PROJECT ALTERNATIVE SCREENING ANALYSIS

Initial Feasibility Assessment of Alternatives for Flood Risk Reduction in Back Bay, Southern Rivers Watershed, Virginia Beach

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FINAL DRAFT REPORT

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REVISION HISTORY

September 4, 2020 – Initial Draft Report

October 21, 2020 – Revised Draft Report, addressing City comments

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January 6, 2021 – Final Draft Report, including the Executive Summary and Recommendations chapter, integrating regulatory agency feedback.

EXECUTIVE SUMMARY

The City of Virginia Beach conducted a high-level conceptual exploration of alternatives suggested by local stakeholders to address flooding concerns for areas adjacent to Back Bay, located in southern Virginia Beach. The effort is summarized below, including the purpose and needs statement, alternatives evaluated, evaluation framework, screening analysis, and regulatory stakeholder consultation.

Purpose and Needs Statement – The purpose of the proposed action is to provide a near-term, cost-effective means to reduce "sunny day", wind-driven flood hazards in the Back Bay. The strategies herein seek to accomplish this by either decreasing flood elevations or slowing down floodwaters entering the bay. These strategies would alleviate impacts on vulnerable, developed properties and enable critical roadway access into and out of communities surrounding northern Back Bay.

Alternatives – A list of alternatives was compiled from stakeholders and ongoing efforts by the City of Virginia Beach to mitigate flooding along the Back Bay. Stakeholder input was gathered through a series of focus group meetings held between the City and stakeholders along the Back Bay shoreline in the summer of 2019. Evaluation of the alternatives against the defined Purpose and Needs Statement allowed for the initial down-selection of alternatives, all of which aligned with stakeholder input. The following alternatives were evaluated:

- Artificial Inlet – an artificial inlet or "cut" in the barrier island between Back Bay and the Atlantic Ocean;
- Inverted Siphon – an inverted siphon system to remove waters from Back Bay and discharge into the Atlantic Ocean;
- Marsh Creation – the restoration of degraded marsh habitat to reduce wind-driven flow into and within Back Bay; and a
- Pump Facility – a pump station to remove waters from Back Bay and discharge into the Atlantic Ocean.

High-level conceptual designs and rough order of magnitude cost estimates were developed for the above alternatives as inputs for the evaluation framework and screening analysis. The conceptualizations are initial approximations and subject to revision given further study.

Evaluation Framework – A standard set of screening factors and ranking criteria enabled a consistent and transparent means of scoring alternatives. A total of seven evaluation factors were established, including: project effectiveness; external impacts; environmental impacts; implementation timeframe; implementation complexity; fiscal considerations; and regulatory stakeholder alignment.

Screening Analysis – The alternatives were systematically evaluated against the established evaluation criteria and screening factors to reveal an overall snapshot of the feasibility of each alternative. In total, thirteen screening factors were established along with ranking criteria. Each ranking consideration was assigned a numerical point score to allow for calculation of a total score for each proposed alternative.

Regulatory Agency Consultation – A consultation meeting with regulatory agencies provided a forum to gather input on the alternatives evaluated and guide further feasibility analyses. The City offered multiple avenues for providing comments – during the meeting, in an online survey form, or via phone or email. Overall, agencies agreed with the outcomes of the initial feasibility assessment as follows:

- The Artificial Inlet Alternative is unlikely to obtain permits and does not align with agency goals and objectives.
- The Inverted Siphon and Pump Facility Alternatives could potentially obtain permits and the approach generally aligns with agency goals. Further analysis is required to further evaluate the feasibility, develop more detailed capital costs and operations and maintenance requirements, and fully understand the cumulative impacts on natural resources, as well as safety considerations.
- The Marsh Creation Alternative is likely to be supported by regulatory agencies given its ability to support the mutually reinforcing goals of flood protection and habitat creation. Further analysis is needed to develop more detailed capital costs and operational and maintenance requirements, quantify the full range of benefits, and to identify a suitable sediment source for building new marsh areas.

Recommendations – Based on the results of this initial feasibility assessment, it is recommended that the City does not pursue further study of the Artificial Inlet Alternative. The other three alternatives (Inverted Siphon, Pump Facility, and Marsh Creation) could provide significant flood benefits to southern Virginia Beach. However, these solutions are expensive, with estimated costs from $200 to $500 million. Each alternative is also subject to significant hurdles such as environmental impacts and permitting. The next steps to advance consideration of the concepts include: 1) gathering additional public feedback, and 2) performing more detailed engineering, feasibility, and environmental analyses for the recommended set of alternatives. It is possible that a combination of the alternatives, or a hybrid approach, will provide the needed level of flood protection while minimizing adverse environmental impacts.

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ACRONYMS

ADCIRC	Advanced Circulation Model for Oceanic, Coastal, and Estuarine Waters
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
CCC	Civilian Conservation Corps
CE	Categorical Exclusion
CFS	Cubic Feet Per Second
CZMA	Coastal Zone Management Act
DEM	Digital Elevation Model
DFE	Design Flood Elevation
DHI	Danish Hydraulic Institute
DOC	Depth of Closure
EA	Environmental Assessment
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
JPA	Joint Permit Application
LEDPA	Least Environmentally Damaging Practicable Alternative
MPH	Mile Per Hour
O&M	Operations & Maintenance
NACCS	North Atlantic Coast Comprehensive Study
NAVD88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NCDENR	North Carolina Department of Environment and Natural Resources
NOAA	National Oceanic and Atmospheric Administration
NWI	National Wetlands Inventory

PASAE	Project Alternative Screening Analysis and Evaluation
PVC	Present Value Coefficient
SCADA	Supervisory Control and Data Acquisition
SLR	Sea Level Rise
SLW	Sea Level Wise
T&E	Threatened and Endangered Species
TOYR	Time of Year Restrictions
USEPA	U.S. Environmental Protection Agency
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VDACS	Virginia Department of Agriculture and Consumer Services
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDGIF	Virginia Department of Game and Inland Fisheries
VDHR	Virginia Department of Historic Resources
VDOT	Virginia Department of Transportation
VDWR	Virginia Department of Wildlife Resources
VIMS	Virginia Institute of Marine Sciences
VMRC	Virginia Marine Resources Commission

1. INTRODUCTION

1.1. BACKGROUND

The City of Virginia Beach (hereinafter referred to as the "City") is proactively addressing solutions for the repetitive and projected increases of flooding. The recently completed *Virginia Beach Sea Level Wise Adaptation Strategy* ("SLW Strategy") report represents a culmination of over five years of sea level rise (SLR) planning and engineering analysis. The strategy presents a holistic framework for addressing flood risks across the City, consisting of four layers – natural mitigations, engineered defenses, adapted structures, and prepared communities. These strategies were applied to each major watershed in the City and tailored to the watersheds' unique characteristics and risk profiles.

Each of the proposed adaptation projects has its own costs, benefits, and implementation challenges. The City is continuing to explore the viability of the proposed adaptation initiatives and remains open to integrating additional alternatives as new ideas and solutions arise. Throughout the SLW Strategy development process, the City engaged over 350 residents in the Southern Rivers Watershed through a series of interactive public engagement meetings, and an online portal for residents who were unable to attend the live community meetings.

In addition to the public outreach meetings, several focus group meetings were held in the summer of 2019 between the City Manager's Office and stakeholders in the Southern Rivers Watershed, to elicit suggestions of alternative strategies to address wind-driven "sunny day" flooding concerns. A unifying theme of these stakeholder-elicited strategies was the need for solutions that would provide immediate relief from the impacts of these flood issues.

In response to these suggestions, the City initiated a preliminary feasibility assessment to explore the stakeholder-derived priorities, including regulatory alignment and agency consultation. The outcome of this effort will be an increased understanding of the technical and permitting feasibility of the identified options, as well as recommendations for future efforts.

1.2. OBJECTIVES

This report outlines the framework for evaluating flood reduction alternatives in Back Bay and presents the results of the Project Screening Analysis and Evaluation (PASAE). Given the scale of the proposed alternatives to address flood risks in the Southern Rivers Watershed, the framework was structured in alignment with the National Environmental Policy Act (NEPA), which requires the following:

- Define the project purpose (presented in Chapter 2);
- Determine and document the need for the project (presented in Chapter 2);
- Determine the range of alternatives that meet the defined purpose and need

(Presented in Chapter 3);

- Develop evaluation criteria (Presented in Chapter 4);
- Screen alternatives against evaluation criteria (Presented in Chapter 5);
- Review evaluation results along with agency consultation (Presented in Chapter 6); and,
- Develop recommendations for additional analysis (Presented in Chapter 7).

These elements of the NEPA process allow for a transparent approach to identify a broad range of alternatives. These alternatives are then evaluated against a standard set of criteria to rank the alternative and eliminate alternatives that do not meet the purpose and need, or the project objectives. It should be noted that although some projects are feasible, they may not be practicable given budgetary or regulatory constraints. Chapter 5 of this report presents the results of the initial screening analysis.

2. PURPOSE AND NEEDS STATEMENT

2.1. PROJECT PURPOSE

The purpose of the proposed action is to provide a near-term, cost-effective means to reduce “sunny day”, wind-driven flood hazards in the Back Bay. The strategies herein seek to accomplish this by either decreasing flood elevations or slowing down floodwaters entering the bay. These strategies would alleviate impacts on vulnerable, developed properties and enable critical roadway access into and out of communities surrounding northern Back Bay.

2.1.1. GOALS AND OBJECTIVES

A Goals and Objective Statement was developed to provide a broad vision for the project and communicate the full range of factors for evaluating the feasibility of the alternatives. The project should:

- Minimize long-term operations and maintenance (O&M) responsibility and cost;
- Minimize adverse impacts within and outside Virginia Beach;
- Minimize impacts on habitats and water quality;
- Be generally aligned with regulations and policies of the regulatory community;
- Maximize the use of municipal properties and minimize impacts on navigation, vehicular, and pedestrian traffic circulation;
- Avoid the use of highly specialized construction methods or contractor; and,
- Have a reasonable implementation timeframe of five to seven years once funding is secured.

2.2. PROJECT NEED

The need for the proposed action is demonstrated through a combination of the factors described below.

2.2.1. MORE FREQUENT WIND-TIDE FLOODING

The proposed action is located in the Southern Rivers Watershed in Virginia Beach. The watershed has the largest amount of low-lying land in Virginia Beach, representing 90% of land area in the City under an elevation of 3 feet below the North American Vertical Datum of 1988 (NAVD88). These low-lying elevations are susceptible to repetitive coastal flooding during periods of sustained southerly winds which push water up from the Albemarle-Pamlico Sound into Currituck Sound and then into Back Bay (Figure 1). Referred to locally as "wind tide flooding", such events can result in widespread flooding of residential homes, businesses, and critical access roads.

Figure 1: Wind tide flooding process.

The City has installed water level gauges and completed multiple studies to improve understanding of the driving factors and processes surrounding wind tide flooding. The U.S. Geological Survey (USGS) Beggars Bridge Creek water level gauge, installed in coordination with the City in 2016, provides insight into the frequency of these “wind tide flooding” events for the Back Bay. A review of the period of record (April 2016 through July 2020) shows that the daily peak water levels in Back Bay average approximately 0.5 feet NAVD88. As a comparison, the mean daily astronomical high tides in the Atlantic Ocean for the same time period average 1.9 feet NAVD88. These relative water levels are illustrated in Figure 2. The reader should note that while the ocean experiences two daily astronomical high tides, Back Bay has negligible astronomical tidal water level fluctuations. Instead, Back Bay water levels are controlled primarily by wind.

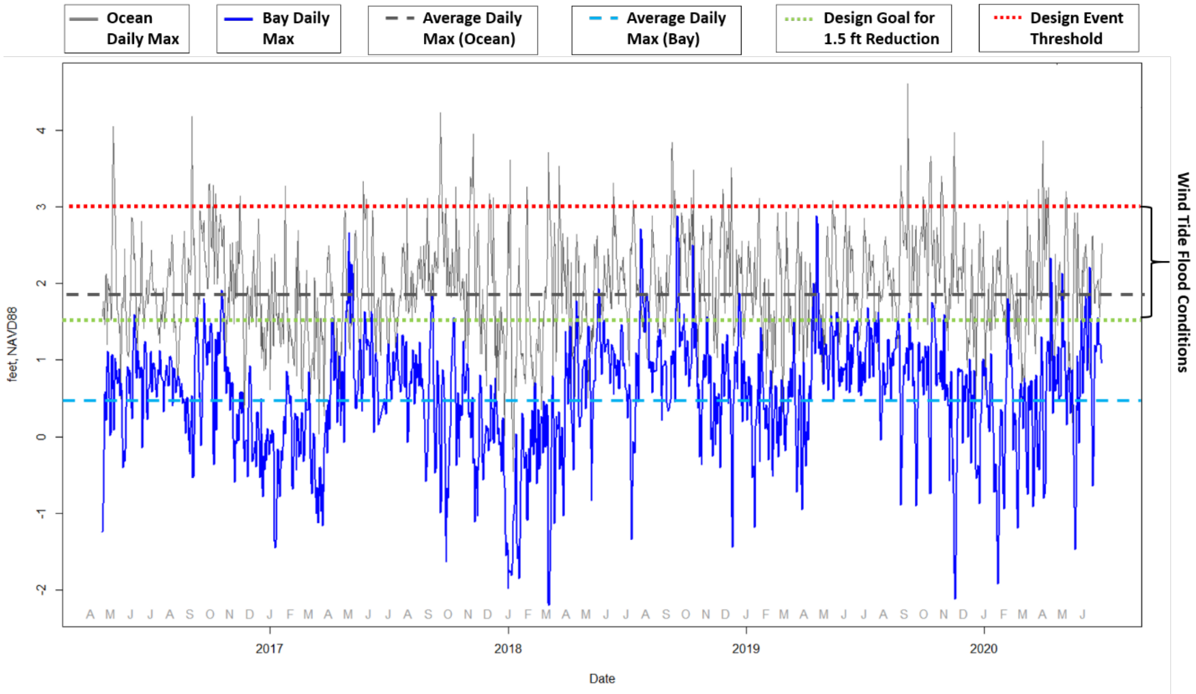

Figure 2: Comparison of observed water levels in the Back Bay (Beggar’s Bridge Creek) and Atlantic Ocean (Duck, North Carolina) from April 2016 to July 2020. Average daily maximum water levels are shown along with the design event threshold and goal for water level reduction. Data sources include the U.S. Geological Survey and the National Oceanic and Atmospheric Administration

Although wind-tide flood events used to be infrequent, residents in the Southern Rivers Watershed are experiencing more intense flooding in recent years. Analysis conducted for the SLW Strategy has found that worsening conditions are attributed primarily to almost a foot of relative sea level increase in the last 50 years in conjunction with degradation and loss of marsh and aquatic vegetation.

Past observations show that flooding can become problematic for residents when Back Bay waters rise above an elevation of 1.5 feet and become more severe as flood waters reach 3 feet NAVD88. Such conditions result in flooded roads and residential structures. More than 20 instances of wind-tide flood conditions have occurred since observations started in April 2016.

This 1.5-foot design threshold and 3-foot design event are further discussed in the design considerations section of this report (Section 3.2.1).

2.2.2. GROWING FLOOD ISSUES AND RISK

A detailed economic flood loss assessment, using the Federal Emergency Management Agency's (FEMA) flood loss estimation software called Hazus, revealed that approximately 17% of the entire risk exposure in the City is concentrated in the Southern Rivers Watershed (CVB 2020a). With 3 feet of SLR, this percentage increases to 45%. Of that risk, 65% is concentrated in northern Back Bay (Figure 3).

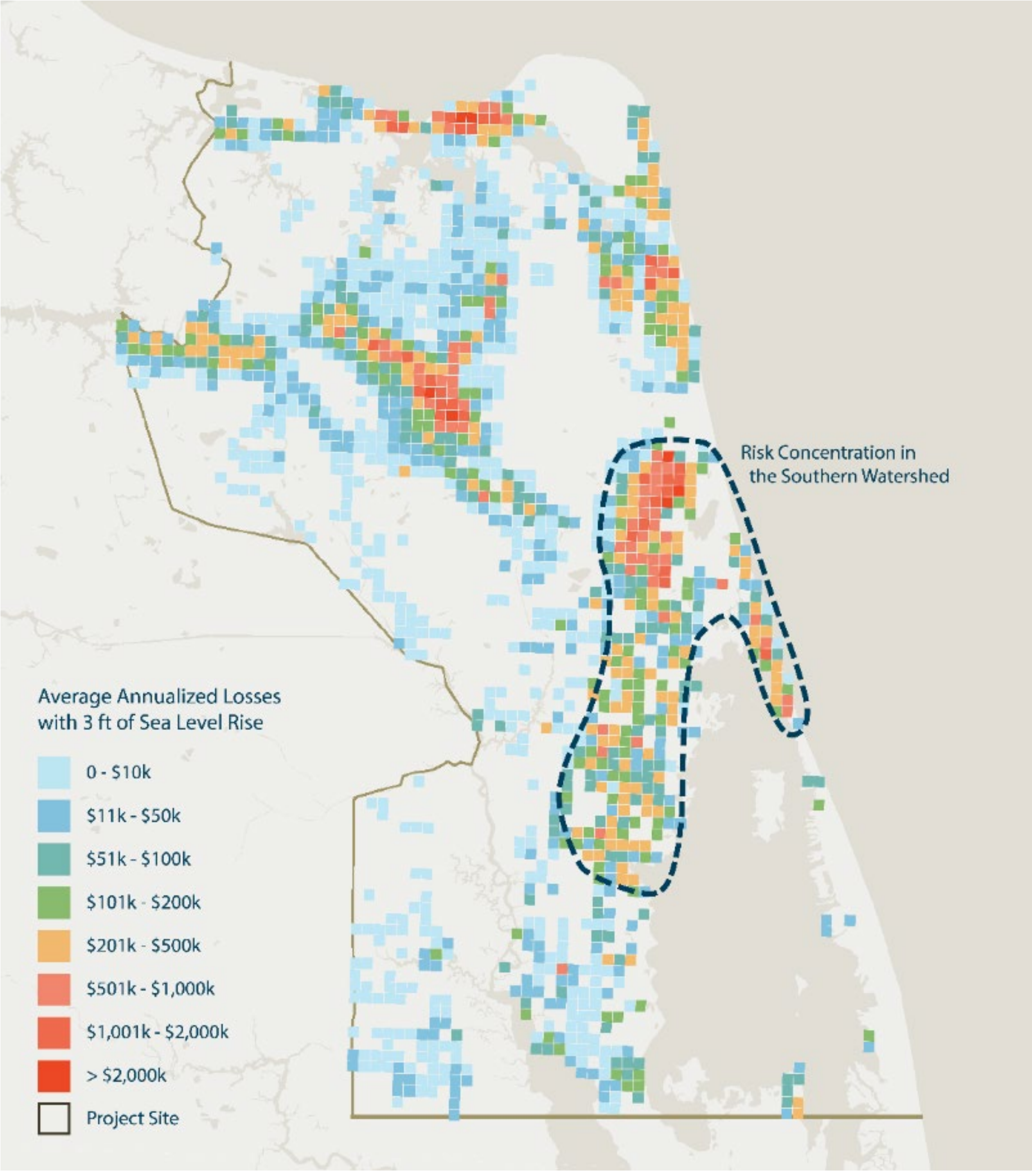

Figure 3: Concentration of flood losses in the Southern Rivers Watershed.

The Southern Rivers Watershed also faces severe threats to its natural environment. Historical analysis has revealed significant degradation of marsh and aquatic grass habitat. The City's *Analysis of Marsh Response to Sea Level Rise* study (CVB 2019) revealed accelerated degradation of marsh islands and fringing marsh in Back Bay (Figure 4). The loss of these systems results in the widening of flood pathways, allowing increased flow into northern Back Bay land areas.

Figure 4: Projected response of habitat to SLR in the Southern Rivers Watershed.

2.2.3. SLW STRATEGIES IN SOUTHERN RIVERS WATERSHED

To address these growing flood risks and issues, the SLW Strategy presents a holistic adaptation vision for the Southern Rivers Watershed. The vision focuses on employing natural mitigations to strategically reduce flow into and within the Back Bay, while also reducing wave heights within the bay. These nature-based strategies are integrated with a system of defense structures, and complimentary adaptation measures such as land-use strategies to improve flood storage, as shown in Figure 5 (CVB 2020b). The following sub-sections discuss whether or not these alternatives meet the purpose or the project goals outlined in Section 2.1.

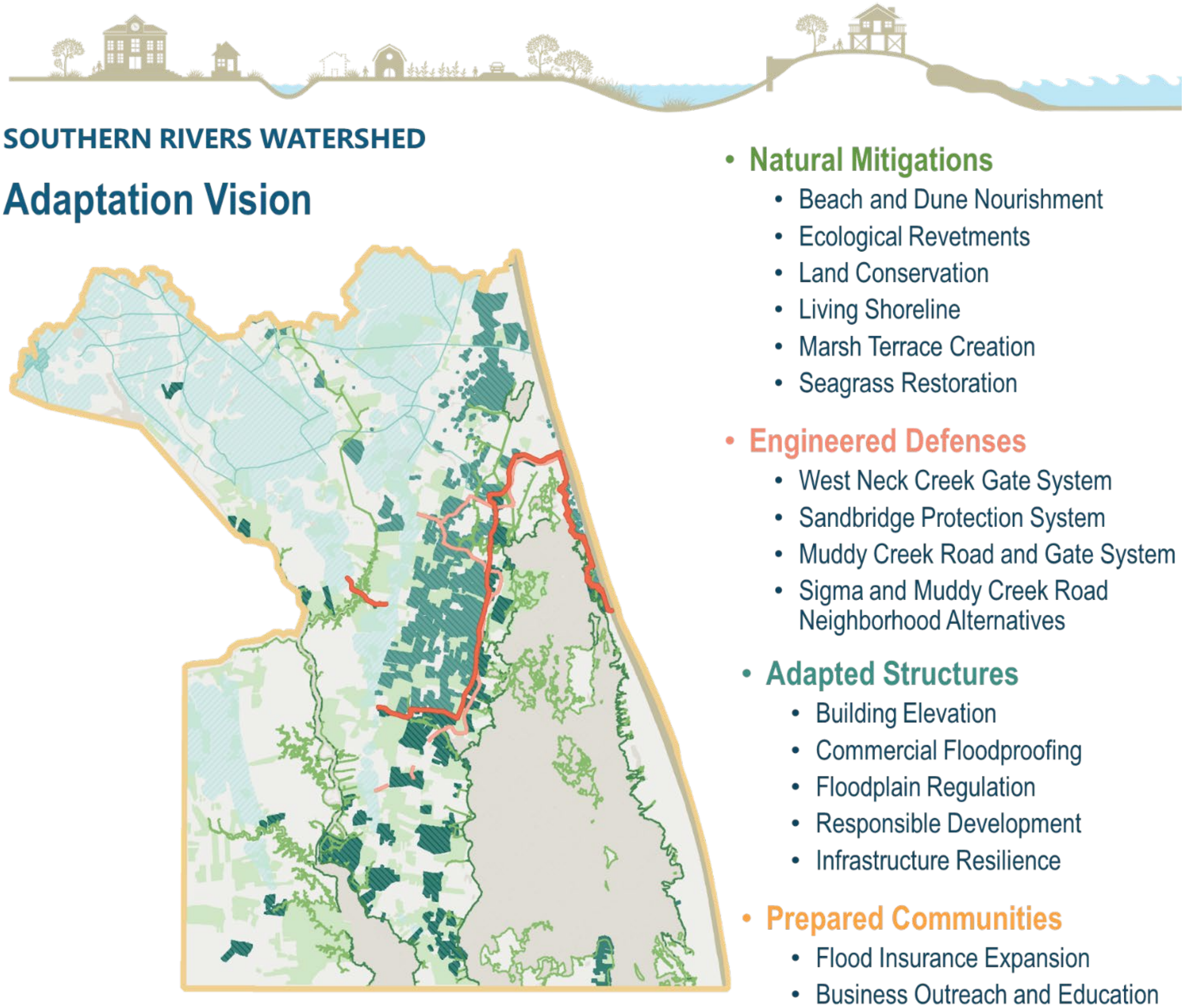

Figure 5: Conceptual adaptation vision for the Southern Rivers Watershed.

2.2.3.1. *Natural Mitigations*

Marsh restoration and creation in Back Bay, presented under the *Natural Mitigations* layer of the SLW Strategy, is recommended for inclusion in this feasibility assessment for the following reasons:

- Marsh island restoration has been conceptually evaluated through the City's *Nature-Based Coastal Flood Mitigation Strategies* (2019a), and found to reduce existing "wind tide flooding" elevations and delay the onset of flooding by several days; and,
- Additional feasibility analysis is required to assess benefits, impacts, costs, and engineering and construction requirements.

2.2.3.2. *Engineered Defenses*

The strategies presented under the *Engineered Defenses* facet of the SLW strategy, which are summarized in more detail in Table 1, are not recommended for inclusion in this feasibility assessment for the following reasons:

- These systems are designed to provide protection from large storm surge events with SLR;
- They will take a significant amount of time (more than five to seven years) to implement; and,
- The City has requested a full feasibility study of these flood defense options with the USACE.

Table 1: Engineered defense alternatives for the SLW adaptation vision for the Southern Rivers Watershed.

Alternative	Description	Estimated Costs	Level of Protection
Muddy Creek Road City-Wide Alignment	A large-scale flood defense system that involves transforming much of Muddy Creek Road into a levee	$282.9 million	100-year storm surge event with 3 feet SLR
Sandbridge City-Wide Alignment	A large-scale flood defense system that involves elevating Sandbridge Road and construction of a network of seawalls, levees, and gates along the Back Bay shorelines of the Sandbridge Resort community	$554.6 million	100-year storm surge event with 3 feet SLR
Alternative to Muddy Creek Road City-Wide Alignment	A neighborhood-scale flood defense system that would raise sections of North Muddy Creek Road	$72.2 million	50-year storm surge event with 3 feet SLR
Alternative to Sandbridge City-Wide Alignment	A neighborhood-scale flood defense system that involves elevating sections of Sandbridge Road and New Bridge Road, and a system of levees and gates	$61.3 million	50-year storm surge event with 3 feet SLR

2.2.3.3. Adapted Structures and Prepared Communities

The strategies included within the *Adapted Structures* and *Prepared Communities* layers are not recommended for inclusion in this feasibility assessment. These are planning and policy-based strategies designed to address long-term SLR issues rather than meeting the current goal of reducing the elevation of water in Back Bay in the near-term as desired.

2.2.4. ONGOING CITY FLOOD REDUCTION PROJECTS

The City has several ongoing or planned flood risk reduction projects in the Southern Rivers Watershed:

- Raise sections of Sandbridge Road, Indian River Road, Pungo Ferry Road, and the New Bridge/Sandbridge Road intersection;
- Dune and beach nourishment of Sandbridge beach and Little Island Park; and,
- Design and permitting of marsh terrace pilot project in Bonney Cove.

These projects are not considered as alternatives in this feasibility assessment given that they are ongoing and have already undergone feasibility assessment and engineering design. The City's ongoing/planned flood risk reduction projects should be considered when determining which alternatives move forward.

2.2.5. STAKEHOLDER-ELICITED STRATEGIES

In the summer of 2019, the City Manager hosted a series of four meetings with Southern Rivers Watershed residents and stakeholders. Topics discussed included:

- Groundwater and flooding
- Erosion
- Great Bridge Lock
- Ditches, culverts, canals, and dredging
- Bulkheads
- Pump, "cut" (an artificial inlet), siphons, floodwalls
- Roads
- Coordination
- Natural and nature-based features
- Voluntary acquisition

A total of 116 responses and 70 suggestions through discussion surrounding these topics were recorded by a City stenographer. A review of the captured information showed that the topic of investigating the feasibility of a pump, an artificial inlet, or siphon solution had the largest number of both responses (24%) and suggestions (34%) from the meeting participants. The topic of nature-based and natural features had the second-largest number of responses (21%) and suggestions (20%) from the focus group results.

- The pump, artificial inlet, or siphon strategies include:
- Use of a pump to draw water from the Back Bay and discharge into the Atlantic Ocean;
- Creating an opening (referred to by the stakeholders as the “cut”), either through lowering of the existing dunes or creating an artificial inlet in the barrier island to allow water from Back Bay to flow into the Atlantic Ocean during wind tide events. Supporting evidence mentioned by participants including historical inlets in the barrier island, and historical areas of washover. In the historical period when these features were present, wind tides were not an issue; and,
- Use of gravity-fed siphons installed between the Back Bay and the Atlantic Ocean to drain water.

The City’s *Assessments of Back Bay Scenarios to Address Flooding and Water Quality Issues* (CVB 2018a) includes a cursory assessment of the artificial inlet option. The pump option received minimal investigation. The siphon approach was quickly reviewed after mention during a public meeting. Additional feasibility analysis is required to assess the benefits, impacts, costs, and engineering and construction requirements of these options. Given the potential to alleviate near-term wind tide flood issues, these solutions are recommended for inclusion in this feasibility assessment.

3. ALTERNATIVES

The adaptation projects presented in the SLW Strategy, along with the Southern Rivers Watershed stakeholder-elicited strategies, were initially screened against the Purpose and Needs statement. Alternatives recommended for further feasibility assessment are summarized in Table 2. The structural and natural mitigation alternatives are discussed separately to reflect the divergent techniques to flood risk management. Structural systems are designed to reduce the amount of water in Back Bay, whereas the function of natural systems is to slow down flow into and within Back Bay.

The following sections provide details on alternative conceptualization, including design considerations, cost estimation assumptions, and conceptual designs. These basic parameters were required inputs for the full screening analysis, which is presented in Chapter 5.

Table 2: Alternatives for inclusion in the evaluation framework screening analysis, listed alphabetically.

Alternative	Type	Description	Source
Artificial Inlet	Structural	An artificial inlet or "cut" in the barrier island between Back Bay and the Atlantic Ocean.	Stakeholder Elicited
Inverted Siphon	Structural	An inverted siphon system to remove waters from Back Bay and discharge into the Atlantic Ocean.	Stakeholder Elicited
Marsh Restoration	Natural Mitigation	Implementation of natural and nature-based strategies, such as large-scale marsh restoration, to reduce wind-driven flow into and within Back Bay.	Stakeholder Elicited / SLW Strategy
Pump Facility	Structural	A pump facility to remove waters from Back Bay and discharge into the Atlantic Ocean.	Stakeholder Elicited

3.1. CAVEATS AND LIMITATIONS

The content in the following sections present initial, high-level conceptual explorations of the proposed alternatives. Such explorations were conducted to parameterize the alternatives for the initial feasibility analysis herein.

Each alternative would require additional engineering and design activities to understand the technical feasibility for implementation and full costs for construction. The presented alternatives, as well as the associated initial design parameters and costs, should be considered initial approximations and subject to revision given further study.

3.2. STRUCTURAL ALTERNATIVES

The common objective of the structural flood defense alternatives is to reduce individual wind tide flood events in Back Bay to an elevation of 1.5 feet NAVD88. This elevation was identified through a review of elevation data for the surrounding shorelines and would result in a significant reduction of flooding to roadways and residences. To achieve this reduction, several design considerations include estimating the volume of water and flow rate that would be required to achieve this reduction, as well as estimating a useful life.

3.2.1. DESIGN CONSIDERATIONS

3.2.1.1. Volume Estimation

The first step in the conceptual design involved estimating the volume of water that would need to be removed from Back Bay to reduce an extreme wind tide event to an elevation of 1.5 feet NAVD88. The design wind tide event was set to 3 feet NAVD88 based on a review of the historical record of wind tide events in Back Bay (Figure 6). The study team leveraged the existing Advanced Circulation Model (ADCIRC) model, developed under the *Numerical Modeling of Wind Tides in Back Bay and North Landing River* (CVB 2019c) study. This effort demonstrated that sustained wind from south-southwest, south, and south-southeast produced the highest water levels within the bay, with a southerly wind producing the greatest water levels (CVB 2019c). Figure 6 shows water surface elevations at the entrance to Beggar's Bridge Creek under southerly wind conditions at specified wind intervals with each wind speed analyzed.

To assess volumetric requirements for the design threshold, results from a coastal numerical model simulation of a sustained 25 mile per hour (mph) were leveraged. Water elevations were extracted at the 4-day time step to capture the water surface across the entire Back Bay when water elevations reach +3.0 feet NAVD88 at Beggar's Bridge.

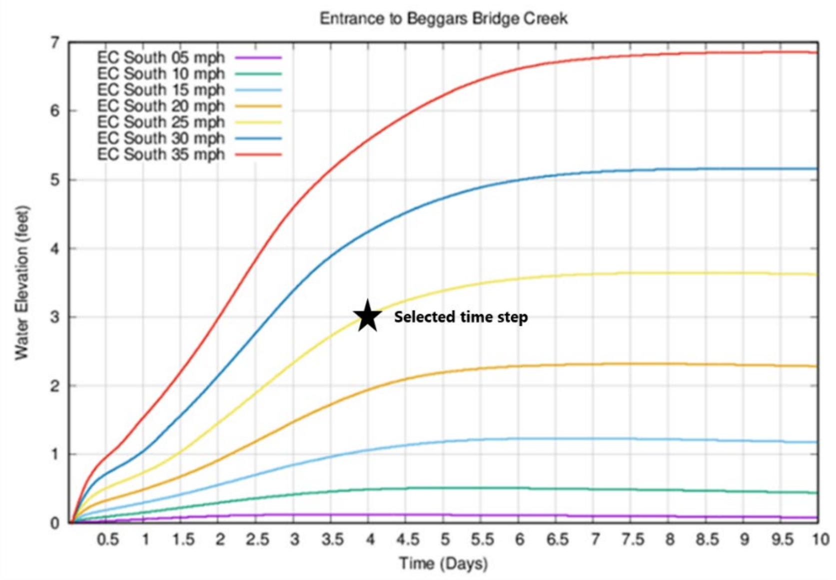

Figure 6: Water level response in the Back Bay was investigated using computer simulations of sustained winds from Duck, NC (CVB 2019c). This information was leveraged to understand water volume requirements for the proposed alternatives.

This spatial result was imported into Autodesk Civil3D to create a spatial representation of the ADCIRC model results. Using tools within ArcGIS, this surface was clipped to the low-lying, flood-prone area surrounding Back Bay, as shown in Figure 7. The clipped surface was used to determine the volume of water above 1.5 feet NAVD88. It was determined that 2.7 billion cubic feet of water would need to be removed from Back Bay. This is equivalent to approximately 31,000 Olympic-size swimming pools of water[1].

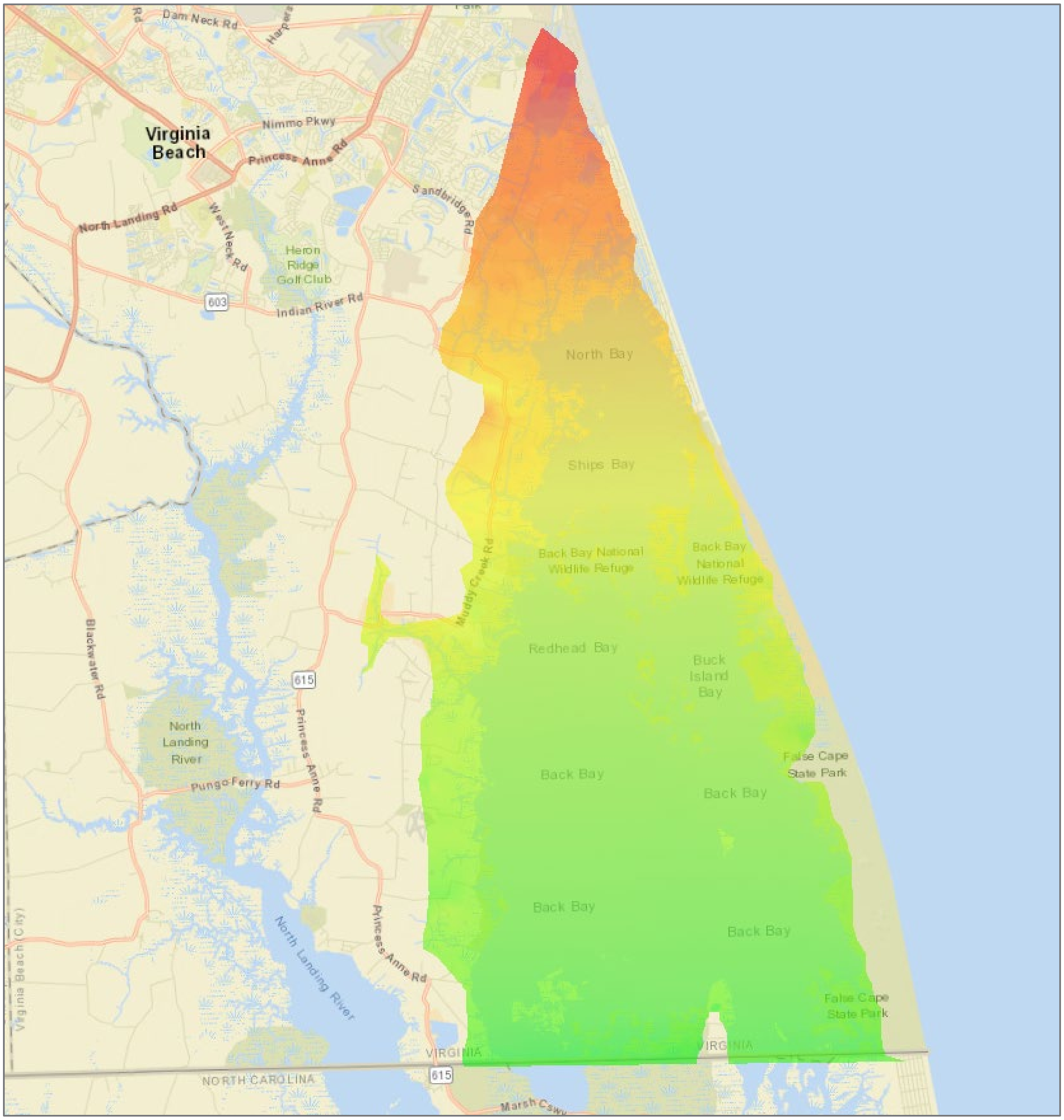

Figure 7: Surface used to determine flooded area and volume

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[1] A standard Olympic-size swimming pool holds approximately 88,000 cubic feet of water.

3.2.1.2. Flow Rate Estimation

To determine the required flow rate for the inverted siphon and pump station alternatives, the modeling results from the 20 and 25 mph wind simulations at the Beggar's Bridge USGS gauge were averaged into a time series. Using this result, the time required for the water surface elevation to reach +1.5 feet NAVD88 was determined. The required volume of water (2.7 billion cubic feet) was then distributed across this time period. The total volume required to reduce water levels by 1.5 feet was then related to reductions in water levels by quarter foot increments. The time and volumes needed to reach various reduction levels can be seen in Table 3 below. On average, the required flow rate is approximately 47 million cubic feet per hour, or 13,000 cubic feet per second (CFS).

Table 3: Time and volume required to lower the water surface elevation, by a quarter of a foot interval.

Time (Hours)	Water Surface Elevation (feet NAVD88)	Volume Removed (cubic feet)
0	0.0	46,660,647
9.00	0.26	466,606,466
19.00	0.51	933,212,933
28.00	0.74	1,353,158,753
38.00	1.00	1,819,765,219
48.00	1.25	2,286,371,685
57.78	1.50	2,741,312,990

3.2.1.3. Location

Options for placement of a structural flood reduction intervention in the north of the bay are limited, due to the extensive development and privately owned property along Sandbridge. Land further south is within the boundaries of a federal wildlife refuge and state parks. This leaves the option of City-owned property at Little Island Park, which is located between the Sandbridge neighborhoods and the north boundary of the Back Bay National Wildlife Refuge, as shown in Figure 8.

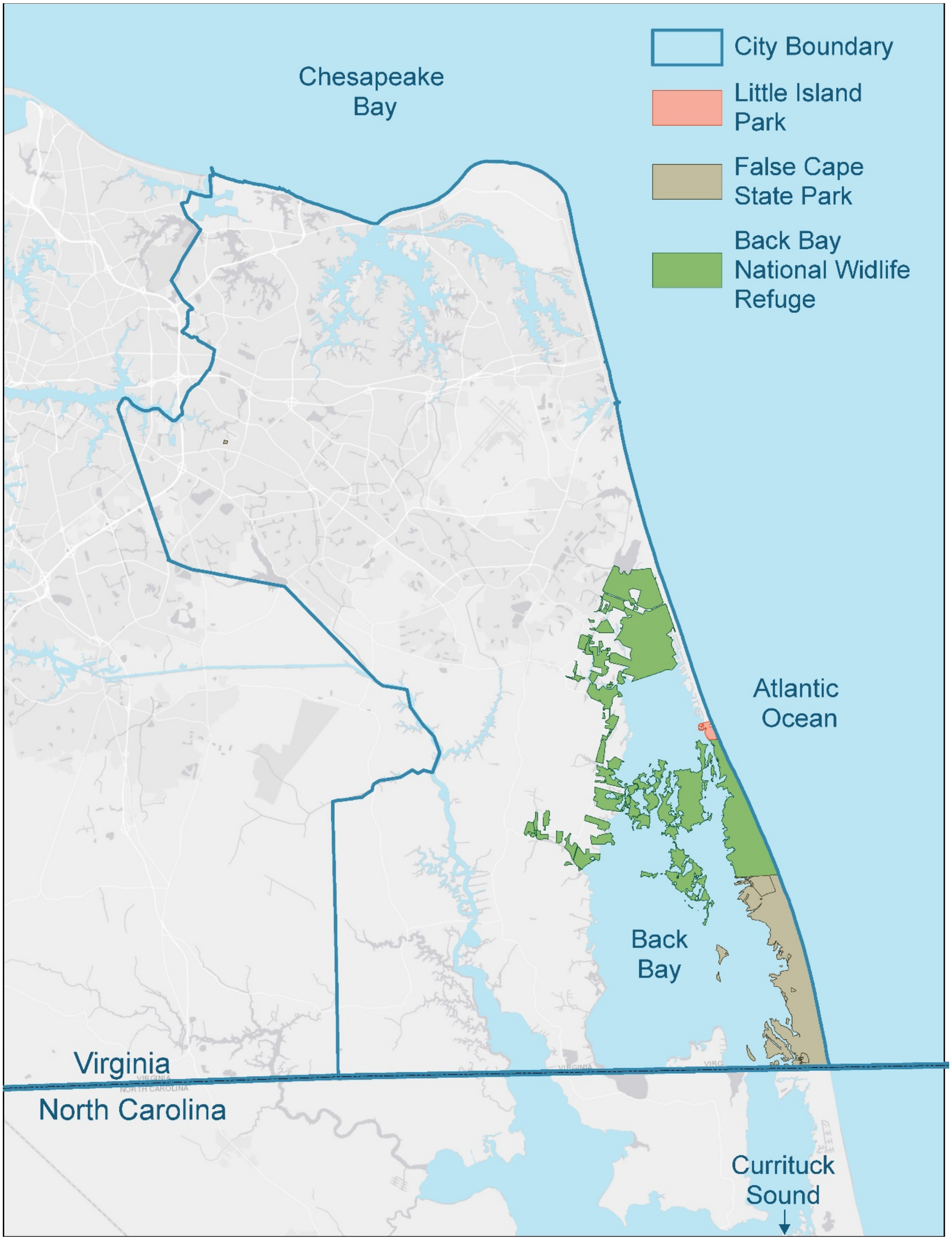

Figure 8: Location of Little Island Park and adjacent conservation park property.

3.2.2. ARTIFICIAL INLET CONCEPT DEVELOPMENT

3.2.2.1. Conceptual Design

Back Bay is separated from the Atlantic Ocean by a relatively narrow barrier island, which has historically been breached and broken repeatedly, creating temporary inlets. Since the closing of Currituck Inlet during a storm in 1830, Back Bay has slowly changed from a tidally influenced saltwater estuary to a wind-tide dominated oligohaline (fresh/brackish) estuary. Back Bay made the final transition to a freshwater system around the 1930s when the Civilian Conservation Corps (CCC) reinforced the dunes to prevent overwash. Establishing an artificial inlet along the barrier island would re-establish the exchange of water between the bay and ocean. In consideration of the hydraulics, the opening should be placed at the north end of Back Bay. Wind tides push a "wedge" of water into the bay, which is higher in the north. The high water elevations offer more of a hydraulic gradient to help push bay water out of an opening into the ocean.

Net alongshore sediment transport at this site is minimal. This means that north of Little Island Park, sand moves north, and vice-versa – to the south of the park, sand moves south (VIMS 2020). Given this, establishment of an inlet at this location would likely have little effect on longshore transport, which, in turn, would limit adverse impacts via increased shoreline erosion to downdrift beaches. Although this may limit the need for a sediment bypass system, the site is expected to experience some quantity of gross sediment transport to the north and south. A sediment budget and adverse impact analysis would be required to fully understand such issues and the degree of potential adverse impacts from sand trapping and downdrift shoreline erosion.

To maintain access to Back Bay National Wildlife Refuge, a bridge would need to be constructed over the inlet. Aside from location constraints, establishing an artificial inlet would require several design features to minimize impacts to the surrounding area. The conceptual plan view is shown in Figure 9, and a conceptual layout is shown in Figure 10.

To construct the artificial inlet, an estimated 760,000 cubic yards of soil, sand, and sediment must be removed from the barrier island and surrounding waterways. The volumes for excavation were determined by utilizing grading tools within Autodesk Civil3D software. A LiDAR-derived Digital Elevation Model (DEM) previously developed for the SLW study effort was used to determine the volume of material excavation. The bottom of the channel is expected to have a constant elevation of -3 feet NAVD88, and have a rip-rap bottom lining; no navigation channel is included in the conceptual design.

The inlet opening would require the stabilization of both north and south banks with rubble-mound structures. The ocean-side opening would require short groins to maintain the channel across the beach face and reduce sediment transport into the opening from adjacent beaches. During flood tides, some material is expected to be transported into Back Bay and removed from the littoral system. Sediment transport and budget analysis would be needed to determine the impacts on adjacent beaches and the regional system and fully inform design and sand management costs for this alternative.

Given the amount of low-lying land in the Back Bay and higher flood elevations from the Atlantic Ocean, the opening would require a gate. It is expected that the gate would be closed at all times except when (a) the bay water level exceeds a certain pre-determined trigger threshold and (b) the bay water level exceeds ocean water level by a pre-set criterion. . The location is within the Atlantic Oceanfront alignment established as a flood protection alternative by the SLW Strategy. As such, it should be designed to the same design flood elevation (DFE) as used in the SLW alignments. The SLW DFE for ocean storm surge barriers is +18 feet NAVD88. This DFE provides protection to the 100-year coastal flood event (or 1% annual chance probability) and includes 2 feet of freeboard, 3 feet of SLR, and wave effects. Assuming a channel depth of 3 feet, this provides a total height of 21 feet for the gate.

A range of options exists for the gate design. One option is in-water movable gates incorporated into the bridge constructed over the inlet. Seawalls would need to extend from the existing roadway to the dune line on both sides of the artificial inlet to ensure that storm surge does not flank the gate structure. An analysis of power requirements for opening and closing the gate has not been performed at this time. It is also anticipated that an on-site generator would be required. Specific costs and design parameters are not required for the analysis presented here and could be addressed in any further feasibility assessment.

Figure 9: Conceptual location and extent for the Little Island Park Inlet Cut alternative

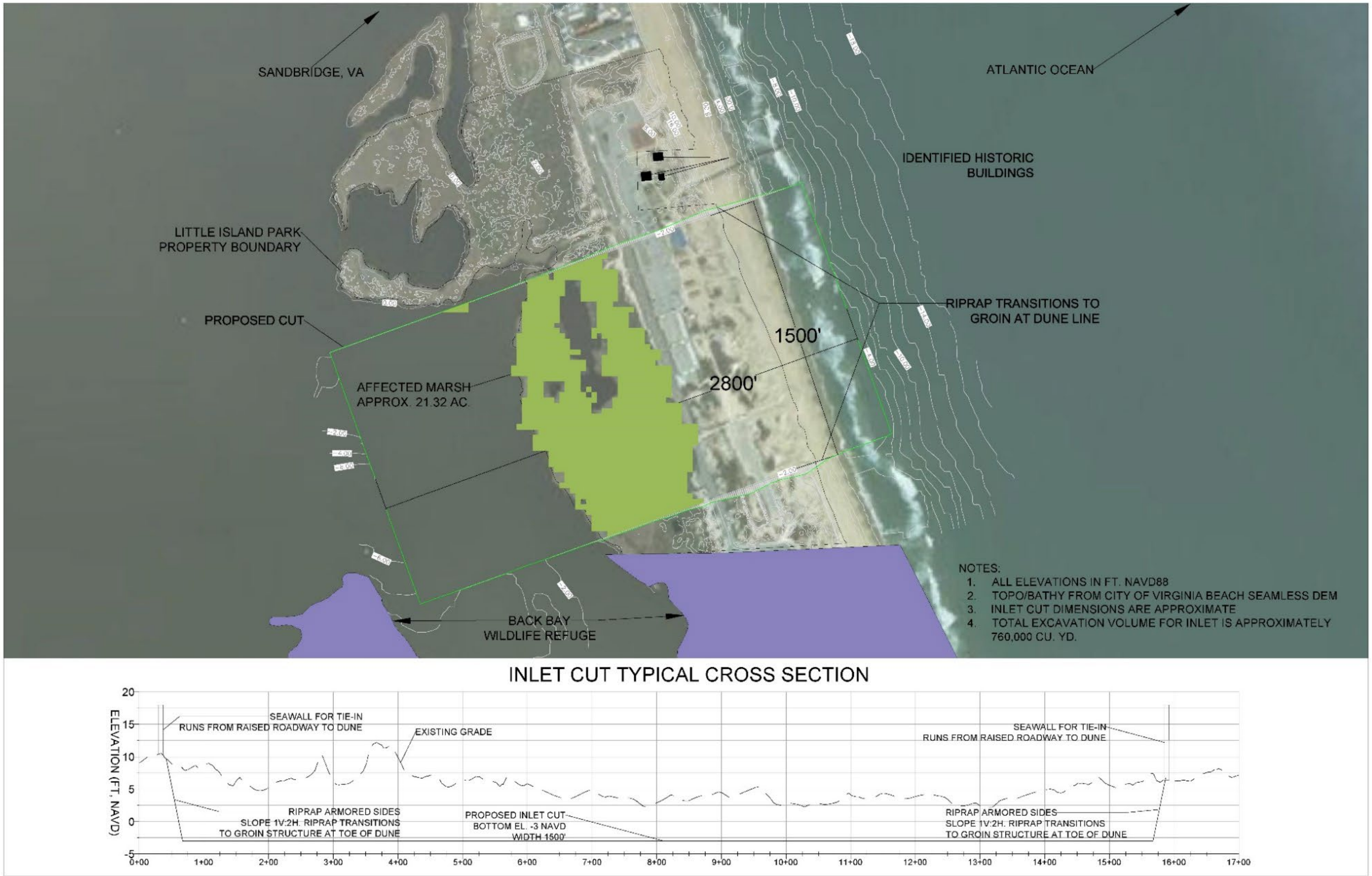

Figure 10: Layout of the Artificial Inlet Alternative at Little Island Park

3.2.2.2. Useful Life Estimation

Project useful life is the period during which the project is anticipated to last. For most flood mitigation projects, the FEMA standard useful life of a project is between 30 and 100 years. A useful life of 50 years was selected for the Artificial Inlet alternative, given that the conceptual design of the storm surge gate across the inlet accommodates a 100-year coastal flood event with 3 feet of SLR.

3.2.2.3. Cost Estimate Development

Construction Costs – Initial cost estimates place the capital costs for the Artificial Inlet Alternative at $575.9 million. This cost estimate includes the costs for material excavation, side-channel rip-rap, bottom-channel lining, the storm surge barrier, seawall tie-in structures from the existing road to the dune line, and a bridge over the inlet. Unit costs for each of these design elements come from the North Atlantic Coast Comprehensive Study (NACCS) performed by the USACE in 2015, the Virginia Department of Transportation (VDOT) district averages, and from the U.S. Department of Transportation Federal Highway Administration (FHWA).

Material excavation consists of only 9% of the total cost. The largest portion of the cost to create the inlet will be the storm surge gate that will need to be constructed across the inlet. The cost of the gate will be approximately $371 million which totals 65% of the total cost of the project. The second-largest cost is the bottom channel lining, which will be approximately $114 million which totals 20% of the total cost of the project.

Operations & Maintenance (O&M) Costs – To remain consistent with the numerous other studies in the region, average O&M unit costs for most of the design elements were taken from the previously mentioned NACCS study. The only element estimated differently is the gates, which follow the convention used in the *City-wide Structural Alternatives for Coastal Flood Protection* report (CVB 2020c). O&M costs will consist of maintenance of the seawalls tie-in structures, the channel bank riprap, road maintenance, gates, and upkeep of the mitigation wetlands. The seawall tie-ins, the channel bank riprap, and the road deck would have an estimated O&M cost of approximately $257,000, $530,000, $121,000, and $1,885,000 respectively, for a total of $2,803,000 annually. Assuming a design life of 50 years, total O&M costs are approximately $140.2 million.

In addition to capital costs, impacts on tidal wetland habitat would incur significant mitigation costs (estimated at approximately $1 million/acre). An estimated 25 acres of tidal wetland habitat could cost up to $27 million in in-lieu fees.

Given the divergence direction of sediment transport at the site, further analysis is required to determine the impact of sand management on O&M costs. Data from the City of Virginia Beach's website shows that beach nourishment occurs roughly every 5 years along the

Sandbridge Resort Area beach. The last project in 2019 was estimated to have a final cost of $21.9 Million

3.2.3. INVERTED SIPHON CONCEPT DEVELOPMENT

Inverted siphons are hydraulic structures placed underground (i.e. below grade) that are typically constructed to move water under an obstruction, such as a road or sand dunes. After passing under the obstruction, the pipe is brought back to the previous grade. These systems depend on gravity to function and the difference in hydraulic head to "push" the water through. The hydraulic head difference between the upstream and downstream sides is the driving force.

The siphon is only functional under specific water conditions because it operates on the hydraulic difference in water levels in the bay and ocean. This conceptual design presents a high-level analysis using the 1.5-foot criteria. However, a more detailed analysis that considers various storm conditions and water levels for both Back Bay and the Atlantic Ocean needs to be considered to ensure the siphon achieves the desired flood reduction during all scenarios.

3.2.3.1. Conceptual Design

The conceptual design for the Inverted Siphon Alternative was also established at Little Island Park to avoid any property acquisition, as shown in Figure 11. The inverted siphon system would be situated approximately 15 feet below the average water level in Back Bay. The conceptual design for the inverted siphon includes 15 feet of elevation loss for the first 200 feet, followed by a stretch of 2 feet of elevation loss for the next 2,500 feet, and an elevation gain of 15 feet over the last 200 feet where the pipes discharge water into the Atlantic Ocean.

The number of pipes needed to remove the 2.7 billion cubic feet of water over 58 hours is presented in Table 4, along with the total length of each siphon and estimated costs. Four pipe sizes were considered: 5 feet, 10 feet, 20 feet, and 30 feet. For each scenario, the number of pipes needed is a function of both the siphon diameter and length of each siphon. Since there is head loss in the pipes, more length results in an additional head loss, where less water can be drained through each pipe. A siphon diameter of 20 feet was selected for this initial assessment as it is the least costly.

Table 4: Minimum number of pipes needed.

Siphon Diameter (feet)	Length of Each Siphon (feet)	Minimum # of Pipes Needed	Estimated Costs (Millions)
5	1700	156	$ 1,095.9
10	1900	24	$ 376.9
20*	2800	5	$ 231.4
30	3700	3	$ 275.2

**Most cost-effective size*

A brief review of siphon applications in the coastal environment did not find any examples for the scale of discharge proposed here, using such a large pipe diameter. Similar sized siphons are found in use in either water resources (reservoirs) or stormwater management. Further analysis outside of the scope of this effort would need to be conducted to evaluate the true feasibility of the proposed alternative.

The extent of the inverted siphon on the ocean side was extended just past the depth of closure (DOC), shown in Figure 11, to reduce wave loading and infilling with suspended sediment. The DOC for the site was assumed to be -20 feet NAVD88 based on *Virginia Beach Erosion Control and Hurricane Protection Project* conducted by USACE (USACE 1990). Cost assumptions are outlined in Section 3.1.3.2.

Additional components of a siphon not shown in the high-level analysis are the inlet structure, any chambers needed for maintenance along the length of the siphon, a tide gate, and outlet structure. Other engineering considerations, outside of the scope of this analysis, should be considered for a more detailed feasibility assessment of the inverted siphon alternative, including:

- Geotechnical study of soil to determine if micro-tunneling would work and if any soil improvements would be needed;
- Sedimentation analysis to determine exit velocities of the inverted siphon;
- Detailed analysis of actual water levels in Back Bay and the Atlantic Ocean;
- Analysis of the effectiveness of inverted siphons in response to SLR;
- A more detailed evaluation of the capital costs and O&M requirements;
- Evaluation of inlet and outlet structures to prevent hydraulic loses, prevent erosion from high water velocities and prevent wildlife entrapment; The inlet structure would have to be designed to prevent sediment from entering and may have to include wildlife barriers to prevent animals from entering the siphon; and,
- Assessment of head loss (friction between the water moving and the physical structure) that occurs in the siphon and other components.

It should be noted that unless the siphon is outfitted with a tide gate to prevent ocean waters from flowing into the bay, this Alternative could impact the bay through increased salinity, decreased temperature. These potential impacts should be assessed to ensure minimal adverse environmental effects.

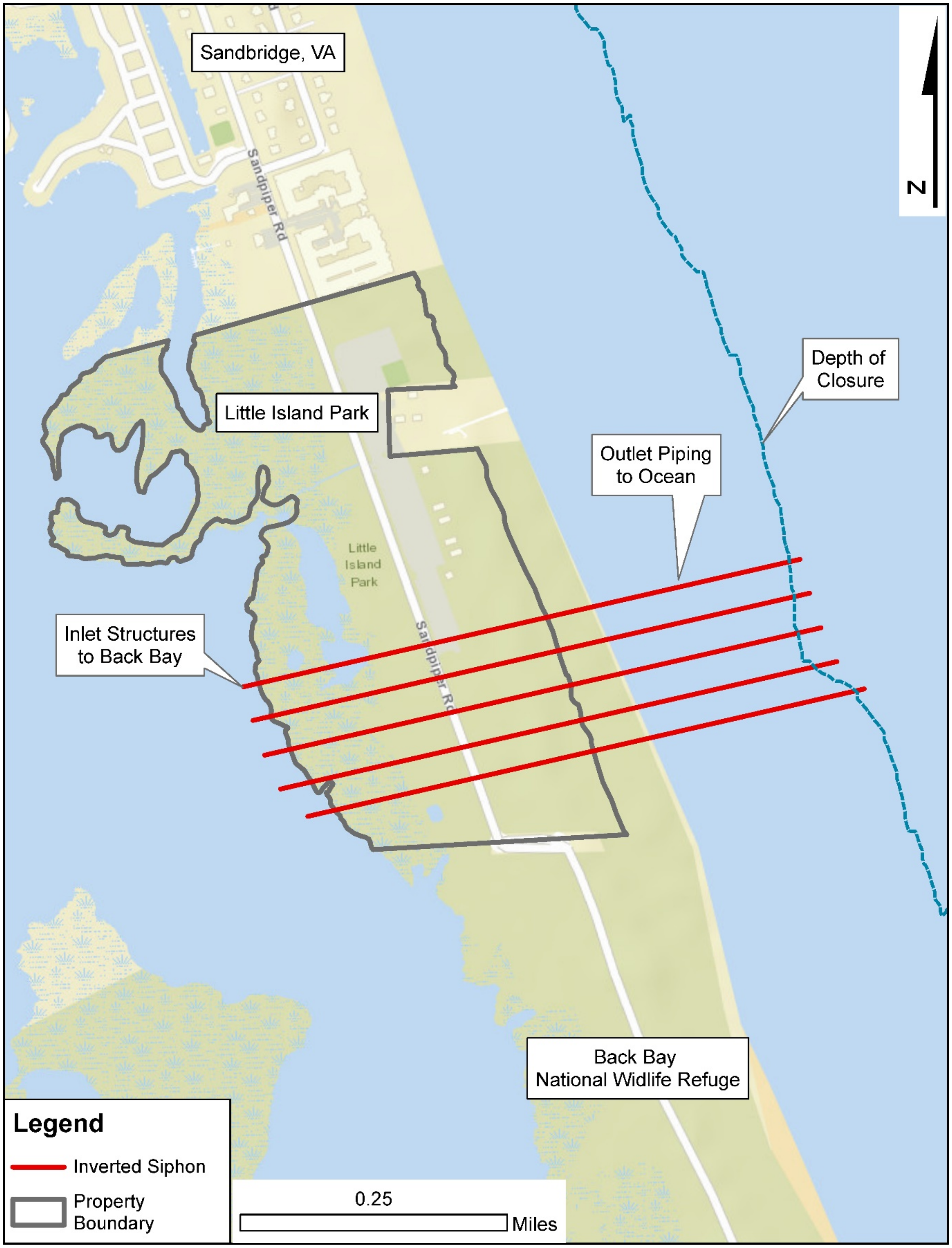

Figure 11: Conceptual location and extent for the Inverted Siphon Alternative.

3.2.3.1. *Useful Life Estimation*

For the Inverted Siphon Alternative, a 100-year useful life was selected. Sea level rise is not anticipated to impact the performance of the system since water levels would increase on both the bay and ocean sides at the same rate. As such, it is anticipated that the relative hydraulic head difference would be maintained.

3.2.3.2. *Cost Estimate Development*

Construction Costs – There are many uncertainties with estimating the cost of the Inverted Siphon Alternative. A geotechnical study of the soil is needed to determine the magnitude of the work involved. Other siphons that were constructed of similar diameter were reviewed to determine an estimate of the construction costs. It should be noted that these other siphons are significantly longer which reduces the cost per foot because the fixed cost remains the same.

Based on the Conceptual Tunnel Cost Analysis Deep Tunnel Study Phase 1, prepared for Harris County Flood Control District, the San Antonio River Authority constructed the "San Antonio River Tunnel" in 1989. The tunnel is 24 feet in diameter and is 3.1 miles long. The total cost for this project was $111 Million or $6,782 per linear foot (in 1989 dollars, Texas). DC Water Constructed the 23 feet diameter Northeast Boundary Tunnel in 2017. The tunnel is 5.1 miles long and costs $225 million or $8,360 per linear foot (in 2017 dollars, Washington DC). Adjusting these costs for inflation and regional cost of livings yields an adjusted cost of $16,968 and $21,758 per linear foot respectively. Using the average cost ($827) per linear foot per diameter from these projects, the cost of a siphon at this location would be approximately $231.4 million.

Operations & Maintenance (O&M) Costs – The primary focus for the maintenance of inverted siphons is the cleaning and removal of sediment, plant growth, and wildlife. Periodic removal of sediment from the siphon would be required. This might include either periodic dewater and the use of a specialized dive team. There would also have to be vegetation and wildlife control both upstream and downstream of the siphon to allow a clear flow channel. Estimating the total cost of cleaning out the siphon would depend on the frequency of cleaning. For this assessment, it was assumed that annual debris removal would cost approximately $150,000 and labor would cost $58,000, for an initial annual O&M cost of $208,000. Total O&M costs are estimated at $2.07 million, for a total of $20.7 million assuming a useful life of 100 years. Construction impacts would depend on the method of construction and could be mitigated post-construction.

3.2.4. PUMP STATION CONCEPT DEVELOPMENT

A pump station facility would actively remove water from Back Bay and discharge the water to the Atlantic Ocean.

3.2.4.1. Conceptual Design

In alignment with the Artificial Inlet and Inverted Siphon alternatives, the conceptual design for the Pump Station Alternative was also established at Little Island Park, as shown in Figure 12. The conceptual layout of the pump station is shown in Figure 12 through Figure 15. The pump station would generally consist of a concrete inlet structure/wet-well, axial flow pumps with medium voltage motors, and diesel generators. The station will also require a building to house the pumps, motors, and emergency generators. The pumps would convey water from the inlet structure to the Atlantic Ocean via outlet piping.

It is estimated that twelve, 2,000 horsepower (hp) high flow, low head axial flow pumps will be required to pump the total required flow rate of 13,000 CFS. Each pump is expected to have a dedicated 12-foot diameter pipe that will extend into the ocean. Similar to the Inverted Siphon Alternative, the outlet piping was extended just past the DOC, shown in Figure 12, to reduce wave loading and infilling with beach eroded sand during major storm events

The required incoming electrical service would be approximately 4,000 volt (V), 3-phase, 4,000amp (A) service from the local electrical utility. The primary electrical switchgear will be in the main-tie-main configuration with the electrical utility being the primary main feed, and the generators being the alternate main feed. Seven approximately 3,000 kilowatt, 4,000 V diesel generators, each with a 72-hour sub-base fuel tank will provide the emergency standby power on the loss of utility service. The seven generators will be paralleled together with a 4,000 V, 3-phase, 4,000 V paralleling switchgear, which outputs to the main electrical switchgear.

The primary electrical switchgear will provide power to two separate 4,000 V, 2,000 A motor control center lineups, which will contain the reduced voltage soft starters for each 2,000 hp motor. Each starter will contain a motor protection relay to protect the pump and the motor, as well as the additional control functions to coordinate with the pump station's Supervisory Control and Data Acquisition (SCADA) system. The primary switchgear will also provide power to two step-down transformers that will provide 480 V, 3-phase service for the pump station.

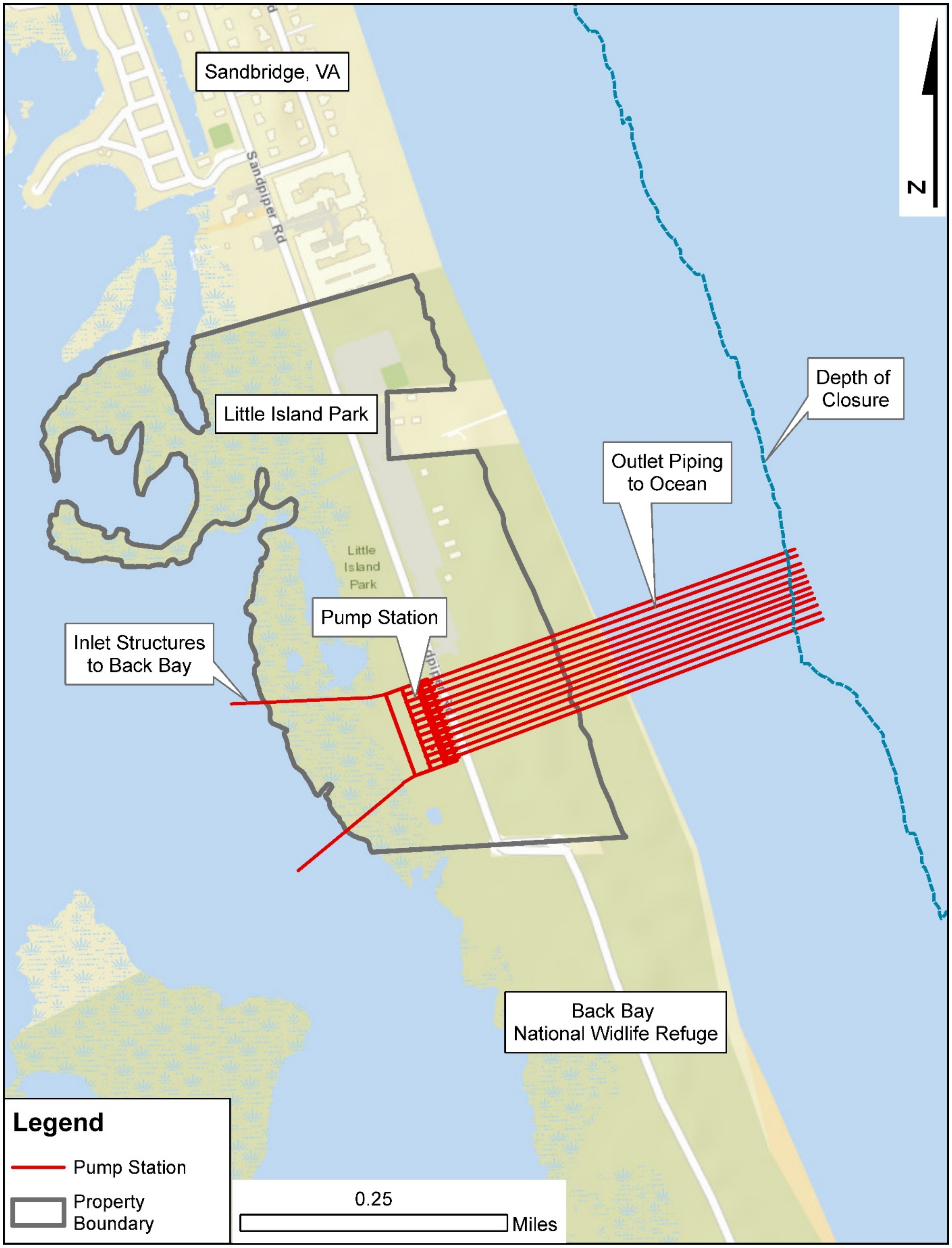

Figure 12: Conceptual location and extent for the Pump Facility

3.2.4.2. Useful Life Estimation

For the Pump Station Alternative, a 30-year useful life was selected, given the anticipated increase in water levels in Back Bay due to SLR over the project lifespan. The City is planning for 1.5 feet of SLR between 2035 and 2050, which falls on the “Intermediate” curve of the most recent SLR projections (Sweet et. al. 2017). Assuming the implementation year of 2025 (at the earliest), approximately 1.25 feet of SLR could occur by the end of the project’s useful life (in 2050).

It is anticipated that flood reduction benefits would diminish towards the end of the project’s useful life. Further, once 1.5 feet of SLR has occurred, the pump station would need additional capacity to remove the additional volume of water in the bay.

3.2.4.3. Cost Estimate Development

Construction Costs – The construction cost estimate for the pump facility alternative is $500 million. This cost estimate was based on budget equipment costs from manufacturers for the pumps and generators, high-level quantity take-off for discharge piping, electrical, process mechanical, building construction, and the inlet channel and wet-well excavation, dewatering, and reinforced concrete. Estimated quantities were based on the preliminary layout of the pump facility.

Operations & Maintenance (O&M) Costs – It is also estimated that a significant annual operating budget will be required for the pumping facility due to the high electrical power requirements, routine maintenance, and annual set aside for replacement/refurbishment of the pumps, motors, and generators. Initial annual O&M costs are estimated at $1.3 million for a total of $39 million, assuming a useful life of 30 years.

In addition to capital costs, impacts on tidal wetland habitat would incur significant mitigation costs (estimated at approximately $1 million/acre). An estimated two acres of tidal wetland habitat could cost up to $2.2 million in in-lieu fees.

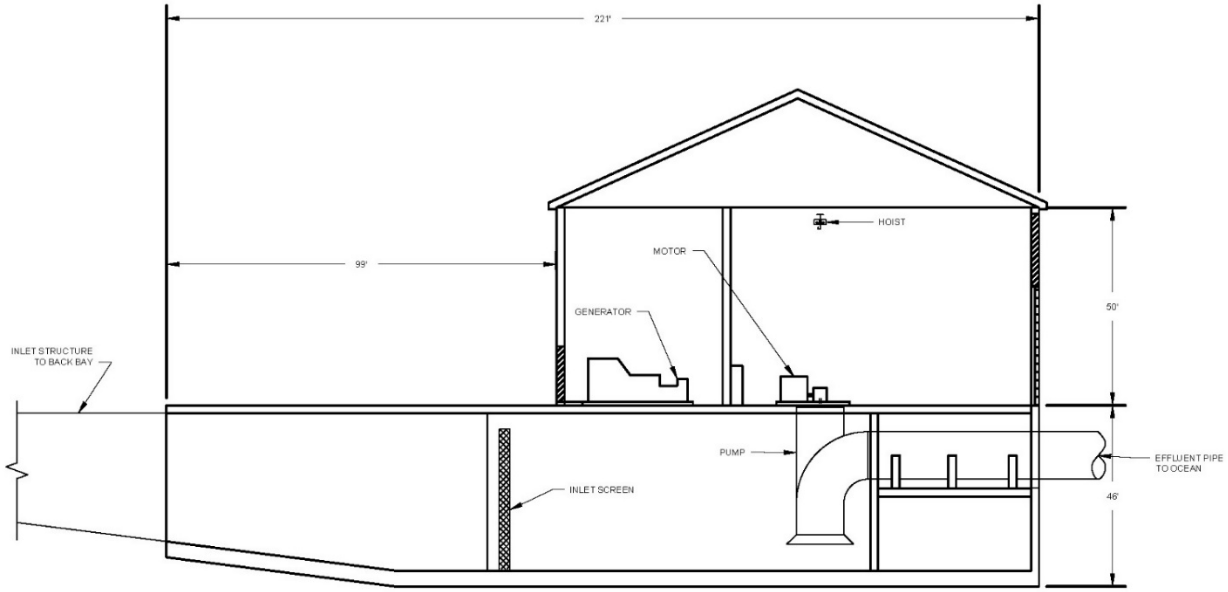

Figure 13: Conceptual layout of the Pump Station Alternative.

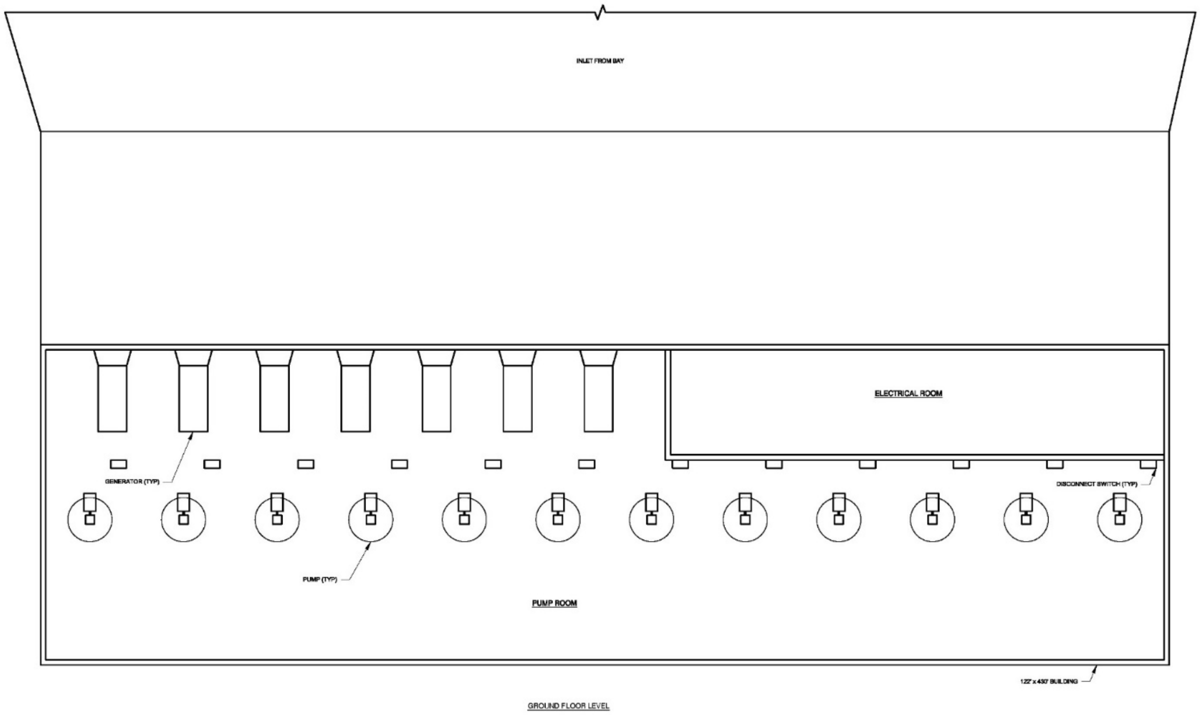

Figure 14: Conceptual layout of the ground floor level of the Pump Station Alternative.

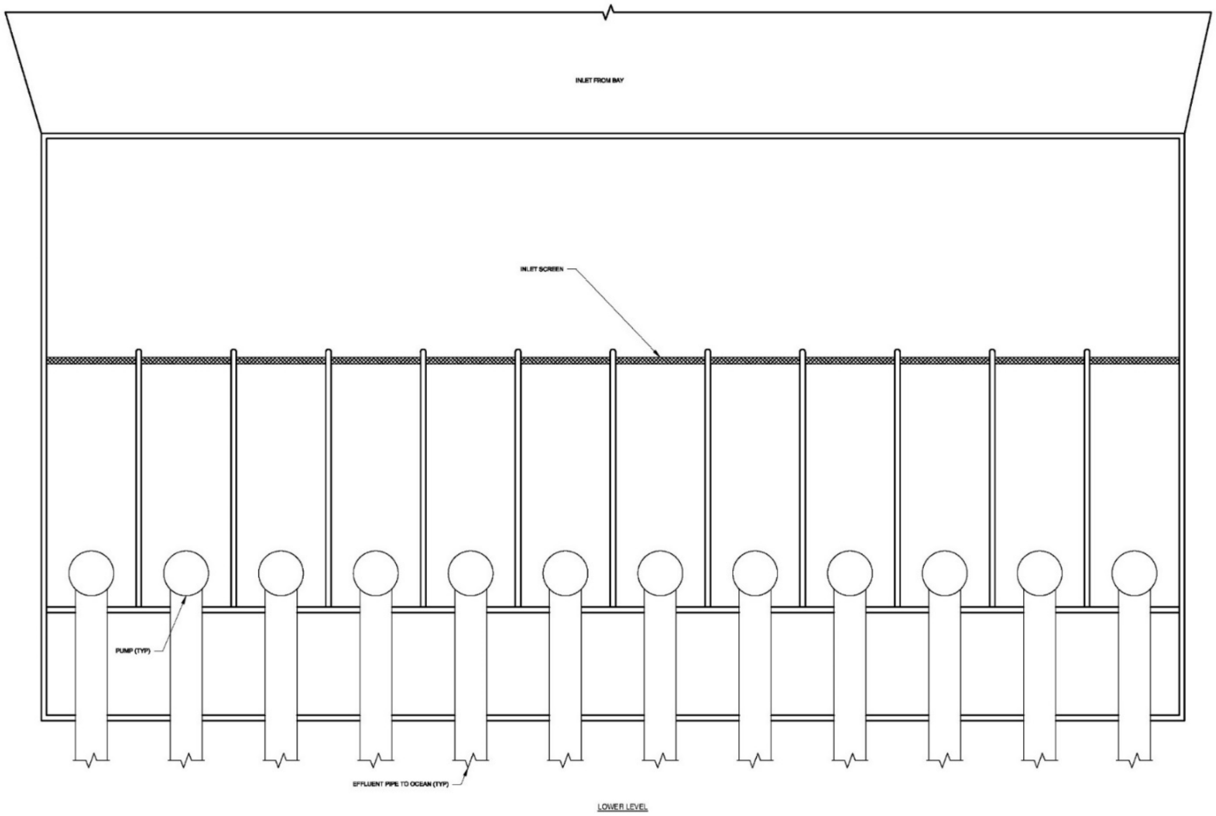

Figure 15: Conceptual layout of the lower level of the Pump Station Alternative

3.3. NATURAL MITIGATION ALTERNATIVES

In contrast to structural flood protection, natural features do not block the movement of water but provide flood risk reduction benefits through increased friction. The vegetation dissipates waves and slows down water velocities. Therefore, relevant design considerations include estimating the impact of marsh creation on the timing of flooding during a wind tide event.

3.3.1. DESIGN CONSIDERATIONS

The flood risk reduction benefits of marsh island creation were conceptually evaluated using the City’s existing Danish Hydraulic Institute’s (DHI) MIKE 21 coastal storm surge model, through adjustment of friction parameters to represent the conversion of open water to intertidal marsh (CVB 2019). Model simulations showed that marsh island restoration today would reduce existing “wind tide flooding” elevations by up to 1.5 feet in some areas, but on average reduced flood elevations by 0.18 feet (or 2.16 inches), as seen in Figure 16.

The conceptual evaluation revealed that the primary benefit provided by marsh island restoration was the delay in the onset of flooding in Back Bay. On average, marsh restoration caused a 4-day delay in flooding. It is possible that if the southerly winds shifted directions before the fourth day of the event, flooding could be avoided altogether.

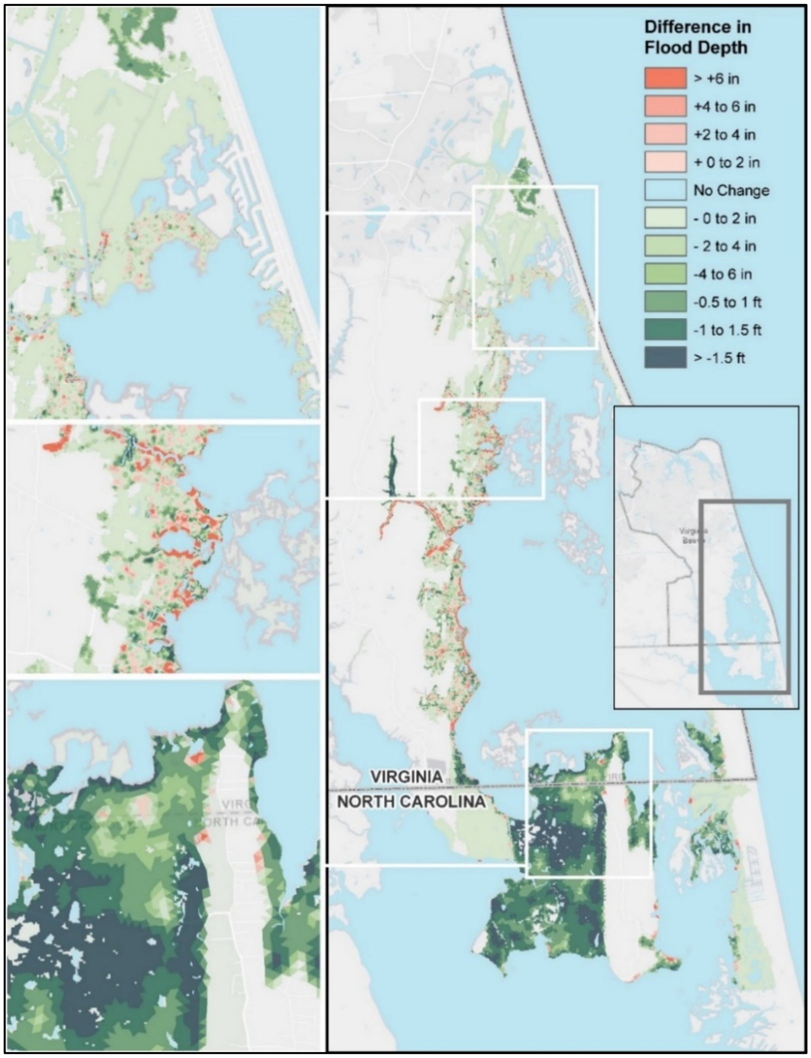

Figure 16: Modeled reduction in maximum flood depth during a wind tide.

3.3.2. MARSH CREATION CONCEPT DEVELOPMENT

Back Bay is particularly well suited to the marsh creation given the shallow nature of the bay and the historical degradation of marsh island habitat. A historical habitat coverage assessment showed that over the past century, approximately 4,000 acres of vegetated marsh island habitat in Back Bay has transformed into open water. An additional 2,400 acres of marsh have been lost within Mackay National Wildlife Refuge and the marsh island system within the Knotts Island channel in northern North Carolina. The conceptual design for the Marsh Creation Alternative focuses on restoring these habitats which historically provided both environmental and flood reduction benefits to the surrounding community.

3.3.2.1. Conceptual Design

Opportunities for marsh creation, both in Virginia Beach and extending into northern North Carolina, are shown in Figure 17. The creation of marsh where it was historically present, through techniques such as marsh terracing, would decrease flow and wave heights, and also mitigate wave effects and consequent erosion. It is important to note that this conceptual alternative represents a comprehensive vision of restoration in Back Bay, and the larger Albemarle-Pamlico estuary, to strategically reduce flow through hydraulic pathways and advance restoration objectives. This vision would likely be accomplished in phases. The City is pursuing the implementation of a pilot marsh island creation in northern Back Bay, which represents the first design project initiated by the City in implementation of the SLW Strategy.

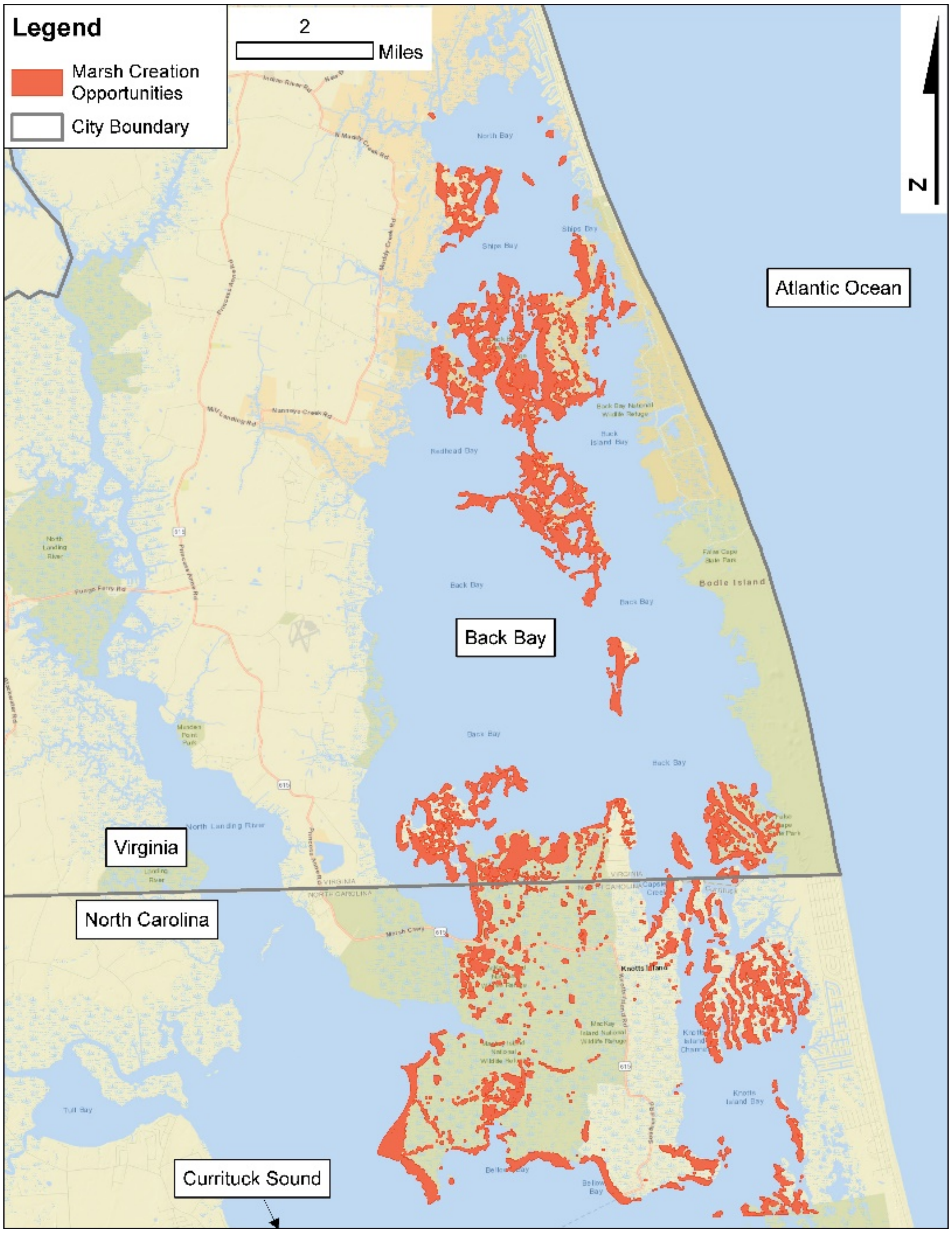

Figure 17: Conceptual location and extent for the Marsh Creation Alternative, in Virginia Beach and northern North Carolina.

3.3.2.1. Useful Life Estimation

When designed properly, restored marsh areas can become self-sustaining systems. Under the right circumstances, coastal marshes can increase their elevation and maintain pace with rising water levels. As such, a useful life of 100 years was selected for the Marsh Creation Alternative. It is important to note that several factors could lead to diminished benefits, including high rates of SLR, changes to sediment input, and other factors that contribute to the erosion of coastal marshes. To mitigate these impacts, created marsh systems can be periodically nourished with sediment.

3.3.2.2. Cost Estimate Development

Construction Costs – The construction cost estimate for the marsh restoration alternative is $386 million. It was assumed that the average construction cost per acre of marsh created is $60,000. This value is based on the average estimate across a sample of marsh creation project construction costs compiled by the Louisiana Coastal Wetlands Conservation and Restoration Task Force. Marsh creation, as shown in Table 5.

Table 5: Range of construction costs for marsh creation; data compiled from the Louisiana Coastal Wetlands Conservation and Restoration Task Force.

Project Name	Total Cost (million)	Total Acres	Cost Per Acre (thousands)
Mid-Breton Land Bridge Marsh Creation and Terracing	$ 40.9	451	$ 90.7
Caminada Headlands Back Barrier Marsh Creation	$ 28.7	395	$ 72.7
Oyster Bayou Marsh Creation and Terracing Project	$ 31.0	600	$ 51.7
Cameron-Creole Watershed Grand Bayou Marsh Creation	$ 24.7	534	$ 46.3
Pecan Island Terracing	$ 2.5	122	$ 20.5
Bayou Dupon - Marsh Creation and Terracing	$ 18.1	232	$ 78.0
Bayou Cane Marsh Creation	$ 33.9	449	$ 75.5
Breton Landbridge Marsh Creation (West) River aux Chenes to Grand Lake	$ 37.5	423	$ 88.7
Long Point Bayou Marsh Creation	$ 13.0	392	$ 33.2
Labranche Central Marsh Creation	$ 42.0	902	$46.6
East Marsh Island Marsh Creation	$ 17.0	362	$47.0

Operations & Maintenance (O&M) Costs – Annual O&M requirements for marsh restoration projects typically include monitoring of vegetative establishment. Permitting agencies typically require monitoring for at least five years following construction. Annual monitoring costs were assumed to be $3,000 per acre per year for the first five years post-construction, for a total of $96 million. Other potential O&M requirements not evaluated as part of this assessment may include sediment nourishment and strategic vegetation plantings at specified time intervals throughout the project design life.

4. EVALUATION FRAMEWORK

The evaluation framework plays an important role in the NEPA process because it is the vehicle for deciding which alternatives remain on the table for more detailed environmental and engineering analysis. Even if an alternative meets or potentially meets the purpose and needs, it can still be eliminated from further consideration as unfeasible based on one or more factors, including engineering and environmental impacts.

The evaluation framework for this effort includes screening factors, criteria, and metrics developed in alignment with the Purpose and Needs and Goals and Objectives statement, which are designed to guide a more detailed feasibility assessment.

4.1. SCREENING FACTORS AND CRITERIA

Seven core screening factors were established, which are shown in Figure 18. The following sections step through each of these factors to establish the criteria, ratings, and scoring factors. The individual factored scores for each metric allow for scores to be totaled across all screening factors.

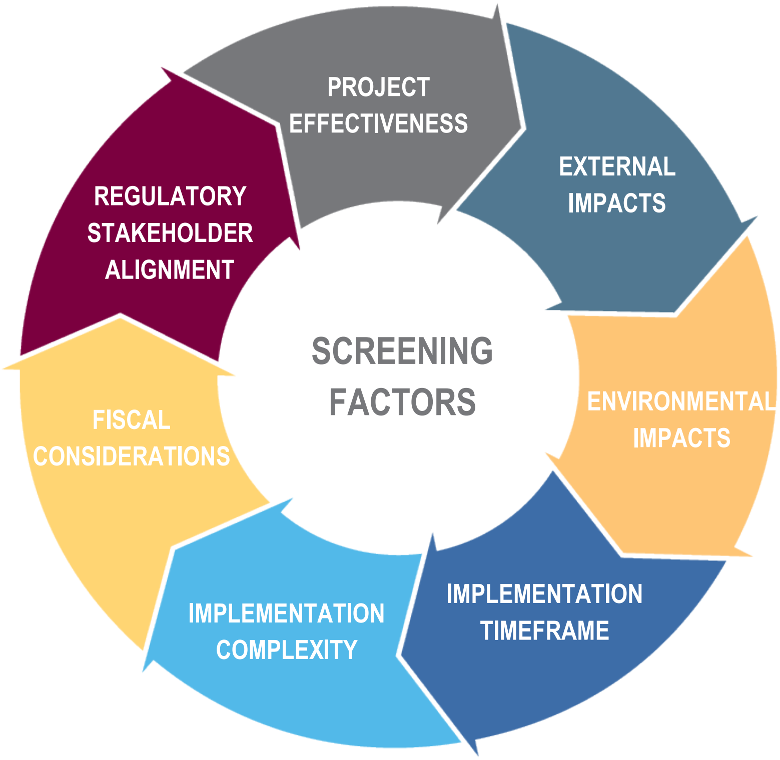

Figure 18: Overview of screening factors.

4.2. FACTOR 1: PROJECT EFFECTIVENESS

The project effectiveness factor will screen alternatives for the ability to provide significant flood risk reduction benefits, including reductions in flood elevations, and impacts on properties and roadways.

Criteria 1a: Reduce flood hazards by decreasing flood elevations or delaying the onset of flooding.

Flood Reduction Rating	**Basis for Rating -** Reduction in wind-driven flood elevations (Level of Flood Reduction)	Factored Score
High	High flood reduction: reduces flood elevations by more than 1.5 feet or delay the onset of flooding by more than 4 days	3.0
Medium	Medium flood reduction: reduces flood elevations between 0.5 and 1.5 feet or delay the onset of flooding by 2 to 4 days	2.0
Low	Low flood reduction: reduced flood elevations by less than 0.5 feet or delay the onset of flooding by less than 2 days	1.0

Criteria 1b: Provide enhanced protection to vulnerable properties surrounding Back Bay.

Protected Structures Rating	**Basis for Rating -** Potential to reduce wind-driven flood impacts to vulnerable, developed properties (Level of Protection)	Factored Score
High	High overall potential to provide enhanced protection to properties: > 50% of developed properties surrounding Back Bay have increased flood protection.	3.0
Medium	Medium overall potential to provide enhanced protection to properties: Between 25% and 50% of developed properties surrounding Back Bay have increased flood protection.	2.0
Low	Low overall potential to provide enhanced protection to properties: < 25% of developed properties surrounding Back Bay have increased flood protection.	1.0

Criteria 1c: Enable roadway access into and out of neighborhoods surrounding Back Bay.

Roadway Access Rating	**Basis for Rating -** Potential to reduce flooding to a point where primary access roads are passable or alternative routes are available to provide access into and out of the communities surrounding Back Bay.	Factored Score
High	Primary access roads are considered passable	3.0
Medium	Primary access roads are not passable, but alternative routes are available and considered passable	2.0
Low	Primary access and alternative routes are not considered passable	0.0

4.3. FACTOR 2: EXTERNAL IMPACTS

The external impacts criteria will screen alternatives for minimizing adverse flood impacts outside of Virginia Beach.

Criteria 2A: Minimize adverse impacts to locations outside of Virginia Beach.

External Impacts Rating	**Basis for Rating –** Potential for adverse impacts or benefits outside of the project area (outside of Virginia Beach)	Factored Score
Positive	Potential for flood risk reduction benefits to areas outside of Virginia Beach	3.0
Neutral	No significant positive or negative adverse impacts to areas outside of Virginia Beach	2.0
Negative	Potential for negative flood impacts to areas outside of Virginia Beach	0.0

4.4. FACTOR 3: ENVIRONMENTAL IMPACTS

The environmental impacts criteria will screen alternatives for minimizing long-term, cumulative impacts on habitats and water quality

Criteria 3a: Minimize cumulative impacts to habitat.

Habitat Considerations Rating	**Basis for Rating –** Potential for habitat benefits/impacts; Remediation requirements	Factored Score
Positive	Potential for significant habitat benefits; Remediation not required or unlikely to be required	3.0
Neutral	Potential for low to moderate habitat benefits; Remediation may be required	2.0
Negative	Potential for zero or negative habitat benefits (e.g. impacts); Remediation likely to be required	0.0

Criteria 3b: Minimize water quality impacts

Water Quality Considerations Rating	**Basis for Rating –** Potential water quality benefits/impacts; Mitigation requirements	Factored Score
Positive	Potential for significant water quality benefits; Mitigation not required or unlikely to be required	3.0
Neutral	Potential for low to moderate water quality benefits; Mitigation may be required	2.0
Negative	Potential for zero or negative water quality benefits; Mitigation likely to be required	0.0

4.5. FACTOR 4: IMPLEMENTATION TIMEFRAME

The implementation timeframe criteria will screen alternatives for the likelihood of implementation within a reasonable timeframe once funding is secured.

Criteria 4a: Have a reasonable implementation timeframe of five to seven years once funding is secured.

Implementation Timeframe Rating	**Basis for Rating –** Likelihood of meeting implementation timeframe of five to seven years once funding is secured	Factored Score
Likely	The project is likely to be implemented within five to seven years once funding is secured	3.0
Unlikely	The project is unlikely to be implemented within five to seven years once funding is secured	0.0

4.6. FACTOR 5: IMPLEMENTATION COMPLEXITY

The implementation complexity criteria will screen alternatives for reasonableness of the design, potential to obtain regulatory permits, and likelihood to maximize the use of municipal lands rather than private or federal land, and avoid impacts on navigation, vehicular, and pedestrian circulation.

Criteria 5a: Reasonable complexity of the design.

Design Complexity Rating	**Basis for Rating -** Level of difficulty to design and implement (Complexity)	Factored Score
Straightforward	The concept is straightforward to design and implement and does not require highly specialized contractors to construct	3.0
Moderately Complex	A moderately complex concept that requires some specialized expertise to design and implement	2.0
Complex	A complex concept that is difficult to design and implement, and requires highly specialized contractors to construct	1.0

Criteria 5b: Potential to obtain regulatory permits.

Permitting Rating	**Basis for Rating –** Likelihood of obtaining regulatory permits	Factored Score
Likely	Fits within the existing regulatory framework; likely to obtain regulatory permits; no impacts to historic or cultural resources	3.0
Possible	Possible to obtain regulatory permits, but some hurdles are likely to be encountered; potential impacts on historic and cultural resources	2.0
Unlikely	Does not fit within existing regulatory frameworks; unlikely to obtain regulatory permits; significant impacts to historic and cultural resources	0.0

Criteria 5c: Maximize the use of municipal lands rather than private or federal lands and avoid major impacts on navigation, vehicular, and pedestrian circulation

Land Use Considerations Rating	**Basis for Rating –** Potential for the use of municipal lands rather than private or federal lands	Factored Score
High	High potential for project footprint to be constrained to municipal lands with no major impacts to navigation, vehicular, or pedestrian traffic circulation	3.0
Moderate	Moderate potential for project footprint to be constrained to municipal lands with minor impacts to navigation, vehicular, or pedestrian traffic circulation	2.0
Low	Low potential for project footprint to be constrained to municipal lands with major impacts to navigation, vehicular, or pedestrian traffic circulation	1.0

4.7. FACTOR 6: FISCAL CONSIDERATIONS

The fiscal considerations criteria will screen alternatives for cost-effectiveness, which is a comparison of flood risk reduction benefits to project costs, as well as reasonable O&M costs as a comparison to the total cost of the project.

Criteria 6a: Cost beneficial.

Cost-Effectiveness Rating	**Basis for Rating –** Benefit-Cost Ratio (BCR)	Factored Score
High	BCR greater than 2.0	3.0
Moderate	BCR between 1.0 and 2.0	2.0
Low	BCR between 0.5 and 1.0	1.0
Unfavorable	BCR less than 0.5	0.0

Criteria 6b: Operations and maintenance (O&M) costs are reasonable.

O&M Requirements Rating	**Basis for Rating –** O&M cost, over the life of the project, estimate compared to total cost of the project	Factored Score
Reasonable	O&M costs are less than 15% of the total cost of the project	3.0
Somewhat Reasonable	O&M costs are between 15% and 30% of the total cost of the project	2.0
Unreasonable	O&M costs are more than 30% of the total cost of the project	0.0

4.8. FACTOR 7: REGULATORY STAKEHOLDER ALIGNMENT

The regulatory stakeholder alignment criteria will screen alternatives for alignment with regulations and policies of the regulatory community.

Criteria 7a: Be generally aligned with the regulations and policies of the regulatory community.

Regulatory Stakeholder Alignment Rating	Basis for Rating – Alignment with regulations and policies of the regulatory community	Factored Score
Aligns	Aligns with regulations and policies of the regulatory community	3.0
Generally Aligns	Generally aligns with regulations and policies of the regulatory community (few deviations)	2.0
Does not Align	Does not align with regulations and policies of the regulatory community	0.0

4.9. IMPORTANCE FACTORS

Overall importance factors for each screening criteria were also established to allow for certain factors to be weighted more heavily. The factors were established after initial definition of the criteria and were not adjusted afterward. The importance factors are shown in Table 6.

Table 6: Importance factors for the screening criteria.

Screening Factors	Screening Criteria	Importance Factor
Project Effectiveness	Flood Reduction	**5.0**
	Protected Structures	**5.0**
	Ingress/Egress Roadway Access	**5.0**
External Impacts	External Impacts	**4.0**
Environmental Considerations	Habitat Impacts	**4.0**
	Water Quality Impacts	**4.0**
Implementation Timeframe	Implementation Timeframe	**2.0**
Implementation Complexity	Design Complexity	**3.0**
	Permitting	**5.0**
	Land Use	**4.0**
Fiscal Considerations	Cost-Effectiveness	**4.0**
	Operations & Maintenance (O&M)	**2.0**
Regulatory Stakeholder Alignment	Regulatory Stakeholder Alignment	**5.0**

5. SCREENING ANALYSIS

This chapter presents the results of the screening and evaluation analysis for each of the alternatives. The analysis was conducted based on the availability of geospatial (GIS) data, and other readily available sources. Each of the following sub-sections presents the overall results of the analysis, followed by an explanation of the approach, data sources, and assumptions of the analysis.

5.1. CRITERIA 1A: FLOOD REDUCTION

The results of the screening analysis for the flood reduction screening criteria are summarized in Table 7. The approach, data sources, and assumptions of the flood reduction analysis are presented in Section 3.2.1 (for the structural alternatives) and Section 3.3.1 (for the natural mitigation alternative).

Table 7: Project effectiveness – flood reduction analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Medium**	Medium flood reduction: reduces flood elevations by 1.5 feet	2.0
Inverted Siphon	**Medium**	Medium flood reduction: reduces flood elevations by 1.5 feet	2.0
Marsh Creation	**Medium**	Medium flood reduction: delays the onset of flooding by 4-days	2.0
Pump Facility	**Medium**	Medium flood reduction: reduces flood elevations by 1.5 feet	2.0

5.2. CRITERIA 1B: PROTECTED STRUCTURES

The results of the screening analysis for the protected structures criteria are summarized in Table 8. The approach, data sources, and assumptions of the analysis are described below.

Table 8: Project effectiveness – protected structures analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	High	367 / 381 developed properties removed from floodplain (~96% of developed properties with increased flood protection)	**3.0**
Inverted Siphon	High	367 / 381 developed properties removed from floodplain (~96% of developed properties with increased flood protection)	**3.0**
Marsh Creation	Low	41 / 381 developed properties removed from floodplain (approximately 11 % of developed properties with increased flood protection)	**1.0**
Pump Facility	High	367 / 381 developed properties removed from floodplain (approximately 96% of developed properties with increased flood protection)	**3.0**

5.2.1. FLOODPLAIN MAPPING

To evaluate the potential for the alternatives to provide enhanced protection to developed properties surrounding Back Bay, flood extents were established to represent the following scenarios:

- The "without alternative" flood extent represents land that is currently inundated during a wind tide event.
- The "with alternative" flood extent represents land that would be inundated during a wind tide event after an alternative was implemented.

Flood extents were generated intersecting the water surface elevations from existing modeling results with the terrain (elevation model) for Virginia Beach. Existing ADCIRC modeling outputs were used for the structural alternatives whereas MIKE21 modeling outputs were used for the marsh restoration alternative. Depth grids, which represent the amount of flooding above land, were also created to support other analyses. Counts of developed properties were then determined by totaling the number of properties in the "without alternative" floodplain versus the "with alternative floodplain". Developed properties for this analysis were considered any building without an agricultural zoning designation.

5.3. CRITERIA 1C: ROADWAY ACCESS

The results of the screening analysis for the roadway access criteria are summarized in Table 9. The approach, data sources, and assumptions of the analysis are described below.

Table 9: Project effectiveness – roadway access analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**High**	Primary access roads are considered passable due to flood depth reduction.	**3.0**
Inverted Siphon	**High**	Primary access roads are considered passable due to flood depth reduction.	**3.0**
Marsh Creation	**Medium**	Delayed timing of flooding results in potential avoidance of flood impacts on primary access roads.	**2.0**
Pump Facility	**High**	Primary access roads are considered passable due to flood depth reduction.	**3.0**

5.3.1. ROADWAY ANALYSIS

To evaluate flood reductions over roadways, the "with alternative" depth grids, described in Section 5.2, were inspected to determine the potential for the alternatives to enable access into and out of communities surrounding Back Bay. Roadways experiencing flood depths of 1 foot or greater were considered to be impassible to most vehicles.

This analysis revealed that the flood risk reduction provided by the structural alternatives enabled the passability of primary access roads, as shown in Figure 19. With the Marsh Creation Alternative, substantial sections of Muddy Creek Road and Sandbridge Road remain impassible, as shown in Figure 20. However, as described in Section 3.3.1, natural features achieve flood reduction for primary access roads by delaying the timing of flooding. The conceptual evaluation showed that on some roads, such as Muddy Creek Road, flooding was avoided altogether in some locations. The magnitude of benefits depends primarily on the duration of the wind tide event. As such, the Marsh Creation Alternative was scored as *Medium* for this screening factor.

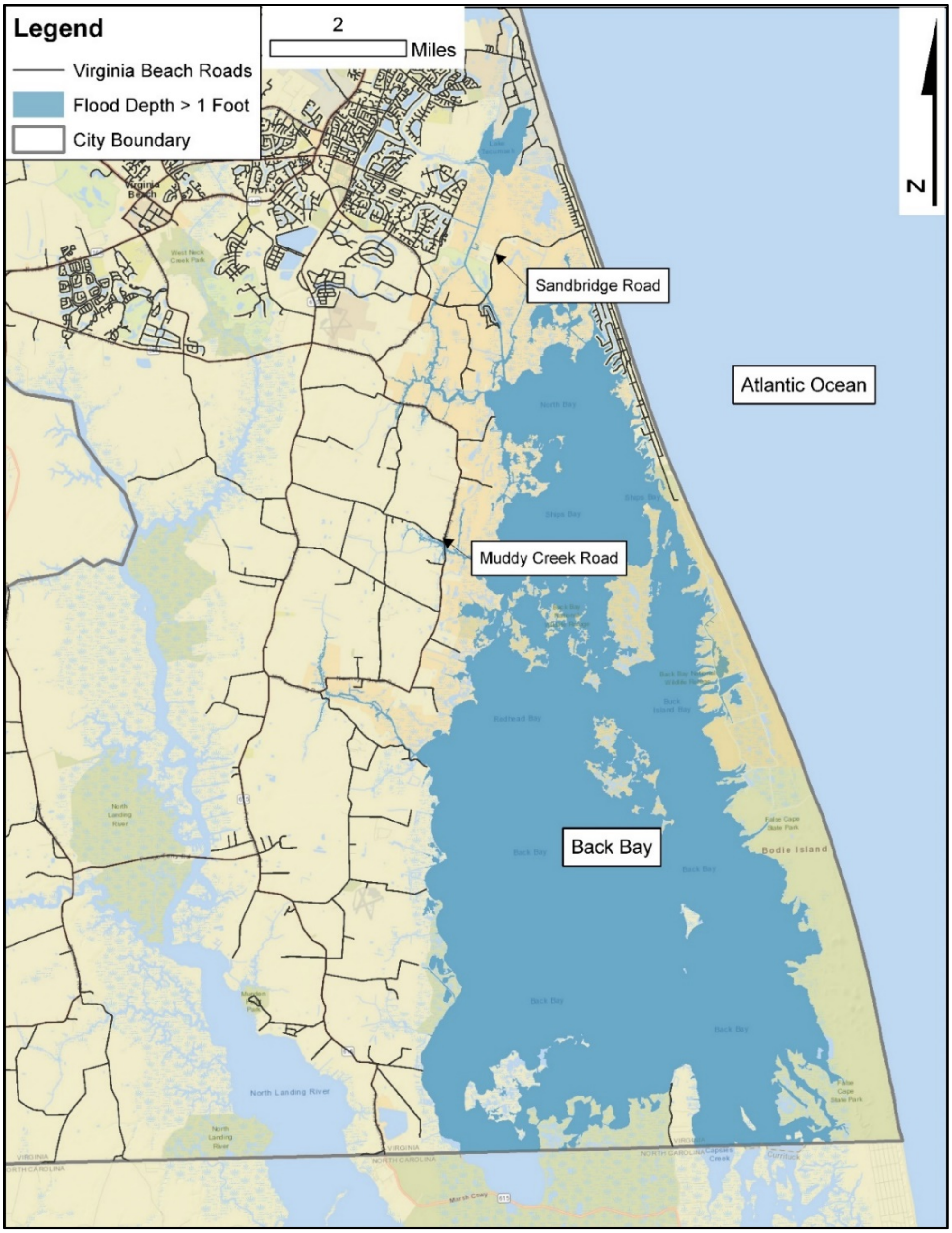

Figure 19: Results of the roadway access analysis for the Structural Alternatives.

Figure 20: Results of the roadway access analysis for the Marsh Creation Alternative.

5.4. CRITERIA 2A: EXTERNAL IMPACTS

The results of the screening analysis for the external impacts criteria are summarized in Table 10. The approach, data sources, and assumptions of the analysis are described below.

Table 10: External impacts analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Negative**	Potential for negative flood impacts to areas outside of Virginia Beach	**0.0**
Inverted Siphon	**Neutral**	No significant positive or negative adverse impacts to areas outside of Virginia Beach	**2.0**
Marsh Creation	**Positive**	Potential for flood risk reduction benefits to areas outside of Virginia Beach	**3.0**
Pump Facility	**Neutral**	No significant positive or negative adverse impacts to areas outside of Virginia Beach	**2.0**

5.4.1. ARTIFICIAL INLET EXTERNAL IMPACTS

The most significant external impact of the artificial inlet would be the discharge of brackish water with lower salinity and potentially higher temperature into the Atlantic Ocean. This could impact marine species, as discussed further in Section 5.6 (Water Quality Impacts). The other potentially significant impact would be to the beneficial use of the beach up- and down-drift of the inlet if water quality incidents occur within the Back Bay watersheds.

Further, the inlet alternative has the potential to have far-reaching impacts on waters in the northern portions of the Currituck Sound in North Carolina. At times when the gated inlet would be left open, ocean waters would enter the bay, and introduce tidal effects that could extend into North Carolina. Further numerical modeling studies will need to be performed to determine the effect of water levels and water quality in the surrounding area.

5.4.2. INVERTED SIPHON AND PUMP EXTERNAL IMPACTS

It is not anticipated that the inverted siphon or pump facility alternatives would have significant positive or negative adverse impacts to areas outside of Virginia Beach.

5.4.3. MARSH RESTORATION EXTERNAL IMPACTS

The conceptual evaluation of marsh restoration using the City's DHI MIKE 21 model demonstrated that comprehensive marsh island restoration could provide flood risk reduction benefits to both Virginia Beach and northern North Carolina.

5.5. CRITERIA 3A: HABITAT IMPACTS

The results of the screening analysis for the habitat impact criteria are summarized in Table 11. The approach, data sources, and assumptions of the analysis are described below.

Table 11: Environmental impacts – habitat analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Negative**	Potential for extensive ecosystem impacts within Back Bay and locally adjacent to the ocean outfall; Extensive documentation and Remediation anticipated to be required	**0.0**
Inverted Siphon	**Neutral**	Potential for low to moderate habitat impacts/benefits; Remediation may be required	**2.0**
Marsh Creation	**Positive**	Potential for significant habitat benefits; Overall increase in marsh habitat and reduction in open-water habitat Mitigation not required or unlikely to be required	**3.0**
Pump Facility	**Negative**	Potential for zero or negative habitat benefits (e.g. impacts); Remediation/Mitigation likely to be required	**0.0**

5.5.1. HABITAT IMPACTS FROM STRUCTURAL ALTERNATIVES

Impacts to wetland habitat were estimated in GIS using the USFWS National Wetlands Inventory (NWI) data. A summary of acres of impact for the structural alternatives is provided in Table 12.

It should be noted that the Siphon Alternative is not expected to impact wetlands if outfitted with a gate, except potentially during construction depending on how pipes are installed. Maps showing the location and extent of wetland impacts from the Artificial Inlet and Pump Station Alternatives are provided in Figure 21 and Figure 22.

Table 12: Estimated acres of wetland impact for the structural alternatives.

Alternative	Acres of Wetland Habitat Impact
Artificial Inlet	Negative (25 acres)
Pump Facility	Negative (2 acres)
Inverted Siphon	Neutral

The project would have to demonstrate avoidance and minimization during preliminary design, and unavoidable wetland impacts would require the development of a mitigation plan. Mitigation will likely require the creation of at least the amount of acres impacted, and likely more to assure no net loss of State Waters. Further, given the proximity of the alternative locations to Back Bay National Wildlife refuge, the potential for the introduction of saltwater to an oligohaline freshwater estuary (particularly for the Artificial Inlet Alternative), and vice versa, could affect the entire ecosystem, from the wetland vegetation, submerged aquatic vegetation to wildlife populations within Back Bay and in the adjacent marine system. Further studies of the entire ecosystem in the potential area of potential effect for the structural alternatives will be required as part of any NEPA document.

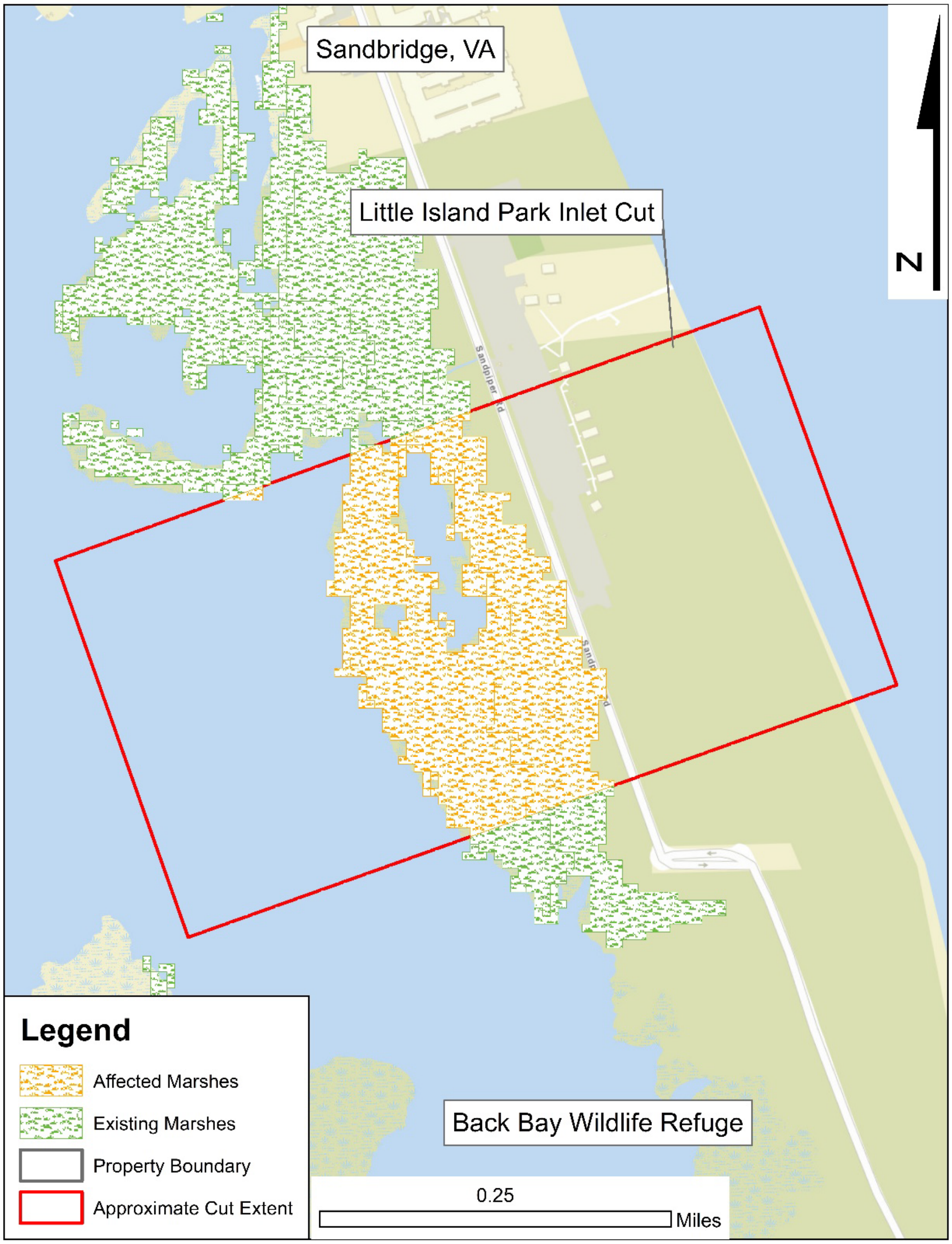

Figure 21: Potential habitat impacts from the Artificial Inlet ("cut") Alternative.

Figure 22: Potential habitat impacts from the Pump Station Alternative.

5.5.2. HABITAT BENEFITS OF MARSH CREATION

Marsh restoration would result in habitat benefits. The up-to 6,400 acres of created marsh island habitat would dissipate waves and slow down the propagation of water through Back Bay.

In turn, the calmer water allows more sunlight to penetrate to the shallow bottom, promoting the establishment and growth of marsh and seagrass.

5.6. CRITERIA 3B: WATER QUALITY IMPACTS

The results of the screening analysis for the water quality impacts criteria are summarized in Table 13. The approach, data sources, and assumptions of the analysis are described below.

Table 13: Environmental Impacts – water quality analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Negative**	Potential for zero or negative water quality benefits; Remediation likely to be required	**0.0**
Inverted Siphon	**Neutral**	Potential for low to moderate water quality benefits; Remediation may be required	**2.0**
Marsh Creation	**Positive**	Potential for significant water quality benefits; mitigation not required or unlikely to be required	**3.0**
Pump Facility	**Neutral**	Potential for low to moderate water quality benefits; Remediation may be required	**2.0**

5.6.1. ARTIFICIAL INLET WATER QUALITY IMPACTS

The largest challenge in water quality presented by the structural alternatives involves the exposure of the bay to ocean salt water and/or the influx of bay water into the ocean, which would have impacts on salinity levels in the Back Bay Wildlife Refuge and/or the adjacent marine systems. These impacts could be significant as not all plant and animal species within Back Bay wildlife refuge may be able to survive in a saltwater environment; likewise, marine species may experience shock when exposed to large amounts of fresher, brackish water entering the ocean from the bay. Further studies of the entire ecosystem in the area of potential effect for the structural alternatives will be required as part of any NEPA document.

5.6.2. INVERTED SIPHON AND PUMP FACILITY WATER QUALITY IMPACTS

The inverted siphon and pump facility alternatives include backflow prevention systems (also referred to as a tide gate) to prevent an influx of ocean water into the bay. This should preclude significant alterations in salinity levels in Back Bay and the potential for associated impacts on flora and fauna. However, the discharge of brackish water into the Atlantic Ocean during flooding events could result in an extreme, localized gradient in salinity that could shock marine fauna via effluent toxicity caused by ion imbalance. It is anticipated that agency approvals (e.g. EPA, NOAA, DEQ), and potential mitigation measures, will be required for discharges associated with each of these alternatives and that a 'WET test for an intermittent or batch discharger' will be required to determine the potential for toxicity of discharges to marine fauna. The WET test, and additional investigations, may be needed to determine if a NPDES/VPDES permit is necessary for anticipated discharges into the Atlantic Ocean. If determined applicable, an individual permit is likely to be required as these alternatives do not conform to a pre-defined category for NPDES/VPDES permitting.

If a WET test identifies the potential for toxicity from discharges, design alterations may be required to address concerns anticipated during agency review of potential impacts to state and federally listed Threatened and Endangered (T&E) species (Section 7 consultations), particularly in reference to several T&E species that have been identified within the project area. These solutions, such as off-shore discharge outfalls and diffuser structures, can add significant costs to the project if deemed necessary.

5.6.3. MARSH CREATION WATER QUALITY CONSIDERATIONS

Within the Back Bay watershed, four tributaries have listed impairments that have resulted in bacterial TMDLs: Nanney Creek (Bacteria/*enterococci*), Hell Point Creek (Bacteria/*enterococci*), Ashville Bridge Creek (Bacteria/*enterococci*, DO, pH), and Muddy Creek (Bacteria/E. coli) (MapTech 2013). Implementation of Bacterial TMDL plans has improved water quality in Back Bay and the 2016 DEQ Water Quality Assessment Report found the Bay to be "Fully Supporting" (DEQ 2020); the Bay remains Fully Supportive of aquatic life in the most recent DEQ Water Quality Assessment Integrated Report (DEQ, 2020). Extensive marsh restoration in Back Bay would help maintain this designation, and contribute to the goals for the Virginia State Wetlands Program Plan for 2015 – 2020 (DEQ 2016).

5.7. CRITERIA 4A: IMPLEMENTATION TIMEFRAME

The results of the screening analysis for the implementation timeframe criteria are summarized in Table 14. The approach, data sources, and assumptions of the analysis are described below.

Table 14: Implementation timeline analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Unlikely**	The project is unlikely to be implemented within five to seven years once funding is secured	**0.0**
Inverted Siphon	**Likely**	The project is likely to be implemented within five to seven years once funding is secured	**3.0**
Marsh Creation	**Likely**	The project is likely to be implemented within five to seven years once funding is secured	**3.0**
Pump Facility	**Likely**	The project is likely to be implemented within five to seven years once funding is secured	**3.0**

5.7.1. TIMEFRAME ASSUMPTIONS

Several assumptions were made to estimate the feasibility of completing each alternative in the defined timeframe (five to seven years):

- Six months to contract the design work
- Two-year design period
- A NEPA process of one to two years for Environmental Assessments two to five years for an Environmental Impact Statement (EIS), if required
- One year to solicit contractors
- Environmental permitting (one to two years) could be achieved in parallel with the NEPA process and contractor solicitations
- Two to three-year construction timeframe

Overall, the greatest amount of uncertainty in the implementation timeline is associated with the NEPA process (assessment of environmental impacts) and the acquisition of environmental permits.

5.7.2. ARTIFICIAL INLET TIMEFRAME

Environmental analysis for this alternative will likely be a complex process that may take several years, especially given the extensive environmental impacts, including a high likelihood of negative water quality impacts. An EIS-level NEPA document could take up to five years alone, as multiple seasons of habitat and species data and extensive public outreach efforts will be required for the assessment. Permitting will also be a cumbersome process, as further described in Section 5.9.

5.7.3. INVERTED SIPHON AND PUMP FACILITY TIMEFRAME

Given that the pump facility, inverted siphon, and marsh restoration alternatives are likely to have neutral or positive water quality benefits, and that there are opportunities during design to minimize impacts to habitat and other natural resources, the NEPA process (assuming an Environmental Assessment-level document will be required for these alternatives) and permitting processes required will be less involved.

5.7.4. MARSH CREATION TIMEFRAME

As noted earlier, the Marsh Creation Alternative represents a comprehensive vision of restoration in Back Bay, and the larger Albemarle-Pamlico estuary. This vision would likely be accomplished in phases, rather than wholesale restoration. Dependent on the extent and location of these restoration activities, this alternative may require an Environmental Assessment (EA)-level NEPA document or qualify for a Categorical Exclusion (CE). Either way, overall implementation is expected to take approximately five years, given that an EIS is not required.

5.8. CRITERIA 5A: DESIGN COMPLEXITY

The results of the screening analysis for the design complexity criteria are summarized in Table 15. The approach, data sources, and assumptions of the analysis are described below.

Table 15: Implementation complexity – design complexity analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Complex**	A complex concept that is difficult to design and implement, and requires highly specialized contractors to construct	**1.0**
Inverted Siphon	**Complex**	Complex implementation due to precision and highly specialized construction techniques.	**1.0**
Marsh Creation	**Moderately Complex**	A moderately complex concept that requires some specialized expertise to design and implement	**2.0**
Pump Facility	**Complex**	Complex implementation due to precision and highly specialized construction techniques.	**1.0**

5.8.1. ARTIFICIAL INLET DESIGN COMPLEXITY

The artificial inlet would likely be the most complex alternative to design and construct. To mitigate impacts on navigation, water quality, and hydrodynamics of the area surrounding Little Island Park, several design features would be required. These features, described in Section 3.1 include the construction of a bridge, jetties, and a storm surge barrier.

The design of the artificial inlet would also need to take into account a variety of complex factors that were not fully analyzed under this initial feasibility study. A detailed numerical modeling study would need to be conducted to understand the impacts to longshore sediment transport on the Atlantic Ocean side of the barrier island, water quality impacts of introducing saltwater into Back Bay, and potential impacts from storm surge if no storm surge barrier is constructed across the artificial inlet. Further analysis of sediment transport within Back Bay would need to be performed to determine if sediment currently in Back Bay could end up on the beaches on the Atlantic Oceanfront.

5.8.2. INVERTED SIPHON DESIGN COMPLEXITY

The design and construction of an inverted siphon of this size and at this location is complex. The siphon is only functional under specific water level intervals because it operates on the hydraulic difference in water levels in the bay and ocean. A more detailed analysis that takes into account various storm conditions and water levels for both Back Bay and the Ocean needs to be considered to ensure the siphon achieves the desired flood reduction during all scenarios. Also, more consideration needs to be taken into the headloss (friction between the water moving and the physical structure) that occurs in the siphon and other components.

Significant work would have to be done to design the inlet and outlet structures to prevent hydraulic losses, prevent erosion from high water velocities, and prevent wildlife entrapment. The inlet structure would have to be designed to prevent sediment from entering and may have to include wildlife barriers to prevent animals from entering the siphon.

Because of the extreme precision required for the siphon to operate, the elevations, bends, shape, and layout would need to extremely precise. Also, for construction, either tunneling or open excavation would have to be done which would require highly specialized construction tools and experience.

5.8.3. MARSH CREATION DESIGN COMPLEXITY

Marsh creation is a common coastal restoration approach. However, the shallow nature of Back Bay and a large amount of protected habitat presents challenges for design and construction. Ongoing marsh restoration design work in Back Bay has required the engagement of specialized, out-of-state contractors.

5.8.4. PUMP FACILITY DESIGN COMPLEXITY

The stormwater pump station would be a complex, multi-disciplined construction project. Significant excavation and dewatering would be required to construct the concrete inlet structure.

5.9. CRITERIA 5B: PERMITTING COMPLEXITY

The results of the screening analysis for the permitting complexity criteria are summarized in Table 16. The approach, data sources, and assumptions of the analysis are described below.

Table 16: Implementation complexity – permitting analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Unlikely**	Does not fit within existing regulatory frameworks; unlikely to obtain regulatory permits	**0.0**
Inverted Siphon	**Possible**	Possible to obtain regulatory permits, but fewer analogous projects permitted.	**2.0**
Marsh Creation	**Likely**	Activity fits within the existing regulatory framework; likely to obtain regulatory permits	**3.0**
Pump Facility	**Possible**	Possible to obtain regulatory permits; Pump stations commonly permitted; use as flood control measures is established; likely to obtain regulatory permits.	**2.0**

5.9.1. REGULATORY STANDARDS FOR THE SOUTHERN RIVERS WATERSHED

Development in the Southern Rivers Watershed is subject to the Southern Rivers Watershed Management Plan, as implemented by the Southern Rivers Watershed Ordinance and adopted by the City as part of the City's Comprehensive Plan (CVB 2018a). The relevant ordinance prohibits development within 50 feet of any wetland or shore except in the establishment of wetlands and shorelines constructed with best management practices. Also, the City has recommended that land use in the Sandbridge Suburban Area be consistent with the environmental objectives of Back Bay National Wildlife Refuge (CVB 2018a), which include the maintenance and enhancement of wetland habitats, native woodlands, and beach/dune areas to preserve and protect wildlife, particularly migratory birds (USFWS 2010).

All Project alternatives are expected to require the following major permits and/or authorizations from USACE, VDEQ, VMRC, VDWR, VDCR, VDACS, EPA, USFWS, and NOAA Fisheries. Consultation with the VDHR will be required to assure the project complies with Section 106 of the National Historic Preservation Act as well as other relevant orders acts and guidelines. Coordination and potential authorizations will be required from the USCG to ensure operations at the Little Island Coast Guard Station #4, and navigation considerations, are not adversely impacted. Also, it is anticipated that a project of this size will require a NEPA document and associated agency scoping, stakeholder consultations, and public hearings; the nature of the NEPA document will vary depending on the complexity of the alternative selected.

It should be noted that local Wetlands Board approvals were not included as it is anticipated the project would be sponsored by a governmental entity or political subdivision thereof, and as such is exempted from having to obtain local wetlands board permits/authorizations.

5.9.2. PERMITTING COMPLEXITY FOR ARTIFICIAL INLET

The permitting process for this option will likely be complex given the extensive construction disturbance, and potential for wholesale ecological changes within Back Bay. Impacts to longshore sediment transport and water quality in Back Bay will likely raise serious concerns from the USACE, EPA, VDEQ, VMRC, and other state and federal agencies. Impacts on wetlands, submerged lands, coastal sand dunes, and beaches, as a result of direct destruction via land conversion and indirect impacts associated with altered salinity regimes, are anticipated to be extensive and require significant mitigation efforts. Additionally, extensive Section 7 consultation for potential threatened and endangered (T&E) species with USFWS, NOAA Fisheries, VDCR, and VDGIF will likely be necessary due to the existence of habitat for several T&E species within and adjacent to the project area. This area also falls under the Coastal Zone Management Act (CZMA) which is administered by VDEQ and overseen by NOAA. The Artificial Inlet Alternative does not appear to align with the conservation and preservation of coastal habitats typically required under this Act.

Due to the extent of impacts on both terrestrial and aquatic systems, multiple Time of Year Restrictions (TOYR) would likely inhibit construction activities. Given the potential for significant environmental Impacts, it is anticipated this alternative would require an EIS-level NEPA document.

Initial research efforts were unable to find a similar project that included the construction of a new inlet between a marine environment and a brackish/freshwater system, other than the Rudee Inlet which occurred before the Clean Water Act. Acquiring appropriate environmental permits from appropriate state and federal agencies in the present regulatory climate will present challenges if authorization can even be obtained. Construction of a new inlet could be interpreted as not in alignment with the goals of existing environmental regulations.

Virginia Administrative Code 28.2 Chapter 12 prohibits most activities that "encroach upon or over or take or use any materials from the beds of the bays, ocean, rivers, streams, or creeks which are the property of the Commonwealth". The only exemption allowed under this regulation is for flood control projects undertaken by the USACE or the US Coast Guard. Virginia Administrative Code 20-44-10 Barrier Island Policy, Section 5- Shore Hardening prohibits the use of jetties and groins, which would be required to protect a new inlet.

The Artificial Inlet Alternative will require public input and involvement at several stages of planning. It is anticipated that this alternative would likely generate a large amount of public opposition, most notably in reaction to the impacts on Little Island Park and habitat.

Additionally, it is unlikely that this alternative satisfies the Southern Rivers Watershed Ordinance as it involves the destruction of both shoreline and wetlands and is not the least impactful practicable alternative. This alternative also does not appear to be the Least Environmentally Damaging Practicable Alternative (LEDPA) as required for the USACE permitting per Section 404 (b) (1) guidelines. Should the impacts of the Artificial Inlet Alterative be allowed, suitable locations for mitigation efforts to offset wetland impacts would be expensive to design, construct, and monitor for success, as demonstrated by the conceptual design and cost estimation in support of the Marsh Creation Alternative.

5.9.3. PERMITTING COMPLEXITY FOR INVERTED SIPHON

The Inverted Siphon Alternative is expected to have less permanent direct impacts than the Artificial Inlet Alternative. The permitting process is expected to require authorizations from USACE, VDEQ, VMRC, VDGIF, VDCR, VDACS, EPA USFWS, and NOAA. Dependent on the extent of impacts to terrestrial and aquatic systems proposed in the final inverted siphon alignments, TOYR imposed to minimize adverse effects to T&E species may inhibit construction activities. This alternative is anticipated to require an EA-level NEPA document as well. Section 106 concerns are anticipated to be less than those with the Artificial Inlet Alternative and minimized due to the reduced visibility of the alternative.

The Inverted Siphon Alternative is expected to be designed with a tide gate to prevent flows from the ocean to the Bay, therefore eliminating or minimizing the impacts from altering the salinity and ecosystem within Back Bay. However, as discussed previously in Section 5.6, it is anticipated a VPDES Individual Permit will be required to permit flood-event discharges. The design of the siphon and the construction methods used will influence the number of project impacts and therefore alter the permitting complexity. Choosing siphon alignments and siting required infrastructure to avoids wetlands, submerged lands, coastal sand dunes, and beach resources can help reduce the permitting complexity. Using construction methods that minimize land disturbance (e.g. boring instead of constructing in open trenches) can also help reduce the project complexity and expedite permit delivery.

Directional drilling methods are preferred by VMRC and are expected to be used for the construction of any pipes required for the Inverted Siphon Alternative. VMRC guidelines for projects in subaqueous areas require a minimum of 3 feet of cover over the upper extremity of the submerged structure when placed in an area where fishing devices are normally employed. Research to determine if fishing devices are used in the footprint of the project may be required. VMRC wetland guidelines for submarine pipeline crossings allow for the installation of pipelines in river bottoms and marshes with authorization. VMRC Barrier Island Policy state no cuts through the dune will be permitted and no permanent structure will be permitted seaward of the crest of the coastal primary sand dune. Further, no permanent alteration of the coastal primary sand dune will be permitted. Temporary vehicular access for purposes of construction will be permitted only by open-pile or "corduroy" ramps. Construction of any pipelines from the sand dunes seaward would need to be buried as much as practicable and constructed to avoid any impacts to sand dunes. In summary, this alternative, while better aligned with regulatory requirements remains challenging to permit.

5.9.4. PERMITTING COMPLEXITY FOR MARSH CREATION

The permitting process for a marsh restoration alternative will involve permitting wetland impacts (and creation) through the Joint Permit Application (JPA) process, which will involve coordination with the USACE, VMRC, and DEQ. It is assumed that marsh habitat will be created out of current open water areas within Back Bay to foster the reestablishment of aquatic vegetation and associated marsh habitat. Section 7 consultation will necessarily be incorporated into the JPA process to ensure proposed marsh restorations do not negatively affect T&E species. Dependent on the extent of the proposed restoration activities, TOYR imposed to minimize adverse effects to T&E species may inhibit construction activities. Dependent on the extent and location of these restoration activities, this alternative may require an Environmental Assessment (EA)-level NEPA document or qualify for a Categorical Exclusion (CE).

While permits to work within tidal wetlands and submerged lands from the VMRC would be required, obtaining authorizations from the VMRC and other regulatory agencies for the Marsh Creation Alternative is expected to be the least problematic of all the alternatives being considered. The Marsh Creation Alternative would be considered a living shoreline strategy. To encourage the use of living shoreline projects, VMRC has recently established living shoreline projects as its preferred alternative in regards to issuing permits specifically intended for shoreline restoration.

5.9.5. PERMITTING COMPLEXITY FOR PUMP STATION

The permitting process for a pump station is anticipated to involve Section 7 consultation with USACE, VDEQ, VMRC, VDGIF, VDCR, VDACS, EPA USFWS, and NOAA. Consultation is necessary to determine the impacts of pumping activities on T&E species and habitat within and adjacent to the project area. Considering the existence of sensitive marine mammal species and anadromous fish in the vicinity of the project area, consultation with the NOAA Fisheries (NMFS) will likely be especially important. It will be necessary to determine the significance of impacts from water withdrawal activities on the safety of species utilizing the Bay, as well as determine if the addition of freshwater to the ocean will result in significant localized dilution of salinity levels that might shock marine species. As discussed previously in Section 5.6, it is anticipated a VPDES Individual Permit will be required to permit flood-event discharges. Dependent on the extent of impacts on terrestrial and aquatic systems proposed in the final pump station design, TOYR imposed to minimize adverse effects to T&E species may inhibit construction activities. Additionally, water quality permitting through the EPA and DEQ to ensure water transport does not negatively impact either water body may be necessary. This alternative is anticipated to require an EIS-level NEPA document.

Obtaining authorizations from VMRC for the Pump Facility Alternative is expected to be similar to the Inverted Siphon Alternative, however, the additional infrastructure to house the required pumps would result in some impacts to wetlands, as mentioned in Section 5.5. Similar to the Inverted Siphon Alternative, construction methods that maximize the use of directional boring for all pipeline installations are recommended to avoid and minimize impacts to wetlands, submerged lands, coastal sand dunes, and beaches.

5.10. CRITERIA 5C: LAND USE

The results of the screening analysis for the land use criteria are summarized in Table 17. The approach, data sources, and assumptions of the analysis are described below.

Table 17: Land use impacts analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	Moderate	Moderate potential for project footprint to be constrained to municipal lands with minor impacts to navigation, vehicular, or pedestrian traffic circulation	**2.0**
Inverted Siphon	Moderate	Moderate potential for project footprint to be constrained to municipal lands with minor impacts to navigation, vehicular, or pedestrian traffic circulation	**2.0**
Marsh Creation	Low	Low potential for project footprint to be constrained to municipal lands with major impacts to navigation, vehicular, or pedestrian traffic circulation	**1.0**
Pump Facility	Low	Moderate potential for project footprint to be constrained to municipal lands with minor impacts to navigation, vehicular, or pedestrian traffic circulation	**2.0**

5.10.1. LAND USE IMPACTS FROM STRUCTURAL ALTERNATIVES

Optimal placement of the structural alternatives on the City-owned Little Island Park property will need to be determined to minimize the loss of public beach access at that location. Further, analysis needs to be performed to determine the optimal dimensions of each of the structural system components to ensure that the necessary volume of water can be removed from Back Bay. Changes in dimensions will alter the impacts on land use at the site. Further, due to the size and potential aesthetics of these alternatives, further analysis will be needed to determine the extent of disturbance to the current park use.

5.10.2. LAND USE IMPACTS FROM MARSH CREATION

The majority of Back Bay is owned by the Commonwealth of Virginia and the Federal Government (through the USFWS). Given the size of the project and location on federal property, the City would need to coordinate with USFWS to prepare an Environmental Assessment (EA)-level document in compliance with NEPA. Further, any restoration projects in North Carolina would require cross-state coordination.

5.11. CRITERIA 6A: COST-EFFECTIVENESS

The results of the screening analysis for the cost-effectiveness criteria are summarized in Table 18. The analysis leveraged existing data to provide a first-order estimate. The approach, data sources, and assumptions of the analysis are described below.

Table 18: Cost-effectiveness analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	Unfavorable	BCR less than 0.5 (BCR for the Artificial Inlet Alternative is estimated to be 0.17).	**0.0**
Inverted Siphon	Low	BCR between 0.5 and 1.0 (BCR for the Inverted Siphon Alternative is estimated to be 0.50).	**1.0**
Marsh Creation	Unfavorable	BCR less than 0.5 (BCR for the Marsh Restoration Alternative is estimated to be 0.02).	**0.0**
Pump Facility	Unfavorable	BCR less than 0.5 (BCR for the Pump Facility Alternative is estimated to be 0.21).	**0.0**

5.11.1. BENEFIT-COST ANALYSIS

The main benefit of the flood reduction alternatives is manifested through a reduction (or elimination) of the amount of flooding that protected areas would experience. Benefit-Cost Analysis (BCA) is used to demonstrate if the benefits of a project outweigh its costs, or the Benefit-Cost Ratio (BCR) is greater than 1.0[2]. Benefits are the avoided damages and losses associated with a proposed project. Costs are the initial and long-term investments associated with a proposed project, including mitigation costs associated with environmental impacts.

Losses avoided for each alternative were estimated using a combination of the wind tide modeling results (from ADCIRC and MIKE) and GIS analysis. For the purposes of this high-level feasibility assessment, flood loss estimates were derived from the economic flood risk analysis conducted using the Hazus flood model. The Hazus results for the 25-year flood event, which has a 4 percent chance of occurrence in a given year, was selected to most closely representing the recurrence of an extreme "wind-tide flood event", where water elevations in Back Bay reach an elevation of 3 feet. The "with alternative" and "without alternative" flood extents, described in Section 5.2.1., were compared in GIS to generate the area that would be removed from the

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[2] The benefit cost ratio is calculated as follows: $BCR = \frac{Benefits}{Costs}$ where the benefits are the avoided damages and losses associated with the project and are calculated as follows:

$$Avoided\ Damages = \sum(Pre\ project\ Event\ Damages) - \sum(Post\ project\ Event\ Damages)$$

Costs are sum of the upfront construction costs and the present value of the annual operations and maintenance costs over the useful life of the project.

wind-tide floodplain. This area was used to total project benefits for building and content loss avoided.

Project benefits occur over a period of time into the future; while most of the project costs are incurred upfront and in the present. FEMA conducts its BCAs on a net present value basis, meaning the present value of the benefits gained from the project over the life of the project is compared to the total project cost to establish the BCR. Because project benefits accumulate over time, project benefits are calculated on an average annual basis ("annualized") and then multiplied by a Present Value Coefficient (PVC)[3] to determine the present value of the annualized benefits. The alternatives were assumed to accrue benefits over the estimated useful life. Considering the Federal Office of Management and Budget discount rate of 7%, the PVC for each alternative is presented in Table 19.

Table 19: Present Value Coefficient (PVC) calculations.

Alternatives	Useful Life (Years)	PVC
Artificial Inlet	50	13.91
Inverted Siphon	100	14.28
Marsh Creation	100	14.28
Pump Facility	30	12.67

Total project benefits for building and contents loss avoided were multiplied by the PVC. This provided the total project benefits. Finally, total benefits were divided by the alternative project cost to determine the BCR for each alternative, which are shown in Table 20. The presented values reflect initial estimates of the BCR given existing information on-hand, and may change significantly with specific analysis of project costs and performance. It is important to emphasize that the BCR analysis was not specifically calculated, but rather estimated using existing data from the SLW study which may or may not truly reflect the actual benefits given the level of flood protection. Further, there are other benefits and costs that could be incorporated into BCR analysis. For example, environmental benefits such as improved water quality and habitat creation could be included to quantify a wider range of benefits for the Marsh Creation Alternative.

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[3] The present value coefficient is calculated as follows: $PVC = \left[\frac{1-(1-r)^{-T}}{r}\right]$
Where: *r* is the discount rate and *T* is the useful life of the project.

Table 20: Benefit-Cost Ratio for each alternative.

Alternatives	Loss Avoided (millions)	Project Benefits (millions)	Construction Costs	O&M (millions)	Mitigation Costs (millions)	Total Cost (millions)	BCR
Artificial Inlet	$ 8.9	$ 123.5	$ 575.9	$ 140.2	$ 27.0	$ 743.1	**0.17**
Inverted Siphon	$ 8.9	$ 126.8	$ 231.4	$ 20.7	-	$ 252.1	**0.50**
Marsh Creation	$ 0.57	$ 8.2	$ 386.0	$ 96.0	-	$ 482.0	**0.02**
Pump Facility	$ 8.9	$ 112.5	$ 500.0	$ 39.0	$ 2.2	$ 541.2	**0.21**

5.12. CRITERIA 6B: OPERATIONS & MAINTENANCE

The results of the screening analysis for the O&M criteria are summarized in Table 21. The cost estimation assumptions for the analysis are described below. O&M costs include potential mitigation costs.

Table 21: Fiscal considerations – operations and maintenance costs analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Somewhat Reasonable**	O&M costs are approximately 29% of the total cost of the project.	**2.0**
Inverted Siphon	**Reasonable**	O&M costs are approximately 9 % of the total cost of the project.	**3.0**
Marsh Creation	**Somewhat Reasonable**	O&M costs are approximately 25% of the total cost of the project.	**2.0**
Pump Facility	**Reasonable**	O&M costs are approximately 8% of the total cost of the project	**3.0**

5.12.1. O&M COST ESTIMATE ASSUMPTIONS

Details on annual O&M costs for each alternative were presented in Chapter 3 of this report. Assumptions for mitigation costs, which were not included in Chapter 3, are as follows:

- According to the VMRC, the Virginia Beach Wetlands Board uses a $25 per square foot (or $1.09 million per acre) standard mitigation fee.
- To account for the likely mitigation costs associated with tidal wetland impacts, the estimated acres of impact (presented in Section 5.5) were multiplied by the standard VMRC mitigation costs.

The total costs of mitigation and O&M, as a percentage of overall project cost, for each alternative are summarized in Table 22.

Table 22: O&M costs in comparison to total construction costs.

Alternatives	Construction Costs (millions)	O&M (millions)	Mitigation Costs (millions)	Total O&M Costs (millions)	O&M Percentage of Total Cost
Artificial Inlet	$ 575.9	$ 140.2	$ 27.0	$ 167.2	**29 %**
Inverted Siphon	$ 231.4	$ 20.7	$ 0.0	$ 20.7	**9 %**
Marsh Creation	$ 386.0	$ 96	$ 0.0	$ 96.0	**25 %**
Pump Facility	$ 500.0	$ 39.0	$ 2.2	$ 41.2	**8 %**

5.13. CRITERIA 7A: REGULATORY STAKEHOLDER ALIGNMENT

The results of the screening analysis for the stakeholder alignment criteria are summarized in Table 23. The approach, data sources, and assumptions of the analysis are described below.

Table 23: Regulatory stakeholder alignment analysis results.

Alternative	Rating	Basis of Rating	Factored Score
Artificial Inlet	**Does Not Align**	Meets flood reduction goals, but does not align with regulations and policies of the regulatory community; is not the least impactful practicable alternative.	**0.0**
Inverted Siphon	**Generally Aligns**	Alternative meets flood reduction goals; some habitat impacts; has the potential to obtain regulatory permits but is not the least impactful practicable alternative.	**2.0**
Marsh Creation	**Aligns**	Alternative meets conservation goals of Southern Watershed Area and Back Bay National Wildlife Refuge; is a net-gain for wetlands/T&E species habitat; Is the least impactful practicable alternative	**3.0**
Pump Facility	**Generally Aligns**	Alternative meets flood reduction goals; some habitat impacts; has the potential to obtain regulatory permits but is not the least impactful practicable alternative.	**2.0**

5.13.1. REGULATORY STAKEHOLDERS & COMMON OBJECTIVES/GOALS

Several agencies and stakeholder groups with interests in the Southern Rivers Watershed area should be considered when evaluating alternatives of this scale. Agencies that have jurisdiction over portions of the project area include the USACE, USFWS, NOAA Fisheries, VMRC, VDCR, and VDEQ In addition, several public-private partnership groups have developed conservation and management plans for the area, including the Albemarle-Pamlico National Estuary Partnership.

Across these groups, the Southern Rivers Watershed is valued for supporting a multitude of natural resources, including extensive wetlands and waterways, recreational beaches, and numerous opportunities for fishing and hunting. The City of Virginia Beach has recommended that land use in the Sandbridge Suburban Area (for which Little Island Park is the southern terminus) be consistent with the environmental objectives of Back Bay National Wildlife Refuge (City of Virginia Beach, 2018), which include the maintenance and enhancement of wetland habitats, native woodlands and beach/dune areas to preserve and protect wildlife, particularly migratory birds (USFWS, 2010).

5.13.2. REGULATORY ALIGNMENT – ARTIFICIAL INLET

This alternative will result in the removal of public recreation areas, including a portion of the beach from Little Island Park. It will also destroy marsh, dune, and beach habitat and significantly alter hydrologic regimes for Back Bay. This is contrary to the listed objectives of the Southern Watersheds Management Ordinance as adopted by the City of Virginia Beach, which prescribes the protection, enhancement, and restoration of the quality of waters within the Southern Rivers Watersheds via measures that protect, restore and maintain plant and animal communities. The creation of this artificial inlet is likely to involve the destruction of a significant amount of marsh, dune, and beach habitat (see Section 5.5), which puts it at odds with the desired goals of several relevant regulatory agencies (e.g. USFWS, NOAA Fisheries, VMRC, USACE, and DEQ). The impacts anticipated from this alternative are directly contrary to the migratory bird population and habitat conservation goals of the Back Bay National Wildlife Refuge, and False Cape State Park. Construction of a new inlet is also expected to require jetties or groin structures that conflict with VMRC Barrier Island Policy that prohibits shore hardening structures (VMRC 2020).

5.13.3. REGULATORY ALIGNMENT – INVERTED SIPHON

The conceptual design for the Inverted Siphon alternative will avoid extensive direct impacts to Little Island Park and, dependent on the chosen alignments, designs and construction methods, could avoid extensive impacts on habitat within the project area. Some impacts are inevitable, both temporary and permanent, from the installation of the siphon and associated infrastructure (e.g. entrapment barriers) that will result in losses to aquatic habitat. In addition, the nature of a siphon system may pose dangers to fauna on either side of the system due to the potential for entrapment and shocks in salinity changes during draining events. However, this alternative is not in direct opposition to the goals and objectives of relevant regulatory agencies and may be designed to minimize impacts on recreational activities and resources of concern.

5.13.4. REGULATORY ALIGNMENT – MARSH CREATION

The restoration of marsh habitat within Back Bay is most in line with the regulatory stakeholders. This option is not anticipated to impact recreational areas existent within Little

Island Park and meets the standards of the Southern Rivers Watershed Ordinance. The creation of additional marsh habitat is anticipated to offer additional water quality enhancement (via ecosystem services provided by wetland areas) as well as restore plant and animal communities within the Southern Rivers Watershed. Potential impacts to cultural and historical resources, as environmental sites of concern, within Little Island Park, would be avoided completely. Additionally, living shoreline techniques including marsh restoration are the preferred alternatives for VMRC

5.13.5. REGULATORY ALIGNMENT – PUMP FACILITY

The conceptual design for the Pump Facility Alternative would have moderate impacts on the use of Little Island Park and the surrounding habitat. Pumping equipment may pose dangers to fauna on either side of the system due to the potential for entrapment and shocks in salinity changes during pumping events. However, much like the Inverted Siphon Alternative, this alternative is not in direct opposition to the goals and objectives of relevant regulatory agencies and may be designed to minimize impacts on recreational activities and resources of concern.

6. ALTERNATIVE EVALUATION

The overall comparison of alternatives evaluated through the screening analysis is presented in Table 24. The *Total Score* column provides a total of factored scores across the individual evaluation criteria. The *Rank* column provides a relative ranking of alternatives based on their total score. The Inverted Siphon and Marsh Creation Alternatives received the highest score, followed by the Pump Facility Alternative, and then the Artificial Inlet Alternative. The scores are intended to serve as a general comparison of alternatives, rather than indicate that a certain alternative should be selected as a "preferred alternative" at this time.

The City recognizes that consultation with regulatory agencies is critical to gather additional perspective on the alternatives evaluated and recommendations for further analysis. The results of the initial screening analysis were presented to the regulatory agencies listed below during a virtual consultation meeting in October 2020 . Regulatory agencies are those governmental organizations that have jurisdictional authority over classes of action that require the issuance of permits or other forms of approval before the action takes place. It should be noted that the Virginia Beach Wetlands Board was not included as it was assumed that any alternatives that move forward would be sponsored by a governmental entity or political subdivision thereof, and as such, is exempted from having to obtain local wetlands board permits/authorizations.

- U. S. Army Corps of Engineers (USACE)
- U. S Fish and Wildlife Service (USFWS)
- U. S. Environmental Protection Agency (USEPA)
- National Oceanic and Atmospheric Administration (NOAA) Fisheries Service
- Virginia Department of Environmental Quality (VDEQ)
- Virginia Department of Conservation and Recreation (VDCR)
- Virginia Marine Resources Commission (VMRC)
- Virginia Department of Wildlife Resources (VDWR), formerly named the Virginia Department of Game and Inland Fisheries (VDGIF)
- North Carolina Department of Environment and Natural Resources (NCDENR)

The City structured the meeting as follows:

- Welcome and Roll Call (*10 minutes*)
- Overview of Project and Screening Analysis of Alternatives (*30 minutes*). Topics covered during the presentation included:
    - Objectives and Approach
    - Project Need and Purpose

    - Overview of Alternatives
    - Evaluation Framework
    - Screening Analysis of Alternatives
- Round-Robin Question and Answer (*45 minutes*). The following questions were provided:
    - Do you have any general questions about the alternatives and how they work?
    - Does your agency generally agree with the ranking regarding potential for the alternatives to obtain permits?
    - Could you identify probable concerns or constraints your agency may have in regard to the alternatives?
    - What critical resources under your jurisdiction may be adversely impacted by the alternatives?
    - Are there other alternatives that should be considered?
    - Are there other evaluation factors that should be considered?
- Open Discussion (*35 minutes*)

Following the virtual consultation meeting, the City circulated the PowerPoint presentation, a draft version of this report, and a link to a GoogleForm survey with the above questions. The project team also solicited additional input via phone calls to individual agencies who did not complete the survey. The following provides an overall synthesis of the feedback received.

1. **Permitting / Regulatory Alignment**: None of the regulatory agencies disagreed with the City's evaluation of potential for the alternatives to obtain permits, or the evaluation of alignment with agency goals and objectives. Some common themes that emerged include:
    - Several of the agencies consulted indicated this initial feasibility assessment was not sufficient to make any formal determinations or recommendations regarding permitting or regulatory alignment. A more formal permit review process would require additional information beyond the scope of this initial feasibility assessment.
    - All of the alternatives would require a USACE permit. Further, any proposed work within the landward boundary of the City of Virginia Beach owned easements to 500 feet into the water would require a Section 408 permission from USACE.
    - In general, agencies agreed that the Artificial Inlet Alternative is unlikely to obtain permits, and does not align with goals to protect the bay, given the anticipated ecological changes within Back Bay (e.g. water quality, degradation of wetland and dune habitat, sediment transport, etc.)
    - In general, agencies agreed that it might be possible for the Inverted Siphon or Pump Facility alternatives to obtain permits; however, additional engineering analysis would be required to better understand and quantify the disruption to marine ecosystems

that both options would create.

- In general, agencies agreed that the Marsh Creation Alternative would likely be able to obtain permits given its ability to support the mutually reinforcing goals of flood protection and habitat creation.

2. **Concerns/Critical Resources**

   - Several agencies expressed concerns about the safety for navigation, boaters, hunters, etc. given the volume of water being moved by the Inverted Siphon and Pump Facility Alternatives.
   - One agency generally recommends against projects that would result in large impacts to wetlands, such as the approximately 25-acre tidal wetland impact associated with the Artificial Inlet Alternative.
   - A more detailed analysis of resources in the vicinity of each proposed alternative would help agencies better evaluate potential resource impacts on the following: benthic habitat, wetlands, submerged aquatic vegetation habitat, mudflats, surface waters, federally listed T&E species (such as sea turtles and Atlantic sturgeon), other Back Bay species (waterfowl, migratory birds, inter-jurisdictional fish, marine mammals) and historic resources. Agencies are concerned about the individual, as well as cumulative impacts, on the above resources for all of the alternatives.
   - Several agencies expressed concern that the impacts on water quality and sediment transport from each of the alternatives was not well understood.

3. **Additional Alternatives**

   - Several agencies suggested a hybrid approach to evaluate the feasibility of a combination of projects that may leverage smaller engineered structures with marsh restoration. For example, the Marsh Creation Alternative could be combined with the Inverted Siphon or Pump Facility Alternative, to provide an integrated flood and environmental protection project.
   - One agency suggested further exploration of Marsh Creation approaches, such as the use of thin layer application to restore and expand existing marshes.
   - One agency suggested minimizing shoreline development along the Back Bay shoreline and within the floodplain to allow for wetland migration with SLR. The City recognizes the importance of land conservation as part of the Adaptation Vision for the Southern Rivers Watershed. As mentioned in Chapter 2 of this report, this strategy was not evaluated as an alternative as it is considered a planning and policy-based strategy that would mitigate flood impacts, but not meet the defined Purpose to decrease flood elevations or slow down floodwaters entering the bay. y.
   - For a complete record of the meeting discussion, survey responses, and follow-up engagement with agencies, please see the Appendix included at the end of this report. Recommendations for further study and evaluation are provided in Chapter

Table 24: Overall alternative evaluation results.

	Flood Reduction	Protected Structures	Roadway Access	External Impacts	Habitat Impacts	Water Quality Impacts	Time-frame	Design Complexity	Permitting	Land Use	Cost-Effectiveness	O&M	Regulatory Stakeholder Alignment	Total Score	Rank
Artificial Inlet	Medium	High	High	Negative	Negative	Negative	Unlikely	Complex	Unlikely	Moderate	Not Favorable	Reasonable	Does Not Align	**45**	**3**
	10	**15**	**15**	**0**	**0**	**0**	**0**	**3**	**0**	**8**	**0**	**4**	**0**		
Inverted Siphon	Medium	High	High	Neutral	Neutral	Neutral	Likely	Complex	Possible	Moderate	Low	Reasonable	Generally Aligns	**111**	**1**
	10	**15**	**15**	**8**	**8**	**8**	**6**	**3**	**10**	**8**	**4**	**6**	**10**		
Marsh Creation	Medium	Low	Medium	Positive	Positive	Positive	Likely	Mod. Complex	Likely	Low	Not Favorable	Somewhat Reasonable	Aligns	**111**	**1**
	10	**5**	**10**	**12**	**12**	**6**	**6**	**6**	**15**	**4**	**0**	**4**	**15**		
Pump Facility	Medium	High	High	Neutral	Negative	Neutral	Likely	Complex	Possible	Moderate	Not Favorable	Reasonable	Generally Aligns	**99**	**2**
	10	**15**	**15**	**8**	**0**	**8**	**6**	**3**	**10**	**8**	**0**	**6**	**10**		

7. RECOMMENDATIONS

Further analysis on the Artificial Inlet Alternative is not recommended given the extensive negative impacts on natural resources, complicated engineering design, and significant hurdles to obtain permits. As a follow-up to this effort, the City should consider pursuing further analysis of the top-scoring options, including the Inverted Siphon, Pump Facility, and Marsh Creation alternatives. It is anticipated that the next level of study could be a more detailed engineering design, feasibility assessment, and evaluation of environmental impacts for the recommended set of alternatives. Further analysis could focus on better understanding each alternative individually, or a combination of the alternatives, as recommended for consideration by regulatory agencies.

Activities the City could explore to further this effort include:

- Additional public engagement to better understand stakeholder perspectives on the alternatives evaluated.
- Literature review of comparable case studies of the proposed alternatives.
- Development of a NEPA study to evaluate and document environmental impacts of each alternative, and/or combinations of alternatives. The NEPA study will need to demonstrate that the preferred alternative (once identified), is the least damaging practicable alternative that meets the Project Purpose and Need. Typical requirements of a NEPA study include:
  - 30% engineering design and construction plans consisting of coastal, civil, structural, geotechnical, mechanical, and electrical disciplines. Unique design considerations that could be future explored for each of the alternatives are listed below.
    - Inverted Siphon
      - A geotechnical study of soils to determine if micro-tunneling would work and if any soil improvements would be needed.
      - Evaluation of inlet and outlet structures to prevent hydraulic loses, prevent erosion from high water velocities and prevent wildlife entrapment.
      - Assessment of head loss (friction between the water moving and the physical structure) that occurs in the siphon and other components.
    - Marsh Creation
      - A geotechnical study of soils in Back Bay are suitable for building new marsh areas proposed as part of the Marsh Creation alternative. The City has planned a geotechnical investigation to support the design and permitting of the

            marsh terrace pilot project in Bonney Cove. If the City explores additional marsh creation opportunities, geotechnical investigations should be conducted in those areas as well.

            - Evaluation of alternative construction methods, such as thin layer placement to expand existing marsh areas.

        - Pump Facility

            - A geotechnical study of soils to determine if soils would support the weight of the proposed elements of the pump facility.

            - A more detailed electrical analysis of power requirements for the flow pumps and generators.

    - Construction cost estimates and O&M requirements based on the 30% design.

    - Cost-benefit analysis based on the 30% design. To appreciate the full potential of alternatives that provide multiple benefits, cost-benefit analysis could be extended to quantify their ecosystem and socio-economic benefits. This would enable a more holistic comparison to traditional engineering approaches. An XBeach model is being developed as part of the marsh terrace pilot project, which could be expanded to include other areas in Back Bay.

    - Analysis to evaluate the impacts of changes in sediment dynamics and turbidity on wetlands and submerged aquatic vegetation habitat, as well as potential for wildlife entrapment.

    - Hydrodynamic modeling to better understand and quantify the changes in flood elevations and flows in Back Bay and the Atlantic Ocean associated with implementation of the preferred alternative.

    - Water quality modeling to better understand and quantify the changes in water quality within Back Bay and the Atlantic Ocean associated with implementation of the preferred alternative. The water quality analysis should evaluate the impacts of freshwater discharges into the Atlantic Ocean.

Should any of the alternatives move forward, consultation with additional parties would be necessary. For example, the Virginia Department of Agriculture and Consumer Services (VDACS) and Virginia Department of Historic Resources (VDHR) require the establishment of a formal project file before coordination and typically are prompted to participate in formal reviews during formal NEPA and permitting processes.

8. REFERENCES

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14. U.S Fish and Wildlife Service (USFWS) (2010). Back Bay National Wildlife Refuge Comprehensive Conservation Plan (PDF).
15. Virginia Institute of Marine Sciences (VIMS) (2020). Atlantic Ocean Beaches and Dunes of Southeast Virginia (Website).
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9. APPENDIX: AGENCY COMMENTS

The City of Virginia Beach Department of Public Works hosted a virtual (WebEx) stakeholder workshop on October 29, 2020, to seek input on several stakeholder-elicited strategies for reduction of wind-tide flooding in Back Bay. A summary of the discussion is provided in the Summary of Meeting Discussion section of this appendix.

On October 30, 2020, a copy of the technical report, PowerPoint presentation, and GoogleForm survey were circulated to meeting participants. Survey responses are provided in the GoogleForm Survey Responses section of this appendix. Lastly, the project team followed up individually with agencies via phone or email to solicit additional input. A record of this feedback is provided in the Summary of Additional Feedback section of this memorandum.

9.1. IN ATTENDANCE

The following provides a record of participants at the October 29, 2020, meeting.

Name	Organization	Email
Toni Alger	City of Virginia Beach (CVB) Department of Public Works	talger@vbgov.com
Sue Kriebel	CVB Department of Public Works	SKriebel@vbgov.com
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Alaurah Moss	Dewberry	amoss@dewberry.com
Kim Larkin	Dewberry	klarkin@dewberry.com
Robert Acker	Dewberry	racker@dewberry.com
Doug Brewer	U.S. Fish and Wildlife Service (USFWS), Back Bay National Wildlife Refuge (NWR)	doug_brewer@fws.gov
Lauren Mowbray	USFWS, Back Bay NWR	lauren_mowbray@fws.gov
Kathy Owens	USFWS, Back Bay NWR	kathryn_owens@fws.gov
Melissa Nash	U.S. Army Corps of Engineers (USACE)	Melissa.A.Nash@usace.army.mil
Jeff Hannah	Virginia Department of Environmental Quality (VDEQ)	Jeffrey.Hannah@deq.virginia.gov
Craig Nicol	VDEQ	Craig.nicol@deq.virginia.gov
Tyler Meader	Virginia Department of Conservation and Recreation (VDCR)	tyler.meader@dcr.virginia.gov
Justin Worrell	Virginia Marine Resources Commission (VMRC)	justin.worrell@mrc.virgnia.gov

Name	Organization	Email
Carrie Traver	U.S. Environmental Protection Agency (USEPA) Region 3	traver.carrie@epa.gov
Samantha Beers	USEPA Region 3	Beers.samantah@epa.gov
Stephanie Kubico	USEPA Region 3	kubico.stephanie@epa.gov
Chad Boyce	Virginia Department of Wildlife Resources (VDWR)	chad.boyce@dwr.virginia.gov
Dave O'Brien	National Oceanic and Atmospheric Administration (NOAA) Fisheries Service	david.l.obrien@noaa.gov
Brian Hopper	NOAA Fisheries Service	Brian.d.hopper@noaa.gov

9.2. SUMMARY OF MEETING DISCUSSION

The following provides a summary of the discussion portion of the meeting, as recorded by the notes compiled from the project team.

- NOAA
  - Would need to consider if there are endangered species that may be affected, such as sea turtles, Atlantic sturgeon
  - Has the City looked at hybrid alternatives, i.e., combining two or more of these presented strategies?
- USEPA Region 3
  - Will need to review information and get back with questions
  - Requested if materials, including documentation of the criteria, evaluation, etc. will be made available for the review (Materials were made available)
  - Noted many questions raised to her from the presentation
  - Will discuss internally and respond in writing
- VDWR
  - Generally agreed with the rankings as presented
  - Have some concerns on further habitat degradation, and on freshwater fisheries in the Back Bay with the inlet and siphon alternatives.
  - Requested additional explanation of the siphon system functionality (provided)
  - Expressed concerns about the level of detail to achieve accurate rankings on some of the criteria. City responded that present analysis was completed to provide initial evaluations to allow feedback from the agencies.
  - Asked if the City had considered restoration of the marshes to the historic shoreline positions, may be more desirable.

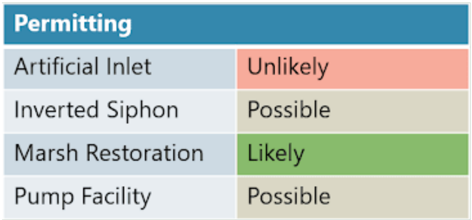
- USFWS, Back Bay NWR
    - The safety of some of these alternatives, in context of boaters, hunters, etc., should be considered given the amount of water being moved
    - Plan on submitting further comments in writing
- USACE
    - All presented options would need a USACE permit
    - Need more time to review material
    - Suggested City consider a hybrid approach of the presented alternatives
    - Some concerns about submerged aquatic vegetation impacts, open water impacts, fill and navigation impacts
- VADEQ
    - Would like to review the document, mentioned that having the purpose and need and why performed would be important for the permit application
    - Impacts and mitigation may require considerations by DCR/DWR
    - Asked if public comments had been solicited (City response: not at this time, only consulting agencies at this stage).
    - Suggested that the City may want to leverage any comparable case studies to support application, when it gets to that stage.
- VRMC
    - Cautious on commenting at this point
    - Mentioned that VMRC represents state ownership of the Back Bay bottom
    - Application would need to consider site and all habitat stakeholders
    - Asked about public interest and review process at this stage (City response: strategies identified from stakeholder meetings but further public engagement has not been undertaken at this point, presenting initial feasibility findings to agencies to help inform next steps).
- VADCR
    - No official comments at this time
    - Will respond after review
    - Asked if the False Cape National Area Preserve was aware and had been engaged. Suggested communicating effort to that group.
- NOAA Fisheries
    - Needed more time to review materials before providing perspective
    - Noted no essential fish habitat in Back Bay

  - May be more palatable to alternatives that would help restore fisheries (City response: Another project underway to assess marsh restoration in Back Bay. Provided invite to scoping meeting for that effort in November).

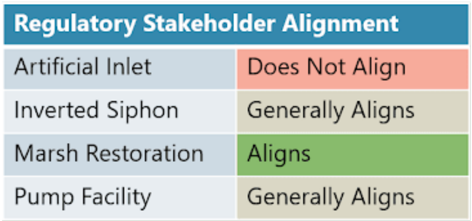
9.3. SURVEY RESPONSES

The following provides a record of survey responses, copied verbatim from the GoogleForms survey record.

- **Question 1**: Do you have any general questions about the alternatives and how they work?
  - EPA (Region 3): no
  - VDEQ: No general questions that weren't answered by the (draft) Project Alternative Screening Analysis report. Sounds like additional studies may be needed regarding applicability and design of the reverse siphon.
  - Back Bay NWR: We have questions about the mechanics of the inverted siphon option and pump facility. We have concerns about safety with the volume of water would be moved through these.
  - USACE: No, the project slides and presentation adequately described the alternatives for this step in the process.
- **Question 2**: Does your agency generally agree with the ranking regarding potential for the alternatives to obtain permits?



Permitting	
Artificial Inlet	Unlikely
Inverted Siphon	Possible
Marsh Restoration	Likely
Pump Facility	Possible



Regulatory Stakeholder Alignment	
Artificial Inlet	Does Not Align
Inverted Siphon	Generally Aligns
Marsh Restoration	Aligns
Pump Facility	Generally Aligns

  - EPA (Region 3): yes.
  - VDEQ: Yes, generally agree. Please note that additional information would be needed for all alternatives during a permit review process. It must be demonstrated that the preferred alternative (once identified) is the least damaging practicable alternative and meets the project's purpose and need.
  - Back Bay NRW: For permitting please consult with our Ecological Services

office. For stakeholder alignment: We agree that the marsh restoration option aligns with our agency goals and the artificial inlet option does not align with our goals to protect the bay and the ecosystem. Though we do have questions about the mechanics of the other two systems we do not believe these would generally align with our mission due to the huge disruption to marine ecosystems both options would create.
    - USACE: Generally, I agree with your rankings.
- **Question 3**: Could you identify probable concerns or constraints your agency may have in regard to the alternatives?
    - EPA (Region 3): Open water filing loosing benthic habitat and impacts to SAV
    - VDEQ: Potential adverse impacts to water quality must be minimized. Permanent and temporary impacts to surface waters and wetlands may require a permit pursuant to §401 of the Clean Water Act, Virginia Code §62.1-44.15:20, and Virginia Administrative Code 9 VAC 25-210-10 et seq.
    - Back Bay NRW: See above response.
    - USACE: Concerns are wetland impacts, impacts to navigation, impacts to federally listed threatened and endangered species, historic resources, screen size for pipes, issues raised by agencies and the public.
- **Question 4**: What critical resources under your jurisdiction may be adversely impacted by the alternatives?
    - EPA (Region 3): Water quality
    - VDEQ: Surface waters, including wetlands
    - Back Bay NRW: The species we would have concerns about impacts are: waterfowl, other migratory birds, sea turtles, interjurisdictional fish, marine mammals. Our concerns are also about the impacts on wetlands and SAV due to massive water flows and turbidity involved in many of these options.
    - USACE: We will coordinate with other agencies.
- **Question 5**: Are there other alternatives that should be considered?
    - EPA (Region 3): No
    - VDEQ: No comment
    - Back Bay NWR: Minimizing shoreline development along the bay and in the floodplain. Designate areas for wetlands to increase as natural protection for changing hydrology. Climate smart planning in all future development.
    - USACE: Cannot think of any.
- **Question 6**: Are there other evaluation factors that should be considered?
    - EPA (Region 3): No

    - VDEQ: The potential effects to water quality from each alternative need to be better understood and expanded upon.
    - Back Bay NWR: We recommend doing a Comprehensive Environment Impact Statement for all future projects in the entire watershed for cumulative impacts. Evaluating projects individually does not capture the relationship between the projects and their overall impact on the ecosystem.
    - USACE: This project will require Section 408 permission from the Corps for any work within the landward boundary of the City of Virginia Beach owned easements to 500 feet into water.

9.4. SUMMARY OF ADDITIONAL FEEDBACK

The following provides a summary of additional feedback provided outside of the meeting or GoogleForm survey. This feedback was recorded as notes during individual follow-up phone conversations with agencies or provided directly through email.

- USEPA Region 3
    - Unable to provide detailed feedback at this time, but would like to stay informed as the effort progresses and more information becomes available.
    - As discussed during the October 29th 2020 meeting, the resource agencies could use additional information regarding resources in the vicinity of each proposed alternative to better evaluate potential resource impacts and trade-offs. It would be helpful if you can provide additional information regarding resources, including habitat types, sediment transport, benthic communities, submerged aquatic vegetation, mudflats, potential impacts to navigation, and other resources.
    - We generally recommend against projects that would adversely impact special aquatic resources, particularly large wetland impacts, such as the approximately 25-acre tidal wetland impact associated with the artificial inlet.
    - While EPA prefers and promotes nature-based solutions such as marsh creation, it is critical that any potential habitat trade-offs are considered early in the process. We also recommend evaluating combinations of projects that may leverage smaller engineered structures with marsh restoration.
    - Some areas where we have questions include:
        - Are there temporary or permanent wetland impacts associated with the siphon? If so, what are they? What design/construction methods will be utilized and how may they result in temporary/permanent impacts to aquatic resources?
        - What are the potential ecological impacts, such as entrainment, from the inverted siphon and pump facility?

        - How will target areas be sited for each of the alternatives? What factors will be considered to identify specific locations for each of the alternatives?
    - In addition to the marsh creation concept, we recommend consideration of thin layer application to restore and expand the existing marshes. Thin layer application could expand the existing marsh, provide flood attenuation, and restore the natural vegetative community. As indicated in our comments for the marsh terrace project, several Natural Wildlife Refuges have completed thin layer application projects to restore marshes, build coastal resilience, and support bird communities that require specific marsh habitat.
- VADEQ
    - The responses provided in the survey capture VDEQ's feedback.
    - The analysis is not detailed enough to provide more formal comments.
- VADCR
    - As a non-regulatory agency, DCR defers to the determinations of VMRC/NOAA at this point. Too little information to determine impacts or make any determinations as to the project; Noted that a combination of the alternatives was discussed but that added further uncertainty regarding what the impacts would be (what combination of alternatives might be used?)
    - DCR primarily attended to listen and determine potential impacts to Natural Heritage resources (notably the Natural Area Preserve and Recreational Resources within False Cape State Park)
    - Goal of project is good, agrees with need to address flooding
    - But overall, it is too early for them to weigh in on process, still too many unknowns, would need a project plan to evaluate
- NOAA Fisheries
    - Primary concern is existing submerged aquatic vegetation/fisheries habitat. Trade-off of habitats is an important consideration. How do current habitats function? What might be lost? Where are structures proposed and can they be placed to avoid submerged aquatic vegetation habitat? (Similar feedback was offered during the Marsh Restoration scoping meeting)
    - Had questions about modeling used to identify flooding reductions. How are/were models vetted? Needed more background information.
    - Artificial Inlet option did not seem feasible; huge impacts, a lot of unknowns
    - Inverted syphon/pump facility – concerned about freshwater inputs into ocean, but not a fatal flaw, could have conversations to determine mitigation etc.
    - Shares same general outlook of Chad Boyce/DWR regarding Back Bay

    habitat/wildlife impact concerns

  - Though not a primary factor in NOAA’s project evaluations, cost/benefit of project important to look at. How many people are regularly impacted by flooding events (are they more rural areas)? What will total cost of project be?

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