Draft Integrated Interim Response Feasibility Report and Environmental Assessment for Actionable Elements

NEW YORK-NEW JERSEY HARBOR AND TRIBUTARIES COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

APPENDIX D ECONOMICS

July 2025

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1 OVERVIEW

This appendix documents the economic assessment conducted for each of the proposed actionable element sites as described in the main body of the draft integrated interim response feasibility report. The economic analyses as presented here focus on the National Economic Development (NED) benefits for each of the three actionable element sites. These benefits are primarily management of coastal storm damages to structures and their contents within the Actionable Element site. Pursuant to current guidance on assessment of comprehensive benefits as outlined in ER 1105-2-103 (5-4(b)), this appendix also details assessments of other project benefits, some of which are quantitatively assessed or qualitatively described. NED CSRM damages and benefits are monetized via the Hydraulic Engineering Center Flood Damage Reduction Analysis (HEC-FDA) software.

Given the independence and separability of the three sites, each was assessed independently. To align the period of analysis for all alternatives, a base year of 2037 was used for all economic calculations with construction assumed to start in 2030. The key years and time periods associated with each alternative, applied in accordance with ER 1105-2-103, are presented in Table 1. All economic values presented in this report are in 2025 price levels. Where applicable, benefits and costs were discounted to the project base year presented in Table 1 using the FY2025 Project Evaluation and Formulation Rate (Federal discount rate) of 3%, as specified in EGM 25-01.

Table 1: Timelines for evaluated actionable elements

Actionable Element	Start of Construction	End of Construction	Base Year	End of Period of Analysis	Years of Full Benefits
Harlem River	2028	2037	2037	2086	50
East Riser	2028	2037	2037	2086	50
Oakwood Beach	2028	2037	2037	2086	50

What follows is a detailed description of the economic assessment conducted for the proposed actionable elements: along the Harlem River, East Riser, and at Oakwood Beach.

2 HARLEM RIVER

Coastal flood risk under the with- and without-project conditions was assessed via HEC-FDA version 2.0 (IWR, 2023), relying primarily on the existing inputs for the HEC-FDA version 1.4.2 model developed for the September 2022 Draft Integrated Feasibility Report and Tier 1 (Programmatic) Environmental Impact Statement (USACE, 2022a). Details of the economic assessment conducted as part of this prior report are provided in Appendix D of the main report (USACE, 2022b). There are several differences between HEC-FDA 1.4 and version 2.0, which necessitated the development of additional model inputs. Where applicable, this appendix details and describes these changes.

The study assessed coastal flood risk at several different sea level conditions, reflecting the full range of potential sea level change over the period of economic analysis, pursuant to ER 1100-2-8162. These results were used to project coastal flood risk over time given USACE (low, intermediate, and high) sea level change scenarios. These projections were discounted to the base year of economic analysis and annualized using a 3% Federal discount rate pursuant to EGM 25-01.

What follows is a summary of the HEC-FDA 2.0 inputs developed and employed for the Harlem River Actionable Element site. This summary is followed by a detailed description of the discounting approach, description of the actionable element modeled in HEC-FDA 2.0, and presentation of the economic analysis results.

2.1 HEC-FDA 2.0 INPUTS

2.1.1 Terrain Data

Prior versions of HEC-FDA included ground elevation data as part of the structure inventory. In contrast, HEC-FDA version 2.0 allows for the import of terrain data via a raster file. For the Harlem River Actionable Element site, the study employs a digital elevation model (DEM) with a horizontal spatial resolution of 1 foot and a vertical accuracy of 3 inches (NOAA, 2017). In conjunction with the structure-specific foundation height specified in the structure inventory, this terrain data directly informs the first-floor elevation of the structures within the Actionable Element site.

2.1.2 Impact Areas

Appendix D of the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS (USACE, 2022b) presents the economic reaches considered during the formulation of the draft comprehensive plan. These reaches were originally delineated based on county boundaries, tidal water bodies, expected maximal extent of damage (corresponding to +20 ft NAVD88), and hydraulic separability. The Harlem River Actionable Element site corresponds to a subsection of economic reach 20-B (Manhattan shoreline along Harlem River), as shown in
Figure 1.

For the purposes of economic assessment, this Actionable Element site is represented by a single impact area[1] (i.e., economic reach) within the model. This impact area is hydraulically separable from the adjacent portions of economic reach 20-B. Along its northern edge, the impact area is bounded by high ground adjacent to Harlem River Drive. Further south along the Harlem River, the impact area follows localized high ground, approximately paralleling Adam Clayton Powell Jr Boulevard. The southernmost extent of the impact area is approximately bounded by 144th Street.

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[1] In HEC-FDA v1.4.2, study areas were discretized into smaller sub-regions, termed damage reaches, also sometimes referred to as economic reaches. Within HEC-FDA v2.0, these sub-regions are instead referred to as impact areas.

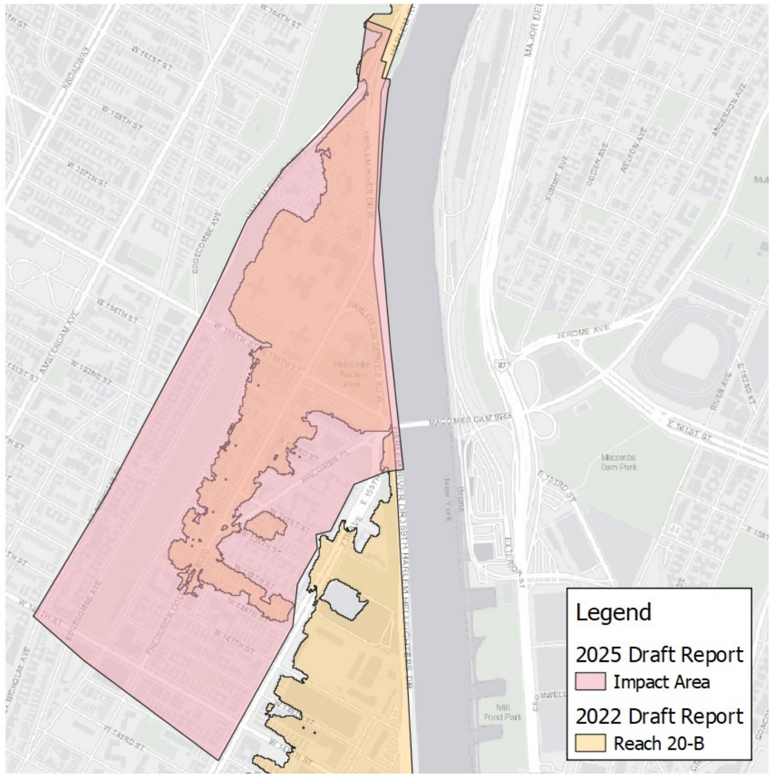

Figure 1: Comparison of the impact area for the Harlem River actionable element and economic reach 20-B from the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS (USACE, 2022b).

2.1.3 Hydraulic Inputs

Prior versions of HEC-FDA, including the version used for the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS (USACE, 2022b) required 1-dimensional hydraulic inputs, specified via model reach. In contrast, HEC-FDA 2.0 requires 2-dimensional hydraulic inputs (i.e., event-specific maps of water surface elevations throughout a floodplain). 2-dimensional hydraulic inputs, in comparison to 1-dimensional hydraulic inputs, are more likely to characterize expected extents of flooding with greater fidelity and allow for the direct sampling of flood depths at specific structures. These hydraulic inputs were developed for several different future conditions, reflecting various future sea levels in the Actionable Element site. Sea level change (SLC) projections under the three USACE curves (low, intermediate, and high) were developed via the Sea Level Analysis Tool (SLAT). As a check, these values were also computed independently using Equation 3 in ER 1100-2-8162 and the linear SLC trend at the Battery tide gauge in New York City (Station ID = 8518750). Figure 2 presents the SLC curves used in this study. From these SLC projections, forecasts of without- and with-project coastal flood risk were developed for n = 4 future SLC conditions (+0.49 ft, +1.06 ft, +1.53 ft, and +5.36 ft) corresponding to various points in future along the USACE intermediate and high projections. Table 2 also outlines these SLC conditions and their corresponding future years under the three USACE SLC projections.

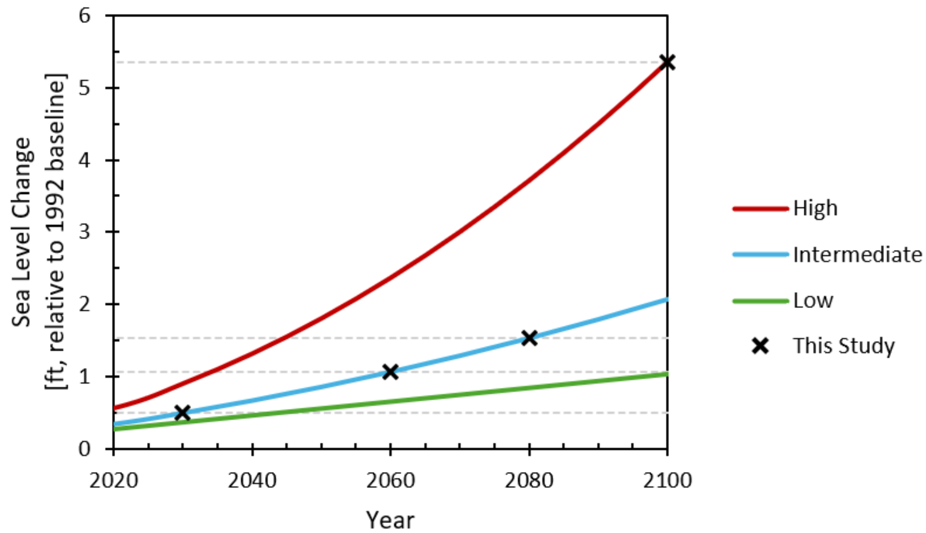

Figure 2: USACE sea level change curves (SLC) for the Battery tide gauge in New York City (Station ID = 8518750) and specific SLC conditions used in this study.

Table 2: Sea level change conditions considered in this study and corresponding future years in USACE SLC projections for the Battery tide gauge in New York City (Station ID = 8518750)

Sea Level Change [ft, 1992 baseline]	Year in Projection		
	Low	Intermediate	High
0.49	2043	2030	2018
1.06	2103	2060	2034
1.53	-	2080	2045
5.36	-	-	2100

In the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS, each economic reach was associated with a particular North Atlantic Coast Comprehensive Study (NACCS) hydrodynamic model save point, which directly informed the water surface profile for each reach. Reach 20-B (Manhattan shoreline along Harlem River) relied upon the water surface profile specified at NACCS save point 13,888. Following the same approach, the baseline mean sea level water surface profile was modulated by the projected increase in sea level to develop future water surface profiles and frequency functions. For each future sea level considered, this study evaluated eight coastal flood events of varying annual exceedance probability (99%, 50%, 20%, 5%, 2%, 1%, 0.5%, and 0.1%). Table 3 summarizes the frequency functions (i.e., water surface elevations vs. AEP) for these eight events for mean sea level (MSL) and future sea level conditions.

Table 3: Frequency functions (water surface elevations at various annual exceedance probabilities; AEPs) under the sea level conditions considered in this study (NACCS save point = 13,888) for the Harlem River Actionable Element site

Scenario	Year	SLC [ft]	AEP	99%	50%	20%	5%	2%	1%	0.5%	0.1%
MSL	**1992**	**0**	**WSEL [ft, NAVD88]**	4.7	5.8	7.1	8.1	9.0	10.2	11.2	12.5
Intermediate	**2030**	**0.49**		5.2	6.3	7.6	9.5	10.7	11.7	12.9	16.8
Intermediate	**2060**	**1.06**		5.8	6.9	8.2	10.1	11.3	12.3	13.5	17.4
Intermediate	**2080**	**1.53**		6.2	7.3	8.7	10.6	11.8	12.7	14.0	17.9
High	**2100**	**5.36**		10.1	11.1	12.5	14.4	15.6	16.6	17.8	21.7

2D mapping of the extent of flooding and associated water surface elevations was developed for each of the eight flood events across the four sea level conditions considered (32 total coastal flood events). Given that the hydrodynamic modeling developed as part of the NACCS study is not readily available in a 2D raster format, the NACCS save point water surface elevation was extrapolated over the Actionable Element site DEM via a raster calculation in QGIS. Though simplified, this approach is consistent with HEC-FDA version 1.4.2, which also relied upon a single water surface elevation to characterize extent and depth of flooding across an entire damage reach. Figure 3 provides an example flood extent developed via this approach. In this manner, gridded data hydraulic inputs were generated for each sea level condition considered in the study. Note that for coastal flood events of higher water surface elevations, there are a few isolated pockets of flooding shown proximal to Frederick Douglass Boulevard. Absent a hydraulic connection to these locations (e.g., stormwater backflow) it is unlikely that these structures would experience inundation, though the inclusion of these areas is consistent with the 1D projection of flood extents within HEC-FDA v1.4.2.

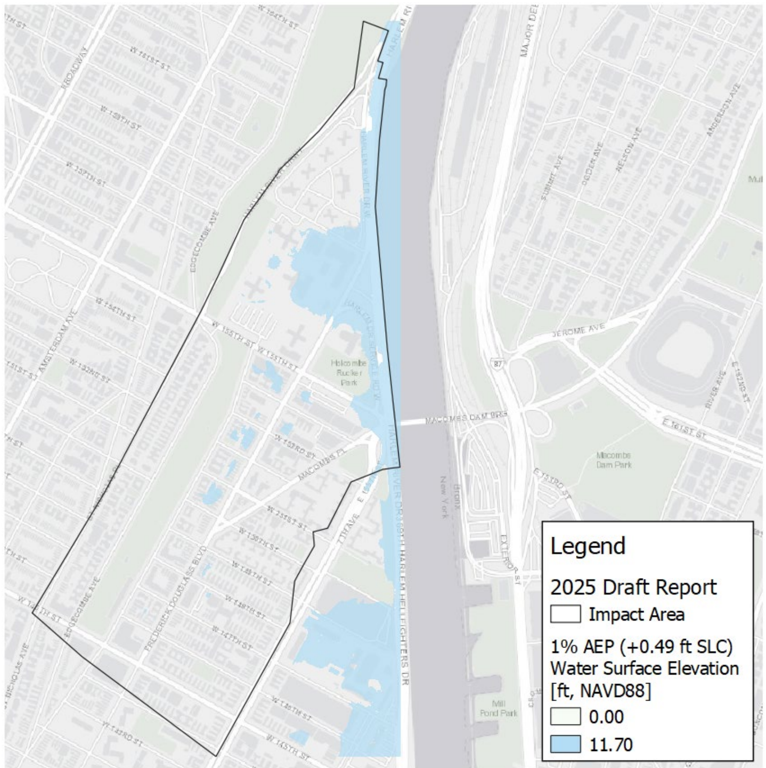

Figure 3: Sample gridded data hydraulic inputs for 1% AEP event with +0.49 ft SLC (USACE intermediate, 2030)

2.1.4 Structure Inventory

The analysis presented in this study largely relies upon the structure inventory developed for the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS; detailed information pertaining to this structure inventory, including how it was generated, can be found in Appendix D (USACE, 2022b). The original structure inventory asset value data was compiled in January 2018 price levels and subsequently escalated to February 2022 price levels via ENR building cost index (USACE, 2022b). For this interim response report, an alternative publicly available price index, the Federal Reserve's Producer Price Index for Final Demand Construction (PPIDCS; BLS, 2025)[2] was used to escalated asset values from January 2018 price levels. The Producer Price Index tracks changes in all nonresidential construction project costs; at the time of writing, there

[2] The USACE Civil Works Construction Cost Index System (CWCCIS) was also considered, though not ultimately used to escalate asset values, as this index tracks a different basket of goods (i.e., construction goods and services for a range of USACE for civil works projects) than that which is contained within the structure inventory.

is not a similar index for residential construction compiled by the Federal Reserve. Relying on the PPIDCS, asset values were escalated from January 2018 price levels to 2025 price levels by applying an escalation factor of 1.49.

Figure 4 provides a visual summary of the structures included within the inventory and additional structures from Reach 20-B of the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS that were not included in this study. Table 4 summarizes the number of structures, expected structure value, and expected content values by occupancy type for the structures shown within the impact area.

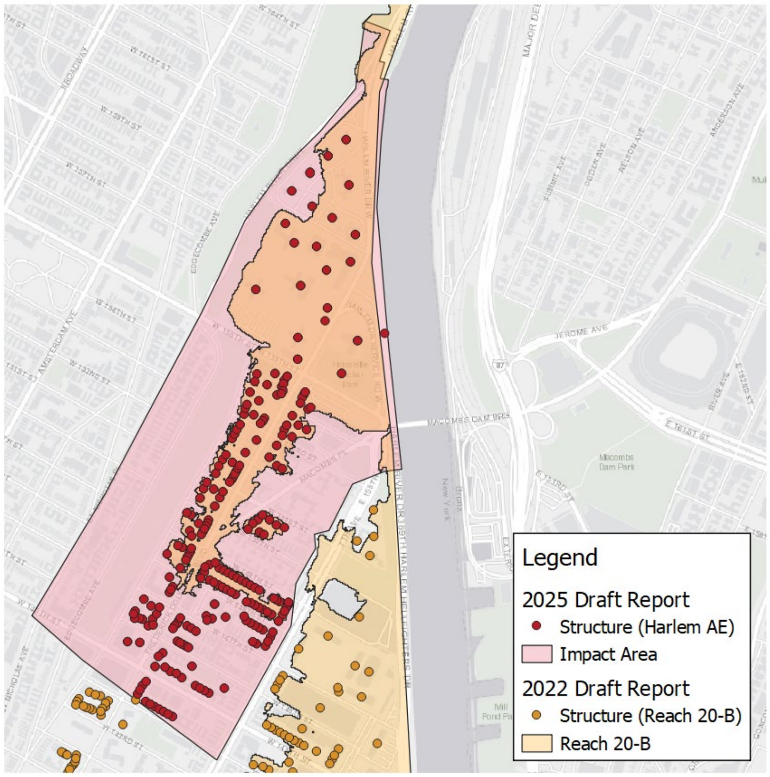

Figure 4: Visual comparison of structures within the Harlem River impact area and Reach 20-B from the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS.

Table 4: Summary of structures inventory included within the Harlem River impact area

Occupancy Type	Number of Structures	Total Expected Structure Value	Total Expected Content Value
Residential	207	$723,235,000	$361,617,500
Commercial	14	$94,265,000	$29,693,000
Infrastructure	2	$265,923,000	$0
TOTAL	223	$1,083,423,000	$391,310,500

In addition to the structure inventory compiled for the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS, an additional desktop survey was conducted to identify critical infrastructure assets within the Actionable Element site. This survey identified the Metropolitan Transit Authority (MTA) New York City Transit (NYCT) 155th St Station and the B & D Line tunnel as additional critical infrastructure within the Harlem River Actionable Element impact area. NYCT has already developed deployable flood barriers at the primary 155 St Station opening and ventilation grates within the Actionable Element site. Per conversations with NYCT and MTA personnel, these assets are likely to be deployed in the future during a coastal flood event, regardless of whether a CSRM feature is constructed within the Actionable Element site. Regardless, the proposed CSRM feature would become the primary coastal flood risk management measure for the NYCT station and tunnel. Given the criticality of the NYCT station and tunnel to the population and economic vitality of NYC, the added layer of risk management provided by the CSRM feature would enhance the resilience of the NYCT subway system to coastal storms.

Given this context, the NYCT station and tunnel are included in the structure inventory. Relying on prior replacement cost estimates for underground heavy rail stations (Martello, 2023) and assuming full depreciation to a terminal value equivalent to half the replacement cost, the 155 St station was valued at $75.9M. A 4,600-foot-long section of the subway tunnel and right-of-way, stretching from west of 155 St Station to the 161 St Station, consisting of three parallel tracks and the subway tunnel itself, was also included in the structure inventory. Relying on replacement costs for typical subway heavy rail assets (Martello, 2023) and a similar estimate of depreciation, this stretch of tunnel was valued at $163.1M. Uncertainty in these asset values was assumed to follow a normal distribution (standard deviation = 38%) in alignment with Martello (2023).

In addition to the NYCT assets within the impact area, an elevated portion of Harlem River Drive is also included in the structure inventory. More specifically, approximately 1,700 linear feet of Harlem River Drive Northbound is supported on a high-level platform, extending over the Harlem River shoreline (NYCEDC, 2016). Based on the data provided within the National Bridge Inventory (FHWA, 2025), this high-level platform (structure number 1055040) has an estimated replacement value of $26.9M (FY2025 price levels). Similar to transit infrastructure, uncertainty in this asset value was assumed to follow a normal distribution (standard deviation = 38%; Martello, 2023). Given the low elevation of this structure (low chord of road deck at approximately +4.6 ft NAVD88) it is particularly vulnerable to coastal inundation. Repairing significant damage to this structure is likely to require prolonged closures and detours of Harlem River Drive Northbound, which is likely to impose additional travel costs for road users. These additional costs have not been quantified as part of this analysis, though they are likely to be significant, given the high volume of traffic that regularly relies on this corridor. As of 2023, this section of Harlem River Drive Northbound carried an estimated 48,292 vehicles per day (i.e., average annual daily traffic; AADT; NYSDOT, n.d.). Even a modest increase in expected travel time for these road users (e.g., 15 minutes) is likely to yield substantial transportation delay costs. Pending data availability, the study will include these disruption costs in the final report.

2.1.5 Occupancy Types

These NYCT assets and Harlem River Drive notwithstanding, within the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS, inventory structures were classified based on their similarity to the building prototypes presented in the NACCS depth-damage report (USACE, 2015). More specifically, within the Actionable Element site, structures were either classified as either urban high rise (Prototype 4A), 3-story apartments with no basement (Prototype 1A-3), or Commercial Non/Pre-Engineered, Nonperishable Contents (Prototype 2 NP). These occupancy type assignments were left unchanged and imported directly from the previously developed HEC-FDA version 1.4.2 file (USACE, 2022b).

2.1.5.1 Harlem River Drive High-Level Platform

The Harlem River Drive Northbound high-level platform can be characterized as an urban bridge. Williams et al. (2025) provide an expert derived minimum and maximum depth-damage function for urban roadway bridges, wherein flood depth is specified relative to the low chord of the bridge deck. Relying on these curves, a most likely damage-function was also developed by averaging these minimum and maximum functions. These depth-damage functions are presented in Figure 5.

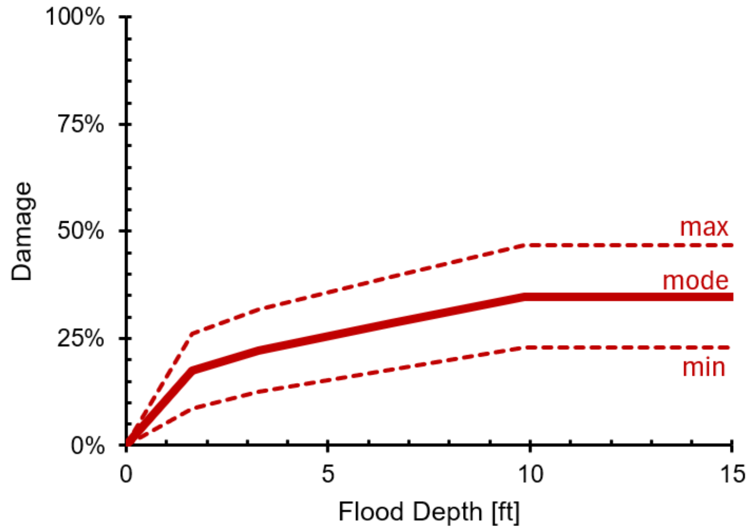

Figure 5: Depth-damage function for urban roadway bridges (Williams et al., 2025)

2.1.6 NYCT Tunnel Depth-Damage Function Development

The NYCT assets in the Actionable Element site (155th St Station and subway tunnel) were assigned a separate occupancy type and depth-damage function. This study developed a volume-informed depth-damage function for these assets following a methodology developed for the City of Boston CSRM Feasibility Study, which is currently ongoing at the time of writing. What follows is a detailed description of this methodology, adapted from the Baltimore CSRM feasibility study (USACE, 2024) and also applied for the ongoing Boston CSRM Feasibility Study.

Unlike most other assets, which are well characterized by a single first floor elevation for the purposes of flood damage modelling, the depth of water within a flooded tunnel will vary along its profile. Consequently, the damage along the length of a flooded tunnel will also vary (Martello & Whittle, 2023). This variation is ultimately a function of the geometry of the tunnel, which informs a relationship between flood volume and damages within the tunnel. Applying a similar approach to the recent Baltimore CSRM Feasibility Study (USACE, 2024), this study developed a generalized tunnel volume-damage relationship. In isolation, this generalized volume-damage relationship is however of little value, as a relation between tunnel inflow volume and flood depth at tunnel openings is also required to develop a depth-damage relationship for a specific tunnel of interest. Relying on a sample set of water surface elevation time series data and hydraulic characteristics of the primary tunnel opening in the Actionable Element site (155th St Station entrance), inflow volumes are estimated for a series of flood events of specified depth. Given this tunnel-specific depth-volume relationship and generalized volume-damage relationship, a depth-damage relationship was developed for the 155th St Station and NYCT tunnel, thereby enabling inclusion of tunnel assets within HEC-FDA 2.0.

2.1.6.1 Volume-Damage Relationship

Developing a volume-damage relationship for a tunnel requires the selection or development of a relationship between flood depth and damage for a unit-length of tunnel. Here, this unit-length depth-damage function is a composite of the functions developed for linear assets included within a unit-length of tunnel: track, signal, third rail, power, lighting, and tunnel structure (Martello et al., 2023). This composite curve is a replacement cost-weighted average of depth-damage curves for each of linear asset types that comprise a segment of the transit tunnel right-of-way (ROW). More formally, the composite depth-damage curve for a ROW segment, $f_{ROW}(d)$, composed of n linear assets can be computed as follows:

$$f_{ROW}(d) = \sum_{i=1}^{n} w_i f_i(d)$$

Wherein the depth-damage function for each linear asset, $f_i(d)$, is multiplied by its respective percentage of the overall ROW replacement-cost, w_i, defined as:

$$w_i = c_i \sum_{i=1}^{n} \frac{1}{c_i}$$

where c_i is the expected replacement cost of a linear asset of interest. Note that the sum of all weights is unity. Under this approach, damage estimates for a given ROW segment are identically equivalent to the sum of the damage estimates for each individual ROW asset. Using this approach, replacement-cost weighted damage estimates were developed for a discrete set of flood depths. These discrete damage estimates were utilized to develop a continuous depth-damage function via a cubic regression:

$$f_{ROW}(d) = (1.74 \cdot 10^{-5})d^3 - (1.72 \cdot 10^{-3})d^2 + (6.28 \cdot 10^{-2})d$$

Lower and upper bound depth-damage functions were developed via the approach outlined in Egorova et al., (2008), applying an uncertainty parameter, k = 0.1. The resulting depth-damage functions shown in Figure 6a. As in the Baltimore CSRM study (USACE, 2024) and the Boston CSRM study (ongoing at the time of writing), the resultant damage function was validated via benchmarking (i.e., comparison of this curve relative to adjacent curves provided elsewhere in literature). Absent relevant empirical data, this type of qualitative comparison is the best available method for assessing the validity of depth-damage curves (Gerl et al., 2016; USACE, 2024). Comparing with adjacent curves for general infrastructure found in the literature (de Moel & Aerts, 2011; Vanneuville et al., 2003) and tunnel structure (Martello et al. 2023), the resulting curve aligns well (Figure 6a). Given that the replacement cost of the tunnel structure is more than 85% of the overall unit length replacement cost, the curve closely aligns with the tunnel structure curve (Martello et al., 2023). The upper bound generally aligns with the other infrastructure curves found in literature. These comparisons suggest that the composite unit-length depth-damage function could reasonably be applied to characterize tunnel damages.

Relying on this depth-damage relationship, a generalized volume damage relationship for a tunnel can be developed through the consideration of two hypothetical tunnel geometries, referred to here as cases A and B. Case A considers a perfectly flat tunnel with no slope. In such a tunnel, any volume of flood water will be distributed evenly across its entire length. That is, across the entirety of the tunnel, the flood depth, and therefore the damage estimate, is constant. The resulting volume-damage relationship under Case A is shown in Figure 6b. Case B considers a tunnel with an infinite slope, that is, a vertical shaft. In such a tunnel (or shaft) any given increment of the tunnel is either fully flooded or completely dry. The resulting volume-damage relationship under Case B is shown in Figure 6c.

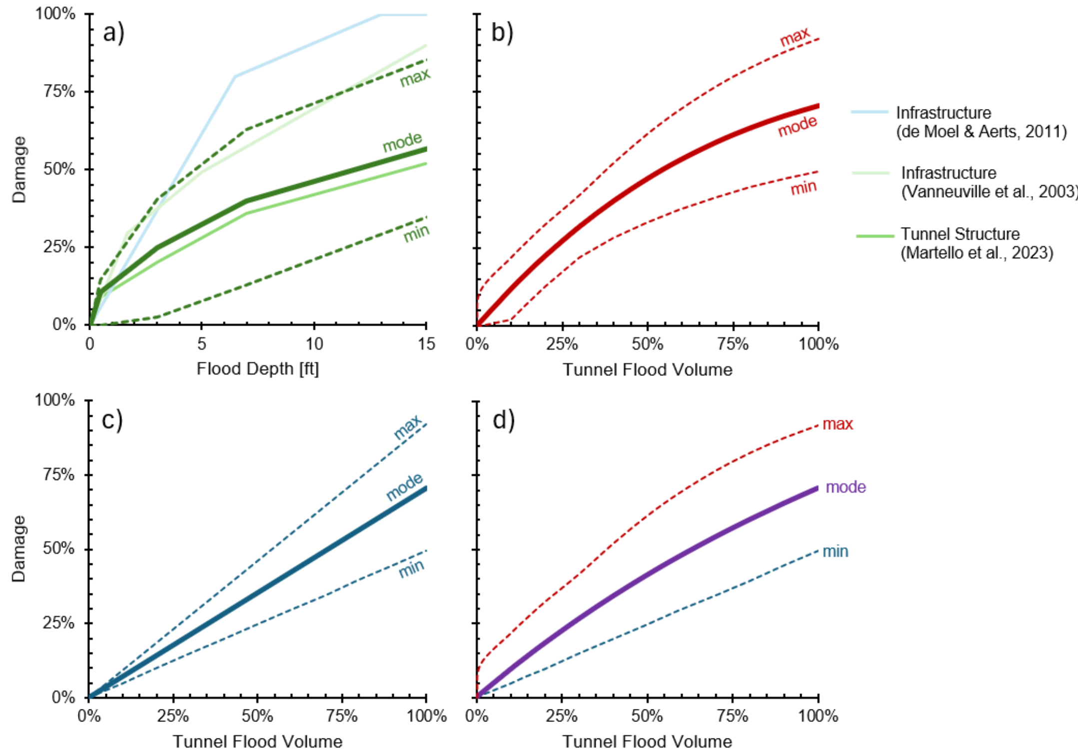

Figure 6: a) depth-damage relationship (IND-6; URS, 2013) characterizing fragility of a unit length of subway tunnel; b) damage-volume relationship under case A (flat tunnel); c) damage-volume relationship under case B (vertical shaft); d) damage-volume relationship under case C (combination of cases A and B)

Tunnels are neither perfectly flat, nor vertical. The slope of a tunnel, which is typically well under a 10% grade, will vary along its longitudinal alignment, and this variation will affect this volume-damage relationship. Adequate characterization of this tunnel-specific variability in the volume-damage relationship for a given tunnel would require hydraulic modeling to characterize the relationship between inflow volume and flood depths along the profile of a tunnel. Rather than expend the significant additional modeling effort that would be required for each tunnel under this approach, here, it is assumed that Cases A and B can be combined to adequately represent a volume-damage relationship for all tunnels. That is, the upper bound of Case A and lower bound of Case B bound the range of possible volume-damage estimates, while an equally weighted average of the mode of Case A and B inform the mode of the generic volume-damage relationship. This equal weighting implies that the most likely average slope in a tunnel is 50%, much higher than what would be realistically expected. However, this assumption is purposefully conservative, as an equal weighting biases the volume-damage relationship closer to the lower bound. Figure 6d provides the resultant generic volume-damage relationship.

2.1.6.2 Depth-Damage Relationship

This generic damage-volume relationship can be employed alongside a tunnel-specific depth-volume relationship to develop a depth-damage relationship for a tunnel of interest. Developing a depth-volume relation for a specific road tunnel requires specification of the hydraulic characteristics of all tunnel openings. Relying on available data from as-built drawings and the study DEM, the elevation, slope, and width of all tunnel portals was found for each road tunnel. Given these characteristics, for a given depth of flooding at a tunnel opening, a corresponding inflow can be computed via a weir flow equation (Martello, 2023):

$$Q(t) = 3.33(w - 0.2d)d^{\frac{3}{2}}$$

Wherein the width of the opening, w, and the depth of flooding, d directly inform inflow into the tunnel. Using this approach, given a sample coastal flood event (defined by a tide and storm surge) a time series of water surface elevations can be used to estimate inflows over time into each tunnel opening. Figure 7 illustrates a sample coastal flood event, wherein water levels are developed based on a tide and a superimposed storm surge. Given a lowest critical location (LCL) for the 155th St Station entrance, the depth of water and corresponding inflows at a tunnel opening can be evaluated for each time step. Given these resultant inflow rates, the overall volume of inflow into each tunnel opening can be computed via numerical integration; the total volume of inflow into the tunnel can be found by summation of inflows at all tunnel openings (Martello & Whittle 2023). In this manner, a depth-volume relationship is developed for each road tunnel, wherein the flood depth corresponds to the maximum water depth at the lowest tunnel opening.

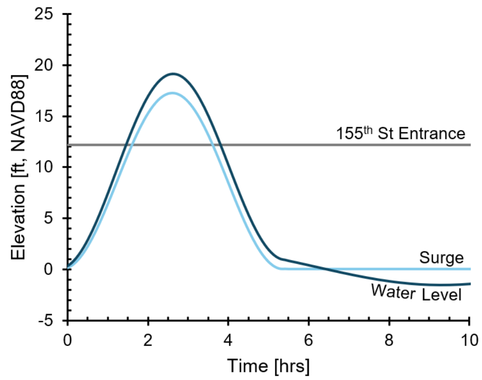

Figure 7: Sample surge, and water surface elevation over time at the 155th St Station entrance

Using this approach, inflow volumes and flood depths were computed for each road tunnel under a set of n=8 sample flood events (peak surge elevations of +12.2, +13.2, +14.2, +15.2, +16.2, +17.2, +18.2, +19.2 ft NAVD88). Inflow volumes were normalized by estimated tunnel volume (4,200,000 ft^3) to develop a percent of flooded tunnel volume. Figure 8a provides the resultant depth-volume relationship. Given this tunnel-specific depth-volume relationships and the generic tunnel volume-damage relationship (Figure 6d), Figure 8b presents a tunnel-specific depth-damage relationships for the 155th St Station and NYCT tunnel.

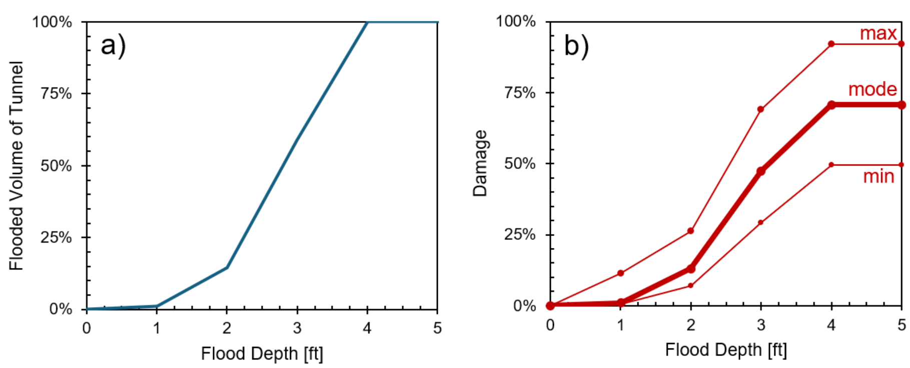

Figure 8: 155th St Station and NYCT tunnel: a) flood depth-volume relationship, b) flood depth-damage relationship.

2.2 DISCOUNTING APPROACH

This study employed HEC-FDA 2.0 to assess expected annual damages (EAD) under the with- and without-project condition for under several future sea level conditions, as highlighted above. While HEC-FDA 2.0 can nominally use this information to assess flood risk over the full period of economic benefits, it is not well suited for analyzing future conditions that change in a nonlinear manner over time, such as is the case under the USACE intermediate and high SLC projections. As such, flood risk over the full period of analysis was assessed and discounted outside of HEC-FDA. Using EAD outputs for the four sea level conditions highlighted in Table 2, projections of future EAD were interpolated via a linear equation for the (USACE low SLC) or a quadratic equation (USACE intermediate and high), ensuring monotonicity over time. EAD for without- and with-project conditions were evaluated over a 50-year period of analysis for each of the three USACE SLC projections. These future EAD values were subsequently discounted to the base year of analysis and annualized using the current FY Federal discount rate (3%, EGM 25-01).

2.3 ACTIONABLE ELEMENT OVERVIEW

The proposed actionable element was modeled within HEC-FDA as a lateral structure assigned to the Harlem River Actionable Element impact area, with a crest elevation[3] of +17.5 ft NAVD88. HEC-FDA 2.0 allows for the fragility of these structures to be characterized via a system response curve. Development of a system response curve is important when evaluating the expected performance of levee systems, as their probability of failure generally increases with flood severity. In contrast, floodwalls and seawalls are designed to ensure that they retain their structural integrity, even during overtopping events. As such, it was assumed that the proposed actionable element will not fail, even during overtopping events (i.e., the system response curve denotes a 0% failure probability at all flood stages).

2.4 RESULTS

Expected annual damages (EAD) for the Harlem River impact area were computed for the four SLC conditions identified in Table 2 using HEC-FDA 2.0. These results are shown in Table 5, wherein total EAD for the impact area and EAD by occupancy type are provided for both the without- and with-project condition. In the without-project condition, EAD for commercial and residential structures are similar in magnitude, with greater EAD shown for residential structures. EAD for infrastructure assets in the Actionable Element site (i.e., 155 St Station and subway tunnel, Harlem River Drive high-level platform) are greater than those estimated for commercial or residential structures. Under the without-project condition, EAD under the highest SLC condition (+5.36 ft) is an order of magnitude greater than under the next highest SLC condition (+1.53 ft). EAD (i.e., residual risk) under the with-project condition is similarly an order of magnitude greater under the highest SLC conditions. Residual risk under the with-project condition is minimal, demonstrating that the proposed actionable element provides a robust level of risk management. For context, the crest elevation of the proposed actionable element (+17.5 ft NAVD88) corresponds to approximately a 0.15% annual exceedance probability with intermediate SLC at the end of period of analysis. Consequently, the CSRM benefit provided by the project is robust to SLC, providing a similar degree of risk management under the +0.49 ft, +1.06 ft, and +1.53 ft SLC conditions, while still providing significant CSRM benefit under the highest SLC condition.

Table 5: Without- and with-project Expected annual damages (EAD) for the Harlem River Actionable Element impact area, (HEC-FDA 2.0 outputs)

	Expected Annual Damage (EAD)							
	Without-Project				With-Project (Residual Risk)			
SLC [ft]	**TOTAL**	**Commercial**	**Residential**	**Infrastructure**	**TOTAL**	**Commercial**	**Residential**	**Infrastructure**
0.49	$ 2,069,000	$ 382,000	$ 391,000	$ 1,296,000	$ 1,000	<$1,000	<$1,000	<$1,000

[3] Referred to as "Top of Levee Elevation" in HEC-FDA version 2.0.

1.06	$ 3,864,000	$ 484,000	$ 618,000	$ 2,763,000	$ 2,000	<$1,000	$ 1,000	$ 1,000
1.53	$ 4,626,000	$ 828,000	$ 745,000	$ 3,054,000	$ 3,000	<$1,000	$ 1,000	$ 1,000
5.36	$ 38,189,000	$ 9,467,000	$ 12,580,000	$ 16,142,000	$ 120,000	$ 19,000	$ 55,000	$ 46,000

FY2025 Price Levels

Relying on these EAD values, and implementing the discounting approach outlined above, annualized coastal storm risk under without- and with-project conditions, along with associated CSRM benefits for each SLC scenario are shown in Table 6. Based on these results, under the intermediate SLC scenario, the proposed actionable element is expected to provide $3.6M [FY2025 price levels] in annualized CSRM benefit to the Actionable Element site. Additionally, Table 6 provides the benefit-cost ratio (BCR) and average annual net benefit (AANB) by SLC scenario. Given the estimated $761,984,000 cost of the Harlem River Actionable Element, this corresponds to a BCR of 0.1 under the intermediate SLC condition.

Table 6: Annualized coastal storm risk and project performance for the Harlem River Actionable Element across USACE SLC scenarios

	Coastal Storm Risk (Annualized)		CSRM Benefit (Annualized)	Benefit-Cost Ratio (BCR)	Average Annual Net Benefit (AANB)
SLC Scenario	Without-Project	With-Project			
Low	$ 2,475,000	$ 1,000	$ 2,474,000	0.1	-$ 27,141,000
Intermediate	$ 3,616,000	$ 2,000	$ 3,614,000	0.1	-$ 26,001,000
High	$ 8,577,000	$ 17,000	$ 8,560,000	0.3	-$ 21,055,000

FY2025 Price Levels; Federal Discount Rate = 3%; 50-year period of analysis (2037-2086)

Performance of the Harlem River actionable element was also computed via HEC-FDA 2.0 pursuant to ER 1105-2-101. Performance was computed relative to the design still water level (+12.2 ft NAVD88). As shown in Table 7, the expected annual exceedance probability of the actionable element is 1.6% with SLC towards the end of period of analysis (USACE intermediate SLC in 2080). The recommended plan will pass the 3.0% AEP event with 90% assurance at the end of period of analysis under the intermediate SLC. The long-term exceedance probability (LTEP) increases with SLC. Under the intermediate SLC scenario, the 10-year LTEP starts at 8.7% in 2030 and increases to 14.9% by 2080. Conversely, assurance decreases over time under the intermediate SLC scenario. For example, under the 1% AEP event, assurance is 63.7% in 2030 and decreases to 36.6% by 2080.

Table 7: Probabilistic performance of Harlem River Actionable Element across SLC conditions

SLC Scenario	Year	SLC [ft]	Annual Exceedance Probability		Long-Term Exceedance Probability			Assurance by Event				
			Expected	90% Assurance	10-yr period	30-yr period	50-yr period	10%	2%	1%	0.40%	0.20%
Int.	2030	0.49	0.9%	1.7%	8.7%	24.0%	36.7%	>99.9%	95.7%	63.7%	18.8%	1.9%
Int.	2060	1.06	1.2%	2.3%	11.7%	31.1%	46.2%	>99.9%	85.1%	47.4%	9.7%	0.7%
Int.	2080	1.53	1.6%	3.0%	14.9%	38.4%	55.4%	>99.9%	68.7%	36.6%	5.1%	0.2%
High	2100	5.39	25.3%	30.7%	94.6%	>99.9%	>99.9%	0.04%	<0.01%	<0.01%	<0.01%	<0.01%

3 EAST RISER

Similar to the Harlem River Actionable Element site, coastal flood risk under the with- and without-project conditions for the East Riser Actionable Element site was assessed via HEC-FDA version 2.0 (IWR, 2023). Where appropriate, this study relies upon the existing inputs from a prior HEC-FDA version 1.4.2 model developed for the NJDEP Rebuild by Design Meadowlands (RBDM) feasibility study (NJDEP, 2021a). Details of the economic assessment conducted as part of this prior study are provided in Appendix E (NJDEP, 2021c). There are several differences between HEC-FDA 1.4 and version 2.0, which necessitated the development of additional model inputs. Where applicable, this appendix details and describes these changes.

This study assessed fluvial flood risk within the southernmost portion of the East Riser Ditch Channel basin. Given the low elevation of the basin, fluvial flood risk in this area is heavily influenced by tidal tailwater conditions. Given the correlation of rainfall and tidal condition within the Actionable Element site (NJDEP, 2021b), the hydraulic modeling relied upon the 2-year tide as a tailwater boundary condition. Expected flow rates within the basin were assessed via HEC-HMS; extent and severity of flooding within the basin was characterized via HEC-RAS. Additional details on the hydraulic modeling can be found in Section 8 of the main report.

The with-project condition assessed in this report includes the effect and performance of a pump station proposed by the RBDM study and expected to be completed prior to end of construction for the East Riser Actionable Element. For the purposes of plan formulation and analysis, it was assumed that the channel improvements under consideration in this study are integral to the performance of the pump station under high flow conditions. Consequently, the analysis presented here assumes that under the without-project condition, it is likely that any reductions in water surface elevation provided by the pump station would be limited and are therefore neglected in the without-project condition. The pump station and channel improvements are designed to increase the flow rate of water out of the East Riser Ditch Channel basin during flood events and minimize the duration of flood events within the basin.

What follows is a summary of the HEC-FDA 2.0 inputs developed and employed for the East Riser Actionable Element site. This summary is followed by a detailed description of the discounting approach, description of the actionable element modeled in HEC-FDA 2.0, and presentation of the economic analysis results.

3.1 HEC-FDA 2.0 INPUTS

3.1.1 Terrain Data

Prior versions of HEC-FDA included ground elevation data as part of the structure inventory. In contrast, HEC-FDA version 2.0 allows for the import of terrain data via a raster file. For the East Riser Actionable Element site, the study employs a digital elevation model (DEM) with a horizontal spatial resolution of 2.56 inches and a vertical accuracy of 1.06 inches (NOAA, 2014). In conjunction with the structure-specific foundation height specified in the structure inventory (see Section 3.1.4), this terrain data directly informs the first-floor elevation of the structures within the Actionable Element site.

3.1.2 Impact Areas

Appendix D of the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS (USACE, 2022b) presents the economic reaches considered during the formulation of the draft comprehensive plan. These reaches were originally delineated based on county boundaries, tidal water bodies, expected maximal extent of damage (corresponding to +20 ft NAVD88), and hydraulic separability. The East Riser Actionable Element site corresponds to a subsection of economic reach 12-RBDMSU (Rebuild by Design Meadowlands Shore-Based Measures Upper Area), as shown in Figure 9. In alignment with the NJ Rebuild by Design Meadowlands (RBDM) study, wherein the economic model reaches (NJDEP, 2021c) were informed by drainage basin delineations (NJDEP, 2021b) and further informed by additional drainage basin delineation provided via USGS StreamStats (USGS, 2025), this study developed a refined set of impact areas, specific to the proposed Actionable Element

Site, shown in Figure 9. In addition to the primary drainage basin of interest, East Riser Ditch Channel South, portions of adjacent RDBM subbasins were also included as these areas are also likely to be influenced by the proposed East Riser actionable element project.

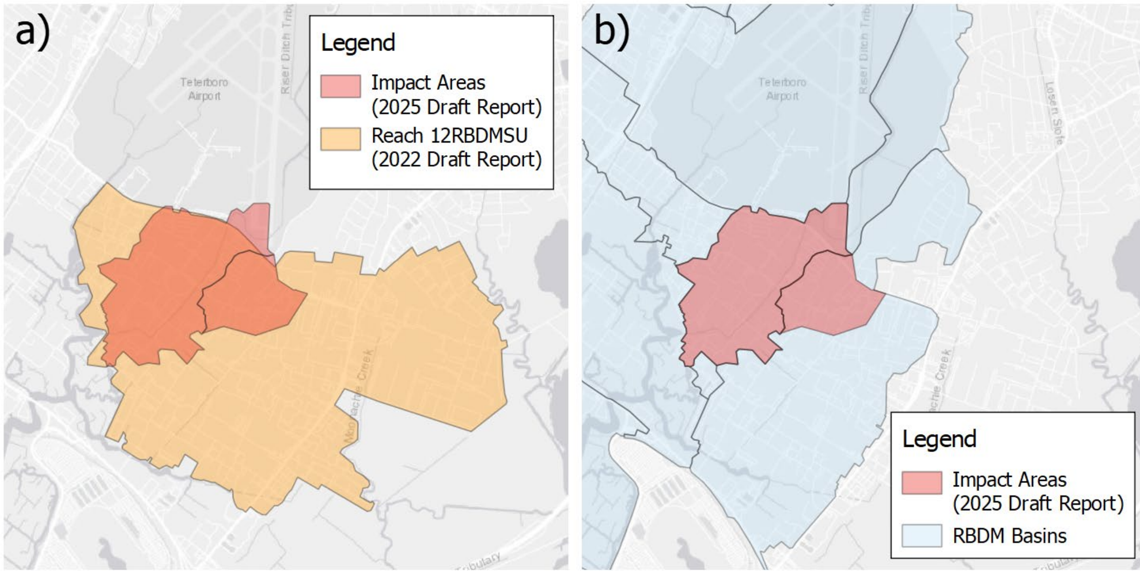

Figure 9: Comparison of East Riser impact areas developed for this study to those developed for: a) September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS, b) Rebuild by Design Meadowlands (NJDEP, 2021c)

3.1.3 Hydraulic Inputs

Given that the proposed Actionable Element project is primarily focused on reducing fluvial flood risk within the East Riser Actionable Element site, the economic analysis presented here considers existing and with-project fluvial flood risk. Due to the low elevation of the East Riser basin and its outfall into Berrys Creek, fluvial flood risk within the Actionable Element site is influenced by tidal boundary conditions. Informed by the hydrology and rainfall tide correlation analysis presented in the RBDM report (NJDEP, 2021b), fluvial flood risk was assessed considering the 1-in-2-year tide condition under present sea level. The East Riser Actionable Element site is also vulnerable to coastal storm risk, though given that the proposed project will primarily reduce fluvial flood risk, coastal storm risk (management) was not evaluated during this phase of the study. Additional analysis of coastal storm risk with future SLC within the General Study Area will likely be included in the final report, pending concurrence from the study team and data availability. The economics appendix of the September 2022 Draft Integrated FR/Tier 1 (Programmatic) EIS (USACE, 2022b) provides additional details on coastal storm risk within this portion of the study area.

This study relies on a HEC-HMS and HEC-RAS modeling initially developed to comply with NJDEP permit requirements for the proposed RBDM project (NJDEP, 2021a). Additional model runs were completed to ensure that a total of 8 flood events were evaluated for each condition of interest. Additional details on this model can be found in Section 8 of the main report. For this phase of the study, the economic modeling assessed flood risk under the existing without-project condition and the existing with-project condition. Future without- and with-project conditions, considering projected nonstationary in model inputs will be completed as-needed prior to the final report release. Table 8 summarizes the existing without- and with-project frequency functions for the East Riser Ditch Channel south impact area.

Table 8: Stage-frequency functions for East Riser Ditch Channel South under the without- and with-project conditions

Annual Exceedance Probability	Existing Without-Project Condition [ft, NAVD88]	Existing With-Project Condition [ft, NAVD88]	With-Project Condition Reduction [ft]
99%	4.4	3.04	1.36
50%	5.08	4.13	0.95
20%	5.49	4.79	0.70
10%	5.77	5.23	0.54
4%	6.07	5.68	0.39
2%	6.25	5.94	0.31
1%	6.42	6.17	0.25
0.5%	6.62	6.38	0.24
0.2%	6.88	6.65	0.23

3.1.4 Structure Inventory

The analysis presented in this study relies on the structure inventory developed as part of the RBDM project (NJDEP, 2021a). The structures in the Actionable Element Site primarily consist of commercial and industrial facilities, along with a number of mobile homes, situated within two separate communities, one of which lies immediately adjacent to the eastern bank of East Riser Ditch Channel. While the structure inventory from the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS included structures within the East Riser Actionable Element site (i.e., those structures contained within economic reach 12RBDMSU), the structure inventory developed for the RBDM project was partially informed by field surveys, which further refined usage, number of stories, foundation heights, basement configuration, structural conditions, and estimates of content values field surveys for structures within the Actionable Element site (NJDEP, 2021c). Consistent with the approach taken for the Harlem River Actionable Element site, structure and content values were escalated from 2016 to 2025 price levels using the Producer Price Index for Final Demand Construction (PPIDCS; BLS, 2025). Relying on the PPIDCS, asset values were escalated from 2016 price levels to 2025 price levels by applying an escalation factor of 1.56. For additional information detailing the structure inventory, see Appendix E of the RBDM study (NJDEP, 2021c).

Figure 10 provides a visual comparison of the structure inventory from the RBDM study (used in this report, shown in red) and the structure inventory from the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS (shown in orange). Table 9 summarizes the number of structures, expected structure value, and expected content values by occupancy type for the structures shown within the East Riser impact areas.

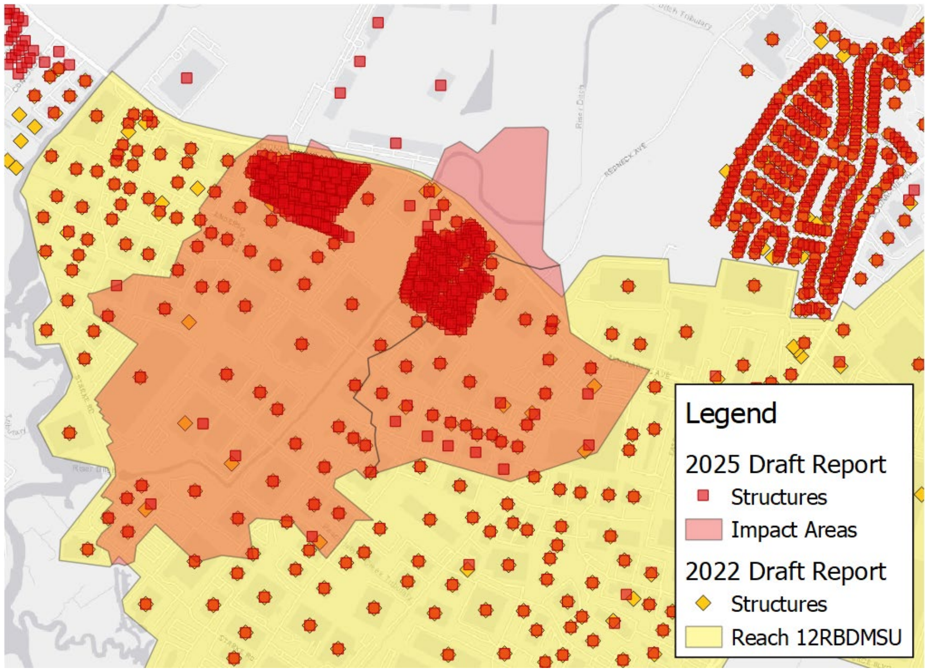

Figure 10: Visual comparison of structures within the East Riser impact area and Reach 12RBDMSU from the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS

Table 9: Summary of structures inventory included within the East Riser impact areas

Occupancy Type	Number of Structures	Total Expected Structure Value	Total Expected Content Value
Residential	428	$46,210,000	$14,556,150
Commercial	19	$141,769,000	$44,657,000
Industrial	74	$579,039,000	$182,397,000
TOTAL	521	$767,018,000	$241,610,150

3.1.5 Occupancy Types

Similar to the structure inventory, this study relies upon the occupancy types developed for the RBDM study (NJDEP, 2021a). Given the additional field reconnaissance completed as part of the RDBM study, though slightly different from those employed in the September 2022 Draft Integrated Feasibility Report/Tier 1 (Programmatic) EIS, these occupancy types were determined to be more representative of the structure-specific sensitivity to flooding. The East Riser Actionable Element site includes industrial, commercial, residential, and utility structures. Corresponding structure and content depth damage functions were imported directly from the RDBM study HEC-FDA v1.4.2 study files. Additional details on the structure inventory can be found in Appendix E of the RBDM report (NJDEP, 2021c).

3.1.6 Discounting Approach

Given that no future without- or with-project condition hydraulic modeling was available for the draft report, the study assumes that the existing without- and with-project conditions adequately represent without- and with-project flood risk for the entire period of analysis (2037-2086). Consequently, the expected annual damages (EAD) under the without- and with-project conditions are equivalent to the annualized flood risk over the full period of analysis. If additional future without- and with-project conditions introduces a linear nonstationary in

EAD, future EAD values can be readily discounted and annualized in HEC-FDA 2.0 to develop annualized flood risk estimates.

3.2 RESULTS

Expected annual damages (EAD) for the East Riser Actionable Element site were computed via HEC-FDA 2.0 given the inputs outlined above. These results are shown in Table 10, wherein total EAD for each impact area and EAD by occupancy type are provided for both the without- and with-project condition. In the without-project condition industrial structures (IND) within the Actionable Element site are responsible for the largest contribution of EAD, with commercial (COM) and residential (RES) structures responsible for a smaller portion of the overall EAD. Given that the proposed Actionable Element moderately reduces the severity and duration of flooding across the Actionable Element Site, all at-risk structures in the Actionable Element Site retain some residual risk. This residual risk reflects an expectation of a modest decrease in even-specific flood damages, proportional to the reduction in water surface elevation provided by the actionable element as shown in Table 8.

Table 10: Without- and with-project Expected annual damages (EAD) for the East Riser Actionable Element impact area, (HEC-FDA 2.0 outputs)

	Expected Annual Damage (EAD)							
	Without-Project				With-Project (Residual Risk)			
Impact Area	TOTAL	IND	COM	RES	TOTAL	IND	COM	RES
ERD South	$ 32,599,000	$ 16,065,000	$ 8,193,000	$ 8,341,000	$ 0	$ 9,144,000	$ 3,666,000	$ 4,808,000
Peach Island Creek	$ 1,078,000	$ 0	$ 14,000	$ 1,064,000	$ 552,000	$ 0	$ 4,000	$ 548,000
TOTAL	$ 33,677,000	$ 16,065,000	$ 8,207,000	$ 9,405,000	$ 18,170,000	$ 9,144,000	$ 3,670,000	$ 5,356,000

FY2025 Price Levels

Relying on these EAD values, and implementing the discounting approach outlined above, annualized fluvial flood risk under without- and with-project conditions, along with associated flood risk management benefits for each impact area scenario are shown in Table 11. Based on these results, under the intermediate SLC scenario, the proposed actionable element is expected to provide $15.5M [FY2025 price levels] in annualized flood risk management benefit to the Actionable Element site. Given the estimated $249,146,000 cost of the East Riser actionable element, this corresponds to a BCR of 1.7.

Table 11: Annualized coastal storm risk under the without- and with-project condition and annualized coastal storm risk management benefit

	Flood Risk (Annualized)		Flood Risk Management Benefit (Annualized)	Benefit-Cost Ratio (BCR)	Average Annual Net Benefit (AANB)
Impact Area	Without-Project	With-Project			
ERD South	$ 32,600,000	$ 17,618,000	$ 14,982,000	-	-
Peach Island Creek	$ 1,064,000	$ 552,000	$ 512,000	-	-
TOTAL	$ 33,664,000	$ 18,170,000	$ 15,494,000	1.6	$ 5,811,000

FY2025 Price Levels; Federal Discount Rate = 3%; 50-year period of analysis (2037-2087)

Performance of the East Riser actionable element was also computed via HEC-FDA 2.0, pursuant to ER 1105-2-101, using a performance threshold of +5 ft NAVD88. This threshold is the flood stage at which damages are expected to begin for residential structures within the mobile home communities in the Actionable Element Site. As shown in Table 12, under the without-project condition, the annual exceedance probability for this threshold is expected to be 60.9% (i.e., in a given year, there is a 60.9% chance that this threshold will be exceeded). By contrast, under the with-project condition, the annual exceedance probability reduces to 14.8%. This reduction in annual exceedance probability translates to a modest reduction in the 10-year long-term exceedance probability for this threshold. Under the with-project condition, over a 10-year period, there is a 79.9% chance of threshold exceedance, compared to a greater than 99% chance in the without-project condition. Similarly, the assurance by event improves considerably, particularly for higher frequency events. For instance, under the with-project condition, there is a 27.5% chance that this threshold will not be exceeded by the 10% AEP event, compared to a 0.07% chance of non-exceedance in the without-project condition.

Table 12: Probabilistic performance of the East Riser Actionable Element across Impact Areas

Alternative	Annual Exceedance Probability		Long-Term Exceedance Probability			Assurance by Event				
	Expected	90% Assurance	10-yr period	30-yr period	50-yr period	10%	2%	1%	0.40%	0.20%
Without-Project	60.9%	78.2%	>99.9%	>99.9%	>99.9%	0.07%	0.04%	0.03%	0.03%	0.01%
With-Project	14.8%	24.8%	79.9%	99.2%	>99.9%	27.5%	4.5%	3.0%	1.3%	0.38%

4 OAKWOOD BEACH

The Oakwood Beach Actionable Element site encompasses an existing dune and wetland system within Great Kills Park, adjacent to Buffalo Street and the Oakwood Beach Wastewater Treatment Plant (WWTP). The proposed actionable element, consisting primarily of dune and wetland restoration, is expected to provide CSRM benefit via long-term shoreline stabilization and wave attenuation. Stabilization of the shoreline and wetland restoration within the Actionable Element site is expected to provide coastal storm risk management benefit to Buffalo Street, and the wetland north of the Actionable Element site. This wetland contains contaminants that are likely to be mobilized if subject to erosion. Additionally, the existing wetland, which consists primarily of invasive phragmites, poses a significant and well documented wildfire risk (NYCDEP, 2012). The proposed wetland restoration would replace this invasive phragmites with spartina and other native plantings, which are less likely to burn as quickly or intensely as phragmites. This is expected to reduce wildfire risk to the South Short of Staten Island (SSSI) floodwall adjacent to the Oakwood Beach WWTP. The following sections detail the analysis conducted to assess the benefits of the proposed actionable element.

4.1 SHORELINE STABILIZATION

Notable coastal storm-driven erosion has occurred along the shoreline of Great Kills Park over the past several decades. Though more immediately noticeable along the shoreline immediately southwest of the Actionable Element site, this erosion is steadily encroaching upon the existing natural dune fronting the tidal wetlands within the Actionable Element site. The crest elevation of this existing dune varies, though generally decreases from southwest to northeast, reaching a maximum crest elevation of approximately +9 ft NAVD88 within the Actionable Element site. At the northeastern extent of the Actionable Element site, proximal to the outfall of the tidal inlet, progressive failure of the existing erosion management structure has allowed for this erosion to accelerate in recent years. Further, sedimentation within the existing channel diversion structure has encouraged flow from the tidal inlet to redirect towards this failing erosion management structure, further accelerating this erosion. Figure 11 visually summarizes the observed shoreline change over time via satellite imagery.

Figure 11: Observations of shoreline erosion via satellite imagery (Google Earth, n.d.)

In the future, absent additional shoreline stabilization measures, it is likely that wave action from coastal storms will continue to erode the existing dune within the Actionable Element Site. Additionally, absent shoreline stabilization measures at the outfall of the existing tidal channel, it is likely that its outflows will continue to accelerate shoreline erosion. Over time, further erosion of the existing natural dune will expose the existing wetland to greater wave action and coastal forcings, which is likely to degrade the condition of the existing wetland. Consequently, the proposed shoreline stabilization and dune restoration is integral to ensuring adequate long-term function of the proposed wetland restoration.

4.2 WAVE ATTENUATION

The long-term function and viability of the restored wetland will also provide a substantive coastal storm risk management benefit, primarily though attenuation of wave action during frequent, low-consequence coastal storm events. It is well documented that wetlands and similar nature-based features, such as mangroves, are capable of attenuating wave energy during coastal flood events (King et al., 2018). The degree of wave attenuation provided by a wetland is a function of several factors, though it is primarily influenced by the extent of vegetative cover (perpendicular to the shoreline) and the type of plant species populating the wetland (Lee & Nepf, 2024). The primary plant species in the existing wetland, an invasive phragmites, is quite effective at attenuating wave energy, though under existing conditions a sizable portion of the wetland is an intertidal mudflat without any vegetative cover. Though the primary plant species specified in the wetland restoration, spartina, is somewhat less effective at attenuating wave energy (Lee & Nepf, 2024) the proposed restoration effort would include these intertidal mudflats, increasing the overall vegetative cover within the wetland.

Given that the degree of wave attenuation directly correlates with the extent of vegetative cover, the shortest section of the wetland is likely to provide the smallest degree of wave attenuation during a coastal storm event. At its shortest width perpendicular to the shoreline, the existing wetland is approximately 300 ft in length, with approximately half of that width consisting of barren mudflat. The wave attenuation benefits provided by the wetland are likely to be smallest along this longitudinal section of the wetland. Focusing on this portion of the wetland and informed by the results presented in Lee & Nepf (2024) and additional correspondence (I.H. Lee, personal communication, May 20, 2025), this study qualitatively evaluated the wave attenuation benefits of the wetland under the existing and with-project restored condition.

For the wetland section of interest under existing (i.e., current without-project) conditions, if healthy, the existing partially vegetated and phragmites-dominated wetland is likely to provide a substantial degree of wave attenuation during coastal storm events, likely reducing wave height by several feet under severe coastal storm events (Lee & Nepf, 2024). Under the proposed future with-project condition, wherein the wetland consists primarily of spartina and other native plantings, it is likely that the wetland would provide a similar magnitude of wave attenuation. The existing without-project conditions is unlikely to be representative of the future without-project conditions, given observed changes in the wetland over time. As observed via satellite imagery, the vegetative cover within the wetland has been decreasing over time (i.e., the size of the barren mudflat has been increasing over time). It is likely that the existing wetland will continue to degrade in future, with further reductions in vegetative cover. As such, a minimal-vegetation condition is likely a more representative future-without project condition; this condition would not provide any wave attenuation. Under both the existing and proposed with-project conditions, if vegetation is dormant (e.g., during the winter months), the wave attenuation benefits would be greatly diminished, though given the expected increase in vegetative cover, it is likely that the restored wetland would provide marginally greater wave attenuation benefits, when compared to a without-vegetation condition. Table 12 summarizes this qualitative assessment of wave attenuation benefits.

Table 13: Summary of qualitative assessment of wave attenuation benefits for the Oakwood Beach Actionable Element site

Wetland Characteristics			Wave Attenuation	
Condition	**Primary Species**	**Vegetative Cover**	**Healthy Vegetation**	**Dormant Vegetation**
Existing (Current without-project)	Phragmites (invasive)	Moderate	Substantial	Minimal
Likely Future-Without Project (minimal vegetation)	Phragmites (invasive)	Minimal	Minimal	None

With-Project (Future with-project)	Spartina (native)	High	Substantial	Minimal

When compared to the condition of the existing phragmites-dominated wetland, the proposed wetland is likely to provide a comparable degree of wave attenuation. However, when compared to the likely future-without project condition, wherein vegetative cover is minimal, the proposed wetland restoration is likely to provide a significantly higher degree of wave attenuation. As such, the proposed wetland restoration is expected to provide a modest increase in wave attenuation over time, when compared to the without-project condition. When compared to a without-project condition, the restored wetland will provide greater erosion risk management for Buffalo Street, wetlands north of the Actionable Element site, and for a component of the South Shore of Staten Island (SSSI) project, the Oakwood Beach WWTP floodwall.

4.2.1 Benefit to South Shore of Staten Island Project

Based on review of internal USACE design documents for the South Shore of Staten Island (SSSI) floodwall, the wave attenuation provided by the existing wetland was neither modeled nor considered when estimating the wave heights, design elevations, or erosion scour protection. Instead, the design relies upon offshore wave heights and forcings as the basis of floodwall design. This approach is reasonable and conservative, particularly given the questionable long-term health and longevity of the existing wetland. However, it is possible that the proposed wetland restoration would significantly attenuate waves impacting the SSSI floodwall around the Oakwood Beach WWTP during a coastal storm event. As such, the current floodwall design, particularly the scour protection at the toe of the floodwall, is likely overly conservative. If further evaluated and quantified, the wave attenuation benefits of the wetland restoration present a value engineering opportunity for the SSSI floodwall, as they could reduce the design requirements and load conditions for the floodwall. This additional analysis could be included for the final report, pending concurrence from the study team and data availability. This could yield a yet to be quantified cost savings for the SSSI project. If the design of the floodwall remains unchanged, these wave attenuation benefits would nonetheless provide benefit to the SSSI floodwall, as they would in effect provide an enhanced factor of safety for the floodwall, particularly for the scour protection at the toe of the CSRM measure.

4.3 WILDFIRE RISK ASSESSMENT

In addition to costal storm risk, the Oakwood Beach Actionable Element site is also vulnerable to wildfire risk. Though the overall risk of wildfires is quite low on average within New York City, particularly when compared to other places across the country, wildfires do regularly occur within the city limits. For instance, during a recent drought in 2024, New York City experienced a significant volume of wildfires, including a two-week span between November 1 to November 14, 2024 when the New York City Fire Department (FDNY) responded to 271 brush fires across all five boroughs (Lander, 2025). These brush fires often occur at the wild-urban interface, particularly in areas where parkland transitions to developed areas. The South Shore of Staten Island, inclusive of the Oakwood Beach Actionable Element site, is laced with such wild-urban interface, and is particularly vulnerable to wildfires.

Wildfires on the South Shore of Staten Island are typically fueled by phragmites. Fires fueled by phragmites typically have a very high flame length and a rapid rate of spread. Particularly when growing in the same location for several years, phragmites stands tend to be thick and dense, providing a high fine fuel load (approximately 8 tons/acre; NYCDEP, 2012). Under moderate fire conditions, phragmites can burn between 81 and 344 feet per minute, with flame lengths as long as 35 feet; under high fire behavior conditions, these fires can burn as much as 804 feet per minute with flame lengths upwards of 54 feet (NYCDEP, 2012). More recent statistics are limited, though such high fire conditions have been occurring with greater frequency within the NYC metro area (NYCDEP, 2012). When such fires reach the urban-wild interface, they pose a significant risk to adjacent structures. Based on these conditions, it is likely that under existing conditions, the SSSI floodwall would be at high wildfire risk. A wildfire risk assessment for the Oakwood Beach Actionable Element site and SSSI floodwall was conducting using RMC TotalRisk v1.0. The following subsections detail the components of this risk assessment.

4.3.1 Wildfire hazard analysis

Understanding the risk posed by wildfires in the Actionable Element Site first requires an understanding and characterization of the wildfire hazard within the Actionable Element Site. The data required to adequately characterize such hazard is rather limited, as such information is not sufficiently reported for the Actionable Element Site on a regular basis. However, sufficient information to characterize wildfire hazard analysis is available via a NYCDEP (2012) report, which highlights that, over a 14-year period from 1996 through 2010, 1,120 wildfires were recorded along the southern shore of Staten Island. Within an approximately 564-acre subset of the South Shore of Staten Island that includes the Actionable Element site, 301 fires were reported (NYCDEP, 2012). Given this observed wildfire frequency, assuming the spatial distribution of wildfire hazard is uniform across the area, there is a 4.3% chance of a wildfire affecting the Oakwood Beach Actionable Element site in any given year. For a bit of context, based on a nation-wide assessment of wildfire burn probability recently conducted by the US Forest Service (Dillon, 2023), this level of wildfire risk is analogous to that of the Pacific Palisades neighborhood of Los Angeles, California, which experienced catastrophic wildfires in January 2025.

Given this expected recurrence rate, this study characterized annual wildfire hazard via a two-part approach, using RMC TotalRisk v1.0. First, a probabilistic hazard function was selected. In any given year, it is most likely (>95% probability) that a wildfire will not occur within the Actionable Element Site. Additionally, it is possible that more than one fire may occur in the Actionable Element Site during a given year. As such, the gamma distribution was selected as the hazard function, as it can be heavily skewed towards a lower bound zero value, whilst retaining an unbounded upper bound. Second, a transformation function was developed to translate the continuous hazard function into a discrete number of wildfires. The corresponding hazard-transform was calibrated to yield an expected annual wildfire risk of 4.3% (gamma distribution: $\theta = 0.16, \kappa = 1.0$, effective record length = 14 years). The resultant hazard, transform, and wildfire occurrence functions are provided in Figure 12.

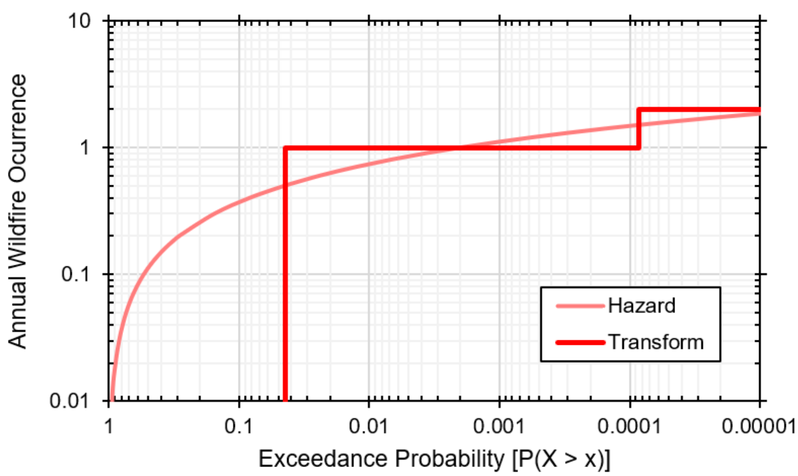

Figure 12: Wildfire hazard and transform function characterizing wildfire risk to the Oakwood Beach Actionable Element site.

4.4 WILDFIRE CONSEQUENCE

The consequence of a wildfire in the Actionable Element site is uncertain. Under existing without-project conditions, wherein the wetland is dominated by phragmites, at a minimum, there will be some nominal cost of suppressing the wildfire[4]. However, given the proximity of the wetland to the proposed SSSI floodwall, it is possible, though unlikely, that a wildfire in the wetland could damage this floodwall. By contrast, under the with-project condition, while a comparatively lower fire fuel load spartina would likely still require fire suppression, it is comparatively far less likely that such a wildfire would reach sufficient intensity to damage the SSSI floodwall. Under both the without- and with-project conditions, the consequence of a single wildfire is characterized via a generalized beta distribution, wherein the most likely consequence is minimal damage ($\alpha = 6.0,\ \beta = 1.0$). The primary difference between the without- and with-project condition is the upper bound of wildfire damages. The remainder of this subsection details how the upper bound of these wildfire consequence functions were developed.

4.4.1 Without-project wildfire consequence function

Given the expected rapidity and severity of a phragmites-fueled wildfire under even moderate fire conditions, it is possible that a wildfire event within the Actionable Element site would spread to the vegetated area in front of the proposed SSSI floodwall. Given the expected intensity of such a wildfire, dependent on fire conditions and duration, it is possible that this wildfire exposure could damage the reinforced concrete floodwall.

If exposed to fire for a prolonged duration, though the material itself is noncombustible, reinforced concrete can still be damaged by fire. At temperatures as low as 300 F, concrete can begin to spall (Borgerson & White, 2021). At temperatures above 570 F, the structural strength of reinforced concrete (RC) can become irreversibly compromised (Kline, 2020). At such temperatures, thermal expansion cracks are likely to develop and propagate within an RC structural member, particularly if the structural member is rapidly quenched during firefighting efforts (Kline, 2020). Additionally, at temperatures above 500F, water entrained in the interstitial void space of the concrete begins to vaporize and rapidly expand into steam (Kline, 2020; Borgerson & White, 2021). This can cause microfractures in the concrete between interstitial voids, significantly weakening the compressive strength of the concrete. Exposure to intense heat can also induce explosive spalling, wherein chunks of concrete rapidly delaminate from the reinforced concrete member (Kline, 2020). Assessment of structural strength in RC structures after a fire requires extensive non-destructive and destructive testing to identify which sections of structural members are compromised (Borgerson & White, 2021). Proper repair of fire-damaged RC structures typically requires demolition and in-kind replacement of structurally compromised RC members (Kline, 2020).

As such, if the SSSI floodwall is exposure to any number ($n \geq 1$) of phragmites-fueled wildfires within a given year, in a worst-case scenario, the entire length of the floodwall bounding the Actionable Element site (57% of the total length of the T-wall portion) would be exposed to temperatures sufficient to compromise the structural integrity of the above-ground portions of the floodwall and require its replacement. Informed by the estimated construction costs of the T-wall portion of the SSSI floodwall, this replacement would cost be approximately $5,407,000. This potential extent of damage serves to bracket the upper bound of potential wildfire consequences to the floodwall. Given this upper bound and the generalized beta distribution parameters specified above, Figure 13 provides the resulting without-project wildfire consequence function.

[4] For simplicity within this analysis, this nominal wildfire suppression cost is neglected (i.e., the minimum wildfire consequence is $0 in damages).

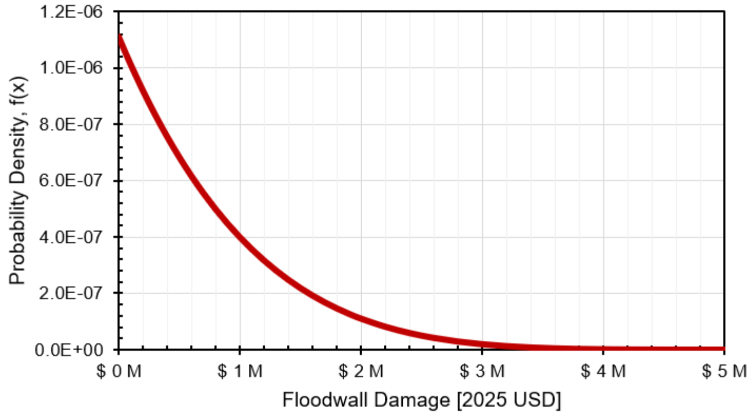

Figure 13: Without-project wildfire consequence function, considering the potential for damage to the SSSI floodwall adjacent to the Oakwood Beach Actionable Element site

4.4.2 With-project wildfire consequence function

Under the with-project condition, while still potentially vulnerable to wildfire, the proposed spartina-dominated wetland will carry a lower fine fuel fire load. The USDA Forest Service provides a range of fire fuel models, based on the characteristics of plant species that can be used within Rothermel's surface fire spread model to understand how wildfires burn and spread (Scott & Burgan, 2005). Within this framework phragmites can be classified as fire fuel model GR8, which is expected to carry a fine fuel load of 7.8 tons per acre and a maximum flame length upwards of 50 feet. By contrast, the proposed spartina-dominated wetland, can be classified as GR3, which is expected to carry a lower fine fuel load of 1.6 tons per acre, which also translates to a much lower rate of spread and significantly shorter flame length, at most 15 feet (Scott & Burgan, 2005). Consequently, it is much less likely that a wildfire in the Actionable Element site under the future with-project condition would reach the SSSI floodwall. Further, it is even less likely that the fire would reach and sustain sufficient temperatures to damage the floodwall. Rather than assume a full reduction in the upper bound wildfire consequences, the wildfire risk reduction provided under the with-project condition is assumed to be proportional to the reduction in fine fuel load (i.e., an 80% reduction), resulting in an upper bound of $1,081,000 in wildfire damages to the SSSI floodwall. Figure 13 provides the resulting without-project wildfire consequence function.

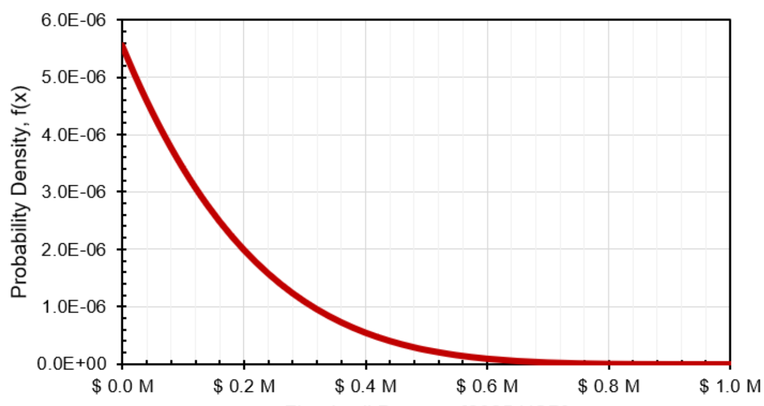

Figure 14: With-project wildfire consequence function, considering the potential for damage to the SSSI floodwall adjacent to the Oakwood Beach Actionable Element site

4.5 ESTIMATED WILDFIRE RISK

Given the assessed wildfire hazard and the consequence functions outlined above, under current without-project conditions, there is approximately $32,000 in expected annualized wildfire risk to the SSSI floodwall. Under the with-project conditions, there is approximately $6,000 in expected annualized wildfire risk. The proposed wetland restoration is therefore expected to provide $26,000 in annualized wildfire risk management benefit. Though future wildfire risk is projected to increase in future (NYCDEP, 2012), neglecting this nonstationary (i.e., making a conservative assumption that wildfire risk will remain stationary over time), the proposed project would provide $26,000 in annualized wildfire risk management benefits. It is assumed that wildfire risk will be independent of future SLC.

4.6 RESULTS

Given these estimated without- and with-project wildfire risk estimates, the proposed actionable element is expected to provide $26,000 [FY2025 price levels] in annualized wildfire risk management benefit to the Actionable Element site. Given the estimated $55,355,000 cost of the Oakwood Beach actionable element, the actionable element has a BCR <0.1; Table 13 summarizes these results.

Table 14: Annualized wildfire risk under the without- and with-project condition and annualized wildfire risk management benefit

	Wildfire Risk (Annualized)		Coastal Storm Risk Management Benefit (Annualized)	Benefit-Cost Ratio (BCR)	Average Annual Net Benefit (AANB)
Impact Area	Without-Project	With-Project			
SSSI Floodwall	$32,000	$6,000	$26,000	<0.1	-$2,125,000
Project area	$0	$0	$0	-	
TOTAL	$32,000	$6,000	$26,000	<0.1	$26,000

FY2025 Price Levels; Federal Discount Rate = 3%; 50-year period of analysis (2037-2086)

5 COMPARISON OF ALTERNATIVES

Given the risk management benefits outlined for each of the actionable element sites, Table 14 provides the national economic development (NED) average annual equivalent costs, benefits, net benefits, and benefit-cost ratios for the actionable element alternatives under consideration.

Table 15: Average annual equivalent (AAEQ) economic costs, benefits, and net benefits of proposed Actionable Element alternatives

ALTERNATIVES		**Alt A: No Action**	**Alt B: NED Plan**			**Alt C: Maximizes Total Net Benefits**			**Alt D: Maximize Total Net Benefits for Study Purpose**			**Alt E: Least Environmentally Damaging**		
ACTIONABLE ELEMENTS		**-**	**East Riser**			**Harlem River, East Riser, and Oakwood Beach**			**Harlem River and East Riser**			**Oakwood Beach**		
P&G Accounts	**Metrics**	**Int. SLC**	**Low SLC**	**Int. SLC**	**High SLC**	**Low SLC**	**Int. SLC**	**High SLC**	**Low SLC**	**Int. SLC**	**High SLC**	**Low SLC**	**Int. SLC**	**High SLC**
National Economic Development	AAEQ Cost	$0	$9,683,000			$41,449,000			$39,298,000			$2,151,000		
	AAEQ Risk Management Benefit	$0	$15,494,000			$18.00 M	$19.13 M	$24.08 M	$17.97 M	$19.11 M	$24.05 M	$26,000 wildfire risk reduction + erosion risk reduction		
	AAEQ Net Benefits	$0	$5,811,000			-$23.40 M	-$23.32 M	-$17.37 M	-$21.33 M	-$20.19 M	-$15.24 M	-$2,125,000		
	Benefit-Cost Ratio	-	1.6			0.4	0.5	0.6	0.5	0.5	0.6	< 0.1		

FY2025 Price Levels; Federal Discount Rate = 3%; 50-year period of analysis (2037-2086)

6 REGIONAL ECONOMIC DEVELOPMENT (RED)

The regional benefit associated with construction is the indirect and induced economic output that would be produced for an assumed construction cost. This analysis uses the USACE RECONS 2.0 input/output (I/O) model, developed by the Institute for Water Resources (IWR), to estimate the regional economic impacts of proposed construction work activities.

Regional economic impacts and contributions are measured as economic output, jobs, income, and value added for three levels of geographic impact area: local, state, and national. Estimates are based on the specific work activity associated with a project. The tool estimates the regional economic impacts and contributions of project expenditures and assesses impacts and contributions associated with project-related spending by systematically mapping expenditures to production and consumption sectors within a particular economy through a series of linkages among industries, households, and government. Changes to purchases of goods and services for final consumption (final demand change) drive I/O models. Each industry that produces goods and services generates demands for other goods and services. For example, when construction firms pay their workers and purchase supplies or services, such as electricians, plumbers, lumber, concrete, etc., economic activity is generated in the local or regional economy through salaries and business and household spending.

The multiplier for construction activity for a highway will differ from the multiplier for sand placement, therefore, the work activity for each project is carefully selected influenced by the type of structure being proposed. The more resource intense the work activity the more the contribution to the regional development account. The following tables present the output for each site.

6.1 EAST RISER

A 2028 year of expenditure is assumed for this site, at a cost of $249 million. The work activity for the East Riser Actionable Element site is Construction and Major Rehabilitation of Earth Levees and Floodways within the Flood Risk Management Business Line.

Table 16: Overall Summary – East Riser

Area	Local Capture	Output	Jobs FTE	Labor Income	Value Added
Local					
Direct Impact		$224,930,000	2,004.9	$178,890,000	$170,580,000
Secondary Impact		$189,240,000	914.9	$72,260,000	$116,430,000
Total Impact	$224,930,000	$414,160,000	2,919.9	$251,150,000	$287,010,000
State					
Direct Impact		$238,930,000	2,245.1	$188,400,000	$180,310,000
Secondary Impact		$238,290,000	1,116.8	$86,560,000	$143,300,000
Total Impact	$238,930,000	$477,220,000	3,361.9	$274,960,000	$323,610,000
U.S.					

Direct Impact		$246,360,000	2,465.3	$190,060,000	$183,250,000
Secondary Impact		$447,980,000	1,944.7	$143,750,000	$245,120,000
Total Impact	$246,360,000	$694,340,000	4,410.0	$333,810,000	$428,370,000

*FTE = full time equivalent

6.2 HARLEM RIVER

A 2028 year of expenditure is assumed for this site, at a cost of $762 million. The work activity for the East Harlem River Actionable Element site in New York County is Construction and Major Rehabilitation of Earth Levees and Floodways within the Flood Risk Management business line.

Table 17: Overall Summary – Harlem River

Area	Local Capture	Output	Jobs FTE	Labor Income	Value Added
Local					
Direct Impact		$591,380,000	4,484.9	$568,450,000	$442,920,000
Secondary Impact		$298,010,000	1,239.9	$128,660,000	$199,920,000
Total Impact	$591,380,000	$889,380,000	5,724.7	$697,110,000	$642,840,000
State					
Direct Impact		$649,590,000	5,587.9	$609,500,000	$482,860,000
Secondary Impact		$627,790,000	2,810.6	$235,220,000	$395,310,000
Total Impact	$649,590,000	$1,277,380,000	8,398.5	$844,720,000	$878,170,000
U.S.					
Direct Impact		$731,490,000	6,117.9	$638,320,000	$519,610,000
Secondary Impact		$1,369,360,000	5,859.1	$437,030,000	$744,460,000
Total Impact	$731,490,000	$2,100,850,000	11,977.0	$1,075,350,000	$1,264,070,000

6.3 OAKWOOD BEACH

A 2028 year of expenditure is assumed for the Oakwood Beach Actionable Element site in Richmond County, at a cost of $55 million. The work activity within the Flood Risk Management business line is Beach Nourishment On-Shore Sand.

Table 18: Overall Summary - Oakwood Beach

Area	Local Capture	Output	Jobs	Labor Income	Value Added
Local					
Direct Impact		$33,140,000	236.7	$21,850,000	$17,260,000
Secondary Impact		$19,550,000	100.1	$6,250,000	$11,520,000
Total Impact	$33,140,000	$52,690,000	336.8	$28,100,000	$28,780,000
State					
Direct Impact		$43,210,000	297.4	$28,090,000	$23,360,000
Secondary Impact		$41,420,000	171.5	$15,450,000	$26,370,000
Total Impact	$43,210,000	$84,640,000	468.9	$43,540,000	$49,730,000
U.S.					
Direct Impact		$54,280,000	360.4	$33,150,000	$29,360,000
Secondary Impact		$106,220,000	431	$32,940,000	$57,360,000
Total Impact	$54,280,000	$160,500,000	791.4	$66,090,000	$86,720,000

6.4 IMPACT SETTING

Economic environment tables are reproduced here to include state comparisons to the respective Actionable Element Sites. In New York State, the Harlem River Actionable Element site is located in New York County and Oakwood Beach AE is in Richmond County (in New York City, boroughs are also counties). In New Jersey, the East Riser Actionable Element site has portions of the Carlstadt and Moonachie boroughs within Bergen County. The Harlem River Actionable Element location has higher unemployment and poverty compared to the state. East Riser municipalities have lower unemployment compared to its state figure. New York County has a higher population than Bergen and will have higher number of unemployed in absolute terms.

Table 19: Economic Environment

	New York State	New York County	Richmond County	New Jersey State	Bergen (County)	Carlstadt Borough	Moonachie Borough
Population	19,872,319	1,694,251	492,734	9,267,014	955,732	6,372	3,106
Households	7,668,956	775,376	170,047	3,478,355	353,307	2,639	937
Poverty	14.2%	15.8%	10.9%	9.7%	6.6%	10.5%	4.0%
Median Income	84,578	104,553	98,290	101,050	123,715	94,854	108,359
Unemployment Rate	6.2%	7.0%	5.5%	6.2%	4.1%	5.4%	4.1%

Highlights: Green indicates better than state; red indicates worse than state.

6.5 VALUE ADD SUMMARY

East Riser

The expenditures associated with All Work Activities, with Ability to Customize Impact Area and Work Activity at Bergen (NJ) are estimated to be $249,000,000. Of this total expenditure, $224,928,789 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $249,000,000 support a total of 2,919.9 full-time equivalent jobs, $251,154,588 in labor income, $287,010,623 in the gross regional product, and $414,164,486 in economic output in the local impact area. More broadly, these expenditures support 4,410.0 full-time equivalent jobs, $333,811,256 in labor income, $428,372,143 in the gross regional product, and $694,342,987 in economic output in the nation.

Harlem River

The expenditures associated with All Work Activities, with Ability to Customize Impact Area and Work Activity at New York (NY) are estimated to be $762,000,000. Of this total expenditure, $591,379,615 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $762,000,000 support a total of 5,724.7 full-time equivalent jobs, $697,112,542 in labor income, $642,844,880 in the gross regional product, and $889,384,660 in economic output in the local impact area. More broadly, these expenditures support 11,977.0 full-time equivalent jobs, $1,075,346,157 in labor income, $1,264,066,996 in the gross regional product, and $2,100,851,817 in economic output in the nation.

Oakwood Beach

The expenditures associated with All Work Activities, with Ability to Customize Impact Area and Work Activity at Richmond (NY) are estimated to be $54,450,000. Of this total expenditure, $33,140,054 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $54,450,000 support a total of 336.8 full-time equivalent jobs, $28,100,945 in labor income, $28,778,958 in the gross regional product, and $52,694,682 in economic output in the local impact area. More broadly, these expenditures support 791.4 full-time equivalent jobs, $66,087,201 in labor income, $86,718,618 in the gross regional product, and $160,500,403 in economic output in the nation.

7 LIFE SAFETY

Life safety is the risk to individuals who may be affected by coastal storms and other events. Individual life risk is influenced by location, exposure, and vulnerability within a risk managed area. Communities in the affected areas have always experienced flooding from coastal storms. Residents generally understand the severe implications of staying in harm's way when a coastal storm is forecasted to affect the area. Because there is typically two to seven days' notice prior to hurricanes and tropical storms, residents are typically given sufficient warning to evacuate. However, residents typically have only a few hours warning before the arrival of smaller storms and rain events that cause flash flooding. Residents should evacuate prior to storms to avoid being stranded, which could pose a danger to their welfare. Emergency vehicles may not be able to reach residents in distress due to the flooding of roads and homes. In addition, there is an increased risk of fire in communities due to the potential compromising of electrical and natural gas systems. The inherent erratic nature and unpredictability of a storm's path and intensity requires early and safe evacuation. A policy of early, total evacuation should be continued even with the projects in place.

In the case of the Harlem River Actionable Element, the proposed floodwall will have tie-offs crossing the Harlem River Drive, which will discourage motorists from trying to use it during flood events. The closed Drive prevents a dangerous situation of motorists being stranded on flooded roads, or even worse, injured or killed in flash flooding situations. As for East Riser, the proposed channelization will bring floodwaters into the channel instead of pooling around businesses and residences, which will reduce life safety risk, as well as exposure to pollutants in the run-off.

7.1 LIFE SAFETY RISK INDICATOR (LSRI)

USACE has developed the LSRI tool which provides a screening-level, relative representation of the life risk that would be reduced if a flood risk management project was constructed. The LSRI incorporates not just consequence information, but also likelihood of the consequences to determine risk. For the 2022 draft report, the LSRI tool was used to gage life loss risk for actionable element areas. It is intended that LifeSim 2.0 will be used to evaluate life safety risk for the final report when site specific hydrology and hydraulics are determined. LifeSim is an agent-based system for estimating life loss with the fundamental intent to simulate population redistribution during an evacuation.

The LSRI tool applies an empirically derived fatality rate to the remaining population once floodplain occupants take protective action. Factored into that fatality rate is how well defined is the community's evacuation planning, residents' perception of flood risk and the effectiveness of emergency management procedures. The population at risk (PAR) represents the initial distribution of people in the floodplain.

7.2 EAST RISER

To gage the life loss estimates for the East Riser Actionable Element Site in the LSRI, certain assumptions about people's responsiveness to the threat are made. A worst-case scenario is modeled where people don't evacuate even though there are official promptings for them to find shelter. The Actionable Element Site spans two municipalities, each municipality with its own flood emergency evacuation planning. Because of the differences in emergency planning for these communities, a general messaging approach is assumed as what is applied at the state level. New Jersey state has all hazards safety directions for residents to practice in the case of any event not specific to floods. Under this assumption, residents may not know what to do or where to go and when to take protective action. Community awareness of the risk of flooding will influence their perception of flood risk. In the Actionable Element Site, the population at risk generally understands that the risk exists because of historical events but they may not have the opportunity to respond to environmental cues of the flood's high consequence potential. Under these worst-case scenarios, i.e., no evacuation, median life loss under a peak inundation scenario is 22 for day population and 14 for night, details are presented in Table 20.

Table 20: LSRI Output – East Riser

Parameter	Day	Night
PAR	3,262	2,136
Exposed Population	3,262	2,136
% of PAR Exposed	100.00%	100.00%
Median Life Loss	22	14
Fatality Rate	0.67%	0.66%
Mean Life Loss (Exposure Weighted)	18.41	
Mean Life Loss as % of PAR	0.71%	
Weighted Fatality Rate (% of Exposed PAR)	0.71%	
Property Damages	$523M	
# Structures Inundated	374	

7.3 HARLEM RIVER

To gage the life loss probability estimates for the Harlem River Actionable Element Site in the LSRI, certain assumptions about people's responsiveness to the threat are made. A worst-case scenario is modeled where people don't evacuate even though there are official promptings for them to take protective action. The Actionable Element Site in Community District 10 in Northern Manhattan does not have its own flood emergency evacuation planning. Instead, New York County emergency planning is assumed for the community which is a general messaging to follow safety directions in any hazard event. Under this assumption, residents may not know what to do or where to go and when to take protective action. Members of the community may have complications as far as taking protective action, for example, some shelters don't allow pets, or they simply don't have the means to get out of the floodplain safely. Their response will depend on awareness of the risk to flooding. In the Actionable Element Site, the population at risk generally understands that the risk exists because the Sandy storm caused damages throughout the city, but they may not have the opportunity to respond to environmental cues of an event's high consequence potential. The worst case of no evacuation is modeled in the LSRI, and results show that median life loss under a peak inundation scenario is low (Table 21). However, the tool only accounts for populations within the delineated boundary and not for through traffic. The Harlem River site has the major Harlem River Drive (HRD) which motorists use to go north and south in the city. The HRD at the Harlem River project area also connects to major conduits such as Interstate 87, Interstate 278 and the FDR Drive. According to state traffic records, Harlem River Drive from East 135th Street and Madison Avenue north to Routes 1 and 95I George Washington Bridge, actual average daily traffic (AADT) counts was 87,420 in 2024. The highest recorded AADT was over 96,000 in 2009. At any moment with this amount of volume the HRD can become the site of significant flooding during an event leaving sections of the road impassable and even relatively shallow flooding can lead to a vehicle being upended or swept away. Motorists will continue to be at risk and may not get the warning in time and may not have the time to respond or know how to respond in the case of a flood event. The life loss risk to motorists is an important consideration but is left unaccounted for in the modeling.

Table 21: LSRI Output Table –Harlem River

Parameter	Day	Night
PAR	3,122	3,941
Exposed Population	370	472
% of PAR Exposed	11.85%	11.96%
Median Life Loss	0	0
Fatality Rate	0.00%	0.00%
Mean Life Loss (Exposure Weighted)	0.01	
Mean Life Loss as % of PAR	0.00%	
Weighted Fatality Rate (% of Exposed PAR)	0.00%	
Property Damages	$33M	
# Structures Inundated	35	

7.4 OAKWOOD BEACH

Life loss is not considered for the Oakwood Beach site where there is zero PAR, and road access is well off site.

8 OTHER SOCIAL EFFECTS

According to memo titled “Comprehensive Documentation of Benefits in Decision Documents” dated 5 January 2021 from the Assistant Secretary of Army, Civil Works, other social effects will consider impacts to life, health, and safety factors; displacement; and long-term productivity.

The problem of attribution where tracing exposure to flooding to health and safety, or economic productivity is difficult therefore, the assessment is limited to accounting for the most vulnerable who typically need the assistance of others in order to remain safe. For example, for life, health and safety considerations, the prevalence of populations with existing respiratory morbidities is documented for each tract within the actionable element site but after project implementation rates of prevalence may or may not be influenced by a project. These documented characterizations provide an opportunity to meaningfully and comprehensively call attention to those who may have relatively more difficulty preparing for and responding to storm events. Displacement, however, may be more easily traced based on depth of flooding. Poorer households are more likely to occupy risky locations and to be in housing that is older and in substandard condition and according to the literature, poorer households are the most likely to be displaced than the financially better off.

8.1 EAST RISER

The study site at East Riser is particularly vulnerable to floods. There are several small creeks that are tidally influenced that serve as sources of flooding. Structures in the inventory fall between Berry’s Creek to the west and East Riser to the east. Multiple sources of flooding coupled with the fact that development in this area is on low lying land illustrates the increased risks to floodplain inhabitants. Without project average flood depths at the East Riser site for select frequencies are presented for residential and nonresidential structures in Table 22. The table shows that even at the 20-percent chance AEP there is over one foot of flooding, enough to increase risk to health and life safety in homes and on roadways. While these depths may be nuisance to many, serious harm can come to the most vulnerable.

Table 22: Average Flood Depth

	Average Flood Depth at 0.2AEP	Average Flood Depth at 0.1AEP	Average Flood Depth at 0.01AEP	Average Flood Depth at 0.002AEP
Nonresidential	1.05	1.32	2.10	2.61
Residential	1.25	1.58	2.58	3.19

Life, Health and Safety

Vulnerable Population

Table 23 provides a summary of populations in the Actionable Element Site who are counted among the vulnerable. According to the US Census data presented in the table, Moonachie and Carlstadt have slightly lower elderly populations compared to state and county figures. Moonachie has a significantly higher percent of people with any disability which indicates dependency on the support of others in the face of a storm event.

Table 23: Vulnerable Population – East Riser

	Population	**Over 65**	**Under 5**	**Any Disability**	**Poverty**
New Jersey State	9,290,841	17.7 (17.6,17.7)	5.6 (5.5,5.7)	10.9 (10.7,10.11)	9.7 (9.4,10.0)
Bergen County	955,732	18.7 (18.6,18.8)	5.1 (5.0,5.2)	9.7 (9.2,10.2)	6.6 (5.2,7.4)
East Riser Tracts					

Moonachie (Census Tract 362)	3,133	15.4 (2.0,28.8)	4.2 (1.6,6.8)	11.9 (8.3,15.5)	4.0 (1.5,6.5)
Carlstadt (Census Tract 50)	6,372	17.5 (12.6,22.4)	5.2 (1.5,8.9)	8.3 (4.0,12.6)	10.5 (2.6,18.4)

Green equals better than both county and state; yellow indicates that the tract outperforms on one level (county or state but not both); red equals worse than both state and county
Population: 2020 Decennial Census
Age demographics: DP05, S0101 | 2023 American Community Survey 5-Year Estimates
Disability: S1810 | 2023 American Community Survey 5-Year Estimates Total civilian noninstitutionalized population
Poverty: S1701 | 2023 American Community Survey 5-Year Estimates
Unemployment: DP03 | 2023 American Community Survey 5-Year Estimates

Respiratory Morbidities

Populations with pre-existing health conditions are more vulnerable to the impact of flooding, particularly those with respiratory diseases. People with asthma or COPD are likely to react badly to floods and mold conditions. CDC PLACES data on the prevalence of respiratory diseases within the East Riser tracts are presented in Table 24. The rate of asthma and COPD in East Riser Actionable Element Site tracts are higher than county rates.

Table 24: Respiratory Disease Prevalence – East Riser

	Asthma	COPD
Bergen County	8.2	4.8
East Riser Site Tracts		
Census Tract 362	8.8	5.9
Census Tract 50	8.9	5.8

Red indicates worse than county
Centers for Disease Control PLACES Local Data for Better Health Application updated on 08/23/2024

Displacement

The poverty rate in Carlstadt is more than twice that of Moonachie and higher than in the state and county (see Table 23 above). People in poverty tend to occupy riskier sections of a community because of financial constraints. The more likely they are to get flooded the likelier it is that they will be displaced. An estimate of the number of persons displaced is derived by estimating the number of people residing in areas where flooding occurs. US Census Persons per Household from the 2019-2023 ACS 5-year estimates is 2.54 for the US and is used to determine population within the Actionable Element Site. The East Riser inventory has 327 structures (includes nonresidential) yielding a population estimate of 831 people. The percent of structures flooded is multiplied by the population estimate to determine number of displaced individuals and is presented in Table 25 for several annual chance exceedance probabilities. To estimate number of people in poverty to be displaced, average poverty rate for the two tracts is used. Average annual rate of displacement among people in poverty in the East Riser Actionable Element Site is 7.

Table 25: Displacement at Various Exceedance Probabilities – East Riser

	Damage Frequencies						
	0.95 AEP	0.75 AEP	0.5 AEP	0.25 AEP	0.05 AEP	0.01 AEP	0.002 AEP
Percent Structures Flooded	10.76%	11.90%	11.90%	12.19%	12.34%	12.49%	12.69%
Number of People Displaced	89	99	99	101	102	104	105

Number of People in Poverty Displaced	6	7	7	7	7	8	8

Long-Term Productivity

Productivity in the local area will depend on robust labor force participation and indirectly depend on whether or not one has health coverage to counter the effects of a health emergency due to a storm event. Table 26 compares East Riser community economic drivers of productivity to state and county figures. The Census data shows not in labor force is generally lower in the East Riser Actionable Element Site compared to state and county rates. Moonachie (Census Tract 362) has a significantly higher rate of persons with no health insurance compared to the state and county. Carlstadt (Census Tract 50) on the other had has a significantly lower rate of persons with no health coverage.

Table 26: Drivers of Economic Productivity Comparison – East Riser

	Population 16 + Universe	Not in labor force	Noninstitutionalized Population Universe	No health insurance coverage
New Jersey	7,477,249	33.7 (33.6,33.8)	19,674,246	7.4 (7.3,7.5)
Bergen County, New Jersey	1,421,588	33.1 (32.7,33.5)	1,619,600	6.2 (5.9,6.5)
East Riser Tracts				
Census Tract 50; Bergen County; New Jersey	7,212	31 (24.6,37.4)	9,279	4.1 (1.6,6.6)
Census Tract 362; Bergen County; New Jersey	4,550	30.9 (25.1,36.7)	5,244	15.9 (9.1,22.7)

Green indicates better than state and county; red indicates worse than state and county

8.2 HARLEM RIVER

Vulnerable Population

The Harlem River Actionable Element Site is located on the shoreline of the tidally influenced Harlem River. Table 27 summarizes East Harlem floodplain vulnerable populations. All of the tracts within the Harlem River site have higher rates of children under 5 when compared to state and county levels and a majority of tracts have higher rates of disabled persons.

Table 27: Vulnerable Populations – Harlem River

	Population	Over 65	Under 5	Any Disability	Poverty
New York State	20,201,249	18.6 (18.5,18.7)	5.3 (5.2,5.4)	13.0 (12.8,13.2)	14.2 (13.9,14.5)
New York County	1,694,251	18.8 (18.7,18.9)	3.9 (3.8,4.0)	12.4 (11.7,13.1)	16.5 (15.3,17.7)
Harlem River Site Tracts					

Census Tract 236	9,907	16.2 (11.4,21.0)	7.8 (3.8,11.8)	18.4 (12.7,24.1)	13.8 (6.7,20.9)
Census Tract 243.02	7,237	12.2 (8.9,15.5)	6.9 (3.3,10.5)	20.7 (14.2,27.2)	42.3 (32.2,52.4)
Census Tract 235.02	2,206	18.3 (13.0,23.6)	3.9 (.8,7.0)	17.6 (11.9,23.3)	42.0 (30.3,53.7)
Census Tract 232	8,061	6.6 (4.9,8.3)	9.0 (5.8,12.2)	16.9 (12.5,21.3)	47.6 (34.6,60.6)
Census Tract 259	4,029	3.6 (2.1,5.1)	5.6 (2.3,8.9)	7.4 (5.0,9.8)	16.6 (10.5,22.7)
Census Tract 234	5,112	7.0 (4.8,9.2)	6.1 (3.0,9.2)	11.6 (6.1,17.1)	30.0 (21.1,38.9)

Green indicates better than state and county; red indicates worse than state and county
Population: 2020 Decennial Census
Age demographics: DP05, S0101 | 2023 American Community Survey 5-Year Estimates
Disability: S1810 | 2023 American Community Survey 5-Year Estimates Total civilian noninstitutionalized population
Poverty: S1701 | 2023 American Community Survey 5-Year Estimates
Unemployment: DP03 | 2023 American Community Survey 5-Year Estimates

Respiratory Morbidities

Populations with pre-existing health conditions are more vulnerable to the impact of flooding, particularly those with respiratory diseases. People with asthma or COPD are likely to react badly to floods and mold conditions. CDC PLACES data on the prevalence of respiratory diseases within the Harlem River Actionable Element Site are presented in Table 28. There are significantly higher rates of asthma in every tract of the Actionable Element Site and only two tracts have lower rates of COPD as compared to the county.

Table 28: Respiratory Disease Prevalence –Harlem River Tracts

	Asthma	COPD
New York County	9.4	5.1
Harlem River Site Tracts		
Census Tract 236	12.4	8.1
Census Tract 243.02	13.1	9.1
Census Tract 235.02	12.2	6.9
Census Tract 232	13.5	9.0
Census Tract 259	11.0	4.7
Census Tract 234	10.7	4.2

Green indicates better than county; red indicates worse than county
Centers for Disease Control PLACES Local Data for Better Health Application updated on 08/23/2024

Displacement

As shown in Table 27 on vulnerability, all of the tracts in the Harlem River site, with the exception of Tract 236, have extremely high rates of poverty illustrating that populations in this area will very likely face displacement. An estimate of the number of persons displaced is derived by estimating the number of people residing in areas where flooding occurs. US Census Persons per Household from the 2019-2023 ACS 5-year estimates for the US is 2.54 which is used to determine population. The Harlem inventory has 221 structures (includes nonresidential) yielding a population estimate of 562 people. The percent of structures flooded is multiplied by the population estimate to determine number of displaced individuals and is presented in Table 28 for several annual chance exceedance probabilities. Average annual rate of displacement among people in poverty in the Harlem River Actionable Element Site is 16.

Table 29: Displacement at Various Exceedance Probabilities –Harlem River

	Damage Frequencies						
	0.95 AEP	0.75 AEP	0.5 AEP	0.25 AEP	0.05 AEP	0.01 AEP	0.002 AEP
Percent Structures Flooded	8.20%	8.80%	8.80%	9.00%	9.40%	9.60%	9.90%
Number of People Displaced	46	49	49	51	53	54	56
Number of People in Poverty Displaced	15	16	16	16	17	17	18

Long-term Productivity

Productivity in the local area will depend on labor force participation, and indirectly depend on whether or not one has health coverage to counter the effects of emergency events. Table 30 compares Harlem River community economic drivers of productivity to state and county figures. The Census data shows not in labor force is significantly higher in the Harlem River Actionable Element Site compared to the state and county rates. There is also a general lack of health insurance coverage at this site that is greater than the state and county rates. This indicates that long term productivity is deficient in the without project and this community will struggle to bounce back from a damaging storm event.

Table 30: Drivers of Economic Productivity Comparison – Harlem River

	Population 16 + Universe	Not in labor force	Noninstitutionalized Population	No health insurance coverage
New York	16,235,440	37.0 (36.9,37.1)	19,674,246	5.1 (5.0,5.2)
New York County, New York	1,421,588	33.1 (32.7,33.5)	1,619,600	4.3 (4.1,4.5)
Harlem River Tracts				
Census Tract 232; New York County; New York	7,212	43.3 (36.6,50)	9,279	8.6 (4.5,12.7)
Census Tract 234; New York County; New York	4,550	30.7 (22.8,38.6)	5,244	13.2 (4.5,12.7)
Census Tract 235.02; New York County; New York	1,511	44.2 (37.6,50.8)	1,872	13.9 (9.1,18.7)
Census Tract 236; New York County; New York	8,273	46.8 (39,54.6)	10,061	6.2 (2.8,9.6)
Census Tract 243.02; New York County; New York	5,724	45.8 (39.6,52)	7,234	7.6 (2.6,12.6)
Census Tract 259; New York County; New York	3,685	20.5 (16.1,24.9)	4,713	14.4 (8.3,20.5)

Green indicates better than state and county; red indicates worse than state and county

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