Prepared for

Town of North Beach
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North Beach Compound Flood Action Plan

DRAFT REPORT

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Prepared by

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EXECUTIVE SUMMARY

The Town of North Beach (Town) is a 220-acre community located on the western shore of the Chesapeake Bay in Calvert County, Maryland. The town has approximately 0.83 miles of shoreline along the Chesapeake Bay and features marsh areas at the northern and southern border of the town's limits. In recent years, the effects of heavier, more frequent flooding due to compound flooding events (i.e., nuisance street-level flooding, more severe damage to homes, vehicles, and critical infrastructure, and increased pollutant runoff into the Chesapeake Bay and adjacent wetlands) have encouraged efforts to develop a more holistic understanding of urban flood patterns and critical areas within the coastal community. BayLand Consultants & Designers, Inc have been tasked with investigating existing concerns and their exacerbation due to sea level rise and increasing precipitation to develop and prioritize flood mitigation strategies of critical flood areas. The study is divided into six overarching tasks:

- Task 1 – Project Initiation
- Task 2 – Information Gathering
- Task 3 – Identify Challenges
- Task 4 – Develop Flood Mitigation Strategies
- Task 5 – Identify Funding Sources
- Task 6 – Developing the Compound Flood Action Plan

Task 1 included coordinating Town representative, stakeholder, and grant funding agency requirements and project objectives. A Quality Assurance Project Plan (QAPP), in accordance with the Environmental Protection Agency (EPA) requirements, was developed to ensure subsequent task requirements adhere to outlined quality standards.

Task 2 examined site conditions at the Town including the existing shoreline protection and flood mitigation measures, elevations, habitat, and storm drainage infrastructure. A field assessment to document drainage characteristics (e.g., flow patterns, flooding, and erosion),note coastal flood extents and signs of deteriorating stormwater and coastal infrastructure was used to determine survey areas for critical elevations of roadways and drainage and coastal infrastructure.

Task 3 identifies areas at risk of flooding due to system deficiencies in the existing stormwater and coastal infrastructure for the conditions determined in Task 2. Five subtasks as described herein.

First, hydrologic and hydraulic and coastal analyses were performed to identify and categorize deficiencies of existing stormwater and coastal infrastructure.

Second, critical areas were prioritized based on evaluated impact of specific flood stressors from stormwater, tidal, and storm surge flooding due to current and future conditions, including:

- Deficiencies in the stormwater infrastructure and/or coastal flood protection system

- Low-lying elevation
- Erosion
- Soil conditions and/or high water tables
- Land subsidence
- Areas of significant impervious coverage.

Third, the Town identified twelve High Priority Areas (HPA) that have significant flooding issues. The community also provided feedback on additional areas during and subsequent and/or pursuant to the public presentation and a community survey.

Fourth, the vulnerability of each identified at-risk area was evaluated based on the following criteria:

- Exposure to flooding (how likely will the area flood?)
- Sensitivity to flood damage (what is the extent of damage due to flooding?)
- Adaptive capacity (how easily can the HPA adapt to more intense or frequent flooding?)

Fifth, the vulnerability evaluation coupled with probabilistic return period of the flooding threat to the HPAs was used to rank the areas in a prioritization table for project implementation, shown in the Table below.

HPA PRIOITIZATION TABLE	
Priority	**Assessment Area Description**
1	7th Street between Bay, Annapolis and Atlantic Avenue
2	5th Street between Chesapeake Avenue and Bay Avenue
3	Atlantic Avenue
4	9th Street between Chesapeake Avenue and Atlantic Avenue
5	Bay Avenue between 5th and 7th
6	Annapolis Avenue between 7th Street and 9th Street
7	Chesapeake Avenue between 4th Street and 6th Street
8	Dayton Avenue between 3rd Street and 6th Street
9	1st Street between Chesapeake Avenue and Bay Avenue
10	Frederick Avenue between 3rd Street and 4th Street
11	Greenwood Avenue and 8th Street
12	Burnt Oaks North Apartments
13	Other Areas Identified by Community Input

Task 4 developed nature-based, structural, and management options to mitigate the flood risk at the 12 HPAs. Hydraulic analyses and developed flood maps were used to address the effectiveness of various mitigation strategies, as appropriate, and inform the alternative analysis, which was used to compare alternative mitigation strategies. Concept alternatives based on four risk management techniques – Risk Tolerance, Risk Prevention, Risk Transfer and Risk Treatment – were developed to examine a range of options for combating the risk and/or effects of flooding. These alternatives were evaluated in a decision matrix to identify the preferred alternative. Concept-level designs for the preferred alternatives were prepared and put into a flood mitigation Implementation Plan.

IMPLEMENTATION PLAN

A total of seventeen projects were developed to address the flooding at the areas listed in the HPA prioritization table. To reduce the risk of flooding, projects categorized as 'Immediate Implementation' should be completed in the next 0 – 10 years, projects categorized as Mid-Term Implementation should be completed in 10 – 20 years, and project categorized as Long-Term Implementation should be completed in +20 years.

IMPLEMENTATION PLAN		
Project	**Description**	**Cost**
Immediate Implementation		
1	Seawall and Revetment at Atlantic Avenue	$7,910,400
2	Construct Earthen Dike at Marsh NW of Bay Avenue	$912,060
3	Stormwater System Upgrades at Atlantic Avenue	$49,632
4	Stormwater System Upgrades at 9th Street	$313,296
5	Stormwater System Upgrades at 7th Street	$635,880
6	Stormwater System Upgrades at 5th Street	$255,000
7	Installation of Seawall and Revetment along Boardwalk	$1,916,400
	Total Implementation Cost	**$11,992,668**
Mid-Term Implementation		
8	Heighten Earthen Dike at end of Annapolis Avenue	$418,800
9	Installation of Seawall within Beach Area	$4,845,000
10	Stormwater System Upgrades at Annapolis Avenue	$49,920
11	Stormwater System Upgrades at Bay Avenue	$71,400
12	Stormwater System Upgrades at Chesapeake Avenue	$171,000
13	Stormwater System Upgrades at Dayton Avenue	$462,600
14	Stormwater System Upgrades at Frederick Avenue	$540,720
15	Stormwater System Upgrades at Greenwood Avenue	$103,200
	Total Implementation Cost	**$6,662,640**
Long-Term Implementation		
16	Revetment Enhancement along Boardwalk	$2,958,240
17	Stormwater System Upgrades at 1st Street	$85,320
	Total Implementation Cost	**$3,043,560**

Using the predicted implementation costs, Task 5 identified funding sources to alleviate undue financial burden on the Town of North Beach. Various funding and implementation strategies are presented.

Task 6 presents the culmination of all work completed in the development of this Compound Flood Action Plan.

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Comprehensive Flood Mitigation Grant Program	CFMGP
Comprehensive Flood Mitigation Grant Program Disaster Recovery	CFMGP DR
Comprehensive Flood Mitigation Grant Program Mitigation	CFMGP MIT
Department of Housing & Urban Development	HUD
Department of Natural Resources	DNR
Digital Elevation Model	DEM
Eastern Shore Regional GIS Cooperative	ESRGC
Emergency Watershed Protection	EWP
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Maryland Environmental Resources and Land Information Network	MERLIN
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North American Vertical Datum of 1988	NAVD88
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Risk Management Strategies	RMS
Runoff curve number	RCN
Sea Level Rise	SLR
Storm Water Management Modal	SWMM
Technical Release 55 or 20	TR-55 or TR-20
U.S. Army Corps of Engineers Coastal Engineering Manual	USACE CEM
United State Geological Survey	USGS
United States Department of Agriculture	USDA

DEFINITIONS

1% Annual Chance Storm Surge – A storm surge with a 1% probability of occurring or being exceeded on an annual basis.

10% Annual Chance Storm Surge – A storm surge with a 10% probability of occurring or being exceeded on an annual basis.

1-year Storm – A rainfall event anticipated to occur on an annual basis.

10-year Storm – A rainfall event with a 10% probability of occurring or being exceeded on an annual basis.

100-year Storm – A rainfall event with a 1% probability of occurring or being exceeded on an annual basis.

Compound Flooding – Flooding that occurs due to two or more flood hazards (i.e. coastal and rainfall)

Contingency – Amount of funds included due to uncertainties that are inherent in the planning-level cost estimating process.

Return Period – a duration of time (typically years) which corresponds to a probability that a given value would be exceeded at least once within a year.

Revetment – sloped, onshore structures with the principal function of protecting the shoreline from erosion caused by wave action, storm surge and currents,

Storm Surge – a rising of the stillwater level as a result of atmospheric pressure changes and wind associated with a storm.

Stormwater – any precipitation in an urban or suburban area that does not evaporate or soak into the ground, but instead collects and flows into storm drains, swales, and/or waterways.

Tailwater – Water located immediately downstream of a structure (i.e. storm drain outfall)

Wave Overtopping – the amount of water flowing over the crest of a coastal structure such as a seawall, dike, or breakwater due to wave action.

1. INTRODUCTION

The Town of North Beach (Figure 1), the northern most coastal community of Calvert County, MD, is home to approximately 2,600 residents. Advertised as a saltwater resort town since its incorporation in 1910, the Town continues its legacy today as a center for beach-going, bay-watching, and nature viewing.

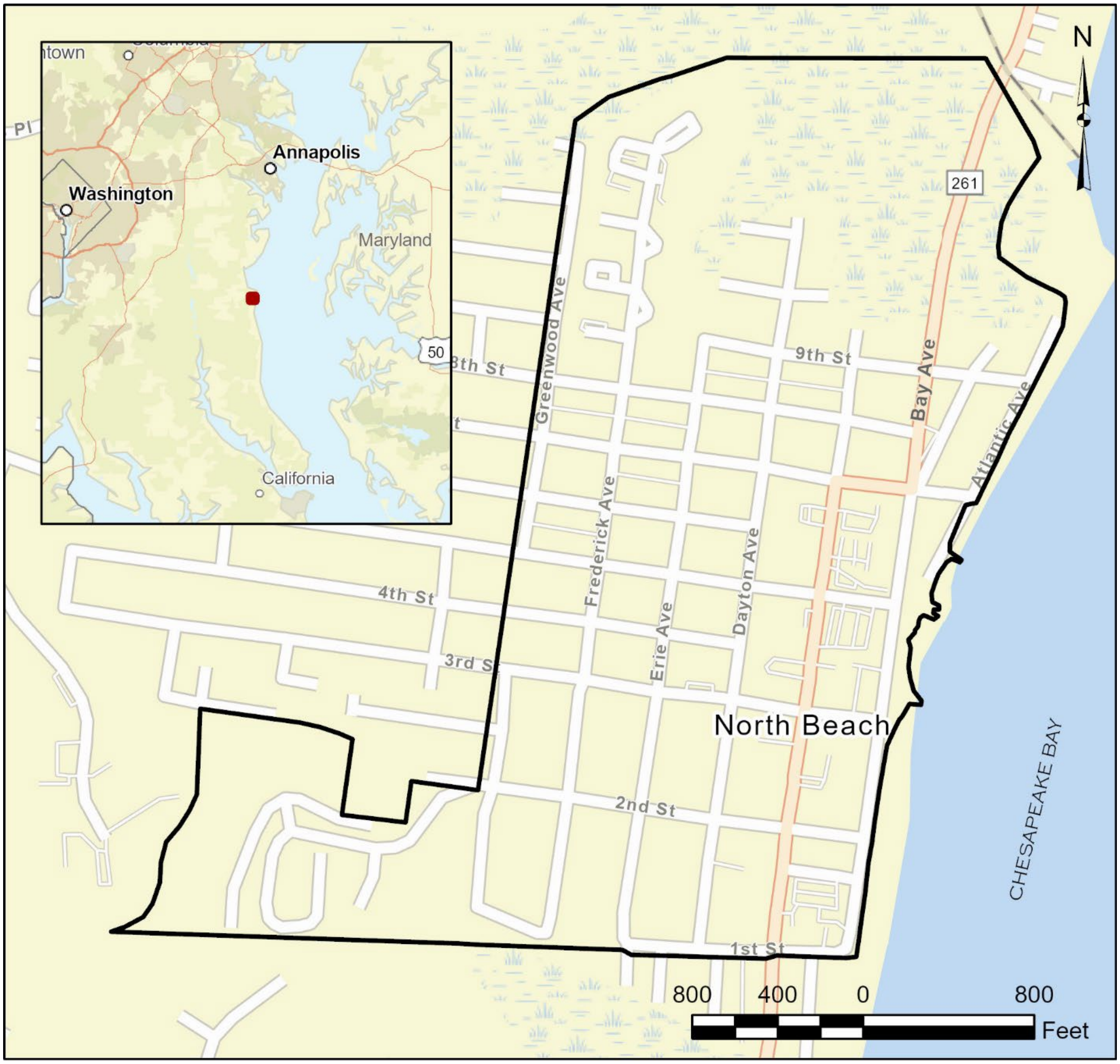


Figure 1 - Study Limits

Though the Town started as a seasonal hub for summer activities, it has since become the permanent residence of an overwhelming majority of its population. Town attractions including the boardwalk, sandy beach, businesses, and nature preserves are low-lying and threatened by more frequent and intense compound flooding events. The looming threat of sea level rise (SLR) and increasing precipitation due to climate change only worsens flooding frequency and magnitude of these events.

The Town of North Beach experiences frequent flooding from storm event surge levels, wave overtopping, and heavy rainfall causes damage to infrastructure and property, impedes travel routes, and diminishes the quality of life for residents and tourists. In recent years, North beach has experienced more frequent rainfall-induced flooding coupled with more severe coastal flooding due to extreme storm events. Street-level flooding in urban environements can cause physical damage to valuable infrastructure overwhelmed by compound flooding volumes, economical strain on local businesses benefitting from tourist economy, and ecological harm to important habitat threatened by prolonged inundation and polluted runoff.

Photo 1 – Flooding along Atlantic Avenue

Photo 1 - Rainfall-induced Flooding at Bay and Atlantic Avenue

Photo 2 – Tropical Storm Isaias Flooding along Bay Avenue

Photo 3 - Flooding from Storm Surge

It is important to note this Flood Action Plan only focuses on the vulnerabilities within the Town to compound flood risks. The effects of other coastal resiliency stressors, such as erosion and saltwater intrusion, were not within the scope of this study.

2. EXISTING CONDITIONS

Data specific to North Beach was collected from Town archives, community input, State LiDAR, County GIS and as-built data, the Maryland Environmental Resources and Land Information Network (MERLIN), and the Maryland Department of Natural Resources (DNR) Coastal Atlas. This data, in addition to field collected data, were analyzed to develop an understanding of the response of the existing site conditions to observed flooding to inform how the current system will respond to the effects of climate change.

2.1. Topography

Topographic data for North Beach was obtained from a digital elevation model (DEM) produced by the United States Geological Survey (USGS) and the National Resource Conservation Service (NRCS). The DEM was processed in 2017 and utilized Light Detection and Ranging (LiDAR) data flown for Calvert County. The data has an approximate resolution of 0.3 meter (0.98 feet) with a point spacing of 0.35 meters (1.1 feet and vertical accuracy of 12.3 cm (4.8 inches). The elevations of the study area are shown in Figure 2.

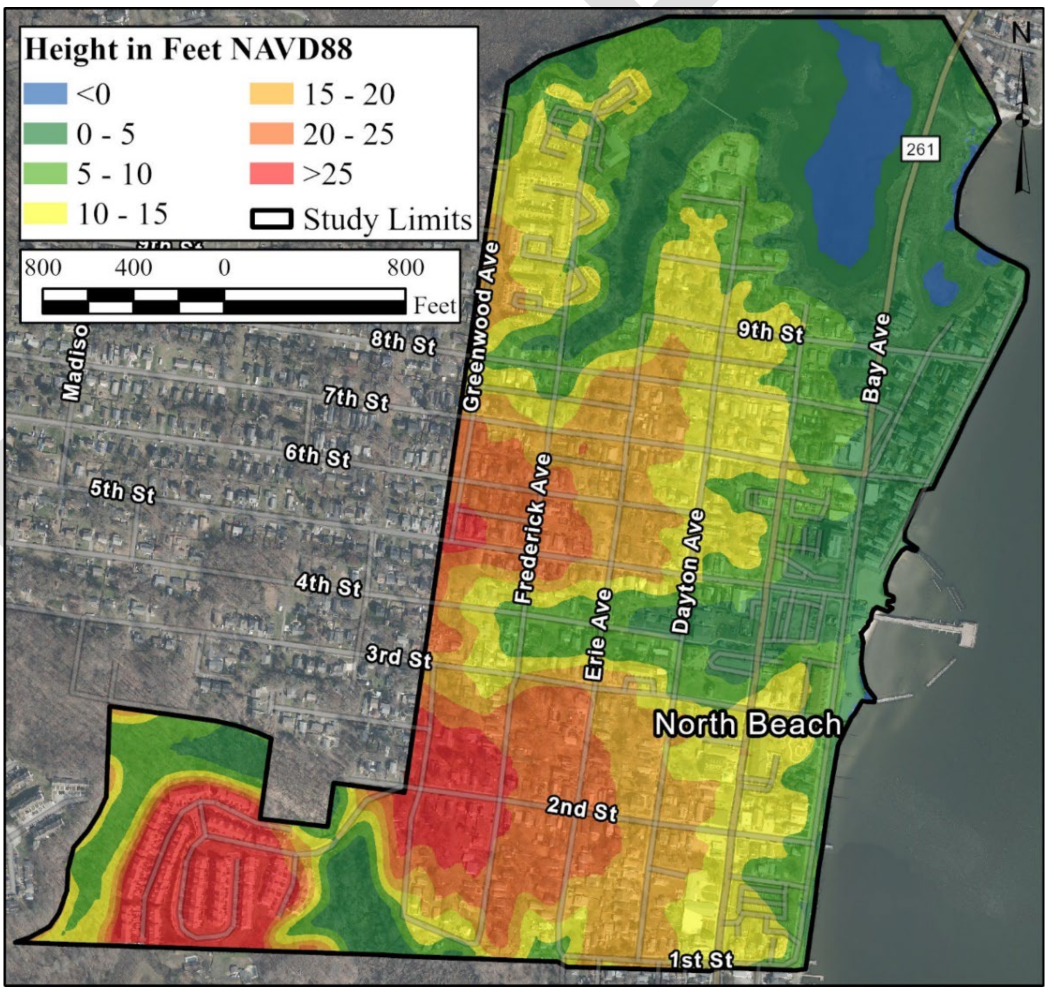


Figure 2 - Elevations within the Town of North Beach

Elevations within the town limits vary between 0 and +70 ft North American Vertical Datum of 1988 (NAVD88). Elevations appear to increase moving landward, with the highest elevation present in the southwestern portion of the Town (the San Francisco on the Bay community). The lowest elevations are located near the shoreline and in the natural marsh areas from both the northern and southern limits of the Town. The highly developed areas of lowest elevations are located between Atlantic Avenue and Bay Avenue. Low areas also exist near the shoreline by the beach area along Bay Avenue around 5th and 7th Streets.

2.2. Shoreline Features

The shoreline along the eastern edge of the town features various shoreline protection structures including breakwaters, revetments, and an earthen berm (Photos 5-10). The breakwaters protect the town recreational beach while revetment lines the eastern shoreline. Natural marshes and a living shoreline (stone structures and marsh) border the northern limits of the town. An earthen berm surrounds the marsh located between the living shoreline just west of the Atlantic Avenue revetment and Bay Avenue. Figure 3 maps the location of shoreline features within the study limits. Existing coastal protection is stressed during current storm events and will become more susceptible to the effects of sea level rise.

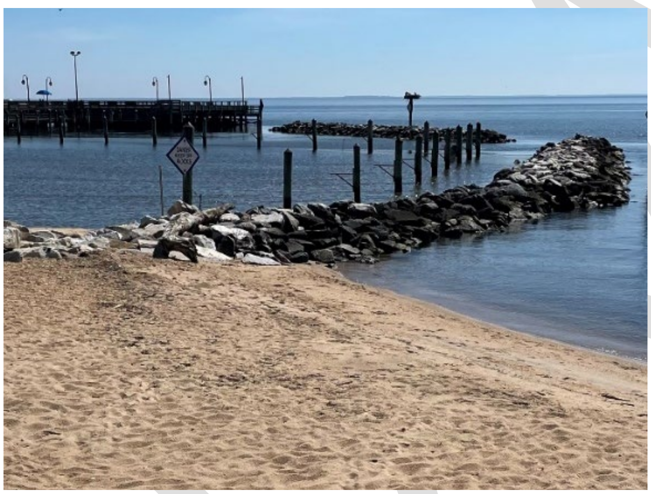


Photo 4 - Town Beach Protected by Breakwater System

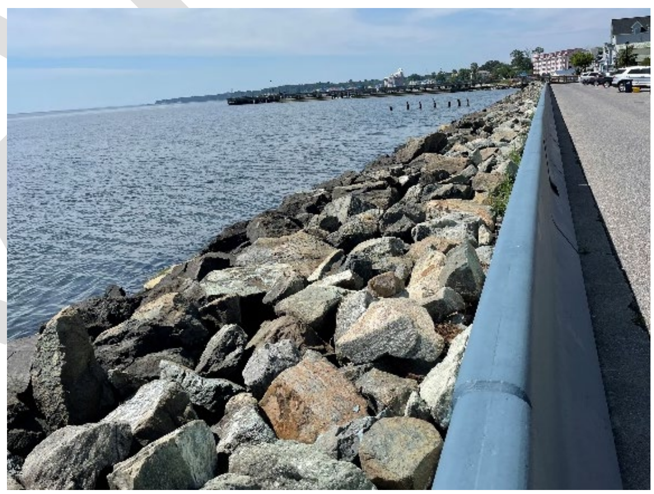


Photo 5 - Jersey Barriers & Revetment along Atlantic Avenue

Photo 6 - Earthen Berm between Bay and Atlantic Avenue

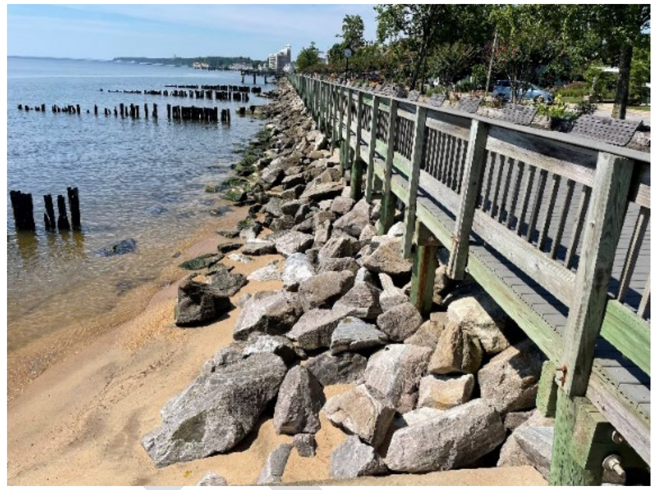


Photo 7 - Revetment along Boardwalk

Photo 8 - Marsh area along Northern Town Limit

Photo 9 - Living Shoreline at Northeastern Town Limits

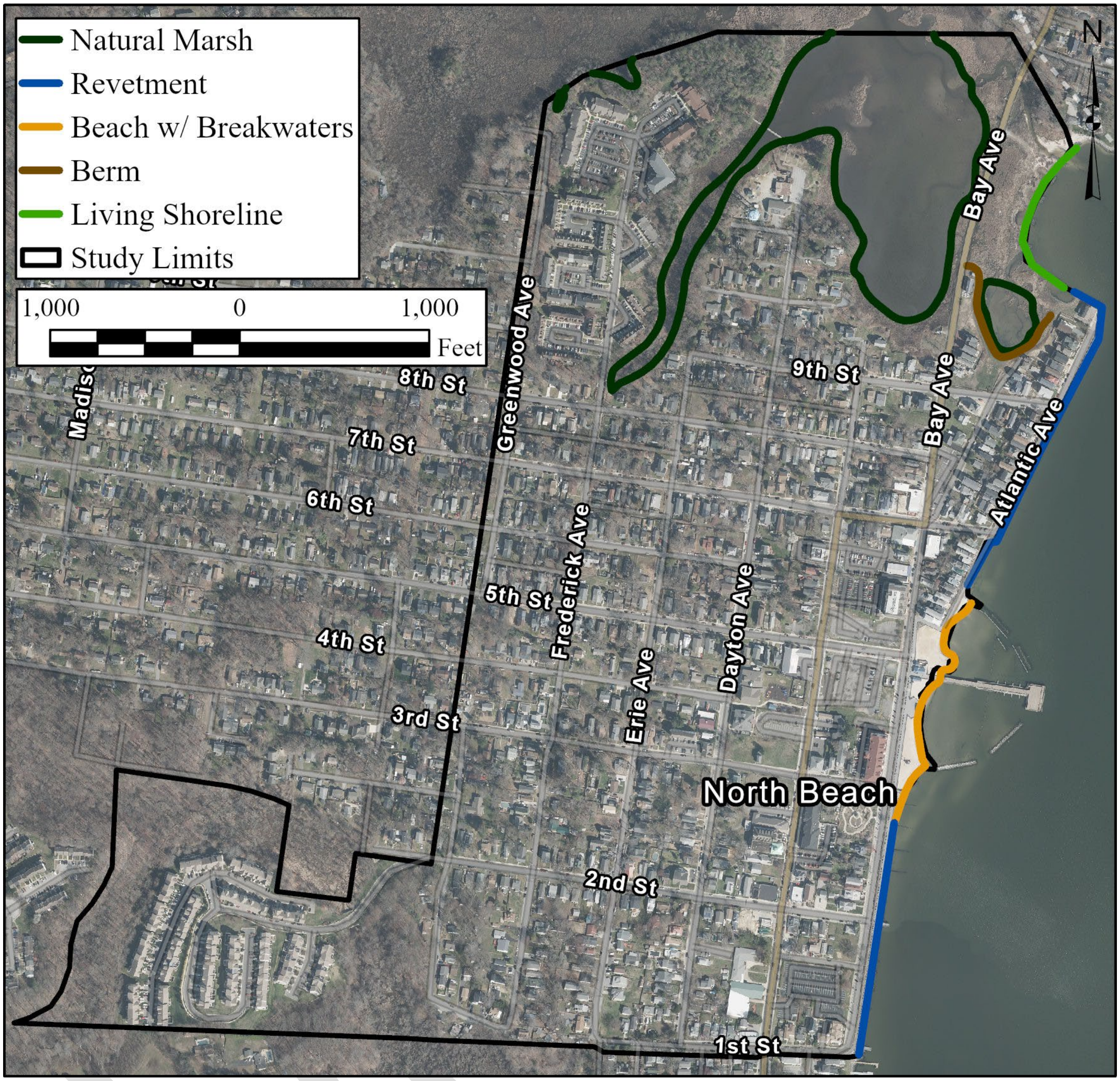


Figure 3 - Existing shoreline features

2.3. Drainage System

A field assessment was conducted to verify Town provided as-built drawings for the drainage system. Additional structures were mapped and structures requiring topographic survey for critical elevations (i.e. top of grate/manhole rim, pipe size/inverts; swale, curb, road elevation, etc.) were identified. The assessment also documented drainage characteristics, identified surface visible infrastructure deterioration and failure, and documented suitable locations for new infrastructure, green infrastructure best management practices (BMP), and other solutions to provide flood relief.

The Town's largest drainage system originates at the Town boundary of Greenwood Avenue and 4th Street and discharges through the 5th Street pumping station outfall.

Approximately 80 acres ultimately discharge at the 5th Street outfall, half of which is upstream County runoff. Approximately 18 outfalls in total discharge stormwater runoff around the Town and ultimately into the Chesapeake Bay. The drainage system to these outfalls generally consists of shorter segments of strain drain infrastructure with some conveyance swales.

Data collected in the field and desktop analysis revealed deficiencies in much of the areas experiencing frequent flooding. Approximately 15 of these outfalls discharge at the tidal interface, the majority below mean low water and lack tide gates. This enables perpetual backwatering and promotes sedimentation within the system, thereby reducing the functional capacity of the system. The majority of existing infrastructure is also reaching its life expectancy and is undersized to handle today's storm events. Undersized drainage systems combined with reduced capacity from tidal backwatering and sedimentation has led to increased frequency and duration of flooding of Town roadways and adjacent private properties (*Photo 10 – Photo 14*). Secondary damage to infrastructure, such as widespread pavement damage, has also occurred as a result of the reoccurring flooding (*Photo 15*).

A conditions assessment for the structural integrity and remaining life expectancy of the storm drain infrastructure was not included as part of this drainage assessment.

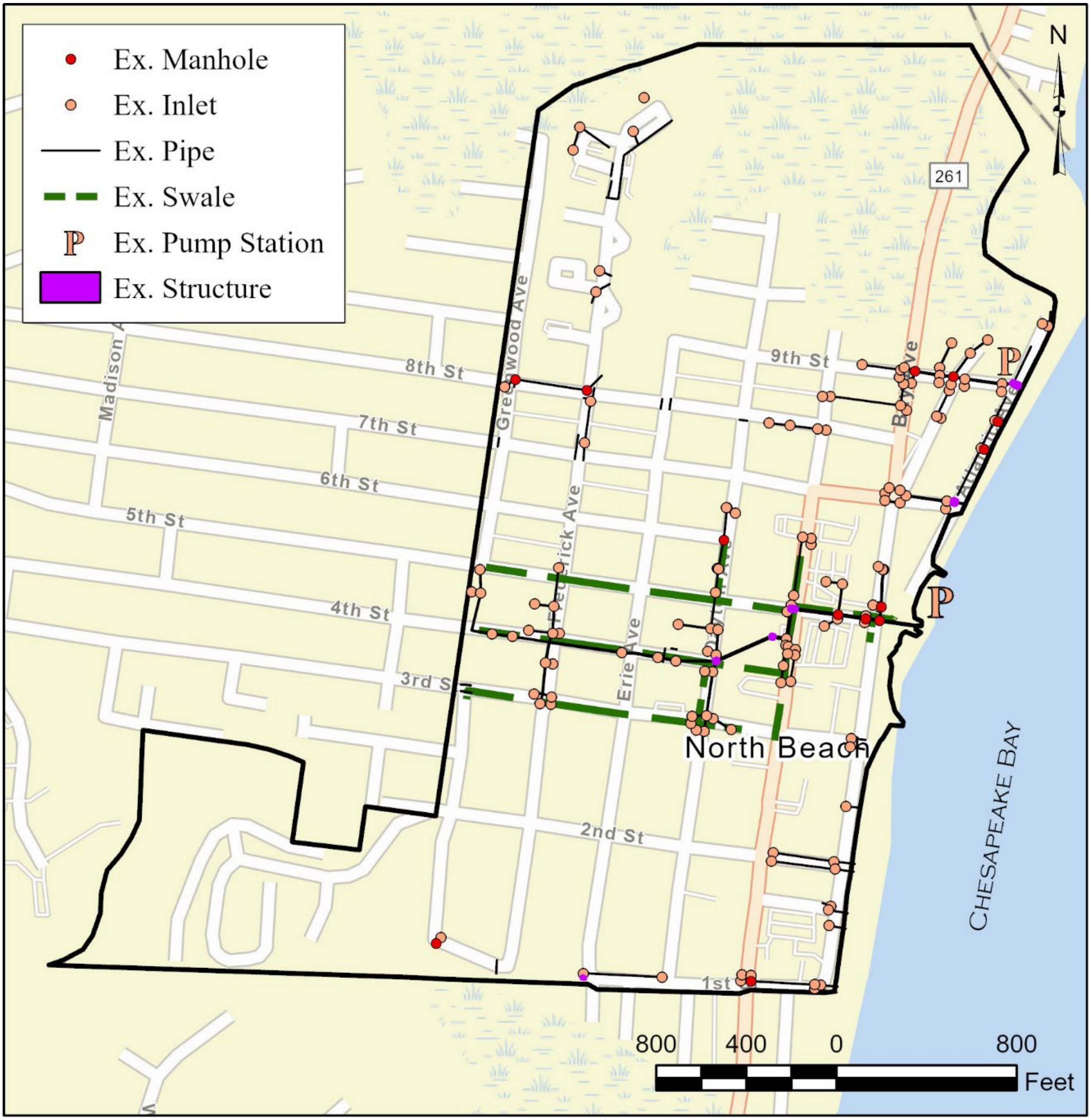


***Figure 4 - Drainage System*[1]**

[1] Note – Existing conditions hydraulic model simulates new 5th Street Pump Station

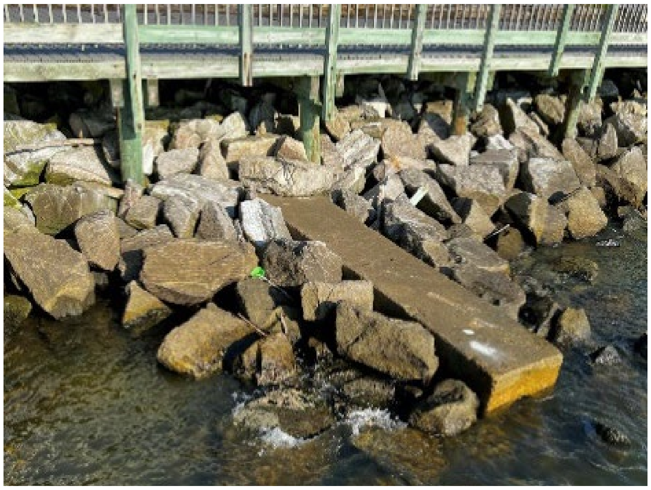


Photo 10 - Outfall Perpetually Backwatered

Photo 11 – New 5th Street Pump Station Outfall

Photo 12 - Backwatered System with Trash

Photo 13 - Inlet Clogged with Debris

Photo 14 – New 5th Street Pump Station Duckbill Valve

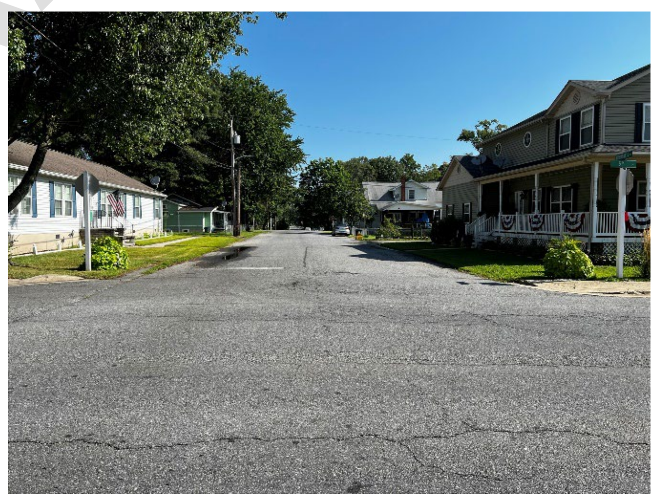


Photo 15 - Pavement Damage

3. FLOODING ANALYSIS

For the purpose of this analysis, flooding was divided into three categories:

1. Flooding due to High Water Levels – when the coastal water level rises higher than the adjacent land, water will inundate the area. For this study, increases in water level due to sea level rise (SLR) and storm surge were evaluated.

    a. SLR – flooding that occurs due to an increase in still water level (water level not including waves) as a result of climate change. With an increase in still water level, areas that have previously not flooded or only flooded during higher-than-usual water levels will become inundated more frequently.
    b. Storm Surge – flooding that occurs due to an increased water level during a storm event. Storm events, such as hurricanes, bring low pressure and high winds that raise the water level along the shoreline, resulting in coastal flooding of areas below the storm surge level.

2. Flooding due to Wave Overtopping – flooding that occurs when static water levels may not be high enough to encroach onto land, but waves overtop structures or runup slopes and deposit water in inland areas. This flooding is typically constrained to areas immediately adjacent to the shoreline.

3. Heavy Rainfall Flooding – flooding that occurs during a period of intense rainfall. This flood event is not associated with coastal water levels. It results from a high intensity rainstorm or 'flash flood' that dumps a large amount of precipitation in a short enough period of time to prevent proper runoff. It can also occur due to prolonged rainfall that has overwhelmed the drainage system. This type of flooding is anticipated to increase in frequency with SLR as a higher static coastal water level may not allow the outfalls to discharge the stormwater, resulting in backwatering of the system. The intensity and frequency of rainfall events is also expected to increase due to factors associated with climate change, which can overwhelm existing storm drain systems from the increased runoff volume.

3.1. Water Levels

A description of the flooding analysis for each type of water level flooding is provided in the sections below.

3.1.1. Sea Level Rise (SLR)

SLR is the increase of average water levels. It is divided into two categories based on contributing factors:

1. Global Sea Level Rise – increase in the global sea level based on the thermal expansion of water (the size of saltwater molecules increases as it warms up)

and ice melt from the glaciers and continental ice masses adding a significant amount of freshwater into the world's oceans.

2. Relative Sea Level Rise – increase in the local sea level along a specific coast based on global SLR land subsidence (sinking of land), tectonic plate movements and other local factors.

Based on water level measurements taken between 1937 and 2019 at the NOAA Tide Station 8577330 at Solomons Island, MD, sea levels in the lower Chesapeake Bay have risen approximately 1.04 feet in 83 years (~0.15 inch/year).

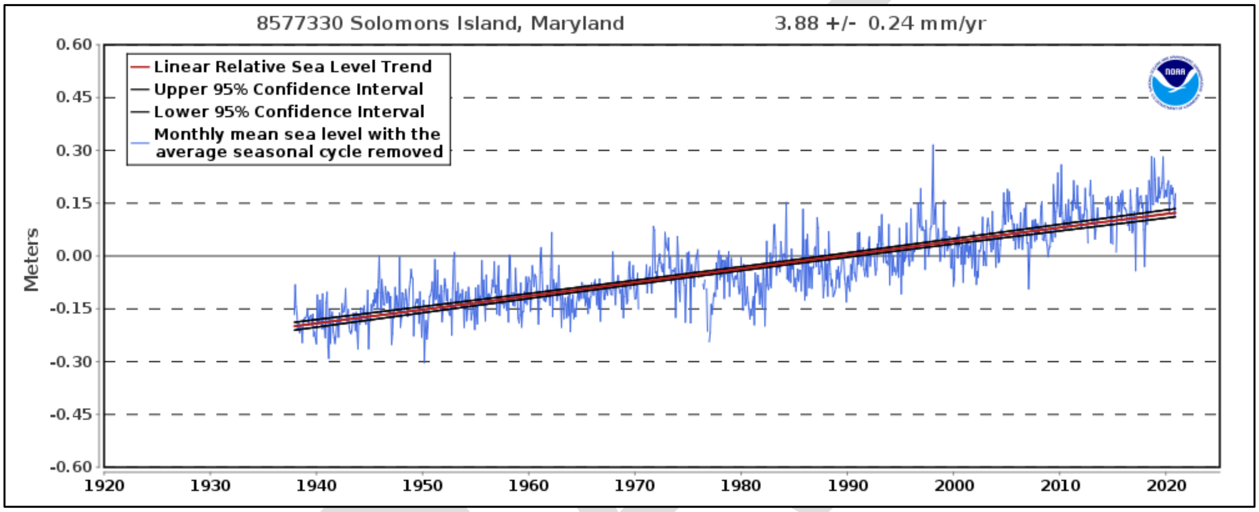


Figure 5 - SLR at Solomons Island between 1937 and 2019

Tide datums, or the average daily water levels experienced during the tidal epoch period between 1983 and 2001 are available from the National Oceanic and Atmospheric Administration (NOAA)-operated Tide Station 8577330 in Solomons Island, MD (Table 1).

Table 1 - Tidal Datums at Station 8577330 Solomons Island, MD

Datum	Water Elevation (ft NAVD88)
Mean Higher High Water (MHHW)	0.63
Mean High Water (MHW)	0.48
North American Datum of 1988 (NAVD88)	0.00
Mean Sea Level (MSL)	-0.09
Mean Low Water (MLW)	-0.69
Mean Lower Low Water (MLLW)	-0.85

Storm surge flood analysis and mapping was performed by the Eastern Shore Regional GIS Cooperative (ESRGC). The full report documenting the methodology used and the results of the flood mapping is attached as Appendix A. The extents of water levels in the years 2030, 2050, and 2100 were mapped using Maryland SLR projections by Robert Kopp of Rutgers University, a leading climate scientist specializing in identifying appropriate regional sea level change projections. More information on the selection of SLR projections for this study is provided in the ESRGC report (Appendix A). SLR predictions at Soloman's Island, MD are shown in Table 2. These projections are based on a 5% probability of occurrence which, though conservative, are appropriate for planning purposes.

Table 2 - SLR Estimates Solomon's Island*	
Year	**SLR Projection:**
2030	1.3 feet
2050	2.4 feet
2100	7.0 feet

* Data provided by ESRGC (*Flood Analysis and Mapping: Technical Support Methodology, 2022*)[2]

Using these SLR Projections, the ESRGC mapped the flood extent and depths referenced to MSL for each SLR scenario presented in Table 2. The maps and flood depths produced are provided in Appendix A.

3.1.2. Storm Surge

Storm surge is the abnormal rise of water, over and above the astronomical tides, generated by a low-pressure weather system. As a result of these events, water levels can increase by several feet. High winds and waves and extreme rainfall often accompany these elevated water levels and cause significant flooding to coastal areas.

ESRGC accounted for this phenomenon by imposing each of the sea level change projections onto the Federal Emergency Management Agency (FEMA) 1% Annual Chance Storm Surge Flood Elevations of +4.3 feet NAVD88[3]. The following combinations of SLR and storm surge were mapped for the Town on North Beach:

Table 3 - Anticipated Storm Surge at Solomon's Island*			
Year	**1% Chance SLR Projection (feet)**	**1% Annual Chance of Exceedance Storm Surge**	**1% Chance SLR + 1% Annual Chance of Exceedance Storm Surge Water Elevation**
2030	1.3	+4.3 feet NAVD88	+5.6 feet NAVD88
2050	2.4	+4.3 feet NAVD88	+6.7 feet NAVD88
2100	7.0	+4.3 feet NAVD88	+11.3 feet NAVD88

* Data provided by ESRGC (*Flood Analysis and Mapping: Technical Support Methodology, 2022*)[4]

A more thorough explanation of the flood mapping methodology utilized by the ESRGC is included in the ESRGC Flood Mapping deliverable packet, attached as Appendix A.

[2] Eastern Shore Regional GIS Cooperative (ESRGC), (2022). Flood Analysis and Mapping: Technical Support Methodology.
[3] Federal Emergency Management Agency, Flood Insurance Study, Calvert County and Incorporated Areas, Maryland, November 19, 2014.
[4] Eastern Shore Regional GIS Cooperative (ESRGC), (2022). Flood Analysis and Mapping: Technical Support Methodology.

3.2. Wave Overtopping

Wave overtopping occurs when continuous wave action overtops the shoreline and deposits floodwater into a normally dry area. North Beach experiences this type of flooding where beach and natural marsh do not offer protection from waves by dissipating the wave energy before it reaches the shoreline, such as the shoreline along Atlantic Avenue and Bay Avenue south of the town beach.

To analyze the flooding occurring from wave overtopping, extreme wave events were estimated by performing an Extreme Value Analysis (EVA). Wind data from the NOAA Station TPLM2 in Thomas Point, MD, analyzed into a wind rose which groups wind speeds by frequency and direction, is presented in Figure 6.

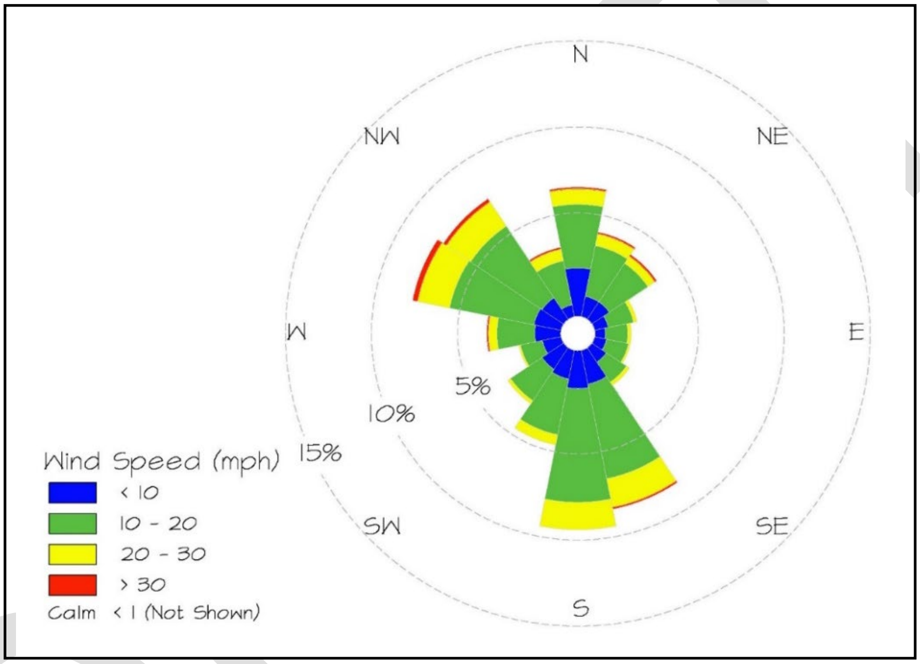


Figure 6 - Thomas Point Lighthouse Wind Rose

Table 4 - Wind Speeds at Thomas Point Lighthouse (TPLM2)	
Return Period (yr)	**Wind Speed (mph)**
2	40.1
10	45.0
100	52.0

Based on wind measurements, the wind frequency of occurrence (Table 4), or approximate length of time between wind speed events, was estimated to calculate the corresponding wave heights. Additionally, wave height is influenced by fetch length, or length of water over which wind blows without obstruction. At North Beach the longest fetch length is 90 miles to the SSE. This direction also corresponds to one of the predominant wind directions (e.g., SSE), as shown in Figure 6. Therefore, it is anticipated that the largest waves impacting the North Beach shoreline will be generated from this direction. The fetch length, wind speed, and predominant wind direction were input into the U.S. Army Corps of Engineers *Automated Coastal Engineering System* (ACES) *Wave Prediction* model to estimate the wave properties (wave height and wave period or frequency) for each return period wind speeds (Table 5).

Table 5 - ACES Wave Parameters

Return Period (yr)	Significant Wave Height - H_{mo} (ft)	Wave Period – T_p (sec)
2	5.87	5.66
10	6.40	6.00
100	7.12	6.44

Wave heights for each of the return periods, or duration of time which corresponds to a probability that a given value would be exceeded at least once within a year, were coupled with storm surge levels obtained from the NOAA Station 8577330 at Solomons Island, MD[5].

Table 6 - Extreme Water Levels at 8577330 Solomons Island, MD

Return Period (yr)	Extreme Water Levels (ft. NAVD88)
1	+2.60
10	+3.25
100	+4.24

Combining the return period wind speed with the return period storm surge level for the 2-year, 10-year and 100-year occurrence frequencies, the estimate wave heights at the shoreline for current and future conditions with SLR are presented in Table 7.

Table 7 - Estimate Wave Height at the Shoreline

Wind Speed & Surge Level Return Period (yr)	SLR Scenario (yr)	Wave Height - H_s (ft)
2	Current	2.47
	2030	2.91
	2050	5.87
	2100	5.87
10	Current	2.57
	2030	3.30
	2050	6.4
	2100	6.4
100	Current	3.45
	2030	3.88
	2050	7.12
	2100	7.12

[5] https://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8577330

Overtopping volumes were calculated following methodology outlined in the U.S. Army Corps of Engineers Coastal Engineering Manual (USACE CEM)[6]. The calculated overtopping volumes for the aforementioned scenarios were then used to classify the traffic and structural safety for each scenario. The results of the analysis are presented in each respective assessment area.

3.3. Hydrologic & Hydraulic Analysis

A hydraulic and hydrologic analysis was performed at study points based on the high priority areas to determine flow patterns and flood extents resulting from rainfall events. The high priority areas are summarized in Section 4.

3.3.1. Hydrologic Analysis

The United States Department of Agriculture (USDA) NRCS Technical Release 55 (TR-55) computer program was used to compute runoff curve number (RCN) for the select study points. The RCN is based on the latest Calvert County GIS planimetric data and USDA Web Soil Survey data. The RCN is determined from the percentages of Open Space, Impervious, and Woods within a drainage area. Soils are classified according to their runoff potential using NRCS Hydrologic Soil Classification, which characterizes the soils and their potential to generate runoff.

These categories range from Hydrologic Soil Group (HSG) A (low runoff, high infiltration) to HSG D (high runoff, low infiltration). The soils in the are primarily HSG B and HSG D soils, resulting in high amounts of runoff and low infiltration (Table 8). The corresponding RCN values were applied to the drainage areas of each study point. The full hydrologic analysis is located in Appendix B.

Table 8 - Soil Summary

HSG	Runoff Rate	Infiltration Rate	Percent of Drainage Area
A	Very Low	Very High	0.0
B	Low	High	27.3
C	High	Low	4.9
D	Very High	Very Low	67.8

Peak discharges for the 1-, 10-, and 100-yr storms in 2030 and 2050 were computed using the NRCS TR-20 computer program. NOAA Atlas 14 Intensity-Duration-Frequency (IDF) precipitation estimates were used with a 24-hour distribution curve to develop runoff parameters The Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) NOAA and RAND Corporation climate projections was then utilized to determine the change factors to the NOAA Atlas 14 IDF data for projected storm events in 2030 and 2050 due to climate change. Change factors were based on

[6] United States. 2006. Coastal Engineering Manual. Washington D.C: U.S. Army Corps of Engineers.

high emissions future Representative Concentration Pathway (RCP) 8.5. and 90th percentile uncertainty range to be consistent with ESGRC sea level rise methodology.

See Appendix B for full hydrologic analysis and peak discharges to select study points.

3.3.2. Hydraulic Analysis

A conceptual-level hydraulic analysis of the storm drain system was performed using the Storm Water Management Model (SWMM) version 5.2, developed by the EPA. EPA SWMM is a 1-dimensional modeling tool; therefore, overflow flooding from one drainage system area (i.e. 7th Street system) into an adjacent drainage system area (i.e. Atlantic Avenue system) is not simulated. The pipe, inlet, and manhole data were taken from the critical elevations obtained during field investigations. Where additional data was necessary for the model, interpolations were assumed based on nearby survey data. Flood duration and proliferation of outfall conditions for storm events were determined based on storm surge and 2030 and 2050 SLR projections discussed in Section 3. Table 9 lists the special conditions and equivalent return periods analyzed for the SWMM scenarios.

Models were developed for existing and proposed conditions for all storm scenarios to demonstrate system behavior based on water levels obtained from the SLR analyses. Data from the SLR analysis was used to establish anticipated semidiurnal tidal cycles for 2030 and 2050. These cycles were utilized for the tailwater conditions at the system outfall locations to the Chesapeake Bay. The peak discharges developed in Section 3.3.1 and MHHW were synchronized to provide more conservative results.

Finally, scenarios were modeled to assuming the effect of proposed pumps and tide valves at major outfalls from the 5th, 7th, and 9th street outfall locations. The 5th street pump station was installed during the development of this assessment and is modeled based on pump station details and operating information provided by the Town. The existing conditions model utilized the as-built plan provided by the Town for the 9th Street pump station. The proposed models for a new 7th Street pump and upgraded 9th Street pump are conceptual and based on several assumptions regarding planned operation parameters subject to detailed topographic survey and engineering analysis. The parameters used are discussed in Sections 8.2 and 8.4.

The full hydraulic analysis is located in Appendix C.

Table 9 - Hydraulic Analysis: Analyzed Storm Scenarios

Storm Event	Tailwater Elevation (ft NAVD88)
1-yr	2030 Tidal Cycle
1-yr	2050 Tidal Cycle
10-yr	2030 Tidal Cycle
10-yr	2050 Tidal Cycle
100-yr	2030 Tidal Cycle
100-yr	2050 Tidal Cycle

4. HIGH PRIORITY ASSESSMENT AREAS

Input from community officials, business owners, and residents highlighted 12 areas of particular concern to the community. These areas currently experience flooding or are believed to be most susceptible to flooding with future conditions. The areas examined in detail in this assessment are presented in Table 10 and Figure 7.

Table 10 - Assessment Areas

ID	Street Intersection
1	Atlantic Avenue
2	9th Street between Chesapeake Avenue and Atlantic Avenue
3	Annapolis Avenue between 7th Street and 9th Street
4	7th Street between Bay Avenue and Atlantic Avenue
5	Bay Avenue between 5th Street and 7th Street
6	5th Street between Chesapeake Avenue and Bay Avenue
7	Chesapeake Avenue between 4th Street and 6th Street
8	1st Street between Chesapeake Avenue and Bay Avenue
9	Dayton Avenue between 3rd Street and 6th Street
10	Burnt Oaks North Apartments Retention Pond
11	Frederick Avenue between 3rd Street and 4th Street
12	Greenwood Avenue and 8th Street
13	Other Areas Identified by Community Input

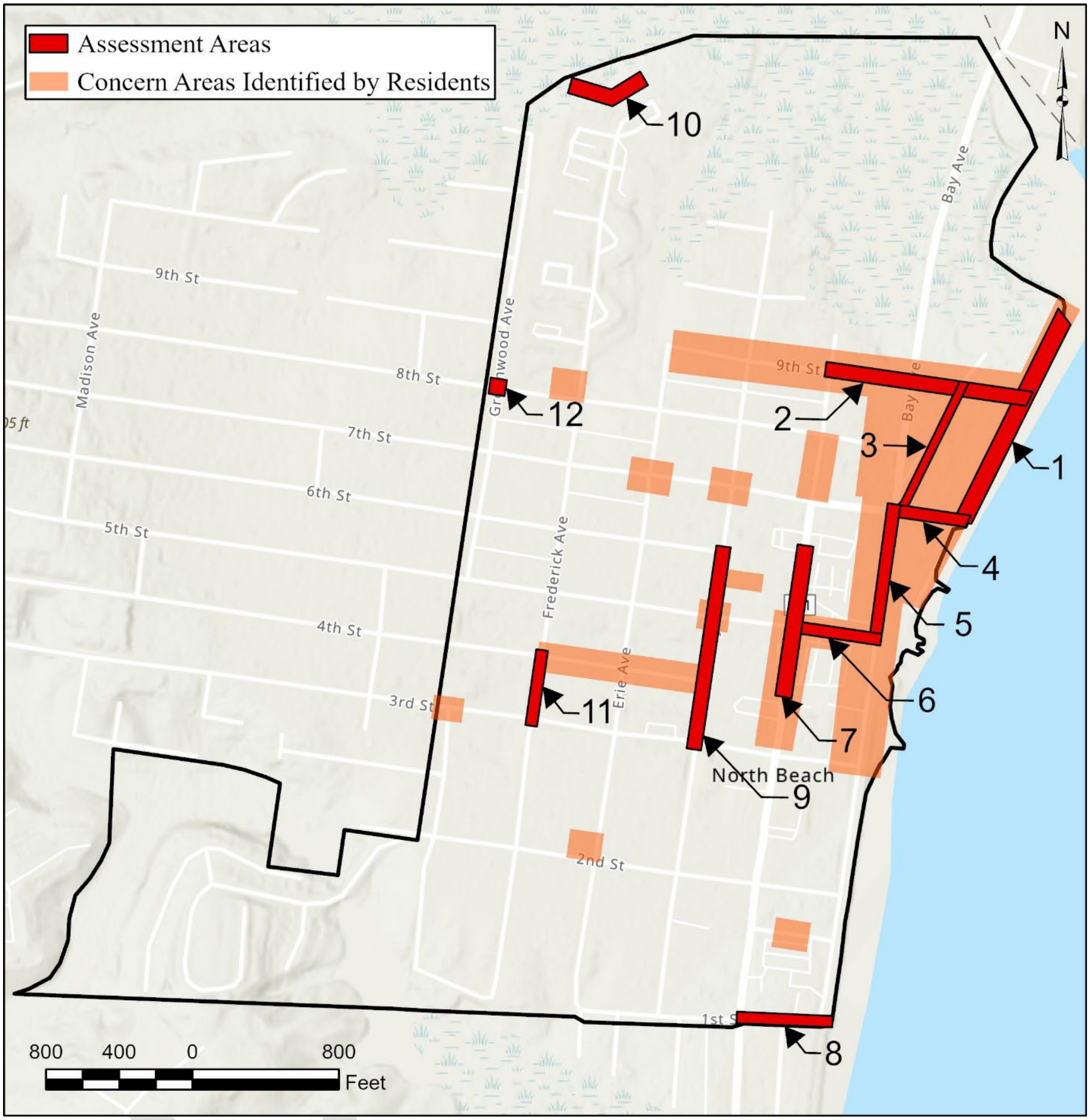


Figure 7 - Prioritized Assessment Areas

4.1. Atlantic Avenue

Atlantic Avenue is located at the northeastern corner of the study limits and runs along the armored shoreline of the Chesapeake Bay. Atlantic Avenue serves as the only access to most of the waterfront homes along this road. A revetment lines the shoreline along the road. The revetment transitions to a stone sill protecting a living shoreline at the northern extent of the Town shoreline. A moderately dense residential area borders the west side of Atlantic Avenue The surveyed elevation of the roadway averages +2.75 feet NAVD88 with lower elevations (approximately +2.25 feet NAVD88) at the northern most part of the street and increasing slightly approaching the intersection at 7th Street (approximately +4 feet NAVD88). An approximate 35-inch jersey barrier lines the edge of the road. The stone revetment was surveyed to have a top elevation of approximately +3.5 feet NAVD88.

The survey conducted shows the road drains towards inlets on the west side of the street. Runoff from Atlantic Avenue is currently collected in undersized slot drains along the sidewalk which transport the collected water to the 9th street stormwater system to be discharged through the revetment at the 9th street outfall.

Photo 16 - Revetment and Jersey Barriers along Atlantic Avenue

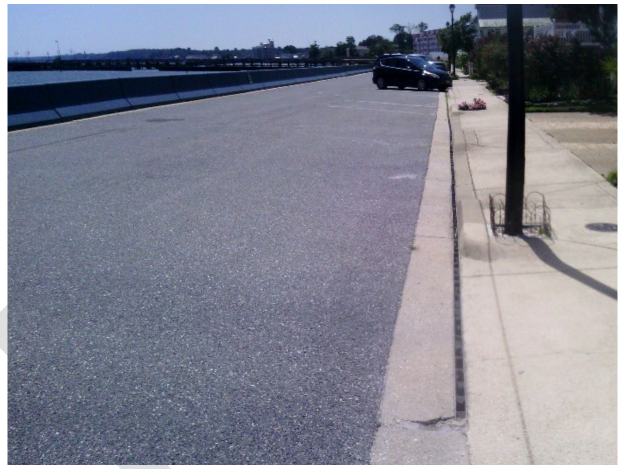


Photo 17- Drainage on West Side of Atlantic Avenue

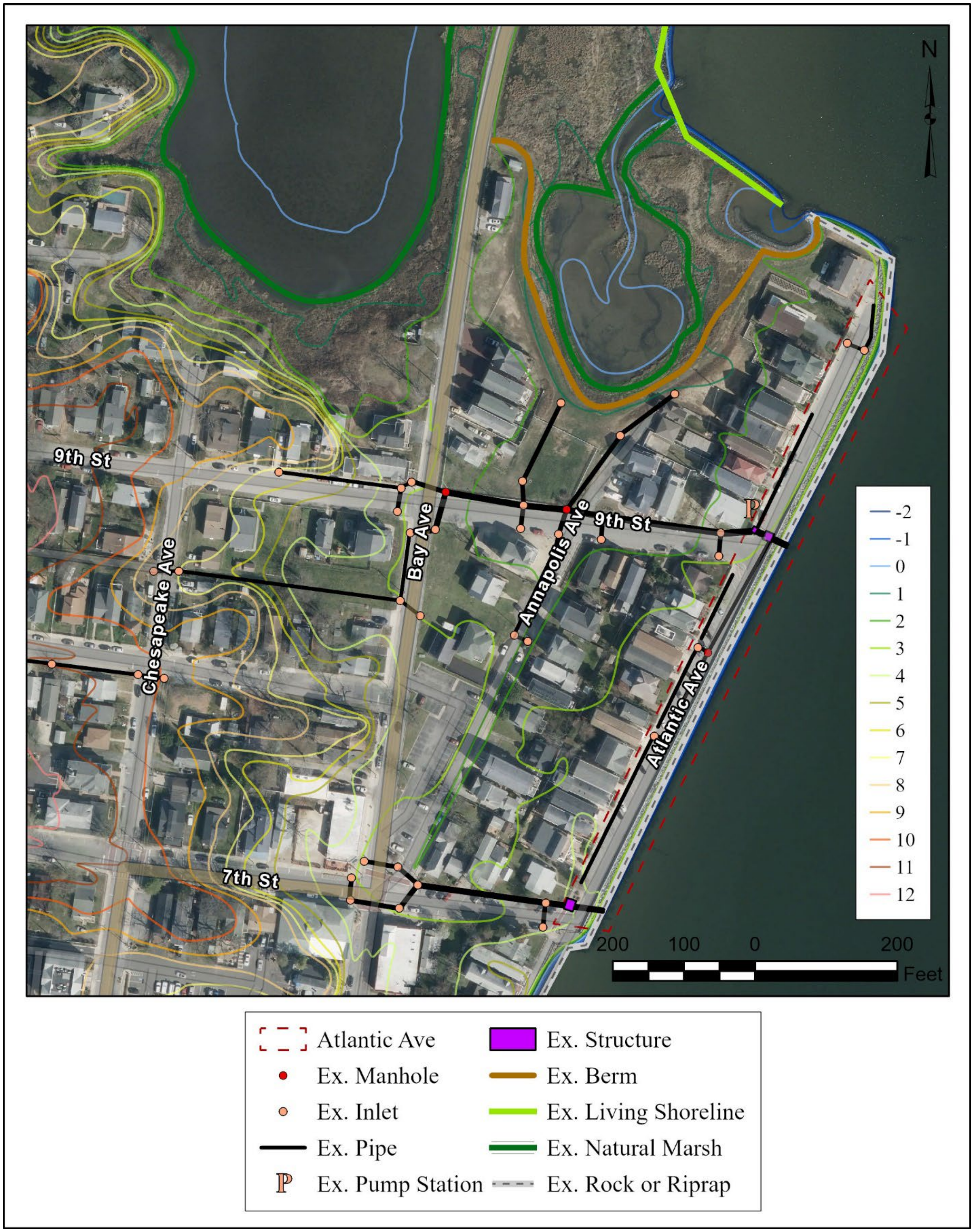


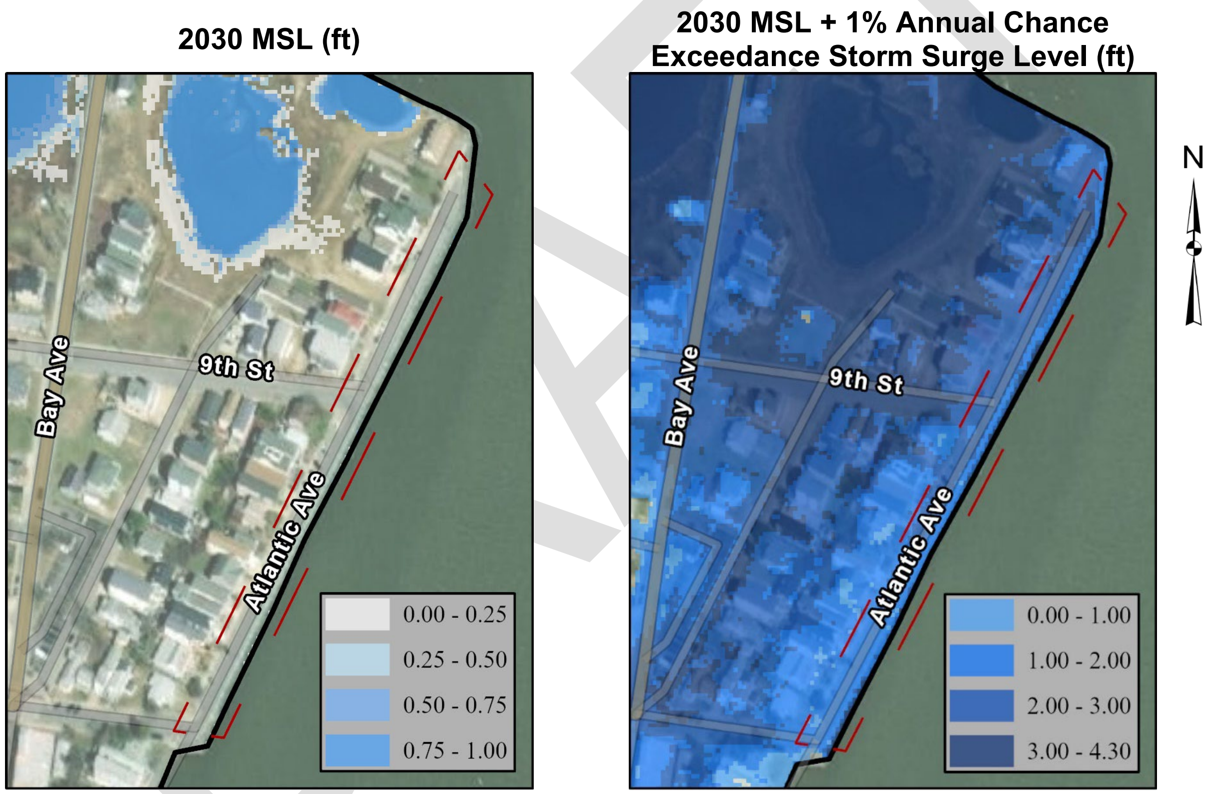
Figure 8 - Atlantic Avenue (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.1.1. SLR and Storm Surge

The flood depths shown in , calculated by the ESRGC, map the flood depths at MSL for each SLR scenario and imposed storm surge level. Atlantic Avenue is threatened by flood waters due to low-lying road elevations and inundation from landward pathways through the marsh and living shoreline areas. The maps presented in show the road and homes along Atlantic Avenue not experiencing flooding due to SLR by 2030. In 2050, water levels may reach the ground level of homes along Atlantic Avenue through the low-lying marshes, however, the road elevation is high enough to prevent daily tidal flooding of the road.

Only Chesapeake Bay MSL elevation in 2100 exceed the elevation of the roadway, and the 1% Annual Chance Exceedance Storm Surge Level imposed on all scenarios floods the entire area.



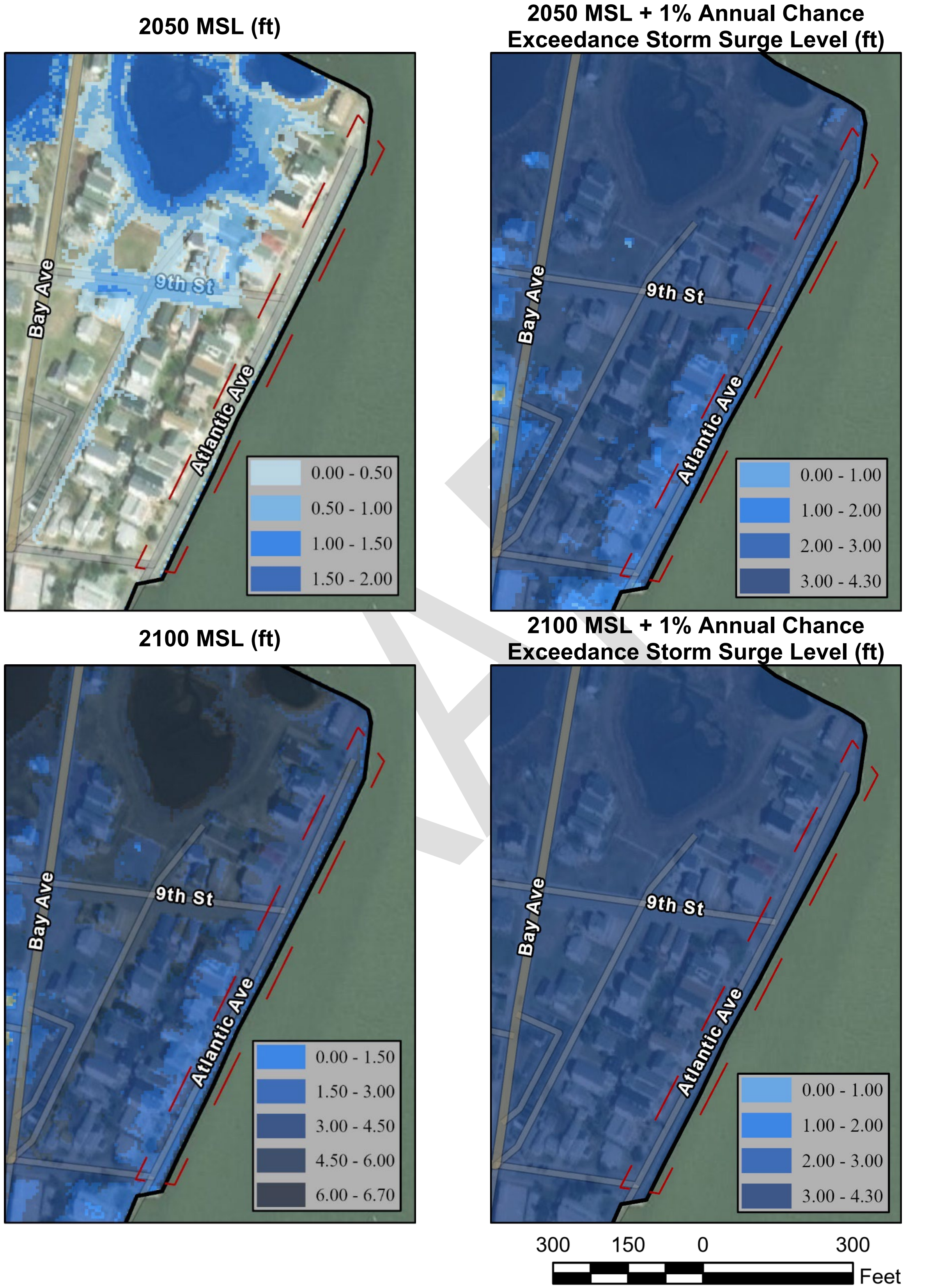


Figure 9 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.1.2. Wave Overtopping

The existing jersey rails and revetment, at approximately +3.0 NAVD88, are particularly vulnerable to damage due to overtopping waves. Though the jersey barriers are secured along Atlantic Avenue, the force of the overtopping waves during periods of strong wave action has resulted in movement of the barriers, as shown in Photo 18. The results of the overtopping assessment are presented in Table 11.

Photo 18 – Jersey Barrier moved during storm event

Table 11 - Overtopping Volume at Atlantic Avenue

Wind Speed & Surge Level Return Period (yr)	SLR Scenario (yr)	q (L/sec per m)
2	Current	236
	2030	1,120
	2050	5,483
	2100	255,609
10	Current	894
	2030	3,281
	2050	9,268
	2100	314,324
100	Current	4,687
	2030	11,329
	2050	18,049
	2100	428,651

The calculated overtopping volume for the return period storms was compared to thresholds presented in the CEM. Along Atlantic Avenue, the current 2-year return period storm paired with no SLR is classified as 'very dangerous' for pedestrian traffic and 'unsafe' for vehicles and the road and revetment are susceptible to damage for this event, as shown in Figure 10. Future conditions will only exasperate the risk of flooding and damage for Atlantic Avenue's vehicle and pedestrian traffic and will suffer structural damage for all scenarios.

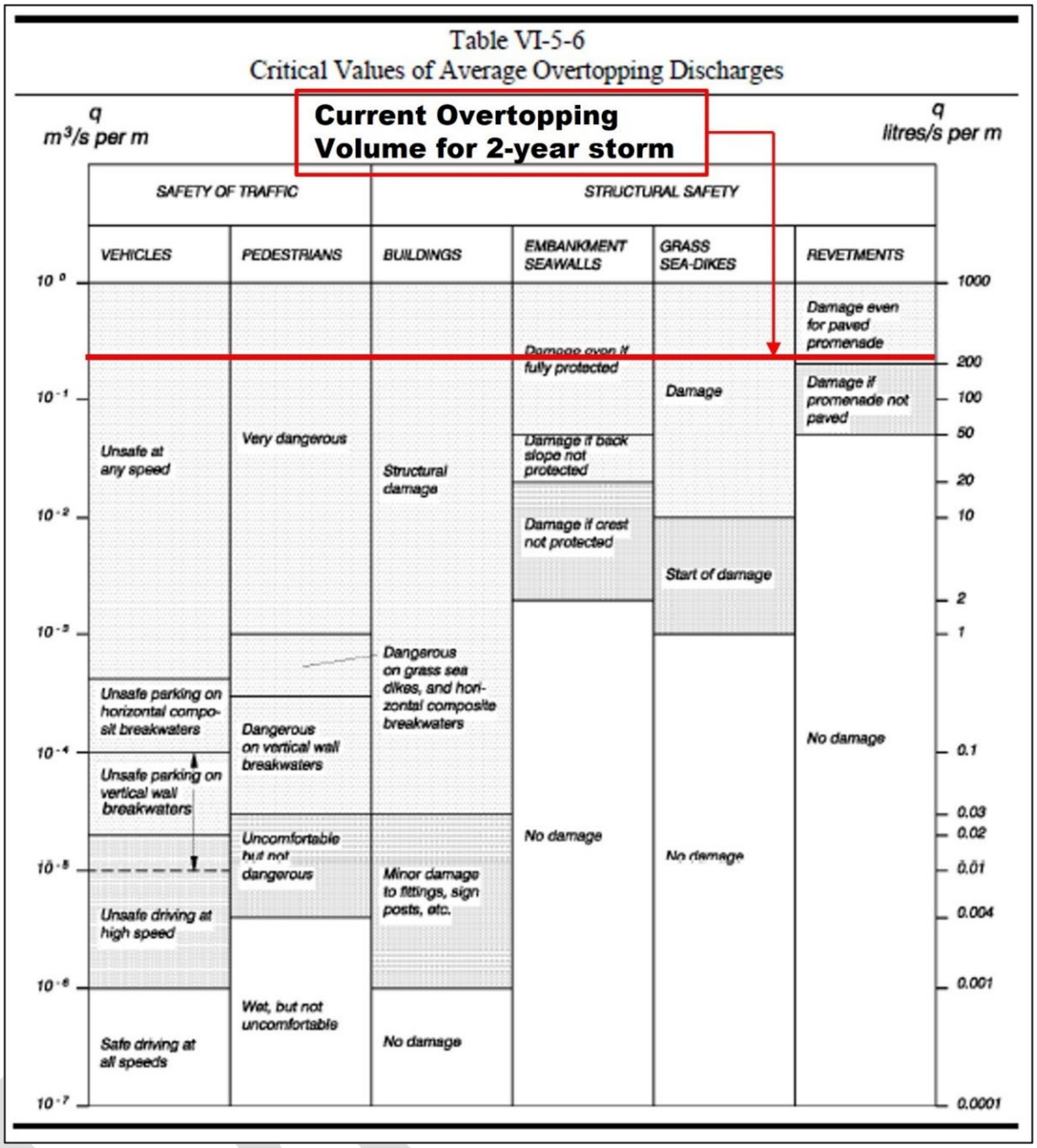


Figure 10 - USACE CEM Critical Values of Average Overtopping Discharges

4.1.3. Storm Drainage

The street experiences significant flooding due to its low elevation and proximity to the shoreline with a large amount of impervious surface. Projected SLR will significantly impact the ability of the system to adequately discharge flow

Table 12 – Flooding at Atlantic Avenue – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Atlantic Avenue	0.0	0.0	0.2	4.3	4.3	4.4

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event due to the northeast inlet surcharging. In the 100-yr storm event (2050) the maximum time the area floods increases to 4.4 hours.

4.2. 9th Street between Chesapeake Avenue and Atlantic Avenue

9th Street, between Chesapeake Avenue and Atlantic Avenue, stretches through a residential area and meets Atlantic Avenue at the Chesapeake Bay. Elevated homes line both sides of the road. At the intersection with Bay Avenue, average elevations of 9th Street are approximately +2.75 feet NAVD88. Elevations dip near the intersection with Annapolis Avenue to a minimum of approximately +1.25 feet NAVD88 before rising again to approximately +3 feet NAVD88 at the intersection with Atlantic Avenue. The 9th Street outfall's storm drain system begins at Dayton Avenue and 8th Street. Runoff enters the system and turns north at Chesapeake Avenue and east between 8th and 9th Street and then north again until reaching the main 9th Street system to the outfall at the Chesapeake Bay. A pump station and tide gate at the 9th street outfall are currently used to remove water from the system when the area is inundated. The pump station has a lead pump startup depth of -3.2 feet NAVD88, a lag pump startup depth of -2.2 feet NAVD88, and a shutoff depth of -4.2 feet NAVD88.The outfall was submerged at the time of survey and the invert elevations were assumed based on the nearby surveyed data. The outfall is routinely backwatered during normal tide cycles.

Photo 19 – 9th Street at Atlantic Ave – Looking West

Photo 20 – Flooding along 9th due to Inadequate Drainage

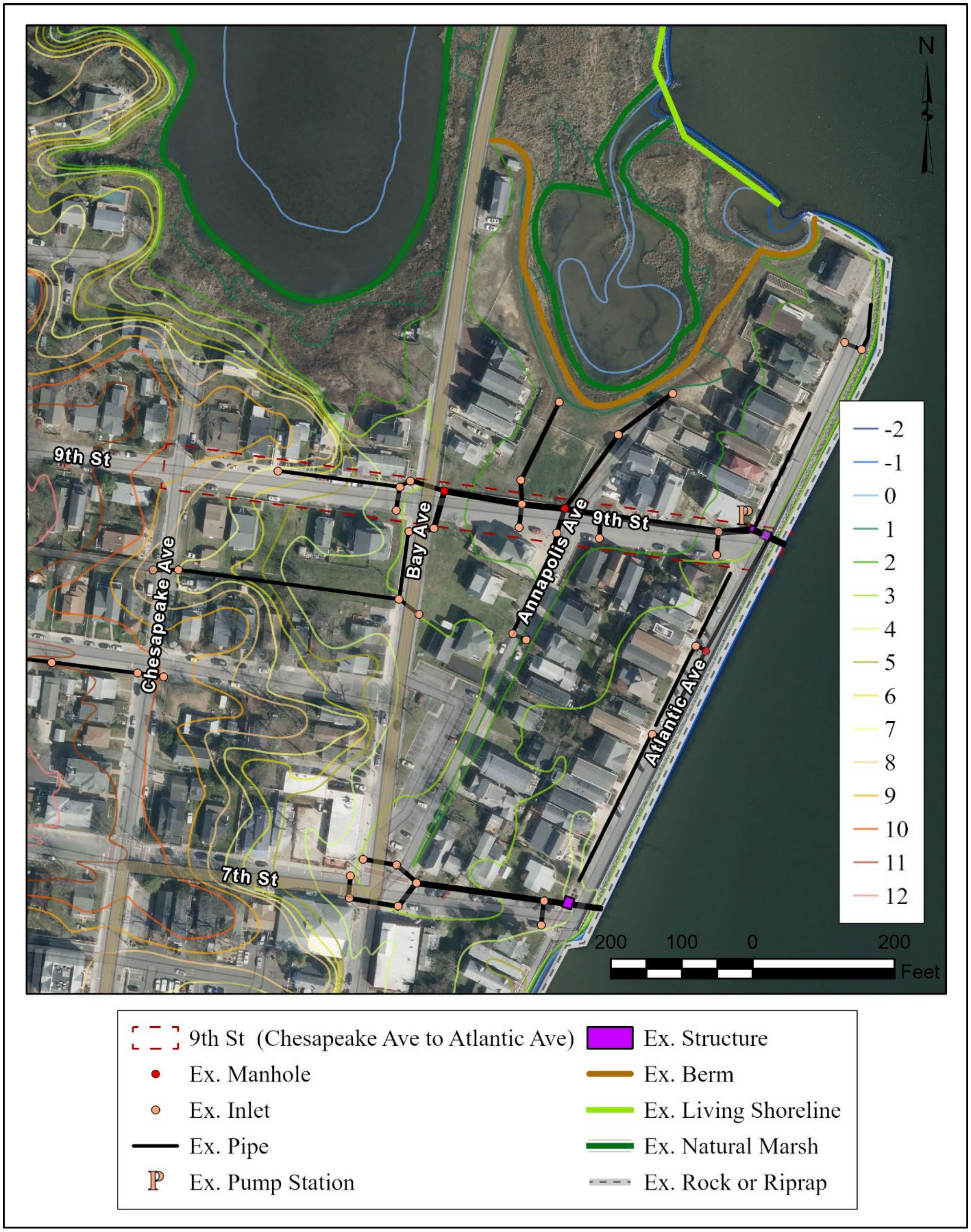


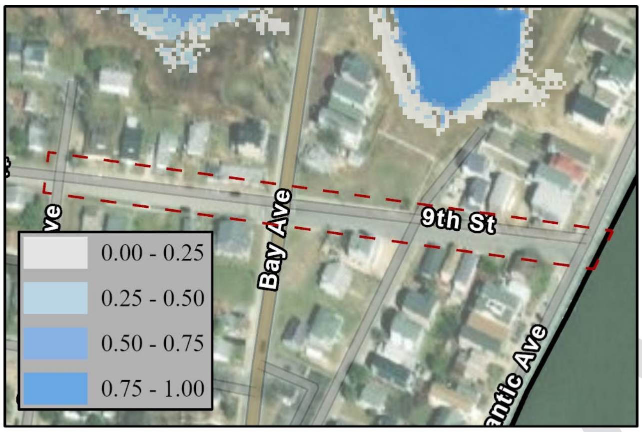
Figure 11 - 9th Street between Chesapeake Avenue and Atlantic Avenue (legend refers to contour elevations in feet (NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

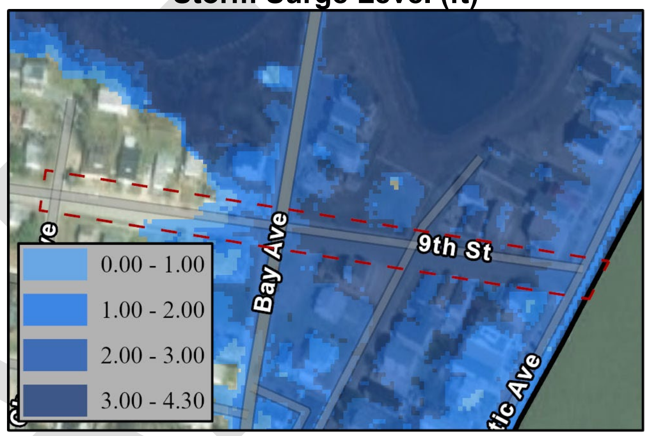
4.2.1. SLR and Storm Surge

Flooding due to SLR alone will not impact 9th Street in 2030. 2050 and 2100 SLR scenarios show 9th Street floods along the road dip between Bay and Atlantic Avenue from pathways through the natural wetlands during daily conditions. SLR by 2100 will result in 75% of the road being flooded between Chesapeake and Atlantic Avenue. The current and future storm surge scenarios all result in inundation of 9th street between Bay and Atlantic Avenue with the 2100 SLR + Storm Surge reaching all the way to Chesapeake Avenue.

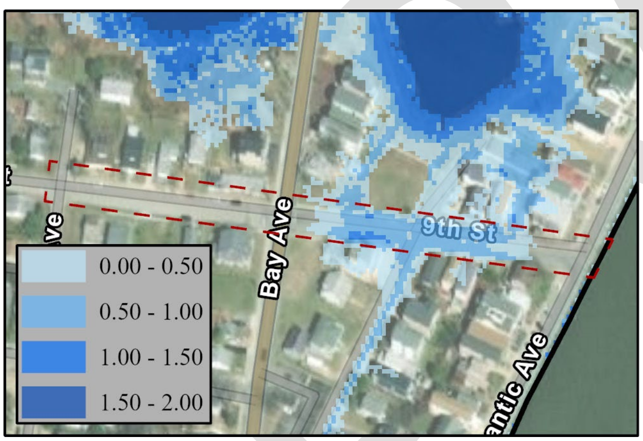
2030 MSL (ft)



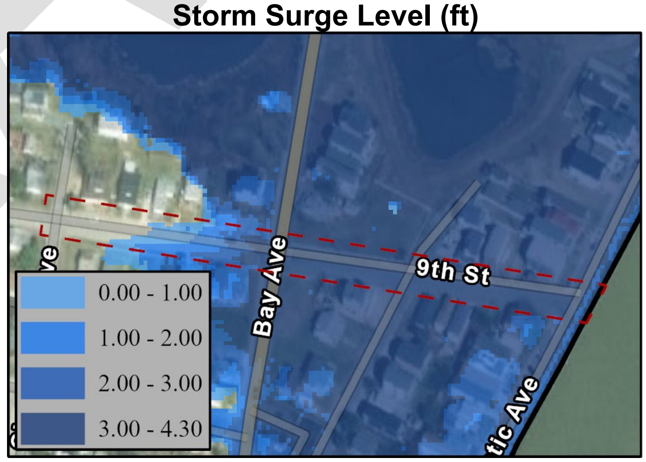
2030 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



2050 MSL (ft)



2050 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



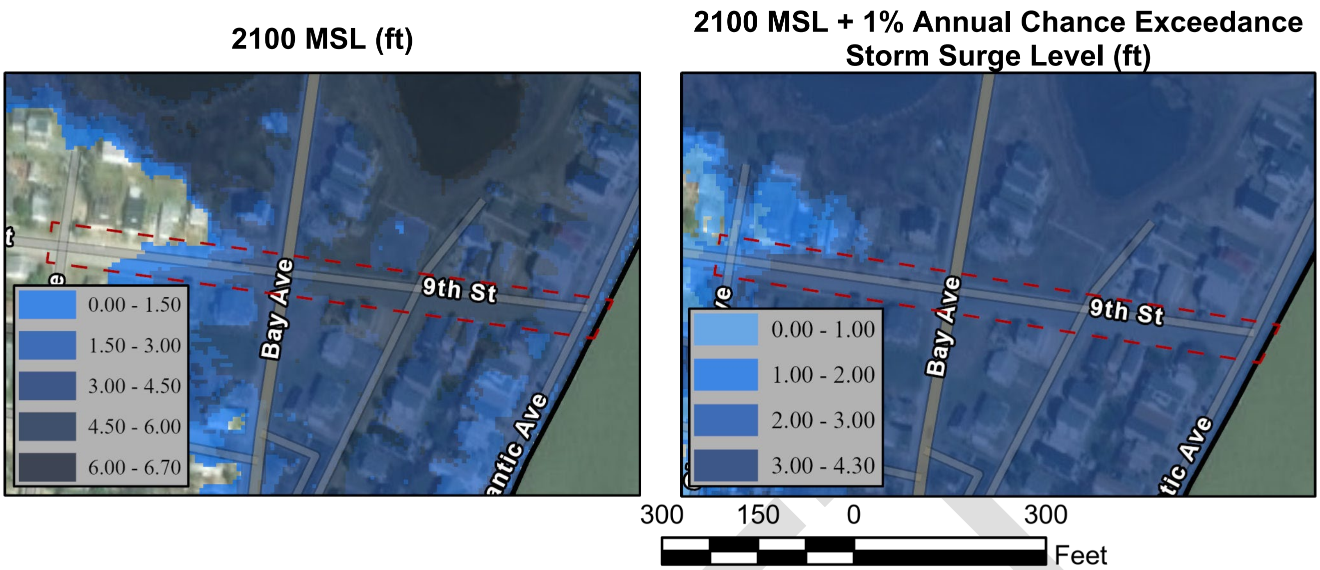


Figure 12 - MHW flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.2.2. Wave Overtopping

The revetment along Atlantic Avenue is extremely vulnerable to wave overtopping for all scenarios. It has been observed that wave overtopping of Atlantic Avenue results in pooling of floodwater in the low-lying portion of 9th Street between Bay and Atlantic Avenue.

4.2.3. Storm Drainage

Flooding along 9th Street is mainly caused by the low elevation of the road and frequent backwatering of the storm drain infrastructure during normal tide cycles which limits the conveyance of water to the Bay during rain events. Flooding along the rest of the system from its origination to the main 9th Street infrastructure is due to a large contributing drainage area for the existing pipe capacity.

Table 13 - Flooding at 9th Street – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
9th Street between Chesapeake Avenue and Atlantic Avenue	1.3	2.1	3.8	1.4	2.2	3.8

In the existing conditions SWMM model, this area begins to flood by the 1-yr storm event. In the 100-yr storm event (2050) 8 out of 23 nodes (35%) experienced flooding and the maximum flood time was 3.8 hours.

4.3. Annapolis Avenue between 7th Street and 9th Street

Residential area borders both sides of Annapolis Avenue with a free public parking lot located near the intersection at 7th Street. Elevations along Annapolis Avenue range between approximately +2.5 feet NAVD88 near 7th Street decreasing to as low as approximately +1.25 feet NAVD88 at the intersection with 9th Street. Most homes along Annapolis Avenue were observed to be built above ground level, however, homes with entry ways at ground level were also observed.

The Annapolis Avenue storm drain system ties into the main 9th Street system and originates approximately 180 linear feet southwest. Runoff from the adjacent, improved lots is directed towards the street and then into the system. Infrastructure at the intersection of Annapolis Avenue and 7th Street is discussed in Section 4.4.

Photo 21 - 7th Street Facing Annapolis Avenue - Looking North

Photo 22 - Annapolis Avenue

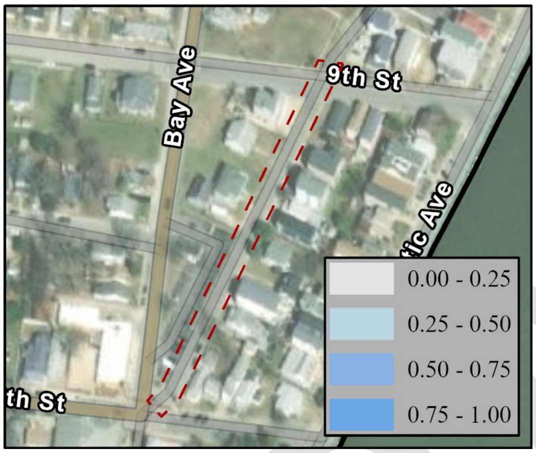
Figure 13 - Annapolis Avenue between 9th Street and 7th Street (legend refers to contour elevations in feet (NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

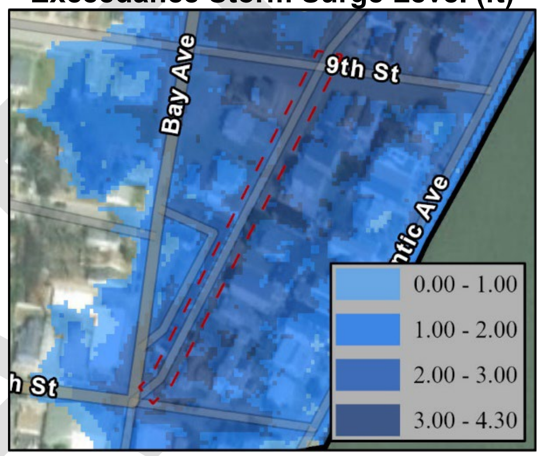
4.3.1. SLR and Storm Surge

Flooding along Annapolis Avenue occurs both during storm surge and rainfall events. Nuisance flooding also occurs frequently due to the backwatering of the stormwater drainage system during periods of elevated water levels. Flooding due to SLR by 2030 will not result in flooding along Annapolis Avenue. However, by 2050, daily water levels will reach the low-lying areas at Annapolis and 9th due to pathways from the marsh and living shoreline areas. Homes along this area will also experience flooding at their ground level daily. SLR by 2100 will inundate the entire road. Storm surge with both current water levels and future SLR will inundate the road completely.

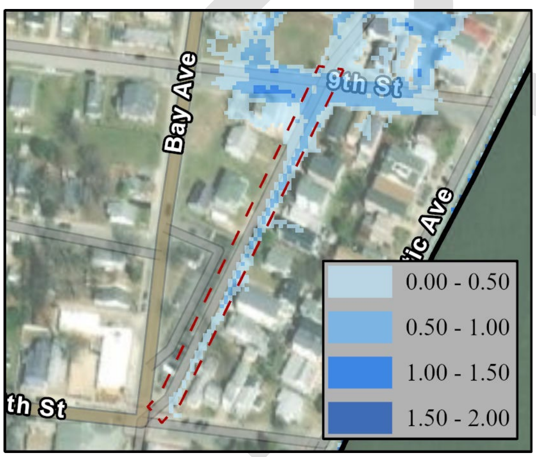
2030 MSL (ft)



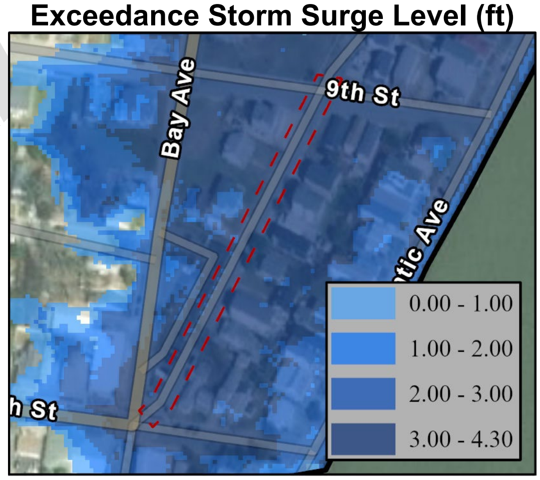
2030 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



2050 MSL (ft)



2050 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



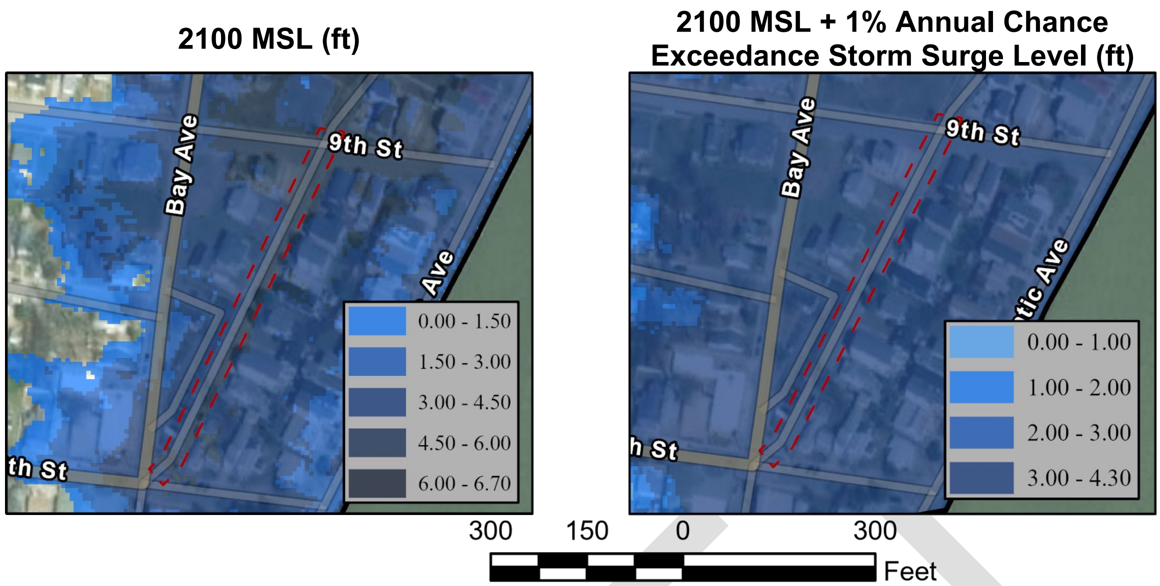


Figure 14 - MHW flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.3.2. Wave Overtopping

Given the offset of Annapolis Avenue to the Chesapeake Bay shoreline, wave overtopping is not anticipated to directly result in flooding in this area.

4.3.3. Storm Drainage

Flooding throughout the northeast half of Annapolis Avenue is primarily due to the 9th street storm drain system being at capacity and backwatering upstream infrastructure.

Table 14 - Flooding at Annapolis Avenue – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Annapolis Avenue between 7th Street and 9th Street	0.4	1.0	1.5	0.4	1.0	1.6

In the existing conditions SWMM model, this area was flooded by the 10-yr storm event. In the 100-yr storm event (2050) 5 out of 5 nodes (100%) experienced flooding and the maximum flood time was 1.6 hours.

4.4. 7th Street between Bay, Annapolis and Atlantic Avenue

A commercial area including restaurants and antique and gift shops is located at the corner of Annapolis Avenue, Bay Avenue, and 7th Street. Residential properties border 7th Street moving towards Atlantic Avenue. An open lot is located directly adjacent to the commercial areas. A Bay lookout pier and access to the boardwalk are at the intersection of 7th and Atlantic. Roadway elevations average +3.0 feet NAVD88 for this segment of 7th Street, with the highest elevations of approximately +3.5 feet NAVD88 being located at the intersection with Atlantic Avenue Home elevations appear to be at or near ground elevation for multiple homes along this area.

The storm drain network runs from the intersection of 7th Street and Bay Avenue to Atlantic Avenue, where it is discharged through the revetment and into the Chesapeake Bay. Multiple inlets collect runoff from 7th Street and Bay and Annapolis Avenues into the main pipeline that outfalls to the Chesapeake Bay. The outfall was submerged at the time of survey and the invert elevations were assumed based on the nearby surveyed data. The outfall is routinely backwatered during normal tide cycles.

Photo 23 - 7th Street at Bay Avenue – Looking East

Photo 24 - 7th Street at Atlantic Avenue - Looking West

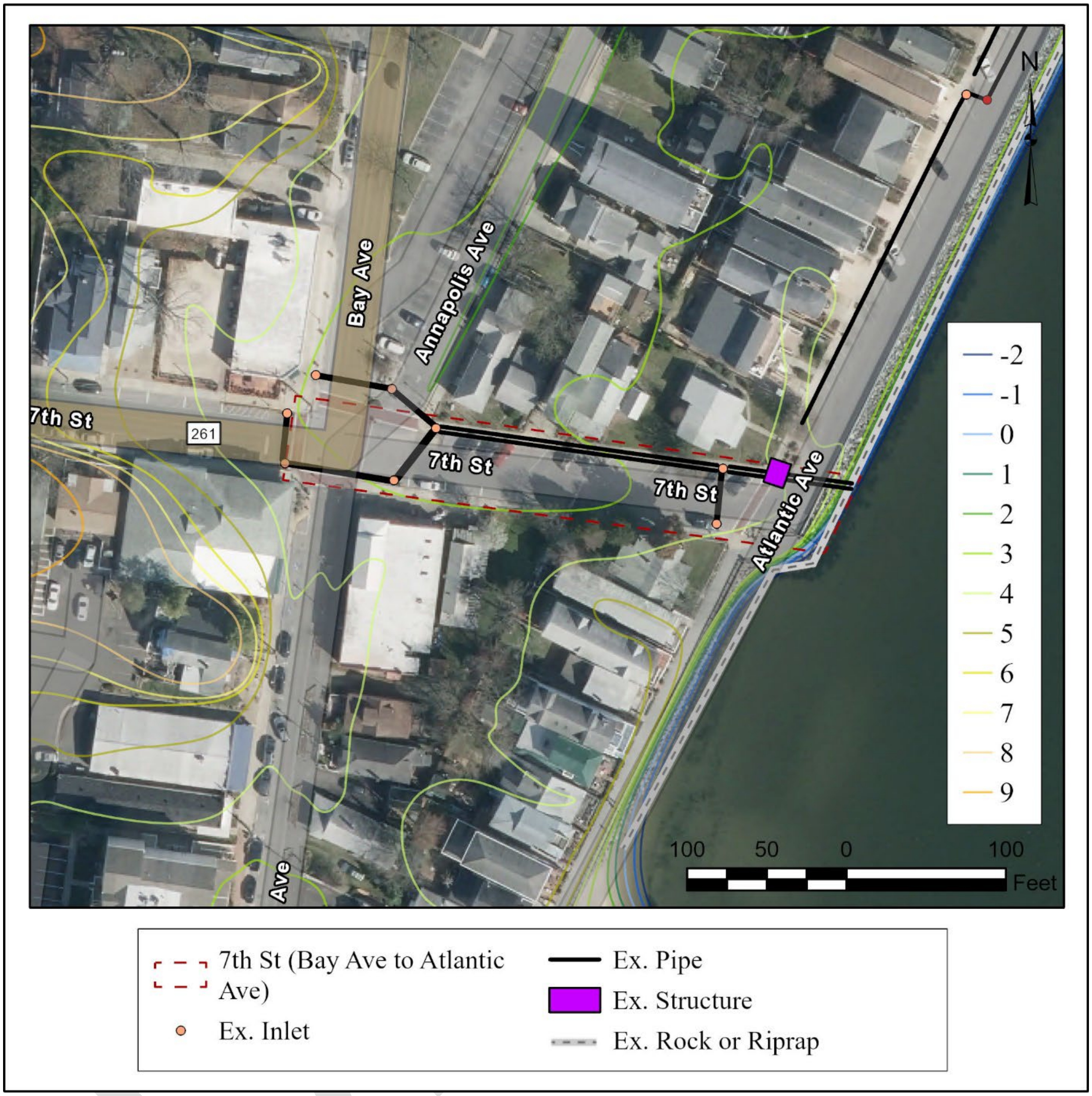


Figure 15 - 7th Street between Bay Avenue and Atlantic Avenue (legend refers to contour elevations in feet (NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.4.1. SLR and Storm Surge

The flood mapping performed by ESRGC shows that flooding will not occur on 7th street between Bay and Atlantic Avenues for neither 2030 nor 2050 SLR alone. SLR in 2100 will inundate the entire road segment. For each of the storm surge scenarios modeled, the 7th Street segment between Bay Avenue and Atlantic will be flooded.

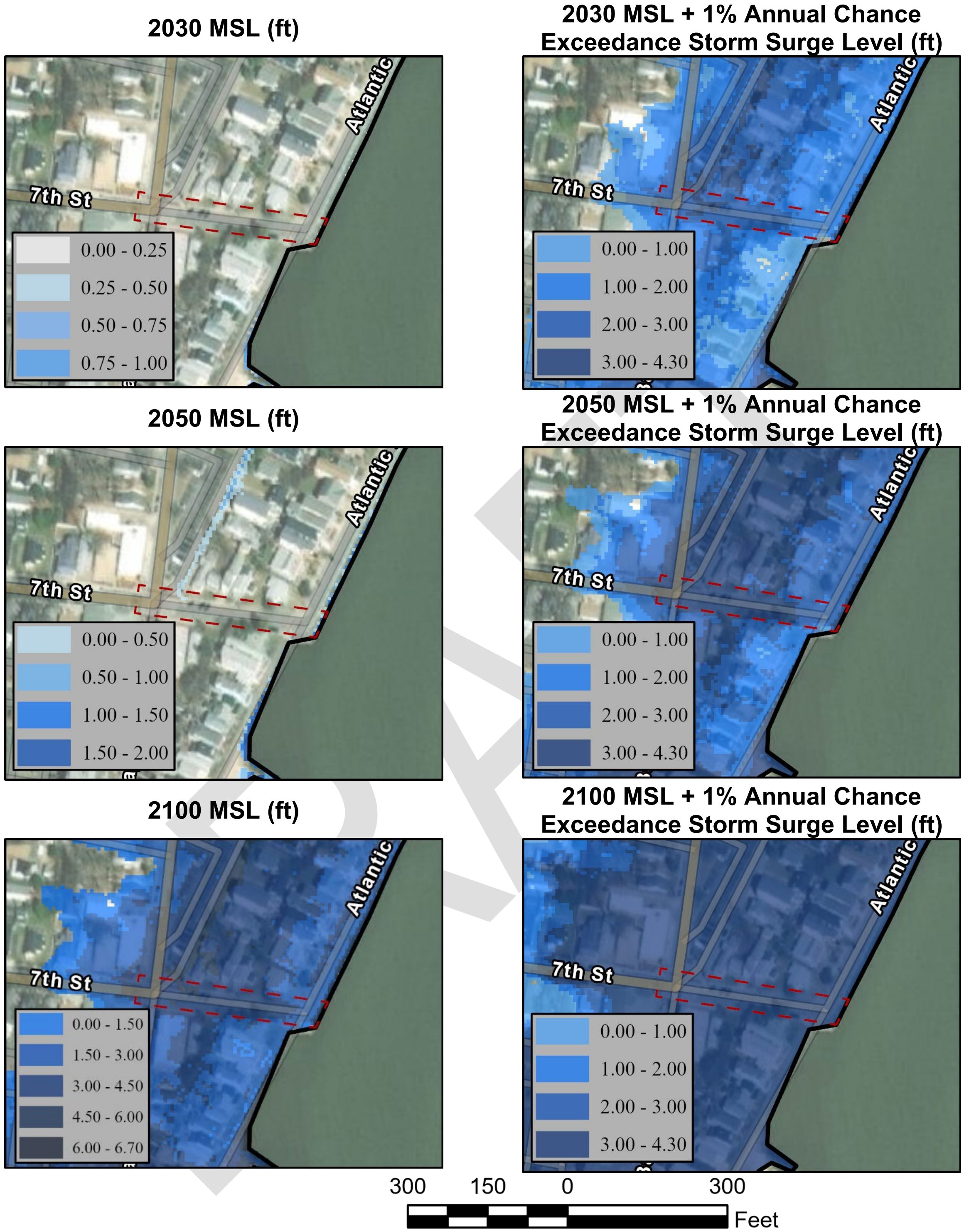


Figure 16 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.4.2. Wave Overtopping

Wave overtopping will result in flooding along this section of road. The overtopping volume will be deposited on Atlantic Avenue and travel landward through the lower elevations of 7th Street. Photo 25 shows flooding along this portion of road and wave overtopping occurring along Atlantic Avenue. Though flooding shown in the photo is likely due to a combination of rainfall, storm surge and wave overtopping, the picture is a good representation of how the volume of water from overtopping waves can result in flooding of inland areas.

Photo 25 - Compound Flooding along 7th Street (Waves Overtopping Atlantic Avenue Jersey Barriers)

For overtopping volumes, reference should be made to the Overtopping Analysis presented in Section 4.1.2.

4.4.3. Storm Drainage

The area receives significant runoff from upstream areas west of the intersection of 7th Street and Bay Avenue, contributing to a high flow through the relatively small system. The flooding of the storm drain system is due to its frequent backwatering and high volume of runoff from the contributing drainage area.

Table 15 - Flooding at 7th Street – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
7th Street between Bay Avenue and Atlantic Avenue	2.5	2.5	2.6	18.4	18.4	18.4

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 3 out of 9 nodes (33%) experienced flooding and the maximum flood time was 18.4 hours.

4.5. Bay Avenue between 5th Street and 7th Street

Beginning at 7th Street, Bay Avenue transitions from primarily residential to commercial approaching the town center. Multiple homes and businesses are at ground level along this portion of road. Approaching 5th Street, a shared commercial and condominium space elevated above the ground level is located on the west side of the street. Landscaping boxes and a bike path run parallel to the street. Near the intersection with 5th Street, the east side of Bay Avenue becomes a public boardwalk along the beach area. The town is currently converting the public parking lot at the corner of 5th and Bay Avenue into a public library.

Elevations of the Bay Avenue between 5th and 7th vary between approximately +3 feet NAVD88 near 7th street and +1.5 feet near 5th Street. The top of the boardwalk between Chesapeake Bay and Bay Avenue near the intersection with 5th Street has an elevation of approximately +4 feet NAVD88.

The storm drain system along Bay Avenue originates 230 linear feet upstream and discharges water into the 5th street storm drain system. Infrastructure at the intersection of Bay Avenue and 7th Street is discussed in Section 4.4.

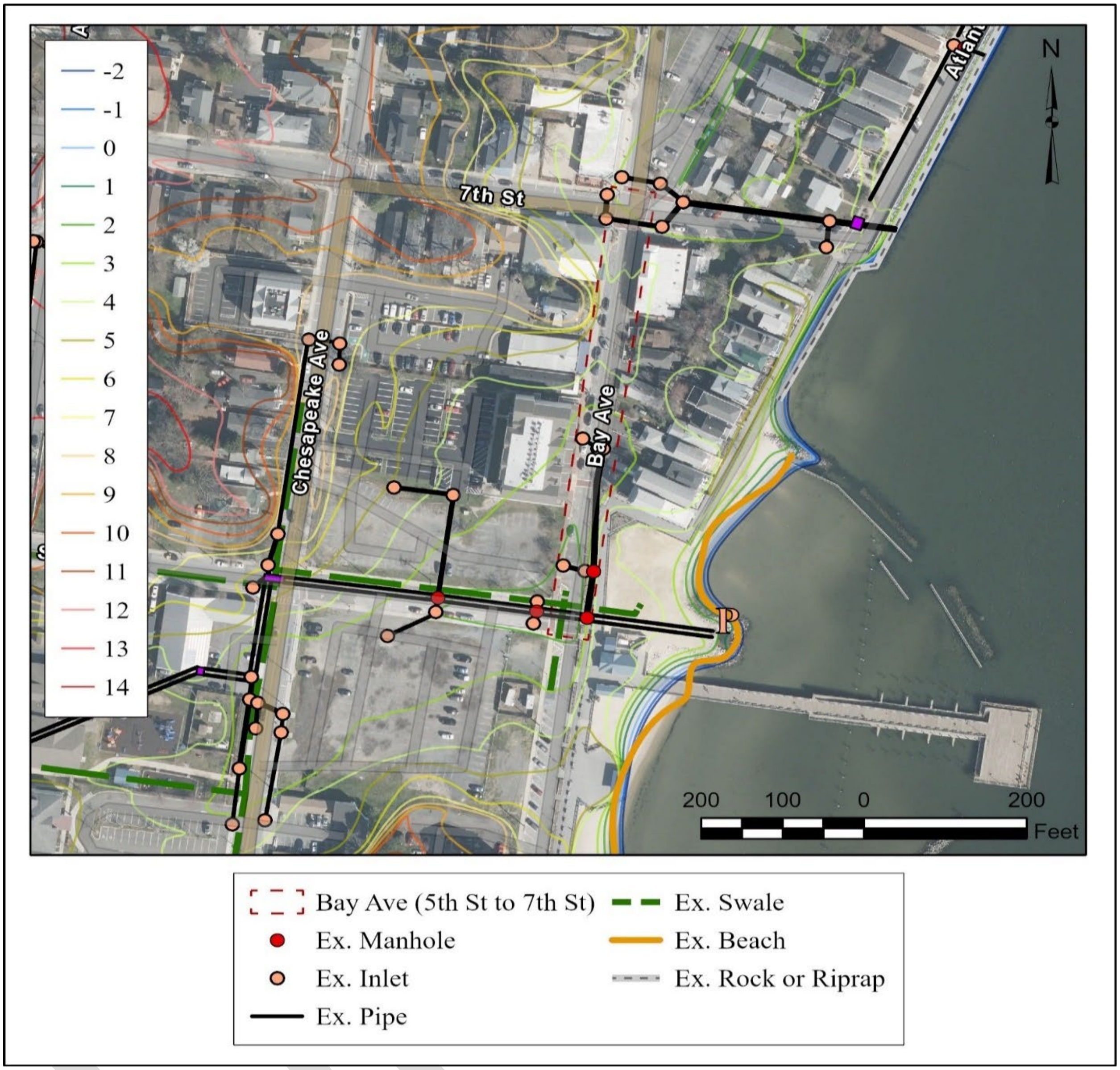


Figure 17 - Bay Avenue between 5th Street and 7th Street (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.5.1. SLR and Storm Surge

The mapping shows that Bay Avenue will not experience flooding between 7th and 5th street from SLR alone by 2030 and 2050. The entire road segment and surrounding areas is mapped as flooded daily by 2100. Each storm surge and 2030, 2050 and 2100 SLR scenario mapped shows the road and surrounding areas flooded during the 1% annual chance storm.

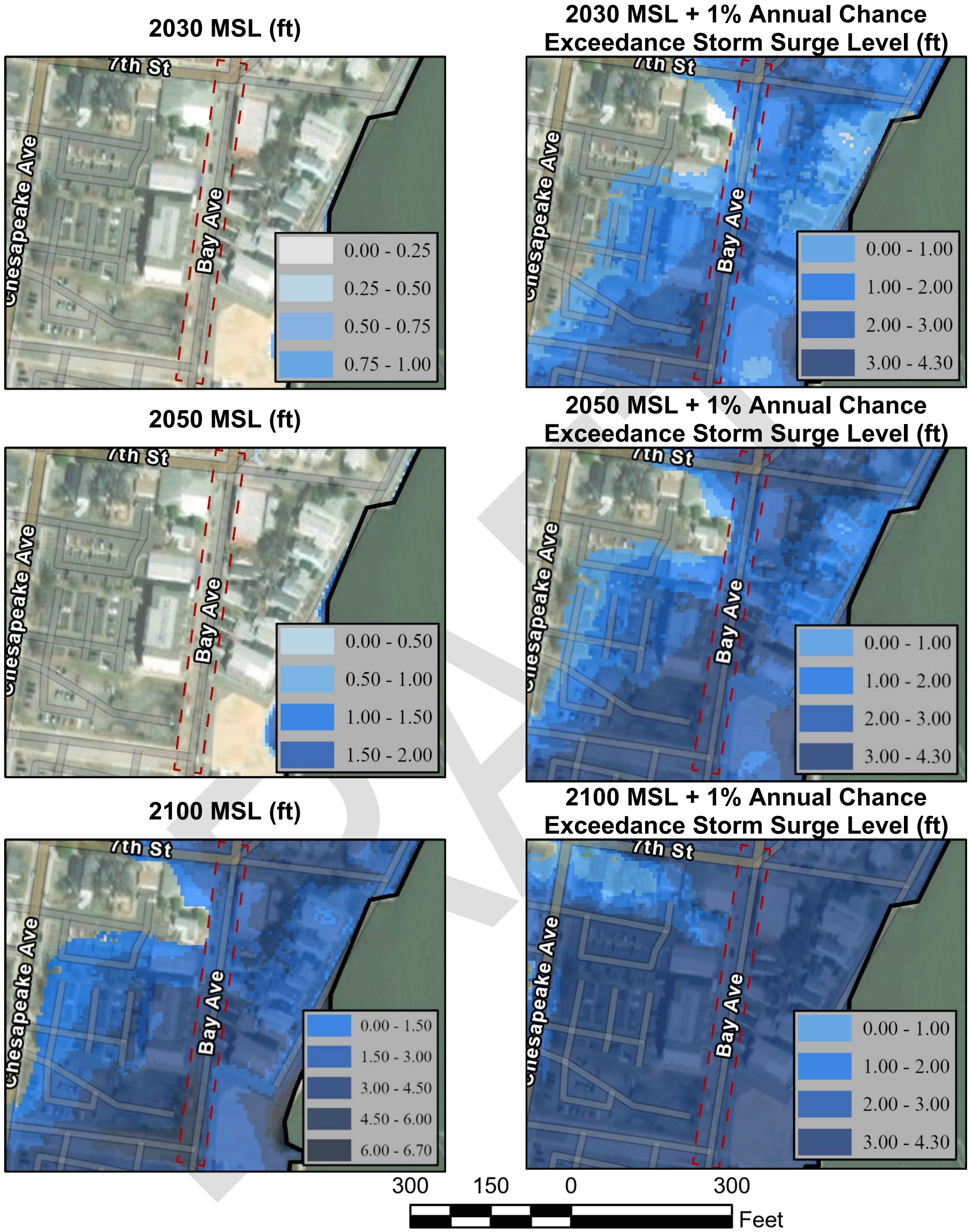


Figure 18 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.5.2. Wave Overtopping

The majority of Bay Avenue between 5th and 7th street and the surrounding homes are offset from the Chesapeake Bay shoreline and, therefore, protected from flooding due to wave overtopping. Only the 165 feet of road near the intersection with 5th street is located along the public beach. However, wave overtopping is not a source of flooding along this low-lying portion of road due to the 100-foot wide beach fronting the boardwalk and the breakwater structures in place to dissipate the wave energy.

4.5.3. Storm Drainage

The area can experience flooding during storm events that overwhelm the main 5th Street storm drain system to full capacity.

Table 16 - Flooding at Bay Avenue – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Bay Avenue between 5th Street and 7th Street	0.2	0.7	1.2	0.0	0.6	1.3

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 2 out of 5 nodes (40%) experienced flooding and the maximum flood time was 1.3 hours.

4.6. 5th Street between Chesapeake Avenue and Bay Avenue

5th Street provides tourists and residents with access to the community beach area. Impervious Public Parking Lots border both sides of this portion of 5th Street, however, the town public library is currently being constructed along the northern side of this road segment. The boardwalk and North Beach Pier access are at the intersection of 5th Street and Bay Avenue. The sandy beach behind offshore breakwaters meets the base of the boardwalk. At its lowest elevation, nearest the beach area, 5th Street is only +1.7 feet above NAVD88 and increases to +5.5 feet (NAVD88) moving towards Chesapeake Avenue.

The 5th Street storm drain system is the main system serving the Town between 3rd Street and 6th Street. The system originates at the Town/County boundary at 5th Street and Greenwood Avenue. The system includes multiple branches and traverses the Town from Greenwood Avenue to Dayton Avenue via 4th Street and returns to 5th Street at the intersection with Chesapeake Avenue and discharges to the Chesapeake Bay through the 5th Street pump station.

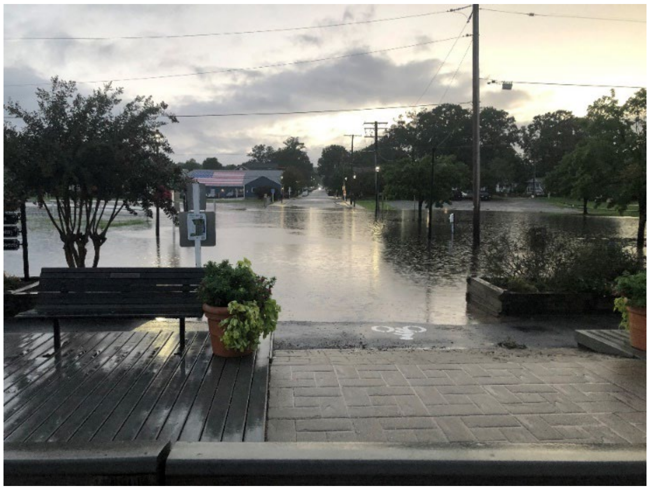


Photo 26 - 5th Street at Bay Avenue - Looking West

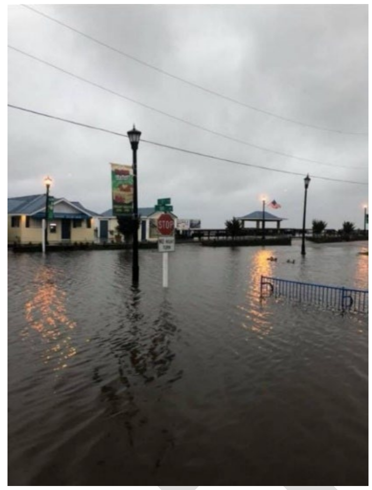


Photo 27 - 5th Street at Chesapeake Avenue - Looking East

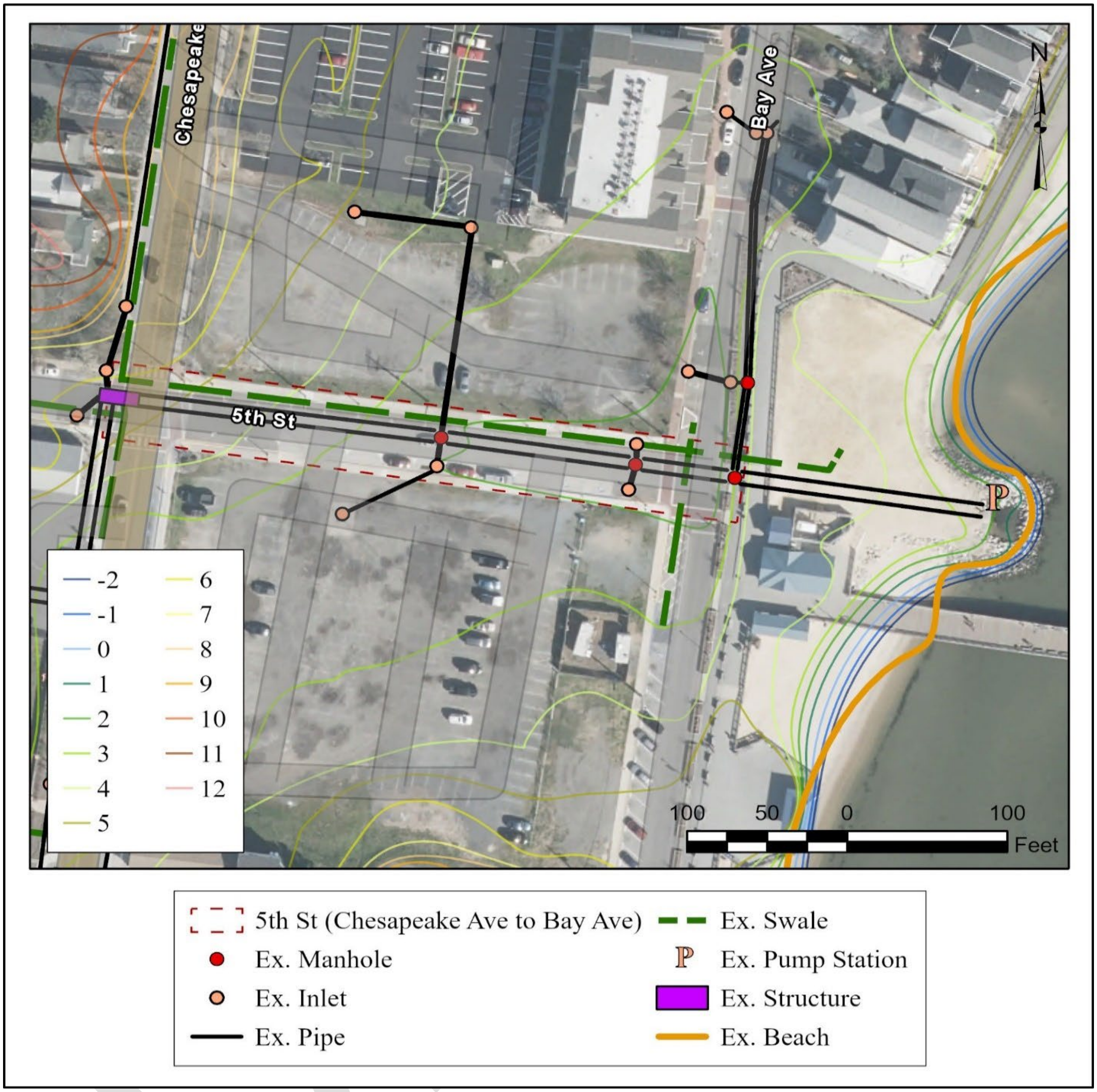


Figure 19 - 5th Street between Chesapeake Avenue and Bay Avenue (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.6.1. SLR and Storm Surge

Daily water levels with 2030 and 2050 SLR will not result in flooding along 5th street between Chesapeake and Bay Avenue. Daily water level in 2100 will inundate the entire portion of road, as will SLR + the 1% annual chance storm surge elevation in 2030, 2050 and 2100.

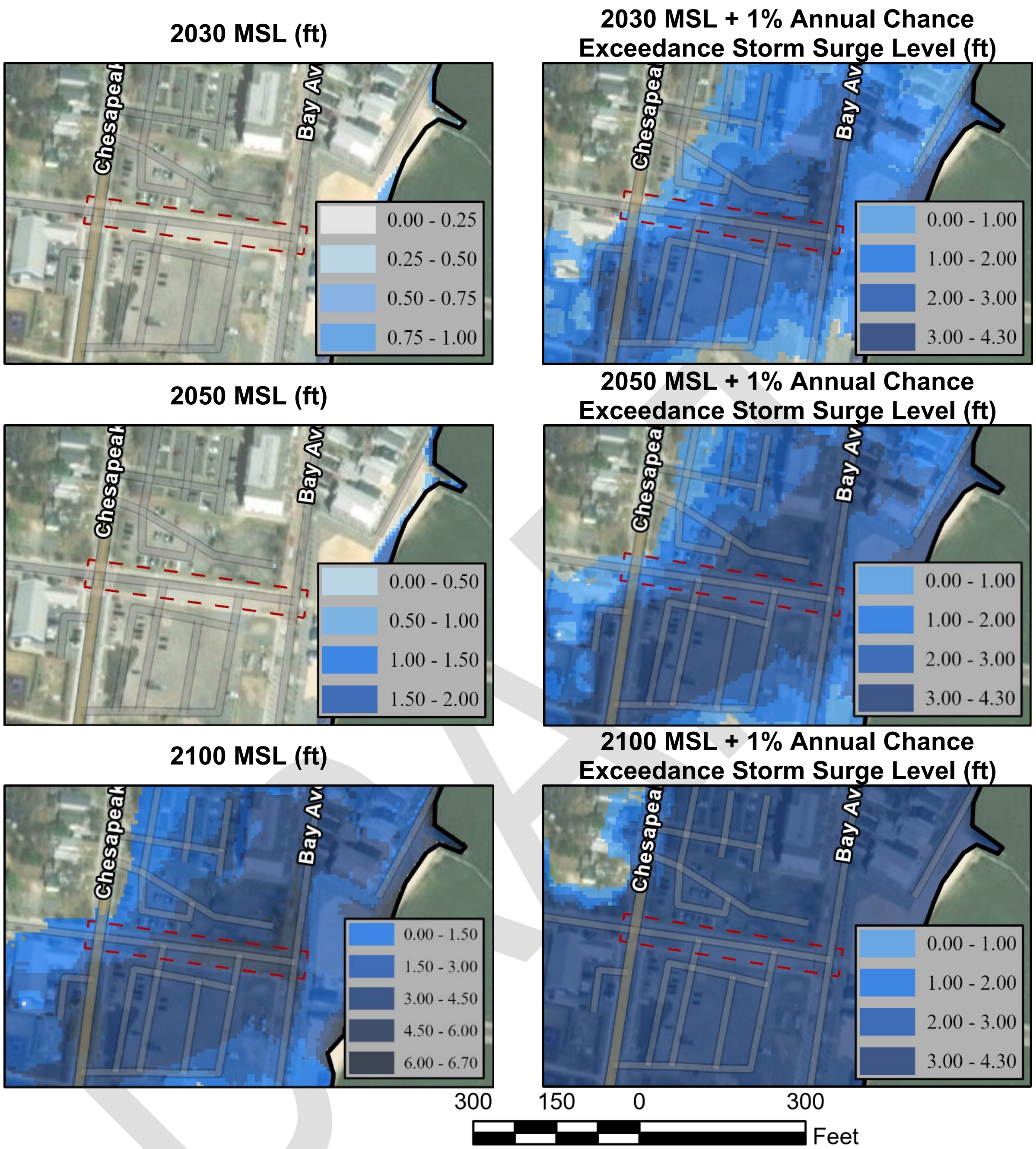


Figure 20 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.6.2. Wave Overtopping

The segment of 5th Street between Chesapeake and Bay Avenue is protected from wave overtopping by the 100-foot wide sandy beach and breakwaters that dissipate the wave energy prior to reaching the shoreline. Therefore, wave overtopping is not a source of flooding for this assessment area.

4.6.3. Storm Drainage

Flooding of this area is significant due to the low elevation of the storm drain system, the significant overall drainage area (83 acres +/-) into the system and much of the system being undersized for the contributing flows.

Table 17 - Flooding at 5th Street – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
5th Street between Chesapeake Avenue and Bay Avenue	3.0	5.6	10.3	6.6	6.6	10.3

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 4 out of 10 nodes (40%) experienced flooding and the maximum flood time was 10.3 hours.

4.7. Chesapeake Avenue between 4th Street and 6th Street

The east side of Chesapeake Avenue between 4th and 6th Streets consists of public parking areas, the new public library construction, and the Chesapeake Manor Hotel. The west side of the street along this segment appears to have both elevated and ground level commercial and residential properties. Road elevations between 4th and 5th street are at approximately +8 feet NAVD88. South of 5th Street, there is a significant dip in the road where elevations reach as low as +2.0 feet NAVD88. Along this low-lying section of road, the Chesapeake Manor Hotel and the North Beach Senior Center, the Boys and Girls Club of Southern Maryland and playground are at ground level. An open field is located just south of the Senior Center.

Two branches of the storm drain system run along Chesapeake Avenue and discharge water into the 5th Street storm drain system at the intersection of Chesapeake Avenue and 5th Street. Infrastructure at the intersection of Chesapeake Avenue and 5th Street is discussed in Section 4.6. The branch to the north of 5th Street originates 300 linear feet upstream. The branch to the south of 5th Street originates 310 linear feet upstream. The north branch originates at a significantly higher elevation than the south branch.

Photo 28 - Chesapeake Avenue at 3rd Street - Looking North


Photo 29 - Chesapeake near 6th Street - Looking South

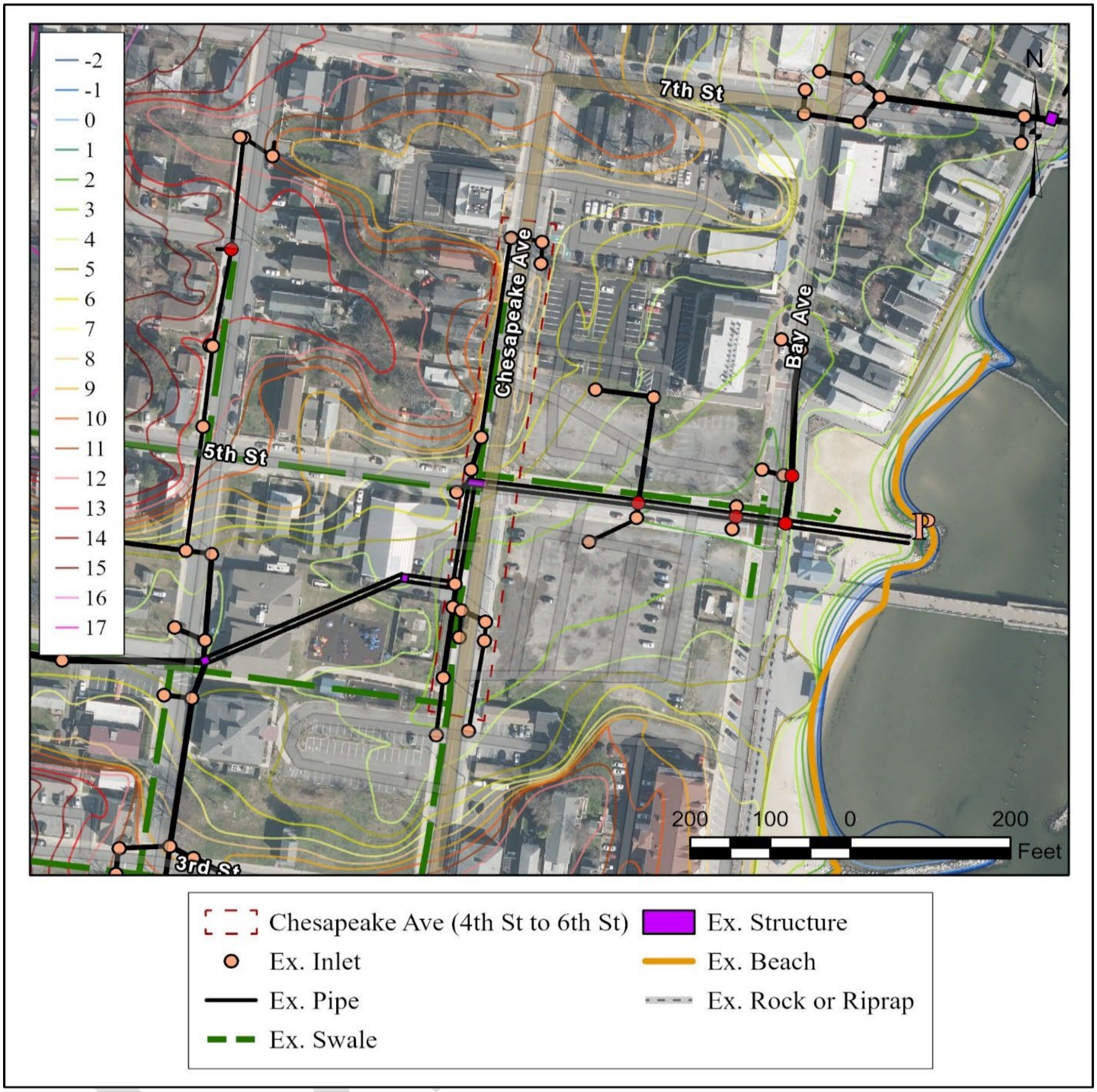


Figure 21 - Chesapeake Avenue between 4th Street and 6th Street (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.7.1. SLR and Storm Surge

This area will not experience daily flooding due to SLR until 2100; however, the 1% Annual Chance Exceedance water level imposed onto those SLR predictions begins to flood the low-lying area between 4th and 5th Street in 2030. Chesapeake Avenue between 5th Street and 6th Street is not flooded until 1% Annual Chance Exceedance Storm water levels are combined with the 2100 SLR projections.

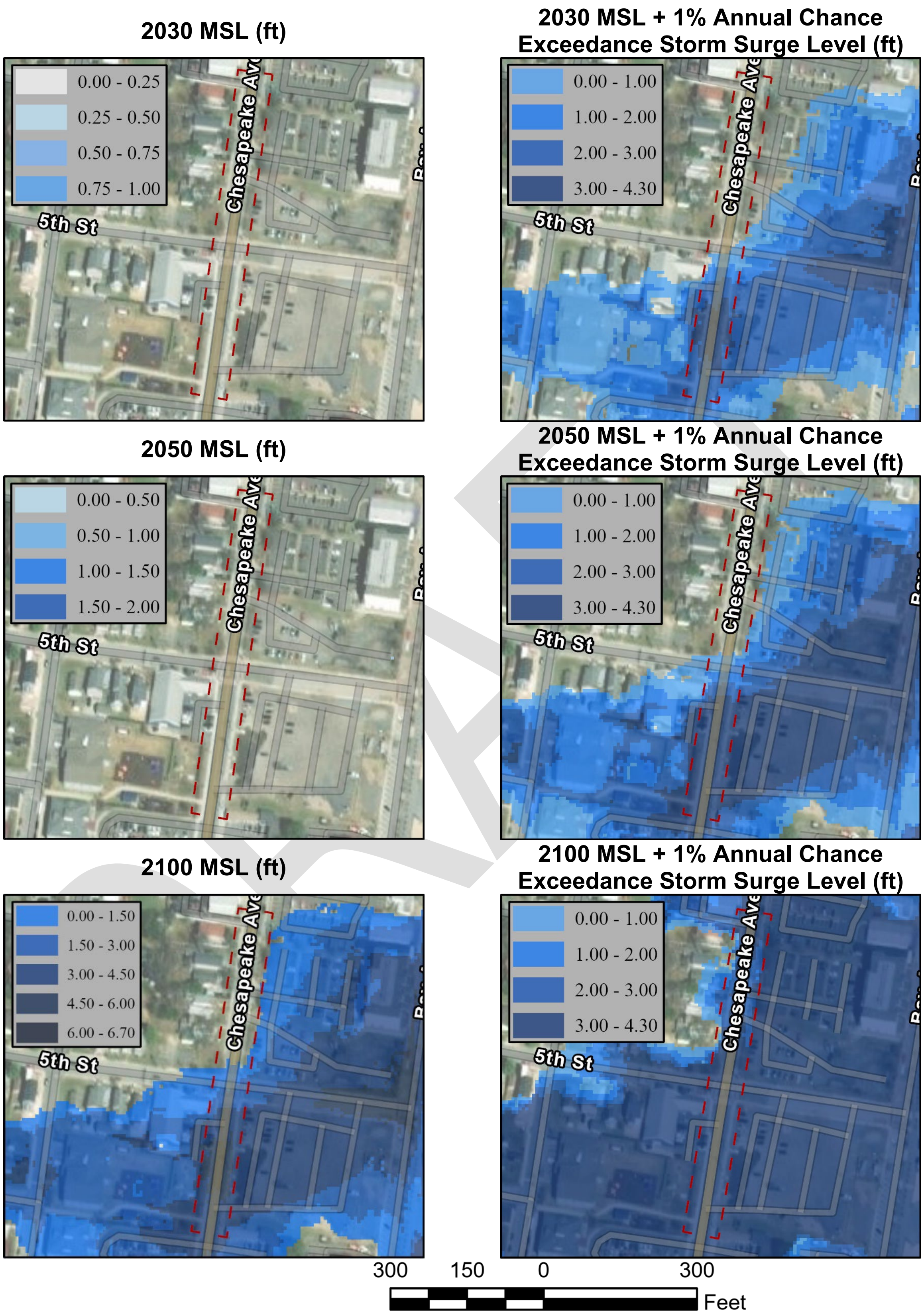


Figure 22 - MHW flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.7.2. Wave Overtopping

Given the offset of Chesapeake Avenue to the shoreline and the beach and breakwaters dissipating the wave energy, wave overtopping will not result in flooding of this area.

4.7.3. Storm Drainage

Both branches are undersized for the contributing flows, which is the primary cause of flooding along Chesapeake Avenue. Flooding is also seen when the infrastructure at Chesapeake Avenue and 5th Street is over capacity. The south branch is much more susceptible to flooding due to its lower elevation than the North branch.

Table 18 - Flooding at Chesapeake Ave – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Chesapeake Avenue between 4th Street and 6th Street	0.0	0.5	0.9	0.0	0.5	0.9

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 8 out of 15 nodes (53%) experienced flooding and the maximum flood time was 0.9 hours.

4.8. 1st Street between Chesapeake Avenue and Bay Avenue

1st Avenue is located at the border of the Town of North Beach and the Town of Chesapeake Beach. The segment of road is mainly residential with only commercial property at the corner of 1st Street and Chesapeake Avenue. A waterfront condominium at the corner of 1st and Bay Avenue overlooks the Chesapeake Bay and beginning of the North Beach Boardwalk protected by a rock revetment. The elevation of the roadway is approximately +10.5 feet NAVD88 at 1st and Chesapeake and only decreases slightly to approximately +8 feet NAVD88 at the intersection of 1st and Bay Avenue.

The 1st Street storm drain system begins at Chesapeake Avenue and 1st Street. Runoff enters the system through multiple inlets at the intersection and flows east along 1st street to the northern 1st Street outfall at the Chesapeake Bay. The northern outfall invert is +0.09 feet NAVD88. A second system begins at Bay Avenue and 1st street and flows to a second, southern outfall at the Chesapeake Bay. The second outfall invert is -0.27 feet NAVD88.

Photo 30 - 1st Street at Bay Avenue - Looking West

Photo 31 - 1st Street past Chesapeake Avenue - Looking East

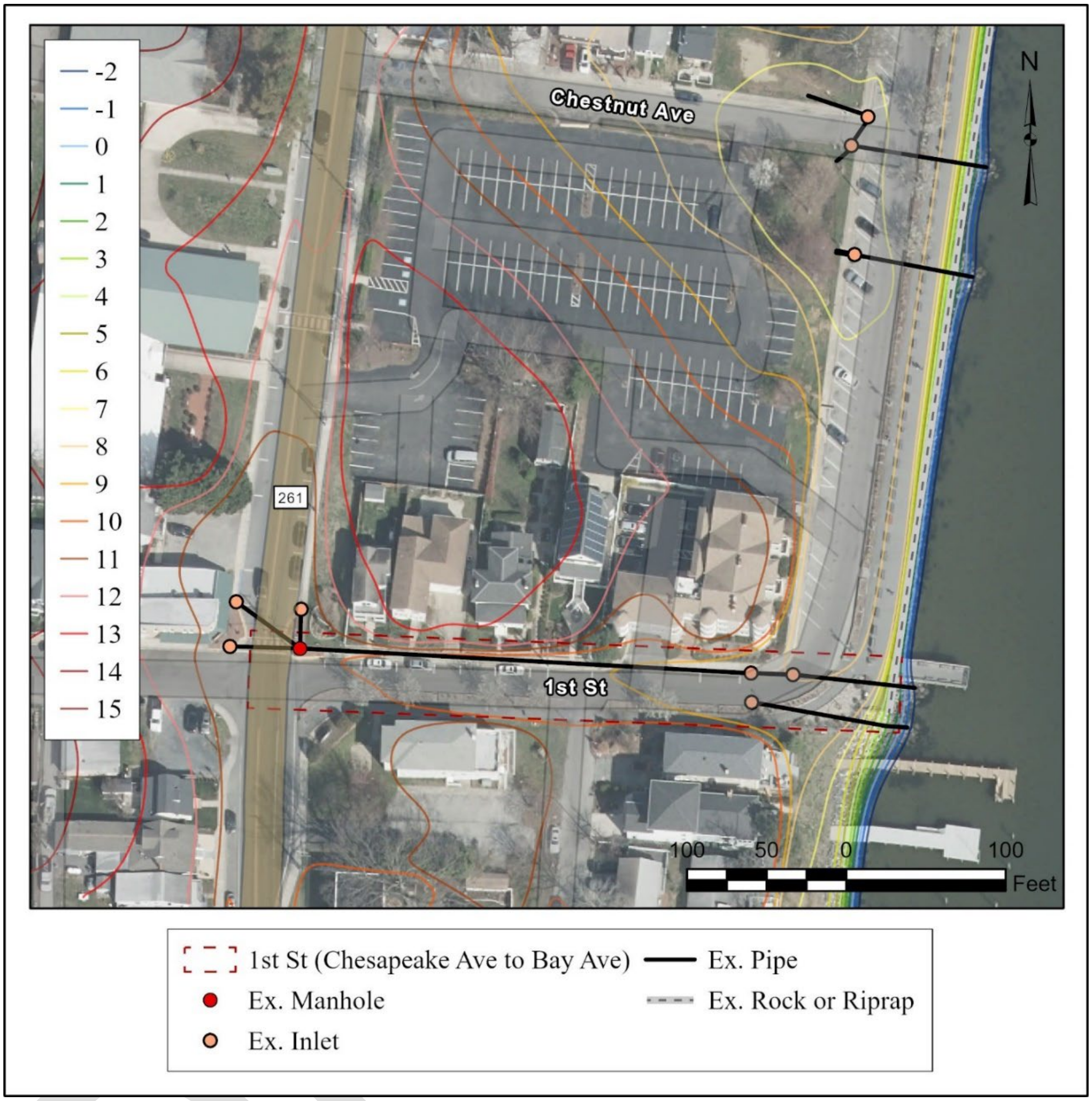


Figure 23 - 1st Street between Chesapeake Avenue and Bay Avenue (legend refers to contour elevations in feet (NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.8.1. SLR and Storm Surge

For the mapped SLR and SLR+Storm Surge scenarios, this area only experiences flooding during the 2100 1% Annual Chance Exceedance Storm Surge Level scenario. At this point, projected flood levels exceed the +8.0 feet (NAVD88) roadway elevation.

Figure 24 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.8.2. Wave Overtopping

The overtopping analysis performed along this area is presented in Table 19. Wave overtopping the Bay Avenue revetment and boardwalk may result in flooding near the intersection of 1st and Bay Avenue, though the high elevations along this area will prevent flooding from wave overtopping until at least 2030. After 2050, storm events could deposit a larger volume of floodwaters onto the roadway causing unsafe travel and structural damage.

Table 19 - Overtopping Volume at 1st Street and Bay Avenue		
Wind Speed & Surge Level Return Period (yr)	**SLR Scenario (yr)**	**q (L/sec per m)**
2	Current	0.00
	2030	0.07
	2050	75.92
	2100	3,539.31
10	Current	0.05
	2030	0.82
	2050	182.91
	2100	6,203.56
100	Current	1.79
	2030	11.77
	2050	529.80
	2100	12,582.20

After 2030, wave overtopping may result in unsafe conditions for pedestrians walking along the boardwalk near 1st and Bay Avenue. In 2050, the 100-year storm could cause structural damage to buildings. All extreme events past 2050 present a major threat to safety and the resiliency of existing infrastructure and coastal protection in the area.

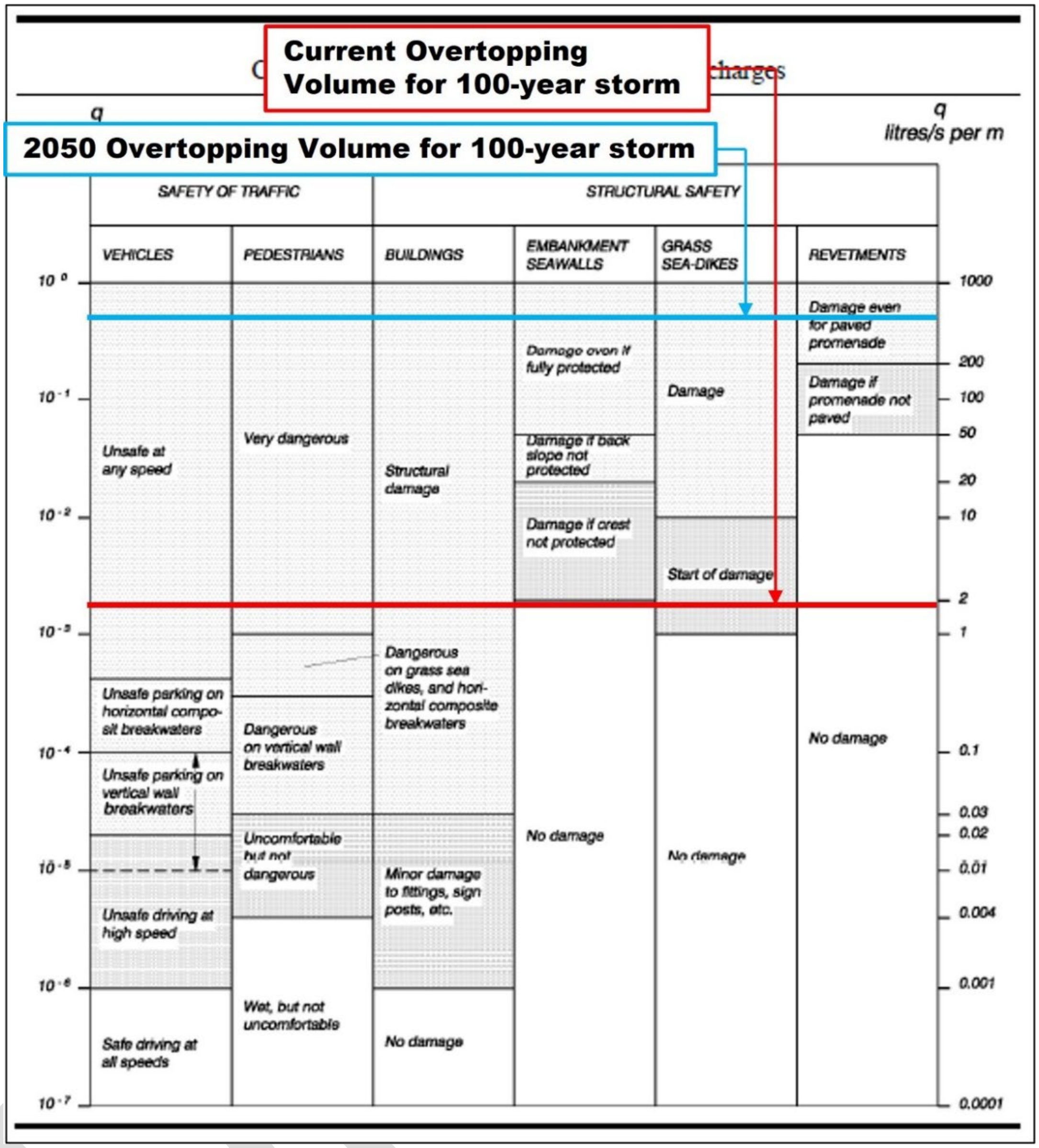


Figure 25 - Overtopping Volume along Bay Avenue at 1st Street

4.8.3. Storm Drainage

Flooding of 1st Street is primarily due to infrastructure that is undersized for the contributing flow from the northwest. Existing infrastructure is inadequate to convey flow from the inlets to the system outfalls.

Table 20 - Flooding at 1st Street – Existing Conditions						
High Priority Area	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
1st Street between Chesapeake Avenue and Bay Avenue	0.0	0.7	1.2	0.0	0.7	1.2

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 2 out of 7 nodes (29%) experienced flooding and the maximum flood time was 1.2 hours.

4.9. Dayton Avenue between 3rd Street and 6th Street

Dayton Avenue between 3rd Street and 6th Street is both commercial and residential. At the corner of Dayton Avenue and 3rd, the Crosswinds Apartment is located on the west side across from a large grassy area. Elevations at this intersection are approximately +9 feet NAVD88. Moving north along the road, elevations begin to decrease until it hits a minimum of +3.3 feet NAVD88 just past the intersection with 4th Steet. Elevations begin to climb again to a maximum of +13.5 feet NAVD88 at the intersection of Dayton Avenue and 6th Street.

The Bayside History Museum is located along Dayton Avenue between 3rd and 4th Street. Across for the Museum is the back side of the North Beach Senior Center. The Boys and Girls Club of Southern Maryland is situated in the lowest lying area just north of the intersections with 4th Street. The remaining area between 4th and 6th Street is residential, with some elevated properties and some located at ground level.

Two branches of the storm drain system run along Dayton Avenue and discharge water into the main 5th Street storm drain system at the intersection of Dayton Avenue and 4th Street. Infrastructure at the intersection of Chesapeake Avenue and 4th Street is discussed in Section 4.6. The branch to the north of 4th Street originates 660 linear feet upstream. There are multiple inlets along the length of the north branch and they receive runoff from large contributing areas to the west. The branch to the south of 4th Street originates at Dayton Avenue and 3rd Street where multiple inlets at the intersection receive runoff from the south.

Photo 32 - Dayton Avenue Looking South

Photo 33 - Dayton Avenue at 4th Street

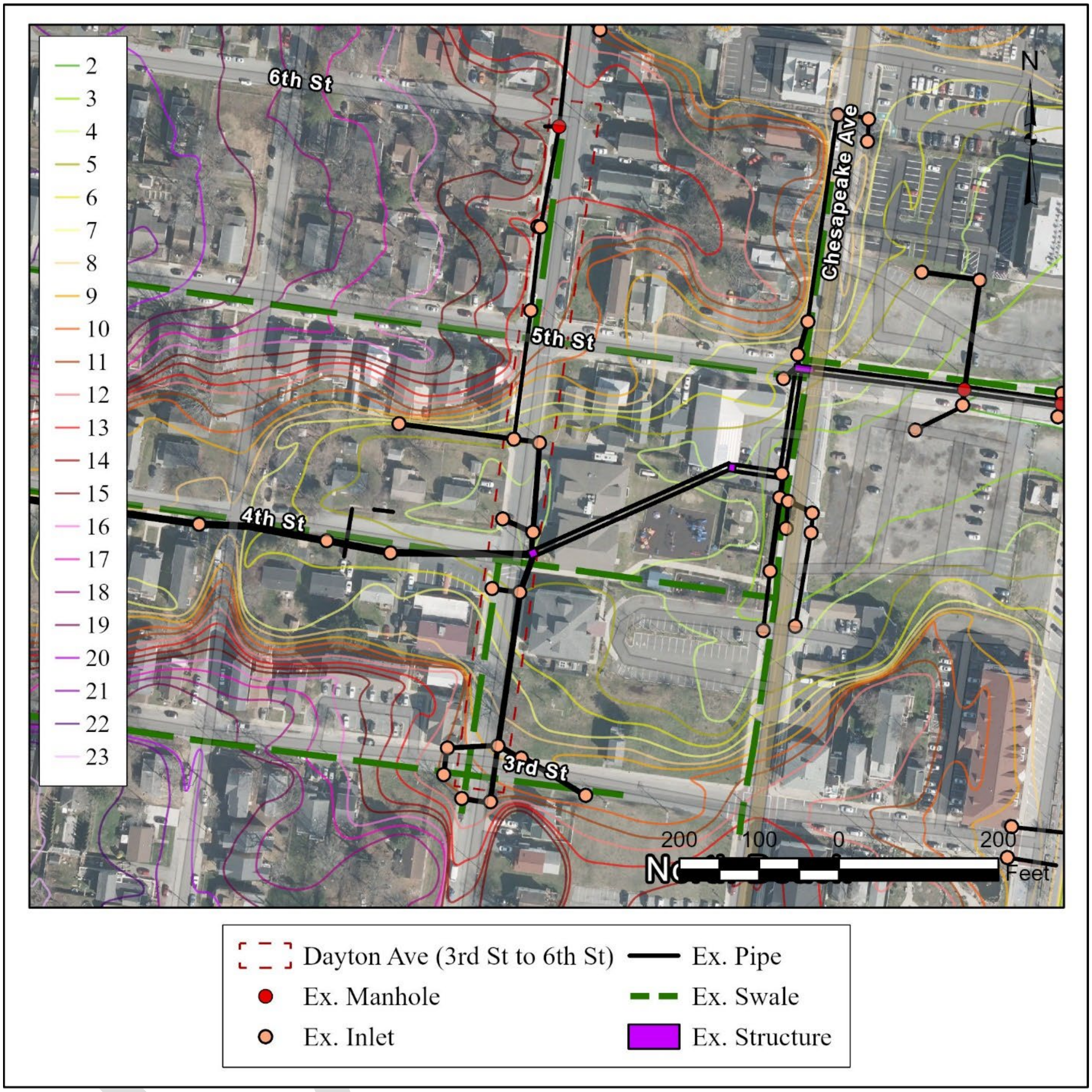


Figure 26 - Dayton Avenue between 3rd Street and 6th Street (legend refers to contour elevations in feet NAVD88)

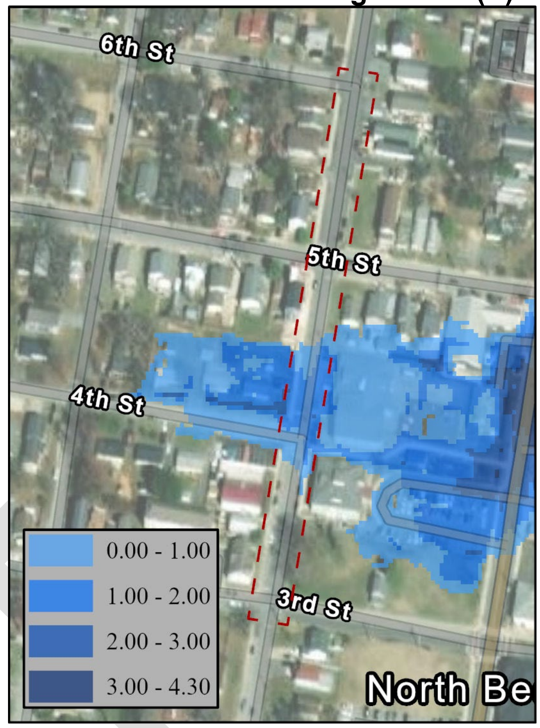
Flooding threats along this high priority assessment area are described in the sections below.

4.9.1. SLR and Storm Surge

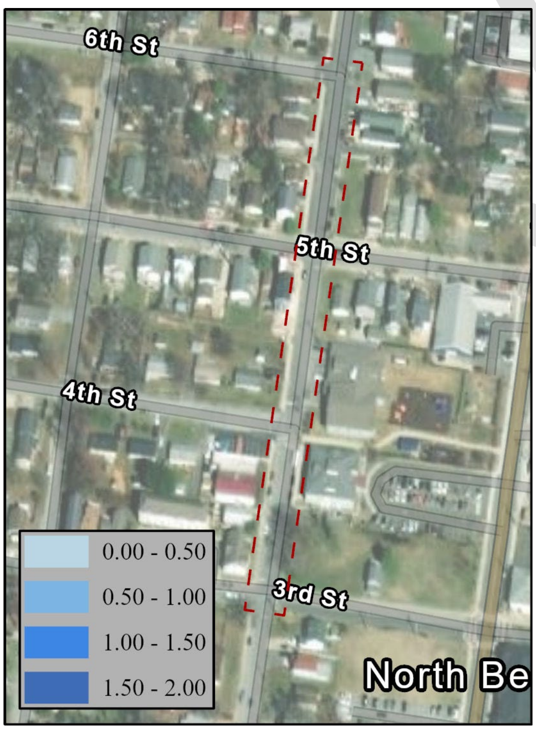
Daily flooding from SLR is only shown in the maps for 2100 SLR. However, for SLR + the 1% annual chance storm surge event, flooding along the lowest portions this road segment is shown for 2030, 2050 and 2100. This is likely a result of low elevations between this area and the shoreline.

2030 MSL (ft)

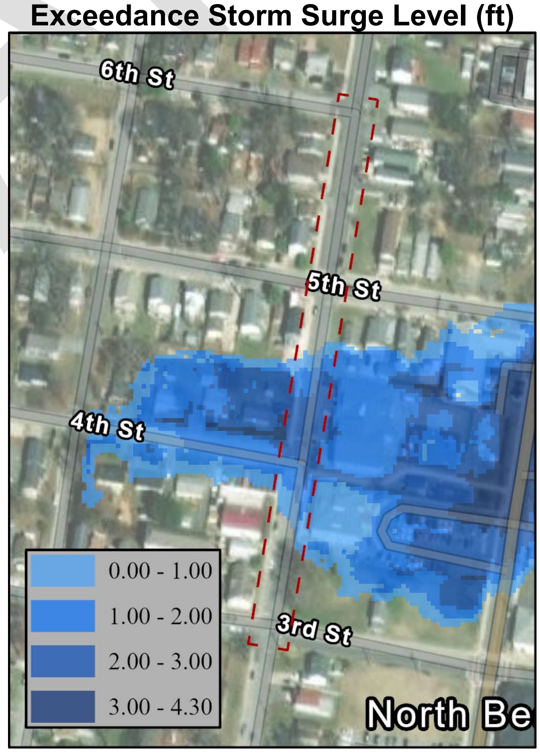
2030 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



2050 MSL (ft)



2050 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



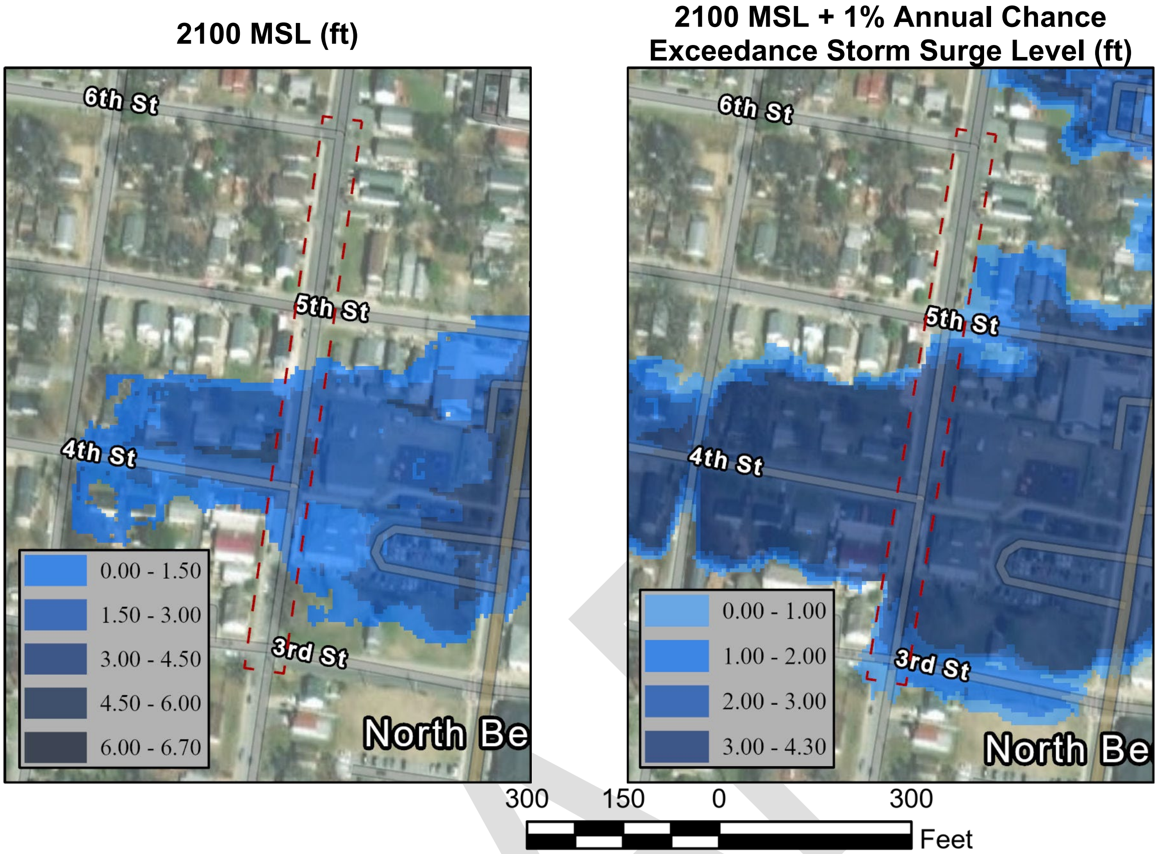


Figure 27 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.9.2. Wave Overtopping

Given the offset of Dayton Avenue to the Chesapeake Bay shoreline, wave overtopping will not result in flooding in this area.

4.9.3. Storm Drainage

Flooding of the two branches is due to the large contributing drainage area of the undersized infrastructure. The current capacity of the branches is inadequate to convey flow to infrastructure at 4th Street, which results in flooding throughout the system.

Table 21 - Flooding at Dayton Street – Existing Conditions

High Priority Area	Hours of Flooding					
	2030 1-yr	**2030 10-yr**	**2030 100-yr**	**2050 1-yr**	**2050 10-yr**	**2050 100-yr**
Dayton Avenue between 3rd Street and 6th Street	0.5	1.0	1.6	0.5	1.0	1.6

In the existing conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 14 out of 22 nodes (64%) experienced flooding and the maximum flood time was 1.6 hours.

4.10. Burnt Oaks North Apartments

The Burnt Oaks North Apartments are located at the northeast border of North Beach town limits and are surrounded by natural marsh area. The residential buildings are at an approximate elevation of +7 to +9 feet NAVD88. There is a sharp decline in elevation along the northern side of the homes where elevations drop quickly to less than 3 feet NAVD88. No shoreline protection structures exist along the surrounding marsh area. The Burnt Oaks north Apartments contains an isolated stormwater system with a retention pond. The community topography has tolerable elevation change to provide suitable conveyance of storm flows. Visual assessment during field investigations reveal washout and erosion issues are likely due to stormwater runoff velocities.

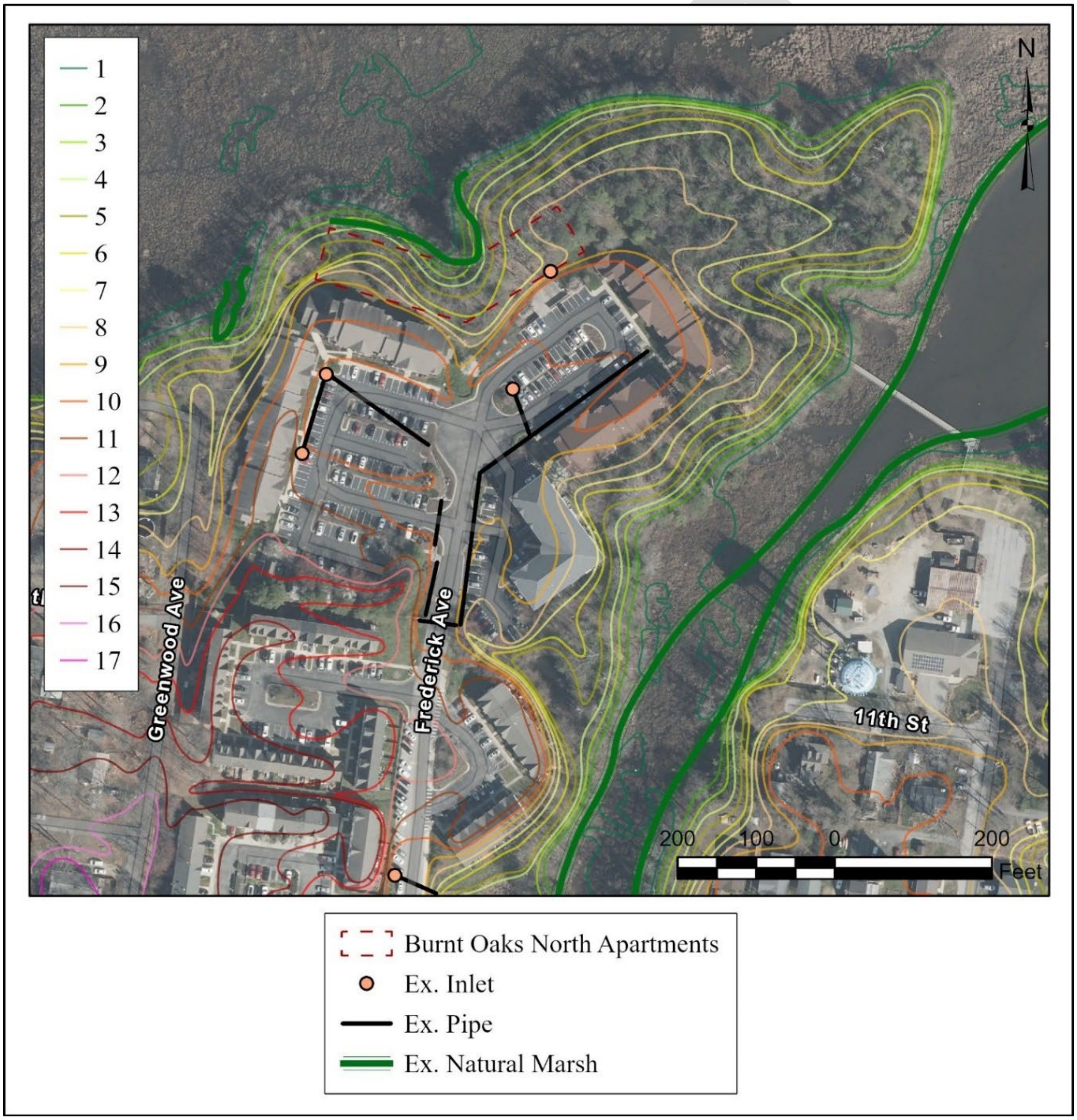


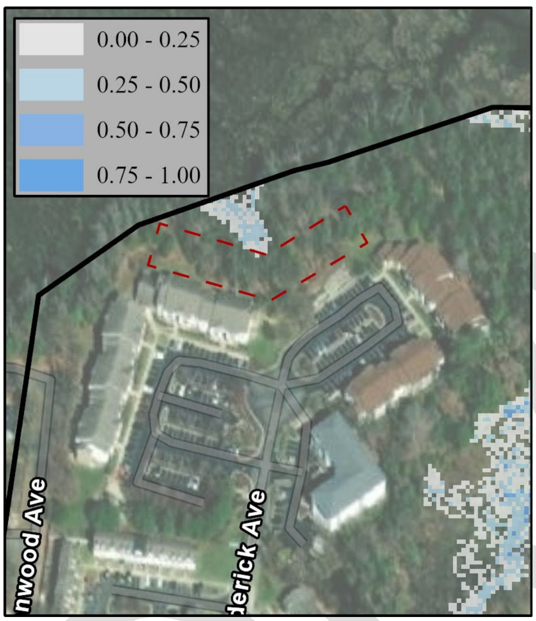
Figure 28 - Burnt Oaks North Apartments (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

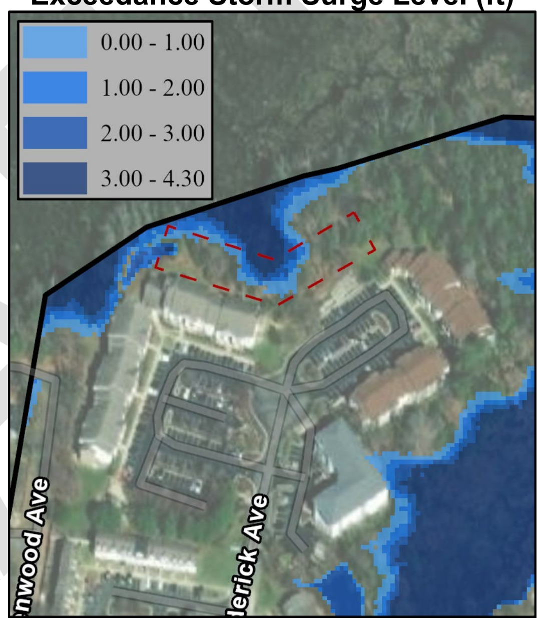
4.10.1. SLR and Storm Surge

The maps produced for MSL in 2030, 2050 and 2100 show that elevations of the buildings and parking lots are high enough to prevent flooding from daily tides due to SLR alone, though water levels will be very close to approximate ground level of some of the buildings. The 2030 and 2050 SLR + 1% annual chance storm surge also will not flood the infrastructure of the complex, but 2100 SLR + the 1% annual chance storm surge will result in flooding of approximately 85% or more of the complex infrastructure.

2030 MSL (ft)



2030 MSL + 1% Annual Chance Exceedance Storm Surge Level (ft)



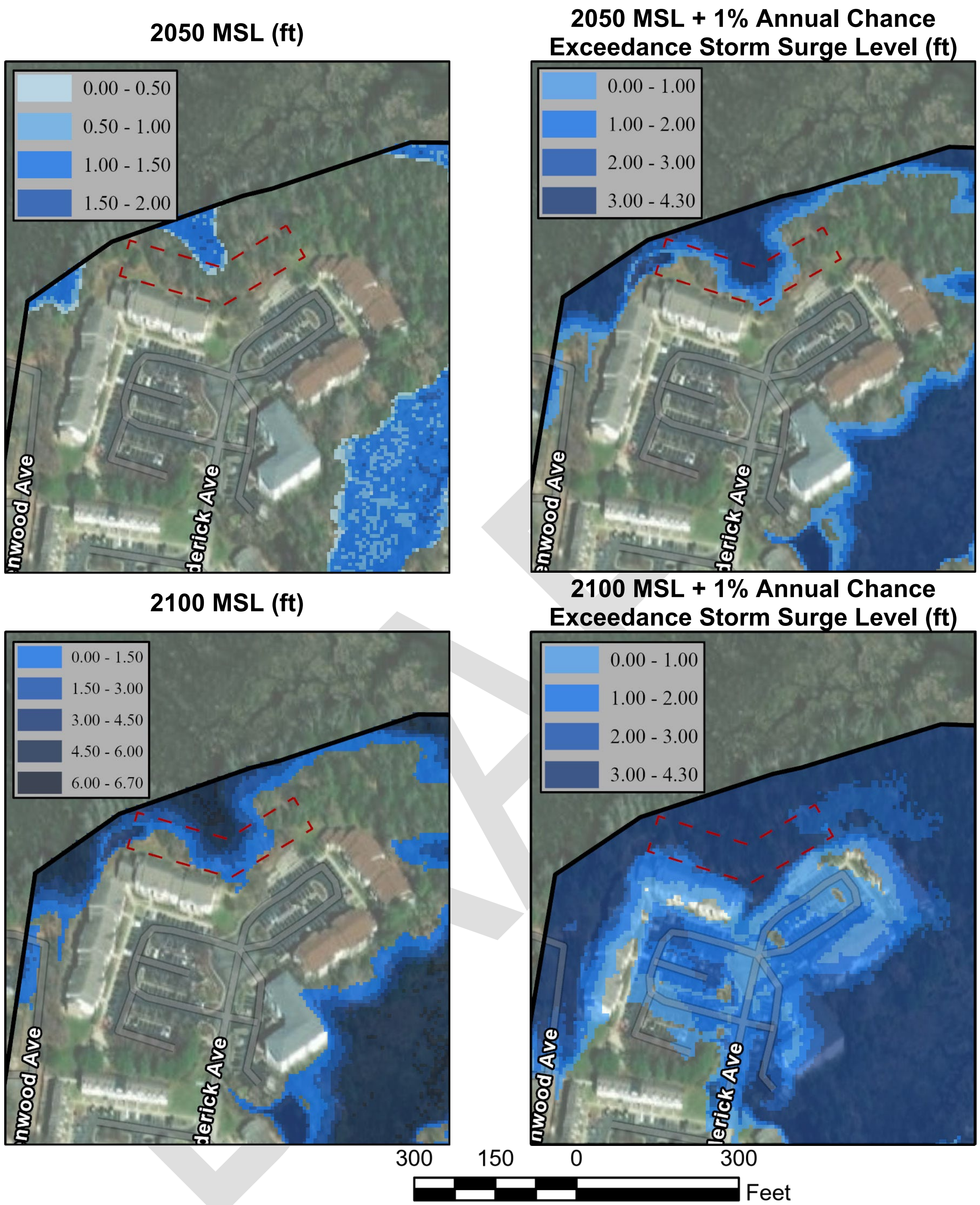


Figure 29 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.10.2. Wave Overtopping

The shoreline along the Burnt Oaks North Apartments assessment area mainly consists of natural marsh. Given its location inland from the Chesapeake Bay shoreline and the steep incline of the topography, wave overtopping will likely not result in flooding, even for the 2100 SLR + 1% annual chance storm surge event.

4.10.3. Storm Drainage

The Burnt Oaks North Apartments is at a higher elevation compared to other areas of the Town and provides positive conveyance of storm flows. Visual assessment during field investigations reveal washout and erosion issues are likely due to stormwater runoff velocities.

4.11. Frederick Avenue between 3rd Street and 4^{th} Street

Frederick Avenue is a residential street with a roadway elevation of +8.5 feet NAVD88 near the intersection with 4^{th} Street. Elevations remain relatively constant for the first 100 feet in the direction of 3^{rd} Street before quickly increasing to +16 feet NAVD88 at the intersection of Frederick Avenue and 3^{rd} Street.

The Frederick Avenue storm drain system begins at Frederick Avenue and 3^{rd} Street where multiple inlets at the intersection receive runoff from the south. The system then flows north until it ties into the storm drain infrastructure at 4^{th} Street. Infrastructure at the intersection of Frederick Avenue and 4^{th} Street is discussed in Section 4.6.

Photo 34 - Frederick Avenue between 3rd and 4th Street

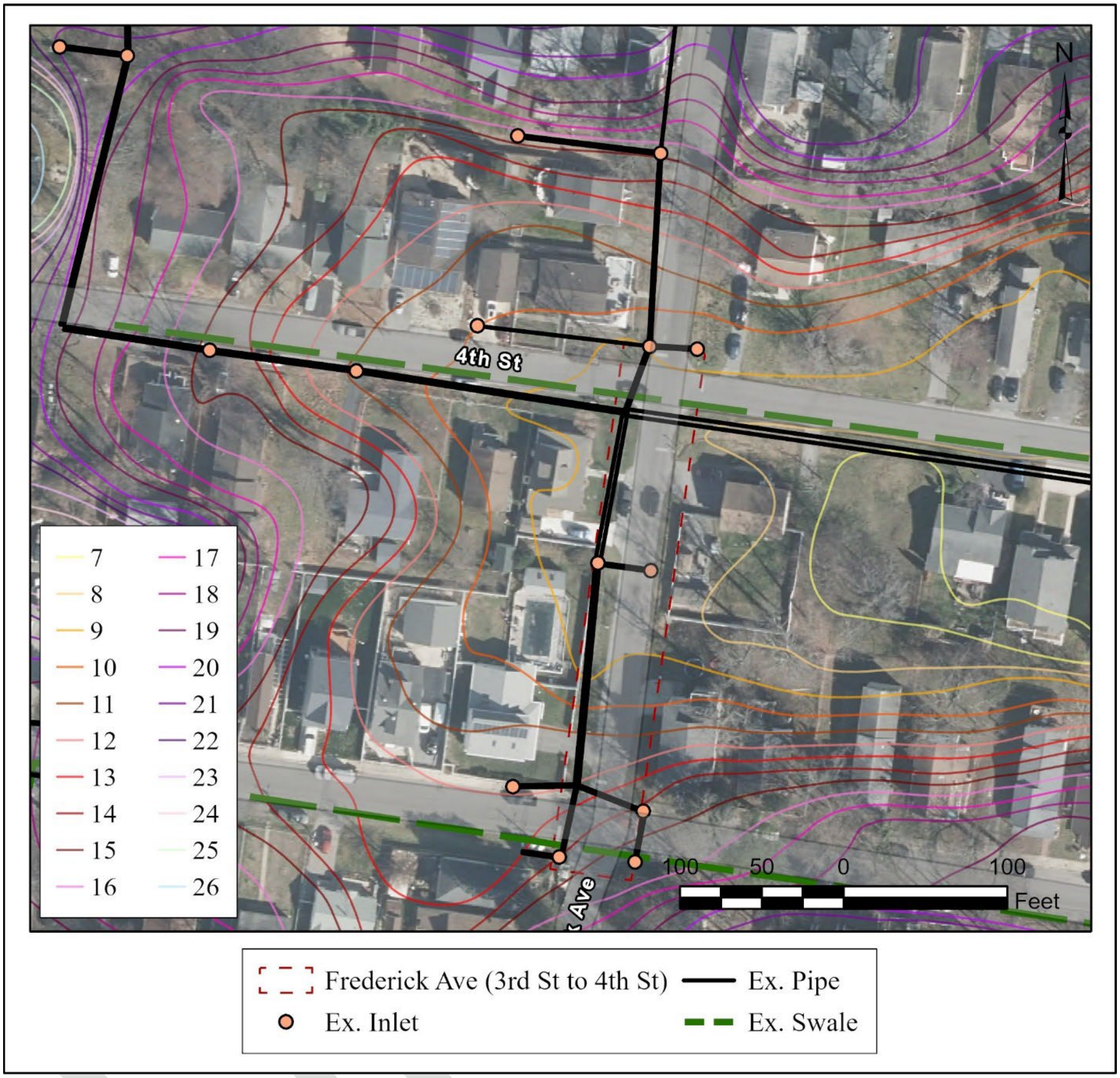


Figure 30 - Frederick Avenue between 3rd Street and 4th Street (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.11.1. SLR and Storm Surge

The area is not threatened by flooding due to SLR until past 2050. The mapping effort shows only the extreme scenario of 2100 SLR levels with the 1% annual chance storm surge elevation of +11.3 feet NAVD88 will result in flooding in this area. The lower ground elevations that extend from the shoreline farther inland will expose Frederick Avenue to this flood event.

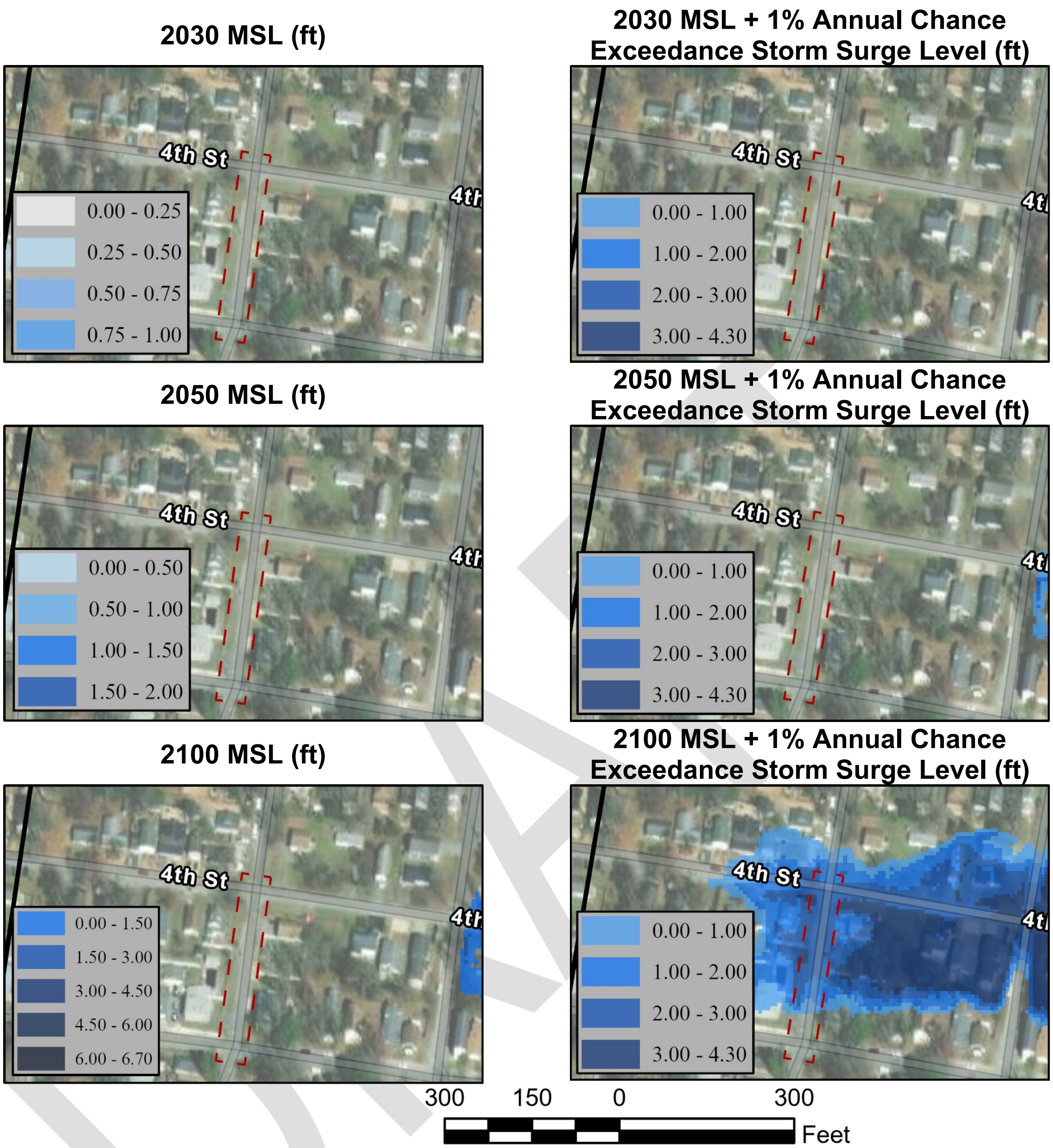


Figure 31 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.11.2. Wave Overtopping

Given the distance between Frederick Avenue to the Chesapeake Bay shoreline, wave overtopping is not a source of flooding in this area.

4.11.3. Storm Drainage

Flooding along Frederick Avenue from its origination to the main 4th Street infrastructure is due to the large contributing drainage area of the undersized infrastructure.

Table 22 - Flooding at Frederick Avenue – Existing Conditions						
High Priority Area	**Hours of Flooding**					
	2030 1-yr	**2030 10-yr**	**2030 100-yr**	**2050 1-yr**	**2050 10-yr**	**2050 100-yr**
Frederick Avenue between 3rd Street and 4th Street	0.0	0.4	1.0	0.0	0.4	1.0

In the existing conditions SWMM model, this area was flooded by the 10-yr storm event. In the 100-yr storm event (2050) 8 out of 9 nodes (78%) experienced flooding and the maximum flood time was 1.0 hours.

4.12. Greenwood Avenue and 8th Street

The intersection of Greenwood Avenue and 8th Street is located in a residential area of the Town. Elevations at this intersection reach approximately +10 feet NAVD88. The County Sewer pump station is located at this intersection.
The intersection of Greenwood Avenue and 8th Street contains an isolated stormwater system. The topography has tolerable elevation change to provide suitable conveyance of storm flows.

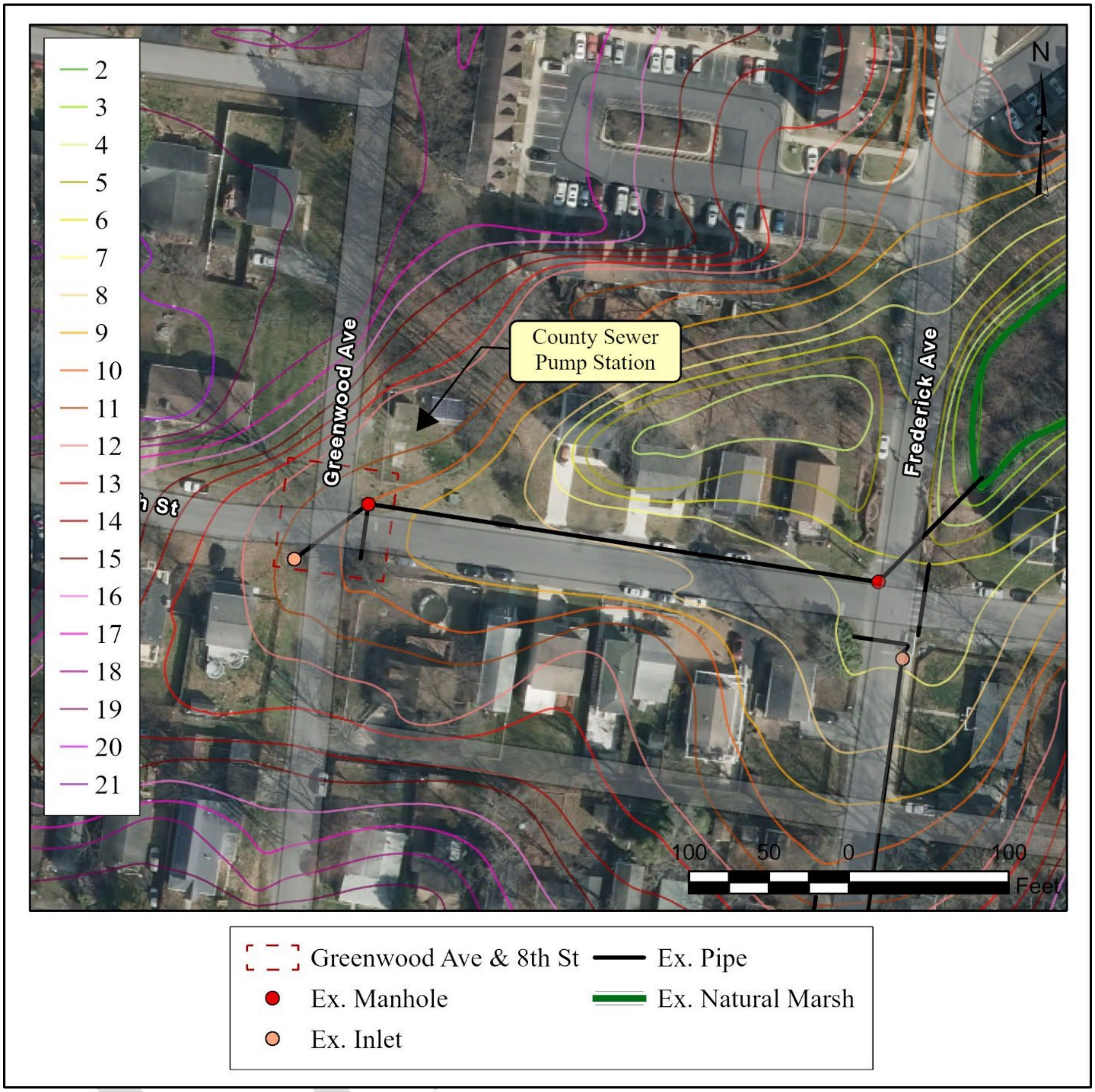


Figure 32 - Greenwood Avenue and 8th Street (legend refers to contour elevations in feet NAVD88)

Flooding threats along this high priority assessment area are described in the sections below.

4.12.1. SLR and Storm Surge

The mapping produced by the ESRGC shows SLR up to 2100 alone will not result in flooding of this intersection. For the SLR + 1% annual chance storm surge, flooding is only shown for 2100 with depths of less than 1 foot.

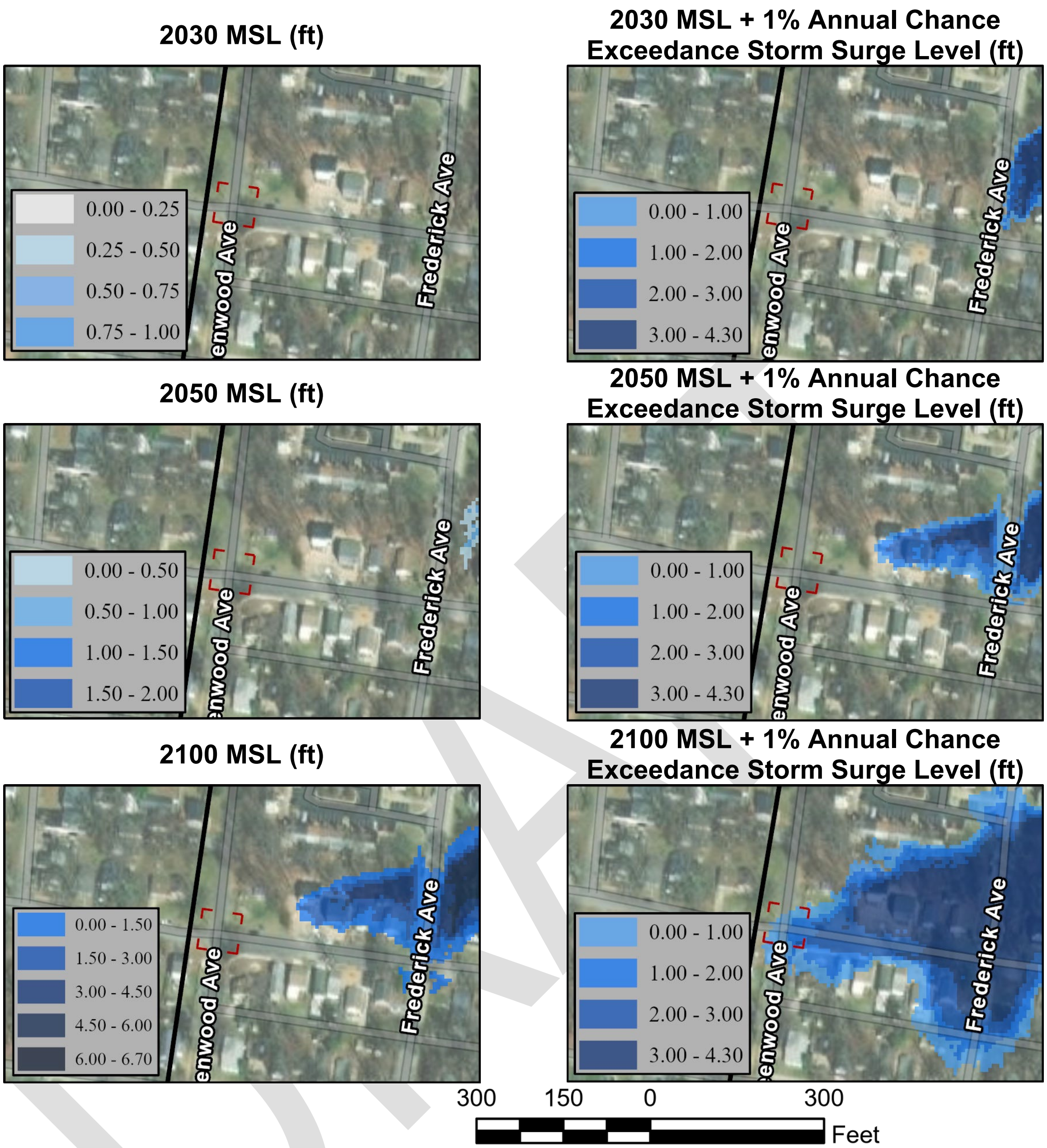


Figure 33 - MSL flood depths (ft) for 2030, 2050, and 2100 and 1% Annual Chance Flood Depth

4.12.2. Wave Overtopping

Given the offset of Greenwood Avenue to the Chesapeake Bay shoreline, wave overtopping will not result in flooding in this assessment area.

4.12.3. Storm Drainage

The stormwater system at the intersection of Greenwood Avenue and 8th Street has adequate topography to provide suitable conveyance of storm flows. Flooding is due to undersized infrastructure for the flows from the upland County contributing drainage area.

4.13. Other Areas Identified by Community Input

4.13.1. San Francisco by the Bay

The San Francisco by the Bay community is located at the southwest border of North Beach town limits and are surrounded by woods. The residential buildings are at an approximate elevation of +20 to +25 feet NAVD88. The rear of the residential buildings are surrounded by steep slopes with tree cover where stormwater flows down the slope and into a tributary that continues to tidally influenced marsh areas and waters southeast of the Town limits. The community topography has considerable elevation change to provide suitable conveyance of storm flows. Visual assessment during field investigations reveal   washout and erosion issues are likely due to stormwater runoff velocities.

4.13.2. Bay Avenue and 8th Street

The intersection of Bay Avenue and 8th Street is a low-lying area with inadequate drainage to prevent water ponding. The inadequate drainage is caused by the surrounding areas of higher elevation and the parking lot adjacent to the intersection. There is no storm drain infrastructure to collect flow at the low points of the area.

Photo 35 - Bay Avenue and 8th Street

4.13.3. Chesapeake Avenue and 7th Street

The intersection of Chesapeake Avenue and 7th Street receives significant runoff from higher elevation areas in the west. The intersection lacks storm drain infrastructure and there are isolated low spots where water ponds.

Photo 36 - Chesapeake Avenue and 7th Street

4.13.4. Dayton Avenue and 7th Street

The intersection of Dayton Avenue and 7th Street receives significant runoff from higher elevation areas in the west. The intersection lacks storm drain infrastructure and there are isolated low spots where water ponds.

Photo 37 - Dayton Avenue and 7th Street

4.13.5. Erie Avenue between 6th Street and 7th Street

The intersection of Erie Avenue and 6th Street receives runoff from the western areas of higher elevation but does not have storm drain infrastructure to intercept the flow. The alley between 6th Street and 7th Street is also an area where runoff converges. Isolated low spots allow water to pond and runoff eventually enters the storm drain system at Dayton Avenue.

Photo 38 - Erie Avenue and 6th Street

Photo 39 - Erie Avenue between 6th Street and 7th Street

4.13.6. Frederick Avenue and 8th Street

The intersection of Frederick Avenue and 8th Street receives significant runoff from higher elevation areas to the south. The isolated storm drain system originates at Greenwood and 7th and flows north until it outfalls to a drainage swale at 8th Street. The storm drain infrastructure at the intersection is undersized and there are low spots where water ponds before being discharged.

Photo 40 - Frederick Avenue and 8th Street

4.13.7. Greenwood Avenue and 3rd Street

The intersection of Greenwood Avenue and 3rd Street receives significant runoff from higher elevation areas in the west. The intersection has basic road culverts crossing Greenwood Avenue, but there are isolated low spots where water ponds due to inadequate site topography.

Photo 41 - Greenwood Avenue and 3rd Street

4.13.8. Erie Avenue and 2nd Street

The intersection of Eire Avenue and 2nd Street receives significant runoff from higher elevation areas in the west. The intersection lacks storm drain infrastructure and there are isolated low spots where water ponds.

Photo 42 - Erie Avenue and 2nd Street

4.13.9. Chestnut Street

Runoff enters Chestnut Street from higher elevation areas in the west and the adjacent parking lot. Inlets at the two ends of the street collect runoff and discharge it in the Chesapeake Bay. Other areas along the street lack storm drain inlets, and due to inadequate topography, there are isolated low spots where water ponds.

Photo 43 - East Chestnut Street


Photo 44 - West Chestnut Street

5. VULNERABILITY ASSESSMENT

The vulnerability of each high priority assessment area can be determined by examining the three components of vulnerability:

1. *Exposure* – how exposed is each area to a hazard such as flooding?
2. *Sensitivity* – is the area sensitive to the consequences of a hazard such as flooding?
3. *Adaptive Capacity* – can the area be easily adapted to the conditions posed by a hazard such as flooding?

For the purposes of this study, the high priority assessment areas examined are already known to experience flooding. However, the source of flooding can be due to a rainfall event or coastal flooding. Exposure for each high priority assessment area is defined for both types of flooding for each high priority area. The following guidelines were used to determine the 'exposure' rating for each area:

- **Very High** – Likely to flood in near future including:
  - SLR + 1% annual chance storm surge by 2030
  - The 1-year or 10-year rainfall event
- **High** – Likely to flood by 2050
  - SLR + 1% annual chance storm surge after 2030 but by 2050
  - The 100-year rainfall event
- **Medium** – Likely to flood past 2050
  - SLR + 1% annual chance storm surge after 2050
  - Extended flooding of 100-year rainfall event in 2050 with flooding lasting more than 0.5 hrs
- **Low** – Unlikely to flood until past 2050.

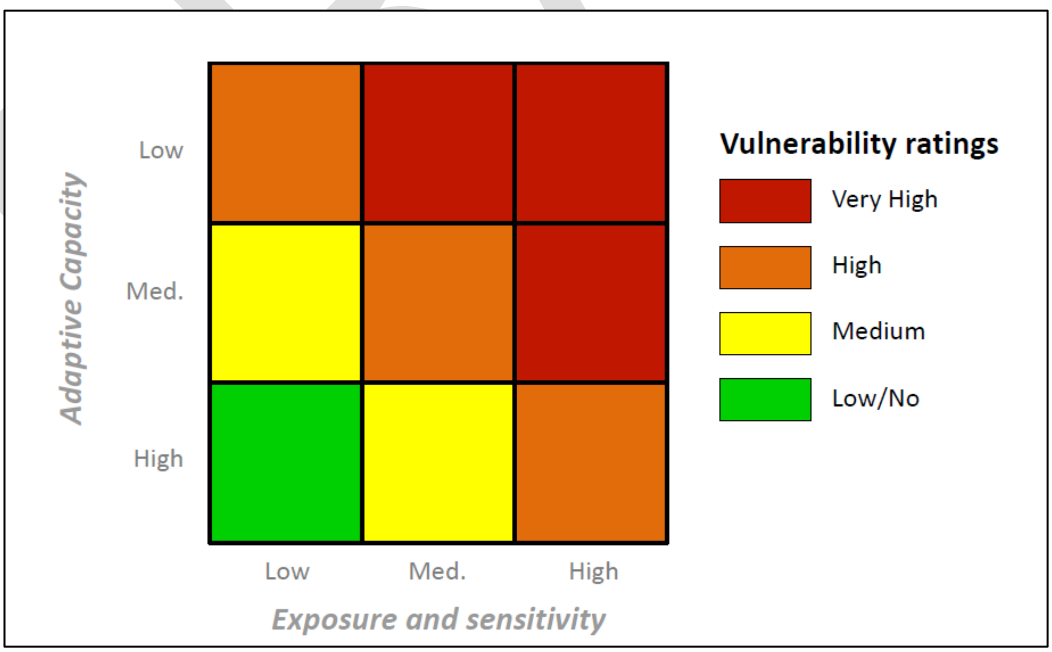


Figure 34 - Determination of Vulnerability Ratings

Sensitivity to flooding was determined by examining the assets within the high priority assessment area. The following classifications were used for 'sensitivity' to flooding:

- **Very High** – Area consists or Town-owned assets, commercial, or critical infrastructure, such as access roads;
- **High** – Area consists of residential properties only;
- **Medium** – Area consists of assets that may experience long-term damage but will not endanger human life, such as parking areas;
- **Low** – Area consists of assets that will not experience long term damage and not endanger human life, such as open space or marsh area.

Finally, the adaptive capacity of each high priority assessment area was examined to determine the vulnerability. The 'adaptive capacity' of the assessment areas was determined using the following guidelines:

- **High** – Area can naturally adapt or rebound after flooding, such as a marsh or wetland;
- **Medium** – Minor modifications are required to adapt an assessment area to mitigate the risk of flooding, such as conversion of open space to a raingarden or retention area.
- **Low** – Major construction is required to adapt an assessment area to mitigate the risk of flooding, such as storm drain upgrades or seawall construction.

Using these metrics, the vulnerability of each high priority area was determined as presented in Table 23.

Table 23 - High Priority Area Vulnerability to Flooding

Assessment Area	Exposure	Sensitivity	Notes	Adaptive Capacity	Vulnerability Rating
Atlantic Avenue	• SLR & Storm Surge – Very High • Wave Overtopping – Very High • Stormwater Drainage – Very High	Very High	• Damage to Town road • Flooding of multiple homes • Area acts as pathway to flooding of inland areas • Street floods during 1-year storm and drains in <30 mins.	Low – major construction project needed to remediate flooding	Very High
9th Street between Chesapeake Avenue and Atlantic Avenue	• SLR & Storm Surge – Very High • Wave Overtopping – High • Stormwater Drainage – Very High	Very High	• Lowest elevations in the town • floodwaters can reach ground level of homes. • flooding occurs for 1-yr storm and drains in 1 hr.	Low – major construction project needed to remediate flooding	Very High
Annapolis Avenue between 7th Street and 9th Street	• SLR & Storm Surge – Very High • Wave Overtopping – Low • Stormwater Drainage – Very High	High	• Lowest elevations in the town • floodwaters can reach ground level of homes. • flooding occurs for 1-yr storm and drains in 1 hr.	Low – major construction project needed to remediate flooding	Very High
7th Street between Bay Avenue and Atlantic Avenue	• SLR & Storm Surge – Very High • Wave Overtopping – Very High	Very High	• Coastal flooding will occur from both surge and wave overtopping;	Low – major construction project needed	Very High

Table 23 - High Priority Area Vulnerability to Flooding

	• Stormwater Drainage – Very High		• flooding occurs from 1-yr rainfall event and doesn't drain for 2+ hrs. • Homes located at or slightly above grade.	to remediate flooding	
Bay Avenue between 5th Street and 7th Street	• SLR & Storm Surge – Very High • Wave Overtopping – Low • Stormwater Drainage – High	Very High	• Low elevation of road near 5th St. • Flooding occurs from 10-yr event and drains in <30 mins. • Homes and/or businesses located at or slightly above grade.	Low – major construction project needed to remediate flooding	Very High
5th Street between Chesapeake Avenue and Bay Avenue	• SLR & Storm Surge – Very High • Wave Overtopping – Low • Stormwater Drainage – Very High	Very High	• flooding occurs from 1-yr rainfall event and doesn't drain for 2+ hours. • New construction of public library	Low – major construction project needed to remediate flooding	Very High
Chesapeake Avenue between 4th Street and 6th Street	• SLR & Storm Surge – Very High • Wave Overtopping – Low • Stormwater Drainage – Very High	Very High	• Flooding occurs from 1-yr rainfall event and drains in <30 mins. • Town owned assets such as senior center, Boys & Girls Club	Low – major construction project needed to remediate flooding	Very High
1st Street between Chesapeake Avenue and Bay Avenue	• SLR & Storm Surge – Medium • Wave Overtopping – Low • Stormwater Drainage – High	High	• coastal flooding mapped only in 2100 • Flooding occurs from 1-yr rainfall and drains in <30 mins.	Low – major construction project needed to remediate flooding	High
Dayton Avenue between 3rd Street and 6th Street	• SLR & Storm Surge – High • Wave Overtopping – Low • Stormwater Drainage – High	Very High	• Residential Area with Town-owned assets • Flooding occurs for 1-yr storm and drains in <30 mins.	Low – major construction project needed to remediate flooding	Very High
Burnt Oaks North Apartments Retention Pond	• SLR & Storm Surge – Medium • Wave Overtopping – Low • Stormwater Drainage – Low	High	• Residential area only • Flooding doesn't reach infrastructure until past 2050	Medium – Erosion control project could be implemented	Medium
Frederick Avenue between 3rd Street and 4th Street	• SLR & Storm Surge – Medium • Wave Overtopping – Low • Stormwater Drainage – Medium	High	• Flooding doesn't occur until past 2050 • Flooding occurs from 10-yr rainfall event and drains in <30 mins.	Low – major construction project needed to remediate flooding	High
Greenwood Avenue and 8th Street	• SLR & Storm Surge – Low • Wave Overtopping – Low • Stormwater Drainage – Medium	Very High	• Flooding doesn't occur until past 2050 • Town Pump Station located within area	Low – major construction project needed to remediate flooding	High

6. ASSESSMENT AREA PRIORITIZATION

Based on the results of the Vulnerability Analysis, the following prioritization table was developed to rank the assessment areas in order of priority for flood management.

Table 24 - Prioritization of High Priority Areas	
Priority	**Assessment Area Description**
1	7th Street between Bay, Annapolis, and Atlantic Avenue
2	5th Street between Chesapeake Avenue and Bay Avenue
3	Atlantic Avenue
4	9th Street between Chesapeake Avenue and Atlantic Avenue
5	Bay Avenue between 5th and 7th
6	Annapolis Avenue between 7th Street and 9th Street
7	Chesapeake Avenue between 4th Street and 6th Street
8	Dayton Avenue between 3rd Street and 6th Street
9	1st Street between Chesapeake Avenue and Bay Avenue
10	Frederick Avenue between 3rd Street and 4th Street
11	Greenwood Avenue and 8th Street
12	Burnt Oaks North Apartments
13	Other Areas Identified by Community Input

7. FLOOD MITIGATION STRATEGIES

This study assessed threats due to compound flooding. Mitigation strategies, presented below, can be used in conjunction with one another to combat the identified vulnerable areas to the exacerbation of flood threats due to climate change and sea level rise.

7.1. Coastal Flooding Mitigation Strategies

Coastal floodwaters enter the Town predominately through flood pathways at the northeastern border of the study limits. Various strategies to inhibit the propagation of coastal floodwaters inland can be used in conjunction with one another to mitigate strain on protective storm infrastructure and urgency to implement adaptivity plans for existing storm water drainage infrastructure.

Strategies for mitigating coastal flooding are presented in the following sections.

7.1.1. Seawall and Revetment

For areas exposed to both wave overtopping and flooding from SLR and storm surge, flooding could be mitigated using a seawall and revetment (Figure 35). The revetment should be designed to reduce the wave overtopping by acting as a barrier to incoming waves and dissipating the wave energy. Dissipation of wave energy will reduce and/or prevent wave overtopping. However, because revetments are porous rock structures, the revetment itself will not be able to prevent tides and storm surge from flooding the area to be protected. For this reason, a seawall is also recommended.

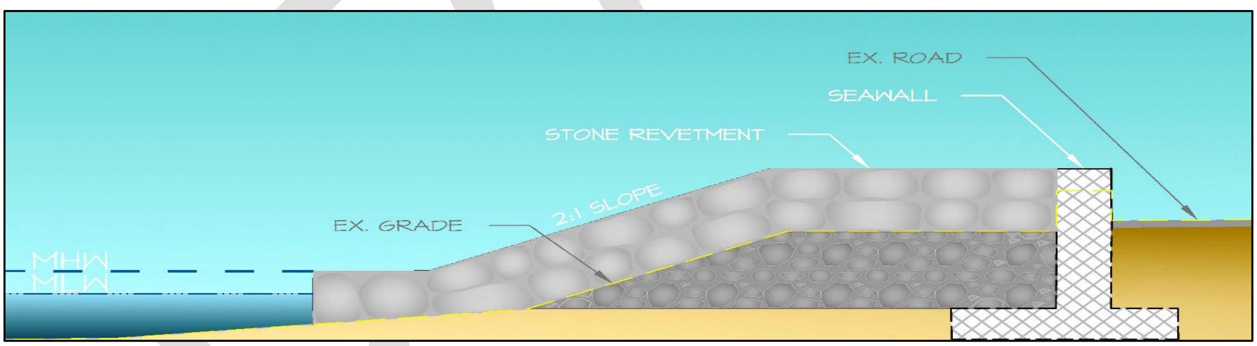


Figure 35 - Revetment and seawall shoreline protection

The seawall will prevent Storm Surge levels due to SLR and storm surge from encroaching inland by increasing the freeboard, or the vertical distance between flood waters and the top of the protective structure. Due to the low-lying nature of existing infrastructure in the identified vulnerable areas, freeboard must be increased to protect against predicted sea levels. Common construction methods of seawall include gravity concrete walls, cantilevered inverted T-type reinforced concrete, or anchored sheet pile walls. The appropriate structure is dependent on the subsurface soil type and wave exposure.

This mitigation strategy presents a strong capacity for adaptability to the desired risk level because revetment and seawall dimensions can be designed for the desired SLR scenario, storm surge elevation, and wave height. A more extreme scenario will increase the revetment encroachment seaward and the height of the seawall. Additionally, various architectural elements can be incorporated into the strategy to gain public support for the project, such as a boardwalk, benches, or flower boxes.
As with the construction of any elevated structure, stormwater management for rainfall-induced flooding must be considered and incorporated into the design.

7.1.2. Seawall

For shorelines along heavily developed areas that are only susceptible to flooding from SLR and storm surge, but not wave overtopping, the proposed flood mitigation strategy is a seawall. This strategy works well when the allowable footprint of the flood protection structure needs to be minimized. As discussed in the previous section, the seawall can take multiple forms depending on the site and geotechnical conditions. The proposed mitigation strategy at North Beach is shown in Figure 36.

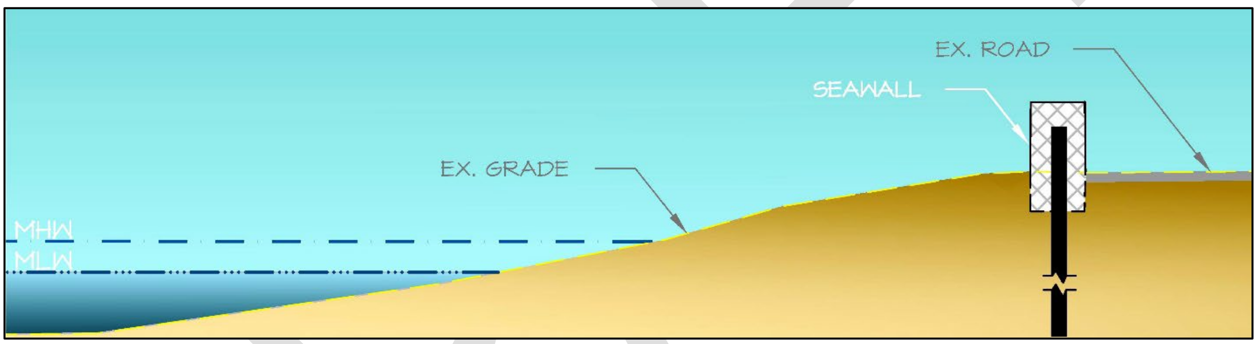


Figure 36 - Z Sheet Pile Seawall with concrete cap

The seawall features cantilever Z Sheeting sufficiently driven into foundation soils to provide protection against seepage and scour erosion during severe storms. The concrete cap provides additional protection along the portion of wall exposed to water levels. Where foundation soils are found to be adequate to support the sheeting, the sheeting can be driven directly into the ground. For areas with less desirable foundation soils, the seawall may require piles to support the structure.

7.1.3. Raising or Constructing New Earthen Berm

For areas exposed to flooding from wave overtopping, SLR and storm surge where an auxiliary goal of the project is to provide natural habitat, an earthen berm is recommended as the coastal flood mitigation strategy. This strategy will require a larger footprint and is, therefore, not recommended in highly-developed area.

Since an existing berm exists between Bay Avenue and Atlantic Avenue at the northern limits of the project, the strategy would be to raise the berm to prevent higher water levels from reaching the areas behind the berm.

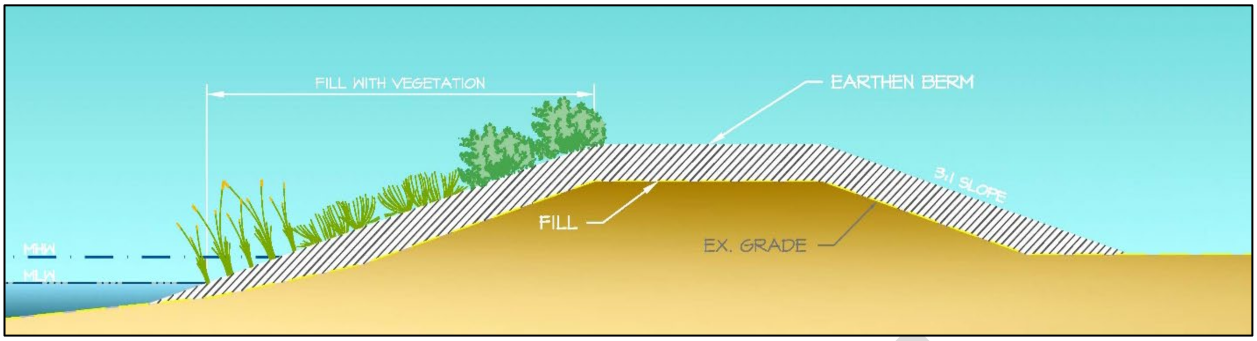


Figure 37 - Raised Earthen Berm

For areas along the natural shoreline where additional habitat is could be implemented, an earthen berm can be constructed with a living shoreline on the seaward edge. The living shoreline would provide additional elevation and a wider buffer for the flooding as well as environmental benefits.

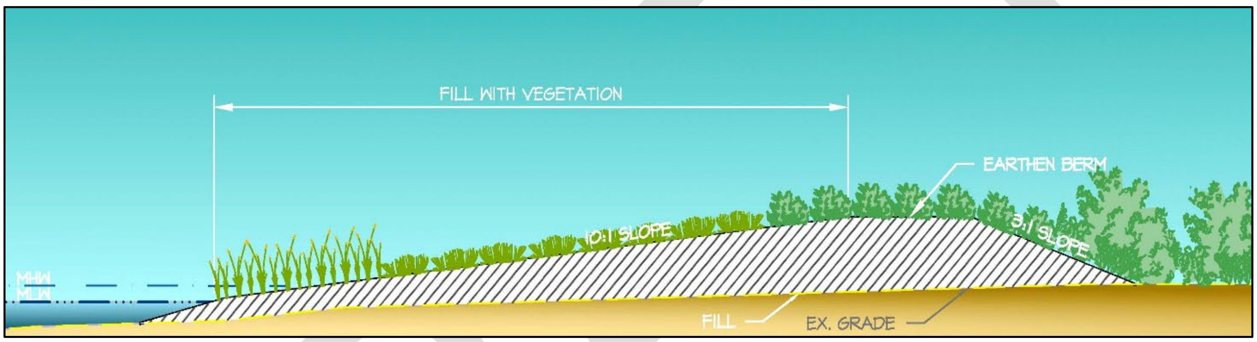


Figure 38 - New earthen berm with living shoreline

7.1.4. Stop Log

For areas where a permanently elevated structure is not feasible because continued access to the shoreline is required, a stop log, or flood barrier structure may be implemented to prevent flood waters from entering during periods of elevated water. These structures are proposed at the entrance to the beach area or Welcome Center or along the piers leading from the boardwalk along Bay Avenue.

Photo 45 - Stop Log Gate along Concrete Wall

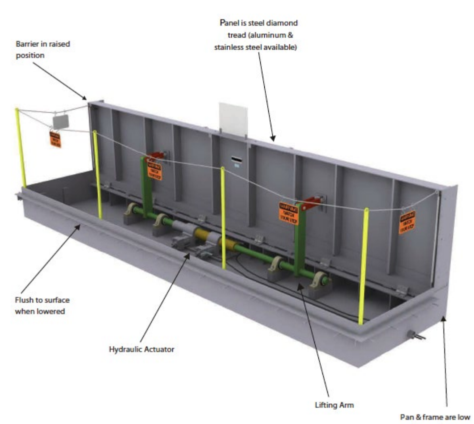


Photo 46 - Stop Log Structure with Hydraulic Lifts

7.2. Stormwater Flooding Mitigation Strategies

Stormwater runoff is collected by branches of the storm drain system and concentrated into several main branches before being discharged. Various strategies to increase the capacity of the system can be used in conjunction with one another to attenuate flooding and efficient utilization of the system.

Strategies for mitigating stormwater flooding are presented in the following sections.

7.2.1. Storm Drain Infrastructure Improvements

Drainage infrastructure improvements to reduce the extents of storm flooding in areas with undersized infrastructure or localized areas lacking storm drain infrastructure. Upgrading the pipe sizes or installing additional pipes in parallel and increasing inlet capacity increase the system's ability to collect and convey runoff and decrease the duration and frequency of storm flooding.

Increasing pipe sizes is limited by the existing topography, storm drain system elevations and other underground infrastructure, but can be used to mitigate flooding at the outer reaches of the system by efficiently conveying the flow to larger, central storm drain conduits. This approach can be used widely in many of the areas to mitigate flooding in areas where above ground practices are not feasible. The design must consider the increased flow being routed to the central storm drain conduits to ensure they do not become inundated.

Photo 47 - Pipe Replacement

7.2.2. Pumping Station

Installation of pumping stations to alleviate flooding from storm flows during low tide. Pumping stations will not prevent flooding during the storm event but will help dewater larger flooded areas in a timely manner. The pumping analysis performed is conceptual and the exact extents and duration of flooding will be subject detailed engineering analysis and design of the pumping station.

Photo 48 - Pumping Station

7.2.3. Tide Gate Valve

For outfalls that will be impacted by SLR, tide gate valve can be installed to prohibit tidal backflow of water into the stormwater outfall. Tide gates are relatively inexpensive compared to other devices, are not manufactured with mechanical parts that can fatigue or corrode and require less pressure head to operate. Tide gate valves can be installed directly at the outfall or upstream in a structure depending on site conditions.

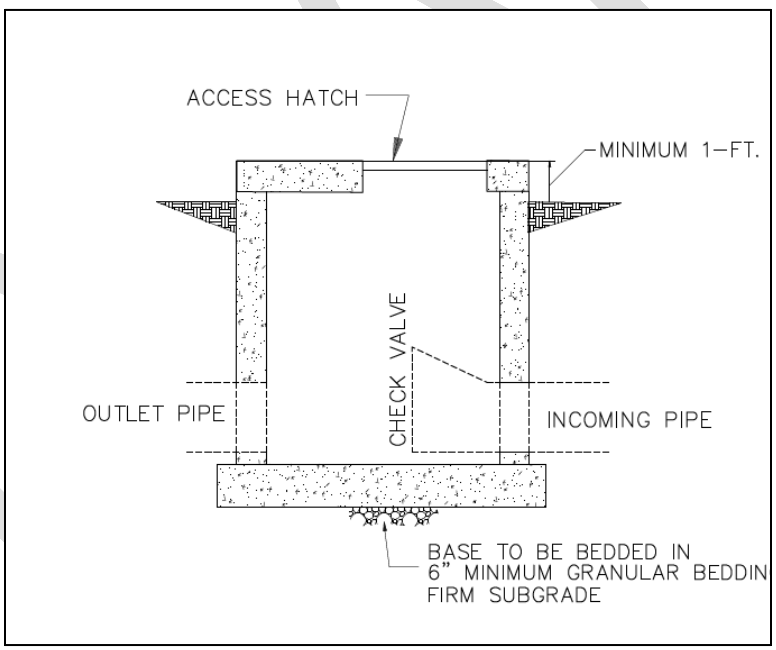


Figure 39 - Tide Gate Valve

7.2.4. Elevated Roadway

For areas where low elevation of the ground surface and stormwater system, the roadway can be elevated to improve flow and reduce flooding potential in the area.

Roadway surface elevations can be raised along with existing underground stormwater infrastructure in the area.

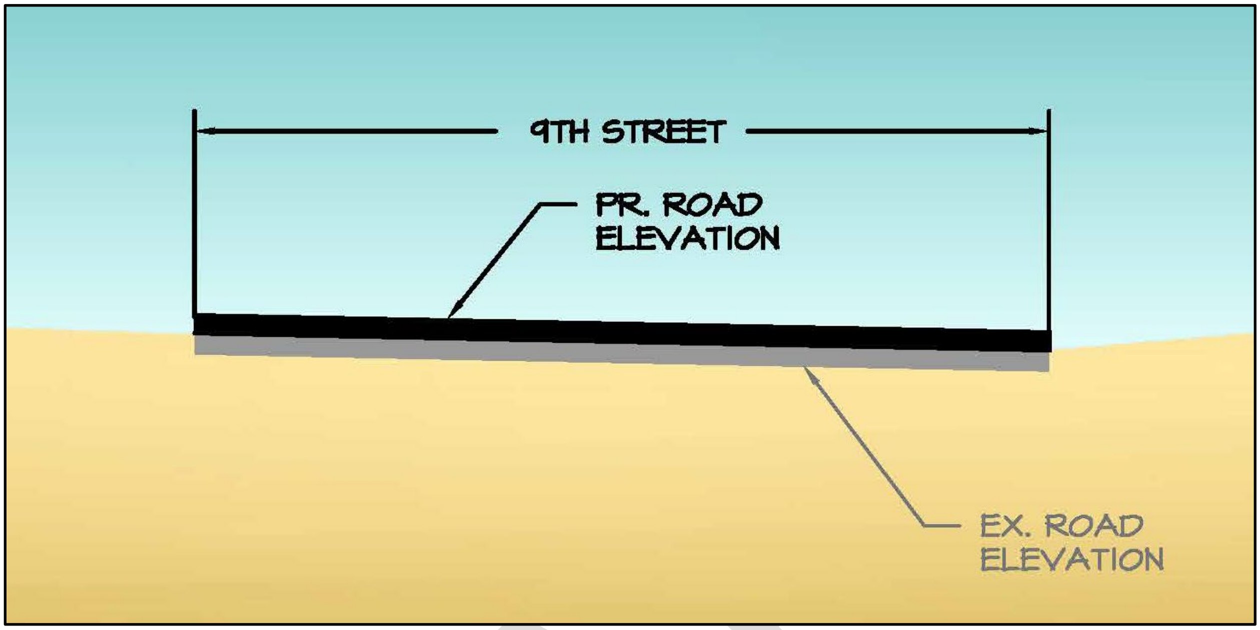


Figure 40 - Elevated Roadway

7.2.5. Underground Storage Vault

For areas with little existing underground infrastructure, underground storage vaults can be used to increase storage capacity within the system and allow the area more time to discharge flow before areas become inundated with flooding. Periods of high intensity rainfall can quickly inundate an area before it has time to discharge through gravity flow or pumping. The additional capacity provided by an underground storage vault attenuates the peak flow and provides more time for the system to discharge flow before flooding occurs at inlets.

7.2.6. Green Infrastructure

Green infrastructure concepts can be used to restore and mimic natural runoff patterns. These practices include bioretention facilities, vegetated swales, and riffle-pool conveyance. The facilities intercept runoff that would otherwise enter the storm drain system and allow for it to infiltrate. The size and location of the practices impact their effectiveness at mitigating runoff, but they can be used to lower overall inflow to the system and decrease peak flow rates.

Green infrastructure concepts can be used to restore and mimic natural runoff patterns. These practices include bioretention facilities, vegetated swales, and riffle-pool conveyance.

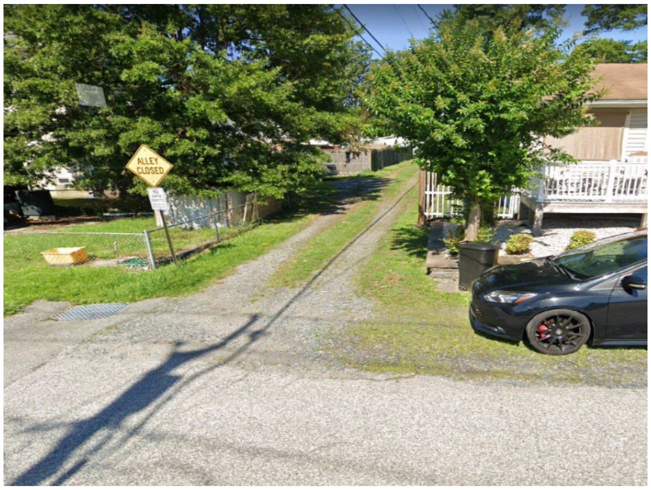


Photo 49 – Alley from Dayton Ave to Chesapeake Ave between 8th St and 9th St

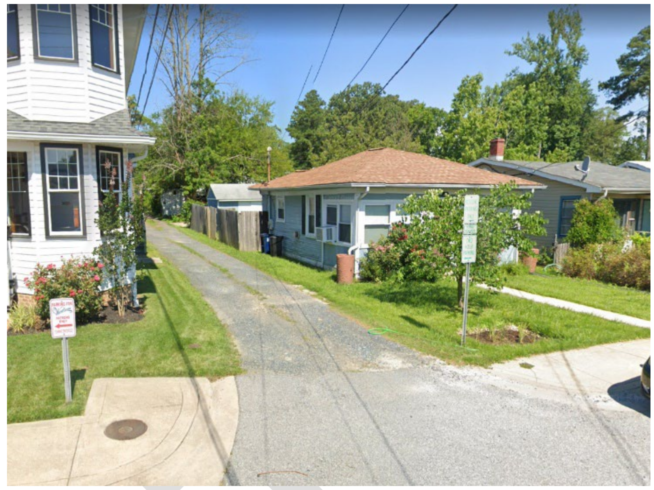


Photo 50 – Alley from Dayton Ave to Chesapeake Ave between 7th St and 8th St

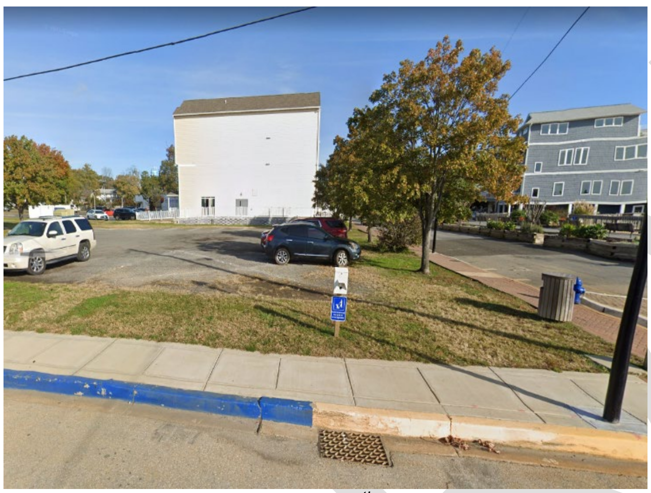


Photo 51 – Northwest Corner of 5th Street and Bay Avenue

Photo 52 – Northeast corner of Dayton Ave and 3rd St

Photo 53 – Greenwood Avenue Alley between 4th Street and 5th Street

Photo 49 - Bioretention Facility

For areas with existing swales and alleys that direct flow to the stormwater system, vegetated swales can be used to attenuate stormwater flow into the system with a small overall footprint. Vegetated swales can be installed in existing runoff flow paths to allow for better infiltration due to lower velocities and more permeable soil within the swale.

Photo 55 - Vegetated Swale

For areas with ample space and an appropriate grade, Riffle-Pool Conveyance may be used to provide extended storage and allow for infiltration of runoff flow to an area, reducing the impact on the existing stormwater system.

Photo 56 - Riffle-Pool Conveyance

7.3. Management Strategies for Flood Mitigation

In addition to the nature-based and structural mitigation strategies proposed in Sections 7.1 and 7.2, the Town can manage flood risk through imposing ordinances, policy updates and design standards on new and/or existing development in vulnerable areas. Different management strategies the Town can consider are:

- ❖ Revise existing or develop new ordinances that regulate development in areas with known flood risk, similar to the Maryland Coast Smart Council – Coast Smart Construction Program 2020, which regulates construction and reconstruction of buildings and highway facilities within the Coast Smart Climate Ready Action Boundary (CS-CRAB).
- ❖ Update applicable codes and permits to require assessing flooding potential for future climate change including higher intensity rainfall events and sea level rise.
- ❖ Consider participation in the Community Rating System (CRS), a voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the National Flood Insurance Program (NFIP) to help lower premiums for properties within the community.
- ❖ Create staff position through grant funding responsible for implementing the Town’s flood mitigation efforts, including but not limited to, operation and oversight, planning, and public outreach.
- ❖ Establish educational program to help educate public on current and future flood risk to help emphasize the importance of implementing flood reduction measures at their homes, such as rain gardens. The program could also connect vulnerable residents with potential grant or funding opportunities to implement small-scale flood protection measures such as wet-proofing and raising utility elevations.
- ❖ Expand land acquisition program – for vulnerable areas where managed retreat is a viable option, the Town can take advantage of buyout or relocation assistance options to convert the areas to more resilient opportunities.

- Encourage the implementation of green infrastructure for stormwater management with the co-benefit of slowing stormwater runoff and removing pollutants that ultimately end up in the Chesapeake Bay and degrade water quality. Encouragement can be done either through policy adjustments or incentives,

8. ALTERNATIVES ANALYSIS FOR RISK MANAGEMENT

Risk management strategies refer to concepts or ideas for handling the risk determined during the Vulnerability Assessment. Options should follow the four T's of risk management, shown in Figure 41.

Figure 41 - The 4 T's of Risk Management

The four types of Risk Management Strategies (RMS) are defined as follows:

- Tolerate – also referred to as Risk Acceptance where the risk is either ignored or accepted.
- Terminate – also referred to as Risk Avoidance where the risk is avoided altogether.
- Transfer – Risk Transfer occurs when a separate entity is given the responsibility for managing the risk, such as the purchase of insurance.
- Treat – also referred to as Risk Mitigation or Risk Reduction. This option will aim at lessening the risk or the impacts should the risk be realized.

Considering the four- T's can help a community assess the options available to them for risk management. For the flood mitigation measures described in Section 7, the RMS alternatives developed will consider flood protection using the 2050 projected flooding from both coastal and rainfall events.

In order to evaluate each RMS alternative against each other, a decision matrix was utilized with a ranking system applied toward each criterion. The criteria were ranked from 0 to 5 depending on how well the alternative met the criteria. The ranking of the criteria utilized is as follows:

- Feasibility – How easily can the alternative be implemented (0 – not at all; 5 – very easily);
- Effectiveness – How well does the alternative reduce the risk from coastal resiliency stressors (0 – not at all; 5 – very well);

- Socio-economic Impacts – How beneficial to the community is the implementation of the alternatives against protecting against the coastal resiliency stressors (0 – not beneficial; 5 – very beneficial);
- Environmental Impacts – How significant are the environmental impacts of the alternative (0 – significant impacts; 5 – few impacts);
- Cost – How expensive will constructing the alternative be (0 – expensive relative to other alternatives; 5 – not expensive relative to other alternatives).

The following sections describe the analysis performed and the preferred alternative for each High Priority Area as ranked in the Prioritization Table.

8.1. 7th Street between Bay, Annapolis and Atlantic Avenue

With both residential and commercial property at risk of increased flooding intensity and frequency, 7th Street between Bay Avenue and Atlantic Avenue was ranked as the highest priority area for protection. Flooding can occur from multiple sources and does not drain efficiently.

8.1.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along 7th Street between Bay Avenue and Atlantic Avenue.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Stormwater flooding along road experienced for 18+ hours in 2050;
    - Storm surge flooding could be multiple feet in 2050;
    - Road perpetually flooded due to backwatering and inability to discharge during rainfall events;
    - Road could be unpassable multiple times a month, restricting access to homes along this segment of road.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +11 feet NAVD88 and revetment with 10-foot crest width to prevent flooding from SLR, the 1% annual chance storm surge and wave overtopping in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7.0 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7.0 feet NAVD88. Elevate Bay Avenue to +7.0 feet to provide a connection between the two earthen berms.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Increase stormwater pipe size 3 times larger than existing
    - Install pump station

- Results:
  - Flooding to be prevented for the 2050 1% annual chance storm surge elevation of 6.7 feet NAVD88.
  - Wave overtopping to be reduced so that vehicles can drive safely on road.
  - Flooding prevented for the 2050 100-year storm event.
- Impacts:
  - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
  - May require land acquisition to accommodate pump station equipment.

- Transfer – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +6.5 feet NAVD88 and revetment with 8-foot crest width to reduce flooding from SLR, storm surge and wave overtopping in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
    - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Install storage vault and upgrade existing stormwater pipes.
    - Construct vegetated swale along Dayton Avenue between 7th and 8th Streets.
    - Install pump station.
  - Results:
    - Flooding to be reduced for the 2050 1% annual chance storm surge but prevented for up to the 2050 10% annual chance storm surge level.
    - Wave overtopping to be reduced for the 10% annual chance storm to prevent damage to road but still result in unsafe driving conditions.
    - Flooding prevented for the 2050 100-year storm event.
  - Impacts:
    - Elevation of seawall unchanged from current elevation of jersey barrier, views will not be impacted;
    - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;
    - Prevention of backwatering from outfall pipes.

The decision matrix to determine the optimal RMS alternative is presented in Table 25.

Table 25 - Decision Matrix for 7th Street						
Options	**Feasibility**	**Effectiveness**	**Socio-economic Impacts**	**Environmental Impacts**	**Cost**	**Total**
RMS 1 – Tolerate Risk	5	0	0	2	5	12
RMS 2 – Terminate Risk	2	5	2	1	1	11
RMS 4 – Treat Risk	4	3	4	2	2	15

8.1.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 42.

A seawall and revetment are proposed to be constructed along Atlantic Avenue to reduce coastal flooding at 7th Street between Bay Avenue and Atlantic Avenue. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members. Additionally, an 8-foot wide revetment at the same elevation is recommended to reduce the wave overtopping and prevent damage to the road during large storm events.

To prevent coastal flooding from flooding 7th Street from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

The proposed stormwater system improvements reduce flooding in the area due to severe rain events during projected high tide conditions at the 7th Street stormwater outfall. A below grade storage vault is proposed along the eastern end of 7th Street. The vault, assumed to be 600 CY (10'Wx20'Lx3'D) in the model, will provide a storage area for excess stormwater and alleviate flooding of upstream structures. Replacing approximately 50 feet of pipe to increase pipe sizes along 7th Street will improve the capacity of the stormwater system and provide adequate conveyance of runoff. A green infrastructure BMP, such as a vegetated swale, is proposed along the Town's alley from Dayton Avenue to Chesapeake Avenue and between 7th Street and 8th Street. The swale would attenuate some of the incoming stormwater runoff by allowing it to infiltrate prior to entering the 7th Street stormwater system.

In the first alternative, a pump station is installed at the 7th street outfall to improve flow through the system during flooding events. The pump station was modeled with a startup depth of -4.2 feet NAVD88. The pump outfall would be coordinated with shoreline upgrades to discharge through the proposed structures with a tide valve into the Chesapeake Bay. If feasible, the pump station could also discharge over the seawall without a tide gate. For this first alternative, additional property would need to be acquired at the intersection of 7th Street and Atlantic Avenue to house the equipment associated with the pump including a generator and control panel. The first alternative is shown in Figure 42.

In the second alternative, a pump station would be installed at the 7th Street outfall to pump flow to the 9th Street outfall. The pump station was modeled with a startup depth of -4.2 feet NAVD88. Approximately 650 feet of additional pipes and conduits would be installed along Atlantic Avenue between 7th Street and 9th Street to connect the two systems. A below grade vault would be built along the new stretch of pipe along Atlantic Avenue for the pumping system. No additional property would be required at the 7th Street outfall, but cost would be significantly higher than the first alternative. The second alternative is shown in Figure 44.

In the first alternative SWMM, none of the nodes experienced flooding during the 100-yr storm event (2050), as shown in Table 26.

Table 26 - Flooding at 7th Street

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	2.5	2.5	2.6	18.4	18.4	18.4
Proposed	0.0	0.0	0.0	0.0	0.0	0.0

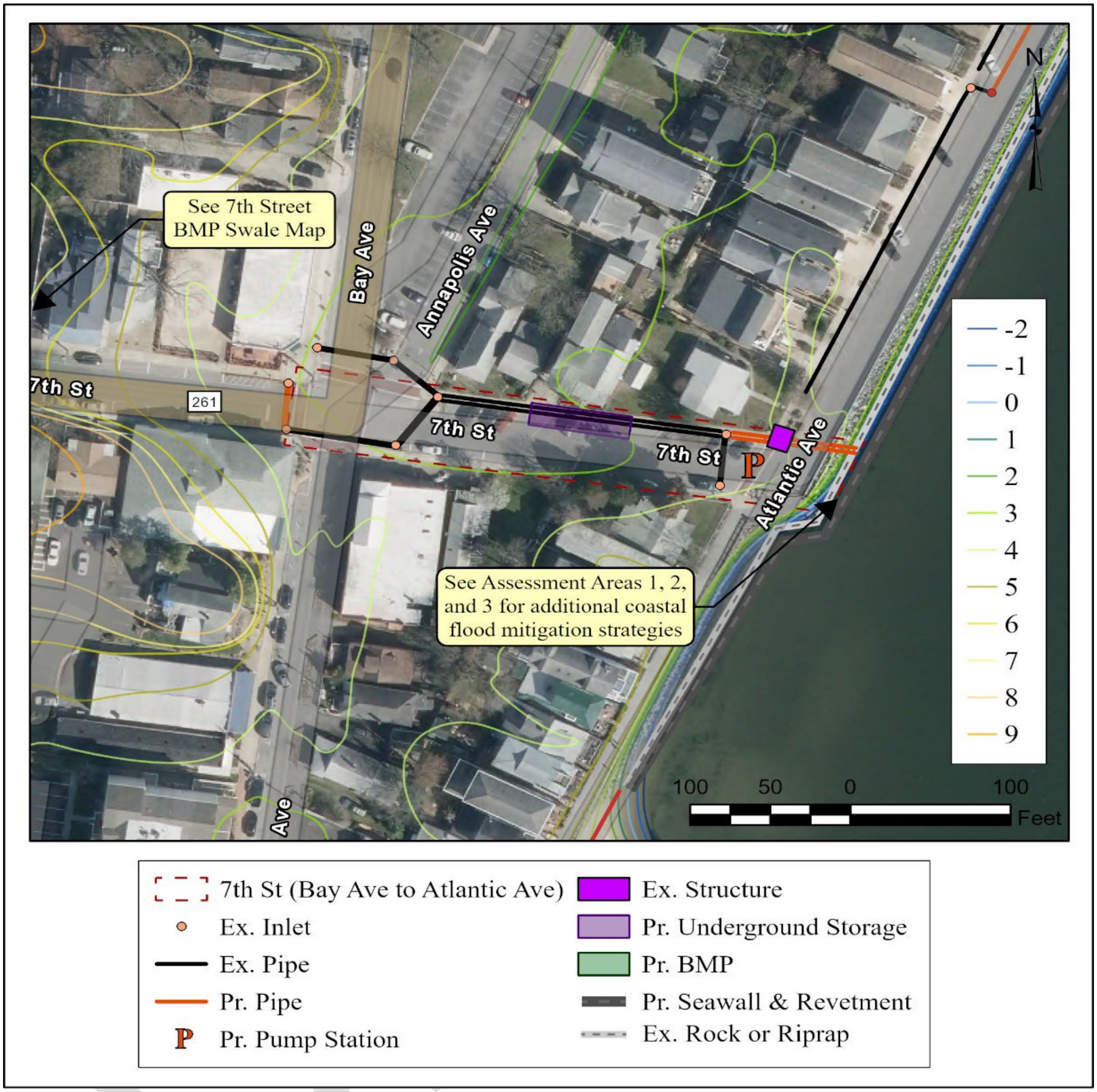


Figure 42 - Strategies for Reducing Flood Risk at 7th Street

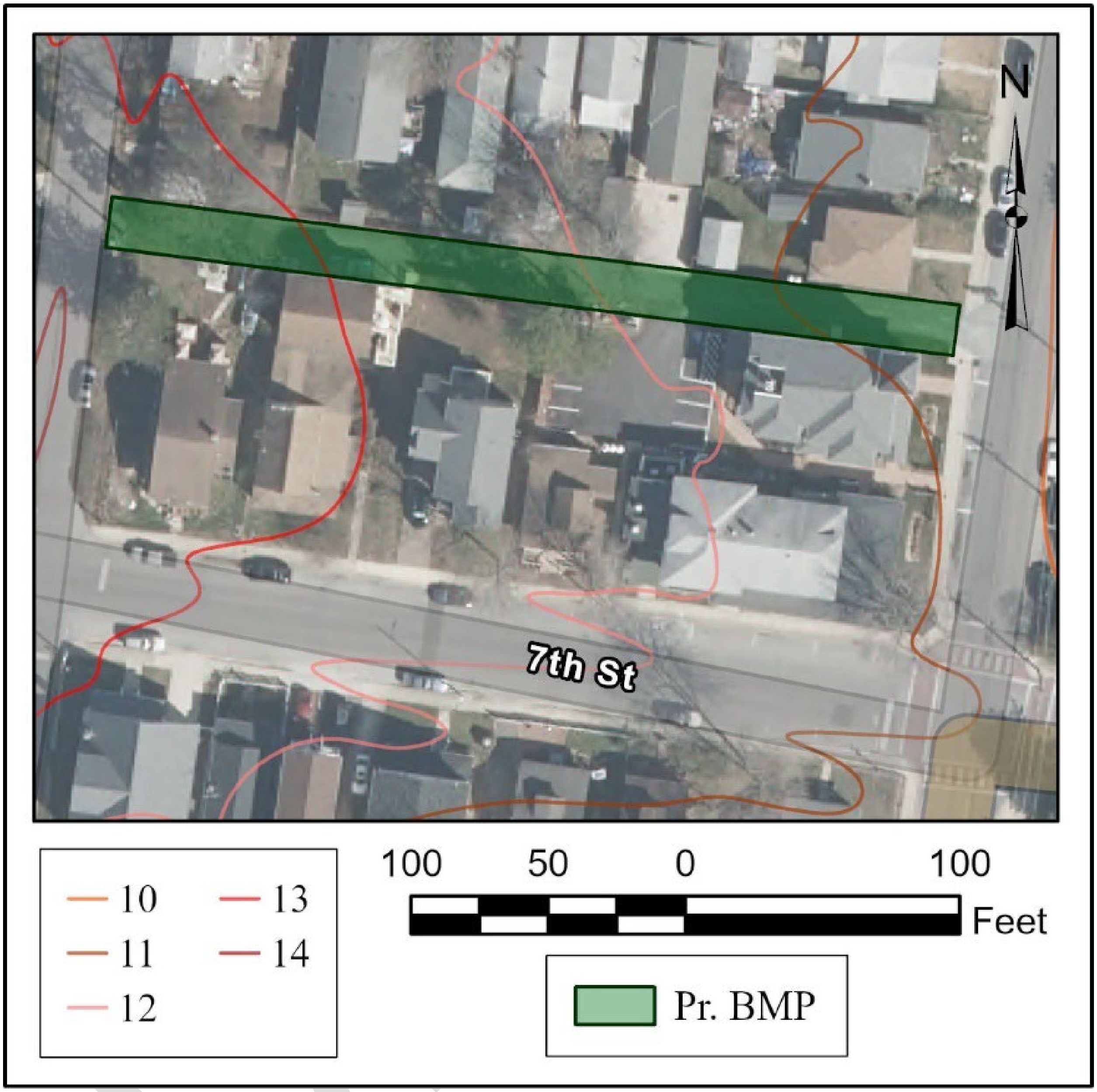


Figure 43 - Vegetated Swale BMP (Dayton Avenue to Chesapeake Avenue)

Figure 44 - Alternative for 7th Street Pump Station Discharge

8.2. 5th Street between Chesapeake Avenue and Bay Avenue

Given the significant amount of impervious area surrounding this portion of road, the large drainage area, the low-lying elevations near the beach entrance and the soon-to-be completed new public library, 5th Street between Chesapeake and Bay Avenue is listed as the 2nd highest priority area. The alternatives analysis and preferred alternative are discussed in subsequent sections.

8.2.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along 5th Street between Chesapeake Avenue and Bay Avenue.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Stormwater flooding along road experienced for 10+ hours in 2050;
    - Storm surge flooding could be multiple feet in 2050;
    - Road perpetually flooded due to backwatering and inability to discharge during rainfall events;
    - Road and parking area would be flooded daily by 2050, restricting access to new library.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue and in front of boardwalk to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Upgrade pipes to 3x their existing size and significantly increase system pipes at pump station to convey total flow during 100-year storm event in 2050.
  - Results:
    - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
    - Flooding to be prevented for the 2050 100-year storm event.
  - Impacts:
    - Significant impact to existing roadway, surrounding infrastructure, and increased design that will dramatically increase cost.
    - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
- Transfer – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue and in front of boardwalk to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
    - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
    - Upgrade existing stormwater pipes.

        - Install green infrastructure infiltration facility at the corner of 5th Street and Bay Avenue.
    - Results:
        - Flooding to be reduced for the 2050 1% annual chance storm surge but prevented for up to the 2050 10% annual chance storm surge level.
        - Flooding prevented at nearly all inlets along 5th street for the 2050 10-year storm event.
        - Flooding duration reduced and restricted to only the area around the existing pump station.
    - Impacts:
        - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
        - Would require replacing the parking lot with green infrastructure.

The decision matrix to determine the optimal RMS alternative is presented in Table 27.

Table 27 - Decision Matrix for 5th Street

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	2	5	12
RMS 2 – Terminate Risk	1	5	3	1	0	10
RMS 4 – Treat Risk	4	3	4	2	1	14

8.2.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 43.

A seawall is proposed to be constructed along Atlantic Avenue and Bay Avenue to reduce coastal flooding at 5th Street between Chesapeake Avenue and Bay Avenue. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members.

To prevent coastal flooding from reaching 5th Street from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

The recently replaced pump station at the 5th Street stormwater outfall improves stormwater flow during system flooding events and reduces the total flooding time. This pump station has a lead pump startup depth of -1.0 feet NAVD88, a lag pump startup depth of -2.0 feet NAVD88, and a shutoff depth of -4.0 feet NAVD88.

Additional proposed stormwater system improvements to further reduce flooding in the area due to severe rain events during projected high tide conditions at the 5th Street stormwater outfall are also proposed. Runoff to the area will be partially attenuated by the green infrastructure project proposed in Section 8.5. Replacing approximately 250 feet of pipe to increase pipe sizes along 5th Street will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The proposed upgrades are shown in Figure 45.

In the proposed conditions SWMM model, this area was flooded by the 1-yr storm event. In the 100-yr storm event (2050) 1 out of 10 nodes (10%) experienced flooding and the maximum flood time was 8.4 hours. This alternative will reduce the number of nodes experiencing flooding and reduce flood duration, as as shown in Table 28.

Table 28 - Flooding at 5th Street

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	3.0	5.6	10.3	6.6	6.6	10.3
Proposed	2.5	4.3	8.3	5.6	5.6	8.4

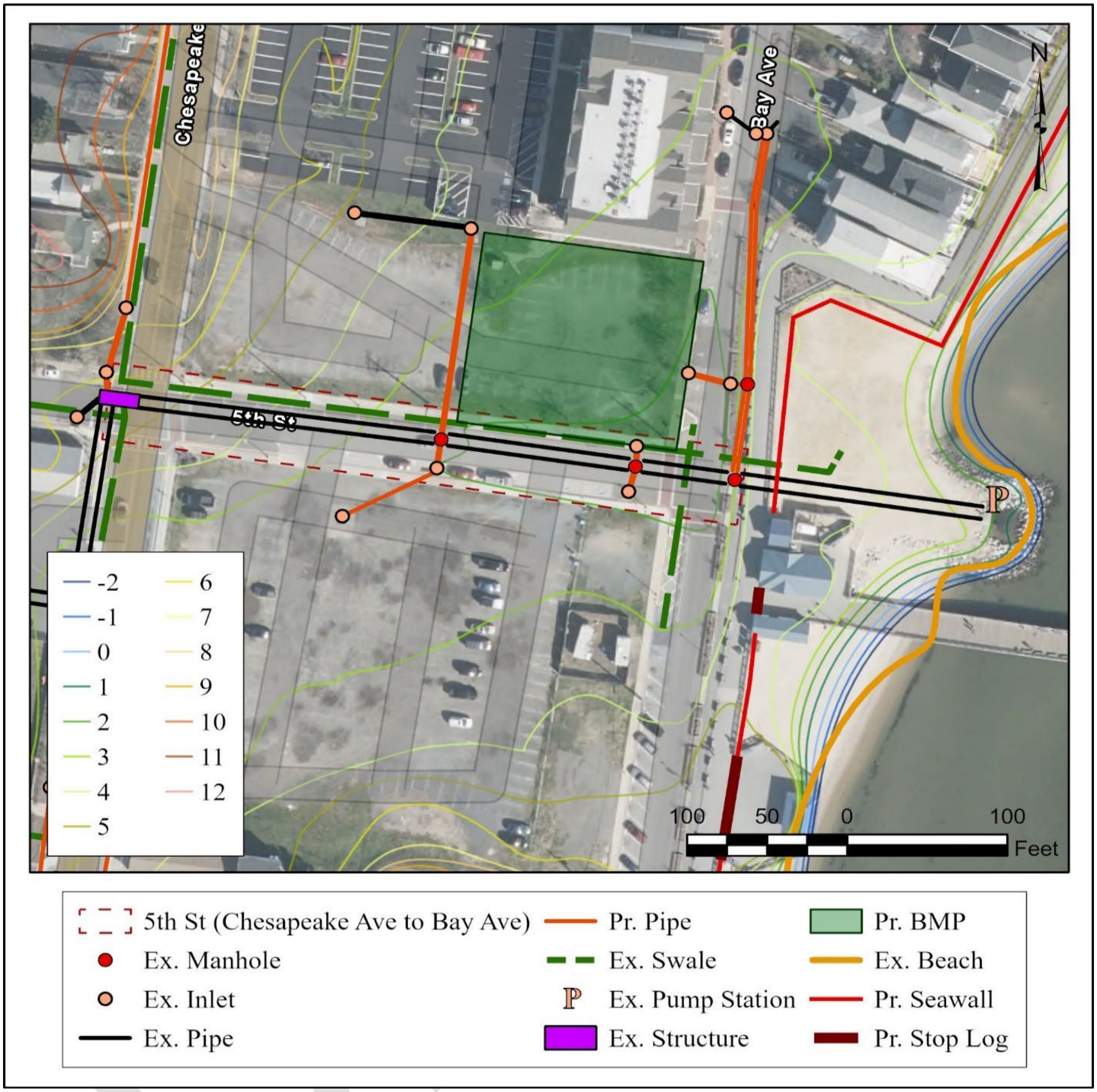


Figure 43 - Preferred Alternative for Flood Risk Management at 5th Street

8.3. 9th Street between Chesapeake Avenue and Atlantic Avenue

The area along 9th Street between Chesapeake Avenue and Atlantic Avenue was identified as the fourth highest priority area as it has some of the lowest elevations in the town and some homes are located at ground level. Flooding occurs from both coastal and rainfall events and does not drain efficiently, even with the presence of a pump station.

8.3.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along 9th Street between Chesapeake Avenue and Atlantic Avenue.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Flooding along road experienced daily in 2050;
    - Storm surge flooding of multiple feet anticipated in 2050;
    - Road perpetually flooded due to backwatering and inability to discharge during rainfall events;
    - Road could be unpassable multiple times a month, restricting access to homes along this segment of road.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Install tide valves at each pipe along Atlantic Avenue outfall to prevent backwatering.
    - Raise elevation of road to mitigate flooding and allow for upgraded stormwater infrastructure.
    - Upgrade existing stormwater pipes.
    - Install storage vault.
    - Construct vegetated swale along Dayton Avenue between 8th and 9th Streets.
  - Results:
    - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
    - Flooding prevented for the 2050 100-year storm event.
  - Impacts:
    - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
- Transfer – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.

- Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
- Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
- Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
- Raise elevation of road to mitigate flooding and allow for upgraded stormwater infrastructure.
- Upgrade existing stormwater pipes.
- Install storage vault.
- Construct vegetated swale along Dayton Avenue between 8th and 9th Streets.

- Results:
  - Flooding to be prevented for up to the 2050 10% annual chance storm surge level, but would occur for higher extreme water levels.
- Impacts:
  - Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers;
  - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;
  - Prevention of backwatering from outfall pipes.

The decision matrix to determine the optimal RMS alternative is presented in Table 29.

Table 29 - Decision Matrix for 9th Street

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	2	5	12
RMS 2 – Terminate Risk	2	5	4	1	1	13
RMS 4 – Treat Risk	4	3	4	2	2	15

8.3.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 46.

A seawall is proposed to be constructed along Atlantic Avenue to reduce coastal flooding at 9th Street between Bay Avenue and Annapolis Avenue. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members.

To prevent coastal flooding from reaching 9th Street from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis

Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

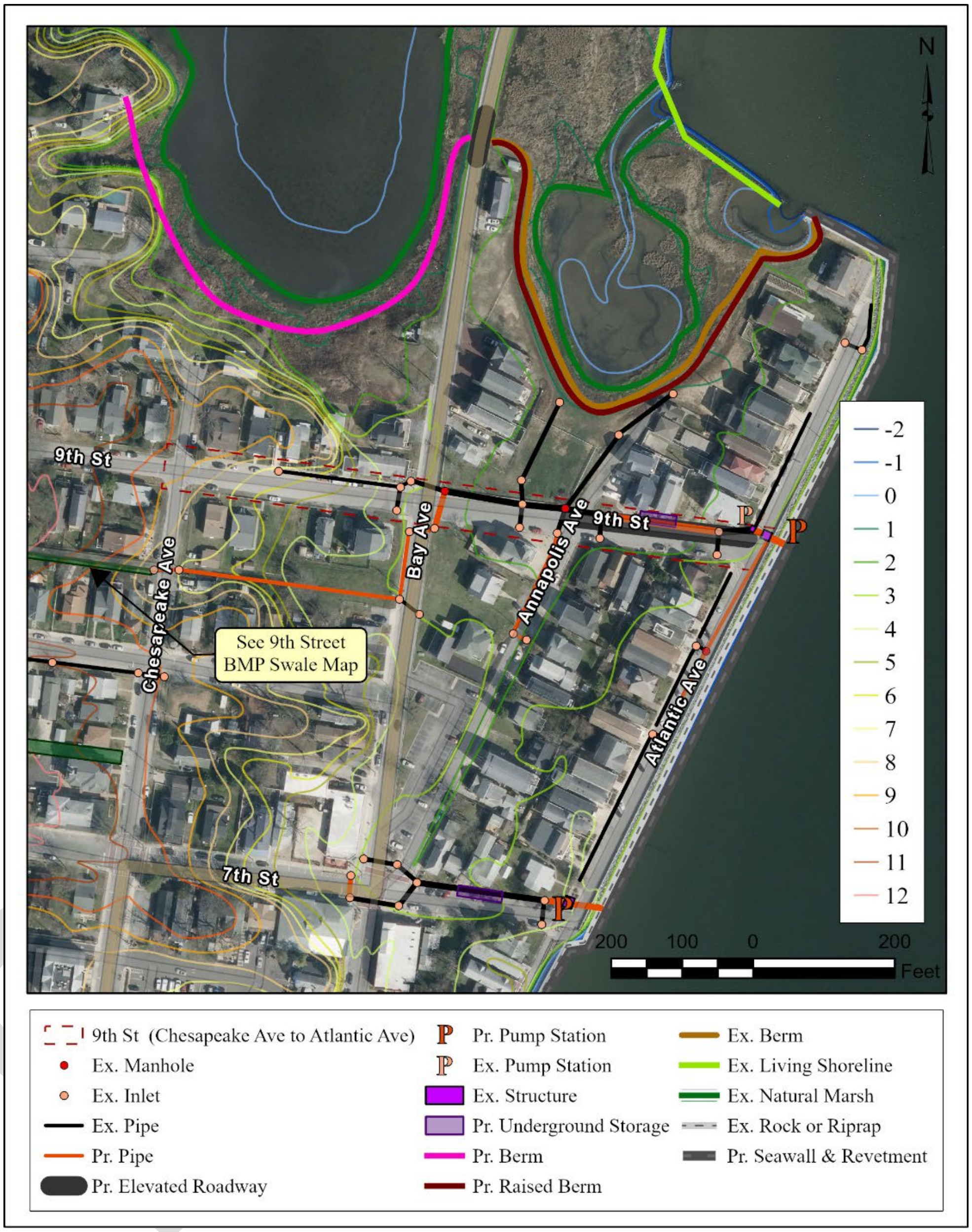


Figure 44 - Preferred Alternatives for Flood Risk Management at 9th Street

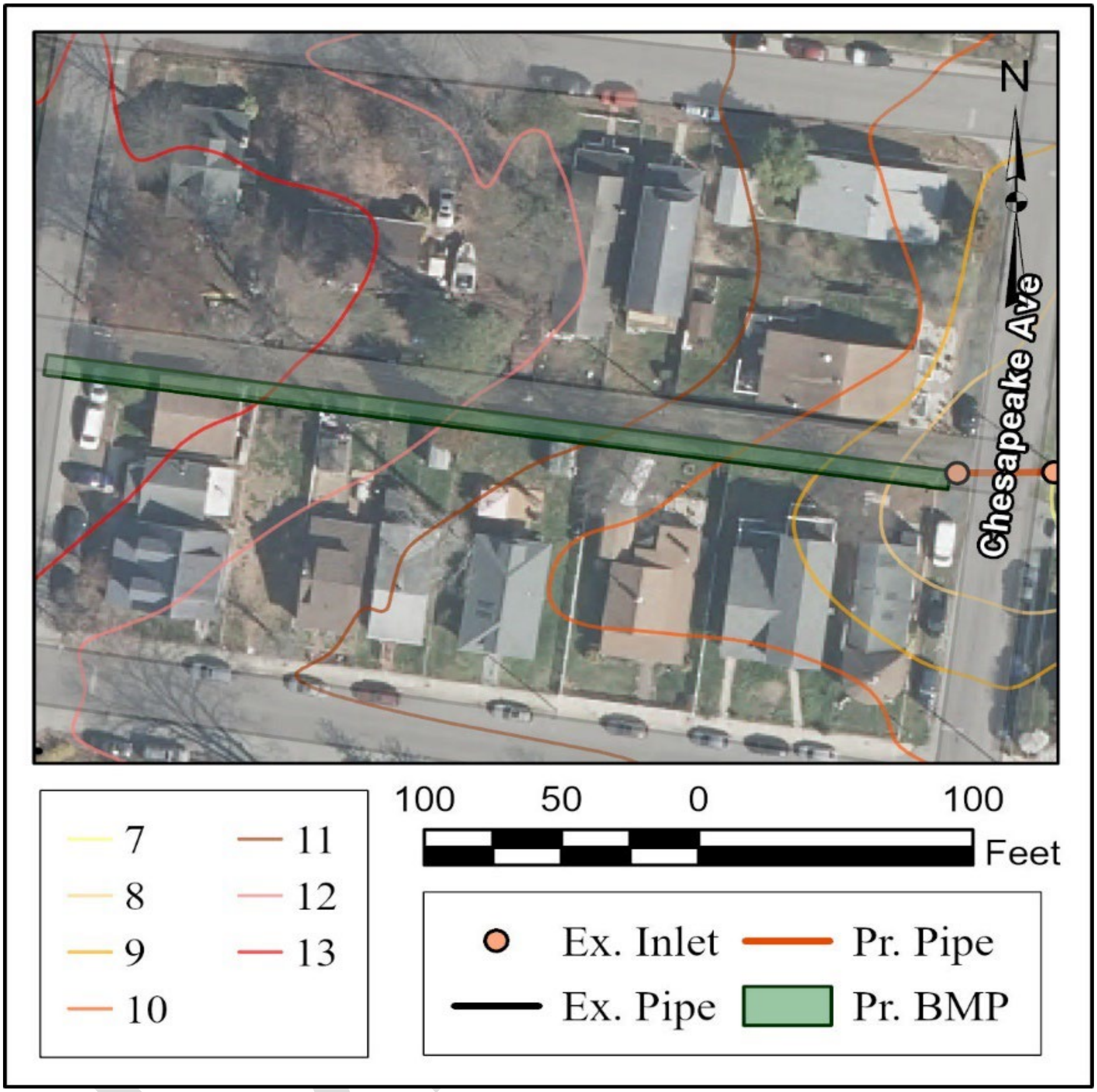


Figure 47 - Vegetative Swale BMP (Dayton Avenue to Chesapeake Avenue)

The proposed stormwater system improvements reduce flooding in the area due to severe rain events during projected high tide conditions at the 9th Street stormwater outfall. There is an opportunity to elevate the 9th Street roadway and associated stormwater system infrastructure to enhance the conveyance of stormwater runoff. A below grade storage vault is also proposed under the eastern end of 9th Street. The vault, assumed to be 600 CY (10'Wx20'Lx3'D) in the model, will provide a storage area for excess stormwater and alleviate flooding of upstream structures. Replacing approximately 700 feet of pipe to increase pipe sizes along 9th Street will improve the capacity of the stormwater system and provide adequate conveyance of runoff. A green infrastructure BMP, such as a vegetated swale, is proposed along the Town alley from Dayton Avenue to Chesapeake Avenue and between 8th Street and 9th Street. The swale would attenuate some of the incoming stormwater runoff by allowing it to infiltrate prior to entering the 9th Street stormwater system. The existing pump station and tide gate valve at the outfall of the 9th street stormwater system was modeled with a pump startup depth of -4.2 feet NAVD88. The proposed upgrades are shown in Figure 48.

In the proposed conditions SWMM model, none of the nodes experienced flooding during the 100-yr storm event (2050) as shown in Table 30.

Table 30 - Flooding at 9th Street

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	1.3	2.1	3.8	1.4	2.2	3.8
Proposed	0.0	0.0	0.0	0.0	0.0	0.0

8.4. Atlantic Avenue

The low elevations of Atlantic Avenue and location directly along the shoreline expose Atlantic Avenue to frequent flooding by 2050. The current revetment and jersey barrier reduce the wave overtopping, however, weep holes and connections between the jersey barrier allow for high surge events to flood the road. The wave overtopping volumes deposited on the road also result in dangerous conditions and flooding. Furthermore, it is anticipated that any significant rainfall event will result in a flood duration of more than 4 hours in 2050.

8.4.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Atlantic Avenue.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Daily water levels could reach street level by 2050, flooding the road daily;
    - Storm surge flooding of multiple feet anticipated in 2050;
    - Road flooded frequently due to backwatering and inability to discharge during rainfall events;
    - Road could be unpassable multiple times a month, restricting ingress/egress to homes along Atlantic Avenue.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +11 feet NAVD88 and revetment with 10-foot crest width to prevent flooding from SLR, the 1% annual chance storm surge and wave overtopping in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7.0 feet NAVD88.

        - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7.0 feet NAVD88. Elevate Bay Avenue to +7.0 feet to provide a connection between the two earthen berms.
        - Upgrade pipes to 3x their existing size to convey total flow during 100-year storm event in 2050.
    - Results:
        - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
        - Wave overtopping to be reduced so that vehicles can drive safely on road.
        - Flooding to be prevented for the 2050 100-year storm event.
    - Impacts:
        - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
        - Significant impacts to water bottom to construct large revetment.
        - Significant impacts to view as new wall will be approximately 5 feet higher than existing jersey barrier.
        - Significant impact to existing roadway and increased design that will dramatically increase cost.
- <u>Transfer</u> – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- <u>Treat</u> – Risk Mitigation
    - Projects:
    -
        - Construct seawall along Atlantic Avenue and revetment with 10-foot crest width to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
        - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
        - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
        - Upgrade existing stormwater pipes
    - Results:
        - Flooding to be reduced for the 2050 1% annual chance storm surge elevation but prevented for up to the 2050 10% annual chance storm surge elevation.
        - Wave overtopping to be reduced for the 10% annual chance storm to prevent damage to road but still result in unsafe driving conditions.
        - Prevention of backwatering past shoreline seawall.
    - Impacts:
        - Elevation of seawall unchanged from current jersey barrier, views will not be impacted;

- Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers.
- Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.

The decision matrix to determine the optimal RMS alternative is presented in Table 31.

Table 31 - Decision Matrix for Atlantic Avenue

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	2	5	12
RMS 2 – Terminate Risk	2	5	4	1	1	13
RMS 4 – Treat Risk	4	4	4	2	2	16

8.4.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 48.

A seawall and revetment are proposed to be constructed along Atlantic Avenue to reduce coastal flooding. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members. Additionally, an 8-foot wide revetment at the same elevation is recommended to reduce the wave overtopping and prevent damage to the road during large storm events. The results of the decreased wave overtopping are shown in Figure 49.

To prevent coastal flooding along Atlantic Avenue from low-lying pathways to the north of the area, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

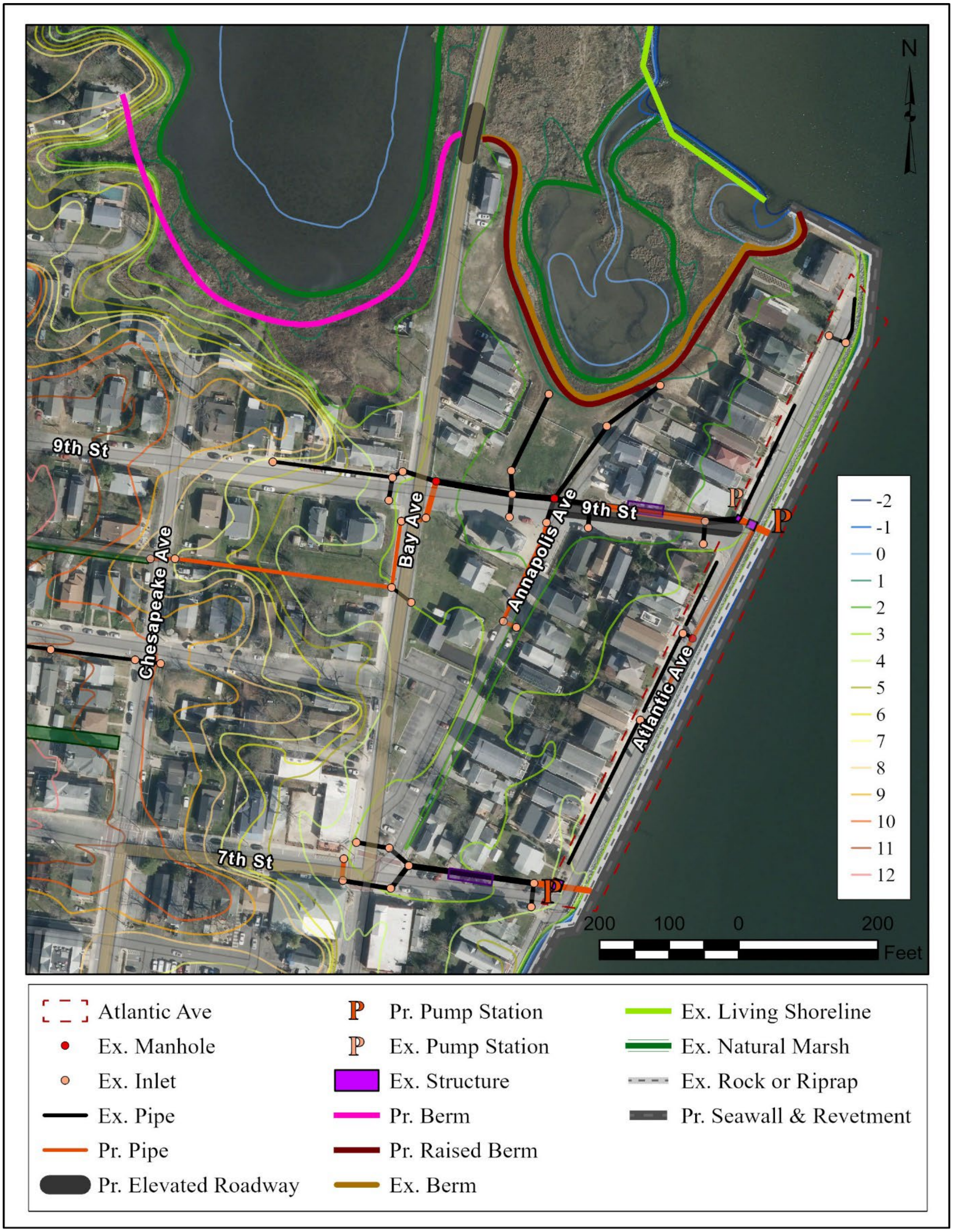


Figure 45 - Strategies for Reducing the Flood Risk at Atlantic Avenue

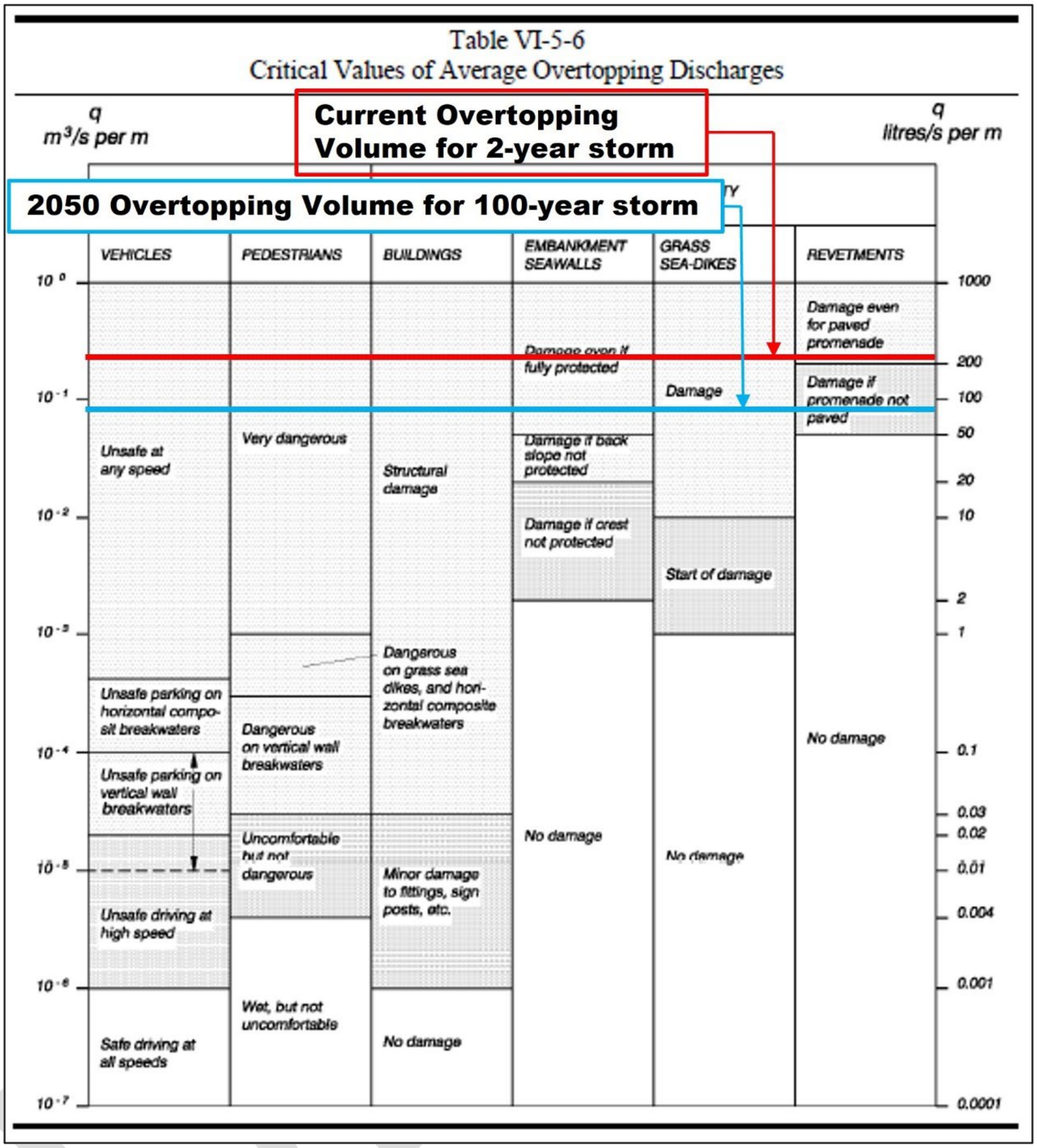


Figure 46 - Wave Overtopping along Atlantic Avenue - Proposed Conditions

Stormwater flooding along Atlantic Avenue will be significantly decreased as a result of the 7th Street and 9th Street improvments. Additonal improvements to further reduce flooding within Atlantic Avenue include Increasing the size of approximately 320 linear feet of existing pipes to increase capacity and effectively transport flow to the 9th street system. The proposed upgrades are shown in Figure 49.

In the proposed conditions SWMM model, this area was flooded by the 2050 1-yr storm event due to the two inlets surcharging. In the 100-yr storm event (2050) 2 out of 2 nodes (100%) experienced flooding and the maximum flood time was 4.4 hours.

Table 32 - Flooding at Atlantic Avenue						
Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.0	0.0	0.2	4.3	4.3	4.4
Proposed	0.0	0.0	0.0	4.2	4.3	4.3

8.5. Bay Avenue between 5th Street and 7th Street

Because this portion of Bay Avenue leads to the most highly trafficked area of town, it has been prioritized for flood protection. The low-lying elevations of the road result in both coastal and stormwater flooding to homes and business along this road. Additionally, the back side of the new public library will be located along this portion of Bay Avenue.

8.5.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Bay Avenue between 5th Street and 7th Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Daily water levels could travel through low-lying pathways and flood portions of Bay Avenue daily by 2050;
    - Storm surge flooding of multiple feet anticipated in 2050;
    - Extreme rainfall event could result in flood durations > 1 hour.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Add stoplog along Bay Avenue to maintain access to beach where needed.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Raise elevation of road to prevent ponding.
    - Upgrade pipes to 3x their existing size to convey total flow during 100-year storm event in 2050.
  - Results:

        - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
        - Flooding to be prevented for the 2050 100-year storm event.
    - Impacts:
        - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
        - Significant impact to existing roadway, underground utilities, and increased design that will dramatically increase cost.
- Transfer – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
    - Projects:
        - Construct seawall along Atlantic Avenue to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
        - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
        - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
        - Add stoplog along Bay Avenue to maintain access to beach where needed.
        - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
        - Upgrade existing stormwater pipes.
        - Install green infrastructure infiltration facility at the corner of 5th Street and Bay Avenue.
    - Results:
        - Flooding to be prevented for up to the 2050 10% annual chance storm surge, but would occur for higher extreme water levels.
        - Flooding prevented for the 2050 1-year storm event and reduced to only a brief duration in the 2050 10-year and 100-year storm event.
    - Impacts:
        - Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers;
        - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;
        - Prevention of backwatering from outfall pipes;
        - Would require replacing the parking lot with green infrastructure.

The decision matrix to determine the optimal RMS alternative is presented in Table 33.

Table 33 - Decision Matrix for Bay Avenue

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	2	5	12
RMS 2 – Terminate Risk	2	4	3	2	1	12
RMS 4 – Treat Risk	4	3	3	2	2	14

8.5.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 50.

A seawall is proposed to be constructed along Atlantic Avenue to reduce coastal flooding at Bay Avenue between 5th Street and 7th Street. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members.

To prevent coastal flooding from reaching Bay Avenue from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

Proposed installation of green infrastructure projects upstream of existing infrastructure reduce flooding in the area due to severe rain events and backwatering from the 5th Street stormwater system. An 8,000 SF green infrastructure project, such as bio-retention or wetland, is proposed in the existing parking lot at the northwest corner of Bay Avenue and 5th Street to attenuate some of the incoming runoff by allowing it to temporarily pond and filtrate before reaching the 5th Street and Bay Avenue stormwater system inlets. Replacing approximately 250 feet of pipe to increase pipe sizes along Bay Avenue will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The additional capacity will improve flow to the main branch of the stormwater system along 5th Street. These proposed upgrades are shown in Figure 50. In the proposed conditions SWMM model, this area was flooded by the 10-yr storm event. In the 100-yr storm event (2050) 1 out of 5 nodes (20%) experienced flooding and the maximum flood time was 0.3 hours as shown in Table 34.

Table 34 - Flooding at Bay Avenue

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.2	0.7	1.2	0.0	0.6	1.3
Proposed	0.0	0.2	0.3	0.0	0.2	0.3

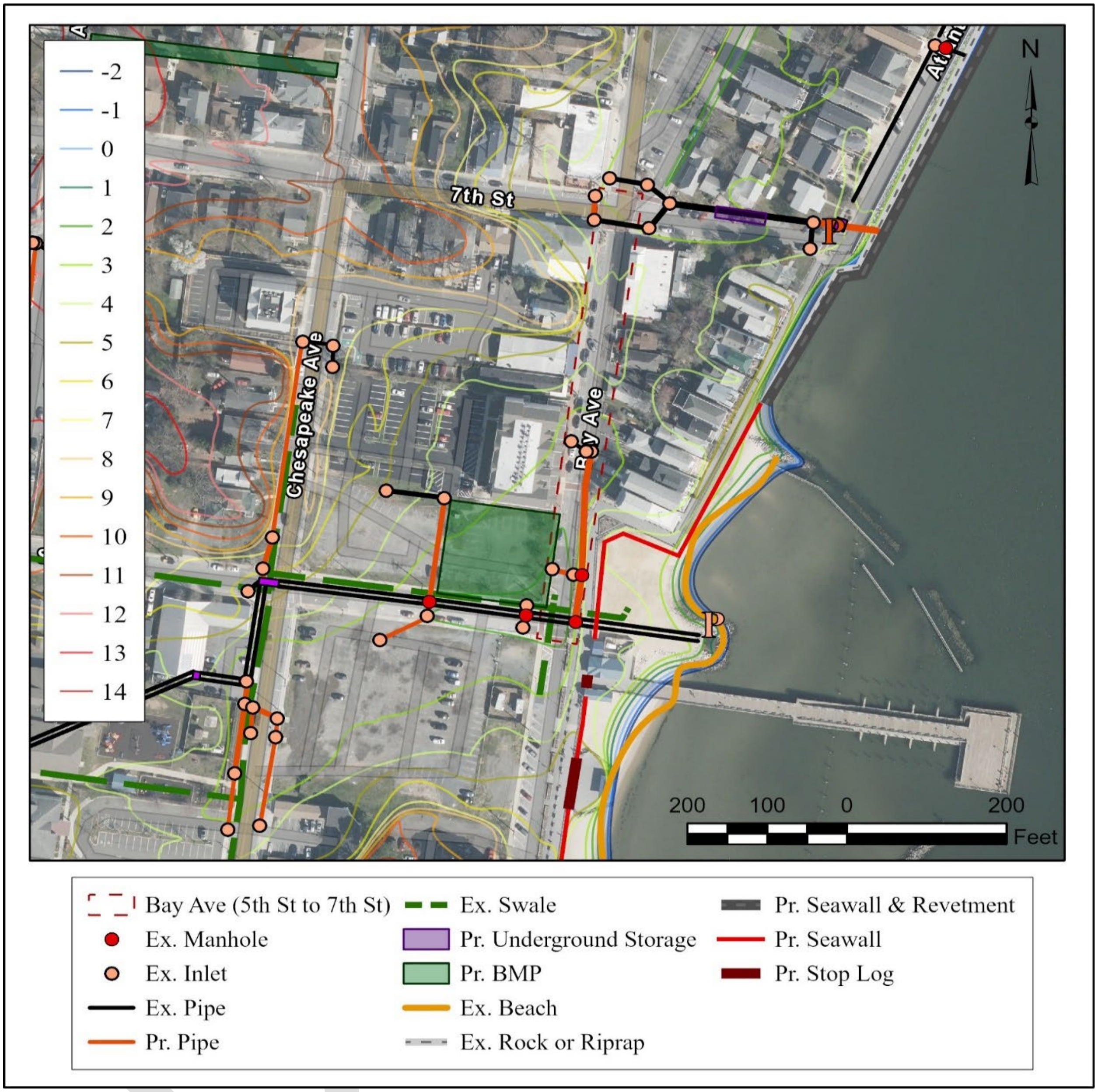


Figure 50 - Strategies for Reducing the Flood Risk at Bay Avenue

8.6. Annapolis Avenue between 9th Street and 7th Street

Annapolis Avenue is a low-lying road bordered by residential homes and a free public parking area. The low elevations and connectivity to flooding pathways will likely result in frequent flooding along Annapolis Avenue in 2050.

8.6.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Annapolis Avenue between 9th Street and 7th Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Nuisance flooding along road experienced frequently in 2050;
    - Storm surge flooding of multiple feet anticipated in 2050;
    - Road perpetually flooded due to backwatering and inability to discharge during rainfall events;
    - Road could be unpassable multiple times a month, restricting access to homes along this segment of road.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Install tide valves at each pipe outfall at Atlantic Avenue to prevent backwatering reaching Annapolis Avenue.
    - Raise elevation of road to prevent ponding.
    - Upgrade existing stormwater system pipes along Annapolis Avenue to convey total flow during 100-year storm event in 2050.
  - Results:
    - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
    - Flooding to be prevented for the 2050 100-year storm event.
  - Impacts:
    - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
- Transfer – Risk Transfer – Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
    - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Raise elevation of road to prevent ponding.

- Upgrade existing stormwater system pipes along Annapolis Avenue to convey total flow during 100-year storm event in 2050.
- Results:
  - Flooding to be prevented for up to the 2050 10% annual chance storm surge level, but would occur for higher extreme water levels.
  - Prevention of backwatering from outfall pipes along Atlantic Avenue.
- Impacts:
  - Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers;
  - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;

The decision matrix to determine the most effective RMS alternative is presented in Table 35.

Table 35 - Decision Matrix for Annapolis Avenue

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	4	5	14
RMS 2 – Terminate Risk	2	5	3	2	1	13
RMS 4 – Treat Risk	3	4	4	3	2	16

8.6.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 51.

A seawall is proposed to be constructed along Atlantic Avenue to reduce coastal flooding at Annapolis Avenue between 9th Street and 7th Street. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members.

To prevent coastal flooding from reaching Annapolis Avenue from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

Stormwater flooding along Annapolis Avenue will be significantly decreased as a result of the 7th Street and 9th Street improvments. Additonal proposed improvements to further reduce Annapolis Avenue flooding include upgrades to the existing storm drain infrastructure. Replacing approximately 200 feet of pipe to increase pipe sizes along Annapolis Avenue will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The capacity of the stormwater system will be improved by upgrading the pipe sizes or installing additional pipes in parallel along Annapolis Avenue. Adequate conveyance will be provided by 200 feet of pipe replacement. The additional capacity will improve flow to the 9th Street stormwater system. The proposed upgrades are shown in Figure 51.

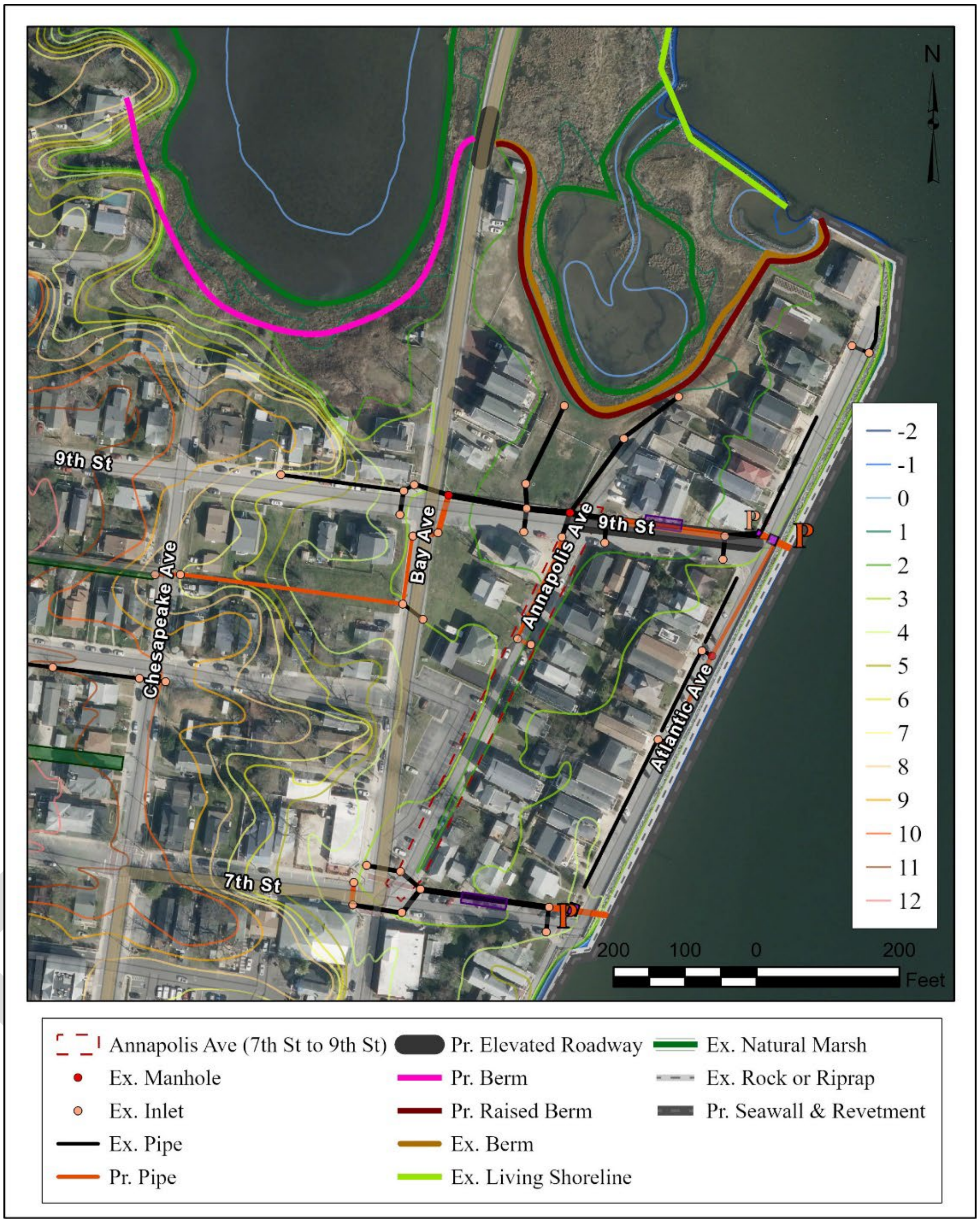


Figure 51 - Strategies for Reducing Flood Risk along Annapolis Avenue

In the proposed conditions SWMM model, none of the nodes experienced flooding during the 100-yr storm event (2050) as shown in Table 36.

Table 36 - Flooding at Annapolis Avenue

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.4	1.0	1.5	0.4	1.0	1.6
Proposed	0.0	0.0	0.0	0.0	0.0	0.0

8.7. Chesapeake Avenue between 4th Street and 6th Street

Chesapeake Avenue between 4th and 6th Street has both residential and commercial properties. The road has an approximate six-foot dip where water regularly collects after rainfall events. The area between 4th and 5th Streets has the lowest elevations and is exposed to flood water pathways that can result in storm surge-induced flooding for the roadway and surrounding area.

8.7.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Chesapeake Avenue between 4th Street and 6th Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Road likely to experience nuisance flooding monthly in 2050. Storm surge events could potentially result in multiple feet of flooding in 2050.
    - Flooding experienced for the 2050 10-year rainfall event.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Raise elevation of road to prevent ponding.
    - Upgrade existing stormwater pipes along Chesapeake Avenue.
  - Results:
    - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
    - Flooding to be prevented for the 2050 100-year storm event.

- Impacts:
  - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
- Transfer – Risk Transfer - Not applicable as the frequency of flooding in 2050 will likely result in this option being unfeasible.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
    - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
    - Install tide valves at each pipe outfall along Atlantic Avenue to prevent backwatering.
    - Upgrade existing stormwater pipes along Chesapeake Avenue.
  - Results:
    - Flooding to be prevented for up to the 2050 10% annual chance storm surge, but could occur for higher extreme water levels.
    - Flooding to be prevented for the 2050 100-year storm event.
  - Impacts:
    - Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers;
    - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;
    - Prevention of backwatering from outfall pipes;

The decision matrix to determine the most effective RMS alternative is presented in Table 37.

Table 37 - Decision Matrix for Chesapeake Avenue

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	1	4	5	15
RMS 2 – Terminate Risk	2	5	3	2	1	13
RMS 4 – Treat Risk	3	4	4	3	2	16

8.7.2. Preferred Alternative

Based on the analysis, the preferred alternative is RMS 4 – Treat the Risk. The projects described as part of this alternative are presented in Figure 52.

A seawall is proposed to be constructed along Atlantic Avenue to reduce the risk of coastal flooding at Chesapeake Avenue between 4th Street and 6th Street. The seawall should have a top elevation of +6.5 feet. This elevation is recommended as the existing jersey barriers have a top elevation just below +6 feet NAVD88. The half-foot of elevation is likely to be acceptable for residents and community members.

To prevent coastal flooding from reaching Chesapeake Avenue from low-lying pathways to the north of the project, the preferred alternative is to raise the existing dike at Annapolis Avenue and construct a new dike northwest of Bay Avenue to an elevation of +6 feet NAVD88. This elevation will prevent flooding for up to the 10% annual chance storm surge elevation and only expose the area to flooding during the highest extreme events in 2050.

Replacing approximately 750 feet of pipe to increase pipe sizes along Chesapeake Avenue will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The proposed stormwater system improvements reduce flooding in the area due to severe rain events and backwatering from the 5th Street stormwater system. The increased capacity will improve flow from the stormwater inlets to the 5th street main branch of the system. The proposed upgrades are shown in Figure 52.
In the proposed conditions SWMM model, none of the nodes experienced flooding during the 100-yr storm event (2050) as shown in Table 38.

Table 38 - Flooding at Chesapeake Avenue

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.0	0.5	0.9	0.0	0.5	0.9
Proposed	0.0	0.0	0.0	0.0	0.0	0.0

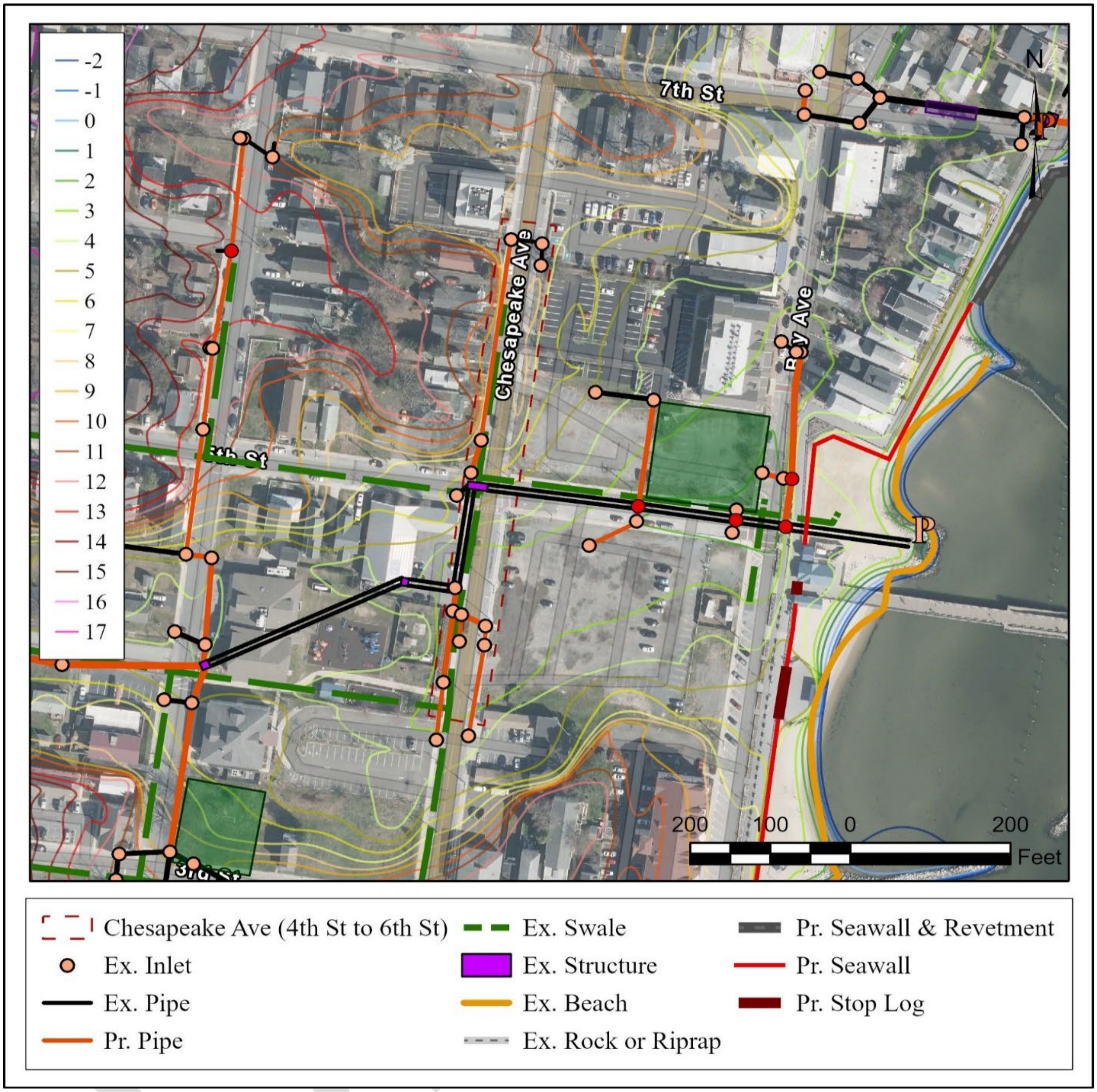


Figure 52 - Strategies for Flood Risk Reduction along Chesapeake Avenue

8.8. Dayton Avenue between 3rd Street and 6th Street

Similarly to Chesapeake Avenue, Dayton Avenue experiences a significant decrease in road elevations between 3rd and 6th Street. Residential and community infrastructure are both exposed to these lower elevations at ground level. However, the low-lying elevations on the road appear to be isolated and surrounded by higher ground. Therefore, they will likely not experience nuisance flooding from coastal sources, but may be inundated by storm surge in 2050. Extreme rainfall events produce flooding that will require a few hours to drain in 2050.

8.8.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Dayton Avenue between 3rd Street and 6th Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Flooding from coastal sources anticipated in 2050 only for extreme storm surges;
    - Flooding will occur for the 1-year storm event in 2050.
- Terminate – Risk Avoidance
  - Projects:
    - Construct seawall along Atlantic Avenue and along boardwalk to a height of +7 feet NAVD88 to prevent flooding from SLR and the 1% annual chance storm surge in 2050.
    - Raise earthen berm located at the northern extent of Annapolis Avenue to a minimum elevation of +7 feet NAVD88.
    - Construct a new earthen berm along the marsh area near the northern extent of 10th Street to a minimum elevation of +7 feet NAVD88. Elevate Bay Avenue at +7 feet to provide a connection between the two earthen berms.
    - Raise elevation of road to prevent ponding.
    - Add multiple additional pipes and upgrade pipes to nearly 3x their existing size to convey total flow during 100-year storm event in 2050.
  - Results:
    - Flooding to be prevented for the 2050 1% annual chance storm surge elevation.
    - Flooding to be prevented for the 2050 100-year storm event.
  - Impacts:
    - Significant impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures.
    - Significant impact to existing roadway, underground utilities, and increased design that will dramatically increase cost.
- Transfer – Risk Transfer
  - Given that flooding is only anticipated for extreme events, the purchase of flood insurance may be an affordable option.
- Treat – Risk Mitigation
  - Projects:
    - Construct seawall along Atlantic Avenue and in front of boardwalk to a height of +6.5 feet NAVD88 to reduce flooding from SLR and storm surge in 2050.
    - Raise earthen dike located at the northern extent of Annapolis Avenue to a minimum elevation of +6 feet NAVD88.
    - Construct a new earthen dike along the marsh area near the northern extent of 10th Street to a minimum elevation of +6 feet

NAVD88. Elevate Bay Avenue to +6 feet NAVD88 to connect the earthen dikes.
    - Upgrade existing stormwater pipes.
    - Construct green infrastructure infiltration facility at the corner of 3rd Street and Dayton Avenue.
  - Results:
    - Flooding to be prevented for up to the 2050 10% annual chance storm surge, but could occur for higher extreme water levels.
    - Flooding prevented for the 2050 10-year storm event and reduced to only a brief duration in the 100-year storm event.
  - Impacts:
    - Views will not be impacted as this elevation is at or above the elevation of the existing jersey barriers;
    - Impacts to water bottom and private tidal wetlands to accommodate large earthen dike structures;.

The decision matrix to determine the most effective RMS alternative is presented in Table 39.

Table 39 - Decision Matrix for Dayton Avenue

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	3	5	5	18
RMS 2 – Terminate Risk	2	5	3	2	1	13
RMS 3 – Transfer Risk	5	3	5	5	4	22
RMS 4 – Treat Risk	3	4	4	3	2	16

8.8.2. Preferred Alternative

Given the low frequency of flooding, lower depths of flooding (< 2 feet even during extreme surge events) and drainage duration (<2 hours for the 2050 100-year storm), the purchase of flood insurance (Risk Transfer) was ranked the highest alternative. Therefore, it is likely that projects aimed at reducing flood risk for this area should be considered for future implementation once flood risk has been reassessed.

Future implementation to reduce flood risk are shown in Figure 53. Proposed installation of green infrastructure projects upstream of existing infrastructure reduce flooding in the area due to severe rain events and backwatering from the 4th Street stormwater system. An 8000 SF green infrastructure project, such as bio-retention or wetlands, is proposed in the existing open space northeast of the intersection of Dayton Avenue and 3rd Street to attenuate incoming runoff by allowing it to pond and filtrate before reaching the intersection's stormwater inlets. Replacing approximately 1250 feet of pipe to increase pipe sizes or add pipes in parallel along 4th Street will improve the capacity of the stormwater system and provide adequate conveyance of runoff.

In the proposed conditions SWMM model, this area was flooded by the 100-yr storm event. In the 100-yr storm event (2050) 1 out of 22 nodes (5%) experienced flooding and the maximum flood time was 0.6 hours. Flooding was eliminated in the 10-year storm event and reduced to only a brief duration in the 100-year storm event as shown in Table 40.

Table 40 - Flooding at Dayton Avenue

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.5	1.0	1.6	0.5	1.0	1.6
Proposed	0.0	0.0	0.5	0.0	0.0	0.5

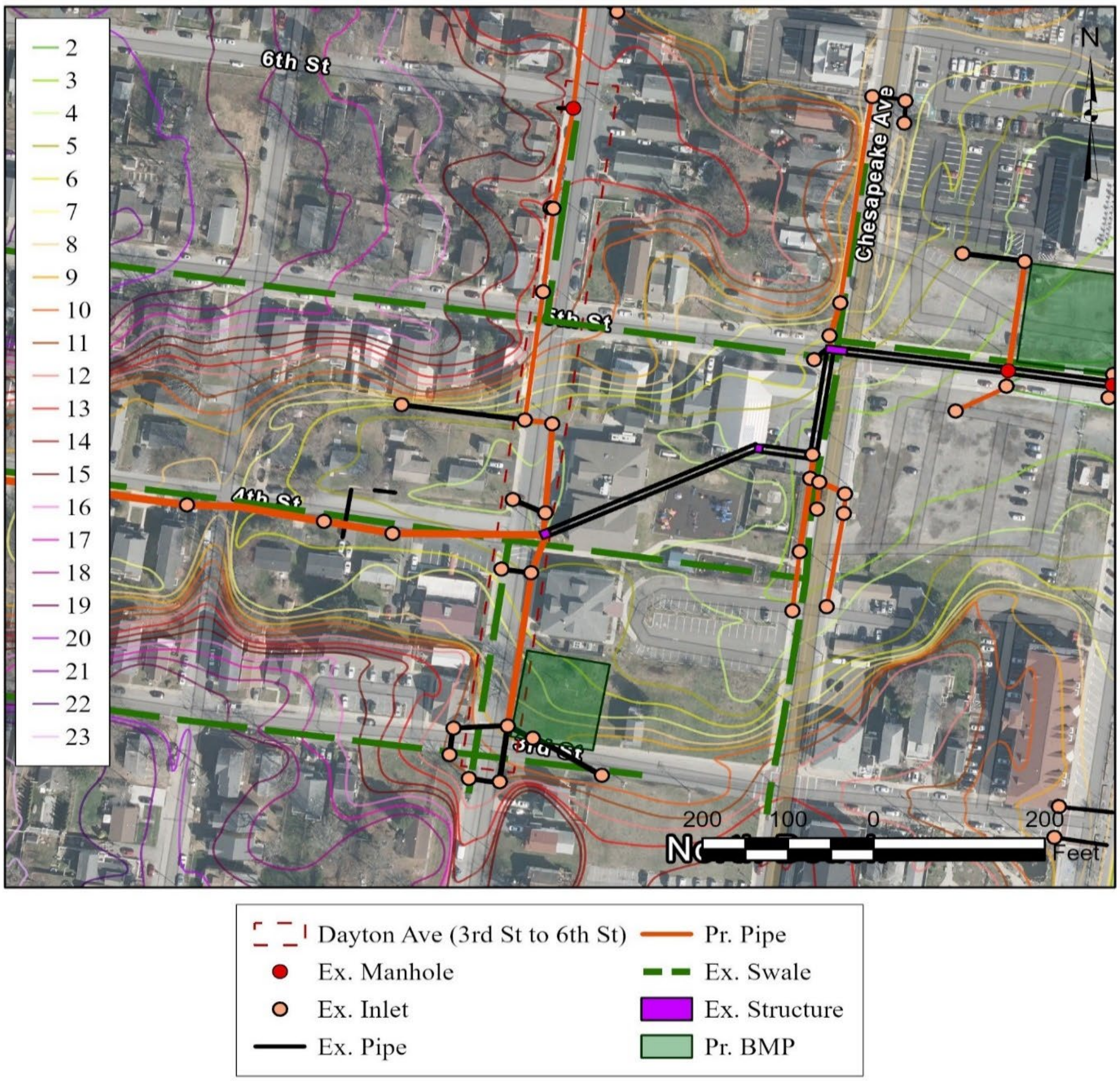


Figure 53 - Strategies to Reduce Flood Risk at Dayton Avenue

8.9. 1st Street between Chesapeake Avenue and Bay Avenue

1st Street between Chesapeake Avenue and Bay Avenue has both commercial and residential properties. Elevations along this portion of road exceed +8 feet NAVD88, which make it the highest elevations shoreline area within the Town of North Beach. Nuisance and storm surge flooding is not anticipated to impact this area until past 2050. Overtopping volume during the 1% annual chance storm surge may result in damage to the road and buildings along 1st Street and Bay Avenue. The existing storm drain infrastructure is undersized and flooding occurs for extreme rainfall events.

8.9.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along 1st Street between Chesapeake Avenue and Bay Avenue

- Tolerate – Risk Acceptance
    - Projects: None
    - Results:
        - Wave overtopping during 2050 extreme coastal storm events will likely result in flooding and may result in damage to road and surrounding infrastructure.
        - Flooding to occur during extreme rainfall events greater than the 1-year rainfall event.
- Terminate – Risk Avoidance
    - Projects:
        - Construct revetment to +11 feet NAVD88 with a 10-foot crest to prevent wave overtopping during the 2050 1% annual chance coastal storm.
        - Upgrade existing stormwater pipes along 1st Street.
        - Install tide valves at outfalls through the revetment along Bay Avenue.
    - Results:
        - Flooding due to overtopping will be prevented for the 2050 1% annual chance coastal storm.
        - Flooding prevented due to backwatering through outfall pipes.
        - Driving will be safe along 1st Street and Bay Avenue during the 2050 1% annual chance coastal storm.
        - Flooding to be prevented for the 2050 1-year storm event.
    - Impacts:
        - Significant impacts to water bottom to construct large revetment.
        - Significant impacts to view as new wall will be approximately 3 feet higher than existing jersey barrier.
- Transfer – Risk Transfer
    - Given that flooding is only anticipated for extreme events, the purchase of flood insurance may be an affordable option.
- Treat – Risk Mitigation
    - Projects:

        - Construct revetment to top elevation of +6.5 feet NAVD88 with 8-foot crest width to reduce flooding from overtopping in 2050.
        - Upgrade existing stormwater pipes along 1st Street.
        - Install tide valves at outfalls through the revetment along Bay Avenue.
    - Results:
        - Flooding due to wave overtopping to be reduced so that road and infrastructure damage does not occur during the 2050 1% annual chance coastal storm, however, driving will continue to be unsafe.
    - Impacts:
        - Impacts to water bottom to construct revetment.

The decision matrix to determine the most effective RMS alternative is presented in Table 41.

Table 41 - Decision Matrix for 1st Street

Options	Feasibility	Effectiveness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	3	5	5	18
RMS 2 – Terminate Risk	1	5	1	1	1	9
RMS 3 – Transfer Risk	5	2	3	5	4	19
RMS 4 – Treat Risk	4	4	3	2	3	16

8.9.2. Preferred Alternative

The preferred alternative for managing flood risk at 1st Street between Chesapeake and Bay Avenues is RMS 3 – Risk Transfer, which recommends purchasing insurance to manage the risk of flooding. This is likely due to the lack of storm surge or nuisance flooding anticipated in 2050, shorter flood duration and lack of infrastructure at ground level. Therefore, it is likely that projects aimed at reducing flood risk for this area should be considered for future long-term implementation once flood risk has been reassessed.

Projects for future implementation to reduce flood risk are shown in Figure 48. The proposed stormwater system improvements reduce flooding in the area due to severe rain events during projected high tide conditions at the 1st Street stormwater outfall. Replacing approximately 450 feet of pipe to increase pipe sizes along 1st Street will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The increased capacity will reduce flooding at stormwater inlets by improving flow to the 1st Street outfall.

Proposed pipe size increases for the other stormwater system outlets along Bay Avenue between 1st Street and 3rd Street reduce flooding in the area due to severe rain events during projected high tide conditions at the Bay Avenue outfalls. The proposed changes result in improved flow of stormwater and reduce tidal backwatering. Additional upgrades for outfalls along Bay Avenue are shown in Figure 54.

In the proposed conditions SWMM model, this area was not flooded by any storm event and the stormwater system was not inundated as shown in Table 42.

Table 42 - Flooding at 1st Street

Model	Hours of Flooding					
	2030 1-yr	2030 10-yr	2030 100-yr	2050 1-yr	2050 10-yr	2050 100-yr
Existing	0.0	0.7	1.2	0.0	0.7	1.2
Proposed	0.0	0.0	0.0	0.0	0.0	0.0

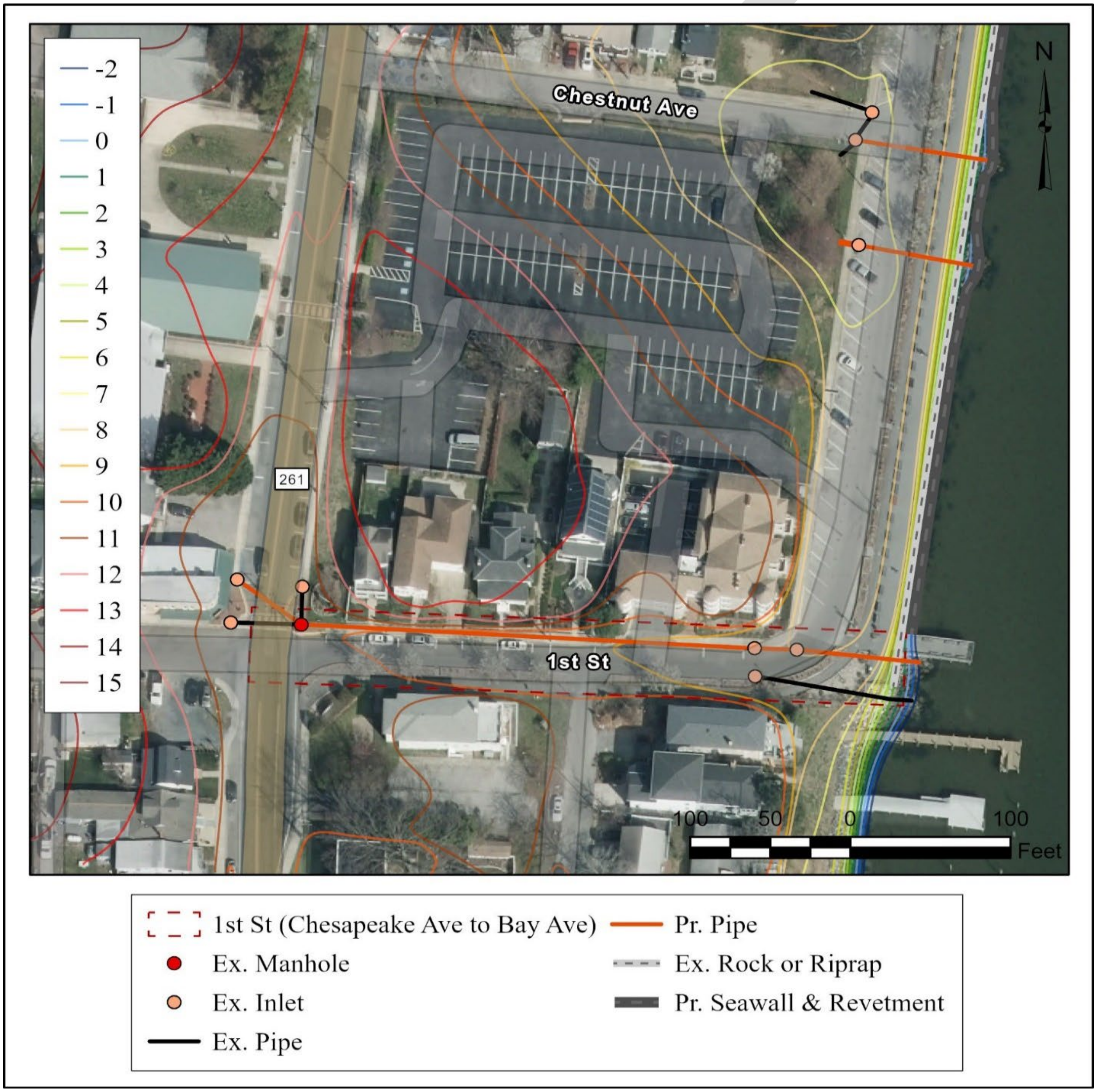


Figure 54 - Strategies for Reducing Flood Risk at 1st Street

8.10. Frederick Avenue between 3rd Street and 4th Street

Frederick Avenue between 3rd and 4th Street is a residential area bordered by homes on both sides. The road is located away from coastal flooding and only experiences flooding from extreme rainfall events due to the large drainage area.

8.10.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along Frederick Avenue between 3rd Street and 4th Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Flooding will occur in 2050 for extreme rainfall events and drain in an hour or less.
- Terminate – Risk Avoidance
  - Projects:
    - Upgrade entire system of pipes to more 2x their existing size to convey total flow during 100-year storm event in 2050.
  - Results:
    - Flooding to be prevented for the 2050 100-year storm event.
  - Impacts:
    - Significant impact to existing roadway, underground utilities, and increased design that will dramatically increase cost.
- Transfer – Risk Transfer
  - Given that flooding is only anticipated for extreme events, the purchase of flood insurance may be an affordable option.
- Treat – Risk Mitigation
  - Projects:
    - Upgrade existing stormwater pipes and install storage vault along Frederick Avenue.
    - Upgrade existing stormwater pipes along 4th Street.
    - Construct step pool system along the alley between 5th Street and 4th Street.
  - Results:
    - Flooding prevented for the 2050 10-year storm event and reduced to only a brief duration in the 100-year storm event.
  - Impacts:
    - Conversion of part of the existing open alley to step pool system.

The decision matrix to determine the most effective RMS alternative is presented in Table 43.

Table 43 - Decision Matrix for Frederick Avenue						
Options	**Feasibility**	**Effectiveness**	**Socio-economic Impacts**	**Environmental Impacts**	**Cost**	**Total**
RMS 1 – Tolerate Risk	5	0	3	5	5	18
RMS 2 – Terminate Risk	1	5	2	3	2	13
RMS 3 – Transfer Risk	5	2	3	5	4	19
RMS 4 – Treat Risk	3	4	3	3	3	16

8.10.2. Preferred Alternative

The preferred alternative for managing flood risk at Frederick Avenue between 3rd and 4th Street is RMS 3 – Risk Transfer, which recommends purchasing insurance to manage the risk of flooding. This is likely due to the lack of storm surge or nuisance flooding anticipated in 2050 and shorter flood duration. Therefore, it is likely that projects aimed at reducing flood risk for this area should be considered for long-term future implementation once flood risk has been reassessed.

Projects for future implementation to reduce flood risk are shown in Figure 55. The proposed stormwater system improvements reduce flooding in the area due to severe rain events and backwatering from the 4th Street stormwater system. A below grade storage vault is proposed along Frederick Avenue between 3rd Street and 4th street. The vault, assumed to be 800 CY (10'Wx20'Lx4'D) in the model, will provide a storage area for excess stormwater and alleviate flooding of upstream structures. Replacing approximately 1700 feet of pipe to increase pipe sizes along Frederick Avenue will improve the capacity of the stormwater system and provide adequate conveyance of runoff. The additional capacity will improve flow to the main branch of the stormwater system along 4th Street.

A step pool system is proposed to replace part of the existing stormwater infrastructure in the alley at the intersection of 5th Street and Greenwood Avenue. This will attenuate incoming runoff through infiltration and decrease the peak flow being delivered to the main branch of the 4th Street stormwater system. An increase in pipe sizes is also proposed along the main branch of the 4th Street stormwater system between Greenwood Avenue to Dayton Avenue. The step pool system and increased pipe sizes will improve stormwater conveyance through the upper reaches of the stormwater system, reducing the amount of flooding experienced in even the largest storm events. The effects of runoff attenuation will propagate downstream and alleviate flooding throughout the entire 5th Street and 4th Street stormwater system. The proposed upgrades between Greenwood Avenue and Frederick Avenue are shown in Figure 55. In the proposed conditions SWMM model, this area was flooded by the 100-yr storm event. In the 100-yr storm event (2050) 3 out of 9 nodes (33%) experienced flooding and the maximum flood time was 0.5 hours. Flooding was eliminated in the 10-year storm event and reduced to only a brief duration in the 100-year storm event as shown in Table 44.

Table 44 - Flooding at Frederick Avenue						
Model	**Hours of Flooding**					
	2030 1-yr	**2030 10-yr**	**2030 100-yr**	**2050 1-yr**	**2050 10-yr**	**2050 100-yr**
Existing	0.0	0.4	1.0	0.0	0.4	1.0
Proposed	0.0	0.0	0.5	0.0	0.0	0.5

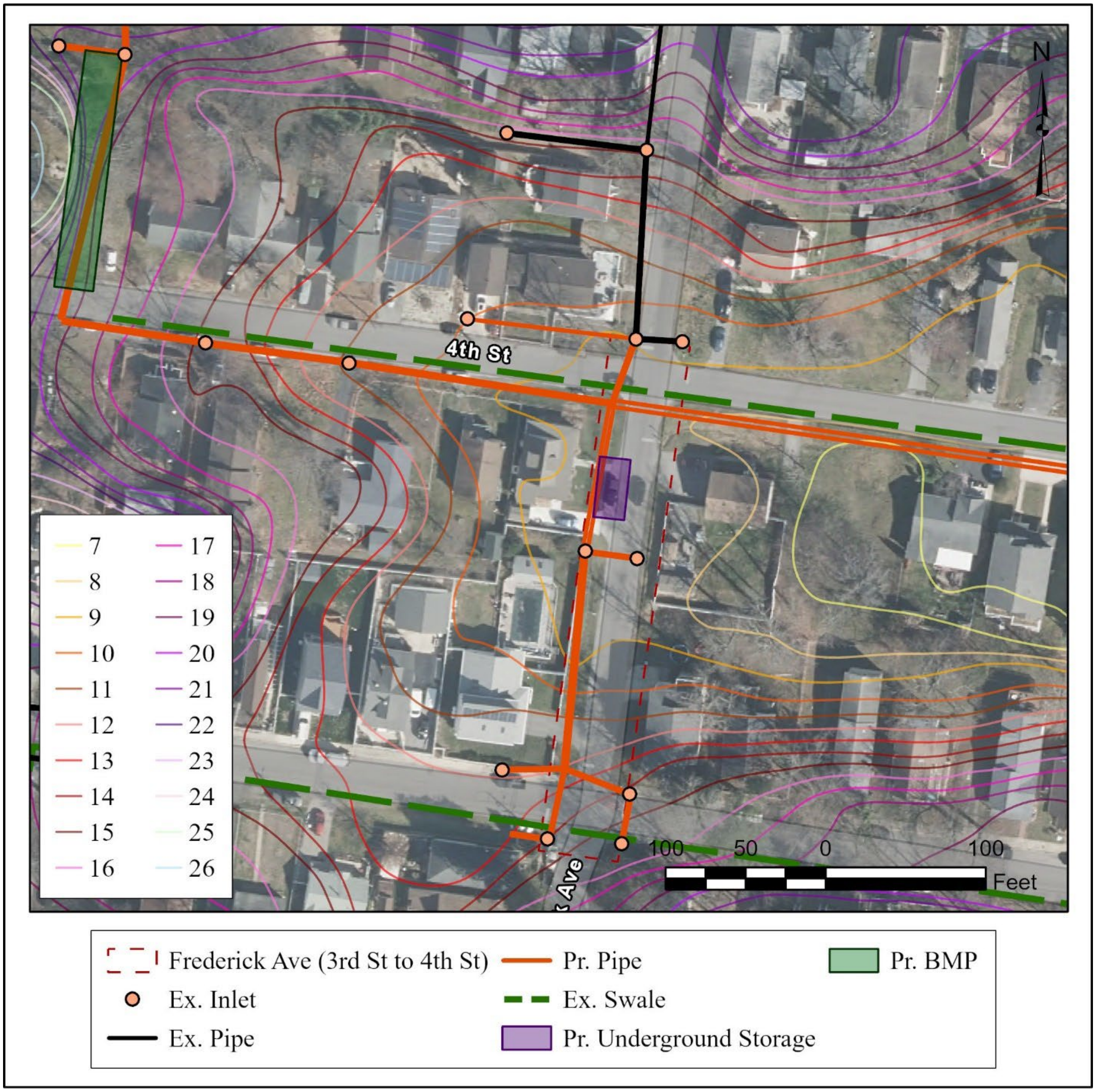


Figure 55 - Strategies for Reducing Flood Risk at Frederick Avenue between 3rd and 4th Street

8.11. Greenwood Avenue and 8th Street

The intersection of Greenwood Avenue and 8th Street is a residential area with a county sanitary sewer pump station. Reported flooding of residential property in the area is a result of upland drainage from the county.

8.11.1. Alternatives Analysis

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Flooding will increase in frequency and quantity.
- Terminate – Risk Avoidance
  - Projects:
    - Upgrade existing stormwater pipes and inlets at Greenwood Avenue and 8th Street.
    - Install new inlets at Greenwood Avenue and 8th Street.
    - Construct an enhanced drainage swale.
  - Results:
    - Flooding of the intersection prevented and directed away from residential property.
  - Impacts:
    - Installation of new stormwater infrastructure in the right-of-way.
    - Possible impacts to existing sanitary sewer pump station.
- Transfer – Risk Transfer
- Treat – Risk Mitigation
  - Projects:
    - Upgrade existing stormwater pipes and inlets at Greenwood Avenue and 8th Street.
  - Results:
    - Flooding reduced and directed away from residential property.
  - Impacts:
    - Possible impacts to existing sanitary sewer pump station.

8.11.2. Preferred Alternative

Adequate conveyance of stormwater runoff can be provided by upgrading the existing inlet structure, installing 2 new inlet structures, installing approximately 100 feet of drainage pipe, increasing the size of approximately 400 feet of existing drainage pipe, and constructing an enhanced drainage swale will increase the stormwater system capacity. The proposed stormwater infrastructure will intercept runoff from the upland drainage area and direct it to infrastructure in the right-of-way instead of allowing it to collect on nearby residential property.

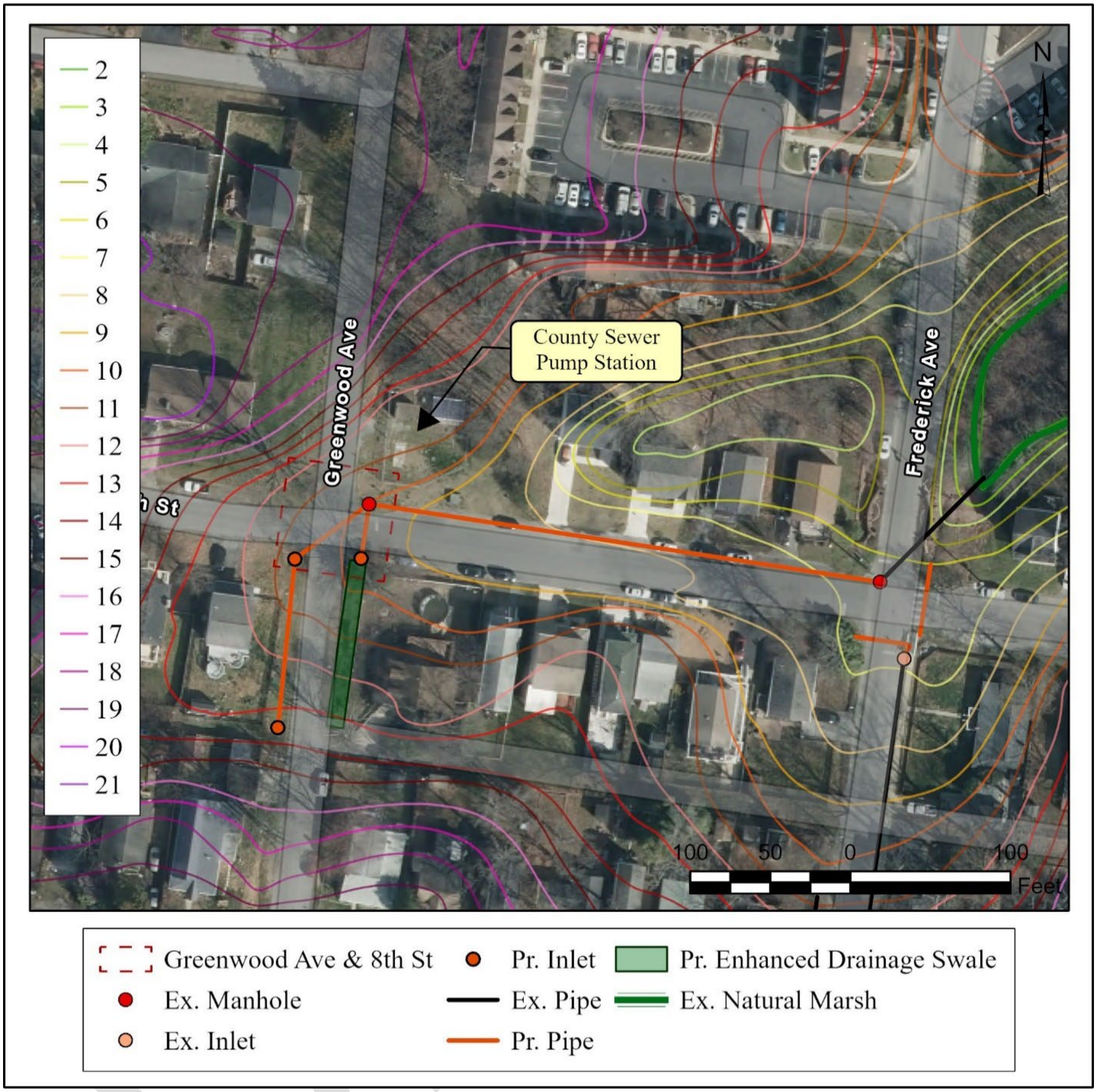


Figure 56 - Strategies for Reducing Flood Risk at Greenwood Avenue and 8th Street

8.12. Burnt Oaks North Apartments

The Burnt Oaks North Apartments is a residential community in an area of higher elevation than the surrounding topography that experiences soil erosion. The reported erosion is more directly related to stormwater runoff than flooding due to sufficient changes in elevation throughout the community. It is recommended that a community specific hydrologic and hydraulic analysis be performed to various study points throughout the community to identify potential erosion remediation measures. Possible remediation measures to prevent further erosion include adequately sized stone slope protection, various slope stabilization measures, and pond retrofit opportunities to attenuate larger flows.

8.13. Other Areas Identified by Community Input

The San Francisco by the Bay community is at significantly higher elevations and the erosion is due to stormwater runoff versus flooding. It is recommended that a community specific hydrologic and hydraulic analysis be performed to various study points throughout the community to identify potential erosion remediation measures. Possible remediation measures to prevent further erosion include adequately sized stone slope protection, various slope stabilization measures, and installation of green infrastructure BMPs to reduce runoff across steep slopes.

The flooding issues at the various intersections and upland roadways are due to the lack of slope and/or storm drain infrastructure to collect and convey storm flows. It is recommended these areas fix localized depressions and investigate the feasibility of extending storm drain infrastructure to these areas. It is also recommended the Town educate and encourage, and incentivize if practicable, individual lot owners to install green infrastructure practices like rain barrels and gardens to provide stormwater management treatment for the untreated impervious areas of lots and help remediate flooding of yards and adjacent roads. Implementation of green infrastructure practices for individual lots will help mimic natural runoff characteristics and slow down runoff to the drainage system.

9. IMPLEMENTATION PLAN

Once the preferred alternatives for risk management were selected, projects are developed and prioritized in the Implementation Plan. The Implementation Plan is meant to focus efforts on the areas most in need and/or projects that will have the greatest benefits. Projects were developed that could address multiple flooding sources (coastal and stormwater) or several high priority areas.

Based on the Vulnerability Assessment and applying the preferred alternatives, the Implementation Plan was divided into three categories, as defined below:

- Immediate Implementation – Action to recognize benefits in 0 – 10 years
- Mid-Term Implementation – Action to recognize benefits in 10 – 20 years
- Long-Term Implementation – Action to recognize benefits in +20 years

The projects developed and prioritized are discussed in subsequent paragraphs.

9.1. Immediate Implementation

Projects defined for 'Immediate Implementation' target high priority areas ranked highly in the Prioritization Table presented in Table 45. Work should begin immediately for securing funding for engineering, permitting and design so that construction can be underway in the near future. Though the projects are shown as individual efforts in the sections below, it is recommended that those in close proximity to each other should be combined to limit disturbance and take advantage of other cost efficiencies. Additionally, the large-scale projects may need to be phased to accommodate funding.

The projects proposed for Immediate Implementation are presented in the following sections.

9.1.1. Project 1 – Seawall and Revetment at Atlantic Avenue

Project 1 consists of constructing a seawall and revetment constructed along Atlantic Avenue to an elevation of +6.5 feet NAVD88 to prevent flooding in 2050 for all events except the 2050 1% annual chance storm surge level, where flooding due to storm surge may still be expected. Flooding due to overtopping will be reduced by building up the existing revetment to a crest elevation of +6.5 feet NAVD88 with a minimum 8-foot crest width. This structure will reduce the overtopping during the 2050 storm events so as not to damage the roadway, however, driving on the Atlantic Avenue during storm events will not be advised. The planning level cost to construct this project is provided in Table 45.

Table 45 - Project 1 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$750,000
Seawall Construction	LF	1,150	$3,000	$3,450,000
Revetment Enhancement	LF	1,150	$2,080	$2,392,000
			Subtotal	$6,592,000
			20% Contingency	$1,318,400
			Total Cost	**$7,910,400**

9.1.2. Project 2 – Construct Earthen Dike

Project 2 involves the construction of an earthen dike northwest of Bay Avenue along the northern natural marsh area. The dike would be constructed to an elevation of +6 feet NAVD88. This elevation will prevent flooding during the 1% annual chance storm surge event in 2030 and will reduce, though not prevent, flooding during the 1% annual chance storm surge level in 2050. Wave overtopping is not a concern in this area as waves are dissipated within the marsh north of the Town of North Beach. The earthen dike will tie-into the existing +6-foot contour near the end of 10^{th} Street. It will follow the marsh and a portion of Bay Avenue until it reaches the area where the existing earthen dike ends. The road will be raised in this area to complete a closed system. The planning level cost to construct this project is provided in Table 46.

Table 46 - Project 2 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$150,000
Dike Construction	LF	670	$890	$596,300
Bay Avenue Raising	LF	50	$275	$13,750
			Subtotal	$760,050
			20% Contingency	$152,010
			Total Cost	**$912,060**

9.1.3. Project 3 – Stormwater System Upgrades at Atlantic Avenue

Project 3 involves upgrading existing stormwater pipes along Atlantic Avenue. It is recommended that this project be constructed in conjunction with the seawall and revetment project for efficiency and cost savings. However, funding limitation may not allow for combining Project 1 and Project 3, so construction of Project 3 alone will provide instant flood protection.

Table 47 - Project 3 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$10,000
Pipe Replacement	LF	320	$98	$31,360
			Subtotal	$41,360
			20% Contingency	$8,272
			Total Cost	**$49,632**

9.1.4. Project 4 – Stormwater System Upgrades at 9th Street

Project 4 consists of upgrading existing stormwater pipes along 9th Street, installation of a storage vault, and construction of a vegetated swale.

Table 48 - Project 4 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$43,000
Pipe Replacement	LF	700	$98	$68,600
Manhole/Inlet	EA	5	$5,000	$25,000
Underground Storage Vault	LF	40	$450	$18,000
Vegetated Swale	SF	4000	$16	$64,000
Roadway Elevation	SF	7080	$6	$42,480
			Subtotal	$261,080
			20% Contingency	$52,216
			Total Cost	**$313,296**

9.1.5. Project 5 – Stormwater System Upgrades at 7th Street

Alternative 1 of Project 5 consists of upgrading existing stormwater pipes along 7th Street, installation of a storage vault, construction of a vegetated swale, and installation of a pump station.

Table 49 - Project 5 Alternative 1 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$88,000
Pipe Replacement	LF	50	$98	$4,900
Manhole/Inlet	EA	2	$5,000	$10,000
Tide Gate Valve	EA	1	$45,000	$45,000
Underground Storage Vault	LF	40	$450	$18,000
Vegetated Swale	SF	4000	$16	$64,000
Pumping Station	EA	1	$300,000	$300,000
			Subtotal	$529,900
			20% Contingency	$105,980
			Total Cost	**$635,880**

Alternative 2 of Project 5 consists of upgrading existing stormwater pipes along 7th Street, installation of storage vaults, construction of a vegetated swale, installation of a pump station, and installation of pipes and conduits along Atlantic Avenue.

Table 50 - Project 5 Alternative 2 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$109,000
Pipe Replacement	LF	50	$98	$4,900
Manhole/Inlet	EA	2	$5,000	$10,000
Tide Gate Valve	EA	1	$45,000	$45,000
Underground Storage Vault	LF	40	$450	$18,000
Vegetated Swale	SF	4000	$16	$64,000
Pumping Station	EA	1	$300,000	$300,000
			Subtotal	$655,700
			20% Contingency	$131,140
			Total Cost	**$786,840**

9.1.6. Project 6 – Stormwater System Upgrades at 5th Street

Project 6 consists of upgrading existing stormwater pipes along 5th Street and construction of a green infrastructure facility.

Table 51 - Project 6 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$35,000
Pipe Replacement	LF	250	$98	$24,500
Manhole/Inlet	EA	5	$5,000	$25,000
Green Infrastructure	SF	8000	$16	$128,000
			Subtotal	$212,500
			20% Contingency	$42,500
			Total Cost	**$255,000**

9.1.7. Project 7 – Installation of Seawall and Revetment along Boardwalk

Project 7 proposes extending the seawall and revetment south of Atlantic Avenue to the start of the Town beach area. The current boardwalk elevation in this area is between +4.5 and +5.25 feet NAVD88, which will likely begin to experience flooding from elevated water levels in the future. The project proposes to extend the seawall constructed along Atlantic Avenue at an elevation of +6.5 feet NAVD88. The existing revetment will also prove to be inadequate at reducing wave overtopping by 2050. The revetment would be upgraded similarly to the Atlantic Avenue revetment, with a top elevation of +6.5 feet NAVD88 and 8-foot crest width. Planning-level costs for this work is present in Table 52.

Table 52 - Project 7 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$200,000
Seawall Construction	LF	275	$3,000	$825,000
Revetment Enhancement	LF	275	$2,080	$572,000
			Subtotal	$1,597,000
			20% Contingency	$319,400
			Total Cost	**$1,916,400**

9.2. Mid-Term Implementation

The Mid-Term Action Plan includes projects that address areas not of immediate concern but will experience more significant and frequent impact in the near future. Engineering, design and permitting is recommended to begin in approximately 5 – 10 years so as to allow for complete project implementation by 2040. The proposed projects are discussed in the following paragraphs.

9.2.1. Project 8 – Heighten Earthen Dike at end of Annapolis Avenue

The current dike around near the living shoreline that connects to the Atlantic Avenue revetment was constructed in 2017 to an elevation of +4.1 feet NAVD88. The elevation of the dike currently provides sufficient protection for most extreme storm surge levels except for the 1% annual chance water level of +4.3 feet NAVD88. With SLR, the effectiveness of the dike will decrease and heightening of the dike crest will be necessary.

Raising the dike to +6 feet NAVD88 would require an additional 1.9 feet of elevation. This will be done by adding fill to the top and seaward face of the dike so as not to encroach further onto neighboring property. The elevated dike will tie into the raised portion of Bay Avenue to the west and the seawall and revetment to the east. Planning-level costs for this work is present in Table 53.

Table 53 - Project 8 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$70,000
Dike Elevation	LF	930	$300	$279,000
			Subtotal	$349,000
			20% Contingency	$69,800
			Total Cost	**$418,800**

9.2.2. Project 9 – Installation of Seawall within Beach Area

The current Town beach area is located behind a series of breakwater structures. These structures protect against wave action that may result in flooding due to wave overtopping. Additionally, the sand located along the boardwalk as part of the beach acts as a buffer to further reduce the wave energy approaching the shoreline. For this reason, wave overtopping is not a concern along the boardwalk in the Town beach area.

The current elevation of the boardwalk behind the beach ranges from +4 to +5 feet NAVD88. Storm surges will result in flooding for current extreme events that will become more frequent in the future. Therefore, the proposed project includes extending the seawall at elevation +6.5 feet NAVD88 constructed as part of Project 7 along the back of the beach. The project also includes adding elevation to the beach to allow it to continue to act as a wave buffer and serve as a recreational asset to the Town. Planning-level costs for this work is present in Table 54.

Table 54 - Project 9 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$300,000
Seawall Construction	LF	975	$3,000	$2,925,000
Stop Log	EA	1	$250,000	$250,000
Beach Elevation	TONS	6,250	$90	$562,500
			Subtotal	$4,037,500
			20% Contingency	$807,500
			Total Cost	**$4,845,000**

9.2.3. Project 10 – Stormwater System Upgrades at Annapolis Avenue

Project 10 consists of upgrading existing stormwater pipes along Annapolis Avenue.

Table 55 - Project 10 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$7,000
Pipe Replacement	LF	200	$98	$19,600
Manhole/Inlet	EA	3	$5,000	$15,000
			Subtotal	$41,600
			20% Contingency	$8,320
			Total Cost	**$49,920**

9.2.4. Project 11 – Stormwater System Upgrades at Bay Avenue

Project 11 consists of upgrading existing stormwater pipes along Bay Avenue.

Table 56 - Project 11 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$10,000
Pipe Replacement	LF	250	$98	$24,500
Manhole/Inlet	EA	5	$5,000	$25,000
			Subtotal	$59,500
			20% Contingency	$11,900
			Total Cost	**$71,400**

9.2.5. Project 12 – Stormwater System Upgrades at Chesapeake Avenue

Project 12 consists of upgrading existing stormwater pipes along Chesapeake Avenue.

Table 57 - Project 12 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$24,000
Pipe Replacement	LF	750	$98	$73,500
Manhole/Inlet	EA	9	$5,000	$45,000
			Subtotal	$142,500
			20% Contingency	$28,500
			Total Cost	**$171,000**

9.2.6. Project 13 – Stormwater System Upgrades at Dayton Avenue

Project 13 consists of upgrading existing stormwater pipes along Dayton Avenue and constructing a green infrastructure facility.

Table 58 - Project 13 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$65,000
Pipe Replacement	LF	1250	$98	$122,500
Manhole/Inlet	EA	14	$5,000	$70,000
Green Infrastructure	SF	8000	$16	$128,000
			Subtotal	$385,500
			20% Contingency	$77,100
			Total Cost	**$462,600**

9.2.7. Project 14 – Stormwater System Upgrades at Frederick Avenue

Project 14 consists of upgrading existing stormwater pipes along Frederick Avenue, of upgrading existing stormwater pipes along 4th Street, installing a storage vault, and constructing a step pool system.

Table 59 - Project 14 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$75,000
Pipe Replacement	LF	1700	$98	$166,600
Manhole/Inlet	EA	19	$5,000	$95,000
Underground Storage Vault	LF	40	$450	$18,000
Green Infrastructure	SF	6000	$16	$96,000
			Subtotal	$450,600
			20% Contingency	$90,120
			Total Cost	**$540,720**

9.2.8. Project 15 – Stormwater System Upgrades at Greenwood Avenue

Project 15 consists of upgrading existing stormwater pipes and inlets, installing new stormwater pipes and inlets, and constructing an enhanced drainage swale along Greenwood Avenue and 8th Street.

Table 60 - Project 15 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design and Permitting	-	-	-	$14,000
Pipe Replacement	LF	400	$98	$39,200
Proposed Pipe	LF	100	$98	$9,800
Manhole/Inlet	EA	3	$5,000	$15,000
Enhanced Vegetated Swale	SF	500	$16	$8,000
			Subtotal	$86,000
			20% Contingency	$17,200
			Total Cost	**$103,200**

9.3. Long-Term Implementation

Long-term implementation refers to projects that should be commenced in the next 10 – 15 years so that project benefits can be recognized by 2050. The proposed projects are discussed in the following paragraphs.

9.3.1. Project 16 – Revetment Enhancement along Boardwalk

Given the high elevation of the boardwalk between 1st and 3rd Street, flooding due to elevated water levels from storm surges is not anticipated to be a concern until well past 2050. However, rising water levels may result in the revetment structures being less capable of breaking wave energy. Wave overtopping during elevated storm surges may then result in flooding along the boardwalk and Bay Avenue. Project 16 proposes to enhance the revetment along the boardwalk between 1st and 3rd Street. Planning-level costs for this work is present in Table 61.

Table 61 - Project 16 Planning Level Cost

Description	Unit Size	Estimate Quantity	Unit Cost	Capital Cost
Design & Permitting	-	-	-	$250,000
Revetment Enhancement	LF	1,065	$2,080	$2,215,200
			Subtotal	$2,465,200
			20% Contingency	$493,040
			Total Cost	**$2,958,240**

9.3.2. Project 17 – Stormwater System Upgrades at 1st Street

Project 17 consists of upgrading existing stormwater pipes along 1st Street.

Table 62 - Project 17 Planning Level Cost				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	-	$12,000
Pipe Replacement	LF	450	$98	$44,100
Manhole/Inlet	EA	3	$5,000	$15,000
			Subtotal	$71,100
			20% Contingency	$14,220
			Total Cost	**$85,320**

9.4. Permitting Considerations

Several proposed mitigation strategies will require coordination and/or various approvals from Federal, State, and/or Local regulatory agencies. Any projects that encroach private property would also require coordination and approval from the landowner.

Land disturbances greater than 5,000 square feet may be subject to local grading permit requirements. Local grading permits will need to address erosion/ sediment control and traffic management during construction. The Town is within the Chesapeake Bay Critical Area, so mitigation solutions requiring land disturbance will be subject to mitigation regulations reviewed by the Critical Area Commission. A Joint Federal/State Permit Application (JPA) submitted to the Maryland Department of the Environment (MDE) and U.S. Army Corps of Engineers (USACE) will be required for the alteration of any Tidal Wetland and/or Tidal Waters. Activities that necessitate a JPA include but are not limited to: construction of new outfalls in tidal waters; the modification of existing outfalls that disturb tidal waters and/or tidal wetlands; construction of shoreline protection structures and/or improvements that disturb or modify tidal/non-tidal wetlands. As part of the JPA and Critical Area approvals, mitigation efforts such as wetland creation will likely be required. Table 60 summarizes the anticipated permitting requirements for the projects proposed.

Table 63 - Anticipated Permitting Requirements				
Project No.	**Project Description**	**Local***	**State/ Federal**	**Critical Area**
1	Seawall and Revetment at Atlantic Avenue	Yes	Yes	Yes
2	Construct Earthen Dike	Yes	Yes	Yes
3	Stormwater System Upgrades at Atlantic Avenue	Yes	Yes	Yes
4	Stormwater System Upgrades at 9th Street	Yes	Yes	Yes
5	Stormwater System Upgrades at 7th Street	Yes	Yes	Yes
6	Stormwater System Upgrades at 5th Street	Yes	No	Yes
7	Installation of Seawall and Revetment along Boardwalk	Yes	Yes	Yes
8	Heighten Earthen Dike at end of Annapolis Avenue	Yes	Yes	Yes
9	Installation of Seawall within Beach Area	Yes	No	Yes
10	Stormwater System Upgrades at Annapolis Avenue	No	No	Yes

Table 63 - Anticipated Permitting Requirements

11	Stormwater System Upgrades at Bay Avenue	No	No	Yes
12	Stormwater System Upgrades at Chesapeake Avenue	Yes	No	Yes
13	Stormwater System Upgrades at Dayton Avenue	Yes	No	Yes
14	Stormwater System Upgrades at Frederick Avenue	Yes	No	No
15	Stormwater System Upgrades at Greenwood Avenue	Yes	No	Yes
16	Revetment Enhancement along Boardwalk	Yes	Yes	Yes
17	Stormwater System Upgrades at 1st Street	No	Yes	Yes

* Local permits necessary for storm drain system upgrades will be subject to detailed engineering analysis and may necessitate local grading permit regulations depending on the extents of excavation.

10. FUNDING OPPORTUNITIES

The projects presented in Section 9 Implementation Plan range from small-scale to multi-million dollar construction. In addition to town and county general funds, additional sources for funding are described in subsequent paragraphs.

10.1. Federal and State Grants for Flood Risk Reduction

Multiple funding sources exist for flood hazard reduction through grants administered by Federal agencies in partnerships with State and local entities. Example of such funding opportunities are:

10.1.1. Federal Emergency Management Agency

Once such partnership exists between the Maryland Department of Emergency Management (MDEM) and the Federal Emergency Management Agency (FEMA), where MDEM administers FEMA grants and serves as a conduit to Presidential Disaster Declarations and federal assistance before, during and after disasters. These funds can be used to acquire/demo property, elevate structures, dry floodproofing, planning and Design & Engineering of flood risk reduction projects. Activities that are ineligible for this funding are repair or replacement of existing infrastructure (without upgrades to reduce risk or deferred maintenance. The Hazard Mitigation Assistance (HMA) is available through three avenues:

- Hazard Mitigation Grant Program (HMGP)
    - Funds available after Presidential Disaster Declaration (within 1 year);
    - Cost share – 75% Federal and 25% Non-Federal;
    - Local Hazard Mitigation Plan must be adopted and approved.
- Flood Mitigation Assistance (FMA)
    - Funds available annually;
    - Nationally Competitive;
    - Cost share – 75% Federal and 25% Non-Federal or 90% Federal/10% non-Federal for small, impoverished communities or for Repetitive Loss;
    - Local Hazard Mitigation Plan must be adopted and approved;
    - Community must be in Good Standing with NFIP and property must carry NFIP policy in perpetuity.
- Building Resilient Infrastructure and Communities (BRIC)
    - Funds available annually;
    - Nationally Competitive;
    - Cost share – 75% Federal and 25% Non-Federal or 90% Federal/10% non-Federal for small, impoverished communities;
    - Local Hazard Mitigation Plan must be adopted and approved.

Additionally, the Comprehensive Flood Management Grant Program (CFMGP) is led by Maryland Department of the Environment (MDE) and will often cost-share the 25% non-Federal funds with local governments. When federal funds do not participate in the project cost, the CFMGP can fund up to 75% of the project cost with the local share being 25%.

10.1.2. Housing and Urban Development (HUD)

Grants for disaster mitigation can also be obtained from the U.S. Department of Housing & Urban Development (HUD) through the federally-funded Community Development Block Grant (CDBG) program. The applicable CDBG funds for the work described in the Implementation Plan would be administered through the CDBG Mitigation (MIT) or CDBG Disaster Recovery (DR) programs, though funding through the CDBG-DR is not permanently authorized and is limited to disasters specifically stated in the appropriation.

10.1.3. National Oceanic and Atmospheric Administration (NOAA)

NOAA provides multiple avenues for obtaining mitigation funding, especially for projects related to coastal zone management and coastal protection. Significant funding will be available through NOAA from the Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act) to increase community resilience to climate change and extreme weather events. These grants typically incorporate habitat creation and/or restoration features which will likely need to be integrated into the flood protection design.

10.1.4. Natural Resources Conservation Service (NRCS)

The NRCS administers multiple initiatives to help vulnerable communities recover after natural disasters such as floods. Projects proposed as part of this plan would be mostly suited for the EWP:

- Emergency Watershed Protection (EWP)
  - Does not require Declaration by Federal or State Governments
  - Can be used to repair or replaced drainage facilities and protection structures.
  - Cost share – 75% Federal and 25% Non-Federal or 90% Federal/10% non-Federal for limited-resources areas;

10.2. Loans and Bonds

Funding for flood protection and adaptation projects are also available in the form of loans or municipal bonds. Additionally, many communities, such as the City of Baltimore, have begun implementing Environmental Impact Bonds (EIB) to fund construction projects where repayment is based on the effectiveness of the project. In the Chesapeake Bay area, the initiative was being led by the Chesapeake Bay Foundation, however, it is understood that they are not currently accepting application for new municipal partners.

11. CONCLUSION

The analysis of the Town of North Beach's shoreline and coastal protection structures and stormwater drainage systems shows deficiencies in multiple areas—primarily drainage infrastructure that is past life expectancy or undersized and protection structures that are not adequate for the combined impact of wave overtopping, storm surge, increased rainfall, and sea-level rise.

The deficiencies explain the frequent flooding from rainfall and coastal high-water levels. But the analysis also indicates that sea-level rise, storm surge, and increased rainfall will continue to overwhelm the current protection structures and stormwater systems, resulting in more frequent and widespread flooding throughout the Town. As sea levels continue to rise, low-lying inland areas of the Town will also become inundated from overland flooding.

If left unchecked, the increase in flooding will likely exacerbate damage to homes, property, businesses, vehicles, and critical infrastructure as well as diminish the sustainability of the Town as a popular waterfront resort.

Thirteen high priority areas were analyzed for the flooding extents and duration due to stormwater and coastal flooding (see Section 6, "Assessment Area Prioritization"), and flood mitigation strategies for the protection of these areas were identified (see Section 7, "Flood Mitigation Strategies"). These strategies encompass both coastal and stormwater solutions including:

- Seawall and revetment construction/enhancement to reduce wave overtopping, provide a barrier to incoming waves, dissipate wave energy, and protect against higher water levels;
- Enhancing the existing earthen berm to prevent flood waters from rencroaching inland;
- Widespread storm drainage infrastructure improvements, stretching from Atlantic Avenue to Greenwood Avenue and 1st Street to 9th Street; and
- Green infrastructure projects.

An alternatives analysis was performed to recommend the alternative that provides the maximum benefit to the Town (See Section 8, "Alternatives Analysis for Risk Management"). This assessment concludes that several deficiencies can be addressed through small-scale improvements while other areas will require significant construction to alleviate the risk of flooding. A recommended alternative for each high-priority area is provided along with design and permitting considerations.

Finally, an implementation plan was developed (See Section 9, "Implementation Plan") and potential funding sources to implement projects were identified (See Section 10, "Funding Sources"). The implementation plan prioritizes the recommended alternatives within an implementation timeframe and cost.

The plan recommends immediate action of seven projects costing a total of approximately $12.0 million dollars. After the immediate action items are addressed, eight additional projects for implementation in the mid-term are presented with a total cost of approximately $6.7 million. Two long-term solutions are proposed to ensure system performance in future conditions for an estimated cost of $3.0 million. The implementation plan developed for use by the Town and stakeholders will aid in prioritizing project selection and timing as well as serve as the foundation for the Town in becoming resilient to storm-induced and tidal flooding.

Appendix A

ESRGC Flood Analysis and Mapping

Flood Analysis and Mapping:
Technical Support Methodology
Town of North Beach, Calvert County

May 9, 2022

Introduction

The Eastern Shore Regional GIS Cooperative (ESRGC) assisted the Town of North Beach with flood analysis, processing, and mapping of data to predict sea level change for North Beach, Calvert County. While much of Calvert County's natural and built environment is expected to be impacted by sea level change, the coastal community of North Beach will be among the first to experience the effects. The data developed by the ESRGC will be used by the Town of North Beach to assess the vulnerability of specific geographic areas in their community; recommend mitigation and adaptation options to address flooding impacts including sea level change; and prepare implementation strategies

The most recently available aerial topographic LiDAR derivatives, current sea level projections for Maryland 2030, 2050, and 2100 (R. Kopp, Rutgers University), and 1% annual-chance flood elevations (FEMA Flood Insurance Study: #24009CV000B; Effective: November 19, 2014) were used in this study to represent sea level rise and periodic flooding for North Beach. For this study the ESRGC developed flood grids representing mean sea level for 2030 and 2050, 1% annual chance flood events for 2030 and 2050, and mean sea level for 2100 with a growing emissions pathway and mean sea level for 2100 with a growing emissions pathway and 1% annual chance flood event.

This methodology document is a high-level review of the ESRGC's technical support for the flood analysis and mapping for the Town of North Beach. Please see the metadata for analysis details.

Definition of Study Area

The Town of North Beach is located in northern Calvert County and experiences flooding from the Chesapeake Bay. Wetland areas to the north and south also flood from the Chesapeake Bay. The study area for this project extends beyond the town boundary to include the Chesapeake Bay and both wetland areas.

Sea Level Change: Depth Grid Development

The ESRGC worked with the Town of North Beach to select the most appropriate methodology and flood scenarios. Professor Robert Kopp, Rutgers University, a leading climate scientist whose emphasis on sea level change was determined to be the most appropriate source for regional sea level change projections.

North Beach selected the years 2030, 2050, and 2100 (RCP8.5 'growing' emissions pathway) for forecasted depth grid development. The Town also selected a low tolerance for the study area. A low tolerance for flood risk suggests buildings and infrastructure are unable to tolerate flooding.

The following table identifies the sea level change estimates over the 2000 benchmark at the Solomon's Island Tidal Gauge:

Year	Low Tolerance for Flood Risk: 1% meet/exceed
2030	1.3 feet
2050	2.4 feet
2100	7.0 feet

Table 1: Solomon's Island Tidal Gauge SLC Estimates over 2000 Benchmark

The Town also chose to include a 1% annual chance storm event for 2030, 2050, and 2100. Table 2 identifies the flood sources and corresponding still water elevations used in modeling the 1% annual chance storm:

Flooding Source	1% Annual Chance Storm Event
Chesapeake Bay at Northern County Boundary	4.30 feet
Chesapeake Bay at Town of North Beach	4.30 feet
Chesapeake Bay at Town of Chesapeake Beach	4.15 feet
Chesapeake Bay at Randle Cliff Beach	4.10 feet

Table 2: Elevations for 1% Annual Chance Storm Events

Tidal Calibration

The ESRGC prepared the digital elevation model (DEM) for analysis. Sea level change for North Beach was localized to the nearest National Oceanic and Atmospheric Administration (NOAA) tidal reference station at Solomon's Island (Station ID: 8577330). Observations were transformed from tidal datum to North American Vertical Datum of 1988 (NAVD 1988). A final correction was applied to account for observed sea level change between the sea level benchmark (2000) and land elevation capture (2017), using the observed relative sea level change at the NOAA Solomon's Island station (3.93 mm/year).

The following table identifies the sea level change estimates adjusted for NAVD 1988 and for use with the land elevation (LiDAR) collected in 2017:

Year	Low Tolerance for Flood Risk: 1% meet/exceed
2030	0.9908071 feet
2050	2.090807 feet
2100	6.6908071 feet

Table 3: Sea Level Change Adjustments

Digital Elevation Model Analysis

The Calvert County DEM, along with the adjacent county DEMs, and an 'open water' GRID of 0.0 values were upsampled to 2-meters and mosaicked to meet the flood study's required extent. The 2-meter upsample maintains horizontal integrity while improving raster processing. Adjacent county LiDAR collections include Anne Arundel, Charles, Prince George's, and St Mary's Counties.

For annual chance depth grid output, the DEM is processed using HAZUS-MH software (v4.2 SP3).

For sea level change depth grid output, the sea level change estimate is subtracted from elevations.

Review of Preliminary Depth Grids

A review of the preliminary sea level change depth grid data is a critical step in the data analysis process.

Traditionally, the ESRGC uses the National Hydrography Dataset (NHD) flowlines to represent water drainage in a study area. However, the scale of the NHD does not lend itself to the scale and geomorphology of the study area and these data were rejected. Lacking a hydro-enforced DEM and data for the location of culverts, the ESRGC used raster analysis to develop a drainage flow line analysis. This analysis allowed the ESRGC to determine where false pooling would likely occur, limiting the true extent of potential flooding.

Local knowledge and investigation from North Beach regarding the location of suspected culverts on public roads further supported the flowline analysis and ultimately, the resulting areas of inundation.

Depth Grid "Clean Up"

The preliminary depth grids must be reviewed for local minima, or "noise" in the data. The ESRGC implemented the following rules for the inclusion of cells in the depth grid:

1. Cells must intersect a flow line(s). Cells not intersecting flow line(s) are considered free from sea level change's direct influence and are excluded.
2. Intersected cells must represent a flood source (Chesapeake Bay) or be directly influenced by the flood source where direct influence is defined as:
    a. Contiguous cell representing a flood source,
    b. Adjacent to (2a) (may share corner vertex only),
    c. Adjacent to (2b) (may share corner vertex only),
    d. Not (2a), (2b), or (2c) because of the DEMs hydrologic limitations (i.e., visual inspection on ground or via aerial imagery confirms the presence of culvert(s) that would otherwise allow for continuous feature).

This validates the data as a sea level change study and not a bathtub model.

Data Development

The ESRGC updated the existing building footprints for six locations using 2019 aerial imagery. The building footprint data assists in the development of first floor flooding. The ESRGC also used the DEM to develop drainage flow lines to support flood analysis for the study area.

Depth Points

The Town of North Beach provided 25 locations for the ESRGC to create water depth points. The points report the depth of water predicted for each projected year and annual chance periodic flood event. The points and depths are shown on the provided maps in a table and in the delivery geodatabase.

The depth points and flood depths of the points are shown on the maps provided to the Town deliverable. The depth of the flood water is shown on a table in each map. Any depth point that does not intersect a flood depth is listed in the table as "-" to indicate a flood depth is not present for the scenario.

Final Products

Mean Sea Level, 2030 Depth Grid

- sweldepth0 - represents projected Stillwater depths in 2030 (feet) during a period free from periodic flooding
- sweldepth100 - represents projected Stillwater depths in 2030 (feet) during a 1% annual chance periodic flood

Mean Sea Level, 2050 Depth Grid

- sweldepth0 - represents projected Stillwater depths in 2050 (feet) during a period free from periodic flooding
- sweldepth100 - represents projected Stillwater depths in 2050 (feet) during a 1% annual chance periodic flood

Mean Sea Level with Growing Emissions Pathway, 2100 Depth Grid

- sweldepth0 - represents projected Stillwater depths in 2100 (feet) with a Growing Emissions Pathway during a period free from periodic flooding
- sweldepth100 - represents projected Stillwater depths in 2050 (feet) with a Growing Emissions Pathway during a 1% annual chance periodic flood

First Floor Flooding

The Town provided six addresses with first floor foundation elevations. These elevations were used to determine the maximum flood depth at the first-floor elevation. As expected, a dwelling with an at grade foundation height will experience more damage from flooding compared to an elevated dwelling. The first-floor maximum flood depth provides valuable information regarding risk exposure. This data is provided in a geodatabase.

Maps

The Town of North Beach chose to map the full overview and three additional areas (Area A, Area B, and Area C) selected by the Town. The ESRGC provided the following maps as deliverables:

1. NB2030_11x14.pdf
2. NB2030_24x36.pdf
3. NB2030_AreaA.pdf
4. NB2030_AreaB.pdf
5. NB2030_AreaC.pdf
6. NB2030+1_11x14.pdf
7. NB2030+1_24x36.pdf
8. NB2030+1_AreaA.pdf
9. NB2030+1_AreaB.pdf
10. NB2030+1_AreaC.pdf
11. NB2050_11x14.pdf
12. NB2050_24x36.pdf
13. NB2050_AreaA.pdf
14. NB2050_AreaB.pdf
15. NB2050_AreaC.pdf
16. NB2050+1_11x14.pdf
17. NB2050+1_24x36.pdf
18. NB2050+1_AreaA.pdf
19. NB2050+1_AreaB.pdf
20. NB2050+1_AreaC.pdf
21. NB2100_11x14.pdf
22. NB2100_24x36.pdf
23. NB2100_AreaA.pdf
24. NB2100_AreaB.pdf
25. NB2100_AreaC.pdf
26. NB2100+1_11x14.pdf
27. NB2100+1_24x36.pdf
28. NB2100+1_AreaA.pdf
29. NB2100+1_AreaB.pdf
30. NB2100+1_AreaC.pdf

Intended Use and Limitations

The datasets represent projected still water depths (ft) in a forecast sea level change scenario. The layers are an aid for researchers seeking to identify potential vulnerabilities along North Beach's shoreline. The data supports North Beach's leadership and planners as they endeavor to mitigate or prevent the impacts of sea level change resulting from land surface subsidence and rising sea levels. The product uses sea-level projections to forecasts areas of inundation for a given scenario.

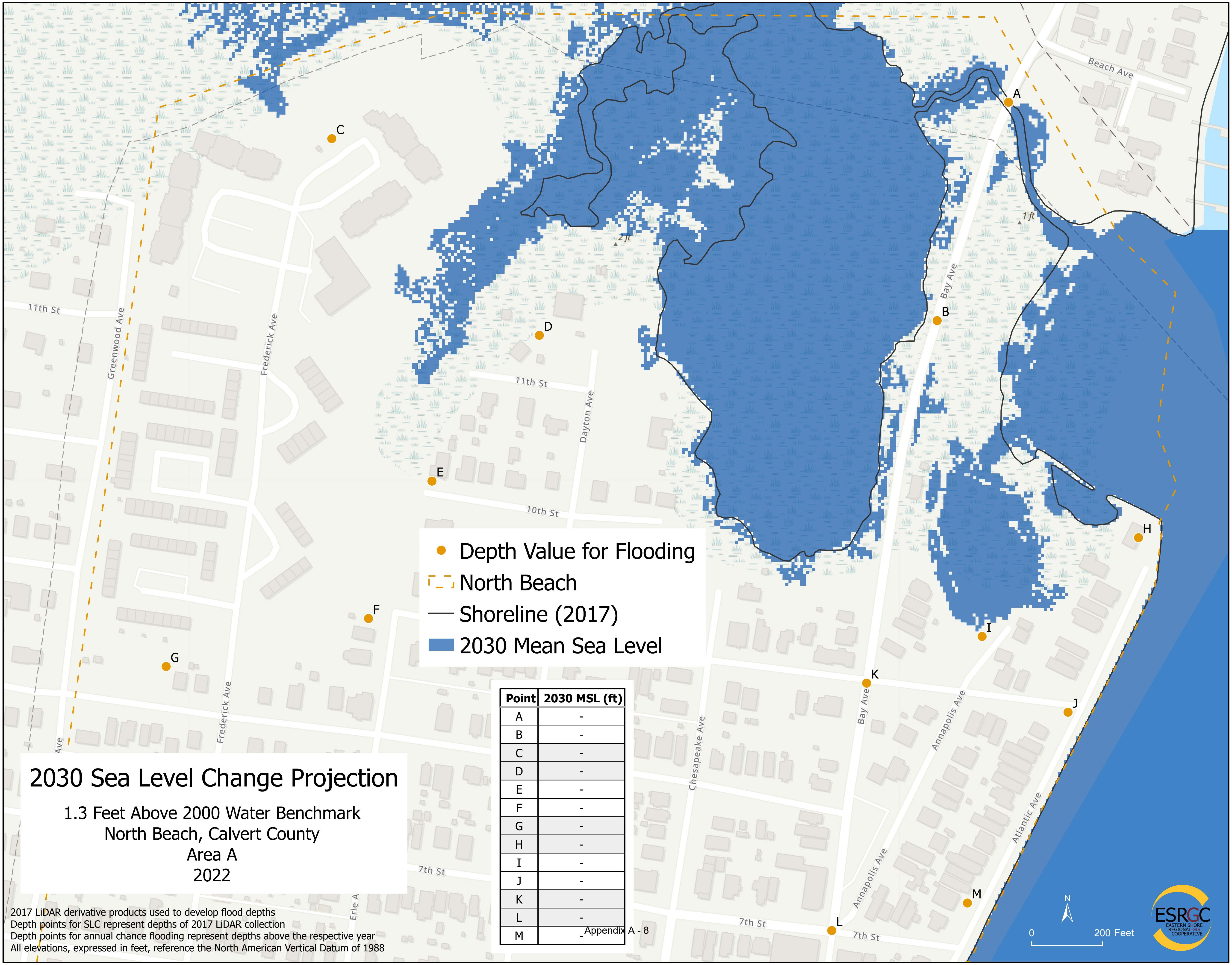
The data may be used and redistributed for free but is not intended for legal use, since it likely contains inaccuracies. The User assumes the entire risk associated with its use of these data and bears all responsibility in determining whether these data are fit for the User's intended use. The information contained in these data is dynamic and will change over time. The data are not better than the original sources from which they were derived, and both scale and accuracy may vary across the data set. These data may not have the accuracy, resolution, completeness, timeliness, or other characteristics appropriate for applications that potential users of the data may contemplate. The User is encouraged to carefully consider the content of the metadata file associated with these data. These data are neither legal documents nor land surveys, and must not be used as such. Eastern Shore Regional GIS Cooperative should be cited as the data source in any products derived from these data. Any Users wishing to modify the data should describe the types of modifications they have performed. The User should not misrepresent the data, nor imply that changes made were approved or endorsed by the Eastern Shore Regional GIS Cooperative. The Eastern Shore Regional GIS Cooperative, nor any of its employees or contractors, makes any warranty, express or implied, including warranties of merchantability and fitness for a particular purpose, or assumes any legal liability for the accuracy, completeness, or usefulness, of this information.

2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
2022

Point	2030 MSL (ft)
A	-
B	-
C	-
D	-
E	-
F	-
G	-
H	-
I	-
J	-
K	-
L	-
M	-
N	-
O	-
P	-
Q	-
R	-
S	-
T	-
U	-
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2030 Sea Level Change Projection

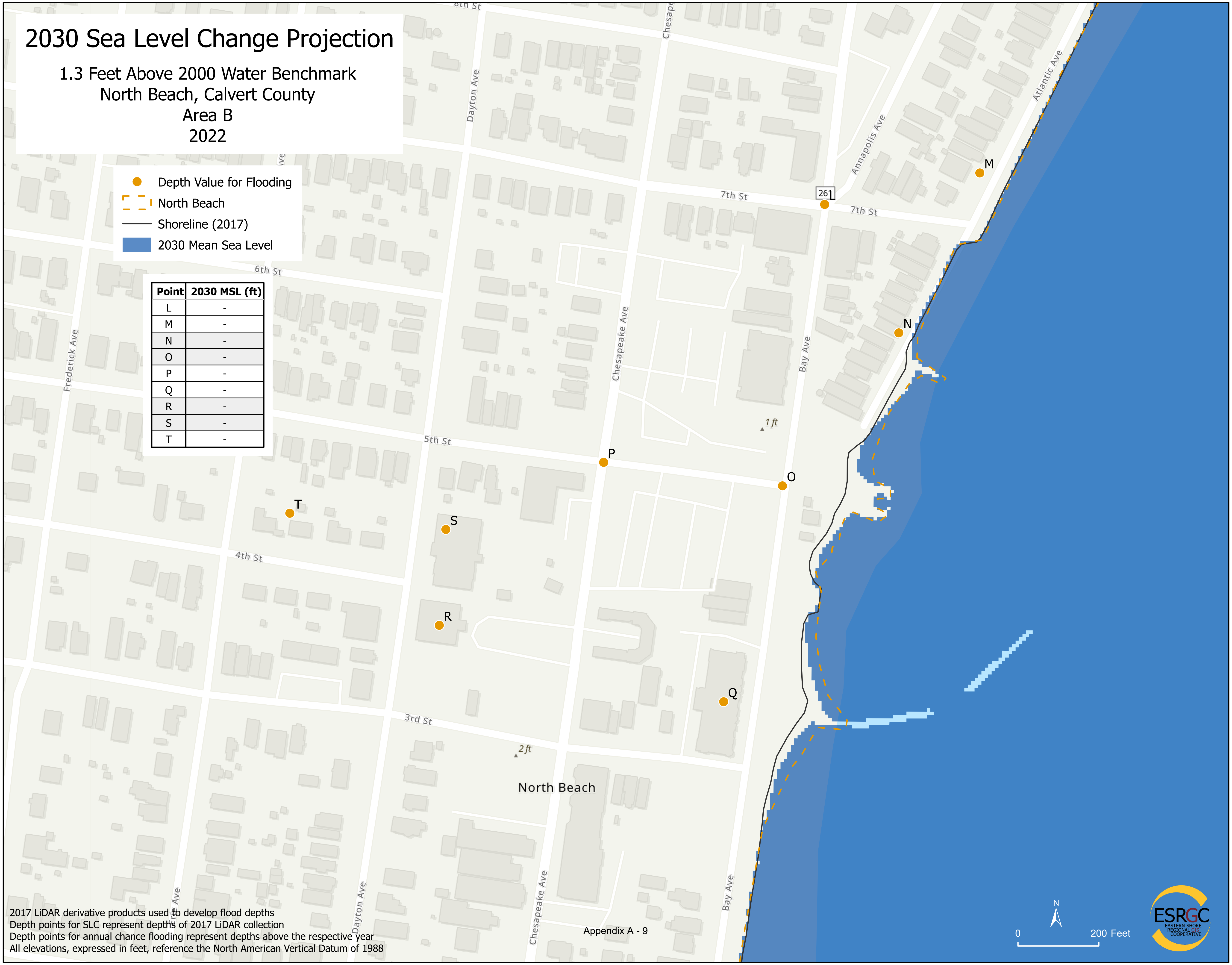
1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2030 MSL (ft)
A	-
B	-
C	-
D	-
E	-
F	-
G	-
H	-
I	-
J	-
K	-
L	-
M	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022

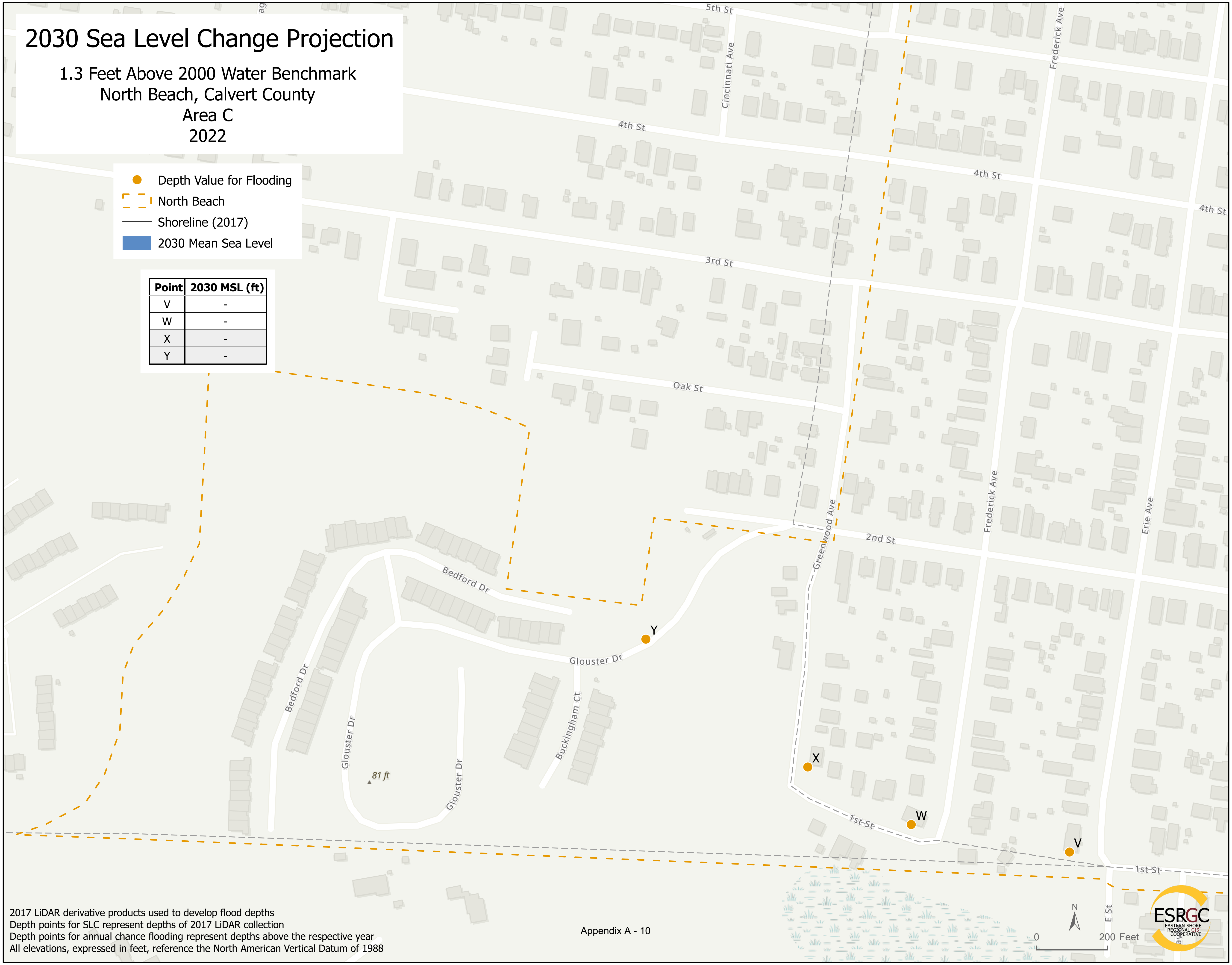


Point	2030 MSL (ft)
L	-
M	-
N	-
O	-
P	-
Q	-
R	-
S	-
T	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area C
2022

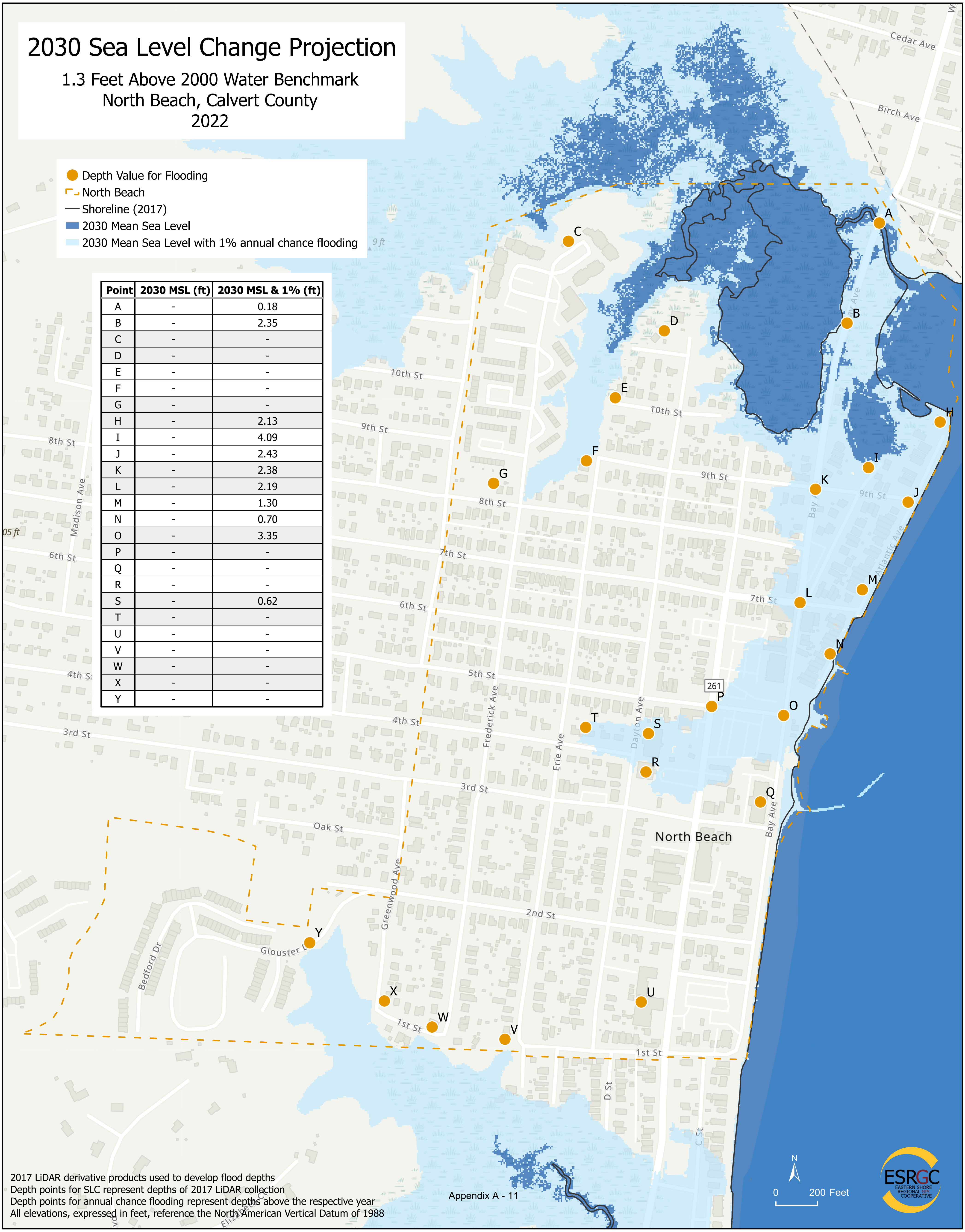


Point	2030 MSL (ft)
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

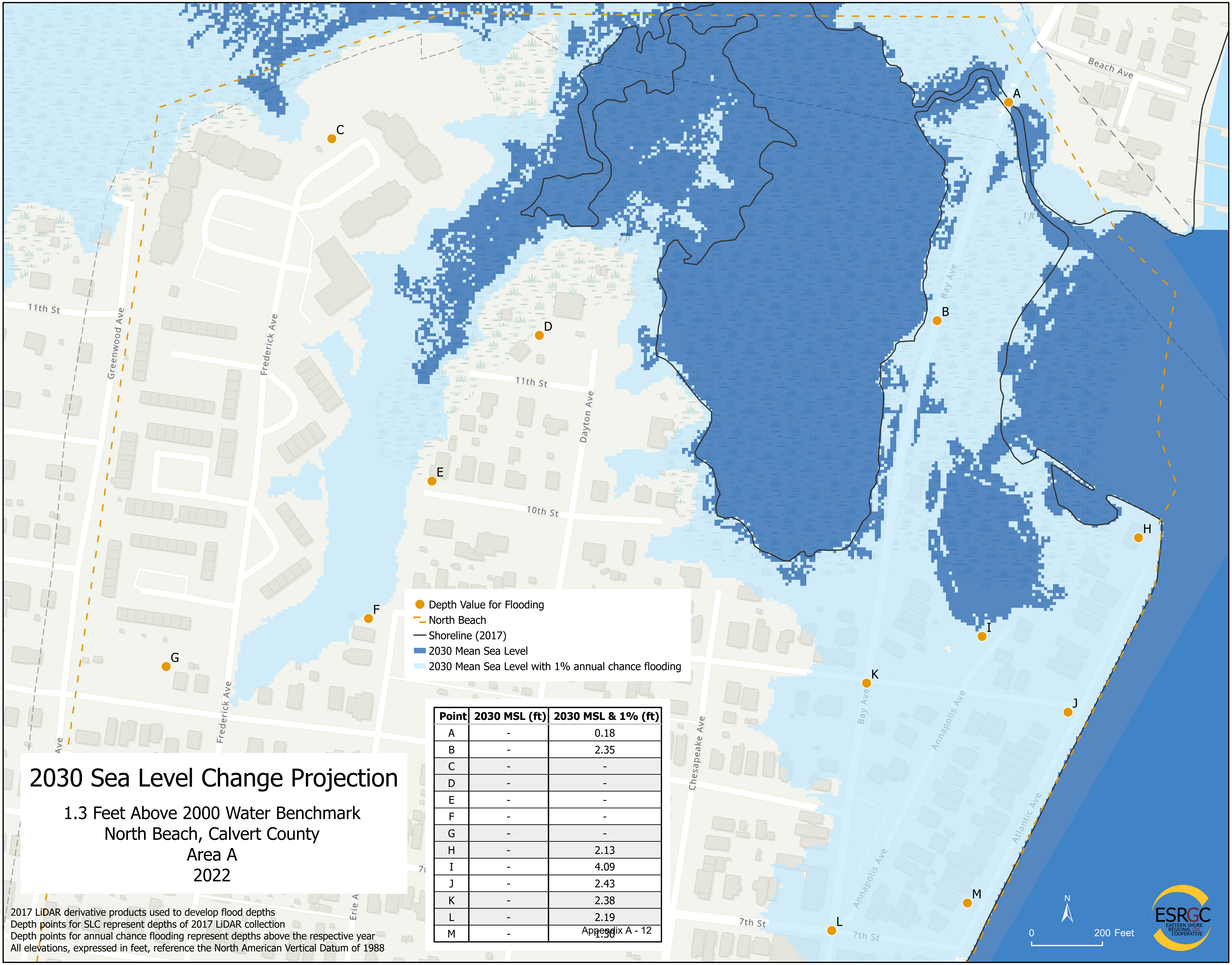
2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
2022



Point	2030 MSL (ft)	2030 MSL & 1% (ft)
A	-	0.18
B	-	2.35
C	-	-
D	-	-
E	-	-
F	-	-
G	-	-
H	-	2.13
I	-	4.09
J	-	2.43
K	-	2.38
L	-	2.19
M	-	1.30
N	-	0.70
O	-	3.35
P	-	-
Q	-	-
R	-	-
S	-	0.62
T	-	-
U	-	-
V	-	-
W	-	-
X	-	-
Y	-	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2030 Sea Level Change Projection

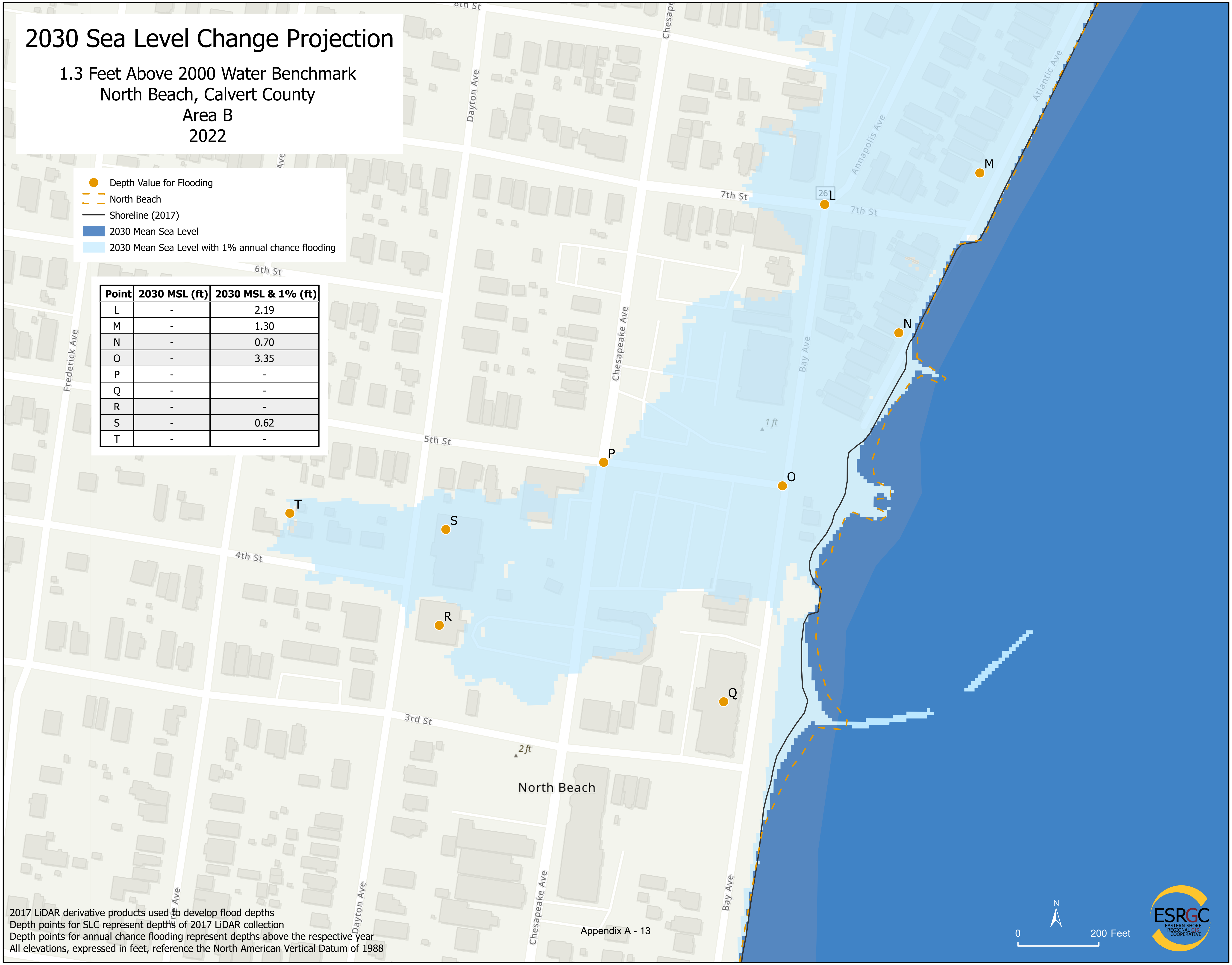
1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2030 MSL (ft)	2030 MSL & 1% (ft)
A	-	0.18
B	-	2.35
C	-	-
D	-	-
E	-	-
F	-	-
G	-	-
H	-	2.13
I	-	4.09
J	-	2.43
K	-	2.38
L	-	2.19
M	-	1.30

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022



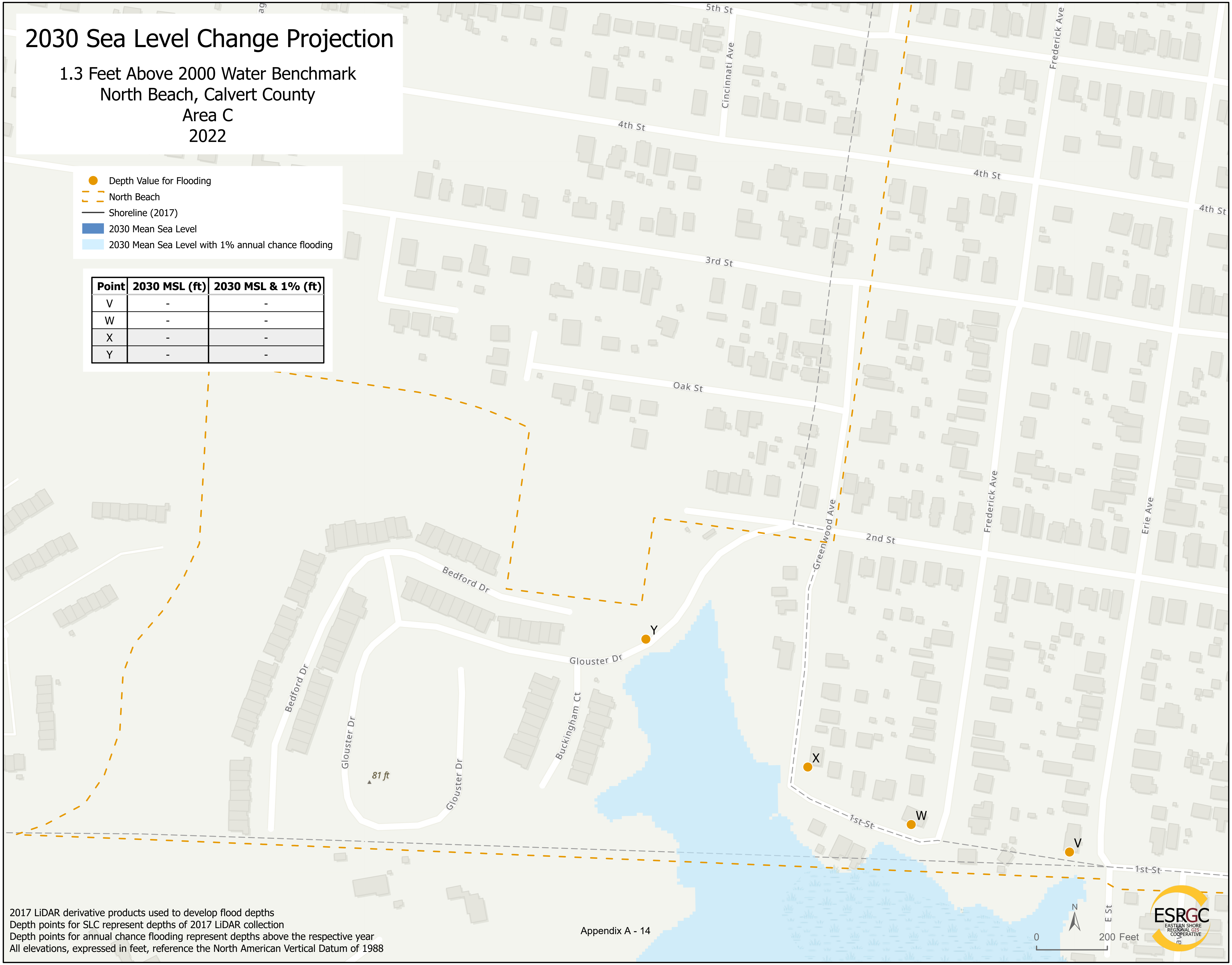
Point	2030 MSL (ft)	2030 MSL & 1% (ft)
L	-	2.19
M	-	1.30
N	-	0.70
O	-	3.35
P	-	-
Q	-	-
R	-	-
S	-	0.62
T	-	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2030 Sea Level Change Projection

1.3 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area C
2022

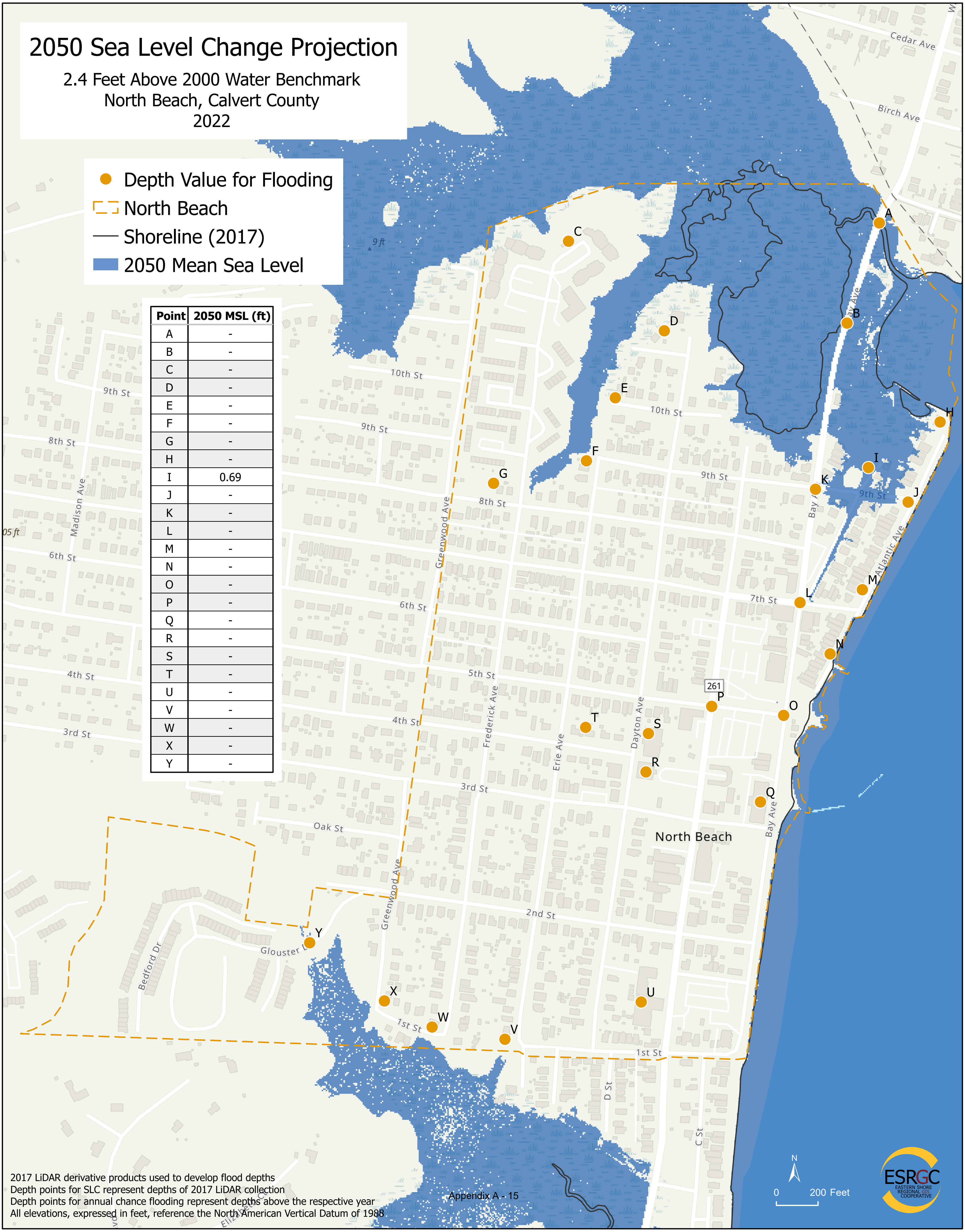
Point	2030 MSL (ft)	2030 MSL & 1% (ft)
V	-	-
W	-	-
X	-	-
Y	-	-



2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

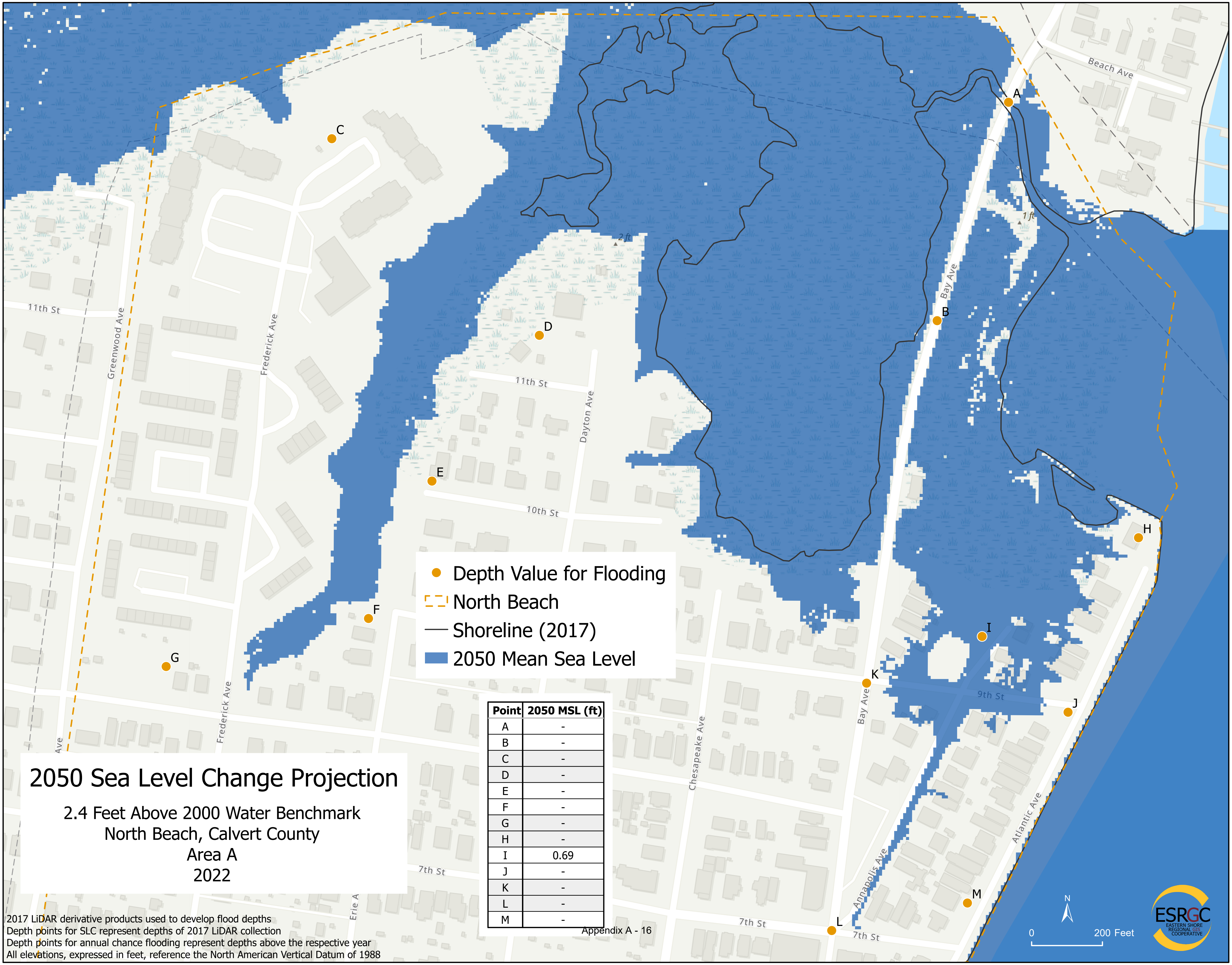
2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
2022



Point	2050 MSL (ft)
A	-
B	-
C	-
D	-
E	-
F	-
G	-
H	-
I	0.69
J	-
K	-
L	-
M	-
N	-
O	-
P	-
Q	-
R	-
S	-
T	-
U	-
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2050 Sea Level Change Projection

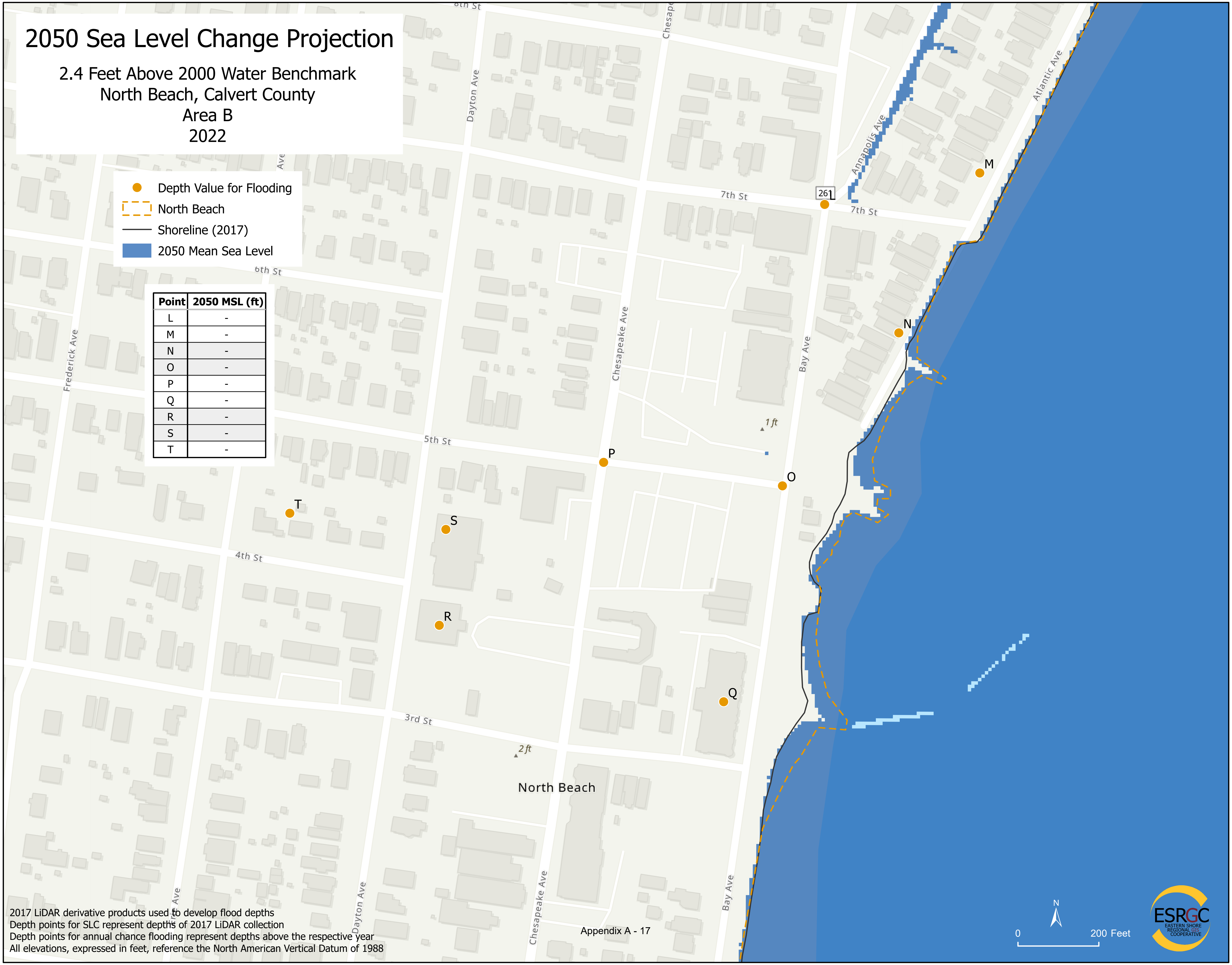
2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2050 MSL (ft)
A	-
B	-
C	-
D	-
E	-
F	-
G	-
H	-
I	0.69
J	-
K	-
L	-
M	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022

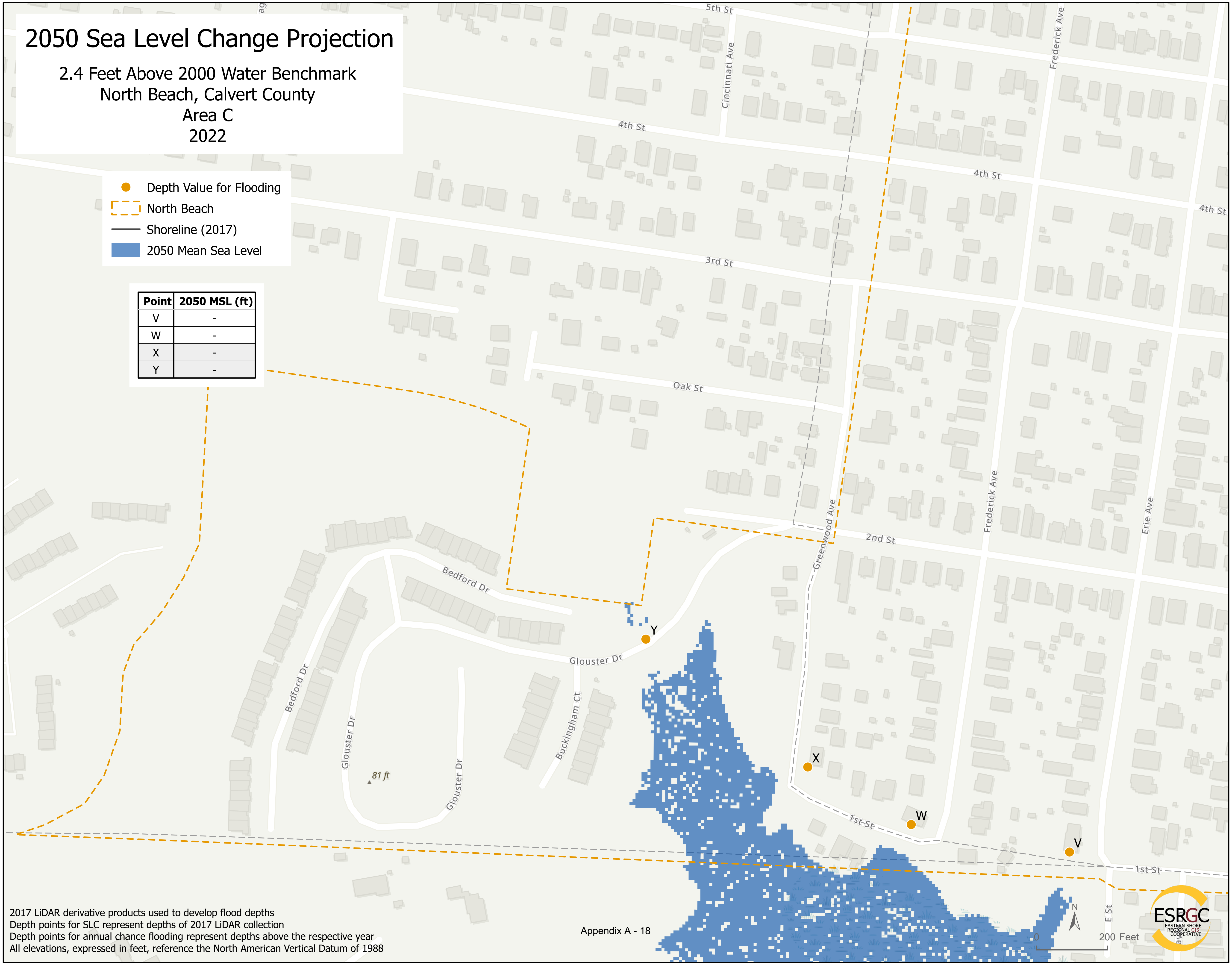


Point	2050 MSL (ft)
L	-
M	-
N	-
O	-
P	-
Q	-
R	-
S	-
T	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area C
2022



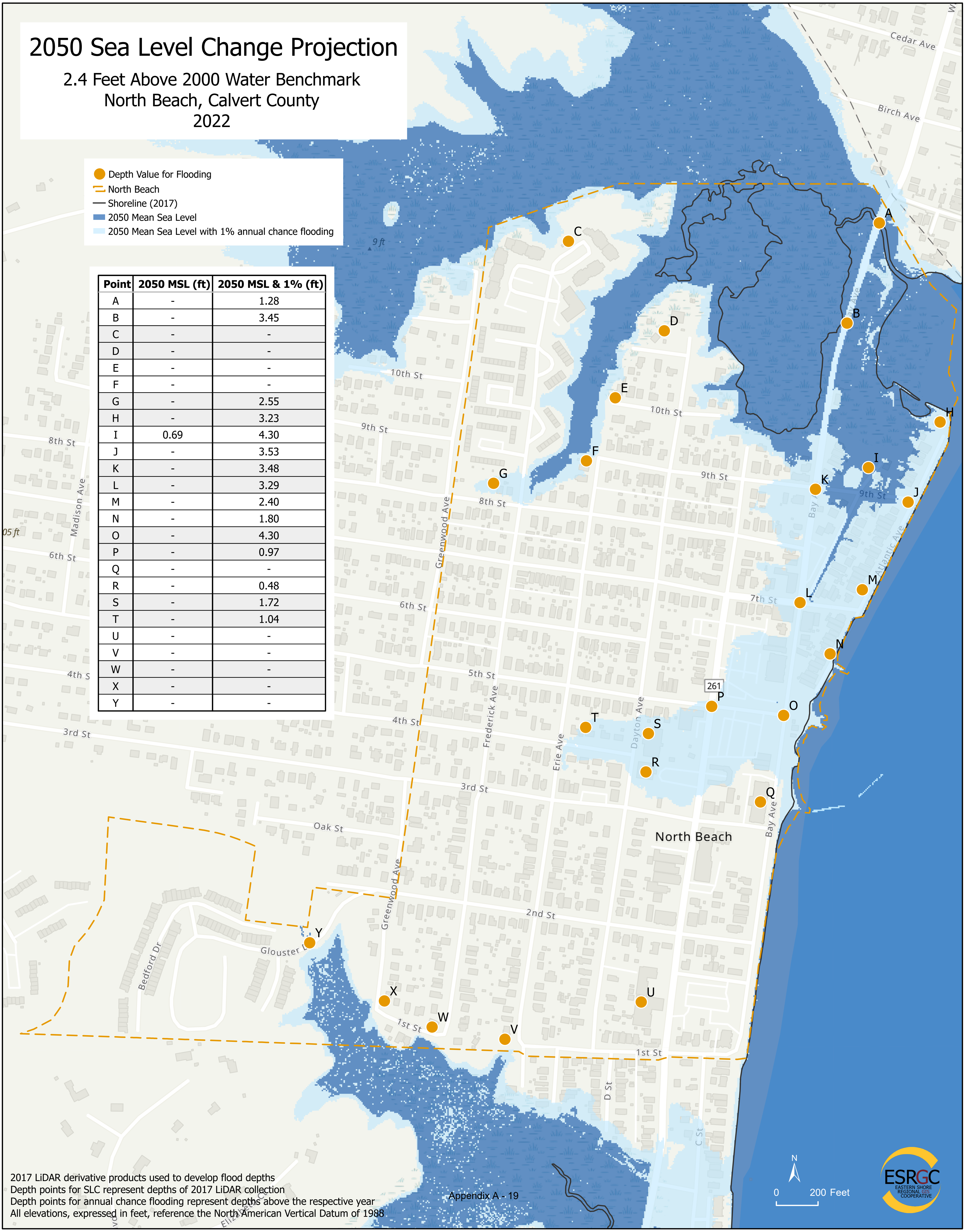
- Depth Value for Flooding
- North Beach
- Shoreline (2017)
- 2050 Mean Sea Level

Point	2050 MSL (ft)
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

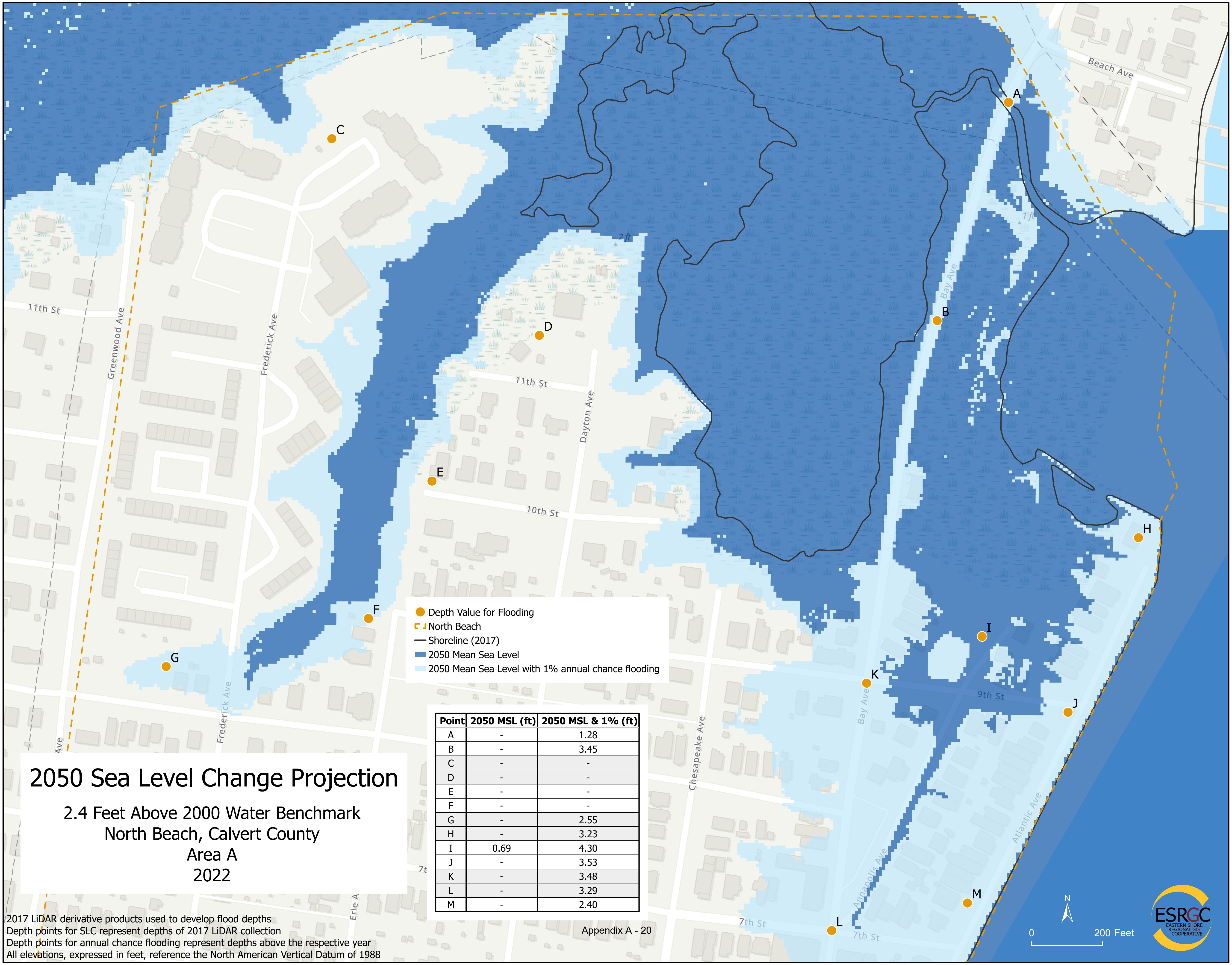
2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
2022



Point	2050 MSL (ft)	2050 MSL & 1% (ft)
A	-	1.28
B	-	3.45
C	-	-
D	-	-
E	-	-
F	-	-
G	-	2.55
H	-	3.23
I	0.69	4.30
J	-	3.53
K	-	3.48
L	-	3.29
M	-	2.40
N	-	1.80
O	-	4.30
P	-	0.97
Q	-	-
R	-	0.48
S	-	1.72
T	-	1.04
U	-	-
V	-	-
W	-	-
X	-	-
Y	-	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2050 Sea Level Change Projection

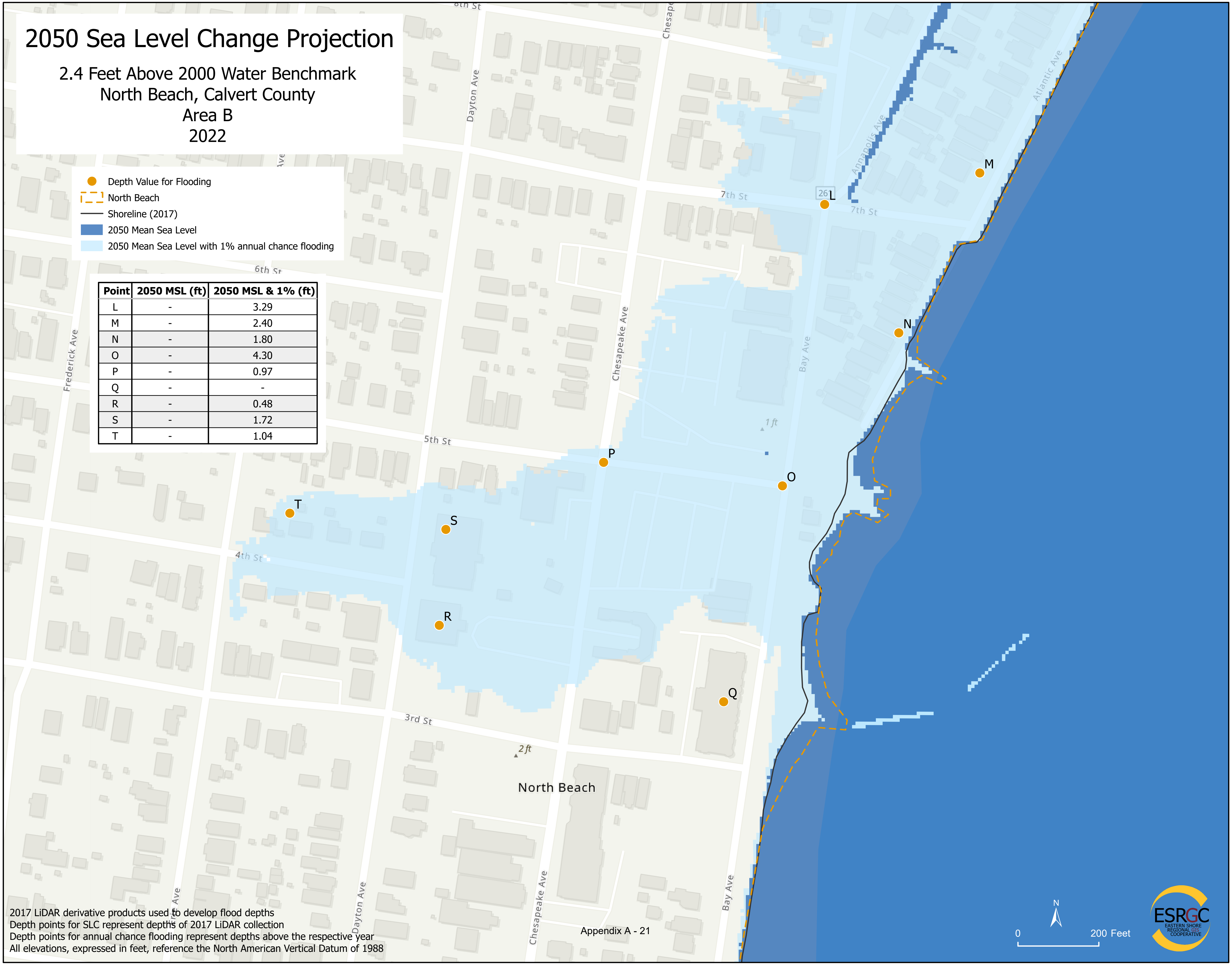
2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2050 MSL (ft)	2050 MSL & 1% (ft)
A	-	1.28
B	-	3.45
C	-	-
D	-	-
E	-	-
F	-	-
G	-	2.55
H	-	3.23
I	0.69	4.30
J	-	3.53
K	-	3.48
L	-	3.29
M	-	2.40

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022



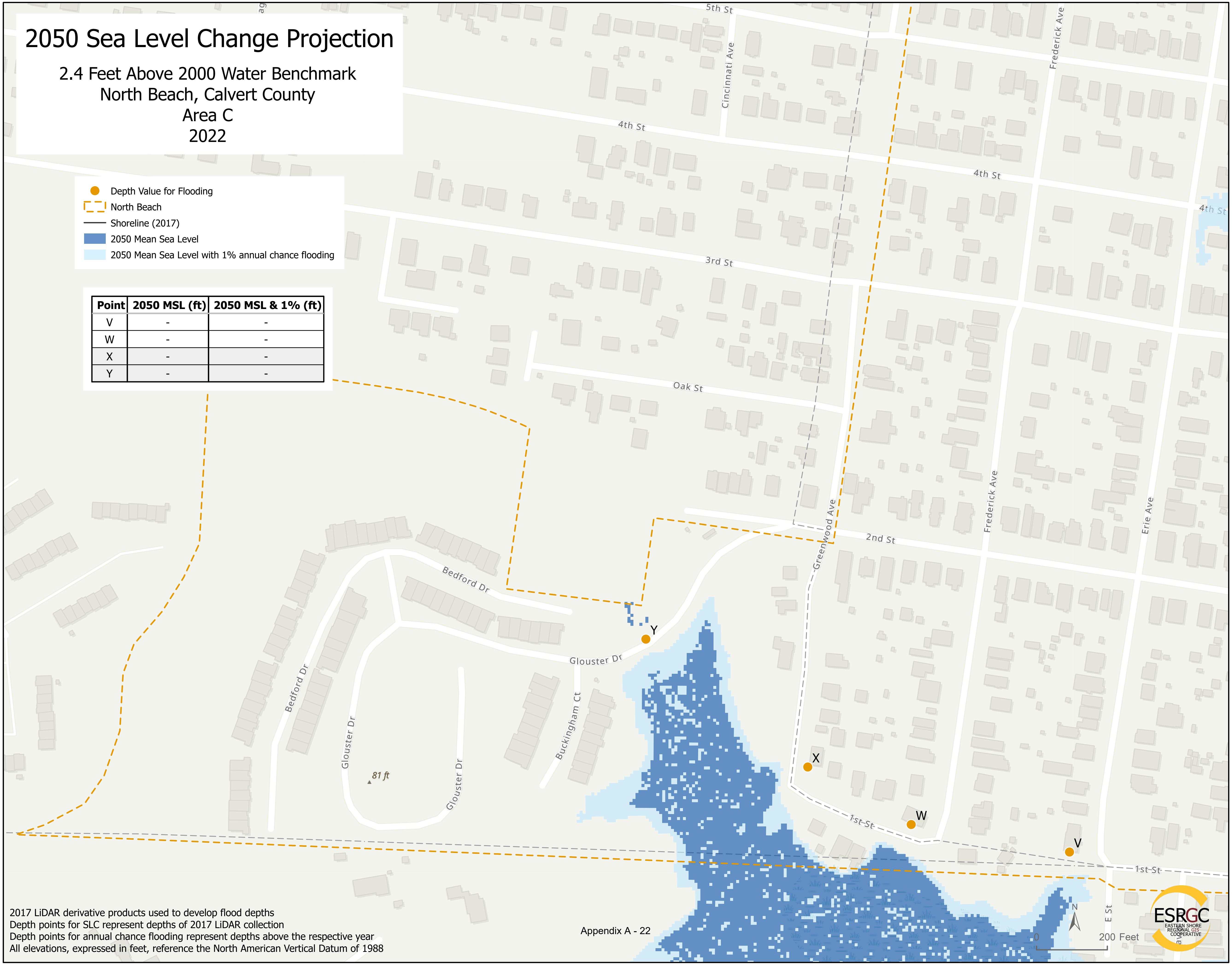
Point	2050 MSL (ft)	2050 MSL & 1% (ft)
L	-	3.29
M	-	2.40
N	-	1.80
O	-	4.30
P	-	0.97
Q	-	-
R	-	0.48
S	-	1.72
T	-	1.04

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2050 Sea Level Change Projection

2.4 Feet Above 2000 Water Benchmark
North Beach, Calvert County
Area C
2022

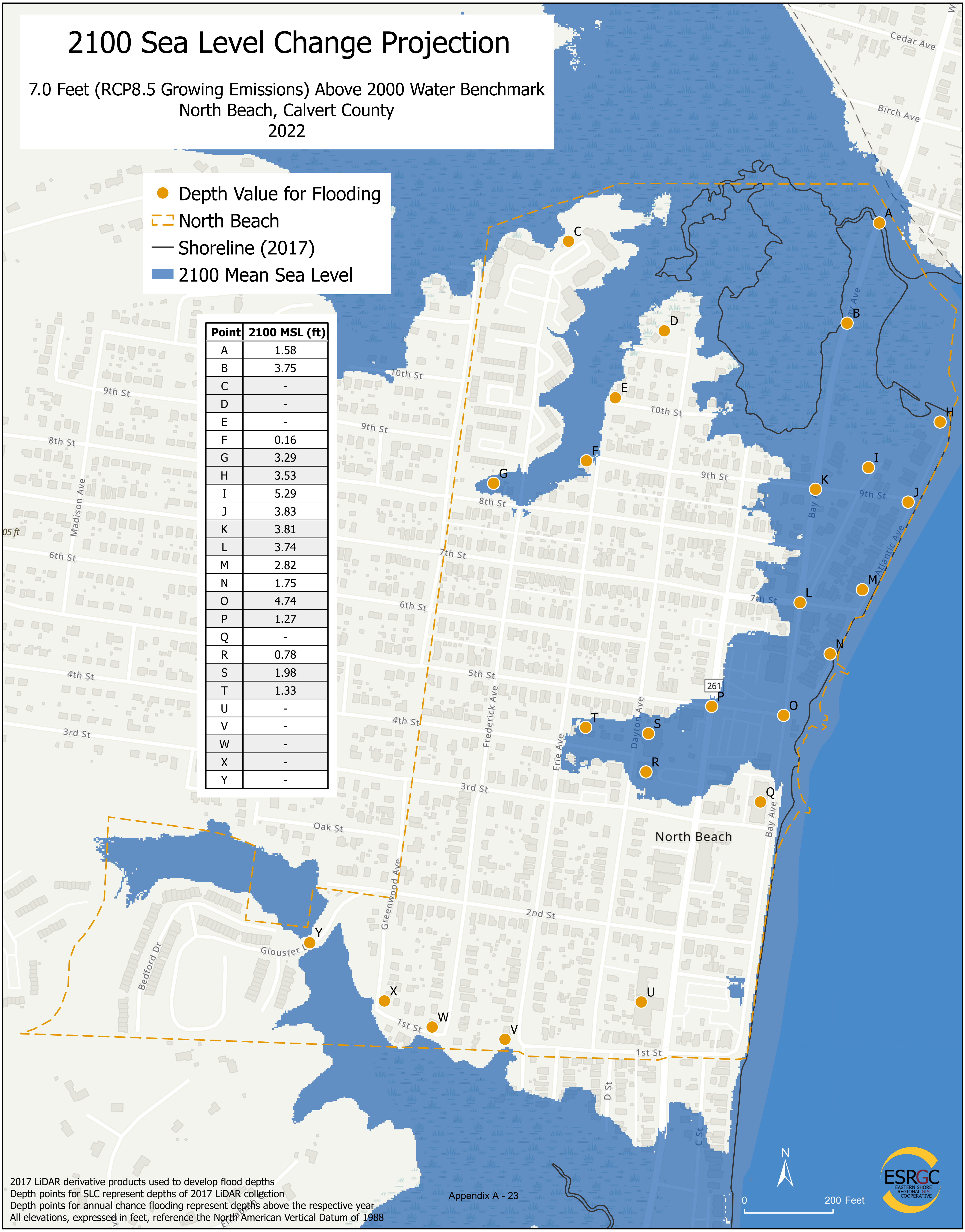
Point	2050 MSL (ft)	2050 MSL & 1% (ft)
V	-	-
W	-	-
X	-	-
Y	-	-



2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

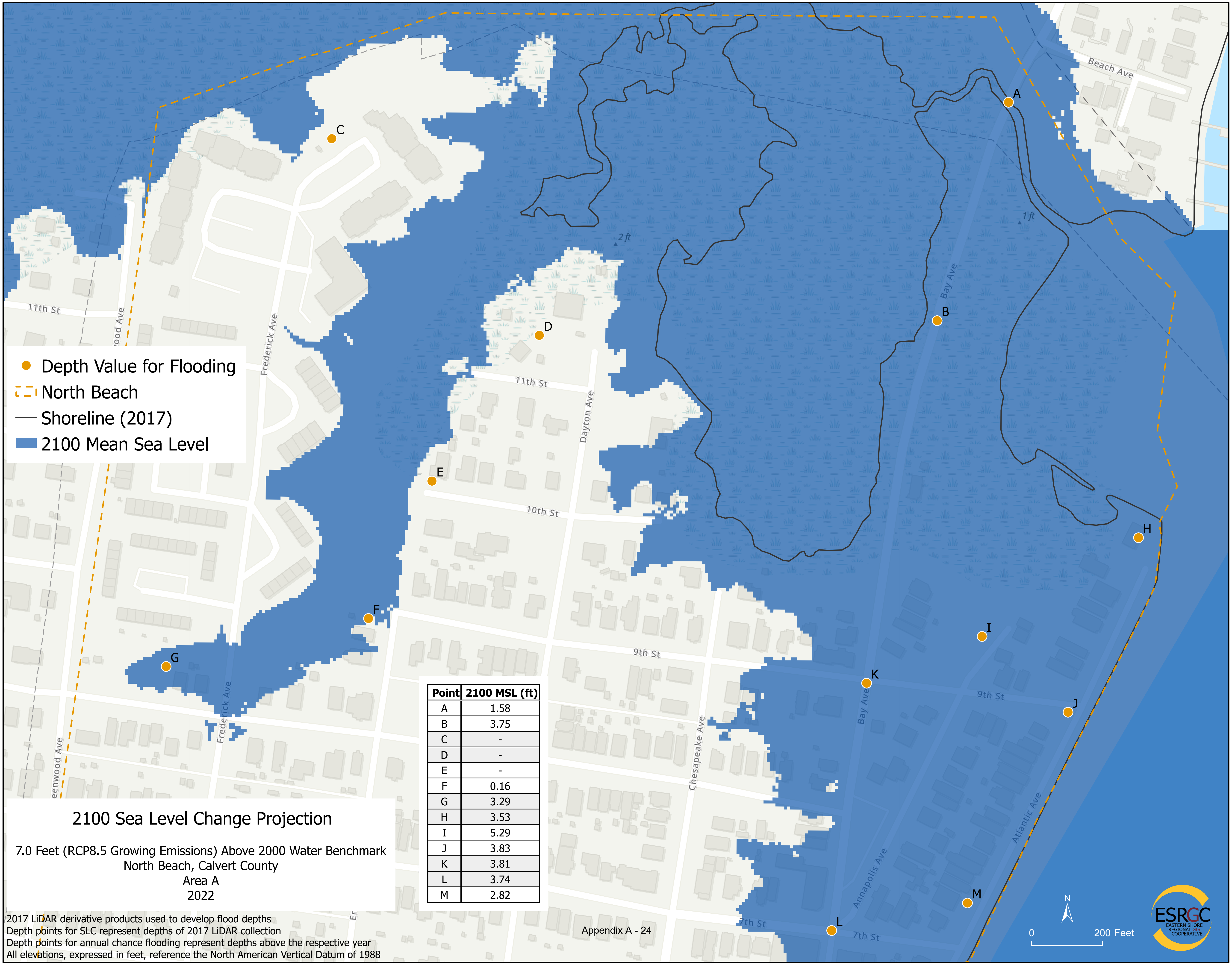
2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
2022



Point	2100 MSL (ft)
A	1.58
B	3.75
C	-
D	-
E	-
F	0.16
G	3.29
H	3.53
I	5.29
J	3.83
K	3.81
L	3.74
M	2.82
N	1.75
O	4.74
P	1.27
Q	-
R	0.78
S	1.98
T	1.33
U	-
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2100 Sea Level Change Projection

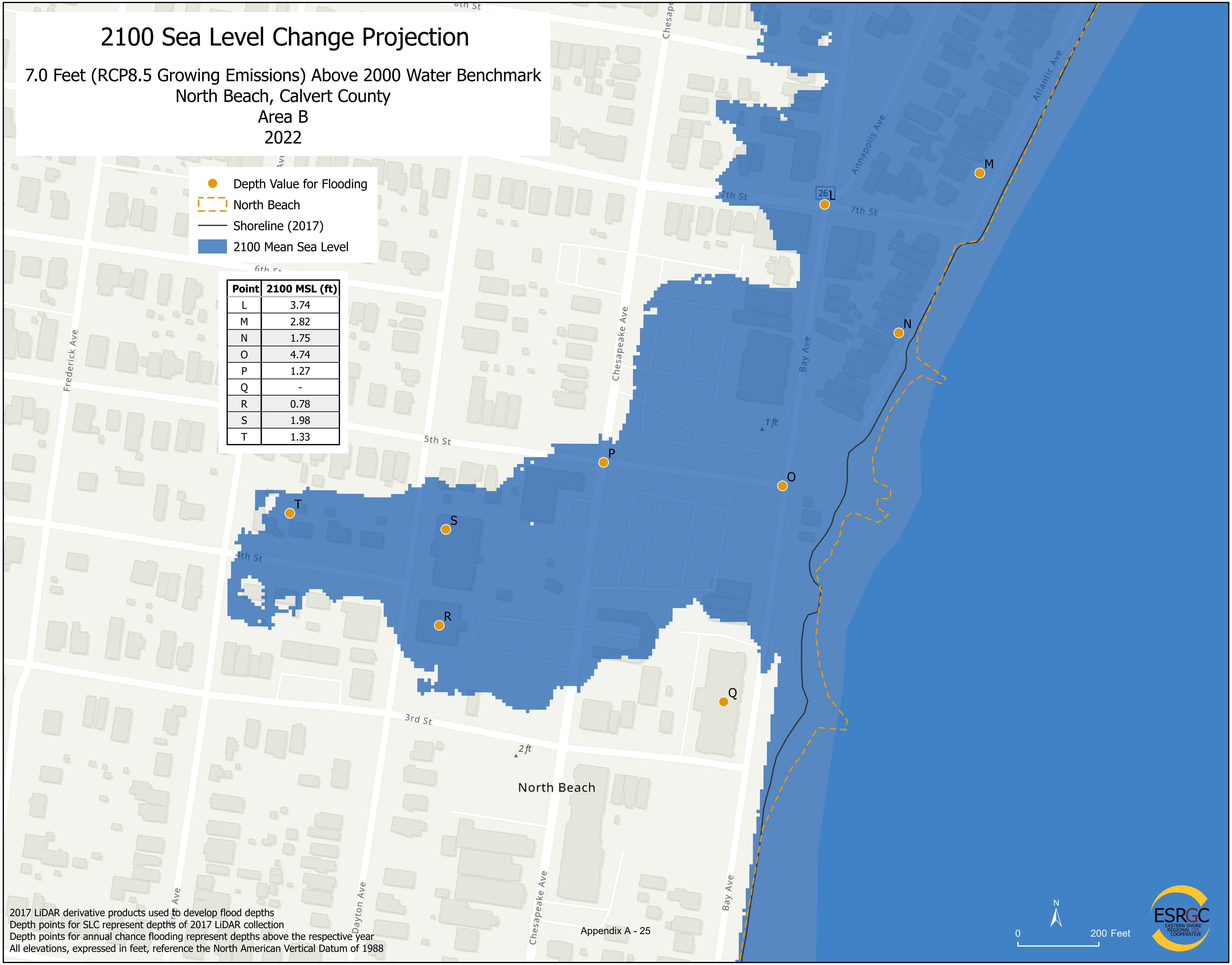
7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2100 MSL (ft)
A	1.58
B	3.75
C	-
D	-
E	-
F	0.16
G	3.29
H	3.53
I	5.29
J	3.83
K	3.81
L	3.74
M	2.82

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022

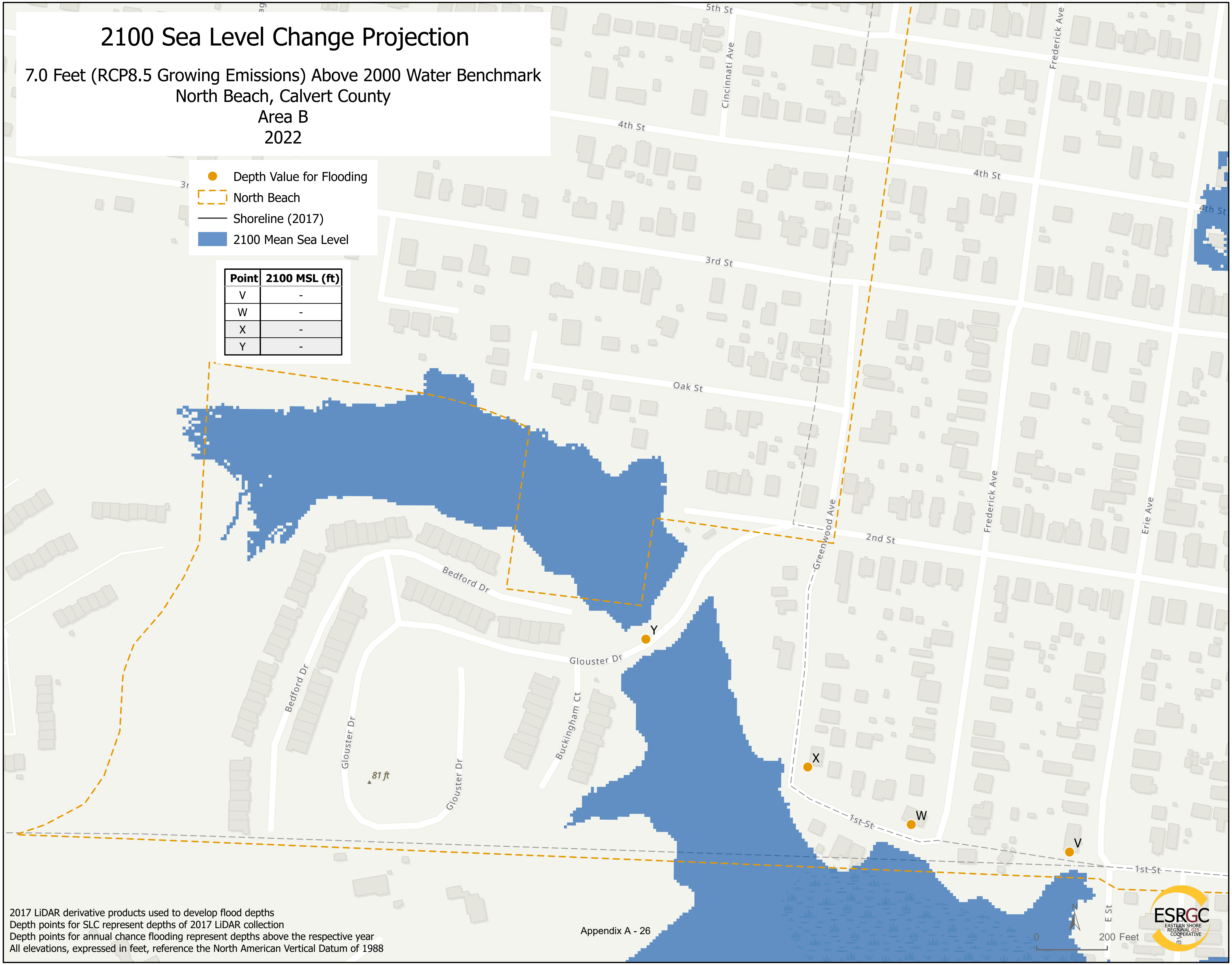


Point	2100 MSL (ft)
L	3.74
M	2.82
N	1.75
O	4.74
P	1.27
Q	-
R	0.78
S	1.98
T	1.33

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022

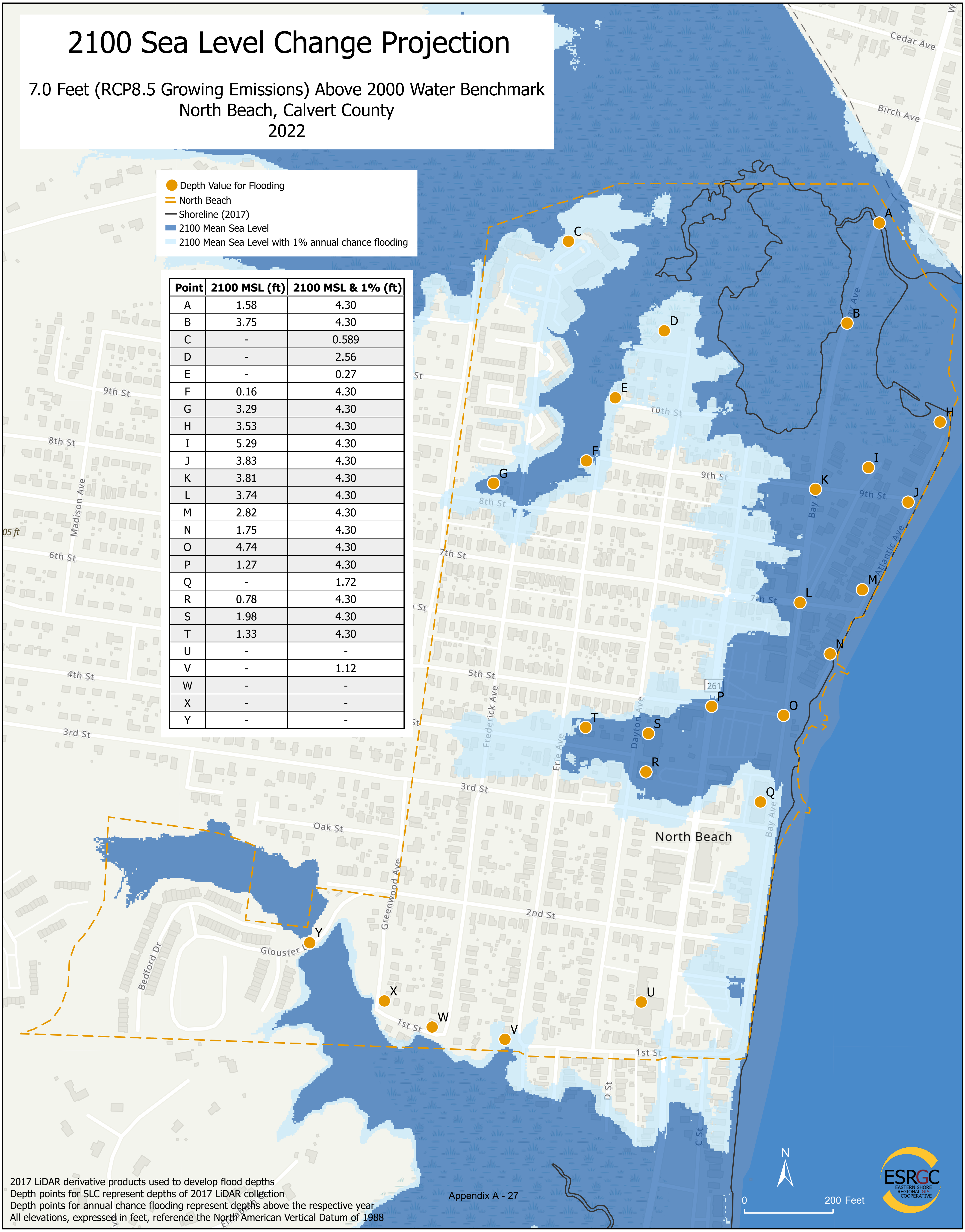


Point	2100 MSL (ft)
V	-
W	-
X	-
Y	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

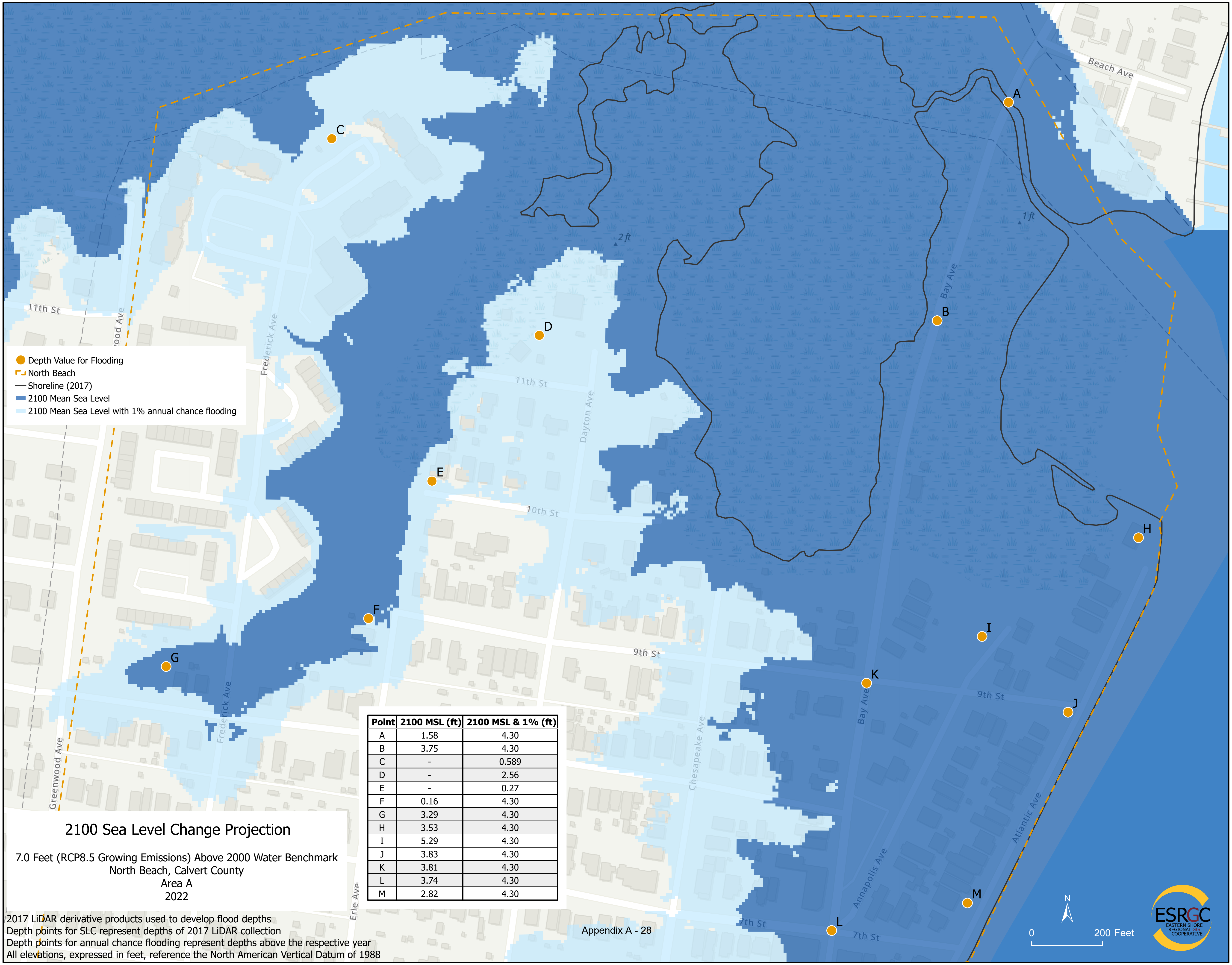
2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
2022



Point	2100 MSL (ft)	2100 MSL & 1% (ft)
A	1.58	4.30
B	3.75	4.30
C	-	0.589
D	-	2.56
E	-	0.27
F	0.16	4.30
G	3.29	4.30
H	3.53	4.30
I	5.29	4.30
J	3.83	4.30
K	3.81	4.30
L	3.74	4.30
M	2.82	4.30
N	1.75	4.30
O	4.74	4.30
P	1.27	4.30
Q	-	1.72
R	0.78	4.30
S	1.98	4.30
T	1.33	4.30
U	-	-
V	-	1.12
W	-	-
X	-	-
Y	-	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988



2100 Sea Level Change Projection

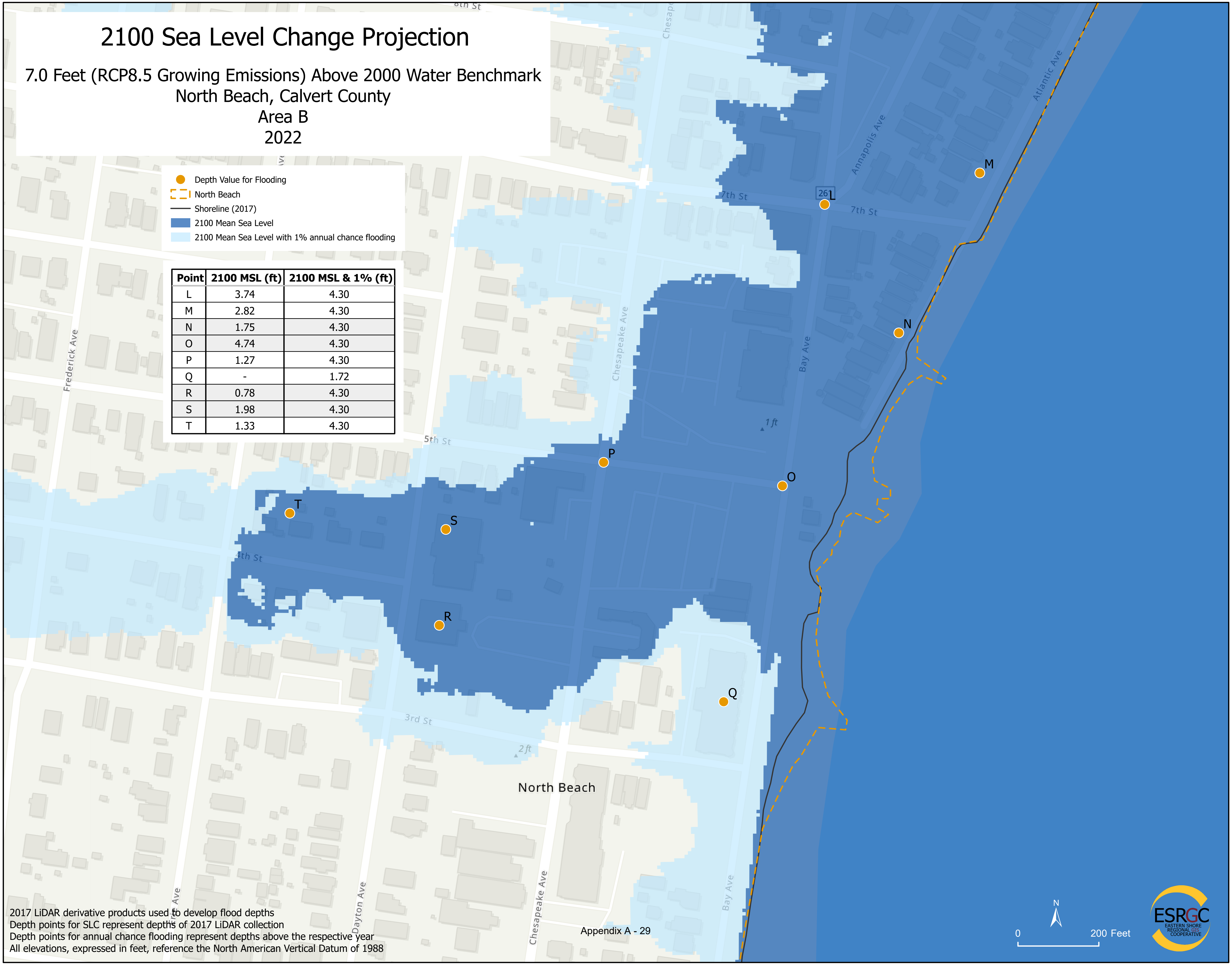
7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area A
2022

Point	2100 MSL (ft)	2100 MSL & 1% (ft)
A	1.58	4.30
B	3.75	4.30
C	-	0.589
D	-	2.56
E	-	0.27
F	0.16	4.30
G	3.29	4.30
H	3.53	4.30
I	5.29	4.30
J	3.83	4.30
K	3.81	4.30
L	3.74	4.30
M	2.82	4.30

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022

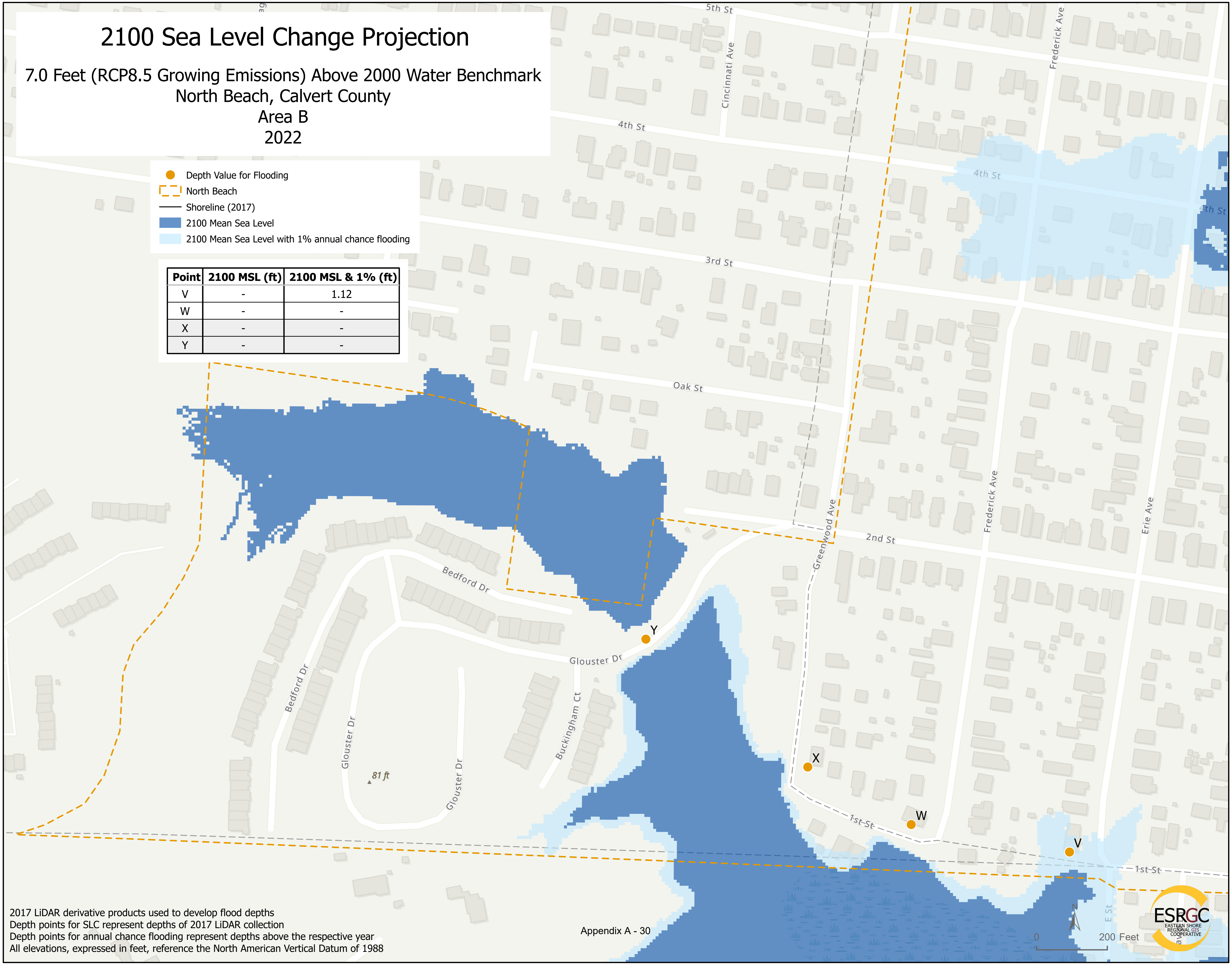


Point	2100 MSL (ft)	2100 MSL & 1% (ft)
L	3.74	4.30
M	2.82	4.30
N	1.75	4.30
O	4.74	4.30
P	1.27	4.30
Q	-	1.72
R	0.78	4.30
S	1.98	4.30
T	1.33	4.30

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

2100 Sea Level Change Projection

7.0 Feet (RCP8.5 Growing Emissions) Above 2000 Water Benchmark
North Beach, Calvert County
Area B
2022



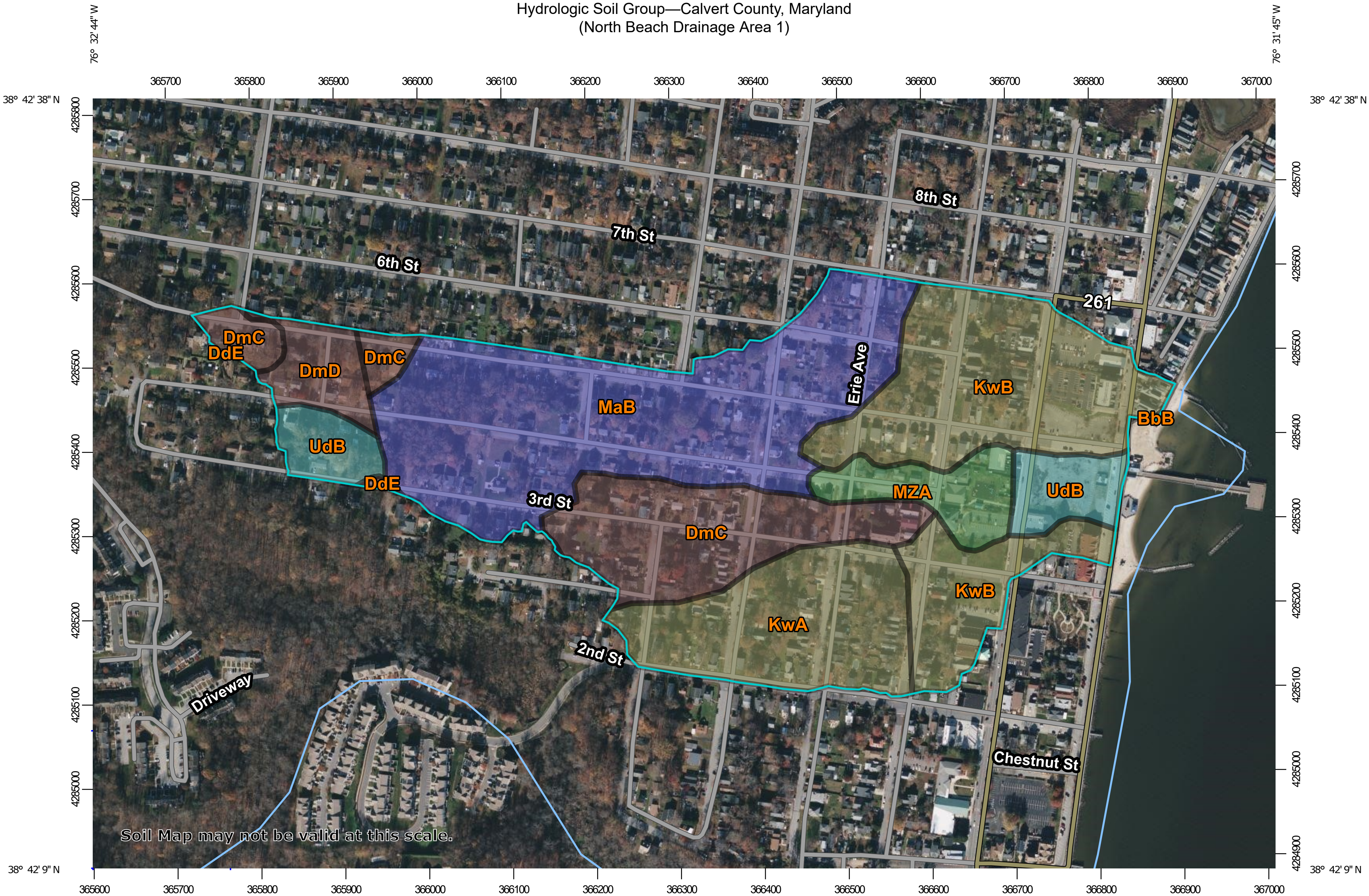
Point	2100 MSL (ft)	2100 MSL & 1% (ft)
V	-	1.12
W	-	-
X	-	-
Y	-	-

2017 LiDAR derivative products used to develop flood depths
Depth points for SLC represent depths of 2017 LiDAR collection
Depth points for annual chance flooding represent depths above the respective year
All elevations, expressed in feet, reference the North American Vertical Datum of 1988

Appendix B

Hydrologic Analysis

Hydrologic Soil Group—Calvert County, Maryland
(North Beach Drainage Area 1)



Map Scale: 1:6,440 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 50, 100, 200, 300

Feet: 0, 300, 600, 1200, 1800

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Calvert County, Maryland
Survey Area Data: Version 19, Aug 26, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Nov 23, 2020—Nov 28, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BbB	Beaches-Brockatonorton complex, 0 to 5 percent slopes	B	0.0	0.0%
DdE	Dodon and Marr soils, 15 to 25 percent slopes	B/D	0.1	0.2%
DmC	Dodon-Marr complex, 5 to 10 percent slopes	B/D	12.4	15.0%
DmD	Dodon-Marr complex, 10 to 15 percent slopes	B/D	2.9	3.5%
KwA	Keyport silt loam, wet subsoil, 0 to 2 percent slopes	C/D	11.4	13.7%
KwB	Keyport silt loam, wet subsoil, 2 to 5 percent slopes	C/D	20.5	24.7%
MaB	Marr-Dodon complex, 2 to 5 percent slopes	B	26.6	32.0%
MZA	Mispillion and Transquaking soils, 0 to 1 percent slopes, tidally flooded	A/D	3.9	4.7%
UdB	Udorthents, loamy, 0 to 5 percent slopes	C	5.1	6.2%
Totals for Area of Interest			**82.9**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Hydrologic Soil Group—Calvert County, Maryland
(North Beach Drainage Area 2)

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

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Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Calvert County, Maryland
Survey Area Data: Version 19, Aug 26, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Nov 23, 2020—Nov 28, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
KwB	Keyport silt loam, wet subsoil, 2 to 5 percent slopes	C/D	8.0	84.4%
MaB	Marr-Dodon complex, 2 to 5 percent slopes	B	1.5	15.6%
Totals for Area of Interest			**9.5**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

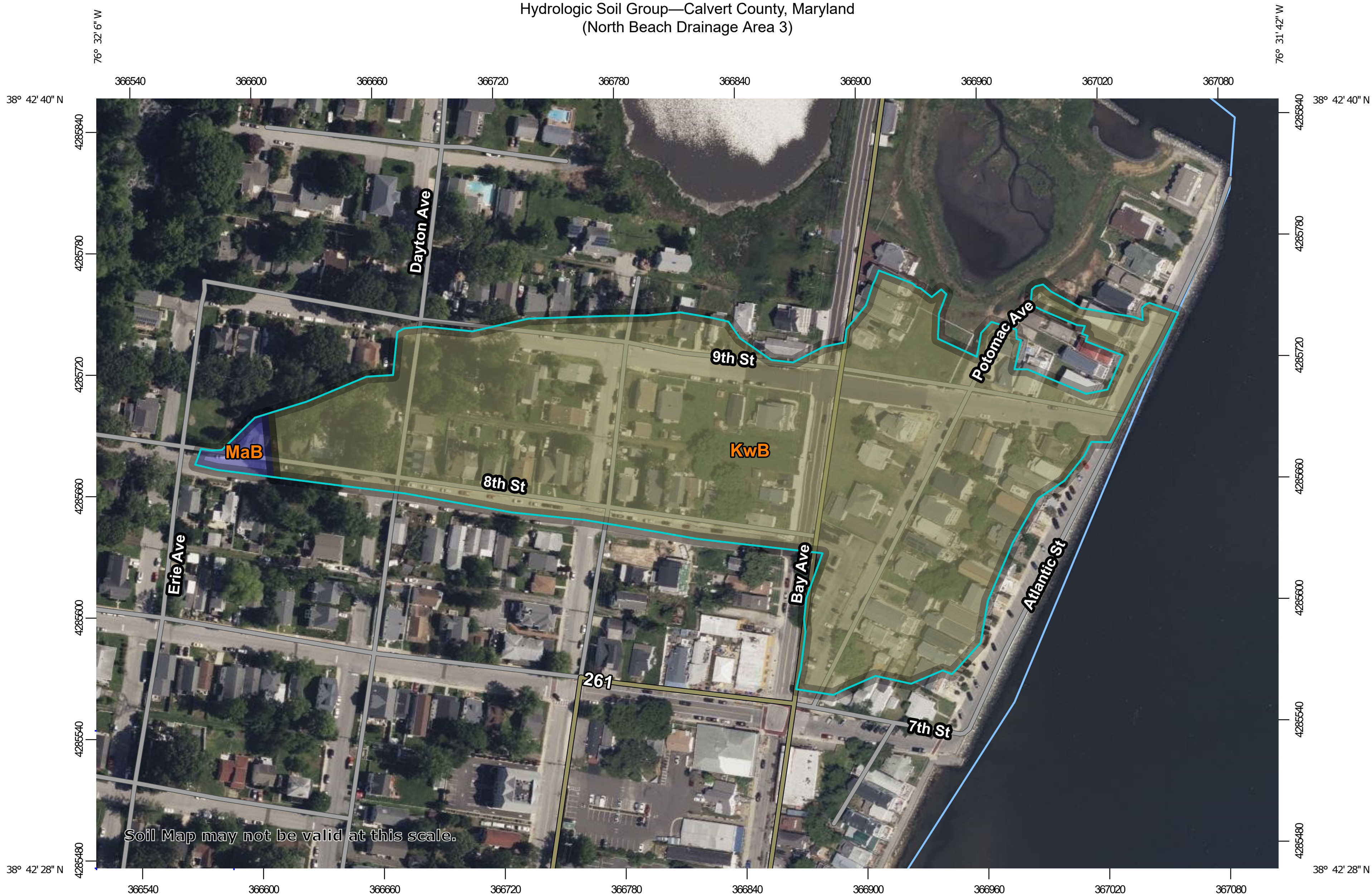
Rating Options

Aggregation Method: Dominant Condition

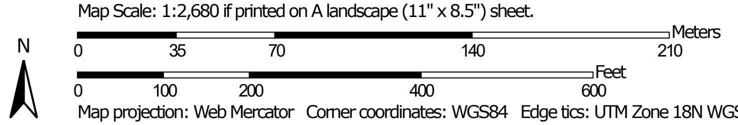
Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Hydrologic Soil Group—Calvert County, Maryland
(North Beach Drainage Area 3)



Map Scale: 1:2,680 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Calvert County, Maryland
Survey Area Data: Version 20, Sep 14, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 29, 2022—May 31, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
KwB	Keyport silt loam, wet subsoil, 2 to 5 percent slopes	C/D	11.0	98.5%
MaB	Marr-Dodon complex, 2 to 5 percent slopes	B	0.2	1.5%
Totals for Area of Interest			**11.1**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

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Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

NORTH BEACH
LAND USE MATRIX

NORTH BEACH LAND USE MATRIX

DRAINAGE AREA	**1**				
TOTAL DA (ACRES)	82.94				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	2.55	2.55
IMPERVIOUS	0.00	3.94	2.70	12.57	19.21
1/8 ACRE LOT	0.00	20.31	2.09	36.05	58.45
WOODS	0.00	2.35	0.31	0.07	2.73

SOIL AREAS	A	B	C	D	TOTAL
	0.00	26.60	5.10	51.24	82.94

DRAINAGE AREA	**2**				
TOTAL DA (ACRES)	9.45				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.22	0.22
IMPERVIOUS	0.00	0.38	0.00	1.79	2.17
1/8 ACRE LOT	0.00	1.07	0.00	5.99	7.06
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	1.45	0.00	8.00	9.45

DRAINAGE AREA	**3**				
TOTAL DA (ACRES)	10.68				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.28	0.28
IMPERVIOUS	0.00	0.06	0.00	2.62	2.68
1/8 ACRE LOT	0.00	0.12	0.00	7.60	7.72
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.18	0.00	10.50	10.68

BayLand Consultants & Designers, Inc.
7455 New Ridge Road, Suite T
Hanover MD 21076
P: 410-694-9401

NOAA Atlas 14, Volume 2, Version 3
Location name: North Beach, Maryland, USA*
Latitude: 38.706°, Longitude: -76.5329°
Elevation: 6.33 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.352 (0.319-0.389)	0.422 (0.382-0.465)	0.502 (0.454-0.554)	0.560 (0.506-0.618)	0.634 (0.569-0.700)	0.688 (0.614-0.761)	0.742 (0.659-0.822)	0.793 (0.700-0.883)	0.857 (0.748-0.961)	0.906 (0.785-1.02)
10-min	0.563 (0.510-0.621)	0.675 (0.611-0.744)	0.804 (0.727-0.887)	0.896 (0.809-0.988)	1.01 (0.906-1.12)	1.10 (0.978-1.21)	1.18 (1.05-1.31)	1.26 (1.11-1.40)	1.36 (1.18-1.52)	1.43 (1.24-1.61)
15-min	0.704 (0.638-0.776)	0.848 (0.769-0.935)	1.02 (0.920-1.12)	1.13 (1.02-1.25)	1.28 (1.15-1.41)	1.39 (1.24-1.53)	1.49 (1.32-1.65)	1.59 (1.40-1.77)	1.71 (1.49-1.91)	1.79 (1.55-2.02)
30-min	0.965 (0.874-1.06)	1.17 (1.06-1.29)	1.45 (1.31-1.59)	1.64 (1.48-1.81)	1.90 (1.70-2.10)	2.09 (1.87-2.31)	2.28 (2.03-2.53)	2.47 (2.18-2.75)	2.71 (2.37-3.04)	2.90 (2.51-3.27)
60-min	1.20 (1.09-1.33)	1.47 (1.33-1.62)	1.85 (1.68-2.04)	2.14 (1.93-2.36)	2.53 (2.27-2.79)	2.83 (2.53-3.13)	3.14 (2.79-3.49)	3.46 (3.06-3.86)	3.89 (3.40-4.37)	4.24 (3.67-4.78)
2-hr	1.43 (1.29-1.58)	1.74 (1.57-1.92)	2.20 (1.99-2.42)	2.56 (2.30-2.82)	3.06 (2.74-3.37)	3.47 (3.09-3.82)	3.89 (3.45-4.31)	4.34 (3.81-4.81)	4.97 (4.31-5.55)	5.47 (4.70-6.15)
3-hr	1.54 (1.40-1.71)	1.88 (1.70-2.07)	2.38 (2.15-2.63)	2.78 (2.50-3.07)	3.34 (2.98-3.69)	3.81 (3.38-4.21)	4.30 (3.79-4.77)	4.83 (4.21-5.37)	5.57 (4.79-6.23)	6.18 (5.25-6.96)
6-hr	1.90 (1.73-2.11)	2.30 (2.09-2.55)	2.91 (2.63-3.22)	3.41 (3.07-3.78)	4.15 (3.70-4.59)	4.78 (4.22-5.29)	5.46 (4.78-6.07)	6.19 (5.36-6.91)	7.28 (6.19-8.19)	8.19 (6.86-9.28)
12-hr	2.29 (2.06-2.58)	2.77 (2.48-3.12)	3.52 (3.15-3.96)	4.17 (3.71-4.69)	5.16 (4.54-5.79)	6.03 (5.25-6.77)	6.99 (6.01-7.87)	8.07 (6.83-9.12)	9.71 (8.04-11.0)	11.1 (9.05-12.7)
24-hr	2.65 (2.40-2.96)	3.22 (2.92-3.59)	4.17 (3.79-4.66)	5.00 (4.52-5.57)	6.27 (5.62-6.94)	7.38 (6.57-8.14)	8.63 (7.61-9.48)	10.0 (8.77-11.0)	12.2 (10.5-13.3)	14.1 (12.0-15.4)
2-day	3.06 (2.78-3.41)	3.72 (3.38-4.14)	4.82 (4.37-5.37)	5.77 (5.20-6.40)	7.19 (6.45-7.96)	8.44 (7.51-9.32)	9.82 (8.67-10.8)	11.4 (9.96-12.5)	13.7 (11.9-15.1)	15.8 (13.5-17.4)
3-day	3.24 (2.95-3.59)	3.93 (3.58-4.36)	5.07 (4.61-5.62)	6.05 (5.48-6.69)	7.51 (6.77-8.29)	8.79 (7.87-9.68)	10.2 (9.06-11.2)	11.8 (10.4-12.9)	14.2 (12.3-15.6)	16.2 (13.9-17.8)
4-day	3.41 (3.12-3.78)	4.14 (3.79-4.58)	5.32 (4.86-5.88)	6.33 (5.77-6.99)	7.84 (7.09-8.63)	9.13 (8.22-10.0)	10.6 (9.45-11.6)	12.2 (10.8-13.4)	14.6 (12.7-16.0)	16.6 (14.4-18.2)
7-day	3.96 (3.65-4.34)	4.77 (4.40-5.24)	6.04 (5.56-6.62)	7.12 (6.53-7.79)	8.72 (7.95-9.51)	10.1 (9.14-11.0)	11.6 (10.4-12.6)	13.2 (11.8-14.4)	15.7 (13.8-17.1)	17.8 (15.5-19.4)
10-day	4.51 (4.18-4.89)	5.41 (5.02-5.87)	6.74 (6.25-7.31)	7.85 (7.26-8.51)	9.46 (8.70-10.2)	10.8 (9.89-11.7)	12.2 (11.1-13.2)	13.8 (12.5-14.9)	16.0 (14.4-17.3)	18.0 (15.9-19.4)
20-day	6.05 (5.66-6.49)	7.20 (6.74-7.72)	8.71 (8.14-9.33)	9.93 (9.27-10.6)	11.6 (10.8-12.4)	13.0 (12.1-13.9)	14.4 (13.3-15.4)	15.9 (14.6-17.0)	18.0 (16.4-19.2)	19.6 (17.8-21.0)
30-day	7.48 (7.02-7.98)	8.87 (8.31-9.45)	10.6 (9.89-11.3)	11.9 (11.1-12.7)	13.8 (12.8-14.6)	15.2 (14.2-16.2)	16.7 (15.5-17.8)	18.2 (16.8-19.4)	20.3 (18.6-21.6)	21.9 (20.0-23.3)
45-day	9.42 (8.90-9.95)	11.1 (10.5-11.7)	13.0 (12.3-13.7)	14.5 (13.7-15.3)	16.4 (15.4-17.3)	17.8 (16.8-18.8)	19.2 (18.1-20.3)	20.6 (19.3-21.8)	22.4 (20.9-23.7)	23.8 (22.1-25.2)
60-day	11.2 (10.6-11.9)	13.2 (12.5-13.9)	15.3 (14.4-16.1)	16.8 (15.9-17.7)	18.8 (17.7-19.8)	20.2 (19.1-21.4)	21.6 (20.3-22.8)	22.9 (21.5-24.2)	24.6 (23.0-26.0)	25.8 (24.0-27.3)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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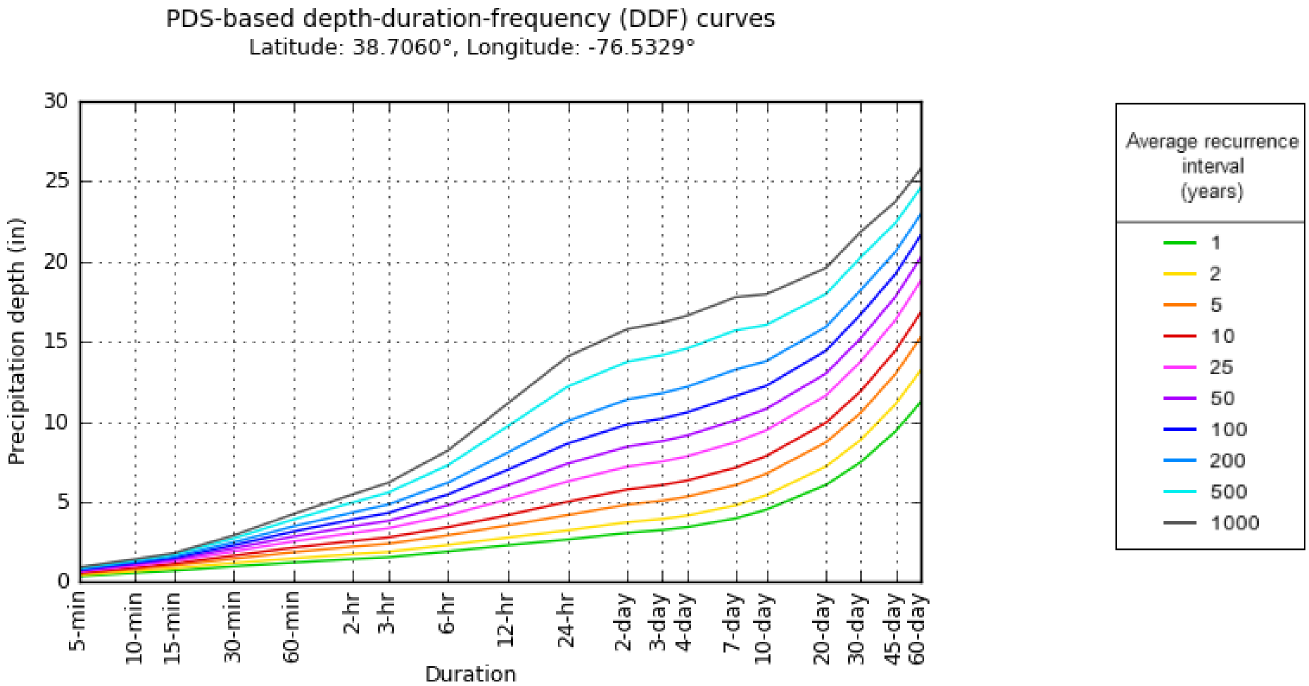
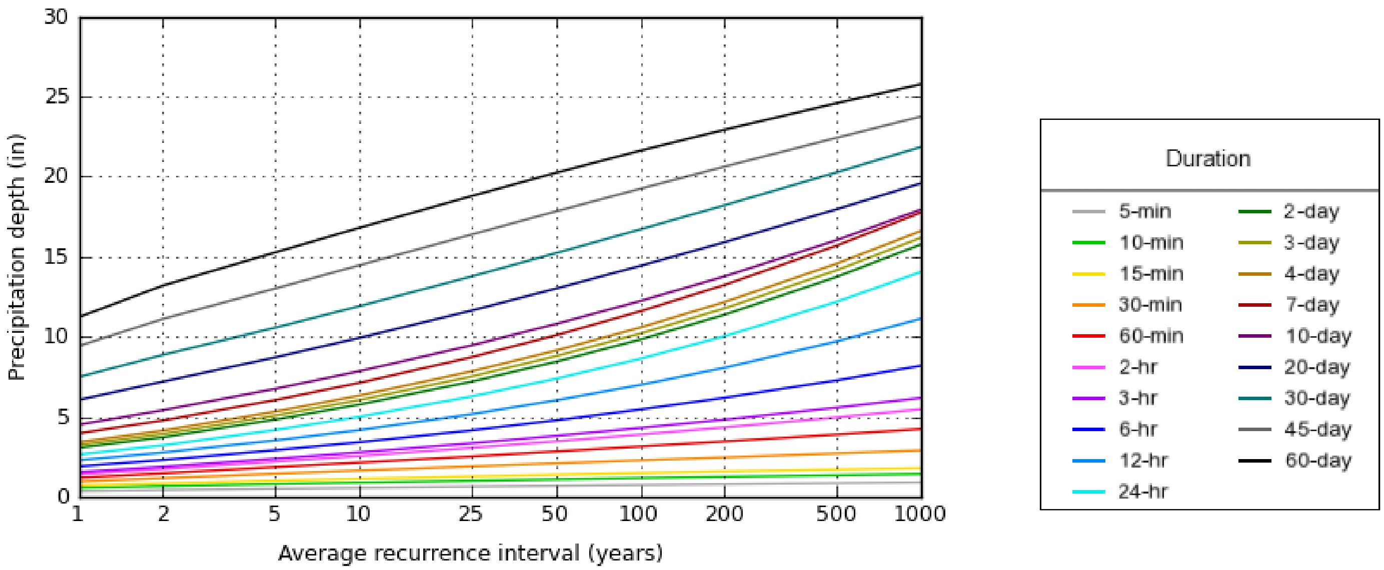
PF graphical





NOAA Atlas 14, Volume 2, Version 3

Created (GMT): Thu Sep 15 13:49:42 2022

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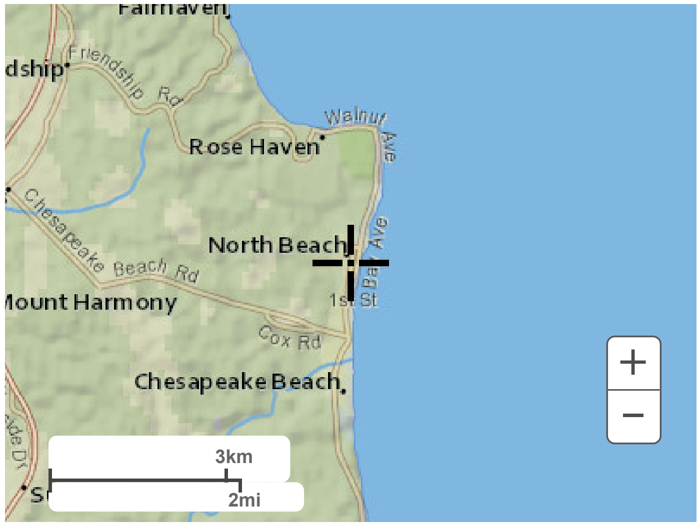
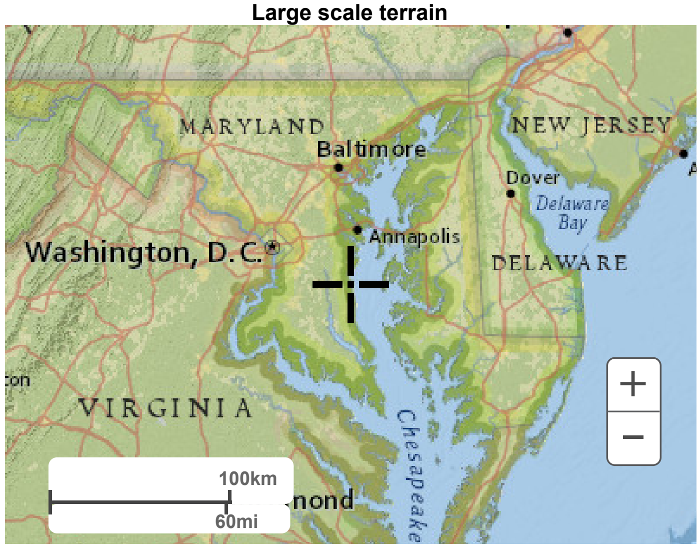
Maps & aerials

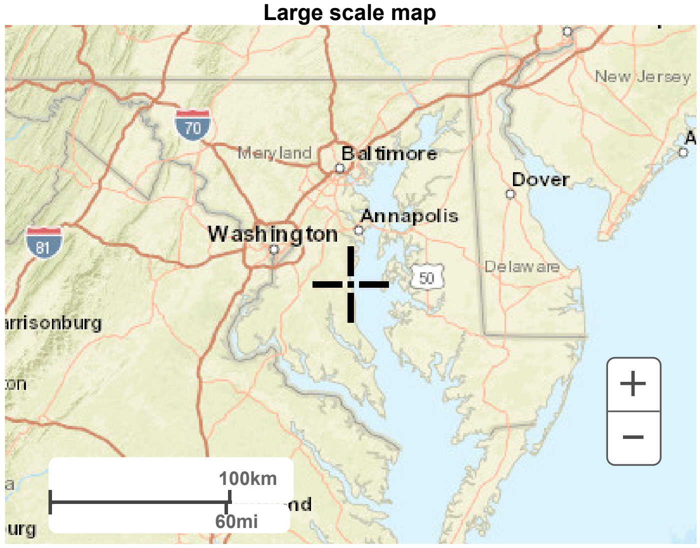
Small scale terrain



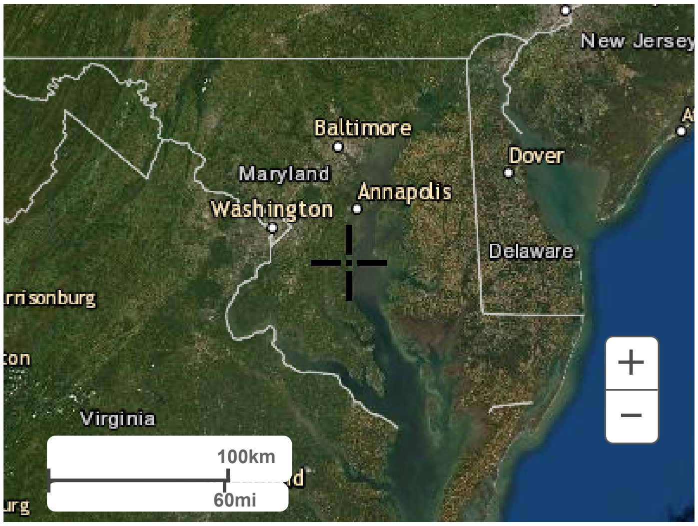
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Appendix C

Hydraulic Analysis

WinTR-55 Current Data Description

--- Identification Data ---

User:	MDB	Date:	3/2/2023
Project:	8_41401 NORTHBEACH	Units:	English
SubTitle:		Areal Units:	Acres
State:	Maryland		
County:	Calvert NOAA-C		
Filename:	P:\8_41401_North Beach Compound FAP\02 Info Gathering\H&H\8_41401_NorthBeach_TR-55.w55		

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA01		Outlet	82.94	90	0.318
DA02		Outlet	9.45	92	.314
DA03		Outlet	10.68	93	0.1

Total area: 103.07 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.32	4.32	5.17	6.48	7.63	8.93	2.73

Storm Data Source: User-provided custom storm data
Rainfall Distribution Type: NOAA_C
Dimensionless Unit Hydrograph: <standard>

Calvert NOAA-C County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.32	4.32	5.17	6.48	7.63	8.93	2.73

Storm Data Source: User-provided custom storm data
Rainfall Distribution Type: NOAA_C
Dimensionless Unit Hydrograph: <standard>

Calvert NOAA-C County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	Peak Flow by Rainfall Return Period 2-Yr (cfs)	10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA01	165.73	286.55	528.50	127.44
DA02	20.28	34.02	61.49	15.85
DA03	34.60	56.94	101.56	27.38
REACHES				
OUTLET	201.19	345.69	635.08	155.38

Calvert NOAA-C County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 2-Yr (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA01	165.73	286.55	528.50	127.44
	12.23	12.23	12.23	12.24
DA02	20.28	34.02	61.49	15.85
	12.23	12.24	12.23	12.23
DA03	34.60	56.94	101.56	27.38
	12.12	12.12	12.12	12.12
REACHES				
OUTLET	201.19	345.69	635.08	155.38

Calvert NOAA-C County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA01	82.94	0.318	90	Outlet	
DA02	9.45	0.314	92	Outlet	
DA03	10.68	0.100	93	Outlet	

Total Area: 103.07 (ac)

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA01							
SHEET	68	0.0147	0.011				0.016
SHALLOW	1850	0.0348	0.050				0.171
CHANNEL	2398					5.100	0.131
					Time of Concentration		0.318
DA02							
SHEET	100	0.0200	0.150				0.160
SHALLOW	223	0.0090	0.050				0.040
SHALLOW	755	0.0146	0.025				0.085
CHANNEL	413					4.000	0.029
					Time of Concentration		.314
DA03							
SHALLOW	740	0.1216	0.025				0.029
CHANNEL	976					4.500	0.060
					Time of Concentration		0.1

Calvert NOAA-C County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA01	Open space; grass cover > 75%	(good)	D	2.55	80
	Paved parking lots, roofs, driveways		B	3.94	98
	Paved parking lots, roofs, driveways		C	2.7	98
	Paved parking lots, roofs, driveways		D	12.57	98
	Residential districts (1/8 acre)		B	20.31	85
	Residential districts (1/8 acre)		C	2.09	90
	Residential districts (1/8 acre)		D	36.05	92
	Woods	(good)	B	2.35	55
	Woods	(good)	C	.31	70
	Woods	(good)	D	.07	77
	Total Area / Weighted Curve Number			82.94	90
				=====	==
DA02	Open space; grass cover > 75%	(good)	D	.22	80
	Paved parking lots, roofs, driveways		B	.38	98
	Paved parking lots, roofs, driveways		D	1.79	98
	Residential districts (1/8 acre)		B	1.07	85
	Residential districts (1/8 acre)		D	5.99	92
	Total Area / Weighted Curve Number			9.45	92
				====	==
DA03	Open space; grass cover > 75%	(good)	D	.28	80
	Paved parking lots, roofs, driveways		B	.06	98
	Paved parking lots, roofs, driveways		D	2.62	98
	Residential districts (1/8 acre)		B	.12	85
	Residential districts (1/8 acre)		D	7.6	92
	Total Area / Weighted Curve Number			10.68	93
				=====	==

```
WinTR-20 Printed Page File      Beginning of Input Data List
C:\Users\Matthew\Desktop\TR20\North Beach\North Beach DA1.inp

WinTR-20: Version 3.20                  0         0         .001      0
NORTHBEACH DA1
 1-YR, 10-YR, 100-YR

SUB-AREA:
          DA01      OUTLET              .13       90.       0.318     Y



STORM ANALYSIS:
          1-YR                          2.86      TYPE NO_C 2         3.48
          10-YR                         5.40      TYPE NO_C 2         3.48
          100-YR                        9.32      TYPE NO_C 2         3.48









GLOBAL OUTPUT:
                              0.1       YY  N     YN  N







WinTR-20 Printed Page File      End of Input Data List

                                       NORTHBEACH DA1
                                     1-YR, 10-YR, 100-YR

                                Name of printed page file:
         C:\Users\Matthew\Desktop\TR20\North Beach\North_Beach_DA1.out

                                                STORM 1-YR

Area or    Drainage  Rain Gage     Runoff   ------------ Peak Flow ------------
 Reach       Area      ID or       Amount    Elevation   Time       Rate       Rate
Identifier  (sq mi)   Location      (in)       (ft)      (hr)      (cfs)      (csm)

DA01          0.130                1.856                 12.23     136.2    1047.68

   Line
Start Time   ------------ Flow Values @ time increment of  0.100 hr ------------
      (hr)     (cfs)      (cfs)      (cfs)      (cfs)      (cfs)      (cfs)      (cfs)

     7.300       0.5        0.5        0.6        0.7        0.7        0.8        0.8
     8.000       0.9        1.0        1.0        1.1        1.2        1.3        1.3
     8.700       1.4        1.5        1.6        1.7        1.8        1.9        2.0
     9.400       2.2        2.4        2.5        2.7        3.0        3.2        3.4
    10.100       3.6        3.9        4.1        4.4        4.7        5.0        5.4
    10.800       6.1        6.8        7.7        8.6        9.8       11.2       12.9
    11.500      14.7       17.2       22.1       28.1       37.2       54.4       89.8
    12.200     131.9      126.4       93.4       68.4       52.7       40.8       32.4
    12.900      27.4       23.9       21.2       18.9       17.1       15.6       14.3
    13.600      13.0       11.9       11.1       10.5       10.1        9.8        9.4
    14.300       9.1        8.8        8.5        8.2        7.9        7.5        7.2
    15.000       6.9        6.6        6.3        6.1        5.9        5.8        5.7
    15.700       5.7        5.6        5.5        5.4        5.3        5.2        5.2
    16.400       5.1        5.0        4.9        4.8        4.7        4.7        4.6
    17.100       4.5        4.4        4.3        4.2        4.2        4.1        4.0
    17.800       3.9        3.8        3.7        3.6        3.6        3.5        3.5
    18.500       3.4        3.4        3.4        3.4        3.4        3.3        3.3
    19.200       3.3        3.3        3.3        3.2        3.2        3.2        3.2
    19.900       3.2        3.1        3.1        3.1        3.1        3.0        3.0
    20.600       3.0        3.0        3.0        2.9        2.9        2.9        2.9
    21.300       2.9        2.8        2.8        2.8        2.8        2.7        2.7
    22.000       2.7        2.7        2.7        2.6        2.6        2.6        2.6
    22.700       2.6        2.5        2.5        2.5        2.5        2.5        2.4
    23.400       2.4        2.4        2.4        2.3        2.3        2.3        2.3
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24.100	2.3	1.5	0.7	0.0

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	------------ Peak Flow ------------ Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
OUTLET	0.130		1.856		12.23	136.2	1047.68

Line Start Time (hr)	------------ Flow Values @ time increment of 0.100 hr ------------ (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
7.300	0.5	0.5	0.6	0.7	0.7	0.8	0.8
8.000	0.9	1.0	1.0	1.1	1.2	1.3	1.3
8.700	1.4	1.5	1.6	1.7	1.8	1.9	2.0
9.400	2.2	2.4	2.5	2.7	3.0	3.2	3.4

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
10.100	3.6	3.9	4.1	4.4	4.7	5.0	5.4
10.800	6.1	6.8	7.7	8.6	9.8	11.2	12.9
11.500	14.7	17.2	22.1	28.1	37.2	54.4	89.8
12.200	131.9	126.4	93.4	68.4	52.7	40.8	32.4
12.900	27.4	23.9	21.2	18.9	17.1	15.6	14.3
13.600	13.0	11.9	11.1	10.5	10.1	9.8	9.4
14.300	9.1	8.8	8.5	8.2	7.9	7.5	7.2
15.000	6.9	6.6	6.3	6.1	5.9	5.8	5.7
15.700	5.7	5.6	5.5	5.4	5.3	5.2	5.2
16.400	5.1	5.0	4.9	4.8	4.7	4.7	4.6
17.100	4.5	4.4	4.3	4.2	4.2	4.1	4.0
17.800	3.9	3.8	3.7	3.6	3.6	3.5	3.5
18.500	3.4	3.4	3.4	3.4	3.4	3.3	3.3
19.200	3.3	3.3	3.3	3.2	3.2	3.2	3.2
19.900	3.2	3.1	3.1	3.1	3.1	3.0	3.0
20.600	3.0	3.0	3.0	2.9	2.9	2.9	2.9
21.300	2.9	2.8	2.8	2.8	2.8	2.7	2.7
22.000	2.7	2.7	2.7	2.6	2.6	2.6	2.6
22.700	2.6	2.5	2.5	2.5	2.5	2.5	2.4
23.400	2.4	2.4	2.4	2.3	2.3	2.3	2.3
24.100	2.3	1.5	0.7	0.0			

STORM 10-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
DA01	0.130		4.263		12.24	302.4	2326.26

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
4.200	0.4	0.5	0.6	0.7	0.7	0.8	0.9
4.900	1.0	1.1	1.2	1.2	1.3	1.4	1.5
5.600	1.6	1.7	1.7	1.8	1.9	2.0	2.1
6.300	2.2	2.3	2.5	2.6	2.7	2.9	3.0
7.000	3.1	3.3	3.5	3.6	3.8	3.9	4.1
7.700	4.3	4.4	4.6	4.8	5.0	5.1	5.3
8.400	5.5	5.7	5.9	6.1	6.3	6.5	6.7
9.100	6.9	7.2	7.6	8.1	8.6	9.1	9.7
9.800	10.2	10.8	11.4	12.0	12.6	13.2	13.8
10.500	14.4	15.2	16.4	18.1	20.0	22.1	24.4
11.200	27.4	30.9	34.9	39.1	45.0	56.6	70.6
11.900	91.2	129.6	206.8	295.2	277.6	202.2	146.5
12.600	111.7	86.0	68.0	57.2	49.8	43.9	39.1
13.300	35.2	32.1	29.4	26.8	24.5	22.7	21.6
14.000	20.7	20.0	19.3	18.6	18.0	17.3	16.7
14.700	16.1	15.4	14.8	14.1	13.5	12.9	12.4
15.400	12.1	11.9	11.7	11.5	11.3	11.2	11.0

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
16.100	10.8	10.6	10.5	10.3	10.1	10.0	9.8
16.800	9.6	9.4	9.3	9.1	8.9	8.8	8.6
17.500	8.4	8.2	8.1	7.9	7.7	7.6	7.4
18.200	7.2	7.1	7.0	7.0	6.9	6.9	6.8
18.900	6.8	6.7	6.7	6.6	6.6	6.6	6.5
19.600	6.5	6.4	6.4	6.4	6.3	6.3	6.2
20.300	6.2	6.1	6.1	6.0	6.0	6.0	5.9
21.000	5.9	5.8	5.8	5.7	5.7	5.7	5.6
21.700	5.6	5.5	5.5	5.4	5.4	5.4	5.3
22.400	5.3	5.2	5.2	5.1	5.1	5.0	5.0
23.100	5.0	4.9	4.9	4.8	4.8	4.8	4.7
23.800	4.7	4.6	4.7	4.5	3.0	1.4	0.6
24.500	0.0						

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
OUTLET	0.130		4.263		12.24	302.4	2326.26

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
4.200	0.4	0.5	0.6	0.7	0.7	0.8	0.9
4.900	1.0	1.1	1.2	1.2	1.3	1.4	1.5
5.600	1.6	1.7	1.7	1.8	1.9	2.0	2.1
6.300	2.2	2.3	2.5	2.6	2.7	2.9	3.0
7.000	3.1	3.3	3.5	3.6	3.8	3.9	4.1
7.700	4.3	4.4	4.6	4.8	5.0	5.1	5.3
8.400	5.5	5.7	5.9	6.1	6.3	6.5	6.7
9.100	6.9	7.2	7.6	8.1	8.6	9.1	9.7
9.800	10.2	10.8	11.4	12.0	12.6	13.2	13.8
10.500	14.4	15.2	16.4	18.1	20.0	22.1	24.4
11.200	27.4	30.9	34.9	39.1	45.0	56.6	70.6
11.900	91.2	129.6	206.8	295.2	277.6	202.2	146.5
12.600	111.7	86.0	68.0	57.2	49.8	43.9	39.1
13.300	35.2	32.1	29.4	26.8	24.5	22.7	21.6
14.000	20.7	20.0	19.3	18.6	18.0	17.3	16.7
14.700	16.1	15.4	14.8	14.1	13.5	12.9	12.4
15.400	12.1	11.9	11.7	11.5	11.3	11.2	11.0
16.100	10.8	10.6	10.5	10.3	10.1	10.0	9.8
16.800	9.6	9.4	9.3	9.1	8.9	8.8	8.6
17.500	8.4	8.2	8.1	7.9	7.7	7.6	7.4
18.200	7.2	7.1	7.0	7.0	6.9	6.9	6.8
18.900	6.8	6.7	6.7	6.6	6.6	6.6	6.5
19.600	6.5	6.4	6.4	6.4	6.3	6.3	6.2
20.300	6.2	6.1	6.1	6.0	6.0	6.0	5.9
21.000	5.9	5.8	5.8	5.7	5.7	5.7	5.6
21.700	5.6	5.5	5.5	5.4	5.4	5.4	5.3
22.400	5.3	5.2	5.2	5.1	5.1	5.0	5.0

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
23.100	5.0	4.9	4.9	4.8	4.8	4.8	4.7
23.800	4.7	4.6	4.7	4.5	3.0	1.4	0.6
24.500	0.0						

STORM 100-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
DA01	0.130		8.108		12.22	555.3	4271.88

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
2.500	0.3	0.5	0.7	0.9	1.1	1.3	1.4
3.200	1.6	1.8	2.0	2.2	2.4	2.5	2.7
3.900	2.9	3.1	3.3	3.4	3.6	3.8	4.0
4.600	4.1	4.3	4.4	4.6	4.8	4.9	5.1
5.300	5.3	5.4	5.6	5.7	5.9	6.1	6.2
6.000	6.4	6.5	6.7	7.0	7.2	7.5	7.8
6.700	8.1	8.4	8.7	9.0	9.3	9.7	10.0
7.400	10.3	10.6	10.9	11.3	11.6	11.9	12.3
8.100	12.6	13.0	13.3	13.7	14.0	14.4	14.7
8.800	15.1	15.4	15.8	16.2	16.8	17.7	18.6
9.500	19.7	20.7	21.8	22.9	24.0	25.1	26.2
10.200	27.4	28.5	29.7	30.9	32.3	34.6	37.9
10.900	41.7	45.7	50.1	55.7	62.6	70.1	77.8
11.600	88.8	110.7	136.9	174.8	245.0	385.5	543.8
12.300	507.0	367.0	264.7	201.1	154.4	121.7	102.2
13.000	88.8	78.4	69.7	62.8	57.2	52.3	47.7
13.700	43.5	40.4	38.3	36.8	35.5	34.3	33.1
14.400	31.9	30.8	29.6	28.5	27.3	26.2	25.0
15.100	23.9	22.8	22.0	21.4	21.0	20.7	20.4
15.800	20.0	19.7	19.4	19.1	18.8	18.5	18.2
16.500	17.9	17.6	17.3	17.0	16.7	16.4	16.1
17.200	15.8	15.5	15.2	14.8	14.6	14.3	13.9
17.900	13.6	13.3	13.0	12.7	12.5	12.4	12.3
18.600	12.2	12.1	12.0	12.0	11.9	11.8	11.7
19.300	11.6	11.6	11.5	11.4	11.3	11.3	11.2
20.000	11.1	11.0	11.0	10.9	10.8	10.7	10.7
20.700	10.6	10.5	10.4	10.3	10.3	10.2	10.1
21.400	10.1	10.0	9.9	9.8	9.7	9.7	9.6
22.100	9.5	9.4	9.4	9.3	9.2	9.1	9.1
22.800	9.0	8.9	8.8	8.8	8.7	8.6	8.5
23.500	8.4	8.4	8.3	8.2	8.1	8.2	8.0
24.200	5.3	2.5	1.1	0.0			

NORTHBEACH DA1
1-YR, 10-YR, 100-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
OUTLET	0.130		8.108		12.22	555.3	4271.88

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
2.500	0.3	0.5	0.7	0.9	1.1	1.3	1.4
3.200	1.6	1.8	2.0	2.2	2.4	2.5	2.7
3.900	2.9	3.1	3.3	3.4	3.6	3.8	4.0
4.600	4.1	4.3	4.4	4.6	4.8	4.9	5.1
5.300	5.3	5.4	5.6	5.7	5.9	6.1	6.2
6.000	6.4	6.5	6.7	7.0	7.2	7.5	7.8
6.700	8.1	8.4	8.7	9.0	9.3	9.7	10.0
7.400	10.3	10.6	10.9	11.3	11.6	11.9	12.3
8.100	12.6	13.0	13.3	13.7	14.0	14.4	14.7
8.800	15.1	15.4	15.8	16.2	16.8	17.7	18.6
9.500	19.7	20.7	21.8	22.9	24.0	25.1	26.2
10.200	27.4	28.5	29.7	30.9	32.3	34.6	37.9
10.900	41.7	45.7	50.1	55.7	62.6	70.1	77.8
11.600	88.8	110.7	136.9	174.8	245.0	385.5	543.8
12.300	507.0	367.0	264.7	201.1	154.4	121.7	102.2
13.000	88.8	78.4	69.7	62.8	57.2	52.3	47.7
13.700	43.5	40.4	38.3	36.8	35.5	34.3	33.1
14.400	31.9	30.8	29.6	28.5	27.3	26.2	25.0
15.100	23.9	22.8	22.0	21.4	21.0	20.7	20.4
15.800	20.0	19.7	19.4	19.1	18.8	18.5	18.2
16.500	17.9	17.6	17.3	17.0	16.7	16.4	16.1
17.200	15.8	15.5	15.2	14.8	14.6	14.3	13.9
17.900	13.6	13.3	13.0	12.7	12.5	12.4	12.3
18.600	12.2	12.1	12.0	12.0	11.9	11.8	11.7
19.300	11.6	11.6	11.5	11.4	11.3	11.3	11.2
20.000	11.1	11.0	11.0	10.9	10.8	10.7	10.7
20.700	10.6	10.5	10.4	10.3	10.3	10.2	10.1
21.400	10.1	10.0	9.9	9.8	9.7	9.7	9.6
22.100	9.5	9.4	9.4	9.3	9.2	9.1	9.1
22.800	9.0	8.9	8.8	8.8	8.7	8.6	8.5
23.500	8.4	8.4	8.3	8.2	8.1	8.2	8.0
24.200	5.3	2.5	1.1	0.0			

Area or Reach Identifier	Drainage Area (sq mi)	----------- Peak Flow by Storm ----------- 1-YR (cfs)	10-YR (cfs)	100-YR (cfs)	(cfs)	(cfs)
DA01	0.130	136.2	302.4	555.3		
OUTLET	0.130	136.2	302.4	555.3		

WinTR-20 Printed Page File   Beginning of Input Data List
C:\Users\Matthew\Desktop\TR20\North Beach\North Beach DA2.inp

WinTR-20: Version 3.20   0   0   .001   0
NORTHBEACH DA1
1-YR, 10-YR, 100-YR

SUB-AREA:
DA02   OUTLET   .02   92.   0.314

STORM ANALYSIS:

1-YR	2.86	TYPE NO_C 2	3.48
10-YR	5.40	TYPE NO_C 2	3.48
100-YR	9.32	TYPE NO_C 2	3.48

GLOBAL OUTPUT:
0.1   YY N   YN N

WinTR-20 Printed Page File   End of Input Data List

NORTHBEACH DA1
1-YR, 10-YR, 100-YR

Name of printed page file:
C:\Users\Matthew\Desktop\TR20\North Beach\North_Beach_DA2.out

STORM 1-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
DA02	0.020		2.029		12.23	22.8	1139.96

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
9.500	0.5	0.5	0.6	0.6	0.6	0.7	0.7
10.200	0.8	0.8	0.9	0.9	1.0	1.0	1.2
10.900	1.3	1.4	1.6	1.8	2.1	2.4	2.7
11.600	3.1	4.0	5.0	6.5	9.4	15.4	22.2
12.300	20.9	15.2	11.1	8.5	6.6	5.2	4.4
13.000	3.8	3.4	3.0	2.7	2.5	2.3	2.1
13.700	1.9	1.8	1.7	1.6	1.6	1.5	1.5
14.400	1.4	1.4	1.3	1.3	1.2	1.2	1.1
15.100	1.1	1.0	1.0	0.9	0.9	0.9	0.9
15.800	0.9	0.9	0.9	0.8	0.8	0.8	0.8
16.500	0.8	0.8	0.8	0.8	0.7	0.7	0.7
17.200	0.7	0.7	0.7	0.7	0.6	0.6	0.6
17.900	0.6	0.6	0.6	0.6	0.6	0.6	0.5
18.600	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19.300	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20.000	0.0						

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
OUTLET	0.020		2.029		12.23	22.8	1139.96

Line

Start Time (hr)	------------ Flow Values @ time increment of 0.100 hr ------------ (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
9.500	0.5	0.5	0.6	0.6	0.6	0.7	0.7
10.200	0.8	0.8	0.9	0.9	1.0	1.0	1.2
10.900	1.3	1.4	1.6	1.8	2.1	2.4	2.7
11.600	3.1	4.0	5.0	6.5	9.4	15.4	22.2
12.300	20.9	15.2	11.1	8.5	6.6	5.2	4.4
13.000	3.8	3.4	3.0	2.7	2.5	2.3	2.1
13.700	1.9	1.8	1.7	1.6	1.6	1.5	1.5
14.400	1.4	1.4	1.3	1.3	1.2	1.2	1.1
15.100	1.1	1.0	1.0	0.9	0.9	0.9	0.9
15.800	0.9	0.9	0.9	0.8	0.8	0.8	0.8
16.500	0.8	0.8	0.8	0.8	0.7	0.7	0.7
17.200	0.7	0.7	0.7	0.7	0.6	0.6	0.6
17.900	0.6	0.6	0.6	0.6	0.6	0.6	0.5

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
18.600	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19.300	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20.000	0.0						

STORM 10-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
DA02	0.020		4.481		12.22	48.4	2419.93

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
6.400	0.5	0.5	0.5	0.6	0.6	0.6	0.6
7.100	0.7	0.7	0.7	0.7	0.8	0.8	0.8
7.800	0.9	0.9	0.9	0.9	1.0	1.0	1.0
8.500	1.1	1.1	1.1	1.2	1.2	1.2	1.3
9.200	1.3	1.4	1.5	1.5	1.6	1.7	1.8
9.900	1.9	2.0	2.1	2.2	2.3	2.4	2.5
10.600	2.6	2.8	3.1	3.4	3.8	4.1	4.6
11.300	5.2	5.8	6.5	7.5	9.4	11.6	15.0
12.000	21.1	33.6	47.4	44.0	31.7	22.9	17.4
12.700	13.4	10.6	8.9	7.8	6.9	6.1	5.5
13.400	5.0	4.6	4.2	3.8	3.5	3.4	3.2
14.100	3.1	3.0	2.9	2.8	2.7	2.6	2.5
14.800	2.4	2.3	2.2	2.1	2.0	1.9	1.9
15.500	1.9	1.8	1.8	1.8	1.7	1.7	1.7
16.200	1.7	1.6	1.6	1.6	1.6	1.5	1.5
16.900	1.5	1.4	1.4	1.4	1.4	1.3	1.3
17.600	1.3	1.3	1.2	1.2	1.2	1.1	1.1
18.300	1.1	1.1	1.1	1.1	1.1	1.1	1.1
19.000	1.0	1.0	1.0	1.0	1.0	1.0	1.0
19.700	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20.400	1.0	0.9	0.9	0.9	0.9	0.9	0.9
21.100	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.800	0.9	0.9	0.8	0.8	0.8	0.8	0.8
22.500	0.8	0.8	0.8	0.8	0.8	0.8	0.8
23.200	0.8	0.8	0.8	0.7	0.7	0.7	0.7
23.900	0.7	0.7	0.7	0.0			

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
OUTLET	0.020		4.481		12.22	48.4	2419.93

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
6.400	0.5	0.5	0.5	0.6	0.6	0.6	0.6
7.100	0.7	0.7	0.7	0.7	0.8	0.8	0.8
7.800	0.9	0.9	0.9	0.9	1.0	1.0	1.0
8.500	1.1	1.1	1.1	1.2	1.2	1.2	1.3
9.200	1.3	1.4	1.5	1.5	1.6	1.7	1.8
9.900	1.9	2.0	2.1	2.2	2.3	2.4	2.5
10.600	2.6	2.8	3.1	3.4	3.8	4.1	4.6
11.300	5.2	5.8	6.5	7.5	9.4	11.6	15.0
12.000	21.1	33.6	47.4	44.0	31.7	22.9	17.4
12.700	13.4	10.6	8.9	7.8	6.9	6.1	5.5
13.400	5.0	4.6	4.2	3.8	3.5	3.4	3.2
14.100	3.1	3.0	2.9	2.8	2.7	2.6	2.5
14.800	2.4	2.3	2.2	2.1	2.0	1.9	1.9
15.500	1.9	1.8	1.8	1.8	1.7	1.7	1.7
16.200	1.7	1.6	1.6	1.6	1.6	1.5	1.5
16.900	1.5	1.4	1.4	1.4	1.4	1.3	1.3
17.600	1.3	1.3	1.2	1.2	1.2	1.1	1.1
18.300	1.1	1.1	1.1	1.1	1.1	1.1	1.1
19.000	1.0	1.0	1.0	1.0	1.0	1.0	1.0
19.700	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20.400	1.0	0.9	0.9	0.9	0.9	0.9	0.9
21.100	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.800	0.9	0.9	0.8	0.8	0.8	0.8	0.8
22.500	0.8	0.8	0.8	0.8	0.8	0.8	0.8
23.200	0.8	0.8	0.8	0.7	0.7	0.7	0.7
23.900	0.7	0.7	0.7	0.0			

STORM 100-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
DA02	0.020		8.352		12.22	87.2	4359.07

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3.400	0.5	0.5	0.5	0.6	0.6	0.6	0.7
4.100	0.7	0.7	0.7	0.8	0.8	0.8	0.9
4.800	0.9	0.9	0.9	1.0	1.0	1.0	1.0
5.500	1.1	1.1	1.1	1.1	1.1	1.2	1.2
6.200	1.2	1.3	1.3	1.4	1.4	1.5	1.5
6.900	1.5	1.6	1.7	1.7	1.8	1.8	1.9
7.600	1.9	2.0	2.0	2.1	2.1	2.2	2.2
8.300	2.3	2.3	2.4	2.4	2.5	2.5	2.6
9.000	2.7	2.7	2.8	3.0	3.1	3.3	3.4
9.700	3.6	3.8	4.0	4.1	4.3	4.5	4.7
10.400	4.9	5.0	5.3	5.6	6.2	6.8	7.4
11.100	8.1	9.0	10.1	11.3	12.5	14.2	17.7

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
11.800	21.8	27.8	38.9	61.1	85.7	78.9	56.6
12.500	40.7	30.9	23.7	18.7	15.7	13.7	12.1
13.200	10.8	9.7	8.8	8.1	7.4	6.7	6.2
13.900	5.9	5.7	5.5	5.3	5.1	4.9	4.8
14.600	4.6	4.4	4.2	4.0	3.9	3.7	3.5
15.300	3.4	3.3	3.3	3.2	3.2	3.1	3.1
16.000	3.0	3.0	2.9	2.9	2.8	2.8	2.7
16.700	2.7	2.6	2.6	2.5	2.5	2.4	2.4
17.400	2.3	2.3	2.2	2.2	2.2	2.1	2.1
18.100	2.0	2.0	1.9	1.9	1.9	1.9	1.9
18.800	1.9	1.8	1.8	1.8	1.8	1.8	1.8
19.500	1.8	1.8	1.8	1.7	1.7	1.7	1.7
20.200	1.7	1.7	1.7	1.7	1.6	1.6	1.6
20.900	1.6	1.6	1.6	1.6	1.6	1.6	1.5
21.600	1.5	1.5	1.5	1.5	1.5	1.5	1.5
22.300	1.4	1.4	1.4	1.4	1.4	1.4	1.4
23.000	1.4	1.4	1.3	1.3	1.3	1.3	1.3
23.700	1.3	1.3	1.3	1.3	1.2	0.8	0.0

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
OUTLET	0.020		8.352		12.22	87.2	4359.07

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3.400	0.5	0.5	0.5	0.6	0.6	0.6	0.7
4.100	0.7	0.7	0.7	0.8	0.8	0.8	0.9
4.800	0.9	0.9	0.9	1.0	1.0	1.0	1.0
5.500	1.1	1.1	1.1	1.1	1.1	1.2	1.2
6.200	1.2	1.3	1.3	1.4	1.4	1.5	1.5
6.900	1.5	1.6	1.7	1.7	1.8	1.8	1.9
7.600	1.9	2.0	2.0	2.1	2.1	2.2	2.2
8.300	2.3	2.3	2.4	2.4	2.5	2.5	2.6
9.000	2.7	2.7	2.8	3.0	3.1	3.3	3.4
9.700	3.6	3.8	4.0	4.1	4.3	4.5	4.7
10.400	4.9	5.0	5.3	5.6	6.2	6.8	7.4
11.100	8.1	9.0	10.1	11.3	12.5	14.2	17.7
11.800	21.8	27.8	38.9	61.1	85.7	78.9	56.6
12.500	40.7	30.9	23.7	18.7	15.7	13.7	12.1
13.200	10.8	9.7	8.8	8.1	7.4	6.7	6.2
13.900	5.9	5.7	5.5	5.3	5.1	4.9	4.8
14.600	4.6	4.4	4.2	4.0	3.9	3.7	3.5
15.300	3.4	3.3	3.3	3.2	3.2	3.1	3.1
16.000	3.0	3.0	2.9	2.9	2.8	2.8	2.7
16.700	2.7	2.6	2.6	2.5	2.5	2.4	2.4
17.400	2.3	2.3	2.2	2.2	2.2	2.1	2.1
18.100	2.0	2.0	1.9	1.9	1.9	1.9	1.9

Line Start Time (hr)	------------ Flow Values @ time increment of 0.100 hr ------------ (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
18.800	1.9	1.8	1.8	1.8	1.8	1.8	1.8
19.500	1.8	1.8	1.8	1.7	1.7	1.7	1.7
20.200	1.7	1.7	1.7	1.7	1.6	1.6	1.6
20.900	1.6	1.6	1.6	1.6	1.6	1.6	1.5
21.600	1.5	1.5	1.5	1.5	1.5	1.5	1.5
22.300	1.4	1.4	1.4	1.4	1.4	1.4	1.4
23.000	1.4	1.4	1.3	1.3	1.3	1.3	1.3
23.700	1.3	1.3	1.3	1.3	1.2	0.8	0.0

NORTHBEACH DA1
1-YR, 10-YR, 100-YR

Area or Reach Identifier	Drainage Area (sq mi)	----------- Peak Flow by Storm ----------- 1-YR (cfs)	10-YR (cfs)	100-YR (cfs)	(cfs)	(cfs)
DA02	0.020	22.8	48.4	87.2		
OUTLET	0.020	22.8	48.4	87.2		

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WinTR-20 Printed Page File      Beginning of Input Data List
C:\Users\Matthew\Desktop\TR20\North Beach\North Beach DA3.inp

WinTR-20: Version 3.20                 0          0          .001      0
NORTHBEACH DA1
 1-YR, 10-YR, 100-YR

SUB-AREA:
          DA03      OUTLET             .02        93.        0.1


STORM ANALYSIS:
          1-YR                         2.86       TYPE NO_C 2          3.48
          10-YR                        5.40       TYPE NO_C 2          3.48
          100-YR                       9.32       TYPE NO_C 2          3.48


GLOBAL OUTPUT:
                              0.1       YY  N      YN  N


WinTR-20 Printed Page File      End of Input Data List
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NORTHBEACH DA1
1-YR, 10-YR, 100-YR

Name of printed page file:
C:\Users\Matthew\Desktop\TR20\North Beach\North_Beach_DA3.out

STORM 1-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
DA03	0.020		2.120		12.12	34.7	1734.49

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
9.100	0.5	0.5	0.6	0.6	0.6	0.7	0.7
9.800	0.8	0.8	0.9	0.9	1.0	1.0	1.0
10.500	1.1	1.2	1.4	1.5	1.7	1.9	2.1
11.200	2.4	2.8	3.1	3.4	5.0	5.8	7.8
11.900	11.1	19.2	33.6	19.0	11.0	7.8	7.0
12.600	5.0	4.3	3.9	3.5	3.2	2.8	2.6
13.300	2.4	2.2	2.0	1.8	1.7	1.6	1.6
14.000	1.5	1.5	1.4	1.4	1.3	1.3	1.2
14.700	1.2	1.1	1.1	1.0	1.0	1.0	0.9
15.400	0.9	0.9	0.9	0.9	0.9	0.9	0.9
16.100	0.8	0.8	0.8	0.8	0.8	0.8	0.8
16.800	0.7	0.7	0.7	0.7	0.7	0.7	0.7
17.500	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18.200	0.6	0.6	0.6	0.5	0.5	0.5	0.5
18.900	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19.600	0.5	0.5	0.5	0.5	0.0		

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
OUTLET	0.020		2.120		12.12	34.7	1734.49

Line

Start Time (hr)	------------	------------	Flow Values @ time	increment of 0.100 hr	------------	------------	------------
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
9.100	0.5	0.5	0.6	0.6	0.6	0.7	0.7
9.800	0.8	0.8	0.9	0.9	1.0	1.0	1.0
10.500	1.1	1.2	1.4	1.5	1.7	1.9	2.1
11.200	2.4	2.8	3.1	3.4	5.0	5.8	7.8
11.900	11.1	19.2	33.6	19.0	11.0	7.8	7.0
12.600	5.0	4.3	3.9	3.5	3.2	2.8	2.6
13.300	2.4	2.2	2.0	1.8	1.7	1.6	1.6
14.000	1.5	1.5	1.4	1.4	1.3	1.3	1.2
14.700	1.2	1.1	1.1	1.0	1.0	1.0	0.9
15.400	0.9	0.9	0.9	0.9	0.9	0.9	0.9
16.100	0.8	0.8	0.8	0.8	0.8	0.8	0.8
16.800	0.7	0.7	0.7	0.7	0.7	0.7	0.7
17.500	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
18.200	0.6	0.6	0.6	0.5	0.5	0.5	0.5
18.900	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19.600	0.5	0.5	0.5	0.5	0.0		

STORM 10-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
DA03	0.020		4.591		12.12	71.5	3576.70

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
5.800	0.5	0.5	0.5	0.5	0.6	0.6	0.6
6.500	0.6	0.7	0.7	0.7	0.7	0.8	0.8
7.200	0.8	0.8	0.9	0.9	0.9	1.0	1.0
7.900	1.0	1.1	1.1	1.1	1.1	1.2	1.2
8.600	1.2	1.3	1.3	1.3	1.4	1.4	1.5
9.300	1.6	1.7	1.8	1.9	2.0	2.1	2.2
10.000	2.3	2.4	2.5	2.6	2.7	2.8	3.1
10.700	3.4	3.8	4.2	4.5	5.1	5.8	6.5
11.400	7.2	7.8	11.4	13.1	17.2	24.1	40.8
12.100	69.6	38.6	22.3	15.8	13.9	10.0	8.5
12.800	7.7	7.0	6.3	5.6	5.1	4.7	4.3
13.500	3.9	3.5	3.4	3.3	3.2	3.1	3.0
14.200	2.9	2.8	2.7	2.6	2.4	2.3	2.2
14.900	2.1	2.0	1.9	1.9	1.9	1.8	1.8
15.600	1.8	1.8	1.7	1.7	1.7	1.7	1.6
16.300	1.6	1.6	1.5	1.5	1.5	1.5	1.4
17.000	1.4	1.4	1.4	1.3	1.3	1.3	1.2
17.700	1.2	1.2	1.2	1.1	1.1	1.1	1.1
18.400	1.1	1.1	1.1	1.1	1.1	1.0	1.0
19.100	1.0	1.0	1.0	1.0	1.0	1.0	1.0
19.800	1.0	1.0	1.0	1.0	1.0	1.0	0.9
20.500	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.200	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.900	0.8	0.8	0.8	0.8	0.8	0.8	0.8
22.600	0.8	0.8	0.8	0.8	0.8	0.8	0.8
23.300	0.7	0.7	0.7	0.7	0.7	0.7	0.7
24.000	0.8	0.0					

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
OUTLET	0.020		4.591		12.12	71.5	3576.70

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
5.800	0.5	0.5	0.5	0.5	0.6	0.6	0.6
6.500	0.6	0.7	0.7	0.7	0.7	0.8	0.8
7.200	0.8	0.8	0.9	0.9	0.9	1.0	1.0
7.900	1.0	1.1	1.1	1.1	1.1	1.2	1.2
8.600	1.2	1.3	1.3	1.3	1.4	1.4	1.5
9.300	1.6	1.7	1.8	1.9	2.0	2.1	2.2
10.000	2.3	2.4	2.5	2.6	2.7	2.8	3.1
10.700	3.4	3.8	4.2	4.5	5.1	5.8	6.5
11.400	7.2	7.8	11.4	13.1	17.2	24.1	40.8
12.100	69.6	38.6	22.3	15.8	13.9	10.0	8.5
12.800	7.7	7.0	6.3	5.6	5.1	4.7	4.3
13.500	3.9	3.5	3.4	3.3	3.2	3.1	3.0
14.200	2.9	2.8	2.7	2.6	2.4	2.3	2.2
14.900	2.1	2.0	1.9	1.9	1.9	1.8	1.8
15.600	1.8	1.8	1.7	1.7	1.7	1.7	1.6
16.300	1.6	1.6	1.5	1.5	1.5	1.5	1.4
17.000	1.4	1.4	1.4	1.3	1.3	1.3	1.2
17.700	1.2	1.2	1.2	1.1	1.1	1.1	1.1
18.400	1.1	1.1	1.1	1.1	1.1	1.0	1.0
19.100	1.0	1.0	1.0	1.0	1.0	1.0	1.0
19.800	1.0	1.0	1.0	1.0	1.0	1.0	0.9
20.500	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.200	0.9	0.9	0.9	0.9	0.9	0.9	0.9
21.900	0.8	0.8	0.8	0.8	0.8	0.8	0.8
22.600	0.8	0.8	0.8	0.8	0.8	0.8	0.8
23.300	0.7	0.7	0.7	0.7	0.7	0.7	0.7
24.000	0.8	0.0					

STORM 100-YR

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Peak Flow Time (hr)	Peak Flow Rate (cfs)	Peak Flow Rate (csm)
DA03	0.020		8.474		12.12	127.3	6364.76

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
2.900	0.5	0.5	0.6	0.6	0.6	0.6	0.7
3.600	0.7	0.7	0.8	0.8	0.8	0.8	0.9
4.300	0.9	0.9	1.0	1.0	1.0	1.0	1.1
5.000	1.1	1.1	1.1	1.2	1.2	1.2	1.2
5.700	1.2	1.3	1.3	1.3	1.4	1.4	1.4
6.400	1.5	1.5	1.6	1.6	1.7	1.7	1.8
7.100	1.8	1.9	1.9	2.0	2.1	2.1	2.2
7.800	2.2	2.3	2.3	2.4	2.4	2.5	2.5
8.500	2.6	2.6	2.7	2.7	2.8	2.9	3.0
9.200	3.2	3.3	3.5	3.7	3.9	4.0	4.2
9.900	4.4	4.6	4.7	4.9	5.1	5.3	5.5

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
10.600	6.0	6.7	7.3	8.0	8.7	9.8	11.0
11.300	12.3	13.6	14.6	21.2	24.0	31.6	43.8
12.000	73.5	124.0	68.3	39.3	27.7	24.5	17.6
12.700	14.9	13.6	12.3	11.0	9.8	8.9	8.3
13.400	7.6	6.9	6.2	5.9	5.7	5.5	5.4
14.100	5.2	5.0	4.8	4.6	4.5	4.3	4.1
14.800	3.9	3.7	3.6	3.4	3.3	3.3	3.2
15.500	3.2	3.1	3.1	3.0	3.0	2.9	2.9
16.200	2.8	2.8	2.7	2.7	2.6	2.6	2.5
16.900	2.5	2.5	2.4	2.4	2.3	2.3	2.2
17.600	2.2	2.1	2.1	2.0	2.0	1.9	1.9
18.300	1.9	1.9	1.9	1.9	1.9	1.8	1.8
19.000	1.8	1.8	1.8	1.8	1.8	1.8	1.7
19.700	1.7	1.7	1.7	1.7	1.7	1.7	1.7
20.400	1.7	1.6	1.6	1.6	1.6	1.6	1.6
21.100	1.6	1.6	1.6	1.5	1.5	1.5	1.5
21.800	1.5	1.5	1.5	1.4	1.4	1.4	1.4
22.500	1.4	1.4	1.4	1.4	1.4	1.4	1.3
23.200	1.3	1.3	1.3	1.3	1.3	1.3	1.2
23.900	1.2	1.5	0.0				

Area or Reach Identifier	Drainage Area (sq mi)	Rain Gage ID or Location	Runoff Amount (in)	Peak Flow Elevation (ft)	Time (hr)	Rate (cfs)	Rate (csm)
OUTLET	0.020		8.474		12.12	127.3	6364.76

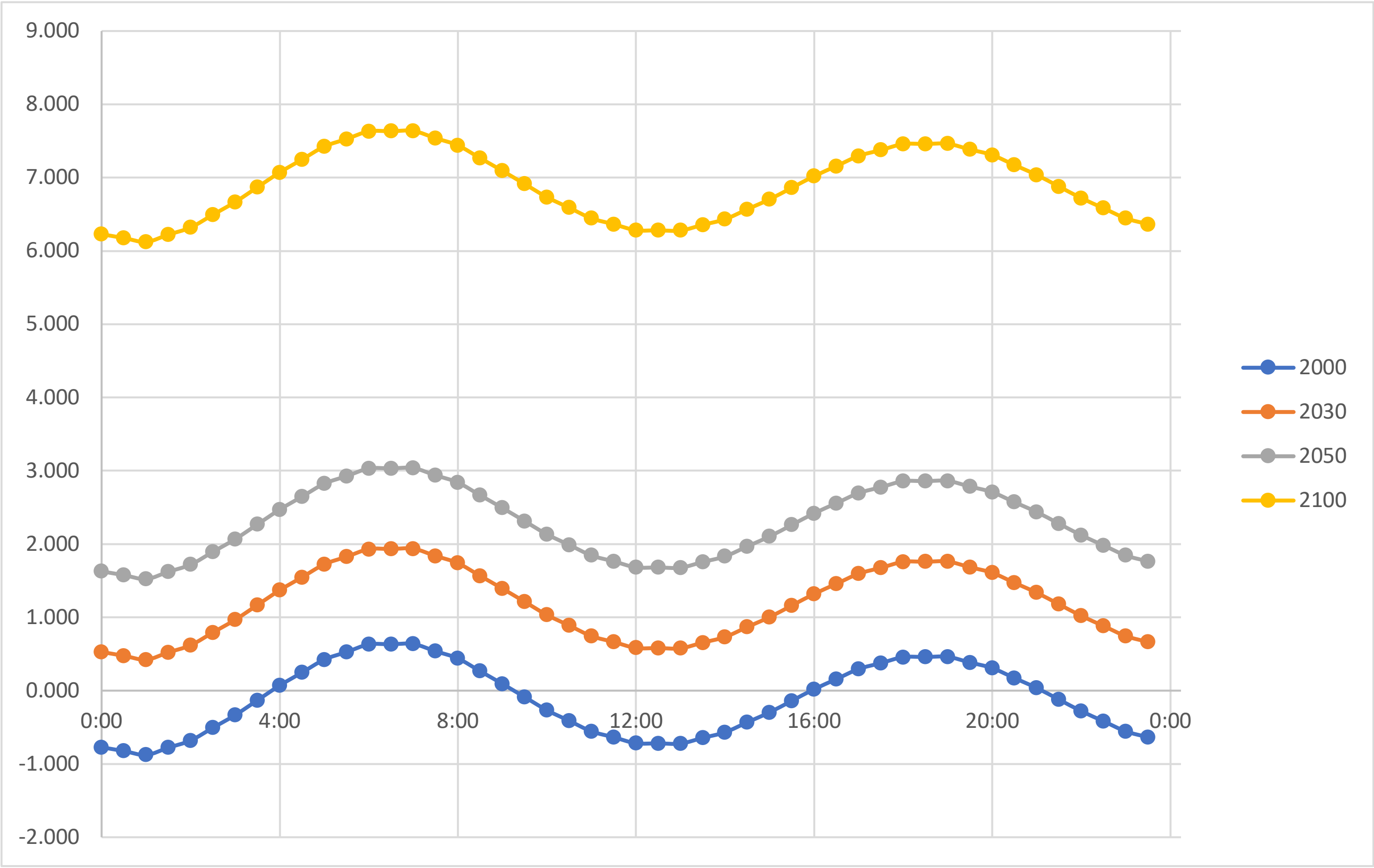
Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
2.900	0.5	0.5	0.6	0.6	0.6	0.6	0.7
3.600	0.7	0.7	0.8	0.8	0.8	0.8	0.9
4.300	0.9	0.9	1.0	1.0	1.0	1.0	1.1
5.000	1.1	1.1	1.1	1.2	1.2	1.2	1.2
5.700	1.2	1.3	1.3	1.3	1.4	1.4	1.4
6.400	1.5	1.5	1.6	1.6	1.7	1.7	1.8
7.100	1.8	1.9	1.9	2.0	2.1	2.1	2.2
7.800	2.2	2.3	2.3	2.4	2.4	2.5	2.5
8.500	2.6	2.6	2.7	2.7	2.8	2.9	3.0
9.200	3.2	3.3	3.5	3.7	3.9	4.0	4.2
9.900	4.4	4.6	4.7	4.9	5.1	5.3	5.5
10.600	6.0	6.7	7.3	8.0	8.7	9.8	11.0
11.300	12.3	13.6	14.6	21.2	24.0	31.6	43.8
12.000	73.5	124.0	68.3	39.3	27.7	24.5	17.6
12.700	14.9	13.6	12.3	11.0	9.8	8.9	8.3
13.400	7.6	6.9	6.2	5.9	5.7	5.5	5.4
14.100	5.2	5.0	4.8	4.6	4.5	4.3	4.1
14.800	3.9	3.7	3.6	3.4	3.3	3.3	3.2
15.500	3.2	3.1	3.1	3.0	3.0	2.9	2.9
16.200	2.8	2.8	2.7	2.7	2.6	2.6	2.5

Line Start Time (hr)	Flow Values @ time increment of 0.100 hr (cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
16.900	2.5	2.5	2.4	2.4	2.3	2.3	2.2
17.600	2.2	2.1	2.1	2.0	2.0	1.9	1.9
18.300	1.9	1.9	1.9	1.9	1.9	1.8	1.8
19.000	1.8	1.8	1.8	1.8	1.8	1.8	1.7
19.700	1.7	1.7	1.7	1.7	1.7	1.7	1.7
20.400	1.7	1.6	1.6	1.6	1.6	1.6	1.6
21.100	1.6	1.6	1.6	1.5	1.5	1.5	1.5
21.800	1.5	1.5	1.5	1.4	1.4	1.4	1.4
22.500	1.4	1.4	1.4	1.4	1.4	1.4	1.3
23.200	1.3	1.3	1.3	1.3	1.3	1.3	1.2
23.900	1.2	1.5	0.0				

Area or Reach Identifier	Drainage Area (sq mi)	----------- Peak Flow by Storm ----------- 1-YR (cfs)	10-YR (cfs)	100-YR (cfs)	(cfs)	(cfs)
DA03	0.020	34.7	71.5	127.3		
OUTLET	0.020	34.7	71.5	127.3		

North Beach Assessment
Forecasted Tide Cycles

Time	Forecast Year				
	2000	2030	2050	2100	
0:00	-0.772	0.528	1.628	6.228	
0:30	-0.824	0.476	1.576	6.176	
1:00	-0.876	0.424	1.524	6.124	MLLW
1:30	-0.778	0.522	1.622	6.222	
2:00	-0.680	0.620	1.720	6.320	
2:30	-0.506	0.794	1.894	6.494	
3:00	-0.333	0.967	2.067	6.667	
3:30	-0.131	1.169	2.269	6.869	
4:00	0.071	1.371	2.471	7.071	
4:30	0.247	1.547	2.647	7.247	
5:00	0.423	1.723	2.823	7.423	
5:30	0.527	1.827	2.927	7.527	
6:00	0.630	1.930	3.030	7.630	
6:30	0.633	1.933	3.033	7.633	
7:00	0.636	1.936	3.036	7.636	MHHW
7:30	0.538	1.838	2.938	7.538	
8:00	0.440	1.740	2.840	7.440	
8:30	0.266	1.566	2.666	7.266	
9:00	0.093	1.393	2.493	7.093	
9:30	-0.087	1.213	2.313	6.913	
10:00	-0.267	1.033	2.133	6.733	
10:30	-0.411	0.889	1.989	6.589	
11:00	-0.555	0.745	1.845	6.445	
11:30	-0.636	0.664	1.764	6.364	
12:00	-0.717	0.583	1.683	6.283	
12:30	-0.719	0.581	1.681	6.281	
13:00	-0.721	0.579	1.679	6.279	MLW
13:30	-0.645	0.655	1.755	6.355	
14:00	-0.568	0.732	1.832	6.432	
14:30	-0.432	0.868	1.968	6.568	
15:00	-0.296	1.004	2.104	6.704	
15:30	-0.139	1.161	2.261	6.861	
16:00	0.019	1.319	2.419	7.019	
16:30	0.157	1.457	2.557	7.157	
17:00	0.295	1.595	2.695	7.295	
17:30	0.376	1.676	2.776	7.376	
18:00	0.457	1.757	2.857	7.457	
18:30	0.459	1.759	2.859	7.459	
19:00	0.461	1.761	2.861	7.461	MHW
19:30	0.385	1.685	2.785	7.385	
20:00	0.308	1.608	2.708	7.308	
20:30	0.172	1.472	2.572	7.172	
21:00	0.036	1.336	2.436	7.036	
21:30	-0.121	1.179	2.279	6.879	
22:00	-0.279	1.021	2.121	6.721	
22:30	-0.417	0.883	1.983	6.583	
23:00	-0.555	0.745	1.845	6.445	
23:30	-0.636	0.664	1.764	6.364	
0:00	-0.717	0.583	1.683	6.283	



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3/2/2023; 9:34 AM
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Typical Tide Cycle_FIG

BayLand Consultants & Designers, Inc.

90th Percentile Flooding Summary			
YEAR	STORM EVENT	TOTAL NODES FLOODED	
		EX	PR
2030	1-YR	14	2
2050	1-YR	17	3
2030	10-YR	35	2
2050	10-YR	39	4
2030	100-YR	59	8
2050	100-YR	63	10

Flooding at High Priority Areas - Existing Conditions						
High Priority Area	**Hours of Flooding**					
	2030 1-yr	**2030 10-yr**	**2030 100-yr**	**2050 1-yr**	**2050 10-yr**	**2050 100-yr**
Atlantic Avenue	0.0	0.0	0.2	4.3	4.3	4.4
9th Street between Chesapeake Avenue and Atlantic Avenue	1.3	2.1	3.8	1.4	2.2	3.8
Annapolis Avenue between 7th Street and 9th Street	0.4	1.0	1.5	0.4	1.0	1.6
7th Street between Bay Avenue and Atlantic Avenue	2.5	2.5	2.6	18.4	18.4	18.4
Bay Avenue between 5th Street and 7th Street	0.2	0.7	1.2	0.0	0.6	1.3
5th Street between Chesapeake Avenue and Bay Avenue	3.0	5.6	10.3	6.6	6.6	10.3
Chesapeake Avenue between 4th Street and 6th Street	0.0	0.5	0.9	0.0	0.5	0.9
1st Street between Chesapeake Avenue and Bay Avenue	0.0	0.7	1.2	0.0	0.7	1.2
Dayton Avenue between 3rd Street and 6th Street	0.5	1.0	1.6	0.5	1.0	1.6
Frederick Avenue between 3rd Street and 4th Street	0.0	0.4	1.0	0.0	0.4	1.0

Flooding at High Priority Areas - Proposed Conditions						
High Priority Area	**Hours of Flooding**					
	2030 1-yr	**2030 10-yr**	**2030 100-yr**	**2050 1-yr**	**2050 10-yr**	**2050 100-yr**
Atlantic Avenue	0.0	0.0	0.0	4.2	4.3	4.3
9th Street between Chesapeake Avenue and Atlantic Avenue	0.0	0.0	0.0	0.0	0.0	0.0
Annapolis Avenue between 7th Street and 9th Street	0.0	0.0	0.0	0.0	0.0	0.0
7th Street between Bay Avenue and Atlantic Avenue	0.0	0.0	0.0	0.0	0.0	0.0
Bay Avenue between 5th Street and 7th Street	0.0	0.2	0.3	0.0	0.2	0.3
5th Street between Chesapeake Avenue and Bay Avenue	2.5	4.3	8.3	5.6	5.6	8.4
Chesapeake Avenue between 4th Street and 6th Street	0.0	0.0	0.0	0.0	0.0	0.0
1st Street between Chesapeake Avenue and Bay Avenue	0.0	0.0	0.0	0.0	0.0	0.0
Dayton Avenue between 3rd Street and 6th Street	0.0	0.0	0.5	0.0	0.0	0.5
Frederick Avenue between 3rd Street and 4th Street	0.0	0.0	0.5	0.0	0.0	0.5

2030 90th Percentile Node Flooding Summary						
Node	Hours Flooded					
	EX 1-yr	EX 10-yr	EX 100-yr	PR 1-yr	PR 10-yr	PR 100-yr
J12	0.2	0.7	1.2	-	-	-
J14	-	-	-	0.1	0.2	0.3
J15	-	-	0.1	-	-	-
J16	0.6	1.4	2.2	2.5	4.3	8.3
J17	3.0	5.6	10.3	-	-	0.2
J18	1.8	3.3	5.4	-	-	-
J27	-	-	0.1	-	-	-
J28	-	0.2	0.6	-	-	-
J33	-	0.2	0.6	-	-	-
J35	-	0.3	0.7	-	-	-
J36	-	0.5	0.9	-	-	-
J38	-	0.4	0.8	-	-	-
J39	-	0.4	0.9	-	-	-
J37	-	0.2	0.5	-	-	-
J42	0.3	1.0	1.6	-	-	0.5
J43	0.2	0.8	1.4	-	-	-
J45	-	0.4	0.7	-	-	-
J47	-	-	0.2	-	-	-
J49	-	-	0.3	-	-	-
J50	-	-	0.5	-	-	-
J51	-	0.6	1.0	-	-	-
J53	0.5	1.0	1.5	-	-	-
J54	-	-	0.4	-	-	-
J57	-	-	0.3	-	-	-
J58	-	-	0.3	-	-	-
J59	-	-	0.2	-	-	-
J60	-	-	0.1	-	-	-
J62	-	-	0.2	-	-	-
J68	-	-	0.3	-	-	-
J70	-	-	0.3	-	-	-
J74	-	0.2	0.8	-	-	-
J75	-	-	-	-	-	0.5
J77	-	-	0.6	-	-	0.1
J79	-	-	0.6	-	-	-
J80	-	-	0.2	-	-	-
J81	-	0.4	1.0	-	-	0.3
J82	-	-	0.7	-	-	-
J83	-	-	0.1	-	-	-
J86	-	-	0.6	-	-	-
J90	2.5	2.5	2.6	-	-	-
J92	-	0.4	0.7	-	-	-
J94	-	0.7	1.2	-	-	-

2030 90th Percentile Node Flooding Summary						
Node	Hours Flooded					
	EX 1-yr	EX 10-yr	EX 100-yr	PR 1-yr	PR 10-yr	PR 100-yr
J99	0.1	0.6	1.0	-	-	-
J100	0.4	1.0	1.5	-	-	-
J102	-	-	0.2	-	-	-
J103	-	0.4	0.7	-	-	-
J104	-	0.5	0.8	-	-	-
J105	-	0.1	0.5	-	-	-
J107	1.3	2.1	3.8	-	-	-
J115	-	0.6	1.0	-	-	-
J116	-	0.7	1.2	-	-	-
J117	-	0.6	1.1	-	-	-
J132	-	-	-	-	-	-
J148	-	-	0.2	-	-	-
J150	-	-	-	-	-	-
J152	-	-	0.3	-	-	-
J157	-	0.2	0.4	-	-	-
J159	-	0.7	1.2	-	-	-
J161	-	-	-	-	-	-
J163	0.7	1.4	2.0	-	-	-
J164	0.6	1.4	2.0	-	-	-
J165	0.7	1.4	2.0	-	-	-
J169	-	-	0.2	-	-	-
J170	-	-	-	-	-	-
S1	-	-	0.3	-	-	0.3

2050 90th Percentile Node Flooding Summary						
Node	Hours Flooded					
	EX 1-yr	EX 10-yr	EX 100-yr	PR 1-yr	PR 10-yr	PR 100-yr
J12	-	0.6	1.3	-	-	-
J14	-	-	-	-	0.2	0.3
J15	-	-	0.1	-	-	-
J16	0.7	1.4	2.2	2.4	4.3	8.4
J17	2.9	5.7	10.3	-	-	-
J18	1.8	3.3	5.4	-	-	-
J27	-	-	0.1	-	-	-
J28	-	0.2	0.6	-	-	-
J33	-	0.2	0.6	-	-	-
J35	-	0.3	0.7	-	-	-
J36	-	0.5	0.9	-	-	-
J38	-	0.4	0.8	-	-	-
J39	-	0.4	0.9	-	-	-
J37	-	0.2	0.5	-	-	-
J42	0.3	0.9	1.6	-	-	0.5
J43	0.2	0.8	1.4	-	-	-
J45	-	0.4	0.7	-	-	-
J47	-	-	0.2	-	-	-
J49	-	-	0.3	-	-	-
J50	-	-	0.5	-	-	-
J51	-	0.6	1.0	-	-	-
J53	0.5	1.0	1.5	-	-	-
J54	-	-	0.4	-	-	-
J57	-	-	0.3	-	-	-
J58	-	-	0.3	-	-	-
J59	-	-	0.2	-	-	-
J60	-	-	0.1	-	-	-
J62	-	-	0.2	-	-	-
J68	-	-	0.3	-	-	-
J70	-	-	0.3	-	-	-
J74	-	0.2	0.8	-	-	-
J75	-	-	-	-	-	0.5
J77	-	-	0.6	-	-	0.1
J79	-	-	0.6	-	-	-
J80	-	-	0.2	-	-	-
J81	-	0.4	1.0	-	-	0.3
J82	-	-	0.7	-	-	-
J83	-	-	0.1	-	-	-
J86	-	-	0.6	-	-	-
J90	18.4	18.4	18.4	-	-	-
J92	0.1	0.4	0.7	-	-	-
J94	-	0.7	1.3	-	-	-

2050 90th Percentile Node Flooding Summary						
Node	Hours Flooded					
	EX 1-yr	EX 10-yr	EX 100-yr	PR 1-yr	PR 10-yr	PR 100-yr
J99	0.1	0.6	1.0	-	-	-
J100	0.4	1.0	1.6	-	-	-
J102	-	-	0.2	-	-	-
J103	-	0.4	0.7	-	-	-
J104	-	0.5	0.9	-	-	-
J105	-	0.1	0.5	-	-	-
J107	1.4	2.2	3.8	-	-	-
J115	-	0.6	1.0	-	-	-
J116	-	0.7	1.2	-	-	-
J117	-	0.6	1.1	-	-	-
J132	6.6	6.6	6.7	5.6	5.6	5.7
J148	-	-	0.2	-	-	-
J150	-	-	0.1	-	-	-
J152	-	0.5	0.9	-	-	-
J157	-	0.2	0.4	-	-	-
J159	-	0.7	1.2	-	-	-
J161	0.1	0.1	0.3	-	-	-
J163	0.7	1.4	2.0	-	-	-
J164	0.7	1.4	2.0	-	-	-
J165	0.7	1.4	2.0	-	-	-
J169	-	-	0.4	4.2	4.2	4.3
J170	4.3	4.3	4.4	-	-	0.2
S1	-	-	0.3	-	-	0.3

Existing 2030 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J12	0.2	12:43
J16	0.6	12:16
J17	3.0	12:12
J18	1.8	12:12
J42	0.3	12:16
J43	0.2	12:12
J53	0.5	12:12
J90	2.5	0:00
J99	0.1	12:12
J100	0.4	12:12
J107	1.3	12:11
J163	0.7	12:12
J164	0.6	12:12
J165	0.7	12:12

Existing 2030 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J12	0.7	12:11
J16	1.4	12:12
J17	5.6	12:12
J18	3.3	12:12
J28	0.2	12:12
J33	0.2	12:16
J35	0.3	12:12
J36	0.5	12:12
J38	0.4	12:11
J39	0.4	12:12
J37	0.2	12:12
J42	1.0	12:12
J43	0.8	12:12
J45	0.4	12:12
J51	0.6	12:12
J53	1.0	12:12
J74	0.2	12:12
J81	0.4	12:12
J90	2.5	0:00
J92	0.4	0:11
J94	0.7	0:00
J99	0.6	12:12
J100	1.0	12:12
J103	0.4	12:12
J104	0.5	12:12
J105	0.1	12:12
J107	2.1	12:12
J115	0.6	12:12
J116	0.7	11:51
J117	0.6	12:12
J157	0.2	12:12
J159	0.7	12:12
J163	1.4	12:12
J164	1.4	12:12
J165	1.4	12:12

Existing 2030 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J12	1.2	12:12
J15	0.1	12:12
J16	2.2	12:13
J17	10.3	12:12
J18	5.4	12:12
J27	0.1	12:12
J28	0.6	12:12
J33	0.6	12:13
J35	0.7	12:12
J36	0.9	12:12
J38	0.8	12:11
J39	0.9	12:12
J37	0.5	12:12
J42	1.6	12:13
J43	1.4	12:12
J45	0.7	12:12
J47	0.2	12:12
J49	0.3	12:13
J50	0.5	12:12
J51	1.0	12:12
J53	1.5	12:12
J54	0.4	12:10
J57	0.3	12:12
J58	0.3	12:12
J59	0.2	12:12
J60	0.1	12:12
J62	0.2	12:12
J68	0.3	12:12
J70	0.3	12:12
J74	0.8	12:12
J77	0.6	12:12
J79	0.6	12:12
J80	0.2	12:12
J81	1.0	12:12
J82	0.7	12:12
J83	0.1	12:12
J86	0.6	12:12
J90	2.6	12:12
J92	0.7	0:00
J94	1.2	12:12
J99	1.0	12:12

Existing 2030 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J100	1.5	12:12
J102	0.2	12:12
J103	0.7	12:12
J104	0.8	12:12
J105	0.5	12:12
J107	3.8	12:12
J115	1.0	12:12
J116	1.2	12:12
J117	1.1	12:12
J148	0.2	12:12
J152	0.3	12:12
J157	0.4	12:12
J159	1.2	12:12
J163	2.0	12:12
J164	2.0	12:12
J165	2.0	12:12
J169	0.2	12:12
S1	0.3	12:12

Existing 2050 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J16	0.7	12:15
J17	2.9	12:12
J18	1.8	12:12
J42	0.3	12:15
J43	0.2	12:12
J53	0.5	12:12
J90	18.4	12:12
J92	0.1	0:13
J99	0.1	12:12
J100	0.4	12:12
J107	1.4	12:11
J161	0.1	0:12
J163	0.7	12:12
J164	0.7	12:12
J165	0.7	12:12
J170	4.3	0:00
J132	6.6	12:00

Existing 2050 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J12	0.6	12:12
J16	1.4	12:13
J17	5.7	12:12
J18	3.3	12:12
J28	0.2	12:12
J33	0.2	12:14
J35	0.3	12:12
J36	0.5	12:12
J38	0.4	12:12
J39	0.4	12:12
J37	0.2	12:12
J42	0.9	12:13
J43	0.8	12:12
J45	0.4	12:12
J51	0.6	12:12
J53	1.0	12:12
J74	0.2	12:12
J81	0.4	12:12
J90	18.4	12:12
J92	0.4	0:00
J94	0.7	12:12
J99	0.6	12:12
J100	1.0	12:12
J103	0.4	12:12
J104	0.5	12:12
J105	0.1	12:12
J107	2.2	12:12
J115	0.6	12:12
J116	0.7	12:12
J117	0.6	12:12
J152	0.5	12:12
J157	0.2	12:12
J159	0.7	12:12
J161	0.1	0:09
J163	1.4	12:12
J164	1.4	12:12
J165	1.4	12:12
J170	4.3	0:00
J132	6.6	12:00

Existing 2050 100-YR 90th Percentile Flooding Summary		
Node	**Hours Flooded**	**Hour of Maximum Flooding**
J12	1.3	12:12
J15	0.1	12:12
J16	2.2	12:14
J17	10.3	12:12
J18	5.4	12:12
J27	0.1	12:12
J28	0.6	12:12
J33	0.6	12:13
J35	0.7	12:12
J36	0.9	12:12
J38	0.8	12:12
J39	0.9	12:12
J37	0.5	12:12
J42	1.6	12:12
J43	1.4	12:12
J45	0.7	12:12
J47	0.2	12:12
J49	0.3	12:13
J50	0.5	12:12
J51	1.0	12:12
J53	1.5	12:12
J54	0.4	12:12
J57	0.3	12:12
J58	0.3	12:12
J59	0.2	12:12
J60	0.1	12:12
J62	0.2	12:12
J68	0.3	12:12
J70	0.3	12:12
J74	0.8	12:12
J77	0.6	12:12
J79	0.6	12:12
J80	0.2	12:12
J81	1.0	12:12
J82	0.7	12:12
J83	0.1	12:12
J86	0.6	12:12
J90	18.4	12:12
J92	0.7	0:00
J94	1.3	12:12
J99	1.0	12:12

Existing 2050 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J100	1.6	12:12
J102	0.2	12:12
J103	0.7	12:12
J104	0.9	12:12
J105	0.5	12:12
J107	3.8	12:12
J115	1.0	12:12
J116	1.2	12:12
J117	1.1	12:12
J148	0.2	12:12
J150	0.1	12:12
J152	0.9	12:12
J157	0.4	12:12
J159	1.2	12:12
J161	0.3	0:09
J163	2.0	12:12
J164	2.0	12:12
J165	2.0	12:12
J169	0.4	12:12
J170	4.4	12:12
J132	6.7	12:00
S1	0.3	12:12

Proposed 2030 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J14	0.1	13:03
J16	2.5	12:11

Proposed 2030 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J14	0.2	13:42
J16	4.3	12:14

Proposed 2030 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J14	0.3	14:29
J16	8.3	12:11
J17	0.2	17:12
J42	0.5	12:15
J75	0.5	12:12
J77	0.1	12:12
J81	0.3	12:12
S1	0.3	12:12

Proposed 2050 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J16	2.4	12:24
J169	4.2	12:18
J132	5.6	12:43

Proposed 2050 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J14	0.2	13:37
J16	4.3	12:15
J169	4.3	12:12
J132	5.6	11:18

Proposed 2050 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J14	0.3	14:29
J16	8.4	12:12

Existing Subcatchments			
Subcatchment	Receiving Node	Drainage Area (AC)	Q (CFS)
DA1	J11	0.1	1.6
DA2	J12	0.6	7.26
DA3	J13	0.17	2.54
DA4	J14	0.51	6.42
DA5	J15	0.33	4.61
DA6	J17	2.46	18.57
DA7	J18	2.02	16.99
DA8	J20	0.13	2.1
DA9	J21	0.54	7.47
DA10	J22	0.08	1.3
DA11	J23	0.07	1.13
DA12	J26	0.2	3.16
DA13	J25	5.1	27.7
DA14	J27	0.55	6.8
DA15	J28	2.38	18.24
DA16	J29	0.16	1.47
DA17	J30	0.01	0.16
DA18	J31	0.99	10.15
DA19	J32	0.1	1.55
DA20	J33	0.08	1.31
DA21	J34	0.07	1.15
DA22	J35	0.21	3.19
DA23	J36	0.75	8.5
DA24	J37	0.43	5.8
DA25	J38	0.87	9.28
DA26	J39	1.27	12.19
DA27	J42	0.38	5.24
DA28	J43	2.27	17.76
DA29	J44	0.1	1.62
DA30	J45	0.33	4.92
DA31	J46	0.07	1.11
DA32	J47	0.16	2.38
DA33	J48	2.21	17.49
DA34	J50	1.81	16.05
DA35	J51	2.33	18.02
DA36	J52	0.89	10.63
DA37	J53	0.73	9.24
DA38	J54	0.15	2.38
DA39	J55	0.33	4.63
DA40	J56	0.11	1.79
DA41	J57	0.33	4.85
DA42	J58	2.8	19.62
DA43	J59	0.26	3.86
DA44	J60	2.45	18.39

Existing Subcatchments			
Subcatchment	Receiving Node	Drainage Area (AC)	Q (CFS)
DA45	J61	0.41	5.67
DA46	J62	1.67	14.95
DA47	J63	0.2	2.93
DA48	J64	0.47	5.98
DA49	J65	0.32	4.63
DA50	J66	3.94	23.68
DA51	J67	0.33	4.63
DA52	J68	1.54	13.77
DA53	J69	0.22	3.37
DA54	J70	0.84	9.58
DA55	J71	0.28	4.31
DA56	J72	0.13	1.97
DA57	J73	0.29	1.91
DA58	J74	0.95	10.04
DA59	J75	0.14	2.2
DA60	J76	0.06	0.99
DA61	J77	6.47	29.22
DA62	J78	0.14	2.26
DA63	J79	4.37	25.05
DA64	J80	1.69	15.29
DA65	J81	6.47	29.41
DA66	J82	0.13	2.02
DA67	J83	0.86	9.29
DA68	J84	2.88	20.37
DA69	J85	0.15	2.25
DA70	J86	10.07	35.63
DA71	J87	0.05	0.82
DA72	J88	0.14	1.35
DA73	J89	0.04	0.66
DA74	J90	0.33	4.75
DA75	J91	1.14	11.54
DA76	J95	0.72	8.8
DA77	J94	4.27	25.26
DA78	J93	0.72	8.91
DA79	J92	0.22	3.45
DA80	J97	0.27	4.14
DA81	J98	0.09	1.46
DA82	J99	0.36	5.04
DA83	J100	0.87	9.67
DA84	J102	0.15	2.37
DA85	J103	0.18	2.73
DA86	J104	0.75	9.78
DA87	J105	1.37	12.9
DA88	J106	0.41	2.12

Existing Subcatchments			
Subcatchment	**Receiving Node**	**Drainage Area (AC)**	**Q (CFS)**
DA89	J107	0.26	3.85
DA90	J109	0.02	0.33
DA91	J110	0.19	2.97
DA92	J111	0.33	4.81
DA93	J112	0.45	6.3
DA94	J113	0.2	3.01
DA95	J114	1.34	3.09
DA96	J115	1.99	16.96
DA97	J116	0.18	2.81
DA98	J117	3.02	21.46
DA100	J133	0.15	2.32
DA101	J142	0.68	8.38
DA102	J141	0.14	2.27
DA103	J137	0.1	1.63
DA104	J138	1.99	3.19
DA106	S1	1.44	13.64
DA107	J154	0.52	7.11
DA108	J156	0.061	1
DA109	J155	0.67	8.34
DA110	J158	0.34	5.01
DA111	J159	4.41	25.8
DA112	J160	0.36	5.26
DA113	J153	0.49	6.83
DA114	J161	0.51	6.55
DA115	J152	1	10.73
DA116	J151	0.16	2.56
DA117	J150	1	21.46
DA118	J146	0.38	5.49
DA119	J148	1.26	13.32
DA120	J147	0.47	6.47
DA121	J149	0.42	5.92
DA122	J145	1.87	16
DA123	J144	0.87	10.28
DA124	J143	0.64	8.15
DA125	J163	0.17	2.31
DA126	J165	0.17	2.02
DA127	J164	0.09	1.24
DA128	J162	0.01	0.16
DA130	J169	0.4	1.64
DA131	J170	0.25	3.73