were ranked low for reducing disruption of critical infrastructure and improving resiliency of critical infrastructure since these areas include

neighborhoods and residences as opposed to Alternatives 4b and 4c which serve a larger community of people and would result in higher damages from an economic standpoint. All alternatives do reduce risk to human health and safety including Alternative 6. However, Alternative 6 ranked low for effectiveness and efficiency for reducing economic damages, reducing disruption to critical infrastructure, and improving resiliency of critical infrastructure since the majority of the structures included in the analysis are public or private residences with occasional businesses.

Alternatives 4c and 5c both address the study objectives and P&G criteria as well as being cost effective and yielding positive net benefits. Alternative 5b1 was included later in the analysis for consideration based on coordination with the City of Alexandria and recent discussions with USACE higher authority. A deployable floodwall in Alexandria coupled with the 6-ft NAVD88 bulkhead the community currently has in the design phase would reduce risk to human health and safety as well as reduce some economic damages. However, it was rated low for reducing economic damages because of the high cost of the deployable floodwall. Since the City of Alexandria's 6-ft NAVD88 bulkhead is an existing condition, Alt 5b1 would not start accruing benefits until a 10 percent AEP is exceeded between Duke and Queen Street.

G2CRM was utilized to evaluate NED benefits for the final array of alternatives (Table 5-10). This evaluation included damages to structures, contents and vehicles as well as debris clean-up costs. Alternative 4c: Arlington WPCP and Alt 5c: Belle Haven Levee & Floodwall yielded positive net benefits (Table 5-11). These alternatives were combined as Alternative 8, the TSP, with net benefits of $450,000 and a BCR of 1.3.

Table 5-10. Economic Evaluation by Alternative

Alternatives	Total Cost	Average Annualized Costs	Average Annualized Benefits	Average Annualized Net Benefits	BCR
Alt 1 (No-Action)		.	.	.	.
Alt 4 (Reagan and WPCP)	$96,050,000	$3,219,000	$243,000	($2,976,000)	0.08
Alt 5 (Four Mile Run, Alexandria and Belle Haven)	$241,765,000	$8,103,000	$3,339,000	($4,764,000)	0.41
Alt 6 (Nonstructural 1% AEP)	$209,738,000	$7,030,000	$1,218,000	($5,812,000)	0.17
Alt 6 (Nonstructural 2% AEP)	$188,233,000	$6,309,000	$1,081,000	($5,228,000)	0.17
Alt 6 (Nonstructural 5% AEP)	$130,742,000	$4,382,000	$831,000	($3,551,000)	0.19
Alt 8 (Combination WPCP and Belle Haven)	$52,606,000	$1,763,000	$2,213,000	$450,000	1.3

Table 5-11. Economic Evaluation by Alternative Components

Alternative Description	Total Cost	Average Annual Cost	Average Annual Benefits	Average Annual Net Benefits	BCR
No Action		.	.	.	.
Structural Alternatives 4, 5 and 8					
Alt 4b: Reagan National Airport .2% AEP	$93,356,000	$3,129,000	$64,000	($3,065,000)	0.02
Alt 4c: Arlington WPCP .2% AEP	$2,694,000	$90,000	$179,000	$89,000	2.0
Alt 5a: Four Mile Run Levee & Floodwall 1% AEP	$35,243,000	$1,181,000	$104,000	($1,077,000)	0.09
Alt 5b1: Alexandria Deployable Floodwall 2% AEP	$157,214,000	$5,270,000	$1,201,000	($4,069,000)	0.23
Alt 5c: Belle Haven Levee & Floodwall 1% AEP	$49,912,000	$1,673,000	$2,034,000	$361,000	1.2
Alt 8: Combination (WPCP & Belle Haven)	**$52,606,000**	**$1,763,000**	**$2,213,000**	**$450,000**	**1.3**
Alternative 6: Nonstructural					
MA10 & MA20: Old Town Alexandria 1% AEP	$61,616,000	$2,065,000	$380,000	($1,685,000)	0.18
MA12: Belle Haven 1% AEP	$128,212,000	$4,297,000	$782,000	($3,515,000)	0.18
MA16: Occoquan Bay 1% AEP	$19,910,000	$667,000	$56,000	($611,000)	0.08
MA10 & MA20: Old Town Alexandria 2% AEP	$55,178,000	$1,849,000	$342,000	($1,507,000)	0.18
MA12: Belle Haven 2% AEP	$113,879,000	$3,817,000	$684,000	($3,133,000)	0.18
MA16: Occoquan Bay 2% AEP	$19,176,000	$643,000	$55,000	($588,000)	0.09
MA10 & MA20: Old Town Alexandria 5% AEP	$34,639,000	$1,161,000	$286,000	($875,000)	0.25
MA12: Belle Haven 5% AEP	$79,624,000	$2,669,000	$514,000	($2,155,000)	0.19
MA16: Occoquan Bay 5% AEP	$16,479,000	$552,000	$31,000	($521,000)	0.06

6 Tentatively Selected Plan*

6.1 Plan Components

The TSP is Alternative 8, the combination plan that incorporates a floodwall and stop log closure at the Arlington WPCP (Figure 3-16), and a levee and floodwall system with pump stations at Belle Haven (Figure 3-19). The TSP includes two locations within the study area where coastal flood risk measures could be implemented (Figure 6-1).

At the Arlington WPCP, a floodwall would be constructed along the left bank of Four Mile Run between Four Mile Run and the Arlington WPCP with a closure structure on the east side of the structure. The new floodwall would tie into the bank to the east just past South Eads Street. The floodwall would wrap around the Arlington WPCP to the west where the stop log closure structure is located along South Glebe Road.

At Belle Haven, a floodwall would be constructed just north of Belle Haven Road from Barrister Place to 10th Street with a closure structure at 10th Street and the GWMP. Closure structures would also be constructed along Belle Haven Road and Belle View Blvd. A floodwall would tie into the closure structure at 10th Street and run south along the west side of the GWMP, curving around Boulevard View to 10th Street. The floodwall would then run west to East Wakefield Drive tying into both sides of a closure structure on Potomac Avenue. The floodwall would continue west to West Wakefield Drive and tie into a small portion of earthen levee ending at Westgrove Dog Park.

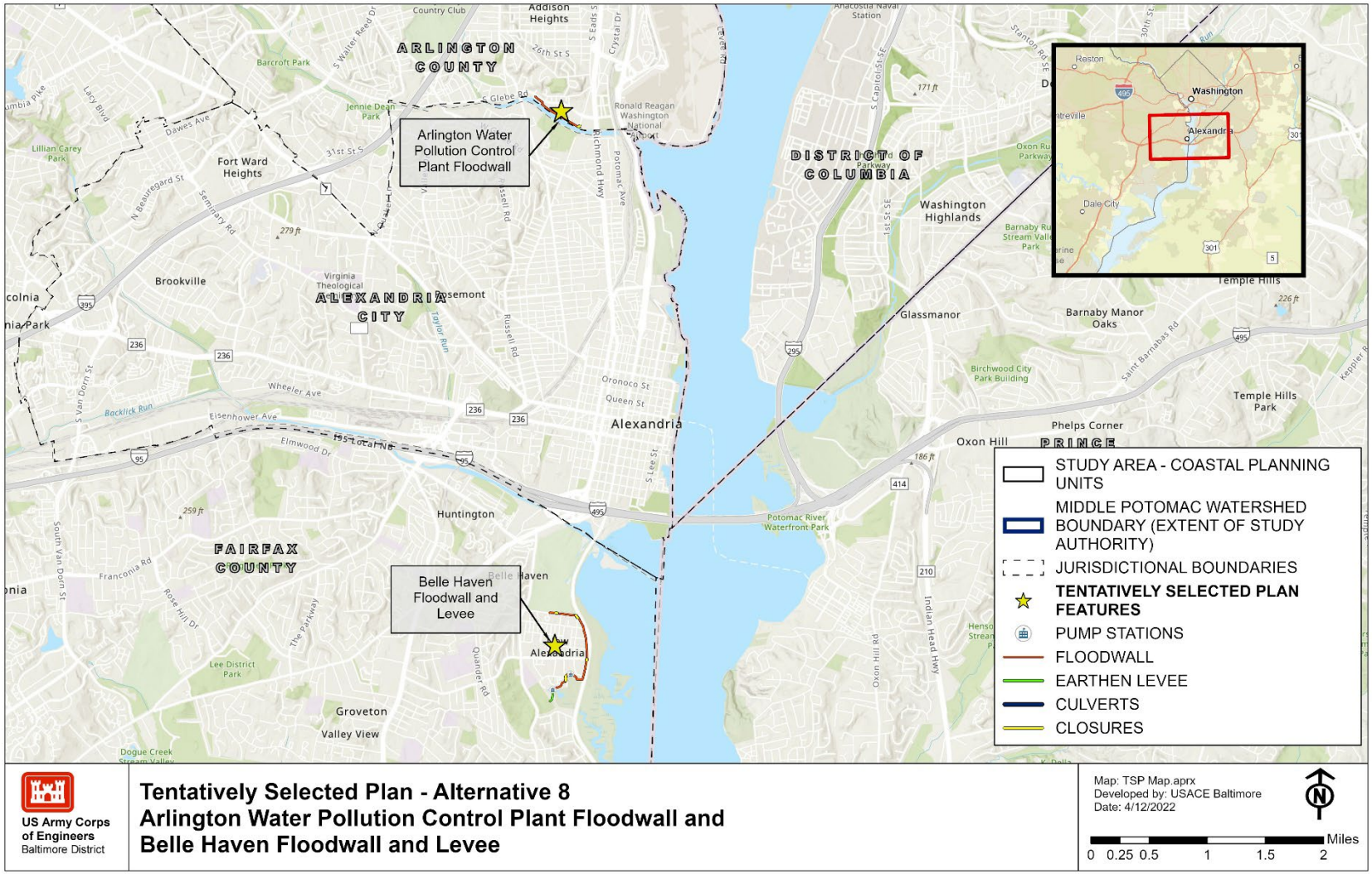

Figure 6-1. Location Map for TSP Implementation

6.2 Cost Estimate and Cost Sharing Breakdown

During project implementation (PED and construction phases), the project would be cost shared 65 percent Federal and 35 percent non-Federal. Lands, easements, rights-of-way, and relocations (LERRs) required for project construction must be provided by the NFS for the non-Federal construction cost share amount as described in Section 6.3 (Table 6-1).

Table 6-1. Metropolitan Washington, District of Columbia CSRM - Cost Sharing.

WBS Number	Features	Federal Share	Non-Federal Share	Project Cost w/ Contingency
02	Relocations	$2,275,000	$1,225,000	$3,500,00
11	Levees and Floodwalls	$6,247,150	$3,363,850	$9,611,000
13	Pumping Plant	$11,995,100	$6,458,900	$18,454,000
15	Floodway Control and Diversion Structure	$2,853,500	$1,536,500	$4,390,000
18	Cultural Resource Preservation	$388,700	$209,300	$598,000
30	Preconstruction, Engineering & Design (PED)[2]	$6,563,050	$3,533,950	$10,097,000
31	Construction Management Supervision and Inspection (S&I)[2]	$2,360,800	$1,271,200	$3,632,000
	Subtotal Construction	$32,683,300	$17,598,700	$50,282,000
01	Lands, Easements, Right-of-Ways, Relocations (LERR)[3]-Federal	$0	$0	$0
01	Lands, Easements, Right-of-Ways, Relocations (LERR)[3]-Non-Federal	$0	$2,029,000	$2,029,000
	Total Project First Costs	$32,683,300	$19,627,700	$52,311,000
	Credit for Non-Federal LERR[4]	$2,029,000	($2,029,000)	
	Total Cost Apportionment	$34,712,300	$17,598,700	$52,311,000

1. Cost is based on Project First Cost (constant dollar basis) on Total Project Cost Summary Spreadsheet, at an effective price level 1 Oct 2021 (Appendix C).
2. PED and Construction cost sharing totals are reflected as 65% Federal/35% non-Federal.
3. These are Real Estate administrative costs and the cost of easements based on a July 2020 appraisal. Escalation from the Total Project Cost Summary (TPCS) accounts for some numerical differences.

4. Credit is given for the incidental costs borne by the non-Federal sponsor for lands, easements, rights of way and relocations (LERR).

6.3 Lands, Easements, Rights-of-Way, and Relocations (LERRs)

A real estate cost estimate was prepared. At this preliminary stage the lands and damages real estate cost estimates of $799,500 for Alternative 4c and $1,167,000 for Alternative 5c were used for TSP planning comparisons.

The Non-Federal Sponsor, MWCOG, currently owns no lands or property required for the two TSP plan alternatives. However, MWCOG partners, Fairfax County and Arlington County, Virginia will likely be the sponsors who cost share PED/Construction and be required to provide LERR within their respective project sites. Fairfax County currently owns a substantial part of one of the Pump Stations in Belle Haven.

For flood control projects, the Non-Federal Sponsor is required to relocate affected facilities and utilities necessary for the construction, operation, and maintenance of a project. A relocation may take the form of an alteration, lowering, raising, or replacement (and attendant removal) of the affected facility/utility or part thereof. This project is expected to result in yet to be determined relocation of multiple public utilities or facilities, which will require the preparation of Reports of Compensability once a recommend plan is approved. For more information on LERRs, reference Appendix F.

6.4 Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R)

The annualized O&M for the Arlington WPCP is $1,000 because the concrete floodwall requires minimal maintenance over the 50-year period of analysis. The closure structure would need to be deployed at minimum once per year which could incur some labor fees.

The annualized O&M for Belle Haven is $16,000. The concrete floodwall would require minimal maintenance over the 50-year period of analysis. The earthen levee may require some maintenance after a storm event, but the majority of these O&M funds would be incurred for maintenance of the two pump stations and inspections of equipment.

For both projects, the O&M would be managed by the sponsor, likely Arlington County for the Arlington WPCP and Fairfax County for Belle Haven.

Combining the above O&M for Alternative 8, the TSP, is $17,000 per year based on a 50-year period of analysis.

6.5 Risk and Uncertainty

Risk and uncertainty are inherent in water resources planning and design. These factors arise due to errors in measurement and from the innate variability of complex physical, social, and economic situations. The measured or estimated values of key planning and

design variables are rarely known with certainty and can take on a range of possible values. Risk analysis in FRM projects is a technical task of balancing risk of design exceedance with reducing the risk from flooding; trading off uncertainty of flood levels with design accommodations; and providing for reasonably predictable project performance. Risk-based analysis is therefore a methodology that enables issues of risk and uncertainty to be included in project formulation.

The USACE has a mission to manage flood risks:

“The USACE Flood Risk Management Program (FRMP) works across the agency to focus the policies, programs and expertise of USACE toward reducing overall flood risk. This includes the appropriate use and resiliency of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, flood proofing, etc.) reduce the risk of loss of life, reduce long-term economic damages to the public and private sector, and improve the natural environment.”

The PDT identified the environmental, modeling and schedule risks discussed below.

Environmental

- The PDT identified 2,250 sqft of stream impacts if Alt 5c: Belle Haven Levee & Floodwall would be implemented. The proposed stream impacts are unavoidable, and mitigation would be required. A conceptual mitigation plan is included in Appendix G. Risk-Medium.
- There is a potential for contaminated groundwater to be present in the locations of Alt 4c: Arlington WPCP Floodwall and Alt 5c: Belle Haven Levee and Floodwall. Per ER 1105-2-100, 2-13 (p) and ER 1165-2-132, any associated clean-up of HTRW would be the responsibility of the non-Federal sponsor. Risk-Medium

Modeling

- The coastal model will be re-run for the with-project condition to ensure flooding is not exacerbated elsewhere in the system with implementation of the TSP. Risk – Medium.

Schedule

Uncertainties that could affect the study schedule/scope are:

- The extent and timeframes for required coordination, e.g., on National Historic Preservation Act Section 106 consultation. To reduce this uncertainty, coordination started early with SHPO and quarterly updated to changes in alternatives, alignments etc. have been provided to project partners and agencies.
- Schedule impacts may be seen for the design and construction phases because two separate agreements would be executed. It is unlikely that both projects would start at the same time, which is the current assumption. To assist with design schedule and engineering coordination, a design manager

would join the project to assist the project manager in managing the schedule and coordinating the design work and reviews.

Additionally, the PDT is working with USACE higher authority and the District Levee Safety Manager to conduct a risk assessment for this study. The team met with the Levee Safety Center on 05 April 2022 to start scoping the risk effort. G2CRM was used to evaluate life loss and the results can be found in Section 5.3.4 above. The areas being evaluated under this study did not present substantial life threats from flooding and therefore, LifeSim was not used to compute life loss. A potential failure modes analysis would be performed on the current TSP feasibility level design to identify potential failure modes that would need to be addressed as the design matures to ensure minimal risk to the public and identify cost risks that may affect the Total Project Cost (TPC). The risk assessment will be included in the final IFR/EA following the guidance in Planning Bulletin (PB) 2019-04 and ER 1105-2-101 for FRM and certain CSRM projects. For more information on Geotechnical and Civil engineering considerations for design, reference (Appendices A and D).

6.6 Design and Construction

The TSP has two project areas, Arlington WPCP and Belle Haven. It is estimated that the construction duration for the Arlington WPCP would be 18 months. There are no time-of-day restrictions and the cost estimate assumes 12-hour days. The construction duration for Belle Haven is four years. Belle Haven does not have any time-of-day restrictions and assumes 12-hour days. For both projects, materials would be brought in by land via by flatbed trucks, trailers and dump trucks.

The design phase assumes two years to start in October 2024 and end in September 2026. The construction window for Arlington WPCP would likely start in 2026 and end in late 2027 or early 2028. Assuming a four-year construction window for Belle Haven, construction would likely start in 2026 and end in late 2030 or early 2031.

For PED to be initiated, the USACE must sign a Design Agreement with a non-federal sponsor to cost share PED. This project would require congressional authorization for both PED and construction. The PED and construction phases are cost shared 65 percent federal and 35 percent non-federal. Implementation would occur provided that sufficient funds are appropriated to design and construct the project. To initiate construction, a Project Partnership Agreement (PPA) would be entered with a non-federal sponsor.

The Arlington WPCP has a cost of $2.7M and could be implemented under Section 205, Flood Damage Reduction, of the Continuing Authorities Program (CAP). This possibility

was raised during discussions with USACE higher authority and will continue to be evaluated as the project moves forward.

6.7 Environmental Consequences*

Arlington WPCP Floodwall

Implementation of the proposed floodwall at the Arlington WPCP may result in temporary and minor effects to natural and physical environmental resources during construction as described in Section 4. No long-term effects are expected.

- The floodwall may adversely affect aesthetics; however, this affect would not be significant because the area is highly developed, and the facility is industrial.
- Contaminated groundwater may be present in the construction area. Per ER 1105-2-100, 2-13 (p) and ER 1165-2-132, any associated clean-up of HTRW would be the responsibility of the non-Federal sponsor.

Belle Haven Levee and Floodwall

Implementation of the proposed levee and floodwall at Belle Haven may result in temporary and minor effects to natural and physical environmental resources during construction as described in Section 4. Long-term effects include permanent fill impacts to the Belle Haven East Channel and obstruction of the view.

- Sediment released from the flap gates and discharge from the pump stations following a storm is expected to result in minor and temporary effects to wetlands and water quality.
- A potential change in inundation depth in the wetlands following construction of the floodwall/levee is not expected to affect the health, character, or integrity of the wetlands.
- Protective buffers would be implemented to minimize adverse effects to nesting bald eagles during construction. A permit from USFWS would be obtained prior to construction if these buffers could not be adhered to.
- Construction of the proposed culvert crossings would result in roughly 2,250 sqft of new permanent fill impacts and 2,000 sqft of temporary impacts to two streams.
- Some recreational amenities (two tennis courts) would be permanently impacted by construction of the floodwall.
- Contaminated groundwater may be present in the construction area. As stated previously, per ER 1105-2-100, 2-13 (p) and ER 1165-2-132, any associated clean-up of HTRW would be the responsibility of the non-Federal sponsor.
- The proposed floodwall may affect the view for the residents of Belle Haven, as well as from historic resources including the GWMP and the Mount Vernon Trail.
- The Belle Haven neighborhood may need to be formally evaluated for listing on the NRHP to determine how it would be affected by construction of the proposed

levee and floodwall. Archaeological surveys may also be needed in the footprint of the proposed levee and floodwall prior to construction.

6.8 Avoidance, Minimization, and Mitigation of Impacts*

6.8.1 Avoidance and Minimization

Sediment and erosion control measures would be implemented to minimize impacts to wetlands and waterways during construction. To minimize impacts to migratory birds, removal of trees (both live and dead trees) and saplings and shrubs would be avoided to the greatest extent practicable.

Protective buffers would be implemented to minimize impacts to nesting bald eagles during construction of the Belle Haven levee/floodwall. A permit from USFWS may be required if the buffers cannot be adhered to.

Realignment of the proposed floodwall at Belle Haven was examined to determine if stream impacts could be avoided or minimized. Due to the location of the channels (running from north to southeast through the Belle Haven community and into Dyke Marsh), crossing the channels cannot be avoided. Shortening the length of the floodwall so that it would not cross the channels would not provide flood protection to the community of Belle Haven. The size of the culvert crossings (amount of fill material placed into the channels) was minimized to the greatest extent practicable.

6.8.2 Mitigation*

Construction of the proposed culvert crossings would result in roughly 2,250 sqft of new permanent fill impacts to two streams. A conceptual mitigation plan to offset the proposed channel impacts has been drafted in accordance with ER 1105-2-100, Appendix C. The draft plan for compensatory mitigation is to purchase in-kind credits from an approved mitigation bank or an approved in-lieu fee program located in the Middle Potomac River Watershed. Specifically, credits will be purchased to compensate for unavoidable loss of stream habitat in Belle Haven.

6.9 Cumulative Impacts*

Potential cumulative effects of induced flooding from the proposed flood protection measures at the Arlington WPCP and at Belle Haven and other existing flood protection measures in the region will be analyzed. Modeling will be conducted to determine the WSELs under the FWP condition. The modeling will take into account other existing flood protection measures in the area. Results of the modeling and the effects of induced flooding will be included in the final IFR/EA.

Permanent stream impacts at Belle Haven will be mitigated. Since the stream impacts will be offset by mitigation, construction of the floodwall at Belle Haven will not result in cumulative impacts to streams.

Construction of the flood protection measures are not expected to result in cumulative effects to wetlands, natural floodplains, threatened and endangered species, migratory birds, bald eagles, water quality, hydrology, air quality including greenhouse gases, recreation, aesthetics, noise, or EJ communities.

Cumulative impacts to cultural resources are not anticipated. A Programmatic Agreement to conduct archeological investigations during the PED phase is currently being developed with the Section 106 of the NHPA consulting parties.

6.10 Environmental Commitments*

- Sediment and erosion controls would be used to minimize impacts to wetlands and waterways.
- Contaminated groundwater may be present in the Arlington WPCP and Belle Haven construction areas. Further investigations are needed to determine the presence of contamination. These investigations would be conducted during the PED phase.
- USACE will resubmit the information for the northern long-eared bat required in the USFWS *Key to the Northern Long-Eared Bat 4(d) Rule for Federal Actions that May Affect Northern Long-Eared Bats* into the USFWS IPaC prior to construction
- To minimize impacts to migratory birds, removal of trees (both live and dead trees) and saplings and shrubs would be avoided to the greatest extent practicable as recommended by the USFWS PAR.
- Protective buffers would be implemented to minimize adverse effects to nesting bald eagles during construction. A permit from USFWS would be obtained prior to construction if these buffers cannot be adhered to.
- A conceptual mitigation plan to offset the new permanent stream impacts in Belle Haven will be finalized.
- Archaeological surveys may also be needed in the footprint of the proposed levee and floodwall in Belle Haven prior to construction. A Programmatic Agreement will be developed with the Section 106 consulting parties.

6.11 Environmental Operating Principles

The USACE Environmental Operating Principles (EOP) were developed to ensure that USACE missions integrate sustainable environmental practices. The EOP relates to the human environment and applies to all aspects of business and operations. The principles

were designed to provide direction on how to better achieve stewardship of air, water, and land resources, and to demonstrate a positive relationship between management of these resources and the protection and improvement of a sustainable environment. The EOP informed the plan formulation process and are integrated into the proposed solution for CSRM.

The Environmental Operating Principles are:

- Foster sustainability as a way of life throughout the organization
- Proactively consider environmental consequences of all USACE activities and act accordingly
- Create mutually supporting economic and environmentally sustainable solutions
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the USACE, which may impact human and natural environments
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs
- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE's actions in a collaborative manner
- Employ an open, transparent process that respects views of individuals and groups interested in USACE activities

Plan selection considered these principles to ensure the sustainability and resiliency of the NED plan while considering the environmental consequences of implementation. In addition to construction best management practices to maintain water quality standards, other opportunities to implement sustainable measures that are cost effective and comply with USACE construction standards will be further evaluated during the PED phase. The study team considered avoiding and minimizing adverse impacts to existing environmental resources and cultural resources within the project area to the extent practicable during the plan formulation process.

6.12 Views of the Non-Federal Sponsor and Other Agencies

MWCOG, Fairfax County, and Arlington County support the TSP, Alternative 8: Combination of Arlington WPCP floodwall and Belle Haven levee and floodwall with pump stations. Specific references to support letters and emails provided in advance of the TSP Milestone are discussed below.

The Project Manager and Study Manger have met with MWCOG on a bi-weekly basis since the study restart and MWCOG has provided extensive support to the project with sharing resources and information through the coordination with their partners. MWCOG verbally expressed support for Alternative 8 both prior to and during the TSP Milestone meeting held on 29 March 2022, and shared their insights into the substantial benefits a project could bring to the region to reduce flood risk.

The Arlington WPCP is vulnerable to flooding, and a major coastal flooding event would significantly impact their ability to protect public health and the environment. Due to damage that would be sustained to critical infrastructure at the facility, it could take several months to recover from an event. Arlington County provided their support in an email dated 28 March 2022 and “believes that there are substantial benefits to better protecting the WPCP through the US Army Corps of Engineers’ tentatively selected plan of constructing a flood wall around the WPCP. The County supports the project and feels that it warrants more detailed analysis to confirm the feasibility” (Appendix G).

Also, on 28 March 2022, the Fairfax County Board of Supervisors sent a letter in support of Belle Haven moving forward as part of the TSP and stated “I am writing to express my support for the proposed levee and floodwall improvements in the Belle Haven community. I am pleased to see that it is among your favored alternatives being considered for reducing flood risks in tidal areas of our region” (Appendix G).

The County of Fairfax, Virginia provided a letter on 29 March 2022 that reads “On behalf of Fairfax County, I am writing to express support for the proposed levee and floodwall improvements in Belle Haven. My team looks forward to working with you to facilitate and assist with any community meetings you expect to hold as part of the public input process” (Appendix G).

As stated in the LERRs discussion, it is likely that Arlington County and Fairfax County would be the project sponsors and signatories for future agreements for design and construction. Both have expressed their support with moving forward with Alternative 8 as described in this Section.

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7 Environmental Compliance*

7.1 Environmental Compliance Table

Compliance with environmental laws and Executive Orders is required for the project alternatives under consideration. Tables 7-1 and 7-2 lists the current compliance status for each environmental and cultural requirement that was identified and considered for the study.

Table 7-1. Status of Compliance with Applicable Environmental and Cultural Resource Laws

LAWS	COMPLIANCE STATUS
Archeological and Historic Preservation Act of 1974	In Progress
Bald and Golden Eagle Protection Act of 1962, as amended	Full
Clean Air Act of 1970, as amended 1977 and 1990	Full
Clean Water Act of 1972, as amended	In Progress
Coastal Barrier Resources Act of 1982	N/A
Coastal Zone Management Act of 1972, as amended	In Progress
Comprehensive Environmental Response, Compensation and Liability Act of 1980	N/A
Endangered Species Act of 1973	In Progress
Fish and Wildlife Coordination Act of 1958, as amended	In Progress
Magnuson-Stevens Fishery Conservation and Management Act	N/A
Marine Mammal Protection Act of 1972, as amended	N/A
National Environmental Policy Act of 1969, as amended	In Progress
National Historic Preservation Act of 1966	In Progress
Noise Control Act of 1972, as amended	Full
Resource Conservation and Recovery Act of 1976	In Progress
Rivers and Harbors Act of 1899	N/A
Wild and Scenic Rivers Act of 1968	N/A

Table 7-2. Status of Compliance with Applicable Executive Orders

EXECUTIVE ORDERS	
Protection and Enhancement of Environmental Quality (E.O. 11514/11991)	Full
Protection and Enhancement of Cultural Environment (E.O. 11593)	In Progress
Floodplain Management (E.O. 11988)	In Progress
Protection of Wetlands (E.O. 11990)	In Progress
Environmental Justice in Minority and Low-Income Populations (E.O. 12898)	Full
Protection of Children from Health Risks and Safety Risks (E.O. 13045)	Full
Chesapeake Bay Protection and Restoration (E.O. 13508)	Full
Invasive Species (E.O. 13112)	N/A
Consultation and Coordination with Indian Tribal Governments (E.O. 13175)	In Progress
Responsibilities of Federal Agencies to Protect Migratory Birds (E.O. 13186)	Full

7.1.1 National Environmental Policy Act (NEPA)

This document follows the "Update to the Regulations Implementing the Procedural Provisions of the National Environmental Policy Act", published by the Council on Environmental Quality (CEQ) in the Federal Register on July 16, 2020. The update affects all NEPA processes that began after September 14, 2020 (85 FR 43304). NEPA requires the preparation of an EIS for any major federal action that could have a significant impact on the quality of the human environment, and the preparation of an Environmental Assessment (EA) for those federal actions that do not cause a significant impact but do not qualify for a categorical exclusion.

NEPA regulations provide for a scoping process to identify the scope and significance of environmental issues associated with a project. The process identifies and eliminates from further detailed study issues that are not significant. USACE used this process to comply with NEPA, and it was determined that an EA was the appropriate NEPA document to prepare for this project because reasonably foreseeable effects to the human environment are not expected to be significant. Adverse environmental effects will be offset by mitigation.

Upon completion of the final IFR/EA and the signing of the Finding of No Significant Impact (FONSI), the project will be in full compliance with NEPA. A draft FONSI is provided in Appendix G.

7.1.2 Clean Water Act

A Section 401 Water Quality Certification (WQC) is required from the VADEQ. USACE will coordinate with VADEQ to discuss WQC requirements and Virginia's Environmental Impact Review process.

7.1.3 Wetlands

Section 404 of the Clean Water Act and the 404(b)(1) Guidelines at 40 CFR Part 230 require that USACE avoid, minimize, and mitigate impacts to wetlands. The TSP would have no direct effects to wetlands. The TSP may result in minor and temporary indirect impacts to wetlands. Construction of the proposed culvert crossings in Belle Haven would result in roughly 2,250 sqft of new permanent fill impacts in the Belle Haven East Channel and the Belle Haven West Channel. A conceptual mitigation plan to offset the proposed stream impacts has been drafted and is located in Appendix G.

7.1.4 Federal Coastal Zone Management Act (CZMA)

A federal consistency determination in accordance with 15 CFR Part 930 Subpart C has been drafted stating that the TSP is consistent with the enforceable policies of the State of Virginia's federally approved coastal management program (Appendix G).

7.1.5 Clean Air Act

An Air Conformity Assessment has been provided as part of this EA and can be found in Appendix G. The actions associated with the TSP are exempt from the General Conformity Rules in Section 176c of the Clean Air Act. Ozone precursors, VOCs and NOx are below the USEPA threshold of 100 tons per year for all maintenance areas. All other annual emission totals and aggregated study emission totals for criteria pollutants are not anticipated to exceed all other USEPA de minimis thresholds; therefore, no mitigation measures are required.

7.1.6 Magnuson-Stevens Fishery Conservation and Management Act

This Act requires federal action agencies to consult with the National Marine Fisheries Service (NMFS) if a proposed action may affect EFH. EFH source documents were used to determine if suitable habitat conditions are present in the study area to support these species. Due to unsuitable habitat conditions, it was determined that the study area does not contain EFH.

7.1.7 U.S. Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) requires Federal agencies to consult with the USFWS, NMFS, and the state fish and wildlife agencies where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified" by any agency under a federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources." The intent is to give fish and wildlife conservation equal consideration with other purposes of water resources development projects. Coordination with USFWS and NMFS for the FWCA will be ongoing through the remainder of the study.

7.1.8 Endangered Species Act (ESA)

The TSP is in compliance with the Endangered Species Act of 1973 (ESA). USACE determined that the TSP would have no effect on federal and state-listed threatened and endangered species due to the lack of suitable habitat conditions, rarity of the species, and/or the lack of documented observances where the effects are likely to occur. A concurrence on USACE's "no effect" determination will be obtained from USFWS. The TSP would have no effect on threatened and endangered species under the purview of NMFS.

7.1.9 Marine Mammal Protection Act

The TSP would have no effect on marine mammals.

7.1.10 Section 106 and 110(f) of the National Historic Preservation Act (NHPA)

The National Historic Preservation Act (NHPA) applies to properties listed in or eligible for listing in the National Register of Historic Places (NRHP); these are referred to as "historic properties." Historic properties eligible for listing in the NRHP include prehistoric and historic sites, structures, buildings, objects, and collections of these in districts. Under Section 106 of the National Historic Preservation Act and its implementing regulations at 36 Code of Federal Regulations Part 800, the USACE assessed potential effects on historic properties that are located within the APE. Coordination with the Virginia SHPO and other Section 106 consulting parties will continue through the remainder of the study.

7.1.11 Resource Conservation and Recovery Act (RCRA)

Further investigations are needed to determine the presence of contaminated groundwater in the construction sites.

7.1.12 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund)

No Superfund sites listed on the National Priorities List are located in or nearby the proposed construction sites.

7.1.13 Executive Order 11988, Floodplain Management

This Executive Order (EO) states that federal agencies shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out agency responsibilities. The TSP would reduce the risk of flood loss, and minimize the impacts of floods on human safety, health, and welfare. USACE is planning to conduct modeling to assess the effects from induced flooding.

7.1.14 Executive Order 11990, Protection of Wetlands

This EO directs all federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance the natural beneficial values of wetlands in the conduct of the agency's responsibilities. The TSP would have no direct effects to wetlands. The TSP may result in minor and temporary indirect impacts to wetlands. Construction of a proposed culvert crossings in Belle Haven would result in roughly 2,250 sqft of new permanent fill impacts to two streams. A conceptual mitigation plan to offset the proposed stream impacts has been drafted and is located in Appendix G.

7.1.15 Executive Order 12898, Federal Actions to Address Environmental Justice

No group of people would bear a disproportionately high share of adverse environmental consequences resulting from the TSP.

7.1.16 Executive Order 13045, Protection of Children from Environmental and Safety Risks

No children would bear a disproportionately high share of adverse environmental consequences resulting from the proposed work and there should be no effect on children.

7.1.17 Executive Order 13186 Responsibilities of Federal Agencies to Protect Migratory Birds

To minimize effects to nesting bald eagles during construction of the Belle Haven levee and floodwall, protective buffers would be adhered to in accordance with the National Bald Eagle Management Guidelines of 2007. If these buffers cannot be adhered to, USACE will contact the USFWS to determine if an eagle disturbance permit is necessary to be in compliance with the prohibitions under the Eagle Act. This coordination would be done during the PED Phase. To minimize impacts to migratory birds, removal of trees (both live and dead trees) and saplings and shrubs would be avoided to the greatest extent practicable as recommended by the USFWS PAR.

7.1.18 Rivers and Harbors Act, 33 U.S.C. 401, et seq.

The TSP does not propose construction of any structure in or over navigable waters of the United States.

7.2 Public Involvement

7.2.1 Scoping

A public open house was held on September 11, 2019, at the Fairfax County Martha Washington Branch Library in Alexandria, Virginia. The open house was attended by 36 participants from the public, government agencies, and non-governmental organizations. The purpose of the open house was to seek public input on coastal flooding concerns and related information. The public viewed informational posters, spoke to USACE personnel about the study, provided information on comment cards and posters, and were provided an overview of the study. The geographic focus of the workshop included Arlington County, the City of Alexandria, Fairfax County, the northern portion of Prince William County, and the Reagan National Airport. The majority of comments focused on flooding that occurs in Alexandria, specifically on Belle View Boulevard and on the GWMP, and on the parkway just south of Alexandria. Table 7-3 provides details on public involvement that has occurred up to release of the draft IFR/EA for public review.

7.2.2 Agency Coordination

The 90-day interagency meeting was held on November 5, 2019. Representatives from NOAA, USFWS, EPA, FAA, Fort McNair, VADEQ, VADCR, MWAA and local jurisdictions participated in the meeting. The purpose of the meeting was to introduce agencies to the study, discuss the study and NEPA schedules, discuss the level of agency involvement during preparation of the NEPA document, and to solicit scoping comments from the agencies. Discussions revolved around the PAR and Virginia's federal consistency

process. Table 7-3 provides details on agency coordination that has occurred up to release of the draft IFR/EA for public review.

7.2.3 Tribal Coordination

In March 2022, USACE sent consultation letters to the following federal-recognized tribes: Catawba Indian Nation, Chickahominy Indian Tribe, Chickahominy Indian Tribe Eastern Division, Delaware Nation, Monacan Indian Nation, Nansemond Indian Nation, Pamunkey Indian Tribe, Rappahannock Indian Tribe, and the Upper Mattaponi Tribe. The purpose of the letters was to update the tribes with the TSP and to request their involvement in the development of a Programmatic Agreement for the project.

Table 7-3. Public and Agency Coordination Record

ORGANIZATION	DATE	ACTIVITY
• Public	18 July 2017	Press release announcing Federal Cost Share Agreement (FCSA) for study.
• U.S. Fish and Wildlife Service (USFWS), Chesapeake Bay and Virginia Ecological Services Field Offices	25 July 2019	USACE obtained USFWS threatened and endangered species list from the IPaC tool
• U.S. Environmental Protection Agency (USEPA), Region III • Federal Aviation Authority (FAA) • Federal Emergency Management Agency (FEMA) Region III • National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) • National Park Service (NPS), National Capital Regional Office • USFWS, Northeast Region	21, 26 August 2019	USACE sent letters inviting agency participation as a cooperating agency in the development of project environmental documents.
• Virginia Department of Environmental Quality (VADEQ) • Virginia Marine Resources Commission (VRMC)	06 September 2019	USACE sent letters inviting agencies to participate in the development of project environmental documents.
• Public	11 September 2019	USACE holds public open house in Alexandria, VA.
• NOAA, NMFS	16 September 2019	NMFS sent letter to USACE declining cooperating agency invitation, but stating NMFS is available for technical assistance and participation in interagency coordination activities.

ORGANIZATION	DATE	ACTIVITY
• USEPA, Region III	18 September 2019	USEPA sent letter to USACE accepting cooperating agency invitation.
• VADEQ	20 September 2019	VADEQ sent email to USACE agreeing to be considered a participating agency.
• Virginia Outdoor Foundation (VOF)	20 September 2019	VOF sent letter to USACE providing comments on proposed project regarding VOF easements in study area.
• Friends of Dyke Marsh (FDM)	21 September 2019	FDM sent letter to USACE providing comments on proposed project.
• Metropolitan Washington Airport Authority (MWAA)	02 October 2019	Call between USACE and MWAA to discuss potential flooding consequences to airports.
• NOAA NMFS	23 October 2019	USACE sent email to NMFS requesting verification of EFH species and life stages.
• NOAA NMFS	25 October 2019	USACE sent email to NMFS requesting verification of ESA species in study area. Reply/confirmation received same day.
• USFWS	04 November 2019	USFWS sent email to USACE agreeing to be considered a participating agency instead of cooperating agency.

ORGANIZATION	DATE	ACTIVITY
• NOAA National Weather Service • Fort McNair • EPA, Region III • FAA • USFWS • National Capital Planning Commission (NCPC) • VADEQ • Arlington County, VA • Fairfax County, VA • Virginia Department of Conservation and Recreation (VADCR) • Northern Virginia Regional Commission (NVRC) • MWAA • Prince William County	05 November 2019	USACE held interagency webinar
• NOAA NMFS	15 November 2019	NMFS sent letter to USACE rescinding 16 September 2019 letter and accepting cooperating agency invitation.
• NPS, George Washington Memorial Parkway (GWMP) and National Capital Region	5 February 2020	USACE and MWCOG held meeting with NPS to discuss and receive feedback on project alternatives.
• NPS, GWMP	6 February 2020	USACE sent a letter inviting agency participation as a cooperating agency in the development of project environmental documents.
• All study stakeholders	27 February 2020	USACE sent email to stakeholders informing them of pause in study due to lack of renewed funding.

ORGANIZATION	DATE	ACTIVITY
• USFWS	14 July 2020	Military Interdepartmental Purchase Request (MIPR) signed between USACE and USFWS for USFWS to complete a Planning Aid Report (PAR) and Fish and Wildlife Coordination Act (FWCA) letter.
• MWAA	28 July 2021	USACE, MWCOG and MWAA held meeting to discuss study & alternatives.
• MWAA	10 August 2021	USACE sent letters inviting MWAA to participate in the development of project environmental documents.
• MWAA	31 August 2021	MWAA accepted USACE invitation to be a participating agency via email.

• Metropolitan Washington Council of Governments (MWCOG) including:
  • Arlington County
  • City of Alexandria
  • Commonwealth of Virginia
  • Fairfax County
  • MWAA
  • Northern Virginia Regional Commission
  • Prince William County
	13 September 2021	USACE and MWCOG participants held kickoff/restart meeting.

• EPA, Region III • MWAA • NPS, GWMP • USFWS, Chesapeake Bay Field Office • VADCR	13 October 2021	USACE and the Metropolitan Washington Council of Governments (MWCOG) held an interagency coordination meeting to review the project objectives and alternatives and

ORGANIZATION	DATE	ACTIVITY
• VADEQ • VRMC		to receive question/feedback from agencies.
• VRMC	13 October 2021	Email from VRMC to USACE stating VRMC would like to be a cooperating agency for NEPA process.
• NPS, National Capital Region DOI Region 1 • Virginia Department of Historic Resources (VDHR), State Historic Preservation Officer (SHPO)	21 October 2021	USACE sent letters to initiate consultation under Section 106 of the National Historic Preservation Act.
• USFWS, Chesapeake Bay and Virginia Ecological Services Field Offices	16 December 2021	USACE obtained updated USFWS threatened and endangered species list from the IPaC tool
• NPS	21 December 2021	USACE and the MWCOG held a meeting with NPS to review project objectives and alternatives, and to confirm the alternatives avoid direct impacts to NPS resources.
• City of Alexandria	5 January 2022	USACE and City of Alexandria met to discuss study.
• City of Alexandria	15 February 2022	USACE and the City of Alexandria met to discuss the flood mitigation projects Alexandria is planning and consider options for partnering on this work in the future.
• Virginia State Historic Preservation Office	21 October 2021	USACE sent a letter to initiate consultation under Section 106 of the National Historic Preservation Act (NHPA).

ORGANIZATION	DATE	ACTIVITY
• Arlington County Historic Preservation Program • Catawba Indian Nation • Chickahominy Indian Tribe • Chickahominy Tribe Eastern Division • Delaware Nation • Fairfax County Historic Preservation and Heritage Resources • FAA, Washington Airports District Office • MWAA • Monacan Indian Nation • Nansemond Indian Nation • National Capital Planning Commission • NPS, GWMP • Office of Historic Alexandria • Pamunkey Indian Tribe • Prince William County, Office of Historic Preservation • Rappahannock Tribe • Upper Mattaponi Tribe • U.S. Commission of Fine Arts	10 March 2022	USACE sent letters to initiate consultation under Section 106 of the NHPA.
• VADEQ	16 MAY 2022	Call to discuss draft report/EA submittal to the VADEQ Environmental Impact Review team

7.2.4 List of Statement Recipients

Placeholder - to be completed after release of the Draft Report.

7.2.5 Public Comments Received and Responses

Placeholder - to be completed after release of the Draft Report.

8 District Engineer Recommendation

The Baltimore District recommends that the coastal storm risk management measures in Arlington and Fairfax Counties, Virginia, be constructed generally in accordance with the selected plan herein, and with such modifications thereof as in the discretion of the Director of Civil Works may be advisable at an estimated total project cost of $52.3 million (October 2021 price level).

Recommendations for provision of Federal participation in the plan described in this report would require the NFS to enter into a PPA, as required by Section 221 of Public Law 91-661, as amended, to provide local cooperation satisfactory to the Secretary of the Army. Such local cooperation shall provide, in part, the following draft items of local cooperation:

a. Provide during the periods of design and construction, a minimum of 35 percent of project costs assigned to coastal and storm damage risk reduction as further defined below:

    (1) Provide, during design, 35 percent of design costs allocated to coastal and storm damage reduction in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    (2) Provide all lands, easements, rights-of-ways, including suitable borrow areas, and perform or assure performance of all relocations, including utility relocations, as determined by Federal government to be necessary for the initial construction, periodic nourishment or operation and maintenance of the project;

    (3) Provide, during construction, any additional amounts necessary to make its total contribution equal to 35 percent of initial project costs assigned to coastal and storm damage reduction;

b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

c. Inform affected interests, at least yearly, of the extent of protection afforded by the flood risk management features; participate in and comply with applicable federal floodplain management and flood insurance programs; comply with

Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12); and publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;

d. Operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal government;

e. For so long as the project remains authorized, ensure continued conditions of public ownership and use of the shore upon which the amount of Federal participation is based;

f. Provide and maintain necessary access to roads, parking areas, and other public use facilities, open and available to all on equal terms;

g. At least twice annually and after storm events, perform surveillance of the project to determine losses of material from the project design section and provide the results of such surveillance to the Federal government;

h. Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

i. Hold and save the United States free from all damages arising from the initial construction, periodic nourishment, operation, maintenance, repair, replacement, and rehabilitation of the project, except for damages due to the fault or negligence of the United States or its contractors;

j. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, and other evidence and required, to the extent and in such detail as will properly reflect total cost of the project, and in accordance with the standards for financial management systems set forth in the Uniform

Administrative Requirements for Grants and Cooperative Agreements to State and local governments at 32 CFR, Section 33.20;

k. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the initial construction, periodic nourishment, operation and mainteance of the project;

l. Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way required for the initial construction, periodic nourishment, or operation and maintenance of the project;

m. Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and, to the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA;

n. Comply with Section 221 of Public Law 91-661, Flood Control Act of 1970, as amended, (42 U.S.C. 1962d-5b) and Section 101(e) of the WRDA 89, Public Law 99-662, as amended, (33 U.S.C. 2211(e)) which provide that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element;

o. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended, (42 U.S.C. 4601-4655) and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way necessary for construction, operation, and maintenance of the project including those necessary for relocations, the borrowing of material, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act;

p. Comply with all applicable Federal and state laws and regulations, including, but not limited to : Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and the Department of Defense Directive 5500.11 issues pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (revising, codifying and enacting without substantive change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c)); and

q. Not use funds from other Federal programs, including any non-Federal contribution required as matching share therefore, to meet any of the non-Federal sponsor's obligations for the project unless the Federal agency providing the funds verifies in writing that such funds are authorized to be used to carry out the project;

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to higher authority as proposals for authorization and implementation funding. However, prior to transmittal to higher authority, the sponsor, the states, interested federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

_____ _____

ESTHER S. PINCHASIN DATE
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9 List of Preparers

9.1 List of Preparers

The PDT team for the study included team members from the USACE and MWCOG (Table 9-1). The team members listed below provided substantial text to the Draft IFR/EA.

Table 9-1. List of Preparers

NAME	AFFILIATION
Katie Perkins	Project Manager, U.S. Army Corps of Engineers, Baltimore District (CENAB)-OPN
Amber Metallo	Plan Formulation, CENAB-PL-P
Brittany Crissman	Public Affairs Specialist, CENAB-CC
Daniel Lovette	Civil Engineer, CENAB-ENC-E
Katherine Dyer	Metropolitan Washington Council of Governments
CJ Ditsious	Chemist, CENAB-ENE-T
Ethan Bean	Archaeologist, CENAB-PL-P
Michael Fritzges	Geotechnical Engineer, CENAP-ECE-G
Komla Jackatey	Lead Economist, CENAB-PL-P
Kristina May	Biologist, CENAB-PL-P
Luan Ngo	Cost Engineer, CENAB-END-T
Luis Santiago	Community Planner, CENAB-PL-P
Syed Qayum	H&H Engineer, CENAB-ENC-W
La-Wanda Carter	Realty Specialist, CENAB-REC
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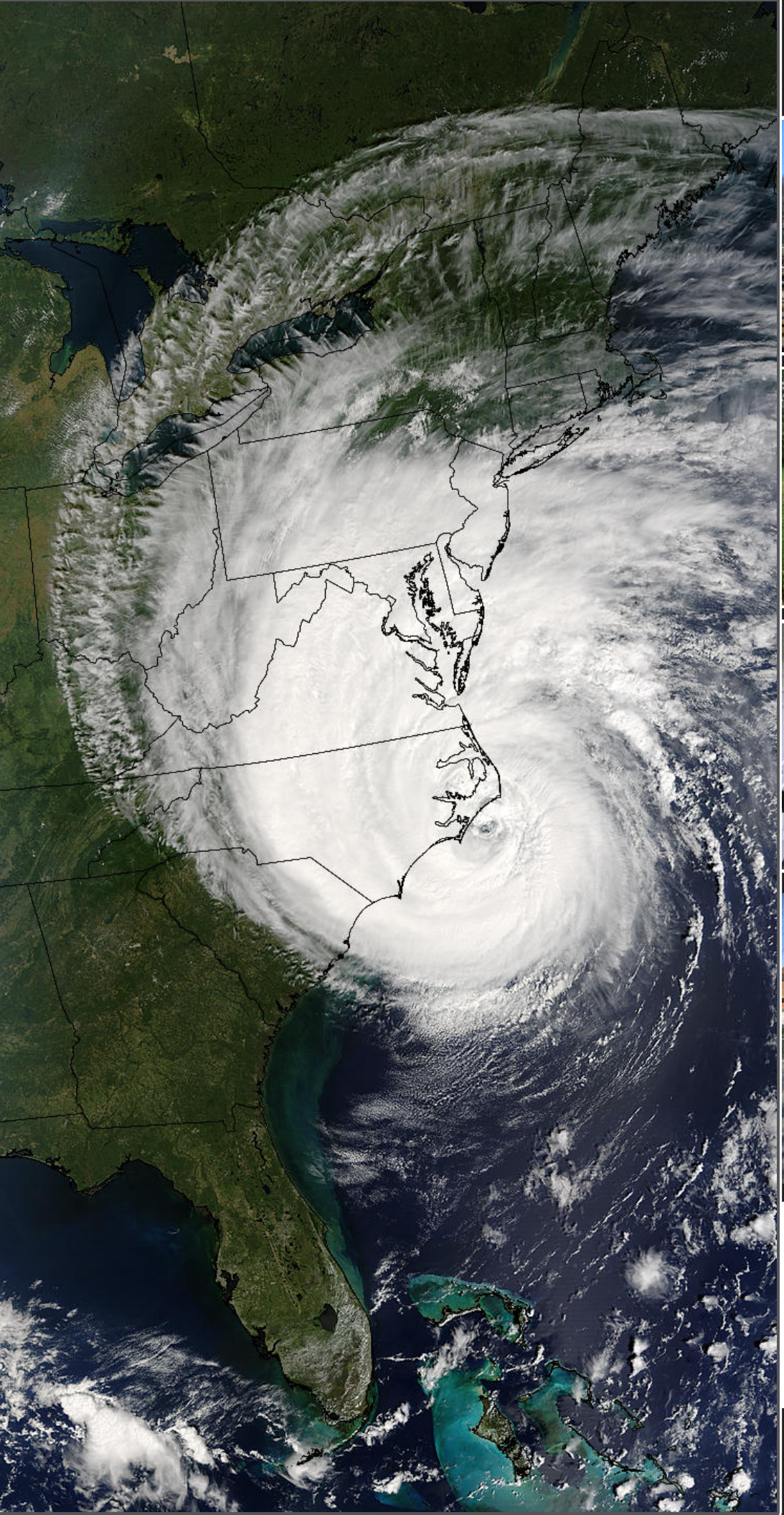

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