Climate Resiliency Assessment Technical Memorandum
North and South Easton Pond Reservoirs

City of Newport
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FUSS & O'NEILL

WOODS HOLE GROUP

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Executive Summary

The North and South Easton Ponds Dams, located in Newport and Middletown, comprise a critical portion of the City of Newport Department of Utilities – Water Division (NWD) safe yield. The objective of this study is to provide a climate change resiliency assessment and identify potential alternatives to improve resiliency of this water supply infrastructure which will support the City's planning for capital improvements.

In order to complete this assessment, a probabilistic model of the projected future sea level rise and coastal storm surge risk for the North and South Easton Pond Dams was completed. The assessment indicated the following vulnerabilities:

- Sea level rise (SLR) effects on the mean higher high water (MHHW) surface elevations during non-storm conditions are not likely to result in overtopping of the South or North Easton Pond Dams.
- Present day, there is a 5% annual chance of saltwater inundation at South Easton Pond and a 1% annual chance of saltwater inundation at North Easton Pond due to the effect of storm surge.
- By 2030, there will a 10% annual chance of saltwater inundation at South Easton Pond and a 2% annual chance of saltwater inundation at North Easton Pond, due to the combined effects of SLR and storm surge.
- A screening level hydrologic and hydraulic (H&H) analysis was completed to assess the spillway capacities of the North and South Easton Ponds Dams under present-day storm surge and projected sea-level rise scenarios for flood events generated from inland storms. The half of the probably maximum flood (½ PMF) event was selected as a spillway design flood for the purpose of the screening level evaluation. The evaluation indicated the following:
    - Saltwater intrusion into South Easton Pond via the spillway is anticipated for present day and projected coastal flood events with a 50-year or greater return frequency (2% Annual Exceedance Probability (AEP)).
    - South Easton Pond Dam embankment is vulnerable to overtopping under the present day SDF when storm surge at Easton Bay is considered. Under projected SLR scenarios, South Easton Pond Dam embankment is anticipated to be overtopped during 100 year storm surge events (1% AEP) by 2030 and 50 year storm surge events (2% AEP) by 2050 when storm surge at Easton Bay is considered.
    - Saltwater intrusion into North Easton Pond via the spillway is anticipated for present day and 2030 and 2050 projected storm surge flood events with a 100-year or greater return frequency (1% AEP).
    - By 2070, North Easton Pond is vulnerable to salt water intrusion via the spillway for events associated with the 50-year and greater storm surge return period (2% AEP).
    - Under present day 500 year storm surge conditions, the South Easton Pond embankments are overtopped by approximately 2.3 feet. The North Easton Pond embankment is overtopped by approximately 0.4 feet.

- Under the projected 2070 SDF and 500 year storm surge scenario, South Easton Pond's embankment is overtopped by approximately 5.6 feet. The North Easton Pond's embankment is overtopped by approximately 3.3 feet.

Based on the findings of this climate change resiliency assessment, portions of the dams are vulnerable to sea level rise and increased frequency and intensity of coastal storms and precipitation. Potential alternatives to improve the resiliency of the embankments and spillways were identified and summarized as follows:

Alternative Number	Detailed description	Order of Magnitude Cost
1 - Modifications to Current Spillway Configuration plus Emergency Spillway	Increase embankment height at South Easton Pond Dam, provide emergency spillway at South Easton Pond Dam, fit South Easton Pond Dam spillway with coastal storm barrier	$16,100,000 to $34,500,000
2 - Modifications to Current Spillway Configuration	Increase the embankment height at South Easton Pond Dam, fit North Easton Pond Dam and South Easton Pond Dam spillways with coastal storm barriers	$17,700,000 to $37,100,000
3 - Temporary Retreat	Focus mid-term improvements on North Easton Pond Dam to protect the North Easton Pond Dam against coastal storms.	$8,300,000 to $17,600,000
4 - Adaptive Spillway Capacity	Increase embankment height at the South Easton Pond Dam and reconfigure South Easton Pond Dam spillway with coastal storm barrier	$16,400,000 to $35,100,000

Alternative 2 and Alternative 4 are recommended to be further studied for feasibility. Alternative 2 and 4 are relatively cost effective compared to the other alternatives and Alternative 4 provides an ancillary benefit as it allows the City to modify the impoundment level through operation of the proposed gates. Alternative 1 is not feasible as it requires a 1,700 foot long emergency spillway to provide adequate flood conveyance for inland storms. Alternative 3 would result in the potential repeated inundation of the South Easton Pond Dam, which may result in the loss of this resource. Recommendations to advance or refine the analyses supporting development of the conceptual alternatives include:

- Complete a detailed topographic survey
- Complete an engineering assessment to evaluate raising the embankment of the South Easton Pond or providing a parapet wall structure
- Identify a design life for the respective proposed resiliency measures
- Complete an Incremental Hazard Evaluation for Inflow Design Flood (IDF) Determination to identify the spillway design flood.
- To ensure that climate change considerations are recognized in future hydrologic assessments, identify a suitable Flood Magnification Factor (FMF) to apply to the inland storm flows generated by the SDF.
- Include an assessment of flow through the Moat channel during inland and coastal storm events in future modeling to identify locations where water surface elevations could potentially result in overtopping of the South Easton Pond Dam embankments.
- Consider the impact to the City related to water supply management of having one or both of the Easton Pond reservoirs temporarily off-line during periods where the system is recovering from a saltwater incursion.
- Upon completion of the feasibility study, develop order of magnitude costs of construction.

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1 Project Study and Assessments Overview

The City of Newport Department of Utilities – Water Division (NWD) has retained Fuss & O'Neill, Inc. (F&O) to complete an assessment of potential climate change projections to evaluate potential risks and impacts to existing water supply infrastructure associated with the North and South Easton Pond Dams in Newport and Middletown, RI. Fuss & O'Neill completed this study with the assistance of Woods Hole Group (WHG) of East Falmouth, MA, which assessed coastal sea-level rise and storm surge projections. This technical memorandum has been prepared in accordance with our proposal and includes the following primary tasks

Figure 1 – Assessment Area Map

- Perform a climate change resiliency assessment for the North and South Easton Pond Dams to assess their vulnerability to projected sea level rise and increased frequency and intensity of coastal storms and precipitation.
- Perform a feasibility evaluation of alternatives for increasing the resiliency of these water supply dams to projected climate change impacts, identify permitting requirements, anticipated construction costs and after review and discussion of the alternatives with the NWD, develop recommended next steps in support of future implementation.
- Conduct an evaluation of FEMA, NOAA, CRMC and other coastal mapping projections for this region.
    - Conduct a statistical analysis of potential coastal storm severity/probability in order to provide an improved assessment of potential future conditions. This will help inform the NWD's consideration of modifications to protect infrastructure from future coastal storm events under sea level rise conditions.
    - Conduct a screening level evaluation of the South Easton Pond Dam spillway's adequacy to convey flood flows under current and future conditions.

1.1 Project Location

The North and South Easton Ponds are raw water supply reservoirs for the NWD and are located adjacent to Easton Bay and north of Memorial Boulevard in Newport and Middletown.

North Easton Pond Dam (State ID 584) is a 14-foot high dam that impounds approximately 574 acre-feet at the normal pool elevation. South Easton Pond Dam (State ID585) is a 12-foot high dam along its southern embankment and impounds approximately 1,225 acre-feet at its normal pool elevation.

Figure 2 – Aerial View of North and South Easton Ponds

1.2 Project Background and Purpose

The NWD operates and maintains the raw water supply reservoirs, embankments, withdrawal/pumping systems, and treatment/ distribution systems for residents and businesses in the City of Newport, the Town of Middletown and a portion of the Town of Portsmouth.

As part of this system, the North and South Easton Ponds are noted to comprise a critical portion of the NWD's safe yield. The NWD seeks to address issues associated with the dams associated with the City's water supply. The objective of this study is to provide an initial assessment model identifying inundation probabilities over several time projections to mitigate risks associated with sea level rise and climate change to support the City's planning for capital improvements.

Figure 3 – Emergency Repairs to Damaged South Easton Pond West Embankment in April 2007 North and South Easton Ponds

The NWD completed a comprehensive assessment of the South and North Easton Pond Dam's spillways and embankments in 2007 following a significant coastal storm that nearly breached South Easton Pond's west embankment. The NWD proceeded to undertake emergency repairs and subsequently designed and completed construction of repairs and improvements to approximately 3,000 feet of damaged embankment in 2014.

The initial assessment in 2007 identified a number of recommended repairs and maintenance actions at other locations on the southern, eastern and northern embankments. These recommendations were prioritized as short- and long-term actions, some of which included further investigations to allow refined assessments of conditions and repair and improvement options at the dams.

A condition assessment of the earthen embankments and spillway structures impounding the North and South Easton Pond Dams was completed by Fuss & O'Neill in 2016 as part of a separate task, which identified areas where maintenance and repair actions are warranted. This assessment of current conditions provides an updated understanding of the deterioration these structures are experiencing due to a number of environmental conditions including wave action, flood flows and scour, woody vegetation growth and wildlife activity.

The inspections and evaluations have identified areas of concern, conceptual repair options, and maintenance, deficiencies in the actual physical components of the dam, and vulnerability to current and future flood and/or storm surge damages. This evaluation is intended to evaluate future conditions, specifically projected increases of coastal flooding and storm surges indicated by recent coastal mapping studies and ensure that any repair strategy recognizes the potential future conditions, such that appropriate planning and prioritization of funding allocations to respective repairs and improvements can be made.

Figure 4 – South Easton Pond Dam Spillway Structure

In addition to condition assessments, the flood conveyance capacity and the potential for impact to the dams from current and projected storm surge conditions is being assessed under this study. The impact of potential sea level rise and storm surge increases on the South Easton Pond Dam will be evaluated using analyses and assessments previously developed by Fuss & O'Neill for related projects. They include:

- a model of hydrologic and hydraulic conditions developed by Fuss & O'Neill from its evaluation of moat channel drainage characteristics and flooding of adjacent areas,
- assessment of tidal and sea level rise influences undertaken by Fuss & O'Neill to support design of the UV treatment facility adjacent to the Memorial Boulevard culvert crossing.

Evaluation of dam breach inundation scenarios for the North and South Easton Pond Dams undertaken by Fuss & O'Neill for development of Emergency Action Plans. An overview of the locations, configurations and general conditions of these dams is provided below.

1.2.1 North Easton Pond Dam

North Easton Pond is located immediately upstream of the South Easton Pond and adjacent to the NWD's Station 1 treatment facility. It has a total embankment length of approximately 2,800-feet, which includes a low, earthen embankment dividing the North and South Easton Ponds. Its main spillway at the eastern end of this dividing embankment is approximately 130-feet in length.

A heavily vegetated emergency overflow spillway and discharge channel exists adjacent to the treatment plant, having a spillway length of approximately 100-feet. A number of gated conduits pass through this embankment, hydraulically connecting these ponds, while one or more water mains or intake pipes reportedly run below the length of the embankment to the treatment facility. A grassed earthen embankment, portions of which are maintained by mowing, continues to the north adjacent to the treatment facility.

Figure 5 – North Eastern Pond Dam
West Embankment

1.2.2 South Easton Pond Dam

South Easton Pond is located downstream of the North Easton Pond and the Station 1 treatment facility. The South Easton Pond is located adjacent to residential neighborhoods, a state highway and a public beach, and was constructed in portions of what was historically a low lying marsh area, therefore requiring the construction of a ring dike around the entire impoundment.

The earthen embankment forming the ring dike has a very narrow crest width and steep slopes which has made maintenance of the dike difficult in the past. Recent reconstruction of the impoundment's northern and western embankments has improved accessibility for maintenance equipment by widening the crests and flattening/armoring upstream and downstream slopes. The armoring of the slopes has also made the embankment more resistant to erosion damage due to reservoir wave action and flood flows in the moat.

Figure 6 – South Easton Pond Dam Overview

Figure 7 – Moat Channel along South Easton Pond North Embankment Spillway Structure (Post-Storm, April 2007)

As noted above, a drainage moat surrounds the majority of the ring dike. The moat was primarily intended to act as a discharge channel to convey outflow from the secondary spillway at the North Easton Pond Dam. Due to the existing topography, the moat also intercepts stormwater runoff from other upland areas to the north and west of the South Easton Pond. The moat ultimately discharges under Memorial Avenue to the south. The moat has limited hydraulic capacity and allows drainage flow to attain scouring velocities causing damage to the earthen embankments, particularly at the south end of the western embankment adjacent to Old Beach Road, and along the length of the southern embankment.

Elevated water levels due to heavy rainfall and the flat hydraulic profile of the moat also saturates the downstream toe of these embankments, making them more susceptible to erosion and cleaving, and more prone to rutting and damage from mowing equipment. Erosion of this channel toward these embankments' downstream slope is gradually reducing the overall width of these embankments, contributing to increased potential for seepage from the reservoir and reduced overall stability.

2 Coastal Sea Level Rise Assessment

As part of the current evaluation program, Woods Hole Group conducted a review of several public-domain mapping portals projecting future sea level rise (SLR) conditions at coastal regions in Rhode Island and across the country.

Woods Hole Group completed a preliminary probabilistic mapping assessment for the site to provide an evaluation of projected future sea level rise (SLR) and coastal storm surge risk at the site. While this effort does not consist of a full dynamic probabilistic model that includes flow dynamics and propagation over land, it is based on detailed hydrodynamic modeling of storms, waves, winds, and sea level rise along the coastline of Easton's Bay. As such, it provides more accurate and detailed information than is available from publicly available mapping products (e.g., RICRMC sea level rise mapping) since it includes the dynamic processes associated with coastal storm events coupled with SLR. The probabilistic approach also provides the distribution of risk that can inform decisions to conduct further refined assessments and allow the NWD to prioritize adaptations to the most critical areas.

The objective of these assessments is to provide the city with a critical review of existing tools, and supplement these tools with more actionable (probabilistic) information to facilitate climate change planning and prioritize adaptation and resiliency measures. These assessments are described in the following sections.

2.1 Review of Existing Mapping Products

A number of tools have been developed to support the assessment of vulnerability to current and potential future coastal flooding, including sea level rise and storm surge. Woods Hole Group conducted a critical review and examined the results at Easton Pond for the following coastal inundation mapping resources:

- FEMA Flood Insurance Rate Maps (FIRMs)
- NOAA Sea, Lake, and Overland Surges from Hurricanes Model (SLOSH)
- NOAA Sea Level Rise and Coastal Flooding Impacts (v2.0)
- RICRMC Individual Inundation Layers for Projected Sea Level Rise
- Climate Central Surging Seas Risk Zone Map
- RICRMC Flood Inundation Maps for Multiple Return Periods

The mapping methodologies and site-specific results are presented in the following sections. Generally, FIRMs and the SLOSH model use historical data to model and predict inundation associated with storm surge, wave run-up and precipitation (FIRMs) or hurricane storm surge (SLOSH). Neither FIRMs nor SLOSH, as it has been currently applied by NOAA, account for future conditions (sea-level rise, landform subsidence/rebound, changing storm intensity).

The various sea level rise viewers utilize a modified bathtub approach to assessing the interaction between the total water surface elevation and the land elevation. These maps do not reflect the dynamic nature of coastal flooding, do not account for joint (i.e. river discharge and storm surge) flooding conditions (though do address storm surge in support of preliminary assessments), and do not account for the variations in tides and how that influences frequency of occurrence. While bathtub based approaches are reasonable to evaluate static increases in water level (e.g., increases in mean water level due to SLR), they are inadequate when considering impacts of storm conditions, and or storms coupled with SLR. Bathtub approaches ignore significant processes (e.g., waves, dynamic winds) that occur during coastal storm events that can influence flooding conditions.

These sea level rise tools generally employ incremental visualizations without associating those water levels to any modeled or estimated planning horizon. To put these sea level rise visualizations in perspective, it is useful to refer to the global sea level rise (SLR) scenarios presented in the U.S. National Climate Assessment (NOAA, 2012), which require local adjustment for regional/local ocean dynamics as well as for vertical land movement, which are provided in *Table 1* below for Newport, RI.

Table 1
U.S. National Climate Assessment
National SLR Projections

Scenario	SLR by 2100 (NAVD88, ft.[1])
Highest	6.6
Intermediate-High	3.9
Intermediate-Low	1.6
Lowest	0.7

The capabilities and limitations of the existing and publically available coastal inundation mapping products reviewed for this project are summarized below.

Table 2
Capabilities and Limitations of Public-Domain Future SLR Coastal Inundation Mapping Products

	SLR	Storm surge (tropical)	Storm surge (extra-tropical)	Waves	Storm water runoff	River discharge	Current storm conditions	Future storm conditions	Hydrodynamic model
FEMA FIRMs		✓	✓	✓	✓	✓	✓		
NOAA SLOSH		✓					✓		
NOAA Sea Level Rise and Coastal Flooding Impacts (v2.0)	✓								
RICRMC Individual Inundation Layers for Projected Sea Level Rise	✓								
Climate Central Surging Seas Risk Zone Map	✓								
RICRMC Flood Inundation Maps for Multiple Return Periods	✓	✓					✓		

The available tools indicate that saltwater incursion to South Easton Pond occurs when the water surface elevation in Easton Bay reaches 5.8 feet above current Mean Higher High Water (MHHW). Saltwater incursion to North Easton Pond occurs after saltwater incursion to the

[1] Unless noted otherwise, all elevations noted within this report refer to the North American Vertical Datum 1988 (NAVD88).

south pond and the water surface elevation of South Easton Pond reaches approximately 2.1 feet above the normal water surface elevation.

- According to the SLR scenarios presented in the U.S. National Climate Assessment (NOAA, 2012), this magnitude of SLR is approximately associated with the highest SLR scenario for 2100 (*Table 1*). However, storm surge and wave overtopping can combine with SLR to have similar impacts on a much shorter time horizon.
- Easton Pond falls within the 1% annual chance floodplain on the current FEMA Flood Insurance Rate Map (FIRM).
- SLOSH indicates that any hurricane, even a Category 1 with low wind speeds and a non-direct storm track, can inundate South Easton Pond and eventually North Easton Pond.
- RICRMC's data indicates that South Easton Pond is within the current 25-year base flood level, and North Easton Pond is within the current 100-year base flood level.

A more detailed review and assessment of the respective mapping products is provided in the following sections.

2.1.1 FEMA Flood Insurance Rate Maps (FIRMS)

Flood zones shown on Flood Insurance Rate Maps (FIRMS) inform insurance rates, but also serve as tools for communities and flood plain managers to understand the risk associated with local flooding and mitigate potential flooding hazards. FIRMS are developed under the Federal Emergency Management Agency (FEMA) and the National Flood Insurance Program (NFIP).

The flood zone mapping process is a lengthy and detailed 3-5 year process that, in this region, utilizes mapping software to model the effects of flooding within entire watersheds (HEC-RAS), compute wave run up elevation based on still water elevation and shore profiles (RUNUP), or determine wave crest elevations based on transects located in areas of major topographic/vegetated/cultural features (WHAFIS). The mapping process results in the determination of a variety of flood zones (VE, AE, AO, A, X) which are based on the 1% annual chance floodplain.

Flood Insurance Studies (FIS) serve as a repository of all data and analyses that support the determination of flood insurance rates for specific areas. Flood Insurance Studies reports, effective FIRMS, and available GIS shapefiles showing flood zones are accessible from the online FEMA Flood Map Service Center website, allowing communities to immediately understand their flood risk. However, FIRMS and supporting material do not consider probable future scenarios of flooding as they are based on local existing conditions only.

The primary purpose of the FIRMS and supporting material is to determine flood insurance rates, which are based on the 1% annual chance floodplain and do not calculate the potential duration of inundation. The biggest limitation; however, is that the FEMA analysis is solely focused on historic storm events and does not include any future climate projections or SLR.

2.1.1.1 Evaluation of FEMA Mapping for Easton Bay and Easton Ponds

An evaluation of FEMA's model approach and mapping resulted in the following findings.

- The most current FEMA Flood Insurance Study (FIS) for Newport County is dated September 4, 2013 (FEMA, 2013). As shown in *Figure 8* below, FEMA characterizes South Easton Pond as a Special Flood Hazard Area (SFHA) in the velocity zone with a base flood elevation (BFE) of 16 ft. NAVD88 (VE16).

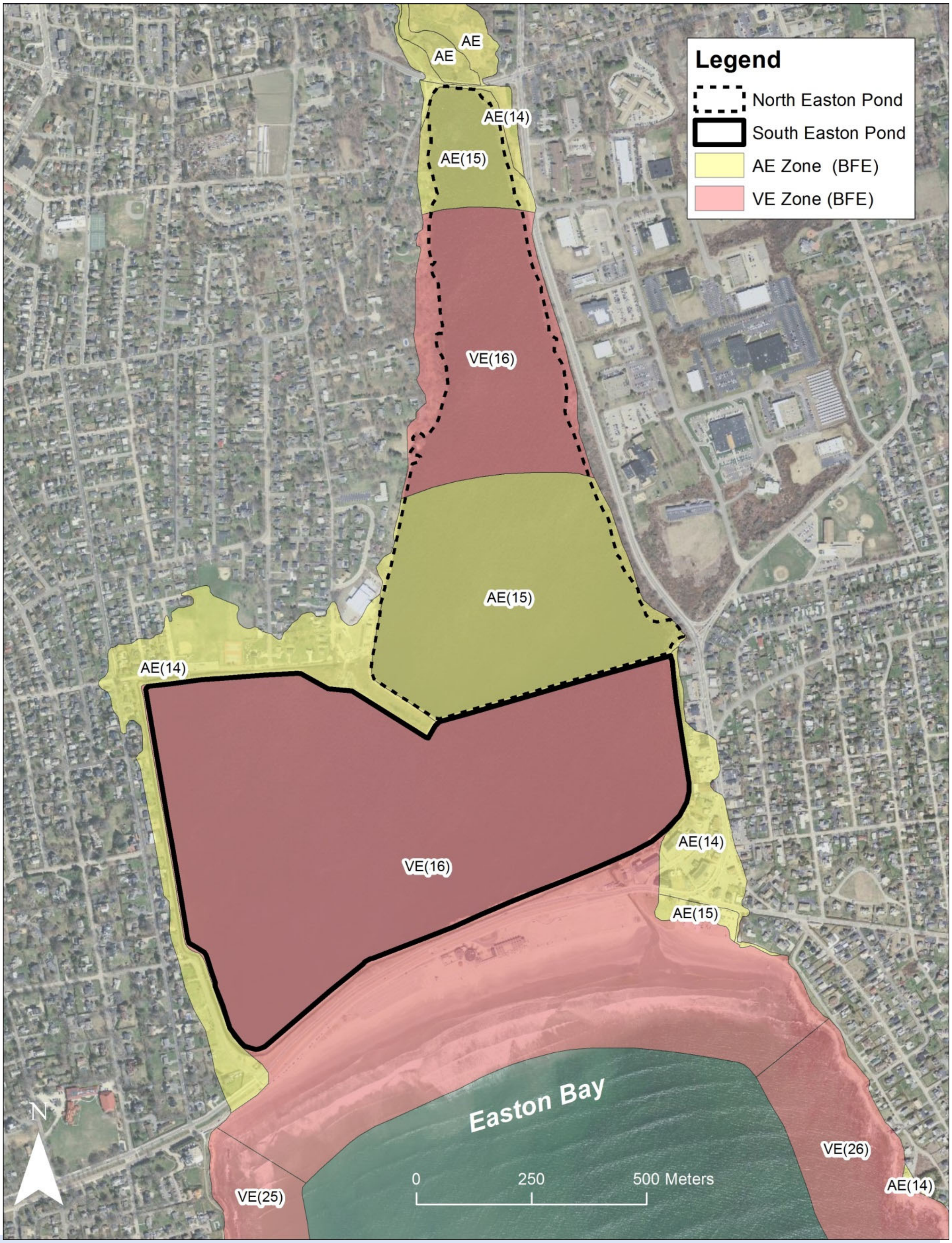


Figure 8 – FEMA Flood Insurance Study (FIS) Mapping at Easton Pond and Easton Bay (dated September 4, 2013)

- North Easton Pond is characterized as a SFHA with a BFE of 15 ft. NAVD88 (AE15) from the upper spillway to the northern extent of Friends Drive, and in the velocity zone (VE16) from Friends Drive to Johnny Cake Hill, due to wind-driven wave build up along the length of the pond.
- North of Johnny Cake Hill, the most landward section of North Easton Pond decreases to AE15.
- Based on local elevation data, the BFE characterizations of Easton Pond are reasonable as they follow appropriate topographic contour lines.
- The WHAFIS flooding parameters used in this FIS included an offshore wave height of 25 feet and a 10second period, which is appropriate for this area.
- It was noted in the FIS that computing wave setup (3.46 feet in this study) to determine total water level was completed by the Direct Integration Method. There is some concern that this method is conservative in that it over-predicts the wave setup height (SWAN 1D may be more appropriate).
- Overall, Easton Pond is mapped in the 1% annual chance floodplain and, therefore, is expected to be vulnerable to saltwater incursion during a current 100-year storm event.

2.1.1.2 Conclusion

FEMA FIRMs are not an appropriate tool for evaluating site-specific vulnerability to coastal climate change impacts because they do not account for potential future sea level rise, do not account for potential future intensification of storms, and have a coarse resolution of analysis.

2.1.2 NOAA Sea, Lake, and Overland Surges from Hurricanes Model

The National Weather Service developed the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model in order to understand storm surges associated with hurricanes. By utilizing various hurricane data/parameters (e.g. atmospheric pressure, forward speed), the wind field driving storm surges can be modeled for historical, hypothetical and predicted hurricanes.

The SLOSH Model uses three approaches to model storm surges – deterministic, probabilistic, and composite.

- The deterministic approach uses a series of physics equations. This method conducts a single simulation requiring intensely accurate weather data, which increases the amount of inherent track errors.
- The probabilistic approach, specifically the Probabilistic Surge (P-Surge), uses historical forecast data to perform model runs. The P-surge product describes the chances that a specific surge height will occur at a specific location and accounts for errors in the cross track, along track, intensity and size of past forecasts.

- The composite approach includes the running of SLOSH thousands of times using different storm conditions of hypothetical hurricanes to produce the Maximum Envelopes of Water (MEOWs) and Maximum of MEOWs (MOMs). This approach is regarded as the best approach for modeling hurricane storm surge because it accounts for the uncertainty in forecasts.

2.1.2.1 Evaluation of SLOSH Mapping for Easton Bay and Easton Ponds

An evaluation of NOAA's SLOSH model and mapping resulted in the following findings.

- The SLOSH model is computationally efficient and regionally adjusted to 32 individual basins along the U.S. Atlantic Coast and Gulf of Mexico. The basins are strategically placed in areas at risk for storm surge based on the configuration of the shoreline, proximity of tidal inlets, high density coastal populations, water depths, harbors and ports, and low laying areas. These sub-basins enable SLOSH to predict more localized, site-specific storm surges.
- SLOSH can resolve flow through barriers, levees, and roads, inland inundation, and barrier system overtopping but does not account for the waves on top of surge. It also does not account for river flow or flooding resulting from rain.
- The outputs of the P-Surge and composite approaches are available to view in the SLOSH Display Package available at NOAA's website. This interface allows the user to choose between historical storms, MEOWs, or MOMs, and then manipulate the wind speed, wind direction, and other storm parameters to analyze storm surge scenarios for the area of particular interest. The outputs available in the SLOSH Display Package are also easily exportable to the ArcGIS platform for further analysis.
- It should be noted that the SLOSH model outputs are presented on a 1 km^2 model grid, so site-specific results considering the unique topographic and infrastructure features at Easton Pond are not available.
- The SLOSH model is helpful for visualizing past storms that have affected Easton Pond, and is useful for evaluating the effects of other hurricane scenarios. For example, a Category 3 hurricane moving in the NE direction at 60mph, hitting Easton Pond at a mean tide would produce a ~9 ft. storm surge in the pond, as reflected in *Figure 9* below.

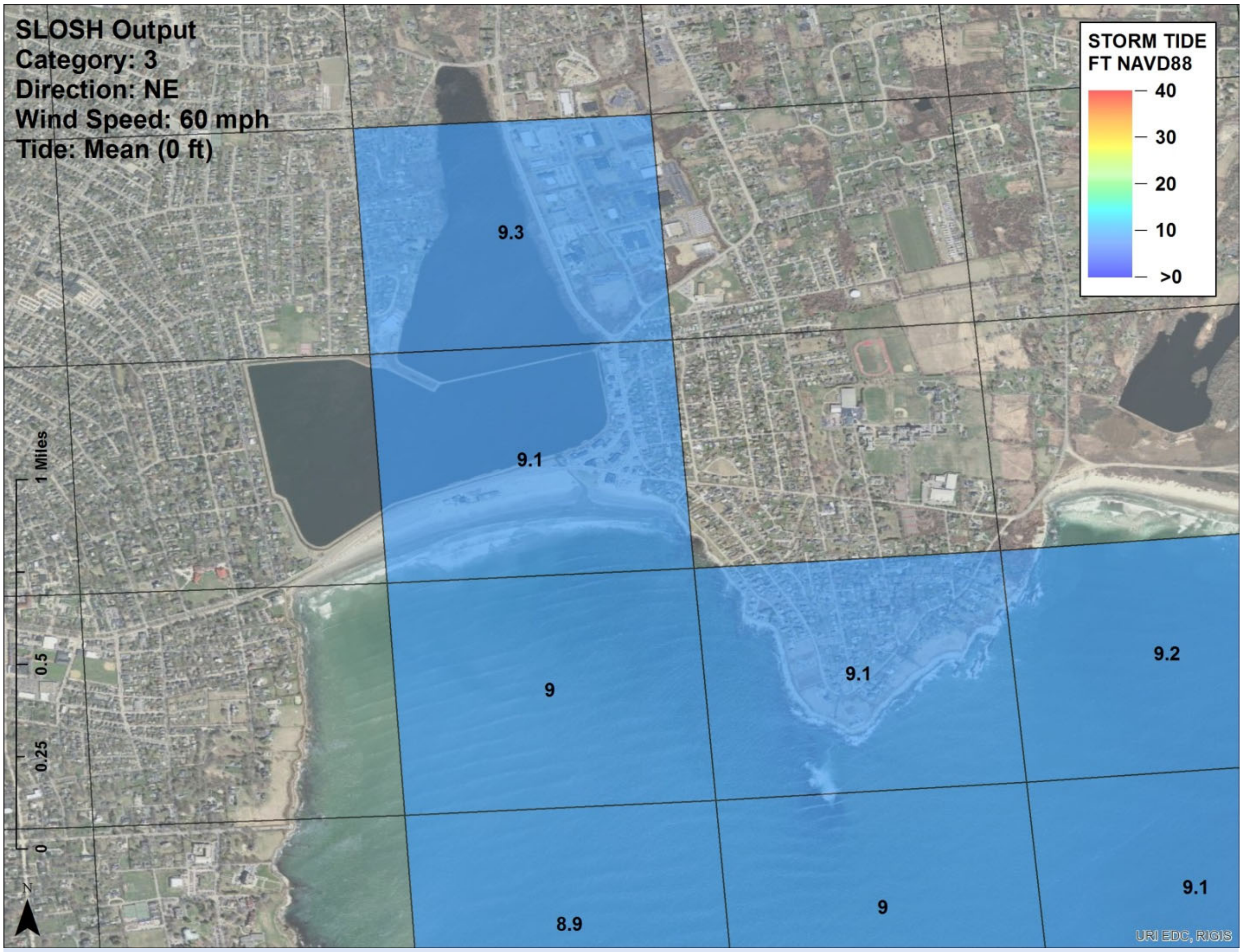


Figure 9 – SLOSH Output in Vicinity of Easton Pond
(example, Category 3 Hurricane, NE at 60 mph during mean tide)

- A scenario analysis for Easton Pond using SLOSH indicates that a hurricane of any category, wind speed, direction or tide will result in saltwater incursion at Easton Pond. Using minimum parameters in SLOSH, a Category 1 hurricane moving in the WNW direction at 10 mph and striking Easton Pond at a mean tide (assumed 0 ft.) produces a 1.4 foot storm surge in Easton Pond, as shown in *Figure 10* below.

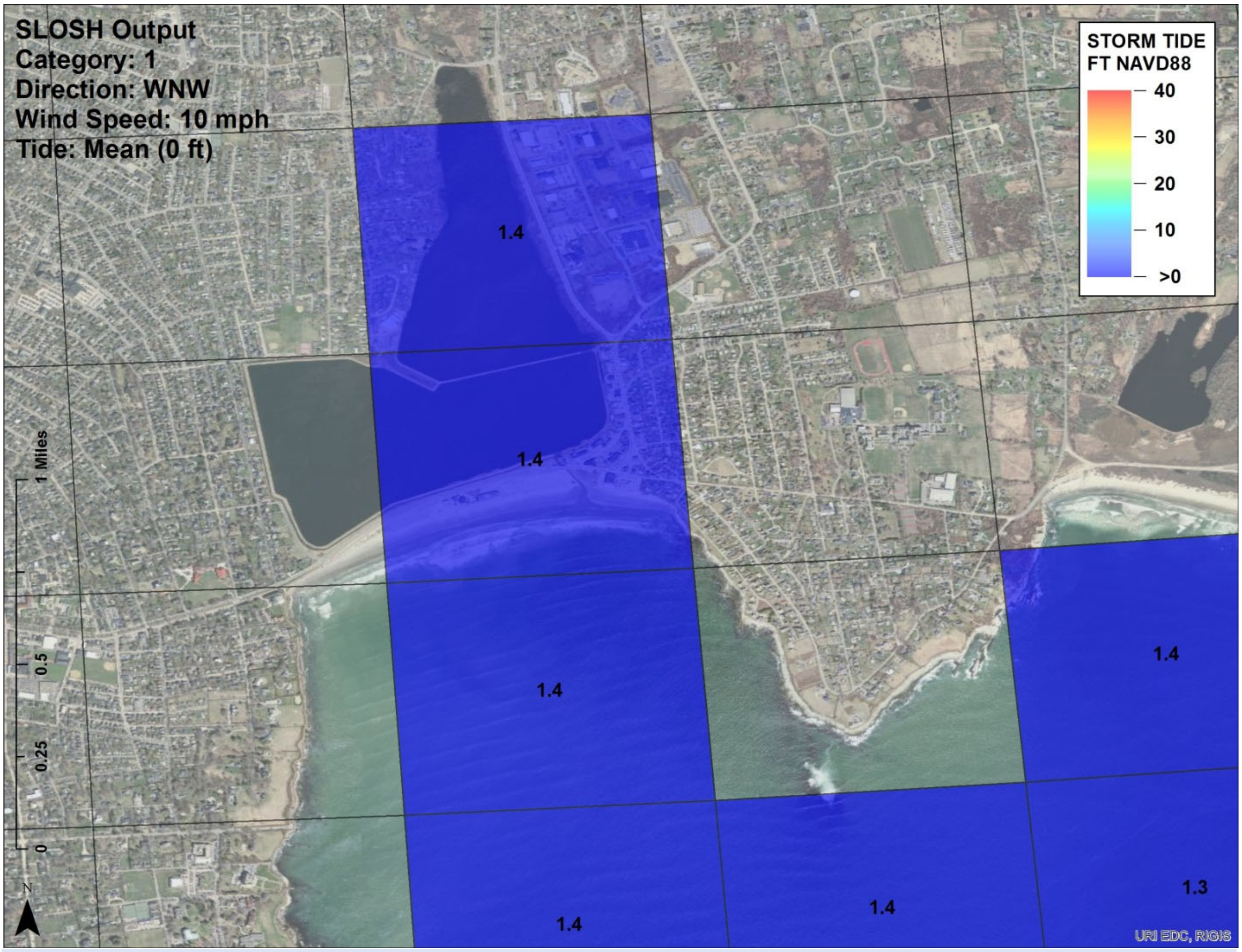


Figure 10 – SLOSH Output in Vicinity of Easton Pond (minimum scenario, Category 1 Hurricane, WNW at 10 mph during mean tide)

- Using maximum parameters in SLOSH, a Category 4 hurricane moving in the NW direction at 60 mph and striking Easton Pond at a high tide (assumed 5 ft.) produces a 22.7 foot storm surge in Easton Pond, as shown in *Figure 11* below.

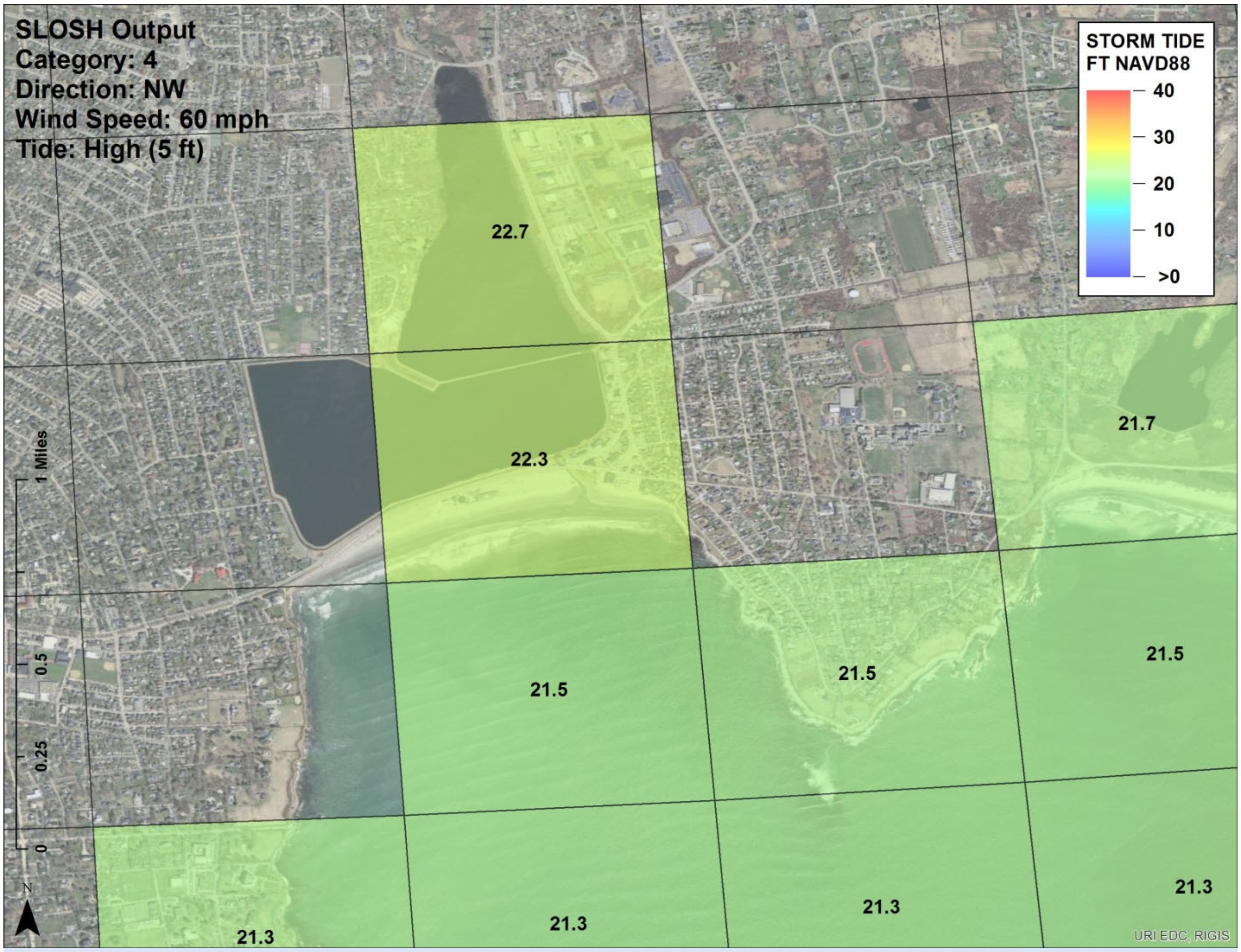


Figure 11 – SLOSH Output in Vicinity of Easton Pond (maximum scenario, Category 4 Hurricane, NW at 60 mph during high tide)

2.1.2.2 Conclusion

SLOSH is not an appropriate tool for evaluating site-specific vulnerability to coastal climate change impacts because it does not account for potential future sea level rise, does not account for potential future intensification of storms, does not account for extra-tropical storms, and has a coarse resolution of analysis.

2.1.3 NOAA Sea Level Rise and Coastal Flooding Impacts (v2.0)

The NOAA Sea Level Rise viewer was developed to provide a screening-level visualization of coastal flooding impacts from multiple sea level rise scenarios. It depicts areas of potential inundation given sea level rise up to 6 feet above current Mean Higher High Water (MHHW) at one foot intervals. Although these one foot increments do not correspond directly to any specific planning horizon, the range generally covers the global 2100 sea level rise scenarios adopted for the National Climate Assessment (NOAA, 2012).

The viewer utilizes NOAA's Coastal Topographic LiDAR and employs a modified bathtub approach (differentiating between hydrologically connected and unconnected low-lying areas) to display the extent and relative depth (shallow vs. deep) of potential inundation at high tide under the various sea level rise scenarios. Mapping accounts for local tidal variability with the NOAA VDATUM model.

2.1.3.1 Evaluation of NOAA Sea Level Rise Viewer Mapping for Easton Bay and Easton Ponds

An evaluation of NOAA Sea Level Rise Viewer model and mapping resulted in the following findings.

- NOAA expressly does not warrant the accuracy of the map, and cautions that it is to be used for planning purposes only – to be supplemented by more detailed site-specific investigations. Specifically, NOAA cautions that the sea level rise viewer does not account for natural processes such as erosion, marsh migration or land subsidence.
- NOAA also points out that the LiDAR data may not capture all of the area's hydrologic features such as canals, ditches or storm water infrastructure.
- The NOAA Sea Level Rise viewer does not address storm surge or probability/timing of potential inundation. It also does not capture any type of dynamic processes (i.e., waves, winds, water flow structures that limit volume exchange, etc.) that may be occurring at a location.
- Based on the outputs of the NOAA Sea Level Rise viewer for the Easton Pond area reflected in *Figure 12* below, Easton Pond is a hydrologically unconnected low-lying area that does not experience inundation until MHHW reaches 6 feet above present levels.

  This magnitude of sea level rise falls between the "Intermediate-High" and "High" global sea level rise by 2100 scenarios presented in the National Climate Assessment presented in *Table 1* (NOAA, 2012). When inundated at this level (MHHW +6ft), water appears to enter the South Pond over the eastern half of Easton Beach and the dam, flood the flanking storm water drainage swales, and overtop the berm between the South Pond and the North Pond.

Figure 12 – NOAA Sea Level Rise and Coastal Flooding Impacts Map for Easton Pond (green indicates disconnected/isolated low-lying areas)

2.1.3.2 Conclusion

The NOAA Sea Level Rise and Coastal Flooding Impacts viewer is not an appropriate tool for evaluating site-specific vulnerability to coastal climate change impacts because it does not specifically assign probability or time horizon to potential future sea level rise, does not account for current storm surge or potential future intensification of storms, and does not account for complex hydrodynamic processes.

2.1.4 RICRMC Individual Inundation Layers for Projected Sea Level Rise

The RICRMC Individual Inundation Layers for Projected Sea Level Rise viewer was developed jointly by URI and RICRMC to enable users to visualize the potential impacts from sea level rise.

The sea level rise viewer depicts the extent of potential flooding of 1ft/2ft/3ft/5ft above Mean Higher High Water (MHHW). Although these increments do not correspond directly to any specific planning horizon, the range generally covers the global 2100 sea level rise scenarios adopted for the National Climate Assessment (NOAA, 2012).

2.1.4.1 Evaluation of RICRMC Individual Inundation Layers for Projected SLR for Easton Bay and Easton Ponds

An evaluation of RICRMC Individual Inundation Layers for Projected Sea Level Rise mapping resulted in the following findings.

- The viewer does not provide information on data sources or analysis methods, but it appears to utilize NOAA's Coastal Topographic LiDAR and employs a modified bathtub approach (eliminating hydrologically unconnected low-lying areas) to display the extent of potential inundation at high tide under the various sea level rise scenarios.
- RICRMC does not make any statements about the intended use or accuracy of the map within the viewer interface. Since it is based on NOAA LiDAR data, it must be assumed to have similar limitations as the NOAA Sea Level Rise viewer. In addition to the limitations of the modified bathtub approach to modeling sea level rise impacts, this tool does not address storm surge or probability/timing of potential inundation.
- As shown in Figure 13 below, none of the default sea level rise scenarios provided in the RICRMC's Individual Inundation Layers for Projected Sea Level Rise viewer result in inundation of any part of Easton Pond.

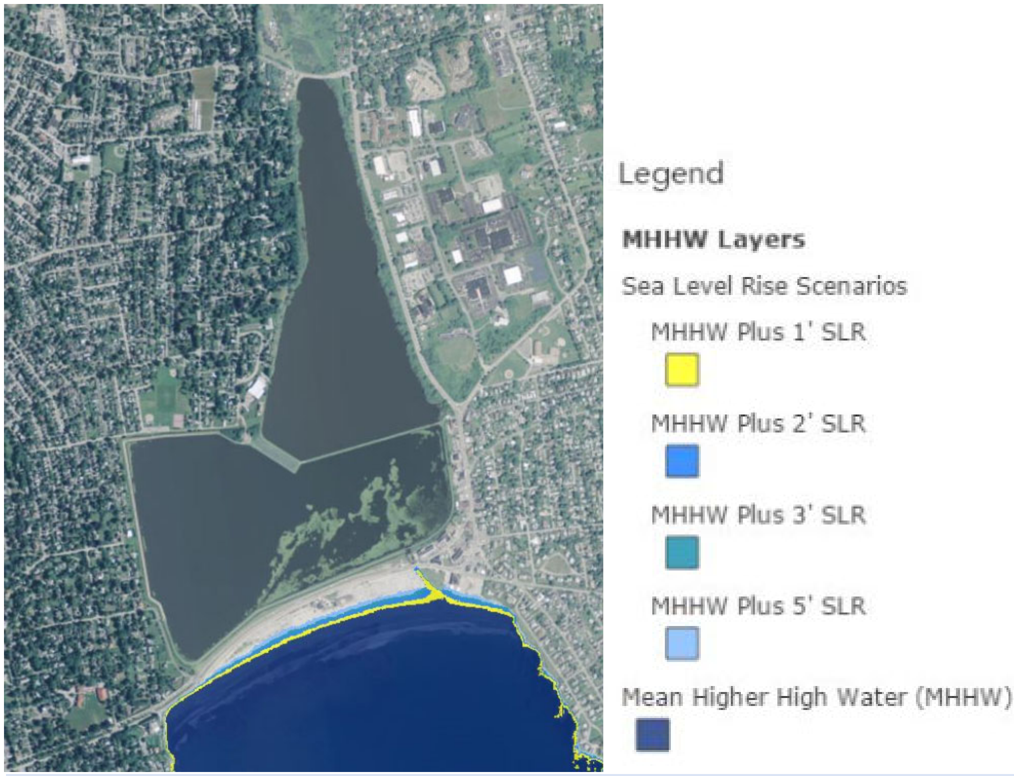


Figure 13 – RICRMC Default Individual Inundation Layers for Projected Sea Level Rise Map for Easton Pond

- As shown in Figure 14 below, a fifth sea level rise scenario (MHHW +7 ft), which is selectable in the content menu but not displayed by default, does show inundation of only the southern portion of Easton Pond.

  In the RICRMC Individual Inundation Layers for Projected Sea Level Rise viewer, MHHW+7ft inundation appears to enter the South Pond over Easton Beach and the dam and flood the flanking stormwater drainage swales, which corresponds to similar results in the NOAA Sea Level Rise viewer.

  However, in the RICRMC Individual Inundation Layers for Projected Sea Level Rise viewer, MHHW+7ft inundation appears to be limited to the South Pond and does not overtop the berm between the South Pond and the North Pond, which conflicts with lower (MHHW+6ft) sea level rise inundation scenarios in other tools. Without metadata, it is impossible to determine the source of this apparent inconsistency.

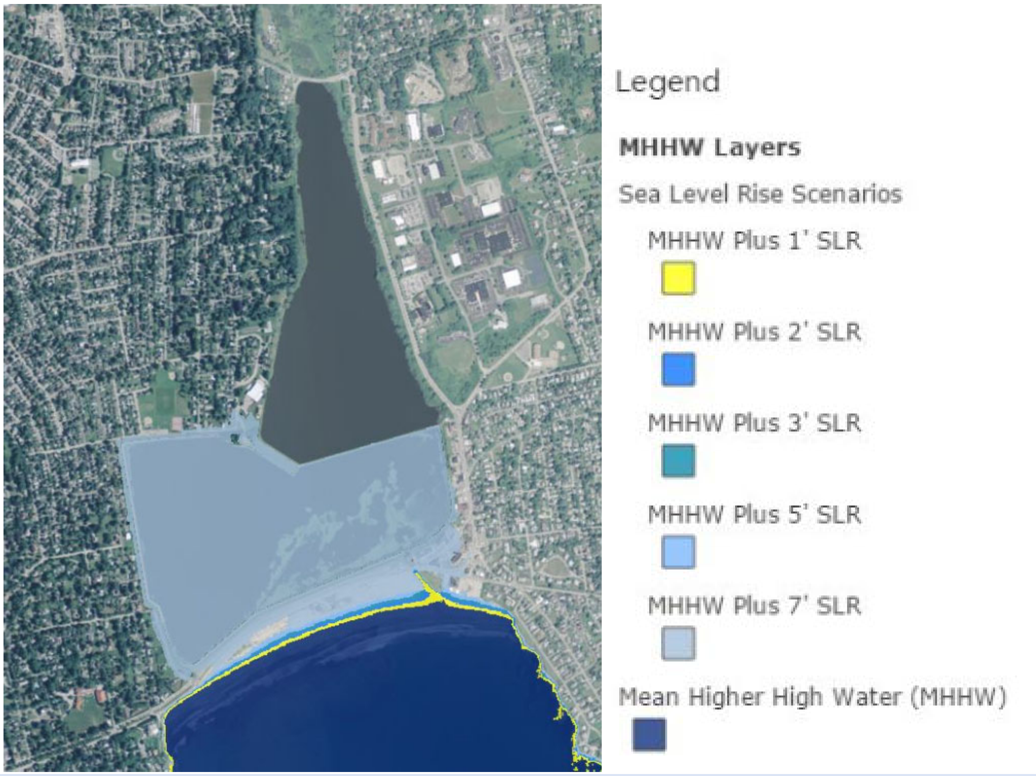


Figure 14 – RICRMC Selected Individual Inundation Layers for Projected Sea Level Rise Map for Easton Pond

2.1.4.2 Conclusion

The RICRMC Individual Inundation Layers for Projected Sea Level Rise viewer is not an appropriate tool for evaluating site-specific vulnerability to coastal climate change impacts because it does not specifically assign probability or time horizon to potential future sea level rise, does not account for current storm surge or potential future intensification of storms, and does not account for complex hydrodynamic processes.

2.1.5 Climate Central Surging Seas Risk Zone Map

The Climate Central Surging Seas Risk Zone Map was developed to provide a screening/scoping tool to assist policymakers in understanding and responding to the risks from sea level rise and coastal flooding. It depicts areas of potential inundation up to 10 feet above current Mean Higher High Water (MHHW) at one foot intervals.

Although the water levels do not correspond directly to any specific sea level rise or storm surge scenario, they are inclusive of the range of possible inundation levels. Additionally, the Risk Zone Map enables users to obtain from local tide gauge predictions an estimate of the likely time horizon for inundation (due to sea level rise or storm surge with sea level rise) for three emissions scenarios (unchecked pollution, moderate carbon cuts, extreme carbon cuts).

Similar to the NOAA's tool, Surging Seas utilizes NOAA's Coastal Topographic Lidar and employs a modified bathtub approach (differentiating between hydrologically connected and unconnected low-lying areas) to display the extent of potential inundation at high tide under the various inundation scenarios. To forecast (and assign probability to) storm surge on top of sea level rise, the Risk Zone Map uses a statistical analysis of historical patterns in extreme water levels from local tide gauges added to the results of global temperature and sea level rise models. The model also accounts for local land subsidence.

2.1.5.1 Evaluation of Climate Central Surging Seas Risk Zone Map for Easton Bay and Easton Ponds

An evaluation of Climate Central Surging Seas Risk Zone mapping resulted in the following findings.

- Climate Central does not warrant the performance, accuracy or suitability of the Risk Zone Map for any purpose other than as a screening/scoping tool.
- Surging Seas tools are not appropriate for site-level assessment or actual hazard assessment. Specifically, Climate Central cautions that the water level data does not account for future erosion or marsh migration.
- Since it relies on NOAA's LiDAR, the data may not capture all of the area's hydrologic features such as canals, ditches or storm water infrastructure.
- Although the tool does address water level exceedance probability influenced by tides, storms and seasonal water level shifts, it does not account for changing storm climatology over time or the effect of storm duration/timing on inland flooding.
- As shown in Figure 15 below, based on the outputs of the Climate Central Surging Seas Risk Zone Map for the Easton Pond area, Easton Pond is a hydrologically unconnected low-lying area that does not experience inundation until MHHW reaches 6 feet above present levels.

  This magnitude of sea level rise is projected to occur in Newport between the years 2140-2200+ (median year of 2190) assuming unchecked pollution, between 2150-2200+ (median 2200+) assuming moderate carbon cuts, and between 2170-2200+ (median 2200+) assuming extreme carbon cuts. The median projected timing of storm plus sea level rise induced flooding of Easton Pond is reflected in *Table 3* below.

Table 3
Climate Central Surging Seas Risk Zone Map Projected Timing of Storm Plus Sea Level Rise Induced Flooding of Easton Pond

	Exceedance Probability					
Scenario	**10% Accrued**	**20% Accrued**	**50% Accrued**	**10% Annual**	**20% Annual**	**50% Annual**
Unchecked Pollution	2040	2050	2080	2100	2120	2130
Moderate Carbon Cuts	2040	2050	2080	2130	2150	2170
Extreme Carbon Cuts	2040	2050	2090	2170	2200	2200+

Patterns of inundation at MHHW+6 ft are identical to those described in the NOAA Sea Level Rise Viewer. As shown in *Figure 15*, further inundation to MHHW+10 ft extends the reach of flooding around Easton Pond only moderately. Flooding north of Green End Avenue at MHHW+9 ft and MHHW+10 ft is not hydrologically connected.

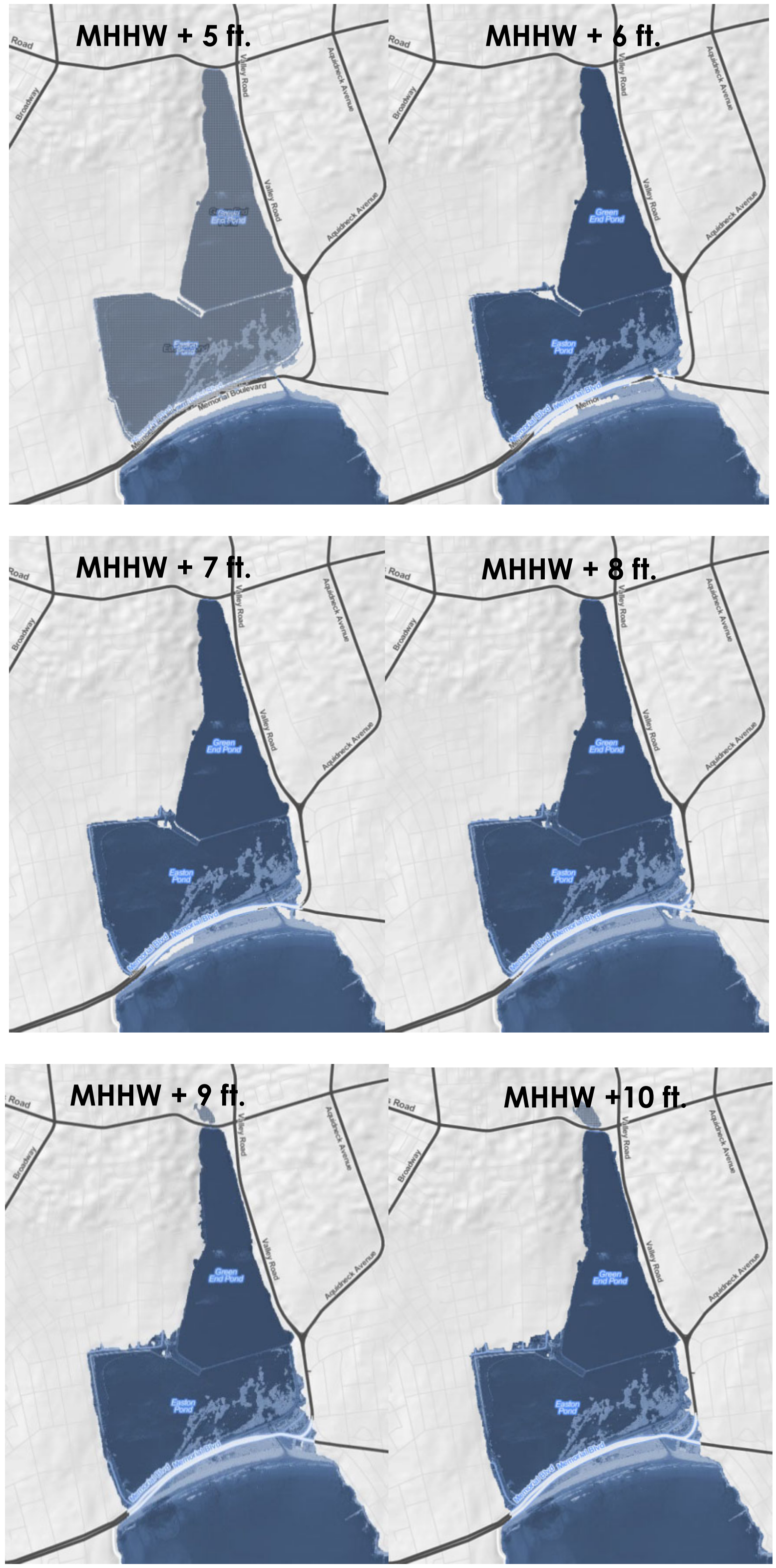


Figure 15 – Climate Central Surging Seas Risk Zone Map for Easton Pond
(shaded area indicates disconnected/isolated low-lying area)

2.1.5.2 Conclusion

The Climate Central Surging Seas Risk Zone Map viewer is a reasonable first-order tool to assess the flooding risk at a site-specific area; however, it is limited by the bathtub approach, non-probabilistic results (a user does not have a good sense of the probability of a scenario occurring), and non-dynamic assessment. Ultimately, the tool is limited because it does not account for potential future intensification of storms, and does not account for complex hydrodynamic processes.

2.1.6 RICRMC Flood Inundation Maps for Multiple Return Periods

The RICRMC Flood Inundation Maps for Multiple Return Periods provide a visualization of the inundation resulting from various sea level rise and storm surge scenarios. These maps visualize the extent of flooding for 25-, 50- and 100-year return period storm events alone and with the sea level rise scenarios used in the RICRMC Individual Inundation Layers for Projected Sea Level Rise viewer (1ft/2ft/3ft/5ft above Mean Higher High Water (MHHW)).

The viewer utilizes LiDAR data from NOAA's 2011 Northeast LiDAR Project and near-shore bathymetric data from the U.S. Army Corps of Engineers and the National Ocean Service. Mapping accounts for local tidal variability with the NOAA VDATUM model.

The mapping employs a modified bathtub approach (differentiating between hydrologically connected and unconnected low-lying areas) to display the extent of potential inundation at high tide under the various sea level rise and storm surge scenarios. The local water levels for the 25-, 50- and 100-year return period storms, to which sea level rise was added, were derived from the NOAA gauging station at Newport, and scaled using the predictions of the NOAA Sea, Lake and Overland Surges for Hurricanes (SLOSH) model. The scaling accounts for the effects of basin shape on storm surge heights (i.e. surge heights increase linearly between Newport and Providence), and has little to no effect on data developed for Easton Pond in Newport.

2.1.6.1 Evaluation of RICRMC Flood Inundation Maps for Multiple Return Periods for Easton Bay and Easton Ponds

An evaluation of RICRMC Flood Inundation Maps for Multiple Return Periods resulted in the following findings.

- RICRMC does not warrant the accuracy or reliability of the Flood Inundation Maps for Multiple Return Periods, since they were developed using a simplified method for estimating coastal inundation and the data are for planning/educational/awareness purposes only. Specifically, RICRMC states that the mapping does not consider future changes in coastal geomorphology or climate conditions (i.e. changes in storm frequency and/or intensity).

- The LiDAR used may not capture all of the area's hydrologic features such as canals, ditches or storm water infrastructure.
- The statistically calculated return period storm inundation levels from SLOSH are based on historical storm data sets and, therefore, do not consider changing storm climatology over time or the effect of storm duration/timing on inland flooding.
- Based on the outputs of the RICRMC Flood Inundation Maps for Multiple Return Periods viewer for the Easton Pond area, Easton Pond is inundated to varying degrees, depending on sea level rise, in all three storm return period scenarios. As shown below in *Figure 16*, a 25-year storm event overtops Easton Beach and inundates the South Pond; adding sea level rise of two feet inundates the North Pond, and adding sea level rise of five feet floods some land on the pond edges.

  A 50-year storm event overtops Easton Beach and inundates the South Pond; adding sea level rise of one foot inundates the North Pond, and adding sea level rise of five feet floods more land on the pond edges – including a large wetland area north of North Pond across Green End Avenue.

  A 100-year storm event overtops Easton Beach and inundates both South Pond and North Pond; adding sea level rise of two feet inundates the large wetland area north of North Pond across Green End Avenue, and adding sea level rise of five feet floods more land on the pond and wetland edges.

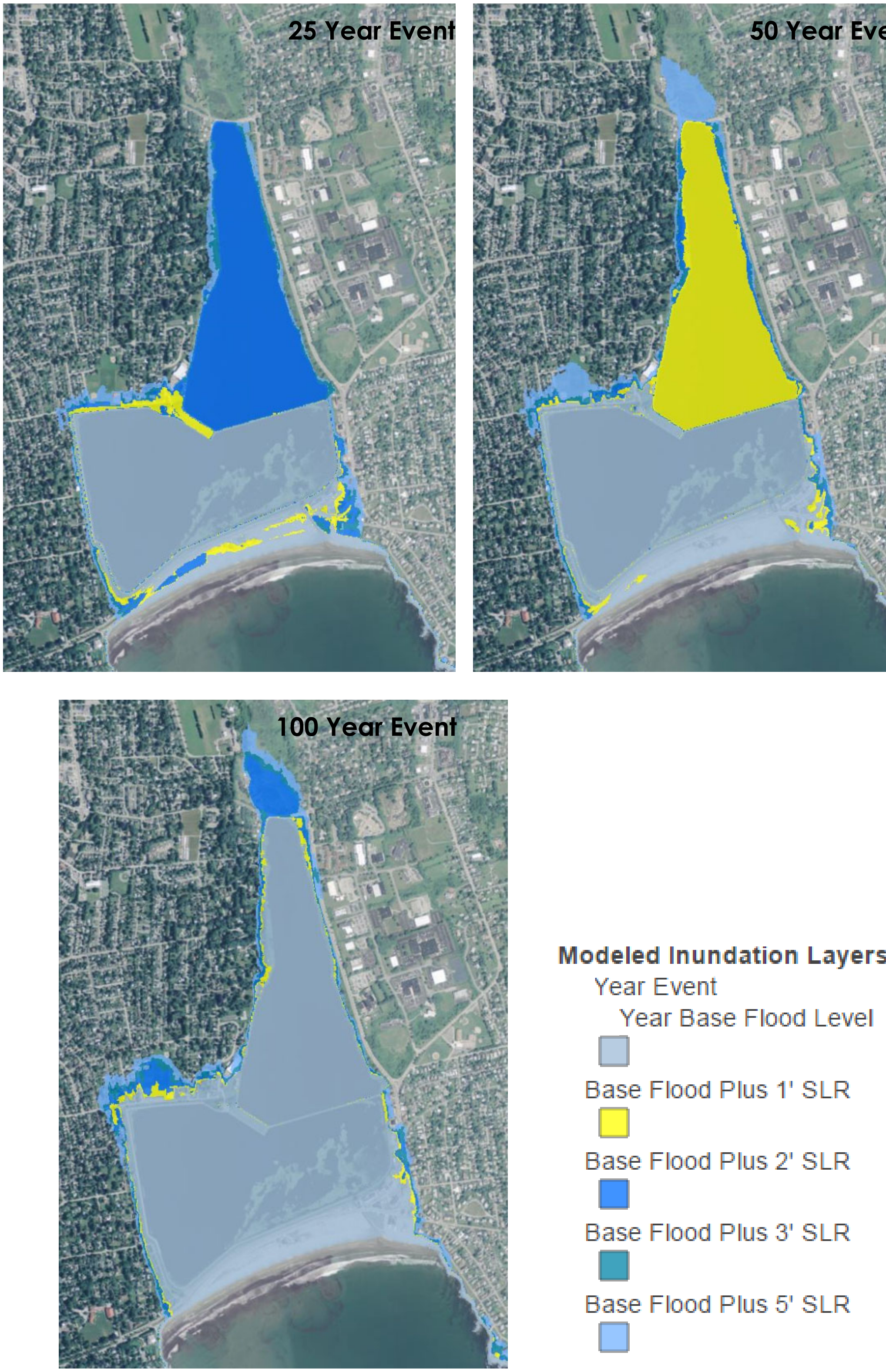


Figure 16 – RICRMC Flood Inundation Maps for Multiple Return Periods Map for Easton Pond

2.2 Preliminary Site-Specific Probabilistic Assessment

2.2.1 Background and Basis of Analysis

Probabilistic assessment gives stakeholders the ability to determine if assets are expected to be flooded and at what probability flooding is expected to occur. This is important for weighing the tolerance for risk, evaluating when adaptation options may need to be considered, and prioritizing funding to optimize adaptation investments.

Modeling and mapping over projected planning horizons (e.g. 2030, 2070) enables an assessment of how flooding may change in intensity and pathway over time. Such analysis allows communities to identify cost-effective regional adaptations (rather than multiple local adaptations) and plan for implementation to precede expected impacts and, if possible, to coincide with the replacement schedule of existing infrastructure.

Woods Hole Group conducted a probabilistic mapping assessment for the North and South Easton Pond Dams to provide an initial evaluation of SLR and coastal storm surge risk at the site. This assessment does not consist of a full dynamic probabilistic model that would also simulate flow over land; rather, it leverages probabilistic results from the USACE's North Atlantic Coast Comprehensive Study (NACCS) model and WHG's regional modeling efforts that produce dynamic flooding results along the coastline of Easton's Bay. NACCS (USACE, 2015) modeled coastal storm (tropical and extra-tropical) wave and water levels using the Coastal Storm Modeling System (CSTORM-MS) to generate joint inundation probabilities for the North Atlantic Coast. Similarly, Woods Hole Group has developed comprehensive dynamic coastal storm modeling (coupled waves and water levels) using a statistically robust set of storms under current and future climate change conditions. These two models were leveraged to provide more detailed water level distributions along Easton's Bay.

2.2.2 Analysis Results for Easton Pond

The preliminary site-specific probabilistic assessment for Easton Pond resulted in the following findings.

- Woods Hole Group selected a NACCS model node representative of conditions in Easton Bay adjacent to Easton Pond, and applied the National Climate Assessment (NOAA, 2012) highest rate SLR scenarios (for 2030 and 2070) to the present day joint probability inundation profile. Further adjustments were made to the Newport Station data based on local tide range and land subsidence.

  The present day and SLR-adjusted (future) joint probability inundation profiles were applied to the most recent LiDAR data (2014 USGS CMGP Sandy or 2011 Rhode Island Statewide, as available) for the Easton Pond vicinity using a modified bathtub approach to account for connectivity in a GIS environment. The adjusted NACCS joint probability inundation profiles are presented in *Table 4* below.

Table 4
Present Day and Adjusted (Future)
NACCS Joint Probability Inundation Profiles

Return Period	Probability	Water Surface Elevation (ft.)			
		Present	2030	2050	2070
MHHW	Tides (no surge)	1.81	2.37	3.53	5.09
1	100.0%	4.55	5.11	6.27	7.83
2	50.0%	5.31	5.87	7.03	8.59
5	20.0%	6.37	6.93	8.09	9.65
10	10.0%	7.22	7.78	8.94	10.50
20	5.0%	8.13	8.69	9.85	11.41
50	2.0%	9.42	9.98	11.14	12.70
100	1.0%	10.53	11.09	12.25	13.81
200	0.5%	11.77	12.33	13.49	15.05
500	0.2%	13.43	13.99	15.15	16.71
1000	0.1%	14.62	15.18	16.34	17.90

- A conceptual profile of the elevations and hydraulic connectivity at North Easton Pond, South Easton Pond, and the lower section of the moat/Easton Bay, is provided below as *Figure 17*. This figure is provided for comparison with the elevations noted in *Table 4*.

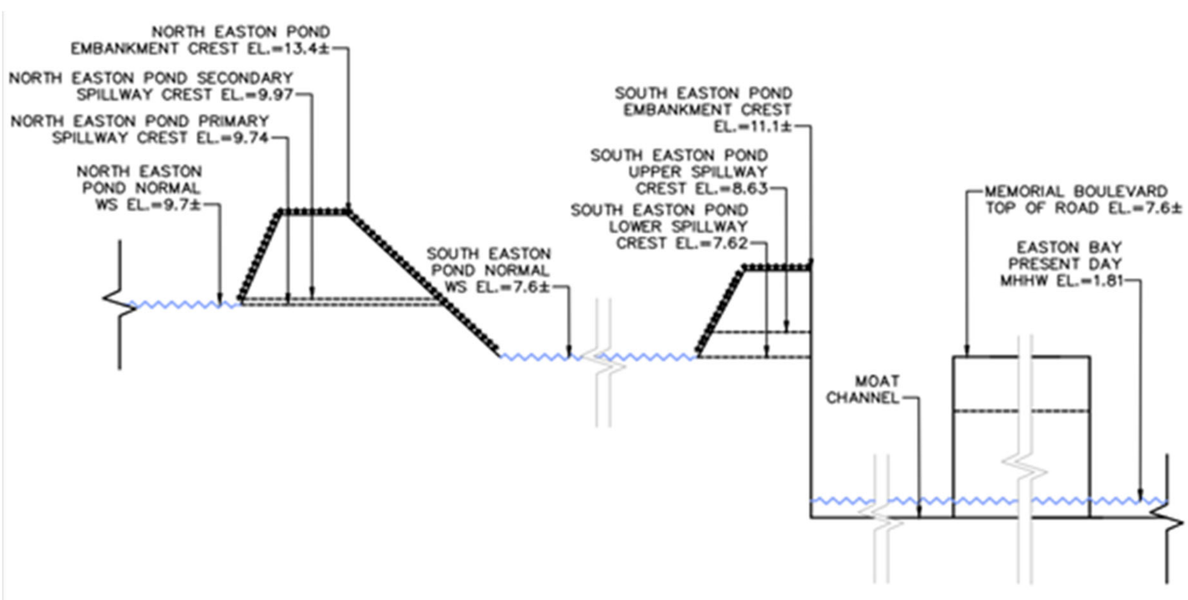


Figure 17 – Conceptual Profile of Spillway and Embankment Elevations at North and South Easton Ponds and Easton Bay

- As shown in *Figures 18, 19 and 20*, sea level rise effects alone (MHHW water surface elevations presented in *Table 4*) do not result in overtopping of South Easton Pond Dam and, therefore, the South and North Ponds do not appear to be vulnerable to saltwater inundation by overtopping a spillway or embankment structure during non-storm conditions. However, intrusion may gradually occur through groundwater pathways under and/or by seepage through the South Easton Pond's southern earthen embankment. Storm conditions would cause salt water intrusion into both North and South Easton Ponds that could result in more significant impacts to these water supplies.
    - Present day, there is a 5% annual chance of saltwater inundation at South Easton Pond and a 1% annual chance of saltwater inundation at North Easton Pond due to the effect of storm surge.
    - By 2030, there will a 10% annual chance of saltwater inundation at South Easton Pond and a 2% annual chance of saltwater inundation at North Easton Pond, due to the combined effects of SLR and storm surge. By 2050, there will be a 20% annual chance of saltwater inundation at South Easton Pond and a 5% annual chance of saltwater inundation at North Easton Pond, due to the combined effects of SLR and storm surge.
    - By 2070, there will be a 100% annual chance of saltwater inundation at South Easton Pond and a 10% annual chance of saltwater inundation at North Easton Pond, due to the combined effects of SLR and storm surge.

Figure 18 – "Present Day" (2013) Mean Higher High Water Inundation Mapping

Figure 19 – 2030 Mean Higher High Water Joint Probability Inundation Mapping

Figure 20 – 2070 Mean Higher High Water Inundation Mapping

- The most probable pathways for saltwater to inundate South and North Easton Ponds are via the spillways (with South Easton Pond having a lower notch at EL 7.62 ft. and the main spillway crest EL of 8.63 ft., and North Easton Pond having its primary spillway at EL 9.74 ft.).

  It is also possible for saltwater to enter North Easton Pond via its secondary spillway (EL 9.97 ft.) if the moat channel is sufficiently inundated.

- As shown in *Figures 12, 13,* and *14* below, this preliminary site-specific probabilistic assessment indicates that coastal storm surge (independent of storm water flow from inland sources) can overtop the embankments at South Easton Pond and North Easton Pond, but the probabilities associated with overtopping the embankments are much lower compared to the probabilities of overtopping the spillways.

  - The assessment also shows some ancillary flooding surrounding Easton Pond. Easton Beach and the commercial/residential area around Wave Avenue and Crescent Road are all vulnerable to inundation now and in the future (up to 20% presently, up to 50% by 2030, and up to 100% by 2070).
  - The residential/recreational area north of Ellery Road is vulnerable to inundation as well (up to 5% presently, up to 10% by 2030, and up to 100% by 2070).
  - The open space/wetland area north of North Easton Pond is vulnerable to inundation via a culvert and over Green End Avenue (up to 1% presently, up to 2% by 2030, and up to 10% by 2070).

Figure 21 – "Present Day" (2013) Joint Probability Inundation Mapping

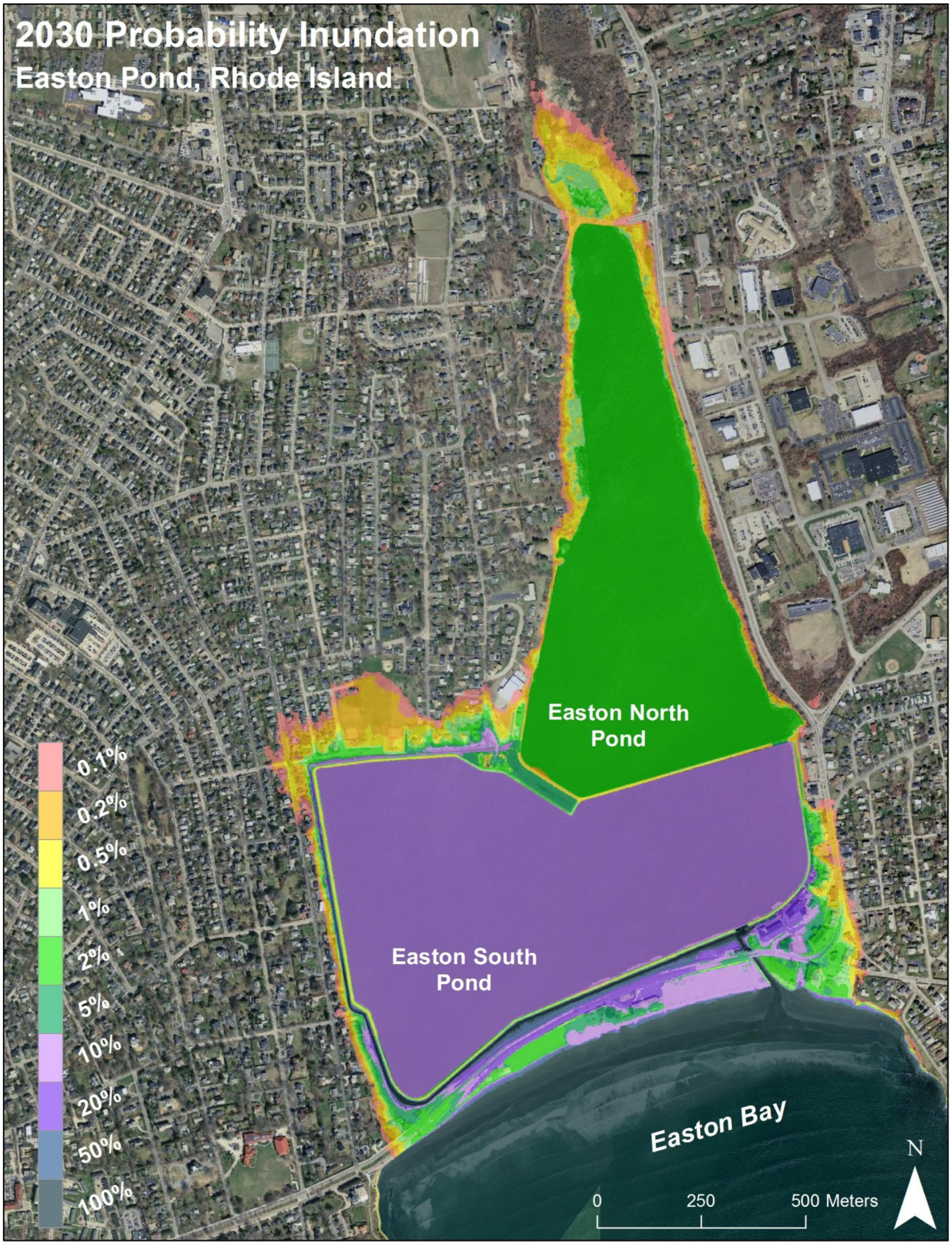


Figure 22 – 2030 Joint Probability Inundation Probability

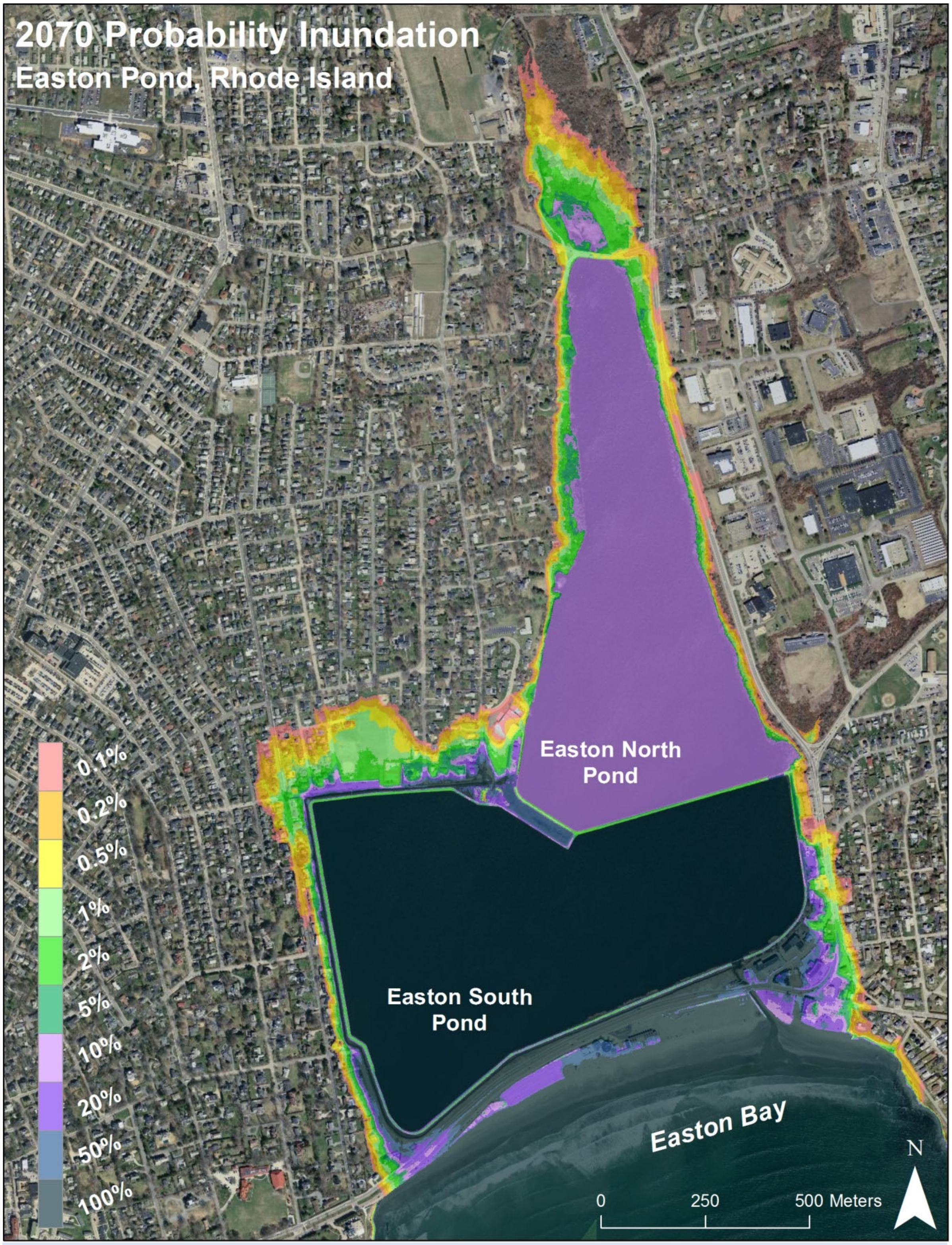
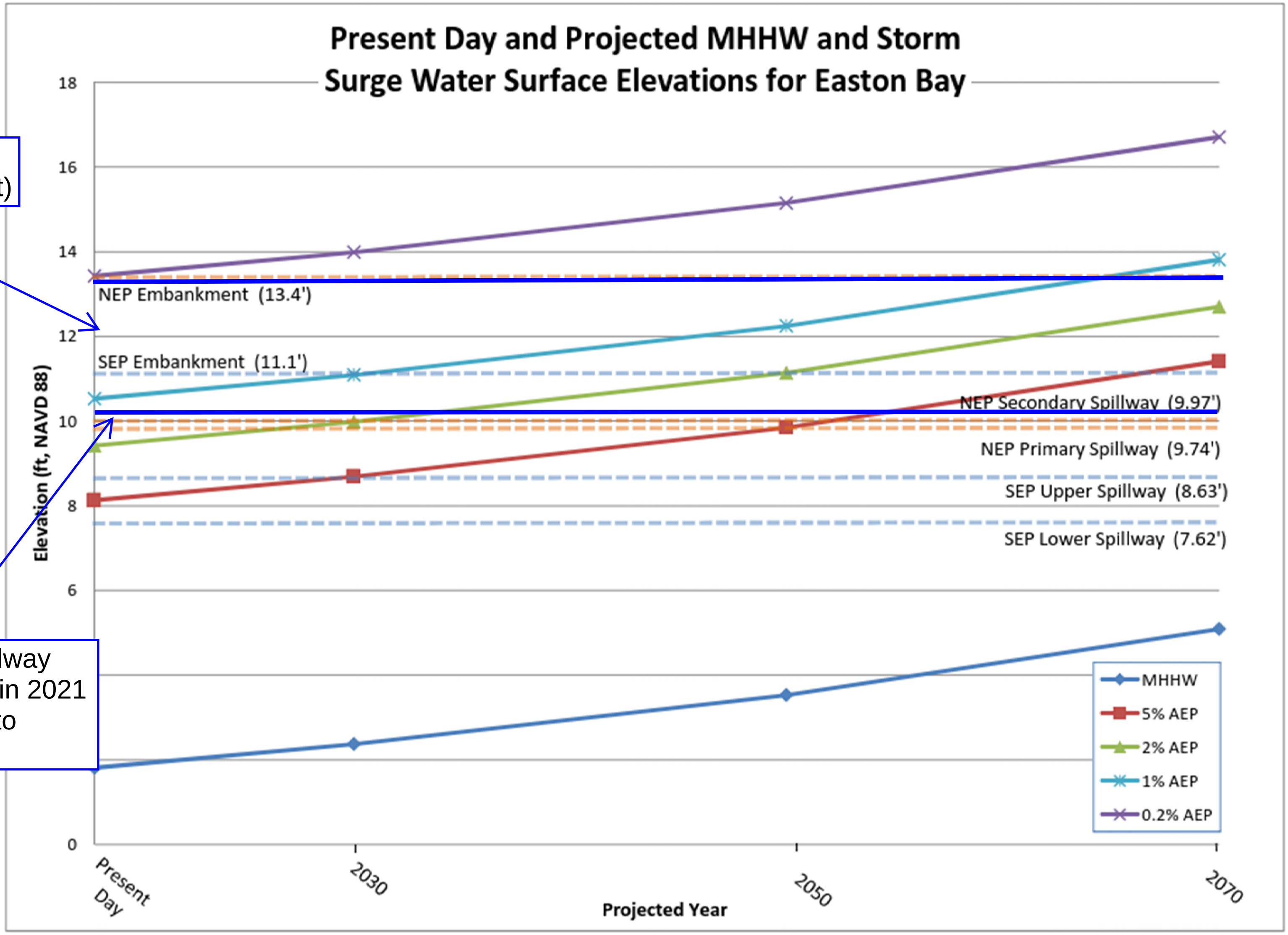


Figure 23 – 2070 Joint Probability Inundation Probability

- The potential for storm-driven saltwater flowing into North and/or South Easton Pond via hydraulically connected vulnerable pathways, thus compromising the drinking water source without causing damage to the embankments, is indicated by the probability of coastal flooding overtopping the various components of Easton Pond infrastructure. Woods Hole Groups assessment determined anticipated annual chance probabilities for this to occur over respective planning horizons, as summarized in *Table 5* below.

Table 5
Annual Chance Probabilities of Saltwater Inundation into North and South Easton Ponds for Current and Projected 2030, 2050 and 2070 Conditions

Case	SEP Lower Spillway (7.62')	SEP Upper Spillway (8.63')	NEP Primary Spillway (9.74')	NEP Secondary Spillway (9.97')	SEP Embankment (11.1')	NEP Embankment (13.4')
Present	5%	2%	1%	1%	0.5%	0.2%
2030	10%	5%	2%	2%	0.5%	0.2%
2050	20%	10%	5%	2%	2%	0.5%
2070	100%	20%	10%	10%	5%	1%



12.1 (west side of SEP embankment)

NEP Aux. spillway El.10.12 (avg in 2021 survey, need to check)

Figure 24 – Storm Surge Water Surface Elevations for Easton Bay and Dam Elevations

Notes:

1. Blue dashed lines demote South Easton Pond Dam spillway and embankment elevations.
2. Orange dashed lines denote the North Easton Pond Dam spillway and embankment elevations.
3. Projected storm surge elevations are based on the adjusted NACCS joint probability inundation profiles presented in *Table 4*.

3 Hydrologic/Hydraulic Inland Analysis of North and South Easton Ponds

A screening level hydrologic and hydraulic (H&H) analysis was completed by Fuss & O'Neill to assess the spillway capacities of the dams under present-day storm surge and sea-level rise scenarios.

The scope of the screening level analyses included the following:

- Approximate the peak flow discharged to the respective impoundments under the recommended Spillway Design Flood (SDF).
- Assess the ability of the respective spillways to safely convey the SDF flow without overtopping the dam embankments.
- Develop recommendations for future improvements to ensure sufficient hydraulic capacity during present-day inland flooding events while considering the resiliency of the system of dams against projected storm surge and sea-level rise scenarios.

F&O conducted this screening level analysis by updating the initial hydrologic and hydraulic analyses previously prepared for the North and South Easton Pond Dams and their contributing watersheds as documented within F&O's *Final Easton Pond Dam and Moat Study Report (September 2007).* Field survey and information of the dams and spillways and embankments obtained from the previous South Easton Pond Dam Repair/Improvement Project and Easton Beach Storm water UV Disinfection System Project were also utilized.

Recommendations have also been provided for refining or advancing these hydrologic/hydraulic screening level modeling evaluations. Such recommendations would improve the accuracy of the screening level hydrologic and hydraulic models and could be used to finalize future improvements.

3.1 Basis of Spillway Design Flood Determination

To determine the appropriate flood event to evaluate spillway adequacy, the data in *Table 5* was utilized as obtained from the Massachusetts Office of Dam Safety's *Dam Safety Regulations (302 CMR 10.14).*

Because the Rhode Island Department of Environment Management's (RIDEM's) Office of Compliance and Inspection Rules and Regulations for Dam Safety do not currently provide spillway design flood (SDF) requirements or recommendations, Massachusetts Department of Conservation and Recreation Dam Safety Regulations (302 CMR 10.00), which have previously been accepted by RIDEM fur such analyses on other dams, were considered.

Both dams are currently classified as High Hazard Dams by RIDEM. Based on the structural height and storage for each dam, the North and South Easton Pond Dams would respectively be considered intermediate and large sized dams if Massachusetts Dam Safety Regulations were to apply. Based on the sizes and hazard classifications of each dam, the recommended SDF for both dams is one half of the probably maximum flood (½ PMF). The recommended SDF is also consistent with the SDF for dams of similar size and hazard potential based on criteria established by the National Dam Safety Program requirements and those of state dam safety agencies such as the New York State Department of Environmental Conservation's Dam Safety Regulations.

3.2 Screening Level Hydrologic and Hydraulic Assessment

The preliminary hydrologic model for South and North Easton Ponds was previously prepared and documented within the *Final Easton Pond Dam and Moat Study Report, prepared by Fuss & O'Neill, September 2007*. The existing model was updated to incorporate updated precipitation data for the 50-and 100-year flood events RIDEM's Rhode Island Stormwater Design and Installation Standards Manual (Amended March 2015). Peak flow runoff rates and volumes generated by contributing subwatershed areas were calculated using the National Resources Conservation Service (NRCS) TR-20 method. Peak inflows for this study are based on present day rainfall runoff and intensity for the respective flood return period and do not account for changes in precipitation intensity resulting from projected climate change scenarios.

Subwatershed areas discharging to North and South Easton Ponds (as well as the moat channel surrounding Easton Pond) were delineated utilizing topographic information provided by USGS mapping services. Drainage structure mapping provided by the City of Newport was also used to refine overall subwatershed delineations. Refer to *Attachment A* for a figure depicting each subwatershed area. Stormwater runoff generated by Subwatersheds 1-A and 1-B drains directly to North Easton Pond; while stormwater runoff generated by Subwatershed 2 drains directly to South Easton Pond.

Figure 25 - Hydraulic Connectivity Plan between North Easton Pond, South Easton Pond, and Easton Bay

The hydrologic model was also developed to account for the hydraulic connectivity that occurs between North Easton Pond, South Easton Pond, and the moat channel during significant storm events. A conceptual profile and plan of hydraulic connectivity at the North and South Easton Ponds are depicted in *Figure 17* and *Figure 25,* respectively. North Easton Pond Dam was constructed with primary and secondary spillways. The primary spillway, located in the southeastern corner of the reservoir, discharges to South Easton Pond when the water level in the north pond reaches an elevation of approximately El. 9.74 feet. The secondary spillway, located in in the southwestern corner of the reservoir adjacent to the Water Department's old water treatment filtration plant, discharges to the moat channel (Moat) surrounding South Easton Pond when the water level in the North Easton Pond reaches an approximate elevation of El. 9.97 feet.

South Easton Pond Dam was constructed with a spillway, located in its southeastern corner, that discharges to the moat and ultimately to Easton Bay. Backflow into South Easton Pond occurs when the water level in the lower section of the moat or storm surge from Easton Bay exceeds an elevation of El. 7.62 feet.

3.2.1 Inland Storm Events

Inflows to and outflow from North and South Easton Ponds during the 50-year, 100-year, and ½ PMF flood events generated from inland storms are summarized in *Table 6* below. These estimates account for storage provided by the impoundments.

Table 6
North and South Easton Pond Inflows and Outflows for Inland Storms[1]

Impoundment	50-Year Inflow / Outflow Rate (cfs)[5]	100-Year Inflow / Outflow Rate (cfs)[5]	½ PMF Inflow / Outflow Rate (cfs)[6]	50-Year Peak Elevation/ Freeboard (ft.)[5]	100-Year Peak Elevation/ Freeboard (ft.)[5]	1/2 PMF Peak Elevation/ Freeboard (ft.)[6]
North Easton Pond	1,603/ 1,424[2]	1,951 / 1,783[3]	2,841/ 2,676[4]	11.66/1.74	12.0/1.40	12.81/0.59
South Easton Pond	1,142/ 594	1,294/ 765	1,700 / 1,217	10.12/0.98	10.44/0.66	**11.17/-0.07**

Notes:

1. Water surface elevations in Moat or storm surge levels from Easton Bay above El. 7.62 feet will result in variations to the outflows and peak elevations indicated in Table 3.
2. Outflow rate indicated is the total outflow from both spillways. Approximately 849 cfs is discharged through the primary spillway; while approximately 575 cfs is discharged through the secondary spillway.
3. Outflow rate indicated is the total outflow from both spillways. Approximately 1,049 cfs is discharged through the primary spillway; while approximately 734 cfs is discharged through the secondary spillway.
4. Outflow rate indicated is the total outflow from both spillways. Approximately 1,548 cfs is discharged through the primary spillway; while approximately 1,128 cfs is discharged through the secondary spillway.
5. 24-hour precipitation values for the 50- and 100-year floods of 7.3 inches and 8.6 inches, respectively, were obtained from RIDEM's Rhode Island Stormwater Design and Installation Standards Manual (Amended March 2015).
6. The ½ PMF peak flow precipitation rate of 11.9 inches was obtained from the Phase I Inspection Report for the Lawton Valley Reservoir Dam that was published by the U.S. Army Corps of Engineers (USACE, March 1980).

Maximum spillway discharge capacities of North and South Easton Ponds, assuming, no tailwater effects from downstream water levels, are summarized in *Table 7* below.

Table 7
Maximum North and South Easton Pond Spillway Capacities

Impoundment	Primary Spillway Capacity (cfs)	Secondary Spillway Capacity (cfs)	Total Spillway Capacity (cfs)
North Easton Pond	2,344	1,700	4,044
South Easton Pond	1,174	N/A	1,174

General Notes:
1. Water surface elevations in Moat or storm surge levels from Easton Bay above El. 7.62 feet will result in impacts to flow through the impoundments and spillways.
2. Capacities were conservatively calculated using the Weir Equation (Q=CLH^3/2) where C=2.7.

For analysis purposes, pond inflows and outflows (as well as spillway capacities) listed above assume no impacts due to backwater effects from the moat and Easton Bay. **Under this scenario, which would be representative of an inland storm with no storm surge, the southern and eastern embankments for South Easton Pond would need to be raised approximately one foot to El. 12.1 feet in order to safely convey the SDF with approximately one foot of freeboard.** This would be approximately equivalent to the same elevation that South Easton Pond's northern and western embankments were recently raised to as part of the South Easton Pond Dam Repair/Improvement Project in 2013-2014.

3.2.2 Coastal Storm Surge and Sea Level Rise Scenarios

High water surface elevations in the moat or storm surge levels from Easton Bay above El. 7.62 feet will result in backwater impacts to flow through the impoundments and spillways. Selected present day mean higher high water (MHHW) and storm surge levels for Easton Bay, with projections for 2030, 2050, and 2070[2] due to sea level rise, are presented in *Table 8* below.

Table 8
Present Day and Projected MHHW and
Storm Surge Water Surface Elevations for Easton Bay

Coastal Flood Return Period (% AEP)	Present Day (ft)	2030 Projection (ft)	2050 Projection (ft)	2070 Projection (ft)
MHHW	1.81	2.37	3.53	5.09
20-Year (5.0%)	***8.13***	***8.69***	***9.85***	***11.41***
50-Year (2.0%)	***9.42***	***9.98***	***11.14***	***12.70***
100-Year (1.0%)	***10.53***	***11.09***	***12.25***	***13.81***
500-Year (0.2%)	***13.43***	***13.99***	***15.15***	***16.71***

Note: Values in italics indicate a water surface elevation that will result in backflow into South Easton Pond (i.e. saltwater intrusion).

[2] Per NACCS Joint Probability Inundation Profiles

A summary of computed water surface elevations in North and South Easton Ponds during the 50-year, 100-year, and ½ PMF (or SDF) in-land flood events, accounting for storm surge and coastal sea-level rise water surface elevations in Easton Bay under present day and projected conditions noted in *Table 8,* is provided in *Table 9* below. Values listed in yellow represent potential saltwater incursion into the impoundment via the respective spillway. Values in orange represent scenarios where both saltwater incursion and embankment overtopping potentially occur. Water surface elevations for the projected coastal storm and present day inland flood return periods are depicted in *Figure 26* below.

Table 9
Present Day and Projected Water Surface Elevations

	Flood Return Period	Easton Bay Elevation (ft)	SEP Elevation (ft)	SEP Freeboard (ft)	NEP Elevation (ft)	NEP Freeboard (ft)
Present Day	50 Year	9.42	10.36	0.77	11.68	1.7
	100 Year	10.53	11.11	0.02	12.19	1.19
	1/2 PMF	13.43	13.43	-2.3	13.74	-0.36
2030 Projection	50 Year	9.98	10.58	0.55	11.74	1.64
	100 Year	11.09	11.24	-0.11	12.24	1.14
	1/2 PMF	13.99	13.99	-2.86	14.04	-0.66
2050 Projection	50 Year	11.14	11.2	-0.07	11.98	1.4
	100 Year	12.25	12.25	-1.12	12.79	0.59
	1/2 PMF	15.15	15.15	-4.02	15.18	-1.8
2070 Projection	50 Year	12.7	12.7	-0.7	12.97	0.41
	100 Year	13.81	13.81	-2.68	13.85	-0.47
	1/2 PMF	16.71	16.71	-5.58	16.71	-3.33

<u>Notes</u>: In order to approximate ½ PMF water surface elevations in North and South Easton Ponds, projected storm surge elevations for the 500 year coastal flood return period were applied as tailwater elevations at the spillways while inland flows generated during the ½ PMF were applied as inflows to both ponds. This approximation could be refined under a joint probability analysis under a future detailed analysis.

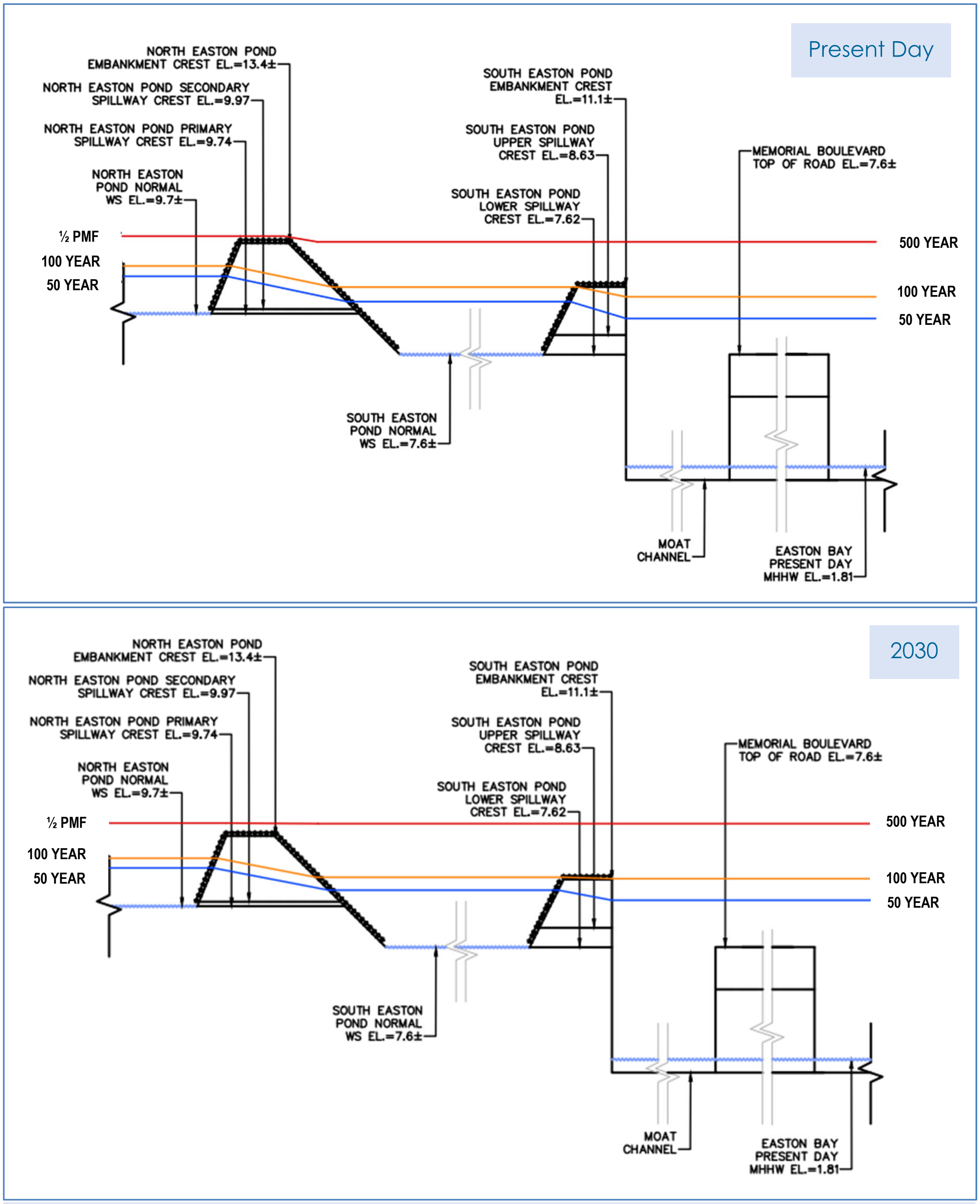
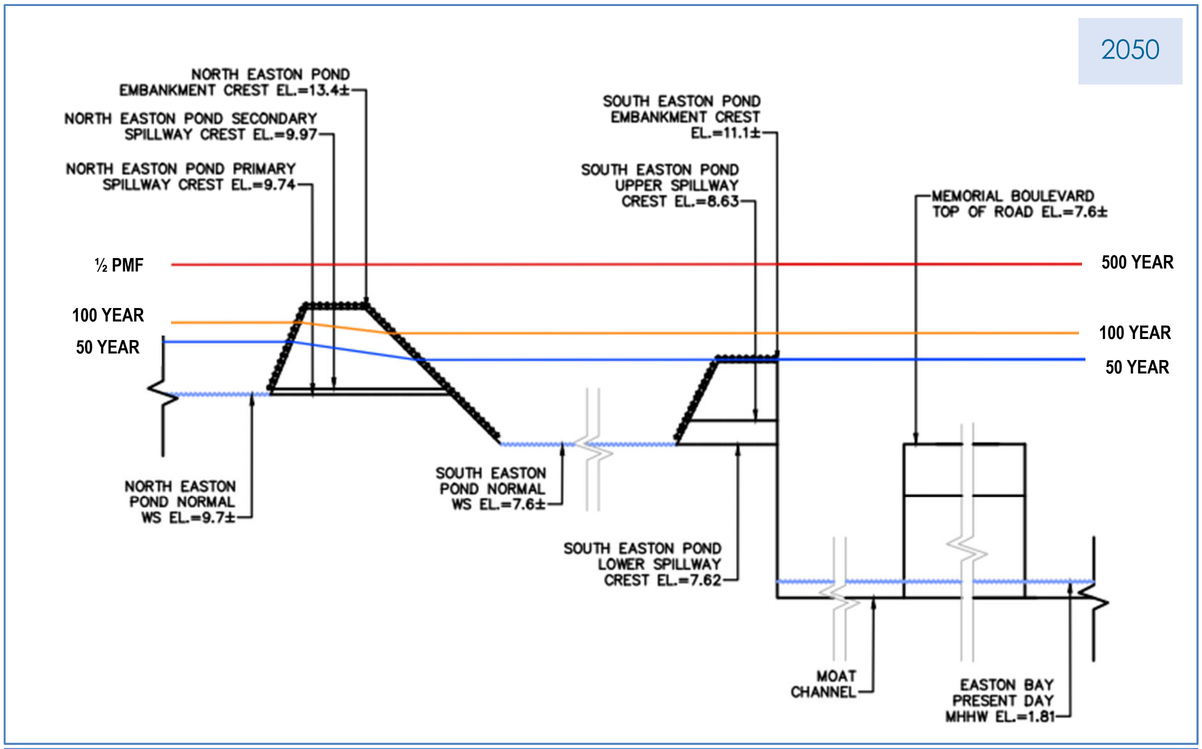


Figure 26 – Present Day and Projected Water Surface Elevations for Inland and Coastal Return Periods



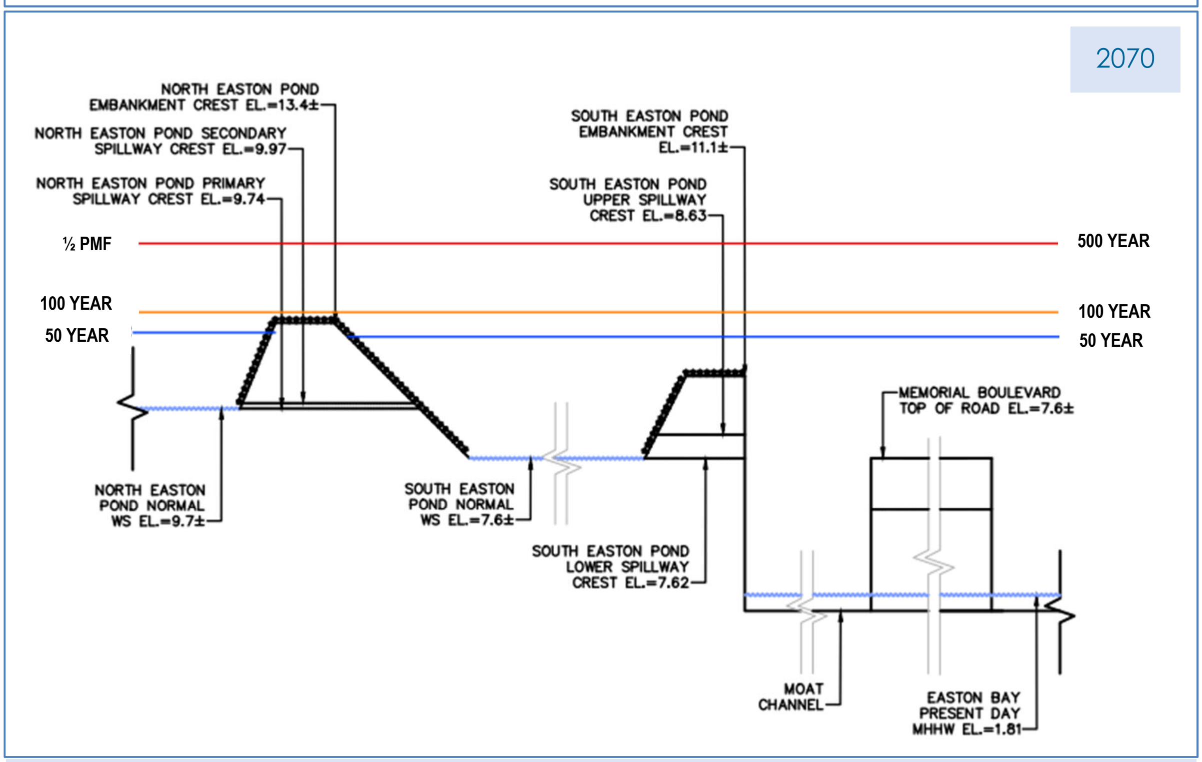


Figure 26 (cont'd) – Present Day and Projected Water Surface Elevations for Inland and Coastal Storm Return Periods

The following assessments are provided based on the findings presented in *Table 9* and *Figures 24 and 26*.

- Saltwater intrusion into South Easton Pond via the spillway is anticipated for present day and projected coastal flood events with a 50-year or greater return frequency (2% Annual Exceedance Probability (AEP)).
- South Easton Pond Dam embankment is vulnerable to overtopping under the present day SDF when storm surge at Easton Bay is considered. Under projected SLR scenarios, South Easton Pond Dam embankment is anticipated to be overtopped during 100 year storm surge events (1% AEP) by 2030 and 50 year storm surge events (2% AEP) by 2050 when storm surge at Easton Bay is considered.
- Saltwater intrusion into North Easton Pond via the spillway is anticipated for present day and 2030 and 2050 projected storm surge flood events with a 100-year or greater return frequency (1% AEP).
- By 2070, North Easton Pond is vulnerable to salt water intrusion via the spillway for events associated with the 50-year and greater storm surge return period (2% AEP).
- Under present day 500 year storm surge conditions, the South Easton Pond embankments are overtopped by approximately 2.3 feet. The North Easton Pond embankment is overtopped by approximately 0.4 feet.
- Under the projected 2070 SDF and 500 year storm surge scenario, South Easton Pond's embankment is overtopped by approximately 5.6 feet. The North Easton Pond's embankment is overtopped by approximately 3.3 feet.

4 Conceptual Resiliency Alternatives

Based on the findings of this climate change resiliency assessment for the North and South Easton Pond Dams, portions of the dams are vulnerable to projected sea level rise and increased frequency and intensity of coastal storms and precipitation. Several models were reviewed to estimate the projected SLR and how the increased water level in Easton Bay would impact the dams. The increased water level in Easton Bay was incorporated into existing H&H models for the dams.

The projected water surface elevations for North and South Easton Ponds presented in *Table 9* suggests that the most immediate and probable vulnerability for the water source is saltwater incursion over the spillways. Coastal flood control measures at the four spillways will be the most effective adaptation measures for implementation in the near- to mid-term. Embankment vulnerabilities (i.e. saltwater incursion via tail water at times when the embankment is overtopped) are less probable and have a relatively long lead time for effects to become significant. If current impact probabilities are acceptable and manageable (using operational controls), a phased adaptation approach can be implemented to enhance embankment resiliency (raise crest elevations) over time, as needed.

While coastal flood control measures at the spillways will address a vulnerability to near-term saltwater incursion, modifications to the embankment are also recommended to address present-day dam safety concerns associated with meeting hydraulic capacity and overtopping instability during the SDF from inland storms.

The following sections describe potential alternatives for consideration in improving the resiliency of the embankments and spillways impounding North and/or South Easton Pond. Although not within the scope of this study, other modifications and improvements could be considered in concert with these alternatives to provide protection along the beach or further seaward that may not only build resilience for the reservoirs, but other infrastructure as well (buildings, roads, etc.) in the communities of Newport and Middletown. These may consist of seawalls, natural berms, tidal control measures, etc., constructed downstream of the spillways.

Order of magnitude opinions of construction costs for each alternative have also been generated. Figures for each alternative are included in *Attachment A*. Order of magnitude opinions of construction costs for each alternative are included in *Attachment B*. The estimated costs include a 30 percent contingency. Since order of magnitude opinions of cost are generated without detailed engineering data, such costs are typically expected to be accurate to within -30% to +50% and do not include engineering, permitting or other project development costs.

4.1 Resiliency Alternative No. 1

In consideration of embankment improvements completed along the northern and western South Easton Pond embankments in 2013-14, which consisted of the raising of the embankments to El. 12.1 ft., one potential alternative to improve resiliency would be to raise the remaining embankments to El. 12.1 in order to provide a consistent crest elevation around the impoundment. Although this improvement would fully contain runoff generated by inland storm events up to the present day ½ PMF while providing almost one-foot of freeboard, South Easton Pond would remain vulnerable to saltwater intrusion via the spillways or wave-induced overtopping that would occur during present-day and future coastal flooding events. Therefore, the embankments surrounding South Easton Pond are also recommended to be protected against damage due to overtopping. Under this alternative, while the North Easton Pond Dam embankment is expected to have sufficient freeboard, the proposed emergency spillway modifications described below would be armored to limit the potential of erosion during flood events.

A spillway with a hydraulic opening equal to that of South Easton Pond's existing spillway and North Easton Pond's secondary spillway would require inflatable or hydraulically hinged gates to prevent saltwater from backing up through the spillways. These spillway gates would define the spillway crest and would be positioned so they could be raised to prevent saltwater intrusion during a coastal flood event, while still passing inland storm runoff during flood events from inland precipitation. Operating the gates to the raised position would reduce the spillway flood conveyance capacity.

A 1,700-foot long emergency spillway (with a crest elevation of El. 11.1) would also be proposed along South Easton Pond's southern embankment. This proposed emergency spillway for South

Easton Pond would also need to be equipped with a storm surge control structure (i.e., inflatable bladder) to prevent saltwater intrusion. North Easton Pond would also be retrofitted to include a 350-foot long emergency spillway (with a crest elevation of El. 12.9) along North Easton Pond's southern embankment. A conceptual plan of this alternative is provided as ALT. 1 in *Attachment A*.

Based on the coastal storm surge elevations provided for present day and various sea-level rise scenarios, this alternative would protect the drinking water supply reservoir from saltwater intrusion and embankment failures for coastal flood events for the 100-year return period (1% AEP) up to 2050 and for the 200-year return period (0.5% AEP) coastal flood up to 2030.

An order of magnitude opinion of construction cost for this alternative is provided in *Table 10* below. The opinion of construction costs assumes that the spillways to be retro-fitted with gates are removed and reconstructed. As part of the design phase, the spillways should assessed structurally to determine if gate installation is feasible or if the existing spillway should be removed and reconstructed.

One disadvantage of this alternative is the 1,700 foot long emergency spillway. Although the height of the emergency spillway is only 12 inches high, the 1,700 foot long inflatable bladder is no feasible due to its relatively long length. Considering that the crest of the dam is accessible to pedestrian traffic, a guard rail or other small barrier will be required to prevent unauthorized contact with the bladder dam. The guard rail is likely to impede flow through the emergency spillway and should be further evaluated if this alternative were selected.

Table 10
Alternative No. 1 Order of Magnitude
Opinion of Construction Cost Range

Embankment Improvements	$ 5,900,000	-	$ 12,600,000
Emergency Spillway Construction	$ 2,300,000	-	$ 4,800,000
Spillway Reconstruction	$ 3,100,000	-	$ 6,700,000
Crest Gates at Existing Spillways and Proposed Emergency Spillway	$ 4,800,000	-	$ 10,400,000
Total Order of Magnitude Opinion of Cost Range	**$ 16,100,000**	**-**	**$ 34,500,000**

4.2 Resiliency Alternative No. 2

Similar to Alternative No. 1, this alternative would also consist of raising the northern, southern and eastern embankments of South Easton Pond to El. 12.1 ft. and providing armor to protect against damage from overtopping as described above. Alternative 2 does not include the proposed emergency spillway provisions noted in Alternative 1 at the SEPD. Omitting the emergency spillway proposed as part of Alternative 1 would result in higher peak SDF flood elevations at NEP and SEP compared to Alternative 1. Armoring would be required at the NEPD to protect against erosion during overtopping. The crest of the NEPD embankment would remain at the current elevation of 13.4 ft. Under Alternative 2, while the embankment and spillways would have sufficient hydraulic capacity to accommodate the SDF without overtopping, there would be no freeboard during SDF conditions. Considering that the proposed alternative includes armoring to protect from damage related to wave run-up induced overtopping, the lack of freeboard under SDF conditions poses a lower risk compared to an un-armored embankment. The existing spillway for the SEP and the secondary spillway for NEP would still need to be retrofitted/reconstructed with coastal storm control structures, such as combination sluice-flap gates to prevent saltwater from backing up through the spillways. A conceptual plan of this alternative is provided as ALT. 2 in *Attachment A*.

Based on WHG's present day and projected sea-level rise coastal storm surge elevations, this alternative would provide protection of the drinking water supply reservoir from saltwater intrusion and embankment failures for coastal flood events for the 100-year return period (1% AEP) up to 2050 and for the 200-year return period (0.5% AEP) coastal flood up to 2030.

An order of magnitude opinion of construction cost for this alternative is provided in *Table 11* below. The opinion of construction costs assumes that the spillways to be retro-fitted with gates are removed and reconstructed. As part of the design phase, the spillways should assessed structurally to determine if gate installation is feasible or if the existing spillway should be removed and reconstructed.

Table 11
Alternative No. 2 Order of Magnitude
Opinion of Construction Cost Range

Embankment Improvements	\$11,600,000	-	\$ 24,800,000
Spillway Reconstruction	\$ 3,600,000	-	\$ 7,000,000
Crest Gates at Existing Spillway	\$ 2,500,000	-	\$ 5,300,000
Total Order of Magnitude Opinion of Cost Range	**\$ 17,700,000**	**-**	**\$ 37,100,000**

4.3 Resiliency Alternative No. 3

Considering that the North Easton Pond is approximately 2.25 feet higher than the embankment of South Easton Pond and the South Easton Pond and existing abutting infrastructure naturally act as a barrier between the North Easton Pond and Easton Bay, a third potential resiliency alternative would be to focus mid-term improvements on North Easton Pond.

Under this alternative, South Easton Pond would be permitted to inundate during significant coastal storm events and North Easton Pond would function as the sole water supply source until the saltwater from South Easton Pond could be managed with treatment processes or pumped out and the water supply restored. For the same magnitude of cost as Alternatives Nos. 1 and 2, focusing efforts on the North Pond would provide for the longer term resiliency of the system. By raising the southern embankment of the North Easton Pond by one foot, the drinking water for North Easton Pond could be protected from inland flooding up the to the ½ PMF return frequency and between the 500 to 1000 year coastal storm (0.2% to 0.1% AEP) up to 2030. The probability of salt water inundation and saltwater management of the South Easton Pond via the spillway assuming that no long term resilience measures are taken at South Easton Pond is provided in *Table 5*. A conceptual plan of this alternative is provided as ALT. 3 in *Attachment A*.

An order of magnitude opinion of construction cost for this alternative is provided in *Table 12* below. It is noted that this table does not include costs for additional operational management of saltwater incursion.

Table 12
Alternative No. 3 Order of Magnitude
Opinion of Construction Cost Range

Embankment Improvements	$ 3,500,000	-	$ 7,500,000
Spillway Reconstruction	$ 500,000	-	$ 1,100,000
Crest Gates	$ 2,900,000	-	$ 6,100,000
Misc. Pumps	$ 1,400,000	-	$ 2,900,000
Total Order of Magnitude Opinion of Cost Range	**$ 8,300,000**	**-**	**$17,600,000**

4.4 Resiliency Alternative No. 4

Rather than retrofitting or reconstructing the existing spillways in kind as discussed in Alternatives 1 and 2, the spillway at SEPD could potentially be reconstructed to provide sufficient hydraulic capacity for the SDF with operable components that can be manipulated to meet the design flood requirements for inland storm runoff and prevent saltwater incursion during coastal storm surge events.

The SEPD spillway was noted to have concrete scour and cracking and other areas of concern noted in visual inspections completed at the dam by others on behalf of RIDEM (2013) and by Fuss & O'Neill under contract to the City (2015). Both inspection reports included recommendations to undertake repairs to the existing spillway or consider removal and replacement.

The proposed spillway should be sized to provide appropriate freeboard during SDF conditions in conjunction with embankment modifications that would provide armor protection against erosion due to overtopping. This alternative would also include the embankment modifications to raise the crest of the northern, southern and eastern embankments to El. 12.1 ft. A series of downward opening slide gates or hinged crest gates at the SEP primary spillway can provide adaptive hydraulic capacity that can be lowered to temporarily gain hydraulic capacity during inland storms, or raised to store additional water in the reservoir. These gates, which control the impoundment level, can be hydraulically actuated and operated remotely. The existing secondary spillway at the North Easton Pond Dam may be removed and reconstructed in a similar manner considering that the secondary spillway is vulnerable to saltwater incursion via the moat. An example of a spillway arrangement similar in concept to the Alternative No. 4 modifications is provided as *Figure 27* which depicts a spillway comprised of aluminum downward opening slide gates.

Figure 27 – Example Spillway Configuration for Adaptive Spillway Capacity

The impoundment can be protected from saltwater intrusion from Easton Bay by installing combination sluice-flap gates at the downstream side of the spillway and in-series with the gates which control the impoundment level. When the sluice gate is down and the hinge at the top of the gate is unlocked, convey flow from the impoundment when the hydrostatic pressure in the impoundment exceeds the hydrostatic pressure in the downstream area. When the hydrostatic pressure in the downstream area is higher than the impoundment, the gate will seal and prevent water from entering the impoundment from the downstream side of the dam through the spillway opening. The combination gate can also be raised and lowered as a traditional sluice gate to control flow from the impoundment. A potential conceptual gate arrangement is depicted in *Attachment A, Figure Alt. 4*.

An order of magnitude opinion of construction cost for this alternative, including embankment modifications at the South Easton Pond embankments and spillway removal and replacement, is provided in *Table 13* below.

Figure 28 – Combination Sluice-Flap Gate (www.goldenharvestinc.com)

Table 13
Alternative No. 4 Order of Magnitude
Opinion of Construction Cost Range

Embankment Improvements	$ 11,600,000	-	$ 24,800,000
Spillway Reconstruction	$ 2,100,000	-	$ 4,500,000
Gates	$ 2,700,000	-	$ 5,800,000
Total Order of Magnitude Opinion of Cost Range	**$ 16,400,000**	**-**	**$ 35,100,000**

4.5 Construction Phasing

A phased construction approach will benefit the community by allowing for long term capital planning. Given the inherent uncertainty of long term SLR projections, it will also allow the City to continue to critically reevaluate and ensure that the most effective adaptations are being implemented.

Potential phasing is described for each of the alternatives in *Table 14*. As identified in *Figure 24*, the most probable SLR vulnerability for the reservoirs is salt water intrusion over the spillway at SEPD. The potential phasing is proposed to prioritize the most immediate and probable vulnerabilities.

4.6 Recommendations

We recommend that Alternative 2 and Alternative 4 be further studied for feasibility. Alternative 2 and 4 are relatively cost effective compared to the other alternatives and Alternative 4 provides an ancillary benefit as it allows the City to modify the impoundment level through operation of the proposed gates. Alternative 1 is not feasible as it requires a 1,700 foot long emergency spillway to provide adequate flood conveyance for inland storms. Alternative 3 would result in the potential repeated inundation of the South Easton Pond Dam, which may result in the loss of this resource. Recommendations to advance or refine the analyses supporting development of the conceptual alternatives are described below. The estimated costs are provided for selected data collection and H&H evaluations. These costs are provided for general information only, they include a 25 percent contingency and are typically expected to be accurate to within -30% to +50%. This should not be considered a proposal.

- A topographic survey is recommended as part of final design for the perspective improvements. The results of the survey should be incorporated into the final design hydrologic model of North and South Easton Ponds. Topographic information is available from surveys previously performed for the northern and western sections of the Moat Channel, the northern and western embankments of South Easton Pond, and the Memorial Boulevard culvert. Bathymetric data for South Easton and North Easton Ponds from Apex Environmental (October 2004) is available, but may not be valid at this time, therefore, an updated bathymetric survey is recommended. Survey information for the majority of the southern and eastern embankments of South Easton Pond as well as the Moat Channel is not available, therefore, topographic survey on these areas is recommended ***(Estimated Cost - $20,000-$25,000)***.

Table 14: Resiliency Alternatives Summary Table

Alternative Number	Detailed description	Protection Level	Order of Magnitude Total Cost[1]	Potential Multi- Year Phasing Approach
Current configuration	N/A	Flood conveyance capacity for inland storms up to the half PMF with no freeboard, however, the unarmored embankments are vulnerable to erosion and wave attack Greater than 5% annual chance of saltwater intrusion to the SEP via the lower spillway under present day conditions	N/A	N/A
1 - Modifications to Current Spillway Configuration plus Emergency Spillway Increase embankment height at SEPD, provide emergency spillway at SEPD, fit SEPD spillway with coastal storm barrier	Raise embankments at SEPD to El. 12.1 ft Fit SEPD spillway with crest gate that protects to El. 12.1 ft Construct a 1,700 foot long emergency spillway at SEPD with crest El. 11.1 ft with a coastal storm barrier (inflatable bladder dam) Construct 350 foot long emergency spillway at NEPD with crest El 12.9 ft	Flood conveyance capacity for inland storms up to the half PMF with 12 inches of freeboard in each impoundment for the inland spillway design flood event (the half PMF) Protection against overtopping during coastal flood events of approximately 1% to AEP (2050) and 0.5% AEP (2030)	\$16,100,000 to \$34,500,000	**Phase 1:** SEPD Spillway reconstruction **Phase 2:** SEPD Coastal Storm Barrier Construction **Phase 3-4:** SEPD Embankment Improvements (assume embankment improvements completed in two phases) **Phase 5:** SEPD Coastal storm barrier construction at emergency spillway
2 - Modifications to Current Spillway Configuration Increase the embankment height at SEPD, fit NEPD and SEPD spillways with coastal storm barriers	Raise embankments at SEPD to El. 12.1 ft, armor the embankment against erosion Remove and reconstruct SEPD primary spillway and NEPD secondary spillway to receive the coastal storm barrier Armor the NEPD embankments against erosion during overtopping, maintain NEPD embankment crest elevation of 13.4 ft Fit SEPD primary spillway and NEPD secondary spillway with crest gate that protects to El. 12.1 ft	Flood conveyance capacity for inland storms up to the half PMF with no freeboard in each impoundment for the inland spillway design flood event (the half PMF) Protection against overtopping during coastal flood events up to approximately 1% to AEP (2050) and 0.5% AEP (2030)	\$17,700,000 to \$37,100,000	**Phase 1:** SEPD Spillway and NEPD secondary spillway reconstruction **Phase 2:** SEPD Coastal Storm Barrier Construction **Phase 3-4:** SEPD Embankment Improvements (assume embankment improvements completed in two phases) **Phase 5-6:** NEPD Embankment Improvements and emergency spillway construction (assume embankment improvements completed within two phases)
3 - Temporary Retreat Focus mid-term improvements on NEPD to protect the NEPD against coastal storms.	Provide provisions for emergency pumping at the SEP to restore the water supply following saltwater intrusion events. Raise the NEPD embankment to El. 14.4 ft. Assess the need for future long term improvements after implementation of mid-term improvements	Flood conveyance capacity for inland storms up to the half PMF Protection against overtopping at NEPD during coastal flood events between 0.5% to 0.2% AEP (2050) and between 0.1% to 0.2% AEP (2030)	\$8,300,000 to \$17,600,000	**Phase 1:** Construct provisions for emergency pumping at SEP (presently at risk of 5% annual chance of saltwater intrusion from Easton Bay) **Phase 2:** Raise the embankment at NEPD to El. 14.4 ft **Future phases as required**
4 - Adaptive Spillway Capacity Increase embankment height at the SEPD and reconfigure SEPD spillway with coastal storm barrier	Raise embankments at SEPD to El. 12.1 ft, armor the embankment against erosion Remove and reconstruct SEPD primary spillway and NEPD secondary spillway to receive the coastal storm barrier Fit SEPD primary spillway and NEPD secondary spillway with a coastal storm barrier that protects to El. 12.1 ft Armor the NEPD embankments against erosion during overtopping, maintain the current NEPD embankment crest elevation of 13.4 ft	Flood conveyance capacity for inland storms up to the half PMF with no freeboard in each impoundment for the inland spillway design flood event (the half PMF) Protection against overtopping during coastal flood events of approximately 1% to AEP (2050) and 0.5% AEP (2030)	\$16,400,000 to \$35,100,000	**Phase 1:** SEPD Spillway and NEPD secondary spillway reconstruction **Phase 2:** SEPD and NEPD Coastal Storm Barrier Construction **Phase 3-4:** SEPD Embankment Improvements (assume embankment improvements completed in two phases) **Phase 5:** NEPD Embankment Improvements and emergency spillway construction

1. Based on 2018 construction costs

- Consider completing an engineering assessment to evaluate raising the embankments of the SEPD above El. 12.1 ft. The proposed elevation was selected considering that the western embankment has already been raised to that elevation. Consideration should be given to raising the embankments to a higher elevation to provide greater protection against saltwater incursion over the embankment for longer term SLR scenarios (2070). Raising the embankments increases the spillway capacity as an ancillary benefit. A parapet wall may be considered as an alternative to raising the earthen embankments with soil fill materials ***(Estimated Engineering Cost - $30,000-$35,000).***

Figure 29 – Parapet Wall on a Dam (http://www.mwra.state.ma.us)

- Identify a design life for the respective proposed resiliency measures. There is considerable uncertainty in modeling future precipitation and SLR scenarios, particularly in long term projections. Understanding the design life of the improvements is valuable in order to select a resiliency measure that is appropriately designed to meet the projected hydraulic and hydrologic and SLR scenarios. Design life could be a determining factor in deciding between reconstructing or retro-fitting the existing, concrete spillway with a coastal storm control structure or undertaking a complete spillway replacement. ***(Estimated Engineering Cost $15,000-$25,000 for coordination with the City at its request).***
- Complete an Incremental Hazard Evaluation for Inflow Design Flood (IDF) Determination to identify the spillway design flood. The SDFs noted here are used for screening purposes only. The Rhode Island Office of Dam Safety currently does not provide guidance on the spillway design flood selection and Massachusetts guidelines were used in the absence of guidelines from Rhode Island. The Federal Emergency Management Agency (FEMA) provides an alternate framework for identifying a site specific inflow design flood (IDF). This reference may be more appropriate for determining and SDF than the Massachusetts regulation given the site constraints at NEPD and SEPD. The objective would be to determine if a smaller IDF (i.e. smaller than the ½ PMF) can be justified based upon an evaluation of the impact of dam failure on downstream areas and structures at varying flood flows. A smaller IDF may result in construction cost savings since the resulting spillway may be smaller than that considered in this study ***(Estimated Engineering Cost - $27,000-$34,000)***.
- To ensure that climate change considerations are recognized in future hydrologic assessments, identify a suitable Flood Magnification Factor (FMF) to apply to the inland

storm flows generated by the SDF. A FMF effectively increases the SDF to account for uncertainty associated with future hydrologic conditions to reduce the risk of inadequate spillway capacity within the structure's design life. Freeboard design provides one factor of safety relating to this uncertainty, but recent research has identified FMF ranges that can be applied to infrastructure to gain a better understanding of vulnerability to potential increases in precipitation due to climate change ***(Estimated Engineering Cost - $15,000-$18,000)***.

- Include an assessment of flow through the Moat channel during respective inland and coastal storm events in future modeling to identify locations where water surface elevations could potentially result in overtopping of South Easton Pond's embankments. This is critical to ensure that the proposed embankment height of North Easton's southern embankment and the existing embankment height of South Easton Pond's northern embankment are above moat channel flood elevations (i.e. given consideration to the inadequate hydraulic capacity of the moat channel) under project SLR conditions ***(Estimated Engineering Cost - $25,000-$30,000)***.
- Consider the impact to the City related to water supply management of having one or both of the Easton Pond reservoirs temporarily off-line during periods where the system is recovering from a saltwater incursion.
- Upon completion of the feasibility study, develop a more detailed order of magnitude costs of construction. ***(Estimated Engineering Cost - $10,000-$14,000)***.

Attachment A

Conceptual Resiliency Alternative Figures

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
1.				

SEAL

SEAL

SCALE:
HORZ.: 1"=200'
VERT.:
DATUM:
HORZ.: NAD83
VERT.: NAVD88
200 100 0 200
GRAPHIC SCALE

FUSS & O'NEILL
317 IRON HORSE WAY, SUITE 204
PROVIDENCE, RI 02908
401.861.3070
www.fando.com

CITY OF NEWPORT

EASTON POND DAM ALTERNATIVE No. 1

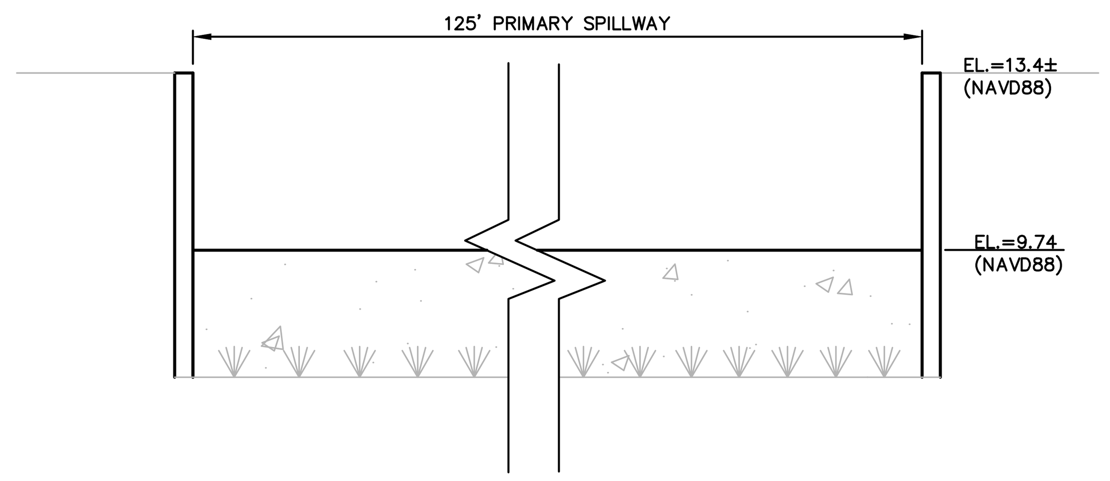
EASTON POND DAMS AND LAWTON VALLEY RESERVOIR DAM EVALUATION AND DESIGN

NEWPORT RHODE ISLAND

PROJ. No.: 20060901.D51
DATE: AUGUST 2016

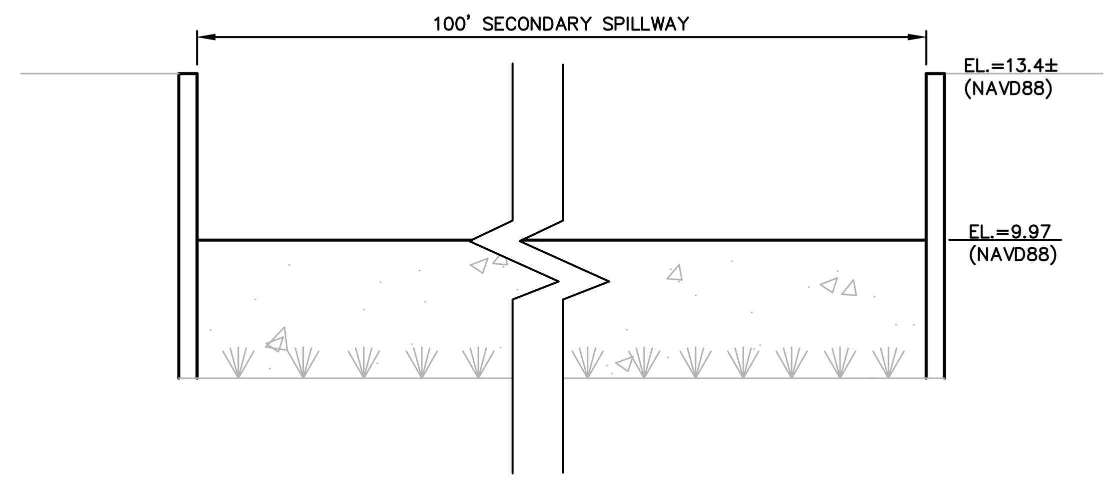
ALT. 1

File Path: J:\DWG\P2006\0901\D51\Civil\HydraFlow\sda_figures_20160804_2.dwg Layout: ALTERNATIVE1 Plotted: Mon, February 11, 2019 - 9:25 AM User: samuda
Plotter: DWG TO PDF.PC3 CTB File: FO.STB
LAYER STATE:
MS VIEW:



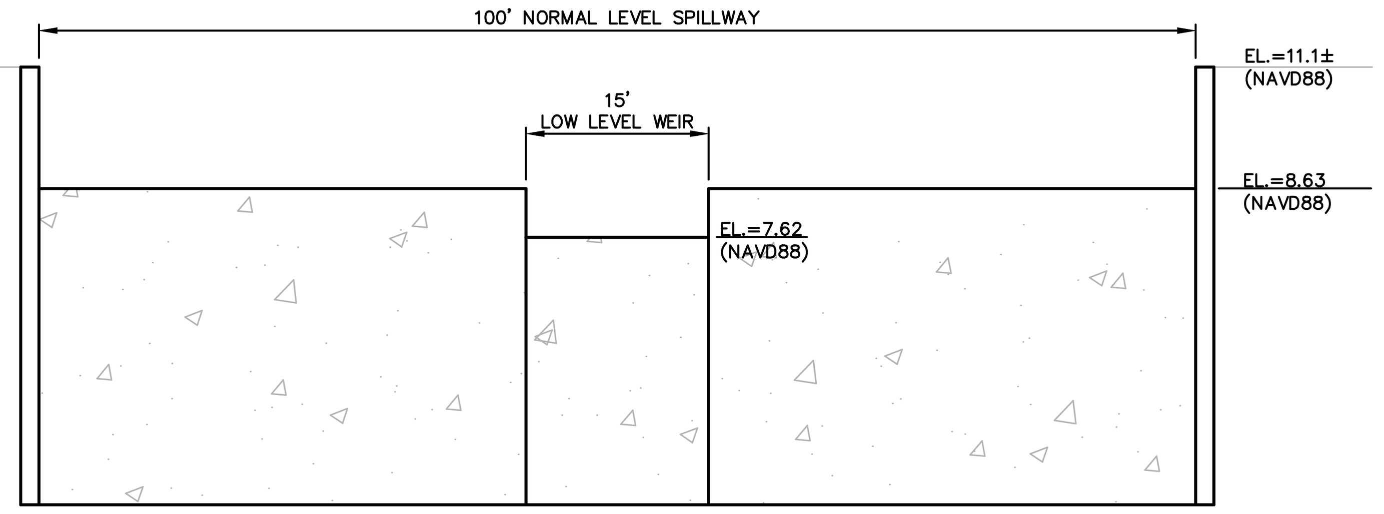
NORTH EASTON POND EXIST. PRIMARY SPILLWAY

NOT TO SCALE



NORTH EASTON POND EXIST. SECONDARY SPILLWAY

NOT TO SCALE



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NOT TO SCALE

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SEAL

SEAL

SCALE:
HORZ.: 1"=200'
VERT.:
DATUM:
HORZ.: NAD83
VERT.: NAVD88
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GRAPHIC SCALE

FUSS & O'NEILL
317 IRON HORSE WAY, SUITE 204
PROVIDENCE, RI 02908
401.861.3070
www.fando.com

CITY OF NEWPORT

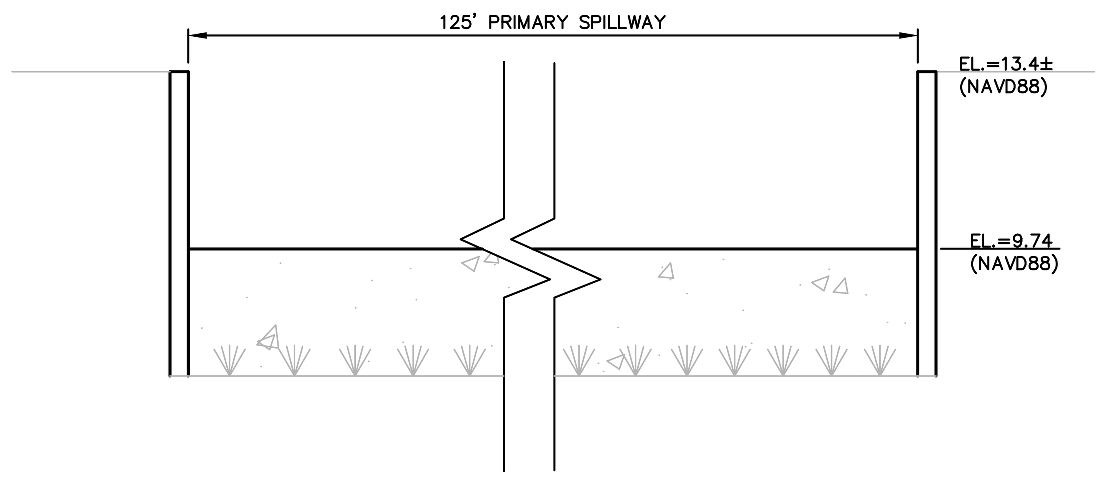
EASTON POND DAM ALTERNATIVE No. 2

EASTON POND DAMS AND LAWTON VALLEY RESERVOIR DAM EVALUATION AND DESIGN

NEWPORT RHODE ISLAND

PROJ. No.: 20060901.D51
DATE: AUGUST 2016

ALT. 2



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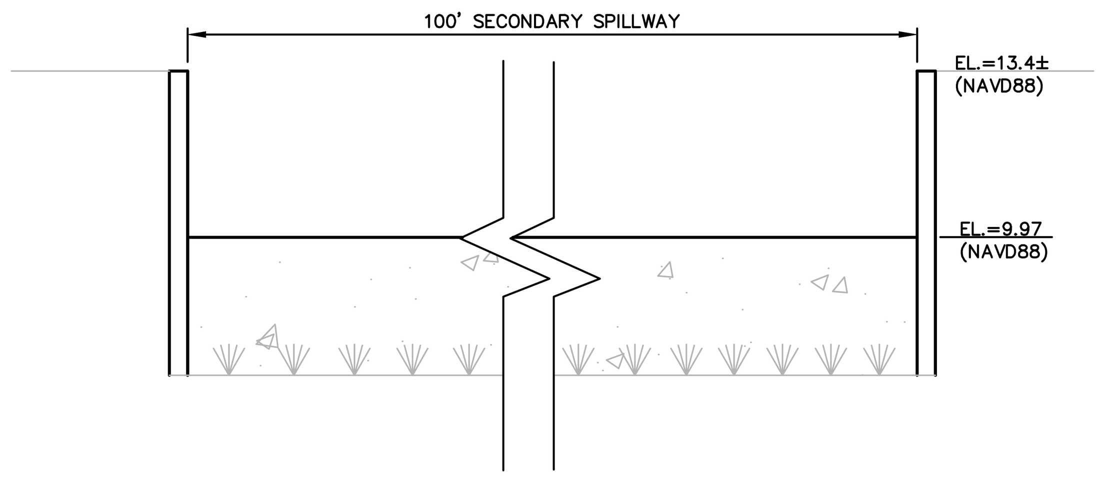

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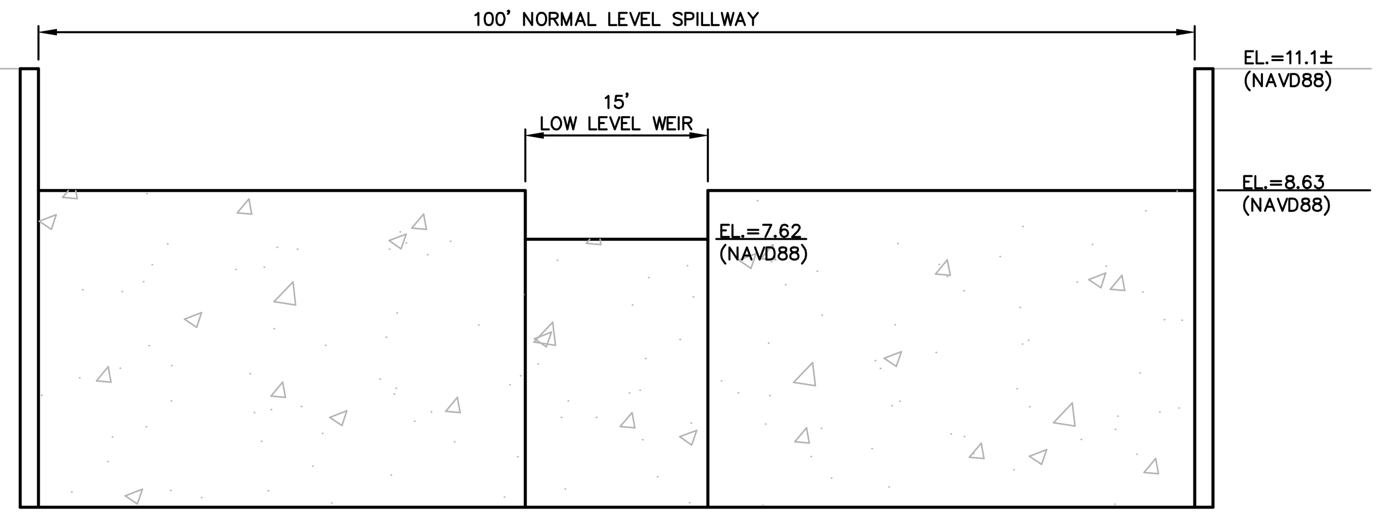
NOT TO SCALE



SOUTH EASTON POND EXIST. SPILLWAY

NOT TO SCALE

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Plotter: DWG TO PDF.PC3 CTB File: FO.STB

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SEAL

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DATUM:
HORZ.: NAD83
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GRAPHIC SCALE

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CITY OF NEWPORT

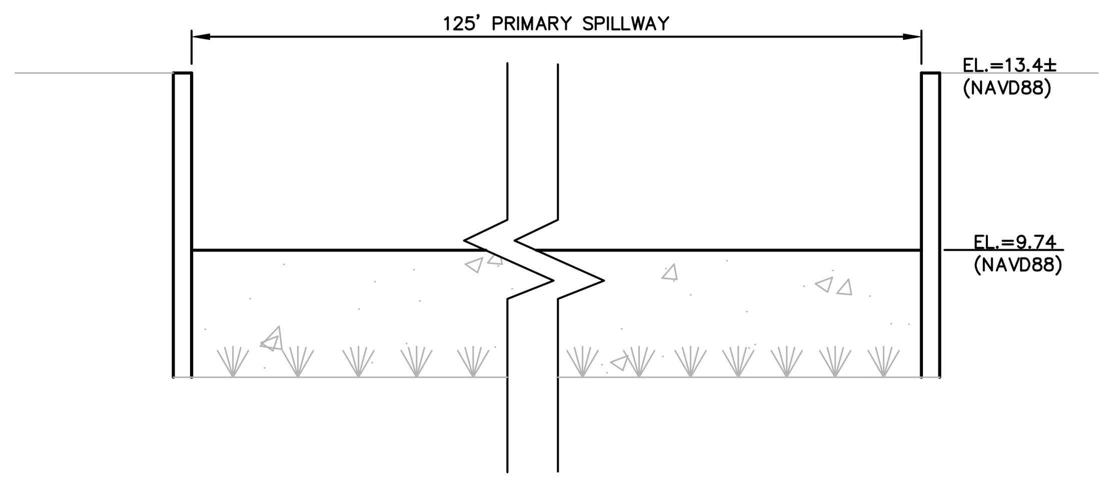
EASTON POND DAM ALTERNATIVE No.3

EASTON POND DAMS AND LAWTON VALLEY RESERVOIR DAM EVALUATION AND DESIGN

NEWPORT RHODE ISLAND

PROJ. No.: 20060901.D51
DATE: AUGUST 2016

ALT. 3



NORTH EASTON POND EXIST. PRIMARY SPILLWAY

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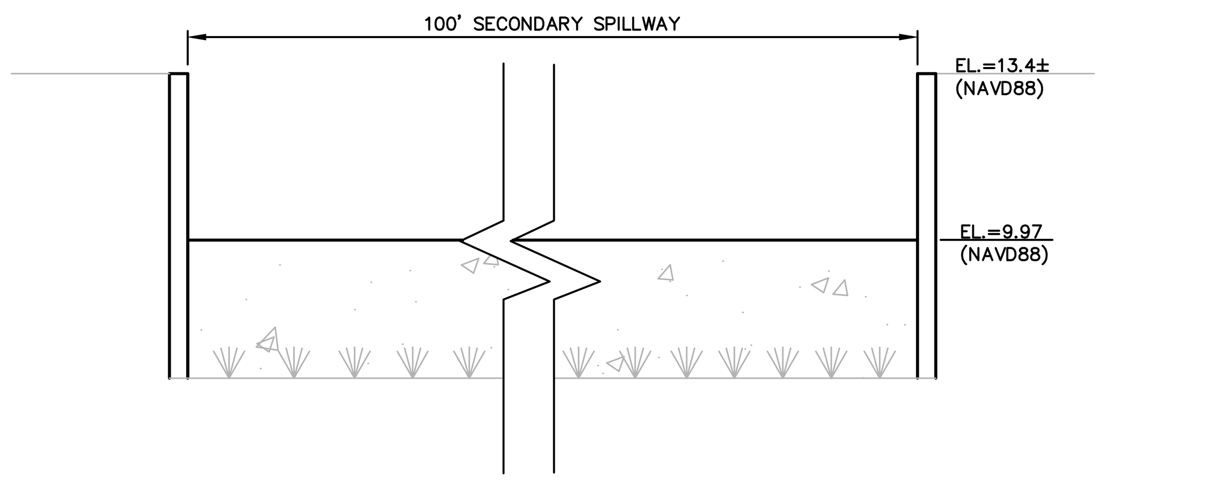

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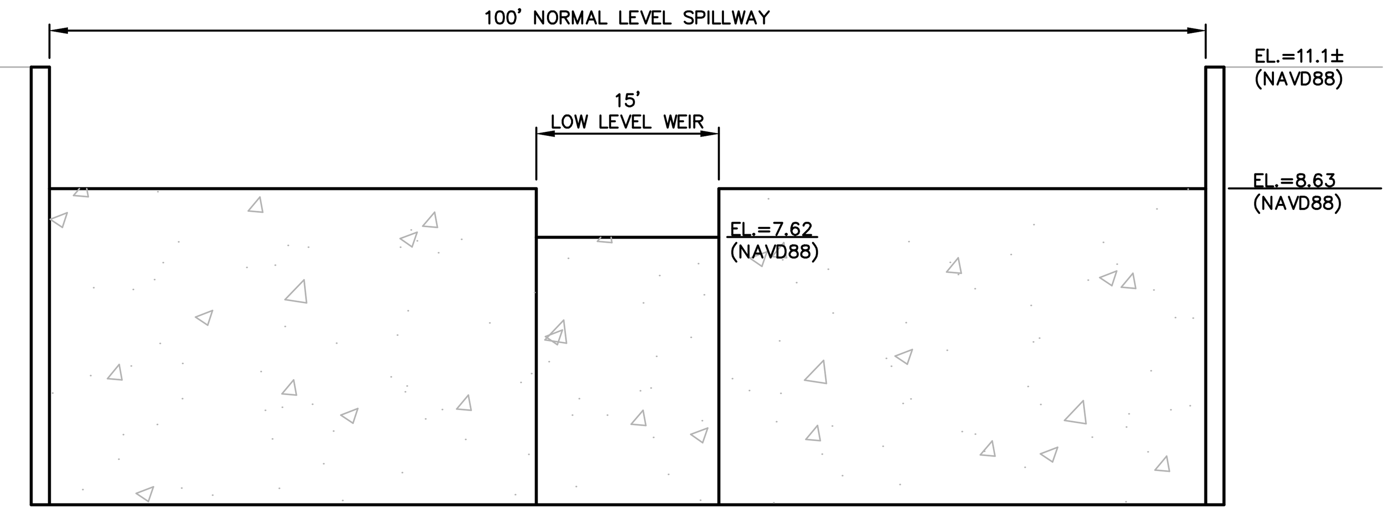

SOUTH EASTON POND EXIST. SPILLWAY

NOT TO SCALE

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
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SEAL

SEAL

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HORZ.: 1"=200'
VERT.:
DATUM:
HORZ.: NAD83
VERT.: NAVD88

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GRAPHIC SCALE

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CITY OF NEWPORT

EASTON POND DAM ALTERNATIVE No. 4

EASTON POND DAMS AND LAWTON VALLEY RESERVOIR DAM EVALUATION AND DESIGN

NEWPORT RHODE ISLAND

PROJ. No.: 20060901.D51
DATE: AUGUST 2016

ALT. 4

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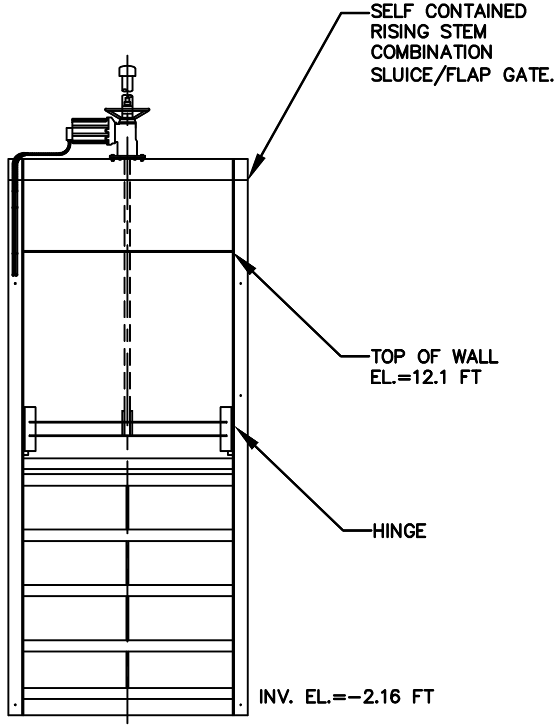
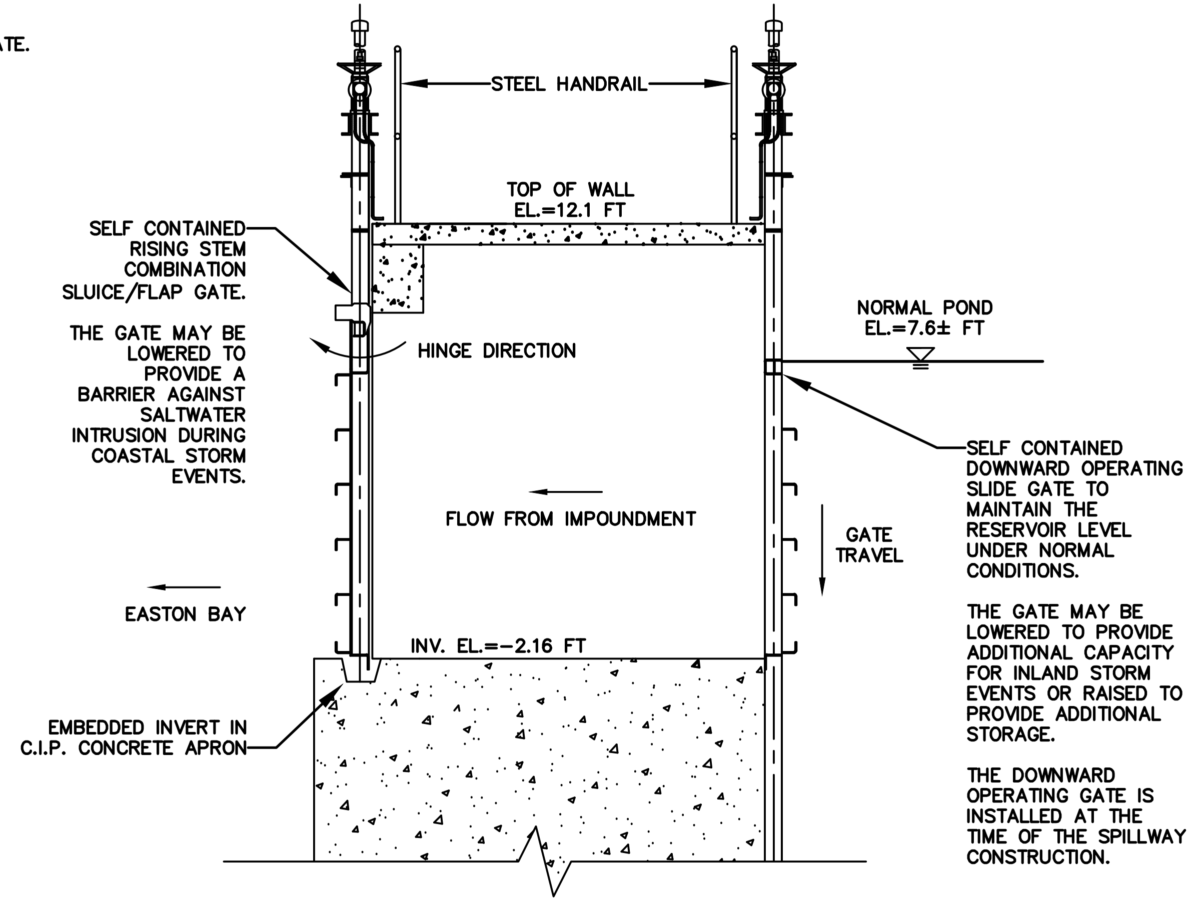


GATE ELEVATION

NTS



SPILLWAY SECTION

NTS

SCALE:	
HORZ.:	
VERT.:	
DATUM:	
HORZ.:	
VERT.:	

0 NOT TO SCALE

GRAPHIC SCALE

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CITY OF NEWPORT

CONCEPT FOR ADAPTIVE SPILLWAY CAPACITY

CLIMATE CHANGE RESILIENCY ASSESSMENT

NEWPORT RHODE ISLAND

PROJ. No.: 20060901.D51
DATE: 10/11/18

ALT. 4

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MS VIEW:
LAYER STATE:

Attachment B

Order of Magnitude Opinions of Cost for Resiliency Alternatives

FUSS & O'NEILL, INC.

307 Iron Horse Way, Suite 204
Providence, RI 02908

ORDER OF MAGNITUDE OPINION OF COST		DATE PREPARED 11/27/2018	SHEET 1 OF 1
PROJECT :	Easton Pond Dams Evaluation and Design Project	BASIS : Costs of Construction Improvements based on overall cost of Easton Pond Dam Improvement Project, Gate Pricing from Willett Pond Project and the Herring River Restoration, and 2015 RIDOT/MASSDOT Weighted Average Bid Unit Pricing, RSMeans, and the Lawton Valley Dam Repair Construction Project.	
LOCATION :	Newport, Rhode Island		
DESCRIPTION:	**North and South Easton Pond Dam Resiliency Alternative No. 1**		
PROJECT NO. :	20060901.D51	ESTIMATOR : SDA/DN/NT	CHECKED BY : NSW/ACJ

Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM DESCRIPTION	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
ALT. 1					
Embankment Improvements					
1	So. Easton Pond Western Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,710	$1,400	$2,394,000
2	So. Easton Pond Southern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,805	$1,400	$2,527,000
3	So. Easton Pond Northern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,115	$1,400	$1,561,000
				Subtotal Embankment Improvements	$6,482,000
				Contingency (30%)	$1,900,000
				Subtotal Embankment Improvements Cost Min. Range (-30%):	**$5,900,000**
				Subtotal Embankment Improvements Cost Max. Range (+50%):	**$12,600,000**
Emergency Spillway Construction					
4	So. Easton Pond Emergency Spillway Construction	SF	102,000	$20	$2,040,000
5	No. Easton Pond Emergency Spillway Construction	SF	21,000	$20	$420,000
				Subtotal Emergency Spillway Construction	$2,460,000
				Contingency (30%)	$700,000
				Subtotal Emergency Spillway Construction Cost Min. Range (-30%):	**$2,300,000**
				Subtotal Emergency Spillway Construction Cost Max. Range (+50%):	**$4,800,000**
Spillway Reconstruction					
6	SEPD Spillway reconstruction	LS	1	$3,450,000	$3,450,000
				Subtotal Spillway Reconstruction	$3,450,000
				Contingency (30%)	$1,000,000
				Subtotal Spillway Reconstruction Cost Min. Range (-30%):	**$3,100,000**
				Subtotal Spillway Reconstruction Cost Max. Range (+50%):	**$6,700,000**
Crest Gates at Existing Spillways and Proposed Emergency Spillway					
7	Spillway Hinged Gate Structure (including concrete support) for So. Easton Pond	LF	95	$14,000	$1,330,000
8	Spillway Hinged Gate Structure for No. Easton Pond	LF	100	$14,000	$1,400,000
9	South Easton Pond Dam Emergency Spillway Bladder Dam	LF	1,700	$990	$1,680,000
10	South Easton Pond Dam Emergency Spillway Bladder Dam Concrete Base	CY	500	$1,800	$900,000
				Subtotal Crest Gates at Existing Spillways and Proposed Emergency Spillway Improvements	$5,310,000
				Contingency (30%)	$1,600,000
				Subtotal Crest Gates at Existing Spillways and Proposed Emergency Spillway Cost Min. Range (-30%):	**$4,800,000**
				Subtotal Crest Gates at Existing Spillways and Proposed Emergency Spillway Cost Max. Range (+50%):	**$10,400,000**
				Alternative 1 Construction Costs (Incl. 30% Contingency)	**$23,000,000**
				Order of Magnitude Cost Min. Range (-30%):	**$16,100,000**
				Order of Magnitude Cost Max. Range (+50%):	**$34,500,000**

FUSS & O'NEILL, INC.

307 Iron Horse Way, Suite 204
Providence, RI 02908

ORDER OF MAGNITUDE OPINION OF COST		DATE PREPARED 11/27/2018	SHEET 1 OF 1
PROJECT :	Easton Pond Dams Evaluation and Design Project	BASIS : Costs of Construction Improvements based on overall cost of Easton Pond Dam Improvement Project, Gate Pricing from Willett Pond Project and the Herring River Restoration, and 2015 RIDOT/MASSDOT Weighted Average Bid Unit Pricing, RSMeans, and the Lawton Valley Dam Repair Construction Project.	
LOCATION :	Newport, Rhode Island		
DESCRIPTION:	**North and South Easton Pond Dam Resiliency Alternative No. 2**		
PROJECT NO. :	20060901.D51	ESTIMATOR : SDA/DN/NT	CHECKED BY : NSW/ACJ

Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM DESCRIPTION	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
ALT. 2					
Embankment Improvements					
1	So. Easton Pond Western Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,710	$1,400	$2,394,000
2	So. Easton Pond Southern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	3,505	$1,400	$4,907,000
3	So. Easton Pond Northern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,115	$1,400	$1,561,000
4	No. Easton Pond Southern Embankment Armoring with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	2,710	$1,400	$3,794,000
				Subtotal Embankment Improvements	$12,700,000
				Contingency (30%)	$3,800,000
				Subtotal Embankment Improvements Cost Min. Range (-30%):	**$11,600,000**
				Subtotal Embankment Improvements Cost Max. Range (+50%):	**$24,800,000**
Spillway Reconstruction					
5	SEPD Spillway reconstruction	LS	1	$3,450,000	$3,450,000
6	North Easton Pond Spillway Reconstruction	LS	1	$550,000	$550,000
				Subtotal Spillway Reconstruction	$4,000,000
				Contingency (30%)	$1,200,000
				Subtotal Spillway Reconstruction Cost Min. Range (-30%):	**$3,600,000**
				Subtotal Spillway Reconstruction Cost Max. Range (+50%):	**$7,000,000**
Crest Gates at Existing Spillway					
7	Spillway Hinged Gate Structure (including concrete support) for No. Easton Pond Auxiliary Spillway	LF	100	$14,000	$1,400,000
8	Spillway Hinged Gate Structure for So. Easton Pond	LF	95	$14,000	$1,330,000
				Subtotal Crest Gates at Existing Spillway	$2,700,000
				Contingency (30%)	$800,000
				Subtotal Crest Gates at Existing Spillway Cost Min. Range (-30%):	**$2,500,000**
				Subtotal Crest Gates at Existing Spillway Cost Max. Range (+50%):	**$5,300,000**
	Alternative 2 Construction Cost (Incl. 30% Contingency)				**$25,200,000**
	Order of Magnitude Cost Min. Range (-30%):				**$17,700,000**
	Order of Magnitude Cost Max. Range (+50%):				**$37,100,000**

FUSS & O'NEILL, INC.

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Providence, RI 02908

ORDER OF MAGNITUDE OPINION OF COST	DATE PREPARED 11/27/2018	SHEET 1 OF 1	
PROJECT : Easton Pond Dams Evaluation and Design Project	BASIS : Costs of Construction Improvements based on overall cost of Easton Pond Dam Improvement Project, Gate Pricing from Willett Pond Project and the Herring River Restoration, and 2015 RIDOT/MASSDOT Weighted Average Bid Unit Pricing, RSMeans, and the Lawton Valley Dam Repair Construction Project.		
LOCATION : Newport, Rhode Island			
DESCRIPTION: **North and South Easton Pond Dam Resiliency Alternative No. 3**			
PROJECT NO. : 20060901.D51	ESTIMATOR : SDA/DN/NT	CHECKED BY : NSW/ACJ	

Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM DESCRIPTION	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
ALT. 3					
Embankment Improvements					
1	No. Easton Pond Southern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	2,730	$1,400	$3,822,000
				Subtotal Embankment Improvements	$3,822,000
				Contingency (30%)	$1,100,000
				Subtotal Embankment Improvements Cost Min. Range (-30%):	**$3,500,000**
				Subtotal Embankment Improvements Cost Max. Range (+50%):	**$7,500,000**
Spillway Reconstruction					
2	North Easton Pond Spillway Reconstruction	LS	1	$550,000	$550,000
				Subtotal Spillway Reconstruction	$550,000
				Contingency (30%)	$200,000
				Subtotal Spillway Reconstruction Cost Min. Range (-30%):	**$500,000**
				Subtotal Spillway Reconstruction Cost Max. Range (+50%):	**$1,100,000**
Crest Gates					
3	Spillway Hinged Gate Structure (including concrete support) for No. Easton Pond Primary Spillway	LF	125	$14,000	$1,750,000
4	Spillway Hinged Gate Structure (including concrete support) for No. Easton Pond Secondary Spillway	LF	100	$14,000	$1,400,000
				Subtotal Crest Gates	$3,150,000
				Contingency (30%)	$900,000
				Subtotal Crest Gates Cost Min. Range (-30%):	**$2,900,000**
				Subtotal Crest Gates Cost Max. Range (+50%):	**$6,100,000**
Misc. Pumps					
5	Pump Intake Piping, Pump, and Structure (10'x30' Enclosure)	EA	1	$1,500,000	$1,500,000
				Subtotal Misc. Pumps	$1,500,000
				Contingency (30%)	$500,000
				Subtotal Mics. Pumps Cost Min. Range (-30%):	**$1,400,000**
				Subtotal Mics. Pumps Cost Max. Range (+50%):	**$2,900,000**
	Alternative 3 Construction Costs (Incl. 30% Contingency)				**$11,700,000**
	Order of Magnitude Cost Min. Range (-30%):				**$8,300,000**
	Order of Magnitude Cost Max. Range (+50%):				**$17,600,000**

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ORDER OF MAGNITUDE OPINION OF COST		DATE PREPARED 11/27/2018	SHEET 1 OF 1
PROJECT :	Easton Pond Dams Evaluation and Design Project	BASIS : Costs of Construction Improvements based on overall cost of Easton Pond Dam Improvement Project, Gate Pricing from Willett Pond Project and the Herring River Restoration, and 2015 RIDOT/MASSDOT Weighted Average Bid Unit Pricing, RSMeans, and the Lawton Valley Dam Repair Construction Project.	
LOCATION :	Newport, Rhode Island		
DESCRIPTION:	**North and South Easton Pond Dam Resiliency Alternative No. 4**		
PROJECT NO. :	20060901.D51	ESTIMATOR : SDA/DN/NT	CHECKED BY : NSW/ACJ

Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM DESCRIPTION	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
ALT. 4					
Embankment Improvements					
1	So. Easton Pond Western Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,710	$1,400	$2,394,000
2	So. Easton Pond Southern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	3,505	$1,400	$4,907,000
3	So. Easton Pond Northern Embankment Raising with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	1,115	$1,400	$1,561,000
4	No. Easton Pond Southern Embankment Armoring with Wave/Overtopping Protection (includes water control, restoration, and other incidentals)	LF	2,710	$1,400	$3,794,000
				Subtotal Embankment Improvements	$12,700,000
				Contingency (30%)	$3,800,000
				Subtotal Embankment Improvements Cost Min. Range (-30%):	**$11,600,000**
				Subtotal Embankment Improvements Cost Max. Range (+50%):	**$24,800,000**
Spillway Reconstruction					
5	North Easton Pond Spillway Reconstruction	LS	1	$550,000	$550,000
6	South Easton Pond Dam Spillway Removal and Replacement	LS	1	$1,717,000	$1,717,000
				Subtotal Spillway Reconstruction	$2,267,000
				Contingency (30%)	$700,000
				Subtotal Spillway Reconstruction Cost Min. Range (-30%):	**$2,100,000**
				Subtotal Spillway Reconstruction Cost Max. Range (+50%):	**$4,500,000**
Gates					
7	South Easton Pond Dam Sluice and Combination Gates.	EA	22	$80,000	$1,760,000
8	North Easton Pond Dam Combination Gates.	EA	15	$80,000	$1,200,000
				Subtotal Gates	$2,960,000
				Contingency (30%)	$900,000
				Subtotal Gates Cost Min. Range (-30%):	**$2,700,000**
				Subtotal Gates Cost Max. Range (+50%):	**$5,800,000**
	Alternative 4 - Construction Costs Total (Incl. 30% Contingency)				**$23,300,000**
	Order of Magnitude Cost Min. Range (-30%):				**$16,400,000**
	Order of Magnitude Cost Max. Range (+50%):				**$35,100,000**

FUSS & O'NEILL

WOODS HOLE GROUP

Attachment C

Referenced Documents

The following reports and studies were referenced during the preparation of this report and the development of the recommendations presented herein.

1. 2016, *Notice of Violation,* April 13, 2016, RIDEM, Providence, RI
2. 2015, *Lawton Valley Reservoir Dam, South Easton Pond Dam & North Easton Pond Dam Spillway Inspection/Evaluation Report*, Date of Inspection: April 13 2015, Fuss & O'Neill, Inc., Providence, RI.
3. 2013, *Visual Inspection/Evaluation – North Easton Pond Dam,* Date of Inspection: September 18, 2013, Pare Corporation, Foxboro, MA.
4. 2013, *Visual Inspection/Evaluation – South Easton Pond Dam,* Date of Inspection: September 18, 2013, Pare Corporation, Foxboro, MA.
5. 2011, *Project Manual, South Easton Pond Dam Repairs and Improvements, Bid No. 11-047*, Fuss & O'Neill, Inc., Providence, RI.
6. FEMA. 2013. Flood Insurance Study: Newport County, Rhode Island. September 2013. 81p.
7. NOAA. 2012. Global Sea Level Rise Scenarios for the United States National Climate Assessment. Prepared by: NOAA Climate Program Office (Silver Spring, MD). December 2012. NOAA Technical Report OAR CPO-1.
8. USACE. 2015. North Atlantic Coast Comprehensive Study (NACCS) Coastal Storm Model Simulations: Waves and Water Levels. Prepared by: U.S. Army Engineer Research and Development Center – Coastal and Hydraulics Laboratory (Vicksburg, MS). August 2015. ERDC/CHL TR-15-14.