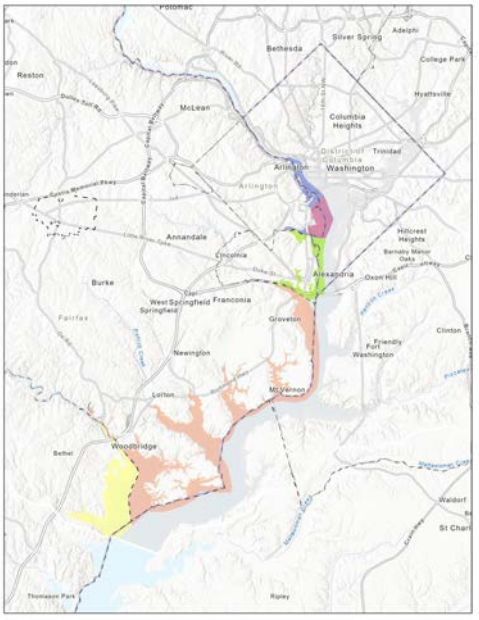
US Army Corps of Engineers

Metropolitan Washington Council of Governments

Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study

Final Integrated Feasibility Report & Environmental Assessment

APRIL 2024



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Executive Summary

This 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.

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 study authority is under the Middle Potomac River Watershed authority, which was adopted by a resolution of the U.S. Senate Committee on Environment and Public Works, dated 23 May 2001. This IFR/EA is 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 as there are other areas to consider for a comprehensive response to flooding in the area. Although the authority allows for other project purposes, this study focused on coastal storm risk management (CSRM).

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 high-risk areas.

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 Middle Potomac River watershed included in the study authority encompasses approximately 11,500 square miles, and includes a diverse landscape with urban, rural, and natural areas in six different ecological regions, 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 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, the GWMP, and laboratory and testing buildings associated with the DCA. 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.

Metropolitan Washington Council of Governments (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 Metropolitan Washington Airports Authority (MWAA). The Metropolitan Washington, D.C. Feasibility Cost Sharing Agreement (FCSA) was signed by USACE and the 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 MWAA. Figure E-1 shows the above counties as follows: Prince William County (yellow), Fairfax County (orange), City of Alexandria (green), MWAA (pink) and Arlington County (blue).

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 (MWAA, Arlington, Alexandria, Fairfax, and Prince William Counties). A FCSA Amendment was signed on 07 April 2021 and an additional $2 million in Federal funds were obtained. The decision was made to use existing geotechnical data and delay new surveys, borings, and related data collection to the design phase, in order to lower study costs.

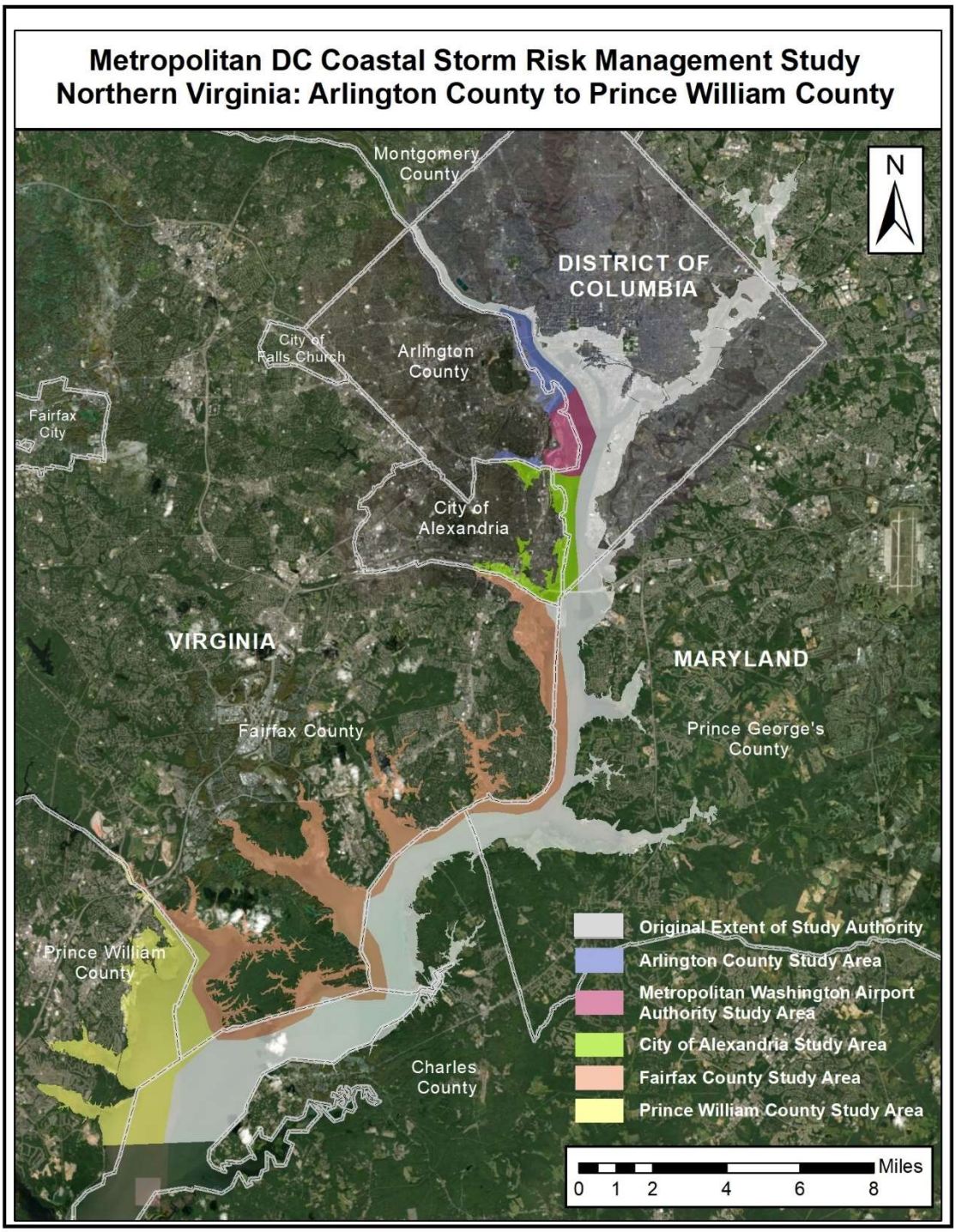

Figure E-1. Northern Virginia Study Area.

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 during post-storm runoff. 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, in 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 of sea level rise at the Washington D.C. tide gauge is 0.00997 feet/year; however, this rate is increasing over time.

The period of analysis for this study is 50-years per Engineer Regulation (ER) 1105-2-103, Chapter 2, Section 2-4. The planning horizon starts in baseline year 2031, when the project is anticipated to begin accruing CSRM 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 include 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.

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 nonstructural and structural measures, and natural and nature-based features, to formulate the final array of 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 CSRM to critical infrastructure, three levee and floodwall alternatives, a nonstructural alternative, and an alternative combining various plans, in addition to the no-action plan. An alternative for Reagan National Airport was not part of the Tentatively Selected Plan (TSP), however USACE recognizes the importance of reducing coastal storm risk to Reagan Airport and proposes a targeted study for Reagan Airport.

The TSP was endorsed as the Recommended Plan at the 04 November 2022 Agency Decision Milestone (ADM) meeting. The Recommended Plan (Alternative 8) included two locations (identified individually as Alternatives 4c and 5c) within the study area, where coastal flood risk management measures could be implemented. These included a floodwall to reduce flood risk to Arlington County Water Pollution Control Plant (WPCP) and a floodwall and levee to reduce flood

risk to the community of Belle Haven in Fairfax County). Post-ADM, the Recommended Plan was optimized, and cost and economic analyses were updated.

The USACE held several coordination meetings with Fairfax and Arlington Counties as the plans were optimized. After thorough discussion of the Belle Haven floodwall and levee plan with the stakeholders and community, Fairfax County sent USACE a letter on 13 March 2023 stating that they "will not support the project as proposed at the present time, and thus will not be providing the USACE with a letter of intent." Subsequently without a non-federal sponsor for implementation, no further analysis was undertaken for the Belle Haven floodwall and levee plan, which was a separable element from the Arlington WPCP. It is noted that based on the FY23 cost and economics analyses (October 2022 price level and 2.5 percent discount rate), the Belle Haven plan (Alternative 5c) is cost effective and yielded positive annualized net benefits of $827,000 and a BCR of 1.3. Since this study is an interim response to the study authority, there could be future opportunities to revisit the Belle Haven planning unit if a NFS requests USACE to reevaluate the area. At that time, the required analysis would need to be completed (i.e. a complete, updated National Environmental Policy Act [NEPA] analysis and engineering analysis). With the Belle Haven plan (Alternative 5c) not moving forward, more detailed environmental evaluation and engineering & design planning for the feasibility study was focused on the Arlington WPCP (Alternative 4c).

The Recommended Plan (Alternative 4c) for the Arlington WPCP includes a 1,180-linear-foot (lf) floodwall (ranging up to about 6ft. in height from ground, at elevation +14.3ft. NAVD88) located along the existing fence line of the facility and will be installed between the Four Mile Run stream and the facility's vulnerable infrastructure. The west end of the floodwall would tie into high ground. In preparation for a flooding event, a temporary 70-ft long aluminum stop log closure would be placed at the east end of the alignment located across South Eads Street. The project would also include a +1 ft curb for approximately 1,280 lf, flap gates at stormwater conduits to prevent backflow, and sluice gates installed at the 36" and 60" stormwater conduits. The Arlington WPCP floodwall (14.3 ft NAVD88) will pass the 0.34% AEP event (~300-year storm) with 90% assurance.

The Recommended Plan (Arlington WPCP) is a critical infrastructure structural solution providing significant positive OSE (including serving six economically disadvantaged communities) and EQ benefits, as well as community resilience. The Recommended Plan would reduce the plant's susceptibility to flood events and reduce the risk of operational failure. Without the proposed project, flooding from Four Mile Run may result in disruption to the operations and damage to the equipment at the facility. It could take weeks to months to place the systems back into operation (DC Water, 2021), presenting public health risks to the service area of approximately 220,000 people. Flooding may also result in impacting approximately 117 acres of wetlands and 812 acres of aquatic habitat through release of contaminated effluent. Arlington County owns the Arlington WPCP. Without CSRM measures to reduce risk to the plant, the plant will not be able to uphold

its mission to safely and economically process wastewater and hazardous waste materials to protect the environment: especially Four Mile Run, the Potomac River, and the Chesapeake Bay.

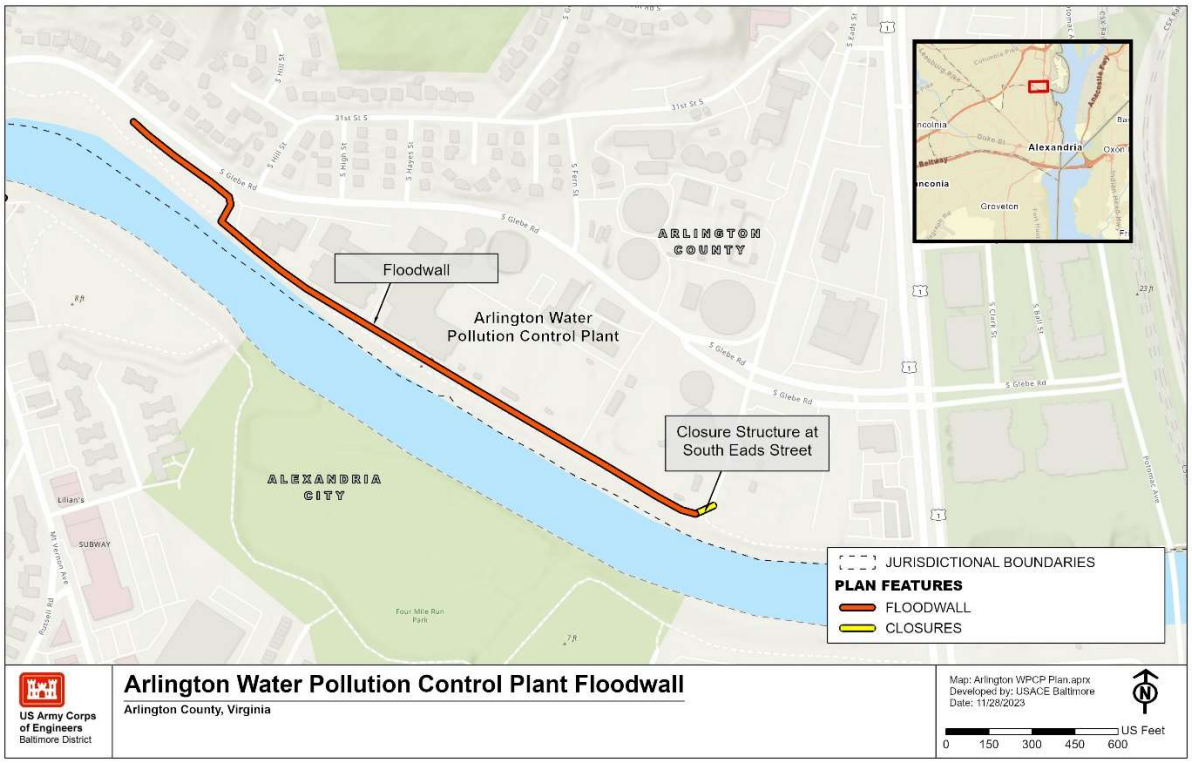

Figure E-2. Recommended Plan.

The Recommended Plan (Alternative 4c) has negative average annualized net benefit of -$212,000, a benefit-cost ratio (BCR) of 0.7, and a project first cost of $15.2 million including a 35 percent contingency (FY24, October 2023 price level) (Table E-1 and Table E-2). The lands and damages real estate cost estimate is $1.1 million (including a 19 percent contingency). Although this project has a BCR of less than 1.0, it was still recommended for implementation due to its importance as critical infrastructure in the area and the maximum total net benefits of the project. Further discussion can be found in Section 5.3 (Four Accounts) of this report. The Assistant Secretary of the Army for Civil Works approved a National Economic Development (NED) policy exception on March 18, 2024. The policy exception allowed the Recommended Plan to include non-economically justified separable elements based on environmental and other social effects. The approval highlighted the importance of providing a risk management solution to ensure this critical infrastructure has minimized risk of operational failure during a coastal storm event.

The annualized cost of Operation, Maintenance, Repair, Rehabilitation, and Replacement (OMRR&R) for the Arlington WPCP is $153,000 over the 50-year period of analysis. The closure structure would need to be deployed at minimum of once per year for testing the system, which would incur some labor costs. The OMRR&R would be managed by the NFS, Arlington County.

It is estimated that the construction duration for the Arlington WPCP would be 18 months. According to the Arlington County noise ordinance, impulsive noise cannot exceed 120 dBA and continuous noise cannot exceed 70 dBA anytime of the day (in Zoning District P-S where the Arlington WPCP is located). The Arlington WPCP assumes 8-hour construction days. Typical construction equipment used to construct the Arlington WPCP floodwall is not expected to exceed the continuous and impulsive noise requirements in the Arlington County noise ordinance. Materials would be brought in by land via by flatbed trucks, trailers, and dump trucks.

The Recommended Plan (Arlington WPCP) will require two standard estates. A perpetual Flood Protection Levee Easement (Estate No. 9) is required for the construction and operation and maintenance of the floodwall and closure structures. Temporary Work Area Easements (TWAE) (Estate No.15) are required for a period of 3 years for the purpose of staging and storage. No compensatory mitigation is required for Recommended Plan (Arlington WPCP).

The PED phase assumes two years to start in January 2025 and end in January 2027. The construction window for Arlington WPCP would likely start in 2027 and end in early 2029. For PED to be initiated, the USACE must sign a Design Agreement with a NFS to cost share PED. The PED phase would be cost shared 65 percent federal and 35 percent non-Federal (Table E-3). The non-Federal Sponsor for the Recommended Plan is Arlington County.

Table E-1. Project Costs. (October 2023 Price Level)

WBS Number	Features	Project First Cost[1] w/ Contingency	Total Project Cost (Fully Funded)[3] w/ Contingency
01	Lands, Easements, Right-of-Ways, Relocations, and Disposals (LERRD)[2]	$1,052,000	$ 1,107,000
02	Relocations	$551,000	$ 616,000
11	Levees and Floodwalls	$4,954,000	$ 5,531,000
15	Floodway Control and Diversion Structure	$560,000	$ 626,000
30	Preconstruction, Engineering & Design[2]	$6,168,000	$ 6,587,000
31	Construction Management Supervision and Inspection (S&I)	$1,944,000	$ 2,223,000
	Project Cost	$15,230,000	$ 16,690,000

1. Cost is based on Project First Cost (constant dollar basis) on Total Project Cost Summary (TPCS) Spreadsheet, at an effective price level 1 Oct 2023 (Appendix C).
2. These are Real Estate administrative costs and the cost of easements based on a February 2023 appraisal.
3. Total Project Cost (Fully Funded) estimates use mid-point of construction in Quarter 2 of 2028.

Table E-2. Equivalent Annual Benefits and Costs
(October 2023 Price Level, 50-Year Period of Analysis, 2.75 Percent Discount Rate)

Investment Costs	
Total Project Construction Costs	$15,230,000
Interest During Construction	$297,000
Total Economic Costs	$15,527,000
Average Annual Costs	
Interest and Amortization of Initial Investment	$575,000
OMRR&R[1]	$153,000
Total Average Annual Costs	$728,000
Average Annual Benefits	$516,000
Net Annual Benefits	-$212,000
Benefit-Cost Ratio	0.7
Benefit-Cost Ratio (computed at 7%)[2]	0.5

[1]Operation, Maintenance, Repair, Replacement, and Rehabilitation.
[2]Per Executive Order 12893.
Note: All values are rounded to the nearest 1,000.

Table E-3. Cost Apportionment After LERRDs Credit. (October 2023 Price Level)

Features	Federal Share (65 percent)	Non-Federal Share (35 percent)	Project Cost w/ Contingency
Project First Costs	$9,899,500	$5,330,500	$15,230,000
Credit for Non-Federal LERRD[1]		($1,052,000)	
Total Cost Apportionment[2]	$9,899,500	$4,278,500	

1. Credit is given for the incidental costs borne by the NFS for lands, easements, rights of way, relocations, and disposal areas (LERRD).
2. Total cash portion required for the project.

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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
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
EP	Engineer Pamphlet
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
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
LERRDs	Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas
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
NHL	National Historic Landmark
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
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
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
sq ft	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 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 from the Recommended Plan are not expected to be significant. 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 was 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 Feasibility Cost Share Agreement 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 (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 07 April 2021.

The study authority is a resolution of the U.S. Senate Committee on Environment and Public Works, dated 23 May 2001. This IFR/EA is 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 as there are other areas to consider for a comprehensive response to flooding in the area.

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 including the Baltimore District, the North Atlantic Division, and Headquarters USACE.

Due to study delays and rescoping of the DC Coastal Study, the USACE 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 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 AMM marks the decision maker's acknowledgement and acceptance of identified study and implementation risks and the strategies to manage those risks. The decision maker affirms the project delivery team’s (PDT) preliminary analysis of the Federal interest, and the projected scope, schedule, and budget for the study.

The Tentatively Selected Plan (TSP) milestone meeting was achieved on 29 March 2022. The TSP Milestone marks the PDT’s selection of, and the decision-maker's endorsement of, a TSP (and locally preferred plan (LPP, if applicable), and that the PDT is prepared to release the draft feasibility report and draft NEPA documentation for concurrent public, technical, legal and policy review and independent external peer review (IEPR), if applicable.

The Agency Decision Milestone (ADM) meeting was achieved on 04 November 2022. The ADM marks the corporate endorsement of the Recommended Plan and proposed way forward to complete feasibility-level design and the feasibility study report package. The USACE’s plan formulation process is described in this report with each subsequent section building off the former. The Recommended Plan is described in Section 6 with final recommendation from this feasibility study located in Section 8.

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), dated 21 March 2013, and Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook (PGN), dated 22 April 2000[1], and follows the Final Feasibility Report Format and Content Guide, dated 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) as well as the optimization of the Recommended Plan.

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*

[1] The Planning Guidance Notebook was updated on 7 December 2023 as ER 1105-2-103, Policy for Conducting Civil Works Planning Studies. The PDT was aware of this new guidance and consulted the draft guidance while completing the study.

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, 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 E-1 shows the counties as follows: Prince William County (yellow), Fairfax County (orange), City of Alexandria (green), MWAA (pink) and Arlington County (blue). The original study area encompassed the tidally influenced reaches from Prince William County, Virginia to Prince George's County, Maryland (Figure E-1). 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 (MWAA, Arlington, Alexandria, Fairfax, and Prince William Counties).

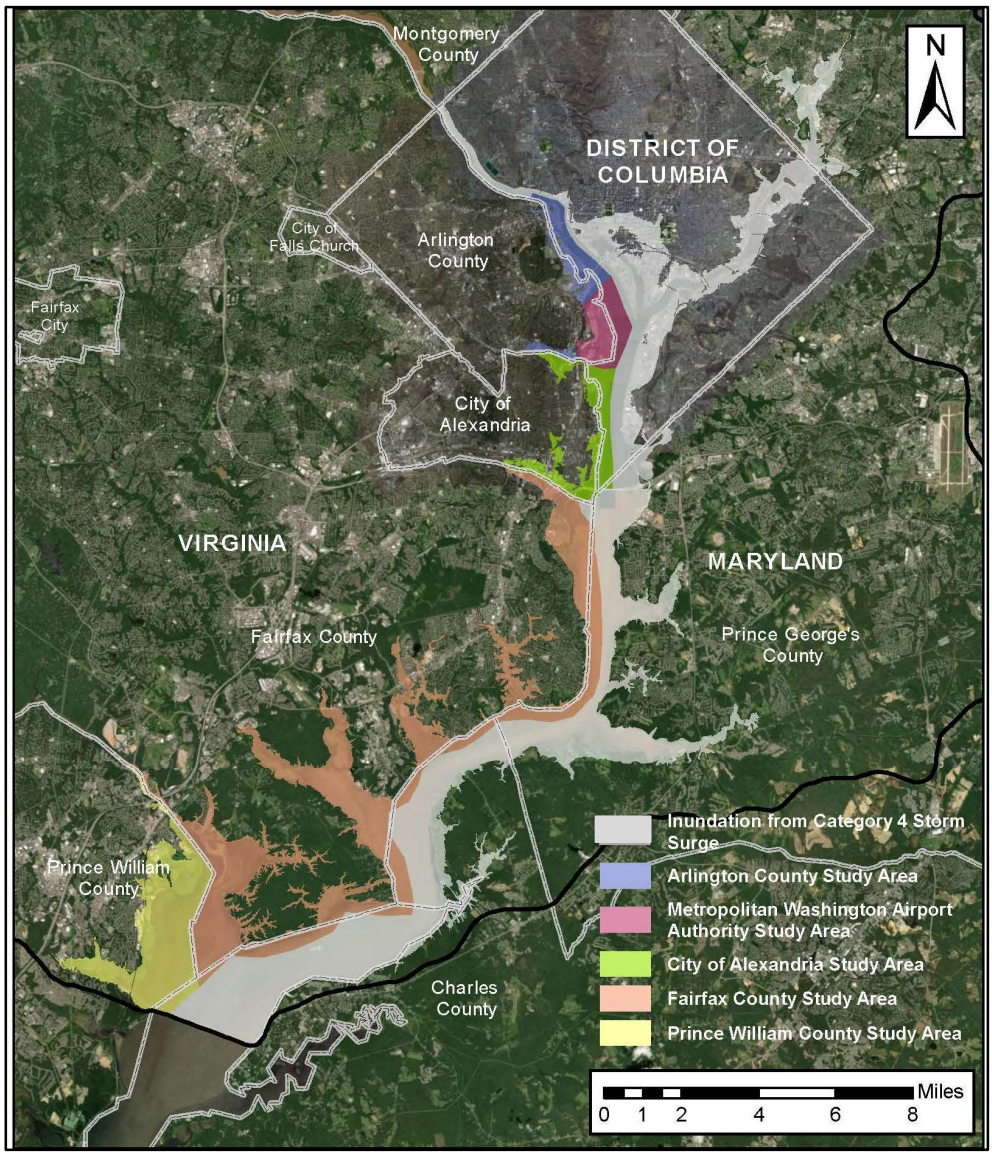

Figure 1-2. Study Area.

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 CSRM 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.

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 economic damages, and critical infrastructure disruption, and life safety, resulting from storm surge inundation caused by coastal storms.

Problems within the study area include:

- 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.

- Life safety: socially vulnerable populations may not be able to evacuate ahead of storm surge.

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 coastal 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, as well as environmental and cultural resources. All the objectives listed below were evaluated over the 50-year period of analysis starting in 2031.

Objectives

- 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.
- Reduce risk to human health and safety from coastal storm impacts in the study area.
-

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 1105-2-103, the Policy for Conducting Civil Works Studies, and EP 1105-2-61 (formerly ER 1105-2-100, Appendix H), define 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 solutions 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 coastal flooding. Reducing the risk of 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 flooding and damages within the tidally influenced reach of the Potomac River and its tributaries. The study scope is to recommend a CSRM plan in the Federal interest 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 and optimization of the Recommended Plan (Section 6).

2.1 Period of Analysis

The period of analysis for this study is 50-years per ER 1105-2-103. The planning horizon starts in baseline year 2031, when the project is anticipated to begin accruing CSRM benefits and ends in year 2080. The base year was based on larger scale alternatives so it is likely that the proposed action in Section 6 may start accruing benefits prior to the year 2031. 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 Recommended Plan. The Recommended Plan was also assessed for engineering and environmental performance out to 100 years from the baseline year to ensure coastal sustainability of the plan and adaptation to sea level rise (SLR). EP 1105-2-61 and EP 1100-2-1 guidance explain that certain environmental factors may consider the evaluation of other periods of analysis. Different planning horizons should be considered throughout alternatives evaluation to help identify the degree of urgency of future actions as well as to determine how these alternatives may perform in the future (i.e., resilience or robustness).

Throughout the analysis and future forecasting, annual exceedance probability (AEP) is used, as well as tying storm event to likelihood by years. A 100-year storm is a 1 percent likelihood that a storm at that magnitude would occur in that timeframe with approximately 95 percent confidence level. A 500-year storm is a 0.2 percent AEP storm. Different agencies use different identifiers to discuss the probability of storm events as well as how these events are tied into the modeling for the future with-project and future without-project conditions.

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 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 Ronald Reagan Washington 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. Although the area is extensively developed, the study area also includes a variety of habitat types including mature mixed hardwood forests, young forests, retired agricultural land, tidal and non-tidal wetlands, and tidally influenced streams and riparian habitats (VADGIF, 2015). 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 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 reduce the risk of 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. Dominant sapling/shrub species included green ash (*Fraxinus pennsylvanica*), silky dogwood (*Cornus amomum*), and spice bush (*Lindera benzoin*). Dominant herbaceous vegetation included broadleaf cattail (*Typha latifolia*), halberdleaf tearthumb (*Polygonum arifolium*), lizard's tail (*Saururus cernuus*), common reed (*Phragmites australis*), jewelweed (*Impatiens capensis*), white grass (*Leersia virginica*), pickerelweed (*Pontederia*

cordata), Pennsylvania smartweed (*Persicaria pensylvanica*), and climbing hempvine (*Mikania scandens*). Dominant trees included red maple (*Acer rubrum*), pin oak (*Quercus palustris*), green ash, American elm (*Ulmus americana*), and cottonwood (*Populus deltoides*). Further details regarding the wetland delineation are 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, 06 January 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. Most 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. All portions of the study area are projected to experience significant population growth by year 2030 (University of Virginia Weldon Cooper Center, 2022).

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 reduce risk to 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 Haven 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 Haven and Prince William County) is undeveloped and natural. These natural floodplains are 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 (WPCP), 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, with hydrilla being the dominant species of SAV. 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 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 Upland Vegetation

2.3.4.1 Existing Condition

The most common genus of tree or shrub found in the study area is *Quercus spp.* (oaks). Oak forests are frequently found in the coastal plain region of Northern Virginia (where the study area is located). Characteristic oaks include white oak (*Quercus alba*), black oak (*Quercus velutina*), and Northern red oak (*Quercus rubra*). Other common trees found in the study area include American beech (*Fagus grandifolia*), ash trees (*Fraxinus spp*.), hickory trees (*Carya spp.*), and black locust (*Robinia pseudoacacia).* Common shrubs include downy serviceberry (*Amelanchier arborea*), wintergreen (*Gaultheria procumbens),* mountain laurel (*Kalmia latifolia*), black huckleberry (*Gaylussacia baccata*), rhododendrons (*Rhododendron maximum*), wild azalea (*Rhododendron periclymenoides),* and blueberries (*Vaccinium spp.*) (VA CZMP, 2014; NPS, n.d.).

2.3.4.2 FWOP Condition

Similar to the wetlands FWOP condition discussed in Section 2.3.1.2, uplands located on managed conservation lands or lands protected under a conservation easement are expected to retain their natural and historic value in the future. Uplands in the study area that are not protected are threatened by pressures from future development. There are no laws or regulations in Virginia that prohibit the removal of individual trees on a single-family property. Approvals may be required in certain jurisdictions for tree removal activities (Fairfax County, Virginia, n.d.-a).

2.3.5 Threatened and Endangered Species

2.3.5.1 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 for this study in January 2021, from the Chesapeake Bay Ecological Services Field Office (USFWS, 2021b) (see Appendix G)
- USFWS Information for Planning and Consultation (IPaC) species list dated 12 April 2023, from the Virginia Ecological Services Field Office (USFWS, 2021c)
- USFWS Consistency Letter for the Northern Long-Eared Bat dated 12 April 2023
- 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 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	TAXA	FEDERAL LISTING STATUS	STATE LISTING STATUS	PRESENCE IN THE STUDY AREA
Northern Long-eared Bat (*Myotis septentrionalis*) *	mammal	endangered	threatened	No known hibernaculum or maternity roosts
Little Brown Bat (*Myotis lucifugus*) *	mammal	proposed endangered	endangered	No known hibernaculum or maternity roosts
Tri-colored Bat (*Perimyotis subflavus*) *	mammal	proposed endangered	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.

2.3.5.2 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. Changes in temperature and precipitation will likely negatively affect habitats for these species. Increased temperatures may lead to heat stress for species, decreased water quality and dissolved oxygen content as well as changes in food availability. The 2015 Virginia Wildlife Action Plan (Northern Virginia Planning Region Final) provides information on conservation strategies to maintain and restore habitats for species of greatest conservation need in the northern Virginia (VADGIF, 2015).

2.3.6 Marine and Anadromous Species

2.3.6.1 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	15 March to 30 November	yes – Chesapeake Bay DPS
				Post yolk-sac larvae (migrating and foraging)	15 March to 15 July; 01 August to 31 January	
				Young-of-year (YOY) (migrating and foraging)	01 January to 31 December	
				Juvenile (migrating and foraging)	01 January to 31 December	
				Subadult (migrating and foraging)	15 March to 30 November	
				Adult (spawning)	15 March to 15 May; 01 August to 30 November	
				Adult (migrating and foraging)	15 March to 30 November	

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	15 March to 30 June	no
				YOY (migrating and foraging)	01 January to 31 December	
				Juvenile (migrating and foraging)	01 January to 31 December	
				Adult (migrating and foraging)	01 January to 31 December	

2.3.6.2 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.

2.3.7 Essential Fish Habitat

2.3.7.1 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.

2.3.8 Anadromous Fish

2.3.8.1 Existing Condition

Anadromous fish are fish that migrate from saltwater to freshwater to spawn. Anadromous fish spend most 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

2.3.8.2 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.).

2.3.9 Migratory Birds

2.3.9.1 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 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	15 October to 31 August
Black-billed Cuckoo (*Coccyzus erythropthalmus*) **	Yes	All	15 May 15 to 10 October
Bobolink (*Dolichonyx oryzivorus*)	Yes	All	20 May to 31 July
Canada Warbler (*Cardellina canadensis*) **	Yes	All	20 May to 10 August
Cerulean Warbler (*Dendroica cerulea*) *	Yes	Gravelly Point, Four Mile Run	29 April to 20 July
Dunlin (*Calidris alpina arcticola*) *	Yes	All	Breeds elsewhere
Eastern Whip-poor-will (*Antrostomus vociferus*) *	Yes	All	01 May to 20 August
Golden Eagle (*Aquila chrysaetos*) *	No	Gravelly Point, Four Mile Run	Breeds elsewhere
Golden-winged Warbler (*Vermivora chrysoptera*) *	Yes	Four Mile Run	01 May to 20 July
Hudsonian Godwit (*Limosa haemastica*)	Yes	Belle Haven	Breeds elsewhere
Kentucky Warbler (*Oporornis formosus*) *	Yes	All	20 April to 20 August
Least Tern (*Sterna antillarum*) *	Yes	All	20 April to 10 September
Lesser Yellowlegs (*Tringa flavipes*)	Yes	All	Breeds elsewhere
Prairie Warbler (*Dendroica discolor*)	Yes	All	01 May to 31 July

SPECIES	BIRD OF CONSERVATION CONCERN	PRESENCE IN STUDY AREA	BREEDING SEASON
Prothonotary Warbler (*Prothonotary warbler*)	Yes	All	01 April to 31 July
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	Yes	All	10 May to 10 September
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	20 April to 5 August
Wood Thrush (*Hylocichla mustelina*) **	Yes	All	10 May to 31 August

*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.

2.3.9.2 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.

2.3.10 Wildlife

2.3.9.1 Existing Condition

Mammals in the study area include bats, beavers, black bears, bobcats, coyotes, deer, red and gray foxes, opossums, groundhogs, raccoons, squirrels, chipmunks, and skunks. Birds include birds of prey, songbirds, Canada geese, and vultures. Amphibians include frogs, toads, and salamanders. Reptiles include lizards, snakes, and turtles. At least 60 species of fish may be found in the study areas including the Eastern mosquitofish (*Gambushia holbrooki*) (Fairfax County, Virginia, n.d.-b).

Table 2-5 lists the priority species of greatest conservation need within the study area from the 2015 Virginia Wildlife Action Plan (Northern Virginia Planning Region Final) (VADGIF, 2015). This list does not include federal or state-listed species or migratory birds. Those species are evaluated in Sections 2.3.5 and 2.3.8.

Table 2-5. Priority Species of Greatest Conservation Need (VADGIF, 2015).

BIRDS	MOLLUSKS	CRUSTACEANS	FISH
Bank swallow (*Riparia riparia*)	Atlantic spike (*Elliptio producta*)	Pizzini's amphipod (*Stygobromus pizzinii*)	Bridle shiner (*Notropis bifrenatus*)
Barn owl (*Tyto alba*)	Carolina lance mussel (*Elliptio angustata*)		
Belted kingfisher (*Megaceryle alcyon*)	Northern lance mussel (*Elliptio fisheriana*)		
Black-and-white warbler (*Mniotilta varia)*	Tidewater mucket (*Leptodea ochracea*)		
Brown thrasher (*Toxostoma rufum*)			
Chimney swift (*Chaetura pelagica*)			
Eastern kingbird (*Tyrannus tyrannus*)			
Eastern meadowlark (*Sturnella magna*)			
Eastern towhee (*Pipilo erythrophthalmus*)			
Eastern wood-pewee (*Contopus virens*)			
Field sparrow (*Spizella pusilla*)			
Glossy ibis (*Plegadis falcinellus*)			
Grasshopper sparrow (*Ammodramus savannarum*)			
Gray catbird (*Dumetella carolinensis*)			
Green heron (*Butorides virescens*)			
King rail (*Rallus elegans*)			
Least bittern (*Ixobrychus exilis*)			
Northern flicker (*Colaptes auratus*)			
Ruffled grouse (*Bonasa umbellus*)			
Rusty blackbird (*Euphagus carolinus*)			
Wood thrush (*Hylocichla mustelina*)			
Yellow-billed cuckoo (*Coccyzus americanus*)			
Yellow-breasted chat (*Icteria virens*)			

2.3.9.2 FWOP Condition

Future development in the region and climate change stressors could reduce the availability of suitable habitat for fish and wildlife.

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 in the Middle Potomac River watershed. Normal flow conditions in streams and wadable rivers in the watershed are 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).

The study area includes the tidal Potomac River. This reach of the River contains only fresh water but is still influenced by tides from the Chesapeake Bay. It extends from Chain Bridge to Quantico, Virginia. It is less than a half mile wide at Washington D.C. and the average depth is 10 feet. In this area, the bottom of the river is a long narrow channel and bordered by shallow shelf areas. Tidal rivers gather sediment and will eventually fill. There are two distinct flow patterns in the tidal river. Unidirectional, pulsating, downstream flow occurs in the narrow channel upstream of Key Bridge. Bi-directional flow occurs in the broader downstream channel (USGS, n.d.).

NOAA Tides and Currents provides the following information for the closest tidal station to the study area (Washington, D.C. station ID 8594900): maximum water level of 7.88 mean higher high water (October 17, 1942), minimum water level of -5.05 mean lower low water (26 February 1967), and a mean tidal range of 2.79 feet (NOAA, 2022).

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 affect 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 nonstructural 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.

There is significant rainfall throughout the year in Northern Virginia. In Fairfax, Virginia, average annual rainfall is 42.3 inches. There is no “rainy season” in Northern Virginia, rather rainfall is

consistent throughout the year. Between 1992 and 2021, rainfall was recorded to be the highest (in inches) in Alexandria, Virginia in March, and September (Climate-Data.org, 2022).

2.4.2.2 FWOP Condition

Precipitation over land has likely increased since 1950, with a faster rate of increase since the 1980s. Climate change is leading to jumps in frequency and intensity of heavy precipitation. On global scale, extreme daily precipitation events are projected to intensify by about 7 percent for every 1 degree of warming (IPCC, 2020). Since 1895, there has been a trend of increasing average annual precipitation and heavy rainfall frequency in Virginia. Increased unpredictably in precipitation is also likely in the future (Allen et al., 2019).

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 and aquatic resources (MWCOG, 2019; USEPA, 2022a). Warming temperatures provide conditions for harmful algal blooms that can be toxic to aquatic resources. More powerful storms that cause changes in the patterns and amount of rainfall degrade water quality through the runoff of pollutants. Wastewater treatment plants can overflow during heavy rainfall events causing water pollution (USEPA, 2022a). 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, 2022b). 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 study area is also located in an Ozone Transport Region (OTR), specifically the Consolidated Metropolitan Statistical Area. For the OTR, the applicable de minimis emission threshold for maintenance and nonattainment (as listed in Table 2-1 in Appendix A4) is 50 tonnes per year (tpy) for volatile organic compounds (VOCs) and 100 tpy of nitrogen oxide (NOx).

The USEPA Environmental Justice (EJ) Screen provides tools to analyze a community's exposure to air pollutants (USEPA, 2022c). 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.

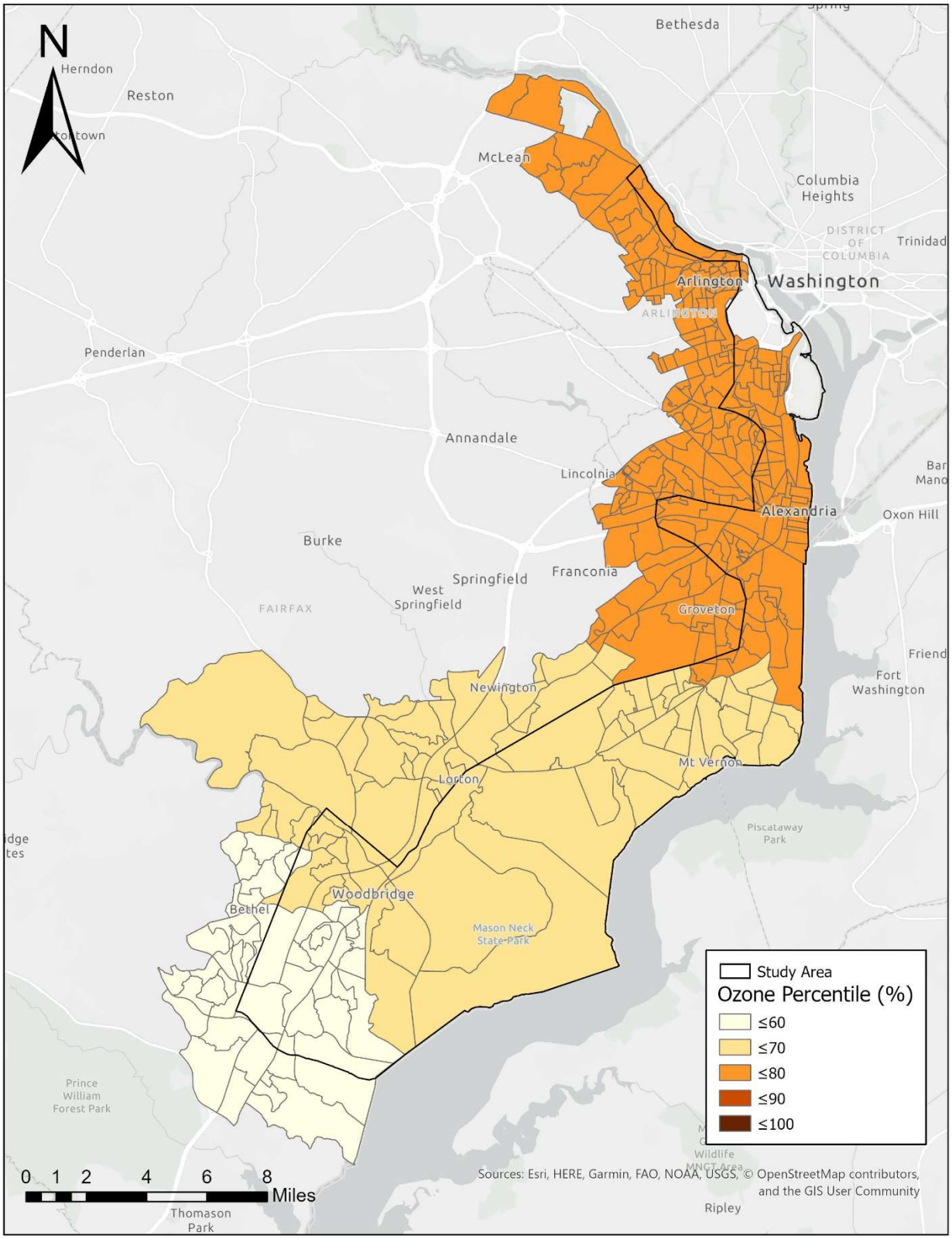

Figure 2-1. Ozone Exposure in Percentiles for the Study Area (USEPA, 2022c).

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 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 WPCP, Four Mile Run Park, Belle Haven, and nearby properties. USACE prepared three HTRW investigation reports in February 2022; a report for the Four Mile Run Floodwall and Levee, a report for the Belle Haven Floodwall and Levee, and a report for the Reagan National Airport Floodwall and Levee. The USACE HTRW Reports are 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). Most 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 WPCP

The investigation revealed that the Arlington 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 near 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 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.
- 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 21 October 2021. USACE initiated Section 106 consultation via letters dated 10 March 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, an APE was defined to identify any potential historic properties that could be affected by the proposed project alternatives. The 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. For this project the APE includes construction areas of proposed levees, floodwalls, pump stations, and any associated staging areas. The APE also includes the viewsheds of any nearby historic properties.

Cultural Contexts

Precontact Cultural Context

American Indian settlement in Northern Virginia is generally divided into three major time periods: the Paleoindian ((16,000 Before Common Era (BCE) to 8,000 BCE), the Archaic (8,000

BCE to 1,000 BCE), and the Woodland (1,000 BCE to 1600 Common Era (CE)). These periods represent various changes throughout the archaeological record, such as fluctuations in settlement patterns, technological utilization, and subsistence strategies, among others (VDHR 2017).

The Paleoindian Period is represented by small, highly mobile bands of hunter-gatherers and marked by fluted projectile points. Example projectile point types include Clovis, Hardaway, Dalton, and Hardaway/Dalton (Barber and Barfield 1989). Well-preserved sites of this time period are rare, and most of them within Virginia tend to be characterized as short-term encampments; however, a few more substantial base camps have been documented in the state. This includes the Cactus Hill site (44SX202) consisting of stratified deposits dating from the Paleoindian to the Woodland Periods. Cactus Hill is also substantial for its pre-Clovis occupation dating from 18,700 BCE to 16,500 BCE, pushing early occupation in Virginia back even further (Boyd 2020).

The Archaic Period is further sub-divided into the Early Archaic (8,000 BCE to 6,500 BCE), Middle Archaic (6,500 BCE to 3,000 BCE), and Late Archaic (3,000 to 1,200 BCE). During the Archaic Period, American Indian populations increased and more intensively used estuarine and floodplain settings; however, there was still a reliance on hunting and gathering as a subsistence strategy. Ground stone tool technology was introduced during the Early Archaic, marking an expansion of previous tool kits. By the Late Archaic, population growth and sedentism increase further, along with increases in technological specialization and trade networks (VDHR 2017).

The Woodland Period is further sub-divided into the Early Woodland (1,200 BCE to 300 CE), Middle Woodland (300 CE to 1,000 CE), and Late Woodland (1,000 CE to 1,600 CE). During the Woodland Period, there was a further increase in sedentism and social complexity through time as groups moved towards living in semi-sedentary villages and further relied on horticulture. By the Late Woodland agriculture became a dominant form of subsistence with village sites located on floodplains, terraces, and ridges overlooking fertile floodplain soils. The Woodland Period is also marked by a widespread adoption and refinement of ceramic vessels.

Historic Cultural Context

The project area is located within the Northern Virginia region, which is bounded by the Potomac River to the east and north. The Upper Rappahannock River is to the south, and the Blue Ridge Mountains are to the west. Settlement in this region generally progressed from east to west, beginning along the Coastal Plain and moving towards the Blue Ridge Mountains and beyond.

The VDHR defines eight temporal periods that provide a context for Virginia's history: Settlement to Society (1607 to 1750), Colony to Nation (1750 to 1789), Early National Period (1789 to 1830), Antebellum Period (1830 to 1860), Civil War (1861 to 1865), Reconstruction and Growth (1865 to 1917), World War I to World War II (1917 to 1945), and the New Dominion (1945 to Present).

The Settlement to Society Period (1607 to 1750) featured significant changes to the landscape and American Indian populations because of European colonization. European exploration of the Chesapeake Bay, south of the Northern Virginia region began in the mid to late sixteenth century

when Spanish Jesuit priests established the Ajacan Mission along the York River; however, the mission only lasted a few months. The first English voyages are well-known and consist of the ill-fated Roanoke colony in North Carolina in 1584 and Jamestown in 1607. In 1608, John Smith surveyed the Potomac River and mapped American Indian villages along its embankments (VDHR 2017).

The Northern Virginia region began as the Northern Neck Proprietary granted by King Charles II to his supporters in 1649. Prior to this, Virginia considered this area indigenous territory. By 1630, the growing Virginia colony recognized the need for more land for its population. In 1645, the colony established Northumberland County between the Rappahannock and Potomac Rivers to allow European settlement into Northern Virginia. During the eighteenth century, Northumberland County was divided into Westmoreland, Stafford, and Prince William County, while Fairfax County was partitioned from Prince William County shortly after (Hening 1819).

Indentured servitude, the plantation system, and the institution of slavery grew during this period. Tobacco cultivation required a large labor force, which was provided by emigration early on during this period. The labor force was initially provided through indentured servitude, but, as emigration slowed, and land became cheaper, the flow of indentured servants slowed as well. The paucity of indentured servants, paired with an increase in the number of individuals stolen from Africa, fueled the plantation system and the institution of slavery (VDHR 2017).

The Colony to Nation Period (1750 to 1789) represents a time when the American colonies diverged from British control to create a new nation. Despite this conflict, some areas, such as Alexandria, boomed due to the increased demand for agricultural products. Additionally, crop failures and the exhaustion of tobacco fields shifted cultivation towards wheat and encouraged the development of flour mills throughout the region. During the last quarter of the eighteenth century, Alexandria became a significant entity in the export of flour to overseas nations.

The Early National Period (1789 to 1830) featured an initial economic expansion of the new nation brought on by increased grain prices and access to European markets. After the Napoleonic Wars and the War of 1812, Europe held a high demand for American produce and agricultural prices increased further. Locally, Alexandria expanded its city limits in 1796 and again in 1797 due to the expanded economy and overseas agricultural trade. Other ports, such as Fredericksburg and Petersburg also became thriving commercial centers.

Expanded roadways during this period connected Alexandria to towns and villages farther south, such as Occoquan. Occoquan was established by an Act of the Virginia Assembly in 1804 on thirty-one acres of land that consisted of numerous dwellings, milling industries, and one of the first cotton mills in Virginia (Martin 1836).

The Antebellum Period (1830 to 1860) featured improvements to Virginia's infrastructure. During this time, the Virginia Board of Public Works worked with private joint stock companies to construct a network of canals, turnpikes, and railroads. Some prominent examples through Alexandria include the Orange and Alexandria Railroad in 1854, the Alexandria and Washington

Railroad in 1857, and the Alexandria, Loudon, and Hampshire Railroad in 1860. They also improved navigable waters to facilitate better access to markets for farmers and merchants.

During the Civil War Period (1861 to 1865) the area, especially Alexandria, did not witness direct military engagement other than occupation. On 24 May 1861, Union troops occupied the city and remained there throughout the war, primarily due to the presence of the Orange and Alexandria Railroad. The railroad provided a direct route from Washington to Richmond, thus proving to be a valuable target for both armies (NVCC 2012).

After the Civil War, during the Reconstruction and Growth Period (1865 to 1917), Virginia experienced a series of changes that allowed it to move away from a heavily agrarian-based economy to an industrialized and urban region. In the late nineteenth century, Virginians transitioned into the mining of coal and mineral resources, exploited forest products, and further expanded railroads and shipping lines. Consequently, although canals resumed operations after the war, they were soon succeeded by railroads due to their constant needs for repair and weather stoppages. (Mitchell 1978).

Transportation and infrastructure improvements in the nineteenth and twentieth centuries set the foundation for what would later become suburbanization. As residents moved out of Washington D.C. and other urban areas for more rural settings, they utilized the improved network of roads, railroads, and trolleys. For many, Fairfax County was the new suburban destination, although substantial suburban development would not take place until after World War II (Smith and Causey 2005).

Suburbanization continued through the World War I to World War II Period (1917 to 1945), especially after World War II. Earlier in the twentieth century, the introduction of automobiles led to a general decline of the railroad system in Northern Virginia. This shift was also exhibited by the construction of the first federally funded and designed parkway in the United States, the Mount Vernon Memorial Parkway, between 1929 and 1932. During World War II, however, an emphasis returned to the railways as the need arose for troop and supply transportation.

Rapid military and civilian mobilization for World War II led to the expansion of government agencies, and the creation of temporary military offices and civilian workforce housing. Prominent examples of this include the construction of the Pentagon in 1943 to centralize military offices and the federally funded Defense Homes Corporation that established civilian housing for workers in wartime industries and government agencies (Baker 1997).

During the New Dominion Period (1945 to Present) the general trend in Virginia was a gradual decline in farmland in favor of housing and development, especially along transportation routes. By 1955, Virginia had more urban residents than those living in rural settings. Spurred by government expansion and an increase in federal and private workforces following World War II, a wave of single-family homes, small subdivisions, and planned communities occurred in Northern Virginia (Netherton et al. 1992). With these communities came an increase in the number of

schools, churches, and shopping centers that could be easily and readily reached by personal automobiles.

Archaeological and Architectural/Above-Ground Resources

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.

During the analysis, a National Historic Landmark (NHL) was documented within 0.5 miles of Alternative 5b1. Section 110(f) of the NHPA requires that Federal agencies, to the maximum extent possible, minimize harm to any NHL that may be directly or adversely affected by an undertaking.

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, or listed as an NHL, are featured below.

Forty-five 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 1,242. Of the 45 historic properties within 0.5 miles, 5 are within, or in the immediate vicinity of, the currently proposed alternative alignments.

Within the vicinity of Alternative 4b is the Mount Vernon Trail, George Washington Memorial Parkway, and the Washington National Airport Terminal and South Hangar Line.

- The Mount Vernon Trail is a bike and pedestrian path constructed adjacent to the GWMP from 1972 to 1974. The multi-use trail extends from the 14th Street Highway Bridge to Mount Vernon and matches the original intent of the Mount Vernon Memorial Highway corridor to be associated with a recreational trail. This resource was recommended as potentially eligible for the NRHP in 2016.

- The section of the GWMP near this alternative is referred to as the Mount Vernon Memorial Highway (MVMH). The MVMH links the southwestern end of the Arlington Memorial Bridge with Mount Vernon in Fairfax County. The MVMH was added to the NRHP in 1980 and constitutes the first parkway constructed and maintained by the Federal Government.

- The Washington National Airport Terminal and South Hangar Line is an 850-acre property along the Potomac River representative of New Deal policies. It is significant as the first federally constructed commercial airport designed for civilian flight, and the Terminal is significant for its representation of the commercial airport building type. The airport was listed in the NRHP in 1997 under Criterion A for transportation history and Criterion C for its association with the Moderne Style. Within the Washington National Airport boundaries are the NRHP eligible Abingdon Research Station, Jet Engine Test Cell, and the Abingdon Ruins; however, these resources are not within the immediate vicinity of Alternative 4b.

Within the vicinity of Alternatives 4c and 5a is the Campsite No. 1 of American Wagon Train, Sept. 1781 archaeological site (44AX0207). Site 44AX0207 is loosely geographically defined and not archaeologically verified, but it is categorized as an open-air camp site associated with Continental and French army encampments during the American Revolution. It remains unevaluated for the NRHP.

Within the vicinity of Alternative 5b1 is the Alexandria Historic District. The Alexandria Historic District represents an example of an early American shipping port along the Potomac River. It is significant for its concentration of eighteenth and nineteenth century buildings, as well as its preserved levels of integrity. There is currently no comprehensive inventory of contributing resources within the historic district, but the 1969 NRHP nomination form notes that 200 surviving buildings reflect Alexandria's early life. The Alexandria Historic District was listed as an NHL in 1966 and listed in the NRHP in 1969. It is important to note that the NHL boundary is smaller than the NRHP boundary, and Alternative 5b1 is not within the NHL boundary.

Within the vicinity of Alternative 5c is the previously discussed GWMP and Mount Vernon Trail.

Potential for Unidentified Cultural Resources

Twenty-four cultural resources investigations have been conducted within 0.5 miles of the project area (Appendix G); however, only three of these have taken place within currently proposed limits of disturbance. The first was an architectural and archaeological survey for the Washington National Airport that documented fifteen structures or groups of structures contributing to the airport's historical integrity and significance. The archaeological survey identified two areas as having the potential to yield significant precontact and historic archaeological resources; however, as the currently proposed APE moves along an existing roadway, the potential for impacts to significant archaeological resources is low.

The second investigation was an architectural and archaeological survey for improvements to the Woodrow Wilson Bridge recommending that the improvements would have adverse effects on architectural and archaeological resources. Alternative 5b1 falls within this survey area, but, as the alternative consists of a temporary enclosure, the potential for impacting significant archaeological

resources is low. The main concern would be the temporary enclosure's visual effect on the NRHP and NHL-listed Alexandria Historic District.

The third investigation was an archaeological survey of a proposed development property within the Alexandria Historic District. The investigation documented the remains of an eighteenth-century wharf surface, portions of a brick furnace and coal bin, and various structures related to an electric power plant. The survey recommended that intact portions of these features may be preserved under existing townhomes. As mentioned previously, the alternative in this area, Alternative 5b1, consists of a temporary enclosure so the potential for impacting significant archaeological resources is low.

The remaining investigations are outside of currently proposed limits of disturbance and tend to focus on infrastructure projects, such as interstates or railways, or individual projects within Alexandria, such as property developments. A review of the investigations and historic maps further supports the enduring history of human occupation in this region, affiliated with both precontact and historic habitation. There is the potential to encounter significant archaeological resources in undisturbed portions of the project area. Additionally, not every building has been formally evaluated for inclusion in the NRHP. Although dependent on final project designs, ground disturbing activities could potentially affect archaeological sites, and above-ground features could diminish the characteristics of historic properties that would make them eligible for inclusion in the NRHP.

Table 2-6. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 4b (Reagan National Airport).

VDHR ID	Resource Name	NRHP/NHL Eligibility
44AR0018	(Not Applicable) N/A	NRHP Eligible
029-0228-0131	Mount Vernon Trail	Potentially NRHP Eligible
029-0218	GWMP	NRHP Listed
000-0045	Washington National Airport Terminal and South Hangar Line	NRHP Listed
500-0001	Richmond, Fredericksburg and Potomac Railroad, Richmond, Fredericksburg, and Potomac Railroad Historic District	NRHP Eligible
000-0041	Abingdon Ruins	NRHP Eligible
000-9706	Aurora Highlands Historic District	NRHP Listed
000-9880	Abingdon Research Station/Department of Transportation Laboratory Buildings	NRHP Eligible
000-9881	Jet Engine Test Cell	NRHP Eligible

Table 2-7. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 4c (Arlington WPCP) and Alternative 5a (Four Mile Run).

VDHR ID	Resource Name	NRHP/NHL Eligibility
44AX0207	Campsite No. 1 of American Wagon Train, Sept. 1781	Potentially NRHP Eligible
44AX0028	Alexandria Canal	Potentially NRHP Eligible
000-0045	Washington National Airport Terminal and South Hangar Line	NRHP Listed
000-9706	Aurora Highlands Historic District	NRHP Listed
029-0218	GWMP	NRHP Listed
100-0136	Town of Potomac Historic District	NRHP Listed
100-5021	Lynhaven Historic District	NRHP Eligible
500-0001	Richmond, Fredericksburg and Potomac Railroad, Richmond, Fredericksburg, and Potomac Railroad Historic District	NRHP Eligible

Table 2-8. Archaeological and Architectural/Above-ground Resources within 0.5 miles of Alternative 5b1 (Old Town Alexandria).

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

Table 2-9. Archaeological and architectural/above-ground resources within 0.5 miles of Alternative 5c (Belle Haven).

VDHR ID	Resource Name	NRHP Eligibility
029-0218	GWMP	NRHP Listed
029-0228-0131	Mount Vernon Trail	Potentially NRHP 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 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 2-10 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 2-10. 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
Westgrove 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 2-11 identifies the per-capita spending on parks and recreation for each jurisdiction in the study area.

Table 2-11. 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).

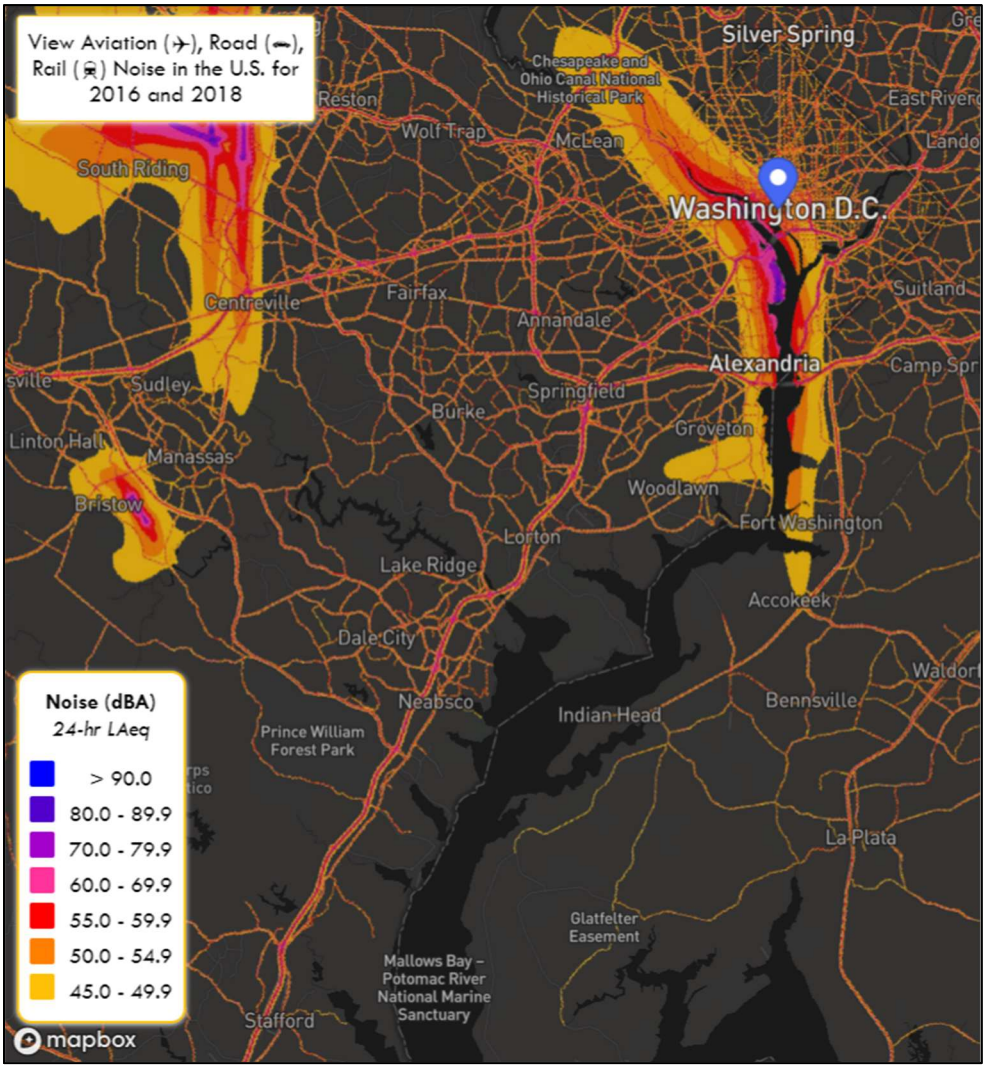

Figure 2-2. Noise Map of Northern Virginia and Washington D.C. from the Bureau of Transportation Safety.

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, 2016; 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 Economically Disadvantaged Communities

2.4.11.1 Existing Condition

Portions of the study area are identified as economically disadvantaged communities. The USEPA EJ Screen was used to identify 141 census block groups identified as economically disadvantaged communities within the study area using the following methods (USEPA, 2022c).

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:

Economically Disadvantaged Community. An economically disadvantaged community is defined as meeting one or more of the following:

a. Low per capita income - The area has a per capita income of 80 percent or less of the national average.

b. Unemployment rate above national average - The area has an unemployment rate that is, for the most recent 24-month period for which data are available, at least 1 percent greater than the national average unemployment rate.

c. Indian country as defined in 18 U.S.C. 1151 or in the proximity of an Alaska Native Village.

d. U.S. Territories; or

e. Communities identified as disadvantaged by the Council on Environmental Quality's Climate and Economic Justice Screening Tool (USACE, 2023).

For purpose of this analysis, a community with a disproportionate percentage of *any* of the following populations may be considered an economically disadvantaged 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 percent 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 percent of the federal poverty line (Figure 2-4). For a household of 4 people, the 200 percent 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).

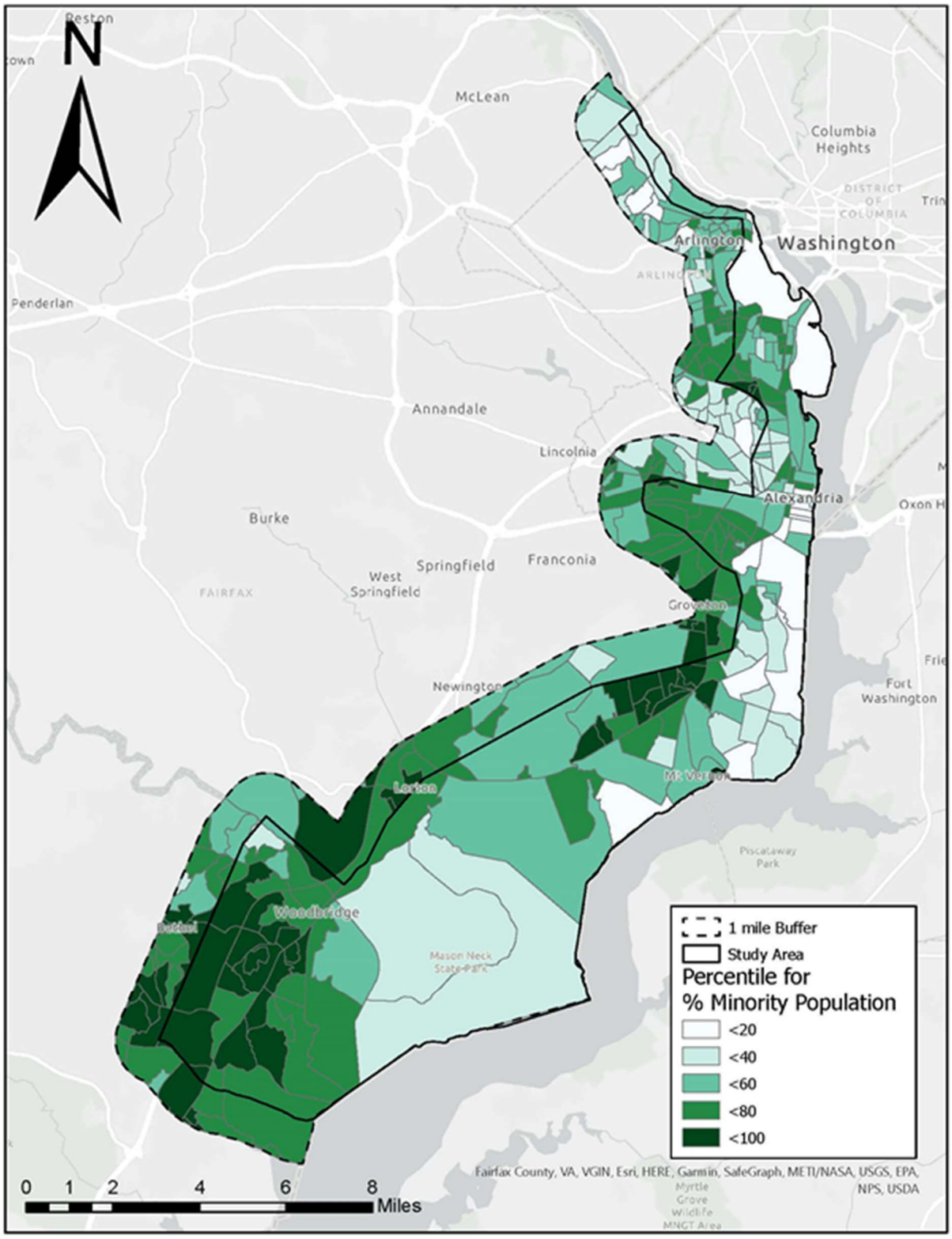

Figure 2-3. Census block groups in the study area and within a 1-mile buffer of the study area and the percent people of color population (percentile) in each census tract (USEPA, 2022c).

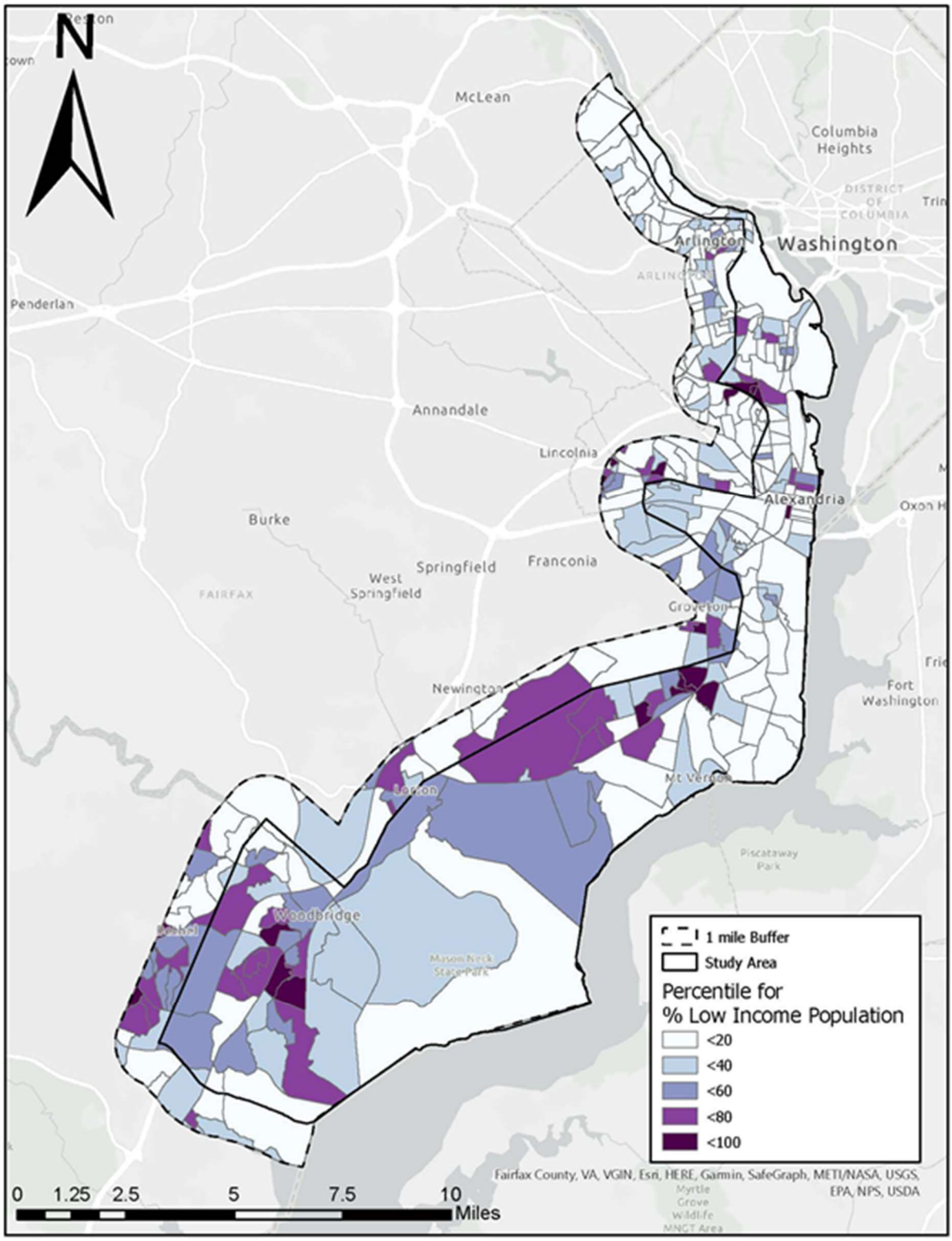

Figure 2-4. Census block groups in the study area and within a 1-mile buffer of the study area and the percent low-income population (percentile) in each census block (USEPA, 2022c).

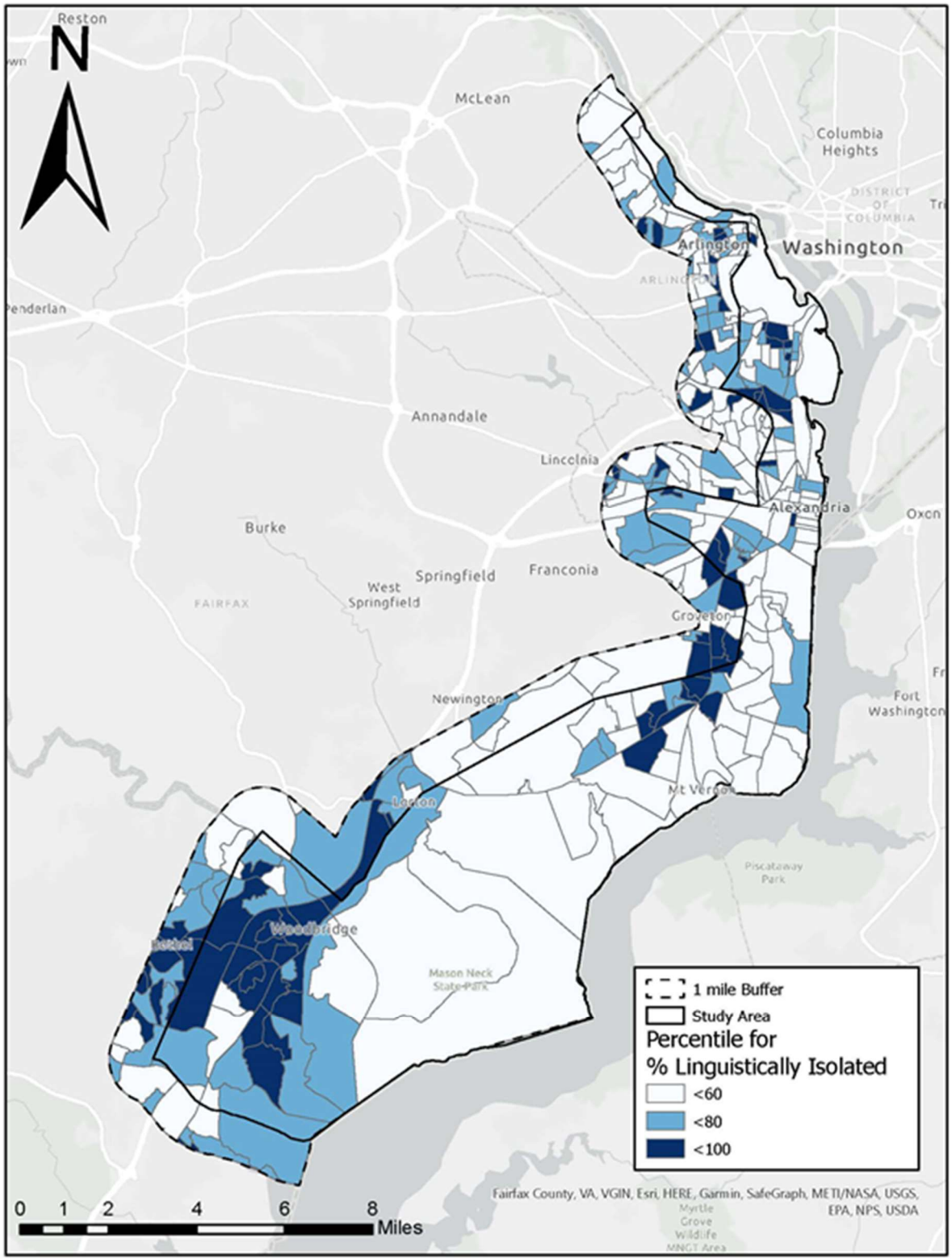

Figure 2-5. Census block groups in the study area and within a 1-mile buffer of the study area and the percent linguistically isolated population (percentile) in each census block (USEPA, 2022c).

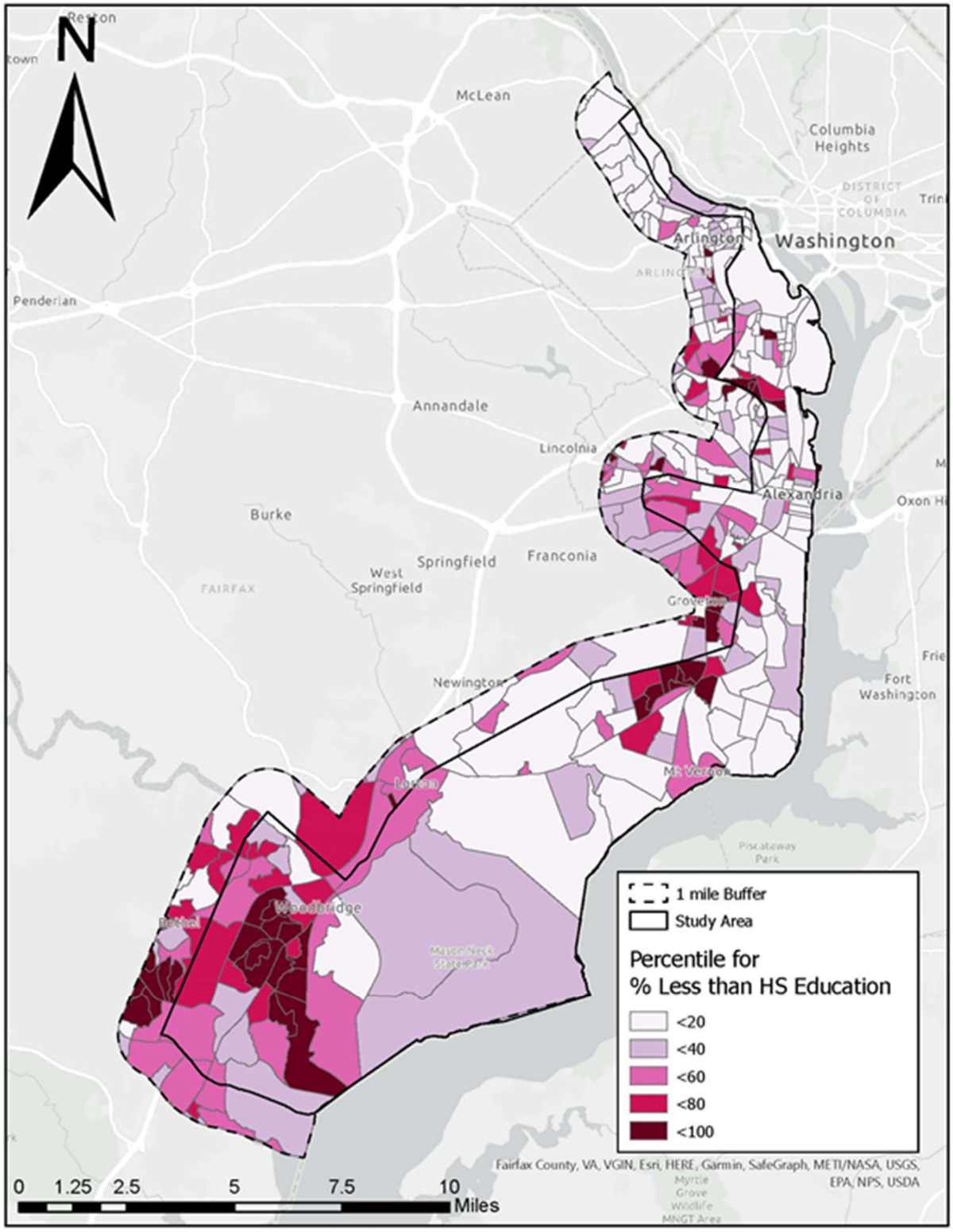

Figure 2-6. Census block groups in the study area and within a 1-mile buffer of the study area and the percent population with less than a high school education (percentile) in each census block (USEPA, 2022c).

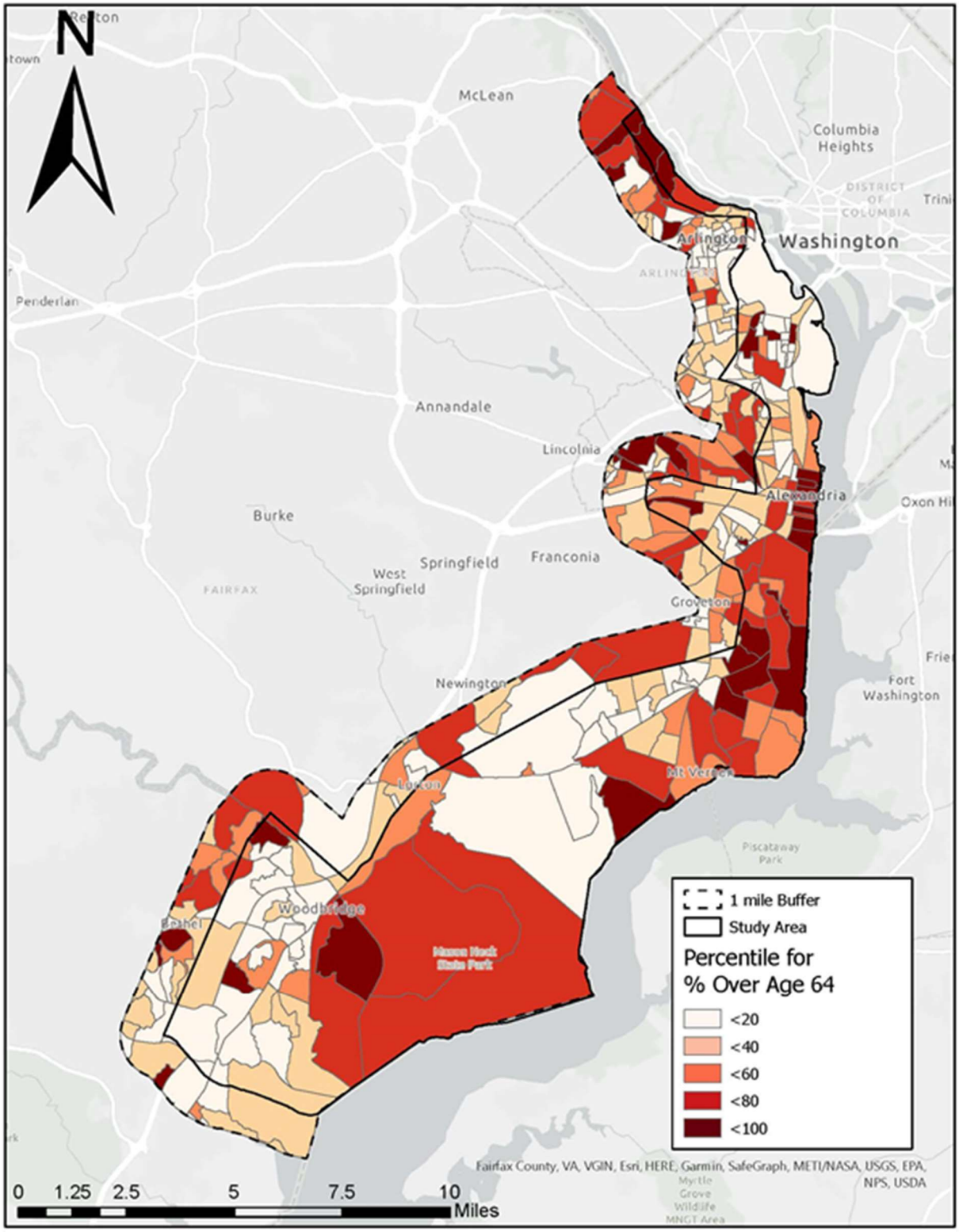

Figure 2-7. Census block groups in the study area and within a 1-mile buffer of the study area and the percent population over age 64 (percentile) in each census block (USEPA, 2022c).

These 141 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 2-12 below.

Table 2-12. 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 census block communities and all census blocks in the study area plus 1-mile buffer in Table 2-13 below:

Table 2-13. Average Percent of Population for Demographic Indicators in Economically Disadvantaged Communities and the Study Area Plus 1-mile Buffer.

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

Traffic Noise

The economically disadvantaged 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 economically disadvantaged communities outlined in yellow. Many of the 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 communities located adjacent to major interstates are likely affected by higher-than-average noise levels.

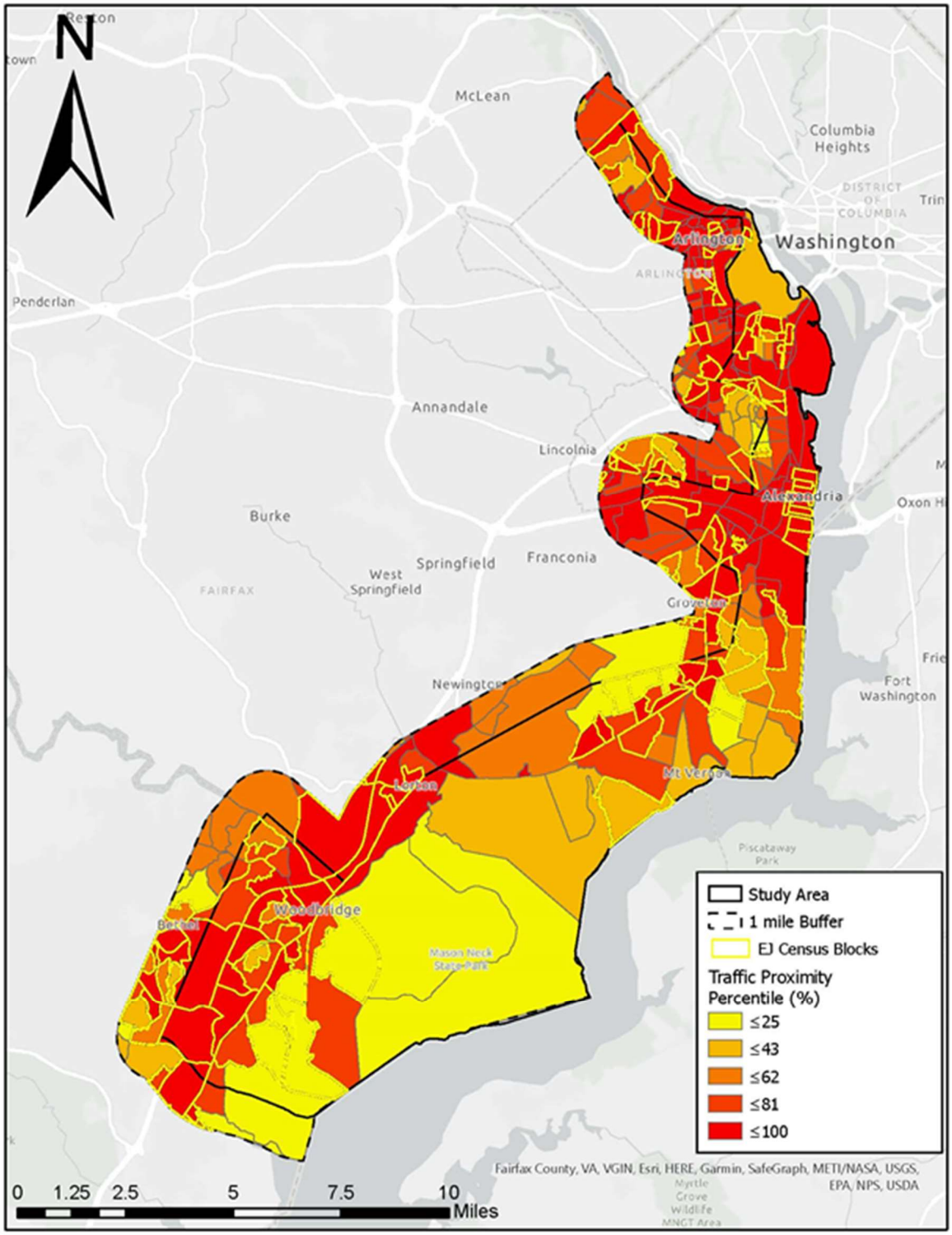

Figure 2-8. Economically disadvantaged communities census block groups proximity to traffic (USEPA, 2022c).

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 economically disadvantaged communities' and their exposure to ozone in percentiles. In general, the communities located closer to Washington D.C. have a higher exposure to ozone than the communities located farther away from the city center.

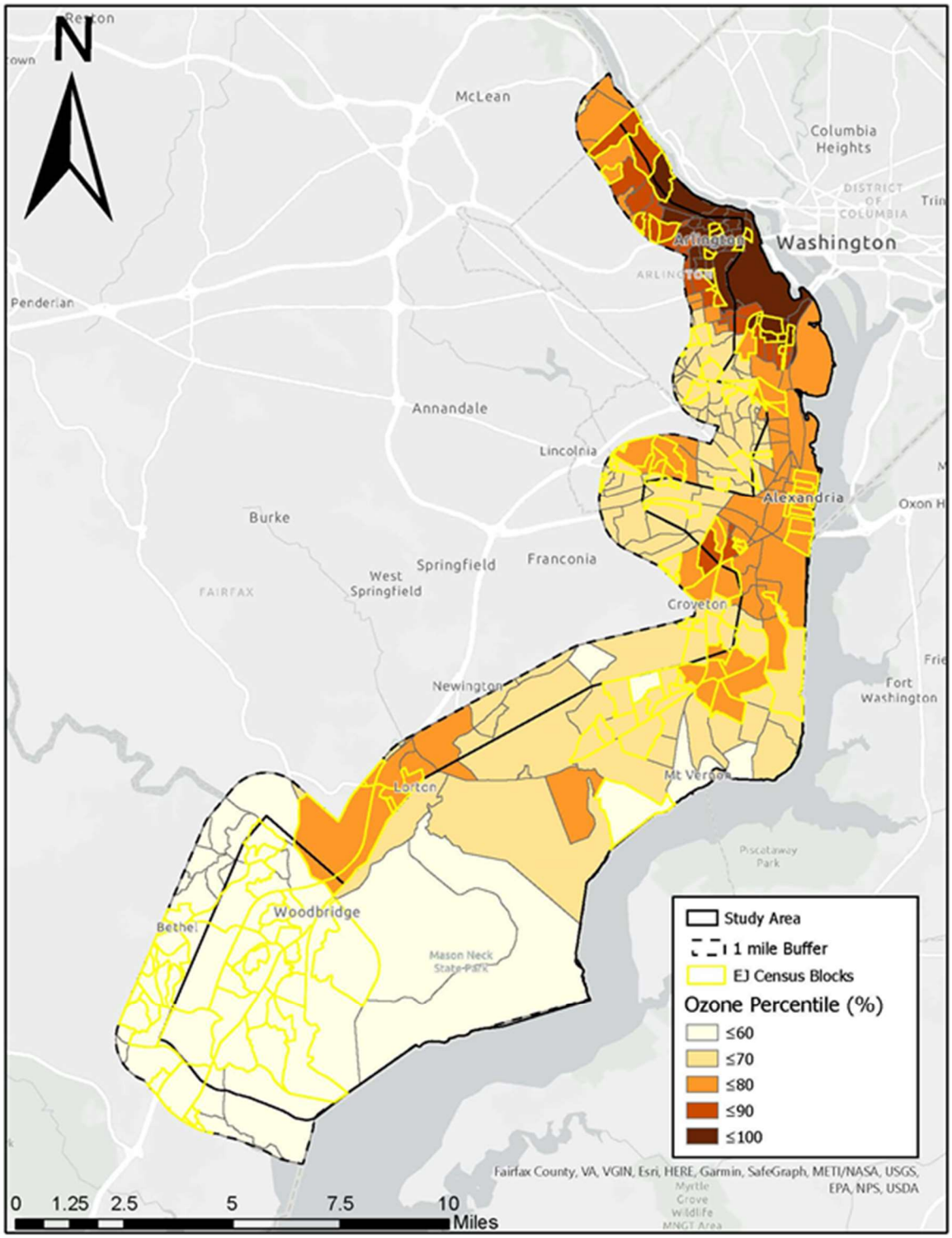

Figure 2-9. Economically disadvantaged communities census block groups and their exposure to ozone (USEPA, 2022c).

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 economically disadvantaged communities' and their proximity to hazardous waste treatment, storage, and disposal facilities. In general, the communities located closer to Washington D.C. have a higher exposure to hazardous waste facilities.

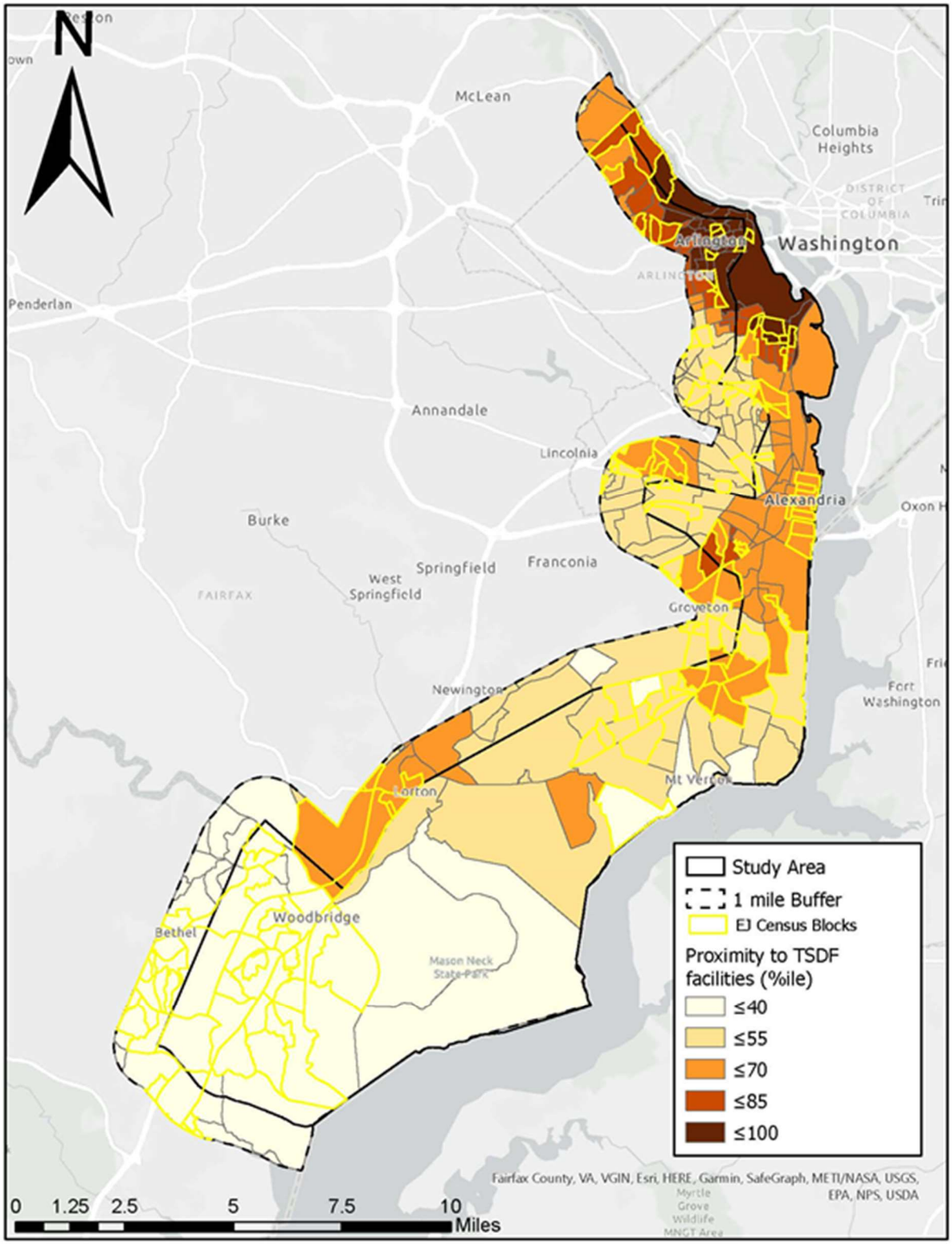

Figure 2-10. Economically disadvantaged communities census block groups and their exposure to hazardous waste treatment, storage, and disposal facilities (USEPA, 2022c).

In summary, economically disadvantaged communities 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 census blocks and all census blocks in the study area plus one mile buffer can be found in Table 2-14 below:

Table 2-14. Average Percentiles for Analyzed Environmental Indicators in the economically disadvantaged communities 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

Without flood risk management measures, economically disadvantaged communities are more vulnerable to the effects of coastal flooding. Vulnerability studies show that these communities are less likely to use measures to mitigate the effects of flooding at their residences prior to a storm, evacuate prior to a storm, return home/work after a storm, or use other measures to mitigate the effects of flooding such as purchasing flood insurance and utilizing emergency response information and post-disaster assistance (Collins et al, 2018).

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)
- *Justice40 Initiative* – A Whole-of-Government initiative to help achieve the target to deliver at least 40 percent of overall benefits from federal investments in climate and critical clean water and waste infrastructure to disadvantaged communities. https://www.whitehouse.gov/environmentaljustice/justice40/ (The White House, 2022)

2.4.12 Prime and Unique Farmland

2.4.12.1 Existing Condition

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses. It could be cultivated land, pastureland, forestland, or other land, but is not urban or built-up land or water areas (USDA, n.d.). Approximately 19 percent of the study area contains soils that qualify as prime farmland or farmland of statewide importance. Refer to the DC Coastal Study Area Web Soil Survey in Appendix G (A14) for a list and acreages of soil types identified as prime farmland or farmland of statewide importance located in the study area.

Unique farmland is land other than prime farmland that is used to produce specific high-value food and fiber crops such as citrus, tree nuts, olives, cranberries, and other fruits and vegetables (USDA, n.d.). No unique farmland was identified in the study area.

2.4.12.2 FWOP Condition

Statistics show a significant loss of farmland since Virginia's early history. Most of the Commonwealth was historically covered with farmland. In 1960, 13.5 million acres of Virginia's 25 million acres remained as farmland. In 2012, Virginia had 8.3 million acres of farmland, a loss of five million acres in 52 years. The need for agricultural land and the businesses it supports is needed now and in the future. The Virginia Department of Agriculture and Consumer Services (VDACS) Office of Farmland Preservation provides programs and tools to help reverse the loss of Virginia's farmland (VDACS, 2022).

2.5 Economic Environment

2.5.1 Existing Conditions

2.5.1.1 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). 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, 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.

2.5.1.2 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 2-15. 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 WPCP, infrastructure at the Reagan National Airport, and debris clean-up costs 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: Economics.

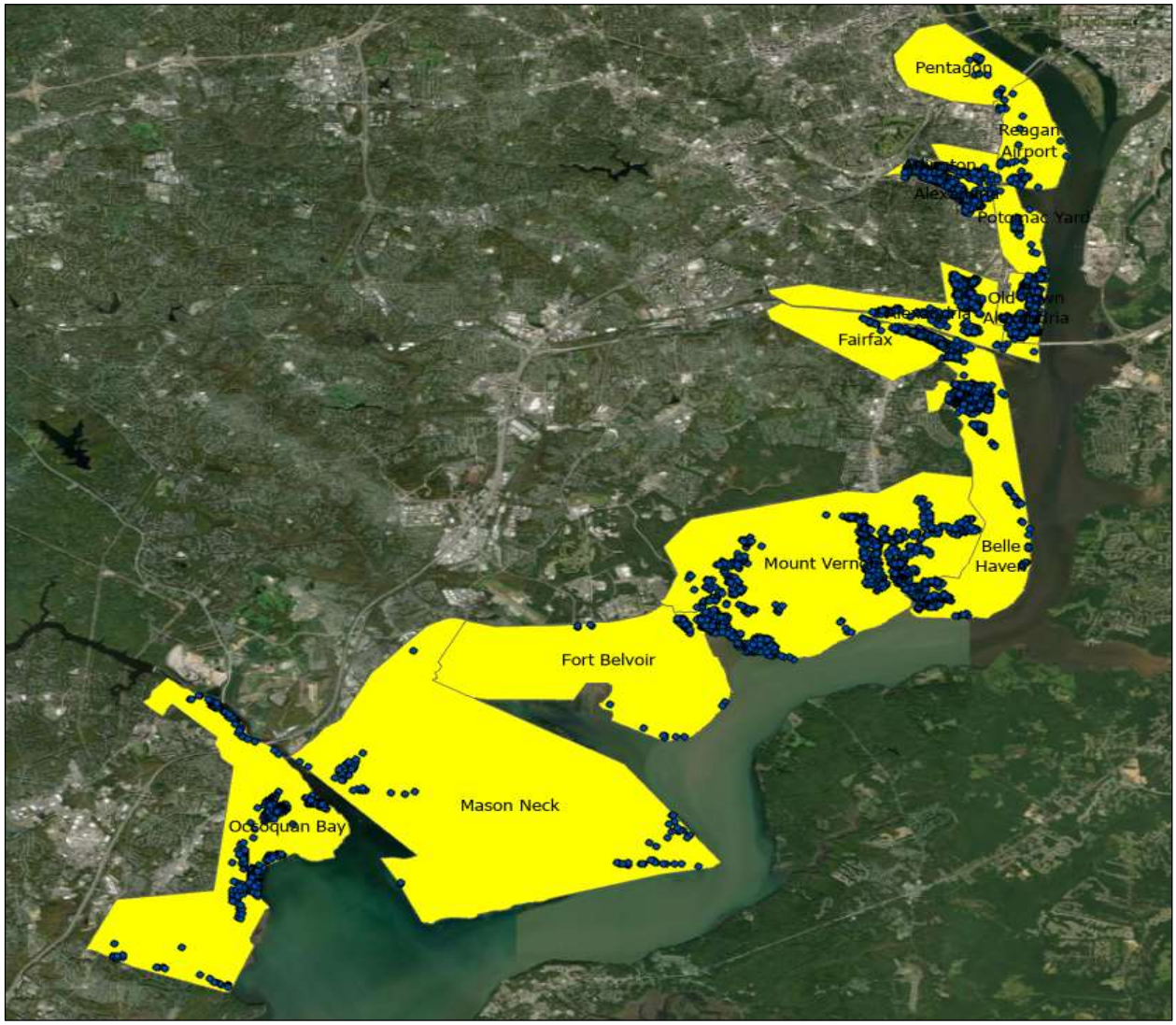

Figure 2-11. Location of Assets by Model Areas.

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. Occupancy type codes are defined in Tables 2-16 and 2-17.

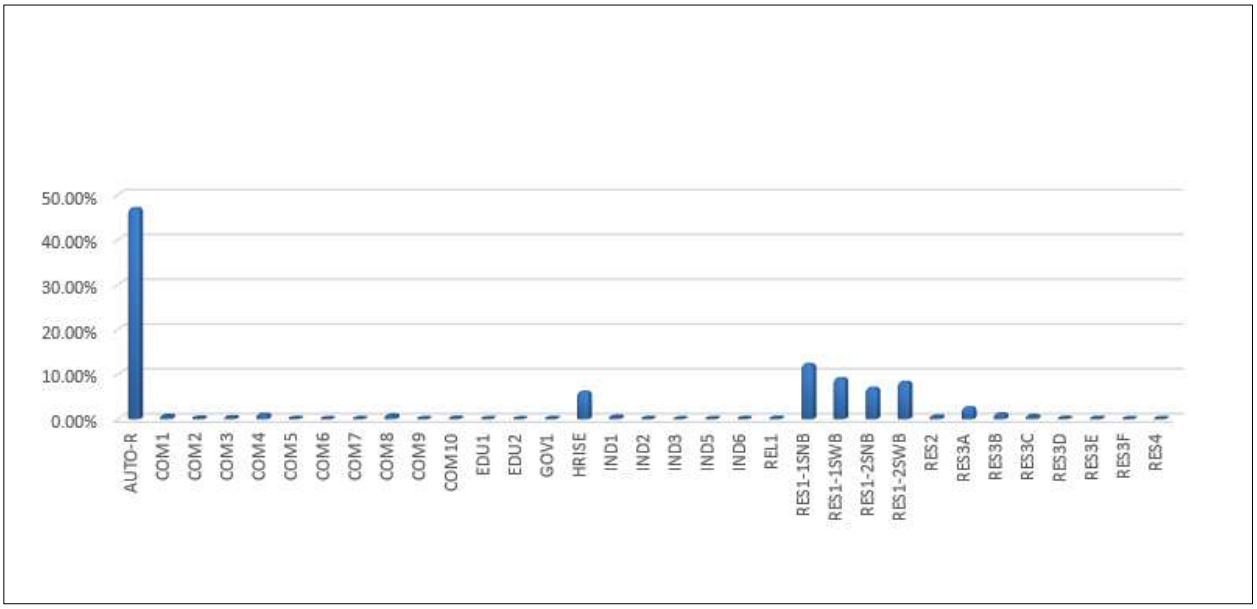

Figure 2-12. Proportion of Occupancy Types in the Northern Virginia Study Area.

2.5.1.2.1 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 2-16, 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 2-16. Content-to-Structure Value Ratios (CSVRs).

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

2.5.1.2.2 Summary of the inventory

The assets were categorized as residential or nonresidential and were further categorized into occupancy types. Table 2-17 displays the count and structure value by occupancy type.

Table 2-17. 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

2.5.1.3 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.

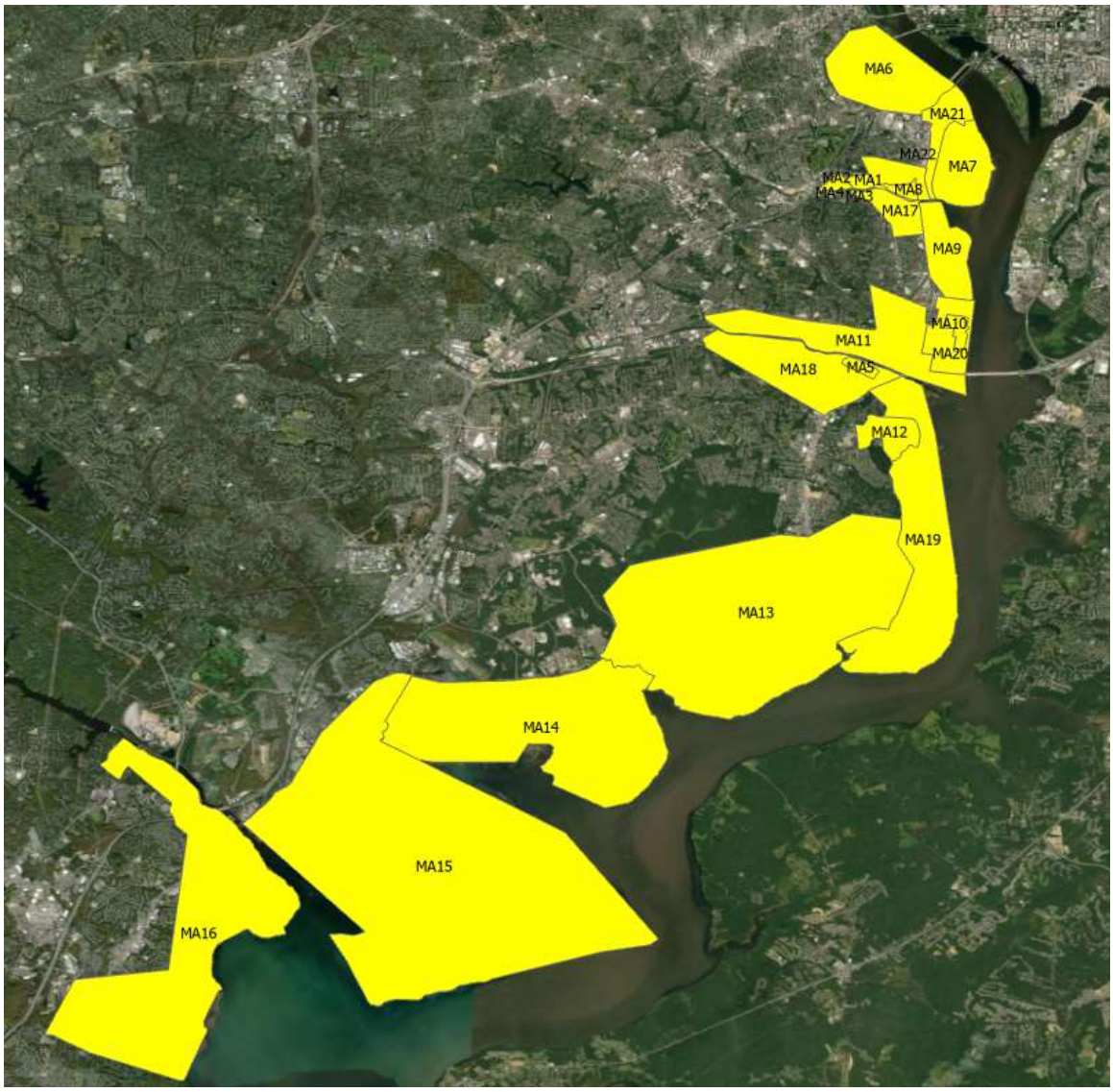

Figure 2-13. Model Area Boundaries and their Description.

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 established for later modeling 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 bulkhead is currently under construction in MA10, by the City of Alexandria. Table 2-18 shows model area type for each model area.

Table 2-18. 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

2.5.1.4 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 the 22 MAs described above. Additional information on volume stage functions can be found in Appendix E: Economics.

2.5.1.5 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 daily. 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 sometimes 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 feet 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 a MA, which is then assigned to an EPZ and then modeled in G2CRM for potential life loss given a storm event.

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. For life loss calculations to be made, the maximum stage in the modeled area must 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 data from flooding.

2.6 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, CSRM 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 of 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 through Huntington Park. The levee has length of 2,900 ft and provides risk reduction from a 0.1 percent annual exceedance probability (AEP) event with approximately 95 percent confidence level.

Belle Haven/New Alexandria Tide Gates – Existing non-Federal CSRM 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 reduces risk to 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 if 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 CSRM 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

CSRM 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 percent AEP storm. 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 was completed in May 2023.

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 underway and is anticipated to be completed in 2025.

While not CSRM infrastructure, another notable piece of infrastructure in the study area is:

Arlington Water Pollution Control Plant (WPCP)- The Arlington WPCP is a wastewater treatment plant located on South Glebe Road in Arlington, Virginia with capacity to treat up to 40 million gallons per day. The Arlington WPCP receives and treats wastewater from most of Arlington County, and portions of Fairfax County, Falls Church, and Alexandria; a population of more than 220,000 people. The area is densely populated with a mix of residential, institutional, and commercial customers. The Ronald Reagan Washington National Airport (National Airport), and federal facilities in Arlington, such as the Pentagon, Navy Annex and Fort Myer, operate their own collection systems and pump their wastewater into the Arlington WPCP for treatment. The WPCP also conveys flow from a portion of Alexandria to Fairfax County – these flows are then conveyed to the Blue Plains Sewage Treatment Plant in Washington, D.C. The Blue Plains Sewage Treatment Plant is currently constructing a +17-foot NAVD88 floodwall (top elevation of wall) to manage risk to the plant from flooding from a 500-year storm (DC Water, 2021).

The Arlington WPCP has capacities to hold and redirect flows during storm events using existing pump infrastructure. If WPCP infrastructure is damaged or chemicals to treat the water are not available, wastewater would flow through the plant without any treatment and into Four Mile Run/Potomac River. There is no backup treatment facility. In a disaster scenario, the WPCP would send partially treated or untreated wastewater directly into Four Mile Run.

2.6.1 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 average annual 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 using Monte Carlo simulation and a total of 100 iterations were executed by the model for this analysis. Every iteration represents expected average annual 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 average annual damages for that modeled simulation. A mean and standard deviation were automatically calculated for the average annual damages for each MA.

2.6.2 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.

2.6.2.1 Sea Level Change

The DC Coastal 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. This average is evaluated based on the middle of the current tidal epoch – year 1992. As per ER 1100-2-8162 and EP 1100-2-1, regional sea level change is an increase or decrease in the mean level of the ocean's surface over a specific region. 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 2-19, Table 2-20, and Figure 2-14, based on the records at the NOAA gauge 8594900 at Washington D.C., the closest to the Northern Virginia area.

Table 2-19. Sea Level Change Projection.

Year	USACE Low	USACE Int	USACE High
2030	0.54	0.67	1.08
2035	0.6	0.76	1.28
2040	0.65	0.85	1.5
2045	0.7	0.95	1.74
2050	0.75	1.05	2
2055	0.8	1.16	2.28
2060	0.86	1.27	2.57
2065	0.91	1.38	2.88
2070	0.96	1.5	3.21
2075	1.01	1.62	3.56
2080	1.06	1.75	3.93
2085	1.11	1.88	4.32
2090	1.17	2.02	4.73
2095	1.22	2.16	5.15
2100	1.27	2.31	5.59
2105	1.32	2.46	6.06
2110	1.37	2.61	6.54
2115	1.43	2.77	7.03
2120	1.48	2.93	7.55
2125	1.53	3.1	8.09
2130	1.58	3.27	8.64

*SLC projections at Washington D.C. Shores, in feet relative to NAVD88, using 1992 as base year.

Table 2-20. Without Project Existing and Future Conditions Water Surface Elevations

Annual Chance Exceedance in %	WSEL in NAVD88	Change in WSEL between 1992 to 2030	Existing Condition WSEL in Base Year, 2030	Future Condition (2080) WSEL with Low Rate of SLC	Future Condition (2080) WSEL with Intermediate Rate of SLC	Future Condition (2080) WSEL with High Rate of SLC
100	2.5	0.67	3.1	3.5	4.2	6.4
50	3.6	0.67	4.3	4.7	5.4	7.5
20	5.4	0.67	6.1	6.5	7.2	9.4
10	6.6	0.67	7.2	7.6	8.3	10.5
5	7.5	0.67	8.1	8.5	9.2	11.4
2	8.5	0.67	9.1	9.5	10.2	12.4
1	9.2	0.67	9.9	10.3	10.9	13.1
0.5	10.1	0.67	10.8	11.2	11.9	14.1
0.2	11.6	0.67	12.3	12.7	13.3	15.5
0.1	12.2	0.67	12.9	13.3	14.0	16.2
0.05	12.8	0.67	13.4	13.8	14.5	16.7
0.02	13.4	0.67	14.1	14.5	15.2	17.3
0.01	13.8	0.67	14.4	14.8	15.5	17.7

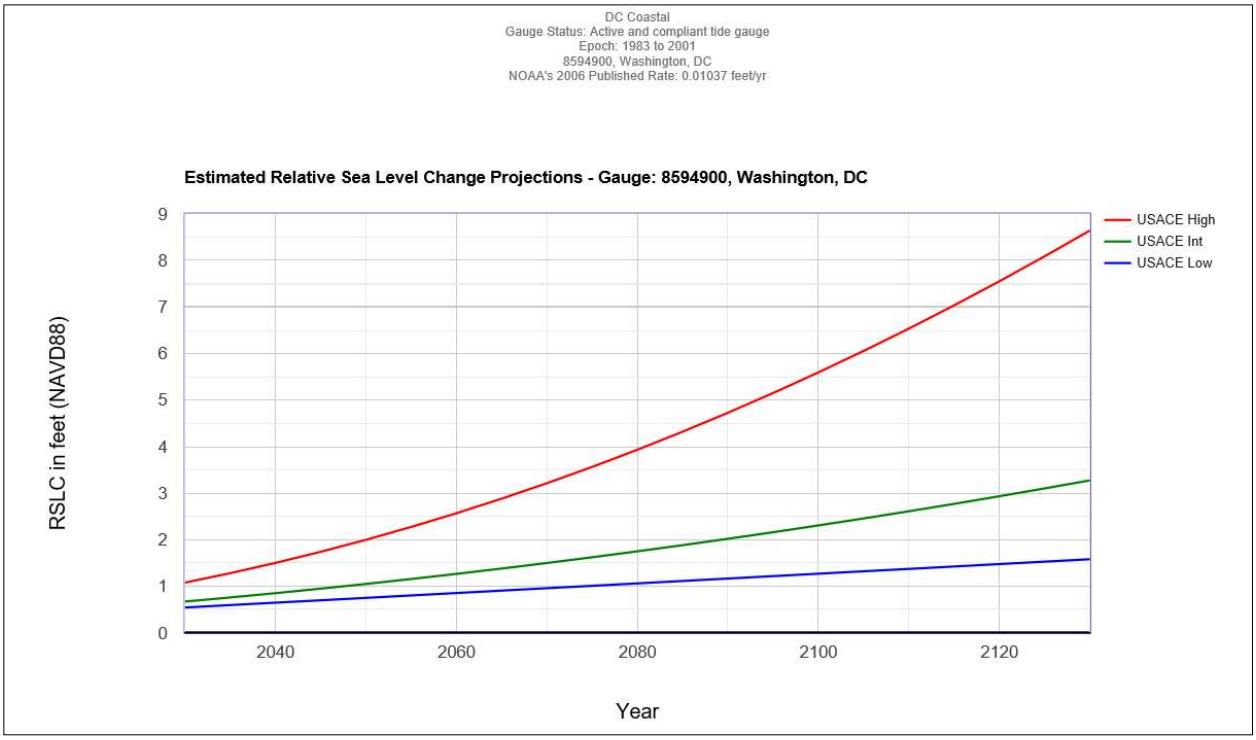

Figure 2-14. Sea Level Change.

To address the flooding problems in the region, coastal flood mitigation infrastructure is currently being designed and constructed in Northern Virginia. The City of Alexandria is currently designing a six-foot (ft) NAVD 88 bulkhead to address a 10 percent AEP storm along the waterfront. Approximately half of the floodwall is already in place. The design of the second half is underway and construction completion is anticipated in 2027. The feasibility study will evaluate the performance of existing infrastructure with the purpose of reducing coastal flooding. The FWOP condition analysis will consist of a comparison of WSELs to top of existing CSRM 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.

2.6.2.2 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 2-21 and Figure 2-15 display the expected average annual damages anticipated to accrue to these structures. In addition, Table 2-20 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 2-21. FWOP Condition Expected Annual Damages by MA.

Model Area	Average Annual Damages
MA1: Four Mile Run Protected Arlington East	$0
MA2: Four Mile Run Protected Arlington West	$0
MA3: Four Mile Run Protected Alexandria East	$54,000
MA4: Four Mile Run Protected Alexandria West	$0
MA5: Cameron Run Protected Huntington Levee	$0
MA6: Pentagon Unprotected	$2,000
MA7: Reagan National Airport Proposed Bulkhead	$76,000
MA8: Four Mile Run Arlington Proposed Bulkhead	$200,000
MA9: Potomac Yard Unprotected	$120,000
MA10: Old Town Alexandria Proposed Bulkhead	$2,008,000
MA11: Cameron Run Alexandria Unprotected	$205,000
MA12: Belle Haven Proposed Bulkhead	$2,602,000
MA13: Mount Vernon Unprotected	$948,000
MA14: Fort Belvoir Unprotected	$38,000
MA15: Mason Neck Unprotected	$318,000
MA16: Occoquan Bay Unprotected	$1,562,000
MA17: Four Mile Run Alexandria Proposed Bulkhead	$124,000
MA18: Cameron Run Fairfax Unprotected	$29,000
MA19: Fort Hunt Unprotected	$545,000
MA20: Old Town Alexandria Unprotected	$524,000
MA21: Reagan National Airport Unprotected	$677,000
MA22: Four Mile Run Arlington Unprotected	$1,142,000
Total	$11,174,000

G2CRM used Monte Carlo simulation to derive the expected average annual 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 average annual damages for that modeled simulation. A mean and standard deviation were automatically calculated for the average annual damages for each MA to account for uncertainty. These average annual damages for each MA were summed to derive the study area expected average annual damages.

The forecasted SLR in the future, without a project in place, resulted in higher expected average annual damages. The total future "without-project" average annual 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.

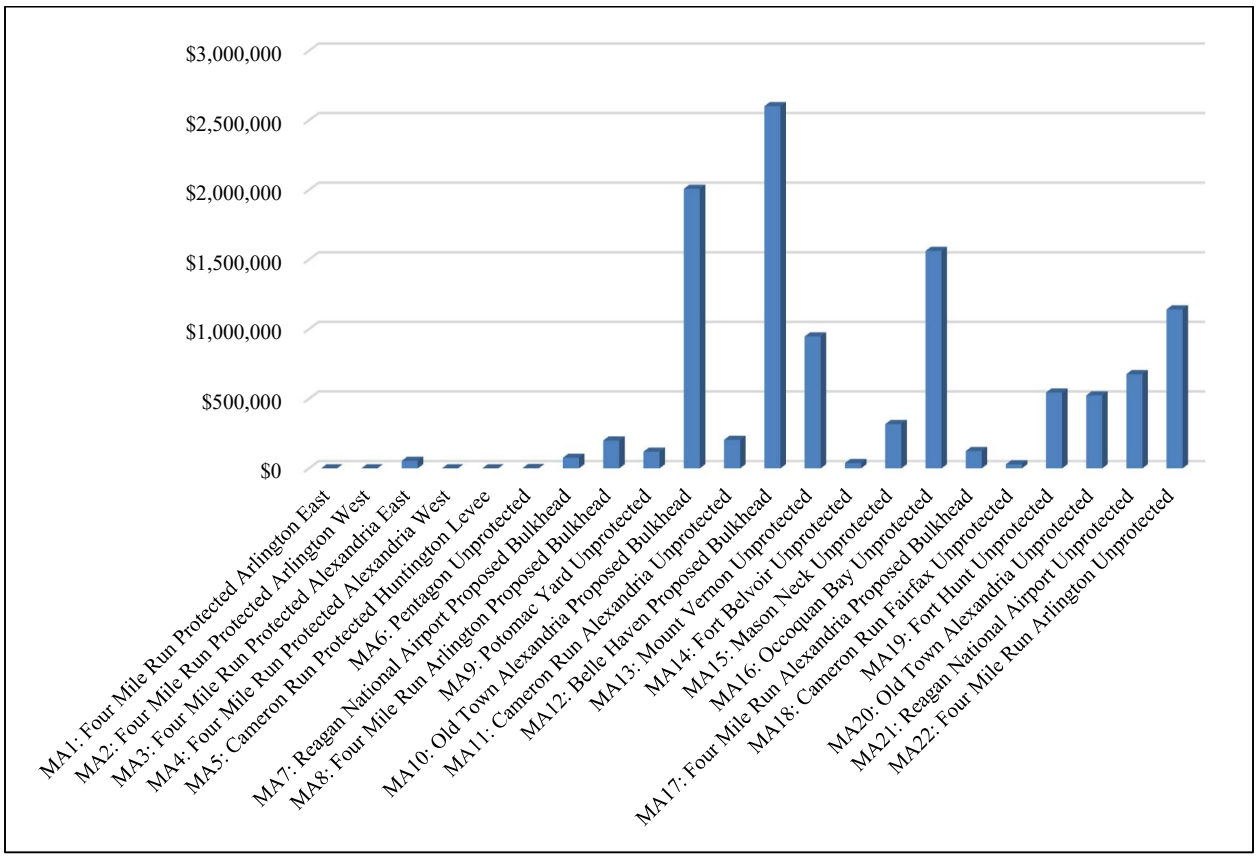

Figure 2-15. FWOP Condition Expected Annual Damages by MA.

3 Plan Formulation and Evaluation*

3.1 Plan Formulation and Evaluation

Plan formulation has been conducted to identify a proposed action that meets the goals and objective of the Civil Works Program of the USACE which is to promote prosperity and democracy and to strengthen national security through the development, management, protection, and enhancement of the Nation's water and related land resources for flood damage reduction, commercial navigation, environmental restoration, and allied purposes. The proposed action is evaluated for maximum total net benefits contributing to National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE).

Structural CSRM measures are man-made, constructed measures that counteract a flood event 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 reduce risk to 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, acquisition, and floodproofing are examples of physical nonstructural measures. Some examples of non-physical nonstructural measures, include flood warning systems, flood insurance, floodplain mapping, flood emergency preparedness plans, land us regulations, zoning, evacuation plans, and risk communication. NNBF CSRM measures work with or mimic natural processes with the aim of wave attenuation and storm surge inundation.

Sea level rise (SLR) was evaluated across multiple modeling scenarios utilizing the USACE intermediate curve of 1.75 feet for the year 2080. It is broadly recognized that SLR is above historical trends (low curve), so it was decided that the low curve was not appropriate for this study. There is a great deal of uncertainty regarding future sea level rise trend. Historic sea level change is captured in the USACE low sea level rise scenario. The performance of the recommended plan was also evaluated under all three SLC curves. The level of performance is based on the 1 percent and 0.2 percent AEP storm with approximately 95 percent confidence level and intermediate SLC curve through year 2080. Further information on Sea Level Trends is discussed in Sections 5.1.2 and 5.6.1 and Appendix B: Hydraulics and Hydrology.

This chapter lays out an iteration of the plan formulation process with later sections building upon the former as alternatives are evaluated, screened and compared to determine first the TSP and then the Recommended Plan.

3.2 Planning Process

The planning process 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 certified model used to analyze the inundation damages. The optimization analysis for the Recommended Plan (after ADM) was conducted using the fiscal year 2023 discount rate of 2.50 percent (October 2022 price level). Then the final iteration of Recommended Plan cost and economic analysis was updated to fiscal year 2024 discount rate of 2.75 percent (October 2023 price level). The base year is 2031. Although the base year is set at 2031 based on the TSP, there is possibility that benefits could start accruing as early as 2029 for the Recommended Plan depending on when construction is completed. Only one of the two separable elements of the Recommended Plan are currently recommended to move forward into further analysis in Pre-Construction Engineering and Design (PED), so the projected construction time is now shorter than if both elements were moving forward at this time. Thus, the possibility for benefits to accrue before 2031.Additional details on Recommended Plan selection are in Section 5 of this report.

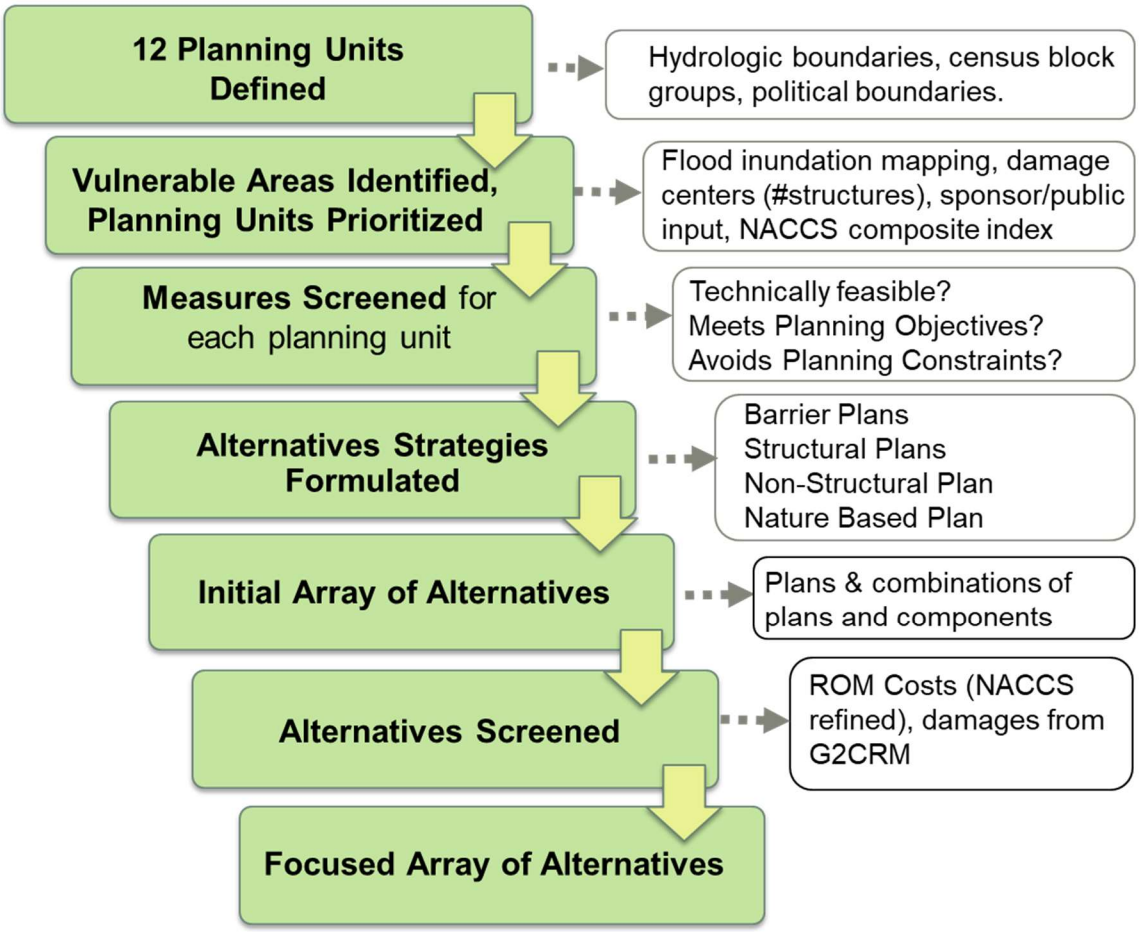

Figure 3-1. Plan Formulation Process for Developing Alternatives.

Eighteen measures were identified and screened down to 13 which were compared against the 12 planning units to determine measure viability by location. Combining measures into alternatives yielded 14 alternatives in the initial array with 5 screened out during the ROM cost and benefits analysis. Nine alternatives were carried into the focused array with one additional alternative added for Alexandria to evaluate a deployable floodwall system. Ten alternatives were carried into the final array and evaluated and compared to determine the TSP.

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. Each planning unit is shown in Figure 3-2. The study area was divided into 12 planning units. The planning units were defined based on hydrologic boundaries, political boundaries, and census block groups. A vulnerability assessment was conducted between January-April 2022 and the results are discussed in Section 3.4.

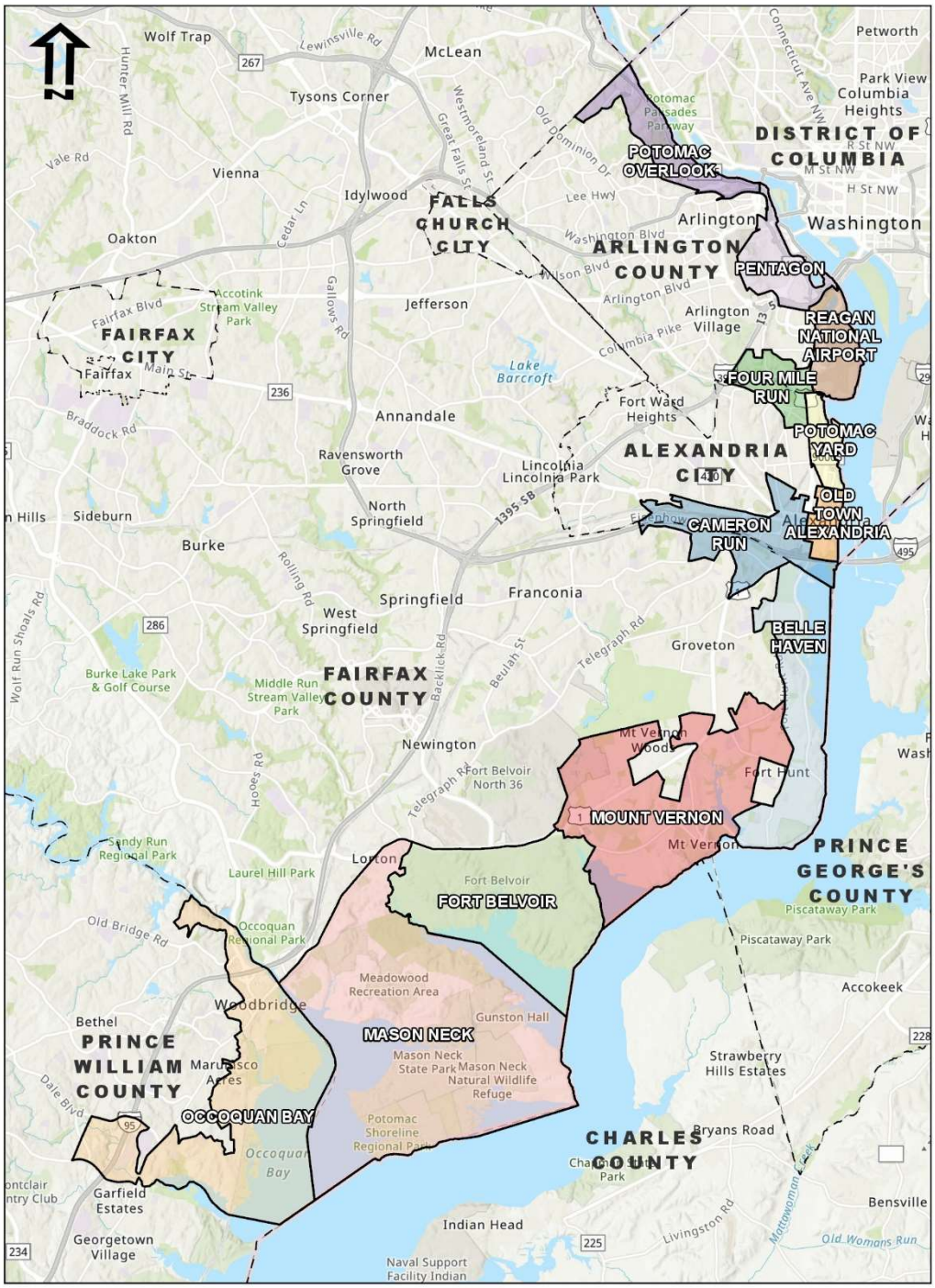

Figure 3-2. Planning units in the study area.

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. NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model maximum inundation extent for the Category 4 storm was used to identify structures inundated by storms and it was determined that no structures were at risk in this area. The SLOSH Maximum of Maximums model exceeds the 0.2 percent AEP storm.

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 storm, only the shoreline along the Potomac is inundated, which includes inundation of the GWMP and the interchanges at the I-395 Bridge. For the 0.2 percent AEP storm, 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 storm 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 storm 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. 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 storm for FWOP conditions with sea level change would result in extensive impacts to Reagan National Airport, including most 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 would be 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 storm, 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 WPCP between Four Mile Run and South Glebe Road is largely inundated.

For the 0.2 percent AEP storm, existing and FWOP, inundation in Four Mile Run Park is even more extensive, extending further south and west, and 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 WPCP.

Arlington County owns the Arlington WPCP. The plant treats wastewater each day for residential and commercial structures, and services multiple jurisdictions including Arlington County (population of 232,965 (2021)), Alexandria County (population of 154,706 (2021)), Fairfax County (population of 1.14 million (2021)) and Falls Church (population of 14,493 (2021)). Of the approximate 1.5 million in total population of the 4 municipalities, the Arlington WPCP serves a portion, approximately 220,000 people. The plant's mission is to safely and economically process wastewater and hazardous waste materials to protect the environment: especially Four Mile Run, the Potomac River, and the Chesapeake Bay. All four of the above planning units are depicted in Figure 3-3.

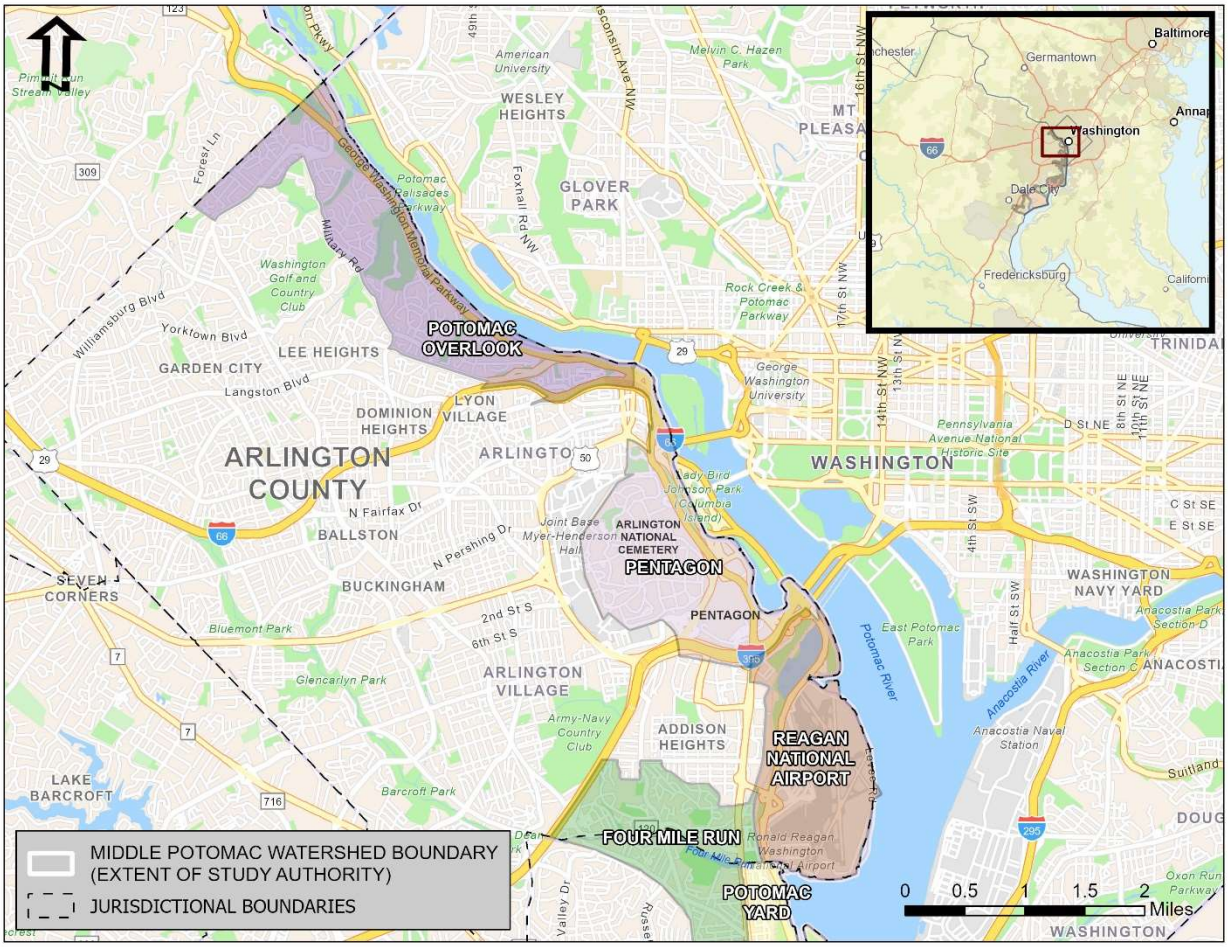

Figure 3-3. Planning Units- Potomac Overlook, Pentagon, Reagan Airport and Four Mile Run.

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 storm 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 storm, with or without SLR.

Old Town Alexandria

The Old Town Alexandria 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 storm 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 storm, 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 storm. 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, 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 reduce risk to this area, including single family residences south of Huntington Park.

Flood inundation for the 1 percent AEP storm 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 storm are similar. Figure 3-4 shows the planning unit areas for Potomac Yards, Old Town Alexandria, and Cameron Run.

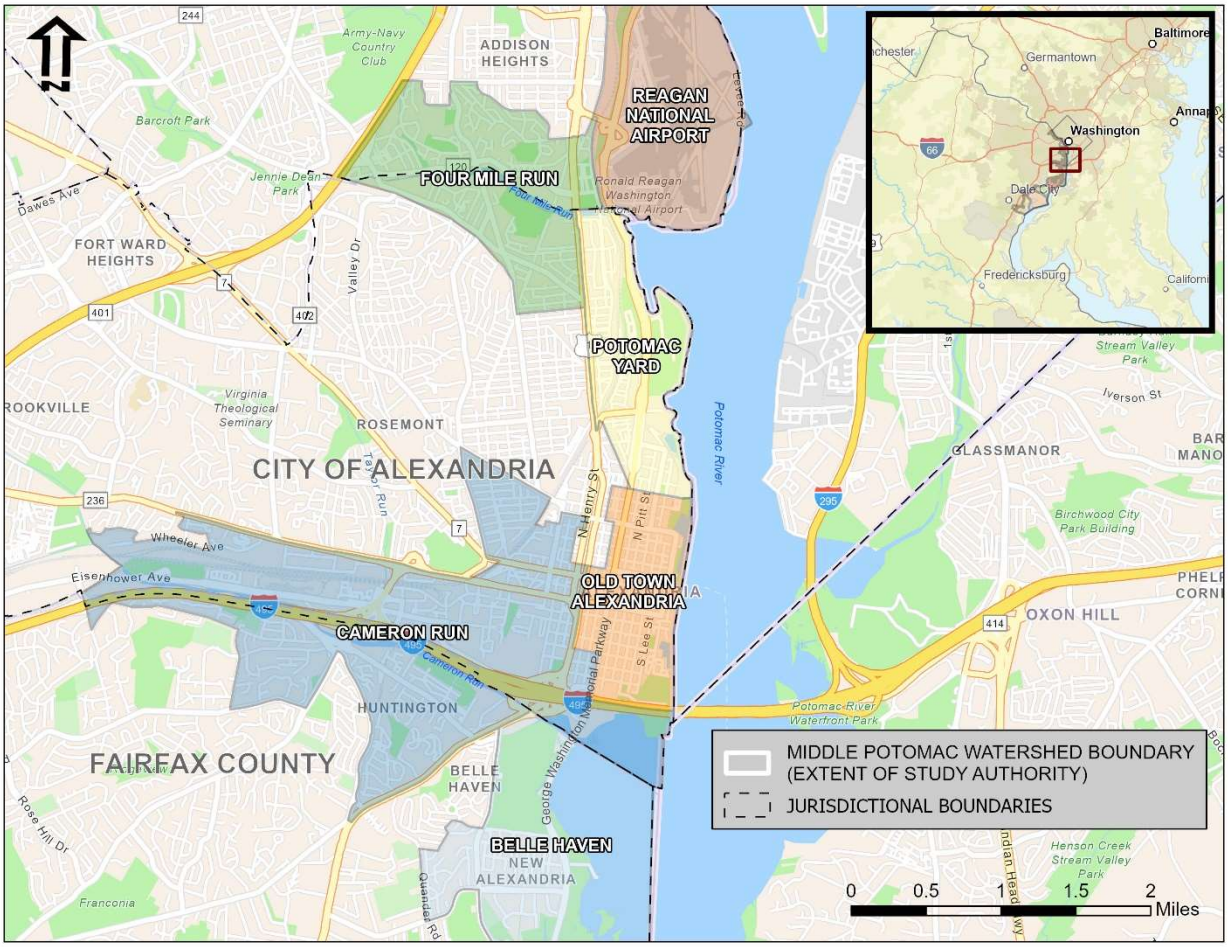

Figure 3-4. Planning Units- Potomac Yards, Old Town Alexandria, Cameron Run.

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 storm, 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 event existing and FWOP condition, with similar impacts for the 0.2 percent AEP event.

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 NFS, 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 storm and 0.2 percent AEP storm 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. The planning units for Belle Haven and Mount Vernon are shown in Figure 3-5.

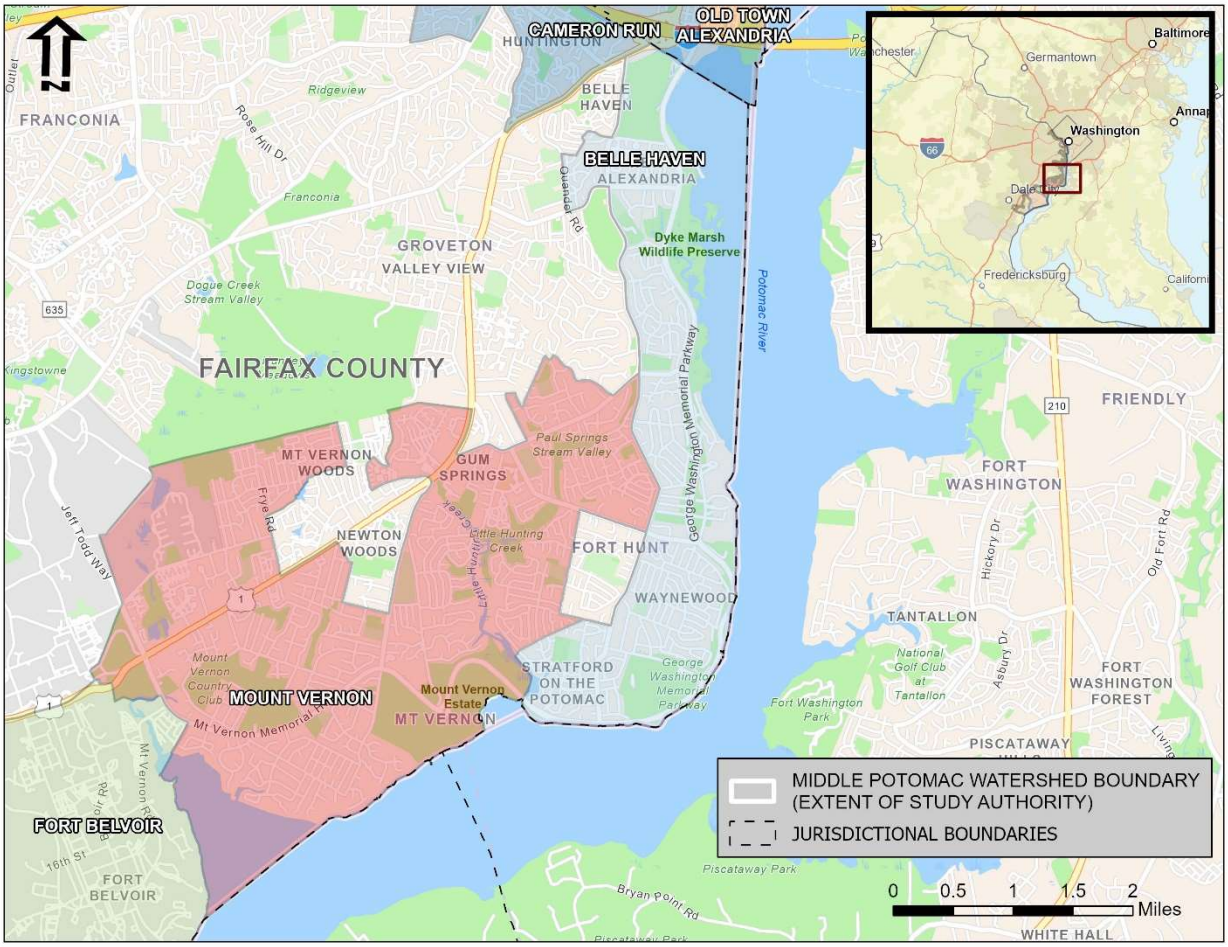

Figure 3-5. Planning Units – Belle Haven and Mount Vernon.

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 storm) 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 that 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 storm). The planning units for Fort Belvoir and Mason Neck are depicted in Figure 3-6.

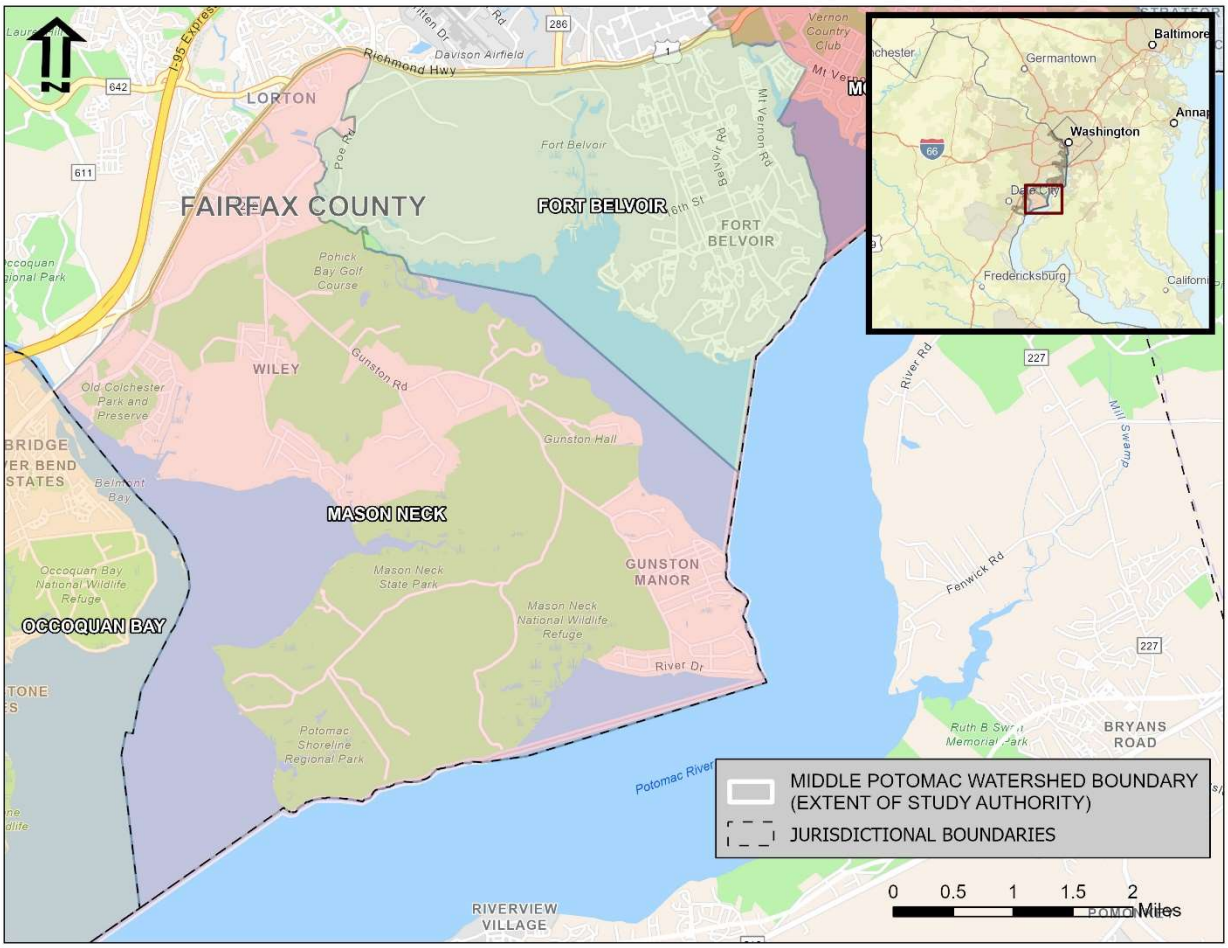

Figure 3-6. Planning Units- Mason Neck and Fort Belvoir.

Occoquan Bay

This planning unit extends from the Occoquan River to Neabsco Creek (Figure 3-7). 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.

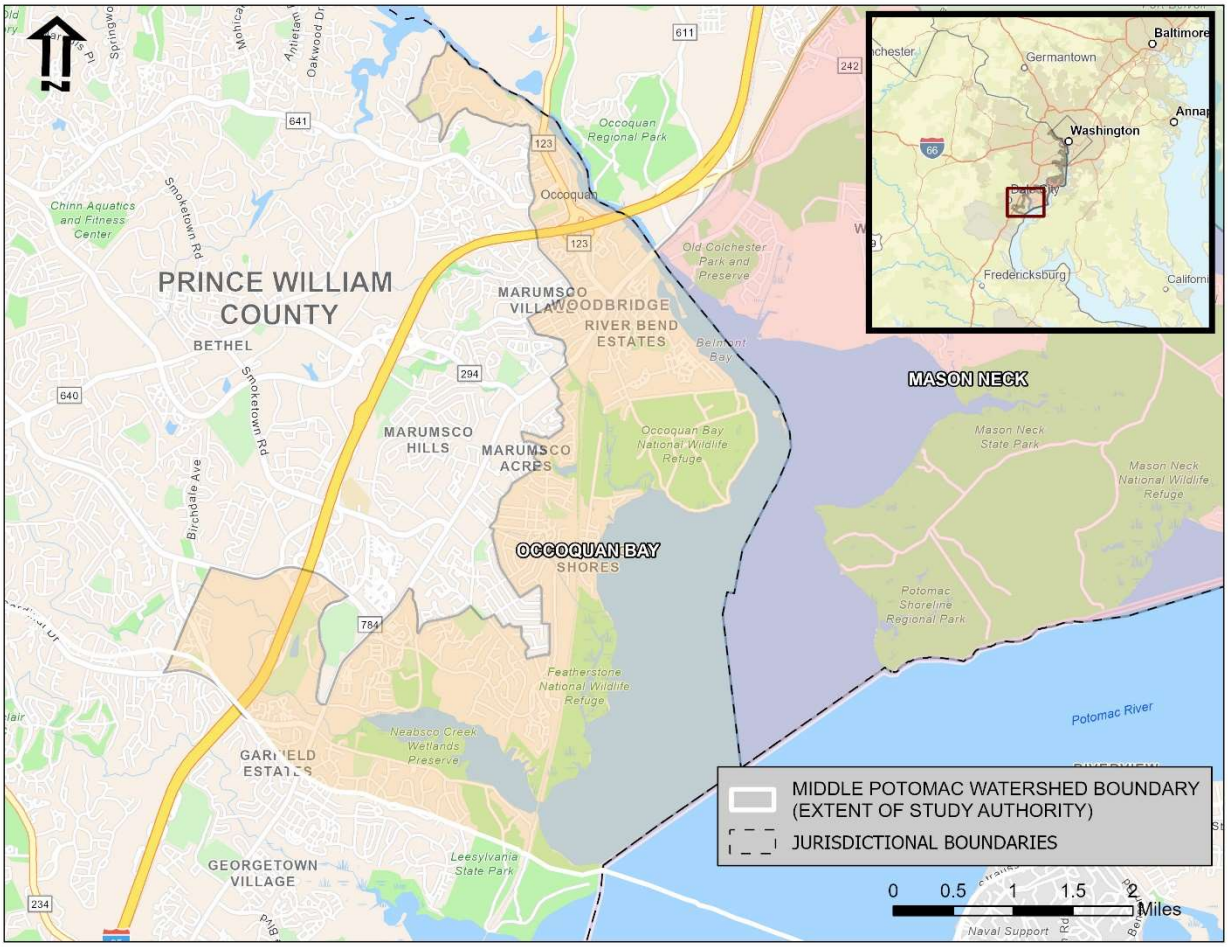

Figure 3-7. Planning Unit – Occoquan Bay

3.4 Vulnerability Assessment

As explained in Section 3.1, vulnerability and risk to populations and structures within the planning units was evaluated for the 1 percent and 0.2 percent AEP storm 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 USACE 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 3-1).

Table 3-1. 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

USACE assessed coastal storm impacts to infrastructure associated with transportation and utility systems. Impacts to infrastructure 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 to infrastructure were assessed for the following utility systems: drinking water treatment, wastewater treatment, and natural gas. System-wide impacts from coastal storms were not evaluated.

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 3-8 shows inundation from the 1 percent AEP event across four SLR scenarios. Table 3-2 shows inundation depths at critical infrastructure depths for a 1 percent AEP storm. The vulnerability assessment for Reagan Airport also evaluated the .1 percent AEP storm or worst-case scenario and can be found as an attachment to Appendix B: Hydraulics and Hydrology Analysis.

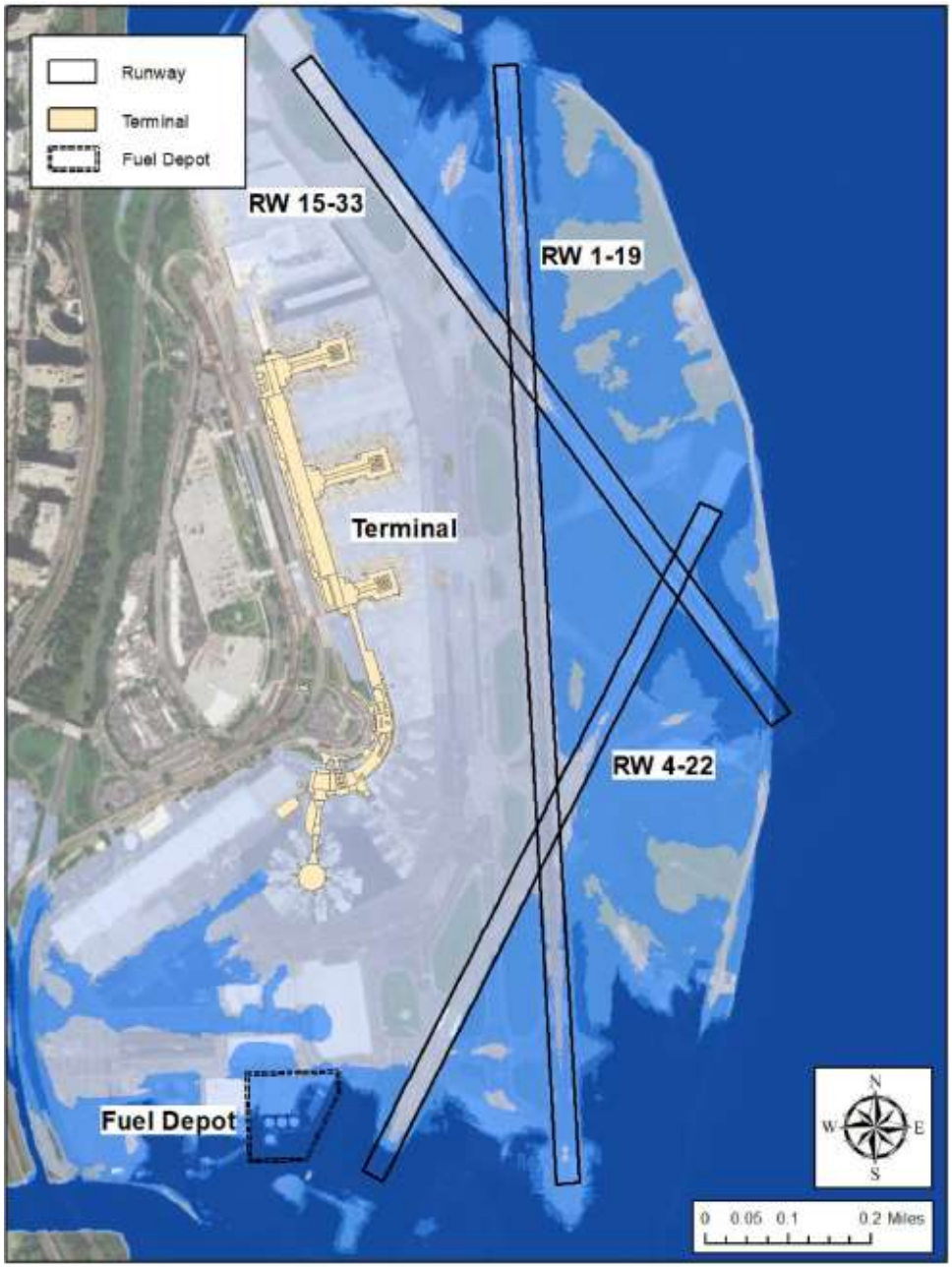

Figure 3-8. Reagan National Airport Runways, 1 percent AEP Inundation Under Various Sea Level Change Scenarios.

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.

Table 3-2. Inundation Depths at Critical Infrastructure Components for a 1 percent AEP Coastal Storm.

Label	Electrical Component or NAVAID	Sea Level Rise (feet)						
		0.0	0.67	1.08	1.75	3.27	3.93	8.64
1	TV-900 Electric Station	3.0	3.1	3.5	4.1	5.4	6.0	10.3
2	Fuel Depot	1.4	1.5	1.9	2.5	3.8	4.4	8.7
3	Crew Lot Electric Sub-Station	1.2	1.3	1.7	2.3	3.6	4.2	8.5
4	Maintenance Shops	1.1	1.2	1.6	2.2	3.5	4.1	8.4
5	High Intensity Approach Lighting System (HIALS) Building (ALSF-2-XFMR)	0.8	0.9	1.3	1.9	3.2	3.8	8.1
6	Control Room @ Transformers 45 and 46.	0.5	0.6	1.0	1.6	2.9	3.5	7.8
7	Workshop	-	-	-	0.2	1.5	2.1	6.4
8	Visual Approach Slope Indicator (VASI) Substation	-	-	-	-	1.4	2.0	6.3
9	Very High-Frequency (VHF) Omnidirectional Range (VOR) System	-	-	-	-	1.2	1.8	6.1
10	Precision Approach Path Indicators (PAPI) Control Station	-	-	-	-	1.0	1.6	5.9
11	TV-150 Electric Station	-	-	-	-	0.9	1.5	5.8
12	TV-100 Electric Station	-	-	-	-	0.6	1.2	5.5
13	TV-600 Electric Station	-	-	-	-	0.6	1.2	5.5
14	Airport Surface Detection Equipment (ASDE)	-	-	-	-	-	0.4	4.7
15	Apparent Aid to Navigation	-	-	-	-	-	-	3.7
16	TV-800 Electric Station	-	-	-	-	-	-	3.5
17	Radar Facility	-	-	-	-	-	-	3.4
18	Apparent Aid to Navigation or Lighting Control	-	-	-	-	-	-	3.1
19	South Distribution Station (Electric Station)	-	-	-	-	-	-	3.1

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 3-9). Under the 0.1 percent AEP coastal storm scenario, inundation started at 3.23 ft of SLR.

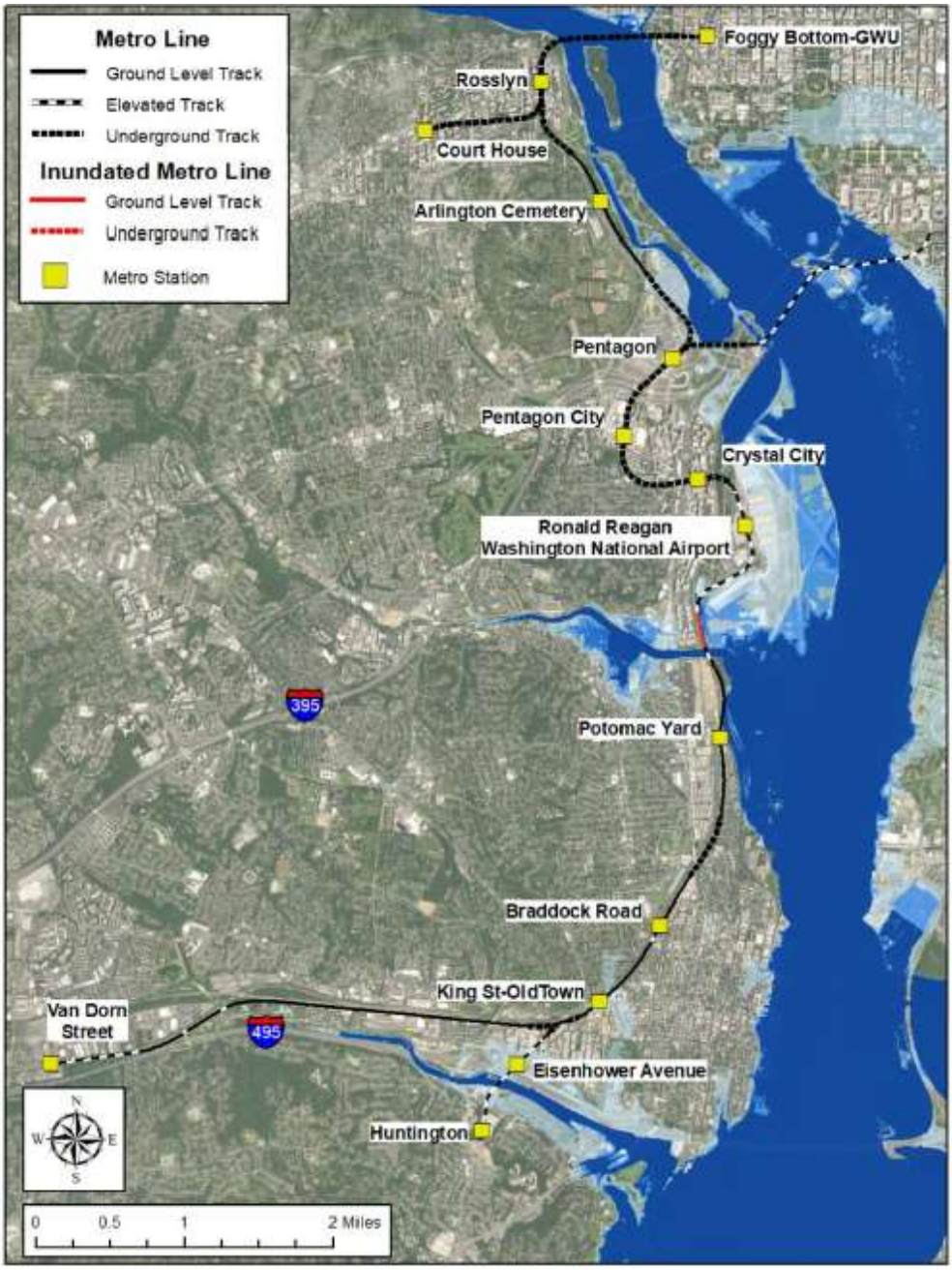

Figure 3-9. Washington Metro Blue and Yellow Lines, 1 percent AEP Inundation.

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 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 storm with 8.64 ft of SLR, and 0.1 percent AEP storm with 3.23 ft of SLR. Figure 3-10 shows the 1 percent AEP coastal storm inundation between Woodbridge Station and Rippon Station.

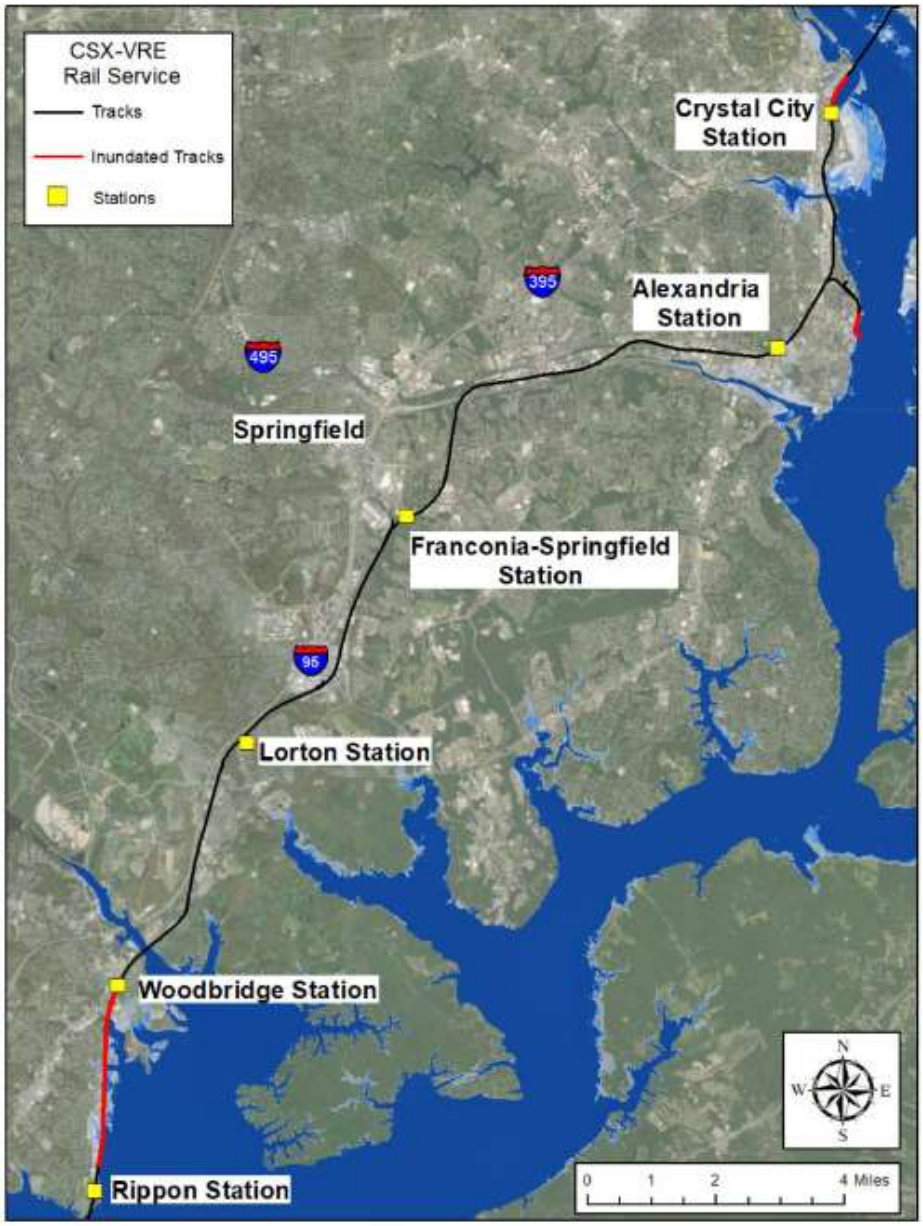

Figure 3-10. CSX Freight and VRE, 1 percent AEP Inundation.

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 of 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 3-11 to 3-15).

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 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 is 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 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 routes feed the GWMP and are significant contributors to reductions in traffic capacity under all coastal storm and SLR scenarios.

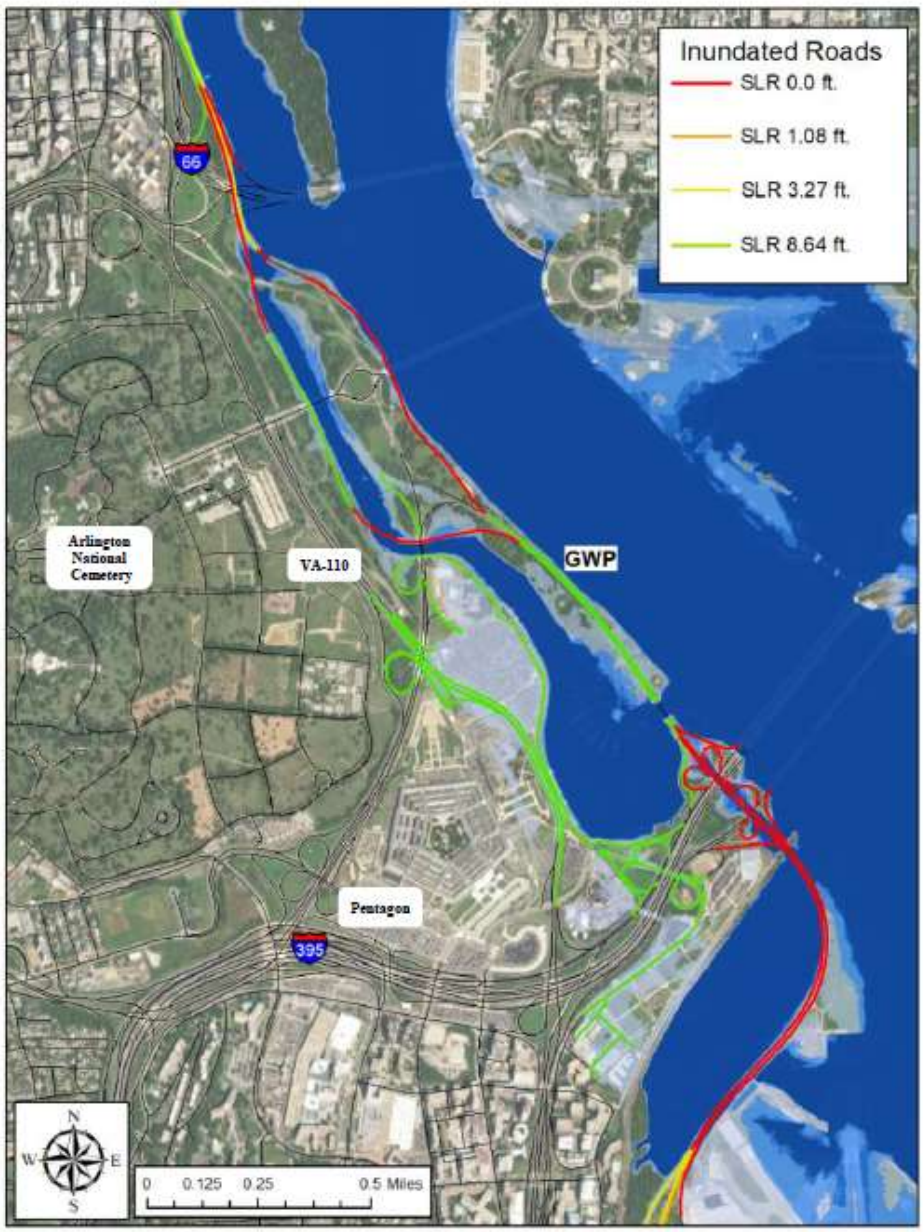

Figure 3-11. GWMP between Reagan National Airport and Key Bridge, 1 percent AEP Inundation.

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.

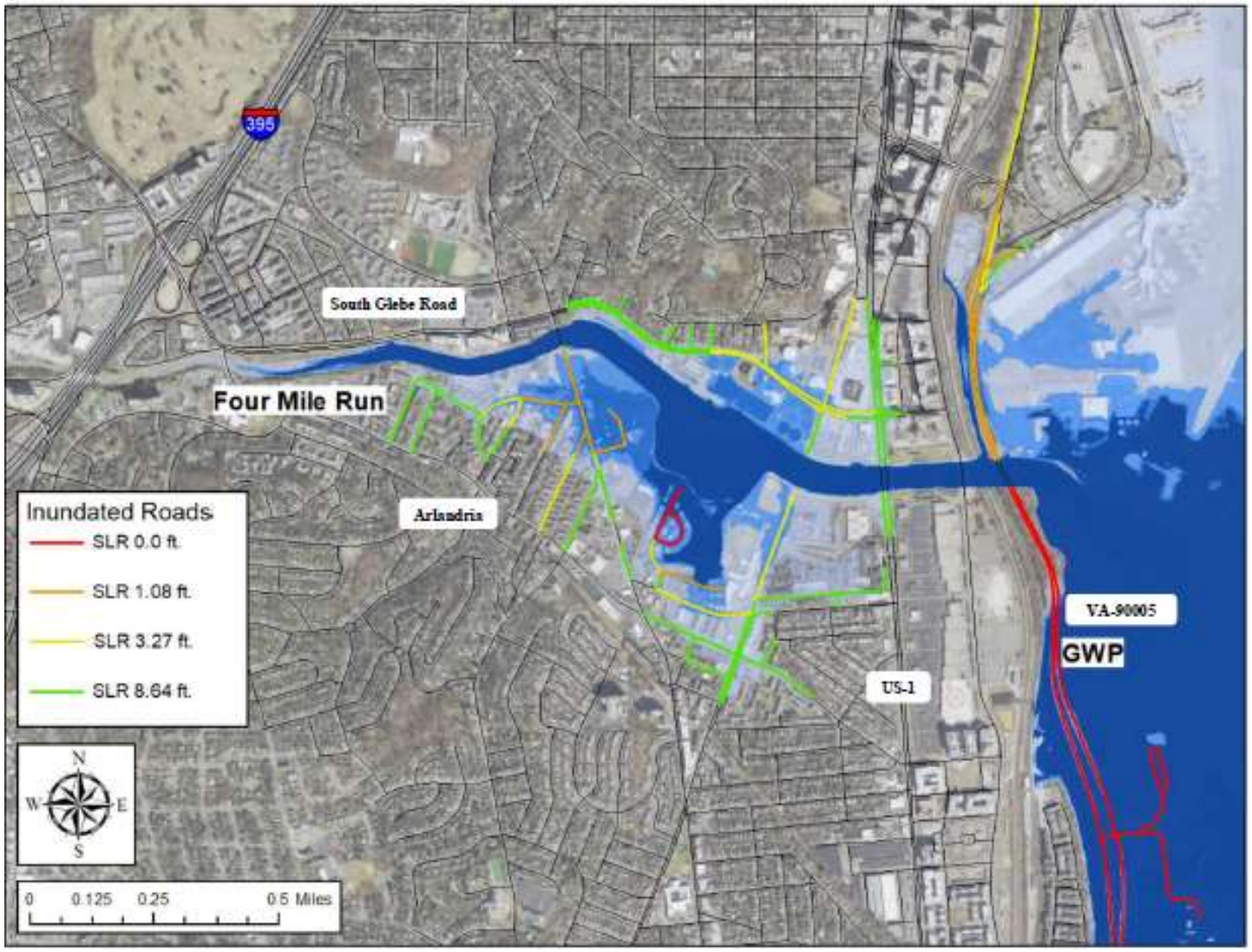

Figure 3-12. Figure 3-12. Four Mile Run, 1 percent AEP Inundation.

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

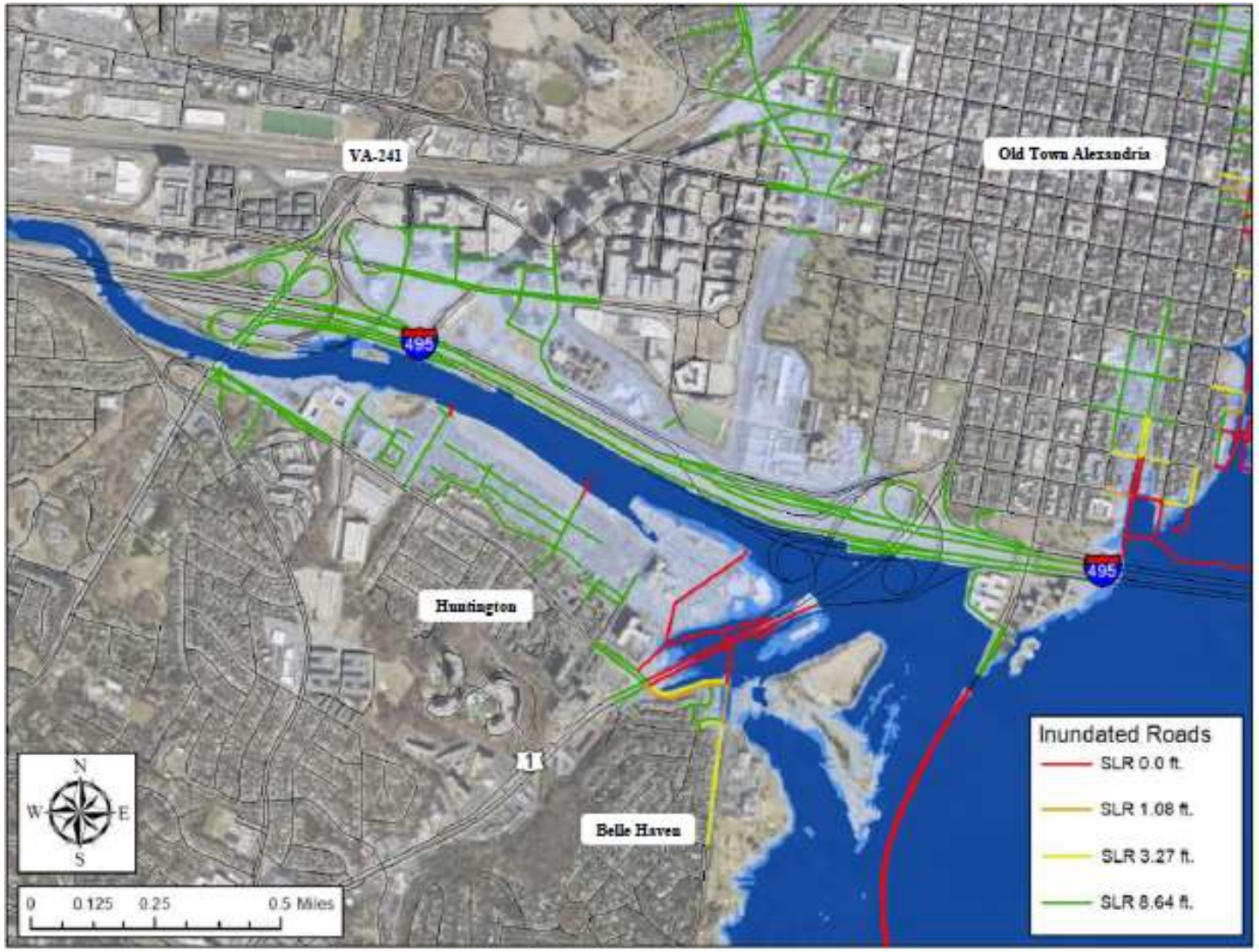

Figure 3-13. I-95/I-495 Corridor between Telegraph Road (VA-241) and the Potomac River, 1 percent AEP Inundation.

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

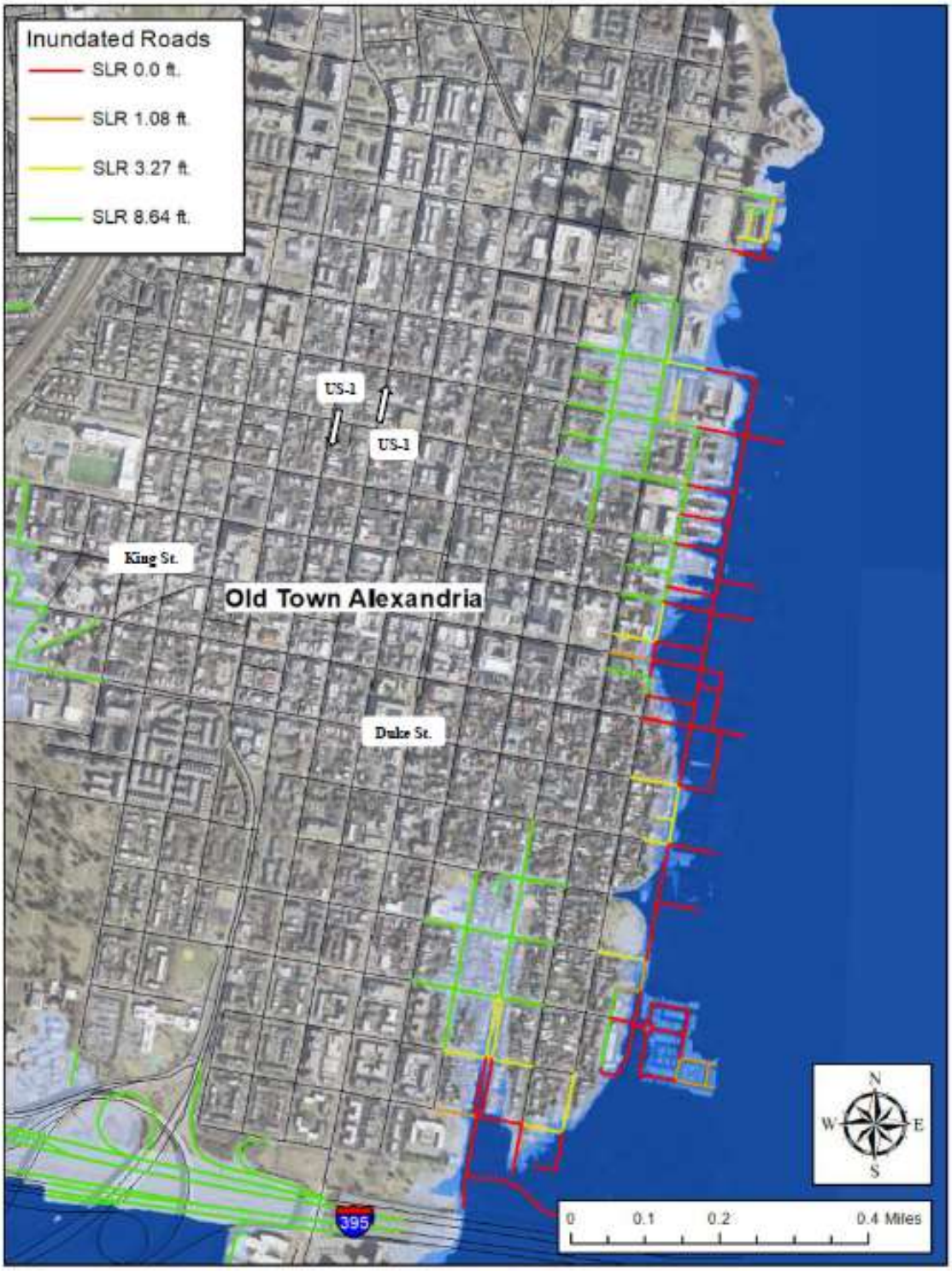

Figure 3-14. Old Town Alexandria, 1 percent AEP Inundation.

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

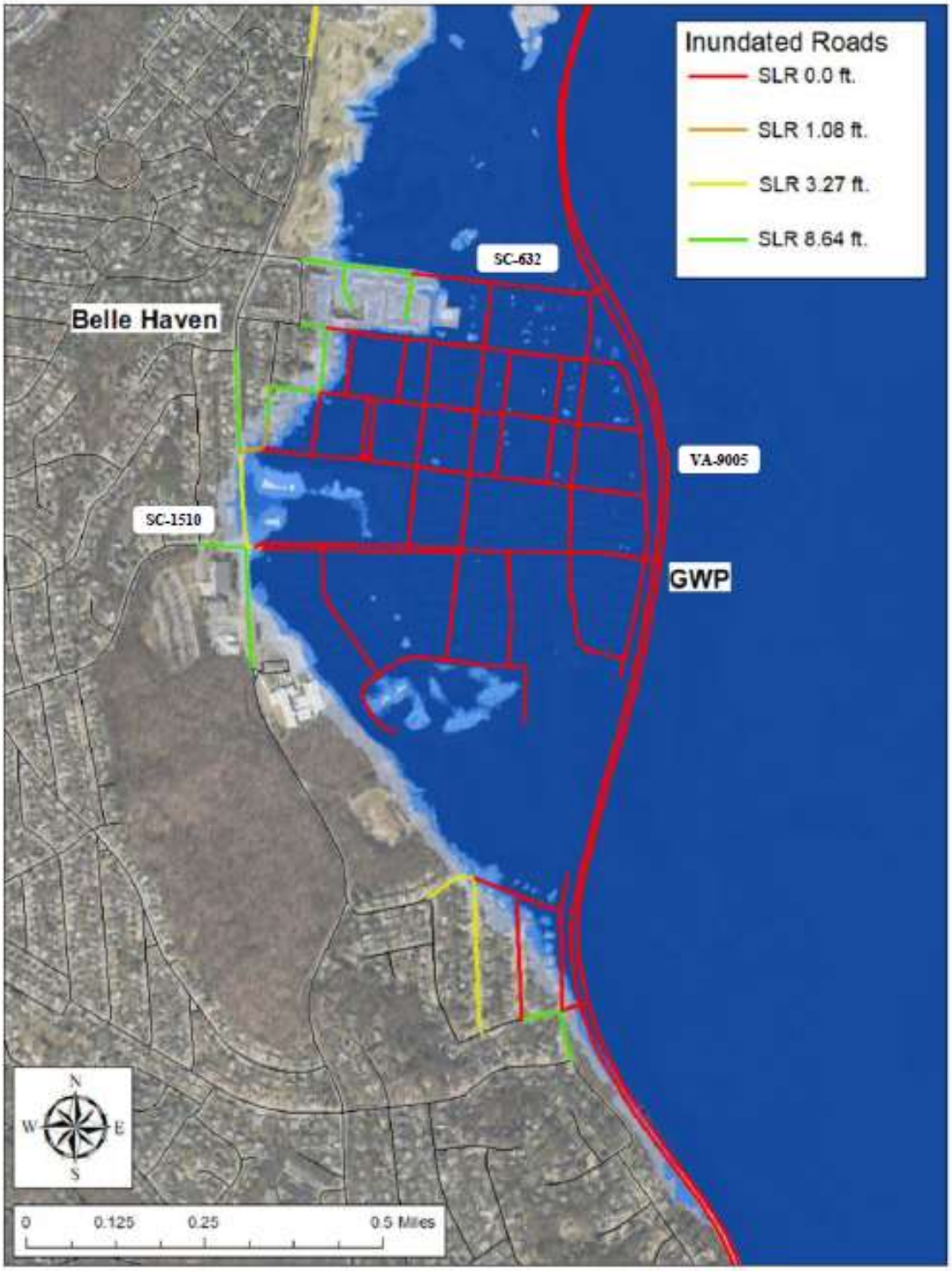

Figure 3-15. Belle Haven, 1 percent AEP Inundation.

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

The Vulnerability Assessment is attached to Appendix B.

3.5 Management Measures

Nonstructural and structural management measures were formulated and evaluated prior to presenting the measures at the Public Scoping Meeting held in Virginia on 11 September 2019. Management measures were evaluated and screened using the feasibility study's planning objectives (Table 3-3). The criteria used were a combination of meeting all four planning objectives and ensuring the proposed measures are appropriate for the topography and hydrology of each planning unit. For each focus area a standard list of coastal storm risk measures was screened, including those identified for certain areas in the NACCS (Table 3-4). Measures were also screened to ensure they avoided the planning constraints.

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 to alter hydrology for CSRM studies whereas an activity is defined as a "nonstructural" action (permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding).

Table 3-3. 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 measures 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
Floodproofing	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

*Measures (rows in blue) were carried into Table 3.4.

Table 3-4. 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	**Nonstructural**	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 performance only when in combination with beach dune

**NNBF will not meet planning objectives as standalone measures addressing storm surge but are considered for optimization of structural and nonstructural measures.

In Table 3-3 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.

Engineering 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; therefore, seawall and bulkhead were removed from further consideration. I-Wall and T-Walls are types of floodwalls which were retained in Table 3-3.

Enhanced warning systems meet two of the study objectives, but with the types of flooding experienced within the study area, it was determined that enhanced warning systems such as a siren would not be advantageous in reducing coastal storm risk. News, radio, and social media already broadcast updates regarding flooding, high tide events, and other events of potential concern.

Inundation from three flood scenarios: 5 percent, 2 percent, and 1 percent AEP event did not result in a high enough water level to warrant relocation/acquisition of any structures. Although relocation/acquisition were originally carried forward, these measures were later screened out and instead the nonstructural plan focused on floodproofing and structure elevation.

Table 3-4 shows the focus areas in which each measure could provide benefit. Tide gates, seawall, shoreline stabilization measures, breakwaters, groins, channel improvements, shoal removal/dredging, reefs, and beach restoration (dunes) are CSRM measures, but are not appropriate features for addressing coastal storm risk along the west bank of the Potomac River. These measures were immediately removed from further consideration.

The remaining measures were investigated to identify means in which they could be combined to improve resiliency from coastal storm risk in Northern Virginia. Although NNBF did not meet the four study objectives, Belle Haven and Old Town Alexandria have opportunities to evaluate NNBF features including wetland restoration, living shoreline and SAVs and these will be considered for optimization of the initial array of alternatives described in the next section. NNBF features may enhance a project and add additional CSRM benefit, but as standalone measures could not reduce risk at a 13 -14 feet level of performance to reduce risk to critical infrastructure during a storm event. Each measure is first compared alone to determine if it could address the problem and objectives and then combined with other measures and evaluated again to determine reduction in damages and level of performance.

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 nonstructural plan.

A structural alternative was also generated for Fort Belvoir. Per ER 1105-2-103, military funds, not Civil Works funds, must be used for Department of Army lands. As stated previously in Section 3.3, wetlands to the west of Fort Belvoir are inundated, but there are no impacts to structures. Most docks/houses affected are along River Road. Fort Belvoir has decided to not be a partner for this study; therefore, the Fort Belvoir alternative was not carried forward for further consideration.

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 nonstructural measures** outside barrier.	Virginia, Washington, D.C., and Maryland protected upstream of Fort Hunt. Nonstructural 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 WPCP
Nonstructural Plan	Application of **nonstructural** 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 on 29 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	**Nonstructural Plan (entire study area or components)**
7	**Alts 3 and 6 (Upper Coastal Barrier + Nonstructural downstream)**
8	**Combination Plan**

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 USACE used the 0.2 percent AEP water surface elevation and Intermediate SLC curve 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 3-7.

Table 3-7. 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 3-16 and 3-17). 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 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 3-18) 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 the TSP milestone. The subcomponents of this alternative include GWMP at 3 locations, Reagan Airport, and the Arlington WPCP.

Alternative 5: Floodwall/Levee Plan

The Floodwall/Levee Alternatives (Figure 3-19) 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: Nonstructural Plan

Figure 3-20 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 USACE evaluated elevation, flood proofing and acquisition based on flood depth.

Alternative 8: Combination Plan

Alternative 8 could 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 nonstructural measure where areas are unprotected by structures.

This Alternative was shared at the AMM and carried forward for consideration. This Alternative was proposed due to the nature of this comprehensive study to account for more than one planning area resulting in positive net benefits. This Alternative will not be further defined or evaluated until the economic analysis has been completed. If more than one planning area results in positive net benefits as well as the identification of a willing and able NFS to cost share design and construction, then this Alternative could contain multiple alternative components. However, these plans would still need to be justified as standalone alternatives and would likely result in multiple NFS letters as well as separate Design Agreements. This combination Alternative allows for several alternatives to be carried forward in the Middle Potomac Watershed.

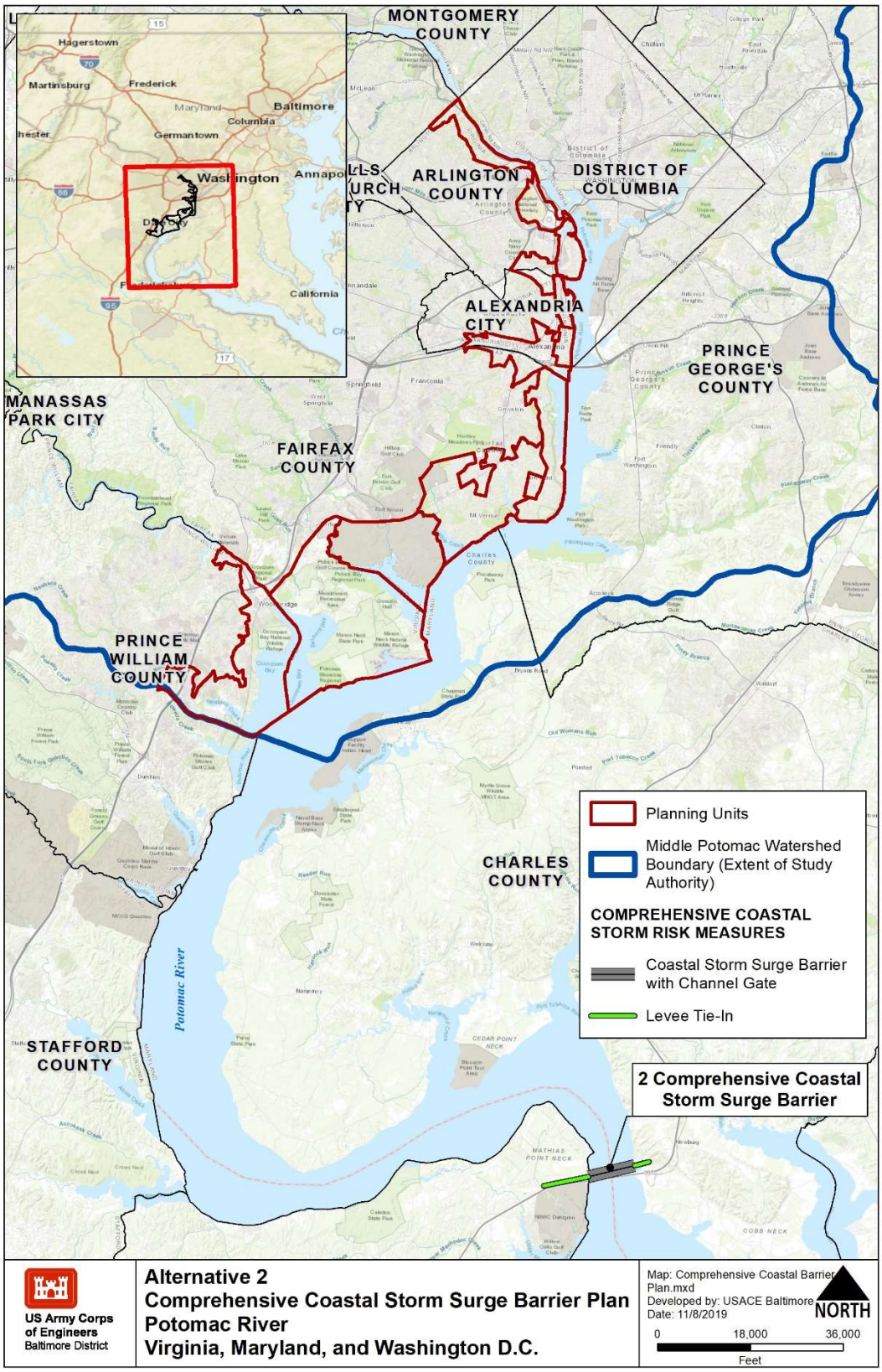

Figure 3-16. Alternative 2 – Comprehensive Coastal (downstream) Surge Barrier.

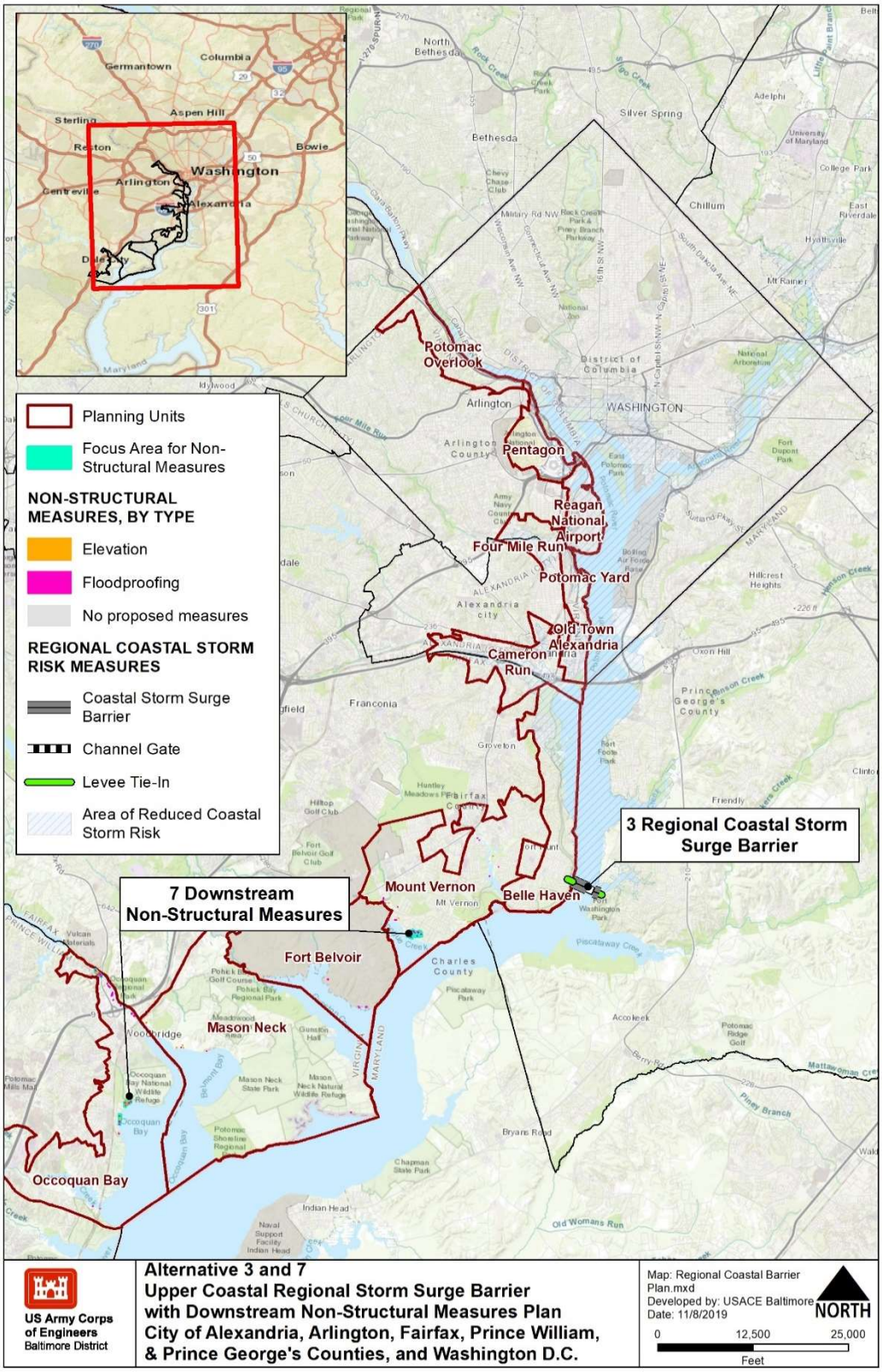

Figure 3-17. Alternative 3 – Upper Coastal (regional - upstream) Surge Barrier with Nonstructural Measures Downstream (Alternative 7).

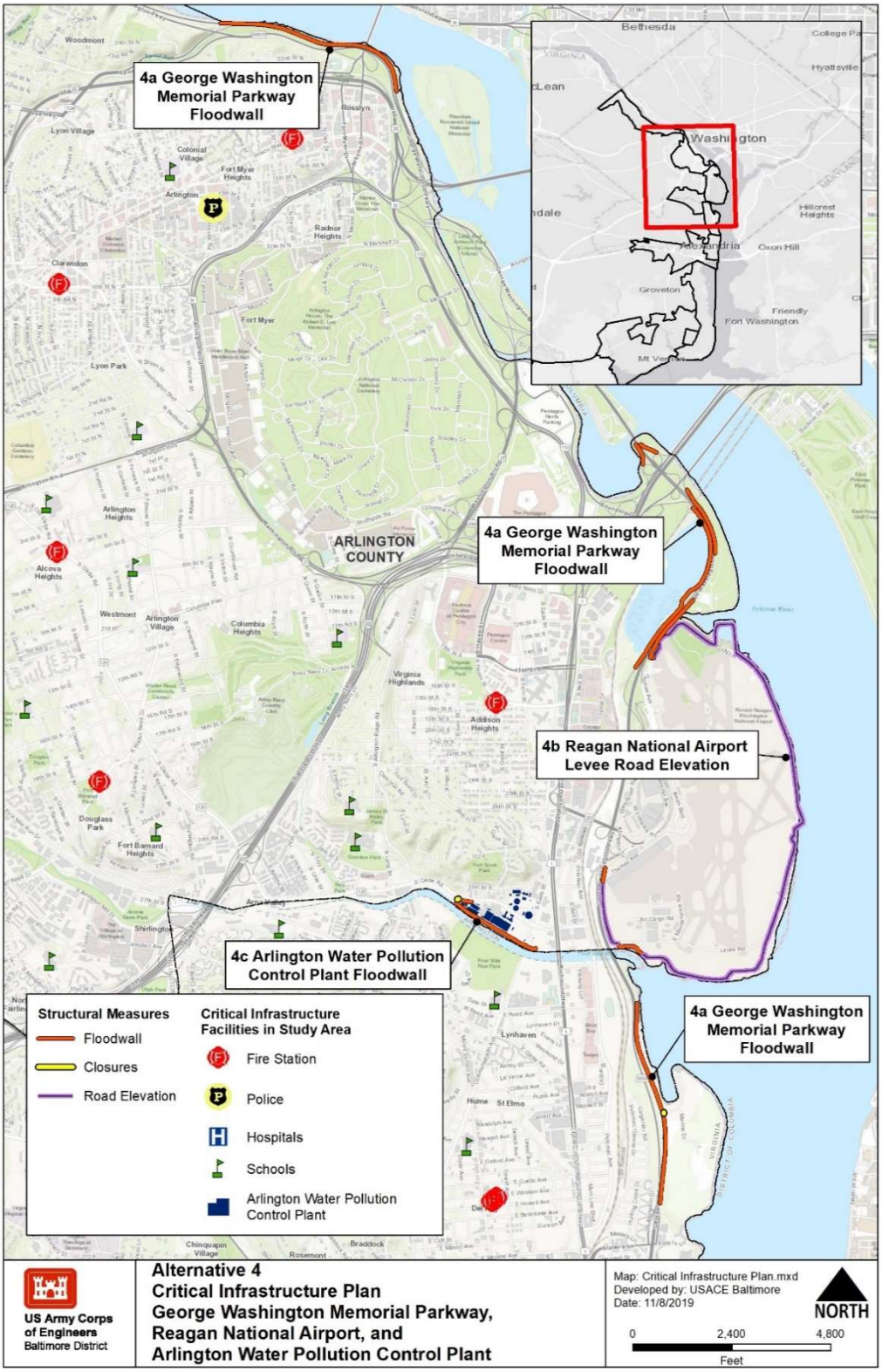

Figure 3-18. Alternative 4 – Critical Infrastructure Plan.

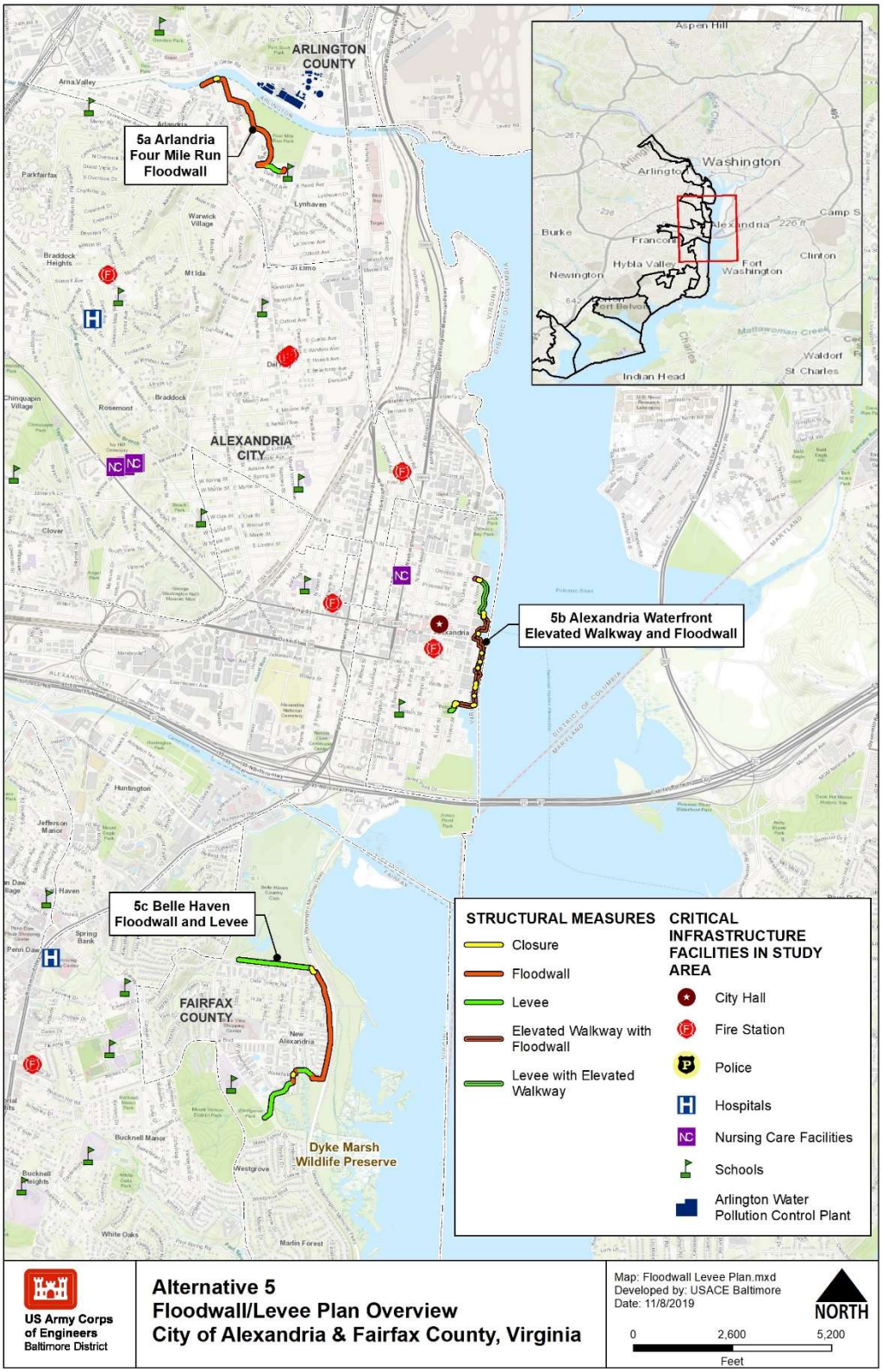

Figure 3-19. Alternative 5 – Floodwall/Levee Plan.

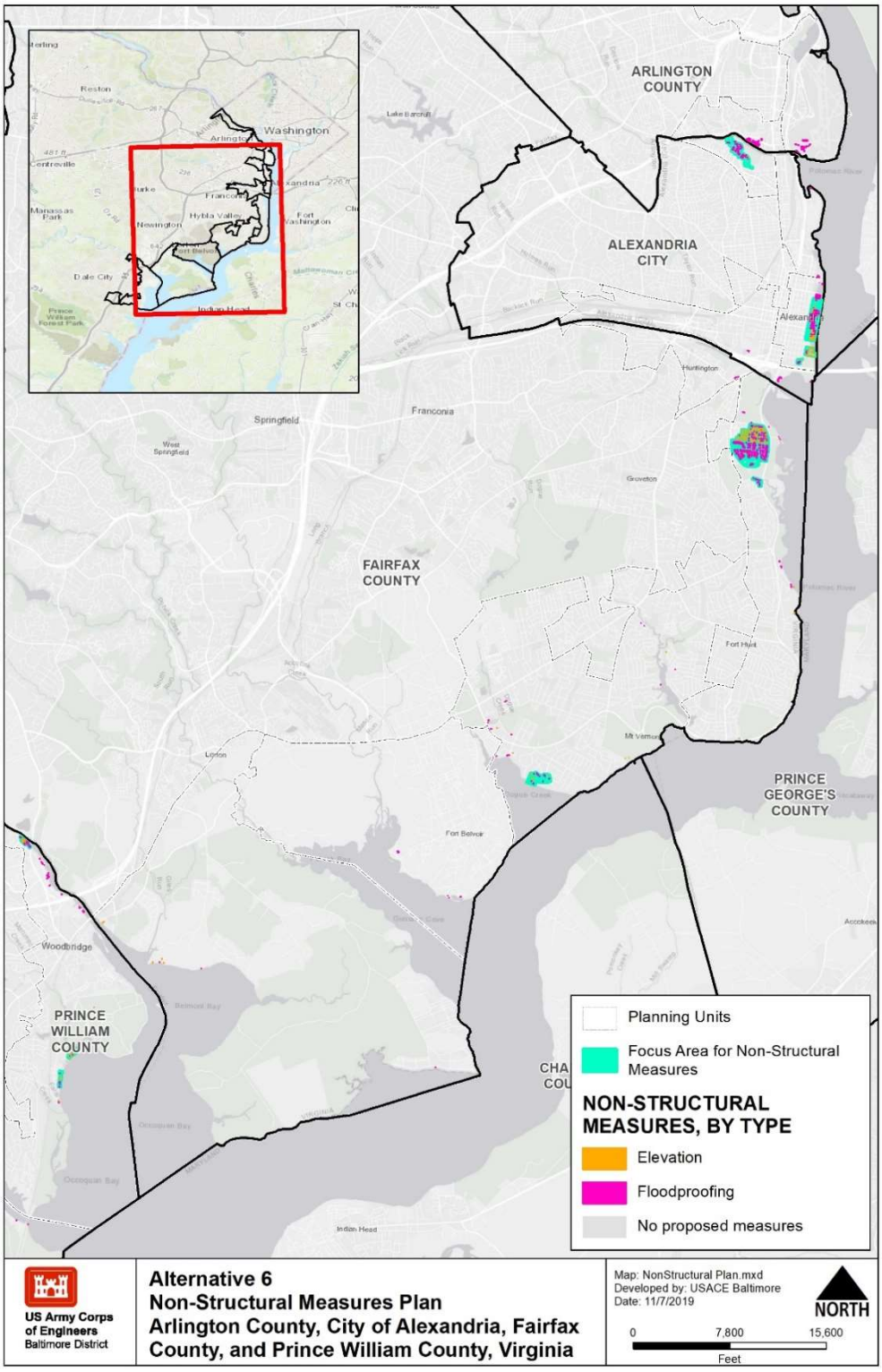

Figure 3-20. Alternative 6 – Nonstructural Plan.

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 3-8).

Table 3-8. 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	**Nonstructural Plan (entire study area or components)**	Retain
7	Alts 3 and 6 (Upper Coastal Barrier + Nonstructural downstream)	Screen
8	Combination Plan	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 $9 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 USACE 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 National Park Service (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.

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 NFS 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. 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 bulkhead at 6-foot NAVD88 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 feet 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 most of the new development sits well above the planned six feet 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 coastal storm risk measures 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 an 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 coastal 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 economic 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 coastal 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 wetland restoration at the Dyke Marsh Wildlife Preserve was discussed during the 2019 public scoping meeting. During implementation of the recent USACE/NPS Dyke Marsh Wetland Restoration Project, there was conflict with State of Virginia natural resource agencies, especially related to impacts to SAV from the restoration of wetlands to their historical extent into the Potomac River. NPS and the public are in favor of additional wetland 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 therefore, restoration was not retained as a measure.

Alternative 6: Nonstructural Plan

A preliminary nonstructural plan was developed for the AMM with a low level of detail. The plan did not include costs, because unit costs developed for NACCS were not appropriate for the study area since they were determined to have 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.

Rough order of magnitude (ROM) costs was developed for the Focused Array of Alternatives and are shown in Table 3-9.

Table 3-9. Rough Order of Magnitude Costs for the Focused 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 3-10.

Table 3-10. 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	**Nonstructural Plan (entire study area or components)**
8	**Combination Plan**

Alternative 4: Critical Infrastructure Plan and Components

Alternatives 4b, Reagan National Airport (Figure 3-21) and 4c: Arlington WPCP (Figure 3-22) are components of the Critical Infrastructure Plan, which include 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 3-21. Alternative 4B - Reagan National Airport.

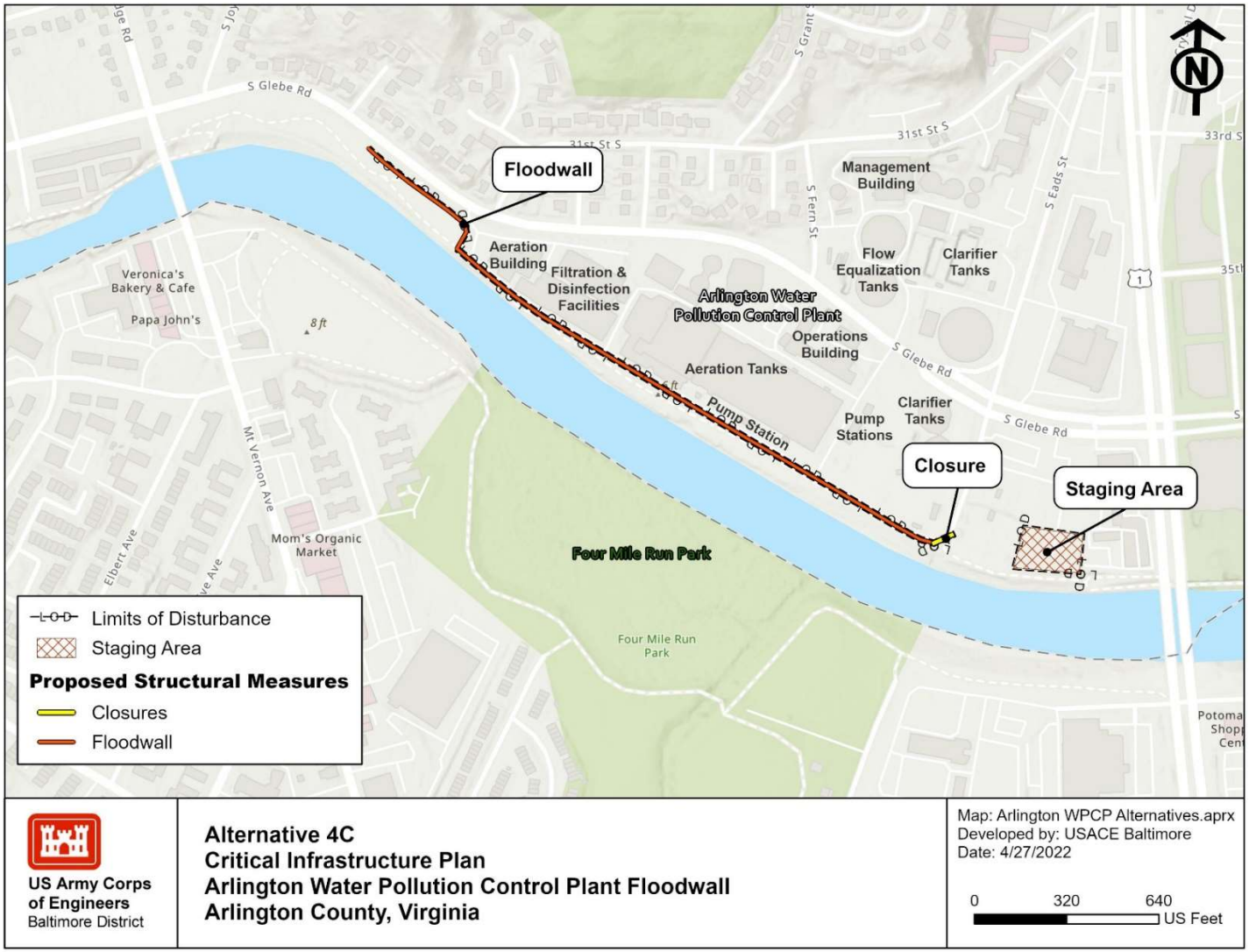

Figure 3-22. Alternative 4C - Arlington WPCP.

Alternative 5: Floodwall/Levee Plan

The Floodwall/Levee Alternatives (Figure 3-23 to Figure 3-25) 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.

Five NNBF measures were evaluated for this study and two were identified as possible measures for the Alexandria alternative (Wetland Restoration and Living Shoreline). The City of Alexandria recently completed a living shoreline project at Windmill Hill Park Waterfront in 2018. The USACE determined that Founder's Park and Oronoco Bay Park could also be areas for living shoreline measures with potential for wetland restoration to the south of the proposed footprint.

During the 22 June 2021 In-Progress Review, the USACE was asked by USACE higher authority to show a ROM analysis for a completely deployable plan (Alternative 5b1) to determine if there were benefits that could be gained above the 10-year level of performance covered by the existing project being implemented by the City of Alexandria. USACE 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 5 evaluated previously. This alternative was carried through final analysis to determine cost and economic benefits.

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. Two new pump stations would be added to remove water behind the floodwall during an event. The construction period would be broken into 2 phases, spanning 4 years.

Five NNBF measures were evaluated for this study and three were identified as possible measures for the Belle Haven plan (SAVs, Wetland Restoration and Living Shoreline). Through coordination with NPS, it was determined that the alignment for Belle Haven would need to move further inland to avoid NPS property and there is no opportunity for SAVs, Wetland Restoration or Living Shorelines between the GWMP and Boulevard view Road. There is a very limited footprint for a project between NPS property and residences and businesses, so USACE has optimized the alignment to work within these constraints. Dyke Marsh could offer opportunity for NNBF; however, it is an on-going USACE project and has maximized FRM benefits with the current NNBF being implemented. Since none of the three NNBF measures evaluated could be constructed in the upland footprint on the west side of the GWMP to avoid NPS property, it was determined that SAVs, Wetland Restoration and Living Shoreline measures could not provide added benefit to the floodwall and levee measures.

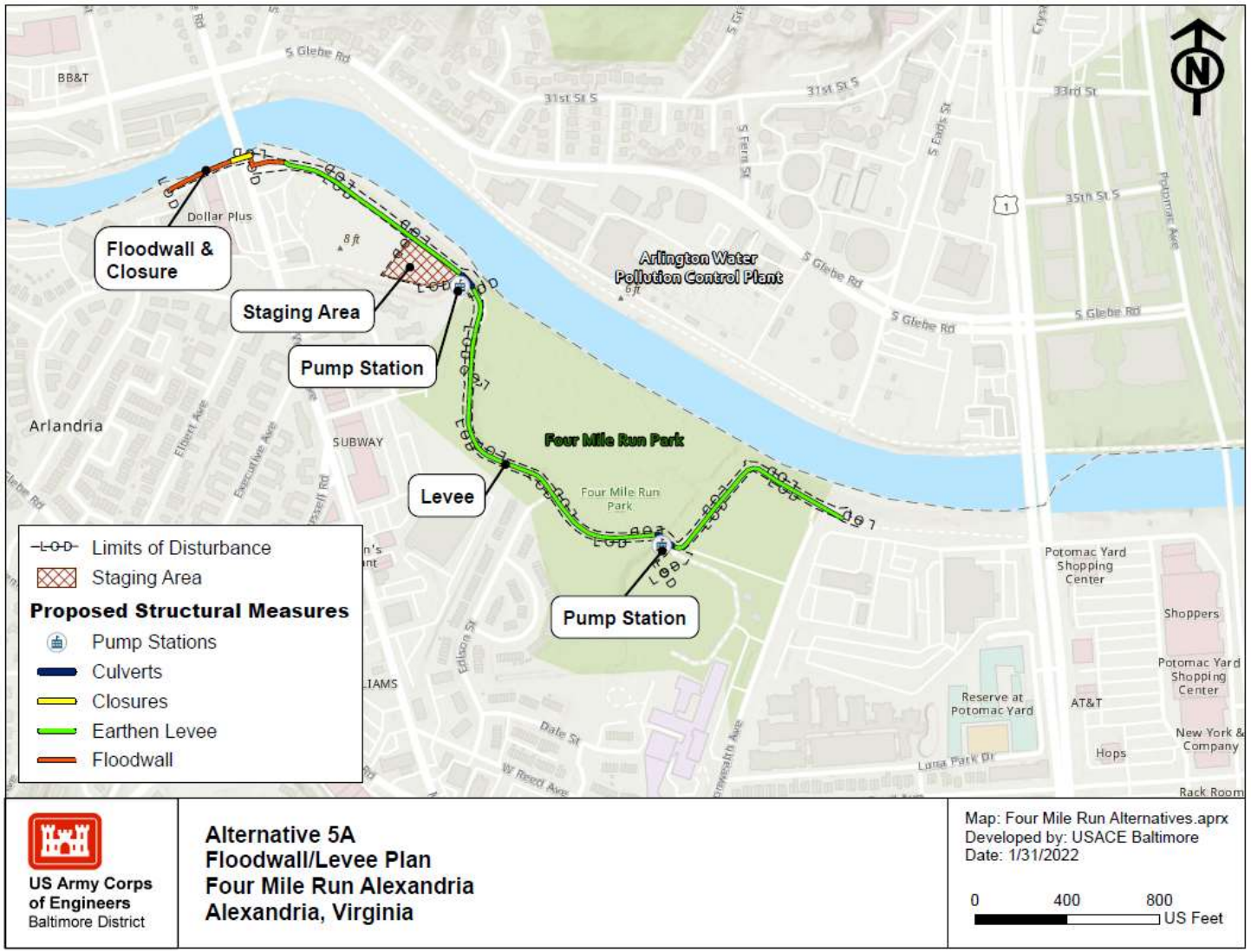

Figure 3-23. Alternative 5A - Four Mile Run.

Figure 3-24. Alternative 5b1: Alexandria Deployable Floodwall.

Figure 3-25. Alternative 5C - Belle Haven.

Alternative 6: Nonstructural Plan

Figures 3-26 through 3-28 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 nonstructural 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 nonstructural 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.

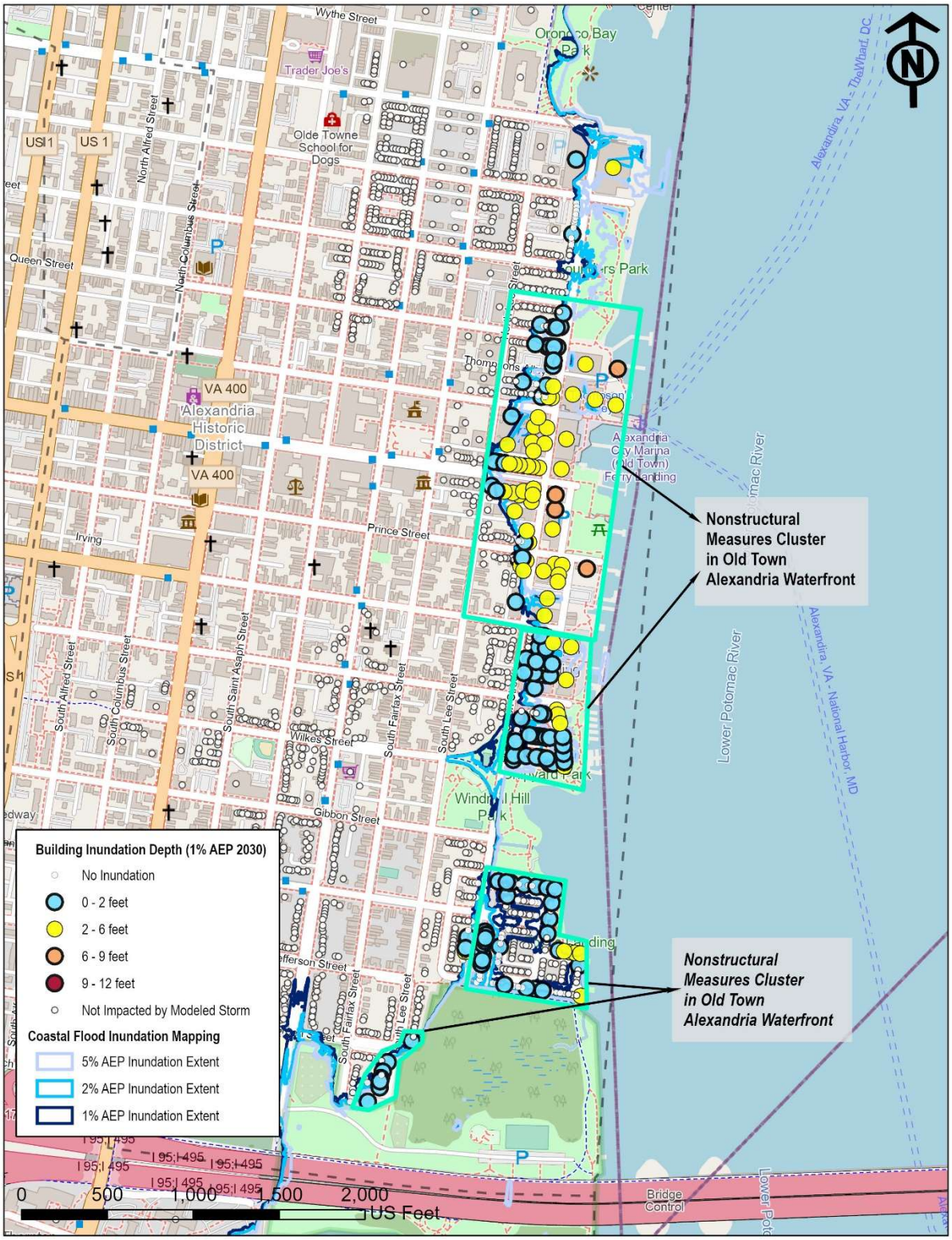

Figure 3-26. Nonstructural Measures Cluster in the Old Town Alexandria Waterfront Neighborhood in the City of Alexandria.

Figure 3-27. Nonstructural Measures Cluster in the Belle Haven Neighborhood in Fairfax County.

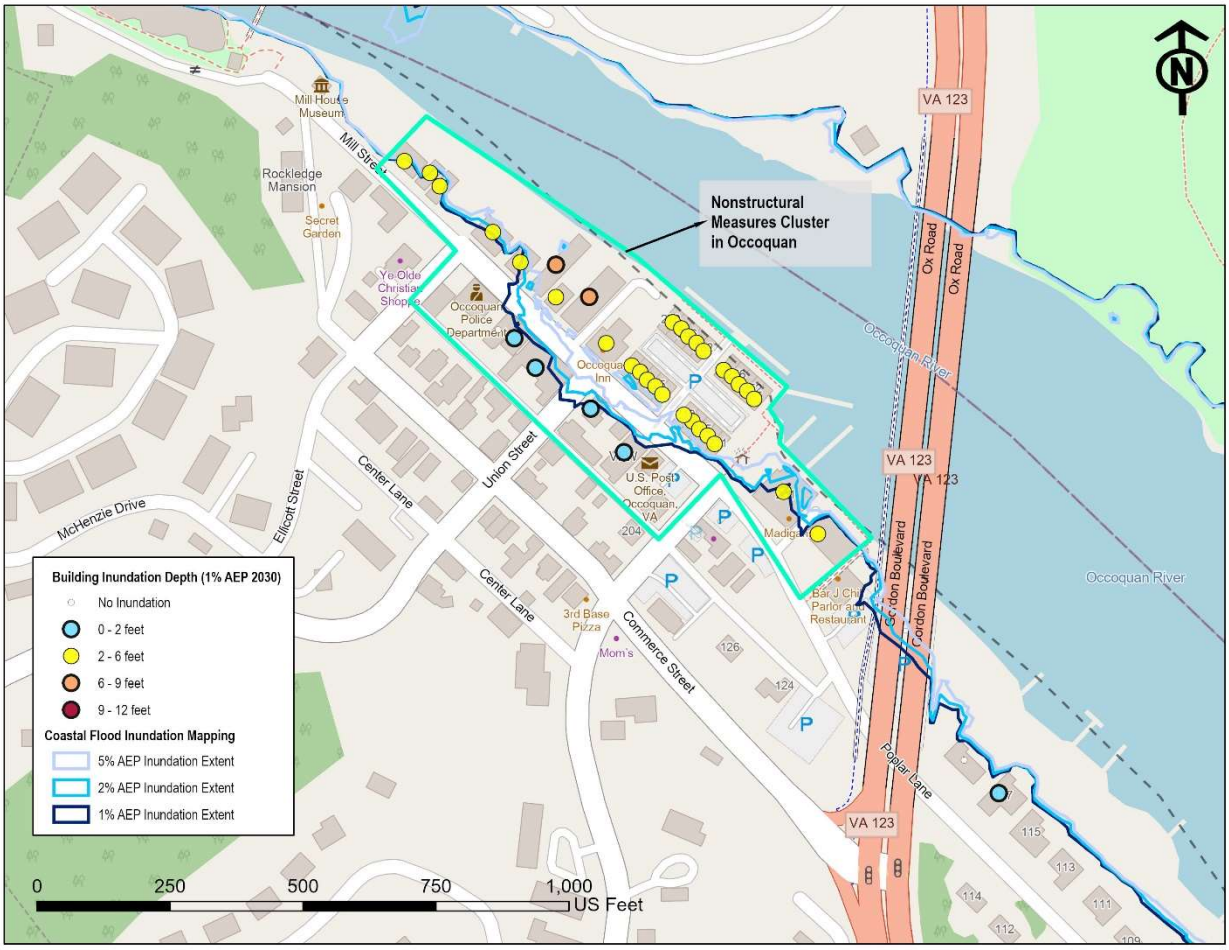

Figure 3-28. Nonstructural Measures Cluster in the Town of Occoquan in Prince William County.

Alternative 8: Combination Plan

Alternative 8 could 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 nonstructural measure where areas are unprotected by structures.

As stated previously, this Alternative was proposed due to the nature of this comprehensive study to account for more than one planning area resulting in positive net benefits. This Alternative will not be further defined or evaluated until the economic analysis has been completed. If more than one planning area results in positive net benefits as well as the identification of a willing and able NFS to cost share design and construction, then this Alternative could contain multiple alternative components.

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 USACE 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. Alternatives have been evaluated for the risk reduction provided to the geographic areas addressed by an alternative.

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 solutions or political expediency.

The results of this initial P&G evaluation are detailed in Table 3-11. No alternatives were screened during the P&G evaluation. Since Alternative 8 may be a combination of more than one alternative, it has been determined that this alternative would also meet all four P&G criteria.

Table 3-11. 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 5b1 – Alexandria Deployable 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 direct, indirect, and cumulative environmental effects and consequences for the final array of alternatives (Alternatives 4b, 4c, 5a, 5b1, 5c, and 6) on each resource topic discussed in Section 2.3, Natural Environment and Section 2.4, Physical Environment. Table 6-3 describes the cumulative effects on each resource topic. 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 4-3 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 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 direct or indirect effects on wetlands.

4c Arlington WPCP 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. Construction of the floodwall may result in temporary and minor indirect effects to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

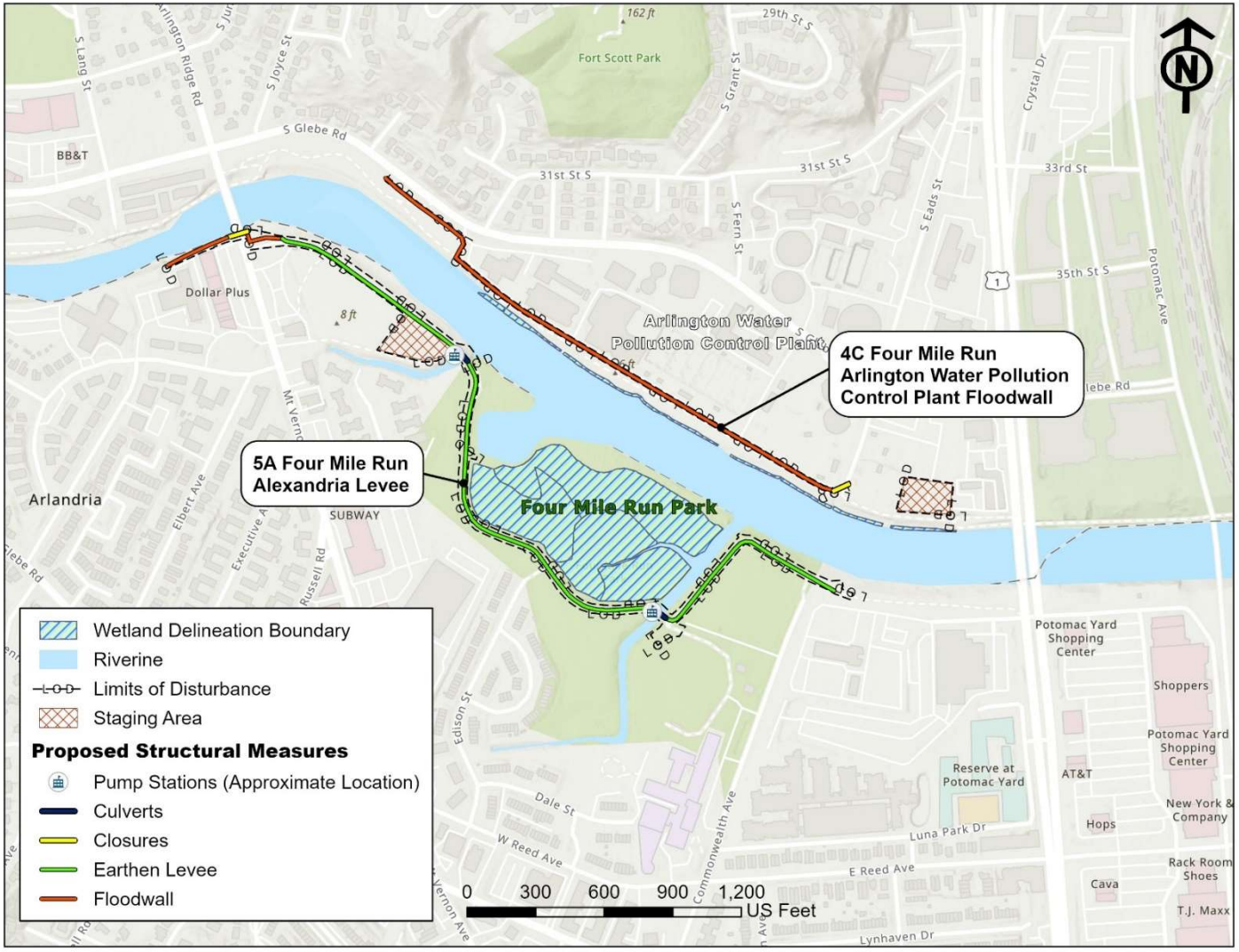

Figure 4-1. Proposed Structural Measures and Limits of Disturbance for Alternatives 4c and 5a and the Location of Wetlands and Riverine Systems at Four Mile Run.

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. Construction of the floodwall may result in temporary and minor indirect effects to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

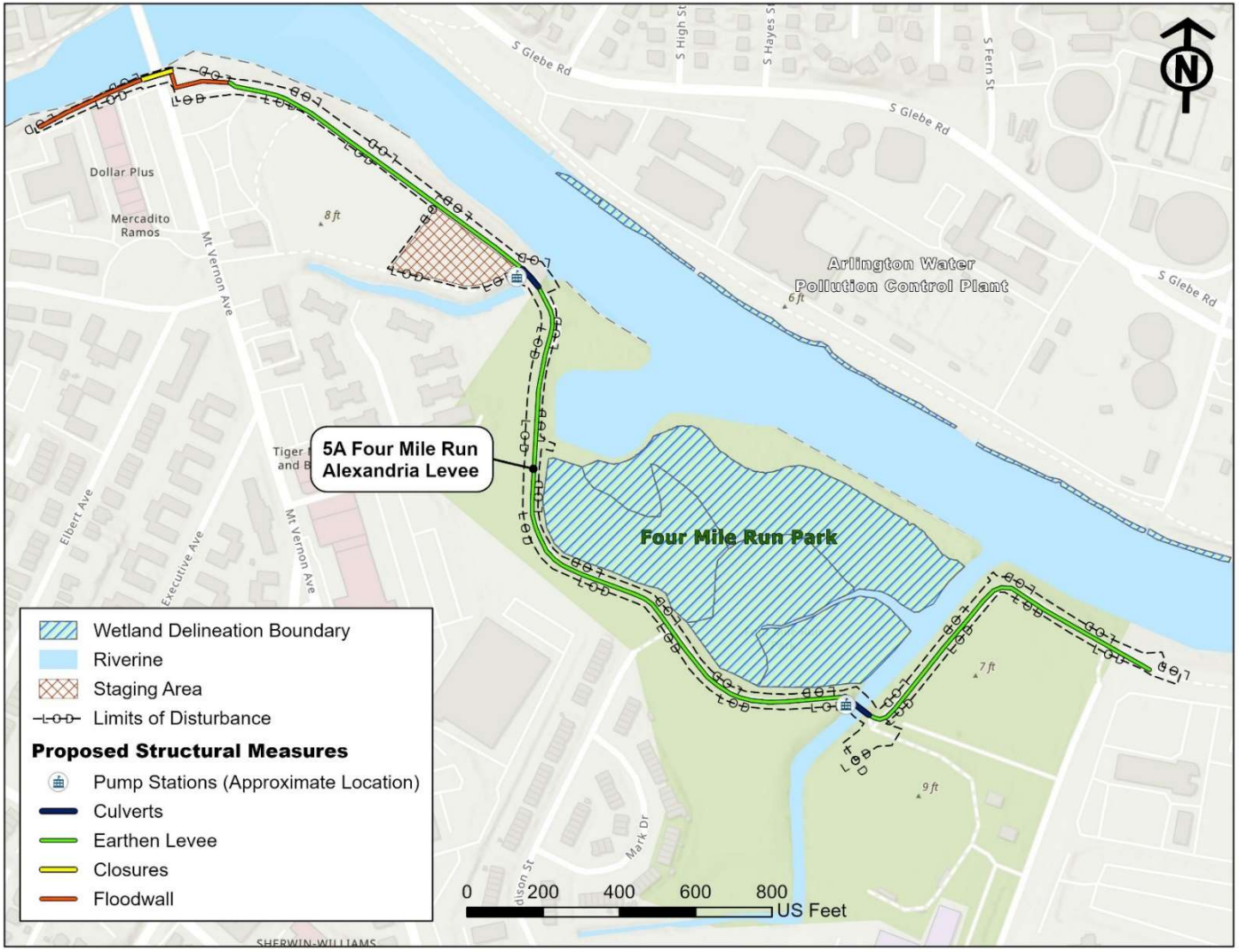

Figure 4-2. Proposed Structural Measures and Limits of Disturbance for Alternative 5a and the Location of Wetlands and Riverine Systems at Four Mile Run.

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. Construction of the floodwall may result in temporary and minor indirect 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

Direct Effects

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. Construction of two culvert crossings would result in stream impacts in the Belle Haven East and West Channels. Stream impacts are discussed in Section 4.2.1.

Indirect Effects

Construction of the levee and floodwall at Belle Haven may result in minor and temporary effects to adjacent 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 modeled the FWP condition to assess the potential for induced flooding in wetlands. Modeling showed that the inundation depth in wetlands during a 1 percent AEP storm event under the FWP condition would be minimal.

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 Nonstructural Plan

Implementation of the nonstructural plan would have no direct and indirect effects 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. To view the delineated features, refer to Figures 5A and 5B in the Wetland Delineation Report located in Appendix G.

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 directly or indirectly 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 nonstructural plan (Alternative 6) would have no direct and indirect effects 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 (sq ft) of temporary, indirect impacts to SAV for a period of up to one year dependent on the exact staging location. At this point, SAV will not be replanted in the area of impact from the barge after construction of this project and monitoring will also not occur. The SAV is expected to recover naturally once the barges are removed.

Implementation of Alternatives 4c, 5a, 5c, and 6 would have no direct or indirect effects on SAV because no SAV is present in the location of these alternatives.

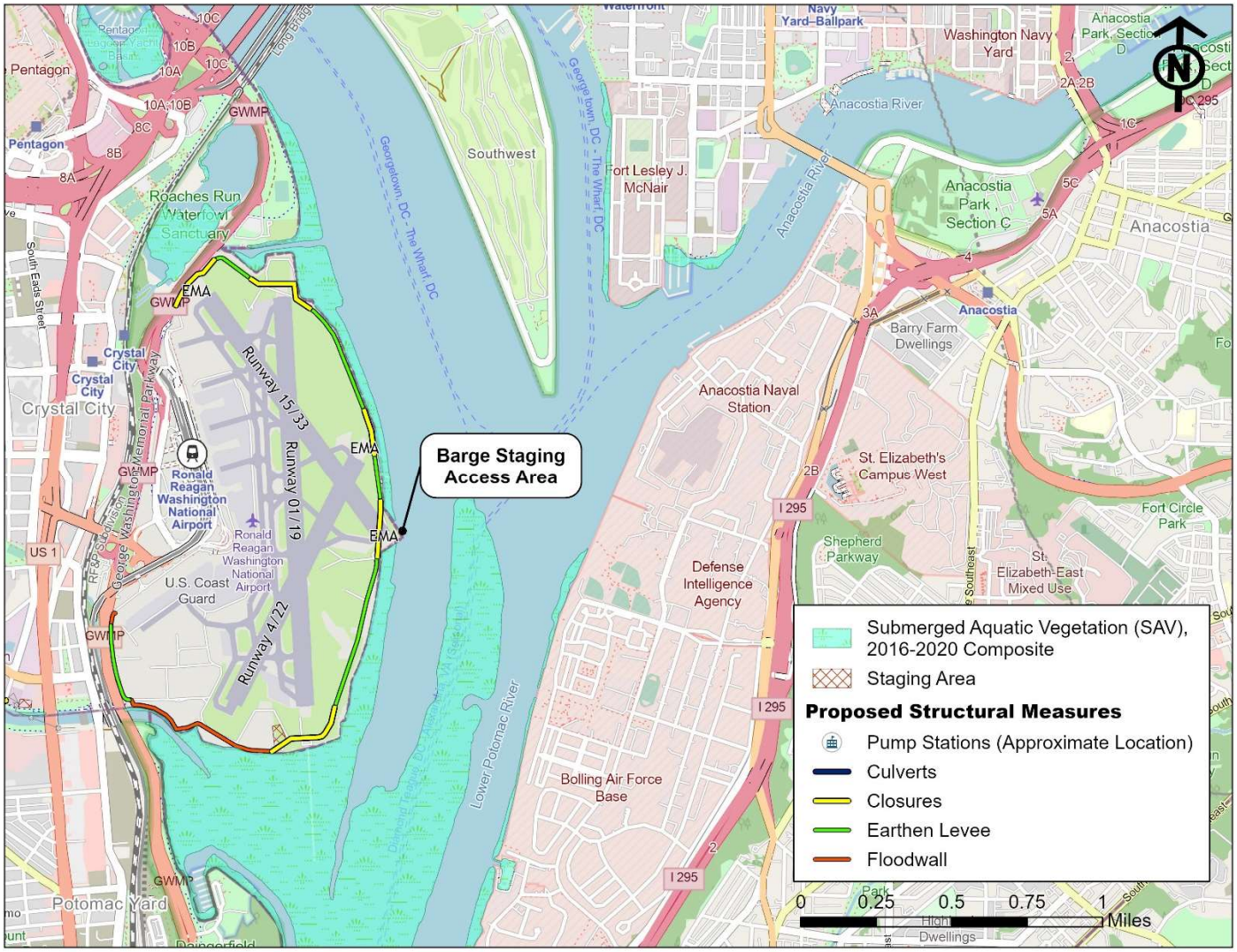

Figure 4-4. Submerged Aquatic Vegetation in the Vicinity of the Reagan National Airport and the Approximate Location of the Barge Staging Area.

5b1 City of Alexandria Deployable Floodwall

As shown in Figure 4-5, SAV may be present (as of 2018) in the shallow waters of the Potomac River along the Alexandria waterfront (VIMS, 2022a). Initial construction and deployment of the floodwall prior to flood events will not directly affect SAV. Initial construction of the deployable floodwall may result in minor and temporary indirect effects to SAV. Sediment from construction could be carried into the water and may affect SAV. Best management practices to avoid indirect effects would be implemented prior to construction and would be maintained during construction. Deployment of the floodwall prior to flood events is not expected to result in indirect effects to SAV.

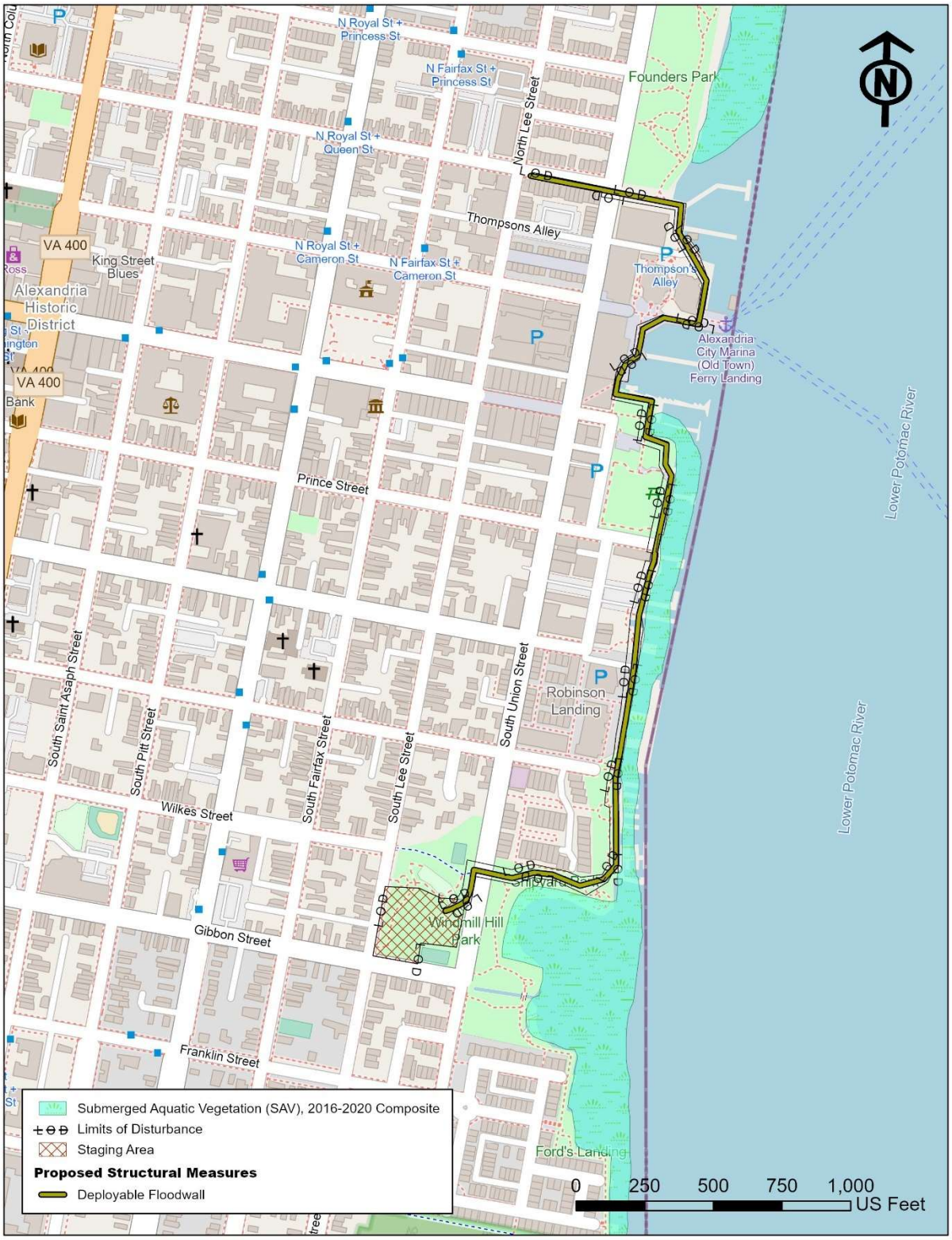

Figure 4-5. Submerged Aquatic Vegetation in the Vicinity of the City of Alexandria Waterfront.

4.1.4 Upland Vegetation

4b Reagan National Airport Levee and Floodwall, 5a Four Mile Run Levee and Floodwall, 5b1 City of Alexandria Deployable Floodwall, 6 Nonstructural Plan
No anticipated direct or indirect effects to upland trees and shrubs.

4c Arlington WPCP Floodwall
Removal of trees and shrubs will be avoided to the maximum extent practicable. However, trees and shrubs in the locations of the construction footprint and 50 feet on either side of the structures will need to be removed to construct the levees/floodwalls and to access these structures for future maintenance. The width of the access areas on either side of the structures may be able to be reduced to avoid established trees. Approximately 20 trees may need to be removed to construct the floodwall. No champion, significant, commemorative, notable, memorial, or specimen trees are located within this area (Arlington County, 2023). This exact number of trees to be removed will be determined during PED. Planting new trees in a different location in the study area may be an option to offset the effects of any tree removal required for the proposed project.

5c Belle Haven Levee and Floodwall
Removal of trees and shrubs will be avoided to the maximum extent practicable. However, trees and shrubs in the locations of the construction footprint and 50 feet on either side of the structures will need to be removed to construct the levees/floodwalls and to access these structures for future maintenance. The width of the access areas on either side of the structures may be able to be reduced to avoid established trees. Approximately 150 trees may need to be removed to construct the levee/floodwall. This exact number of trees to be removed will be determined during PED. Planting new trees in a different location in the study area may be an option to offset the effects of any tree removal required for the proposed project.

4.1.5 Threatened and Endangered Species

4.1.5.1 Terrestrial and Freshwater Species

The final array of alternatives would have no direct or indirect effects 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 direct or indirect effects 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). 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. Since the time that the PAR was finalized in January of 2021, the status of the NLEB changed from threatened to endangered. Therefore, the 4(d) rule no longer applies, as the species in no longer listed as threatened. A key was developed by USFWS to determine the effects to NLEB from a proposed project. Using the USFWS key, USACE determined that the project alternatives would have no effect on the NLEB. A consistency letter for the NLEB from the USFWS was received on 12 April 2023 (Appendix G).

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 and indirectly 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.

4.1.5.2 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 direct and indirect effects 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 direct and indirect effects to shortnose sturgeon from this alternative are discountable.

Temporary Habitat Modification from Barges Shading SAV

Indirect 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 sq ft). 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 indirect 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 indirect effect of this alternative on Atlantic sturgeon 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 direct effect of this alternative on the risk of a vessel strike to Atlantic sturgeon 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 indirect 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 indirect effect of this alternative to Atlantic sturgeon due to construction noise would be insignificant.

Implementation of Alternatives 4c, 5a, 5b1, 5c and 6 would have no direct and indirect effects 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.

4.1.6 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 in Belle Haven. Therefore, it is highly unlikely that anadromous fish would be present in the streams 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. There would be no indirect effects to anadromous fish due to construction of the culvert crossings for Alternatives 5a and 5c.

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. There would be moderate indirect effects to anadromous fish due to closure of the flap gates during and after a storm because fish would be trapped for up to 48 hours.

Implementation of Alternatives 5a and 5c would have no direct effects to anadromous fish. Implementation of Alternatives 4c, 5b1, and 6 would have no direct or indirect effects to anadromous fish because anadromous fish are not present where the effects would likely occur.

4.1.7 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 direct effects and additional indirect effects to migratory birds.

4c Arlington WPCP Floodwall, 5a Four Mile Run Levee and Floodwall, 5b1 City of Alexandria Deployable Floodwall

Birds could experience temporary disturbance during construction. No direct effects are expected. No migratory bird breeding habitat is known to occur in or adjacent to the construction LOD. Construction of this alternative may result in temporary, minor indirect effects to migratory birds. No long-term effects are expected. Approximately 20 trees that could potentially provide migratory bird habitat may need to be removed to construct the floodwall. This exact number of trees to be removed will be determined during PED. Planting new trees in a different location in the study area may be an option to offset the effects to migratory birds from tree removal. 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). Construction will not result in direct effects to bald eagles. To minimize adverse indirect 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 conducted during PED. 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 Nonstructural Plan

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

4.1.8 Wildlife

For all the alternatives, wildlife may temporarily avoid the construction areas during construction and for a short period of time following construction. Construction noise and disturbance should not adversely affect squirrels, chipmunks, opossum, and racoon because these animals thrive and

are accustomed to the noise and activity typical of urban environments. No direct effects to wildlife are expected. No long-term effects to wildlife 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 (Table 4-1).

Table 4-1. Level of Performance by Project Area.

Project Area	NACCS ID/ Virtual ID	Level of Performance for Levees/Floodwalls 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

For Old Town Alexandria, Four Mile Run, and Belle Haven the level of performance is based on a 1 percent AEP storm with approximately 95 percent confidence level and intermediate SLC curve through year 2080. For critical infrastructure, Reagan Airport and Arlington WPCP, the level of performance is based on .2 percent AEP storm with approximately 95 percent confidence level and intermediate SLC curve through year 2080.

Refer to Appendix A for a description of the level of performance for the structural measures. Project elements would be designed accordingly during PED.

To understand the hydrology and evaluate the effects of induced coastal flooding across the study area after the project is constructed, USACE modeled the WSELs under the future with-project condition for Alternatives 4c and 5c. The results of this analysis are described in the report: *The Probabilistic Coastal Hazard Analysis: D.C. Metropolitan Coastal Study* located in Appendix B.

An analysis of the overall system response to the inclusion of proposed levees at the Arlington WPCP and Belle Haven shows that changes in water level response to the simulated storms are limited to the region near the proposed levees (refer to Appendix B for more information).

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

These alternatives would not directly affect any waterways. Construction may result in minor and temporary indirect effects. 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. Based on future with-project modeling results, the proposed floodwall along the Arlington WPCP will not cause any increase in 1 percent AEP storm. Interior drainage analysis results show that water may occur on the inside (north side) of the floodwall during a 100-year rainfall event.

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 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 4-6). 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 sq ft of new direct 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 sq ft of direct temporary impacts from construction of the crossing (40 ft x 58 ft).

Figure 4-6. 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 4-7). 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 sq ft of direct 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 sq ft of direct 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 sq ft of new permanent fill impacts (2,250 sq ft minus 2,100 sq ft).

Figure 4-7. 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 sq ft of direct temporary impacts during construction and roughly 2,760 sq ft of new direct permanent fill impacts to the existing streams. A mitigation plan for the permanent fill impacts will be required if this alternative is constructed in the future.

Construction is likely to result in minor and temporary indirect effects to the East and West streams during construction. 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.

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 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 4-8). 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 sq ft of new direct 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 sq ft of direct temporary impacts from construction of the crossing (40 ft x 30 ft).

Figure 4-8. 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 4-9). 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 sq ft of direct 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 sq ft of direct temporary impacts (40 ft x 20 ft).

Figure 4-9. 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 sq ft of direct temporary impacts in the East and West Channels, and roughly 2,250 sq ft of new direct 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 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).

Construction is likely to result in minor and temporary indirect effects to the East and West Channels during construction. 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.

4.2.2 Water Quality

Construction of the proposed alternatives would have temporary and minor indirect effects 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. For the Ozone Transport Region, the actions associated with Alternatives 4b, 4c, 5a, and 5c would fall below the applicable de minimis emission thresholds for maintenance and nonattainment of 50 tpy for VOCs and 100 tpy of NOx. 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 4-2 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. A GHG analysis was not performed for alternatives 5b1 and 6 because these alternatives were added into the analysis after the air quality and GHG analysis were conducted for the final array of alternatives. Limited study funding has precluded performing a GHG analysis for these alternatives. However, Alternative 5b1 (Alexandria deployable floodwall) would be a temporary measure implemented before and after a storm event and is expected to release only limited localized emissions from equipment used to install and remove the deployable floodwall. Alternative 6 (nonstructural) would involve floodproofing and elevation of structures which are anticipated to have limited emissions during construction. Floodproofing would not involve heavy construction equipment and is expected to only result in minimal GHG emissions.

Table 4-2. 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 from direct and

indirect effects of HTRW 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 confirm that no contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented to protect workers from direct and indirect effects of HTRW.

Further investigations would be needed to confirm that no groundwater contamination is present in the footprint of the construction site.

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 confirm that no contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented to protect workers from direct and indirect effects of HTRW.

5b1 City of Alexandria Deployable Floodwall, 6 Nonstructural 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 nonstructural plan (USEPA, 2021b). Based on a desktop analysis of the EPA cleanup website, Alternatives 5b1 and 6 would have no direct or direct effects on HTRW areas. However, if these alternatives were carried forward for design and construction, an HTRW report and on-site investigation may need to be conducted to determine the presence of HTRW in these locations.

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 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 confirm that no contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented to protect workers from direct and indirect effects of HTRW.

4.2.6 Cultural Resources

USACE evaluated the direct and indirect effects to previously identified 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, or the NRHP-eligible Abingdon Research Station, Jet Engine Test Cell, and Abingdon Ruins, 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. An NRHP eligibility determination and viewshed assessment for the Mount Vernon Trail would be needed to fully determine effects to this resource.

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. No cultural resources survey work is recommended for this alternative.

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 would need to be archaeologically surveyed to fully determine their effects to this resource.

5b1 City of Alexandria Deployable Floodwall
A deployable floodwall along the waterfront in Old Town Alexandria would influence 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, an architectural survey and formal NRHP evaluation of buildings 50 years or older within the alternative's viewshed would be needed to fully determine how it may be affected by the proposed alternative. Additionally, Phase I archaeological surveys would be needed in locations of proposed levee and floodwall construction.

6 Nonstructural 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 nonstructural alternatives to buildings within the Alexandria Historic District, Occoquan Historic District, and Belle Haven. Mitigation would be required for nonstructural 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 architectural survey and determination of eligibility, or, at a minimum, individual buildings over 50 years old proposed for nonstructural 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 have no direct or indirect effects to the aesthetics of the airport.

4c Arlington WPCP Floodwall
The Arlington WPCP is 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 would have indirect effects on aesthetics by changing the viewshed. 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. It was noted during the public comment period that this area of Four Mile Run was part of a “living shoreline” enhancement approximately 6 years ago. Components of this project included public art installed on the metal fence surrounding the WPCP, a public art bench (imported from the Netherlands) located along this fence, an observation platform, as well as fish murals painted occasionally along the trail. These items, as well as the shoreline itself, are all likely to be directly affected by the proposed floodwall and should be protected/relocated. USACE would identify and coordinate any relocations with the NFS during PED. Construction of the floodwall would result in the removal of approximately 20 trees which would also directly affect aesthetics.

5a Four Mile Run Levee and Floodwall
The Four Mile Run levee and floodwall would be 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 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 would have no direct effects on aesthetics but would have indirect effects on the viewshed. 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 have no direct effects on aesthetics but would have indirect effects on the viewshed of the Potomac River. 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

Construction of the proposed levee and floodwall would result in the removal of trees which would directly affect aesthetics. The floodwall would also have indirect effects on the viewshed. The floodwall may permanently obstruct the view of the natural areas located south of Belle Haven and the GWMP for 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 4-10 and 4-11 are renderings from a 2009 Fairfax County Flood Risk Management Study of a proposed floodwall at Belle Haven (USACE, 2009).

Figure 4-10. Rendering of a 6.5-ft-tall Floodwall Along the East Side of Boulevard View.

Figure 4-11. Rendering of a 6.5-ft Floodwall South of the River View Condominiums Located at Boulevard View and 10th Street.

6 Nonstructural Plan
The nonstructural plan may have direct effects on aesthetics because trees may need to be removed during construction. The nonstructural plan may also have indirect effects on aesthetics. 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. There would be no direct effects to recreation from construction of the levee/floodwall. 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, indirect 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 to construct the floodwall (a period of 18 months). This alternative would have no permeant direct or indirect effects 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 direct or indirect effects 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 direct or indirect effects on recreation.

5c Belle Haven Levee and Floodwall
Construction of the levee and floodwall would directly affect recreation for the Belle Haven community and may affect recreation at Westgrove Park. Access to the tennis courts, walking paths, and other recreational amenities may be closed during construction (a period of 4 years). Two tennis courts adjacent to the Belle Haven East Channel are 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. Construction of the levee in Westgrove Dog Park may temporarily interfere with recreational activities at the park. Only a small area of the park would be affected, resulting in minor effects to recreation at the park during construction. No permanent effects to recreation at Westgrove Dog Park are expected.

Construction would also result in indirect effects to recreation. 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.

6 Nonstructural Plan
Implementation of the nonstructural plan would have no direct or indirect effects 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. Therefore, construction of the levee and floodwall would have temporary indirect effects to the surrounding community from noise.

4c Arlington WPCP Floodwall
Construction at the Arlington WPCP would occur during the daytime (8-hour construction days) and total construction time is anticipated to be 18 months. According to the Arlington County noise ordinance, impulsive noise cannot exceed 120 dBA and continuous noise cannot exceed 70 dBA anytime of the day (in Zoning District P-S where the Arlington WPCP is located) (Arlington County, Virginia, 2020). 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 floodwall would have minor and temporary indirect effects on the surrounding community due to noise. It is not expected that construction of the Arlington WPCP would generate continuous and impulsive noise levels that exceed the restrictions in the Arlington County noise ordinance. 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 floodwall would have minor and temporary indirect effects on the surrounding community due to noise. 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

Construction of the deployable floodwall would have minor and temporary indirect effects on the surrounding community due to noise. 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 (8-hour construction days) and total construction time is anticipated to be four years. According to the Fairfax County noise ordinance, outdoor construction noise is allowed from 7 a.m. to 9 p.m., Monday through Friday, and from 9 a.m. to 9 p.m. on Saturday and Sunday and on federal holidays. The maximum decibel level cannot exceed 90 dBA in residential areas. The Fairfax County noise ordinance allows for an 8-hour construction day not to exceed 90 dBA in the residential community of Belle Haven (Fairfax County, Virginia, 2016). 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). Construction of the floodwall would have moderate and temporary indirect effects on the surrounding community due to noise. 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 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.

6 Nonstructural Plan

Construction of the nonstructural measures would generate noise during construction. Construction of the nonstructural measures would have minor and temporary indirect effects on the surrounding community due to noise. Noise is not expected to be significant and would be temporary during the period of construction.

4.2.10 Economically Disadvantaged Communities

4b Reagan National Airport Levee and Floodwall

One economically disadvantaged community is located in close proximity to the Reagan National Airport. This community is located in Arlandria and has a population of approximately 8,000 people primarily including Hispanic or Latino ethnicities. Indicators of burden in this community include projected flood risk (95th percentile nationally), linguistic isolation (96th percentile nationally), high school education (33 percent of people 25 years and older whose education is less than a high school diploma), and low income (82nd percentile nationally) (CEQ, 2022).

Using EPA's EJ Screen to analyze environmental justice indices as compared to the state, many economically disadvantaged communities were identified within proximity to the Reagan National Airport in Virginia and Washington, DC. These communities have many indicators of burden (above the 80th percentile statewide) including exposure to pollution (ozone, particulate matter, traffic proximity, etc.), and socioeconomic indictors including low income and limited English speaking (EPA, 2022c).

Using Virginia's EJScreen+, several communities in close proximity to Reagan National Airport were identified as low income communities (30 percent of the population under HUD 80 percent annual median income and under two times the federal poverty level) (VADEQ, 2024).

Construction of the levee and floodwall at Reagan National Airport will cause an increase in noise, air emissions, traffic, and may effect aesthetics within and surrounding the airport. These indirect

effects will be minor and temporary during construction and are not expected to cause an undue burden on economically disadvantaged communities. No direct effects to economically disadvantaged communities are expected from construction and operation of the levee and floodwall at the Reagan National Airport.

4c Arlington WPCP Floodwall

Six economically disadvantaged communities are served by the Arlington WPCP. Economically disadvantaged communities make up approximately 13 percent of the population that is located within the Arlington WPCP sewershed (approximately 27,500 residents and 11,653 households). The communities highlighted in Figure 1 and summarized in Table 1 in Appendix G14 are identified as disadvantaged primarily due to the following indicators of burdens (as compared to the rest of the United States): housing cost, linguistic isolation, lack of high school education, low median income, and low income (CEQ, 2022). The disadvantaged communities are primarily Hispanic and white with Spanish and Asian pacific island as the primary language (EPA, 2022c). These communities are in Fairfax and Arlington Counties, Virginia approximately 2.5 to 5 miles northeast of the WPCP. The percentiles for the indicators of burdens are mostly comparable between the state and national levels (Table 1 in Appendix G14).

Due to high housing prices in Arlington County (approximately 220 percent higher than the national average), Arlington's poverty level line is approximately 150 percent above the federal poverty level. The highest poverty zip code in Arlington is 22204, which includes three of the disadvantaged communities served by the Arlington WPCP. Approximately 14 percent of the population living in this zip code are below the Arlington County poverty level. The Barcroft, Arlington Mill, and Buckingham neighborhoods are the highest poverty neighborhoods in Arlington. These neighborhoods are in the disadvantaged communities served by the Arlington WPCP (Arlington Community Foundation, 2023).

The cumulative environmental justice (EJ) impact represents the overall environmental impacts and vulnerabilities in a census tract compared to other census tracts in the state. Four disadvantaged communities served by the Arlington WPCP are identified as having the highest cumulative EJ impacts as compared to the rest of the state. The other two disadvantaged communities served by the WPCP have high cumulative EJ impacts as compared to the rest of the state. Figure 2 in Appendix G14 shows the cumulative EJ impacts for the six disadvantaged communities (Mapping for Environmental Justice, 2021).

Census tracts located directly south of the WPCP (across Four Mile Run), and one tract located approximately 0.5 miles north of the WPCP are in the 95th to 99th percentiles (as compared to the state) for potential exposure to toxic chemicals in wastewater discharge. Although the census tract located directly south of the WPCP is not served by the Arlington WPCP, it is a disadvantaged community (CEQ, 2022; EPA, 2022c). The wastewater discharge environmental indicator uses the EPA's Risk Screening Environmental Indicators Model to determine the amount of toxic chemicals released or transferred from facilities, together with factors such as the chemical's fate

and transport through the environment, each chemical's relative toxicity, and potential human exposure (EPA, 2022c).

Economically disadvantaged communities identified as low income typically have less resources to cope with crises or disasters. Vulnerable residents may be less able to afford preparedness actions such as making home improvements to increase resilience to disasters. Paying to fix damages from sewer backups places an extra burden on vulnerable residents that are already in an area with high housing cost (spending more than 30 percent of income on housing), and that have low incomes.

Approximately 27,500 vulnerable residents face many barriers to receiving aid to help them repair their homes and meeting their other needs:

- Due to the language barrier, linguistically isolated communities may have a harder time finding programs to help pay for the cost of repairs.
- Vulnerable residents may have a harder time finding alternative housing if their residence is uninhabitable due to a sewer backup.
- Vulnerable residents may not have the means to drive farther away to find food and other essential needs if these businesses are shut down.
- Vulnerable residents may not have the means to find childcare if schools are shut down.
- Fishing in Arlington/Alexandria along the Potomac River may be unsafe for vulnerable residents that rely on fishing for food.

5a Four Mile Run Levee and Floodwall

Alternative 5a is in census block 51510201203 and has been identified as an economically disadvantaged community due to the percentage of the population identified as low income, linguistically isolated, higher education non-enrolled. The Climate and Economic Justice Screening Tool also identified this census tract as disadvantaged due to a high percentage of the population that are exposed to diesel particulate matter (diesel exhaust in the air) (CEQ, 2022). Construction of the levee and floodwall in Four Mile Run Park would not disproportionately affect the community. Air emissions and noise generated during construction would not significantly affect nearby communities. Further investigations would be needed to confirm that no groundwater contamination is present 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.

5b1 City of Alexandria Deployable Floodwall

According to CJEST, no economically disadvantaged communities were identified within or near the location of Alternative 5b1 in Virginia. The closest economically disadvantaged community is located approximately 3 miles north of the location of Alternative 5b1. This is the same community described in the first paragraph under Alternative 4b. Several economically disadvantaged

communities are located across the Potomac River from the project location in Washington, DC. These communities are considered disadvantaged because they meet the threshold for several indicators of burden including health (asthma and low life expectancy), housing (housing cost), workforce development (low median income, poverty, unemployment), and these communities are also considered low income (CEQ, 2022).

Using EPA's EJ Screen to analyze environmental justice indices as compared to the state, many economically disadvantaged communities were identified within proximity of the location of Alternative 5b1 in Virginia and Washington, DC. These communities have many indicators of burden (above the 80th percentile statewide) including exposure to pollution (ozone, particulate matter, traffic proximity, etc.), and socioeconomic indictors including low income, unemployment rate, and limited English speaking (EPA, 2022c).

Using Virginia's EJScreen+, three communities in close proximity to the location of Alternative 5b1 were identified as low income communities. No low income communities were identified within the project location (VADEQ, 2024).

Installation and removal of the deployable floodwall will cause an increase in noise, air emissions, traffic, and may effect aesthetics within and surrounding the Alexandria waterfront before and after a storm. These indirect effects will be very minor and temporary during installation and removal of the floodwall and are not expected to cause an undue burden on economically disadvantaged communities located 3 miles from the project location. No direct effects to economically disadvantaged communities are expected from installation and removal of the deployable floodwall.

5c Belle Haven Levee and Floodwall

According to CJEST, no economically disadvantaged communities were identified within or adjacent to Belle Haven. The closest economically disadvantaged community is located approximately 1 mile southwest of Belle Haven. This community has a population of approximately 5,000 people primarily including white and Hispanic or Latino ethnicities. Indicators of burden in this community include linguistic isolation (93rd percentile nationally) and high school education (13 percent of people 25 years and older whose education is less than a high school diploma) (CEQ, 2022).

Using EPA's EJ Screen to analyze environmental justice indices as compared to the state, economically disadvantaged communities located approximately one mile west of Belle Haven were identified. These communities have socioeconomic indictors of burden including unemployment rate and limited English speaking (EPA, 2022c). No low income communities were identified by Virginia's EJScreen+ in the vicinity of Belle Haven (VADEQ, 2024).

Construction of the levee and floodwall will cause an increase in noise, air emissions, traffic, and may effect aesthetics within and surrounding Belle Haven. These indirect effects will be minor and temporary during construction of the levee and floodwall and are not expected to cause an undue burden on economically disadvantaged communities located one mile from the project

location. The indirect effects will have moderate effects on the Belle Haven residents, which are not considered economically disadvantaged. No direct effects to economically disadvantaged communities are expected from construction of the Belle Haven levee and floodwall.

6 Nonstructural Plan

Nonstructural measures are proposed in the locations of the Arlington WPCP, Four Mile Run, Belle Haven, the Alexandria waterfront, and in Occoquan Bay. Effects to economically disadvantaged communities in the locations of the Arlington WPCP, Four Mile Run, Belle Haven and the Alexandria waterfront would be similar to the effects analyzed above for Alternatives 4b, 4c, 5a, 5b1, and 5c.

CJEST was used to identify economically disadvantaged communities that may be effected by the proposed nonstructural measures in Occoquan Bay. No economically disadvantaged communities were identified in the project location; however, several communities were identified directly west of the project location. Indicators of burden in these communities include housing cost, linguistic isolation, low median income, and above 10 percent of the population (25 years and older) has less than a high school education (CEQ, 2022).

Using EPA's EJ Screen to analyze environmental justice indices as compared to the state, economically disadvantaged communities located approximately one mile west of Occoquan Bay were identified. These communities have socioeconomic indictors of burden including low income and limited English speaking. These communities are also located in the proximity of high traffic and in a high percentile for air toxics cancer risk (EPA, 2022c). Many of these communities were also identified by Virginia's EJScreen+ as being low income (VADEQ, 2024).

Construction of the non-structural measures will cause an increase in noise, air emissions, traffic, and may effect aesthetics within and surrounding Occoquan Bay. These indirect effects will be very minor and temporary during construction and are not expected to cause an undue burden on economically disadvantaged communities located one mile away from the project location. The indirect effects will have moderate effects on the residents of Occoquan Bay in the immediate location of construction, which are not considered economically disadvantaged. No direct effects to economically disadvantaged communities are expected from construction of the nonstructural measures.

4.2.11 Prime and Unique Farmland

The Farmland Protection Policy Act (P.L. 97-98, Sec. 1539-1549; 7 U.S.C. 4201, et seq.) is intended to minimize the impact federal activities have on the unnecessary and irreversible conversion of farmland to non-agricultural uses. None of the alternatives have the potential to convert important farmland to non-farm use. Although the locations of Alternatives 5a and 5c have soils that qualify as prime farmland, these locations are in urban settings and are not currently being used as farmland.

4b Reagan National Airport Levee and Floodwall and 4c Arlington WPCP Floodwall
Alternatives 4b and 4c would have no direct or indirect effects on prime or unique farmland. The soils in the locations of these alternatives consists of urban and built-up land with no prime farmland.

5a Four Mile Run Levee and Floodwall
The wetlands and waterways in Four Mile Run Park are identified as prime farmland consisting of Woodstown sandy loam with 2 to 7 percent slopes. These wetlands and waterways are not used as farmland and are conserved for scenic preservation (VADCR, 2022). Uplands consist of grist mill sandy loam with 0 to 25 percent slopes and urban land, soils not characterized as prime farmland. Therefore, construction of the Four Mile Run levee and floodwall would have no direct or indirect effects on prime or unique farmland.

5b1 City of Alexandria Deployable Floodwall
Installation of the deployable floodwall would have no direct or indirect effects on prime or unique farmland. Soils consist of grist mill sandy loam with 0 to 25 percent slopes and urban land, soils not characterized as prime farmland.

5c Belle Haven Levee and Floodwall
Upland forested lands located south of the River Towers condominiums are identified as prime farmland consisting of Mattapex loam with 2 to 7 percent slopes. These forested lands are not used as farmland and are conservation lands managed by NPS (VADCR, 2022). Other soils in the location of this alternative consist of a grist-mill Woodstown complex with 2 to 7 percent slopes, grist-mill sandy loam with 0 to 25 percent slopes and urban land, soils not characterized as prime farmland. Therefore, construction of the Belle Haven levee and floodwall would have no direct or indirect effects on prime or unique farmland.

6 Nonstructural Plan
The nonstructural plan would have no direct or indirect effects on prime or unique farmland. Soils in the location of the nonstructural plan consists of urban and built-up land with no prime farmland.

4.3 Summary of Effects

Table 4-3 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 4-3. 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 WPCP Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Nonstructural Plan
Wetlands	Wetlands located on managed lands expected to maintain natural and historic value. SLR threatens low-lying wetlands.	No direct or indirect effects.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. 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 direct or indirect effects.
Floodplains	Expected to move inland as sea levels rise.	Reduction in the amount of floodplain for coastal floodwaters. No direct or indirect effects to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No direct or indirect effects to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No direct or indirect effects to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No direct or indirect effects to natural floodplains.	Reduction in the amount of floodplain for coastal floodwaters. No direct effects to natural floodplains. Minor indirect effects to the natural floodplain south of Belle Haven.	No direct or indirect effects.
Submerged Aquatic Vegetation	Potential effects from stressors associated with climate change.	No direct effects expected. **Up to 15,000 sq ft of temporary, indirect impacts to SAV due to shading from the barges.**	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.
Threatened and Endangered Species	Habitats located in low-lying areas are threatened by SLR. Successful management strategies may help recover species.	No direct or indirect effects to terrestrial and freshwater species. No direct effects to marine species. Insignificant indirect effects to Atlantic sturgeon and critical habitat and shortnose sturgeon.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.
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.	No direct effects to anadromous fish. 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 direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.	No direct or indirect effects.
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 direct effects. No additional indirect effects to migratory birds outside of effects generated by the bird cannons.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. Temporary and minor indirect effects during construction.	No direct effects. Temporary and minor indirect effects during construction. Protective buffers to minimize adverse effects to nesting bald eagles would be implemented during construction. A permit from USFWS would be obtained if these buffers could not be adhered to.	No direct effects. Temporary and minor indirect effects during construction.

Resource Topic	1 No-Action Alternative	4b Reagan National Airport Levee and Floodwall	4c Arlington WPCP Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Nonstructural Plan
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.	No direct effects. Temporary and minor effects during construction.	No direct effects. Temporary and minor effects during construction. Interior drainage analysis results show that water may occur on the inside (north side) of the floodwall during a 100-year rainfall event.	**Roughly 4,320 sq ft of temporary direct impacts and roughly 2,760 sq ft of new direct permanent fill impacts to waterways. A mitigation plan for the permanent fill impacts will be required.** Temporary and minor indirect effects.	No direct effects. Temporary and minor effects during construction.	**Roughly 2,000 sq ft of temporary direct impacts and roughly 2,250 sq ft of direct permanent fill impacts to streams. A conceptual mitigation plan for the permanent fill impacts has been developed.** Temporary and minor indirect effects.	No direct or indirect effects.
Water Quality	Reaching long-term water quality goals would depend on efforts to reduce nutrients and sediments from both point and non-point sources.	No direct effects. Temporary and minor indirect effects on water quality.	No direct effects. Temporary and minor indirect effects on water quality.	No direct effects. Temporary and minor indirect effects on water quality. Temporary and minor effects to water quality from sediment released from the flap gates following a storm event.	No direct effects. Temporary and minor indirect effects on water quality.	No direct effects. Temporary and minor indirect effects on water quality. Temporary and minor effects to water quality from sediment released from the flap gates following a storm event.	No direct or indirect effects.
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.	Minimal and temporary emissions during construction.	2,826 tons of CO2 emissions during construction.	Minimal and temporary emissions during construction.
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 confirm the no groundwater contamination is present in these areas.	**Potential adverse direct and indirect 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 direct and indirect effects to human health. Further investigations are needed to confirm that no groundwater contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	**Potential adverse direct and indirect effects to human health. Further investigations are needed to confirm the no groundwater contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	No direct or indirect effects.	**Potential adverse direct and indirect effects to human health. Further investigations are needed to confirm that no groundwater contamination is present in the construction area. If contamination was encountered, safety precautions and appropriate disposal of contaminated material would be implemented.**	No direct or indirect effects.
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 direct or indirect effects.	**Potential permanent adverse effects to site 44AX0207, an archaeological site that has not been evaluated for listing in the NRHP. An archeological survey of**	Potential temporary visual effects to the NHL-listed Alexandria Historic District during floodwall deployment.	**Potential visual effects from the GWMP and Mount Vernon Trail of the proposed floodwall. The Belle Haven neighborhood has never been evaluated for the**	**Mitigation would be required for nonstructural measures proposed for buildings within the Alexandria and Occoquan Historic Districts. Belle Haven**

Resource Topic	1 No-Action Alternative	4b Reagan National Airport Levee and Floodwall	4c Arlington WPCP Floodwall	5a Four Mile Run Levee and Floodwall	5b1 Alexandria Deployable Floodwall	5c Belle Haven Levee and Floodwall	6 Nonstructural Plan
				the levee/floodwall and staging area would need to be conducted to determine effects to this site.		**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.**	**would require a formal determination of NRHP eligibility, or, at a minimum, individual buildings proposed for nonstructural 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 and historic sites are expected to retain their natural and historic value in the future.	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. USACE would identify and coordinate any relocations of public art with the NFS during PED.	**View of natural areas and the GWMP would be permanently obstructed.**	View obstructed by elevated structures in some locations.
Recreation	Future recreational opportunities in the study area are outlined in VADCR's 2018 Outdoors Plan.	No direct effects. Minor, permanent indirect effects.	Temporary direct and indirect effects during construction.	Temporary direct and indirect effects during construction.	Temporary direct and indirect effects during construction.	Temporary direct and indirect effects during construction. **Permanent direct effects to recreation due to impacts to tennis courts adjacent to the Belle Haven East Channel.**	No direct or indirect effects.
Noise	Construction and traffic noise would be expected to intensify in the study area as population and development increases.	Temporary indirect effects during construction. Noise levels generated by construction equipment are not expected to exceed levels generated by approaching aircraft.	Temporary indirect effects during construction.	Temporary indirect effects during construction.	Temporary indirect effects during construction.	Temporary indirect effects during construction.	Temporary indirect effects during construction.
Economically Disadvantaged Communities	There are many ongoing efforts to promote fair and equitable treatment of all communities throughout Northern Virginia.	Minor and temporary indirect effects during construction.	**Benefits to economically disadvantaged communities by minimizing flood risk and supporting continued operations of the WPCP during a flood event.**	**The levee and floodwall would build the community's resilience to coastal flooding.**	Minor and temporary indirect effects during construction.	Minor and temporary indirect effects during construction.	Minor and temporary indirect effects during construction.
Prime and Unique Farmlands	The need for agricultural land and the businesses it supports is needed now and in the future. The VDACS Office of Farmland Preservation provides programs and tools to help reverse the loss of Virginia's farmland.	No prime or unique farmlands.	No prime or unique farmlands.	Soils that qualify as prime farmland are present in the location of this alternative; however, this alternative would not convert farmland to non-agriculture use.	No prime or unique farmlands.	Soils that qualify as prime farmland are present in the location of this alternative; however, this alternative would not convert farmland to non-agriculture use.	No prime or unique farmlands.

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 4-4. Table 4-4 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 4-4.

Measures for impacts that are considered greater than "minor impacts" are shown in Table 4-3 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 for the Recommended Plan, Arlington WPCP are in Section 6.

Table 4-4. 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 5c – Belle Haven Levee and Floodwall	**Measure**: Route alignment so that it does not cross waterways.	**Measure:** Reduce the permanent footprint of the	No mitigation measures were identified.	**Measure:** Purchase credits from a mitigation bank or approved in-lieu fee program

Alternative	Avoid	Minimize	Mitigate	Compensate
	Objective: Avoid impacts to streams. **Impact Addressed:** Prevents loss of stream bed. **Relevant Laws:** CWA, FWCA, WRDA	floodwall that crosses waterways. **Objective:** Minimize impacts to stream bed. **Impact Addressed:** Reduces the amount of stream bed lost. **Relevant Laws:** CWA, FWCA, WRDA		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 – Nonstructural 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: Economics.

The comparison of plans leading to the identification of the TSP was conducted using the FY22 price level and discount rate of 2.25 percent. The Recommended Plan has been updated to the FY24 price level and discount rate of 2.75 percent which is current at the signing of this IFR/EA.

5.1 With-Project Condition

As stated previously, the top level of performance for the alternatives was used to determine the 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	Average Annual Damages
(Alt-4b) MA7: Reagan National Airport	$12,000
(Alt-4c) MA8: Four Mile Run Arlington	$21,000
Total	$33,000

When the project alternative future conditions were compared to the FWOP conditions, Alternative 4 reduced the annual average damages in Reagan National Airport MA by 84 percent, Four Mile Run Arlington WPCP MA by 89 percent, and by 88 percent for both combined MAs.

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

Model Area	Average Annual Damages
(Alt-5b1) MA10: Old Town Alexandria	$432,000
(Alt-5a) MA12: Belle Haven	$568,000
(Alt-5c) MA17: Four Mile Run Alexandria	$20,000
Total	$1,020,000

When the project alternative future conditions were compared to the FWOP conditions, Alternative 5 reduced the average annual 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 (or 4 percent AEP) 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 percent AEP)		Nonstructural Measures (2 percent AEP)		Nonstructural Measures (5 percent 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

5.1.1 With-Project Induced Flooding

ERDC performed with-project condition modeling to determine the effect of the proposed alternative plans at Belle Haven and Arlington WPCP using save points and virtual IDs. A Virtual ID (or Virtual Gauge) is an identifier based on the NACCS study which informed the focus areas for this current study. A save point is a point of interest in the study area. From 23 save points modeled in the study area, the save point 598194 was selected in the middle of the channel between the Reagan National Airport and the Bolling Air Force Base to run G2CRM since the other save points have approximately the same water level within a 200 km radius circle of the project site. This save point contained the water elevations and wave heights for each of the storm to be used in the model and eventually used to represent 22 model areas. Three save points; 5984, 14608, and 14731 were used by engineering to define the top of protective system elements. These water elevations will be applied to the model areas along with economic inputs to derive flood damages in the existing conditions, future without-project conditions, and future with-project conditions for the Northern Virginia study area.

An analysis of the overall system response to the inclusion of proposed floodwalls and levees at Arlington WPCP and Belle Haven shows that changes in water level response to the simulated storms are limited to the region near the proposed levees. The most noticeable reduction in maximum water level is in the area protected by the Belle Haven levee for the storms with the most extreme response. Because the difference in water level with the inclusion of the with-project levees and floodwalls is limited to these isolated areas, the analysis presented in the ERDC report focuses on the localized changes in water level attributed to the levees and floodwalls.

Eight additional save points (Virtual ID 22-29 as shown in Figure 5-1) are included in the analysis to evaluate the impact of the levees/floodwall projects on water levels. Figure 5-2 identifies the maximum water levels for the five representative storms for existing and with-project conditions on either side of the two with-project proposed structures. Based on modeling results, the proposed floodwall along the Arlington Wastewater Treatment Plant does not cause any increase in 1 percent AEP storm.

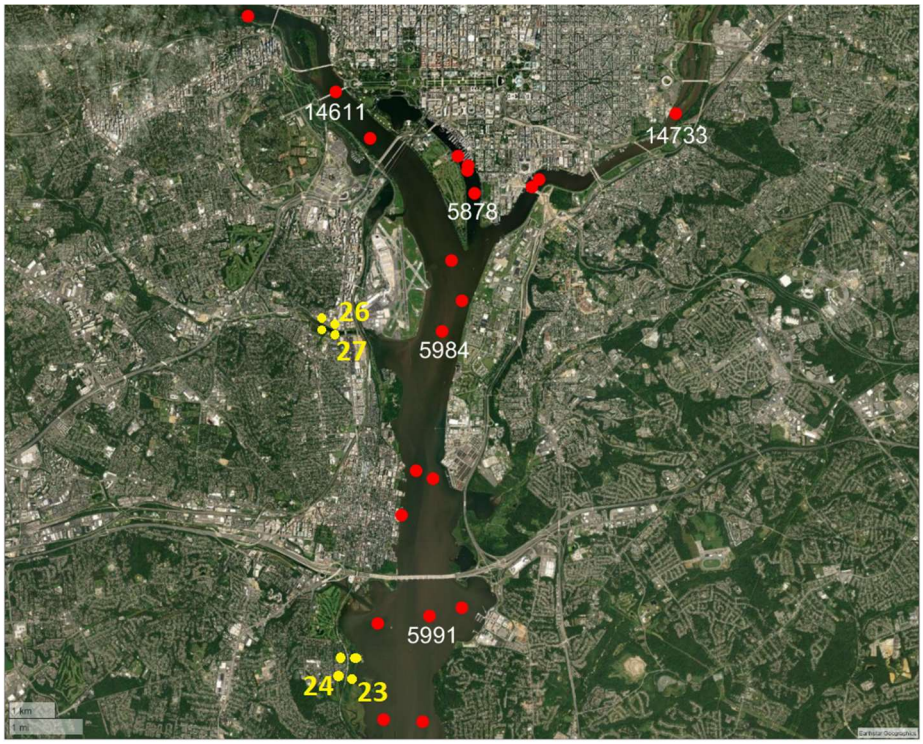

Figure 5-1. Additional Virtual ID Locations (in yellow) and Save Points (in red) Surrounding the D.C. Metro Study.

Modeling results near the Arlington WPCP are shown in the following figures for Virtual ID 26 and 27. Figure 5-2 shows the proposed project does not cause an increase in WSEL until .1 percent AEP storm. Figure 5-3 below shows negligible increases in WSEL for lower frequencies. However, for larger frequency events such as .1 percent AEP storm the WSEL will decrease.

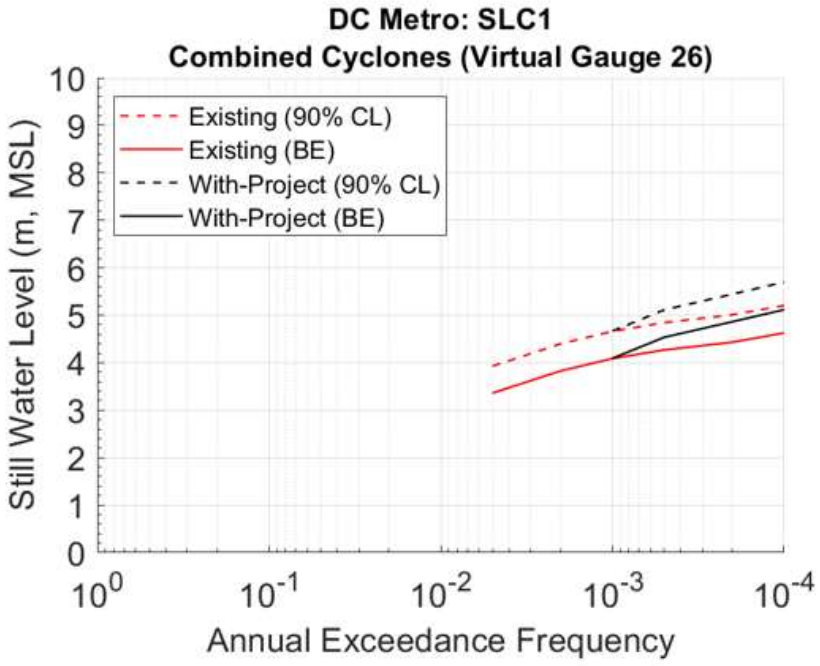

Figure 5-2. Comparison of FWOP and FWP Condition WSEL Virtual ID 26.

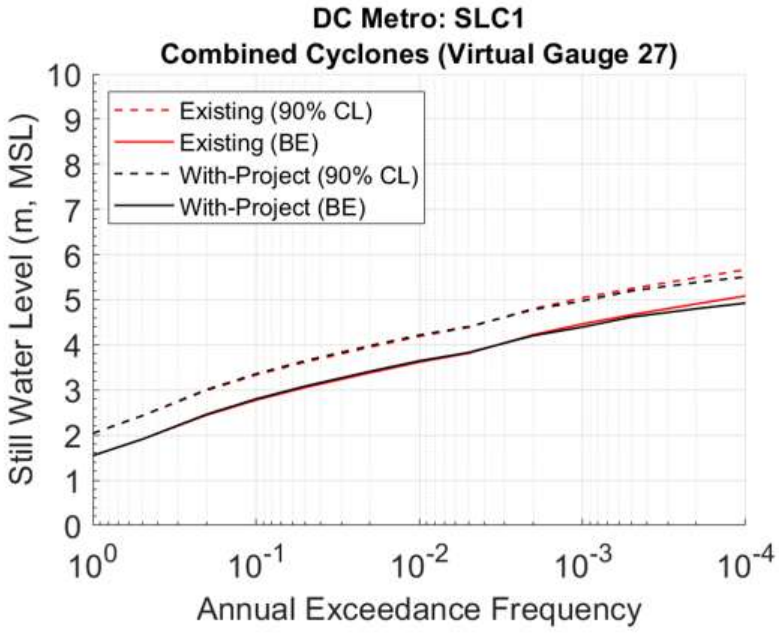

Figure 5-3. Comparison of FWOP and FWP Condition WSEL Virtual ID 27.

The ERDC report for the FWP modeling is included as an attachment to Appendix B: Hydraulics and Hydrology.

5.1.2 Climate Change Adaptability

The study area is most vulnerable to SLC, therefore adaptability of SLC is discussed in this section. The relative sea level rates considered a low rate based on an extrapolation of the historic rate, and intermediate and high rates which include future acceleration of the eustatic sea level change rate. These rates of rise correspond to 1.09 feet, 1.75 feet, and 3.93 feet from 2031– 2080 under the low, intermediate, and high rates of USACE RSLC projections, respectively. It is anticipated that the project will be constructed in 2031, which will be the start of monitoring sea level change for the project. The USACE determined that the plan heights would be developed to the intermediate SLC scenario. The following Figure 5-4 shows that the current SLC trend is higher than that of the USACE intermediate scenario and therefore the consideration for adaptability of proposed plans in the future is discussed qualitatively later in this report. Periodic monitoring of SLC trend may help understand the risk and adaptation. Opportunities for implementing adaptations to any proposed structures based on the planning 100-year adaptation horizon would be evaluated further in PED. Additional information on adaptability for SLC can be found in Section 5.6.1 and in Appendix B: H&H Analysis.

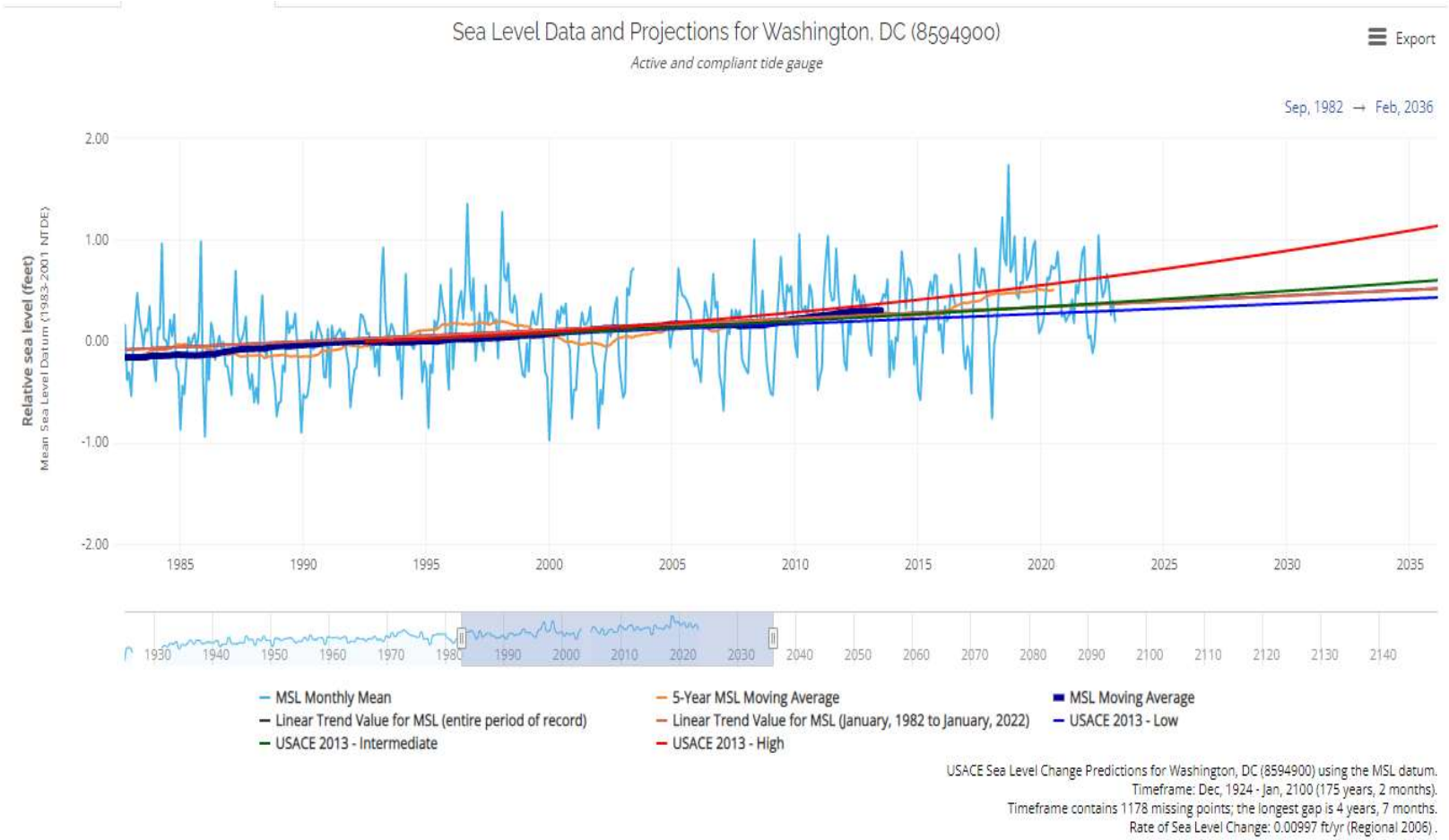

Figure 5-4. Current SLC Trend for Arlington WPCP and Belle Haven.

5.2 With-Project Benefits

The difference in expected mean average annual damages in the DC Coastal Study area between the FWOP condition and future with-project condition represents the CSRM 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 1105-2-103, dictates that the calculation of net NED benefits for a plan is calculated in average annual equivalent terms. Therefore, the average annual damages were converted to average annual damages and the costs were annualized using the FY22 discount rate of 2.25 percent and a 50-year period of analysis for the purpose of the comparison of plans to identify the TSP in March 2022.

As stated previously, Alternative 8, Combination Plan, was developed to provide the opportunity to carry forward more than one alternative if more than one alternative yielded positive net benefits. After evaluating plans individually, the team combined the Arlington WPCP and Belle Haven (which both yielded positive net economic benefits based on the initial cost estimates) as Alternative 8. Both of these alternatives serve separate planning areas, but would both reduce coastal storm risk to their respective counties.

The equivalent annual benefits were compared to the average annual cost to develop net economic benefits and a BCR for each alternative. The net economic 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 economic 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 percent AEP storm)	$209,738,000	$7,030,000	$1,218,000	($5,812,000)	0.17
Alt 6 (Nonstructural 2 percent AEP storm)	$188,233,000	$6,309,000	$1,081,000	($5,228,000)	0.17
Alt 6 (Nonstructural 5 percent AEP storm)	$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

1. FY22 discount rate of 2.25 percent.

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 percent AEP storm[2]	$93,356,000	$3,129,000	$64,000	($3,065,000)	0.02
Alt 4c: Arlington WPCP 0.2 percent AEP storm	$2,694,000	$90,000	$179,000	$89,000	2.0
Alt 5a: Four Mile Run Levee & Floodwall 1 percent AEP storm	$35,243,000	$1,181,000	$104,000	($1,077,000)	0.09
Alt 5b1: Alexandria Deployable Floodwall 2 percent AEP storm	$157,214,000	$5,270,000	$1,201,000	($4,069,000)	0.23
Alt 5c: Belle Haven Levee & Floodwall 1 percent AEP storm	$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 percent AEP storm	$61,616,000	$2,065,000	$380,000	($1,685,000)	0.18
MA12: Belle Haven 1 percent AEP storm	$128,212,000	$4,297,000	$782,000	($3,515,000)	0.18
MA16: Occoquan Bay 1 percent AEP storm	$19,910,000	$667,000	$56,000	($611,000)	0.08
MA10 & MA20: Old Town Alexandria 2 percent AEP storm	$55,178,000	$1,849,000	$342,000	($1,507,000)	0.18
MA12: Belle Haven 2 percent AEP storm	$113,879,000	$3,817,000	$684,000	($3,133,000)	0.18
MA16: Occoquan Bay 2 percent AEP storm	$19,176,000	$643,000	$55,000	($588,000)	0.09
MA10 & MA20: Old Town Alexandria 5 percent AEP storm	$34,639,000	$1,161,000	$286,000	($875,000)	0.25
MA12: Belle Haven 5 percent AEP storm	$79,624,000	$2,669,000	$514,000	($2,155,000)	0.19
MA16: Occoquan Bay 5 percent AEP storm	$16,479,000	$552,000	$31,000	($521,000)	0.06

1. FY22 discount rate of 2.25 percent.
2. This evaluation addresses damages to structures but does not evaluate system impacts and potential service disruption, potentially increasingly frequent in the future.

Alternatives were first compared by group to show annualized net benefits for Alternatives 4, 5, 6 (at 5 percent, 2 percent, and 1 percent AEP event) and 8. Only Alternative 8 yielded positive annualized 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 event) and Alternative 8 were evaluated, Alternatives 4c, 5c and 8, as explained previously, yielded positive annualized net benefits. Alternative 4c and 5c yielded positive annualized net benefits of $89,000 and $361,000, respectively. It was determined that based on the highest positive net economic benefits along with other environmental and social factors, Alternative 8 is the NED Plan because it reasonably maximizes total annualized net benefits.

5.3 Four Accounts Evaluation

5.3.1 National Economic Development (NED)

In accordance with the Federal objective, and as discussed previously, the NED plan is defined as the cost-effective plan that maximizes net economic 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	OMRR&R	Total Cost	Average Annualized Costs	Average Annualized Benefits	Average Annualized Net Benefits	BCR
Alternative-1	$0	$0	$0	$0	$0	$0	$0	$0	0.0
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_1 percent AEP storm	$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_2 percent AEP storm	$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_5 percent AEP storm	$123,020,000	$7,722,000	$130,742,000	-	$130,742,000	$4,382,000	$831,000	($3,551,000)	0.2

1. **FY22 discount rate of 2.25 percent.**

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)

To evaluate the EQ account, effects to environmental, cultural, and socioeconomic resources were qualitatively assessed for each alternative. Effects to natural resources including wetlands, SAV, and wildlife, cultural resources, and socioeconomic resources including effects to economically disadvantaged communities were assessed and compared for each alternative. Sections 2 and 4 describe the information used to assess the effects.

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 using the FWOP as a baseline. The numbers in Table 5-7 show the incremental life loss or reduction in life loss with implementation of that alternative. For all structural solutions, life loss to people under 65 is reduced to “0”, with negative numbers showing how much of a reduction that would be from the FWOP condition (or incremental life loss). For the nonstructural solutions, there is less of a reduction in life loss regardless of age due to the residual risk of flooding during an event. Even if the house is elevated or flood-proofed, there is still a risk that people will not have the time to evacuate depending on the storm event (and flood inundation, debris etc. along evacuation routes). Life loss over 65 remains for a few of the alternatives due to immobility issues (medical equipment, disability, ability to climb stairs/ladder to evacuate to higher elevations, etc.) impairing a person’s ability to evacuate during an event and instead needing to shelter in place. Table 5-7 does not include Alternative 8 because it has not been defined at this point in the plan formulation process. Once plans are compared in Section 5.4,

USACE would be able to establish whether more than one alternative should be combined and carried forward in a combination plan.

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_1 percent AEP storm) (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_2 percent AEP storm) (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_5 percent AEP storm) (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 CSRM measures for critical infrastructure and other structures were developed for each alternative as part of this study.

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 economic benefits. Per ER 1105-2-103, the calculation of net NED benefits for a plan is calculated in average annual equivalent costs (AAEQ). Therefore, the total damages were converted to average annual damages and the costs were annualized using the FY22 discount rate of 2.25 percent and a 50-year period of analysis for the purpose of the comparison of plans to identify the TSP in March 2022.

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 effects of each alternative on natural resources including wetlands, SAV, and wildlife, cultural resources, physical resources including air quality, and socioeconomic resources including economically disadvantaged communities in the study area. The overall effects from each alternative were then categorized as minor, moderate, or significant. Alternative 4c would reduce the risk of the Arlington WPCP from flooding and potential damage. Should the treatment plant experience a disruption in service over 800 acres of aquatic habitat and over 110 acres of wetlands could be negatively impacted.

Effects of the alternatives on economically disadvantaged communities were considered when comparing the alternatives. Implementation of Alternatives 4b, 5b1, 5c, and 6 would have no direct or indirect adverse or beneficial effects on economically disadvantaged communities. No economically disadvantaged communities are located within or adjacent to these alternatives. Implementation of Alternative 5a, Four Mile Run Floodwall, would have beneficial effects on the economically disadvantaged community located adjacent to Four Mile Run Park. Alternative 4c, Arlington WPCP Floodwall, is located across Four Mile Run from Alternative 5a. FWP modeling showed that the implementation of the floodwall at the Arlington WPCP would not induce flooding on the economically disadvantaged community adjacent to Four Mile Run Park during a 1 percent AEP storm. Alternative 4c would support the health and safety of approximately 27,500 vulnerable residents in the service area, in six economically disadvantaged communities, by avoiding a disruption in wastewater service that may result from a flooding event. It would also avoid placing an extra burden on residents to repair damages or find alternative housing during a disruption of wastewater service.

The OSE account was estimated using the G2CRM model. Each structure has an associated with-storm surge lethality. The vulnerable group, the population 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. Maximum Total Net Benefits Evaluation of Alternative Plans.

Plan Alternatives	Alternative Area Description	NED	RED		OSE	EQ	
		Net Benefits ($1,000)	US Jobs	Value Added ($1,000)	Incremental Life Loss	Effects	Impact
Alt-4b	BH7: Reagan National Airport Proposed Bulkhead	($3,065)	1491	$166,890	0.0	Approximately 15,000 sq ft of temporary impacts to SAV, Contaminated soils, Mount Vernon Trail Historic Resource	Moderate
Alt-4c	BH8: Four Mile Run Arlington WPCP Proposed Bulkhead	$89	43	$4,816	0.0	Potential Contaminated Soils. Would prevent contaminated effluent from damaging ~24.5 acres of wetlands. Preserves recreational activities. Preserves fishing in Arlington/Alexandria along the Potomac River for vulnerable residents that rely on fishing for food.	Minor
Alt-5a	BH17: Four Mile Run Alexandria Proposed Bulkhead	($1,077)	562	$63,003	-0.1	Approximately 2,750 sq ft 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)	2496	$279,967	-0.3	During Construction	Minor
Alt-5c	BH12: Belle Haven Proposed Bulkhead	$361	795	$89,227	-3.4	Approximately 2,520 sq ft of permanent stream impacts, Potential contaminated soils, Viewshed from historic resources, Aesthetics	Moderate
Alt-6 NS_1 percent AEP storm	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($5,812)	3,342	$374,946	-1.0	Alexandria and Occoquan Historic Districts	Minor
Alt-6 NS_ 2 percent AEP storm	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($5,228)	2,999	$336,499	-0.8	Alexandria and Occoquan Historic Districts	Minor
Alt- 6 – NS_5 percent AEP storm	MA10 & MA20: Old Town Alexandria MA12: Belle Haven MA16: Occoquan Bay	($3,551)	2,084	$233,724	-0.7	Alexandria and Occoquan Historic Districts	Minor

Plan Alternatives	Alternative Area Description	NED	RED		OSE	EQ	
		Net Benefits ($1,000)	US Jobs	Value Added ($1,000)	Incremental Life Loss	Effects	Impact
Alt 8	BH8: Four Mile Run Arlington WPCP Proposed Bulkhead BH12: Belle Haven Proposed Bulkhead	$450	838	$94,043	-3.4	Potential Contaminated Soils Approximately 2,520 sq ft of permanent stream impacts, Potential contaminated soils, Viewshed from historic resources, Aesthetics	Moderate

The plan that reasonably maximizes net benefits across all benefit categories is Alternative 8, combination of a floodwall at the Arlington WPCP and a levee and floodwall at Belle Haven with pump stations. Alternative 8 yields annualized net economic benefits of $450,000 and a BCR of 1.3 (FY22 discount rate of 2.25 percent). Alternative 8 covers two planning units which means there are more opportunities for regional economic development benefits during construction. Additionally, there is a greater reduction to health and life safety issues since implementing two CSRM projects in the Northern Virginia area. Even as a standalone alternative, the proposed plan at Belle Haven provides the greatest reduction to incremental life loss at -3.4. There would be minimal environmental impacts associated with implementing CSRM measures at the Arlington WPCP, but there would be approximately 2,520 sq ft of permanent stream impacts at Belle Haven.

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). The table below is a qualitative assessment of how each alternative meets the study objectives on a low, medium, high scale when looking at acceptability, completeness, effectiveness, and efficiency.

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.			Efficient.			Accept.			Complete.			Effective.			Efficient.		
	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.			Efficient.			Accept.			Complete.			Effective.			Efficient.		
	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, which includes nonstructural solutions. 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 most of the structures included in the analysis are public or private residences with occasional businesses.

As mentioned previously, the City of Alexandria began development of the Alexandria Waterfront Small Area Plan, which was approved by the City Council in 2012. 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 event. 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, to mitigate flooding, but still allow residents to be connected to the river.

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 event is exceeded between Duke and Queen Street. These recommendations were shared with the City for consideration in their Waterfront Small Area Plan. Therefore, USACE is not further evaluating any structural, nonstructural or NNBF plans for City of Alexandria.

G2CRM was utilized to evaluate NED benefits for the final array of alternatives. 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 were cost effective and yielded positive net economic benefits (See Appendix E: Economics). These alternatives were combined as Alternative 8, the TSP, with net economic benefits of $450,000 and a BCR of 1.3.

Alternative 5a, Four Mile Run Levee and Floodwall, did not yield positive net economic benefits due to the performance of the elevated walkway along the shoreline. G2CRM outputs did not show inundation of structures until about the year 2080, which is the end of the 50-year period of economic life. The park to the west of the community also serves as natural flood storage during a high-water event. Evaluating for the high SLR curve, there may be some overtopping of the walkway prior to the year 2080, however due to the low benefits and limited structures getting inundated in the model, this was not evaluated further in this study.

As stated previously, the City of Alexandria is implementing a 6ft NAVD 88 bulkhead along the waterfront and this was included in the FWOP condition. Since a USACE project can only capture benefits above the 10-year level of performance, this eliminated several of the structures that would get inundated in the 6-9 feet category and reduced the number of structures that could see 2-6ft of inundation. Several structures that could be raised or floodproofed have already taken these measures to reduce their risk and new infrastructure must follow strict building codes to raise them out of the 100-year floodplain. Many of the remaining structures in the 2-6ft inundation area are historic buildings which cannot be raised, or flood proofed without negatively impacting the integrity of the historic structure. The City of Alexandria is aware of these structures and have been working on the Alexandria Waterfront Small Area Plan since 2009 to reduce their coastal storm risk.

The Belle Haven nonstructural evaluation yielded several properties seeing anywhere from 0-2ft and 2-6ft of inundation. There were also a few properties in low-lying areas that are in the 6-9ft category. USACE has been coordinating with the Fairfax County for well over a decade to implement coastal storm risk measures to reduce risk to this community during a storm event. There has been significant public opposition to any proposed plan resulting in the original FPMS study being terminated. Nonstructural measures would not eliminate the risk of inundation to vehicles, roadways, and some businesses, but could reduce damages to some residential and commercial structures. The cost of nonstructural measures is high and is challenging in Belle Haven due to the high number of apartment/condominium buildings. The other challenge with nonstructural measures is that they would be voluntary and the same opposition to coastal storm risk measures that was shared during the original FPMS study has not changed over the past decade. USACE has received numerous negative comments and letters from the public and community organizations about USACE pursuing a project in this location. With a BCR under 0.2 for all nonstructural scenarios and the high cost and voluntary nature of non-structural implementation, a nonstructural plan was not carried forward for further evaluation at Belle Haven.

Occoquan Bay was evaluated for nonstructural measures for the 1 percent, 2 percent, and 5 percent AEP storm. The 1 percent AEP storm identified 25 structures that could be elevated and 35 structures that could be flood-proofed to reduce coastal storm risk. This community has already started to raise critical infrastructure out of the 100-year floodplain and is in the process of removing some of the structures that could be impacted at the marina as sea levels rise. Accounting for the communities plans to address their coastal storm risk under the FWOP condition greatly reduced benefits that could be realized by this proposed plan (BCR range was 0.06-0.09). Due to the limited benefit a USACE project could offer in this location, further evaluation was not conducted for this planning unit.

5.5 Critical Infrastructure Evaluation

Reagan Airport and Arlington WPCP are the two areas of critical infrastructure within the final array of alternatives evaluated for this study. The proposed CSRM measures at Arlington WPCP yielded positive average annualized net-benefits of $89,000 and a BCR of 2.0. Arlington WPCP

was included in Alternative 8 as a component of the Recommended Plan at the ADM milestone. The proposed CSRM measures at Reagan Airport yielded negative average annualized net benefits of -$3,065,000 and a BCR of 0.02. The economic analysis for the airport addressed damages to structures but did not evaluate system impacts and potential service disruption, potentially increasing frequent in the future. Additional analysis could be undertaken by FAA or other non-Federal parties. The alternative for the Reagan Airport was screened from further consideration based upon several factors such as: (1) a BCR below unity, (2) lack of engagement from MWAA, and (3) that CSRM design and construction would be the responsibility of the FAA (as the federal government owner of the airport) or that of a non-federal party.

5.5.1 Arlington WPCP

The Arlington WPCP is considered critical infrastructure that operates 24 hours per day, 7 days per week, 365 days per year. Critical infrastructure includes structures in the floodplain that are critical to the nation or a particular region (USACE, 2023a). The Arlington WPCP is infrastructure that has a tremendous service value to the community, but also poses as a risk to the population due to the presence of chemical materials. Damage to the components and infrastructure of the WPCP facility and disruption of service could have detrimental effects on the community including economically disadvantaged communities, as well as the environment. The time it would take to place the systems back in operation after a flood event could be weeks or months.

The WPCP not being able to accept wastewater or discharging untreated wastewater can result in public health impacts to the entire sewershed and the region. Wastewater contains a wide range of hazardous constituents including microbial pathogens and toxic chemicals. If not properly treated, wastewater discharge can cause serious public health outcomes, such as outbreaks of infectious diseases and acute and chronic toxicity events. The COVID-19 virus (SARS-CoV-2) can be detected in untreated wastewater. The Centers for Disease Control and Prevention's (CDC) National Wastewater Surveillance System tracks the presence of SARS-CoV-2 in wastewater samples to determine the spread of COVID-19 in a community (CDC, 2023).

A disruption in wastewater service may have public health impacts if nursing homes, hospitals, urgent care centers, etc. are shut down. There are three hospitals, two nursing homes, and two health clinics located with the Arlington WPCP sewershed. One of the nursing homes is in the neighborhood of Glencarlyn, which is an economically disadvantaged community served by the sewershed (EPA, 2022). Nursing homes and assisted living facilities provide safe housing, specialized on-site medical and nursing care for the most vulnerable members of the community. These facilities also provide a sense of community for their residents. If a nursing homes or assisted living facility experience damage, the residents would have to be relocated to other sites to provide for their needs, ultimately disrupting the community.

Large volumes of water are generated at airports. Certain types of water at airports, including from aircraft lavatories and recaptured de-icing fluids, are wastewater. The wastewater generated at National Airport is collected on site and sent to the Arlington WPCP for treatment. If left untreated,

wastewater generated at the airport could have a negative effect on the environment since it contains a relatively high concentration of contaminants. It is unclear how much wastewater can be collected and stored in the airport's wastewater collection system and for how long; however, backup of wastewater at National Airport may result in flight delays and cancelled flights. Due to its proximity to the national capital, National Airport is the primary airport for members of Congress to arrive and depart from Washington, D.C. National Airport has 819 scheduled arrivals and departures of commercial flights per day. The airport's main runway is the busiest in the U.S. (MWAA, 2023).

Federal facilities in Arlington including the Pentagon, Navy Annex, and Fort Myer collect and pump their wastewater to the Arlington WPCP. Government officials and military personnel may not be able to work at the facilities if there is a disruption of wastewater service.

If WPCP infrastructure is damaged or chemicals to treat the water are not available, wastewater would flow through the plant without any treatment and into Four Mile Run/Potomac River. There is no backup treatment facility. In a disaster scenario, the WPCP would send partially treated or untreated wastewater directly into Four Mile Run. Untreated sewage carries organic waste and nutrients leading to oxygen depletion and disease-causing bacteria and parasites if the exposure to elevated nutrients in untreated wastewater persists for weeks or months. This can temporarily affect fish and wildlife and submerged aquatic vegetation found in the Potomac River. Approximately 117 acres of wetlands and 812 acres of SAV could be affected. The river may also be temporarily unfit for recreational purposes.

The extent of wastewater service disruption in the service area will depend upon the combination of components and structures that are inundated and the depth of inundation. Many of the components and structures at the WPCP may be elevated in a way that manages risk from flood damage or from flood service disruption. For example, operational controls may be housed in buildings with elevated first floors or aeration tanks may be surrounded by rims that manage risk from up to several feet of flooding (USACE, 2022).

The Northern Virginia Infrastructure System Vulnerability Assessment conducted by the Engineer Research and Development Center (ERDC) for this study identified the following WPCP components and infrastructure that are vulnerable to flooding from a 100-year coastal storm under seven sea level rise scenarios: Secondary Aeration Tank 5-6 (ID#30), Secondary Aeration Tank 1-4 (ID#9), West Mixed Liquor Flow (ID#62), Secondary Clarifier 7 (ID#47), Secondary Clarifier 8 (ID#46), Advanced Backwash Building (ID#42), Wet Weather Filter Facility (ID#4), Filtration and Disinfection Facility (ID#17), PTB Backup Flow Distribution Structure (ID#57), and PTB Structure (ID#58). Figure 5-5 shows the location of these components and structures and the inundation footprint under a 100-year coastal storm given existing sea-level and three sea-level rise scenarios (USACE, 2022).

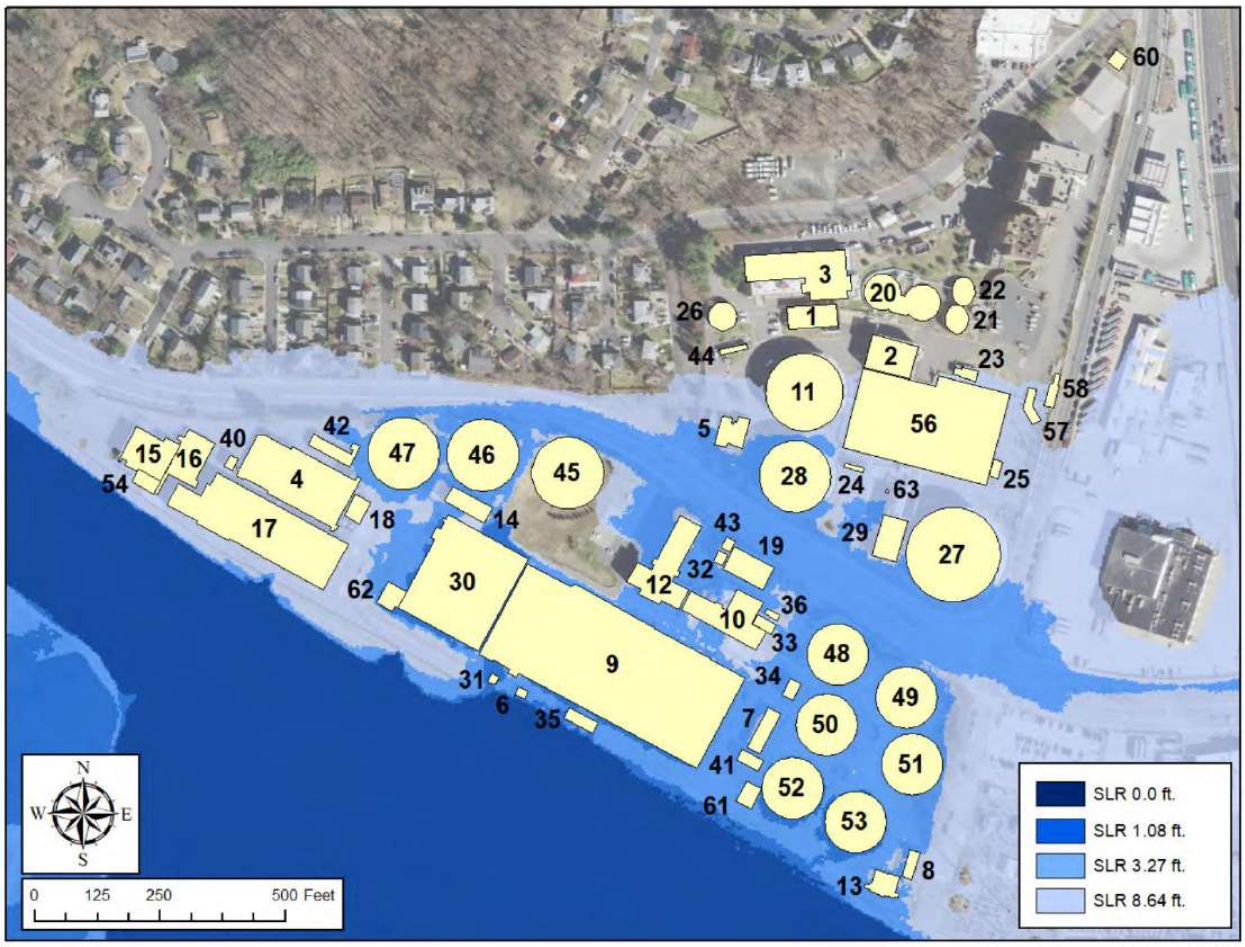

Figure 5-5: Arlington Water Pollution Control Plant 100-year coastal storm. Inundation of Arlington Water Pollution Control Plant components and structures by a 100-year coastal storm given existing sea level and three sea level rise scenarios (1.08 ft., 3.27 ft., 8.64 ft.). (Figure 6.1 in Appendix B: Hydraulics and Hydrology 321)

5.5.2 Reagan National Airport

The USACE recognizes the importance of reducing coastal storm risk to Reagan and proposes a targeted study for Reagan Airport. The targeted study could evaluate a tiered approach and address coastal storm risk over the planning horizon instead of a single large-scale plan which was evaluated in this study due to the comprehensive nature of this interim assessment. To do this, USACE would need the leaseholder, MWAA, to request a study and work closely with FAA to ensure any solutions are in full compliance with FAA advisory circulars and orders pertaining to runway safety areas, protection zones, and approach and departure surface requirements as well as ensuring avoidance of the engineered material arresting systems (EMAS) at the Runways 22, 15, and 33 ends.

Through coordination with MWCOG, MWAA, and FAA, it was determined that the runways would be shut down during any level of inundation. The FAA also identified engineering

constraints during alternative development to include deployable floodwalls at the end of the runways. Due to the lack of structures at Reagan Airport and the fact that most structures are on high ground based on the G2CRM outputs, damage reductions do not support flood protective system elements around the critical facilities, which includes electrical facilities, NAVAIDS, fuel farm, and runways. The USACE has worked to engage with MWAA since the Summer 2022 along with the help of MWCOG, but no additional information has been provided to improve the discussion and analysis of these facilities. Due to the nature of the feasibility planning process timeline and considering that this study has a set amount of supplemental funding and additional time per the 3x3x3 policy exception signed 05 February 2021, the USACE has determined that there is not enough information to justify an NED exception for the Reagan Airport alternative.

During the ADM and subsequent meetings on Reagan Airport, there was additional discussion regarding other entities having responsibility for climate change analysis and funding to improve resiliency at the Airport. A review of the FAA website yielded some discussion regarding the September 2021 project that the FAA and the Department of Transportation's (DOT) Volpe Center initiated to identify best practices and solutions and uncover priorities and opportunities related to climate resilience at several coastal airports. This research is expected to continue through 2026 (FAA 2022).

Concerns were raised by NPS during the public comment period that the proposed alignment at Reagan Airport would impact NPS property on the west side of the airport. No project is being recommended at Reagan Airport due to lack of benefits, therefore, there are no impacts to NPS resources.

The FAA and MWAA also provided comments during the public review period. If Alternative 4b is subject to future consideration, or any action involves property within the MWAA leasehold, the FAA may have a federal action and will reengage in the project. The FAA may need to concur with the proposed action and issue an approval. Additional analysis would be required to ensure the alternative's compliance with FAA advisory circulars and orders pertaining to runway safety areas, protection zones, and approach and departure surface requirements as well as ensuring avoidance of the engineered material arresting systems (EMAS) at the Runways 22, 15, and 33 ends. If a plan was justified at Reagan Airport in the future, the USACE would engage with FAA as well as other stakeholders during plan development.

MWAA shared that the measures included in Alternative 4b would lead to capital expenditures and MWAA does not have funding allocated for these capital improvements. Additional concerns include operational capabilities of three runways that cannot be impacted, MWAA has concerns over implementation and constructability, MWAA has concerns of capital expenditures for Alternative 4b.

Alternative 4b considered relative sea level rates of 1.09 feet (low), 1.75 feet (intermediate), and 3.93 feet (high) from 2031-2080 based on USACE RSLC projections. The SLR tracking tool was not available when this study began in 2017 and so the decision was made to design to the

intermediate SLC curve instead of the high SLC curve (or extreme case). Alternative 4.b accounts for 1.75 feet of relative sea level rise based upon the middle of the current tidal epoch for 1992. If current SLC trend continues, then the alternative could experience overtopping earlier than 2080. If the trend follows the "USACE High SLC Scenarios" then in year 2045 the project could start seeing overtopping and the project would begin to fail to function as designed. The trigger for first adaptations is when sea level rise exceeds the design seal level rise threshold, 1.75 feet. If the actual SLC trend follows higher than the "intermediate" scenario and lower than the "High" scenario, then the threshold may be exceeded any time between the years 2045 and 2080. Periodic monitoring of the SLC trend may help understand the risk and adaptation decision.

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. Planning 100-Year Adaptation Horizon

5.6 Planning 100-Year Adaptation Horizon

As mentioned in Section 2.1, ER 1105-2-103 and EP 1100-2-1 guidance explain that certain environmental factors may consider the evaluation of other periods of analysis. For the planning horizon a 100-year period was evaluated (not to be confused with the 50-year period of economic life). The 100-year planning adaptation horizon is 2031-2131 for the Recommended Plan, Arlington WPCP, (Alternative 4c). This section evaluates Arlington WPCP location and future opportunity to improve resilience and robustness of the proposed coastal storm risk measures.

5.6.1 Arlington WPCP

Arlington WPCP is critical infrastructure and was therefore evaluated for the .2 percent AEP flood event accounting for intermediate SLR for the year 2080. The current floodwall foundation design does not include for future floodwall raising. Reasoning for not expanding foundations are cost (including additional real estate acquisition), constructability, and limited space. Limited space includes existing road located on the Arlington WPCP property that must remain operational, existing power poles, and existing bike path that must remain operational. There is a cost risk if floodwall would need to be adapted. The existing foundation and floodwall would need to be removed and replaced with a higher and thicker floodwall and wider foundation if adaptations are necessary in the future.

The current proposed floodwall design accounts for 1.75ft of relative sea level rise, shown as orange dashed line in Figure 5-6. If current higher SLC trend continues, then the project may experience overtopping earlier than 2080. If the trend follows "USACE High SLC Scenarios" then in year 2045 the project start seeing overtopping, and project will start failing to function as designed. Note: the floodwall was designed (using Design Resiliency Check load case) to prevent it from failing catastrophically if exposed to overtopping. The trigger for 1st adaptations is when

sea level rise exceeds the design sea level rise threshold, 1.75ft. If the actual SLC trend follows higher than "intermediate" scenario and lower than "High" scenario, then threshold may exceed any time between years 2045 and 2080. Periodic monitoring of SLC trend may help understand the risk and potentially mitigated using pumps.

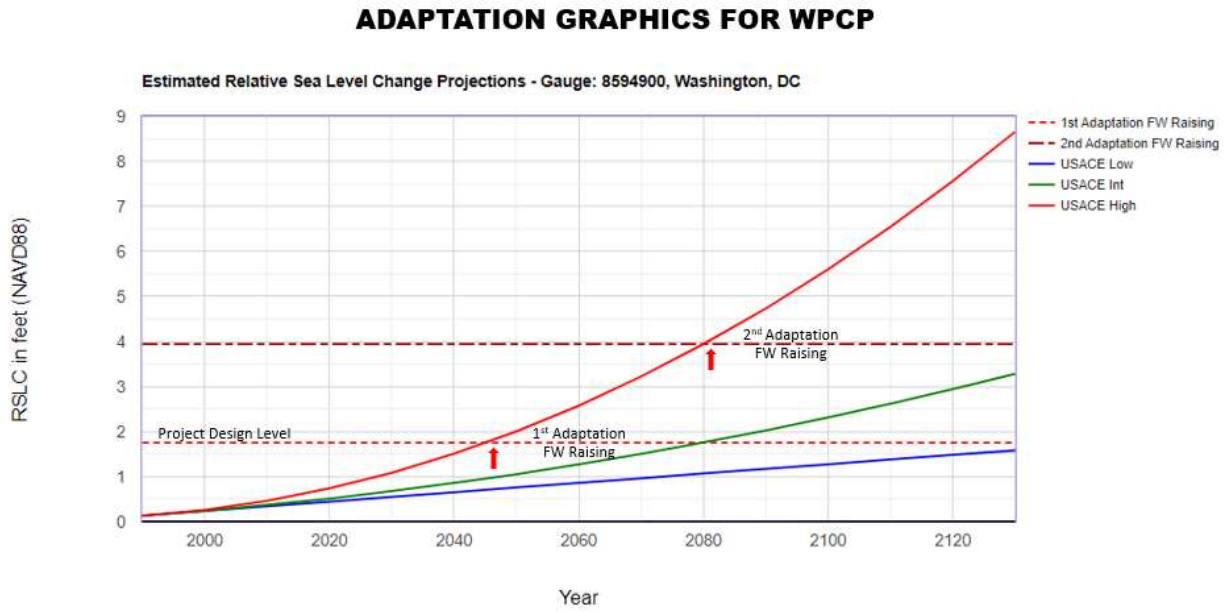

Figure 5-6. Adaptation Graphic for WPCP using SLC Scenarios

Figure 5-7 shows areas inundated at the 14.3 feet NAVD88 2080 WSEL with the proposed floodwall in place (blue area). The Arlington WPCP floodwall (14.3 ft NAVD88) will pass the 0.34% AEP event (~300-year storm) with 90% assurance. If a 500-year storm (0.2 AEP flood event) occurs (16.8 feet NAVD88 2080 WSEL) then the inundation is represented by the yellow area on the map. A 500-year storm would overtop the proposed Arlington WPCP floodwall. The risk of overtopping is small if overtopped barely above 14.3ft in elevation, pumps would mitigate without interruption to Arlington WPCP. If a flood event overtopped the floodwall (such during a 500-year storm level), then the Arlington WPCP would be at risk of flooding impacting operations of sewer treatment and lead to back up if pump station became non-operational. There could be damage to electrical switches, mechanical systems, waste treating microbes, etc. There would be costs incurred for repairs and time to get waste treatment systems back online, along with cost to population for lack of treatment services. Furthermore, there would be environmental degradation to the waterway due to not meeting effluent standards. As stated earlier in this section, the current +14.3 feet NAVD88 floodwall cannot be raised further, such as to 16.8 feet NAVD88 (0.2 AEP flood event, 500-year storm) due to cost (including additional real estate acquisition, constructability, and limited space.

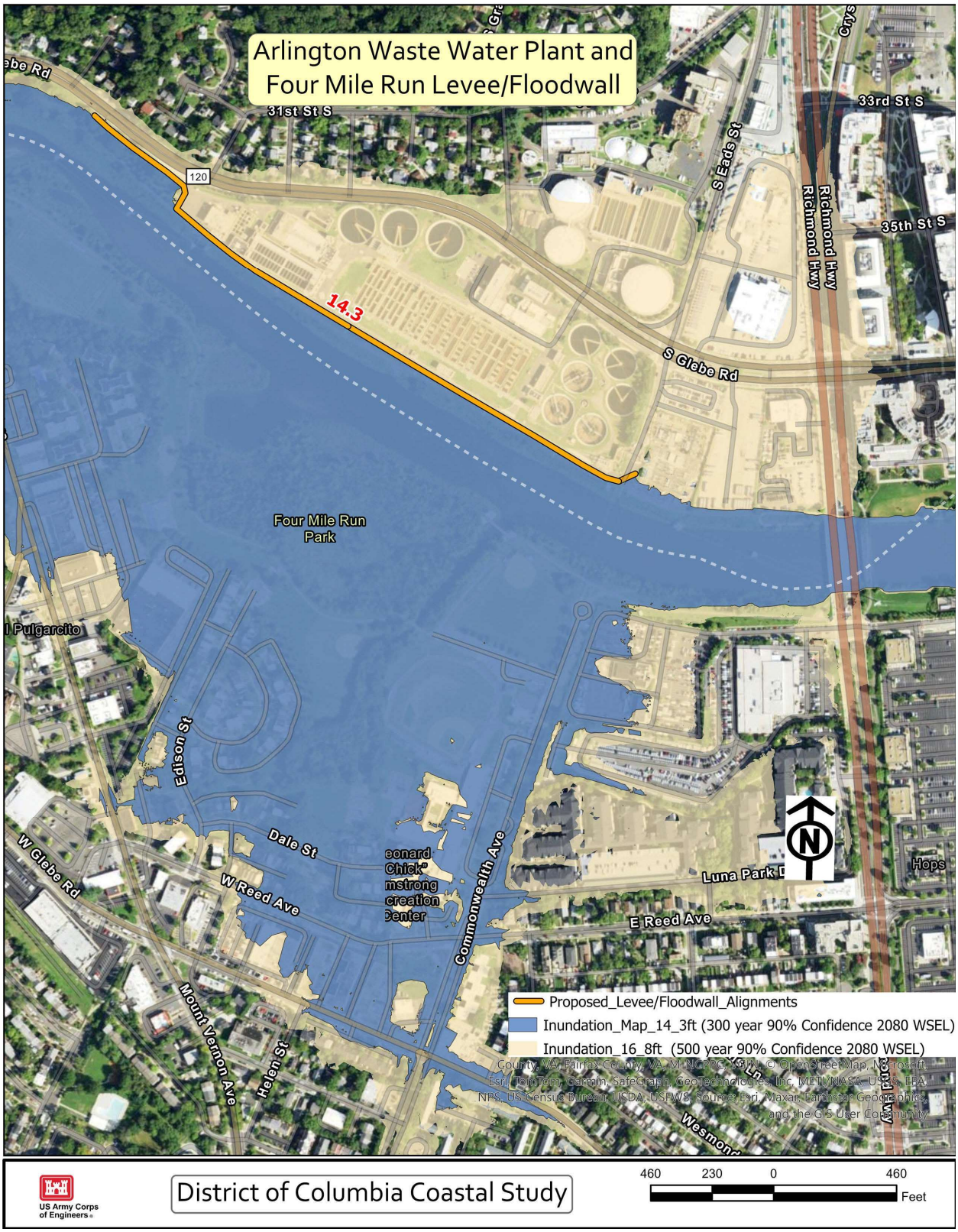

Figure 5-7. Arlington Wastewater Treatment Plant Floodwall Storm Inundation Map

5.7 Selection of the Recommended Plan

The TSP was previously identified as Alternative 8 on 29 March 2022, which is the combination plan that incorporates a floodwall and stop log closure at the Arlington WPCP (Figure 3-18), and a levee and floodwall system with pump stations at Belle Haven (Figure 3-19). The TSP was endorsed as the Recommended Plan at the 04 November 2022 Agency Decision Milestone meeting. The Recommended Plan included two locations within the study area where coastal flood risk measures could be implemented (Figure 6-1). Post ADM, the Recommended Plan was optimized, and cost and economic analyses were updated. The USACE also held several coordination meetings with Fairfax and Arlington Counties as the plans were optimized.

After thorough discussion of the Belle Haven floodwall and levee plan with the stakeholders and community, Fairfax County sent USACE a letter on 13 March 2023 stating that they "will not support the project as proposed at the present time, and thus will not be providing the USACE with a letter of intent." Given the lack of a non-federal sponsor for implementation of the Belle Haven floodwall and levee plan, no further detailed engineering analysis was conducted for that separable element. It is noted that based on the FY23 cost and economics analysis, the Belle Haven plan (Alternative 5c), as a separable element, is cost effective and yielded positive annualized net benefits of $827,000 and a BCR of 1.3 (FY23, October 2022 price level and 2.50 percent discount rate). Because this study is an interim response to the study authority, there could be future opportunities to revisit the Belle Haven planning unit and proposed plan if a NFS requests USACE to reevaluate the area for the purpose of reducing coastal storm risk. At that time, the required analysis would need to be completed (i.e. a complete, updated National Environmental Policy Act [NEPA] analysis and engineering analysis). Also, as stated in Section 5.5.2, USACE recognizes the importance of reducing coastal storm risk to Reagan Airport and proposes that FAA and its leaseholder conduct a targeted study for Reagan Airport. With the Belle Haven plan (Alternative 5c) not moving forward, more detailed environmental evaluation and engineering & design planning for the feasibility study was focused on the Arlington WPCP (Alternative 4c).

5.8 Economic Analysis for Recommended Plan

Arlington WPCP (Alternative 4c) had positive net economic benefits with average annualized net benefits of $44,000 and a BCR of 1.1 (FY23, October 2022 price level and 2.50 discount rate), as well as a willing and able NFS for design and implementation (PED). Alternative 4c was a component of the Maximum Total Net Benefits Plan.

When the project costs, which included improvements in the designs for the floodwall and the closure structure, and economic analysis were updated to FY24 (October 2023) price level and 2.75 discount rate, the annualized net benefits became negative at -$212,000 with a BCR of 0.7 (Table 5-10). Alternative 4c was still being pursued to move forward because of the significant maximum total net benefits discussed a part of the four accounts analysis (Section 5.3).

Table 5-10. Recommended Plan Benefits.

Recommended Plan	Economic Cost	Average Annualized Costs	Average Annualized Benefits	Average Annualized Net Benefits	BCR
Alt-4c (MA8): Arlington WPCP	$19,658,000	$728,000	$516,000	-$212,000	0.7

1. Economic Cost includes IDC.
2. FY24, October 2023 price level, discount rate of 2.75 percent.

The Assistant Secretary of the Army for Civil Works approved a National Economic Development (NED) policy exception on March 18, 2024. The policy exception allowed the Recommended Plan to include non-economically justified separable elements based on environmental and other social effects. The approval highlighted the importance of providing a risk management solution to ensure this critical infrastructure has minimized risk of operational failure during a coastal storm event.

6 Recommended Plan*

6.1 Overview

Arlington WPCP (Alternative 4c), as an actionable CSRM measure, is the Recommended Plan moving forward due to the significant non-monetary benefits of the project. Arlington WPCP has negative average annualized net benefits of -$212,000, a BCR of 0.7, and a project first cost of $15.2 million (which includes a 35 percent contingency and is at the FY24, October 2023 Price Level). The Recommended Plan is a complete solution, in and of itself, for the Arlington WPCP. Once the feasibility phase is completed and approval and funding are received to move forward into design, USACE would negotiate a Design Agreement with Arlington County to cost share PED. The PED phase would be cost shared 65 percent federal and 35 percent non-Federal.

6.2 Plan Optimization

At the Arlington WPCP, a 1,180-linear-foot floodwall (ranging up to about 6ft. in height from ground, at elevation +14.3ft. NAVD88) would be constructed along the left bank of Four Mile Run stream between Four Mile Run and the Arlington WPCP along the facility's fence line. A 70 ft long aluminum stop log closure structure would be installed on the east side of the structure in preparation for a flooding event. The aluminum stop logs will be stored in an existing building to be determined by the NFS during PED. The floodwall would tie into the riverbank to the west of the WPCP (Figure 6-1). The project would also include a +1 ft curb for approximately 1,280 lf, flap gates at stormwater conduits to prevent backflow, and sluice gates installed at the 36" and 60" stormwater conduits. Additional storm drain analysis (including closures, sluice gates, and flap gates) will be further evaluated in PED. The Arlington WPCP floodwall (14.3 ft NAVD88) will pass the 0.34% AEP event (~300-year storm) with 90% assurance.

It was noted during the public comment period that this area of Four Mile Run was part of a "living shoreline" enhancement approximately six years ago. Components of this project included public art installed on the metal fence surrounding the WPCP, a public art bench (imported from the Netherlands) located along this fence, an observation platform, as well as fish murals painted occasionally along the trail. These items may be impacted by the proposed floodwall and should be protected/relocated. USACE would confirm and coordinate anticipated relocations with the NFS during PED, which was included in the final cost estimate (i.e., replacing the security fence, repairing asphalt/sidewalk and moving art boards/benches along the recreational trail). The security fence would be added on top of the floodwall since the floodwall is following a similar footprint. The art boards/benches would be moved to a different undisturbed location along the recreational trail in coordination with the NFS. A temporary security fence would also be required during construction. In coordination with the NFS, USACE plans to minimize impacts to the recreational trail and instead use the road that runs parallel on the inside of the security fence (on WPCP property) for access and would repair asphalt, as needed.

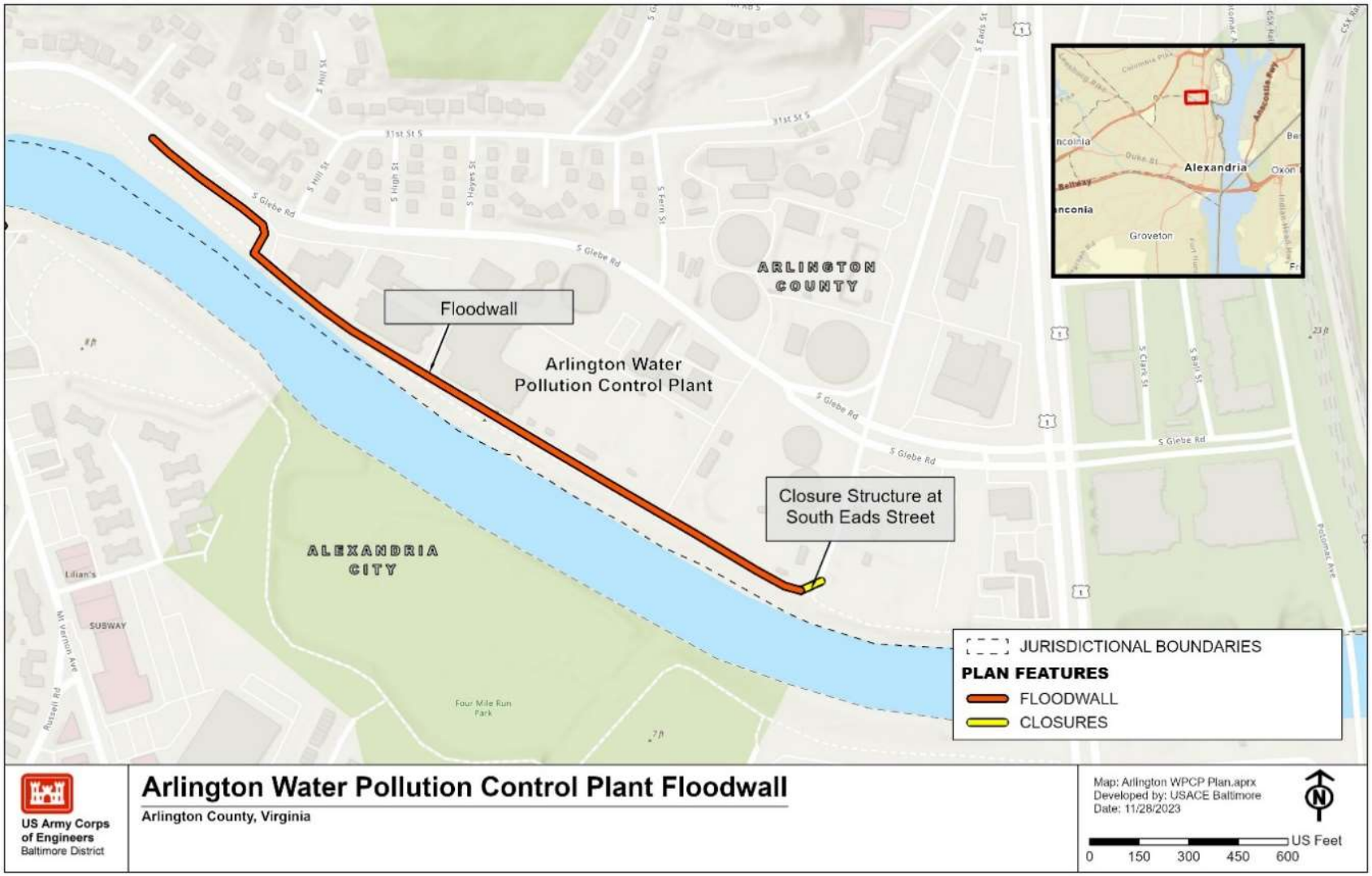

Figure 6-1. Recommended Plan.

6.3 Cost Estimate and Cost Sharing Breakdown

The total costs and benefits for the Recommended Plan, Arlington WPCP, are summarized in Table 6-1.

Table 6-1. Project Cost and Equivalent Annual Costs and Benefits for the Recommended Plan.

Investment Cost		
Total Project Construction Costs	$	15,230,000
Interest During Construction	$	297,000
Total Economic Costs	$	15,527,000
Average Annual Costs		
Interest and Amortization of Initial Investment	$	575,000
OMRR&R[1]	$	153,000
Total Average Annual Costs	$	728,000
Average Annual Benefits	$	516,000
Net Annual Benefits	$	-212,000
Benefit-Cost Ratio (BCR)		0.7
Benefit-Cost Ratio (computed at 7%)[2,]		0.5

[1]Operation, Maintenance, Repair, Replacement, and Rehabilitation.
[2]Per Executive Order 12893.
Note: All values are rounded to the nearest 1,000.
All costs in the table are in October 2023 (FY 2024) price levels and values have been annualized using a 2.75 percent discount rate unless otherwise stated.

During PED, the project would be cost shared 65 percent Federal and 35 percent non-Federal. The project first cost is $15.2 million, which includes a 35 percent contingency and is at the FY24, October 2023 price level. Lands, Easements, Right-of-Ways, Relocations, and Disposal Areas (LERRDs) required for project construction must be provided by the NFS for the non-Federal construction cost share amount as described in Section 6.3 (Tables 6-2 and 6-3). Appendix F: Real Estate Plan shows the estimated LERRDs cost of $1.1 million (includes overall 19 percent contingency [15 percent for admin costs and 20 percent for lands]).

Table 6-2. Metropolitan Washington, District of Columbia CSRM – Project First Cost.

WBS Number	Features	Project First Cost w/ Contingency
01	Lands, Easements, Right-of-Ways, Relocations, Disposal Areas (LERRD)[2]	$1,052,000
02	Relocations	$551,000
11	Levees and Floodwalls	$4,954,000
15	Floodway Control and Diversion Structure	$560,000
30	Preconstruction, Engineering & Design[2]	$6,168,000
31	Construction Management Supervision and Inspection (S&I)	$1,944,000
	Project First Cost	$15,230,000

1. Cost is based on Project First Cost (constant dollar basis) on Total Project Cost Summary (TPCS) Spreadsheet, at an effective price level 1 Oct 2023 (Appendix C).
2. These are Real Estate administrative costs and the cost of easements based on a February 2023 appraisal.

Table 6-3. Metropolitan Washington, District of Columbia CSRM - Cost Apportionment After LERRDs Credit.

Features	Federal Share (65 percent)	Non-Federal Share (35 percent)	Project Cost w/ Contingency
Project First Costs	$9,899,500	$5,330,500	$15,230,000
Credit for Non-Federal LERRD[1]		($1,052,000)	
Total Cost Apportionment[2]	$9,899,500	$4,278,500	

1. Credit is given for the incidental costs borne by the NFS for lands, easements, rights of way, relocations, and disposal areas (LERRD).
2. Total cash portion required for the project.

6.4 Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas (LERRDs)

A real estate cost estimate was prepared from an appraisal conducted in February 2023. The lands and damages real estate cost estimates is $1.1 million (includes a overall 19 percent contingency [15 percent for admin costs and 20 percent for lands]).) as stated in the previous section.

The NFS for feasibility, MWCOG, currently does not own lands or property required for the Recommended Plan, Arlington WPCP. However, MWCOG partner, Arlington County, Virginia has provided a letter of intent to partner with the USACE for PED and provide the LERRDs and cost-sharing for the project.

For CSRM projects, the NFS 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. For more information on LERRDs, reference Appendix F.

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

The annualized OMRR&R for the Arlington WPCP is $153,000 each year over 50 years due to required maintenance of the concrete floodwall. The closure structure would need to be deployed at minimum once per year, which could incur some labor costs. The OMRR&R would be managed by the NFS, Arlington County, Virginia.

6.6 Risk and Uncertainty

6.6.1 Study Risk

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 CSRM 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.

A cost schedule risk analysis was conducted in January 2022 with an update in February 2023 to identify cost, schedule, and implementation risks for the final array of alternatives. Some remaining risks include utility relocations, foundation uncertainty due to limited Geotechnical information, and potential remediation for HTRW. Based on these risks and the need for additional information and analysis, a 35 percent contingency was added to the final project cost in the TPCS.

Environmental

- There is a potential for contaminated groundwater to be present in the location of Alt 4c: Arlington WPCP Floodwall. Per ER 1105-2-103, and ER 1165-2-132, any associated clean-up of HTRW would be the responsibility of the NFS. The investigation of this risk would be cost-shared and resolved in PED prior to any acquisitions beginning. Risk - Medium

Engineering

- There was limited geotechnical analysis available for the design assumptions made during feasibility for the foundation of the floodwall. No additional geotechnical analysis was conducted during the feasibility phase. Geotechnical investigation will

need to be completed during PED to confirm the foundation assumptions for the design. This risk item is the main driver for the conservative foundation assumptions and high-cost contingency. Risk – High.

6.6.2 Implementation Risk

There has been on-going coordination between USACE Real Estate and Arlington County during the study phase, but there is still risk associated with utility relocations. There are a few utility poles along or adjacent to the alignment for the floodwall which will need to be worked around during design. It is unlikely that these poles would be able to be relocated and, if they could be relocated, this action would be costly.

Some costs were added to the estimate for asphalt and other repairs post construction at the Arlington WPCP; however, road impacts on Arlington County property have not been well defined at this stage. In discussions with Arlington County, the preference to shift the alignment towards the road parallel to the project site was voiced to minimize impacts to the pedestrian trail along Four Mile Run. The NFS would prefer that access to the pedestrian trail is maintained during construction. There are also security concerns with the project removing the existing security fence during construction and a temporary fence will need to be installed that meets the requirements of the NFS for security of the facility. A permanent security fence will be re-installed on top of the floodwall during construction.

The project cost assumes stop log closures due to the location of the closure structure. There is limited green space to install a swing gate or sliding gate at the intersection without impacting nearby businesses on the corner of South Eads Street. The design for this closure structure will be further evaluated in PED.

6.6.3 Residual Risk

Reduction in coastal storm risk with implementation of a project does not remove all the risk to an area. Additionally, areas evaluated for this study that were not justified by project benefits will continue to realize risk under the future without-project condition. This section discusses the residual risk for the Recommended Plan, Arlington WPCP, as well as the other study locations where a project was not recommended based on lack of project benefits and decision by the NFS to pursue action outside of what was proposed by USACE

Four planning units evaluated under this study will not realize benefits from a constructed project. The highest residual risk of flooding is Reagan Airport, which was discussed in Section 5.5. Although a project at Reagan Airport is not being recommended by this study, there is opportunity for either MWAA or FAA to continue to evaluate future flood risk management measures due to SLC and coastal storms. There are limitations for structural solutions in this area due to ground clearance considerations at the end of the runways. Deployable floodwalls are costly but could be

considered as an alternative to a levee or floodwall. Additionally, MWAA could look at electrical facilities in the floodplain and develop a plan to raise or relocate these structures to minimize shutdowns during an event. USACE received limited information to justify a plan at this location using maximum total net benefits. USACE recognizes the importance of planning for and implementing resiliency measures for this critical infrastructure at Reagan Airport.

The other area of critical infrastructure in the study area is Arlington WPCP which is the Recommended Plan. A floodwall and closure structure would reduce risk under the .2 percent AEP storm with Intermediate SLC. Adaptation measures could be required to increase risk reduction over the 100-year planning horizon including increasing the height of the floodwall and closure to the level of performance under the high SLC curve based on future predictions of SLC along the eastern coast of the United States. Adaptation measures were discussed in Section 5.6.

The risk that remains in the study area after the proposed coastal storm risk management project is implemented is residual risk. It includes the consequence of capacity exceedance as well as consideration of the project flood risk reduction. Hence, given the hydrological, environmental, and economic constraints, the residual risk cannot be mitigated. Three metrics; Expected Annual Damages, Life Loss, and Number of Structures at risk were used to assess the residual risk as shown in Table 6-4.

Table 6-4: Residual Risk

Expected Annual Damages (2.75% interest rate; 50-year analysis; $ in FY2024 price levels)	
Future without Project	12,546,000
Less: Risk Reduction	516,000
Residual Risk	**12,030,000**
RR as % of FWOP	*96%*
Life Loss	
Future without Project	107.9
Less: Risk Reduction	0
Residual Risk	**107.9**
RR as % of FWOP	*100%*
Number of Structures at Risk[1]	
Future without Project	6,453
Less: Risk Reduction	86
Residual Risk	**6,367**
RR as % of FWOP	*99%*

[1] A structure is at risk if expected inundation damage is greater than 5% of its value

In Table 6-4, the residual risk is listed percentages and dollars. Using the intermediate sea level change, the average annual damages remaining in the study area with the implementation of the

Recommended Plan (Alt-4c) is $12.0 million damages, which represent a 96-percent of the future without project condition or potential flood damages remaining.

The life loss statistics with high level of uncertainty at inundated structures were assessed using G2CRM. The results should be viewed as more qualitative as opposed to a quantitative assessment of life loss even though the results are stated in numerical values. Since there is not life loss benefits with respect to the Recommended Plan (Alt 4c), the life loss residual risk remain a 100-percent for the Recommended Plan.

The last metric used to assess residual risk is the number of structures at risk of inundation damages. A structure is at risk if its expected damages is greater than 5% of its structure and contents value. The number of structures continue to be at risk after the implementation of the Recommended Plan is 6,367, an equivalent of a 99-percent of the original 6,453.

Residual risk is displayed in Figure 5-7 in the modeled 500-year storm (16.8 feet NAVD88 2080 WSEL) inundation, which overtops the proposed Arlington WPCP floodwall. The proposed floodwall (14.3 ft NAVD88) will pass the 0.34% AEP event (~300 year storm) with 90% assurance.

The City of Alexandria is raising the waterfront bulkhead to 6 feet NAVD 88 (approximately 2-3 feet from ground) which is equivalent to a 10-year storm event. This raising may reduce regular nuisance flooding from extreme high tides, but the community remains vulnerable during a larger storm event. The City is continuing to discuss future resiliency measures for the area but have challenges due to many historic structures as well as community opposition to losing viewshed and aesthetics to any permanent structures along the waterfront. A costly deployable floodwall was considered for this area in addition to the City's bulkhead, which resulted in negative net economic benefits.

Four Mile Run is a neighborhood across the water from the Arlington WPCP. The neighborhood has an existing USACE floodwall project constructed in 1984 to address riverine flood risk that ties into a raised pedestrian trail that provides some risk reduction for coastal surge at Four Mile Run Park. The coastal storm surge modeling did not show overtopping of the trail until about 2080 which is the end of the 50-year period of analysis. There may be future needs for coastal storm risk reduction in this location, but currently the community is partially protected during a flood event, which resulted in negative net economic benefits for a project alternative at this location.

As stated in Section 6.1, a CSRM project at Belle Haven has positive net economic benefits and could move forward if a willing and able NFS is identified in the future. The proposed plan had significant public opposition due to the proximity of a project to people's homes and residences. The project footprint is limited in this location due to NPS-land. Belle Haven will continue to experience flooding without implementing CSRM measures. Fairfax County has been educating the public on their flood risk as well as proposing some nonstructural planning level resiliency measures that families and businesses can implement individually in the absence of a structural project.

6.6.4 Remaining Risk and Uncertainty

As stated previously, there is uncertainty with the current feasibility-level design based on the limited availability of geotechnical data available for the selected project location. The PDT worked to reduce this risk by providing a more conservative foundation for the Arlington WPCP floodwall as well as increasing the cost contingency to account for utility relocations, moving and replacing benches and signage on the pedestrian trail, road repairs post-construction, and temporary security fence parameters. The PDT will continue to optimize the design and reduce uncertainties and subsequent contingency in PED.

6.7 Design and Construction

It is estimated that the construction duration for the Arlington WPCP would be 18 months. According to the Arlington County noise ordinance, impulsive noise cannot exceed 120 dBA and continuous noise cannot exceed 70 dBA anytime of the day (in Zoning District P-S where the Arlington WPCP is located) (Arlington County, Virginia, 2020). The Arlington WPCP project assumes 8-hour construction days. Typical construction equipment used to construct the Arlington WPCP floodwall is not expected to exceed the continuous and impulsive noise requirements in the Arlington County noise ordinance. Materials would be brought in by land via by flatbed trucks, trailers, and dump trucks.

The PED phase assumes two years to start in January 2025 and end in January 2027. The construction window for Arlington WPCP would likely start in 2027 and end in early 2029.

6.7.1 Interior Drainage Analysis

Interior drainage analysis was performed for the Arlington WPCP to assess the residual flooding in the area protected by the proposed Levee/Floodwall system (Figure 6-2). The WPCP facility is located along Four Mile Run stream. The recommended floodwall/levee system will reduce risk to the Arlington WPCP from a 0.2 percent AEP coastal flood. This analysis looks at both the impacts of rainfall within the leveed area and flood stages on the Potomac River and the interaction between the interior and exterior conditions. The 0.8 square mile interior watershed that could contribute to direct flooding in the Arlington WPCP is on the north side of the floodwall and is explained further in Appendix B: H&H Analysis. The interior drainage analysis focused on flooding in the immediate vicinity of the proposed project and did not evaluate the larger watershed to include the Potomac River.

Figure 6-2. Arlington WPCP Facility and Proposed Floodwall.

Using the U.S. Army Corps of Engineers (Corps) HEC-RAS software a 2-D model was developed to analyze interior drainage flooding on the protected side of the levee/floodwall project. NOAA Atlas 14 precipitation frequency estimates for a 1 percent AEP flood were utilized for the analysis. The City of Arlington provided stormwater pipe and inlet and outlet information for the Arlington WPCP. This pipe network information was utilized for the interior drainage analysis. Results of 2D modeling results for the 100-year rainfall event is shown in Figure 6-3.

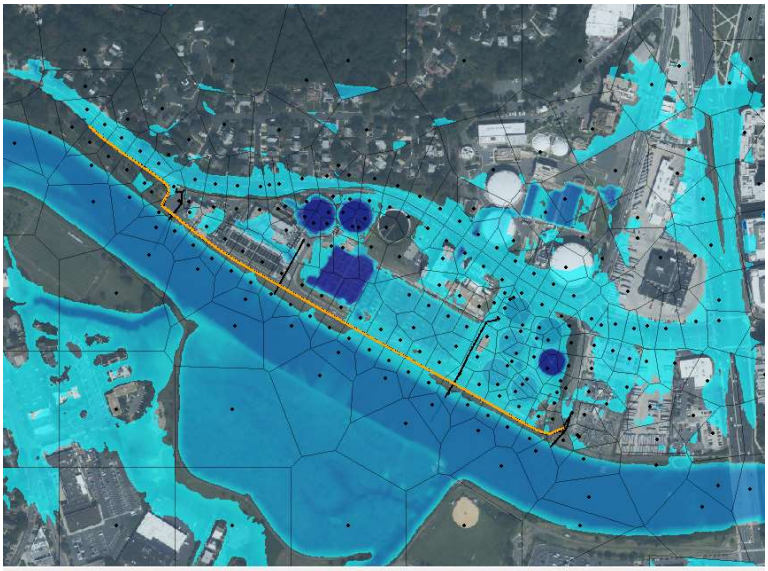

Figure 6-3. Interior Drainage Mapping for the Arlington WPCP Facility.

Most of the sewage treatment tanks are at ground level and any flooding will inundate them (dark blue in Figure 6-3). The maximum depth of flooding is up to 4.5 feet as shown in Figure 6-3.

6.8 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. It was noted during the public comment period that this area of Four Mile Run was part of a "living shoreline" enhancement approximately 6 years ago. Components of this project included public art installed on the metal fence surrounding the WPCP, a public art bench (imported from the Netherlands) located along this fence, an observation platform, as well as fish murals painted occasionally along the trail. These items, as well as the shoreline itself, are all likely to be impacted by the proposed floodwall and should be protected/relocated. USACE would identify and coordinate any relocations with the NFS during PED.
- Construction of the floodwall may result in temporary and minor indirect effects to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.
- Approximately 20 trees may need to be removed to construct the floodwall. The exact number of trees to be removed would be determined during PED. Planting new trees in a different location in the study area may be an option to offset the effects of any tree removal required for the proposed project. 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.
- Users of the existing asphalt pedestrian path may be temporarily affected during construction of the floodwall. The portion of the existing path in between the Arlington WPCP and Four Mile Run may need to be temporarily closed to construct the floodwall (a period of 18 months). USACE would identify and coordinate any relocations/closures of the pedestrian path with the NFS during PED.
- Contaminated groundwater may be present in the construction area. Further investigations would be needed to confirm that no groundwater contamination is present in the footprint of the construction site. Per ER 1105-2-103 and ER 1165-2-132, any associated clean-up of HTRW would be the responsibility of the NFS.

6.9 Avoidance, Minimization, and Mitigation of Impacts*

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.

6.10 Cumulative Effects*

The Arlington WPCP is located in a highly urbanized area along the hardened flood control channel of Four Mile Run. USACE in partnership with the City of Alexandria and Arlington County constructed a flood control channel in the lower portion of Four Mile Run in the 1970s and early 1980s. Several levees and floodwalls were also constructed along portions of Four Mile Run by various entities. Channel maintenance including dredging, repairing erosion damage, fixing stream corridor degradation, vegetation maintenance, and storm sewer infrastructure maintenance along the banks of Four Mile Run is routinely conducted by Arlington County to ensure that Four Mile Run is able to convey a 100-year storm. In-stream dredging work was most recently completed by the County in spring of 2023 (Arlington County, 2024). The Four Mile Run Wetlands Restoration Project, completed in December 2015 by Arlington County, the City of Alexandria, and the Northern Virginia Regional Commission, included construction of nine living shoreline features on the edge of the stream restoring ½ acres of wetlands. Existing stone riprap that used to cover the stream banks was removed and replaced with five acres of native plant meadows (Arlington County, 2022). Present projects along Four Mile Run include tree planting by Arlington County, and maintenance of the existing Four Mile Run Trail at South Glebe Road and Four Mile Run Drive. Additionally, the City of Alexandria is currently constructing a new Four Mile Run Wetland Trail Bridge that is expected to be complete in spring of 2024 (City of Alexandria, 2024).

Past CSRM projects in the region include the Huntington earthen levee and pump station constructed along Cameron Run by Fairfax County from 2017 to 2019 to protect the Huntington Community against the 100-year flood event (Fairfax County, 2019). In 1939, a levee was constructed between the Lincoln Memorial and the Washington Monument, a portion of P Street SW was raised adjacent to Fort McNair, and temporary sandbar closures were installed at three locations (DC Levee Project). In January 2007, USACE determined that the sandbag jersey barrier closure at 17th Street was unreliable. A post and panel closure structure was completed in December 2014. Additional future project modifications include replacement of the temporary closure structure at 23rd Street and Construction Avenue with a permanent closure and raising the levee. A study is currently underway by USACE and NPS to analyze the feasibility of these project modifications.

Ongoing projects in the region include construction of a floodwall at the Blue Plains Wastewater Treatment Plant (WWTP) to protect against the 500-year flood event. The first segment of the wall

was constructed as part of the Enhanced Nitrogen Removal Project. Construction of the second segment was completed in July 2021. Three remaining segments are expected to be completed by 2026 (DC Water, 2024).

Future projects in the region include project modifications to the DC Levee Project as described above, construction of the remaining segments of the Blue Plains WWTP floodwall and raising the existing levee at Joint Base Anacostia-Bolling (JBAB). The Navy and Air Force have plans to raise the existing levee to protect against the 500-year storm event as well as repair/replace the existing seawall. USACE is working with the Navy and Air Force to design project alternatives. Construction is anticipated to begin in 2028 and be complete in 2030. USACE is currently running a model to determine the locations of any induced flooding from the existing and proposed flood risk management projects in the region. Initial results of this model are expected to be available in April 2024.

The above projects were taken into account when assessing cumulative impacts of the Arlington WPCP with other past, present, and future projects in Four Mile Run and in the region. The Recommended Plan, Arlington WPCP, is not expected to result in significant cumulative effects. Construction of the Recommended Plan, Arlington WPCP, along with other construction activities in the area may cumulatively result in a temporary disturbance to migratory birds and a temporary increase in noise. There would also be a temporary increase in air emissions. However, these temporary disturbances would occur in a highly urbanized area on previously developed land. Given the urban nature of the area, noise from construction of these projects should not be greater than the ambient noise of the surrounding area. Air emissions from these projects would not significantly degrade the region's air quality. Wildlife that inhabits this metropolitan area is used to the urban nature and noise of the region and would avoid these areas during construction. Table 6-5 below describes the cumulative effects on each resource topic.

Table 6-5. Summary of Cumulative Effects on Each Resource Topic.

Resource Topic	Cumulative Effect
Wetlands	No cumulative effects expected. Effects to wetlands would be temporary and minor.
Floodplains	No cumulative effects expected.
Submerged Aquatic Vegetation	No cumulative effects expected
Threatened and Endangered Species	No cumulative effects expected
Anadromous Fish	No cumulative effects expected
Migratory Birds	No cumulative effects expected. The Recommended Plan may temporarily disturb migratory birds during construction.
Waterways and Hydrology	No cumulative effects expected. Effects to waterways would be temporary and minor.
Water Quality	No cumulative effects expected.
Air Quality	Air emissions will be below de minimis air quality standards and would not have a cumulative effect on air quality in the region.
Greenhouse Gases	No cumulative effects expected
Hazard, Toxic and Radioactive Waste (HTRW)	Contamination may be present in the proposed construction areas. However, the Recommended Plan would not introduce new HTRW during construction.
Cultural Resources	Cumulative impacts to cultural resources are not anticipated.
Aesthetics	No cumulative effects expected. USACE would identify and coordinate any public art relocations with the NFS during PED.
Recreation	No cumulative effects are expected. Relocation of the pedestrian trail (if needed) during construction would be temporary.
Noise	Construction noise along with other ambient noise in these areas would result in a temporary cumulative effect from noise during construction.
Economically Disadvantaged Communities	No cumulative effects expected
Prime and Unique Farmlands	No cumulative effects expected

6.11 Other Social Effects and Environmental Quality Benefits

Other Social Effects (OSE) Benefits

The Recommended Plan, Arlington WPCP, would keep the WPCP fully functional (receive and treat wastewater) during and after a flood event. The main goal of wastewater treatment facilities is to protect humans and the ecosystem from harmful and toxic elements found in wastewater. Keeping the wastewater treatment plant operational is one piece of the overall storm recovery picture.

- The WPCP promotes human health and safety by collecting and treating sewage and wastewater from residential and commercial facilities.
- Maintain community cohesion, identity, and resiliency by avoiding displacement of residents.
- Supports recreational activities such as kayaking and fishing on the Potomac River in Arlington and Alexandria, Virginia.
- Supports physical health and safety of residents of disadvantaged communities by increasing resiliency of the community.
- Removing impurities from sewage prevents diseases and other health issues. Safely managed water, sanitation and hygiene services are an essential part of preventing disease and protecting human health during infectious disease outbreaks, including the COVID-19 pandemic.
- Manage the risk of the immediate and long-term impacts of natural disasters on vulnerable communities by protecting the limited financial assets of community members.
- Reduce risk to critical infrastructure so that these services are still available during and after disaster events.
- Meets the requirements of EOs 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations), 13990 (Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis), 14091 (Further Advancing Racial Equity and Support for Underserved Communities Through the Federal Government), and 14096 (Revitalizing Our Nation's Commitment to Environmental Justice for All), and the Justice40 Initiative.

Environmental Quality (EQ) Benefits

- The wastewater treatment process preserves the environment, preventing contaminated effluent from damaging sensitive ecosystems.

Table 6-6 below provides a synopsis of the OSE and EQ benefits to the community served by the Arlington WPCP, including disadvantaged communities, by managing coastal storm risk.

Table 6-6. Other Social Effects and Environmental Quality Benefits Gained by Managing Coastal Storm Risk.

Element	Benefits
Community Served by the Arlington WPCP	OSE Benefits
	Supports the health and safety of over 220,000 residents by providing wastewater service to residences, critical infrastructure, and the surrounding community.
	Protection from harmful pollutants including complex organic materials, nitrogen and phosphorus-rich compounds, and pathogenic organisms (bacteria and viruses) found in wastewater that could result in serious public health outcomes after a storm.
	Maintains community cohesion and resiliency by avoiding displacement of residents.
	Keeps critical services open including three hospitals, two nursing homes, eight fire stations, and three police stations during and after a storm.
	National Airport and federal facilities such as the Pentagon, Navy Annex, and Fort Myer could remain operational following a storm.
	No disruption in the conveyance of wastewater from a portion of Alexandria to Fairfax County to the Blue Plains Sewage Treatment Plant in Washington, D.C.
	EQ Benefits
	Preserves the environment, preventing contaminated effluent from damaging sensitive ecosystems including approximately 24.5 acres wetlands located directly south of the WPCP in Four Mile Run Park.
	Preserves recreational activities such as fishing and kayaking following a storm.
Disadvantaged Communities	OSE Benefits
	Supports the health and safety of approximately 27,500 vulnerable residents by providing wastewater service. Would not place an extra burden on residents to repair damages or find alternative housing during a disruption of wastewater service.
	Would not place an extra burden on linguistically isolated communities that may have a harder time finding services to fix the damage or alternative housing due to the language barrier.
	Vulnerable residents would not have to drive in unsafe conditions following a storm to find food or other essentials if businesses in the area are shut down due to a disruption in wastewater service.
	Childcare facilities (daycares and schools) may remain open, which would lessen the burden on vulnerable residents that may not have alternative childcare.
	EQ Benefits
	Preserves fishing in Arlington/Alexandria along the Potomac River for vulnerable residents that rely on fishing for food.

6.12 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 PED. The study team considered avoiding and minimizing adverse impacts to existing environmental resources within the project area to the extent practicable during the plan formulation process.

6.13 Views of the Non-Federal Sponsor (NFS) and County Partners

MWCOG and Arlington County support the Recommended Plan, Alternative 4c: Arlington WPCP floodwall. Specific references to support letters and emails provided by the NFS and county partners are discussed below in the order in which they were received.

The Project Manager and Study Manger have met with MWCOG on a bi-weekly basis since the study restart in April 2021 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 the TSP 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).

Fairfax County, 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).

During the public comment period in May-June 2022, significant public opposition was raised for the proposed Belle Haven plan. Since then, the PDT has coordinated extensively with MWCOG, Fairfax County and NPS regarding the proposed measures. Although the proposed plan was optimized post-ADM based on discussions with the NFS and partners, there was not enough community support for Fairfax County to support a plan at this time. On 13 March 2023, Fairfax County sent an email to USACE stating that they "will not support the project as proposed at the present time, and thus will not be providing the USACE with a letter of intent." It is noted that based on the FY23 cost and economics analysis, the Belle Haven plan is cost effective and yielded positive annualized net benefits of $827,000 and a BCR of 1.3 when optimized after the ADM milestone (FY23 price level and 2.5 percent discount rate). Since this study is an interim response

to the study authority, there could be future opportunities to revisit this planning unit and proposed plan if a NFS requests USACE to reevaluate the area in the future to reduce coastal storm risk.

The Arlington WPCP (Alternative 4c) floodwall is an actionable CSRM measure that is the Recommended Plan from this study for further analysis in the Pre-Construction Engineering and Design (PED) phase. Alternative 4c has negative average annualized net benefits of -$212,000, a BCR of 0.7 and a project first cost of $15.2 million (which includes a 35 percent contingency and is at the FY24, October 2023 Price Level). Although this project has a BCR of less than 1.0, it was still recommended for implementation due to its importance as critical infrastructure in the area and the maximum total net benefits of the project.

A self-certification of financial capability was signed by Arlington County on 18 August 2023.

A Letter of Intent was signed by Arlington County on 04 January 2024.

No locally preferred plan was requested by Arlington and/or Fairfax Counties.

The Assistant Secretary of the Army for Civil Works approved a National Economic Development (NED) policy exception on 18 March 2024. The policy exception allowed the Recommended Plan to include non-economically justified separable elements based on environmental and other social effects. The approval highlighted the importance of providing a risk management solution to ensure this critical infrastructure has minimized risk of operational failure during a coastal storm event.

7 Environmental Compliance Table

Compliance with environmental laws and Executive Orders is required for the Recommended Plan, Arlington WPCP. 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	Full
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	Full
Coastal Barrier Resources Act of 1982	N/A
Coastal Zone Management Act of 1972, as amended	Full
Comprehensive Environmental Response, Compensation and Liability Act of 1980	N/A
Endangered Species Act of 1973	Full
Farmland Protection Policy Act of the 1981 Farm Bill	Full
Fish and Wildlife Coordination Act of 1958, as amended	Full
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	Full
National Historic Preservation Act of 1966	Full
Noise Control Act of 1972, as amended	Full
Resource Conservation and Recovery Act of 1976	Full
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)	Full
Floodplain Management (E.O. 11988)	Full
Protection of Wetlands (E.O. 11990)	Full
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)	Full
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 16 July 2020. The update affects all NEPA processes that began after 14 September 2020 (85 FR 43304). This document also follows *the National Environmental Policy Act Implementing Regulation Revisions* published by CEQ in the Federal Register on 20 April 2022, which amended 40 CFR Parts 1502, 1507, and 1508. 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.

Upon completion of this IFR/EA and the signing of the Finding of No Significant Impact (FONSI), the project will be in full compliance with NEPA.

7.1.2 Clean Water Act

A Section 401 Water Quality Certification (WQC) is not required because the Recommended Plan, Arlington WPCP, will not result in discharges into waters of the U.S.

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 Recommended Plan, Arlington WPCP, would have no direct effects to wetlands. The Recommended Plan may result in minor and temporary indirect impacts to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

7.1.4 Federal Coastal Zone Management Act (CZMA)

A federal consistency determination in accordance with 15 CFR Part 930 Subpart C was prepared stating that the Recommended Plan, Arlington WPCP, is consistent with the enforceable policies of the State of Virginia's federally approved coastal management program (Appendix G). The Virginia Department of Environmental Quality reviewed and concurred with the federal consistency determination (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 Recommended Plan, Arlington WPCP, 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 was conducted. Measures to avoid/minimize adverse effects to fish and wildlife will be conducted during construction.

7.1.8 Endangered Species Act (ESA)

The Recommended Plan, Arlington WPCP, is in compliance with the Endangered Species Act of 1973 (ESA). USACE determined that the Recommended Plan, Arlington WPCP, 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 where the effects are likely to occur. USFWS had no comments on USACE's No Effect Determination (located in Appendix G). The Recommended Plan, Arlington WPCP, would have no effect on threatened and endangered species under the purview of NMFS.

7.1.9 Marine Mammal Protection Act

The Recommended Plan, Arlington WPCP, 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. 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.

Section 110(f) of the NHPA requires that Federal agencies, to the maximum extent possible, minimize harm to any NHL that may be directly or adversely affected by an undertaking. The Recommended Plan, Arlington WPCP, would have no impact on NHLs.

7.1.11 Resource Conservation and Recovery Act (RCRA)

Further investigations are needed to confirm that no contaminated groundwater is present 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 in or nearby the proposed construction sites.

7.1.13 Farmland Protection Policy Act of the 1981 Farm Bill

The Recommended Plan, Arlington WPCP, would not convert farmland to non-agricultural uses.

7.1.14 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 Recommended Plan, Arlington WPCP, would reduce the risk of flood loss, and minimize the impacts of floods on human safety, health, and welfare. The Recommended Plan, Arlington WPCP, is not expected to induce coastal flooding on adjacent properties during the 1 percent AEP storm.

7.1.15 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 Recommended Plan, Arlington WPCP, would have no direct effects to wetlands. The Recommended Plan, Arlington WPCP, may result in minor and temporary indirect impacts to wetlands. Sediment and erosion controls would be used to minimize the amount of sediment that may be carried into wetlands during construction.

7.1.16 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 Recommended Plan, Arlington WPCP.

7.1.17 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.

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

Migratory birds could experience temporary disturbance during construction of the Recommended Plan, Arlington WPCP. No direct effects are expected. No migratory bird breeding habitat is known to occur in or adjacent to the construction LOD. Construction of the Recommended Plan may result in temporary, minor indirect effects to migratory birds. No long-term effects are expected. Approximately 20 trees that could potentially provide migratory bird habitat may need to be removed to construct the floodwall. This exact number of trees to be removed will be determined during PED. Planting new trees in a different location in the study area may be an option to offset the effects to migratory birds from tree removal. 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.

7.1.19 River and Harbor Act, 33 U.S.C. 401, et seq.

The Recommended Plan, Arlington WPCP, 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 11 September 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. Most 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 Public Meetings on Draft Report

A public notice announcing release of the draft IFR/EA was sent out to the public and agencies on 31 May 2022. The public notice is in Appendix G (A16). One in- person public meeting was held on 14 June 2022 and a virtual public meeting was held on 16 June 2022. The public comment period was also extended through the end of July 2023 due to a request from Fairfax County. Significant public opposition was raised regarding the proposed plan at Belle Haven (Table 7-3).

USACE received approximately 196 total comments (120 emails and extensive conversation at the public meetings).

Table 7-3. Public Comment - Common Themes.

Common Themes	Resolution
Significant opposition to Belle Haven alignment (i.e., property concerns, access to GWMP, public request that USACE reengage with NPS to shift project to river side of the GWMP)	After coordination meetings and thorough discussion of the Belle Haven floodwall and levee plan with the stakeholders and community, Fairfax County sent USACE a letter on 13 March 2023 stating that they "will not support the project as proposed at the present time, and thus will not be providing the USACE with a letter of intent." Subsequently without a non-federal sponsor for implementation, no further analysis was undertaken for the Belle Haven floodwall and levee plan. Since this study is an interim response to the study authority, there could be future opportunities to revisit the Belle Haven planning unit if a NFS requests USACE to reevaluate the area. At that time, the required analysis would need to be completed (i.e. a complete, updated National Environmental Policy Act [NEPA] analysis and engineering analysis). USACE examined a floodwall/levee on NPS property, riverside of the GWMP; however, shifting the levee/floodwall alignment to NPS property would result in a project that was more expensive and not economically justified. Additionally, the NPS was not supportive of construction of a structural measure on NPS property.
NPS Viewshed and Resource Impacts to the GWMP	Meeting held on 04 October 2022 with NPS to hear NPS stance on viewshed and resource impacts from proposed floodwall. Refinements to alternative alignment were completed during feasibility level design.
Access to bike path for recreational use at WPCP	Coordination with NFS during construction to minimize impacts to bike path and determine temporary alternate route.
Aesthetics and access to the river at Belle Haven	Closure structures and material options (i.e., brick, stone etc.) would be evaluated during a potential future study.
Dyke Marsh and NNBF	NNBF features are being considered at Belle Haven; USACE reviewed modeling for Dyke Marsh and although improvements under the current project could alleviate wave impacts, storm surge risk remains under the FWP condition
Pump stations and interior drainage	Interior drainage analysis included in final report; if Belle Haven was considered in a future study, then pump station optimization would occur at that time.

7.2.3 Agency Coordination

The 90-day interagency meeting was held on 05 November 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. An interagency meeting was held on 13 October 2021. Representatives from EPA, MWAA, NPS, USFWS, VADCR, VADEQ and VRMC participated in the meeting. The purpose of the meeting was to review the project objectives and alternatives and to receive question/feedback from agencies. Comments on the draft IFR/EA were received from EPA, FAA, NOAA NMFS, NPS, VADEQ, VADWR, MWAA, Fairfax County, andArlington County. Table 7-4 provides details on agency coordination. Documentation of agency coordination for cultural resources is in Appendix G: Environmental and Cultural Resources.

7.2.4 Cooperating Agency Coordination

In August and September 2019, USACE sent letters inviting the following agencies to be cooperating or participating agencies in the NEPA process: EPA, FEMA, NOAA NMFS, USFWS, FAA, NPS, VADEQ, VMRC, and MWAA. The following agencies accepted the invitation to be cooperating agencies: EPA, NOAA NMFS, NPS and VMRC. Participating agencies include MWAA, USFWS, and VADEQ. These agencies participated in meetings and provided comments on the draft IFR/EA. Documentation of cooperating agency coordination is in Appendix G: Environmental and Cultural Resources.

7.2.5 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 (PA) being drafted for the project at the time. The Delaware Nation accepted the invitation to be a consulting party. Ultimately, a PA was not needed since USACE determined that the Recommended Plan would have no adverse effect on historic properties. Documentation of tribal coordination is in Appendix G: Environmental and Cultural Resources.

Table 7-4. 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.
• USEPA, Region III	18 September 2019	USEPA sent letter to USACE accepting cooperating agency invitation.

ORGANIZATION	DATE	ACTIVITY
• 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.
• 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)	05 November 2019	USACE held interagency webinar

ORGANIZATION	DATE	ACTIVITY
• Northern Virginia Regional Commission (NVRC) • MWAA • Prince William County		
• 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	05 February 2020	USACE and MWCOG held meeting with NPS to discuss and receive feedback on project alternatives.
• NPS, GWMP	06 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.
• 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.

ORGANIZATION	DATE	ACTIVITY
• 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 • VADEQ • VRMC	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 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

ORGANIZATION	DATE	ACTIVITY
		alternatives, and to confirm the alternatives avoid direct impacts to NPS resources.
• City of Alexandria	05 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).
• 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	10 March 2022	USACE sent letters to initiate consultation under Section 106 of the NHPA.

ORGANIZATION	DATE	ACTIVITY
• U.S. Commission of Fine Arts		
• City of Alexandria • Alexandria Archeology	11 March 2022	Email from the City of Alexandria Historic Preservation Division stating they would like to participate as a consulting party for the project.
• CFA	14 March 2022	CFA responding to USACE stating they would like to participate in the project as a consulting party.
• Fairfax County	15 March 2022	Fairfax County responding to USACE stating they would like to become a consulting party and participate in the development of the programmatic agreement.
• Arlington County	17 March 2022	Arlington County responding to USACE stating they would like to become a consulting party.
• Delaware Nation	23 March 2022	Formal letter emailed to USACE accepting the invitation for consultation for the project.
• NPS	28 March 2022	Formal letter emailed to USACE requesting to be an invited signatory to the project's programmatic agreement and requesting a status on overall Section 106 consultation to date.
• City of Alexandria	19 April 2022	City of Alexandria responding to USACE stating they no longer need to be a consulting party due to the screening of Alternative 5b1.
• NCPC	03 May 2022	USACE and NCPC met virtually to discuss project alternative's and delineate NCPC's interest in the project as a consulting party.
• VADEQ	16 May 2022	Call to discuss draft report/EA submittal to the VADEQ Environmental Impact Review team

ORGANIZATION	DATE	ACTIVITY
• Public and agencies	14 June 2022	In-person meeting held at the Belle View Elementary School. USACE presented the draft IFR/EA and received public comments.
• Public and agencies	16 June 2022	Virtual meeting. USACE presented the draft IFR/EA and received public comments.
• FAA	08 July 2022	Provided comments on the draft IFR/EA
• VADEQ	14 July 2022	Provided comments on the draft IFR/EA
• Fairfax County, MWCOG	21 July 2022	Discussed the path forward for the study.
• Fairfax County	28 July 2022	Provided comments on the draft IFR/EA
• NPS	29 July 2022	Provided comments on the draft IFR/EA
• Fairfax County Historic Commission	30 July 2022	Formal letter emailed to USACE requesting to be a consulting party.
• Arlington County • Fairfax County Park Authority	31 July 2022	Provided comments on the draft IFR/EA
• USEPA	01 August 2022	Provided comments on the draft IFR/EA
• MWAA	12 August 2022	Provided comments on the draft IFR/EA
• Alexandria Archaeology • CFA • Fairfax County • Arlington County • Delaware Nation • NPS • VA SHPO • NCPC • Fairfax County Historic Commission	23 November 2022	Email to consulting parties sending the preliminary draft PA for review and comment.

ORGANIZATION	DATE	ACTIVITY
• CFA	28 November 2022	Email to USACE stating that since the project alternatives have been refined such that they are outside of CFA's jurisdiction, they no longer need to be a consulting party.
• Alexandria Archaeology	01 December 2022	Email to USACE stating they have no comments on the draft programmatic agreement at this time.
• Fairfax County	23 December 2022	Email to USACE submitting revisions and comments on the draft programmatic agreement. Specifically, they requested the inclusion of the Fairfax County Architectural Review Board as a consulting party.
• ACHP	01 February 2023	Formal letter emailed stating they will not be participating in consultation for the project.
• VA SHPO	01 February 2023	Email submitting revisions and comments on the draft programmatic agreement.
• VA SHPO • NPS • Delaware Nation • Alexandria Archaeology • Arlington County • Fairfax County • Fairfax County History Commission • NCPC	09 June 2023	Formal letter emailed updating the consulting parties with the Recommended Plan and requesting concurrence on the determination of no adverse effect.
• VA SHPO	07 July 2023	Email concurring with USACE's determination of no adverse effect for the Recommended Plan.

8 District Engineer Recommendations

The Baltimore District recommends that the coastal storm risk management measures in Arlington County, 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 project first cost of $15.2 million (FY24, October 2023 price level; includes a 35 percent contingency). Constructing a floodwall and closure structure along the riverbank of Four Mile Run would reduce coastal storm risk to the Arlington Water Pollution Control Plant. The proposed floodwall includes a 1,180-linear-foot floodwall (ranging up to about 6ft. in height from ground, at elevation +14.3ft. NAVD88) located along the existing fence line of the facility and will be installed between the Four Mile Run stream and the facility's vulnerable infrastructure. The west end of the floodwall would tie into high ground. In preparation for a flooding event, a temporary 70ft long aluminum stop log closure would be placed at the east end of the alignment located across South Eads Street. The project would also include a +1 ft curb for approximately 1,280 lf, flap gates at stormwater conduits to prevent backflow, and sluice gates installed at the 36" and 60" stormwater conduits. The Arlington WPCP floodwall (14.3 ft NAVD88) will pass the 0.34% AEP event (~300-year storm) with 90% assurance.

Alternative 4c, as defined herein, has negative average annualized net benefits of -$212,000 and a benefit-to-cost ratio of 0.7 (FY24, October 2023 price level, 2.75 discount rate). Although this project has a BCR of less than 1.0, it is still recommended for implementation due to its importance as critical infrastructure in the area and the maximum total net benefits of the project. The Assistant Secretary of the Army for Civil Works approved a National Economic Development (NED) policy exception on March 18, 2024. The policy exception allowed the Recommended Plan to include non-economically justified separable elements based on environmental and other social effects. The approval highlighted the importance of providing a risk management solution to ensure this critical infrastructure has minimized risk of operational failure during a coastal storm event.

The Recommended Plan (Arlington WPCP) is a critical infrastructure structural solution providing significant positive OSE (including serving six economically disadvantaged communities) and EQ benefits, as well as community resilience. The Recommended Plan would reduce the plant's susceptibility to flood events and reduce the risk of operational failure. Without the proposed project, flooding from Four Mile Run may result in disruption to the operations and damage to the equipment at the facility. It could take weeks to months to place the systems back into operation (DC Water, 2021), presenting public health risks to the service area of approximately 220,000 people. Flooding may also result in impacting approximately 117 acres of wetlands and 812 acres of aquatic habitat through release of contaminated effluent. Arlington County owns the Arlington WPCP. Without CSRM measures to reduce risk to the plant, the plant will not be able to uphold its mission to safely and economically process wastewater and hazardous waste materials to protect the environment: especially Four Mile Run, the Potomac River, and the Chesapeake Bay.

Recommendations for provision of Federal participation in the plan described in this report would require the non-Federal Sponsor to enter into a Project Partnership Agreement, as required by Section 221 of Public Law 91-611, 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 35 percent of construction costs, as further specified below:

1. Provide, during design, 35 percent of design costs 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-way, and placement areas and perform all relocations determined by the Federal government to be required for the project;

3. Provide, during construction, any additional contribution necessary to make its total contribution equal to at least 35 percent of construction costs;

b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) that might reduce the level of coastal storm risk reduction the project affords, 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 risk reduction afforded by the project; participate in and comply with applicable Federal floodplain management and flood insurance programs; prepare a floodplain management plan for the project to be implemented not later than one year after completion of construction of the project; 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 the project;

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

e. 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 to inspect the project, and, if necessary, to undertake work necessary to the proper functioning of the project for its authorized purpose;

f. Hold and save the Federal government free from all damages arising from design, construction, operation, maintenance, repair, rehabilitation, and replacement of the project, except for damages due to the fault or negligence of the Federal government or its contractors;

g. Perform, or ensure performance of, any investigations for hazardous, toxic, and radioactive wastes (HTRW) that are determined necessary to identify the existence and extent of

any HTRW regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675, and any other applicable law, that may exist in, on, or under real property interests that the Federal government determines to be necessary for construction, operation and maintenance of the project;

h. Agree, as between the Federal government and the non-Federal sponsor, to be solely responsible for the performance and costs of cleanup and response of any HTRW regulated under applicable law that are located in, on, or under real property interests required for construction, operation, and maintenance of the project, including the costs of any studies and investigations necessary to determine an appropriate response to the contamination, without reimbursement or credit by the Federal government;

i. Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the owner and operator of the project for the purpose of CERCLA liability or other applicable law, and to the maximum extent practicable shall carry out its responsibilities in a manner that will not cause HTRW liability to arise under applicable law; and

j. 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. 4630 and 4655) and the Uniform Regulations contained in 49 C.F.R Part 24, in acquiring real property interests necessary for construction, operation, and maintenance of the project including those necessary for relocations, and placement area improvements; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

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.

8 APR 2024

ESTHER S. PINCHASIN
COL, EN
Commanding

DATE

9 List of Preparers

The USACE and MWCOG team for this study is listed in **Error! Reference source not found.**. The team members listed below provided substantial text to this IFR/EA.

Table 9-1. List of Preparers.

NAME	AFFILIATION
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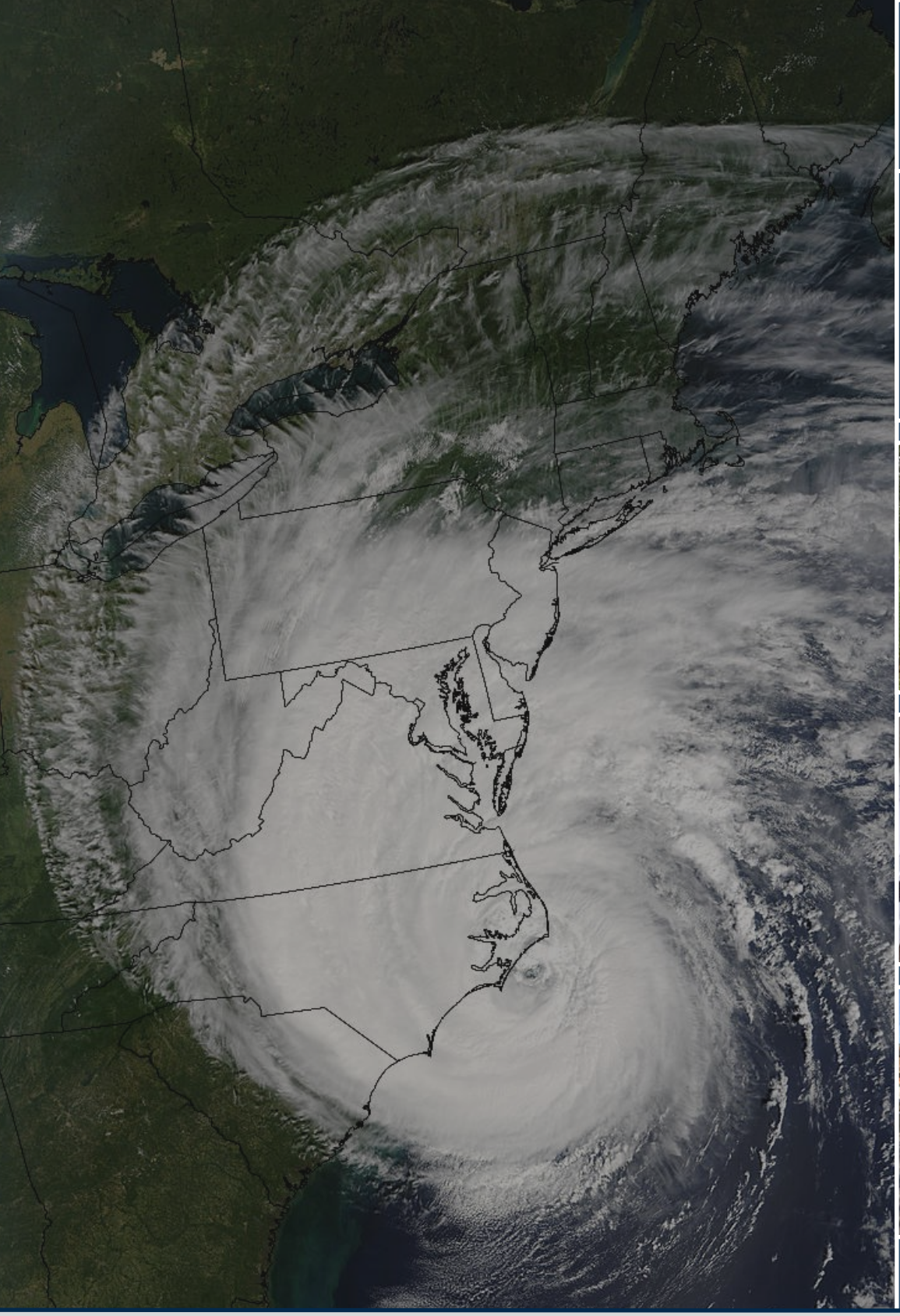

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