ECONOMICS APPENDIX

NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT
FEASIBILITY STUDY

PHILADELPHIA, PENNSYLVANIA

APPENDIX C

August 2021

U.S. Army Corps of Engineers
Philadelphia District

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EXECUTIVE SUMMARY

The New Jersey Back Bays study area is a major metropolitan area that stretches over five New Jersey counties: Cape May, Ocean, Atlantic, Monmouth, and Burlington. The study area encompasses over 674,000 permanent residents (2020), millions of seasonal visitors, and over $40 billion in annual GDP (2019). This Appendix presents the economics methodology, assumptions, and resulting analysis for determining Federal interest in managing storm risk to the New Jersey Back Bays over a 50-year period of analysis from 2030 to 2080.

Analysis includes a Feasibility-level assessment of the New Jersey Back Bays, an area that includes over 172,000 assets. The majority are single-family residential units, but the inventory also includes multi-family apartments, commercial structures, industrial facilities, high value high-rises, traditional infrastructure (such as bridges, utilities, roadways), and critical infrastructure (such as wastewater treatment plants, pump stations, fire stations). In total, the asset inventory is valued at over $72 billion (FY2021 Price Level). Additional NED categories, such as transportation delay, non-transferrable income loss, local costs foregone, and emergency costs, further expand the total NED damage pool to over $90 billion total (FY2021 Price Level).

The following figures and narrative will summarize the Future Without-Project (FWOP) condition National Economic Development (NED) damages and the Future With-Project (FWP) condition reduction in damages in order to determine a Tentatively Selected Plan (TSP). Sections C-1 through C-7 detail the initial creation of the structure inventory, the development of the focused array of alternatives, and the preliminary HEC-FDA model results. These Sections use the then-current FY2018 Project Evaluation and Formulation Rate (Discount Rate) of 2.75% and then-current FY2018 Price Level. Sections C-8 through C-12 discuss the update of the structure inventory, the re-evaluation of initial modeling methodologies, and the results of the new model runs. Descriptive statistics in these Sections are presented in the then-current FY2019 Price level, while costs and results are presented using the FY2021 Price Level and FY2021 Discount Rate of 2.5% in accordance with EGM 21-01 *Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2021*.

All economic analyses and results presented are in accordance with USACE policy and guidance with specific emphasis on ER 1105-2-100 *Planning Guidance Notebook*, ER 1105-2-101 *Risk Assessment for Flood Risk Management Studies*, ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs*, and EM 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies*.

The TSP, NED Plan, and Nonstructural-Only plans can be seen in the Table below. The analysis below was completed using the Intermediate Relative Sea Level Change curve, though the High and Low (Historic) curves were also modeled and are discussed in this Appendix.

Tentatively Selected Plan (TSP) / Total Benefits Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$393,372,000
Total Reduced AAD	**$1,415,238,000**
Total Initial Construction	$16,067,536,000
OMRR&R	$195,710,000
Average Annual Cost (AAC)	**$803,107,000**
Average Annual Net Benefits	**$612,131,000**
Benefit-Cost Ratio	**1.8**
Residual Damages	21.7%
Eligible Nonstructural	18,800
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4G(8)**
South Region	**5A**

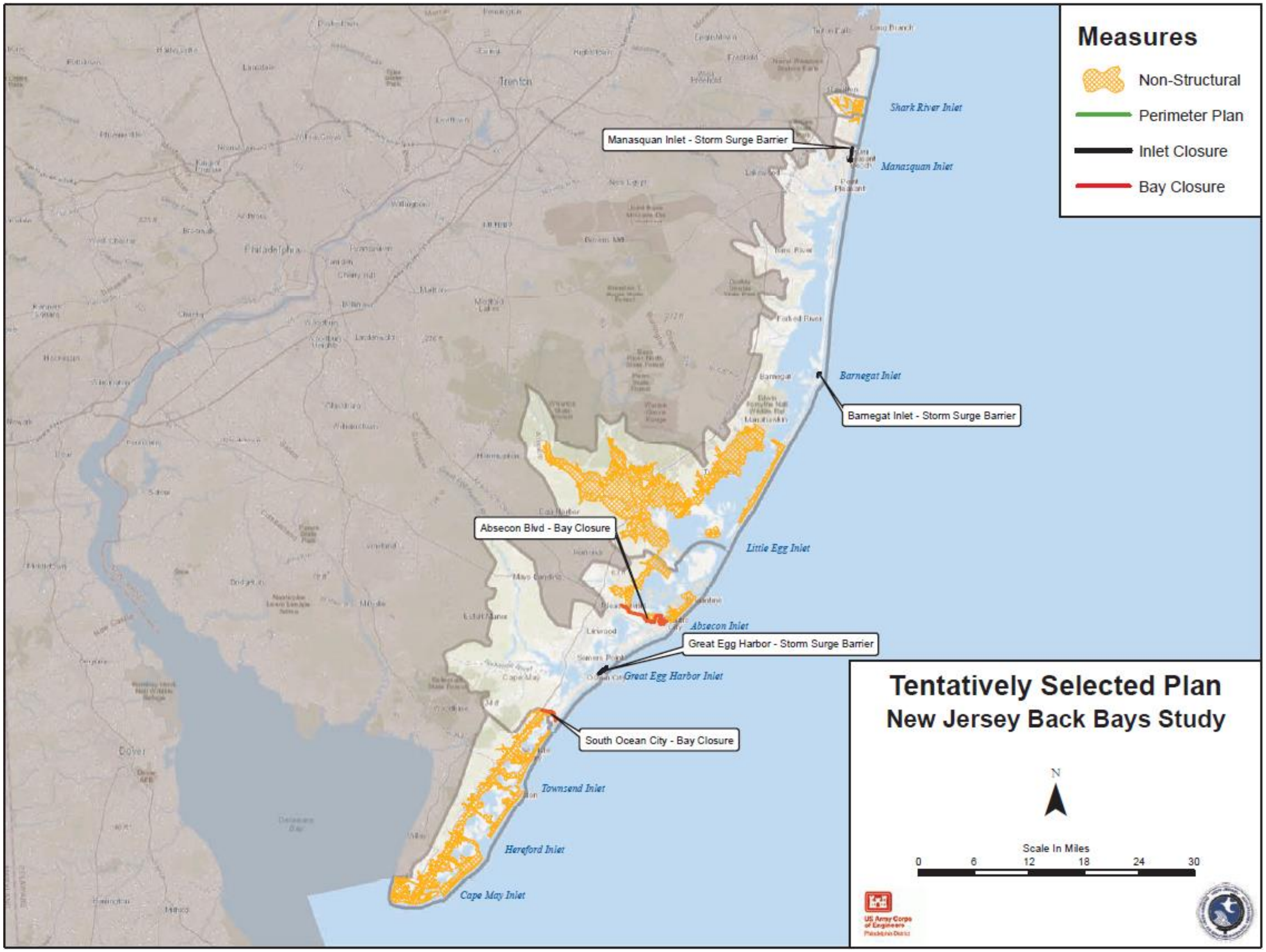
National Economic Development (NED) Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$417,176,000
Total Reduced AAD	**$1,391,434,000**
Total Initial Construction	$16,492,814,000
OMRR&R	$134,957,000
Average Annual Cost (AAC)	**$758,956,000**
Average Annual Net Benefits	**$632,478,000**
Benefit-Cost Ratio	**1.8**
Residual Damages	23.1%
Eligible Nonstructural	19,900
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4D(1)**
South Region	**5A**

Nonstructural Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$710,695,000
Total Reduced AAD	**$1,097,915,000**
Total Initial Construction	$13,947,220,000
OMRR&R	$0
Average Annual Cost (AAC)	**$491,752,000**
Average Annual Net Benefits	**$606,163,000**
Benefit-Cost Ratio	**2.2**
Residual Damages	39.3%
Eligible Nonstructural	42,800
Shark River / Coastal Lakes	**2A**
North Region	**3A**
Central Region	**4A**
South Region	**5A**

The Figures below provide a visual overview of the measure components and locations of the Tentatively Selected Plan, the National Economic Development Plan, and the Nonstructural Plan, respectively. The three plans overlap in their prescriptions for Shark River / Coastal Lakes and the South Region, as nonstructural only (represented in the maps with yellow crosshatching) is all that is recommended. The North Region's plan is the same for both the TSP and the NED plan: for both, two storm surge barriers, located at Manasquan Inlet and Barnegat Inlet, are recommended.

The difference between the three plans is largest in the Central Region. The NED plan recommends justified perimeter measures and complementary nonstructural, while the TSP recommends a storm surge barrier at Great Egg Harbor, two bay closures (at Absecon Boulevard and South Ocean City) and accompanying nonstructural. The nonstructural plan only considers nonstructural for the whole region. A side-by-side comparison of the TSP, NED Plan, and Nonstructural-Only Plan is shown in Section C-11, along with a discussion of the qualitative and semi-qualitative reasons, such as Sea Level Change (SLC) adaptive capacity, resiliency, and life safety risk, for the selection of the TSP.

At the end of the Executive Summary is a workflow document intended to provide clarity on the framework and structure of the Economics Appendix. As the Appendix is written in chronological order from Feasibility study inception to current plan selection, the economic analysis spans over several price levels, discount rates, and cycles of plan evaluation/comparison/screening. Though the appendix aims to explicitly state the methodology and price level (and discount rate) used in each cycle of analysis, the workflow document provides a comprehensive reference sheet to easily track the economic assessment process from commencement to plan selection.



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Shark River Inlet
Manasquan Inlet - Storm Surge Barrier
Manasquan Inlet
Barnegat Inlet
Barnegat Inlet - Storm Surge Barrier
Little Egg Inlet
Absecon Blvd - Bay Closure
Absecon Inlet
Great Egg Harbor - Storm Surge Barrier
Great Egg Harbor Inlet
South Ocean City - Bay Closure
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover
Tentatively Selected Plan
New Jersey Back Bays Study
N
Scale In Miles
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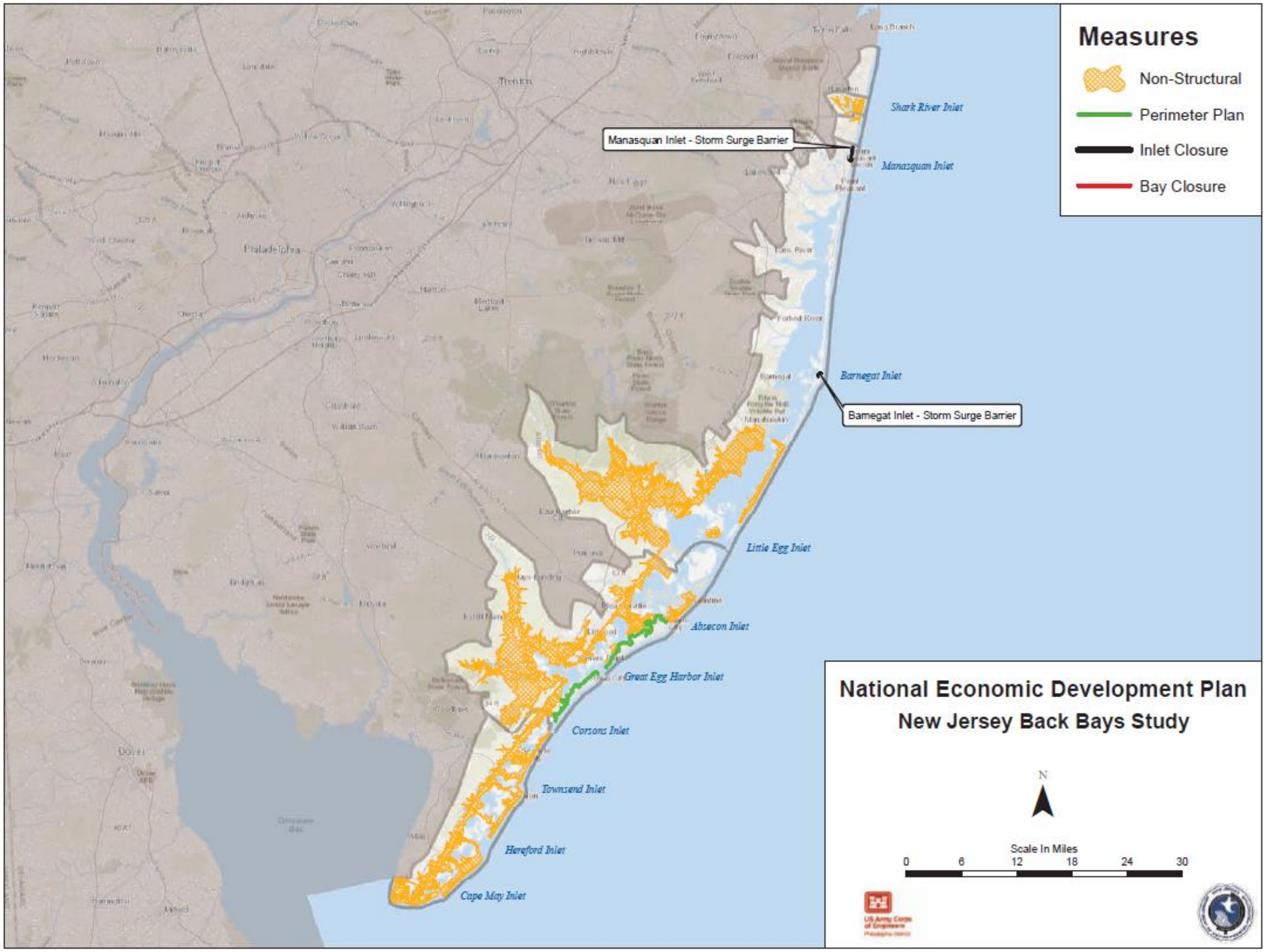
US Army Corps of Engineers


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Philadelphia
Trenton
National Economic Development Plan
New Jersey Back Bays Study
N
Scale In Miles
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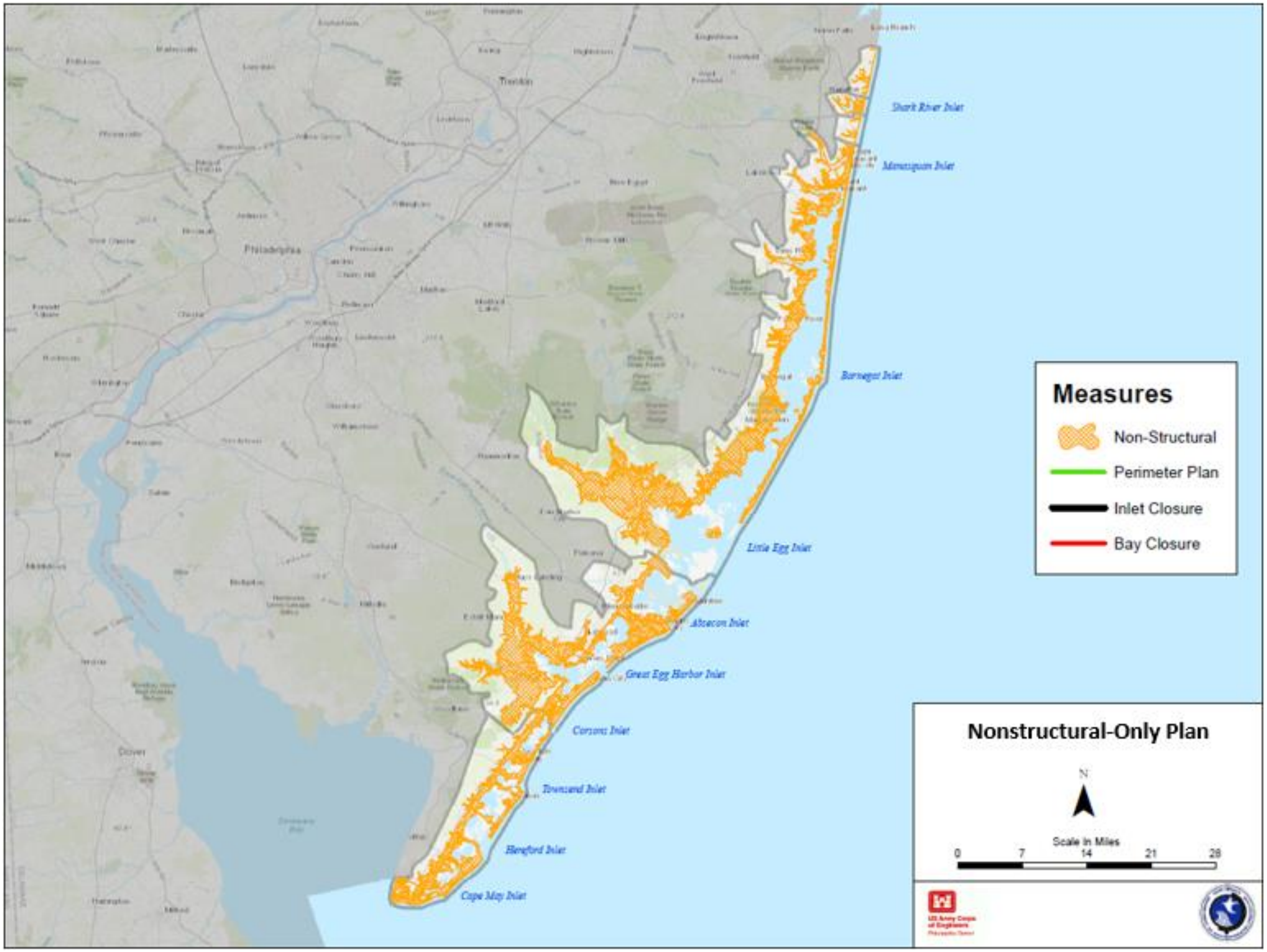

Nonstructural-Only Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
N
Scale In Miles
0
7
14
21
28
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover

Section Title	Price Level / Discount Rate	Key Items
Section C-3	FY2018 Price Level FY2018 Discount Rate 2.75%	- Initial structure inventory development (182,930 structures) - First Marshall & Swift Residential Estimator assessment effort - Content-to-Structure Value Ratios (CSVRs) – Only EM 1110-2-1619 - First Foundation Height stratified random sample assessment effort - First "Probability of Already Elevated" stratified random sample assessment effort - Depth-Percent Damage Functions - NACCS only - Vehicles, Critical Infrastructure, Transportation Delay, Emergency Services – Quantified outside HEC-FDA using placeholder percentages - 226 Reaches aggregated to 5 Regions (Coastal Lakes, Shark River, North, Central, South)
Section C-4	FY2018 Price Level FY2018 Discount Rate 2.75%	- $1.57 billion FWOP Average Annual Damages (Intermediate SLC)
Section C-5	FY2018 Price Level FY2018 Discount Rate 2.75%	- Individual Measure Analysis o **Perimeter** ▪ Cycle 0 – Qualitative screening of low density / low DRV locations • **↓ 49 locations** ▪ Cycle 1 – Semi-quantitative Excel screening with parametric costs (NACCS) • **↓ 13 locations** ▪ Cycle 2 – Quantitative HEC-FDA screening with Class Level 5 costs • **↓ 7-10 locations** ▪ Cycle 3 – Transition to multi-measure "hybrid" alternatives analysis o **Nonstructural** ▪ Quantitative HEC-FDA screening with parametric costs (NACCS) ▪ Residential structures only (elevation) ▪ 31,660 structures o **Storm Surge Barriers** ▪ Quantitative HEC-FDA screening with Class Level 5 costs ▪ 11 Storm Surge Barriers and 8 Bay Closures
Section C-6	FY2018 Price Level FY2018 Discount Rate 2.75%	- Multi-Measure "Hybrid" Alternatives Analysis o HEC-FDA quantitative assessment o 226 Reaches across 4 Regions (Shark River and Coastal Lakes Regions combined) o 51 measure combinations (alternatives) of potential CSRM measures • **↓ HEC-FDA NED screening** o 20 measure combinations (alternatives) that may reasonably maximize net NED benefits

Section C-7	FY2018 Price Level FY2018 Discount Rate 2.75%	- Focused Array of Alternatives (20 measure combinations from Section C-6)
Section C-8	FY2019 Price Level (Inventory Values) FY2021 Price Level FY2021 Discount Rate 2.5% (In HEC-FDA)	- Continued structure inventory development (172,988 structures) o Addition, deletion, and aggregation of inventory structure assets - Re-classification of non-residential structure types using visual survey - Separation of "Mainland" and "Barrier" residential structures - Vehicles added to HEC-FDA w/ $676 million damageable value (EGM 09-04) - CSVRs – expanded sources to EM 1110-2-1619, IWR Expert Elicitation (2013), Southwest Coastal Louisiana (2016) - Second Foundation Height stratified random sample assessment effort - Second "Probability of Already Elevated" stratified random sample assessment effort - Second Marshall & Swift Residential Estimator assessment effort - Depth-Percent Damage Functions – sources expanded to NACCS, IWR Expert Elicitation (2013) and Southwest Coastal Louisiana (2016) - Critical Infrastructure identified by type and location - Transportation Delay, Non-Transferable Income Loss, Emergency Services, Potential Local Costs Foregone – Quantified outside HEC-FDA
Section C-9	FY2021 Price Level FY2021 Discount Rate 2.5%	- $1.81 billion FWOP Average Annual Damages (Intermediate SLC) - $1.45 billion FWOP Average Annual Damages (Low SLC) - $3.89 billion FWOP Average Annual Damages (High SLC) - Regional Economic Development impacts – RECONS and Business Losses (qualitative) - Other Social Effects impacts – Abbreviated Life Safety and Population at Risk (PAR)
Section C-10	FY2021 Price Level FY2021 Discount Rate 2.5%	- Nonstructural expanded to floodproofing for non-residential structures - Perimeter – Class Level 4 cost estimate - Nonstructural – Class Level 4 cost estimate - Storm Surge Barriers – Class Level 5 cost estimate
Section C-11	FY2021 Price Level FY2021 Discount Rate 2.5%	- Tentatively Selected Plan - **$612,131,000 AANB** - NED Plan – **$632,478,000 AANB** - Nonstructural-Only Plan – **$606,163,000 AANB** - Sea Level Change Adaptive Capacity (ER 1100-2-8162) - Project Performance (ER 1105-2-101)
Section C-12	FY2021 Price Level FY2021 Discount Rate 2.5%	- Conclusion

C-1) INTRODUCTION

This appendix presents the economics methodology, assumptions, and resulting analysis for managing coastal storm risk within the New Jersey Back Bays system. This report will detail each step of the analytical process and describe relevant inputs and results for each region of the study area. The assessment is conducted at a Feasibility level and covers 950 square miles within New Jersey.

Spanning over five counties, the study area captures approximately 173,000 structures with over $90 billion in damageable assets, critical infrastructure, emergency services costs, and other benefit categories. The study area is delineated into the possible maximum study area extent and modeled for the 0.2% Annual Exceedance Probability (AEP) event floodplain for FY2080 with Intermediate Relative Sea Level Change (RSLC).

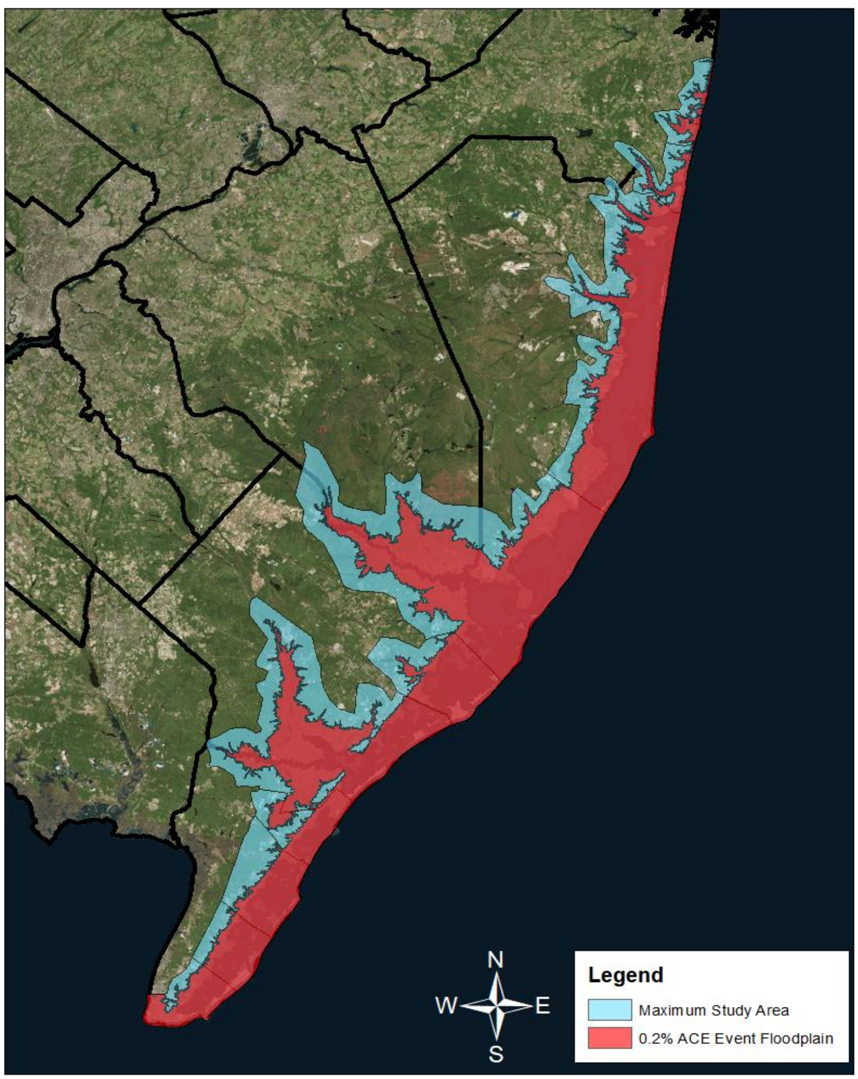

Figure 1: New Jersey Back Bays – Study Area Extent

C-2) HEC-FDA MODEL SOFTWARE DESCRIPTION

The Hydrologic Engineering Center – Flood Damage Reduction Analysis (HEC-FDA) software version 1.4.2 is used to model Future Without-Project Conditions and a variety of scenarios for Future With-Project Conditions.

HEC-FDA ver. 1.4.2 provides integrated hydrologic engineering and economic risk analysis during the formulation and evaluation of flood damage reduction plans in compliance with policy regulations ER 1105-2-100 *Planning Guidance Notebook* and ER 1105-2-101 *Risk Analysis for Flood Damage Reduction Studies*. Uncertainty in discharge-exceedance probability, stage-discharge, and damage-stage functions are quantified and incorporated into economic and engineering performance analyses of alternatives. The process applies Monte Carlo simulation, a numerical-analysis procedure that computes the expected value of damage while explicitly accounting for uncertainty in the basic parameters used to determine flood inundation damage.

Data on historic storms, water surface profiles, depth-percent damage functions, and residential, commercial, and public structures within the study area will be used as input for the HEC-FDA software. In conjunction with Hydrologic modeling, HEC-FDA will also incorporate Historic (Low), Intermediate, and High Relative Sea Level Change (RSLC) analysis in compliance with ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs* and ER 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies.*

Future Without-Project Conditions are used as the base condition over the 50-year period of analysis and are compared against potential alternatives to determine potential with-project National Economic Development (NED) benefits. The model will use the FY2021 Project Evaluation and Formulation Rate (Discount Rate) of 2.5%.

C-3) STRUCTURE INVENTORY DEVELOPMENT

This Section will cover the creation of the structure inventory and describe the final hydrologic engineering inputs for HEC-FDA known as Water Surface Profiles (more detail can be found in the Engineering Appendix).

This Appendix is designed to provide a chronological account of the methodology and economic results of the analysis from study initiation to identification of the Tentatively Selected Plan (TSP) and National Economic Development (NED) Plan. Analysis descriptions and results from Section C-3 to Section C-7 were used to screen from all possible alternatives to the Focused Array of Alternatives. Section C-8 to Section C-12 describe inventory adjustments and model improvements to justifiably screen from the Focused Array of Alternatives to the identified TSP.

The initial structure inventory was developed between November 2017 and May 2018. The inventory was then periodically updated for each cycle of analysis.

Structure Identification and Valuation

The structure inventory for the study area was created using materials supplied by the New Jersey Department of Environmental Protection (NJDEP), New Jersey Department of Transportation (NJDOT), New Jersey Geographic Information Network (NJGIN), and the Tax Assessor's Office for each of the five New Jersey counties included in the study.

Development of the structure inventory involves surveying existing floodplain structures to collect the data necessary to determine expected coastal storm damages. The purpose for collecting this information is to determine what structures are located in the floodplain, the depreciated replacement value of the structures and their associated contents, and the zero-damage elevation at which they are initially susceptible to flooding.

County tax parcel and assessment records provide the basis for Depreciated Replacement Value (DRV) in compliance with EM 1110-2-1619 *Risk Based Analysis for Flood Damage Reduction Studies*. Specifically, tax assessor records offer information on structure location (Northing & Easting Coordinates), structure address and municipality, category type, occupancy type, parcel ID number, and county tax assessment value.

Only structures within the 0.2% Annual Exceedance Probability (AEP) event floodplain are included in the HEC-FDA model inventory as structures with ground elevations above that threshold experience damages so infrequently that their exclusion does not affect the calculated Average Annual Damages for the study area.

Figure 2 shows an example tax parcel overlay for the area directly around Manasquan Inlet. This includes a partial view of Point Pleasant Borough and Point Pleasant Beach Borough in Ocean County and Brielle Borough and Manasquan Borough in Monmouth County. The tax parcel overlay with associated tax record values are not yet clipped to the 0.2% AEP Event floodplain.

Figure 3 shows the same area with the FY2080 0.2% AEP event floodplain with Intermediate Relative Sea Level Change (RSLC) shaded in blue. This shaded area is the model extent of the economic analysis.

Figure 4 shows the inventory after the tax parcel polygons are converted to a singular data point, or centroid, and then clipped to the 0.2% AEP event floodplain. The markers shown have GPS coordinates, tax assessor values, and information on structure use and design. This same process was completed for all 950 square miles of study area.

Figure 2: Manasquan Inlet Example – Tax Parcel Overlay

Figure 3: Manasquan Inlet Example – 0.2% Annual Exceedance Probability (AEP) Event Floodplain

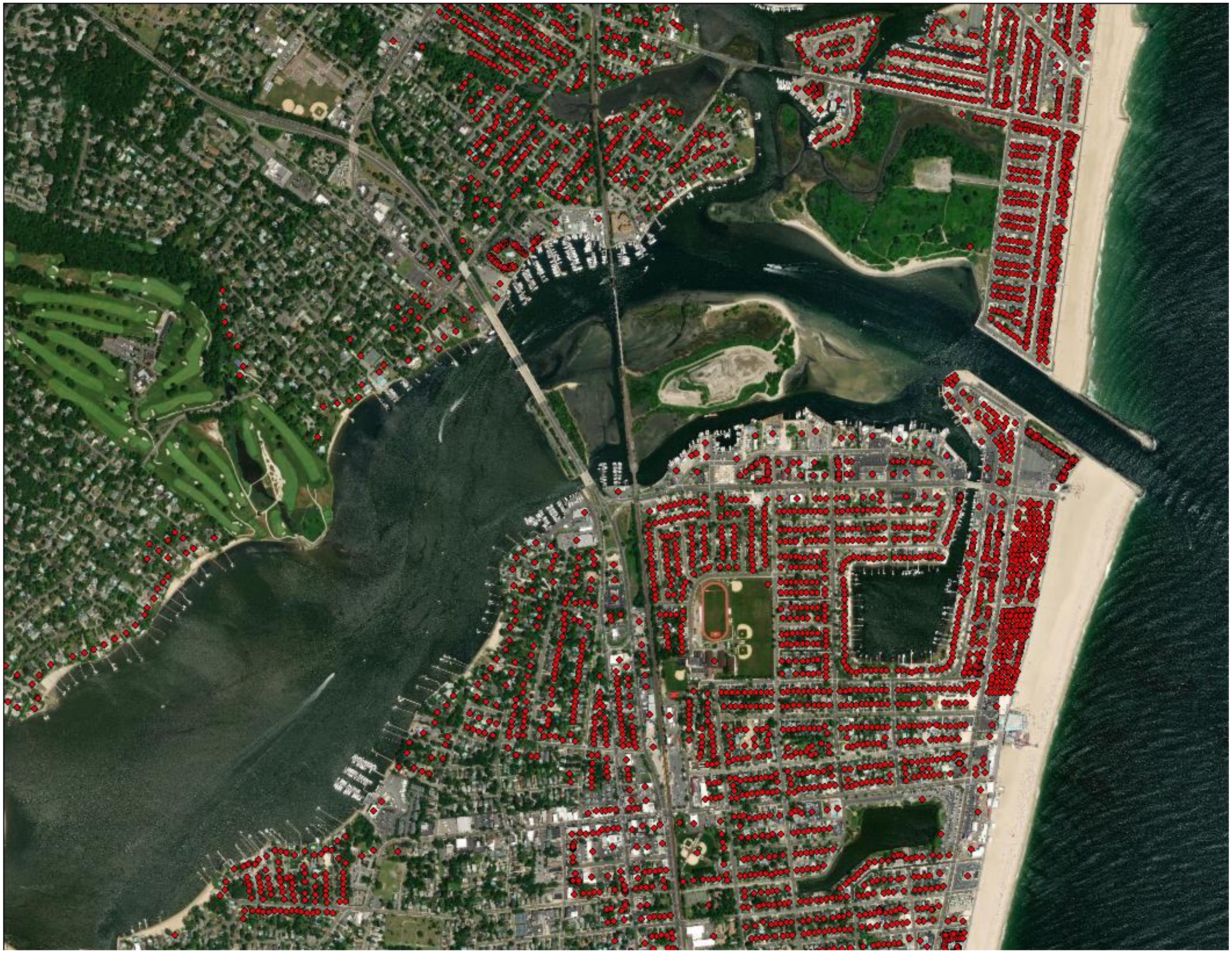

Figure 4: Manasquan Inlet Example – Structure Inventory

In total, structures are located in 84 separate municipalities across five counties. Table 1 shows the 25 municipalities with the largest volume of structures within the study area and a summary row detailing the structure category breakdown for all 182,930 structures in all 84 municipalities.

Table 1: Structure Count by Category Type by Municipality

Municipality	TOTAL	RES	COM	PUB	IND	HIGH	% TOTAL
Ocean City	17882	17192	573	115	1	1	9.78%
Toms River	13689	13332	262	83	12	0	7.48%
Brick	9772	9519	160	92	1	0	5.34%
Long Beach	8217	8036	151	30	0	0	4.49%
Atlantic City	7782	6098	1136	476	9	63	4.25%
Sea Isle City	6330	6146	143	41	0	0	3.46%
Brigantine	6285	6095	120	60	0	10	3.44%
North Wildwood	5681	5441	198	40	0	2	3.11%
Margate City	5510	5350	119	41	0	0	3.01%
Avalon	5304	5153	121	30	0	0	2.90%
Wildwood Crest	5098	4930	124	30	0	14	2.79%
Little Egg Harbor	4964	4871	51	42	0	0	2.71%
Stafford	4864	4801	36	27	0	0	2.66%
Point Pleasant	4818	4586	197	35	0	0	2.63%
Lacey	4772	4673	58	40	1	0	2.61%
Ventnor	4574	4392	135	41	1	5	2.50%
Berkeley	4374	4290	48	35	1	0	2.39%
Cape May	3788	3480	240	63	0	5	2.07%
Stone Harbor	3114	2878	192	44	0	0	1.70%
Wildwood	3078	2534	478	57	5	4	1.68%
Pt Pleasant Beach	2869	2627	214	28	0	0	1.57%
Lavallette	2551	2480	53	18	0	0	1.39%
Beach Haven	2384	2251	107	26	0	0	1.30%
Surf City	2248	2131	94	23	0	0	1.23%
Belmar	2169	2041	98	30	0	0	1.19%
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Remaining	40813	38518	1683	572	34	6	22.31%
TOTAL	**182930**	**173845**	**6791**	**2119**	**65**	**110**	**100.00%**
PERCENT TOTAL	**-**	**95.03%**	**3.71%**	**1.16%**	**0.04%**	**0.06%**	**100.00%**

Residential structures comprise the overwhelming majority of structure in the study area with over 95% of total inventory by volume. Non high-rise commercial or public structures comprise most of the remaining 5% of structures by volume. For this study, structures with six or more floors are considered high-rises and are separated into their own category due to their unique damage mechanisms.

It should be noted that Section C-8 discusses further inventory work completed after initial FWOP and Focused Array of Alternatives modeling and evaluation. Among other changes, the total number of structures was updated to 172,988 total assets. The largest reason for the change is aggregating individual units (e.g., apartments) into a single apartment building.

Tax assessor structure values, noted as *Improvement Value*, provide a base for determining depreciated replacement value of structures, but need to be adjusted to account for deviations between assessed value and replacement value while also accounting for discrepancy between the date of the assessment and the date of the study. Further information on this technique can be found in EM 1110-2-1619 *Risk Based Analysis for Flood Damage Reduction Studies.*

For this study, the value adjustment is completed by developing a stratified random sample of structures and independently estimating their depreciated replacement value using Marshall & Swift Residential Estimator 7 and then comparing the stated tax assessor value against M&S depreciated replacement value. Assuming the stratified random sample is representative of the entire population, the average percent difference between the two values can then be applied to the entire inventory of structures to adjust the individual assessor value for each structure to a unique depreciated replacement value. This initial limited stratified random sampling is expanded after the Focused Array of Alternatives and detailed in Section C-8.

Figure 5 provides the M&S Standard Report output for a structure in Cape May City. Random structures were selected both along the barrier islands and on the mainland.

Standard Report

Estimate ID:	CapeMay_140
Property Owner:	[redacted]
Address:	
City:	Cape May
State/Province:	New Jersey
ZIP/Postal Code:	08204
Surveyed By:	[redacted]
Survey Date:	

Single-family Residence		Floor Area:	4,000 Square Feet
Effective Age:	10	Quality:	3 Average
Cost as of:	March, 2017	Condition:	3 Average
Style:	2 1/2 Story Finished		
Exterior Wall:	Frame, Hardboard Sheets 100%		
Plumbing Fixtures:	11		

	Units	Cost	Total
Base Cost	4,000	66.46	265,840
Plumbing Fixtures	11	1,822.40	20,046
Wood Shingle	4,000	2.97	11,880
Raised Subfloor	4,000	11.39	45,560
Floor Cover Allowance	4,000	5.27	21,080
Forced Air Furnace	4,000	4.92	19,680
Plumbing Rough-ins	1	737.00	737
Appliance Allowance	1	4,355.00	4,355
Basic Structure Total Cost	4,000	97.29	389,178
Replacement Cost New	4,000	97.29	389,178
Physical + Functional Depreciation 9.0%			35,025
Total Depreciated Cost			354,153
Total			$354,153

Cost data by Marshall & Swift/Boeckh, LLC and its licensors.

Figure 5: Marshall & Swift Residential Estimator 7 – Standard Report

Content values are established using a Content-to-Structure Value Ratio (CSVR) with the implicit assumption that the content values of a structure are directly related to the value of the structure itself. The exact CSVR utilized is determined by the category type of the structure and are pulled from EM 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies*.

Table 2 shows the Structure and Content value for each County isolated by category type.

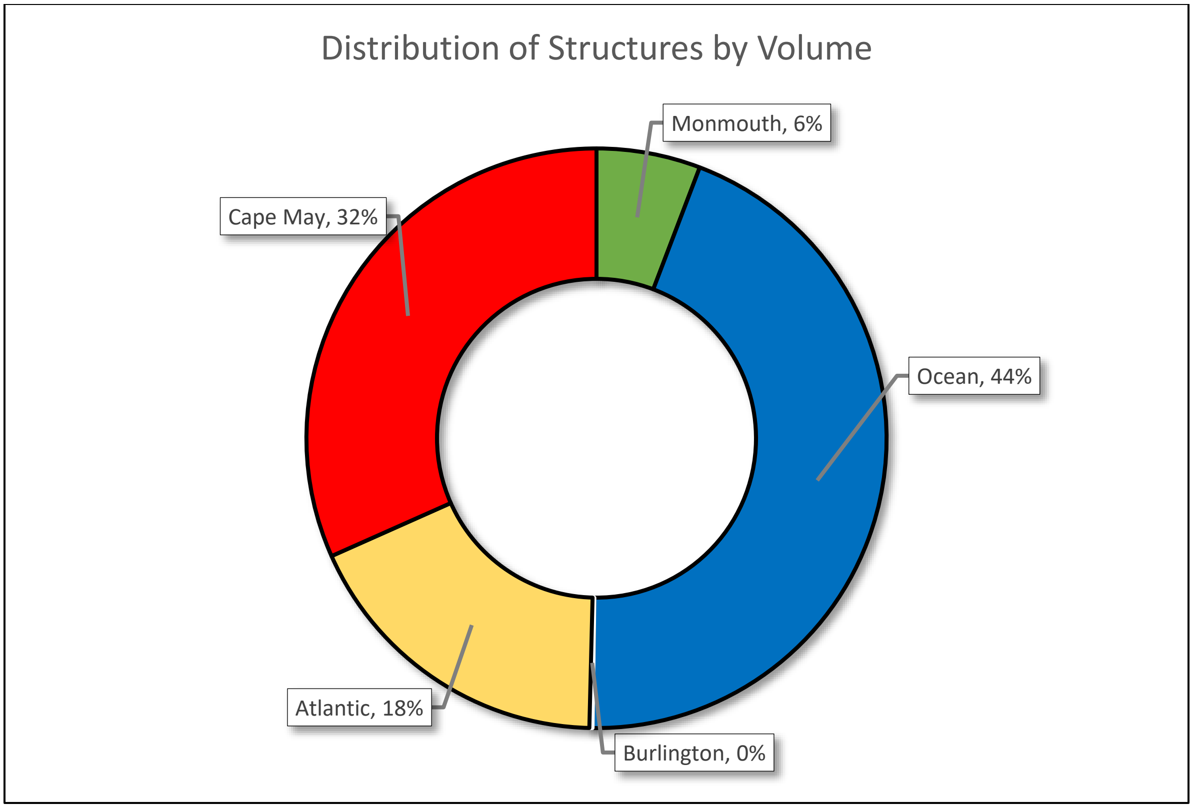
Table 2: Total Structure and Content Value by County by Category Type ($1000s)

County	Count	TOTAL	RES	COM	PUB	IND	HIGH
Monmouth	10598	$4,357,499	$3,932,765	$228,731	$179,399	$16,604	$0
Ocean	81262	$25,034,179	$23,030,635	$1,514,747	$475,772	$13,025	$0
Burlington	322	$99,498	$63,088	$31,755	$4,655	$0	$0
Atlantic	32825	$20,842,858	$9,405,230	$2,712,856	$3,724,643	$16,936	$4,983,192
Cape May	57923	$21,890,206	$19,168,233	$1,761,709	$773,244	$39,455	$147,565
TOTAL	**182930**	**$72,224,240**	**$55,599,951**	**$6,249,799**	**$5,157,714**	**$86,020**	**$5,130,757**
AVERAGE	**-**	**$394**	**$319**	**$920**	**$2,434**	**$1,323**	**$46,643**

Residential properties, with 95% of structures by volume still contribute the majority of structure and content value with 77% of total value but have the lowest average structure and content value of the five categories. High-rise structures, particularly the high value structures in Atlantic City, have the highest average structure and content value and contribute over 7% of total value though only representing .06% of structures by volume.

Figure 6 on the following page shows a comparison between the structure volume by County and the structure value by County. Atlantic County has the largest divergence between structure volume and structure value with 18% of structures contributing 29% of total value. This disparity is directly correlated with the presence of high value structures on Absecon Island, primarily Atlantic City.

Together, Atlantic County and Ocean County contribute 62% of total structures by volume with 64% of total structure and content value.



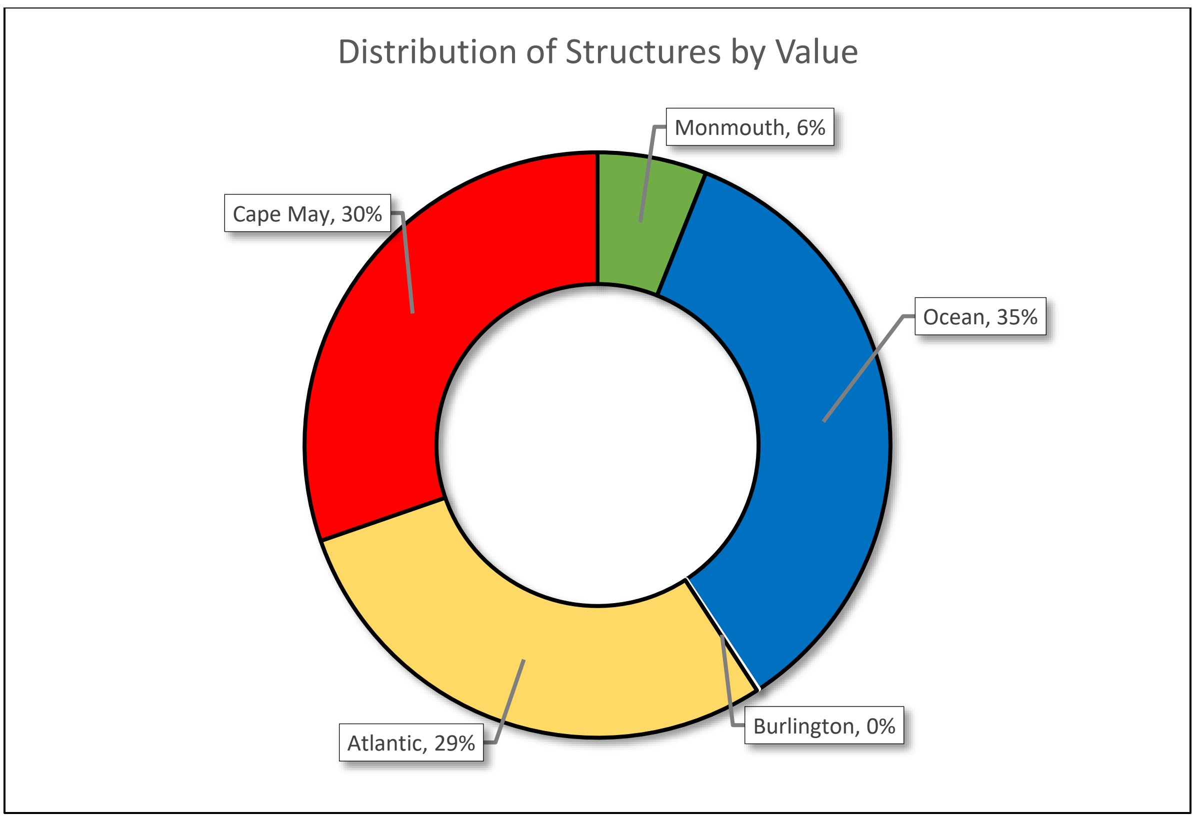


Figure 6: Structure Volume and Depreciated Replacement Value by County

While HEC-FDA does have the capacity for other damageable asset inputs, the remaining benefit categories at this point of the study were calculated outside of the model due to limitations in available valuation data and Depth-Percent Damage Curves. These benefit categories include Vehicle Damages, Critical Infrastructure, Transportation Delays, and Emergency Services Costs. These benefit categories are calculated as percentages of the HEC-FDA derived values.

During model refinement in Cycle 3 of the analysis, HEC-FDA outputs were expanded to include Vehicles Damages. Non-HEC-FDA benefits were developed using empirical models based on historical damages for Critical Infrastructure, Transportation Delays, Emergency Services Costs, Non-Transferrable Income Loss, and Local Costs Foregone (detailed in Section C-9).

Life Safety Risk is not considered an NED benefit though it may be used as a decision criterion for identification of the Tentatively Selected Plan and contributes to estimation of Other Social Effects (OSE). Life Safety Risk is assessed qualitatively after development of the Focused Array of Alternatives (as detailed in Section C-11) and a comprehensive quantitative Risk Assessment will be completed before release of the final Feasibility Report.

Structure First Floor Elevation

First Floor Elevation (FFE) is the addition of Ground Elevation and Foundation Height to measure the absolute elevation of the main floor of the structure. For this study, all structures in the inventory are assumed to have a pile foundation without basements and a damage point of zero. In other terms, HEC-FDA only begins to quantify damages at that individual structure when the flood stage height reaches the main floor elevation.

Ground Elevation is the height of the land at the inventory marker location; typically at the central point of the structure. Ground Elevation is calculated at a population level with the availability of a National Oceanic and Atmospheric Administration (NOAA) Digital Coast Bare Earth Light Detection and Ranging (LiDAR)-derived Digital Elevation Model (DEM). As the LiDAR-derived DEM is available for the entire study area, each individual structure is provided a unique, calculated Ground Elevation with a high degree of certainty.

Figure 7 on the following page shows an example Digital Elevation Model for a section of Atlantic City in Atlantic County. The areas shaded in red have the lowest elevation with areas shaded in green or blue having the highest. The structure inventory is overlaid as red markers. Each structure Ground Elevation is calculated at the intersection of their marker and the underlying Digital Elevation Model. This process is repeated for all 182,930 structures.

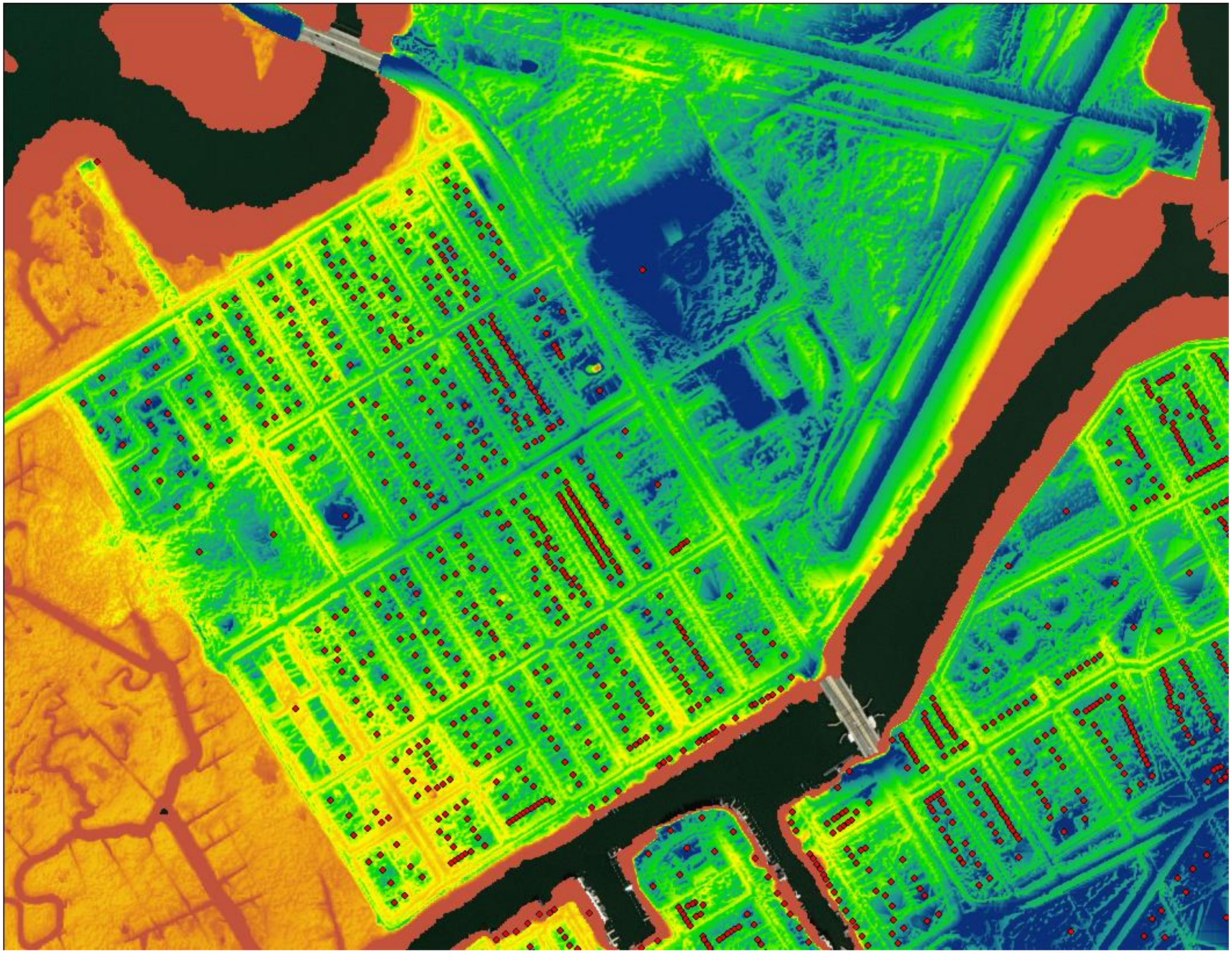


Figure 7: LiDAR-derived Digital Elevation Model – Atlantic City Example

Foundation Height is more difficult to measure and attribute for each individual structure. While techniques such as field surveys or mobile LiDAR can theoretically calculate Foundation Height for every structure with a high degree of certainty, the size of the inventory makes these methods prohibitively time and resource consuming. To individually measure all 182,930 structures would require years of intense resource allocation. Additionally, population level data such as New Jersey tax records do not offer a measurement for Foundation Height nor can available aerial imagery provide insight on main floor height above Ground Elevation.

To calculate the First Floor Elevation for structures within the model inventory, a stratified random sample is collected of structures within each occupancy type, from both the barrier islands and mainland, to assign a typical foundation height per structure type. The average foundation height for a given occupancy type is then added to the structure's unique Ground Elevation to calculate final FFE.

Foundation Height samples were collected using Google Earth Pro street view for 2,430 structures, or 1.3% of the total inventory. Table 3 provides the assigned Foundation Height results of that effort.

Table 3: Foundation Height by Occupancy Type

CATEGORY	OCCUPANCY	FOUNDATION
RES	Single Family Residential One Story (SFR1)	1.5ft
	Single Family Residential Multi Story (SFRM)	2.5ft
	Apartment Complex	0.5ft
COM	Commercial	0.5ft
PUB	Public	0.5ft
IND	Industrial	0.5ft
HIGH	High-Rise	0.5ft

Non single-family residential structures were predominantly constructed at grade to comply with Americans with Disabilities Act (ADA) requirements or due to limitations in elevating structures of certain sizes or uses. To account for some non-single-family residential structures having elevated foundations, a Foundation Height of 0.5ft is applied across the population in lieu of 0.0ft.

For single-family residential structures, buildings with multi stories were more likely to have elevations at least 2ft above ground level while structures with only one story were typically at grade or elevated only 1ft above ground level. Foundation Heights of 1.5ft and 2.5ft for SFR1 and SFRM occupancy types were assigned, respectively.

The final piece for assigning the First Floor Elevation of residential structures is to estimate the probability of structures already elevated outside the 1% Annual Exceedance Probability (AEP) event floodplain. Structures may have been initially constructed already elevated or owner's may have already implemented elevation work following a previous storm event. Especially along the barrier islands, many residential structures are elevated 7ft-10ft above ground to prevent inundation from high to moderate frequency storm events.

To investigate this variable, 1,630 structures were sampled from the barrier islands while 400 were sampled from the mainland and a further 400 were sampled from "finger canal" communities along the mainland such as Mystic Islands or Beach Haven West. Figure 8 provides aerial imagery of an example finger canal community.

Figure 8: Finger Canal Community Example – Beach Haven West (Stafford Township)

As shown in Figure 8, these finger canal communities are unique along the mainland due to the presence of inland canals adjacent to almost all structures within the society. A result of this type of community planning is that the structure types and probabilities are more closely related to communities along the barrier island than closer communities on the mainland.

From the Foundation Height sample, residential structures on the barrier islands, or within finger canal communities, were found to have an approximate 33% probability of being elevated outside the 1% AEP event floodplain while mainland residential communities were found to have a 5% probability of elevation above the 1% AEP event floodplain.

To account for this probability, one third of all residential structures located on the barrier islands or in finger canal communities were elevated to 13ft NAVD88 within the HEC-FDA model inventory to prevent these structures from experiencing damage from any high or moderate frequency storm event. Similarly, one twentieth of all residential structures on the mainland were raised to 13ft NAVD88 within the inventory. The residential structures designated as "elevated" were selected based on a true random method within their respective community types. These methodologies are revised in Section C-8.

For modeling purposes, the maximum FFE allowed in the inventory is 40ft NAVD88. At this stage, modeled damages are impossible for any storm event.

While this method of assigning average foundation height by occupancy type and selecting a certain volume of residential structures as “elevated” provides a reasonable accuracy for estimating First Floor Elevation across a large population, it does not allow for knowing the true FFE for each individual structure within the inventory; only the assigned FFE for a typical structure of a given occupancy type at that location. This has some impact on later plan formulation and evaluation, particularly for nonstructural measures.

As shown in Figure 9, the First Floor Elevation assignment follows a normal distribution with a slight right-tailed skew. The outlier at 13ft NAVD88 is due to the “elevation” assignment methodology discussed earlier with the randomly assigned structures shaded in red.

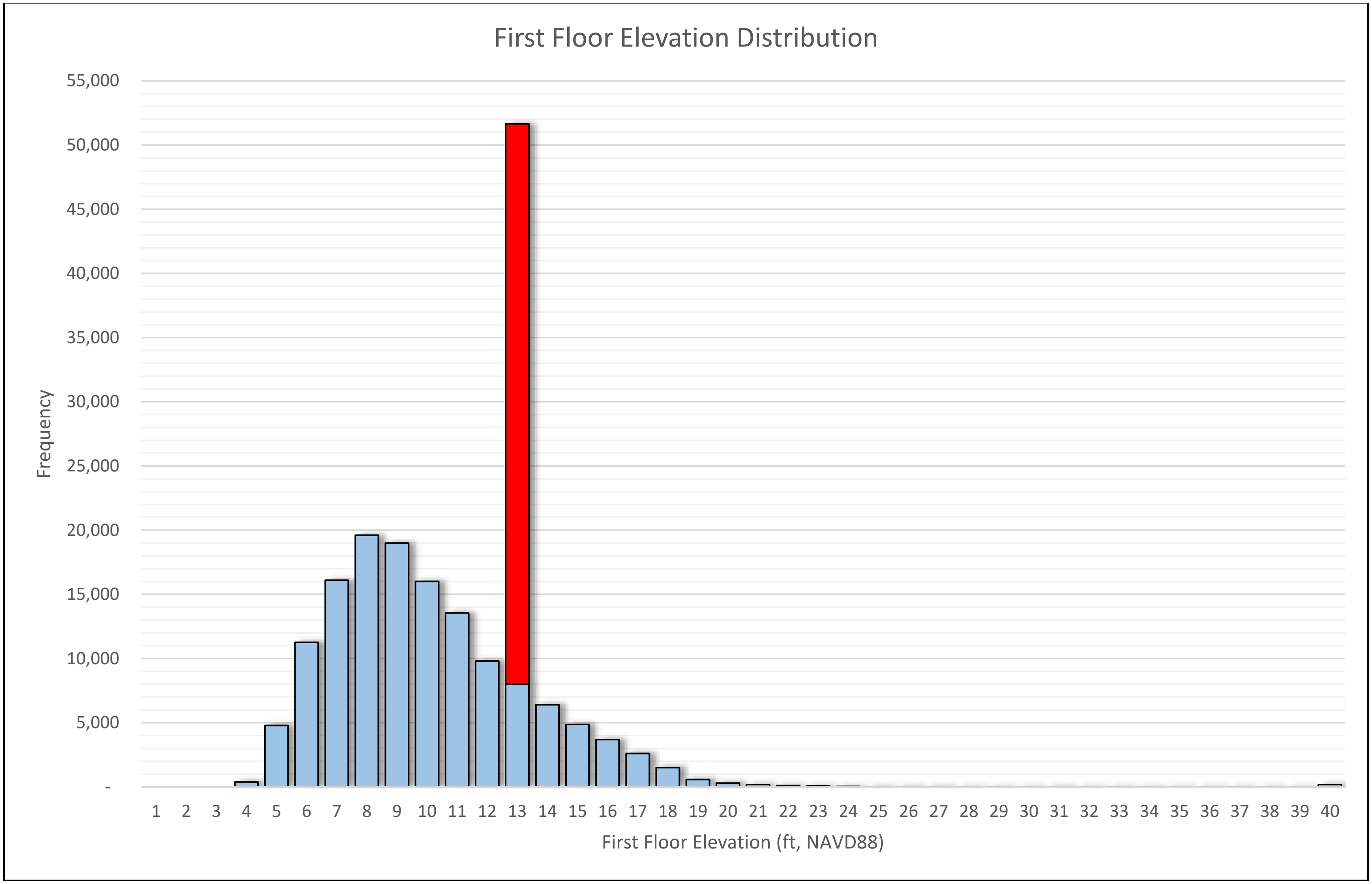


Figure 9: First Floor Elevation Distribution

Depth-Percent Damage Functions

Damage functions are user-defined curves applied within the model to determine the extent of storm-induced damages attributable to inundation. Depth-percent damage curves are created for both structures and contents and for all structure occupancy types.

Damage is determined as a percentage of overall structure or content value using a triangle distribution of values: Minimum, Most Likely (ML), and Maximum. For inundation, damage is determined by the storm-surge heights in excess of the first floor elevation. While depth-percent damage curves do provide the option for quantifying damages at thresholds below the First Floor Elevation, the begin damage point for all occupancy types is set to 0ft.

The depth-percent damage functions utilized in this study (Table 4) are developed by the North Atlantic Coast Comprehensive Study (NACCS) - *Resilient Adaptation to Increasing Risk: Physical Depth Damage Function Summary Report*. Due to the limited availability of damage curves, as well as the similarity in foundation height, foundation type, and risk levels, the same depth-percent damage function is repurposed for commercial, public, and industrial structures.

Table 4: Depth-Percent Damage Functions by Structure Occupancy Type

Single Family Residential One Story (SFR1)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	5	0	0	0
0.0	0	1	10	0	0	5
0.5	6	10	20	5	20	30
1.0	10	18	30	18	40	60
2.0	16	28	40	34	60	84
3.0	20	33	45	60	80	100
5.0	30	42	60	80	90	100
7.0	42	55	94	100	100	100
10.0	55	65	100	100	100	100

Single Family Residential Multi Story (SFRM)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-2.0	0	0	0	0	0	0
-1.0	0	0	2	0	0	0
-0.5	0	1	3	0	0	3
0.0	0	5	8	0	5	8
0.5	5	10	10	5	12	20
1.0	9	15	20	15	25	30
2.0	15	20	25	25	35	40
3.0	20	25	30	32	45	60
5.0	25	30	40	40	55	80
7.0	40	50	55	50	70	100
10.0	50	60	70	60	80	100

Commercial (COM) / Public (PUB) / Industrial (IND)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0.0	0	5	9	0	5	8
0.5	5	10	17	5	18	28
1.0	12	20	27	17	35	50
2.0	18	30	36	28	39	58
3.0	28	35	43	37	43	65
5.0	33	40	48	43	47	65
7.0	43	53	60	50	70	90
10.0	48	58	69	50	75	90

Apartment Complex (APT)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0.0	0	5	8	1	2	8
0.5	5	8	12	5	10	15
1.0	7	20	25	8	15	20
2.0	10	28	29	15	20	25
3.0	18	28	30	20	25	30
5.0	20	38	44	25	30	32
7.0	35	46	50	30	35	40
10.0	35	50	60	37	45	50

High-Rise (HIGH)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-8.0	0	0	0	0	0	0
-5.0	0.5	6.5	10	0	0.25	0.5
-3.0	1.75	9	12.5	0	0.25	1.25
-1.0	3.5	13	16	0	0.5	2.5
-0.5	3.5	13.25	17.75	0	1.5	3.5
0.0	5.5	13.75	18.5	0	4	5
0.5	6.75	14.25	19.25	1.5	5	6
1.0	8	15.5	20	2.6	5	8
2.0	8.75	17.5	22.5	4	7	11
3.0	9.5	19	24	5.5	7.5	13.5
5.0	10.25	21.5	25	6.5	10	16
7.0	11.15	22.5	25.5	8	11	20
10.0	12.5	23.5	26.5	9	12	20

Reach Delineation

Damage reaches are specific geographical areas within a floodplain. They are used to define consistent data for plan evaluations and to aggregate structure and other potential flood inundation damage information by stage of flooding. Reaches are drawn according to hydrologic or municipal boundaries and can be aggregated as necessary to present damages by municipality, proposed alternative, or any other required grouping.

Due to the size of the study area extent and the variability in water conditions as well as the presence of 84 municipal boundaries, the study area is divided into 226 unique, independent reaches. Each of the 182,930 structures fall into exactly one reach.

Figure 10 shows the reach delineation breakdown for the entire study area.

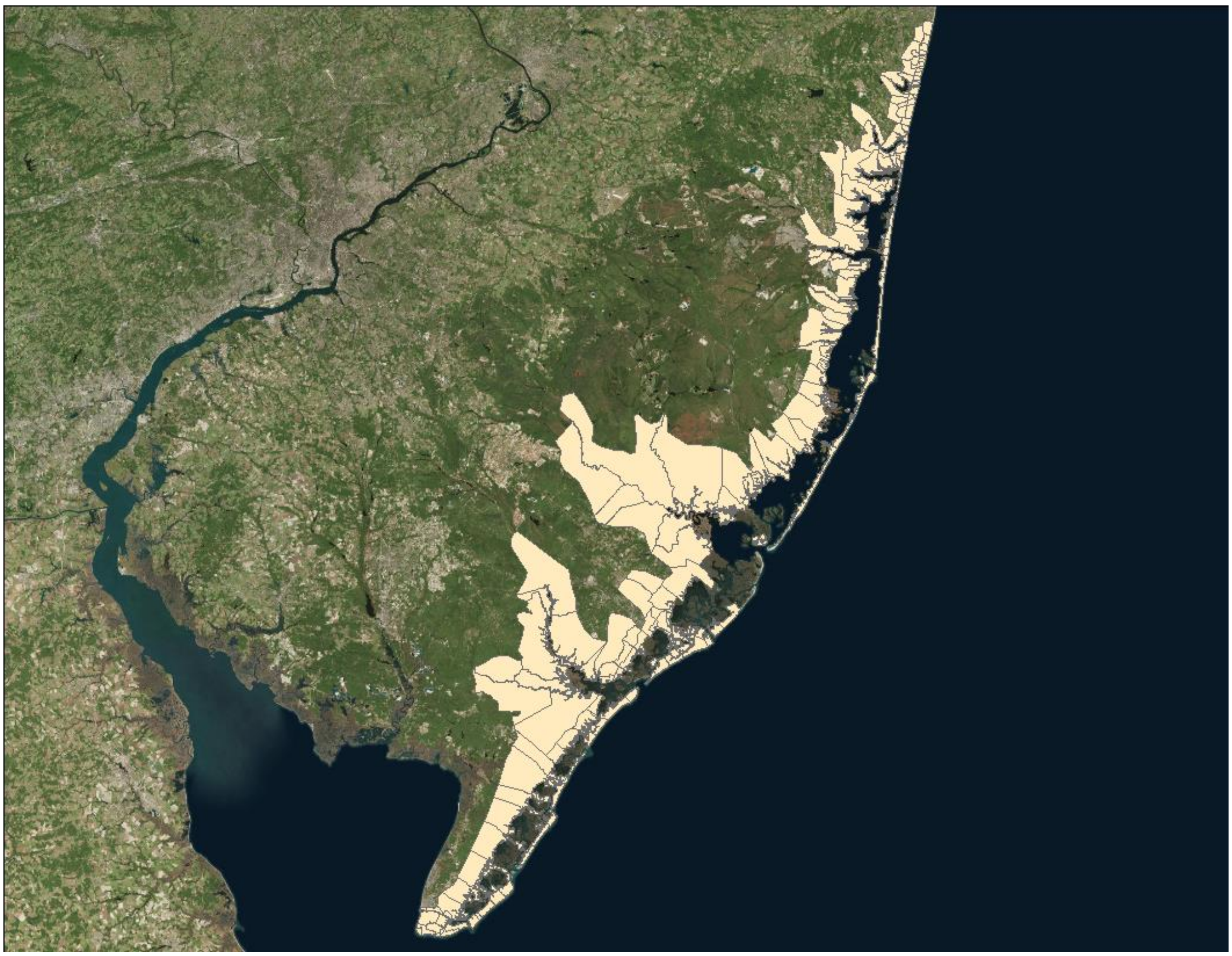


Figure 10: HEC-FDA Reaches – Study Wide

Figure 11 on the following page provides a close-up example at Wildwood Island and West Wildwood Island. From the 15,593 structures (Figure 12) across seven reaches, damages can be presented for each individual reach, each municipality, the entire island, or as part of a regional or study wide alternative.

Figure 11: HEC-FDA Reaches – Wildwood Island and West Wildwood Island – Boundary

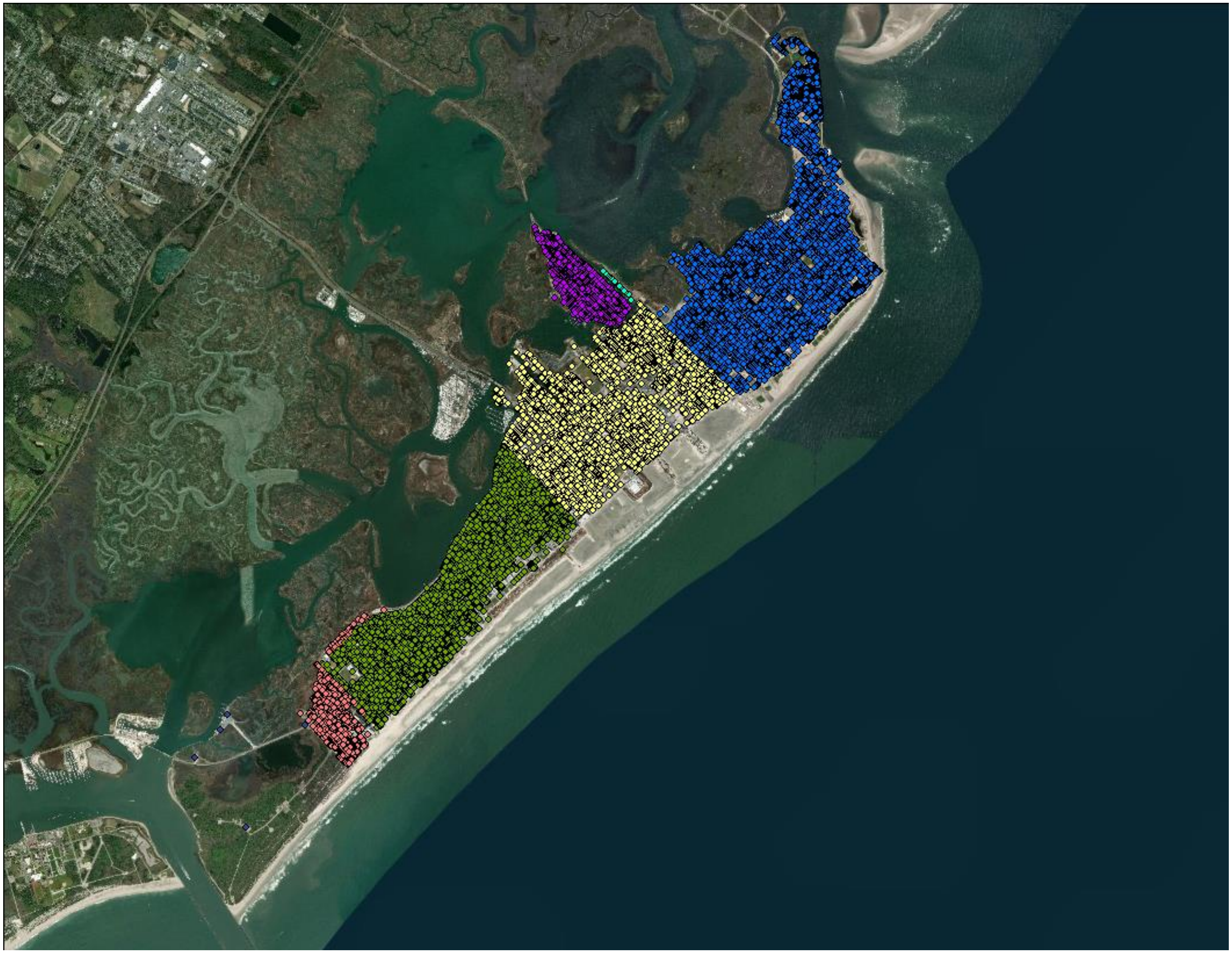


Figure 12: HEC-FDA Reaches – Wildwood Island and West Wildwood Island – Inventory

Water Surface Profiles

Each damage reach has a single Water Surface Profile (WSP). A Water Surface Profile is the water surface stage at that location associated with thirteen separate flood events. While a reach may not have more than one associated WSP, several reaches may have the same WSP if they share similar hydrologic conditions but are divided due to political or other non-hydrologic boundaries.

Water Surface Profiles are developed for the Without-Project Condition for the Base Year and Future Year, with each Relative Sea Level Change (RSLC) scenario (Low, Intermediate, High), for all 226 reaches as well as for each With-Project Condition for the Base year and Future Year, with each RSLC scenario, for all 226 reaches. Detailed information on the development and application of Water Surface Profiles for all HEC-FDA scenarios and reaches can be found in the Engineering Appendix.

Figure 12 shows an example Water Surface Profile for North Wildwood City on the northeast corner of Wildwood Island (Reach 26) for the Without-Project Condition scenario with Intermediate RLSC in the Base Year (FY2030).

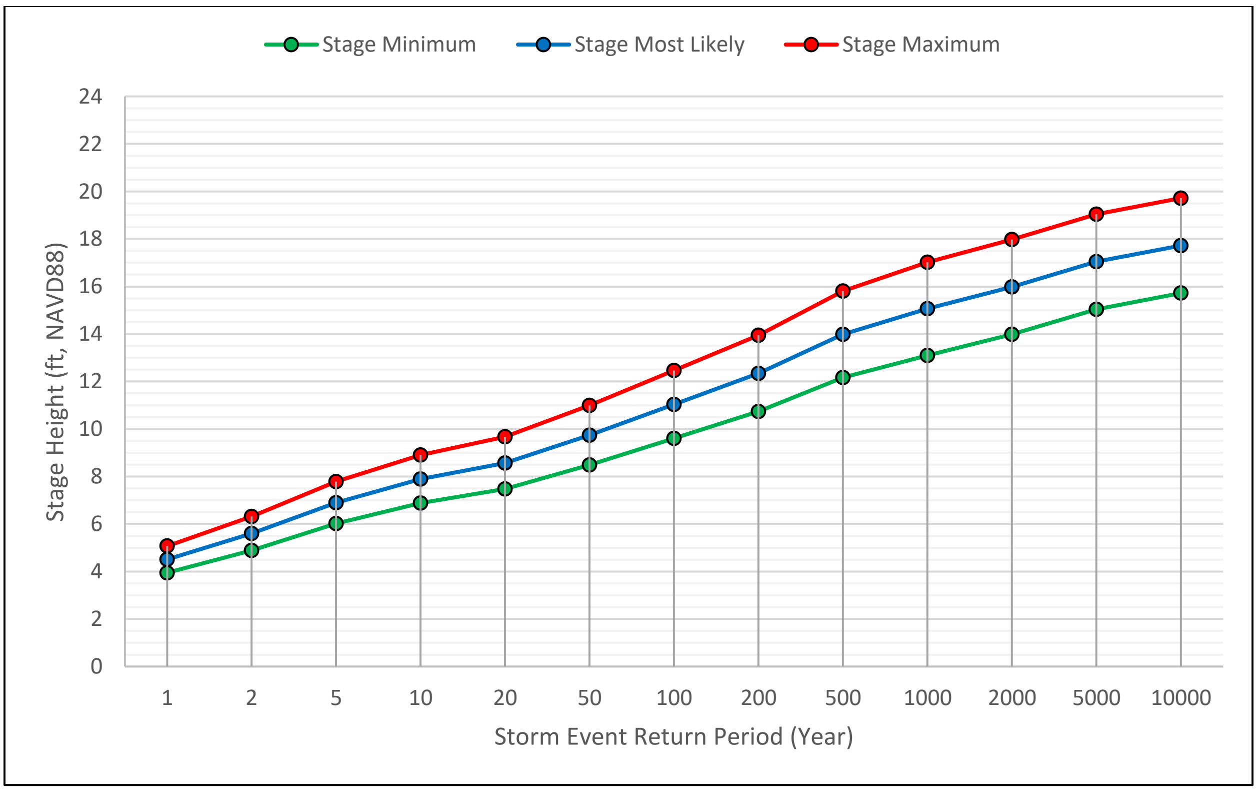


Figure 13: Water Surface Profile Example – North Wildwood City (Reach 26)

It is important to note that Water Surface Profiles are also developed with a triangle distribution of values. The “Stage Maximum,” or upper extent, of the Intermediate RSLC curve is not the same as the High RSLC curve. Each RSLC scenario has a unique set of 13 data points per reach and its own Minimum, Most Likely, and Maximum extent.

C-4) FUTURE WITHOUT-PROJECT CONDITION

HEC-FDA links the predictive capability of hydraulic and hydrologic modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the total damages under various proposed alternatives while accounting for risk and uncertainty. The model output is then used to determine the net National Economic Development (NED) benefits of each project alternative in comparison with the No-Action Plan, or Future Without-Project Condition.

Storm damage is defined as the monetary loss to contents and structures incurred as a direct result of inundation caused by a storm of a given magnitude and probability.

For the Future Without-Project Condition (FWOP) and Future With-Project Conditions (FWP), the structure inventory and assigned values are considered static throughout the 50-year period of analysis. Though this approach may ignore future condemnations of repeatedly damaged structures or, conversely, increases in the number or value of structures in the inventory due to future development, the variability and limitations of projecting future inventory changes over 50 years across such a wide study area are too significant to assign any reasonable level of certainty to the predicted inventory alterations.

As mentioned earlier, Future Without-Project Condition damages are used as the base condition and potential project alternatives are measured against this base to evaluate the project effectiveness and cost efficiency. Future Without-Project Condition damages in this section are presented as Average Annual Damages (AAD) over a 50-year period of analysis with the then-current FY2018 Project Evaluation and Formulation Rate (Discount Rate) of 2.75% and then-current FY2018 Price Level.

The following model results for Future Without-Project Condition analysis are based on estimated structure and content damages with additional damages such as vehicles, critical infrastructure, emergency costs, and transportation delays accounted for using a percentage increase at the reach level. The methodology for quantifying damage in the additional damage categories is updated in Section C-8.

Current data reflects primary, or direct, damage values and future analysis will incorporate secondary, or indirect, damage from disruptions to critical infrastructure. This includes interruptions to power plants, wastewater treatment facilities, and communication centers.

Model Results

The New Jersey Back Bays study area experiences a total of $1,571,616,000 in Without-Project Average Annual Damages (AAD) over a 50-year period of analysis with Intermediate RSLC. Table 5 shows the breakdown in Average Annual Damages across all 84 municipalities. It is important to note the values in Table 5 only reflect the AAD of the sections of the municipality that intersect with the study area. AAD within the municipality that are outside the study area are not included.

While Average Annual Damages per Structure fluctuates by municipality, Atlantic City has the highest mean AAD per Structure at $41,605 followed by Ocean City at $12,292. The total study area has a mean AAD per Structure at $8,591.

Figures 14 and 15 shows the relative contribution to Average Annual Damages by Reach. The generated heat map shows high damage areas in red and lower damage areas in green.

Table 5: Without-Project Average Annual Damages by Municipality

Municipality	AAD	Municipality	AAD
Atlantic City	$323,774,000	Absecon	$4,393,000
Ocean City	$219,809,000	Eagleswood	$4,217,000
Toms River	$69,526,000	Mantoloking	$3,778,000
Sea Isle City	$62,714,000	Bass River	$3,656,000
North Wildwood	$59,807,000	West Cape May	$3,545,000
Long Beach	$54,554,000	Hamilton	$3,329,000
Brick	$53,293,000	South Toms River	$3,168,000
Brigantine	$37,997,000	Mullica	$3,090,000
Avalon	$37,841,000	Galloway	$2,906,000
Wildwood	$36,102,000	Cape May Point	$2,720,000
Little Egg Harbor	$33,981,000	Linwood	$2,573,000
Margate City	$28,530,000	Wall	$2,474,000
Point Pleasant	$28,009,000	Brielle	$2,333,000
Bay Head	$27,066,000	Belmar	$1,989,000
Manasquan	$26,571,000	Avon-by-the-Sea	$1,969,000
Stone Harbor	$25,008,000	Neptune	$1,902,000
Ship Bottom	$24,660,000	Barnegat	$1,786,000
Stafford	$24,308,000	Island Heights	$1,711,000
Pt Pleasant Beach	$23,860,000	Port Republic	$1,534,000
Egg Harbor	$23,113,000	Spring Lake	$1,436,000
Ventnor City	$21,304,000	Corbin City	$1,268,000
Lavallette	$21,111,000	Dennis	$1,103,000
Surf City	$20,869,000	Sea Girt	$621,000
Cape May	$20,732,000	Weymouth	$483,000
Beach Haven	$19,537,000	Beachwood	$392,000
Berkeley	$17,259,000	Pine Beach	$303,000
West Wildwood	$17,177,000	Northfield	$235,000
Middle	$16,636,000	Estell Manor	$210,000
Tuckerton	$15,354,000	Lake Como	$188,000
Somers Point	$13,650,000	Washington	$167,000
Harvey Cedars	$11,974,000	Asbury Park	$162,000
Lower	$11,906,000	Neptune City	$132,000
Wildwood Crest	$11,189,000	Spring Lake Heights	$128,000
Seaside Heights	$10,706,000	Bradley Beach	$125,000
Upper	$10,666,000	Loch Arbour	$93,000
Longport	$10,400,000	Allenhurst	$35,000
Lacey	$8,760,000	Ocean (Monmouth)	$21,000
Seaside Park	$8,238,000	Interlaken	$21,000
Ocean Gate	$7,566,000	Lakewood	$18,000
Barnegat Light	$5,733,000	Egg Harbor City	$18,000
Pleasantville	$5,100,000	Deal	$8,000
Ocean Township	$4,981,000	Long Branch	$5,000
		TOTAL	**$1,571,616,000**

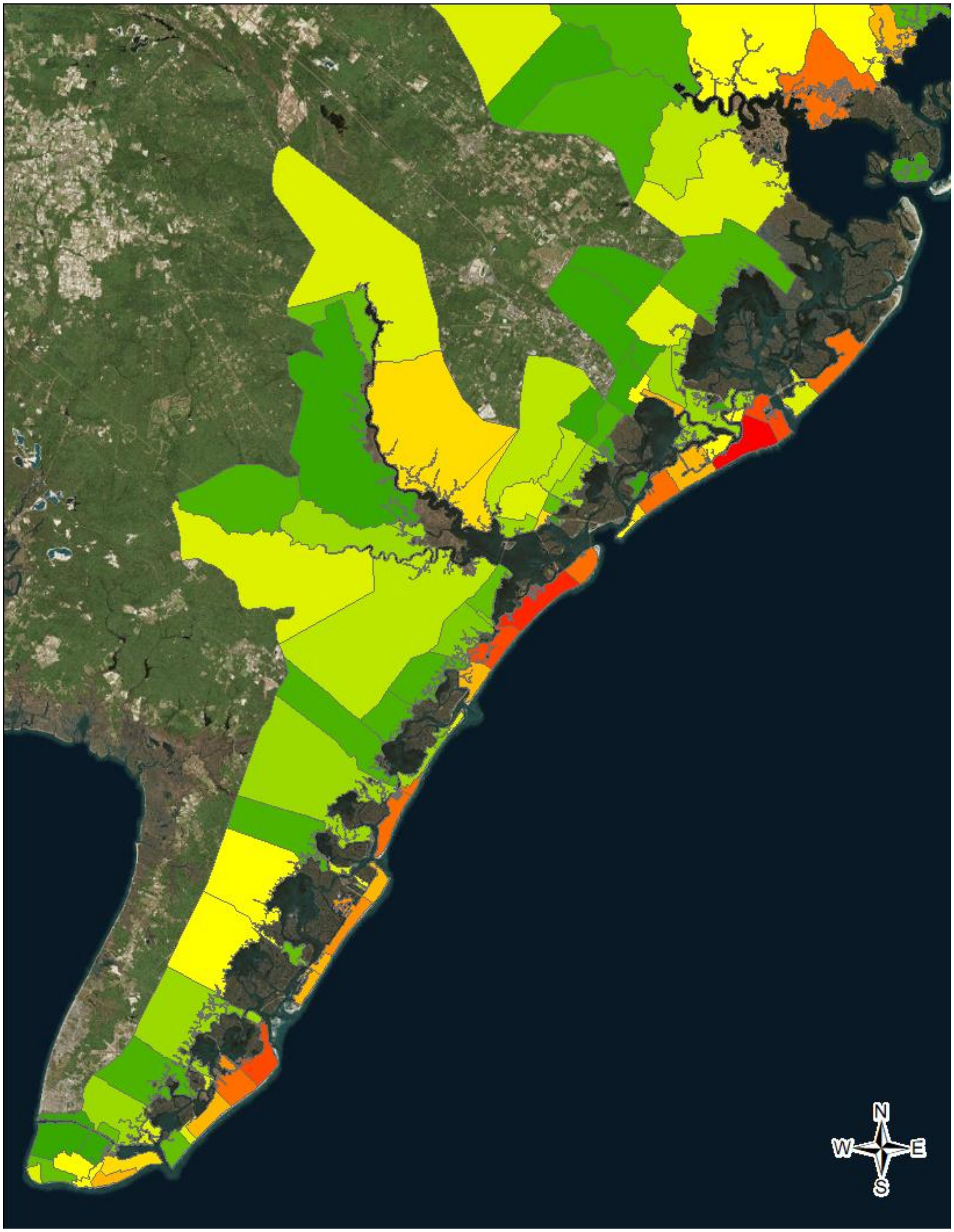


Figure 14: FWOP Damages – Heat Map (Cape May + Atlantic)

For Cape May County and Atlantic County, the majority of estimated Future Without-Project Condition damages are focused on the southern tip of New Jersey and along the barrier islands. These areas typically have a higher density of structures, higher average value per structure, and increased inundation risk due to lower ground elevations.

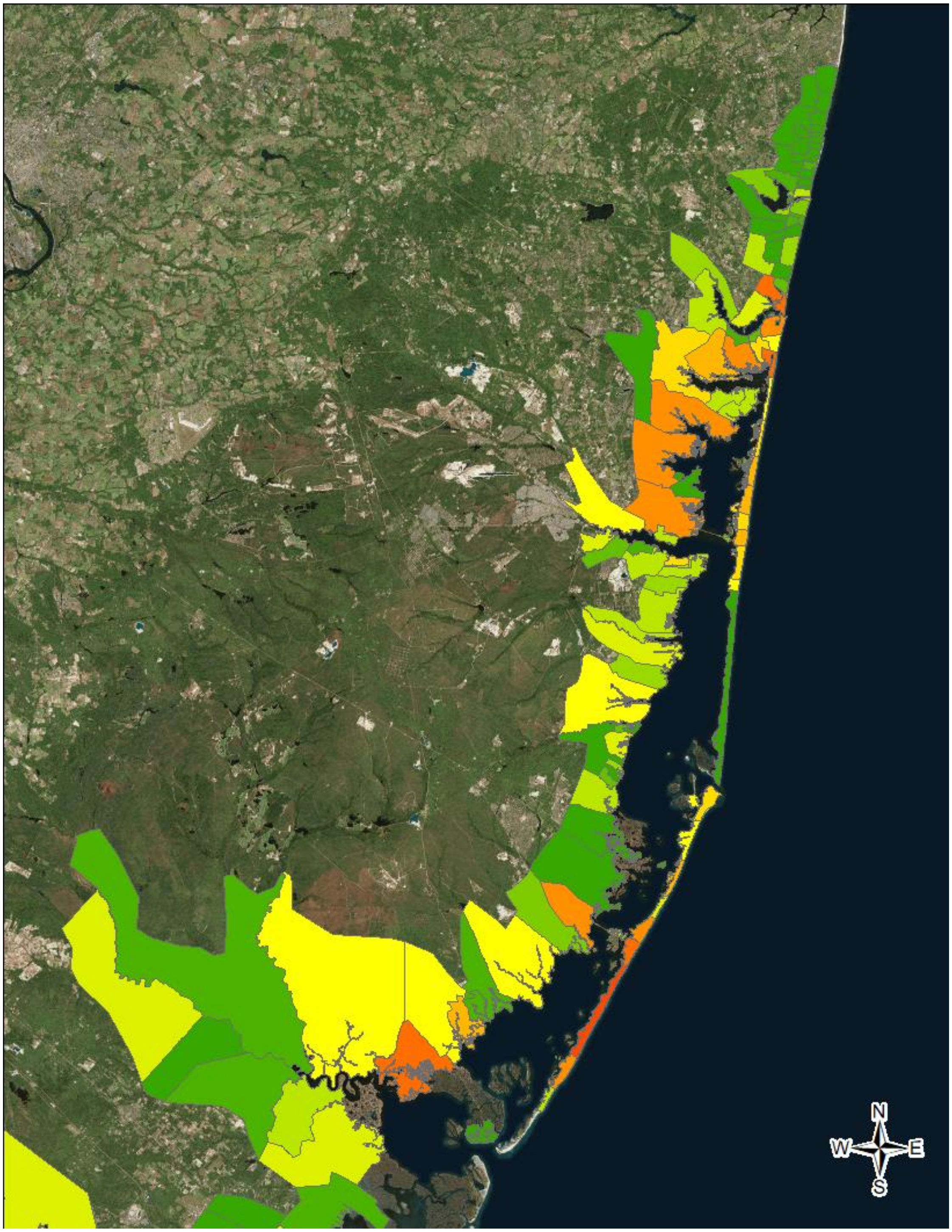


Figure 15: FWOP Damages – Heat Map (Burlington + Ocean + Monmouth)

For Burlington, Ocean, and Monmouth counties, damages are focused along the barrier islands, within the “finger canal” communities, and at the northern extent of Barnegat Bay. These areas share the same high density, high value, low elevation conditions.

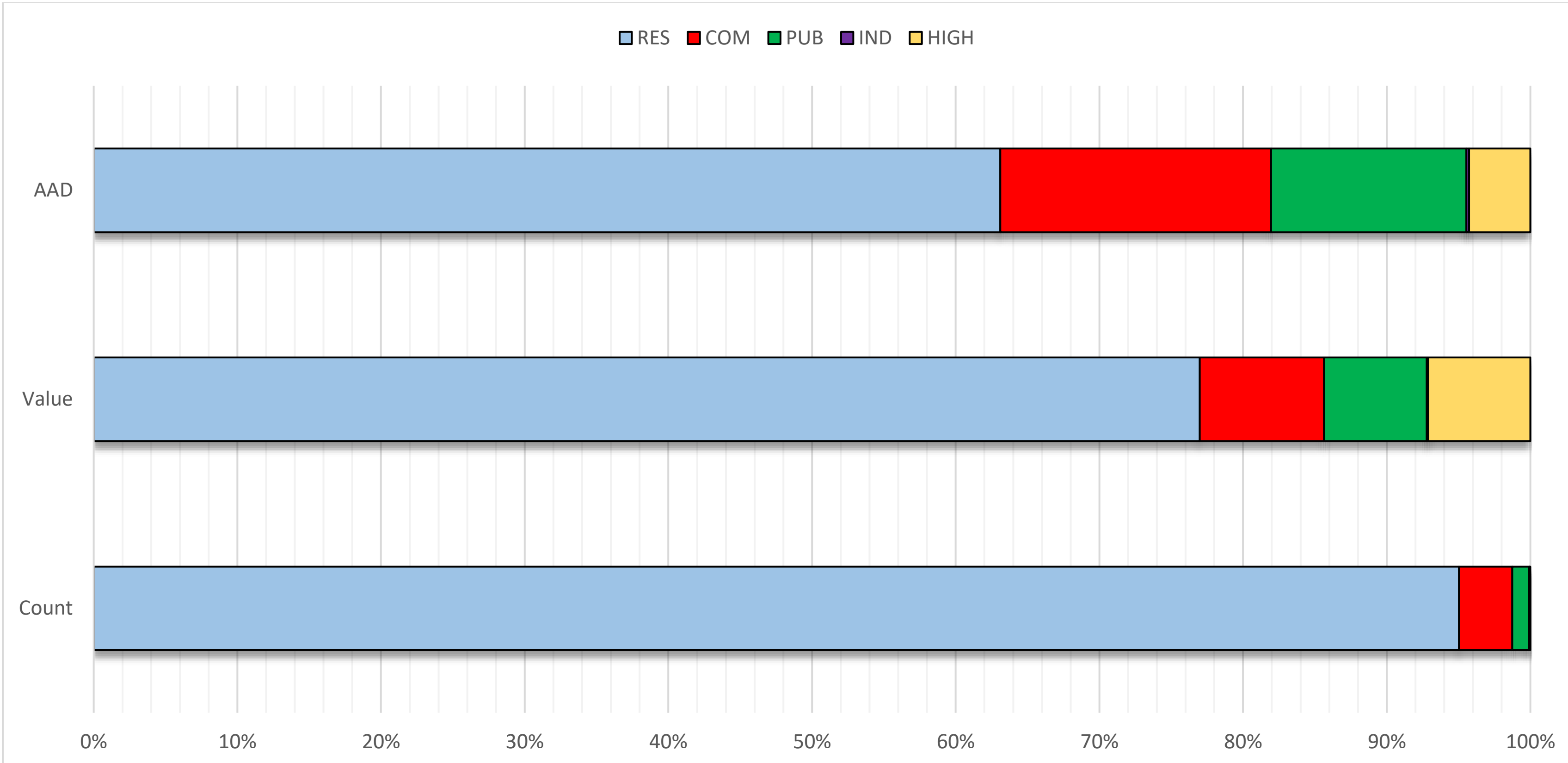


Figure 16: Comparison of Structure Count, Value, and Average Annual Damage by Type

Figure 16 shows a comparison between structure volume, structure/content value, and contribution to Average Annual Damages (AAD).

Residential structures represent over 95.0% of total structure by count, but only contribute 77.0% of total value by occupancy type and only 63.1% of total Average Annual Damages. Commercial and Public structures represent 3.7% and 1.2% of total structures by volume, respectively, but contribute 18.9% and 13.6% of total AAD. Higher AAD estimates for Commercial and Public structures stem from their higher average structure/content value as well as greater risk to inundation due to lower foundation heights.

High-rise structures represent 7.1% of total inventory value, but only 4.3% of total AAD due to a relatively flat inundation damage curve.

C-5) FUTURE WITH-PROJECT CONDITION

Performing economic analysis on proposed alternatives within the study area was an iterative process with complex interdependence between study reaches and between certain measure combinations. Additional details can be found in the Plan Formulation Appendix, but economic analysis centered on three possible measure types: Perimeter (floodwalls and levees), Nonstructural (building elevations), and Storm Surge Barriers (inlet gates). Each measure was first evaluated independently for all relevant study area locations and then combined with other measure types to create NED optimizing and comprehensive “hybrid” alternatives.

This Section will detail the methodology and results of investigating each measure type in isolation and the following Hybrid NED (Multi-Measure) Alternative Section will combine these measures into implementable and complete proposed alternatives.

Perimeter Measures Analysis

Economic evaluation of perimeter measures was completed using three iterative cycles of analysis. The investigative cycles include an initial comprehensive qualitative analysis, an excel-based quantitative analysis, and a final HEC-FDA based quantitative analysis.

Cycle 0

The initial analysis effort was to create a comprehensive qualitative screening of potential perimeter measure locations across the entire study area. The analysis completed in Cycle 0 did not assign refined costs nor benefits to identified perimeter locations, but merely identified areas where a perimeter solution was physically implementable and then only screened out areas where a theoretically possible perimeter solution was massively more expensive than even the highest conceivable value of the inventory landward of the measure.

Cycle 0 identified 49 remotely possible perimeter locations across the barrier islands, mainland, and finger canal communities. These locations represent the widest possible base for future analysis and all successive cycles of analysis worked to refine cost and benefit inputs to screen these identified locations to only the economically justified alternatives. Cycle 1 used these 49 locations for initial cost and benefit evaluations.

Figure 17 shows all 49 identified perimeter locations. Due to the size of the study area, the locations are shown in sections moving South to North. Measures include floodwalls and/or levees depending on ground conditions. In total, Cycle 0 presents 1.8 million feet of perimeter length.

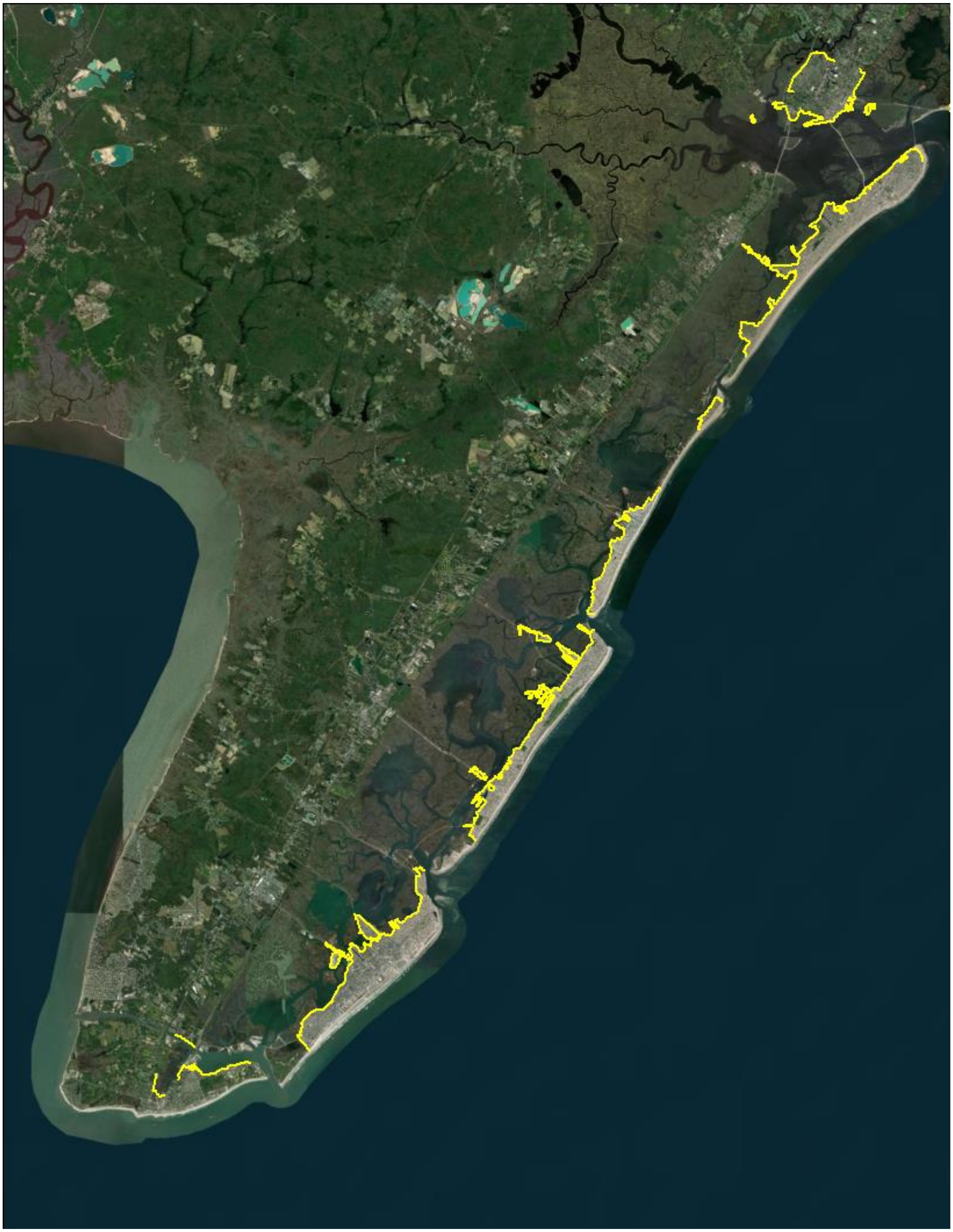
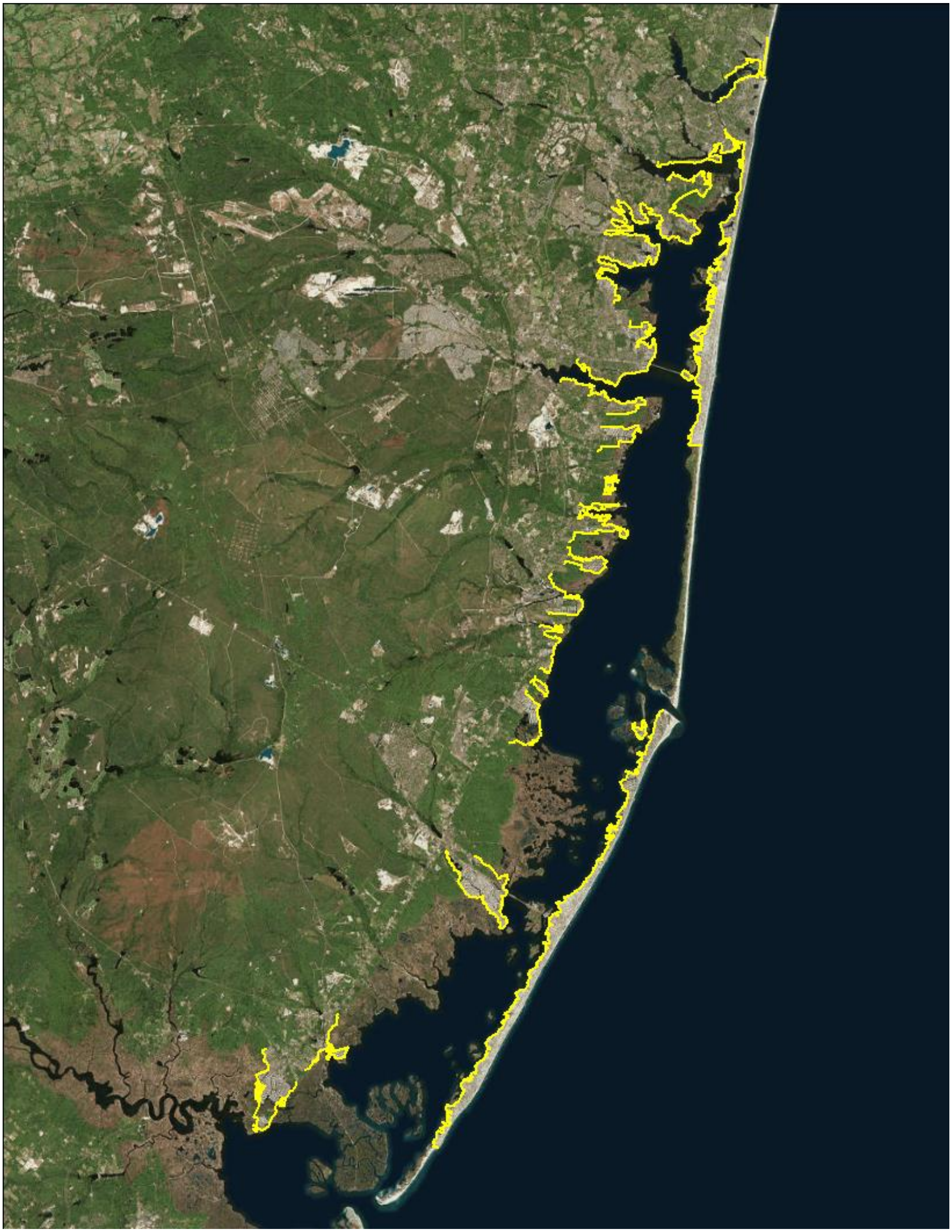
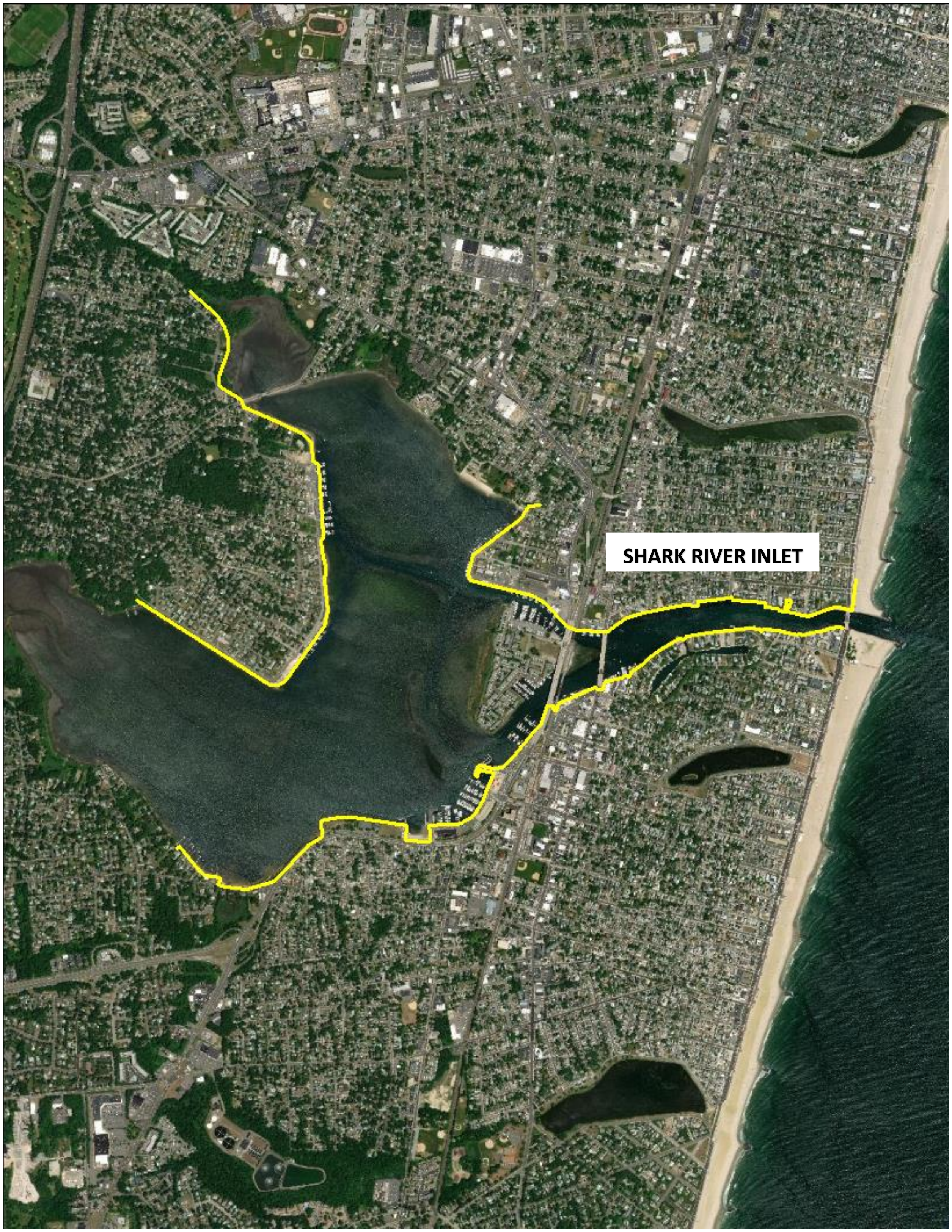


Figure 17: Perimeter Measure Analysis – Cycle 0




SHARK RIVER INLET

Cycle 1

Using the results of Cycle 0 as the widest possible number of potentially justified alternatives, Cycle 1 introduced more refined cost inputs and benefit estimates to assign preliminary Benefit-Cost Ratios to each of the 49 identified locations. The most promising locations would then continue further into the analysis while less promising locations would be screened from further study. At this stage of the analysis, the decision was made to use lower than anticipated cost estimates and higher than expected benefit assessments to capture the largest number of theoretically justified perimeter locations.

Perimeter costs were adapted from the North Atlantic Coast Comprehensive Study (NACCS) and benefits were calculated using an excel-based model with preliminary structure inventory data and a simplified depth-percent damage curve. Cost estimates included $8,000 per linear foot of floodwall with additional costs added for miter gates, sluice gates, or road closures where applicable. Analysis was completed using the then-current FY2018 Federal Discount Rate of 2.75% with a 50-year period of analysis.

Table 6 shows the 12 perimeter locations that displayed a BCR above 1.0. Strathmere was also included for future analysis due to near economic viability (0.8 BCR) and location (barrier island).

Table 6: Perimeter Measure Analysis – Cycle 1 Results

ID	Location	Length	Initial Const.	AAC	AAD	AANB	BCR
1	Cape May City	15,757	$133,361,310	$6,273,439	$16,961,371	$10,687,932	2.7
2	Wildwood Island	54,070	$491,161,680	$23,104,697	$93,958,647	$70,853,950	4.1
4	West Wildwood	11,727	$100,154,110	$4,711,341	$11,938,657	$7,227,316	2.5
5	Stone Harbor / Avalon	96,936	$858,289,730	$40,374,738	$63,320,119	$22,945,381	1.6
10	Sea Isle City	34,954	$329,939,900	$15,520,676	$38,710,939	$23,190,263	2.5
11	Strathmere	8,165	$77,850,490	$3,662,159	$2,777,660	-$884,499	0.8
12	Ocean City	78,573	$703,272,670	$33,082,593	$186,282,803	$153,200,210	5.6
18	Absecon Island	97,409	$977,008,560	$45,959,381	$400,981,475	$355,022,094	8.7
23	Brigantine	48,590	$431,911,960	$20,317,536	$52,970,720	$32,653,184	2.6
26	Long Beach Island	206,561	$1,883,468,300	$88,600,081	$145,286,947	$56,686,867	1.6
42	Island Beach	186,140	$1,784,578,000	$83,948,190	$160,691,242	$76,743,052	1.9
45	Manasquan Inlet (North)	22,642	$235,353,970	$11,071,267	$32,182,394	$21,111,127	2.9
52	West Cape May	4,481	$57,882,910	$2,722,865	$15,923,307	$13,200,441	5.8
TOTAL		**866,005**	**$8,064,233,590**	**$379,348,963**	**$1,221,986,280**	**$842,637,317**	**3.2**
ROUNDED		**866,000**	**$8,064,234,000**	**$379,349,000**	**$1,221,986,000**	**$842,637,000**	**3.2**

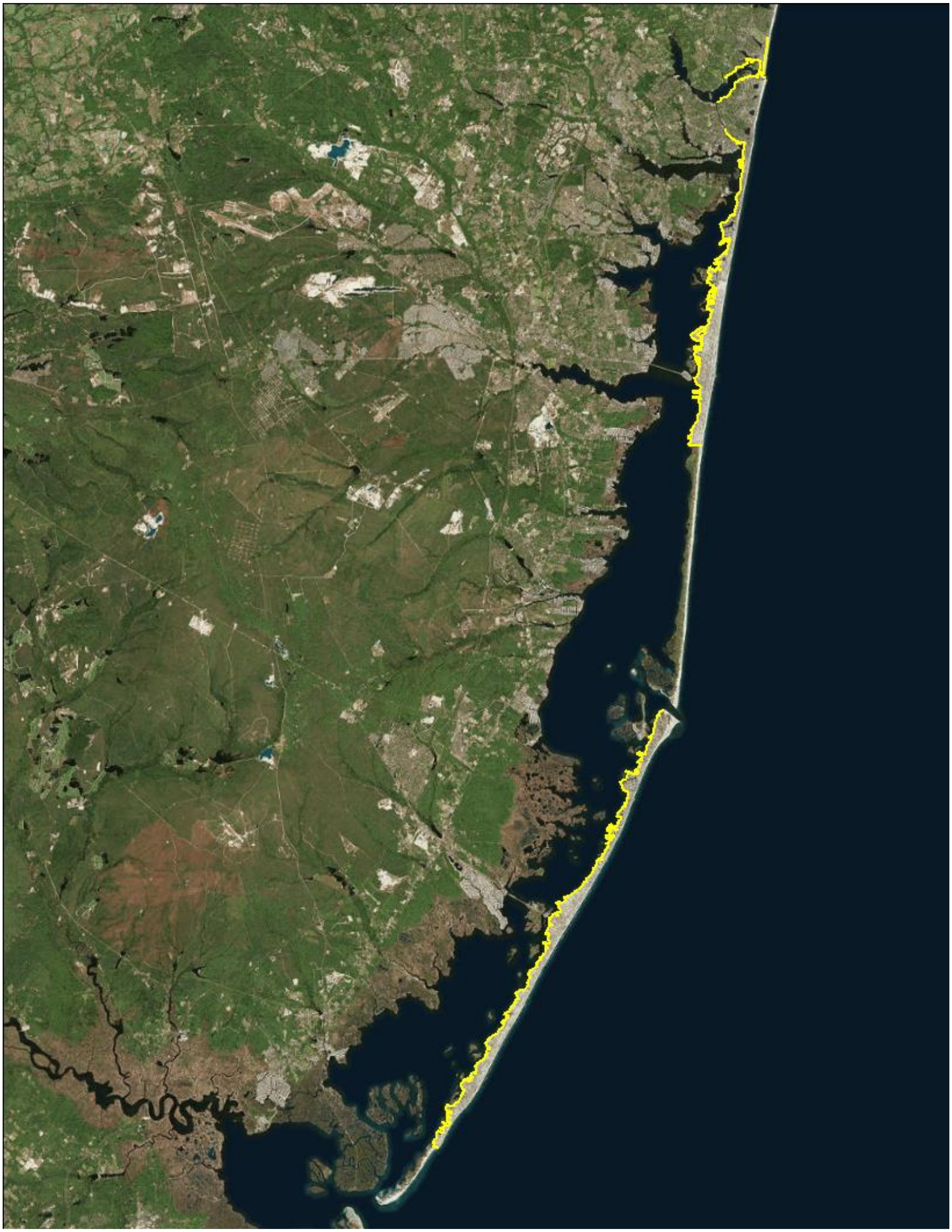
In Table 6 above, Average Annual Cost includes Operations, Maintenance, Repair, Rehabilitation, & Replacement (OMRR&R) and Average Annual Damages includes estimates for vehicle damages, infrastructure damages, transportation delays, and emergency costs.

All 13 of the locations identified in the chart above were later evaluated further using HEC-FDA in Cycle 2. This includes Strathmere with a 0.76 Benefit-Cost Ratio as this was the only community on the barrier islands without an initial BCR above 1.0.

Though Cycle 1 analysis operated with a high degree of uncertainty, none of the 36 screened locations could reasonably be expected to attain future economic justification with perimeter measures and their exclusion presents no risk to final study results.

Figure 18 shows the 13 remaining perimeter measure locations. Again, due to the size of the study area, the locations are shown in sections moving South to North. In total, Cycle 1 presents 840,000ft of perimeter length.

Figure 18: Perimeter Measure Analysis – Cycle 1



Cycle 2

The final analysis cycle for perimeter measures transferred modeling from preliminary Excel-based tools to USACE-certified HEC-FDA modeling. Evaluation with HEC-FDA allows for significantly greater complexity and accuracy than possible with excel-based methods.

Cost estimates were also updated with modifications to perimeter measure placement and lengths as well as efforts to improve accuracy with changes to cost per linear foot and applied contingencies.

Table 7: Perimeter Measure Analysis – Cycle 2 Results

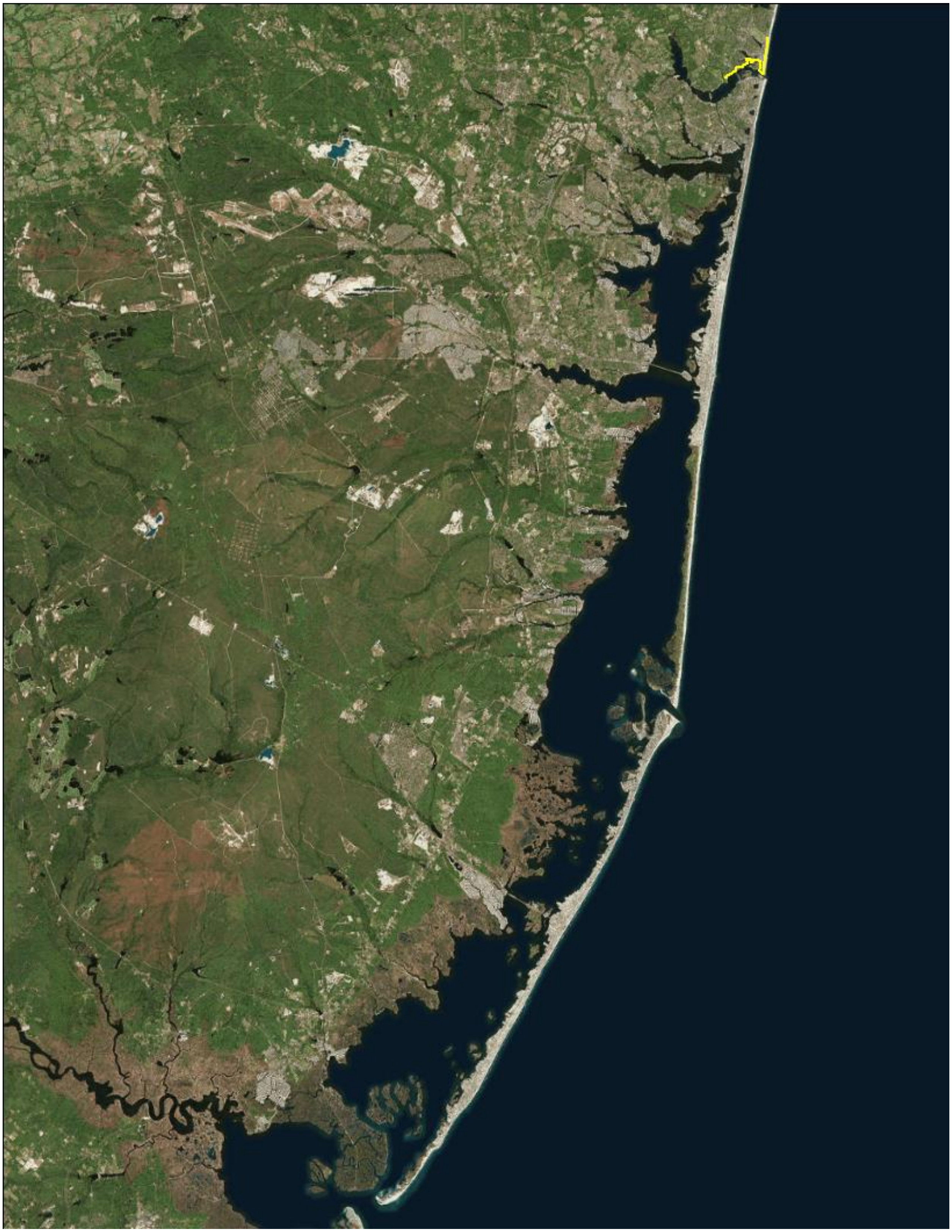
ID	Location	Length	Initial Const.	AAC	AAD	AANB	BCR
1	Cape May City	15,825	$249,540,895	$11,738,633	$9,887,438	-$1,851,196	0.8
2	Wildwood Island	54,171	$810,770,180	$38,139,375	$84,907,400	$46,768,025	2.2
4	West Wildwood	11,726	$170,039,200	$7,998,800	$15,864,050	$7,865,250	2.0
5	Stone Harbor / Avalon	97,225	$1,443,894,068	$67,922,105	$46,650,575	-$21,271,530	0.7
10	Sea Isle City	35,166	$544,084,466	$25,594,234	$31,810,925	$6,216,691	1.2
11	Strathmere	8,187	$117,797,150	$5,541,286	$2,472,163	-$3,069,124	0.4
12	Ocean City	78,732	$1,149,394,269	$54,068,563	$182,588,238	$128,519,674	3.4
18	Absecon Island	111,114	$1,755,389,808	$82,575,151	$320,230,675	$237,655,524	3.9
23	Brigantine	48,699	$714,920,468	$33,630,516	$30,157,550	-$3,472,966	0.9
26	Long Beach Island	209,124	$3,172,187,591	$149,222,621	$118,660,075	-$30,562,546	0.8
42	Island Beach	186,871	$3,092,467,435	$145,472,512	$107,272,863	-$38,199,649	0.7
45	Manasquan Inlet (North)	22,820	$461,553,732	$21,711,912	$30,560,638	$8,848,726	1.4
52	West Cape May	4,480	$88,265,089	$4,152,071	$8,890,325	$4,738,254	2.1
TOTAL ESTIMATED		**884,140**	**$13,770,304,352**	**$647,767,779**	**$989,952,913**	**$342,185,134**	**1.5**
ROUNDED		**884,000**	**$13,770,304,000**	**$647,768,000**	**$989,953,000**	**$342,185,000**	**1.5**

In comparison with the data shown in Table 6, estimated Average Annual Costs increased 71% over their Cycle 1 values. Average Annual Benefits decreased 19% when transferring from excel-based Cycle 1 to HEC-FDA based Cycle 2 analysis. This results in a total 59% decrease in Average Annual Net Benefits.

Of the 13 identified locations, 7 remain economically justified and a further 3 sites (shaded yellow) could realistically attain justification with optimizations to measure placement or type. However, Strathmere does not have the inventory to remain economically feasible and the sheer length of floodwall necessary to protect Long Beach Island or Island Beach creates an insurmountable cost hurdle.

Figure 19 shows the locations of the 7 to 10 economically feasible perimeter locations.

Figure 19: Perimeter Measure Analysis – Cycle 2



Nonstructural Measures Analysis

Nonstructural measures fall into four broad groups resulting from the inventory and screening process (as discussed in the Nonstructural Appendix) including Acquisition / Relocation, Building Retrofit (floodproofing, elevations), Land Use Management (zoning changes, undeveloped land preservation), and Early Flood Warnings (evacuation planning, emergency response systems). Refinements to the National Flood Insurance Program (including increasing homeowner participation and increasing municipal protection in the Community Rating System) also represent a nonstructural opportunity, though they are outside the scope and authority of this assessment. Each measure type has a varying level of storm damage reduction function / adaptive capacity and a complete nonstructural alternative would include each of the four measures as necessary to optimize CSRM benefits.

At this stage of the analysis, nonstructural economic assessment incorporates only building retrofits (elevations) to residential structures. Additional analysis after selection of the Focused Array of Alternatives expands build retrofit analysis to all structure occupancy types (Section C-10) and includes wet / dry floodproofing measures. Future analysis prior to the release of the final Feasibility Report will continue to expand nonstructural analysis to additional measures (acquisition / relocation) and additional methods of identifying nonstructural eligibility.

Building retrofits, while effective in reducing the potential risk for storm damage to that specific structure, has no positive impact on reducing storm damage risk to surrounding property, vehicles, or infrastructure. Furthermore, emergency access and evacuation are not improved solely with the implementation of building retrofits and property owners should still evacuate vulnerable properties during storm events lest they become trapped by rising storm surge. While this Section details the cost and benefits analysis for implementing only nonstructural measures, the most likely optimal alternative will ultimately incorporate nonstructural as a supplemental measure to either perimeter measures, storm surge barriers, or both.

Cost Estimates

Building elevation costs are adapted from the North Atlantic Coast Comprehensive Study (NACCS) and are centered on quantifying the cost for elevating a typical (median) Single Family Residential One-Story (SFR1) structure and the cost for elevating a typical Single Family Residential Multi-Story (SFRM) structure.

A true building elevation cost is developed on a house-by-house basis and includes a number of factors including foundation type, wall type, size of structure, condition, available workspace, local labor rates, and many additional variables. Given the size of the study area and the limitations of the structure inventory, building elevation costs are based on the sampled median foundation size per occupancy type (SFR1 vs. SFRM). Total initial construction costs are then based on the estimated number of structures that require elevation in a given reach multiplied by the typical elevation cost per occupancy type. This method does not allow the identification of the exact structures that require elevation but provides an estimate for overall cost and benefit quantification per reach.

NACCS building elevation costs incorporate values for engineering and design, administrative fees, temporary housing for inhabitants, and other inputs. Table 8 provides the full cost breakdown for elevating a typical SFR1 structure and Table 9 provides the full cost breakdown for a typical SFRM structure. Both tables use the then-current FY2018 price level.

Table 8: Building Retrofit Costs – Single Family Residential One Story

Item	Number	Unit	Unit Cost	Total Cost
Elevation	1,559	SQFT	$87.57	$136,483
Temporary rehousing	1	ea	$10,000	$10,000
Subtotal				***$146,483***
Contingency	25%			$36,621
Total Construction				***$183,104***
E&D	$10,000			$10,000
S&A	10%			$18,310
TOTAL ESTIMATED INTITAL CONSTRUCTION				**$211,414**

Median square footage for a typical SFR1 structure in the study area was quantified using a sample of 48,287 building footprint GIS files (provided by New Jersey Department of Environmental Protection (NJDEP)) that intersected with SFR1 inventory markers, or a 63.9% sample of SFR1 structures. The median structure base was calculated at 1,559 square feet. All other cost inputs, including unit cost and contingency, are pulled from the NACCS.

Table 9: Building Retrofit Costs – Single Family Residential Multi Story

Item	Number	Unit	Unit Cost	Total Cost
Elevation	1,839	SQFT	$87.57	$161,016
Temporary rehousing	1	ea	$10,000	$10,000
Subtotal				***$171,016***
Contingency	25%			$42,754
Total Construction				***$213,770***
E&D	$10,000			$10,000
S&A	10%			$21,377
TOTAL ESTIMATED INTITAL CONSTRUCTION				**$245,147**

Similar to SFR1 structures, the typical SFRM structure square footage base was quantified using a sample of 59,852 building footprint shapefiles provided by NJDEP, or a 61.4% sample. The median structure base was calculated at 1,839 square feet.

Structures are elevated to a Design Flood Elevation (DFE). This is the Base Flood Elevation (BFE) + 3ft. The additional height is added to mitigate risk from sea level rise.

Additional information on nonstructural cost methodology and development can be found in the Nonstructural Appendix.

Structure Identification

Identifying structures eligible for building elevation focused on identifying structures with the highest coastal storm damage risk levels. Residential structures with high vulnerability to coastal storm damage, whether due to geographic conditions or first floor elevation, are considered prime candidates for building retrofits.

Nonstructural analysis focused on structures within the 20% Annual Exceedance Probability (AEP) event floodplain (05YR Storm Event), the 10% AEP event floodplain (10YR Storm Event), and the 5% AEP event floodplain (20YR Storm Event). Each of the 226 study reaches has a unique water surface profile with a set stage height for the 20% AEP, 10% AEP, and 5% AEP events. All structures with first floor elevations equal to or below any of the three storm event stage heights (FY2030 Intermediate RSLC curve) is considered high risk and eligible for building retrofit evaluation.

Figure 20 shows the number of structures contained within each layer as determined by first floor elevation in comparison to the storm event return frequency.

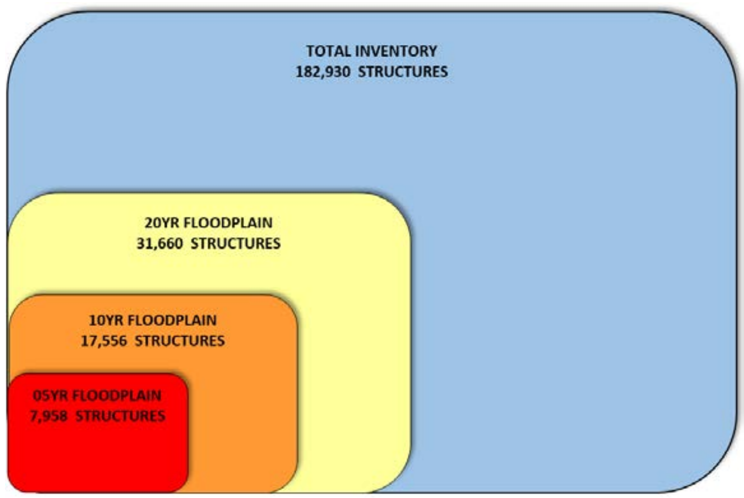


Figure 20: Nonstructural Building Retrofit Volume

Of the 182,930 structures captured in the study inventory (including 172,971 SFR1 / SFRM structures), only 4.6% of SFR1 and SFRM structures fall within the 20% AEP event floodplain (05YR Storm Event). 10.1% of total SFR1 or SFRM structures fall within the 10% AEP event floodplain (10YR Storm Event) and a final 18.3% fall within the 5% AEP event floodplain (20YR Storm Event).

Benefit Analysis

Nonstructural economic analysis is conducted using HEC-FDA with the then-current FY18 Federal Discount Rate of 2.75% over a 50-year period of analysis. All SFR1 and SFRM structures with first floor elevations below the 5% AEP event stage height were "elevated" to 15ft NAVD88 within the model. This elevation height was selected only to remove any possibility of damage for these structures for any storm more frequent than the 1% AEP event. In reality, the exact elevation necessary for each structure (Design Flood Elevation) will fluctuate depending on the municipality and specific area conditions.

One limitation of HEC-FDA is the requirement of a static inventory for the entirety of the period of analysis. Structures cannot be added, removed, nor elevated within the model. To circumvent this limitation for nonstructural analysis, two separate HEC-FDA models are developed. One model has the Without-Project Condition from FY2030 to FY2080 (results shown in Table 5) and a separate model has the With-Project Condition (updated inventory) from FY2030 to FY2080. The difference in calculated average annual damages between the model results is the coastal storm damage reduction benefits of retrofitting 31,660 of the 182,930 structures in the inventory.

Additional damage categories such as infrastructure, vehicle damage, emergency costs, and transportation delays are not mitigated through nonstructural measures and are included in the residual damage category.

Table 10: Nonstructural Measure Evaluation – 5% AEP Event Floodplain

Item	Number	Unit Cost	Total Cost
SFR1 Elevations	20,338	$211,414	$4,299,737,932
SFRM Elevations	11,322	$245,147	$2,775,554,334
Total Initial Const.	***31,660***		***$7,075,292,266***
Period of Analysis			50
FY18 Discount Rate			2.75%
Capital Recovery Factor			0.037041
Total AAC			***$262,075,331***
Without AAD			$1,571,616,063
With AAD			$1,119,950,393
Reduced AAD			***$451,665,670***
AANB			***$189,590,339***
BCR			***1.72***
Residual Damage			***71.3%***

The nonstructural alternative is economically justified, however, the alternative has an exceptionally high residual damage percentage. As stated earlier, these residual damages stem from damage to non-elevated surrounding property, vehicle damage, infrastructure damage, emergency costs, and transportation delays.

Storm Surge Barrier Measure Analysis

Storm Surge Barrier analysis was an iterative process with greater complexities due to the interdependence of some inlets throughout the study area. Additional modeling was completed by the Engineering Research and Design Center (ERDC) and more information on the exact nature of the hydrologic modeling efforts can be found in the Engineering Appendix. This Section will cover the economic analysis of the final suite of proposed storm surge barrier and inland bay closure alternatives.

Unlike perimeter measure analysis in HEC-FDA, where water surface profiles are unchanged and "floodwalls" are added to the model to estimate damage reduction, or nonstructural measure analysis, where water surface profiles are unchanged and the inventory is altered to account for building elevations, storm surge barrier analysis involves with- and without-project water surface profiles with differing stage heights to measure the benefits of reduced inundation levels.

Additional information on the development of storm surge barrier water surface profiles can be located in the HHC Section of Engineering Appendix.

Study Regions

The New Jersey Back Bay area can be divided into five regions of relative independence. Within each region, all of the inlets are interdependent, with project performance requiring the closure of all inlets to maintain any reasonable level of stage height reduction during coastal storm events. Figure 21 on the following page shows the five study regions. Though not shown, all 226 HEC-FDA reaches are contained within one of the five regions and each HEC-FDA reach is restricted to exactly one Region with no overlaps. This allows for HEC-FDA reach outputs to be aggregated at the Region level and then Region-level results to be aggregated (if necessary) to calculate a study wide proposed alternative combination.

The South Region extends from Cape May City up north of Corson's Inlet. The Central Region extends from Corson's Inlet to Little Egg / Brigantine Inlets. The North Region extends from Little Egg / Brigantine Inlets to just north of Manasquan Inlet. Shark River Region is the area directly affected by Shark River Inlet and the Coastal Lakes Region includes all of the coastal lakes not already covered by the North or Shark River Regions.

Storm Surge Barrier and bay closure alternatives are presented by each Region with determination that the alternatives proposed within each Region have no impact on the project performance of an alternative proposed at a different Region.

All storm surge barrier alternatives are calculated using the then-current FY2018 Federal Discount Rate of 2.75% with a 50-year period of analysis and Intermediate RSLC.

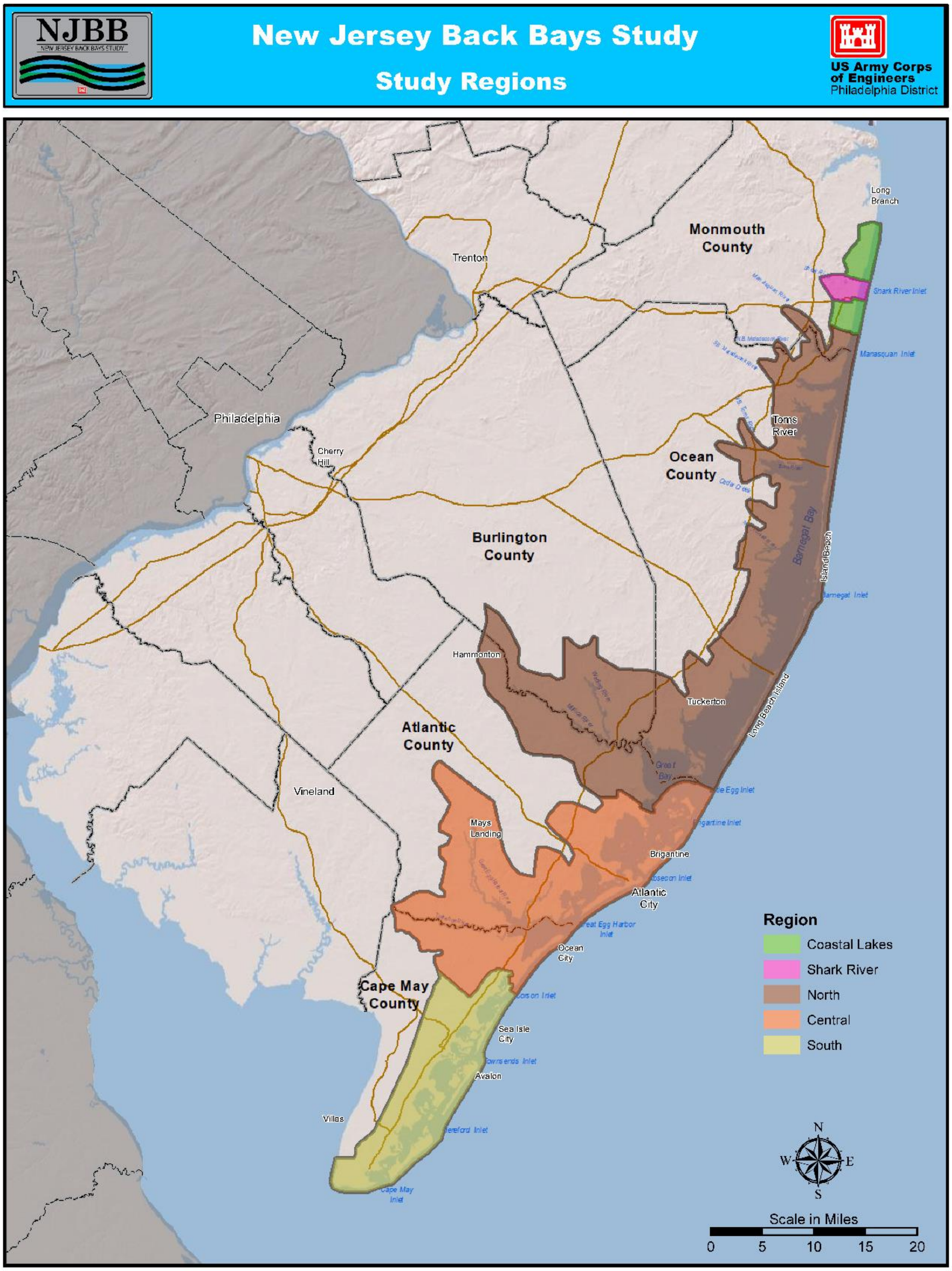


Figure 21: Study Area Regions

Cost Estimates

Detailed storm surge barrier designs and cost estimation methodology can be found in the Engineering Appendix, but this Section will only cover the cost estimates used for the economic analysis.

Detailed cost estimates were calculated for eleven possible inlet closures and eight possible bay closures. Estimates are based on barriers with navigable sector gates and vertical life gates to allow tidal flow outside of storm events. Figure 22 shows an example barrier diagram for Barnegat Inlet.

Figure 22: Storm Surge Barrier Example Design – Barnegat Inlet

Cost estimates are shown in Table 11 and Table 12 with values for initial construction, contingency, interest during construction (IDC), and OMRR&R.

Table 11: Storm Surge Barrier Cost Estimates ($1000s)

Region	Barrier	Init. Const.	Contingency	Total Const.	Duration (Month)	IDC	Subtotal AAC	OMRR&R	Total AAC
South	Cape May Canal	$389,412	$145,232	***$534,644***	55	$67,387	$22,300	$8,250	***$30,549***
South	Cape May Inlet	$1,203,163	$448,721	***$1,651,884***	113	$427,769	$77,032	$25,500	***$102,532***
South	Hereford Inlet	$1,001,373	$373,463	***$1,374,836***	66	$207,944	$58,628	$21,222	***$79,850***
South	Townsends Inlet	$785,109	$292,807	***$1,077,916***	56	$138,333	$45,051	$16,638	***$61,689***
Boundary	Corson Inlet	$686,898	$256,179	***$943,077***	61	$131,834	$39,816	$14,556	***$54,372***
Central	Great Egg Harbor	$2,838,878	$1,058,762	***$3,897,641***	126	$1,125,444	$186,060	$60,175	***$246,235***
Central	Absecon Inlet	$2,065,920	$770,487	***$2,836,407***	127	$825,513	$135,641	$43,789	***$179,430***
Boundary	Brigantine to Little Egg Inlet	$4,390,448	$1,637,421	***$6,027,869***	143	$1,975,383	$296,448	$93,066	***$389,514***
North	Barnegat Inlet	$1,251,230	$466,647	***$1,717,878***	105	$413,364	$78,943	$26,519	***$105,462***
North	Manasquan Inlet	$605,604	$225,861	***$831,465***	81	$154,341	$36,515	$12,833	***$49,348***
Shark	Shark River Inlet	$430,712	$160,635	***$591,347***	48	$65,048	$24,313	$9,125	***$33,439***
TOTAL ESTIMATED AMOUNT		**$15,648,749**	**$5,836,214**	***$21,484,962***	**-**	**$5,532,359**	**$1,000,746**	**$331,673**	***$1,332,419***

Table 12: Bay Closure Cost Estimates ($1000s)

Region	Barrier	Init. Const.	Contingency	Total Const.	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
South	Wildwood Blvd	$641,899	$238,183	***$880,082***	55	$110,927	$36,708	$13,248	***$49,956***
South	Stone Harbor Blvd	$828,572	$306,461	***$1,135,034***	56	$145,663	$47,438	$16,782	***$64,220***
South	Sea Isle Blvd	$426,966	$158,037	***$585,003***	50	$67,032	$24,152	$8,692	***$32,844***
Central	52nd Street	$307,798	$113,822	***$421,620***	49	$47,344	$17,371	$6,234	***$23,605***
Central	Absecon Blvd	$720,765	$265,805	***$986,570***	50	$113,045	$40,731	$14,381	***$55,112***
Central	North Point	$2,256,894	$840,313	***$3,097,206***	133	$944,003	$149,690	$47,431	***$197,121***
North	Holgate	$2,459,847	$915,349	***$3,375,197***	125	$966,853	$160,834	$51,543	***$212,376***
North	Point Pleasant Canal	$233,064	$86,919	***$319,984***	49	$35,932	$13,183	$4,934	***$18,117***
TOTAL ESTIMATED AMOUNT		**$7,875,807**	**$2,924,890**	***$10,800,696***	**-**	**$2,430,798**	**$490,107**	**$163,245**	***$653,351***

Benefit Analysis

Storm Surge Barriers provide coastal storm risk management benefits by lowering flood stage heights during storm events. The effectiveness of the storm surge barrier alternative is dependent upon the combination of storm surge barriers and bay closures as well as hydrologic conditions in the study Region.

SHARK RIVER REGION

Shark River Inlet is the only inlet in the study area with full independence from all other inlet systems. The Region experiences $9,828,750 in average annual damages, or just 0.6% of all damages in the study area. Due to local conditions around the inlet, the Shark River Storm Surge Barrier requires a coastal structure, either dune or floodwall, along the ocean front to provide high ground for the storm surge barrier to tie into.

Figure 23 shows the extent of the Shark River Region as well as the outline of the potential storm surge barrier measure.

The Shark River Storm Surge Barrier has a projected $33,349,000 average annual cost (AAC) with $6,149,000 in average annual benefits (AAB) for -$27,289,000 in average annual net benefits (AANB) with a 0.18 benefit-cost ratio (BCR). The storm surge barrier does prevent 62.6% of storm damage in the Region, but the potential damage pool is too small to support the barrier cost.

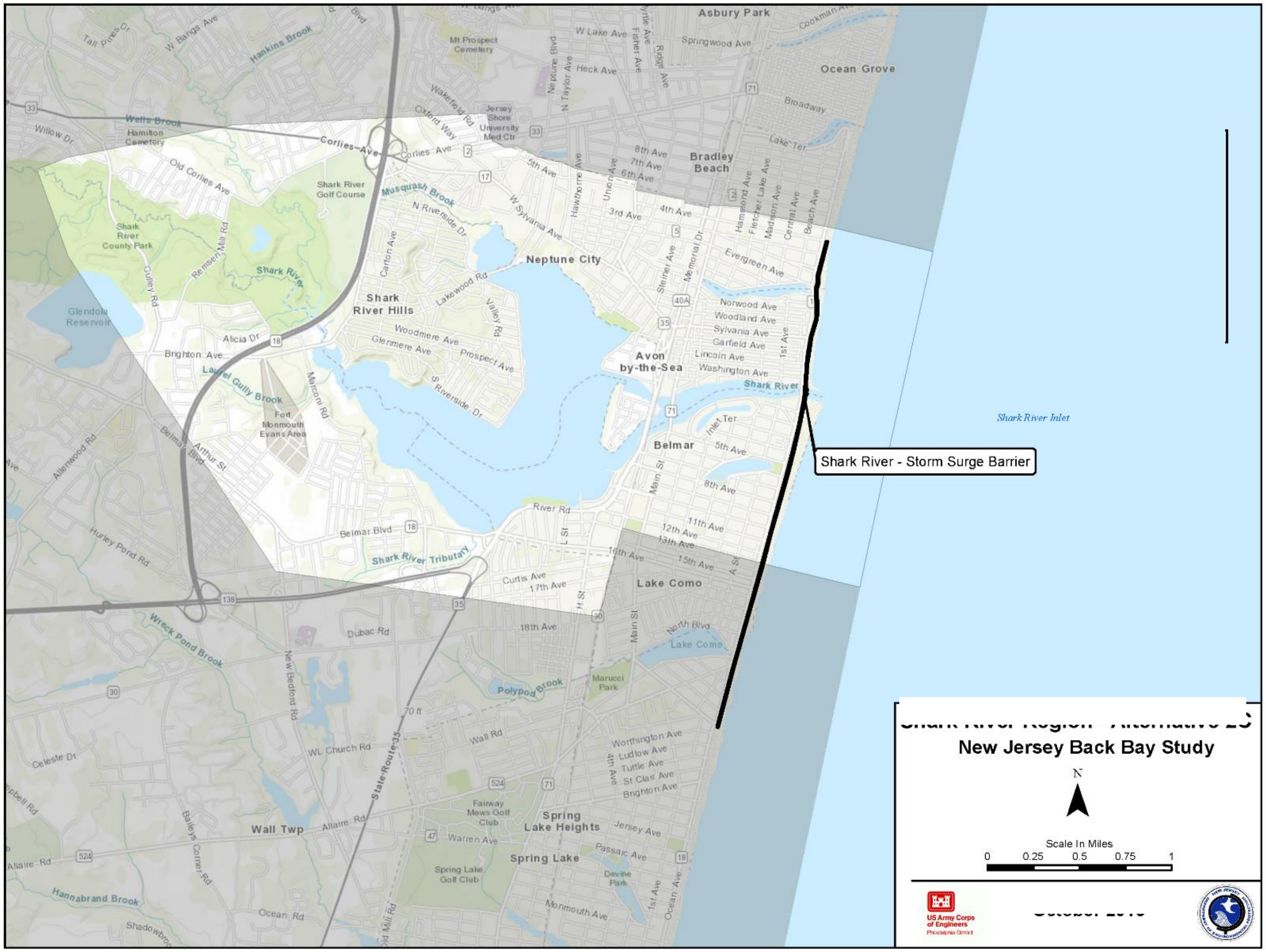


Figure 23: Shark River Region Storm Surge Barrier Alternatives

NORTH REGION

North Region includes the possibility of two storm surge barriers, Barnegat Inlet SSB and Manasquan Inlet SSB, as well as two bay closures, Point Pleasant Canal BC and Holgate BC. The combination of these measures creates the three alternatives shown in Figure 24.

Table 13 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 13: North Region Storm Surge Barrier Alternatives

ITEM	**Manasquan SSB + Barnegat SSB**	**Manasquan SSB + Barnegat SSB + Holgate BC**	**Manasquan SSB + Pt. Pleasant BC**
Initial Construction	$2,549,342,000	$5,924,539,000	$1,151,448,000
AAC	***$154,810,000***	***$367,186,000***	***$67,465,000***
AAD Without	$548,225,000	$548,225,000	$548,225,000
AAD With	$239,397,000	$113,711,000	$505,723,000
AAB	***$308,828,000***	***$434,515,000***	***$42,502,000***
AANB	***$154,018,000***	***$67,329,000***	***-$24,963,000***
BCR	***1.99***	***1.18***	***0.63***
Residual Damage	43.7%	20.7%	92.2%
O&M	$39,351,000	$90,894,000	$17,766,000

Closing Manasquan Inlet and Barnegat Inlet with storm surge barriers has the highest NED AANB of the three SSB and BC alternatives. Adding a bay closure at Holgate does reduce residual damages by approximately 23% but has 56.3% fewer AANB and a considerably higher AAC and OMRR&R cost.

The final alternative, constructing only the Manasquan storm surge barrier and the Point Pleasant Canal closure, is not economically justified and does nothing to mitigate damages for over 92% of the Region.

It is important to note that any of the alternatives discussed so far can be combined with other measure types to further drive down residual damages and boost AANB. The combination of perimeter, nonstructural, and storm surge barrier alternative is discussed in the following section (C-6).

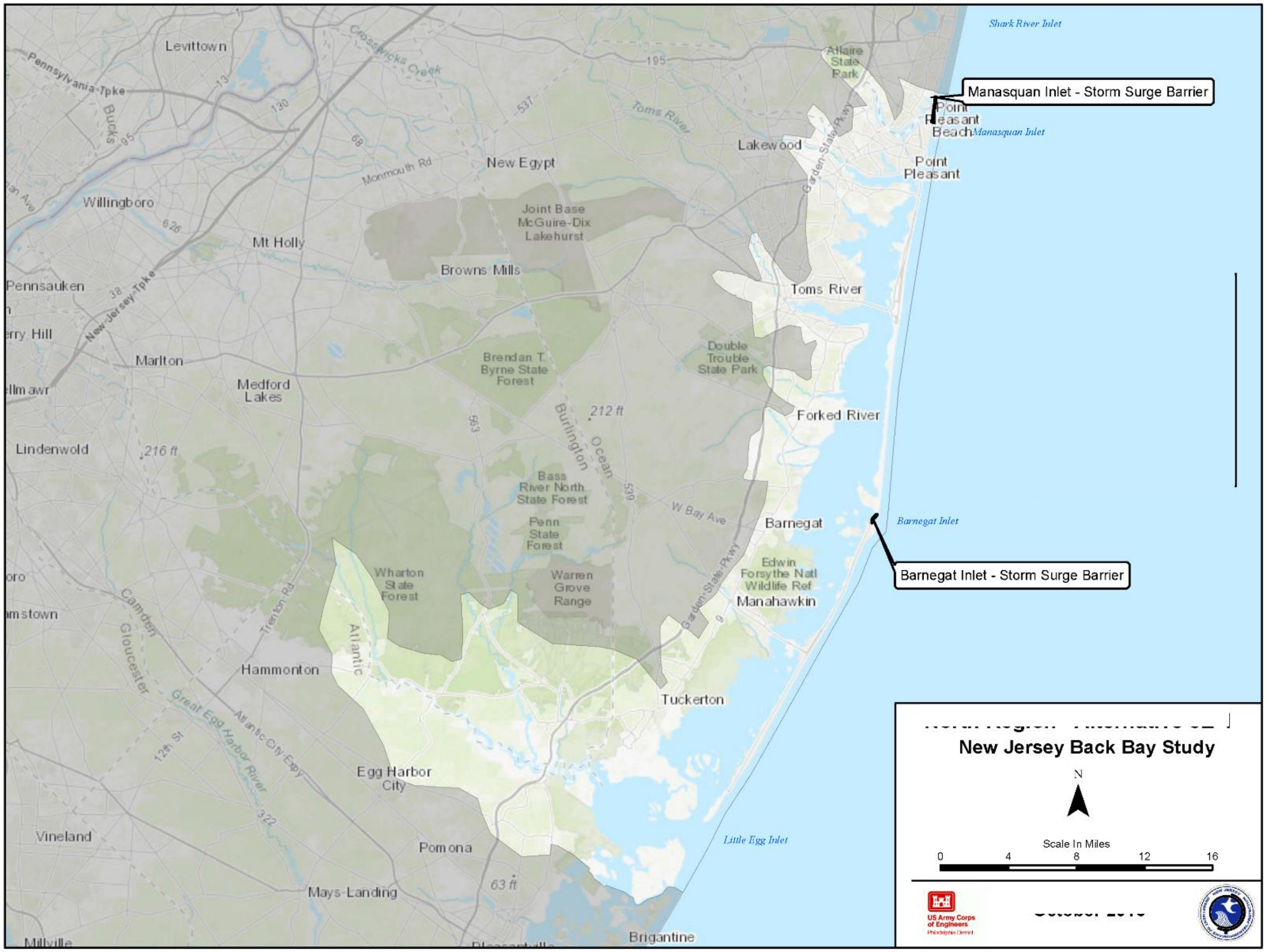
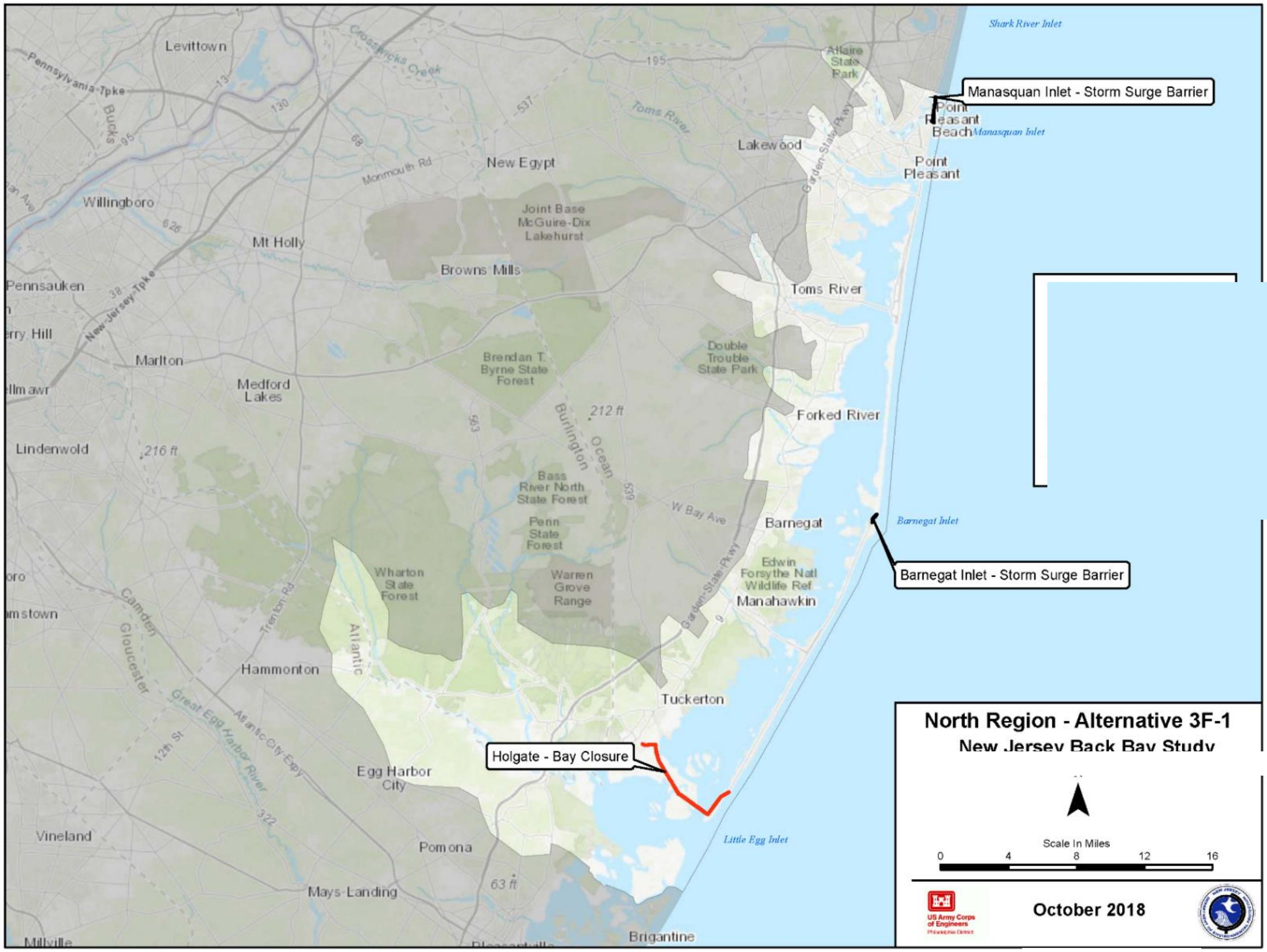
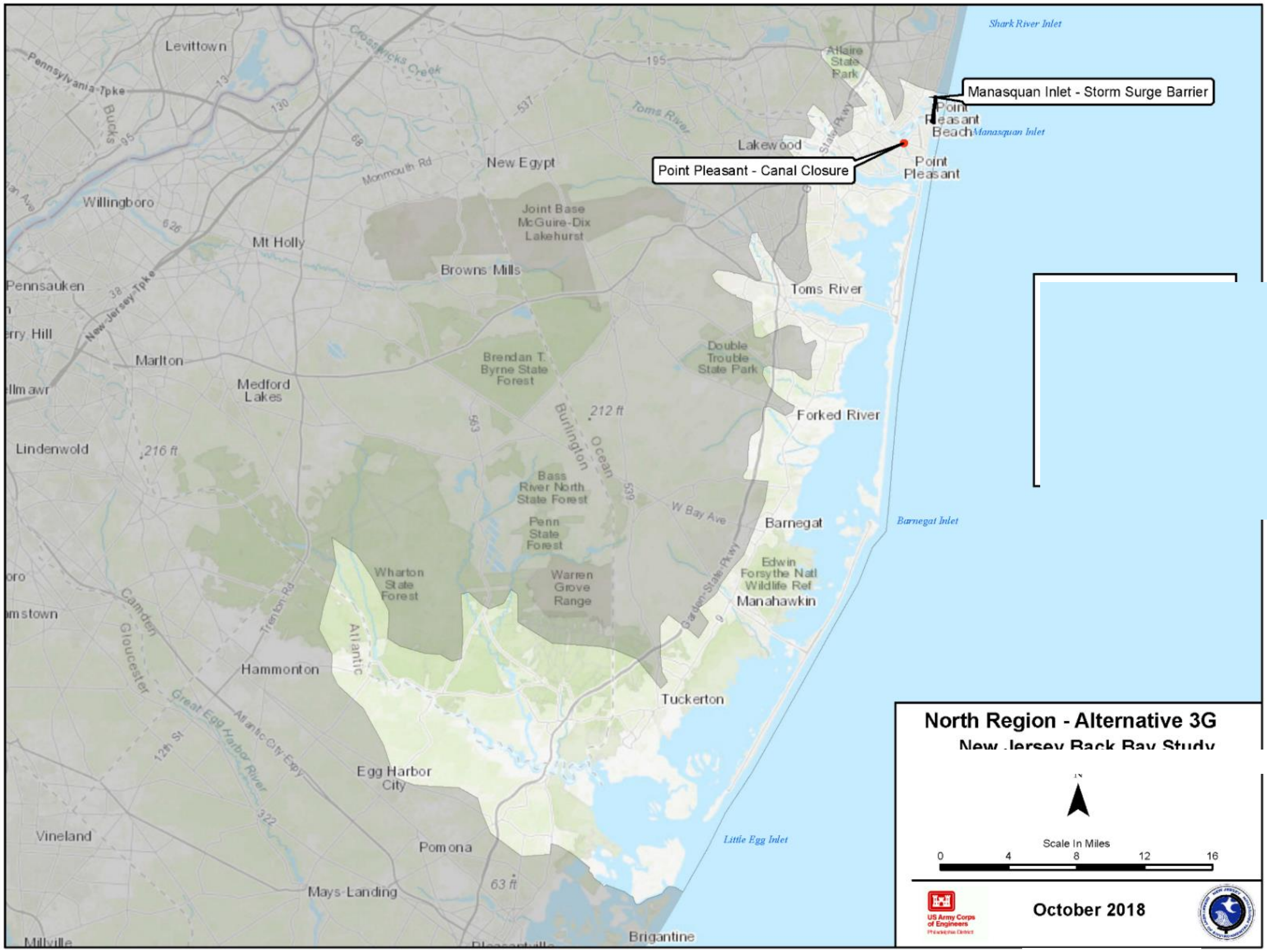


Figure 24: North Region Storm Surge Barrier Alternatives



Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
North Region - Alternative 3F-1
New Jersey Back Bay Study
Scale In Miles
0 4 8 12 16
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Lakewood
Point Pleasant
Point Pleasant Beach
Brigantine
Egg Harbor City
Hammonton


Manasquan Inlet - Storm Surge Barrier
Point Pleasant - Canal Closure
North Region - Alternative 3G
New Jersey Back Bay Study
Scale In Miles
0 4 8 12 16
October 2018
US Army Corps of Engineers
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Point Pleasant Beach
Point Pleasant
Lakewood
New Egypt
Levittown
Willingboro
Mt Holly
Browns Mills
Joint Base McGuire-Dix Lakehurst
Allaire State Park
Toms River
Pennsauken
Marlton
Medford Lakes
Brendan T. Byrne State Forest
Double Trouble State Park
Forked River
Lindenwold
Bass River North State Forest
Penn State Forest
Barnegat
Edwin Forsythe Natl Wildlife Ref
Manahawkin
Wharton State Forest
Warren Grove Range
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine

CENTRAL REGION

Initial analysis of the Central Region includes the possibility for two storm surge barriers, Absecon Inlet SSB and Great Egg Harbor SSB, and two bay closures, North Point BC and Absecon Blvd BC. The combination of these measures creates the three alternatives shown in Figure 25.

During further analysis, a third bay closure was modeled at South Ocean City (north of Corson's Inlet). That bay closure is not presented here but is included in the "hybrid" alternative analysis in the following section (C-6).

Table 14 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 14: Central Region Storm Surge Barrier Alternatives

ITEM	Absecon SSB + Great Egg Harbor SSB	Absecon SSB + Great Egg Harbor SSB + North Point BC	Great Egg Harbor SSB + Absecon Blvd. BC
Initial Construction	$6,734,047,000	$9,831,254,000	$4,884,211,000
AAC	***$425,665,000***	***$622,785,000***	***$301,347,000***
AAD Without	$702,936,000	$702,936,000	$702,936,000
AAD With	$132,766,000	$50,016,000	$108,652,000
AAB	***$570,170,000***	***$652,920,000***	***$594,284,000***
AANB	***$144,506,000***	***$30,135,000***	***$292,937,000***
BCR	***1.34***	***1.05***	***1.97***
Residual Damage	18.9%	7.1%	15.5%
O&M	$103,964,000	$151,395,000	$74,556,000

Closing Absecon Inlet and Great Egg Harbor Inlet is economically justified with over $144,000,000 in AANB. Adding North Point bay closure does reduce residual damages down to 7.1%, but results in $114,371,000 in lost AANB due to the estimated $3 billion initial construction cost (Table 12).

Construction of a bay closure at Absecon Blvd (southwest of Brigantine Island) slightly increases residual damages in comparison to the North Point BC, but is considerably less expensive than either the Absecon SSB or North Point BC and maximizes NED AANB at $292,937,000 with a BCR of 1.97. The addition of the South Ocean City bay closure during additional analysis further reduced residual damages and increased AANB.

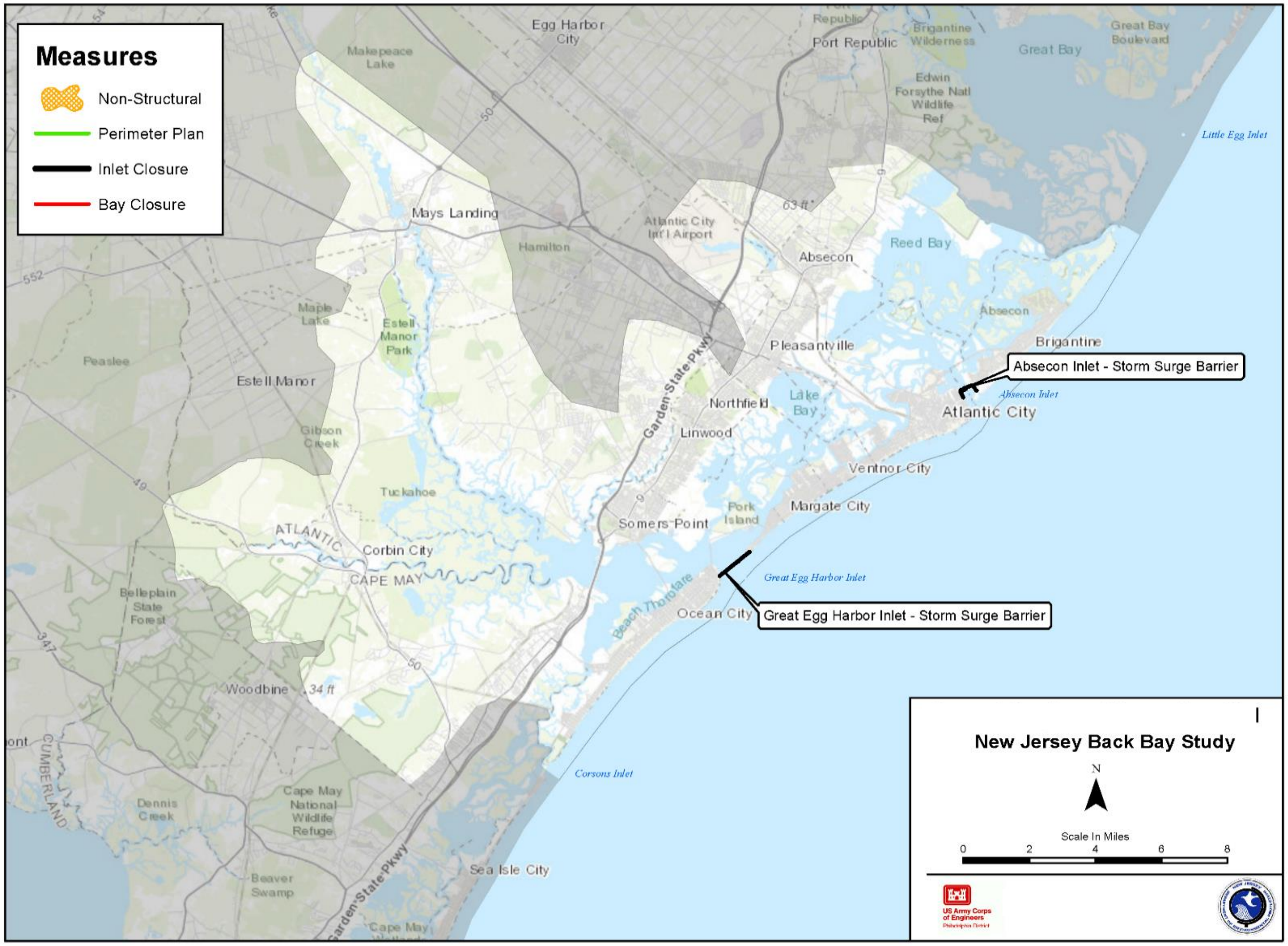
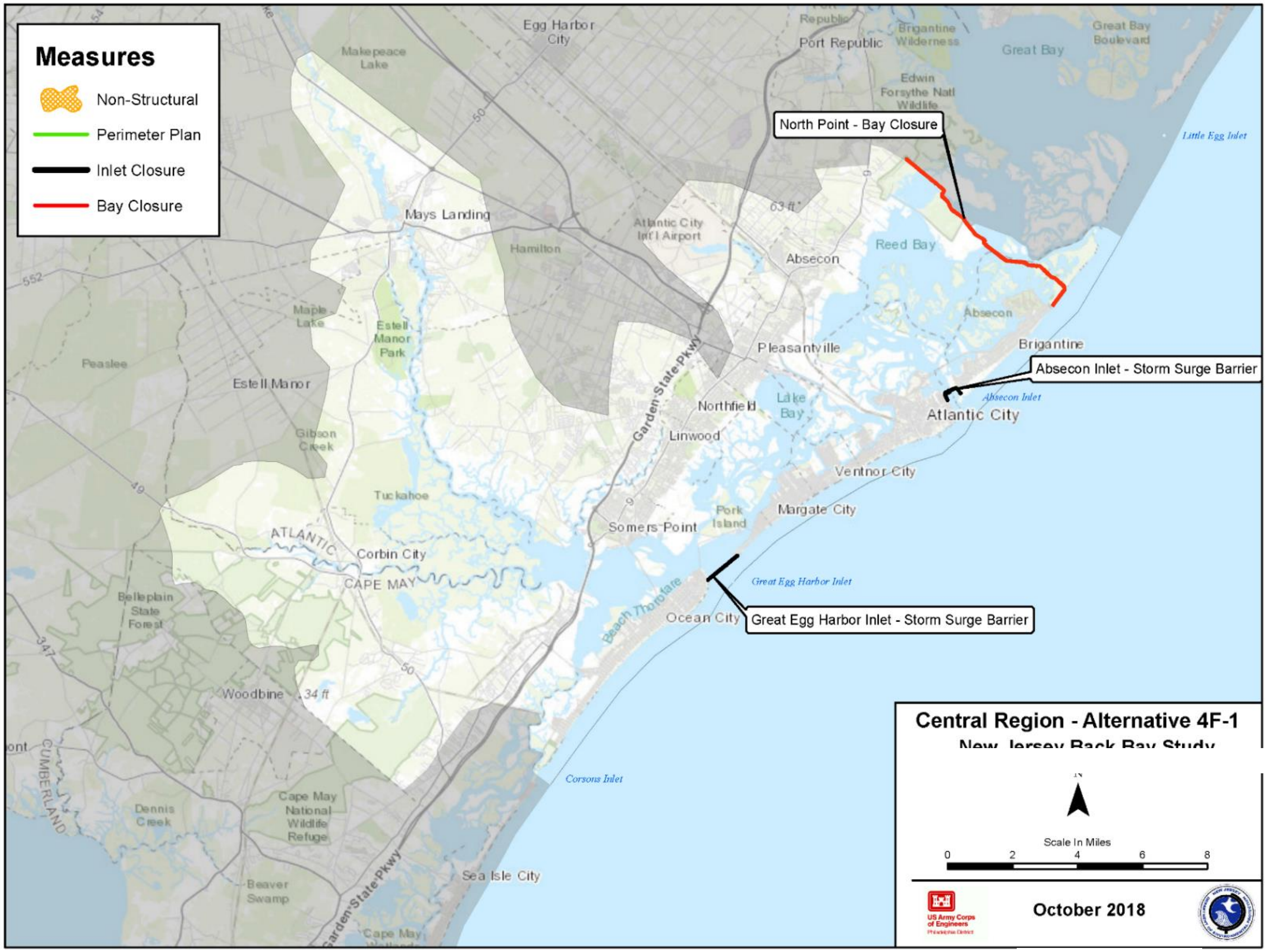
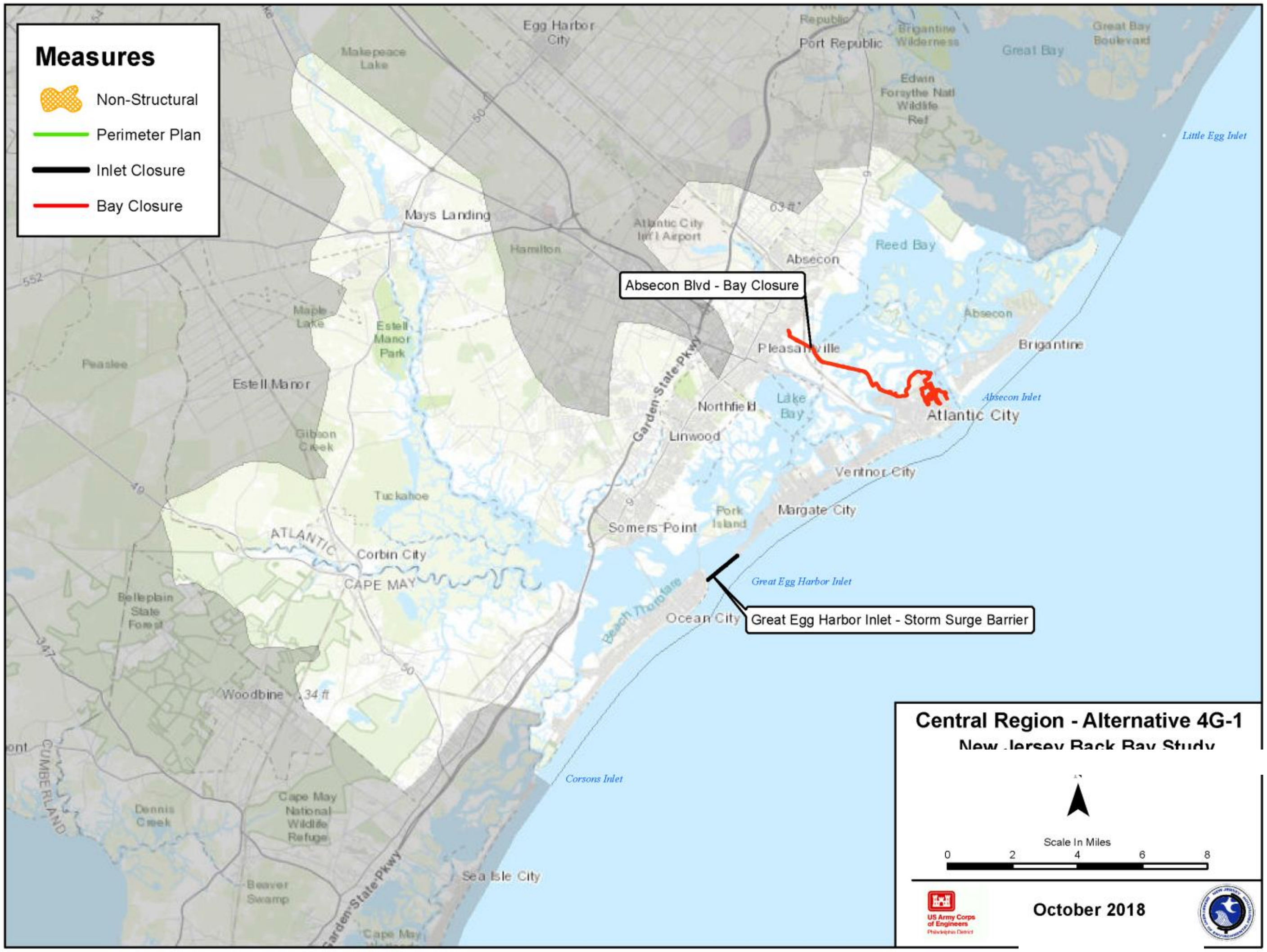


Figure 25: Central Region Storm Surge Barrier Alternatives


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4F-1
New Jersey Back Bay Study
Scale In Miles
0
2
4
6
8
October 2018
US Army Corps of Engineers


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4G-1
New Jersey Back Bay Study
Scale In Miles
0 2 4 6 8
October 2018
US Army Corps of Engineers
Egg Harbor City
Port Republic
Mays Landing
Atlantic City
Pleasantville
Absecon
Brigantine
Northfield
Linwood
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
Estell Manor
Tuckahoe
Woodbine
Sea Isle City
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Reed Bay
Great Bay
Lake Bay
Garden State Pkwy

SOUTH REGION

Analysis of the South Region includes four storm surge barriers, Cape May Canal SSB, Cape May Inlet SSB, Hereford Inlet SSB, and Townsends Inlet, and three bay closures, Wildwood Blvd BC, Stone Harbor Blvd BC, and Sea Isle Blvd BC. The combination of these measures creates the three alternatives shown in Figure 26.

The South Region has four inlets with a high level of interdependency plus environmental concerns at Hereford Inlet. For any proposed alternative to have a noticeable impact on stage height reductions, all four inlets need to be closed. In Table 15 and Figure 26, the last two alternatives have some nonstructural measures included due to concerns about induced damages, but the additional AAB and AAC from these components is minor and does not affect the economic justification of the alternatives.

Table 15 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 15: South Region Storm Surge Barrier Alternatives

ITEM	**Cape May Canal + Cape May Inlet + Hereford Inlet + Townsends Inlet**	**Cape May Canal + Cape May Inlet + Hereford Inlet + Townsends Inlet + Sea Isle Blvd BC**	**Cape May Canal + Cape May Inlet + Wildwood Blvd BC + Stone Harbor Blvd BC + Townsends Inlet + Sea Isle Blvd BC**
Initial Construction	$4,639,279,000	$5,265,569,000	$5,924,476,000
AAC	***$274,620,000***	***$308,994,000***	***$344,010,000***
AAD Without	$310,626,000	$310,626,000	$310,626,000
AAD With	$19,772,000	$12,431,000	$16,702,000
AAB	***$290,854,000***	***$298,195,000***	***$293,924,000***
AANB	***$16,233,000***	***-$10,799,000***	***-$50,086,000***
BCR	***1.06***	***0.97***	***0.85***
Residual Damage	6.4%	4.0%	5.4%
O&M	$71,610,000	$80,302,000	$89,110,000

Closing all four of the inlets in the South Region is economically justified, but ignores serious environmental concerns and potential mitigation costs at Herford Inlet.

Adding a bay closure at Sea Isle Blvd does drive down residual damages, but decreases overall AANB and drives the BCR below 1.0. Replacing the storm surge barrier at Hereford Inlet with two bay closure avoids some of the potential mitigation costs, but adds significant construction costs to the alternatives and drives the BCR further below 1.0.

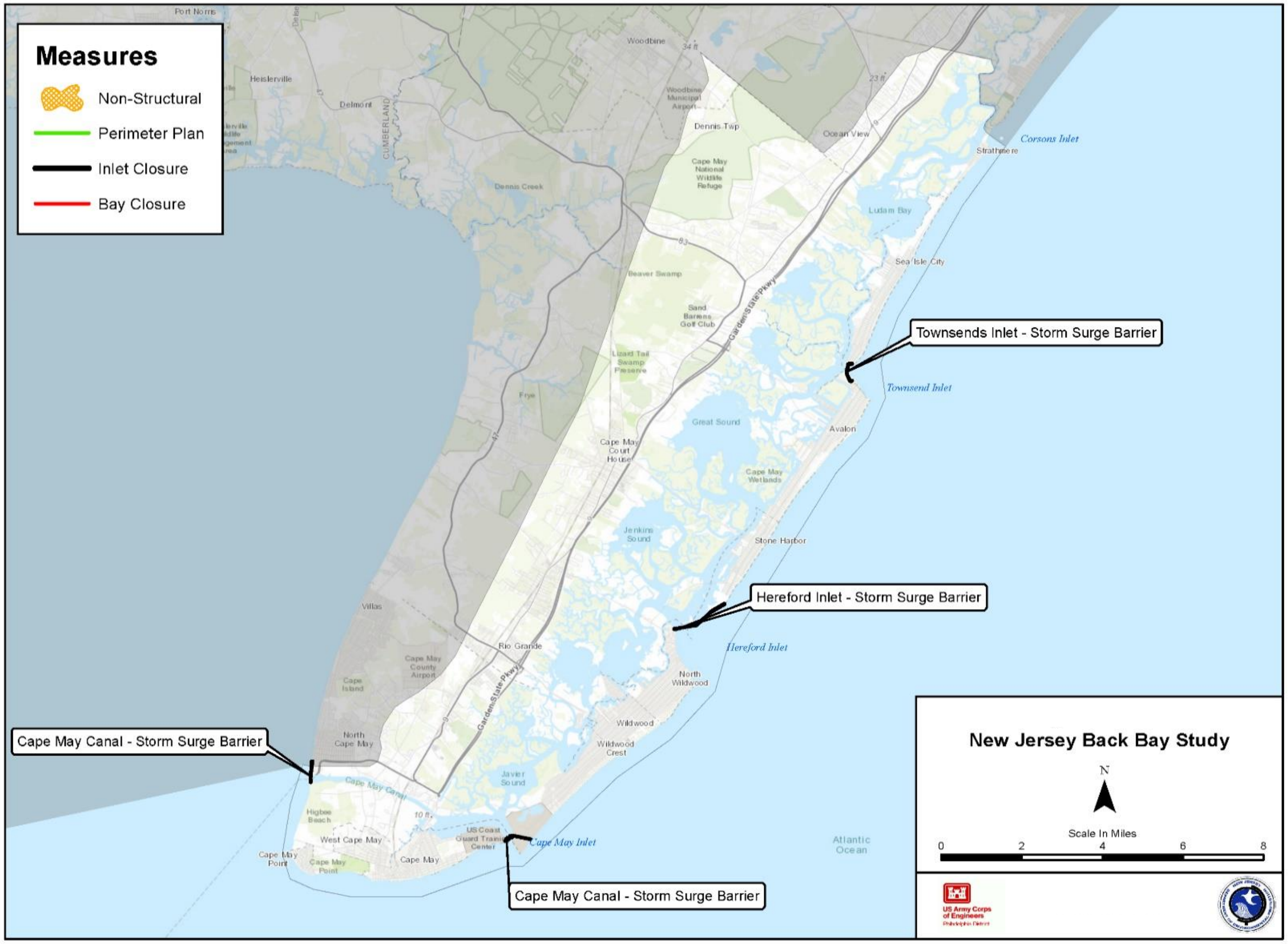
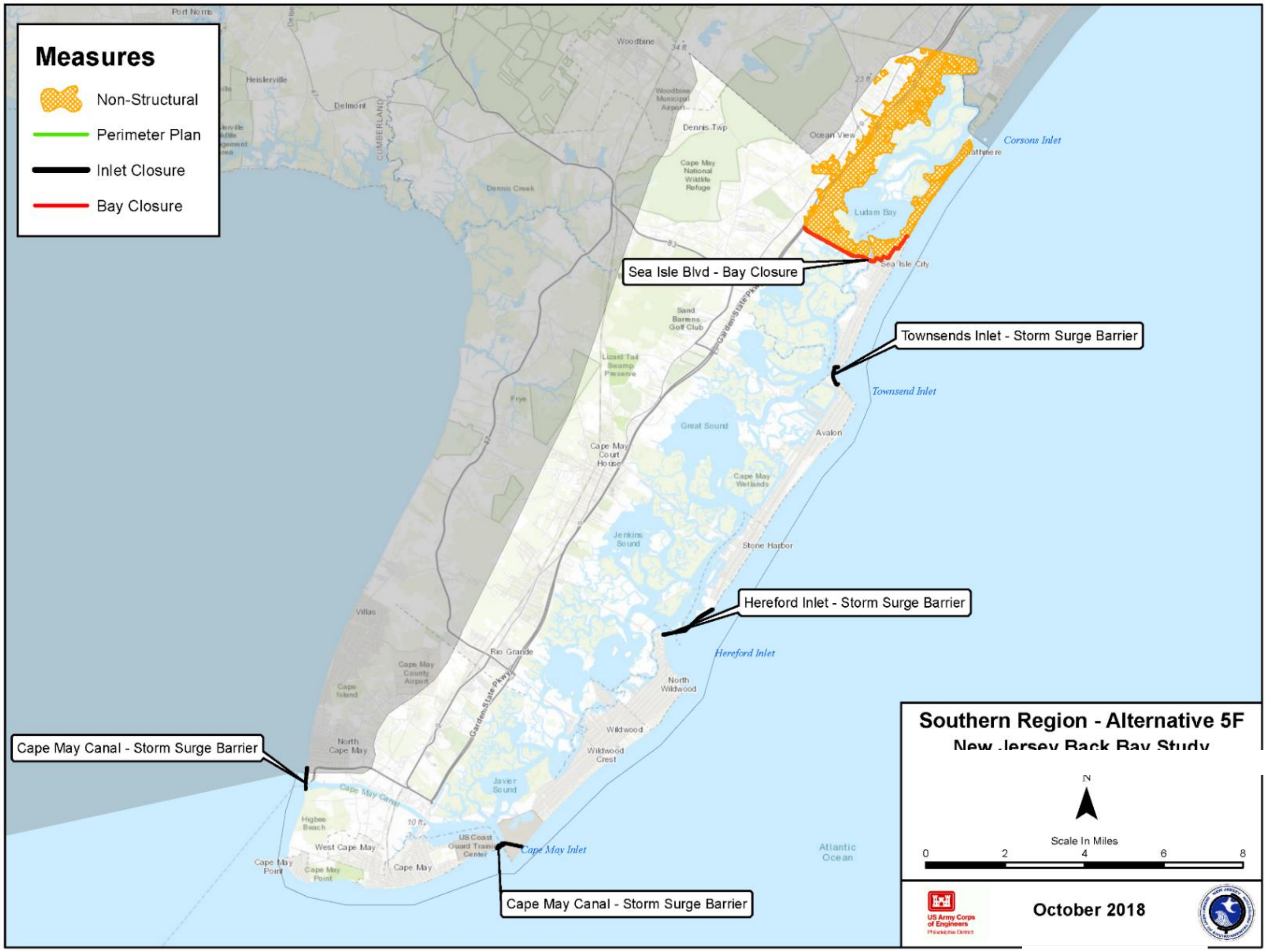
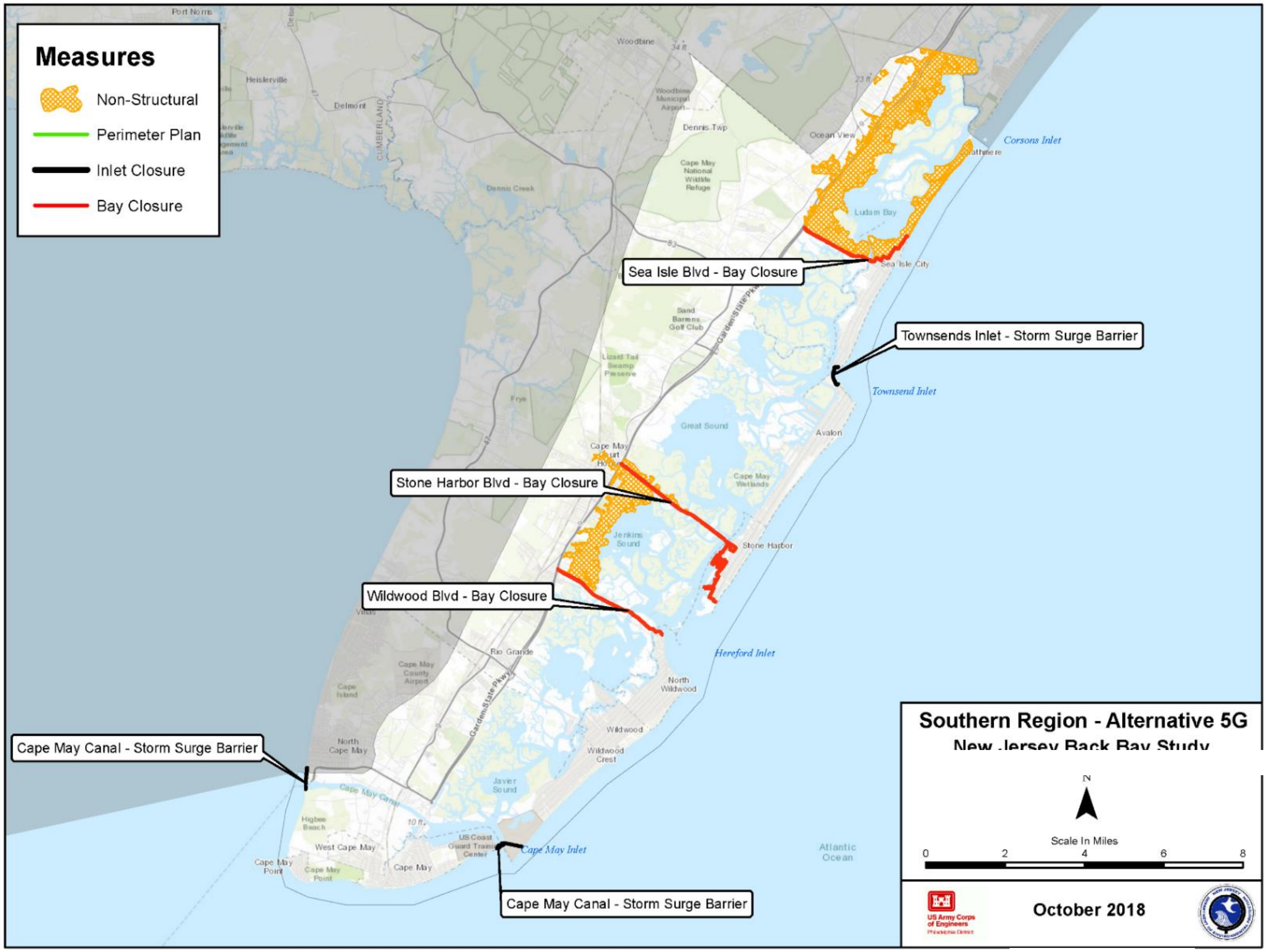


Figure 26: South Region Storm Surge Barrier Alternatives


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Hereford Inlet - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Ludam Bay
Sea Isle City
Ocean View
Avalon
Stone Harbor
North Wildwood
Wildwood
Wildwood Crest
Great Sound
Jenkins Sound
Cape May Wetlands
Cape May Court House
Rio Grande
Villas
North Cape May
West Cape May
Cape May
Cape May Point
Cape May Canal
Atlantic Ocean
Woodbine
Dennis Twp
Dennis Creek
Delmont
Heislerville
Port Norris
Southern Region - Alternative 5F
New Jersey Back Bay Study
N
Scale In Miles
0
2
4
6
8
October 2018
US Army Corps of Engineers


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Stone Harbor Blvd - Bay Closure
Wildwood Blvd - Bay Closure
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Ludam Bay
Great Sound
Jenkins Sound
Jarvis Sound
Sea Isle City
Avalon
Stone Harbor
North Wildwood
Wildwood
Wildwood Crest
Rio Grande
Cape May
West Cape May
North Cape May
Cape May Point
Atlantic Ocean
Southern Region - Alternative 5G
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
US Army Corps of Engineers
October 2018

C-6) HYBRID NED (MULTI-MEASURE) ALTERNATIVES

Following the evaluation of each potential measure type in isolation, potential CSRM solutions are combined into hybrid, or multi-measure, alternatives. Combining the highest reasonable NED AANB measure from each Region into a single, comprehensive alternative maximizes NED benefits and optimizes CSRM performance.

Description

The following tables show 51 potential measure combinations though not all hybrid alternatives are considered complete nor environmentally acceptable. All 51 alternatives are shown to provide transparency on the transition from isolated single-measure alternatives to a final Focused Array of complete and implementable hybrid multi-measure plans.

The Focused Array of Alternatives is presented in the following Section and is displayed at a Region level.

The 51 alternatives display the incremental combination of measures starting with (A) nonstructural only, (B) perimeter only (including non-incrementally-justified perimeter measures), (C) justified perimeter only, (D) justified perimeter with nonstructural (plus permutations for reasonably marginal perimeter measure locations), (E) storm surge barriers with nonstructural and/or perimeter, (F) storm surge barriers with nonstructural and/or perimeter and bay closures, and finally (G) storm surge barriers with nonstructural and/or perimeter and a different combination of bay closures.

Table 16 provides a brief description of each alternative and Figure 27 provides the visual map for each of the 51 alternatives. Table 17 provides economic data on each measure combination.

It is important to note that the first four alternatives presented are not shown by Region, but displayed as study wide single-measure alternatives. These four alternatives do not consider completeness nor environmental acceptability and should only be viewed as a rough baseline for which NED optimizing hybrid alternatives can improve upon.

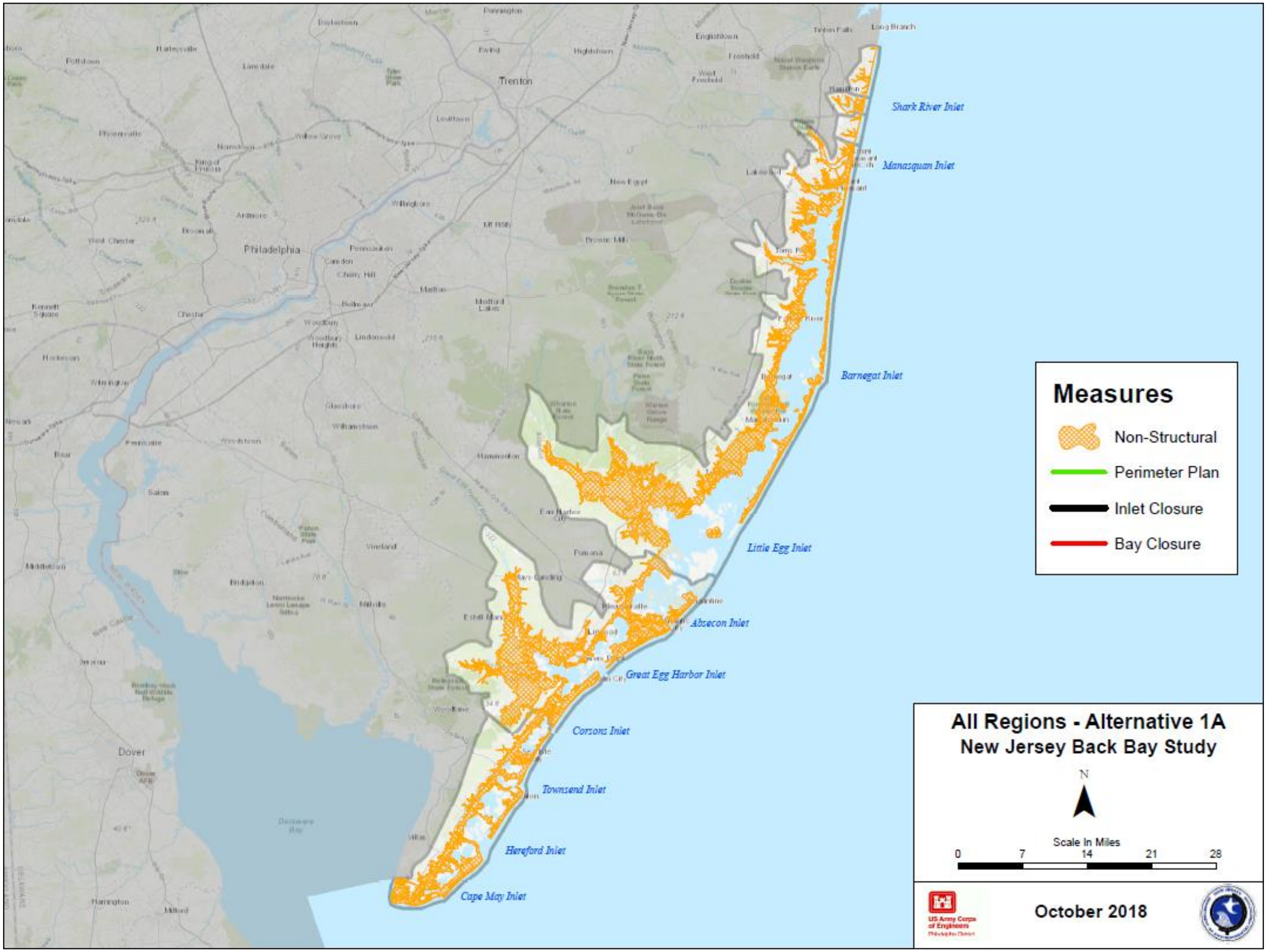
Table 16: Comprehensive List of 51 Regional Alternatives

REGION	PLAN	DESCRIPTION
STUDY WIDE	1A	Nonstructural ONLY
	1B	Perimeter (justified) ONLY
	1C	Storm Surge Barrier ALL INLETS
	1D	Storm Surge Barrier ALL INLETS minus Little Egg Harbor Inlet
SHARK RIVER	2A	Nonstructural ONLY
	2B	Perimeter ONLY
	2C	Storm Surge Barrier ONLY
NORTH REGION	3A	Nonstructural ONLY
	3B	Perimeter ONLY
	3C	Perimeter (justified) ONLY
	3D	Perimeter (justified) + Nonstructural
	3E(1)	Storm Surge Barrier ONLY
	3E(2)	Storm Surge Barrier + Nonstructural
	3E(3)	Storm Surge Barrier + Nonstructural + Perimeter
	3F(1)	Storm Surge Barrier + Bay Closure (Holgate)
	3F(2)	Storm Surge Barrier + Bay Closure (Holgate) + Nonstructural
	3G	Storm Surge Barrier + Bay Closure (Point Pleasant Canal)
CENTRAL REGION	4A	Nonstructural ONLY
	4B	Perimeter ONLY
	4C	Perimeter (justified) ONLY
	4D(1)	Perimeter (justified) + Nonstructural
	4D(2)	Perimeter (justified and non-justified) + Nonstructural
	4E(1)	Storm Surge Barrier ONLY
	4E(2)	Storm Surge Barrier + Nonstructural
	4E(3)	Storm Surge Barrier + Nonstructural + South Ocean City Perimeter
	4E(4)	Storm Surge Barrier + Nonstructural + South Ocean City Bay Closure
	4F(1)	Storm Surge Barrier + Bay Closure (North Point)
	4F(2)	Storm Surge Barrier + Bay Closure (North Point) + Nonstructural
	4F(3)	Storm Surge Barrier + Bay Closure (North Point) + Nonstructural + South Ocean City Perimeter
	4F(4)	Storm Surge Barrier + Bay Closure (North Point) + Nonstructural + South Ocean City Bay Closure
	4G(1)	Storm Surge Barrier + Bay Closure (Absecon Blvd)
	4G(2)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Nonstructural
	4G(3)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Nonstructural + South Ocean City Perimeter
	4G(4)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Nonstructural + South Ocean City Bay Closure
	4G(5)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City No-Action
	4G(6)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Nonstructural
	4G(7)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Perimeter
	4G(8)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Bay Closure
	4G(9)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City No-Action
	4G(10)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Nonstructural
	4G(11)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Perimeter
	4G(12)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Bay Closure
SOUTH REGION	5A	Nonstructural ONLY
	5B	Perimeter ONLY
	5C	Perimeter (justified) ONLY
	5D(1)	Perimeter (justified) + Nonstructural
	5D(2)	Perimeter (justified and non-justified) + Nonstructural
	5E(1)	Storm Surge Barrier ONLY
	5E(2)	Storm Surge Barrier + Nonstructural
	5F	Storm Surge Barrier + Nonstructural + Bay Closure (Sea Isle Blvd)
	5G	Storm Surge Barrier + Nonstructural + Bay Closure (Sea Isle Blvd, Wildwood Blvd, Stone Harbor Blvd)

*NS = Nonstructural, PM = Perimeter Measure

Figure 27: Comprehensive List of Figures for 51 Regional Alternatives

See Following Maps: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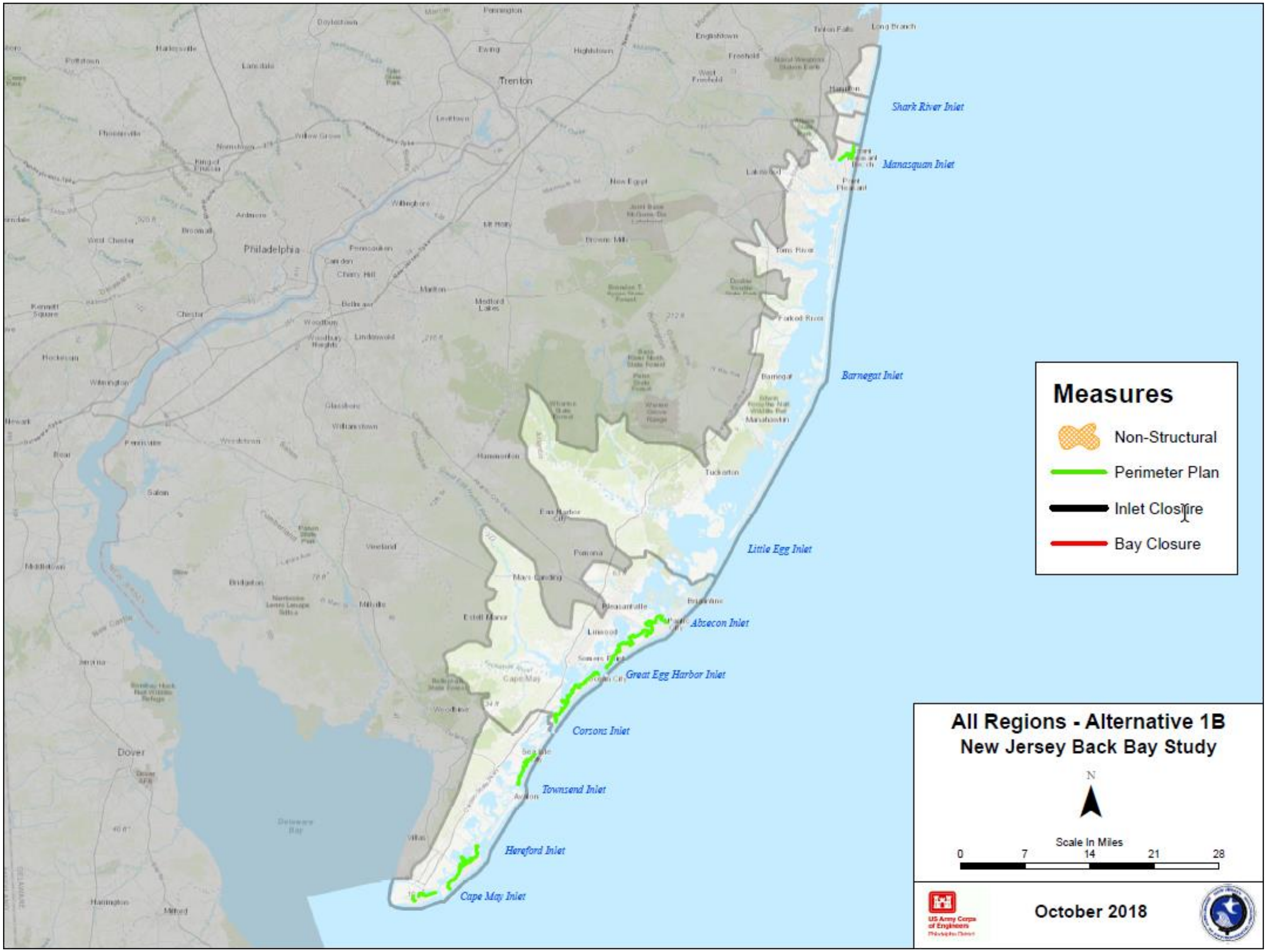
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1A
New Jersey Back Bay Study
N
Scale In Miles
0 7 14 21 28
October 2018
US Army Corps of Engineers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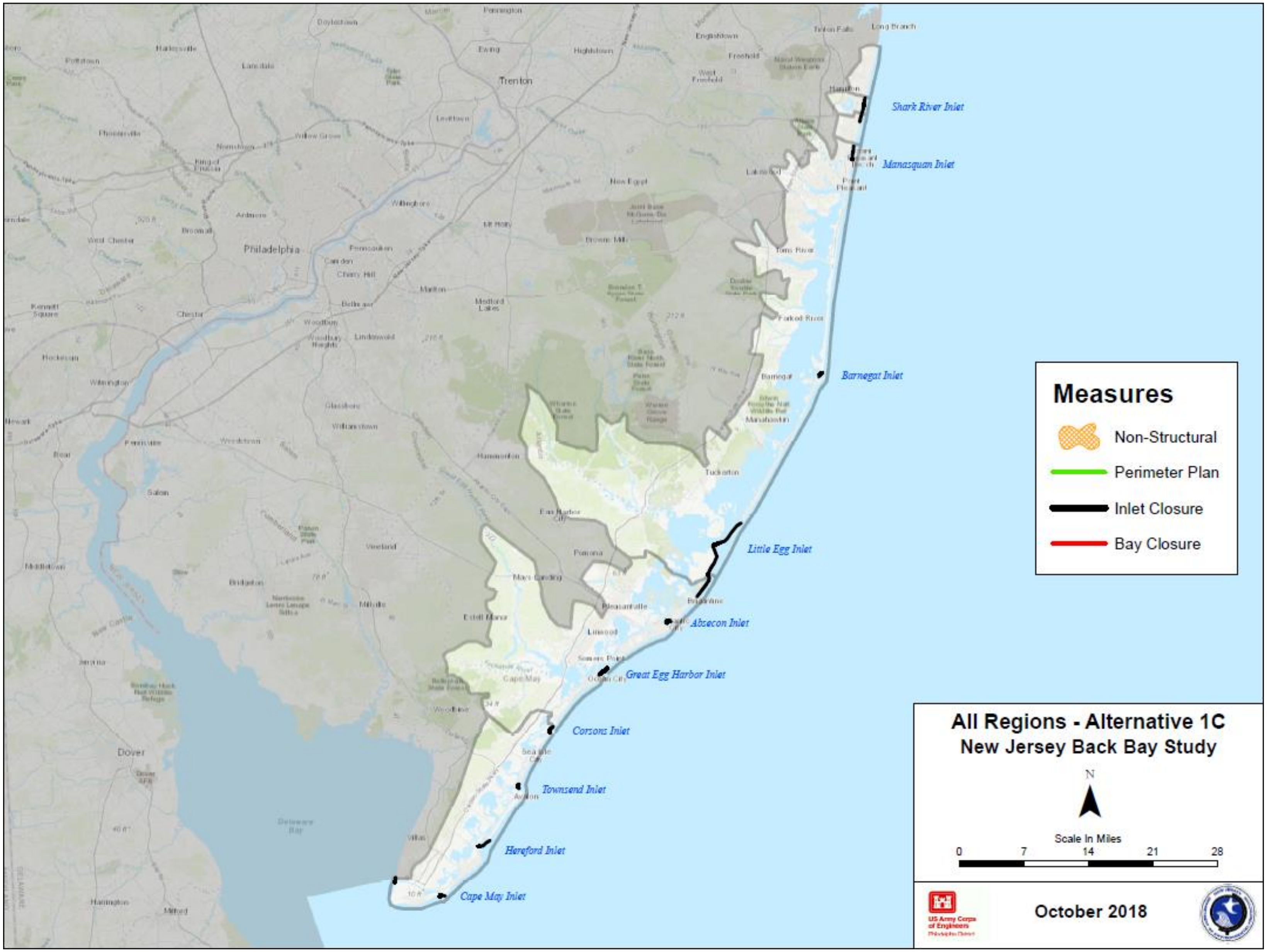
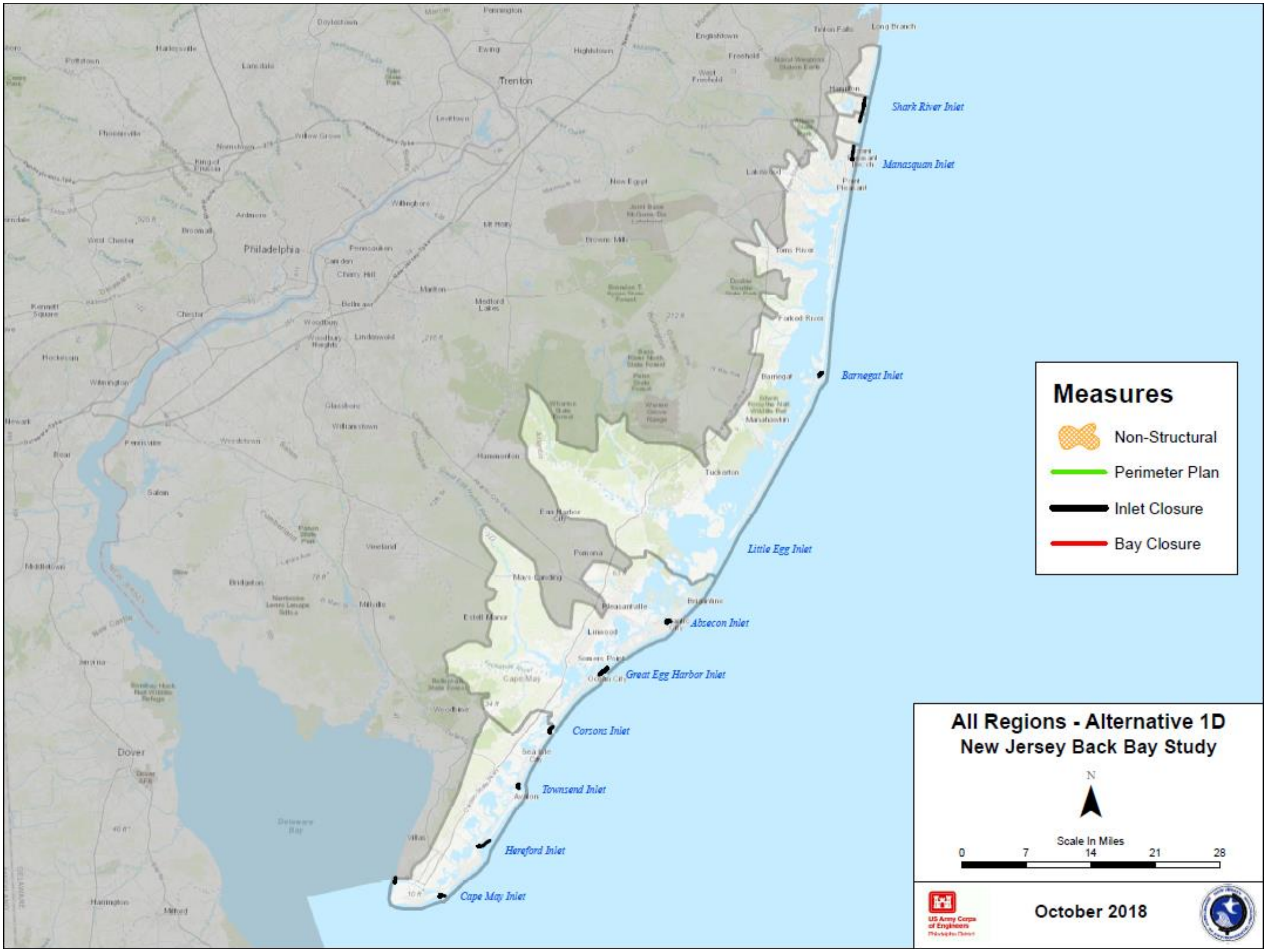
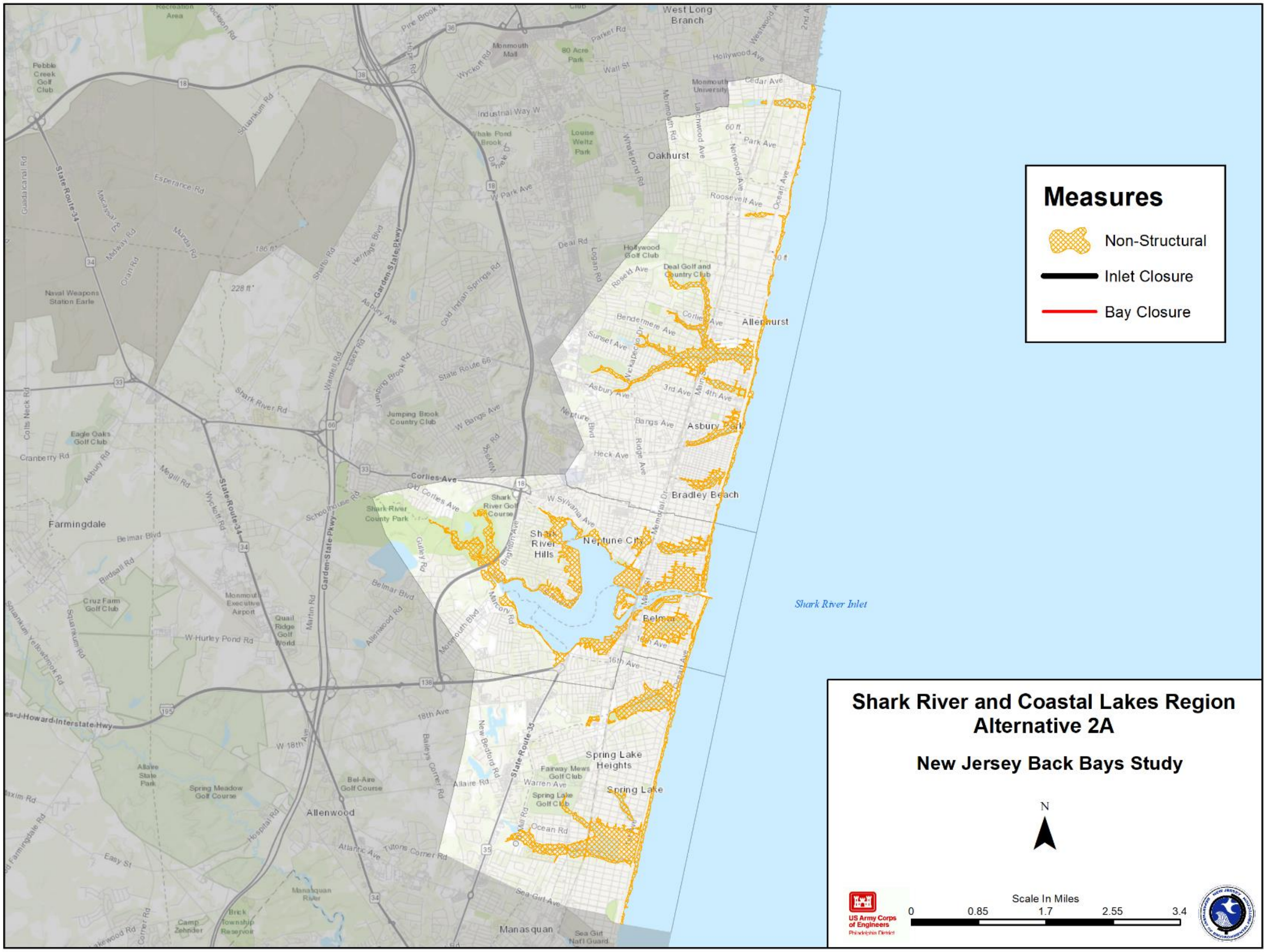
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1B
New Jersey Back Bay Study
N
Scale In Miles
0
7
14
21
28
October 2018
US Army Corps of Engineers


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1C
New Jersey Back Bay Study
N
Scale In Miles
0 7 14 21 28
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1D
New Jersey Back Bay Study
N
Scale In Miles
0 7 14 21 28
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Dover


Measures
Non-Structural
Inlet Closure
Bay Closure
Shark River and Coastal Lakes Region
Alternative 2A
New Jersey Back Bays Study
N
Scale In Miles
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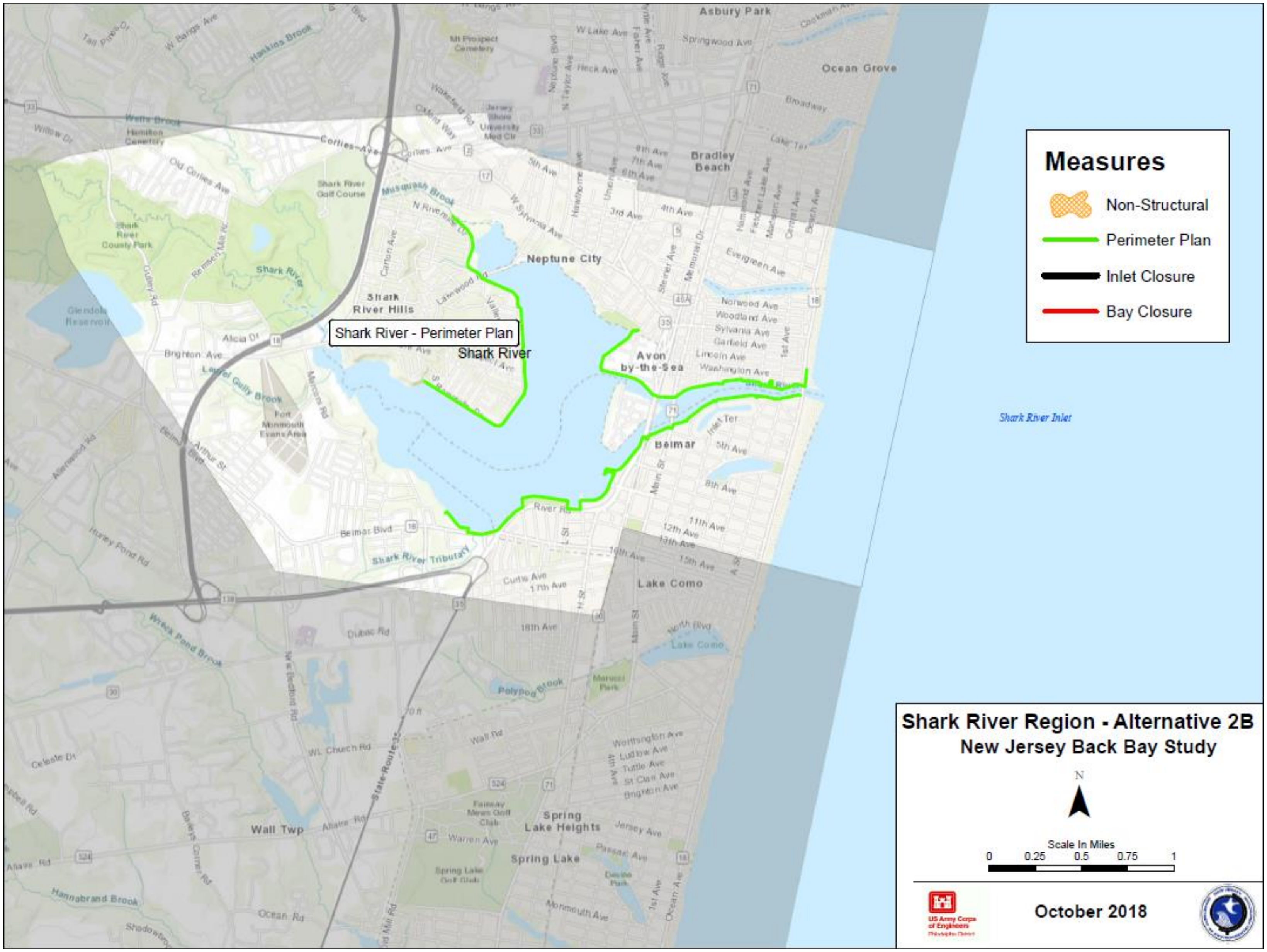
Shark River Inlet
US Army Corps of Engineers


Measures
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Perimeter Plan
Inlet Closure
Bay Closure
Shark River - Perimeter Plan
Shark River
Shark River Inlet
Shark River Region - Alternative 2B
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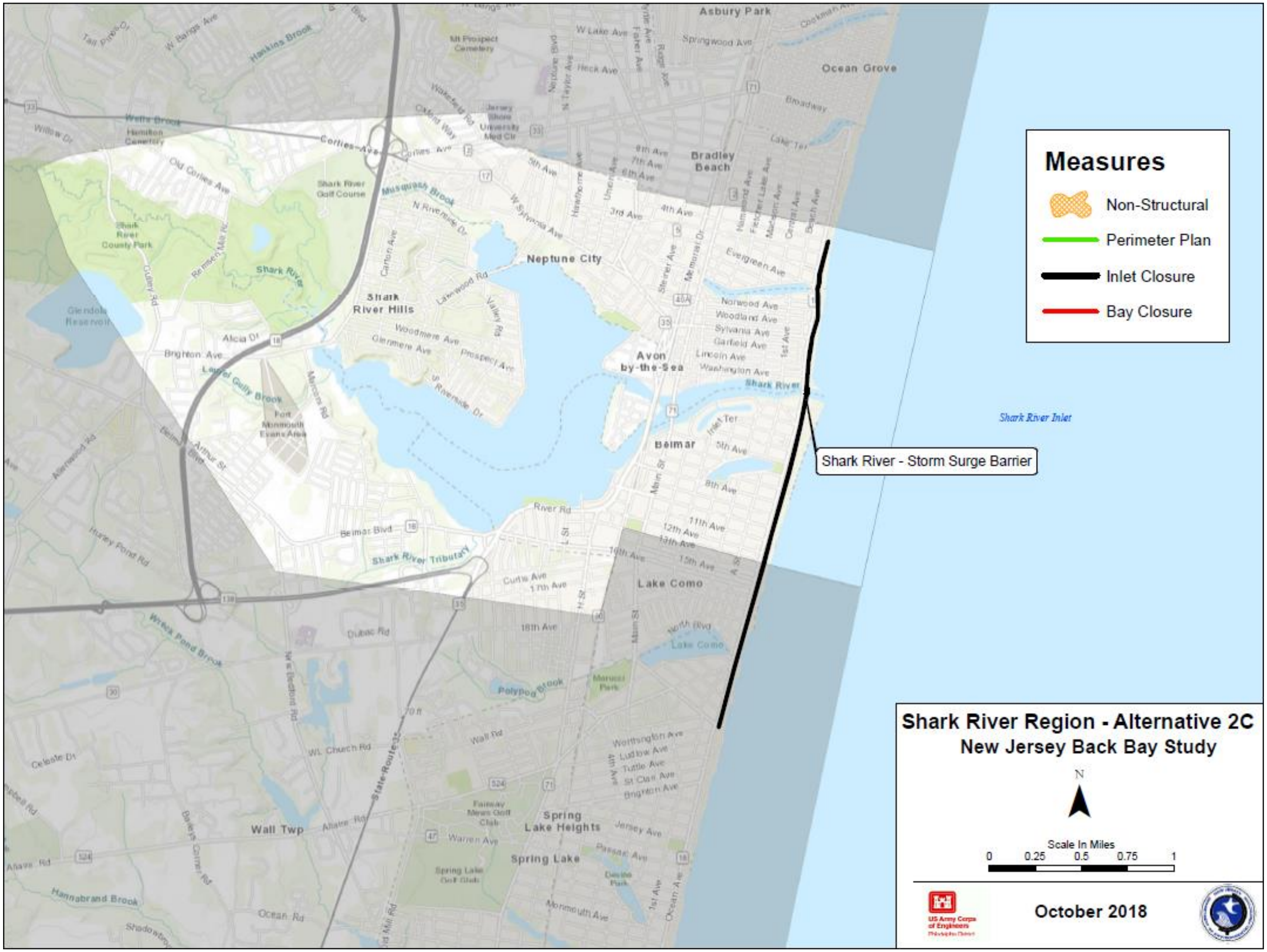
October 2018



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Shark River - Storm Surge Barrier
Shark River Inlet
Asbury Park
Ocean Grove
Bradley Beach
Neptune City
Shark River Hills
Avon by-the-Sea
Belmar
Lake Como
Spring Lake Heights
Spring Lake
Wall Twp
Shark River Region - Alternative 2C
New Jersey Back Bay Study
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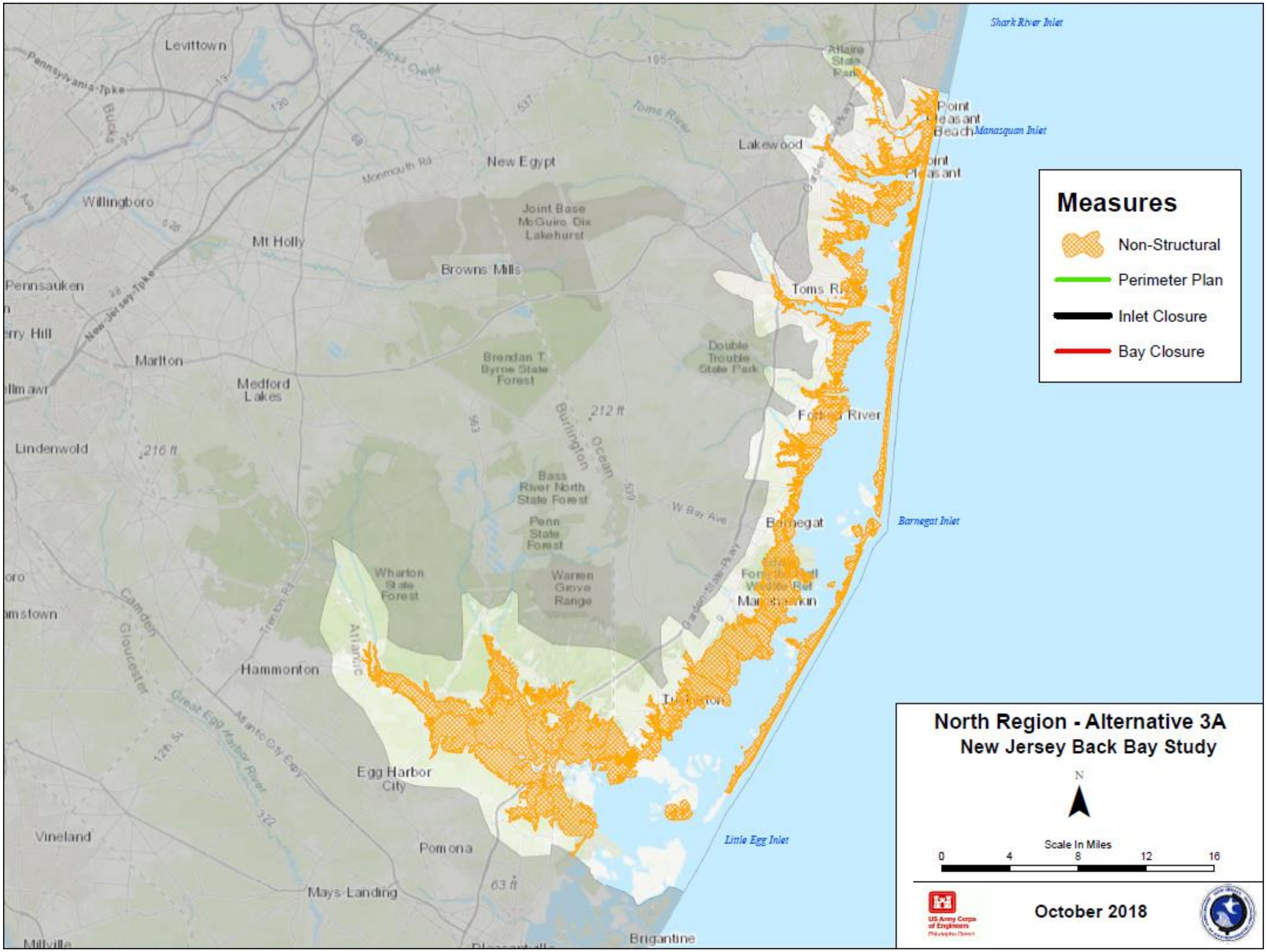
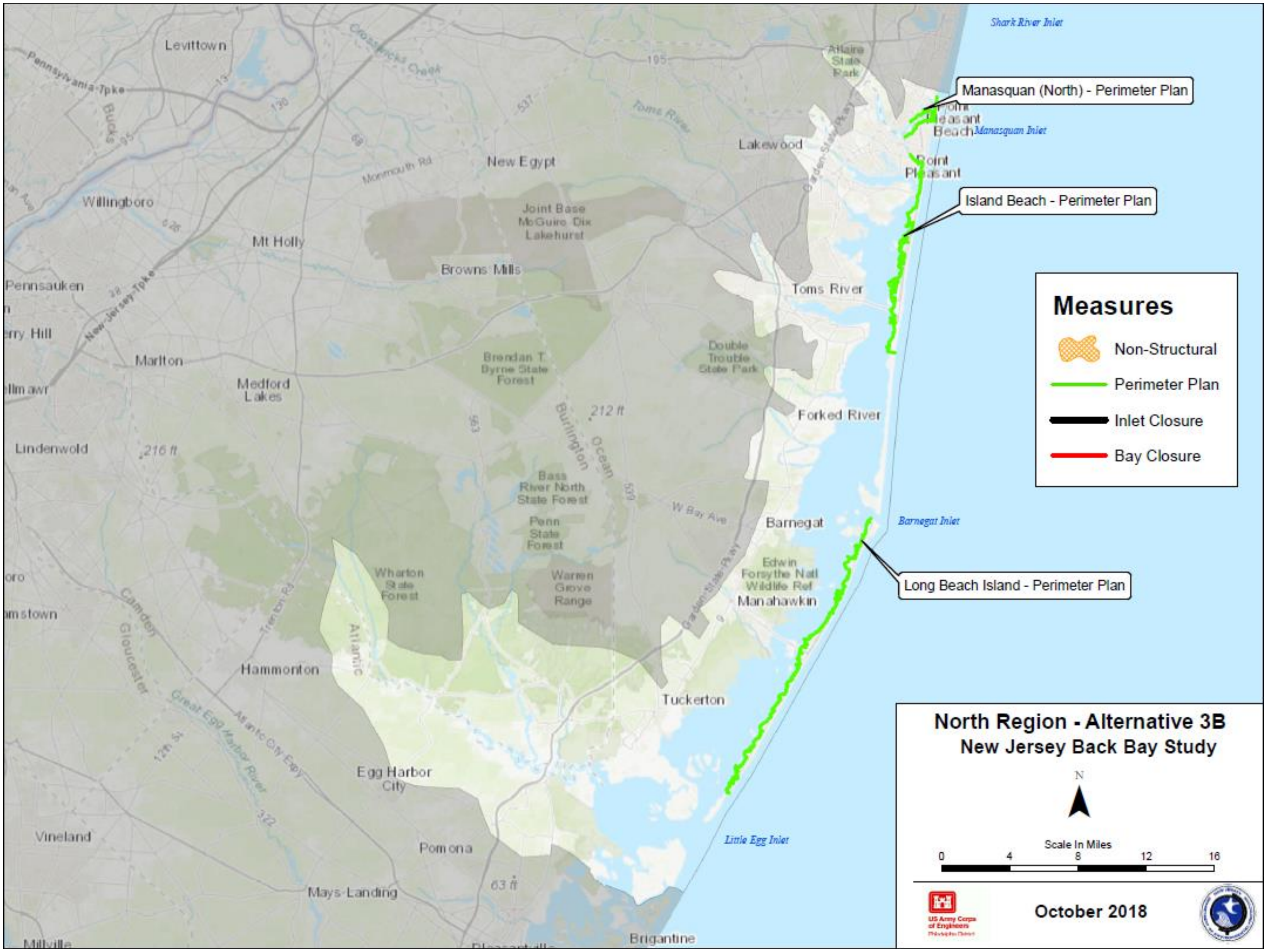
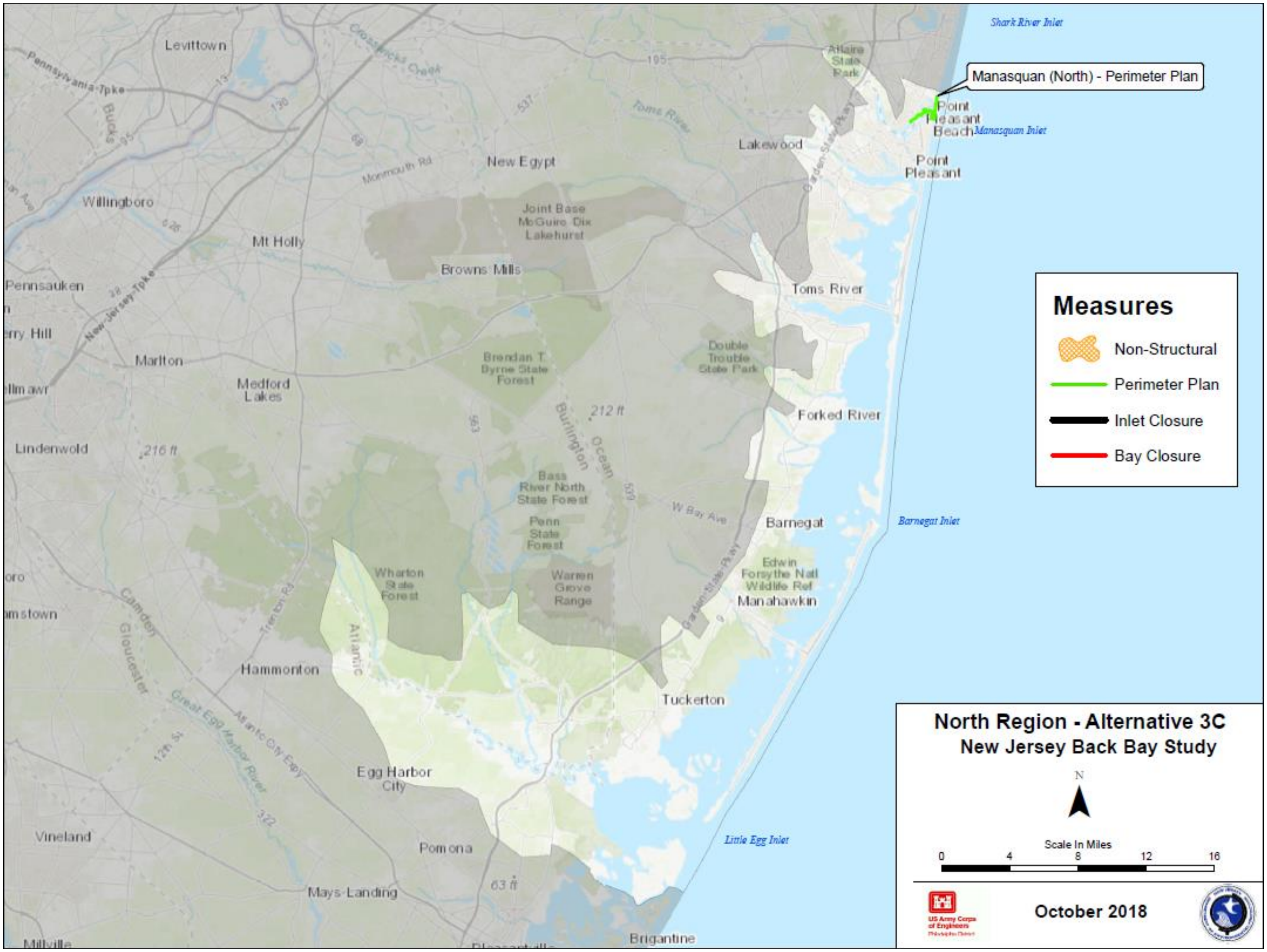
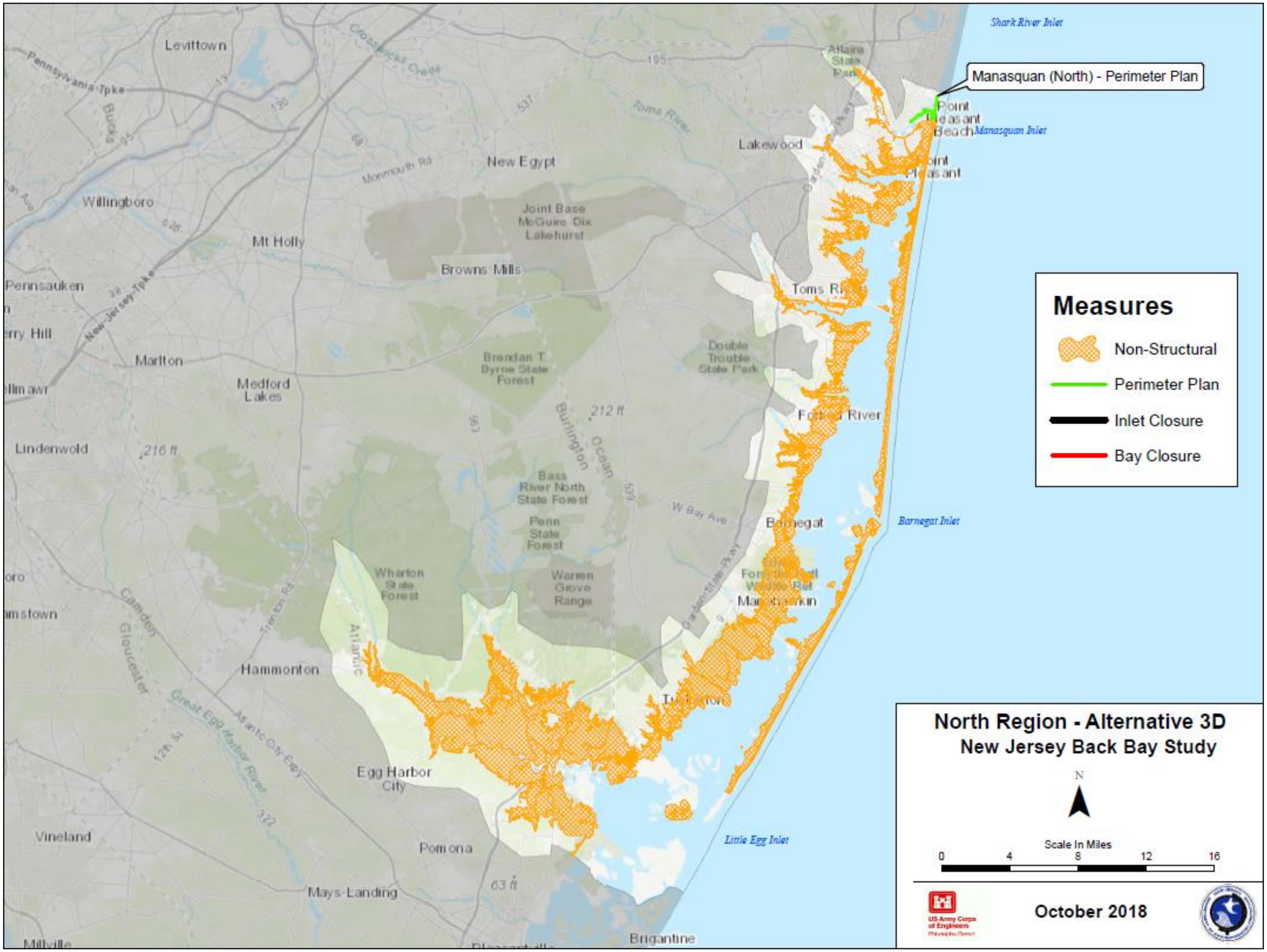
Scale In Miles
0 0.25 0.5 0.75 1
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3A
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
October 2018
US Army Corps of Engineers
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Browns Mills
Pennsauken
Marlton
Medford Lakes
Lindenwold
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
Toms River
Barnegat
Joint Base McGuire Dix Lakehurst
Brendan T. Byrne State Forest
Double Trouble State Park
Bass River North State Forest
Penn State Forest
Wharton State Forest
Warren Grove Range

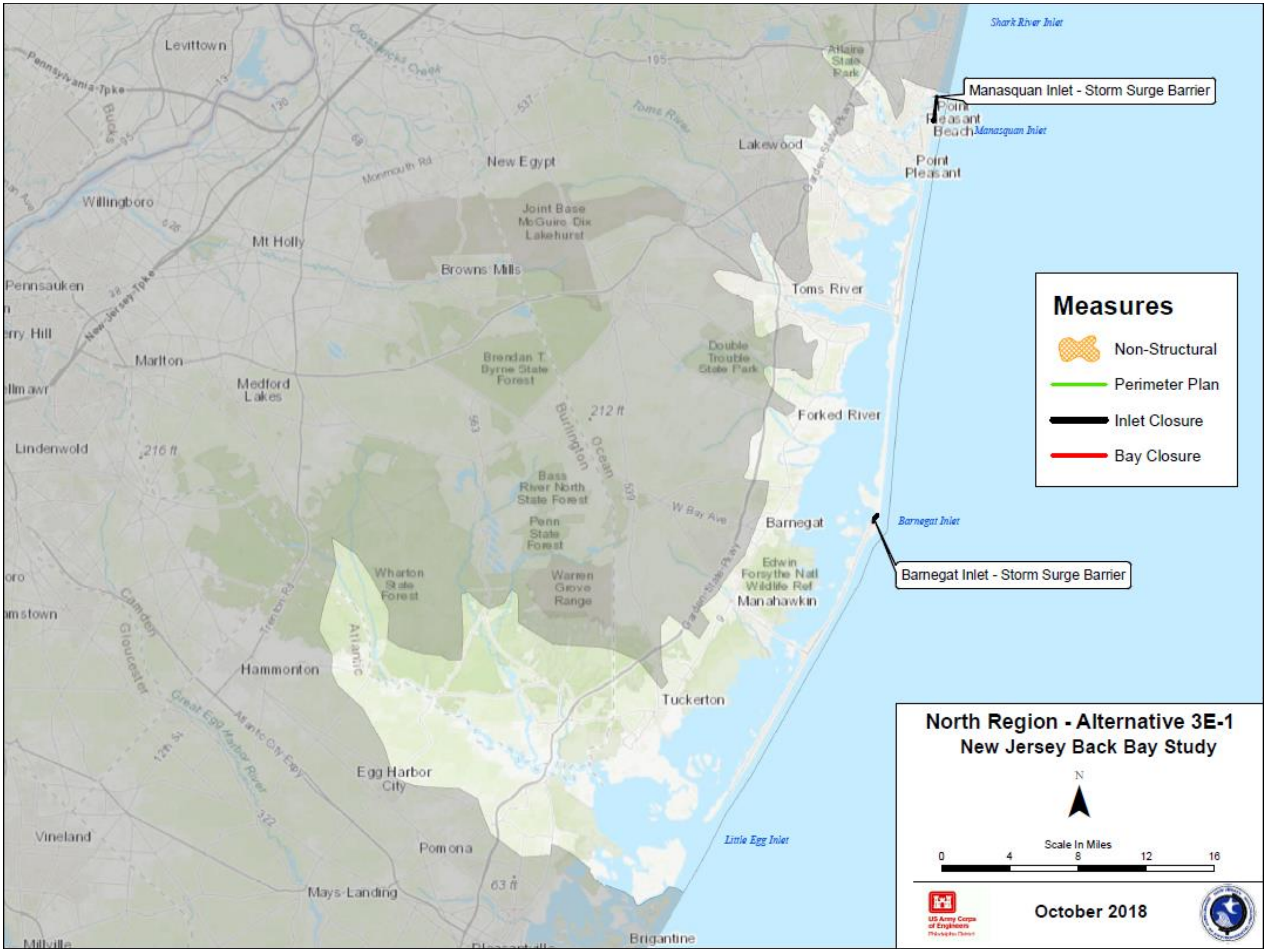


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Manasquan (North) - Perimeter Plan
Island Beach - Perimeter Plan
Long Beach Island - Perimeter Plan
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
North Region - Alternative 3B
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
October 2018


Manasquan (North) - Perimeter Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3C
New Jersey Back Bay Study
Scale In Miles
0 4 8 12 16
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Point Pleasant Beach
Point Pleasant
Lakewood
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Brigantine
Egg Harbor City
Hammonton
Pomona
Mays Landing
Vineland
New Egypt
Browns Mills
Mt Holly
Willingboro
Levittown
Pennsauken
Marlton
Medford Lakes
Lindenwold



Manasquan (North) - Perimeter Plan
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3D
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
US Army Corps of Engineers


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3E-1
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant Beach
Point Pleasant
Joint Base McGuire Dix Lakehurst
Browns Mills
Pennsauken
Marlton
Medford Lakes
Lindenwold
Toms River
Double Trouble State Park
Brendan T Byrne State Forest
Forked River
Bass River North State Forest
Penn State Forest
Barnegat
Wharton State Forest
Warren Grove Range
Edwin Forsythe Natl Wildlife Ref
Manahawkin
Hammonton
Tuckerton
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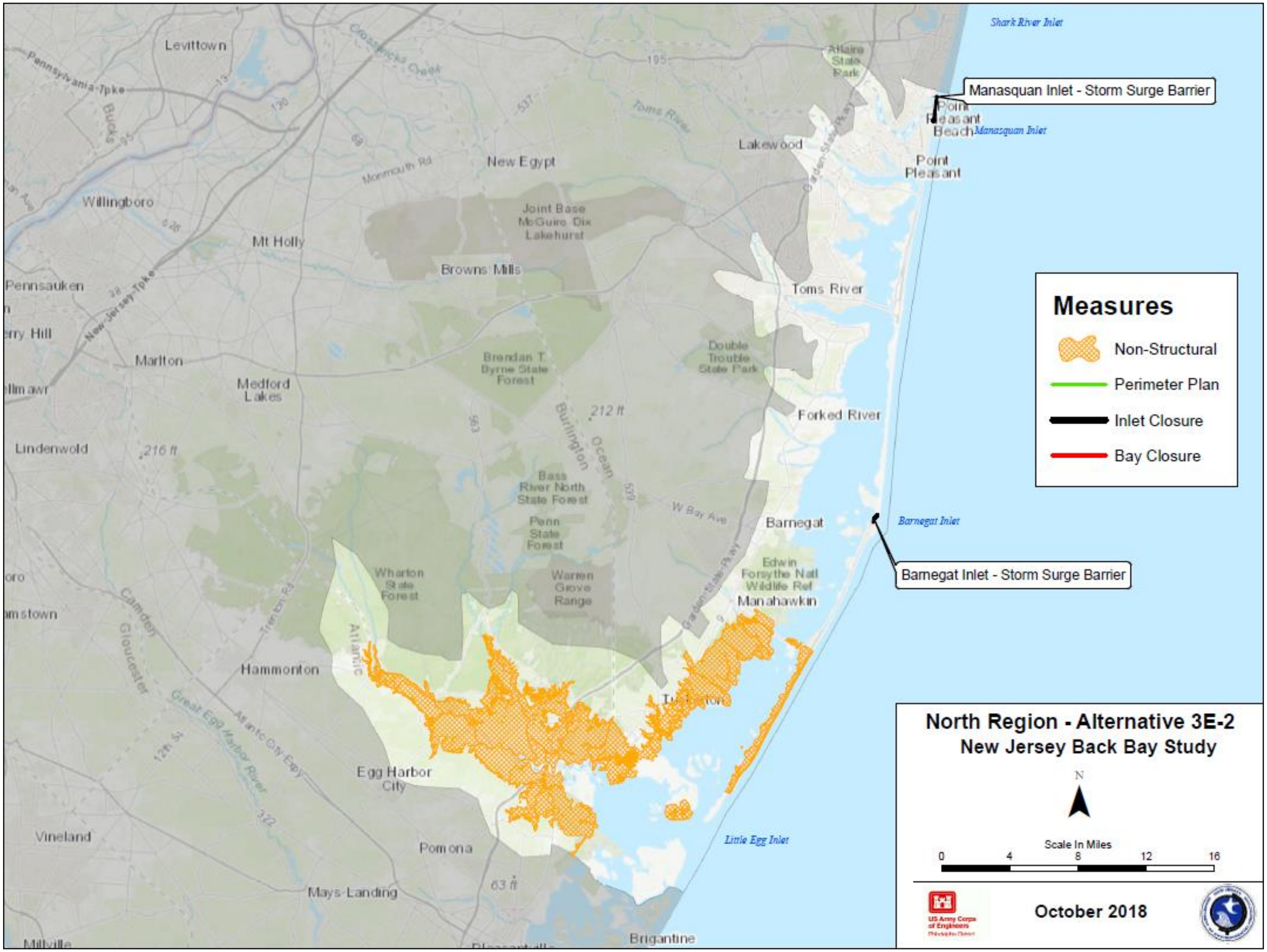
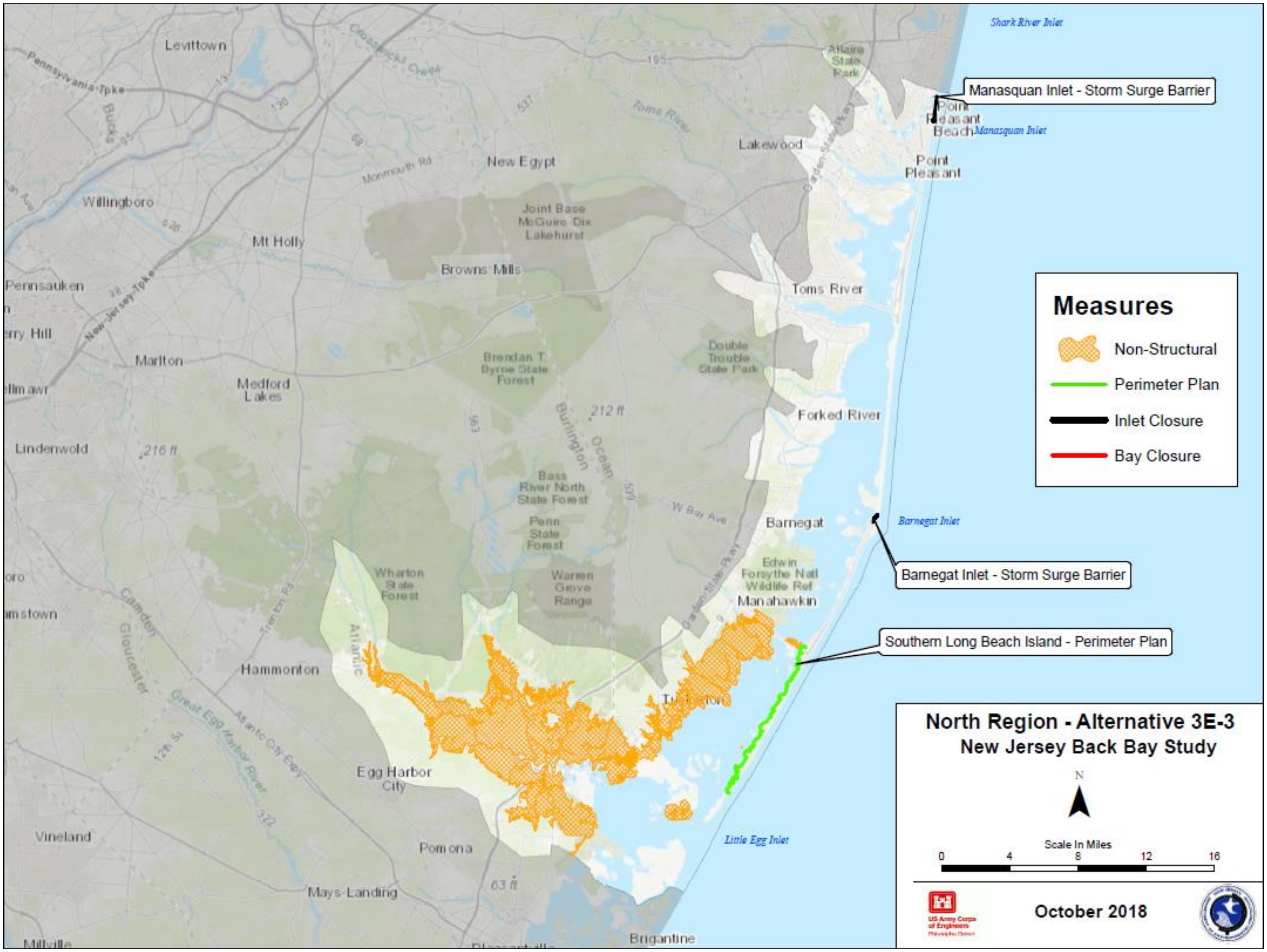
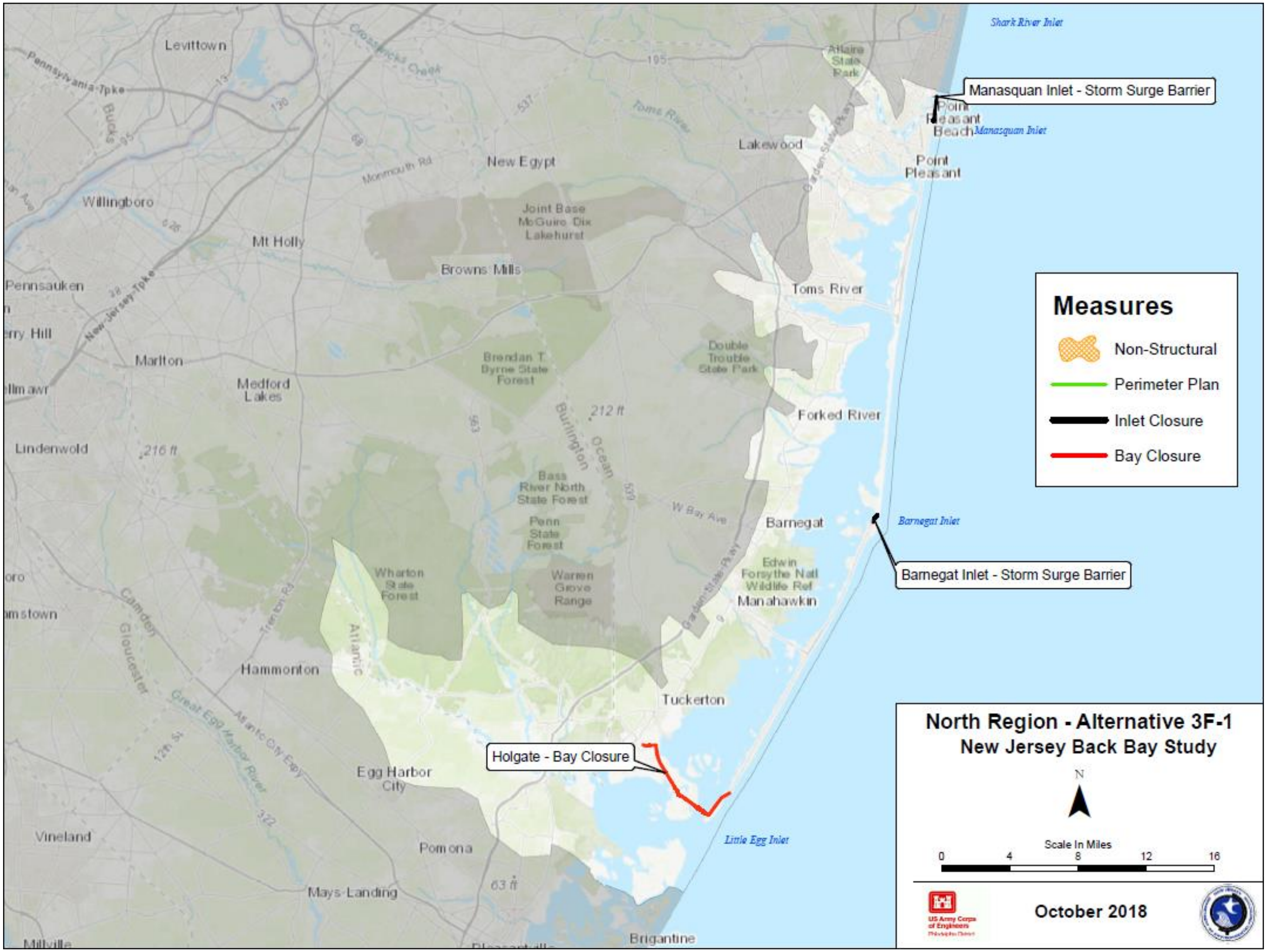
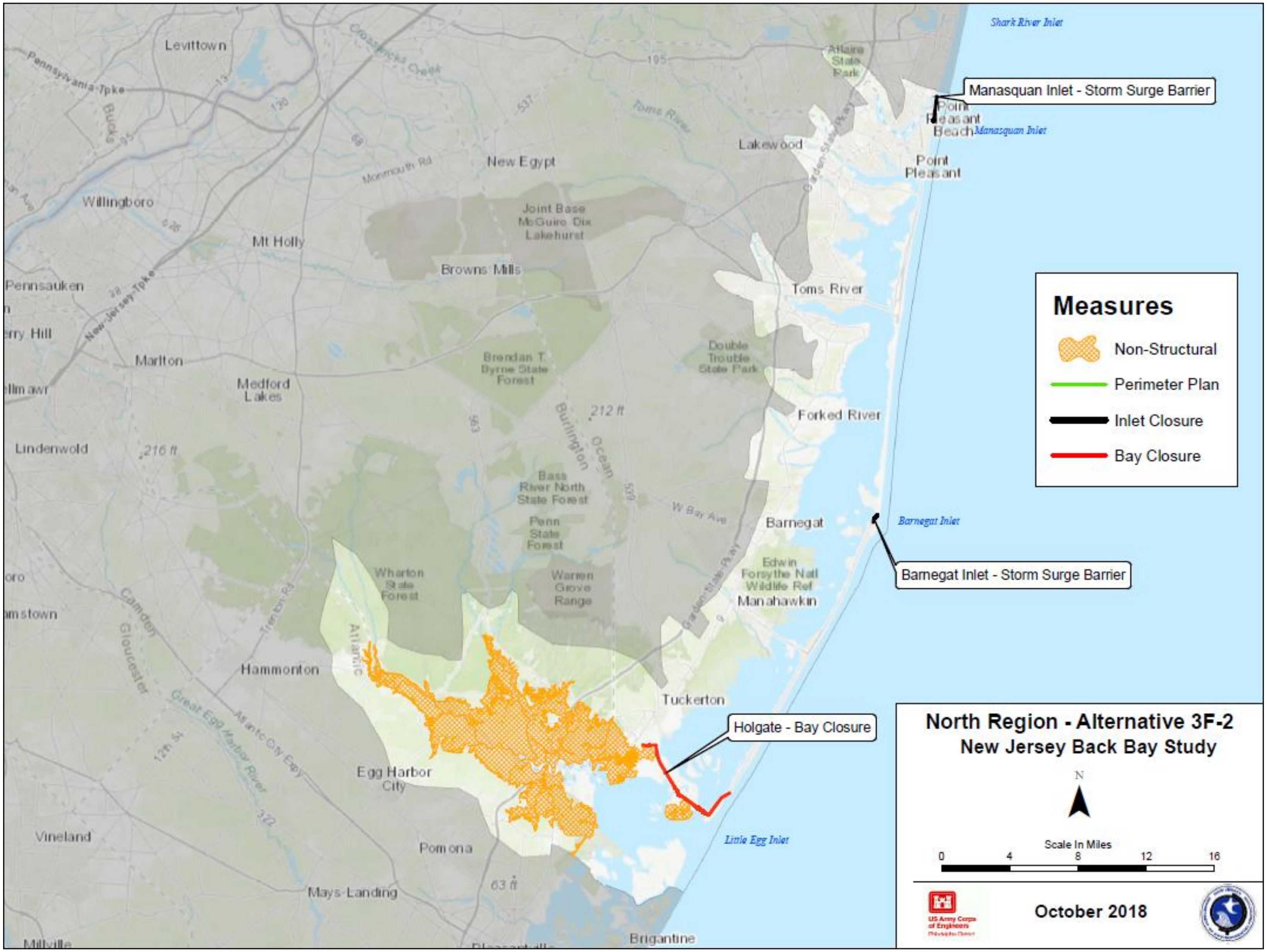
Mays Landing
Brigantine
Millville



Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3E-2
New Jersey Back Bay Study
Scale In Miles
0 4 8 12 16
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant
Point Pleasant Beach
Toms River
Forked River
Barnegat
Manahawkin
Browns Mills
Pennsauken
Marlton
Medford Lakes
Lindenwold
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
Millville


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Southern Long Beach Island - Perimeter Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3E-3
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
Pennsauken
Marlton
Medford Lakes
Lindenwold
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
New Egypt
Browns Mills
Joint Base McGuire Dix Lakehurst
Brendan T. Byrne State Forest
Bass River North State Forest
Penn State Forest
Wharton State Forest
Warren Grove Range
Lakewood
Point Pleasant Beach
Point Pleasant
Toms River
Double Trouble State Park
Forked River
Barnegat
Edwin Forsythe Natl Wildlife Ref
Manahawkin
Allaire State Park


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3F-1
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
Pennsauken
Marlton
Medford Lakes
Lindenwold
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
New Egypt
Browns Mills
Joint Base McGuire Dix Lakehurst
Lakewood
Point Pleasant Beach
Point Pleasant
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Brendan T Byrne State Forest
Wharton State Forest
Bass River North State Forest
Penn State Forest
Warren Grove Range
Double Trouble State Park
Edwin Forsythe Natl Wildlife Ref
Allaire State Park
Millville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Perimeter Plan
Inlet Closure
Bay Closure
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Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant Beach
Point Pleasant
Joint Base McGuire Dix Lakehurst
Browns Mills
Pennsauken
Marlton
Medford Lakes
Toms River
Brendan T. Byrne State Forest
Double Trouble State Park
Forked River
Lindenwold
Bass River North State Forest
Penn State Forest
Barnegat
Wharton State Forest
Warren Grove Range
Edwin Forsythe Natl Wildlife Ref
Manahawkin
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
Millville
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New Jersey Back Bay Study
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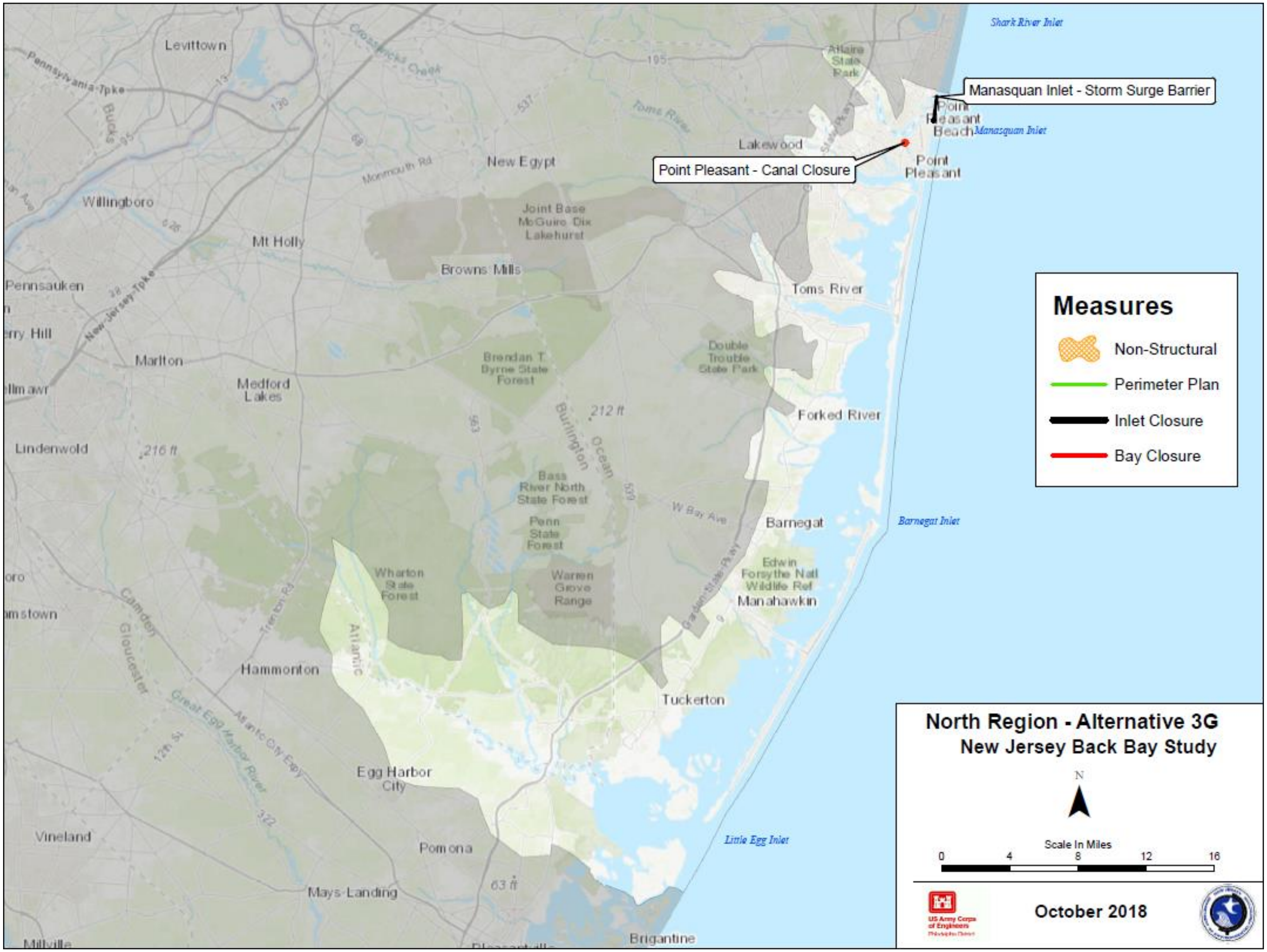
8
12
16
October 2018
US Army Corps of Engineers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Bay Closure
North Region - Alternative 3G
New Jersey Back Bay Study
Scale In Miles
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October 2018
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant Beach
Point Pleasant
Joint Base McGuire Dix Lakehurst
Browns Mills
Toms River
Pennsauken
Marlton
Medford Lakes
Brendan T Byrne State Forest
Double Trouble State Park
Forked River
Lindenwold
Bass River North State Forest
Penn State Forest
Barnegat
Wharton State Forest
Warren Grove Range
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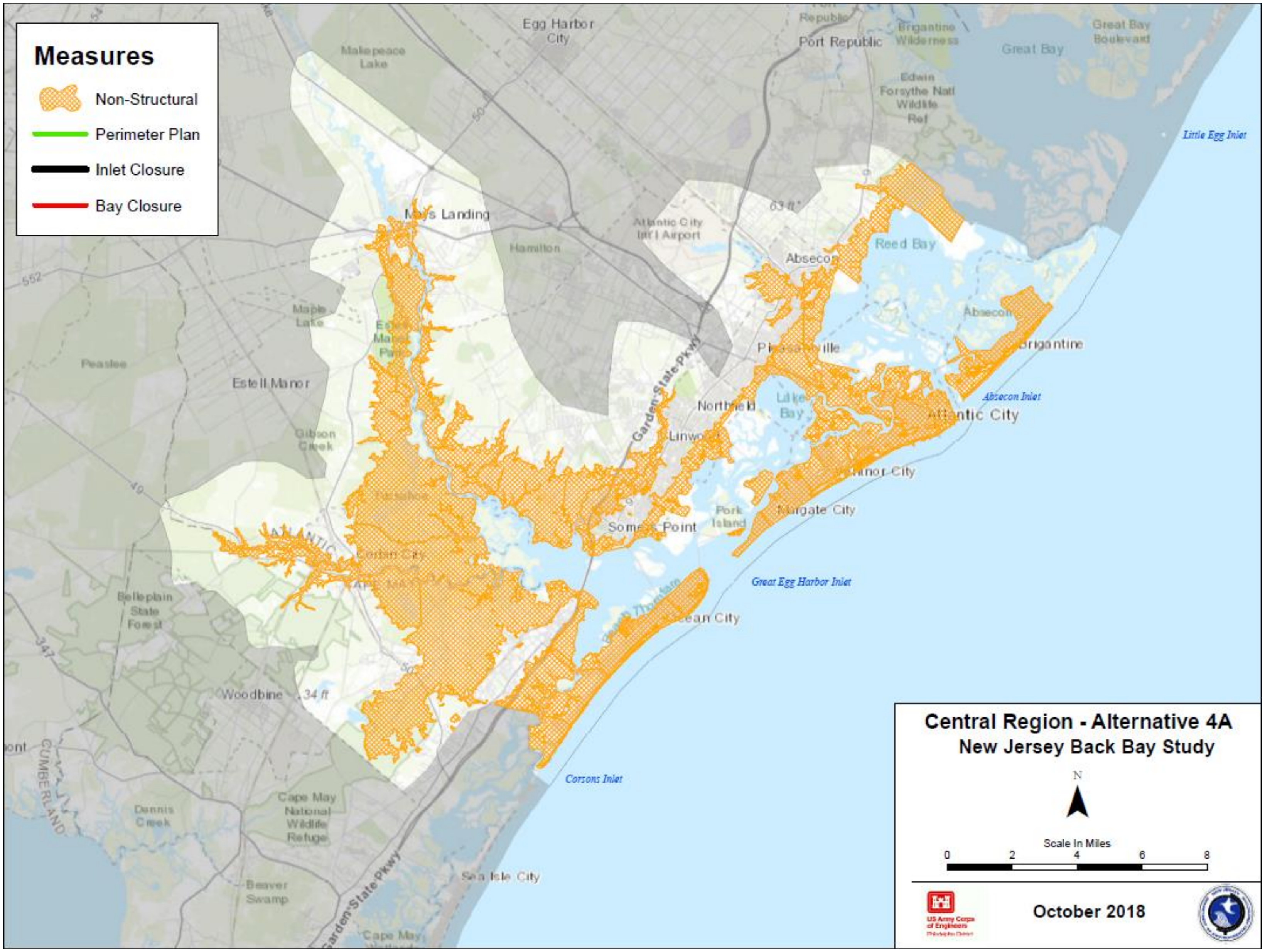
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October 2018
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Port Republic
Great Bay
Mays Landing
Absecon
Reed Bay
Brigantine
Absecon Inlet
Atlantic City
Northfield
Linwood
Lake Bay
Ventnor City
Margate City
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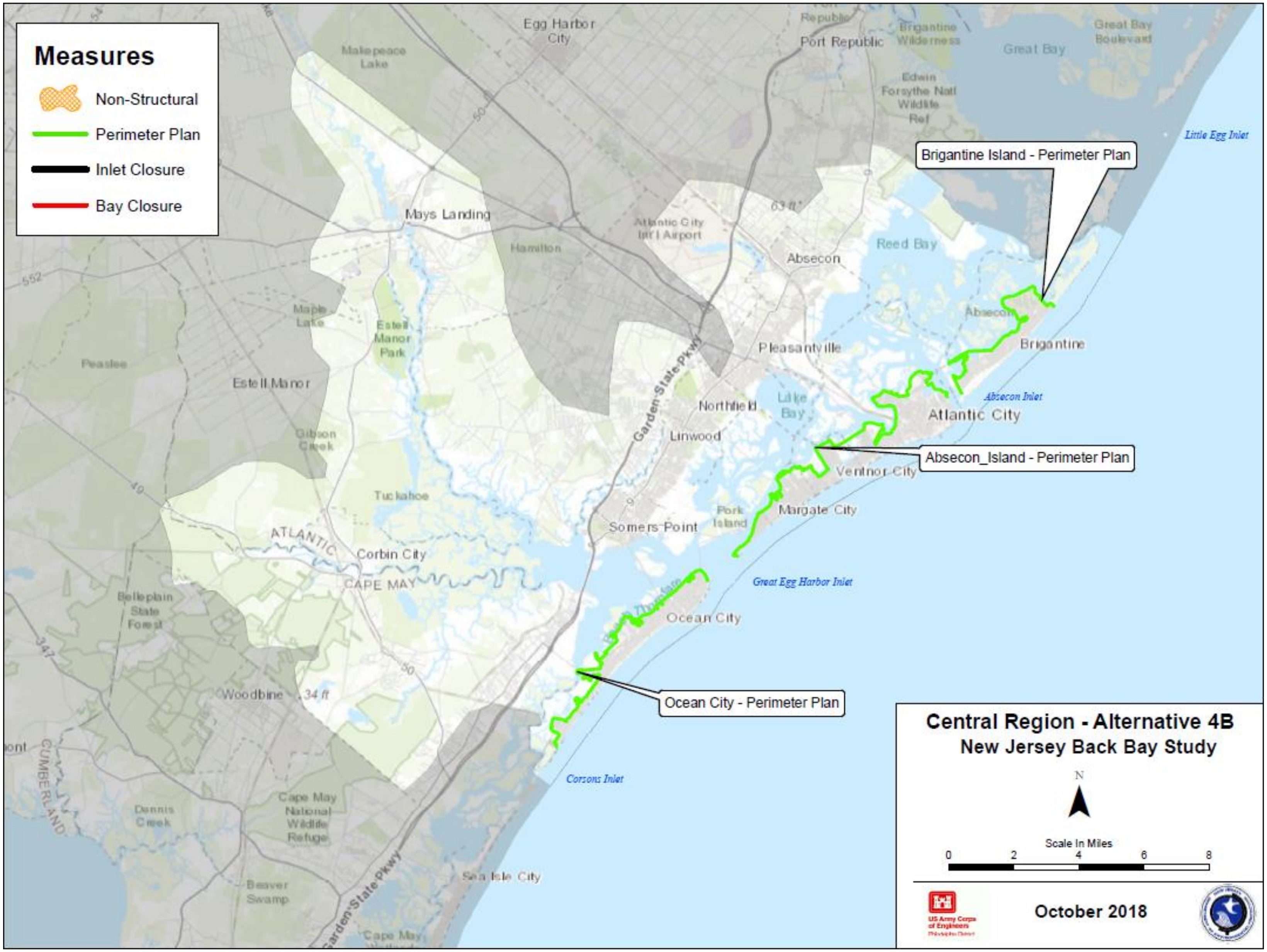
Ocean City
Estell Manor
Woodbine
Corsons Inlet
Sea Isle City
Little Egg Inlet
Garden State Pkwy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Ocean City - Perimeter Plan
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New Jersey Back Bay Study
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Scale In Miles
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October 2018
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Absecon Inlet
Atlantic City
Northfield
Linwood
Lake Bay
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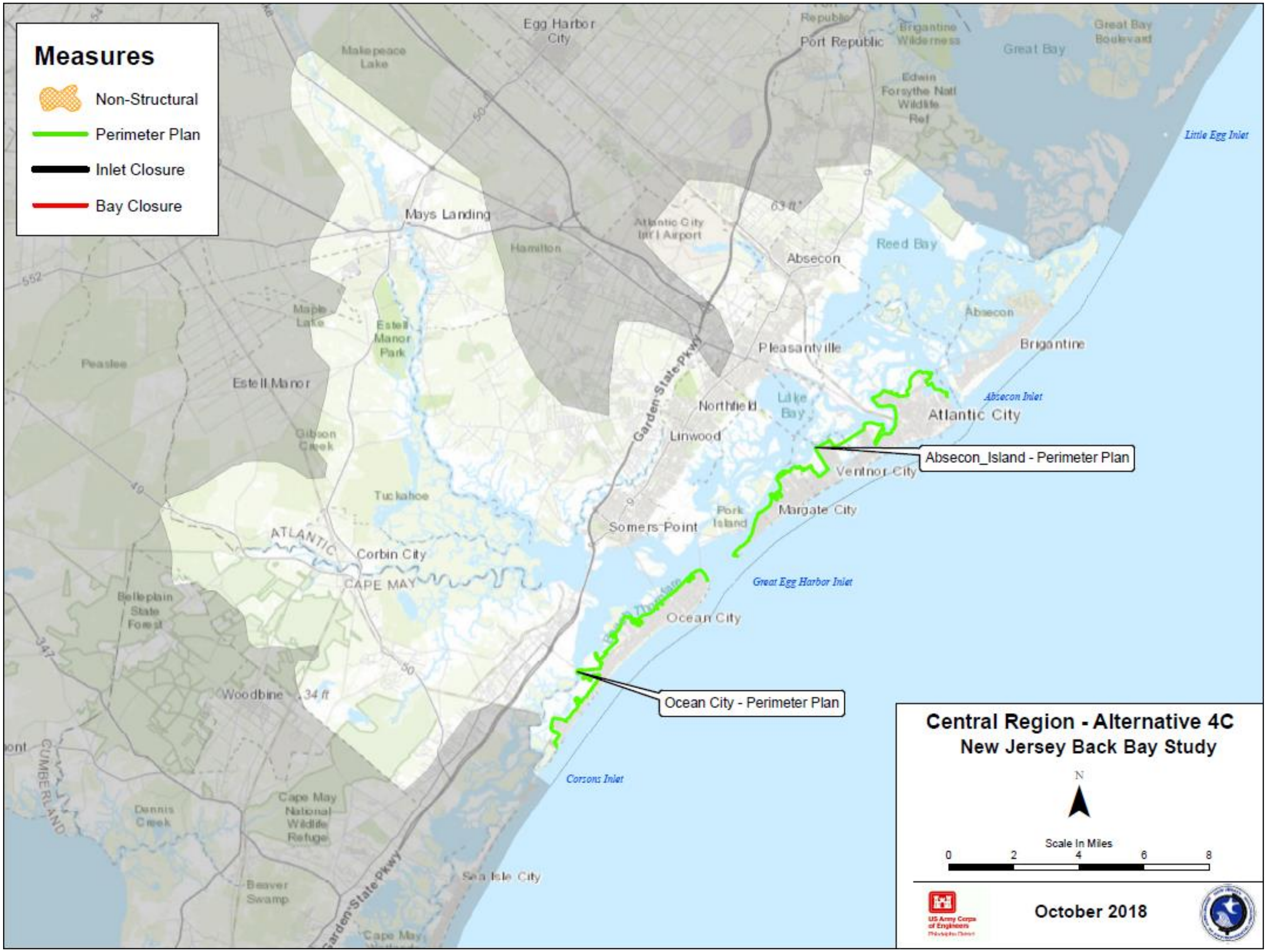
Ocean City
Woodbine
Corsons Inlet
Sea Isle City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Ocean City - Perimeter Plan
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New Jersey Back Bay Study
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Scale In Miles
0 2 4 6 8
October 2018
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Absecon Inlet
Atlantic City
Northfield
Linwood
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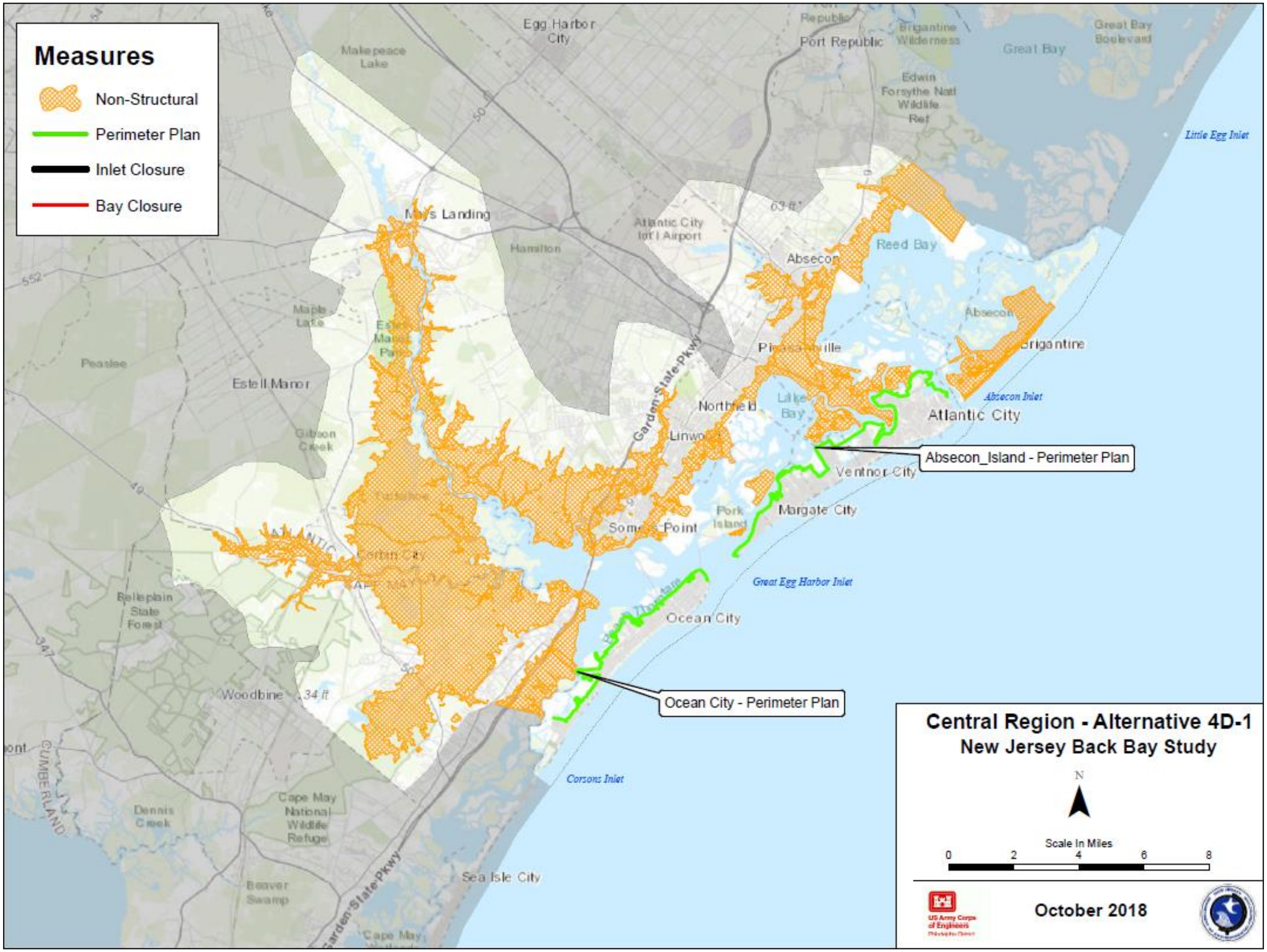
Sea Isle City
Garden State Pkwy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Scale In Miles
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4
6
8
October 2018
Mays Landing
Egg Harbor City
Port Republic
Great Bay
Reed Bay
Absecon
Brigantine
Atlantic City
Absecon Inlet
Little Egg Inlet
Ventnor City
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Sea Isle City
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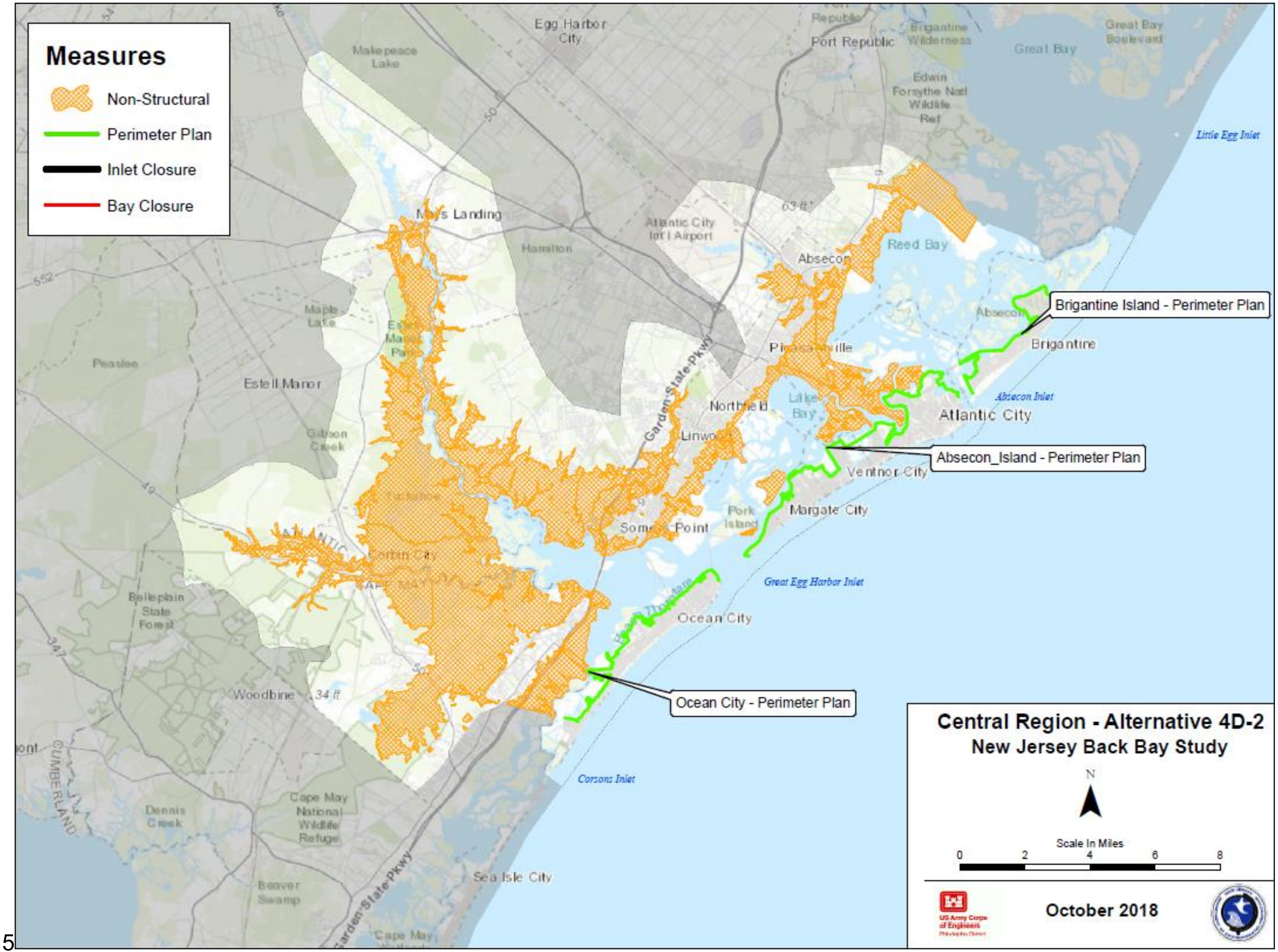
Woodbine
Garden State Pkwy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Absecon_Island - Perimeter Plan
Ocean City - Perimeter Plan
Central Region - Alternative 4D-2
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
October 2018
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Mays Landing
Absecon
Reed Bay
Brigantine
Absecon Inlet
Atlantic City
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Woodbine
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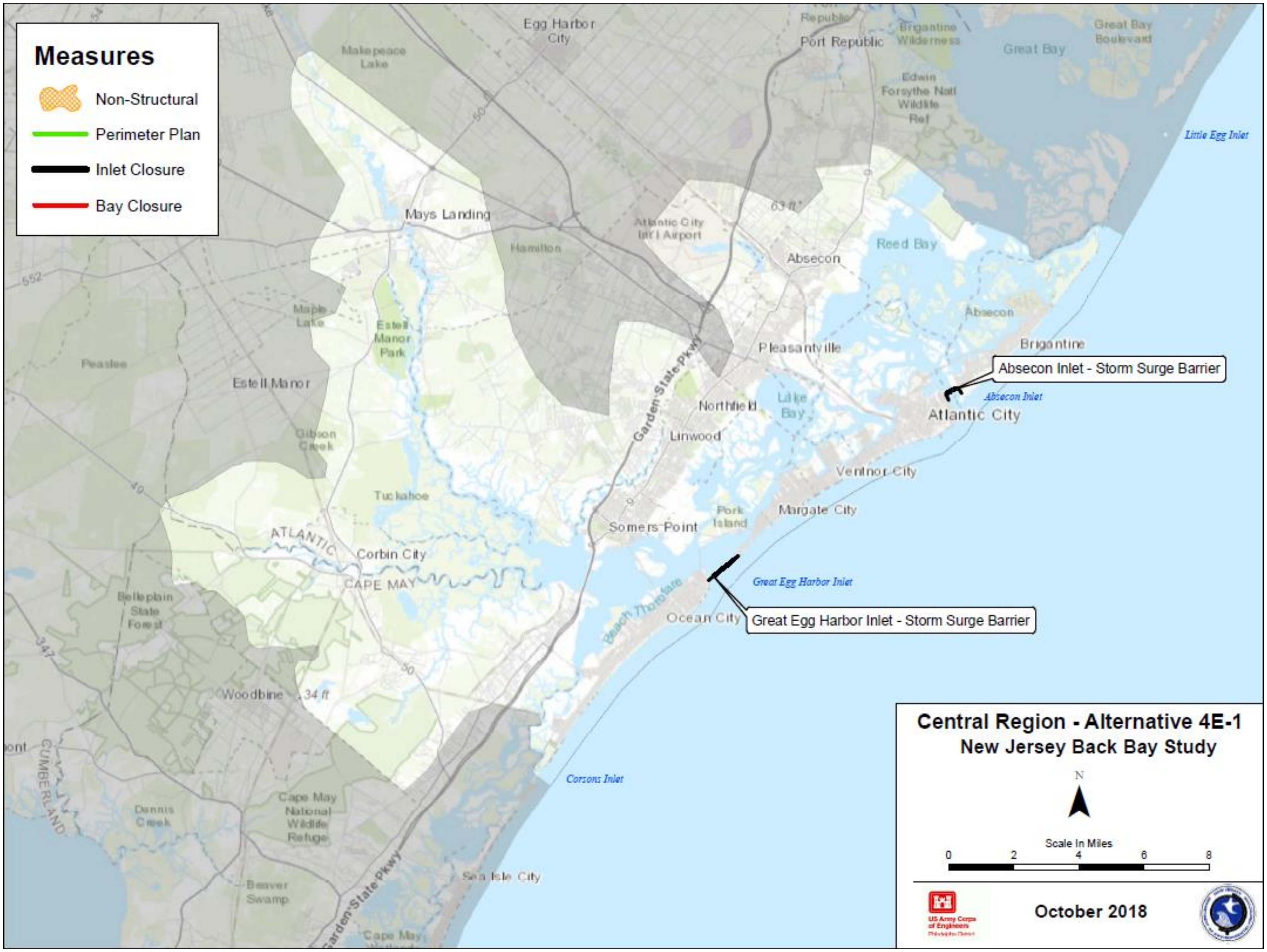
Sea Isle City

5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Bay Closure
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Great Egg Harbor Inlet - Storm Surge Barrier
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Egg Harbor City
Port Republic
Great Bay
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Northfield
Linwood
Atlantic City
Ventnor City
Margate City
Somers Point
Ocean City
Estell Manor
Tuckahoe
Corbin City
Woodbine
Sea Isle City
Garden State Pkwy
Central Region - Alternative 4E-1
New Jersey Back Bay Study
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Scale In Miles
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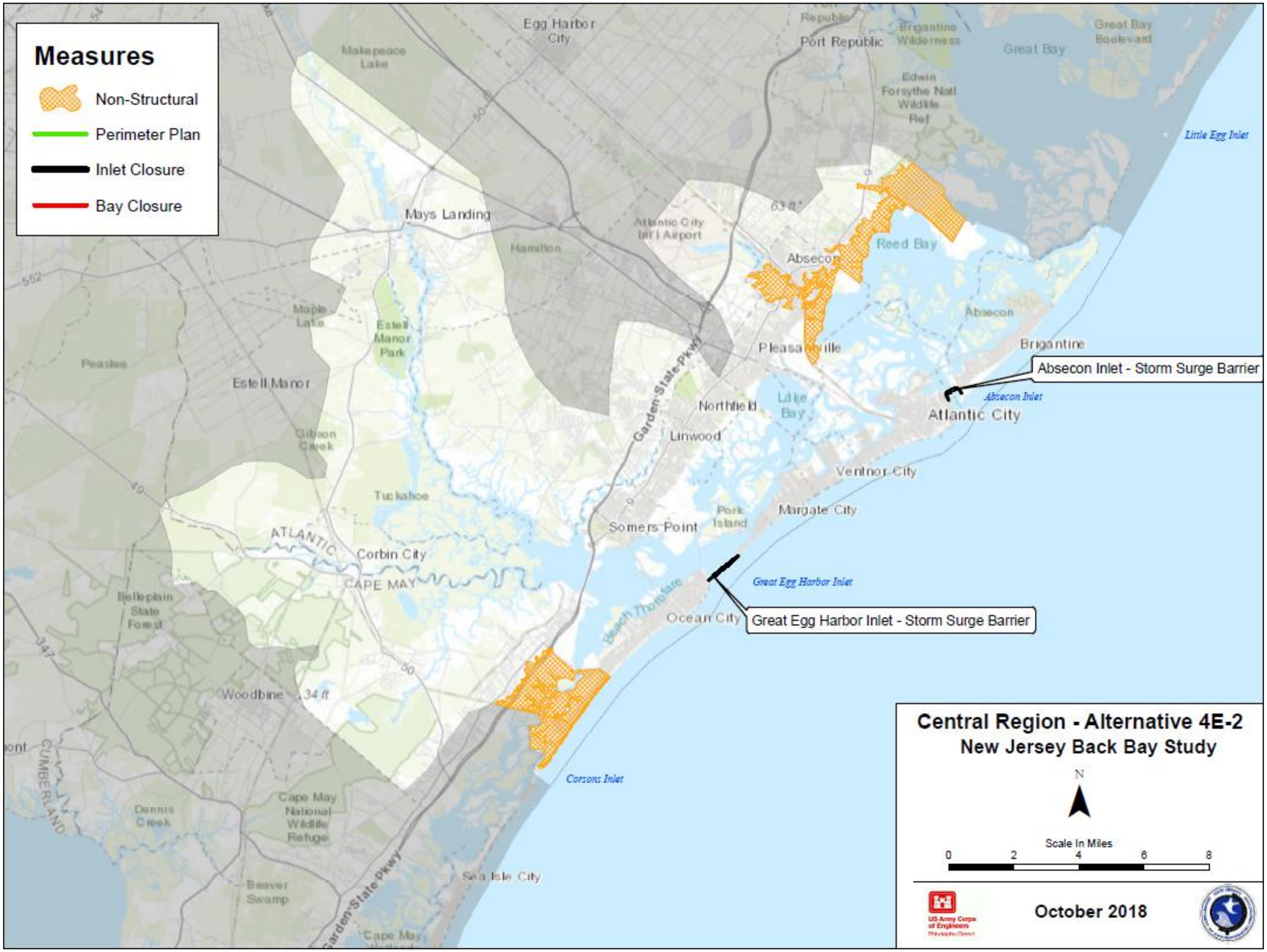
October 2018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Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4E-2
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
October 2018
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Mays Landing
Absecon
Reed Bay
Pleasantville
Brigantine
Absecon Inlet
Atlantic City
Northfield
Linwood
Estell Manor
Tuckahoe
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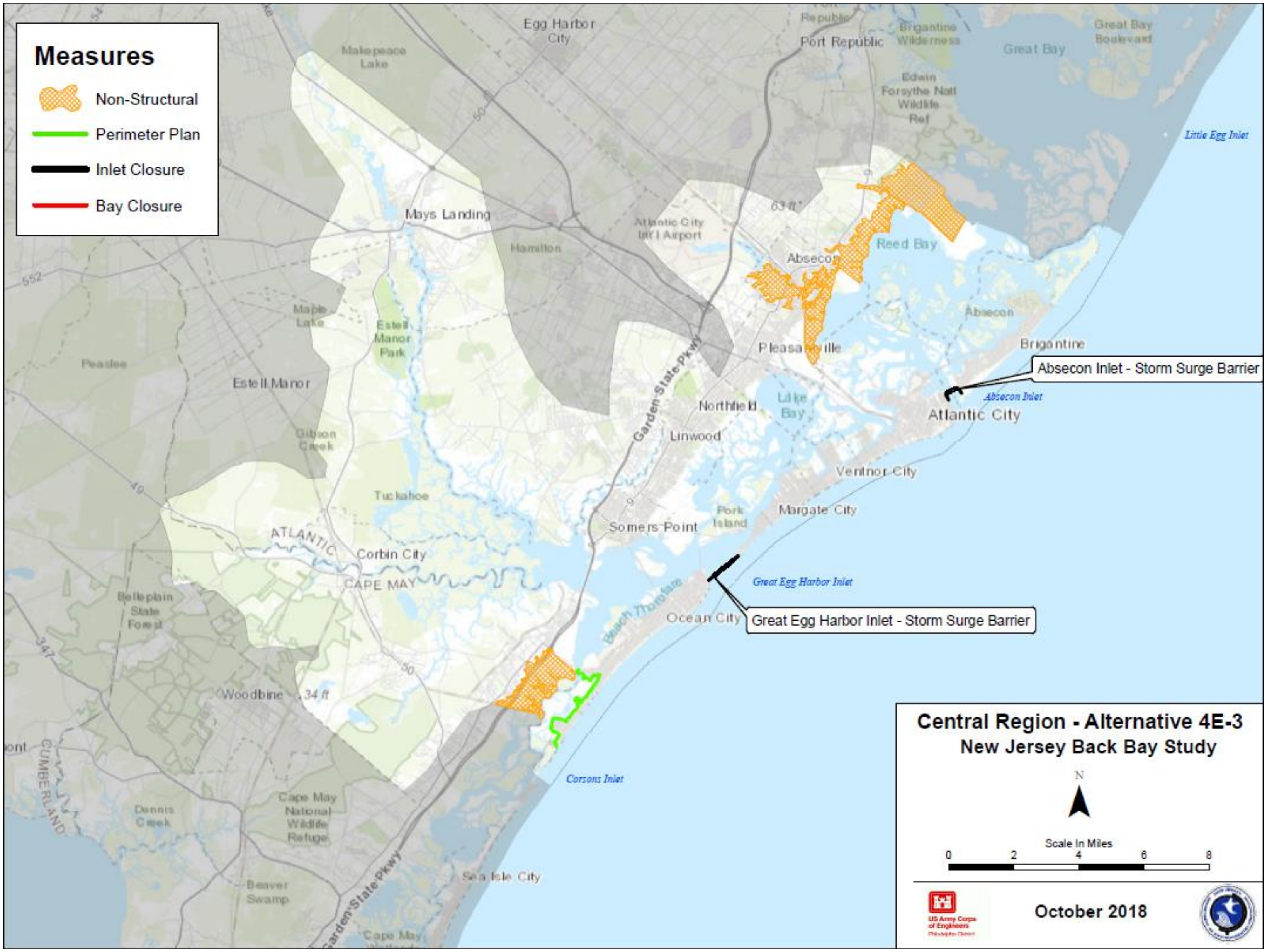
Sea Isle City
Garden State Pkwy



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Great Egg Harbor Inlet - Storm Surge Barrier
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New Jersey Back Bay Study
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Scale In Miles
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October 2018
Mays Landing
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Reed Bay
Absecon
Pleasantville
Brigantine
Absecon Inlet
Atlantic City
Northfield
Linwood
Lake Bay
Ventnor City
Margate City
Somers Point
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Corbin City
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Woodbine
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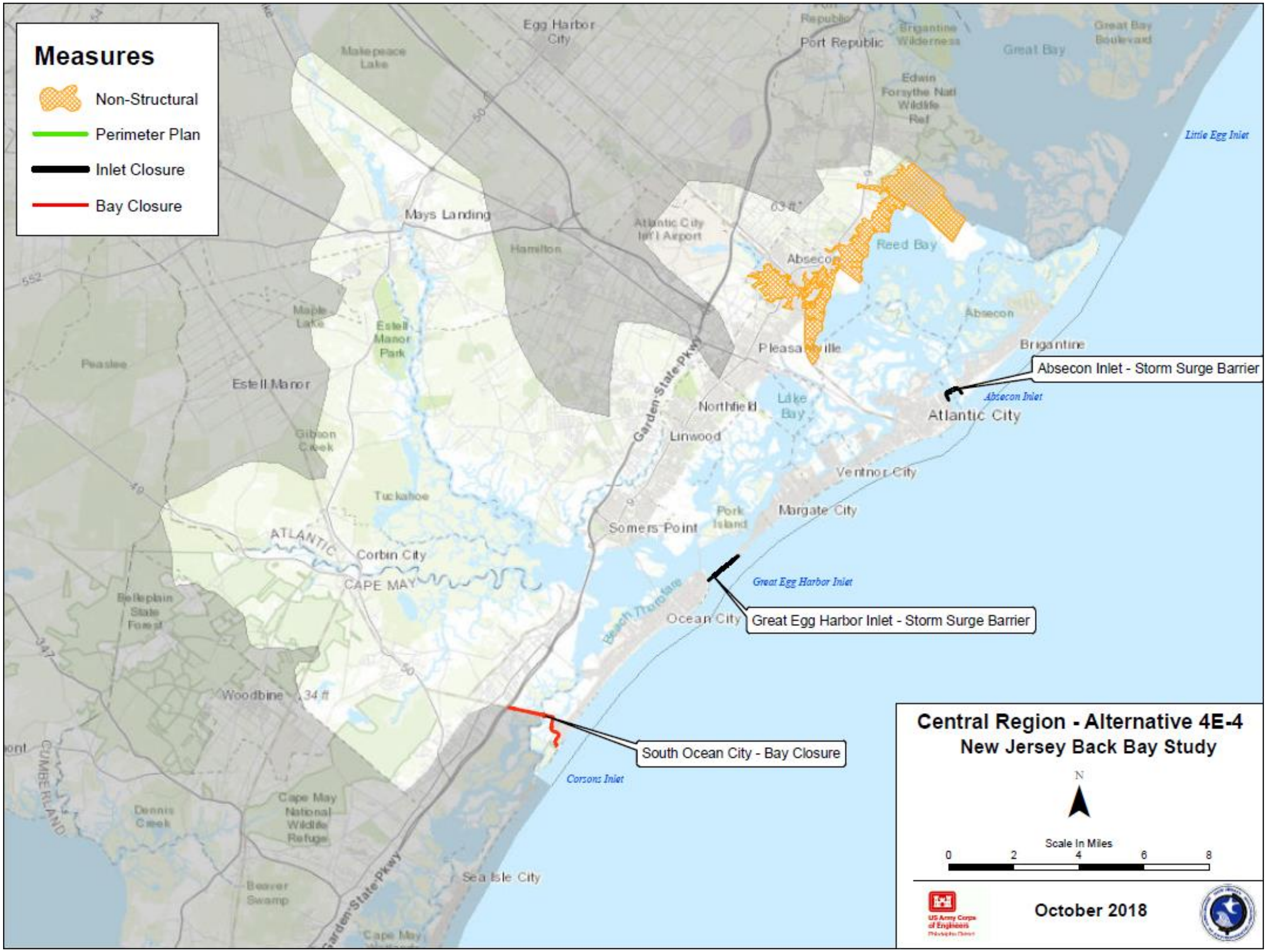
Sea Isle City
Garden State Pkwy



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Bay Closure
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Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Egg Harbor City
Port Republic
Great Bay
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Atlantic City
Northfield
Linwood
Lake Bay
Ventnor City
Margate City
Somers Point
Ocean City
Estell Manor
Corbin City
Tuckahoe
Woodbine
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Scale In Miles
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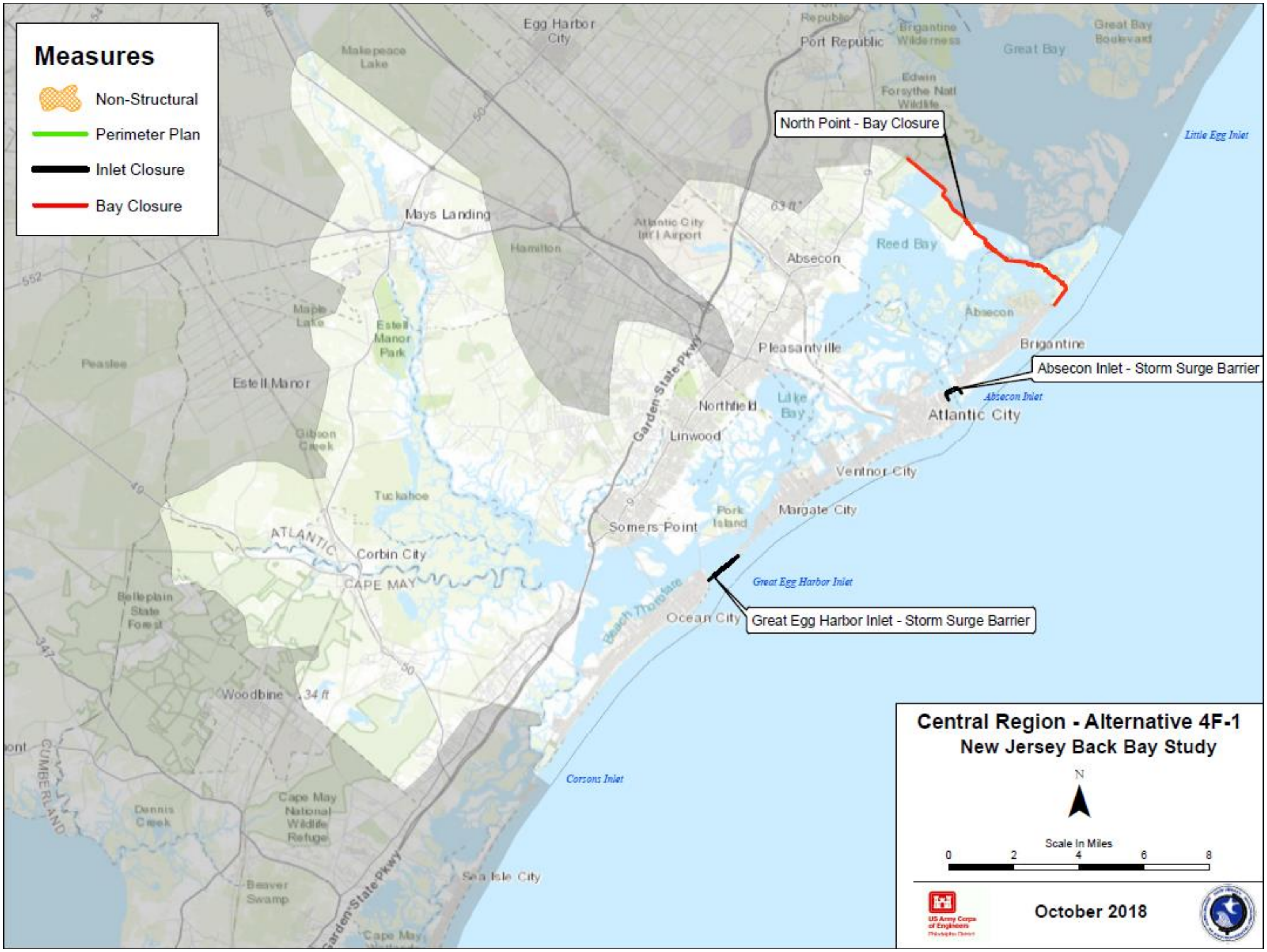
October 2018



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Bay Closure
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Great Egg Harbor Inlet - Storm Surge Barrier
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Corsons Inlet
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Port Republic
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Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Atlantic City
Northfield
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Lake Bay
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
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Estell Manor
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Central Region - Alternative 4F-1
New Jersey Back Bay Study
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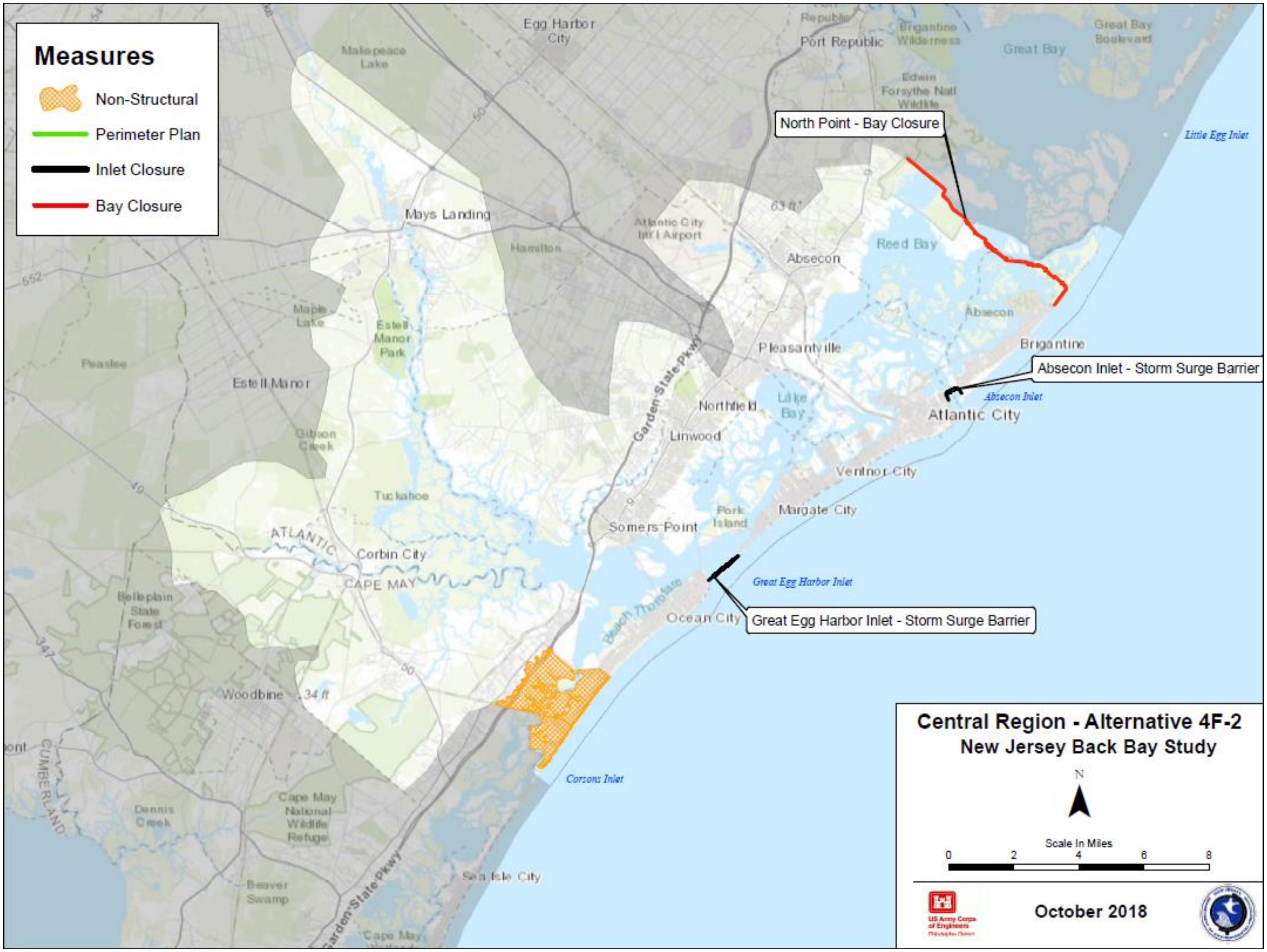
October 2018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Central Region - Alternative 4F-2
New Jersey Back Bay Study
N
Scale In Miles
0
2
4
6
8
October 2018
Egg Harbor City
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Great Bay
Little Egg Inlet
Mays Landing
Absecon
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Brigantine
Pleasantville
Northfield
Linwood
Atlantic City
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Ventnor City
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Sea Isle City
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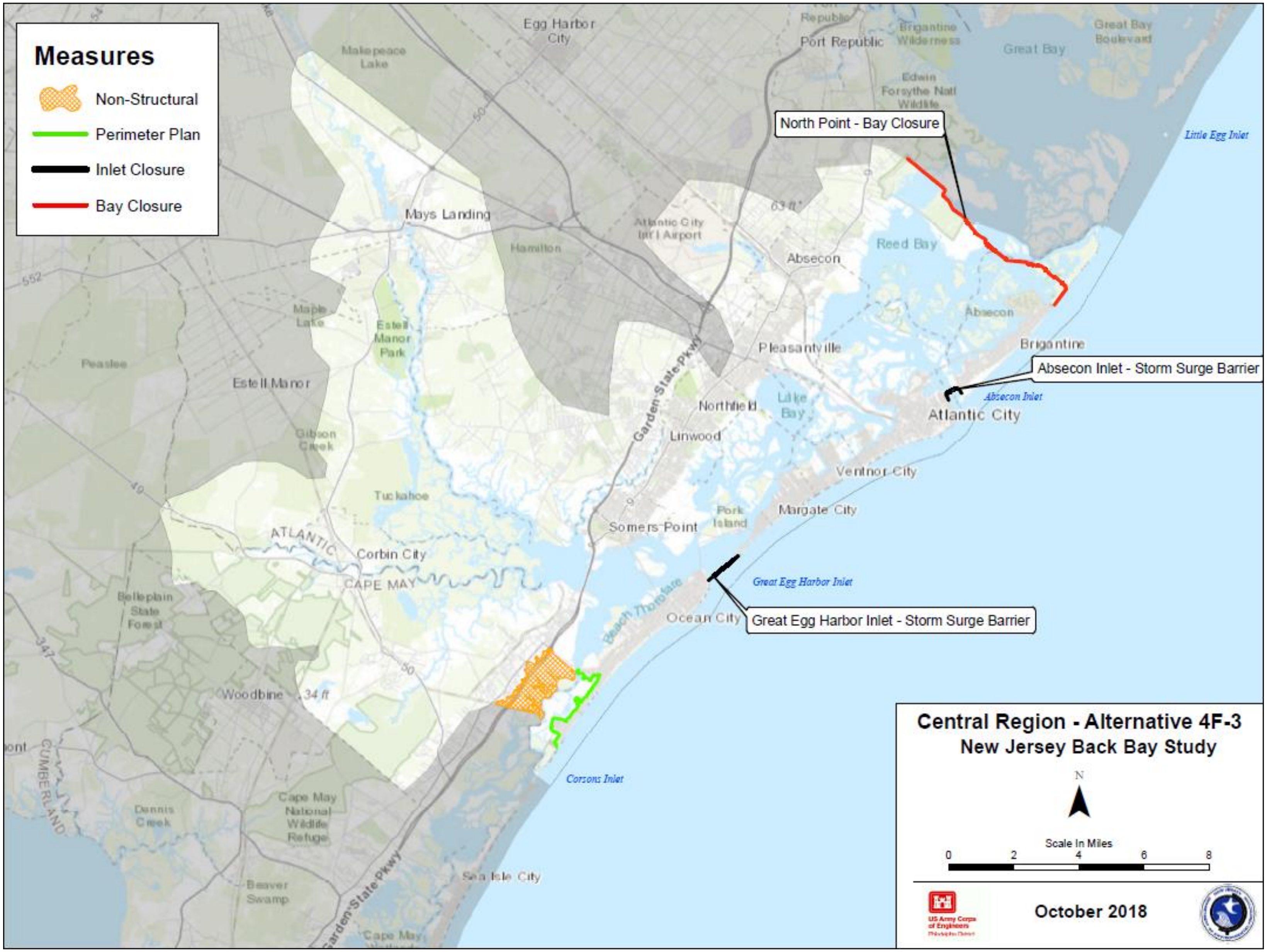
Tuckahoe
Garden State Pkwy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Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4F-3
New Jersey Back Bay Study
Scale In Miles
0
2
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8
October 2018
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Port Republic
Great Bay
Little Egg Inlet
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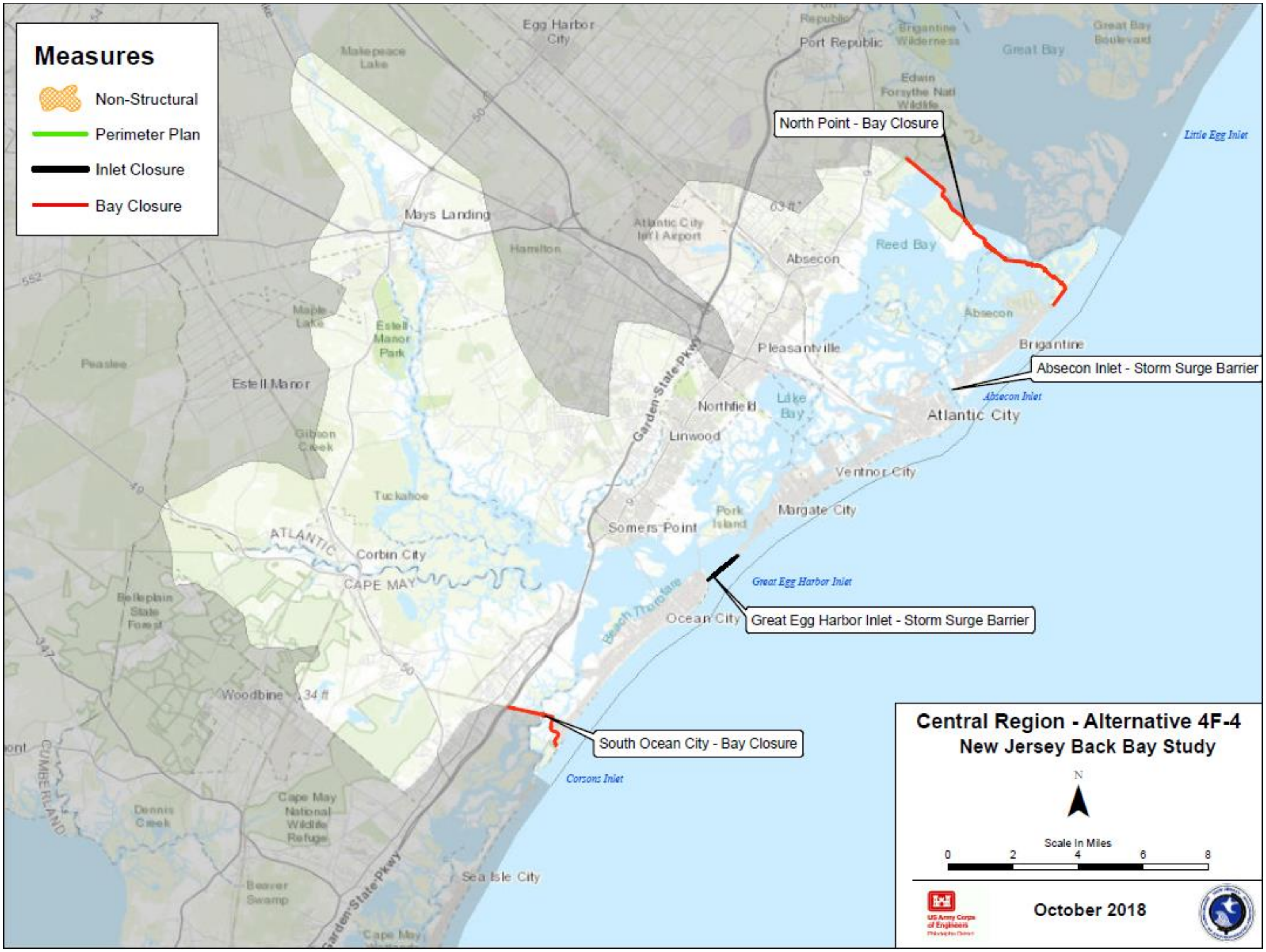

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North Point - Bay Closure
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Great Egg Harbor Inlet - Storm Surge Barrier
South Ocean City - Bay Closure
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet
Mays Landing
Estell Manor
Atlantic City
Brigantine
Pleasantville
Northfield
Linwood
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
Tuckahoe
Woodbine
Sea Isle City
Egg Harbor City
Port Republic
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Garden State Pkwy
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New Jersey Back Bay Study
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Scale In Miles
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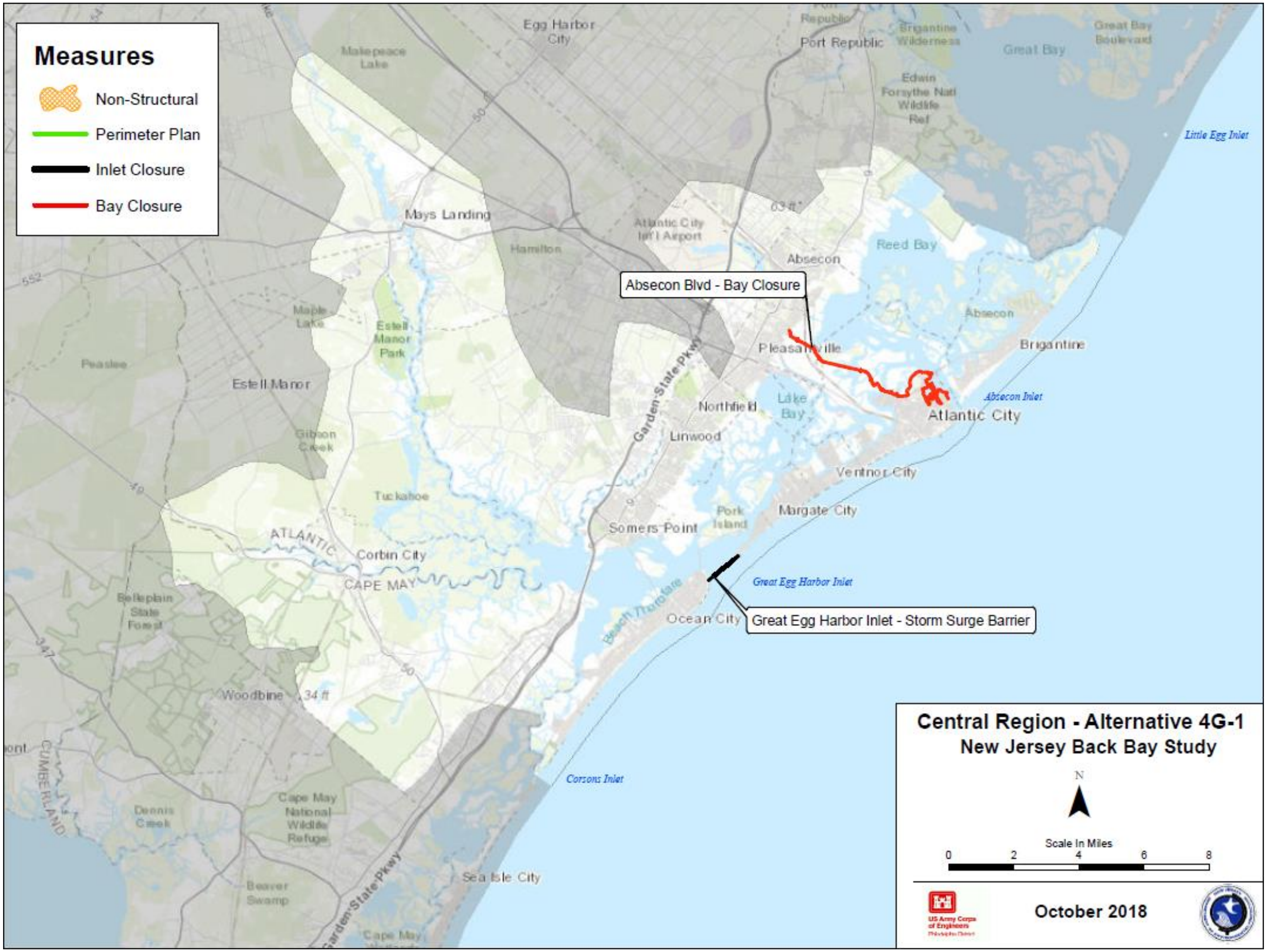
October 2018



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Little Egg Inlet
Corsons Inlet
Atlantic City
Brigantine
Ventnor City
Margate City
Ocean City
Somers Point
Linwood
Northfield
Pleasantville
Absecon
Mays Landing
Estell Manor
Corbin City
Tuckahoe
Woodbine
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Port Republic
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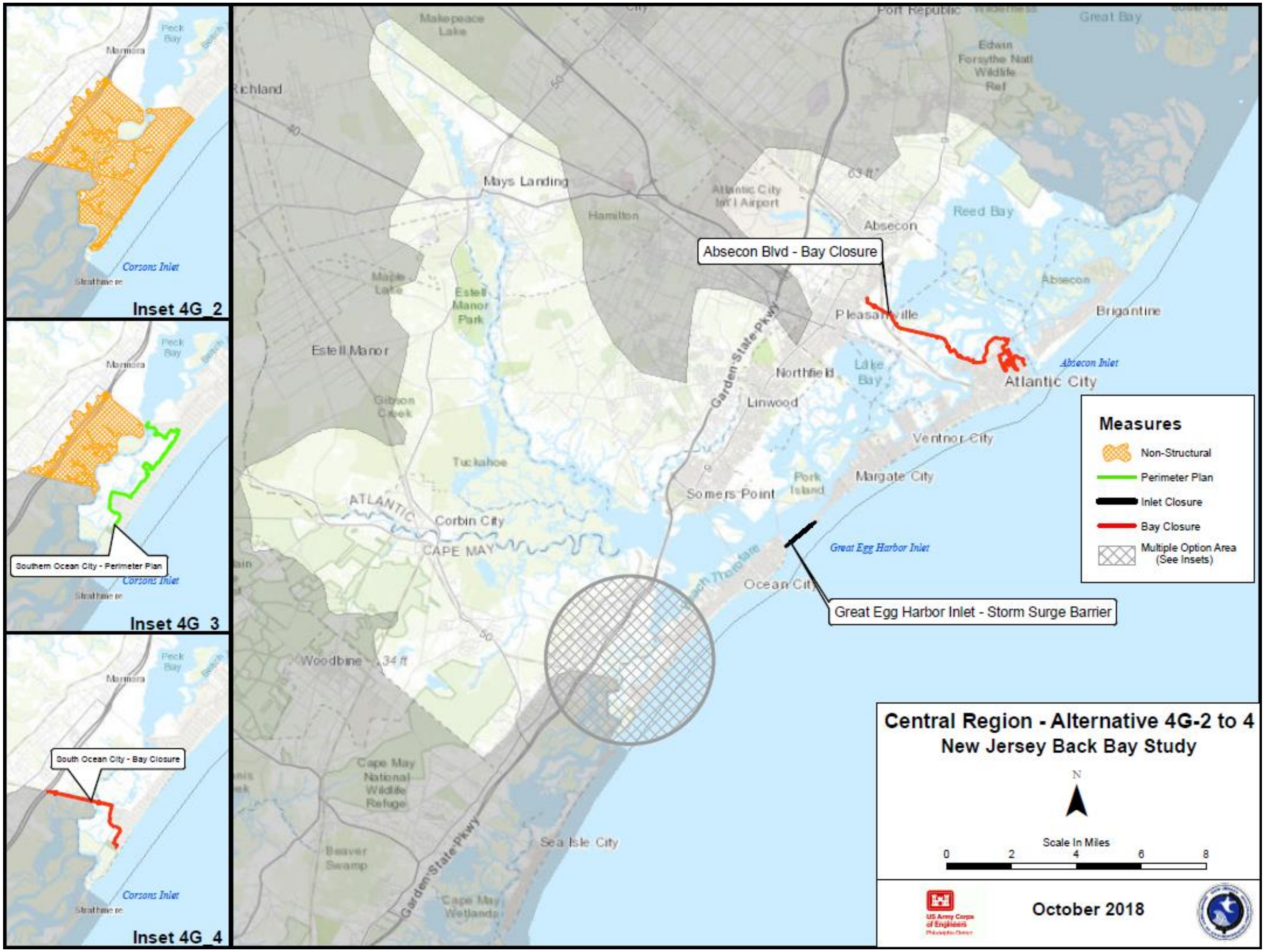
October 2018



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Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Great Egg Harbor Inlet
Absecon Inlet
Atlantic City
Brigantine
Pleasantville
Absecon
Reed Bay
Northfield
Linwood
Somers Point
Margate City
Ventnor City
Ocean City
Sea Isle City
Mays Landing
Estell Manor
Tuckahoe
Corbin City
Woodbine
Richland
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Multiple Option Area (See Insets)
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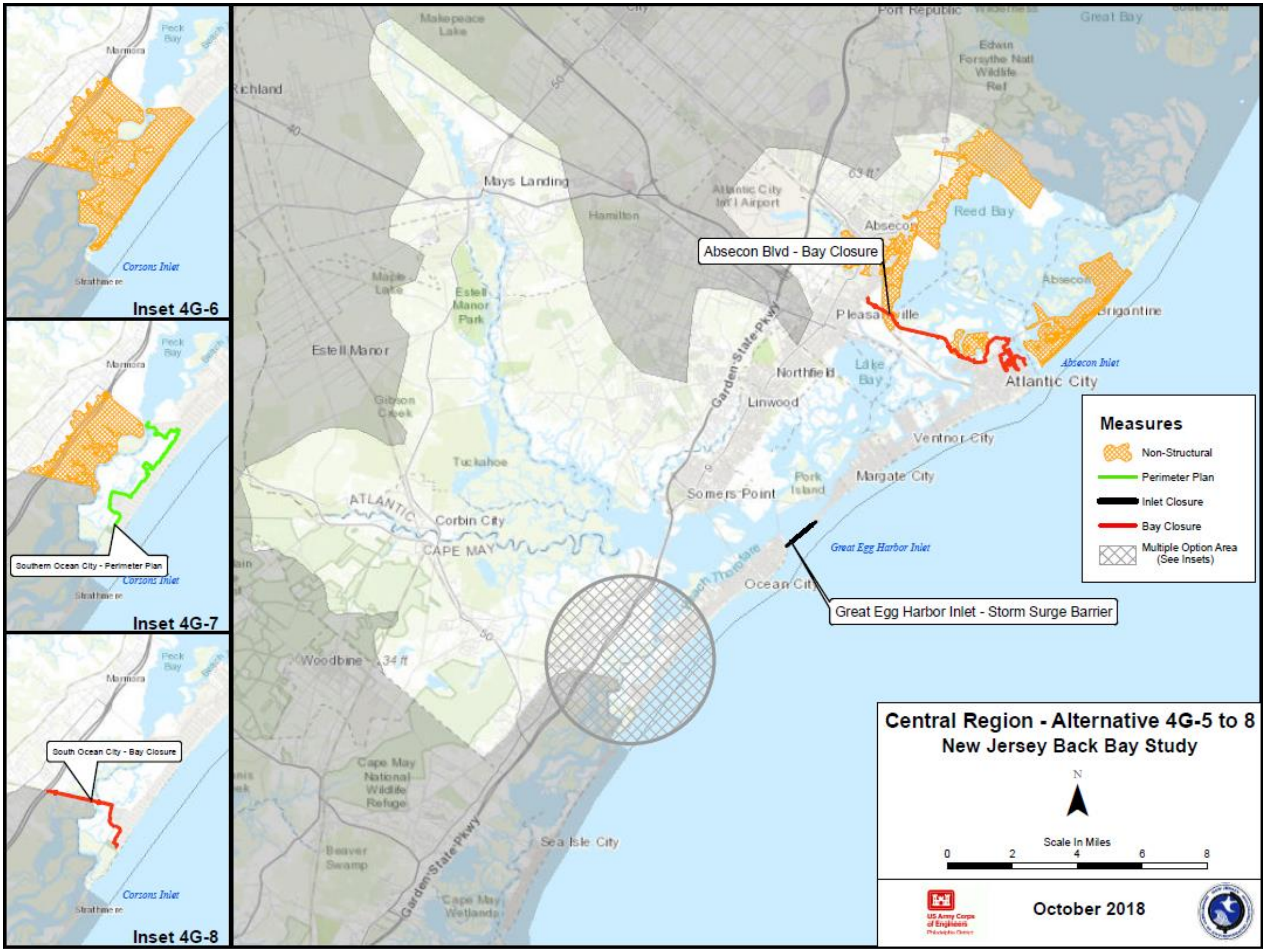
October 2018
US Army Corps of Engineers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Perimeter Plan
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Bay Closure
Multiple Option Area (See Insets)
Scale In Miles
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4
6
8
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Inset 4G-6
Inset 4G-7
Southern Ocean City - Perimeter Plan
Inset 4G-8
South Ocean City - Bay Closure
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Great Egg Harbor Inlet
Absecon Inlet
Atlantic City
Brigantine
Reed Bay
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Margate City
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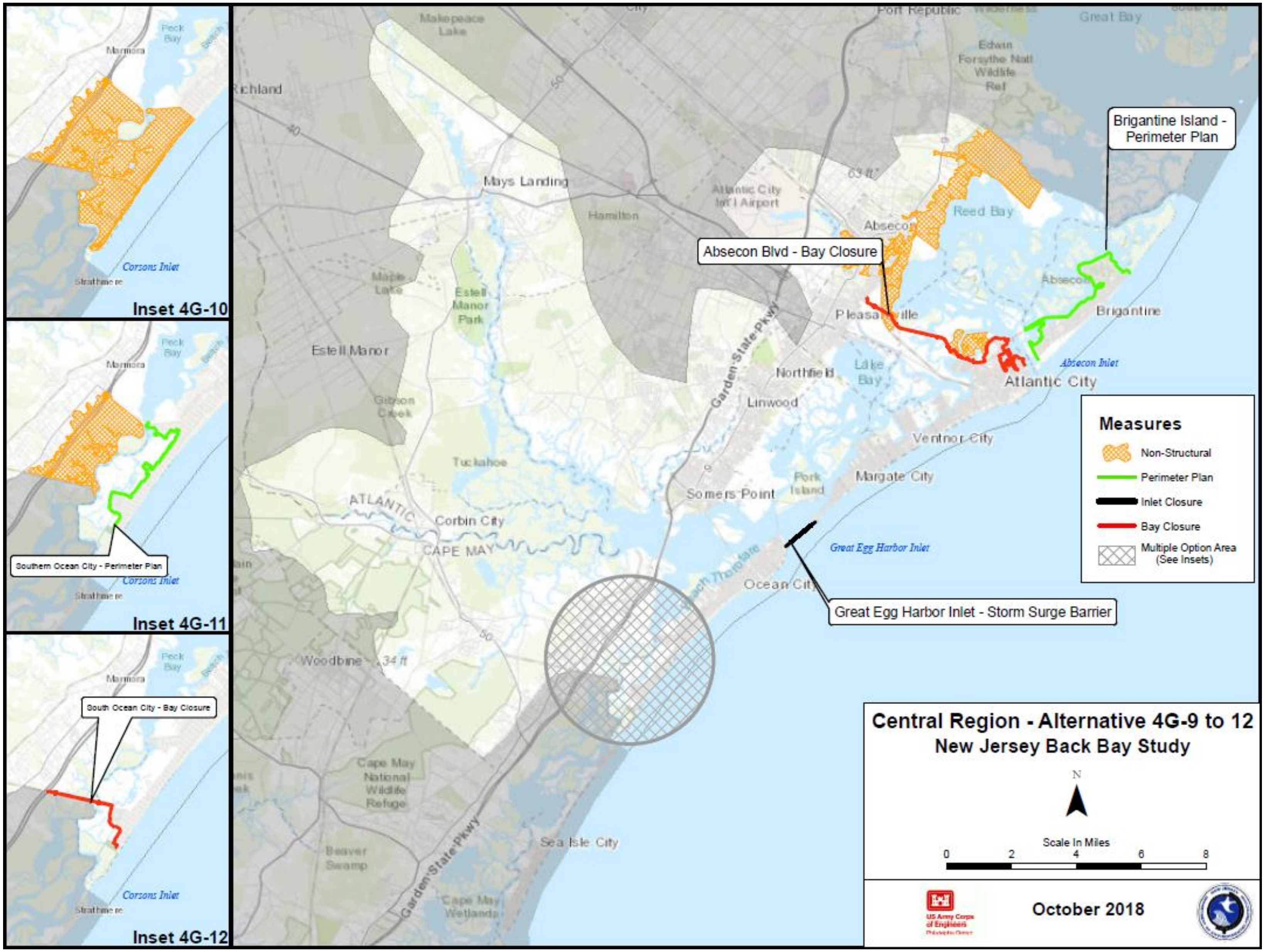
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Inset 4G-12
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Brigantine Island - Perimeter Plan
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Great Egg Harbor Inlet
Absecon Inlet
Atlantic City
Brigantine
Pleasantville
Ocean City
Margate City
Ventnor City
Somers Point
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Northfield
Mays Landing
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Corbin City
Tuckahoe
Woodbine
Sea Isle City
Richland
Reed Bay
Lake Bay
Great Bay
Measures
Non-Structural
Perimeter Plan
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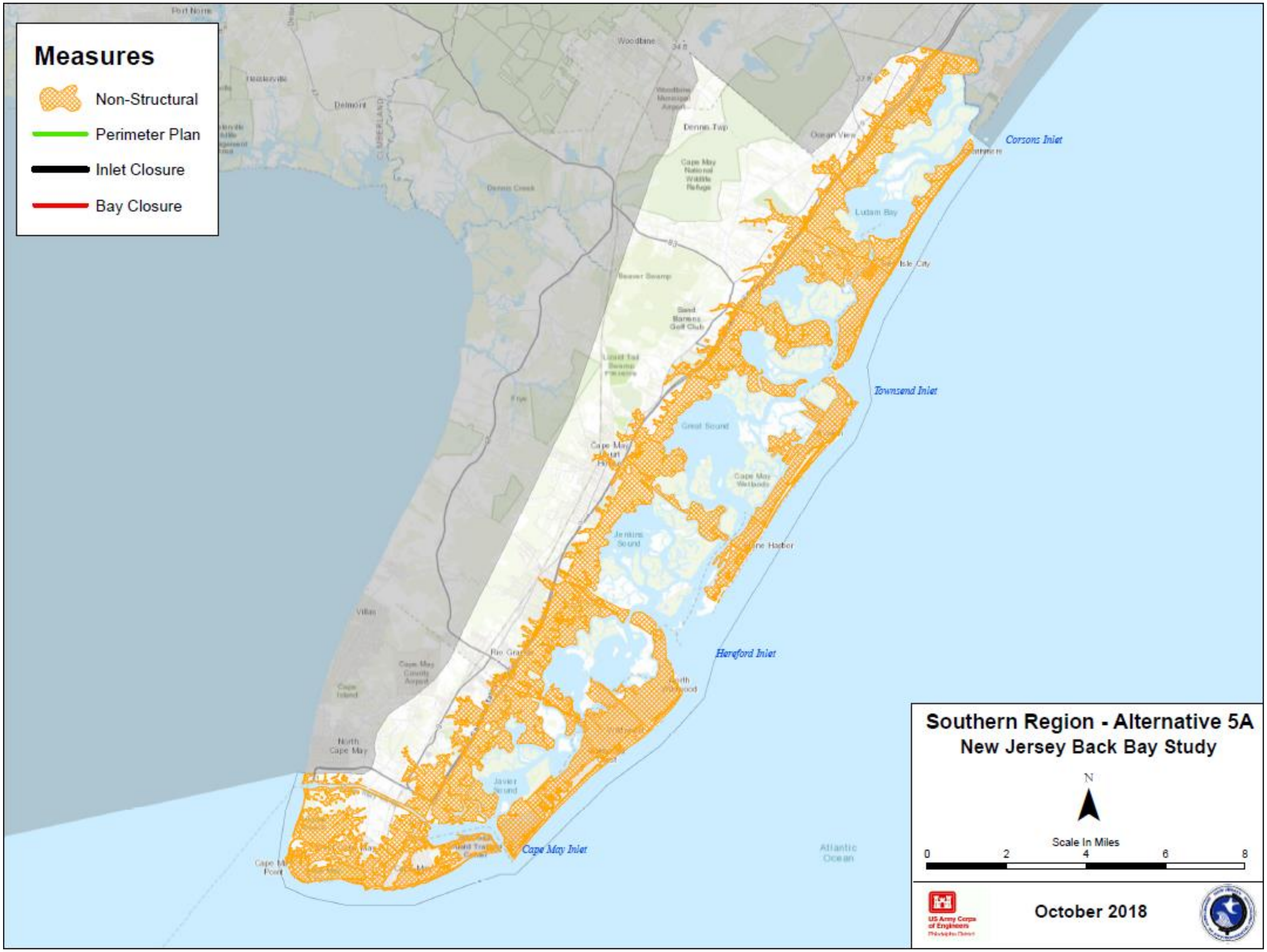
October 2018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Bay Closure
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Townsend Inlet
Hereford Inlet
Cape May Inlet
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Ludam Bay
Great Sound
Jenkins Sound
Jarvis Sound
Southern Region - Alternative 5A
New Jersey Back Bay Study
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Scale In Miles
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2
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6
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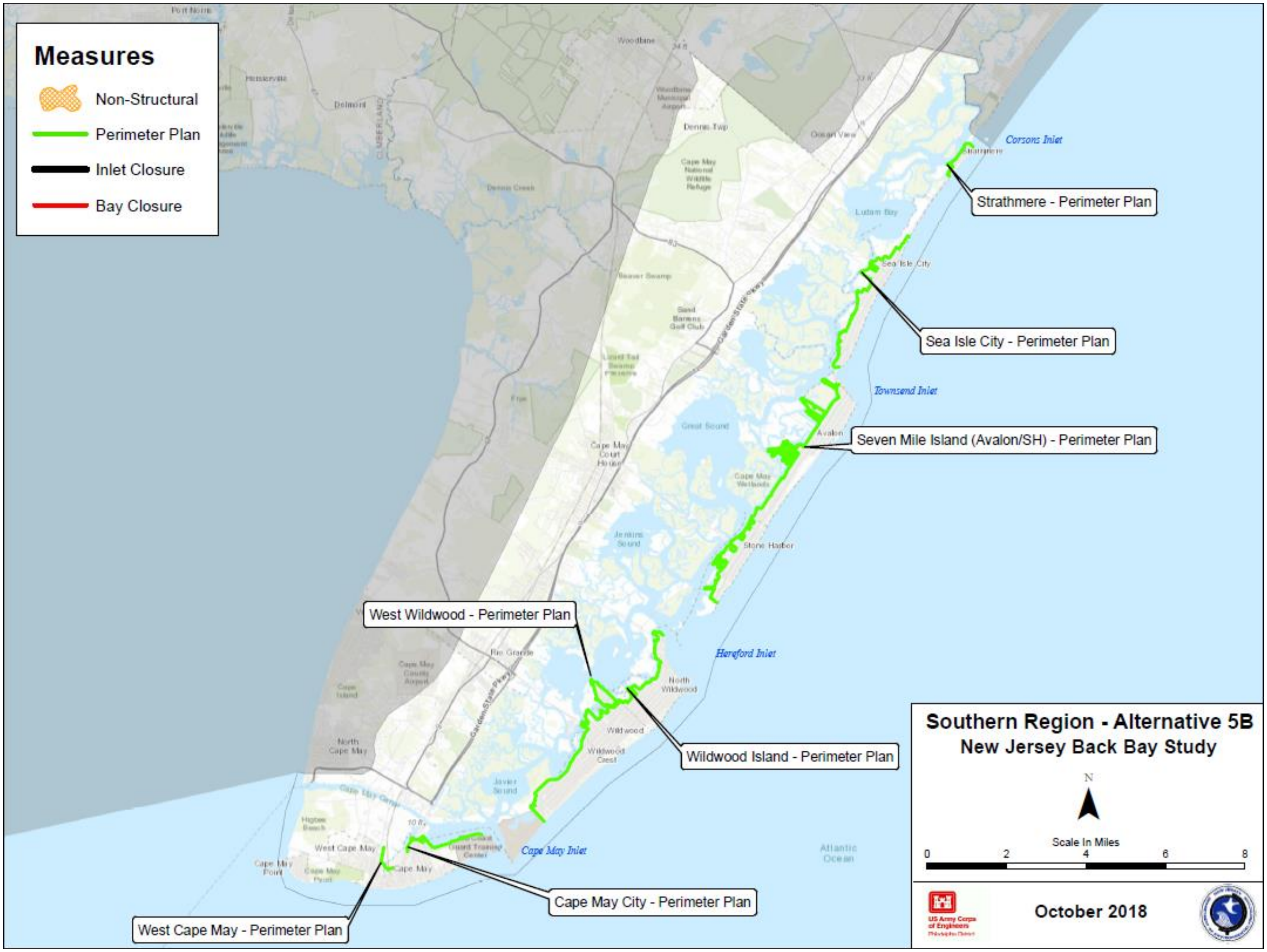
October 2018
US Army Corps of Engineers



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Sea Isle City - Perimeter Plan
Townsend Inlet
Seven Mile Island (Avalon/SH) - Perimeter Plan
West Wildwood - Perimeter Plan
Hereford Inlet
Wildwood Island - Perimeter Plan
Cape May Inlet
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
Southern Region - Alternative 5B
New Jersey Back Bay Study
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Scale In Miles
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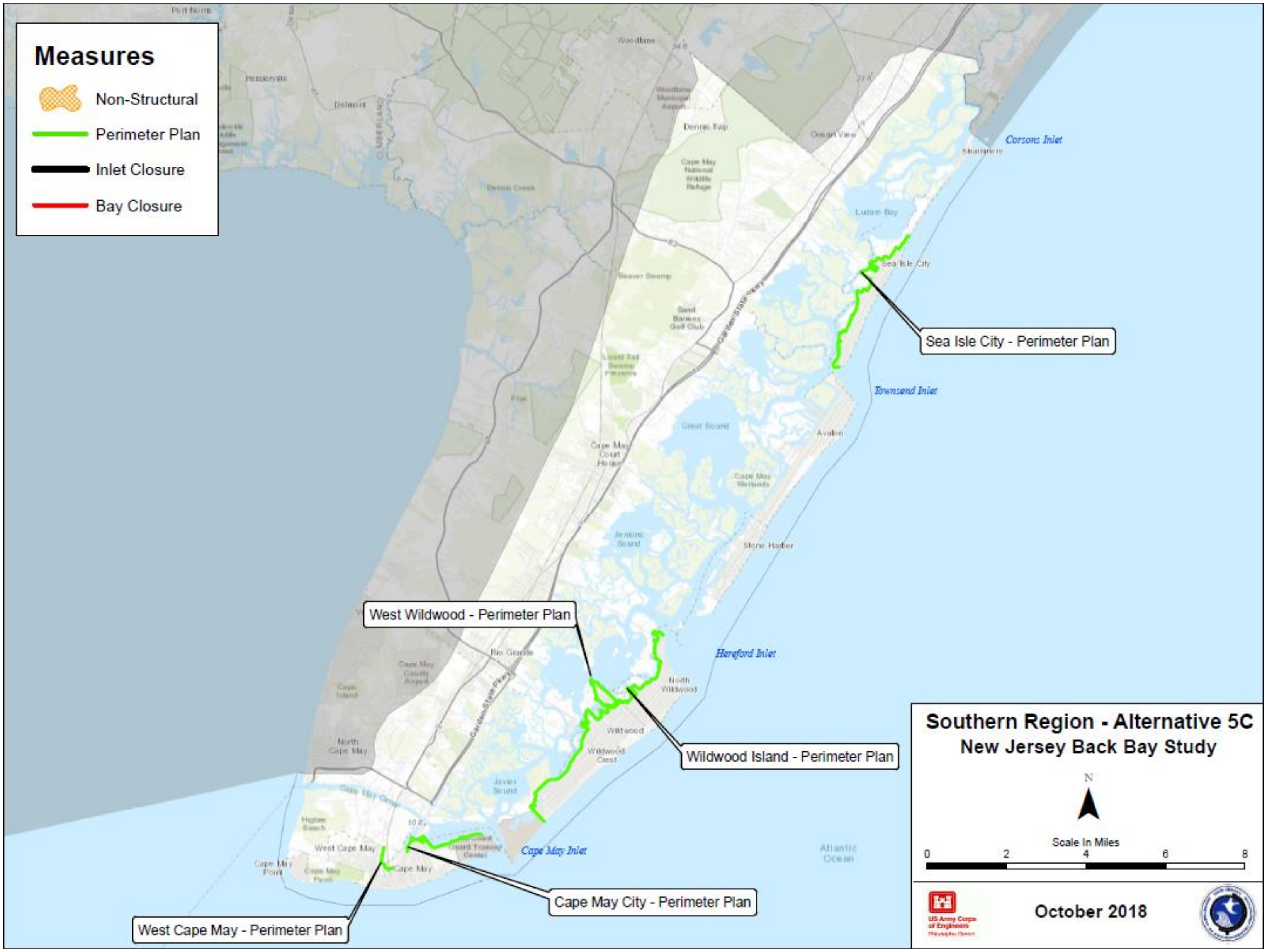
8
October 2018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Wildwood Island - Perimeter Plan
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West Cape May - Perimeter Plan
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Townsend Inlet
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Cape May Inlet
Southern Region - Alternative 5C
New Jersey Back Bay Study
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Scale In Miles
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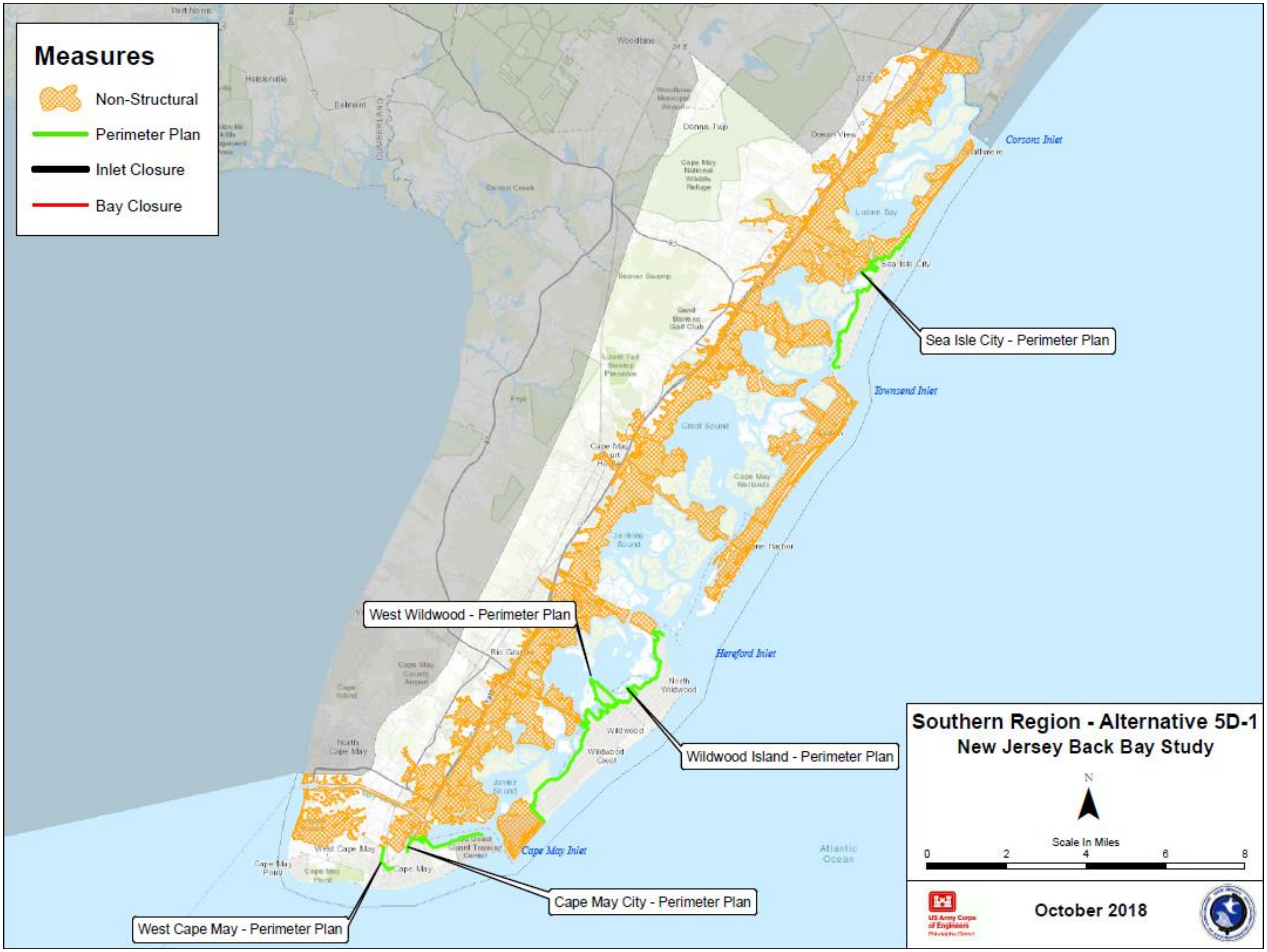
October 2018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Bay Closure
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Wildwood Island - Perimeter Plan
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West Cape May - Perimeter Plan
Corsons Inlet
Townsend Inlet
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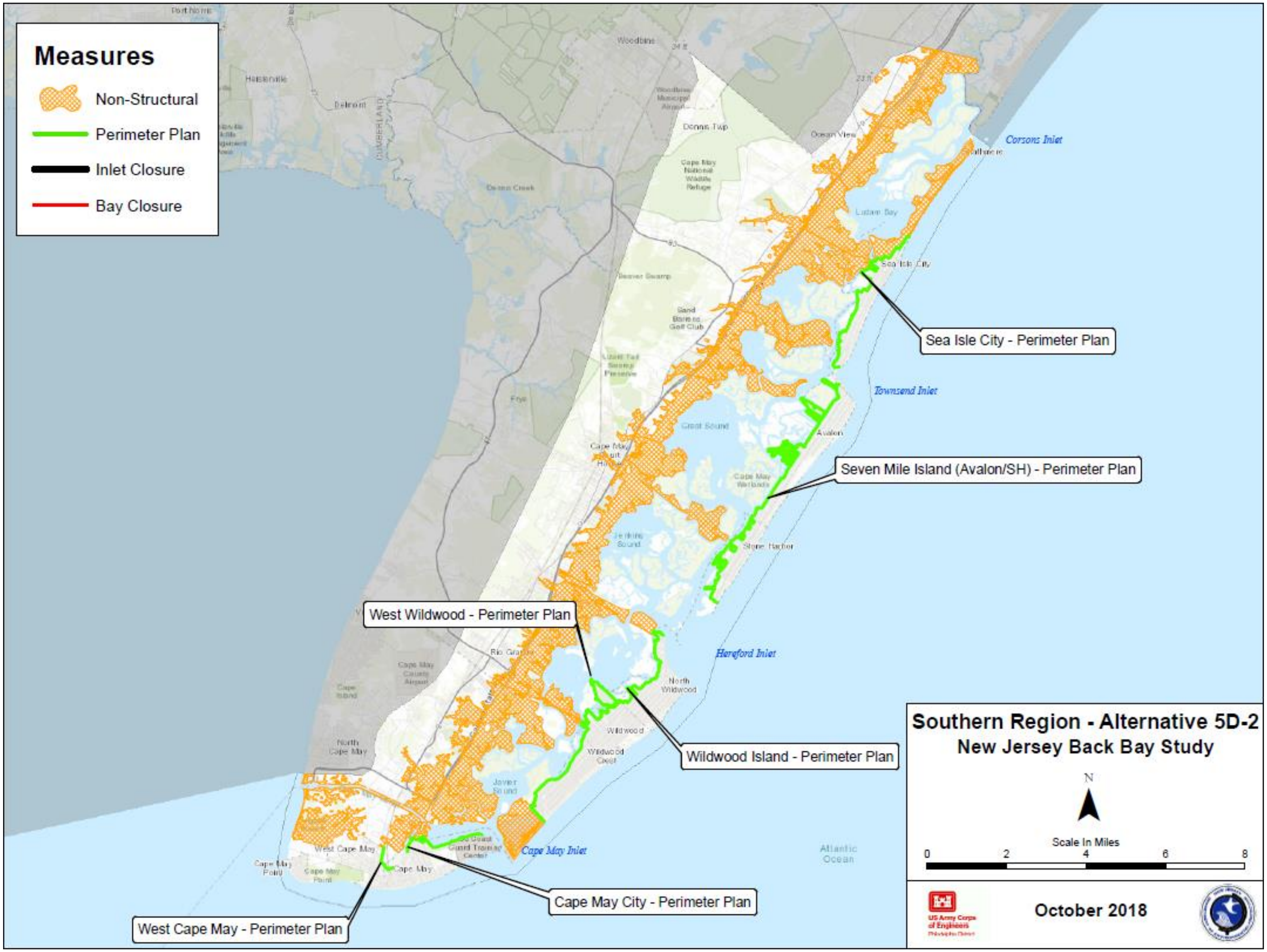
October 2018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Perimeter Plan
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Bay Closure
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Seven Mile Island (Avalon/SH) - Perimeter Plan
West Wildwood - Perimeter Plan
Wildwood Island - Perimeter Plan
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
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New Jersey Back Bay Study
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Scale In Miles
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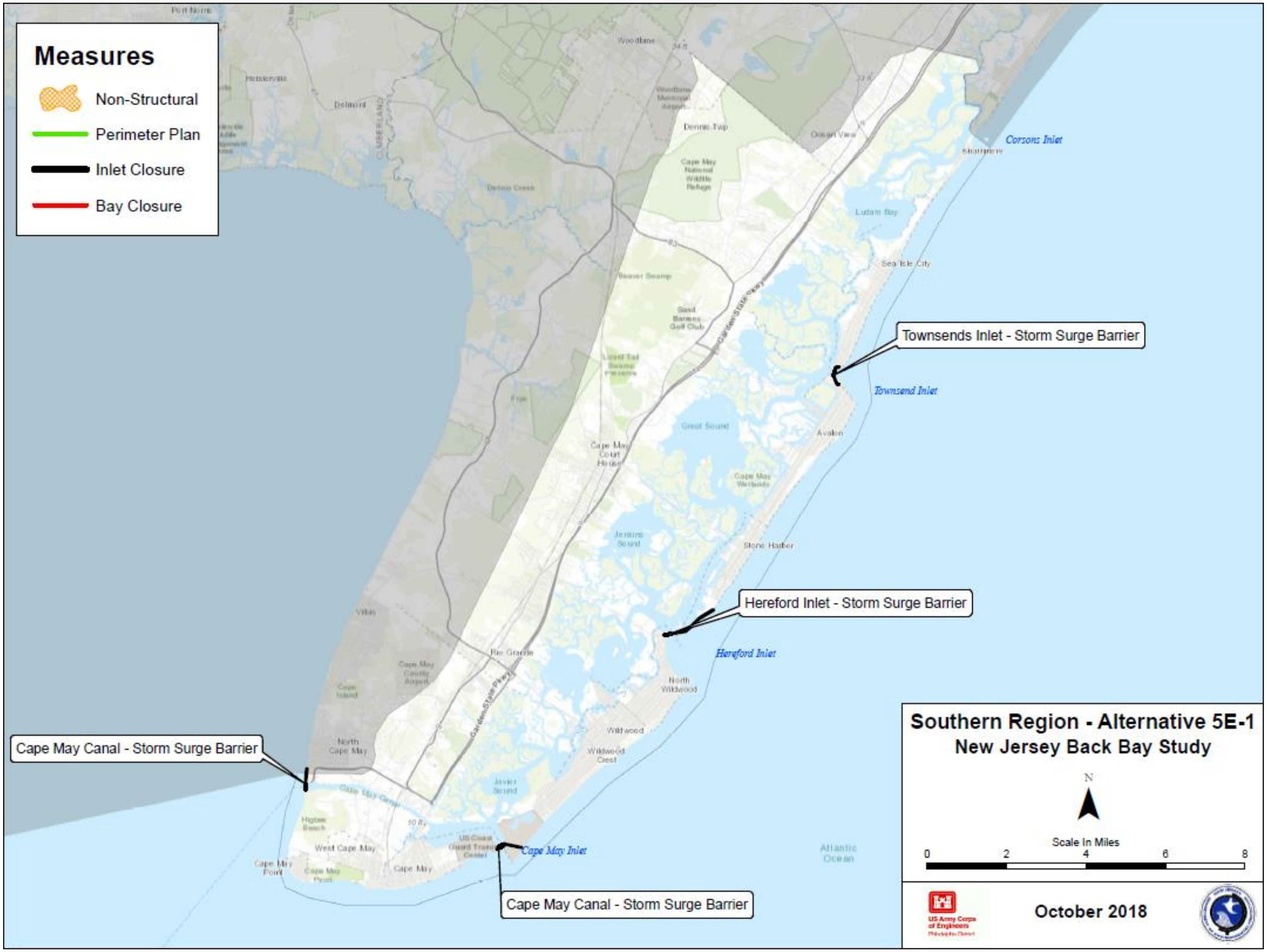
October 2018



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Bay Closure
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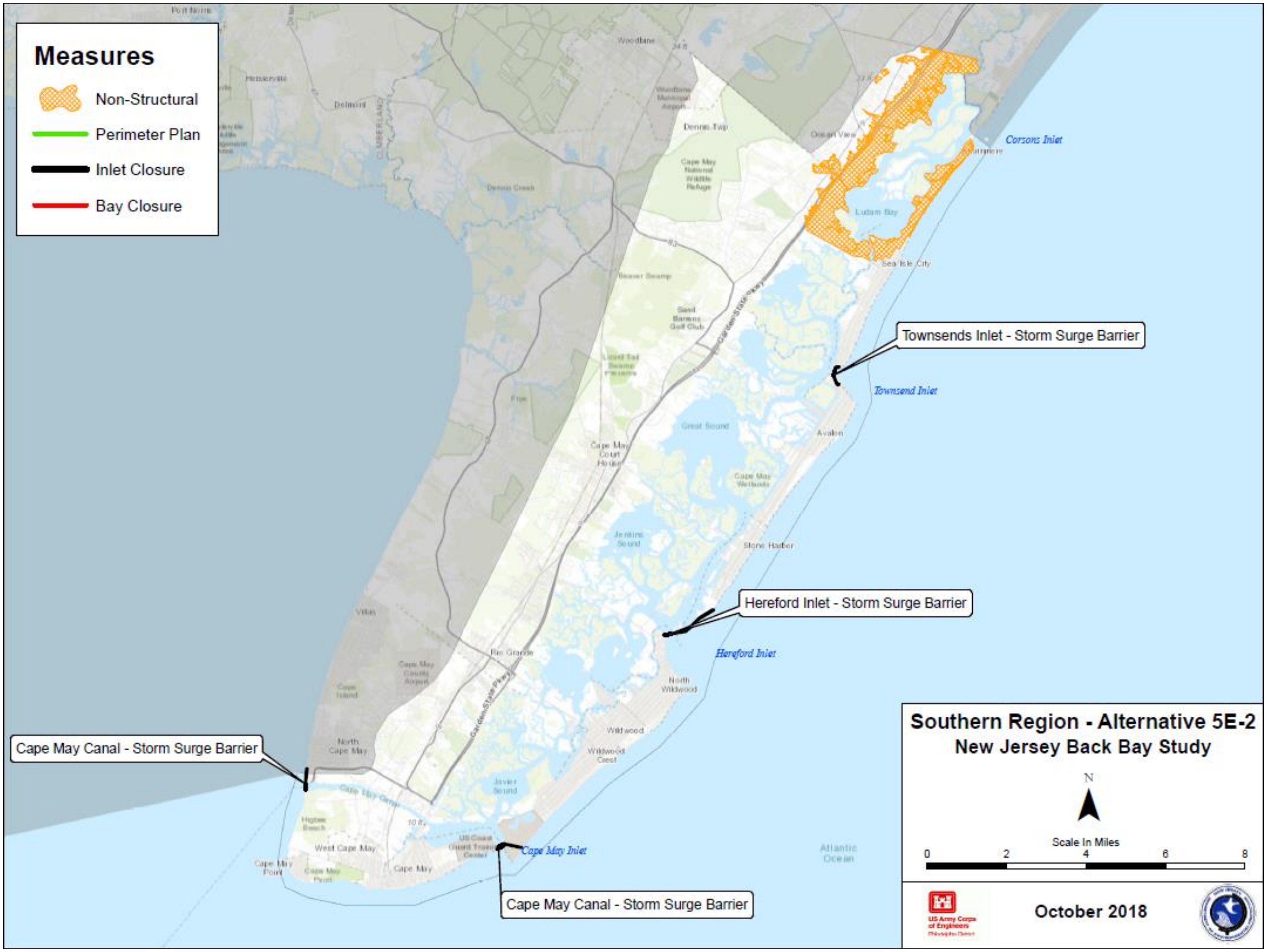
Hereford Inlet - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Southern Region - Alternative 5E-1
New Jersey Back Bay Study
N
Scale In Miles
0
2
4
6
8
October 2018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Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Corsons Inlet
Townsends Inlet - Storm Surge Barrier
Townsend Inlet
Hereford Inlet - Storm Surge Barrier
Hereford Inlet
Cape May Canal - Storm Surge Barrier
Cape May Inlet
Cape May Canal - Storm Surge Barrier
Sea Isle City
Avalon
Stone Harbor
North Wildwood
Wildwood
Wildwood Crest
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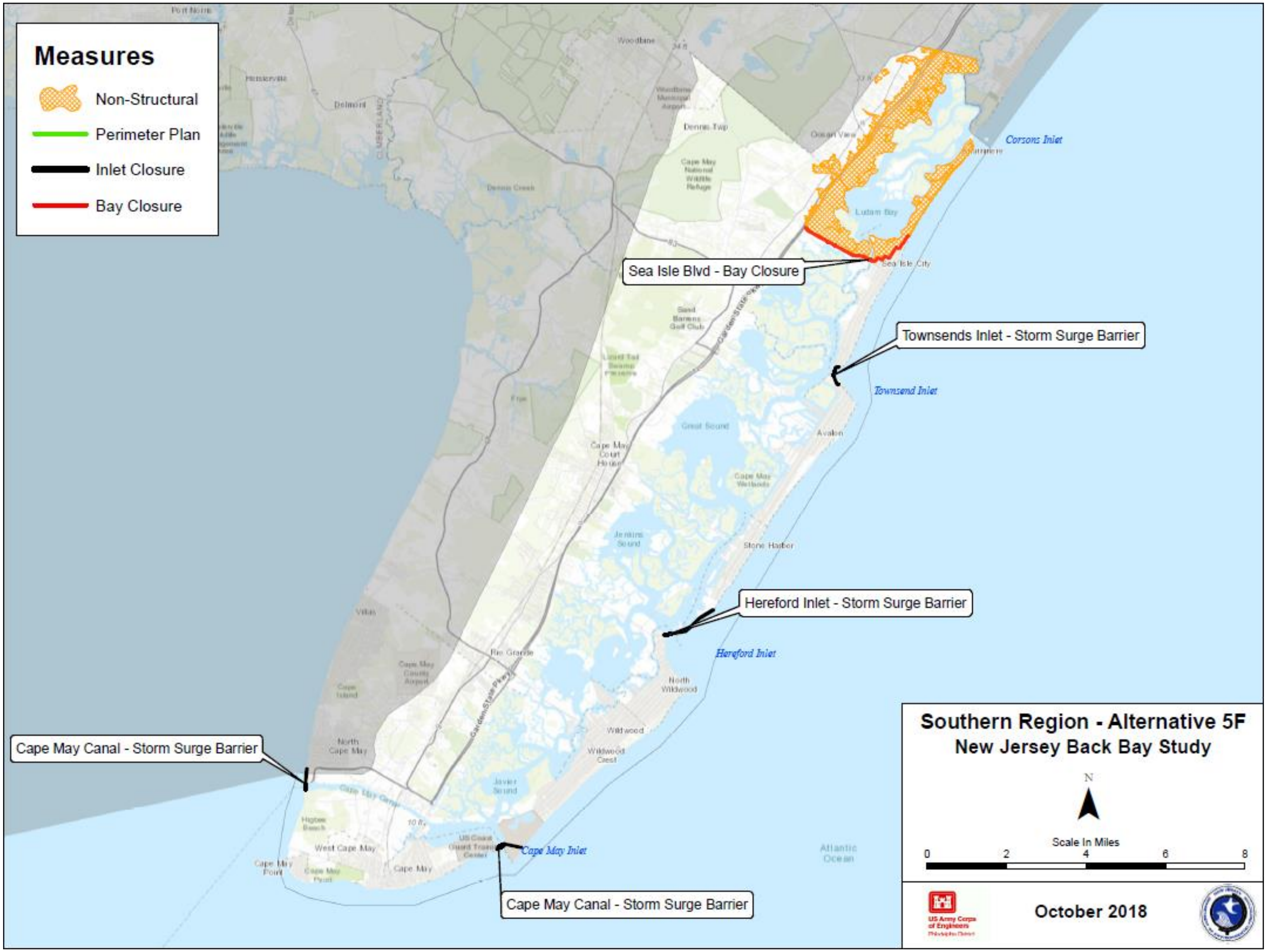
US Army Corps of Engineers
October 2018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Cape May Canal - Storm Surge Barrier
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Townsend Inlet
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Southern Region - Alternative 5F
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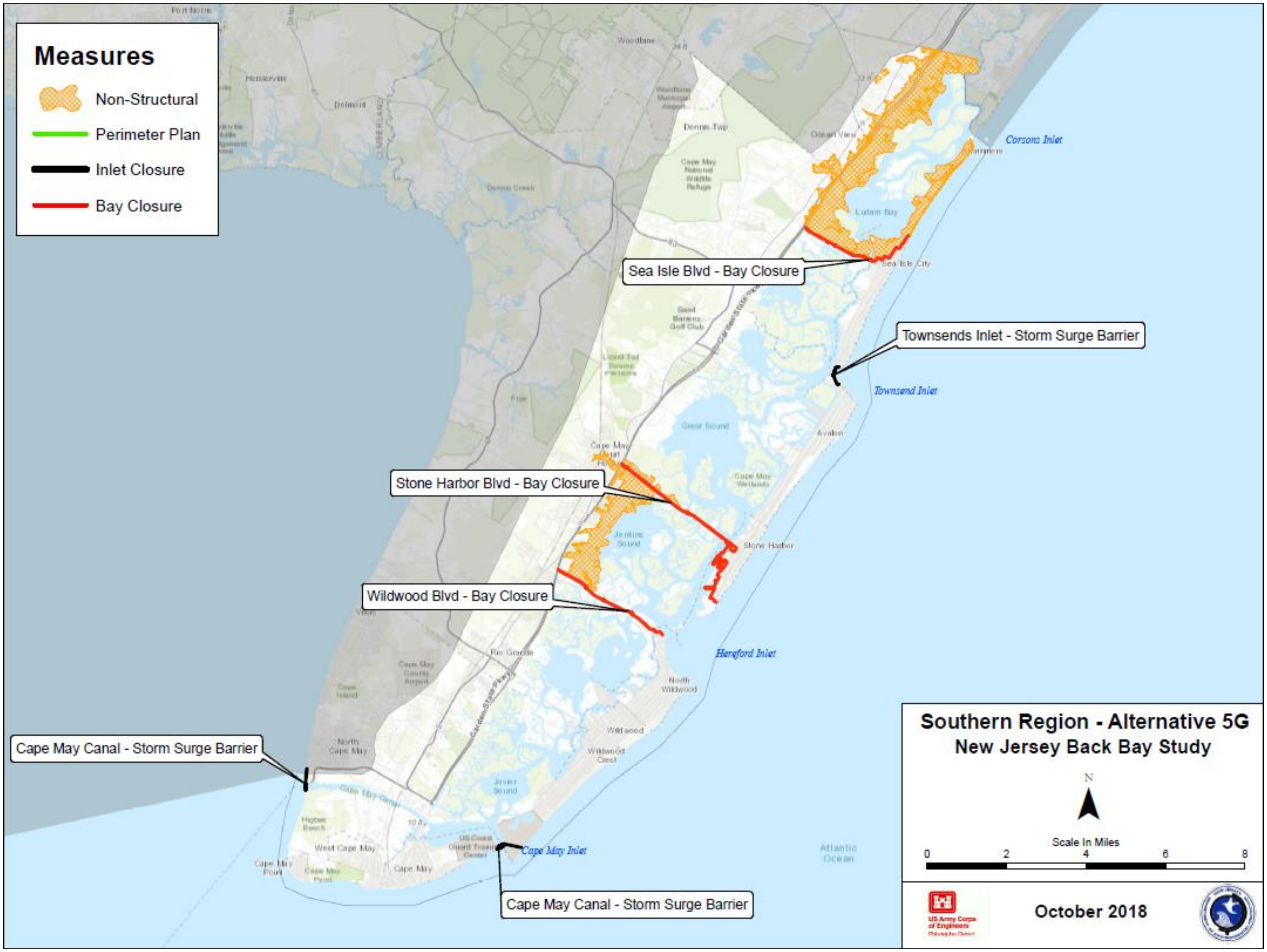


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Stone Harbor Blvd - Bay Closure
Wildwood Blvd - Bay Closure
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Sea Isle City
Avalon
Stone Harbor
North Wildwood
Wildwood
Wildwood Crest
Cape May
West Cape May
Atlantic Ocean
Southern Region - Alternative 5G
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
October 2018
US Army Corps of Engineers

Evaluation

Table 17 provides the economic analysis results for the baseline study wide results and each of the Regional alternatives. Each Region is presented independently with results for Average Annual Net Benefits (AANB), Benefit-Cost Ratio (BCR), Residual Damages, and projected annual Operations, Maintenance, Repair, Rehabilitation, & Replacement (OMRR&R).

All nonstructural measures are evaluated using the 5% AEP (20YR) floodplain extent.

Any alternatives shaded in green denote inclusion in the Final Array of Alternatives.

Table 17: Economic Analysis Results for 51 Regional Alternatives

STUDY WIDE (BASELINE)

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
1A	$7,075,292,000	$262,075,000	$451,666,000	$189,590,000	1.72	71.26%	$0
1B	$5,229,038,000	$281,177,000	$738,568,000	$457,392,000	2.63	53.01%	$52,290,000
1C	$21,484,962,000	$1,332,419,000	$1,478,075,000	$145,656,000	1.11	5.95%	$331,673,000
1D	$15,457,093,000	$942,905,000	$1,219,060,000	$276,155,000	1.29	22.43%	$238,606,000

Each of the study wide single-measure alternatives are theoretically economically justified though the nonstructural alternative only plan (1A) and incrementally justified perimeter only plan (1B) have exceedingly high residual damages at 71% and 53%, respectively. Alternative 1A does not mitigate vehicle damage, infrastructure damage, emergency costs, transportation delays, or storm damage to structures within existing FFE above the 5% AEP floodplain. Alternative 1B is effective at reducing CSRM damages for the communities within perimeter measures, but does nothing to mitigate damages for structures outside the perimeter locations.

The All Closed (1C) and All Closed except Little Egg Harbor Inlet (1D) are also theoretically justified, but both plans ignore serious environmental concerns at Corson's Inlet and Hereford Inlet. Environmental concerns are expanded in the Main Report and Environmental Appendix.

As such, while these plans provide valuable context for the Region-specific evaluations, none are considered acceptable nor implementable.

SHARK RIVER AND COASTAL LAKES REGIONS

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
2A	$24,468,000	$906,000	$1,133,000	$227,000	1.25	88.47%	$0
2B	$512,216,000	$25,747,000	$3,771,000	-$21,976,000	0.15	61.63%	$5,122,000
2C	$591,347,000	$33,439,000	$6,149,000	-$27,289,000	0.18	37.44%	$9,125,000

The economic assessment presented above contains both the results for the Shark River Inlet HEC-FDA reaches and the Coastal Lakes HEC-FDA reaches (Figure 21). To reiterate, the Coastal Lakes Region covers only the coastal lakes not already included in either the North

Region or Shark River Region. The results are aggregated here due to the exceptionally minor influence of either Shark River Region or Coastal Lakes Region on the overall study area.

Both the perimeter and storm surge barrier alternatives are economically nonviable and only nonstructural (2A) is considered an economically justified plan.

NORTH REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
3A	$3,629,095,000	$134,425,000	$203,011,000	$68,586,000	1.51	62.97%	$0
3B	$6,726,209,000	$437,164,000	$276,635,000	-$160,529,000	0.63	49.54%	$67,262,000
3C	$461,554,000	$22,731,000	$26,258,000	$3,528,000	1.16	95.21%	$4,616,000
3D	$3,898,614,000	$150,042,000	$214,874,000	$64,831,000	1.43	60.81%	$4,616,000
3E(1)	$2,549,342,000	$154,810,000	$308,828,000	$154,018,000	1.99	43.67%	$39,351,000
3E(2)	$3,837,663,000	$202,530,000	$362,691,000	$160,160,000	1.79	33.84%	$39,351,000
3E(3)	$4,838,353,000	$268,041,000	$399,903,000	$131,861,000	1.49	27.06%	$53,997,000
3F(1)	$5,924,539,000	$367,186,000	$434,515,000	$67,329,000	1.18	20.74%	$90,894,000
3F(2)	$6,354,659,000	$383,118,000	$455,972,000	$72,854,000	1.19	16.83%	$90,894,000
3G	$1,151,448,000	$67,465,000	$42,502,000	-$24,963,000	0.63	92.25%	$17,766,000

Nonstructural (3A) is economically justified and environmentally acceptable, though it has the same limitations as Alternative 1A with 63% in residual damages. Alternative 3B is not economically feasible due to the high cost of Long Beach Island and Island Beach. Alternative 3C includes only the justified Manasquan North perimeter measure, but results in 95% residual damages.

Alternative 3D has the highest NED AANB of any non-SSB plan but, like the nonstructural plan, has very high residual damages.

Alternative 3E(1) is economically practicable, but is improved by both Alternatives 3E(2) and 3E(3). The addition of nonstructural in Alternative 3E(2) maximizes AANB at $160 million while the addition of perimeter measures in Alternative 3E(3) reduces residual damages down to 27% while maintaining $132 million in AANB. At the current level of analysis, either 3E(2) or 3E(3) could be considered the alternative that reasonably maximizes NED benefits.

The inclusion of the Holgate Bay Closure in Alternatives 3F(1) and 3F(2) does not drop the storm surge barriers alternatives below 1.0, but does eliminate over $90 million in AANB, thus removing these alternatives from further consideration as the NED Plan.

Alternative 3G is not economically justified and has exceedingly high residual damages at 92%.

CENTRAL REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
4A	$1,954,627,000	$72,401,000	$148,963,000	$76,562,000	2.06	78.81%	$0
4B	$3,619,705,000	$201,070,000	$562,047,000	$360,976,000	2.80	20.04%	$36,197,000
4C	$2,904,784,000	$164,102,000	$530,764,000	$366,662,000	3.23	24.49%	$29,048,000
4D(1)	$3,336,914,000	$180,109,000	$557,779,000	$377,671,000	3.10	20.65%	$29,048,000
4D(2)	$3,822,130,000	$208,568,000	$576,257,000	$367,689,000	2.76	18.02%	$36,197,000
4E(1)	$6,734,047,000	$425,665,000	$570,170,000	$144,506,000	1.34	18.89%	$103,964,000
4E(2)	$7,140,707,000	$425,665,000	$585,964,000	$160,299,000	1.38	16.64%	$103,964,000
4E(3)	$7,169,796,000	$446,873,000	$592,968,000	$146,094,000	1.33	15.64%	$107,923,000
4E(4)	$7,173,761,000	$449,940,000	$595,793,000	$145,853,000	1.32	15.24%	$110,198,000
4F(1)	$9,831,254,000	$622,785,000	$652,920,000	$30,135,000	1.05	7.12%	$151,395,000
4F(2)	$10,219,820,000	$637,178,000	$669,220,000	$32,041,000	1.05	4.80%	$151,395,000
4F(3)	$10,248,909,000	$643,324,000	$677,241,000	$33,918,000	1.05	3.66%	$155,354,000
4F(4)	$10,252,874,000	$646,390,000	$680,097,000	$33,706,000	1.05	3.25%	$157,629,000
4G(1)	$4,884,211,000	$301,347,000	$594,284,000	$292,937,000	1.97	15.46%	$74,556,000
4G(2)	$5,272,777,000	$315,740,000	$610,169,000	$294,429,000	1.93	13.20%	$74,556,000
4G(3)	$5,301,866,000	$321,885,000	$617,831,000	$295,946,000	1.92	12.11%	$78,516,000
4G(4)	$5,305,831,000	$324,952,000	$620,672,000	$295,720,000	1.91	11.70%	$80,790,000
4G(5)	$5,132,009,000	$310,526,000	$611,147,000	$300,622,000	1.97	13.06%	$74,556,000
4G(6)	$5,520,576,000	$324,918,000	$627,032,000	$302,114,000	1.93	10.80%	$74,556,000
4G(7)	$5,549,665,000	$331,064,000	$634,694,000	$303,630,000	1.92	9.71%	$78,516,000
4G(8)	$5,553,629,000	$334,130,000	$637,535,000	$303,405,000	1.91	9.30%	$80,790,000
4G(9)	$5,617,225,000	$338,985,000	$634,873,000	$295,888,000	1.87	9.68%	$81,706,000
4G(10)	$6,005,792,000	$353,378,000	$650,758,000	$297,380,000	1.84	7.42%	$81,706,000
4G(11)	$6,034,880,000	$359,524,000	$658,420,000	$298,897,000	1.83	6.33%	$85,665,000
4G(12)	$6,038,845,000	$362,590,000	$661,261,000	$298,671,000	1.82	5.93%	$87,939,000

Though limited by the same drawbacks as previously discussed nonstructural only options, Alternative 4A is economically feasible with 79% residual damages. Alternatives 4B and 4C (perimeter only) are economically viable, but both are improved by Alternatives 4D(1) and 4D(2). Alternative 4D(1) adds nonstructural and maximizes NED AANB benefits while Alternative 4D(2) adds nonstructural and a perimeter measure to Brigantine Island. Alternative 4D(2) reduces residual damages with only a 2.6% decrease in AANB.

Alternative 4E(1) is justified yet improved with the inclusion of other measure types in 4E(2), 4E(3), 4E(4). Even though Alternative 4G has higher AANB than Alternative 4E, the 4E alternatives are also included in the Focused Array to mitigate any study risk stemming from uncertainties surrounding bay closure costs estimates and environmental impacts.

The inclusion of the North Point Bay Closure in Alternative 4F severely dropped AANB in comparison with other storm surge barrier alternatives. Alternative 4F increased AAB by 14.5%, but required a 46.3% increase in AAC.

Alternative 4G(1) is economically practicable, but improved by adding either nonstructural or perimeter measures to Brigantine Island and nonstructural, perimeter, or bay closure measures to South Ocean City (Alternatives 4G(6) – 4G(8) and 4G(10) – 4G(12)).

SOUTH REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
5A	$1,467,103,000	$54,343,000	$98,558,000	$44,216,000	1.81	68.27%	$0
5B	$3,424,391,000	$181,379,000	$231,893,000	$50,514,000	1.28	25.35%	$34,244,000
5C	$1,862,700,000	$94,344,000	$181,546,000	$87,202,000	1.92	41.55%	$18,627,000
5D(1)	$2,286,822,000	$110,054,000	$206,462,000	$96,408,000	1.88	33.53%	$18,627,000
5D(2)	$3,428,552,000	$180,266,000	$237,575,000	$57,310,000	1.32	23.52%	$33,066,000
5E(1)	$4,639,279,000	$274,620,000	$290,854,000	$16,233,000	1.06	6.37%	$71,610,000
5E(2)	$4,680,566,000	$276,150,000	$292,784,000	$16,634,000	1.06	5.74%	$71,610,000
5F	$5,265,569,000	$308,994,000	$298,195,000	-$10,799,000	0.97	4.00%	$80,302,000
5G	$5,924,476,000	$344,010,000	$293,924,000	-$50,086,000	0.85	5.38%	$89,110,000

The nonstructural only alternative (5A) is again economically justified though with 68% residual damages. Alternatives 5B and 5C (perimeter only) are economically viable, but both are improved by Alternatives 5D(1) and 5D(2). Alternative 5D(1) adds nonstructural and maximizes NED AANB benefits while Alternative 5D(2) adds nonstructural and a perimeter measure to Seven Mile Island.

Alternatives 5E(1) and 5E(2) are feasible, but with significantly fewer AANB than other alternatives and does not fully address the environmental concerns at Hereford Inlet. Adding the Sea Isle Blvd Bay Closure (5F) drops residual damages, but also drops the BCR below 1.0. Avoiding an inlet closure at Hereford Inlet with the inclusion of two bay closures (5G) even further drops the BCR below 1.0.

C-7) FOCUSED ARRAY OF ALTERNATIVES

From the 51 presented Regional alternatives, 20 alternatives are still considered for further evaluation with perimeter alternatives prevalent in the South and Central Regions and storm surge barrier alternatives available in the North and Central Regions.

Table 18 provides a brief recap of the available options for each Region.

Table 18: Focused Array of Alternatives

Region	Overview	Alternative	NONSTRUC	PERIMETER	SSB	BC
SHARK RIVER	2A	2A	X			
NORTH	3A	3A	X			
	3D	3D	X	X		
	3E	3E(2)	X		X	
		3E(3)	X	X	X	
CENTRAL	4A	4A	X			
	4D	4D(1)	X	X		
		4D(2)	X	X		
	4E	4E(2)	X		X	
		4E(3)	X	X	X	
		4E(4)	X		X	X
	4G	4G(6)	X		X	X
		4G(7)	X	X	X	X
		4G(8)	X		X	X
		4G(10)	X	X	X	X
		4G(11)	X	X	X	X
		4G(12)	X	X	X	X
SOUTH	5A	5A	X			
	5D	5D(1)	X	X		
		5D(2)	X	X		

Region	Overview	Alternative	INIT. CONST.	AANB	BCR	RESIDUAL
SHARK RIVER	2A	2A	$24,468,000	$227,000	1.25	88.47%
NORTH	3A	3A	$3,629,095,000	$68,586,000	1.51	62.97%
	3D	3D	$3,898,614,000	$64,831,000	1.43	60.81%
	3E	3E(2)	$3,837,663,000	$160,160,000	1.79	33.84%
		3E(3)	$4,838,353,000	$131,861,000	1.49	27.06%
CENTRAL	4A	4A	$1,954,627,000	$76,562,000	2.06	78.81%
	4D	4D(1)	$3,336,914,000	$377,671,000	3.10	20.65%

		4D(2)	$3,822,130,000	$367,689,000	2.76	18.02%
	4E	4E(2)	$7,140,707,000	$160,299,000	1.38	16.64%
		4E(3)	$7,169,796,000	$146,094,000	1.33	15.64%
		4E(4)	$7,173,761,000	$145,853,000	1.32	15.24%
	4G	4G(6)	$5,520,576,000	$302,114,000	1.93	10.80%
		4G(7)	$5,549,665,000	$303,630,000	1.92	9.71%
		4G(8)	$5,553,629,000	$303,405,000	1.91	9.30%
		4G(10)	$6,005,792,000	$297,380,000	1.84	7.42%
		4G(11)	$6,034,880,000	$298,897,000	1.83	6.33%
		4G(12)	$6,038,845,000	$298,671,000	1.82	5.93%
SOUTH	5A	5A	$1,467,103,000	$44,216,000	1.81	68.27%
	5D	5D(1)	$2,286,822,000	$96,408,000	1.88	33.53%
		5D(2)	$3,428,552,000	$57,310,000	1.32	23.52%

The Focused Array of Alternatives is presented by Region as even just the remaining 20 alternatives have a total of 144 unique, non-repetitive combinations if they were aggregated to a study wide level. In addition, each Region (with the exception of Shark River) has multiple alternative types still under consideration with further analysis necessary to identify the Tentatively Selected Plan and NED Plan.

Cycle 3 began after selection of the Focused Array of Alternatives and includes analysis improvements across all disciplines in the study. For Economics, this includes refinements to the inventory totals, first floor elevation assessment, depreciated replacement value computation, content-to-structure value ratio assignment, depth-percent damage function specificity, non-HEC-FDA benefits inclusion, and development of other decision criteria including Long-Term Exceedance Probability, SLC Adaptability, and Life Safety Risk (as detailed in the following sections).

Cycle 3 improvements also extended to Plan Formulation, Engineering, Nonstructural, and Environmental. Those adjustments and refinements can be located in the Main Report and their respective Appendices.

C-8) STRUCTURE INVENTORY REFINEMENT (Cycle 3)

This Section will cover the new work done in Cycle 3 to refine estimates and reduce uncertainty in the economic inputs. Adjustments include inventory identification, occupancy type classification, DRV computation, CSVR application, FFE assessment, and additional depth-percent damage function inclusion and assignment. Values are shown at the FY2019 price level, though were updated to FY2021 dollars within HEC-FDA using EM 1110-2-1304 *Civil Works Construction Cost Index System*, 31 March 2021.

Structure Identification, Reclassification, and Valuation

A majority of the benefits of a potential coastal storm risk management project will come in the form of inundation damages mitigated for structures within the study area. In order to quantify these benefits, a comprehensive inventory of the structures in the potential damage pool must be established as initially started in Section C-3. This inventory must include per-structure data on location, first floor elevation, and occupancy type (residential, commercial, etc.). The location and first floor elevation inform the coastal storm vulnerability of the structure and the occupancy type determines the severity of the impact caused by the inundation. Depreciated replacement values and content-to-structure value ratios translate those vulnerability and damage characteristics to NED monetary losses.

Section C-3 details the creation of the initial structure inventory which was comprised of 182,930 structures totaling over $72 million in damageable assets. This Section will discuss the addition, deletion, and aggregation of structures from that inventory, giving a new total of 172,988 structures with over $68 million in damageable assets. Though the structure inventory total damage value dropped in Cycle 3 compared to Cycle 2, overall Average Annual Damages in the future without-project condition rose due to the inclusion of additional NED damage categories and a lower current Federal Discount Rate of 2.5%.

Spatial data from NJDEP, NJGIN, and the Tax Assessor's Offices were used to create the initial structure inventory, but to ensure that these data accounted for all structures in the project area (the FY2080 0.2% AEP event floodplain with Intermediate RSLC), a visual survey was completed using recent high resolution aerial imagery and Google Earth Street View to add in any structures that had been left out. This visual survey added 1,552 structures to the structure inventory.

Each structure added during the visual survey was manually assigned an occupancy type based on the street view characteristics of the structure. A base improvement value was assigned by identifying nearby structures with the same occupancy type as the manually added asset. A buffer of 1,000 feet was used to locate structures of the same occupancy type. The mean of these structures' values was then assigned to the newly added structure to provide a base improvement value. Figure 28 shows two of the structures in Strathmere (Cape May County) that were added via the visual survey and the structures within the 1,000 foot search radius of the same occupancy type whose structure values were averaged to determine the newly added structures' improvement values. In this particular example, all the structures in the 1,000-foot search radius were the same occupancy type.

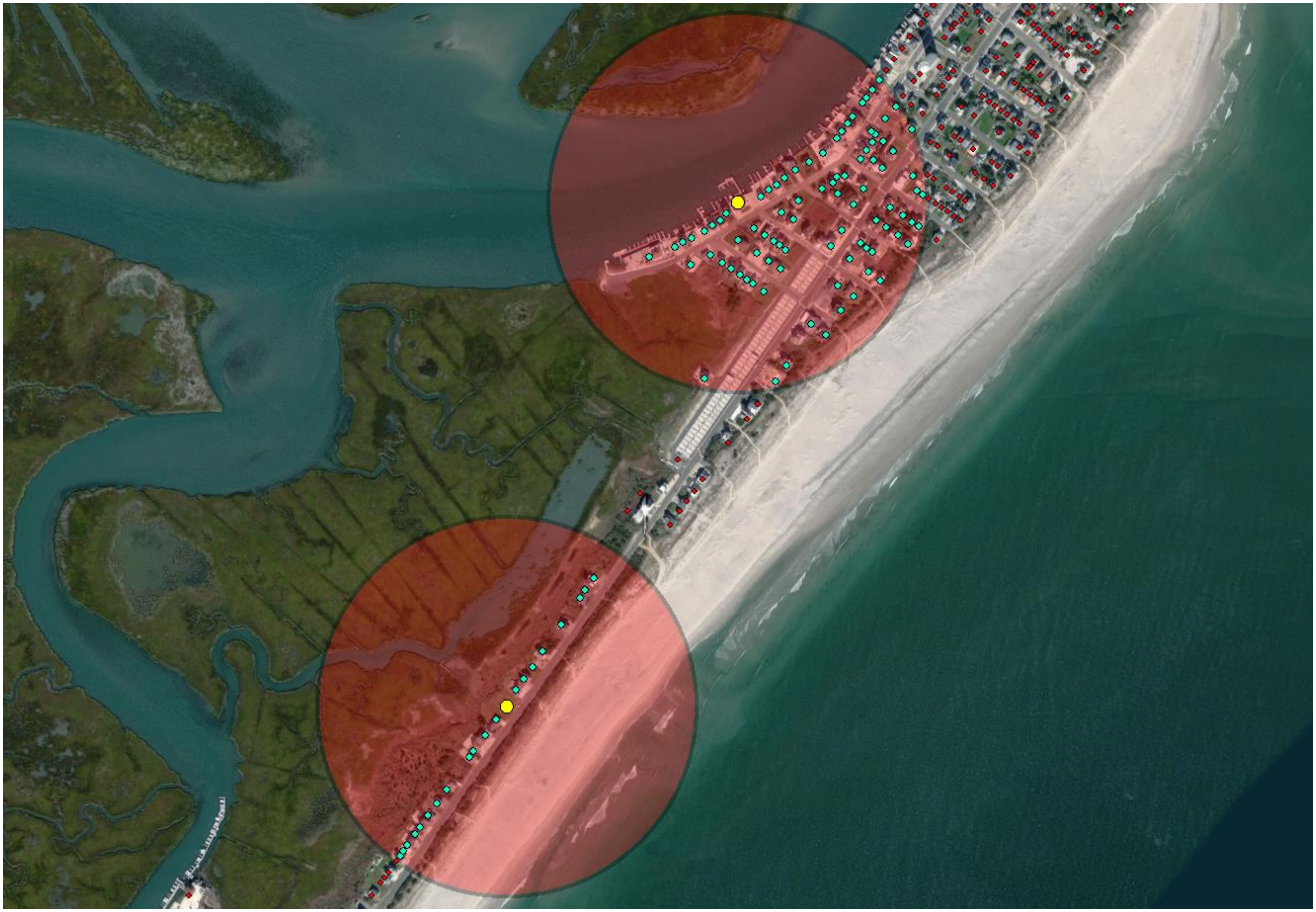


Figure 28: Example of Buffer around Newly Added Structures

Structural aggregation involves grouping housing units previously labeled as single-family residences into Apartments or High-Rise complexes to improve assessment on how these assets receive damage. Within County tax parcel and assessment records, there can be entries for individual units (e.g., “935 OCEAN AVE UNIT 1A,” “935 OCEAN AVE UNIT 1B”) that are actually subsections of a larger structure. Figure 29 shows an example of this in Avalon: the seven structures outlined in red have multiple tax assessment records within them.

Figure 29: Examples of Multiple Tax Assessor Records in a Structure

Treating these individual units as standalone structures would likely misstate damages, as the depth-percent damage curve for single-family homes is different than those for apartments and high-rises (see Section C-3). Treating the individual units as aggregated singular structures also impacts their assigned first floor elevation and content-to-structure value ratios.

To rectify this problem, if a single address had five or more records associated with it, these records were aggregated into one entry (e.g., “935 OCEAN AVE”). The aggregated entry was assigned a new occupancy type and given the aggregated improvement value of the previously independent units. Using this methodology, 12,008 entries were aggregated into 786 entries with no alteration in base improvement value.

These aggregated structures were reclassified as either high-rises or apartments. Structures with 5 or more floors were reclassified as high-rises (HIGH) while structures with fewer than 5 floors were reclassified as apartments (APT). Examples of a high-rise and an apartment in Ocean City can be seen in Figure 30. This differentiation was important because apartments and high-rises take damage at different rates during storm events. The new entries that consisted of the most aggregated records were visually inspected to ensure that they were reclassified correctly.

The structures that were not visually inspected were all classified as APT, with the assumption that structures with only a few aggregated units were smaller and therefore unlikely to be high-rises. In total, of the 786 new entries, 26 were classified as HIGH and 760 were classified as APT.

Figure 30: Example of a High-Rise and an Apartment

An additional refinement to the structure inventory involved sub-classification of residential structure occupancy types based on geographic location. During the foundation height survey, it was discovered that structures on the barrier islands (and finger canal communities) have different population characteristics for variables such as foundation height and structure value and, as such, should not be aggregated with the structures on the mainland.

Structures on the mainland were classified as “mainland” structures (either SFR1-M or SFRM-M), while structures on either the barrier islands or on the finger canal portions of the mainland were classified as “barrier” structures (either SFR1-B or SFRM-B). The results of this refinement can be seen in Table 19. Mainland and Barrier residential structures retain the same CSVRs and depth-percent damage function assignments.

Table 19: Residential Structure Count by Barrier / Mainland

Occupancy Type	Barrier or Mainland	Total Structures
SFRM		**89,060**
	Barrier	68,288
	Mainland	20,772
SFR1		**74,471**
	Barrier	50,911
	Mainland	23,560

Because the Public structure category elements were heterogeneous, a visual survey of all 2,129 structures was conducted. During the visual survey, 271 structures were removed, as they were undamageable assets such as parking lots, paved areas, or tennis courts. A further 804 of the Public structures were reclassified as COM, HIGH, APT, or RES based on this visual inspection. In total, 1,054 structures remained classified as Public structures (e.g., churches, schools).

Figure 31 shows an example of an asset that carries an improvement value of $161,100 in the tax assessor data but was removed from the inventory because it appears undamageable.

Figure 31: Undamageable Asset Example

Figure 32 shows an example structure that was filed as Public in the tax assessor data due to its tax status or structure usage but shares the characteristics and damage aspects of a residential structure. This structure was reclassified as SFRM-M. Correctly specifying the occupancy type of a structure allows for the appropriate depth-percent damage curve, begin damage point, and content-to-structure value ratio to be assigned.

Figure 32: Reclassified PUB Structure Example

The 1,051 structures remained classified as Public after the visual analysis differed widely in their construction and characteristics. During the visual survey, structure material type was noted (masonry, wood, metal, other) in order to assign more accurate depth-percent damage curves. The results of the Public reclassification survey can be found in Table 20.

Table 20: PUB Reclassification Survey Results

Occupancy	Count	Occupancy	Count
APT	4	**PUB-Wood**	347
COM	35	**SFR1-B**	173
HIGH	14	**SFR1-M**	89
PUB	29	**SFRM-B**	400
PUB-Masonry	665	**SFRM-M**	89
PUB-Metal	13	**TOTAL**	**1,858**
Entries Removed: 271			

172,988 structures remained in the inventory after the visual survey, reclassification, and aggregation efforts. The occupancy types of these structures can be seen in Figure 33.

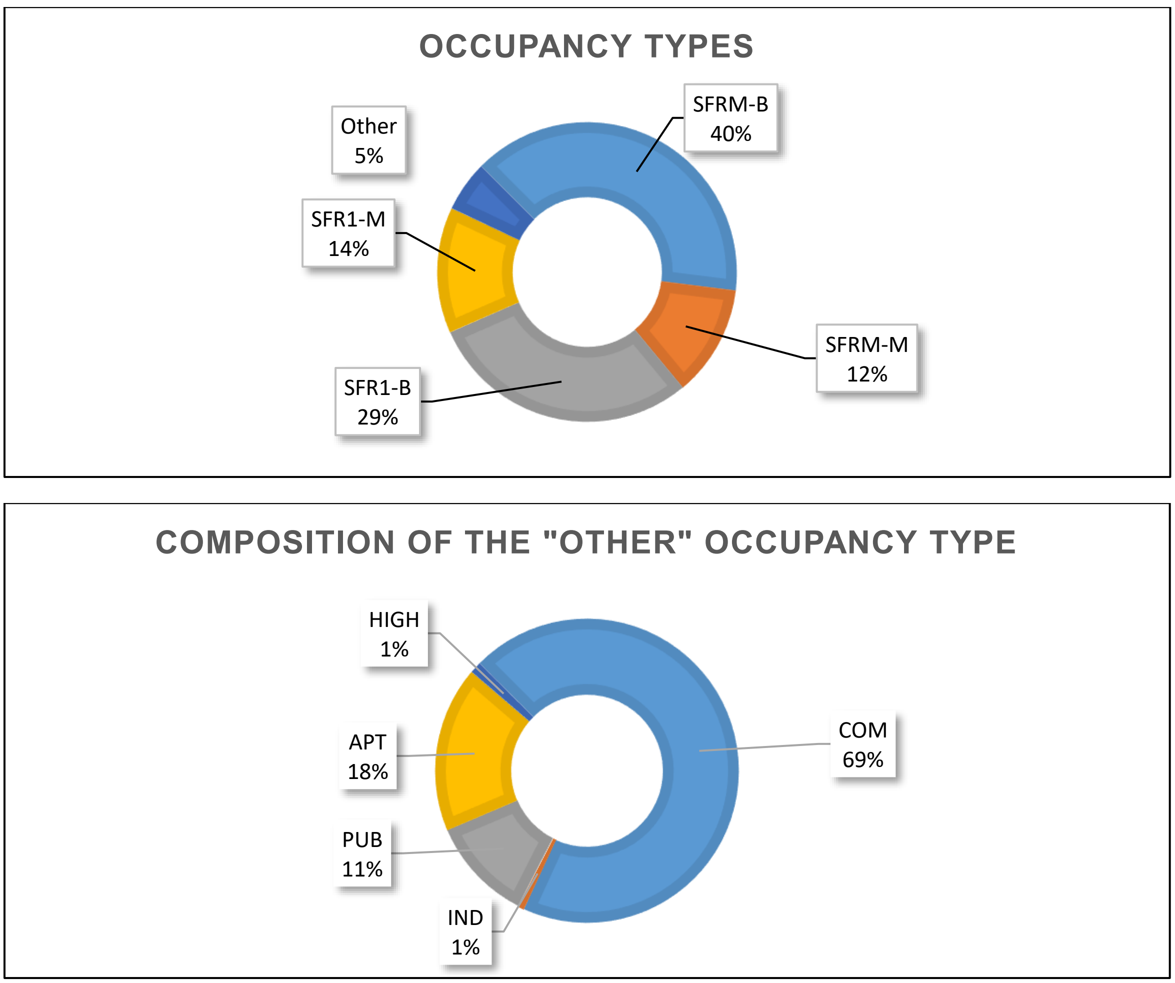


Figure 33: Occupancy Types of Structures

The overall breakdown of structures by occupancy type is not dissimilar from previous estimates provided in Section C-3, though the confidence in inventory classification is greater. The inventory is still dominated by residential structures, but the location and characteristics of non-residential structures is much more refined in Cycle 3 than before identification of the Focused Array of Alternatives.

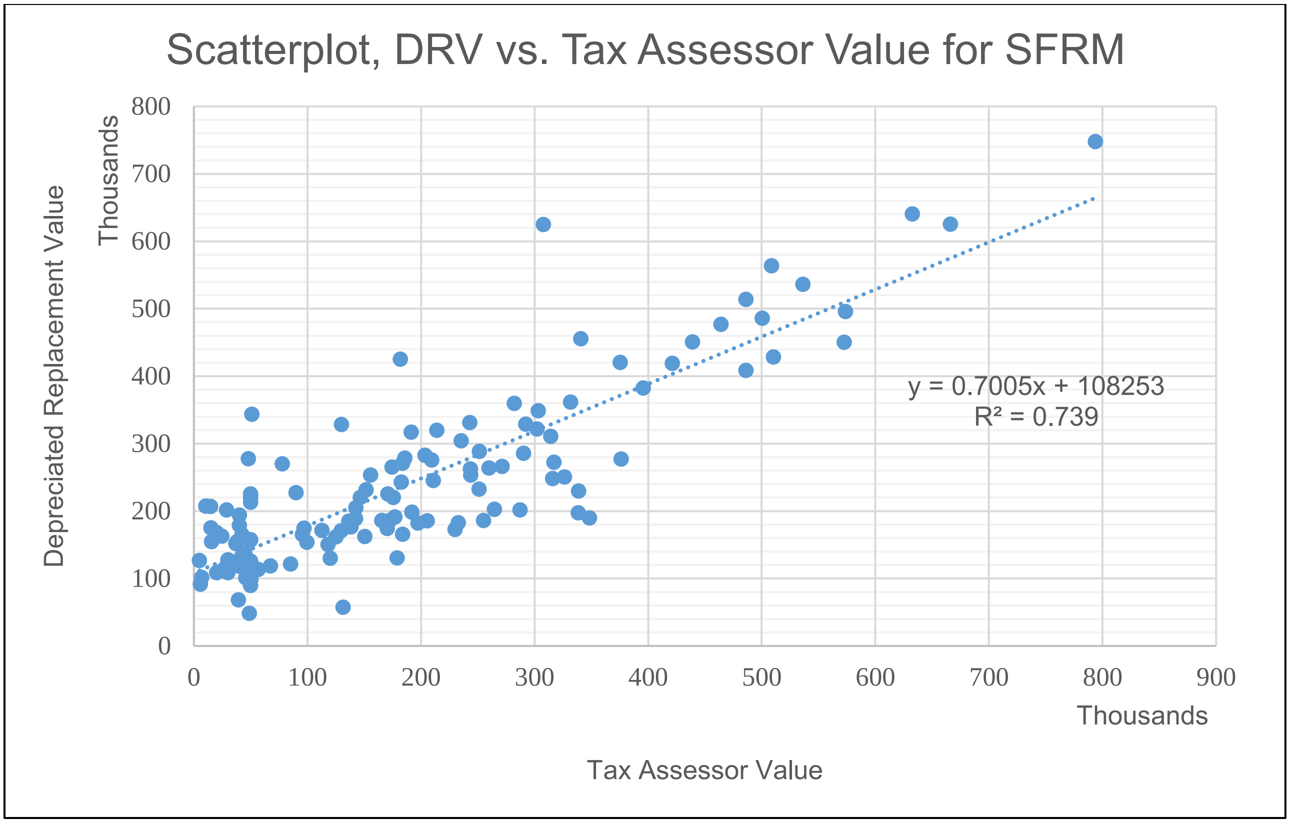
Vehicles were added to the HEC-FDA model following the methodology laid out in EGM 09-04 *Generic Depth-Damage Relationships for Vehicles*. Using data from Census Bureau's American FactFinder, households in the counties in the study area were found to have an average of 1.73 cars. Edmunds and CarGurus.com found that the average price of a used vehicle in the relevant New Jersey counties was $20,100. EGM 09-04 provided the percentage of vehicles that were likely to evacuate during a storm event. Assuming households have at least 12 hours of warning time, 88.1% of vehicles are expected to evacuate or be moved to higher ground. Multiplying the average price ($20,100) by the average number of vehicles per household (1.73) by the percentage of vehicles that will remain in the study area after 12 hours warning (11.9%) provides the per-household damageable vehicle value of $4,138 for the study area.

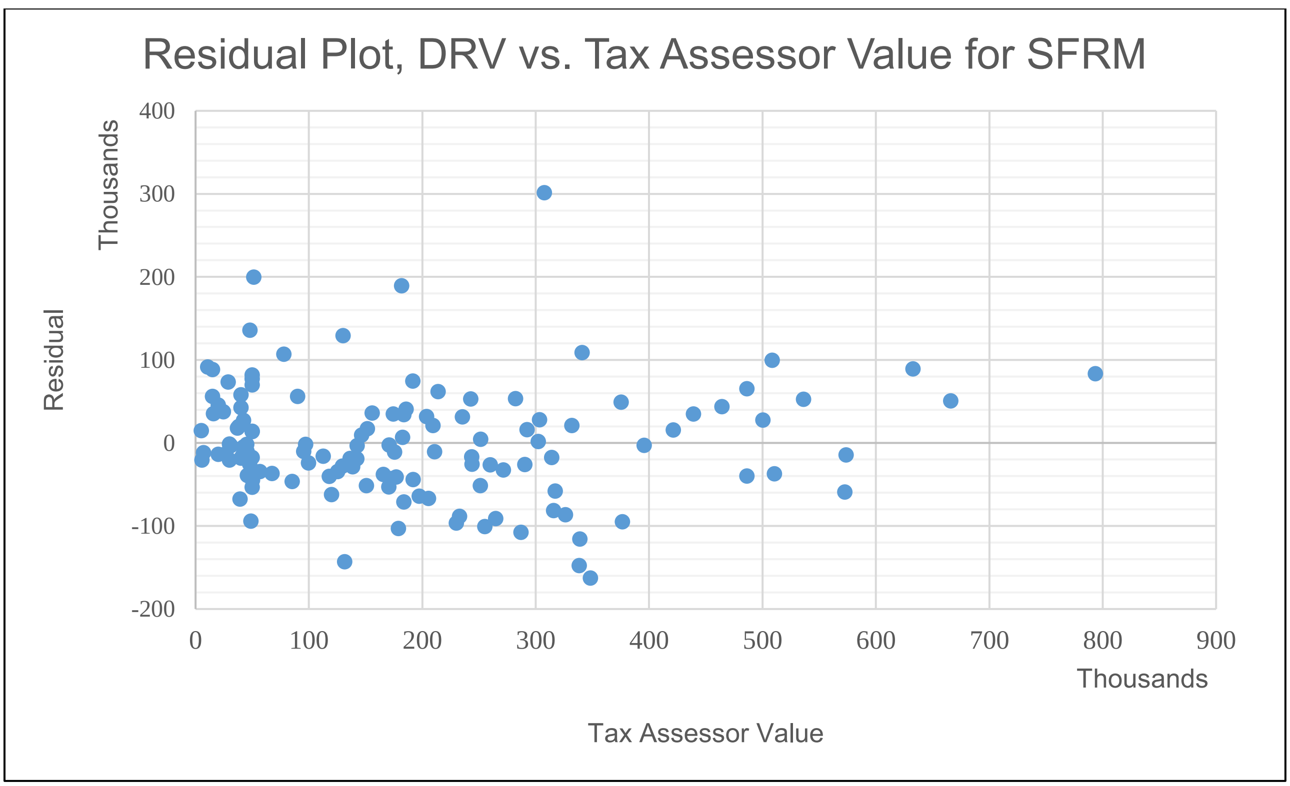
With 172,988 structures in the study area, total damageable vehicle value is approximately $715 million. Vehicles are assigned the same ground elevation as their respective structure.

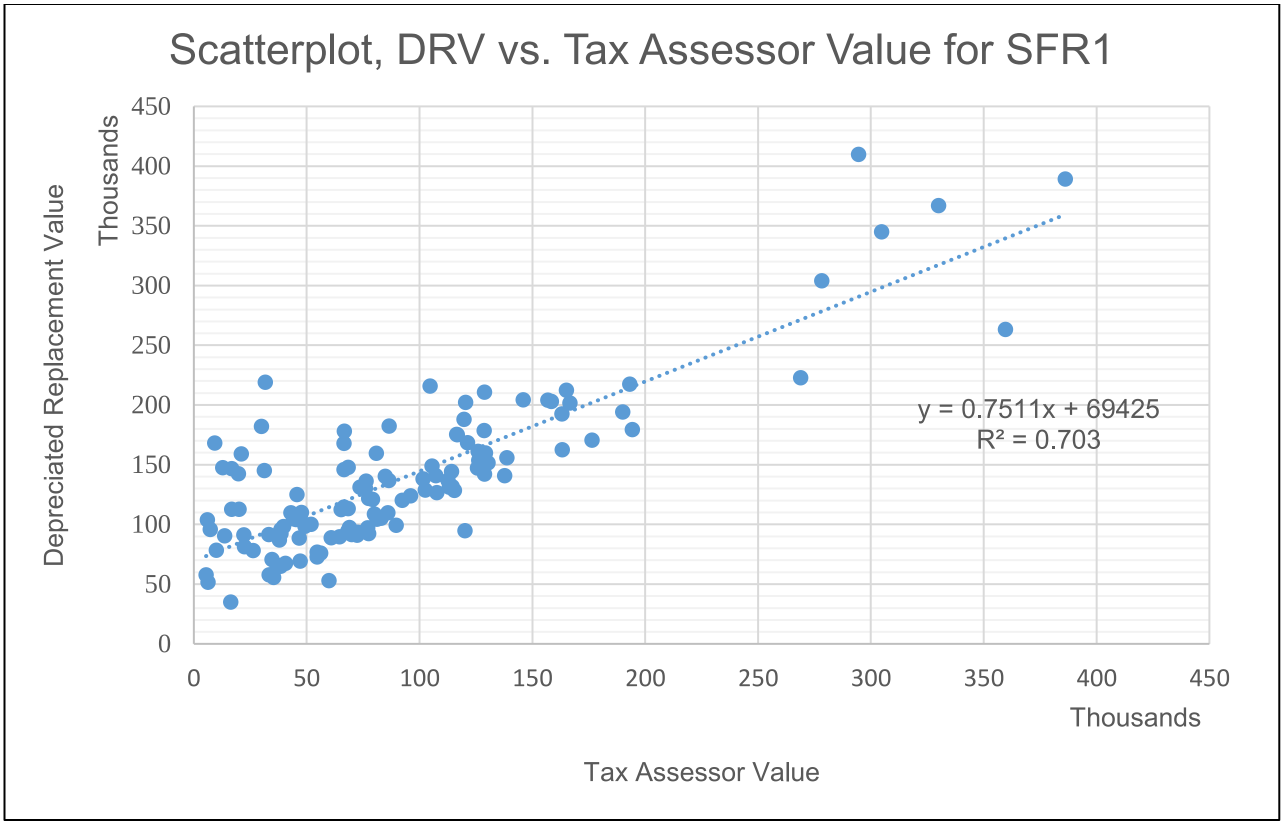
As stated in Section C-3, tax assessor structure values, here referred to as "improvement values," provide a base for determining Depreciated Replacement Values (DRVs) in compliance with EM 1110-2-1619 *Risk Based Analysis for Flood Damage Reduction Studies*. The DRVs of a stratified random sample of SFRM and SFR1 structures were independently estimated using Marshall & Swift Residential Estimator 7 (a sample Marshall & Swift DRV report can be seen in Section C-3, Figure 5). By assuming the stratified random sample was representative of the entire population, the sample could then be used to create a model to transform the tax assessor values of the entire inventory into DRVs at the then-current FY2019 Price Level.

123 representative SFR1s and 131 representative SFRMs were evaluated using Marshall & Swift and, using those results, a simple linear regression model was generated to transform the tax assessor value to a DRV for the remaining structures in the inventory. Other structure variables, such as ground stage or locational variables, were considered to be added to the linear regression model but were ultimately dismissed due to questions regarding their predictive power. The linear models, scatterplots, and residuals for SFRM and SFR1 can be seen in Figure 34.

The linear models fit the data reasonably well (R^2 of .74 and .70) and the residual scatterplots do not show any signs of non-linearity or heteroskedasticity, suggesting this linear model is a good model for transforming improvement values into DRVs.


Scatterplot, DRV vs. Tax Assessor Value for SFRM
Depreciated Replacement Value
Thousands
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
Thousands
Tax Assessor Value
y = 0.7005x + 108253
R² = 0.739


Residual Plot, DRV vs. Tax Assessor Value for SFRM
Residual
Thousands
400
300
200
100
0
-100
-200
0
100
200
300
400
500
600
700
800
900
Thousands
Tax Assessor Value



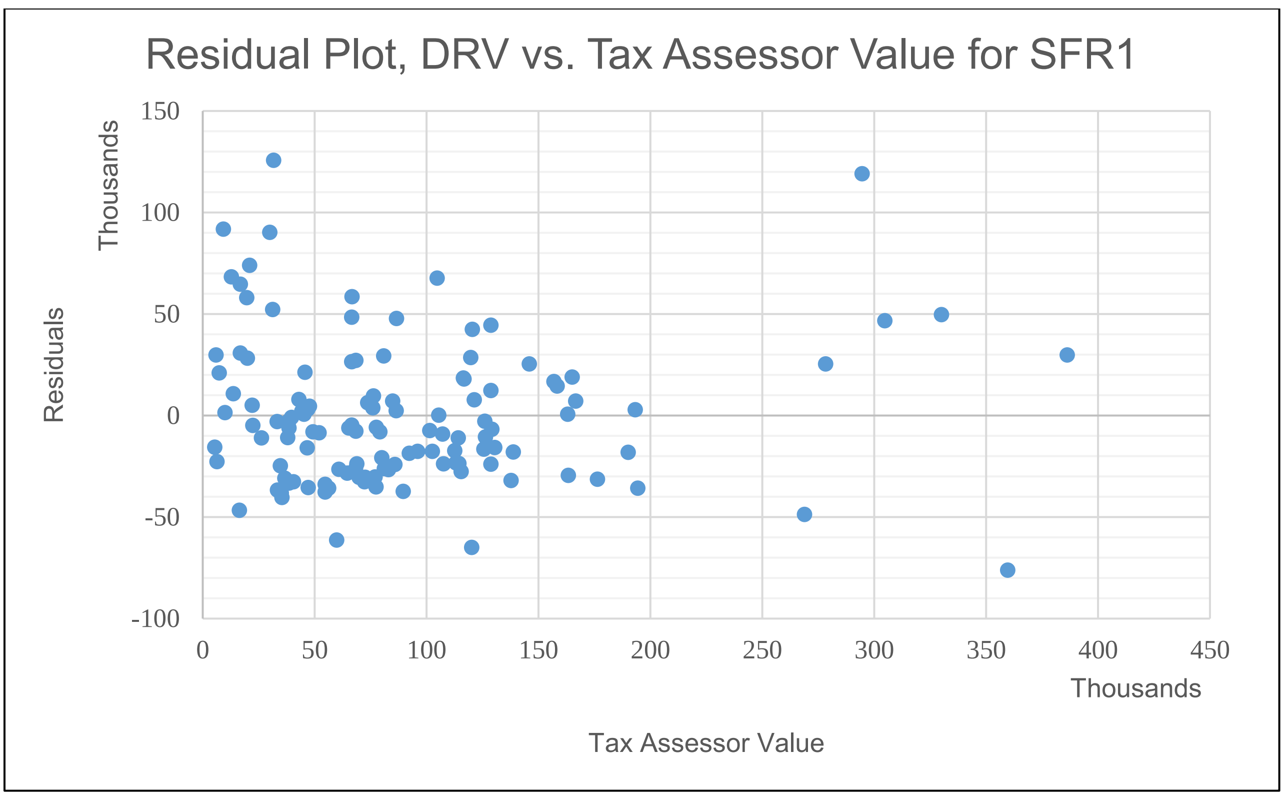


Figure 34: Scatterplots and Residuals for Linear Model Transforming Improvement Values to DRVs

A Depreciated Replacement Value adjustment equation for non-residential structures was not explicitly calculated as the tax assessor values as given were considered the best estimate of DRV. As non-residential structure values can vary significantly based on structure-by-structure characteristics, a population-wide adjustment equation was not appropriate. Inventory values were, however, updated to FY2019 price levels and then further updated to FY2021 price levels in the HEC-FDA model.

Content-to-Structure Value Ratios (CSVRs) were taken from three sources: the Institute for Water Resource's *Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation* (*Revised 2013*); *Southwest Coastal Louisiana Expert Elicitation* (*April 2016*); and EM 1110-2-1619 *Risk-Based Analysis For Flood Damage Reduction Studies (August 1996)*. The CSVRs selected for each structure type are detailed in Table 21. The CSVR for COM was selected to be the average of the CSVRs for the four most common commercial types in the study area: retail-clothing, fast food, non-fast food, and convenience stores.

Table 21: Structure Type CSVRs

Occupancy Type	CSVR	Source
SFR1	0.43	EM 1110-2-1619
SFRM	0.40	EM 1110-2-1619
COM	0.30	IWR 2013
APT	0.40	IWR 2013
IND	0.38	IWR 2013
HIGH	0.10	IWR 2013
PUB	0.14	Southwest Coastal Louisiana 2016

Future work will seek to refine the classification of COM structures in order to assign CSVRs more accurately and to identify Regional Economic Development losses due to business interruption. This ongoing work is discussed in more detail in Section C-9 and will be completed prior to release of the final Feasibility Report.

Table 22 provides a comprehensive overview of the model inventory in terms of number of structures, structure value, and content value.

Single-family residential structures are 95% of the inventory, but only make up 72% of the total depreciated replacement value of all the structures in the inventory. Because they have the highest content-to-structure value ratio, however, they make up 83% of the content value of the inventory. On the other hand, high-rises have very high structure values, comprising 10% of the structure value of the inventory, despite being less than a percent of the inventory in terms of number of structures. The CSVR for high-rises is relatively low, however, as the value of the contents in the structure is dwarfed by the massive value of the structure itself.

Table 22: Structure and Content Value by Occupancy Type ($1000s)

Occupancy Type	Structure Value	% of Total Structure Value	Content Value	% of Total Content Value	% of Total Structures
RES	36,579,800	72%	15,077,600	83%	94.5%
COM	3,704,100	7%	1,096,400	6%	3.8%
HIGH	4,840,800	10%	484,100	3%	0.1%
APT	2,393,100	5%	962,000	5%	1.0%
IND	30,800	0%	11,700	0%	<0.1%
PUB	3,214,200	6%	450,000	2%	0.6%
TOTAL	**50,762,800**	**100%**	**18,081,800**	**100%**	**100%**

Structure First Floor Elevation

The first floor elevation (FFE) of an asset, which is related to the stage at which a structure begins to take damage, is the sum of the ground elevation where the structure is located and the foundation height of the structure. The ground elevation of each structure in the study area was determined using the National Oceanic and Atmospheric Administration (NOAA) Digital Coast Bare Earth Light Detection and Ranging (LiDAR)-derived Digital Elevation Model (DEM), as shown in Section C-3, Figure 7. For some structures built on piers over water, as is seen in some parts of Lacey and Stafford Townships, the LiDAR ground elevation returned as zero. As such, the ground elevation for structures in these communities was set at a minimum of 3ft NAVD88 and, when possible, visually surveyed on Google Earth Street View to identify the most appropriate ground floor elevation.

A histogram of the average ground elevation (NAVD88) for the communities (cities, townships, boroughs, etc.) in the study area can be found in Figure 35.

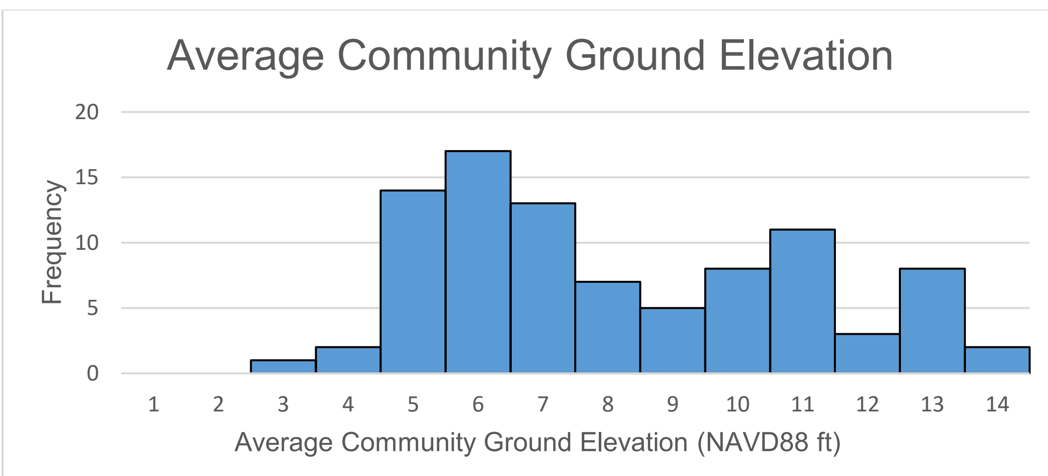


Figure 35: Histogram of Average Community Ground Elevation

As mentioned in Section C-3, measuring the foundation height of each of the structures in the study area would be prohibitively time and resource consuming. A visual survey of a stratified random sample of foundation heights was taken in order to determine the mean foundation height and the distribution of foundation heights for each occupancy type. A pilot survey was first done for SFRM and SFR1, where 1% (966 and 744 structures, respectively) of the structures were examined in Google Earth Pro in order to measure their foundation heights. Structures were still assumed to have pile foundations without basements. Details of the survey are in Table 23.

Table 23: Foundation Height Samples for Residential Structures

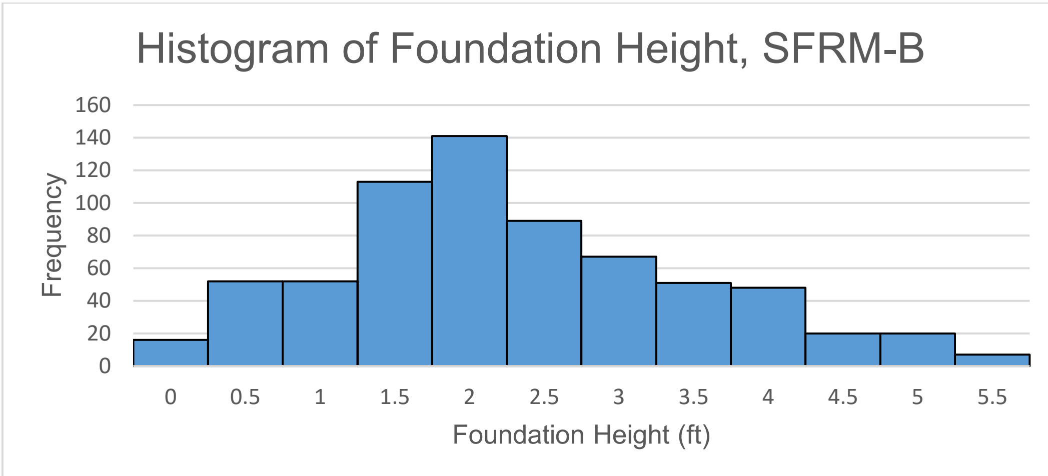
Category	Subcategory	Total	Sample n	% Sample Taken	Total elevated	% elevated
SFRM		**89,060**	**966**	**1.1%**	**116**	**12%**
	Barrier	68,288	787	1.2%	111	14%
	Mainland	20,772	179	0.9%	5	3%
SFR1		**74,471**	**744**	**1.0%**	**67**	**9%**
	Barrier	50,911	497	1.0%	62	12%
	Mainland	23,560	247	1.0%	5	2%

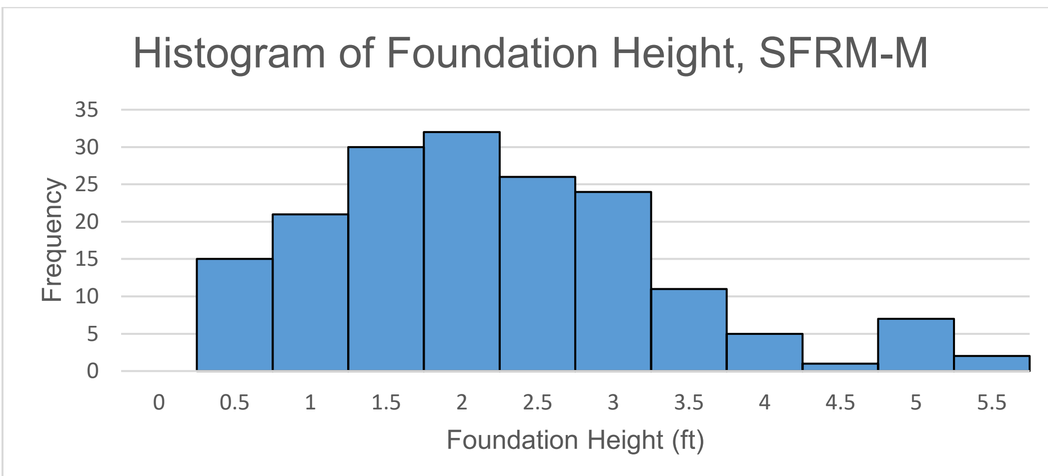
During the survey, structures that were found to have a foundation height of 6 or more feet were considered “elevated” and treated as a separate group, since the inclusion of those data changed the distribution of the foundation heights from normal to bimodal. In order to account for the elevated structures, a percentage of the unsurveyed structures from each occupancy type within the inventory were randomly given a foundation height of 10 feet instead of the rounded mean foundation height of their occupancy subcategory.

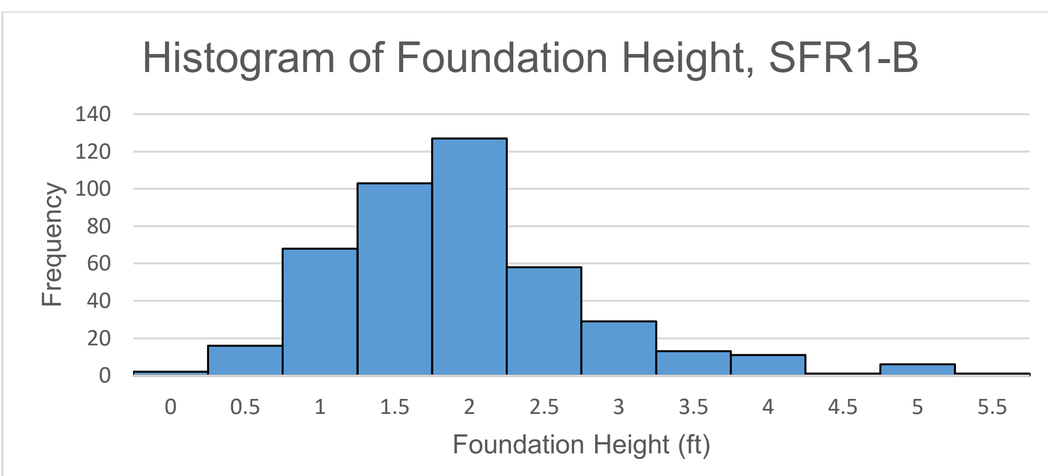
To be conservative, a larger percentage of each occupancy type was randomly elevated than was seen in the survey: 20% of barrier residential structures (SFRM-B and SFR1-B) and 5% of mainland residential structures (SFR1-M and SFR1-M). The 20% elevation number for barrier structures is lower than the initial 33% estimate that was applied to that occupancy type in the initial iteration of the model (see Section C-3), but higher than the measured 13.4% in this more recent larger survey.

In practice, these percentages (20% and 5%) are applied to the full inventory by giving each structure the percentage chance of being elevated that corresponds to the population percentage of structures in that occupancy type that are elevated. For example, an SFRM-B structure is assigned a foundation height of 2.25 (see Table 24 below), but there is a 20% chance that its foundation height is changed to 10 before the model is run to simulate the fact that roughly 20% of the SFRM-B structures in the study area are elevated. HEC-FDA does not have an option that allows this to be done as part of the Monte Carlo simulation, so it was done outside of HEC-FDA before the simulation. Future analysis will reveal how sensitive the model is to this selection process and whether a change in the methodology is appropriate.

The distributions of the foundation heights of the non-elevated structures in the survey can be seen in Figure 36.







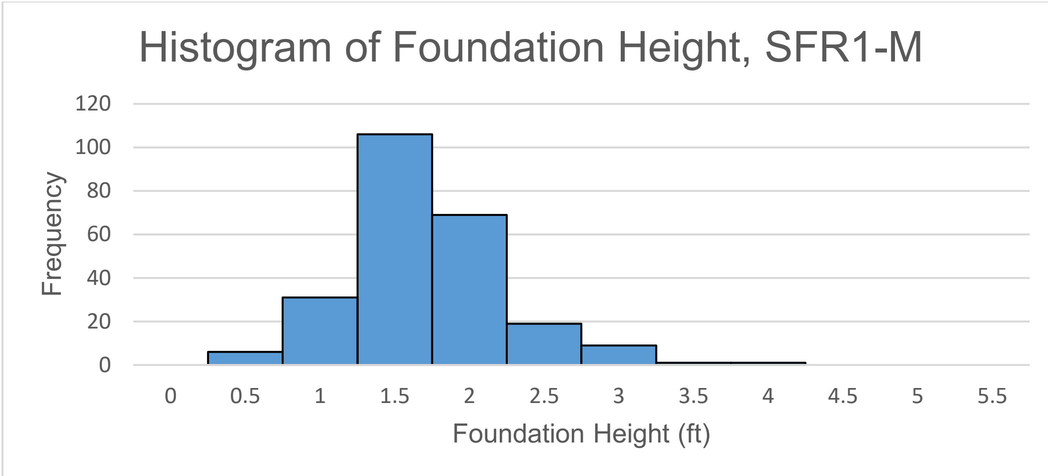


Figure 36: Foundation Height Histograms for Residential Structures

From the survey results, the assumption will be made that the foundation heights of the four groups are all normally distributed, though truncated at 0 and 5.5 (due to limitations with the HEC-FDA model, the truncation will be ignored and the distributions will be modeled as normal).

As the distributions of the residential structures are close to fitting a normal distribution, a confidence interval was calculated for the mean foundation heights using the following formula:

$$CI = \overline{x} \pm 1.96 * \frac{\sigma}{\sqrt{n}}$$

These confidence intervals span less than half a foot each for each residential occupancy type and suggest the initial pilot survey is a sufficiently large sample size. The foundation height mean, standard deviation, standard error, and confidence intervals for the non-elevated residential structures are detailed in Table 24.

Table 24: Foundation Heights and Confidence Intervals, Residential Structures

Occupancy Type	Occupancy Subtype	Foundation Height Mean	Std. Dev	SE of the Mean	Mean 95% CI, Lower Bound	Mean 95% CI, Upper Bound
SFRM		2.27	1.20	0.04	2.19	2.35
	Barrier	2.30	1.21	0.05	2.20	2.39
	Mainland	2.20	1.14	0.09	2.03	2.37
SFR1		1.79	0.79	0.03	1.73	1.85
	Barrier	1.86	0.88	0.04	1.78	1.94
	Mainland	1.64	0.52	0.03	1.57	1.70

There is no statistically significant difference in the mean foundation heights for SFRM-B and SFRM-M (their confidence intervals overlap), but there is a significant difference between the mean foundation heights for SFR1-B and SFR1-M, as well as a significant difference between the SFRM and SFR1 group means. The rounded means and standard deviations from Table 24 are used by HEC-FDA in the Monte Carlo simulation: for each trial, HEC-FDA randomly pulls a foundation height for each structure from a normal distribution that has the parameters outlined above. This foundation height is added to the ground elevation to determine the applied first floor elevation.

A visual survey was completed to measure a stratified random sample of foundation heights for the non-residential structures as well. The results of these surveys can be found in Table 25 and Table 26, and the distribution of the foundation heights of the structures for each occupancy type can be found in Figure 37. For IND, all the structures were surveyed, and for HIGH, all of the structures that could be seen on Google Earth Pro were surveyed. Each of these occupancy types was concluded to have their foundation heights normally distributed and truncated at 0 and 5.5.

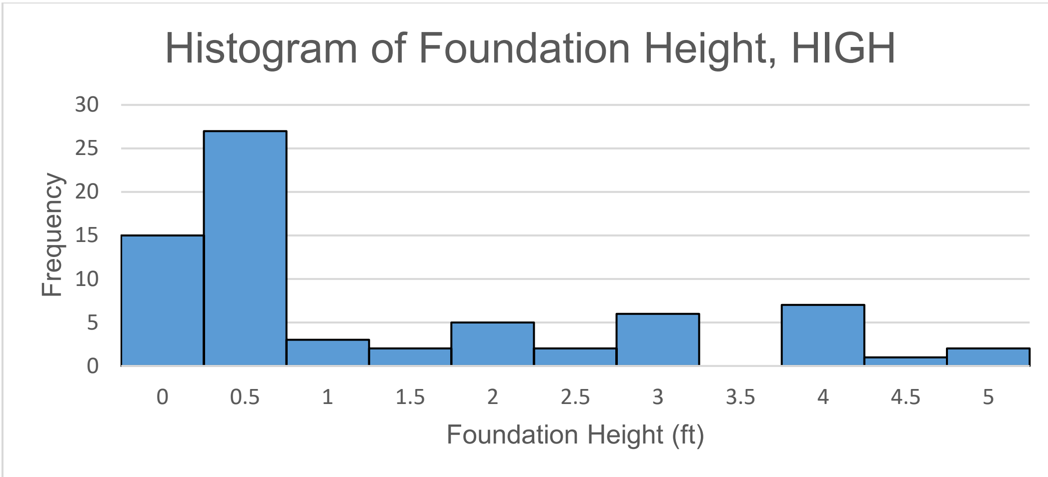
Table 25: Foundation Height Samples for Non-Residential Structures

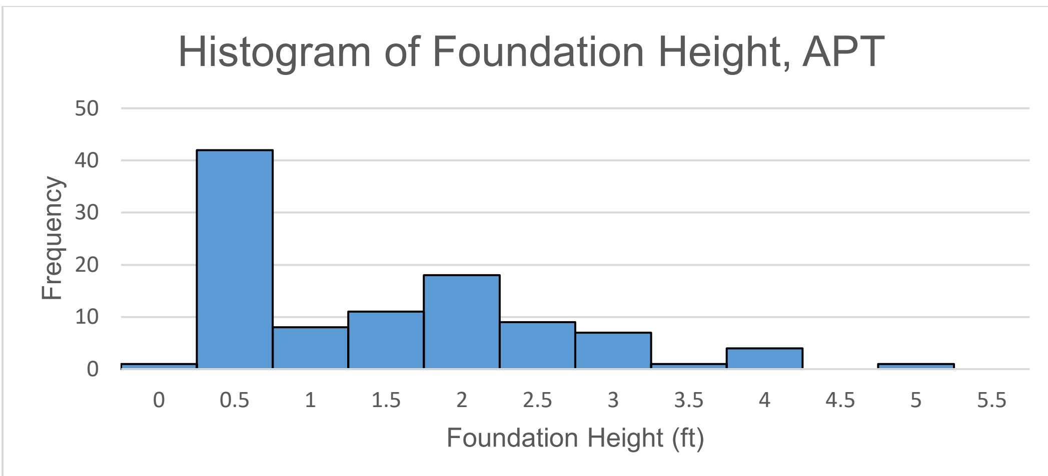
Category	Total	Sample n	% Sample Taken	Total elevated	% elevated
IND	62	62	100%	0	0%
COM	6,558	67	1%	3	4%
PUB	1,051	17	2%	0	0%
APT	1,669	133	8%	31	23%
HIGH	117	102	87%	32	31%

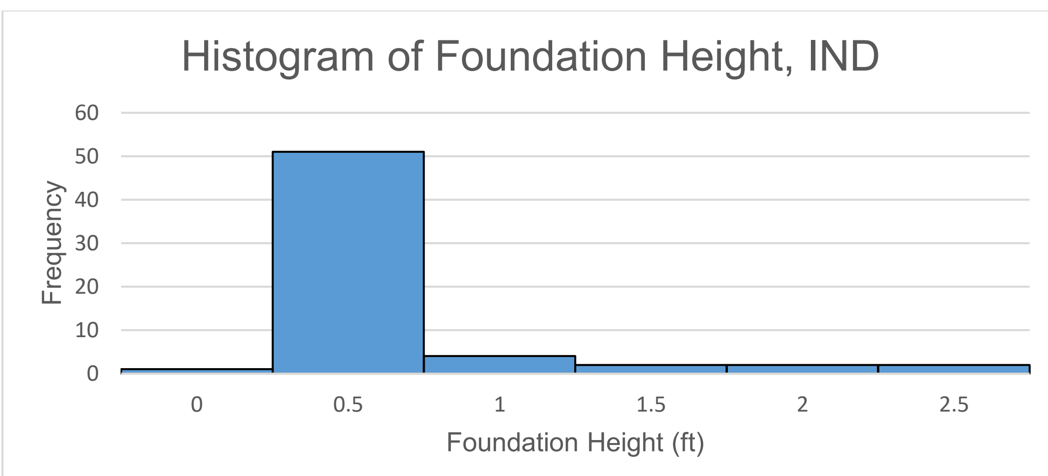
The measured sample for Public structures, in absolute terms, is lower than other non-residential types as some of the sampled structures were reclassified to other occupancy types, reducing the sample still applicable to Public (see Table 20). Though Public structures account for only 0.6% of the total structure inventory, and minor variations in applied assumptions are not expected to alter study decision points, a larger sample will be taken prior to the final Feasibility Report to confirm the current distribution parameters.

Table 26: Foundation Heights and Confidence Intervals, Non-Residential Structures

Category	Foundation Height Mean	Std. Dev	SE of the Mean	Mean 95% CI, Lower Bound	Mean 95% CI, Upper Bound
IND	0.65	0.44	0.06	0.54	0.76
COM	1.03	1.07	0.13	0.77	1.29
PUB	1.59	1.07	0.26	1.08	2.10
APT	1.43	1.06	0.10	1.23	1.64
HIGH	1.36	1.45	0.17	1.02	1.70


Histogram of Foundation Height, HIGH
Frequency
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Foundation Height (ft)


Histogram of Foundation Height, APT
Frequency
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Foundation Height (ft)


Histogram of Foundation Height, IND
Frequency
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
Foundation Height (ft)

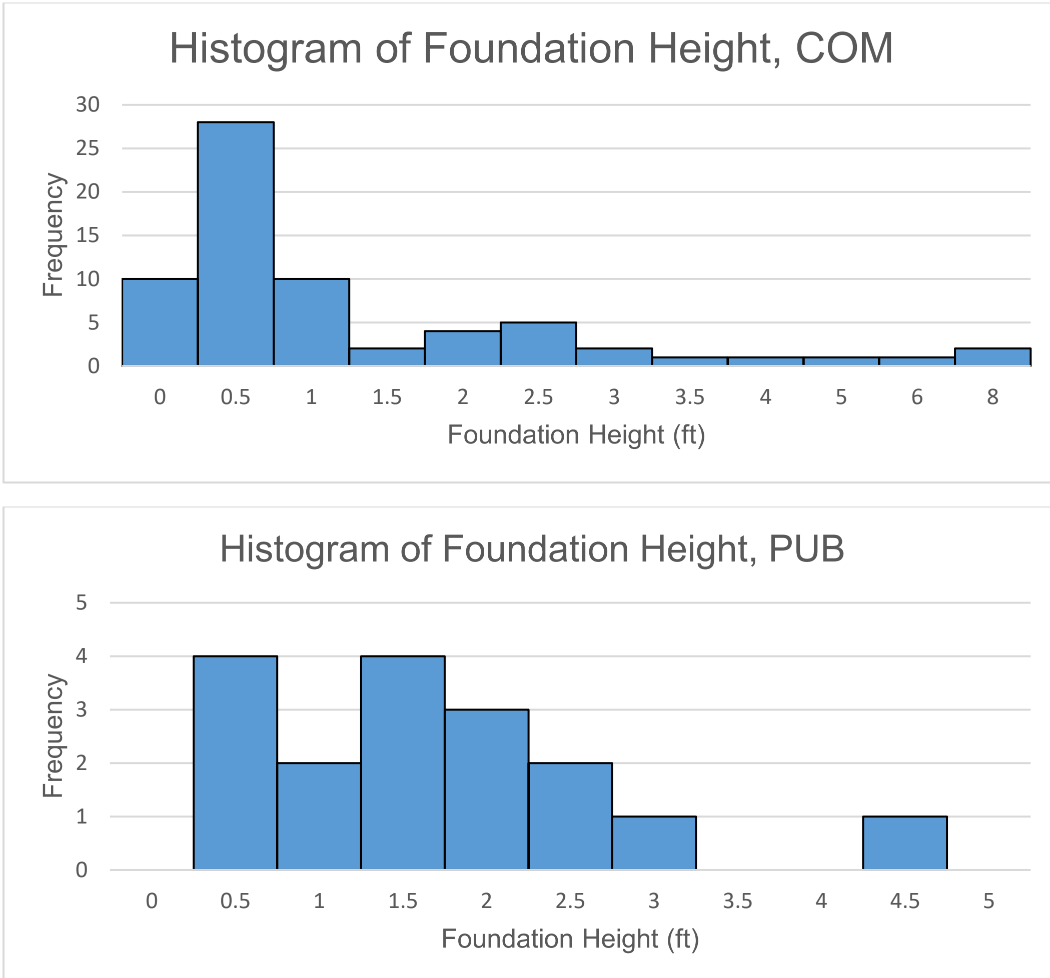


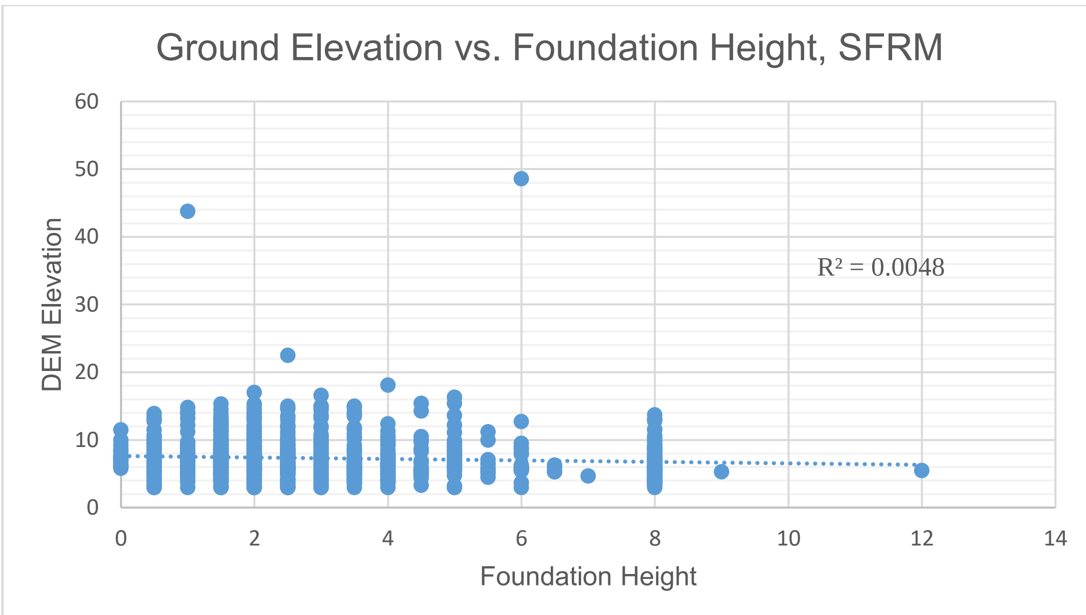
Figure 37: Foundation Height Histograms for Non-Residential Structures

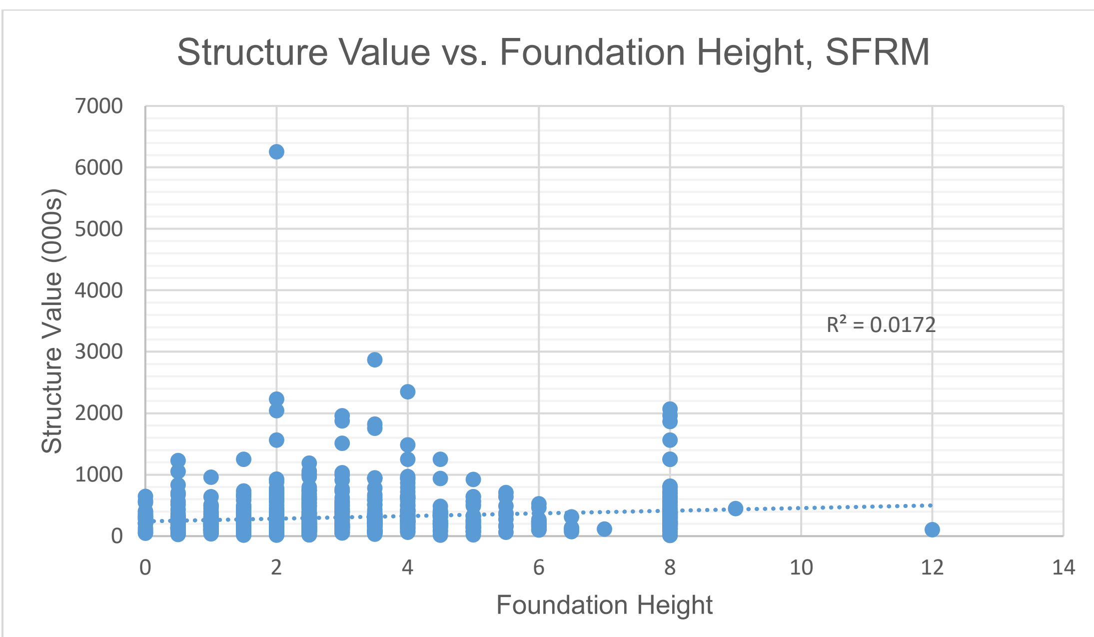
As with the residential structures, during each trial of the Monte Carlo simulation, HEC-FDA randomly pulls a foundation height for each structure from a distribution that has that rounded mean and standard deviation from Table 26. Future work will be to finish the population-level surveys, continue the survey for COM and PUB, and use the foundation heights for the structures themselves in the model as opposed to the distributions of structures to reduce uncertainty.

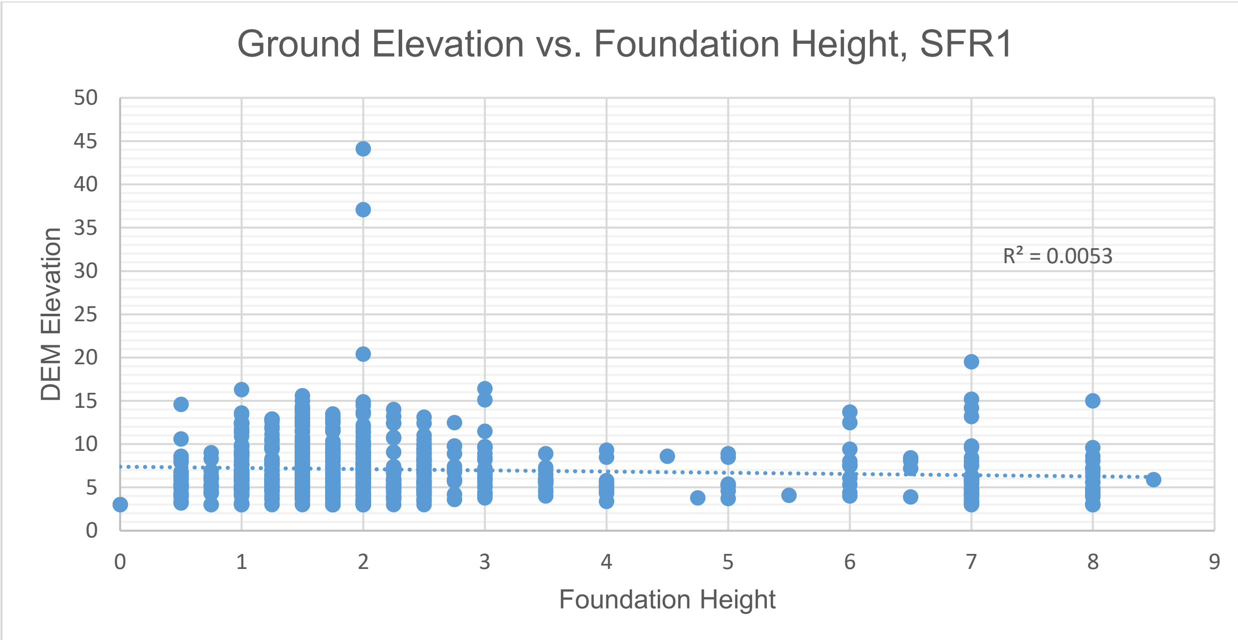
Structures are assigned their occupancy type mean outside of HEC-FDA, but within HEC-FDA, the Monte Carlo simulation draws foundation heights thousands of times for each structure from a distribution with the specified occupancy type mean and standard deviation. As such, it is important to specify the population parameters correctly and ensure that structures are assigned to the right populations.

To support this assumption, it is imperative to determine if foundation height is correlated with other variables, as correlation between variables could violate current assumptions and necessitate a change in methodology. Two possible hypotheses evaluated for the study area is a possible inverse correlation between foundation height and ground elevation or a possible direct correlation between foundation height and structure value. If either hypothesis is supported by surveyed data, it would require further specification of the occupancy type groupings to correctly assign mean foundation heights to inventory structures.

Figure 38 contains scatterplots that show ground elevation by foundation height and scatterplots that show structure value by foundation height for both SFR1 and SFRM structures. In each case examined, there is no correlation between the two variables and further specification would not improve model accuracy.







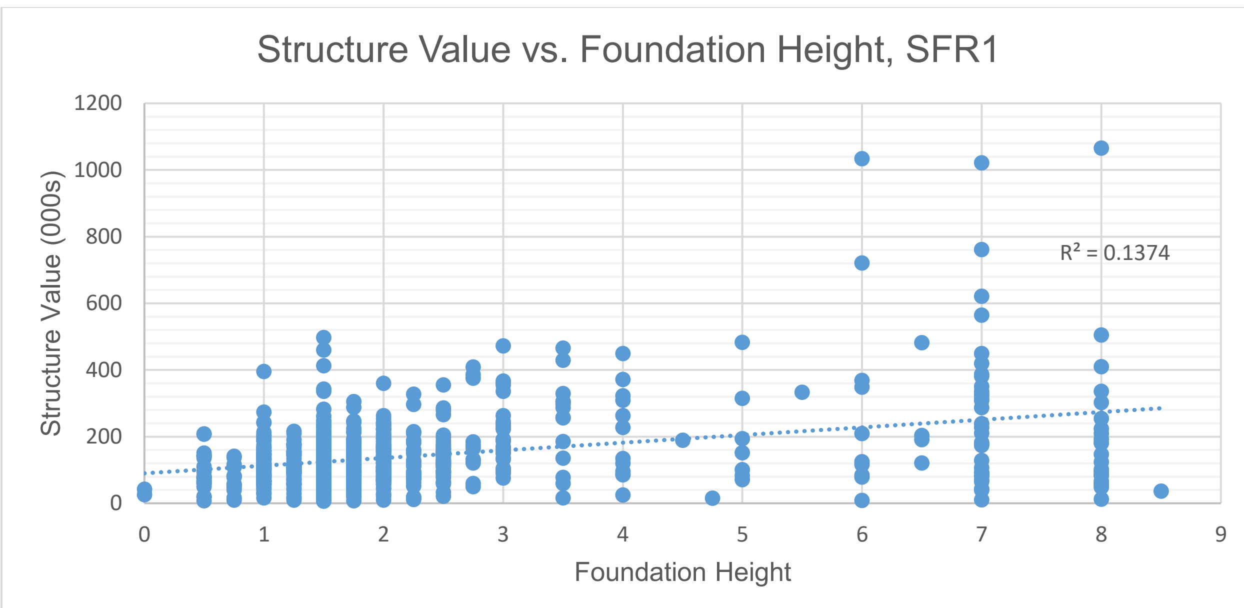


Figure 38: Scatterplots Checking for Correlation between Variables

Depth-Percent Damage Functions

The methodology regarding assignment of depth-percent damage functions from Section C-3 was refined in this stage of the study. The curves for SFR1, SFRM, COM, APT, and HIGH were maintained as the ones from the North Atlantic Coast Comprehensive Study (January 2015) (see Section C-3, Table 4). The curves for PUB and IND were disaggregated to reflect their differing damage characteristics. The IND curve now comes from the Institute for Water Resource's *Nonresidential Flood Depth-Damage Functions Derived From Expert Elicitation*, while the PUB curves come from the *Southwest Coastal Louisiana Expert Elicitation (April 2016)* (with the exception of PUB-Other, which continues to use the curve from Section C-3).

Finally, a damage curve for the newly added vehicle category was taken from EGM 09-04 *Generic Depth-Damage Relationships for Vehicles*. The source for each structure type's depth-percent damage function, along with its begin-damage point, can be seen in Table 27.

In order to be conservative, the begin-damage points were often set higher than where a structure could theoretically be damaged according to its depth-percent damage function. The newly added triangle distribution depth-percent damage functions from IWR 2013, EGM 09-04, and Southwest Coastal Louisiana Expert Elicitation 2016 are located in Table 28 on the following two pages.

Table 27: Occupancy-Level Depth-Percent Damage Curves and Begin-Damage Points

Occupancy Type	Depth-Damage Function Source	Begin Damage Point
SFR1	NACCS 2015	-0.5
SFRM	NACCS 2015	-0.5
COM	NACCS 2015	-0.5
APT	NACCS 2015	-0.5
IND	IWR 2013	-0.5
HIGH	NACCS 2015	-1
PUB	Southwest Coastal Louisiana 2016	-0.5
VEHICLE	EGM 09-04	0.5

Table 28: Depth-Percent Damage Curves by Structure Occupancy Type

Industrial (IND)

Stage	Structure			Contents		
	ML	Min	Max	ML	Min	Max

-1	0	0	0.7	0	0	0
-0.5	0	0	0.7	0	0	0
0	0	0	1.9	5	0	8
0.5	6.2	3.4	11.3	18	5	28
1	8.9	6	16.8	35	17	50
2	17.4	10.4	28.4	39	28	58
3	19.8	13	35.2	43	37	65
5	31.8	24.4	46.7	47	43	65
7	37.1	27	60.6	70	50	90
10	53.1	41	70.4	75	50	90

Public (PUB)—Metal

Stage	Structure			Contents		
	ML	Min	Max	ML	Min	Max
-1	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0	4	3.9	4.1	0	0	0
0.5	15.9	15.2	16.6	80	60	88
1	18.1	17.3	18.9	85	63.8	93.5
2	23.3	22.1	24.5	86.6	65	95.3
3	25.75	24.4	27.1	100	75	100
5	34.1	31.9	36.3	100	75	100
7	35.4	32.8	38	100	75	100
10	49.35	45.8	52.9	100	75	100

Public (PUB)—Masonry

Stage	Structure			Contents		
	ML	Min	Max	ML	Min	Max
-1	0	0	0	0	0	0
-0.5	0.55	0.5	0.6	0	0	0
0	0.55	0.5	0.6	0	0	0
0.5	13.7	13.1	14.3	80	60	88
1	17.65	16.7	18.6	85	63.8	93.5
2	22.3	21.1	23.5	86.6	65	95.3
3	24.8	23.4	26.2	100	75	100
5	29.65	28	31.3	100	75	100
7	33.1	31.6	34.6	100	75	100
10	51.45	48.8	54.1	100	75	100

Public (PUB)—Wood

Stage	Structure			Contents		
	ML	Min	Max	ML	Min	Max

-1	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0	0	0	0	0	0	0
0.5	27.6	27.1	28.1	80	60	88
1	32.2	31.6	32.8	85	63.8	93.5
2	37.1	36.3	37.9	86.6	65	95.3
3	38.75	37.8	39.7	100	75	100
5	48.4	47.1	49.7	100	75	100
7	53.15	51.7	54.6	100	75	100
10	65.65	63.5	67.8	100	75	100

Vehicle

Stage	Structure			Contents		
	ML	Min	Max	ML	Min	Max
-1	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0	0	0	0	0	0	0
0.5	7.6	7.6	7.6	0	0	0
1	28	28	28	0	0	0
2	46.2	46.2	46.2	0	0	0
3	62.2	62.2	62.2	0	0	0
5	87.6	87.6	87.6	0	0	0
7	100	100	100	0	0	0
10	100	100	100	0	0	0

Critical Infrastructure Identification

The existing inventory detailed above contains critical infrastructure assets, such as schools, hospitals, fire departments, and police stations, which means it accounts for the physical losses to these structures. Non-physical losses that occur due to the impairment of critical infrastructure—for instance, the economic losses incurred when a community loses power or wastewater services—are not currently accounted for. This is due to the difficulty in tying water levels to consequences for these secondary effects. Additionally, damages to roads, ports, utilities, telecommunication lines, water supply infrastructure, and other resources that do not have rigorously defined USACE depth-percent damage curves are not currently included in HEC-FDA (or are included only using generic depth-percent damage curves).

Section C-9 discusses deriving an AEP-damage curve using historical critical infrastructure loss data, but the analysis is limited due to the lack of longitudinal and granular data. This Section treats critical infrastructure qualitatively, allowing for the identification of vulnerable critical infrastructure assets within the study area and the gauging of their level of risk to coastal storm events. Future work will develop this Section further, using the qualitative analysis to help derive bespoke stage-damage curves for physical and non-physical losses for vulnerable assets.

There are approximately 1,785 critical infrastructure assets within the study area. Of these, 656 of them are or may be vulnerable to inundation by 2080 under the Intermediate SLC curve. The data are from the HSIP Gold 2015 geodatabase from the National Geospatial Intelligence Agency and the vulnerability determination was made evaluating whether the asset would be in the 2080 1% AEP event floodplain. To display these data visually, the various types of critical infrastructure were weighted using the risk scores used in *Planning Appendix C* of the North Atlantic Coast Comprehensive Study (NACCS). The weights ranged from 5 (for bus stations and ferries) to 30 (for fire stations, hospitals, and wastewater infrastructure). A list of the types of vulnerable infrastructure in the study area, their counts, and their risk scores is shown in

Table 29 below:

Table 29: Vulnerable Critical Infrastructure Counts

Type of Infrastructure	Count	Risk Score
Airport	1	15
Amtrak Station	2	15
Bus Station	8	5
Cell Tower	16	10
Colleges	2	15
Electric Power	10	25
Emergency Medical Services	57	25
Ferry	1	5
Fire Station	53	30
Gas Station	61	20
Hospital	3	30
Law Enforcement	29	25
National Shelter	36	20
Natural Gas Compressor	1	15
Nursing Home	4	25
Petroleum Pumping Station	43	10
Pharmacy	41	15
Place of Worship	25	15
Private School	11	10
Public School	41	15
Railroad Bridge	11	20
Railroad Station	3	20
Railroad Yard	1	20
Road/Bridge	170	20
Substation Electric	13	20
Urgent Care	3	20
Wastewater Infrastructure	10	30
Grand Total	**656**	

The weights were used to generate the reach-based heat map seen below in Figure 39, while the points themselves, color-coded based on risk score, are displayed in Figure 40:

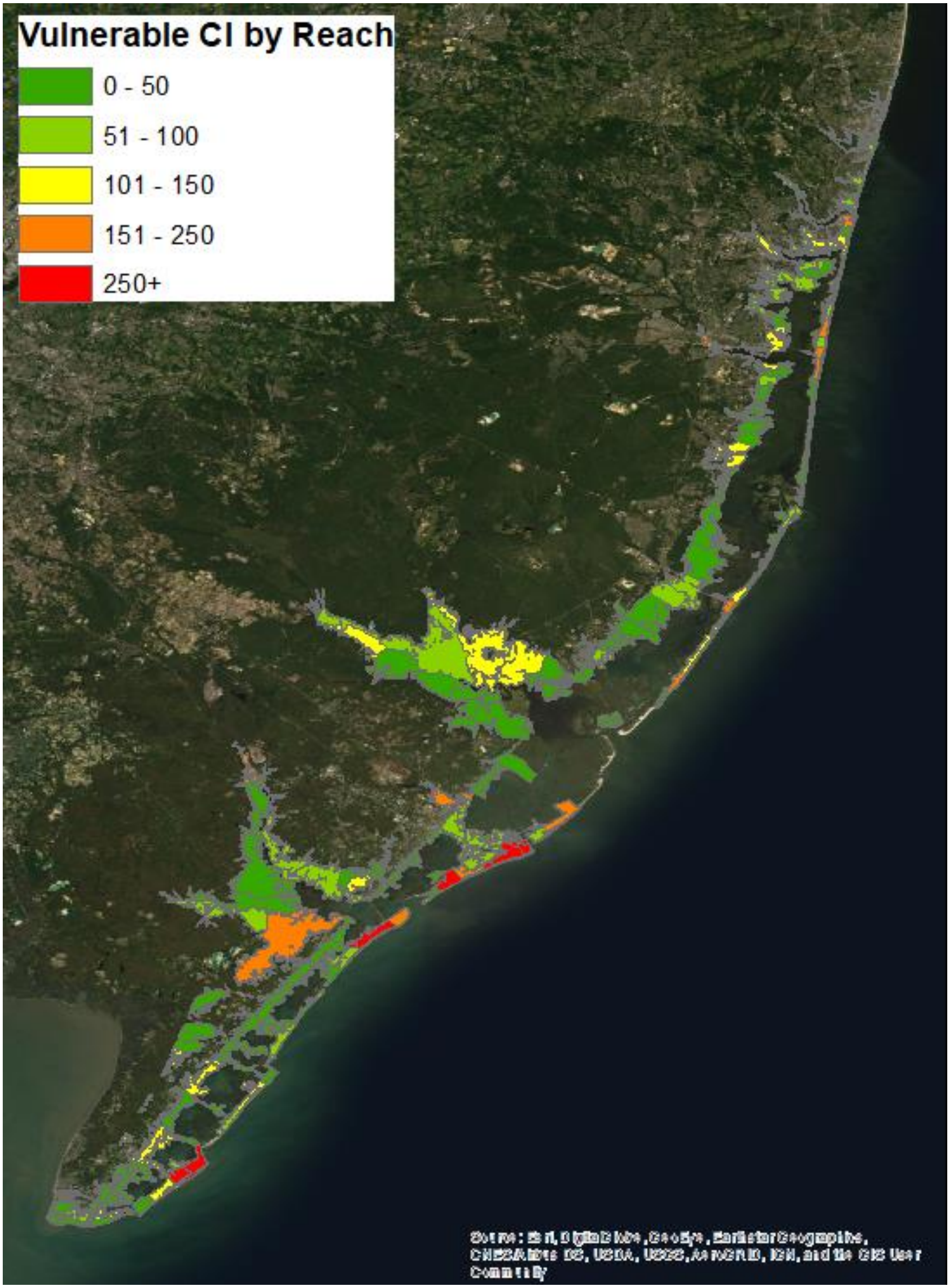


Figure 39: Heat Map of Vulnerable Critical Infrastructure by Reach

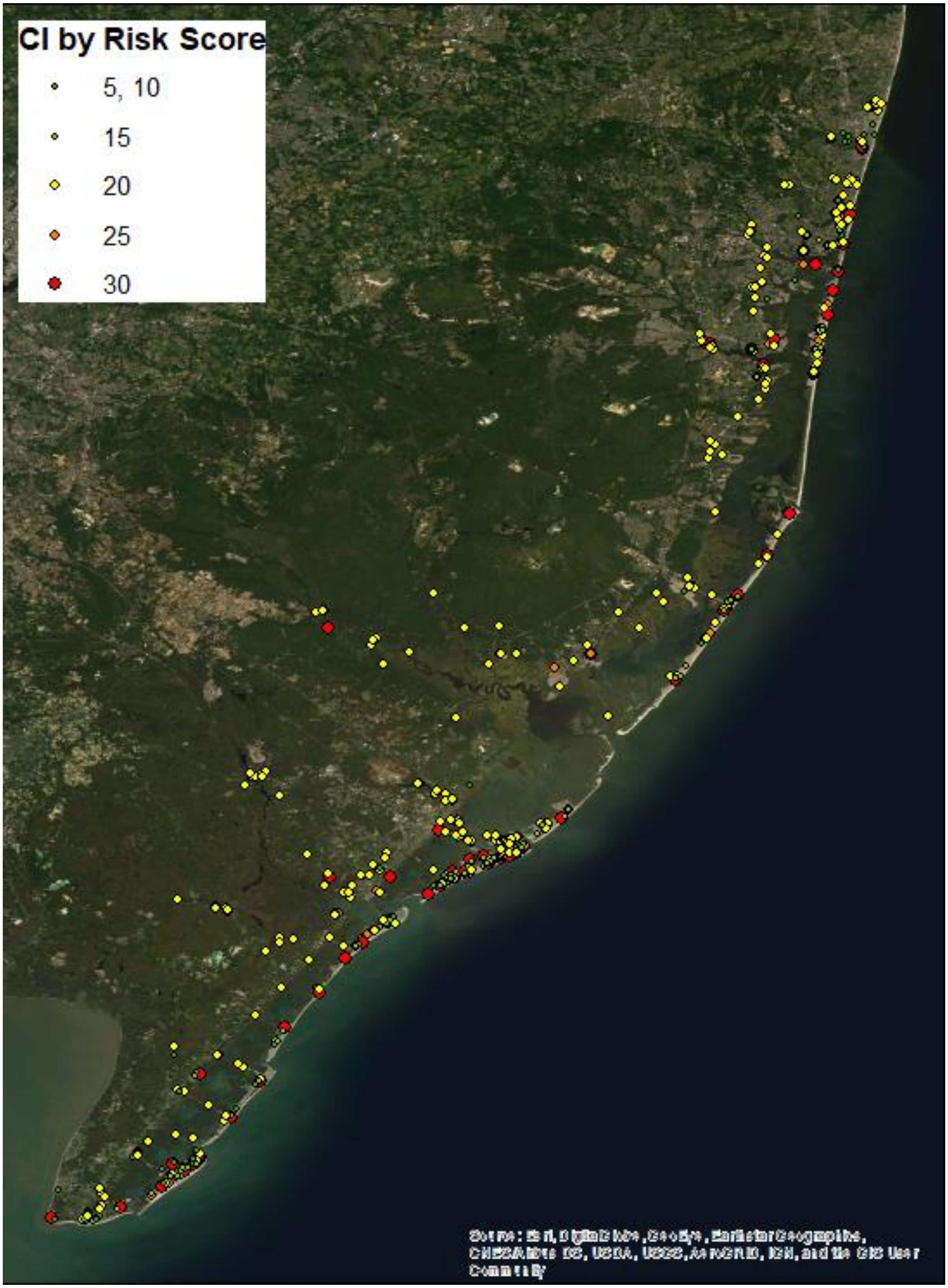


Figure 40: Depiction of all Vulnerable Critical Infrastructure Assets in Study Area

As can be seen in the heat map, the highest concentrations of vulnerable critical infrastructure (weighted by risk score) are in Atlantic City, Ocean City, and Wildwood—places that, not coincidentally, also have high risk for other flood damages. In fact, the critical infrastructure heat map is very similar to the FWOP damages heat map (see Section C-9, Figure 41), though it shows less vulnerability along Long Beach Island, which has relatively fewer critical infrastructure assets.

Moving forward, the vulnerable assets will be examined in more detail. The structure values for the critical infrastructure assets will first be reassessed using RSMeans industrial dollar per square foot estimates and their corresponding CSVRs will be updated. For assets where damage may lead to secondary NED losses, like a power plant becoming flooded and its customers losing power, a deep dive will be performed to determine both vulnerability and consequences. For many types of assets, including wastewater plants, hospitals, and electric plants, these secondary damages may be quantified using a methodology derived from the FEMA manual *Benefit-Cost Sustainment and Enhancement*. Other options for determining consequences involve collaborating with the utilities to determine the consequences of flooding, thereby allowing for the construction of bespoke depth-percent damage curves on a utility-by-utility basis.

Non-HEC-FDA Damage Categories

During storms, there are costs incurred beyond only damages to structures. For instance, there is a cost for emergency services needed during the storm, a cost from the transportation delay that occurs during and after a storm, and a cost from the non-transferrable income loss that arises from people being unable to do economically-beneficial activities in the aftermath of a storm. Additionally, there are impacts that can't be modeled in HEC-FDA because of a lack of existing depth-percent damage curves, such as damage to certain critical infrastructure asset types. To derive a rough order of magnitude calculation of these damages, empirical models were created using historical data on the "costs" of storms. These historical damages were matched with the return frequencies of the events during which the damage was incurred to build functions from which AAD could be derived.

Transportation delay is the public and private delay expense from cars, rail, air, or other transportation means. Within the study area, flood events impact the Garden State Parkway and the Atlantic City Expressway. Several local roads and bridges can be closed due to flooding or damages associated with flooding as well. Beyond car traffic, the North Jersey Coast commuter rail line and the Atlantic City commuter rail line stand at risk of flooding damage. Airports may close in the study area before, during, and immediately after storm events, though the expected impacts are minimal due to the small size of the airports within the area and the close proximity of alternative airports.

Non-transferrable income loss is defined in IWR 2011-R-09 *Coastal Storm Risk Management: National Economic Development Manual* as "the loss of wages or profits to business over physical damages that cannot be deferred or transferred regionally." Non-transferrable income loss by commercial, industrial, and other business firms is difficult to measure because of the complexity involved in determining whether the firm's loss is recovered at another location, at a later time, or by another firm. If it is recovered, even by another firm, it is considered only a regional loss. Non-transferrable loss is quantified in Table 30 below, while regional losses are discussed qualitatively in the Section on Regional Economic Development (RED) losses from business interruption.

Critical infrastructure damage is the damage that occurs to the physical structures that don't have depth-percent damage curves associated with them. For instance, when a flood occurs, a road may be damaged, but the lack of study area specific, or even general use, depth-percent damage curves causes issues for inclusion in HEC-FDA. As such, critical infrastructure for this study is estimated through empirical modeling outside of HEC-FDA. Some of the critical infrastructure considered in this manner are roads, bridges, water supply systems, and electricity generation systems. A qualitative examination of the critical infrastructure assets in the study area is discussed above, while a rough order of magnitude estimate of critical infrastructure losses follows.

Emergency services costs are the expenses of reacting to the scope of the storm. Examples of emergency services include flood fighting, medical care and transport, evacuation and sheltering, firefighting, and search and rescue.

Local costs foregone is a broad economic category that captures the economic burden placed on local citizens and municipalities in combating coastal storm issues that is not already captured in other categories. Examples include public and private protective measures or reduced maintenance on existing storm risk mitigation infrastructure. While potential local costs foregone are captured in the FWOP condition, only certain measures would alleviate local stakeholders of these costs and be captured as FWP benefits. Otherwise, these local costs remain as residual costs in the FWP condition. Additionally, projecting the CSRM activities of local stakeholders throughout the Period of Analysis is exceedingly difficult with any degree of certainty. For this analysis, only the most necessary actions (e.g., raising local bulkheads to mitigate tidal and nuisance flooding) are assumed to occur.

The quantification of historical damages in the above categories and the empirical model used to generate an AAD for them will be discussed in Section C-9.

C-9) UPDATED FUTURE WITHOUT-PROJECT CONDITION

As stated in Section C-4, HEC-FDA links the predictive capability of hydraulic and hydrologic modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the total damages under various proposed alternatives while accounting for risk and uncertainty. The model output is then used to determine the net National Economic Development (NED) benefits of each project alternative in comparison with the No-Action Plan, or Future Without-Project Condition.

Future Without-Project Condition damages are used as the base condition and potential project alternatives are measured against this base to evaluate project effectiveness and cost efficiency. Future Without-Project Condition damages are presented as Average Annual Damages (AAD) over a 50-year period of analysis with an FY2021 Project Evaluation and Formulation Rate (Discount Rate) of 2.5%.

The following model results for Future Without-Project Condition analysis are based on HEC-FDA estimated structure, content, and vehicle damages with additional non-HEC-FDA benefit streams for transportation delay, non-transferrable income loss, emergency services, local costs foregone, and critical infrastructure.

Current data for all HEC-FDA and non-HEC-FDA benefit streams reflect only primary, or direct, damage values. Future analysis will incorporate secondary, or indirect, damage from disruptions to critical infrastructure including interruptions to power plants, government operation centers, wastewater treatment facilities, utility lines, and communication centers.

This section will detail summary statistics, non-HEC-FDA benefit methodology, and a visualization of the damage centers in the study area after Cycle 3 refinements.

HEC-FDA Model Results

The New Jersey Back Bays study area experiences a total of $1,808,610,000 in Without-Project Average Annual Damages (AAD) over a 50-year period of analysis with Intermediate RSLC. Table 30 below shows the breakdown of AAD by benefit stream and its relative contribution to the overall Future Without-Project Project damage pool.

Table 30: Future Without-Project Damage Pool

Damage Type	Source	AAD	Relative %
Structures/Contents	HEC-FDA	$1,543,076,000	85.3%
Vehicles	HEC-FDA	$99,919,000	5.5%
Critical Infrastructure	Historic Damages	$63,856,000	3.5%
Emergency Services	Historic Damages	$41,059,000	2.3%
Income Loss	Historic Damages	$28,081,000	1.6%
Transportation Delay	Historic Damages	$2,701,000	0.1%
Potential Local Costs Foregone	Historic Damages	$29,918,000	1.7%
TOTAL DAMAGES	**-**	**$1,808,610,000**	**100.0%**

While non-HEC-FDA benefit streams, based on historic damages accounts, are important for presenting the true vulnerability of the study area, they account for only 9.2% of total AAD damages. HEC-FDA modeled damages account for the remaining 90.8% of total AAD damages with structure and content damages comprising the majority of estimated impacts.

For sensitivity analysis, the HEC-FDA model was also run using the Low (Historical) and High RSLC curves. The total AAD under the Low curve was $1,453,586,000, while the total AAD under the High curve was $3,890,675,000.

Figure 41, Figure 42, and Figure 43 on the following pages show the heat map of FWOP damages across the 226 reaches in the New Jersey Back Bays study area. Similar to Figures 14 and 15 in Section C-4, damages are concentrated on the barrier islands due to the islands' higher average Depreciated Replacement Values, density of structures, and increased vulnerability to inundation impacts. Of the 226 study area reaches, only 72 fall on the barrier islands, but these reaches account for 76.8% of total Average Annual Damages.

Absecon Island, Ocean City, and Wildwood Island (shown in red) are estimated to receive the most significant coastal storm related impacts over the 50-year period of analysis.

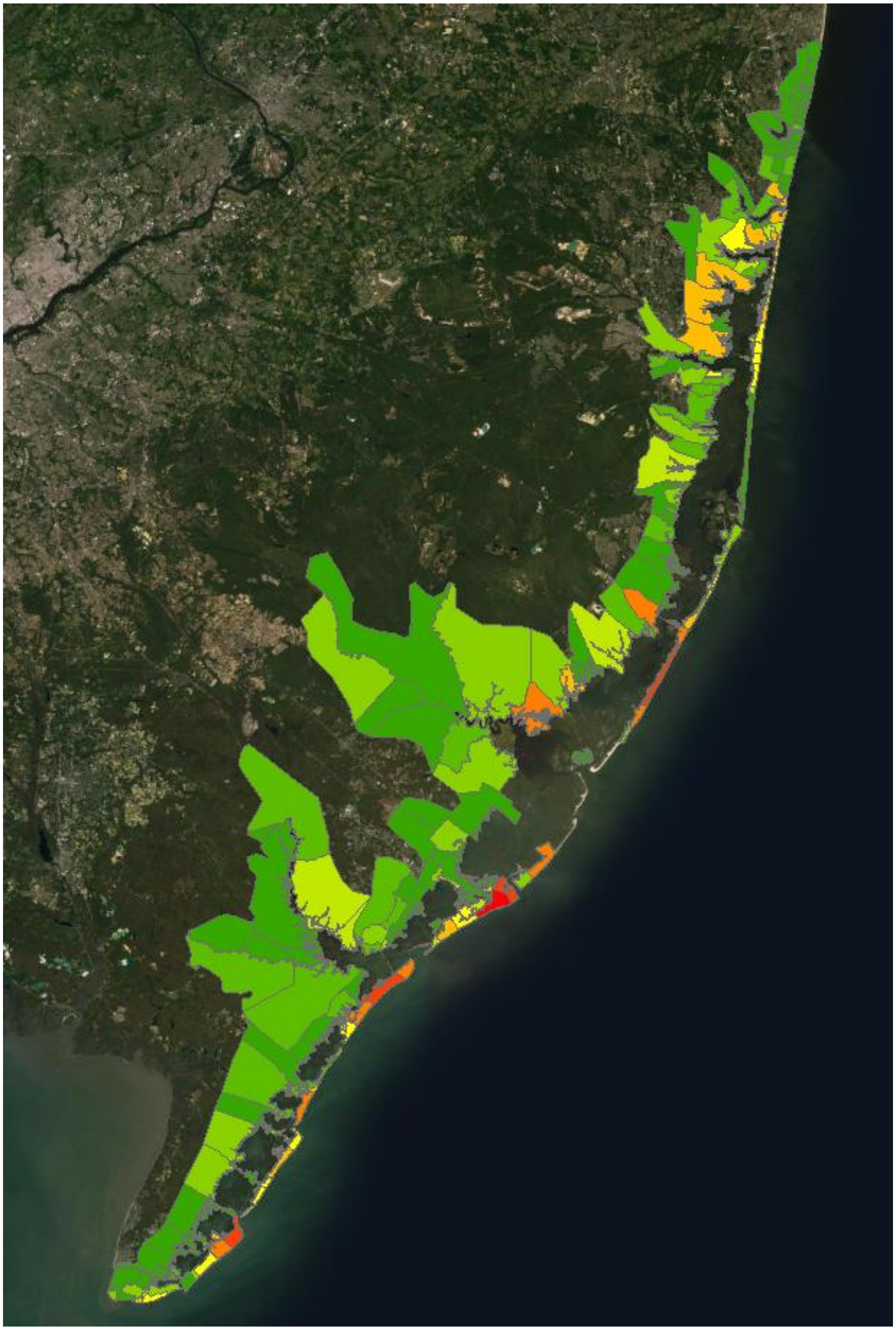


Figure 41: FWOP Damages--Heat Map (Full Study Area)

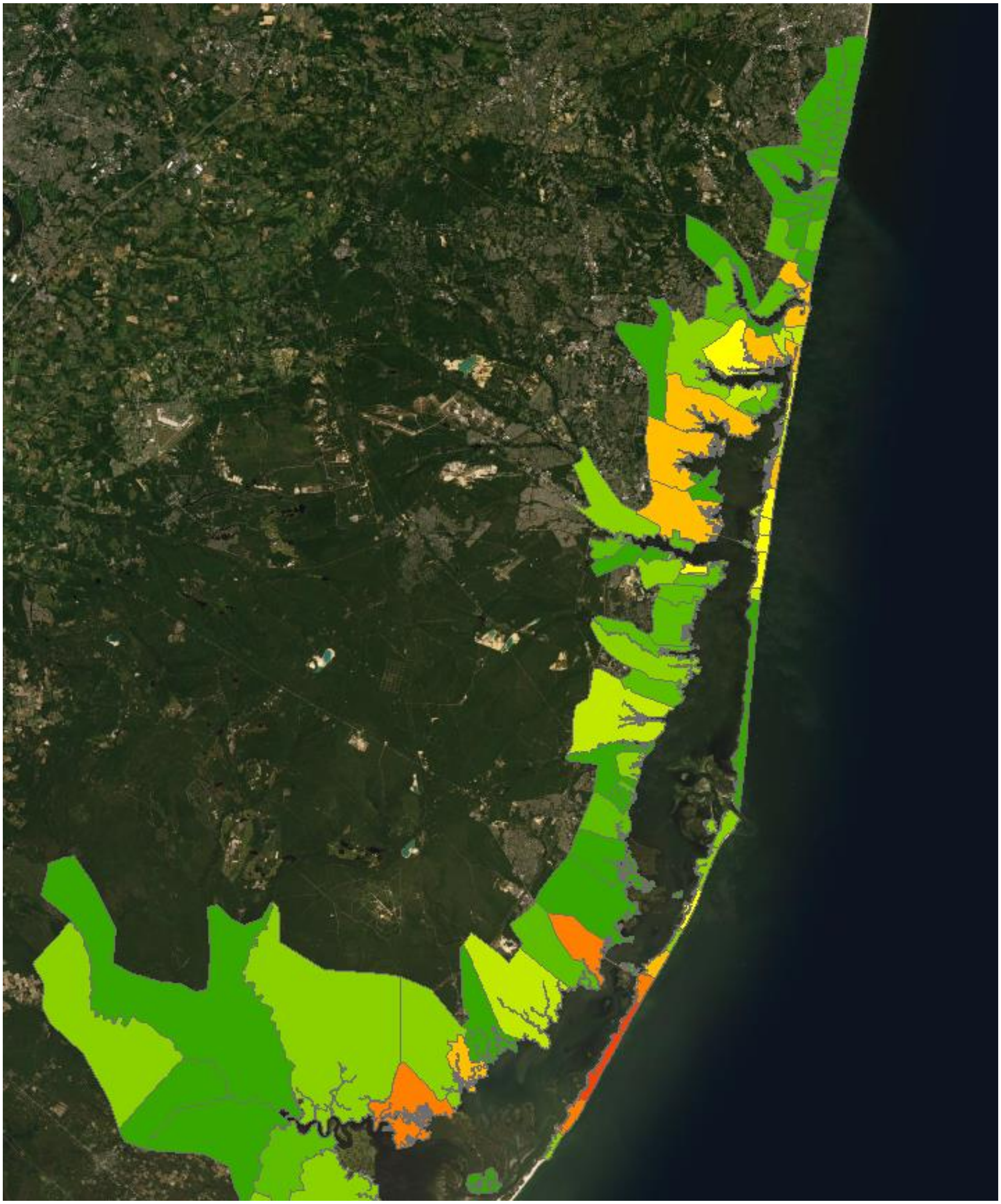


Figure 42: FWOP Damages--Heat Map (Burlington and Ocean and Monmouth)

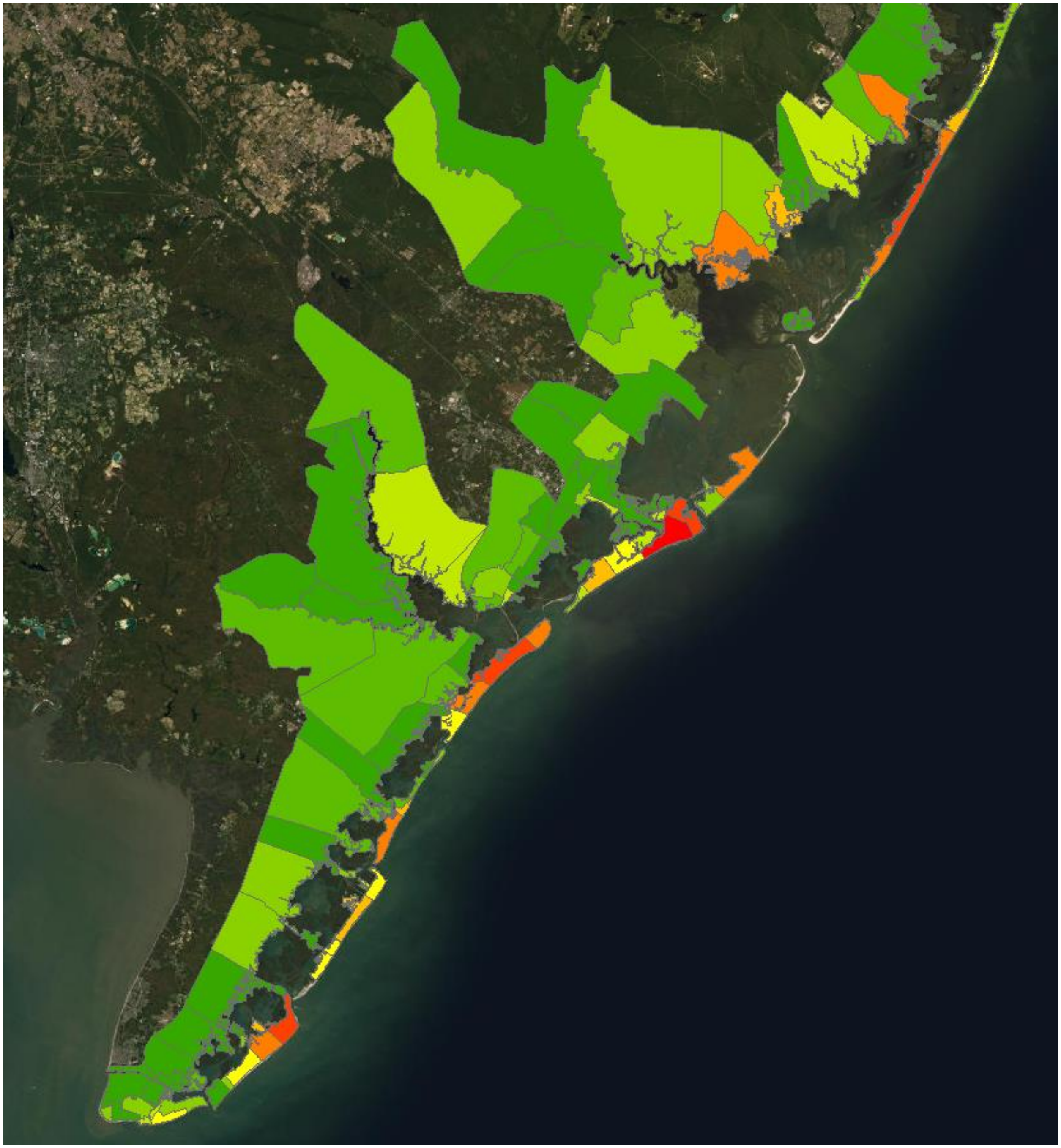


Figure 43: FWOP Damages--Heat Map (Cape May and Atlantic)

Non-HEC-FDA Category Results

As shown in Table 30 above, non-HEC-FDA benefits account for approximately 9% of the total FWOP Average Annual Damages in the study area. This section will detail the methodology and historic damage data utilized to calculate those results.

In building an empirical model to calculate AADs for the non-HEC-FDA inputs, a damage-frequency function is required to interface the absolute value of NED damages with the probability of their occurrence. The damage-frequency function shows how much damage, in dollars, is expected when a storm of a certain return frequency hits. To derive this, historical county damages from various storm events were collected with an emphasis on Hurricane Sandy due to its highly detailed post-storm data and wide-ranging impacts. The return frequency of Hurricane Sandy in different parts of New Jersey can be seen in Figure 44.

Though Hurricane Sandy is of course only one storm event, the return frequency of the storm is different relative to the location of the county or area from which the storm characteristics are measured. For example, in New York City, Long Island, and Northern New Jersey where Hurricane Sandy had the largest impact, the return frequency can range from a 0.9% Annual Exceedance Probability (AEP) event to a 0.4% AEP event. However, in Cape May County or Atlantic County, located further south of the hurricane's path, the return frequency ranges only from a 20% AEP event to a 4% AEP event. By investigating storm damages at a county level with an understanding of the underlying damage curve structure, it is possible to estimate a reasonable damage-frequency function from historic values.

This methodology was used to estimate the damage-frequency functions for critical infrastructure, emergency services, income loss, and transportation delay. (Local costs foregone is estimated using forecasted local expenditures on coastal storm damage mitigation infrastructure and will be further explained in its segment later in this section.) Though the methodology is mathematically sound, it is based on a small data set and, as such, it is only used to derive rough order of magnitude estimates of damages. These methodologies will be re-examined in the next study phase and finalized before release of the final Feasibility Report.

Summary information is provided in Table 39 at the end of the section.

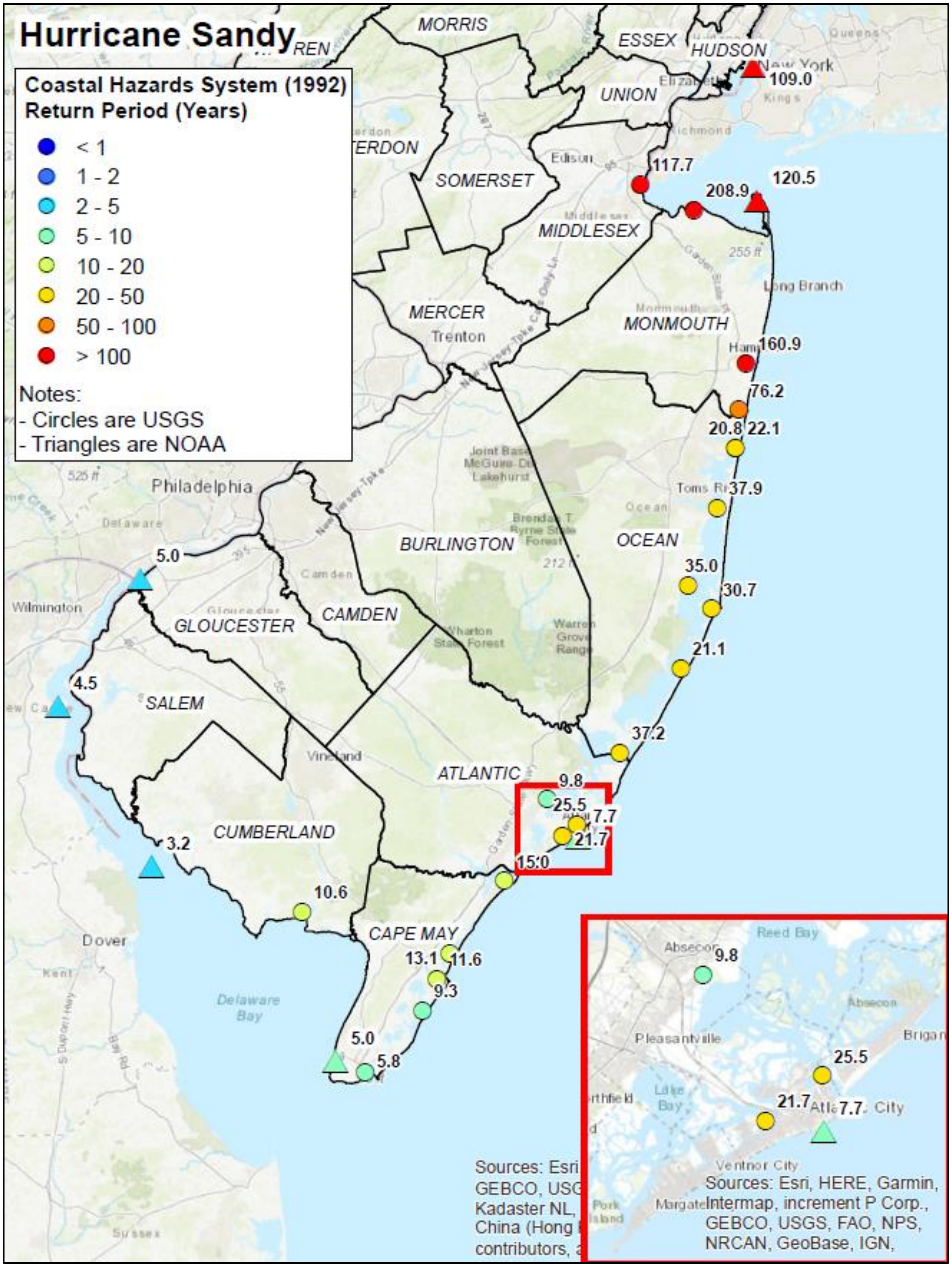


Figure 44: Return Frequency of Hurricane Sandy in Different Parts of New Jersey

Critical Infrastructure

As discussed in Section C-8, HEC-FDA already captures direct damages to critical infrastructure classified as structures (hospitals, fire departments, police stations, etc.), but does not account for damage to other assets essential for maintaining government operation and health services or for expediting post-storm recovery efforts. This includes damages to roads, ports, utilities, telecommunication lines, water supply infrastructure, and other resources that do not have rigorously defined depth-percent damage curves. Adding a non-HEC-FDA benefit stream based on historic damage estimates allows for the study to capture these impacts.

Section C-8 discusses the qualitative identification of the critical infrastructure within the study area. That work will be expanded in the next study phase: critical infrastructure assets will be re-valuated, bespoke depth-percent damage curves will be derived, and secondary NED and RED impacts will be calculated. Using historical damages to generate a rough order of magnitude estimate of study area damages is sufficient for this phase of the study, but future analysis will further develop these estimates to limit uncertainty and improve confidence in the results.

Infrastructure loss data were derived from a variety of sources including the Department of Transportation (DOT), NJ Transit, and the Federal Emergency Management Agency's (FEMA) Public Assistance program categories for Roads and Bridges, Water Control Facilities, Public Utilities, and Recreational and Other. Each of these sources had county-level data on infrastructure damage from major events including Hurricane Sandy and Hurricane Irene. Some of the post-storm expenditures had large amounts of money that were labeled "statewide," as opposed to being appropriated for any individual county. For this study, those values were allocated to the individual counties in the proportions that the other expenditure within the data set were apportioned.

While the amalgamation of these datasets is not considered a total comprehensive measurement of historic critical infrastructure damages, it does provide a reasonable estimate of the NED damages from historic events without risk of erroneous double-counting. Results can be seen in Table 31.

Table 31: Critical Infrastructure Damages by County, Hurricane Sandy

County	FEMA County	FEMA Statewide	NJT County	NJT Statewide	DOT County	DOT Statewide	TOTAL
Atlantic	20,752,000	29,297,000	-	-	1,082,000	47,000	51,177,000
Cape May	32,366,000	45,694,000	-	-	164,000	7,000	78,232,000
Monmouth	129,631,000	183,009,000	837,000	775,000	2,614,000	114,000	316,980,000
Ocean	69,450,000	98,047,000	3,009,000	2,788,000	108,305,000	4,722,000	286,320,000

In order to compare damage by county numbers against each other, the data had to be normalized based on a relevant underlying variable. Without normalization, the difference in damage could be due to a variety of factors, but normalization can isolate the effect of return frequency and allow for the creation of a damage-frequency curve.

For infrastructure damage, the normalization was accomplished by taking the ratio of total critical infrastructure damage to total damageable assets. For emergency services, the normalization was completed based on the total number of structures in the study area. For transportation delay, the normalization was completed based on the population in the part of each county within the study area. The normalization for critical infrastructure can be seen in Table 32, but this type of procedure was done for each of the categories with the exception of local costs foregone.

Table 32: Critical Infrastructure Damage Normalization

County	Return Frequency (yrs)	Total Damageable Assets ($)	Total Critical Infrastructure Damage ($)	Ratio Crit Int Damage to Damageable Assets
Atlantic	21.7	13,081,189,000	51,177,000	0.4%
Cape May	11.6	12,533,236,000	78,232,000	0.6%
Monmouth	120.5	2,505,874,000	107,773,000	4.3%
Ocean	37.9	14,220,254,000	286,320,000	2.0%

The normalized data were then plotted against the unique return frequencies of the events by county. For instance, Hurricane Sandy was a 0.83% AEP event (120-year storm) in Monmouth County, but only a 9% AEP event (11-year storm) in Cape May County. The data were then fit to a logarithmic trendline, which was used to determine Average Annual Damage. The fitting of the trendline can be seen in Figure 45, while the derivation of AAD from the trendline can be seen in Table 33.

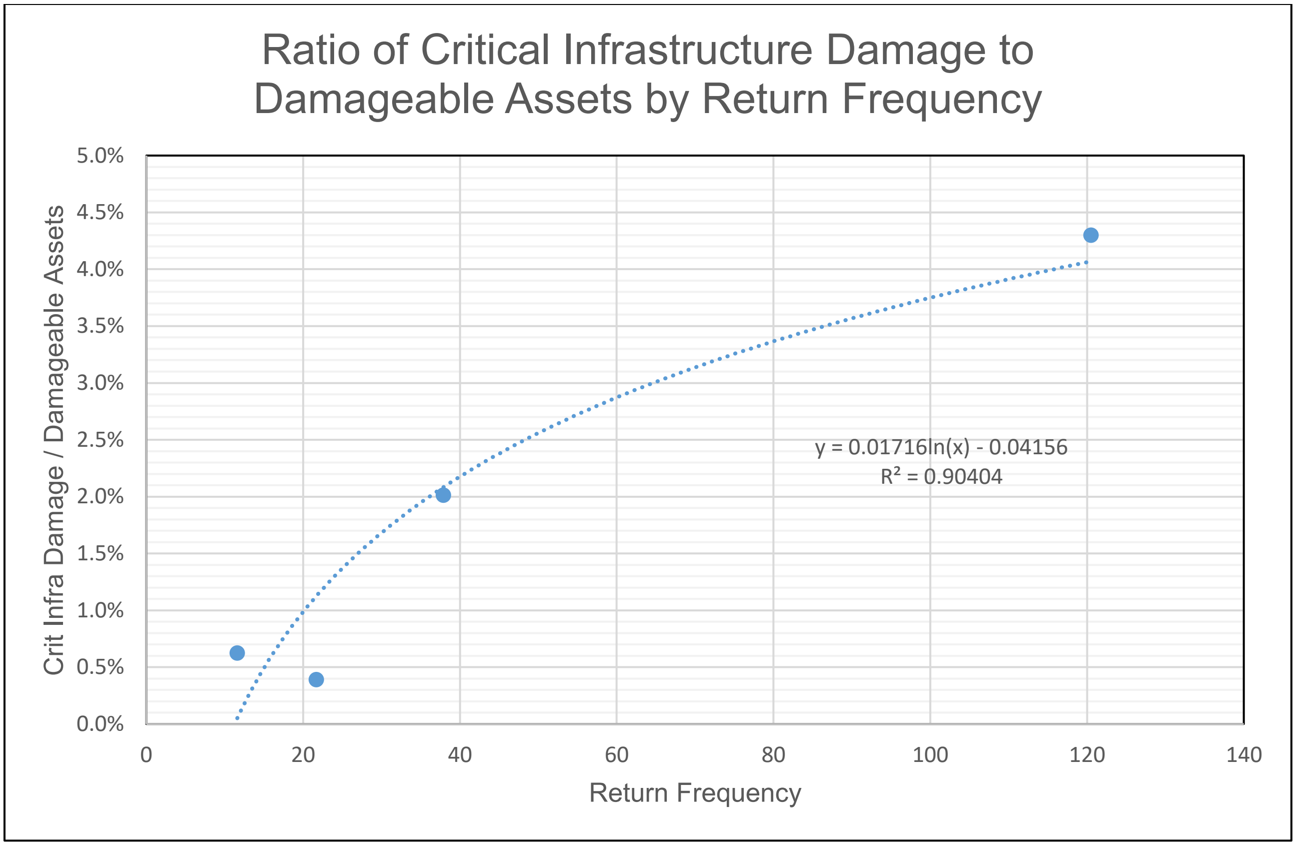


Figure 45: Normalized Critical Infrastructure Damage by Return Frequency

The figure shows a reasonably good fit for the logarithmic trendline with an R^2 of 90.4%. It also suggests that damages for critical infrastructure are not present until stage heights exceed the 10% AEP return frequency. Given the minimal critical infrastructure damage data cited in high-frequency events, the model output aligns with perceived study area conditions.

Table 33: AAD for Critical Infrastructure Damage

Return Interval	Prob	Probability Interval	Return Interval * Beta	Total Damage by Event ($000s)	Interval Average Damages ($000s)	Interval Damage Calculation ($000s)
2	0.5		-	-		
		0.3			-	-
5	0.2		-	-		
		0.1			-	-
10	0.1		-	-		
		0.06			290,000	17,000
25	0.04		0.01	579,000		
		0.02			831,000	17,000
50	0.02		0.03	1,083,000		
		0.01			1,334,000	13,000
100	0.01		0.04	1,586,000		

		0.006			1,919,000	12,000
250	0.004		0.05	2,252,000		
		0.002			2,504,000	5,000
500	0.002		0.07	2,756,000		
					AAD (in $000s):	**63,856**

As an additional empirical model check, the HEC-FDA model outputs were graphed against return frequency intervals to confirm that, with a static inventory, damages increase at a decreasing rate and fit a logarithmic trendline.

This goes against the so-called "power rule," which says that, as storms increase in size, the damage increases exponentially. This rule is true but, when the structure inventory is static, once a storm is large enough, it will affect the entire inventory. Once that happens, damages by ever-larger storms are not driven by new structures being damaged but only by structures that have already been damaged taking even more damage. These marginal damages are less than the initial damages and, as such, damage within the finite model area increases at a decreasing rate.

The HEC-FDA output is presented in Figure 46 below and can be well-fit to a logarithmic trendline, which was what the AAD function for Critical Infrastructure was fit to.

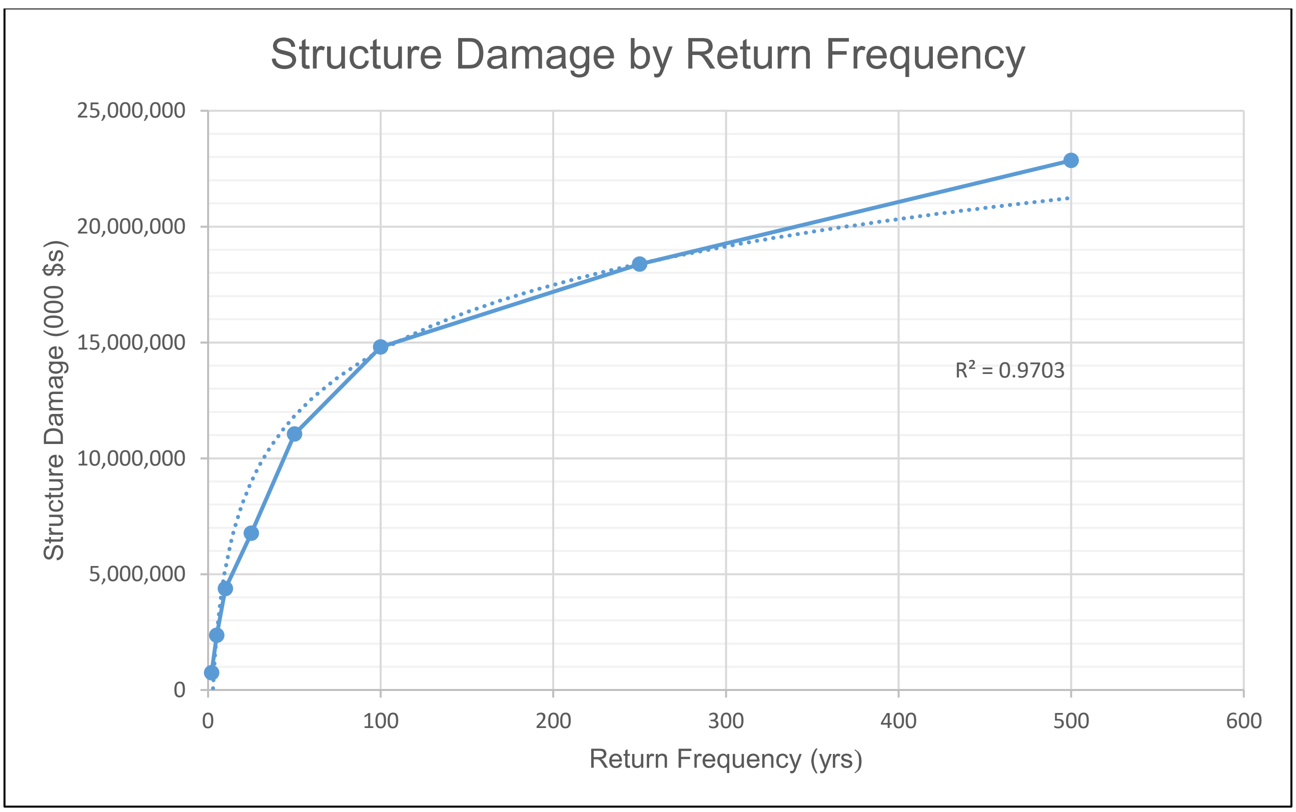


Figure 46: HEC-FDA Output, Structure Damage by Return Frequency

Following the principles outlined in ER 1105-2-101 *Risk Assessment for Flood Risk Management Studies*, uncertainty was introduced to the non-HEC-FDA curves through the creation of confidence intervals using the formula below.

$$CI_j = \mathrm{t} * SE_{reg} * \sqrt{\frac{(x_j - \overline{x})^2}{\sum(x_i - \overline{x})^2}}$$

Where t is the critical value and SE_{reg} is the standard deviation of the residuals. Within the confidence bounds, a few assumptions were made. One, a storm's damage cannot be lower in a less-frequent event than in a more-frequent event. Two, in the upper bound, damages were conservatively assumed to begin in the year they start in the most-likely outcome. Table 39 at the end of this Section displays the damages with the upper and lower bounds.

Emergency Services

Emergency Services encompass the expenses from the risk of a storm and the expenses from the storm itself, including monitoring, forecasting, providing services for evacuation, storm fighting efforts, administrative expenses, increased policing, and post-storm cleanup and recovery. Historic damage data is based on FEMA Public Assistance categories for Debris Removal and Emergency Protective Measures. Again, while the dataset is not considered a total comprehensive measurement of historic emergency services damages, it does provide a defensible preliminary rough order of magnitude estimate of the NED damages for the study area. Table 34 displays the damages by county from Hurricane Sandy.

Table 34: Emergency Services Damages by County, Hurricane Sandy

County	FEMA County	FEMA Statewide	TOTAL
Atlantic	13,174,000	7,620,000	20,794,000
Cape May	8,837,000	5,112,000	13,949,000
Monmouth	121,723,000	70,408,000	192,131,000
Ocean	192,139,000	111,138,000	303,277,000

Emergency Services followed the same normalization, annualization, and confidence banding methodology previously shown for Critical Infrastructure. Table 39 at the end of this Section displays the damages with the upper and lower bounds.

Transportation Delay

Transportation Delay costs are formulated in accordance with IWR Report 91-R-12 *Value of Time Saved for Use in Corps Planning Studies: A Review of the Literature and Recommendations.* Damages are calculated by estimating the total additional time required for each commuter and traveler in a post-storm environment to commute, then multiplying that by the total number of travelers, and then finally assigning that "delay time" a dollar value based on the objective of the travel (e.g., work, vacation).

Table 35: Weekday and Weekend Travel Numbers

Weekday

County	# of Travelers	Avg. Delay	Value of Avg. Delay	Total Delay Value
Atlantic	122,038	24.2 min.	$5.97	$728,000
Cape May	40,085	22.9 min.	$6.12	$245,000
Ocean	235,356	30.7 min.	$8.66	$2,037,000
Monmouth	99,139	33.6 min.	$13.22	$1,311,000

Weekend

County	# of Travelers	Avg. Delay	Value of Avg. Delay	Total Delay Value
Atlantic	81,399	24.2 min.	$4.64	$378,000
Cape May	26,737	22.9 min.	$4.76	$127,000
Ocean	156,982	30.7 min.	$6.73	$1,057,000
Monmouth	66,126	33.6 min.	$10.29	$680,000

Total

County	# of Travelers	Avg. Delay	Value of Avg. Delay	Total Delay Value
Atlantic	772,988	24.2 min.	$5.59	$4,321,000
Cape May	253,899	22.9 min.	$5.73	$1,455,000
Ocean	1,490,744	30.7 min.	$8.11	$12,090,000
Monmouth	627,947	33.6 min.	$12.38	$7,774,000

Conservatively, delay impacts are expected to end one week after the storm event. The total number of commuters is estimated using data from the U.S. Census Bureau and the average delay time was conservatively assumed to be a 100% increase in commuting time, though post Hurricane Sandy records indicated commute delay times after the event could be higher. The average value of delay time is estimated based on the nature of the travel and the average dollar value per hour by County. Delay time for work is valued higher than delay time for personal business or social/recreation.

The data shown in Table 34 are normalized, annualized, and banded according to the same methodology as Critical Infrastructure and Emergency Services. Table 39 at the end of this Section displays the damages with the upper and lower bounds.

Non-Transferable Income Loss

Income Loss is the forfeiture of wages or profits to business before, during, or after storm events that cannot be deferred or transferred regionally. It is imperative to stress that income loss can only be considered a potential NED benefit stream if the losses cannot be compensated by postponement of an activity or transfer of the activity to another establishment. Regional impacts can be significant following storm events but are captured under the separate Regional Economic Development (RED) account.

Within the study area, income loss stems from significant impacts to the County's largest industries. While County specific, this generally includes Accommodations (Tourism), Casinos, Commercial Fishing, Recreational Fishing, Food Service, and Retail. There are of course substantial secondary and tertiary storm impacts due to the many industries that rely on the continued and uninterrupted operation of the above listed businesses. However, calculating those impacts is exceedingly difficult and, to remain conservative, only the direct impact to the major industries in the study area is computed for this study.

Data are sourced from the U.S. Census Bureau and the U.S. Department of Commerce. Non-transferrable income loss is shown in Table 36 and the relative contribution from each major industry shown in Table 37.

Table 36: Income Loss by County

County	NED Income Loss
Atlantic	$47,245,000
Cape May	$32,844,000
Monmouth	$9,329,000
Ocean	$17,665,000

Table 37: Income Loss by Industry

Industry	Revenue Loss	Relative Contribution
Casinos	$22,489,000	21%
Accommodations	$31,014,000	29%
Commercial Fishing	$14,992,000	14%
Recreational Fishing	$12,221,000	11%
Retail	$26,367,000	25%
TOTAL	**$107,083,000**	**100%**

The data in Table 36 are normalized and annualized to produce a damage-frequency curve. Confidence bounds could not be estimated for income loss due to a lack of data so the widest bounds from the other non-HEC-FDA categories were used in the assumption that the uncertainty of the category is not widely dissimilar from the uncertainty of other categories. Table 39 at the end of this Section displays the damages with the upper and lower bounds.

Continued analysis is necessary to clearly delineate the separation between NED non-recoverable income losses and RED transferable losses. That analysis will be completed before release of the final Feasibility Report.

Local Costs Foregone

Local Costs Foregone is a broad NED benefit category meant to capture economic and financial burdens faced by local stakeholders in the future without-project condition scenario that may be alleviated in the future with-project condition scenario depending on the proposed measure or plan. As Emergency Services expenditures are already captured under a separate NED benefit category, Local Costs Foregone will focus on local efforts to mitigate coastal storm impacts with future public and private protective measures. Reduced maintenance of existing storm risk mitigation infrastructure can also contribute to Local Costs Foregone.

As noted earlier, Local Costs Foregone is not calculated based on historic storm damages, but rather on broadly predicting future local expenses for coastal storm protective measures that have been recently constructed or are currently under development. Estimating the exact type or cost or timing of future expenditures is not feasible, but it is possible to review recent local coastal infrastructure projects to gauge the magnitude of cost and the likely location and characteristics of future local construction expenditures—especially for smaller-scale projects that seek to mitigate coastal risk for tidal or nuisance flooding events.

For this study, formulated using the Intermediate SLC curve, it is assumed that future local measures would be effective in mitigating nuisance flooding events (events with greater than a 100% AEP) across the 50-year period of analysis. As these local projects are typically not constructed to USACE guidelines or standards, it is not reasonable to rely on their long-term effectiveness in mitigating coastal storm impacts for anything other than high-frequency events.

While these sub-1-year events do not typically result in measurable direct damages and are not captured in HEC-FDA, the inundation from these events can cause serious local and regional issues including commuting delays, minor property damage, and reduced housing prices; as such, there is substantial evidence that local stakeholders will expend resources to avoid these impacts.

Additional information on High Frequency Flooding can be found in the Main Report and the HHC Section of the Engineering Appendix.

Estimated local costs per linear foot of bulkhead are based on projects constructed in Ocean Township (Ocean County), Barnegat Light (Ocean County), and Atlantic City (Atlantic County). While the projects vary in size, scope, and materials, the Most Likely condition estimated a cost of $1,800 per linear foot with a lower bound of $1,560 and an upper bound of $3,000. These values are coarse and will need to be refined with future re-evaluation but are intended to reflect the cost per linear foot to design, manage, and construct lower elevation CSRM measures (vinyl or steel bulkheads) by local stakeholders. These values do not reflect other likely costs such as pump stations, real estate, infrastructure repair, utility relocation, or litigation.

The predicted length of future construction to mitigate high-frequency flooding impacts is based on the results from Cycle 1 of the analysis. While impacts are present throughout the study area, inventory on the back side of the barrier islands was shown to be particularly vulnerable and constitutes the most likely placement of low-elevation bulkheads. This is not an indication nor recommendation for where local construction should be focused, but rather a general forecast of the most likely location. Cycle 1 identified 884,139 linear feet of shoreline that would benefit from some type of hardened structure.

As impacts from high-frequency flooding magnify over the 50-year future without-project condition, predicting the exact timing of local intervention to combat those impacts is not practical. To avoid over- or under-stating the present value of those expenditures, the total predicted Local Costs Foregone value is discounted to Year 25 of the study (mid-point) and then annualized using the FY2020 Federal Discount Rate of 2.75%. These damages were then updated to the FY2021 price level and FY2021 Discount Rate of 2.5% when presenting final FWOP and FWP results.

Table 38: Local Costs Foregone

Local Costs Foregone	**Lower**	**Most Likely**	**Upper**
Cost per Linear Foot	$1,560	$1,800	$3,000
Length of Bulkheading	884,139	884,139	884,139
Present Value Cost	**$1,379,257,000**	**$1,591,450,000**	**$2,652,417,000**
Study Mid-Point (Year)	25	25	25
FY20 Federal Discount Rate	2.75%	2.75%	2.75%
Mid-Point Discount Factor	0.5075	0.5075	0.5075
Mid-Point Value Cost	**$700,002,000**	**$807,695,000**	**$1,346,158,000**
Capital Recovery Factor	0.037041	0.037041	0.037041
Average Annual Cost	**$25,929,000**	**$29,918,000**	**$49,863,000**

A summary table of the non-HEC-FDA damage categories, their AADs, and the confidence intervals on those AADs can be seen in Table 39.

Table 39: AADs with Confidence Bounds for Non-HEC-FDA Categories

Damage Category	**AAD ($)**	**Lower Bound ($)**	**Upper Bound ($)**
Critical Infrastructure	63,856,000	40,363,000	77,399,000
Emergency Services	41,059,000	19,101,000	57,115,000

Income Loss	28,081,000	13,063,000	32,737,000
Transportation Delay	2,701,000	2,002,000	3,149,000
Local Costs Foregone	29,918,000	25,929,000	49,863,000
Total	**165,615,000**	**100,458,000**	**220,263,000**

Total System of Accounts

In water resource projects, USACE examines benefits in four distinct categories: National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ). The *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) established the four accounts to display the effects of plans while maximizing potential benefits relative to project costs. Though the P&G stated that determining RED and OSE benefits was discretionary, the memorandum from the Assistant Secretary of the Army entitled "Comprehensive Documentation of Benefits in Feasibility Study" (April 2020) directed USACE "to identify, analyze and maximize all benefits in the NED, RED, and OSE." What follows is a semi-quantitative discussion of RED benefits in the New Jersey Back Bays study area and a qualitative discussion of potential OSE and EQ. A complete examination of RED and OSE impacts and benefits will be conducted in the next study phase

RED Benefits from Construction

Per IWR 2011-RPT-01 *Regional Economic Development (RED) Procedures Handbook* (March 2011), RED impacts are defined as the transfers of economic activity within a region or between regions in the FWOP and for each alternative plan. Spending in an area can spur economic activity, leading to increases in employment, income, and output of the regional economy, while chronic or catastrophic flooding can lead to regional losses of employment and income. This section will first quantify RED benefit multipliers from construction spending and afterwards qualitatively discuss RED losses in the FWOP due to flooding.

IWR 2011-RPT 01 defines three types of RED impacts: direct, indirect, and induced.

• *Direct effects* are the impacts direct federal expenditure have on industries that directly support the new project. Labor and construction materials are considered the direct components of a project.

• *Indirect effects* represent changes to secondary industries that support the direct industry. For example, rock quarries used in making cement could be considered indirect pieces of a project.

• *Induced effects* are changes in consumer spending patterns caused by changes in employment and income within the direct and indirect industries. The additional income earned by workers may be spent in numerous different ways within the region.

These impacts associated with construction spending are calculated using the USACE Regional Economic System (RECONS) certified regional economic model. The RECONS model uses IMPLAN modeling system software to trace the economic ripple, or multiplier, effects of project spending in the study area. The model is based on data collected by the U.S. Department of

Commerce, the U.S. Bureau of Labor Statistics, and other federal and state government agencies. Nationally developed input-output tables represent the relationships between the many different sectors of the economy to allow an estimate of changes in economic activity on the larger economy brought about by spending in the project area. Estimates are provided for three levels of geographic impact area: local, state, and national.

Within RECONS, the direct effects are equal to "local capture." Local capture measures what percentage of federal spending is captured within the impact area. It is calculated by applying the level-specific (local, state, or national) Local Purchase Coefficients (LPCs) to the expenditures for each industry and aggregating the local capture across all industries. For example, labor costs may be entirely captured at the local level (if the laborers all live locally), while something like cement manufacturing may be only be captured at the state or national level (meaning federal spending on cement manufacturing is not a direct effect for the locality). Both the LPCs and the spending profile (the proportions of construction dollars spent in different sectors) are preset within RECONS; the LPCs vary by location, while the spending profiles vary based on the type of project. More information on LPCs, spending profiles, and the different types of effects measured within RECONS can be found in the *RECONS 2.0 User Guide (April 2019)*.

The percentage of spending captured (i.e., the direct effects) at each level is reported by county in Table 40 below:

Table 40: Local Capture by County

	Cape May	**Atlantic**	**Burlington**	**Ocean**	**Monmouth**
Local	71%	75%	83%	76%	81%
State	89%	87%	88%	87%	87%
US	95%	95%	95%	95%	95%

Though it is a transfer (and, as such, not an NED benefit), the federal funding spent in a community represents a benefit when it is captured locally. For example, 83% of the federal spending in Burlington County is captured by local interests within the county, providing them tangible RED benefits. As such, the local capture is equal to the monetary direct effect of federal spending.

Secondary impacts, which include indirect and induced impacts, are multiplier effects on top of the direct impacts. Indirect impacts include payments to industries that support the directly affected industries, while induced effects occur when workers associated with the direct and indirect industries spend their salaries in the impact area, creating additional jobs and income. The secondary impact multipliers are listed in Table 41 below for each county and should be applied to the initial federal outlay (i.e., multiplying the multiplier by the initial outlay yields the secondary impact).

Table 41: Indirect and Induced Impact Multipliers

	Cape May	Atlantic	Burlington	Ocean	Monmouth
Local	.41	.59	.76	.55	.67
State	.85	.83	.92	.83	.83
US	1.76	1.76	1.76	1.76	1.76

It should be intuitive that the secondary impacts increase as the scale (locality, state, U.S.) becomes larger, since more of the impacts are internalized within the larger area, thereby continuing to provide compounding benefits.

Table 40 and Table 41 together provide the direct and secondary benefits that occur for any given level of spending. For example, if $1,000 were spent in Cape May County, $710 (.71* $1,000) of it would be captured locally (direct benefits), which would then provide $410 (.41 * $1,000) of secondary benefits. This would yield $1,110 of local RED benefits on spending of $1,000.

Spending in the study area will also spur job growth. On average, each $125,000 spent in the study area will directly create one job and indirectly create half of another. On the national level, that amount of spending would create a total of 2.2 jobs. This implies that both the nonstructural and structural alternatives considered in this study would create thousands of jobs locally, regionally, and nationally.

RED Losses from Business Interruption

The above discusses the direct and secondary benefits of federal spending in the NJBB study area, but a USACE project could also potentially prevent regional economic losses—a separate benefit stream. Back bay flooding can cause physical damages to the over 6,500 commercial and industrial structures in the study area, which can in turn lead to business interruption. Some of the major sectors that may be impacted include healthcare and tourism. Preventing the physical damage can prevent the business interruption.

These business interruption losses are often transferrable, as spending that is prevented due to flooding may simply be spent elsewhere or deferred to a later time. Still, these losses are acutely felt by the local communities that bear them.

During the next study phase, these RED impacts will be quantitatively assessed by tying RED losses to individual commercial and industrial structures within the asset inventory. RED depth-percent damage curves will be developed for each asset based on HAZUS data that tie length of business interruptions to flood depths (relative to first floor elevation). These business interruptions will then be linked to a dollar loss, which will be determined by the size and type of the commercial structure. These new “RED loss” assets will be put into HEC-FDA to determine the expected RED losses over the 50-year study timeframe.

Successfully quantifying RED losses will give a more complete picture of the vulnerability of the study area. To do this work, the commercial structures in the inventory will have to be surveyed to determine their type (e.g., office, retail, restaurant) so that accurate RED loss depth-percent damage curves can be assigned. The parameters for the curves will have to be developed and new HEC-FDA import files will need to be created to actuate new model runs. The quantified RED losses will help inform the selection of the Total Benefits Plan (the plan that maximizes benefits across all benefit categories).

OSE Impacts

In compliance with ER 1105-2-100 *Planning Guidance Notebook* and ER 1105-2-101 *Risk Assessment For Flood Risk Management Studies*, a comprehensive life safety risk assessment of the Tentatively Selected Plan and NED Plan is scheduled to occur during the next phase of the study. An abbreviated qualitative life safety risk assessment is detailed in this section. This risk assessment includes a description of the various types of safety risks, a qualitative assessment of key life safety metrics, and an outline of the Tolerable Risk Guidelines (TRGs) as recommended by USACE Planning Bulletin (PB) 2019-04 *Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies*.

Life safety risk assessments are a systematic approach for describing the nature of coastal storm risk including the likelihood and severity of occurrence while explicitly acknowledging the uncertainty in the analysis. Life loss consequences are the determination of the population at risk and the estimated statistical life loss in a given area. An assessment of the various types of risk, including residual risk, transferred risk, transformed risk, and incremental risk, can help inform whether the Recommended Plan provides a tolerable level of safety for the study area in the future with-project condition.

Residual risk is the coastal storm risk that remains in the floodplain even after a proposed coastal storm risk management project is constructed and implemented. Physical damages, as well as potential life loss consequences, can remain even after the project is implemented due to a variety of causes.

Population at Risk (PAR) provides a brief overview of the vulnerable population within the study area. Demographic information, including the percentage of population older than 65 years (21.7%), below the poverty line (9.1%), or living with a disability (8.2%) is derived from the U.S. Census Bureau (Population Estimates Program, V2019). These demographics are highlighted as these populations are particularly vulnerable to coastal storm events. Though the study area hosts a considerable volume of seasonal tourists, the PAR information provided is only for the permanent population.

Table 42: Population at Risk (PAR)

Category	Persons
Population at Risk	674,388
Age 65+	146,511
Age Under 18	140,778
Age Under 5	36,754
Persons in Poverty	61,201
Persons w/ Disability	55,131

Transferred and transformed risks are also components of a future with-project life safety risk assessment. Transferred risk is the result of an action taken in one region shifting the risk burden to another region in the system. For nonstructural measures, transferred risk is a not a significant concern. However, storm surge barriers, particularly bay closures, do have the potential to transfer risk to neighboring areas and the level of transferred risk will need to be investigated in the next study phase.

Transformed risk is a new risk of flooding that emerges or increases as a result of mitigating another risk. For instance, the magnitude and nature of the risk of flooding is different with a floodwall compared with conditions without a floodwall. A floodwall may transform the flood risk from one that may be gradual and observable before emergency action would be necessary for the originally protected properties to flood risk that may be sudden and catastrophic. If a floodwall breaches or malfunctions, then the sudden increase in flood waters in vulnerable areas can increase the potential for life loss.

The NED plan (discussed in Section C-11) involves constructing economically justified perimeter measures in the Central region. Both the NED Plan and Tentatively Selected Plan recommend construction of storm surge barriers (and/or bay closures). Transformed risk is a significant concern for both alternatives though particularly so for perimeter measures. Though transformed risks can be mitigated for perimeter measures by drafting emergency action plans (EAPs) for vulnerable areas being protected by the coastal floodwalls, any potential breach or failure mechanism would result in immediate catastrophic flooding. The barrier islands in the Central Region have almost no available uninhabited storage areas which means that any failures along the perimeter system would instantly inundate structures and vulnerable populations. As the source of flooding is the Atlantic Ocean, the minimal storage would almost instantly be filled during a storm event in the event of a failure.

For Storm Surge Barriers, and Bay Closures, a potential breach is less catastrophic as the bay itself acts as a natural storage area. Closure of the barriers during low tide prior to the storm event provides a massive storage area to mitigate impacts from barrier failures. Overtopping or breaching water would first need to fill this storage before vulnerable structures or populations are inundated. This greatly reduces the life safety risk in comparison to lengthy perimeter measures.

This divergence in life safety risk between perimeter and storm surge barrier/bay closure measures is a contributing reason for identifying the Tentatively Selected Plan in addition to the NED Plan. Further discussion of the transformed risk and the selection of the TSP can be found in Section C-11.

In the next project phase, a comprehensive life safety risk assessment will be completed to investigate estimated statistical life loss in the FWOP and the effectiveness of the various alternatives in reducing this life loss. Special attention will be paid to transformed and transferred risk in the FWP. The comprehensive life safety risk assessment will also fully cover the four TRGs detailed in USACE PB 2019-04 *Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies*. An outline and qualitative assessment of the TRGs is completed below. Like all planning objectives, the extent to which the TRGs objectives can be met will vary based on the conditions in the study area and the efficiency and effectiveness of measures that contribute towards meeting the objectives.

TRG 1 – Understanding the Risk. The first tolerable risk guideline involves considering whether society is willing to live with the risk associated with the costal protective system to secure the benefits of living and working in that area. To properly understand the risk, an assessment of life safety risk will cover both societal and individual life risks. Societal risk is the risk of widespread or large-scale catastrophes from the inundation of a vulnerable area that would result in a negative societal response. Conversely, individual risk the risk represented by the probability of life loss for the identifiable person or group by location that is most at risk of loss of life due to a structural failure. Individual life risk is influenced by location, exposure, and vulnerability within an area. Life Safety risk encompasses understanding the societal, individual, economic, and environmental risks associated with the construction of a project in the study area.

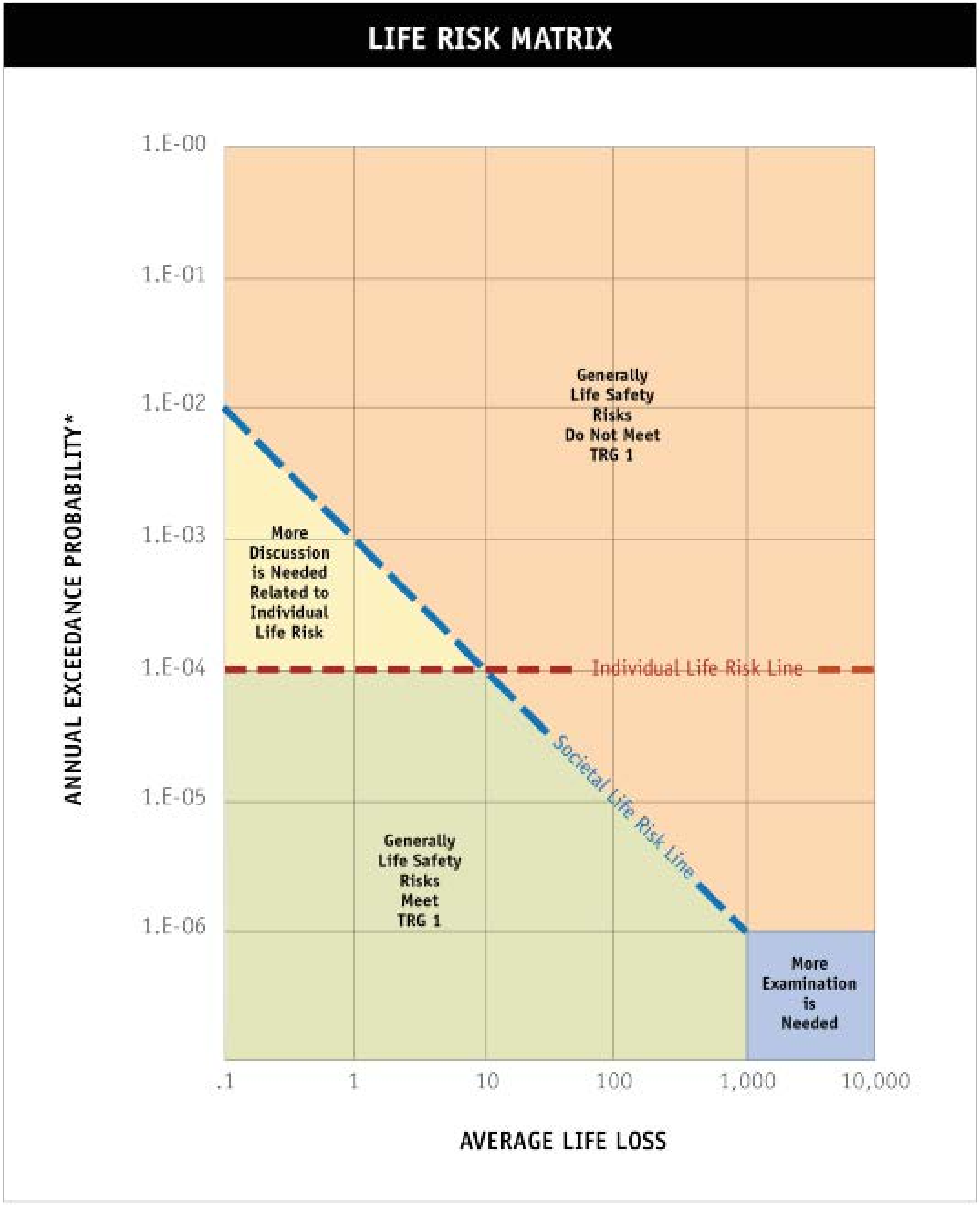
The Life Risk Matrix in Figure 47 below shows the framework for quantitatively determining whether the life safety risk is tolerable for the study area. The full quantitative effort will be completed during the comprehensive life safety risk assessment in the next study phase.

TRG 2 – Building Risk Awareness. The second tolerable risk guideline involves determining that there is a continuation of recognition and communication of the floodwall risk. A proper EAP is required to ensure risk awareness within the vulnerable population as well as to maintain risk communication such as public engagement activities, media stories, and a current community website. The comprehensive life safety risk assessment will include recommendations for the EAP and floodplain management plan.

TRG 3 – Fulfilling Daily Responsibilities. The third tolerable risk guideline involves determining that the risks associated with the floodwall system are being properly monitored and managed by those responsible for managing the risk. This responsibility is met by demonstrating monitoring and risk management activities such as documented regular inspections, updated and tested emergency plans, instrumentation programs, and interim risk reduction measures plans. Proper Operations, Maintenance, Repair, Rehabilitation, and Replacement (OMRR&R) mitigates the risk of failure and corresponding life safety consequences.

TRG 4 – Actions to Reduce Risk. The fourth guideline is determining if there are cost effective, socially acceptable, or environmentally acceptable ways to reduce risks from an individual or societal risk perspective. The comprehensive life safety risk assessment will investigate whether complementary risk reduction measures are feasible or appropriate for the study area.

Figure 47: Life Risk Matrix (PB 2019-04)



*OR ANNUAL PROBABILITY OF INCREMENTAL LIFE LOSS

EQ Impacts

The direct impacts of the construction of storm surge barriers, bay closures, and perimeters (include the construction of sector gates, vertical lift gates (auxiliary gates), impermeable barriers, seawalls, floodwalls, levees, miter gates and sluice gate structures) within coastal wetlands and shallow bay waters would be the loss of these habitats within the footprint alignment of the structures. These losses would result from either their removal from excavations or burial from fill placement. Additionally, temporary losses may be experienced through the placement of de-watering structures and either temporary fills or excavations for temporary access points to the work segment. Preliminary estimates of the affected wetland and shallow water habitats are based on existing mapping (NJDEP 2012 wetland mapping and National Wetlands Inventory - NWI), the current (preliminary) alignments, and an assumed width of the disturbance offset from the structure. These estimates can be seen in Environmental Appendix F4.

Storm surge barriers and bay closures may pose long-term significant indirect effects on wetlands and other aquatic habitats. Depending on the design, the available openings to pass tidal flows when open during normal conditions would be more constricted than existing inlets and other waterways. A constriction would change the tidal prism by limiting incoming (flood) tides that could result in tidal amplitudes where a lowered high tide elevation and the outgoing (ebb) tides could result in higher low tides, thereby affecting wetland and aquatic habitats at each end of the tidal range on a bay-wide scale.

Perimeter plan footprints may pass through subtidal, intertidal, and supratidal regimes, which include 14 different aquatic and wetland habitat types. The habitats most affected by the perimeter plans are the subtidal soft bottom areas with hardened (bulkhead, concrete wall) shorelines, intertidal mudflats and sandy beaches, low and high tidal saltmarshes, scrub-shrub habitats, and *Phragmites*-dominated marshes. A high number of these habitats are encountered as small pockets along heavily developed bay shorelines of the barrier islands. However, since the perimeter plan segments tend to be several miles long, the impacts are cumulative and significant.

Nonstructural measures involve a significant construction effort whether it be from building retrofits such as elevation (including raising a structure on fill or foundation elements such as solid perimeter walls, pier, posts, columns, or pilings) or buyout/ relocations that are likely to involve demolition, grading, and soil stabilization/ revegetation. However, existing structures would most likely be in upland urbanized settings where construction activities would not result in any direct wetland and aquatic habitat impacts. Therefore, the need for compensatory mitigation for wetland and aquatic impacts is not expected.

For additional information on environmental impacts, including environmental costs, see Environmental Appendices F2-F4.

C-10) UPDATED FUTURE WITH-PROJECT CONDITION

This section details future with-project condition scenario results for individual measures and for the entirety of the Focused Array of Alternatives. Nonstructural methodology changes are also highlighted as they supersede those explained in Section C-5.

Model Results

Table 46, Table 47, and Table 48 below show the updated economic analysis results for the Focused Array previously presented in Table 18 in Section C-7 of this appendix. The Tables show the results under the Intermediate, Low, and High Sea Level Curves, respectively. Economic examination uses a 50-year period of analysis with the FY2021 Federal Discount Rate of 2.5%. Previous Sections have shown values in an FY2019 Price Level, but these estimates were updated to the FY2021 Price Level prior to calculating the revised results.

Costs for each of the twenty alternatives in the Focused Array have been updated to the FY2021 Price Level and their development is further explained in the Cost Section of the Engineering Appendix. The summary costs for the individual measure components of each alternative (previously provided in Tables 11 and 12) are shown below in Table 43 and Table 44. Nonstructural costs are provided in Table 45 and further explained in the Nonstructural Appendix.

The methodology for nonstructural evaluation is slightly changed in Cycle 3 compared to Cycle 2, primarily due to the adjustments made to the inventory. These changes are detailed following Table 48. The application of perimeter and storm surge barrier measures remains the same as Cycle 2, though the results have been updated and refined.

The results shown in Table 46, Table 47, and Table 48 are presented as deterministic values, but are actually the means for a distribution of outcomes. Due to limitations with HEC-FDA 1.4.2, results by iteration are not accessible, though the summary statistics display the quartile values of the distribution. While future work will more fully describe what the distribution of the iteration results looks like, it is important to acknowledge the uncertainty associated with the current values. Uncertainty in key inputs such as foundation height, depreciated replacement value, depth-percent damage functions, and water surface profiles implies that the outputs take a range of values rather than a deterministic variable. HEC-FDA Monte Carlo modeling provides a range of future scenarios that can be combined with the triangle distribution of non-HEC-FDA benefit streams to estimate the overall distribution of AAD future results for each proposed alternative.

Using the distributions of NED results by alternative can inform the decision-making process by attaching uncertainty to what are often considered deterministic values. Instead of asserting that the identified plan is necessarily the NED plan, the plan can instead be selected with a level of confidence attached to it. Additionally, plan selection should be achieved not only with NED results by alternative, but with acknowledgment of other relevant decision metrics such as residual risk, adaptability to sea level change, reliability, and life safety.

Table 43: Storm Surge Barrier Cost Estimates

Region	Description	Construction Duration (Months)	Initial Construction	Interest During Construction*	**Total First Construction Cost**	Annual OMRR&R**	**Average Annual Cost (AAC)**
North	Manasquan Inlet SSB	95	$1,146,890,852	$117,760,238	**$1,264,651,090**	$22,937,817	**$67,526,957**
North	Barnegat Inlet SSB	122	$2,517,077,609	$336,630,759	**$2,853,708,368**	$50,341,552	**$150,957,764**
Central	Absecon Inlet SSB	111	$2,367,232,830	$286,387,909	**$2,653,620,739**	$47,344,657	**$140,906,168**
Central	Great Egg Harbor SSB	137	$3,524,739,775	$533,544,429	**$4,058,284,204**	$70,494,796	**$213,582,011**
Central	Absecon Blvd Bay Closure	65	$2,064,490,714	$143,619,476	**$2,208,110,190**	$41,289,814	**$119,143,489**
Central	Ocean City Bay Closure	50	$532,290,857	$28,099,164	**$560,390,021**	$10,645,817	**$30,404,080**

* Interest During Construction is developed in accordance with IWR Report 88-R-2 and BPG 2020-01. Calculation is based on the mid-period of construction duration with a federal discount rate of 2.5%. Information on construction duration can be located in the Cost Section of the Engineering Appendix.

** Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) is a broad category meant to capture the ongoing costs to the non-Federal sponsor after initial construction of the project is completed. OMRR&R is estimated based on the type of measure proposed and the initial construction cost of that measure.

Table 44: Perimeter Cost Estimates

Region	Description	Construction Duration (Months)	Initial Construction	Interest During Construction*	**Total First Construction Cost**	Annual OMRR&R**	**Average Annual Cost (AAC)**
North	Manasquan Inlet (North)	26	$787,837,592	$21,359,327	**$809,196,918**	$7,878,376	**$36,409,087**
North	Partial Long Beach Island	111	$3,232,691,144	$391,091,085	**$3,623,782,229**	$32,326,911	**$160,094,432**
Central	Absecon Island	126	$3,748,279,447	$518,814,993	**$4,267,094,440**	$37,482,794	**$187,932,253**
Central	Ocean City	89	$2,419,530,025	$232,013,029	**$2,651,543,054**	$24,195,300	**$117,683,556**
Central	Brigantine Island	55	$1,543,246,736	$89,846,169	**$1,633,092,905**	$15,432,467	**$73,012,150**
Central	Partial Southern Ocean City	33	$781,566,480	$26,991,634	**$808,558,115**	$7,815,665	**$36,323,853**
South	Cape May City	18	$545,709,170	$10,200,400	**$555,909,570**	$5,457,092	**$25,057,383**
South	Wildwood Island	62	$1,741,972,080	$114,739,769	**$1,856,711,849**	$17,419,721	**$82,883,773**
South	West Wildwood	13	$375,455,619	$5,055,515	**$380,511,134**	$3,754,556	**$17,170,639**
South	Stone Harbor / Avalon	110	$3,349,372,453	$401,346,248	**$3,750,718,701**	$33,493,725	**$165,736,778**
South	Sea Isle City	40	$1,153,935,372	$48,480,209	**$1,202,415,581**	$11,539,354	**$53,934,191**
South	West Cape May	5	$192,045,530	$990,484	**$193,036,014**	$1,920,455	**$8,726,530**

Table 45: Nonstructural Totals and Cost Estimates by Alternative

Alternative	SFRM	SFR1	COM	HIGH	APT	IND	PUB	TOTAL	IDC ($)*	Total Cost ($)	AAC ($)
2A	66	49	13	-	-	-	7	**135**	$143,071	**$43,354,957**	**$1,528,612**
3A	8,773	13,073	1,072	-	95	8	131	**23,152**	$22,713,432	**$6,882,858,073**	**$242,676,202**
3D	8,478	12,593	1,050	-	95	8	129	**22,353**	$21,981,578	**$6,661,084,392**	**$234,856,893**
3E(2)	3,308	5,023	464	-	25	1	48	**8,869**	$8,568,271	**$2,596,445,767**	**$91,545,633**
3E(3)	1,183	3,487	98	-	1	1	15	**4,785**	$4,255,488	**$1,289,541,885**	**$45,466,741**
4A	4,522	5,079	1,050	18	87	10	129	**10,895**	$12,401,945	**$3,758,165,087**	**$132,505,599**
4D(1)	971	1,110	220	1	8	2	28	**2,340**	$2,502,696	**$758,392,839**	**$26,739,458**
4D(2)	405	594	164	1	7	2	16	**1,189**	$1,376,235	**$417,040,889**	**$14,704,051**
4E(2)	577	1,279	30	1	2	1	7	**1,897**	$1,733,368	**$525,262,960**	**$18,519,751**
4E(3)	132	48	13	1	-	-	3	**197**	$211,407	**$64,062,735**	**$2,258,728**
4E(4)	41	46	12	1	-	-	3	**103**	$114,731	**$34,767,028**	**$1,225,818**
4G(6)	1,143	1,795	86	1	3	1	20	**3,049**	$2,870,668	**$869,899,463**	**$30,670,965**
4G(7)	698	564	69	1	1	-	16	**1,349**	$1,348,707	**$408,699,238**	**$14,409,941**
4G(8)	607	562	68	1	1	-	16	**1,255**	$1,252,032	**$379,403,531**	**$13,377,031**
4G(10)	577	1,279	30	1	2	1	8	**1,898**	$1,744,207	**$528,547,514**	**$18,635,558**
4G(11)	132	48	13	1	-	-	4	**198**	$222,246	**$67,347,288**	**$2,374,535**
4G(12)	41	46	12	1	-	-	4	**104**	$125,570	**$38,051,582**	**$1,341,625**
5A	4,501	3,040	764	3	185	4	82	**8,579**	$10,767,379	**$3,262,842,062**	**$115,041,471**
5D(1)	1,275	743	269	-	27	-	20	**2,334**	$2,770,433	**$839,525,088**	**$29,600,023**
5D(2)	248	319	76	-	2	-	11	**656**	$743,205	**$225,213,755**	**$7,940,599**

** Construction duration is assumed to be three months for any particular structure*

Table 46: Focused Array of Alternatives, Intermediate SLC

Alternative	Initial Const.	AAC	EAD Without	EAD With	EAD Reduced	AANB	BCR	Residual
2A	$43,354,957	$1,528,612	$10,264,564	$7,020,414	$3,244,150	$1,715,538	2.1	68.4%
3A	$6,882,858,073	$242,676,202	$759,948,512	$248,421,222	$511,527,290	$268,851,088	2.1	32.7%
3D	$7,448,921,984	$271,265,980	$759,948,512	$242,771,943	$517,176,569	$245,910,589	1.9	31.9%
3E(2)	$6,260,414,228	$310,030,354	$759,948,512	$167,490,200	$592,458,312	$282,427,957	1.9	22.0%
3E(3)	$8,186,201,490	$424,045,894	$759,948,512	$139,130,562	$620,817,950	$196,772,056	1.5	18.3%
4A	$3,758,165,087	$132,505,599	$674,965,863	$311,421,183	$363,544,680	$231,039,081	2.7	46.1%
4D(1)	$6,926,202,310	$332,355,267	$674,965,863	$98,833,508	$576,132,356	$243,777,088	1.7	14.6%
4D(2)	$8,128,097,097	$393,332,011	$674,965,863	$85,483,726	$589,482,137	$196,150,127	1.5	12.7%
4E(2)	$6,417,235,565	$373,007,930	$674,965,863	$106,847,190	$568,118,673	$195,110,743	1.5	15.8%
4E(3)	$6,737,601,820	$393,070,759	$674,965,863	$92,851,235	$582,114,628	$189,043,869	1.5	13.8%
4E(4)	$6,459,030,490	$386,118,077	$674,965,863	$98,201,822	$576,764,041	$190,645,965	1.5	14.5%
4G(6)	$6,459,129,953	$363,396,465	$674,965,863	$83,674,719	$591,291,144	$227,894,679	1.6	12.4%
4G(7)	$6,779,496,208	$383,459,294	$674,965,863	$69,678,764	$605,287,099	$221,827,805	1.6	10.3%
4G(8)	$6,500,924,878	$376,506,612	$674,965,863	$75,029,351	$599,936,512	$223,429,900	1.6	11.1%
4G(10)	$7,661,024,739	$424,373,208	$674,965,863	$70,324,938	$604,640,926	$180,267,717	1.4	10.4%
4G(11)	$7,981,390,995	$444,436,037	$674,965,863	$56,328,983	$618,636,881	$174,200,843	1.4	8.3%
4G(12)	$7,702,819,665	$437,483,355	$674,965,863	$61,679,569	$613,286,294	$175,802,939	1.4	9.1%
5A	$3,262,842,062	$115,041,471	$363,430,771	$143,832,251	$219,598,520	$104,557,049	1.9	39.6%
5D(1)	$4,848,642,860	$217,372,539	$363,430,771	$76,611,164	$286,819,607	$69,447,068	1.3	21.1%
5D(2)	$7,583,703,979	$361,449,893	$363,430,771	$52,084,146	$311,346,625	-$50,103,269	0.9	14.3%

Table 47: Focused Array of Alternatives, Low SLC

Alternative	Initial Const.	AAC	EAD Without	EAD With	EAD Reduced	AANB	BCR	Residual
2A	$43,354,957	$1,528,612	$8,236,923	$5,558,603	$2,678,320	$1,149,708	1.8	67.5%
3A	$6,882,858,073	$242,676,202	$588,167,789	$198,400,179	$389,767,610	$147,091,408	1.6	33.7%
3D	$7,448,921,984	$271,265,980	$588,167,789	$193,598,408	$394,569,381	$123,303,402	1.5	32.9%
3E(2)	$6,260,414,228	$310,030,354	$588,167,789	$124,885,424	$463,282,366	$153,252,011	1.5	21.2%
3E(3)	$8,186,201,490	$424,045,894	$588,167,789	$100,693,947	$487,473,842	$63,427,948	1.1	17.1%
4A	$3,758,165,087	$132,505,599	$541,962,134	$251,527,594	$290,434,540	$157,928,941	2.2	46.4%
4D(1)	$6,926,202,310	$332,355,267	$541,962,134	$82,299,197	$459,662,937	$127,307,670	1.4	15.2%
4D(2)	$8,128,097,097	$393,332,011	$541,962,134	$71,939,952	$470,022,182	$76,690,171	1.2	13.3%
4E(2)	$6,417,235,565	$373,007,930	$541,962,134	$80,553,846	$461,408,288	$88,400,358	1.2	14.9%
4E(3)	$6,737,601,820	$393,070,759	$541,962,134	$69,101,810	$472,860,324	$79,789,565	1.2	12.8%
4E(4)	$6,459,030,490	$386,118,077	$541,962,134	$73,143,634	$468,818,500	$82,700,423	1.2	13.5%
4G(6)	$6,459,129,953	$363,396,465	$541,962,134	$66,758,950	$475,203,184	$111,806,719	1.3	12.3%
4G(7)	$6,779,496,208	$383,459,294	$541,962,134	$55,306,914	$486,655,220	$103,195,926	1.3	10.2%
4G(8)	$6,500,924,878	$376,506,612	$541,962,134	$59,348,739	$482,613,395	$106,106,784	1.3	11.0%
4G(10)	$7,661,024,739	$424,373,208	$541,962,134	$56,399,706	$485,562,428	$61,189,220	1.1	10.4%
4G(11)	$7,981,390,995	$444,436,037	$541,962,134	$44,947,669	$497,014,465	$52,578,427	1.1	8.3%
4G(12)	$7,702,819,665	$437,483,355	$541,962,134	$48,989,494	$492,972,640	$55,489,285	1.1	9.0%
5A	$3,262,842,062	$115,041,471	$298,823,403	$121,630,743	$177,192,660	$62,151,189	1.5	40.7%
5D(1)	$4,848,642,860	$217,372,539	$298,823,403	$64,949,667	$233,873,736	$16,501,197	1.1	21.7%
5D(2)	$7,583,703,979	$361,449,893	$298,823,403	$45,298,864	$253,524,539	-$107,925,355	0.7	15.2%

Table 48: Focused Array of Alternatives, High SLC

Alternative	Initial Const.	AAC	EAD Without	EAD With	EAD Reduced	AANB	BCR	Residual
2A	$43,354,957	$1,528,612	$26,345,538	$20,372,488	$5,973,050	$4,444,438	3.9	77.3%
3A	$6,882,858,073	$242,676,202	$1,685,131,702	$663,798,822	$1,021,332,880	$778,656,678	4.2	39.4%
3D	$7,448,921,984	$271,265,980	$1,685,131,702	$650,459,431	$1,034,672,270	$763,406,290	3.8	38.6%
3E(2)	$6,260,414,228	$310,030,354	$1,685,131,702	$607,355,639	$1,077,776,063	$767,745,709	3.5	36.0%
3E(3)	$8,186,201,490	$424,045,894	$1,685,131,702	$564,280,848	$1,120,850,854	$696,804,960	2.6	33.5%
4A	$3,758,165,087	$132,505,599	$1,430,601,421	$755,565,811	$675,035,610	$542,530,011	5.1	52.8%
4D(1)	$6,926,202,310	$332,355,267	$1,430,601,421	$257,323,368	$1,173,278,054	$840,922,786	3.5	18.0%
4D(2)	$8,128,097,097	$393,332,011	$1,430,601,421	$223,608,345	$1,206,993,076	$813,661,065	3.1	15.6%
4E(2)	$6,417,235,565	$373,007,930	$1,430,601,421	$361,182,581	$1,069,418,840	$696,410,910	2.9	25.2%
4E(3)	$6,737,601,820	$393,070,759	$1,430,601,421	$327,834,252	$1,102,767,169	$709,696,410	2.8	22.9%
4E(4)	$6,459,030,490	$386,118,077	$1,430,601,421	$346,730,953	$1,083,870,468	$697,752,391	2.8	24.2%
4G(6)	$6,459,129,953	$363,396,465	$1,430,601,421	$255,790,199	$1,174,811,222	$811,414,757	3.2	17.9%
4G(7)	$6,779,496,208	$383,459,294	$1,430,601,421	$222,441,871	$1,208,159,550	$824,700,256	3.2	15.5%
4G(8)	$6,500,924,878	$376,506,612	$1,430,601,421	$241,338,572	$1,189,262,849	$812,756,238	3.2	16.9%
4G(10)	$7,661,024,739	$424,373,208	$1,430,601,421	$222,075,177	$1,208,526,244	$784,153,036	2.8	15.5%
4G(11)	$7,981,390,995	$444,436,037	$1,430,601,421	$188,726,848	$1,241,874,573	$797,438,536	2.8	13.2%
4G(12)	$7,702,819,665	$437,483,355	$1,430,601,421	$207,623,549	$1,222,977,872	$785,494,517	2.8	14.5%
5A	$3,262,842,062	$115,041,471	$732,200,219	$327,492,879	$404,707,340	$289,665,869	3.5	44.7%
5D(1)	$4,848,642,860	$217,372,539	$732,200,219	$179,842,908	$552,357,311	$334,984,771	2.5	24.6%
5D(2)	$7,583,703,979	$361,449,893	$732,200,219	$116,325,090	$615,875,129	$254,425,235	1.7	15.9%

Nonstructural Measure Analysis

As discussed in Section C-5, nonstructural measures fall into four broad groups: Managed Coastal Retreat, Building Retrofit, Land Use Management, and Early Flood Warnings. At this stage of analysis, only building retrofit measures (elevation / floodproofing) are quantified for NED benefits. All structure occupancy types are considered for elevation or wet / dry floodproofing.

Acquisition / relocation costs and identification criteria have been evaluated but have not been inserted into HEC-FDA analysis. Comprehensive information on nonstructural methodology and implementation guides can be found in the Nonstructural Appendix.

For nonstructural measures, the current selection criterion for identifying structures eligible for nonstructural selection remains broadly the same as the methodology outlined in Section C-5, though the estimated number of structures has changed due to adjustments to the inventory and the inclusion of non-residential structures. For residential and non-residential structures, eligibility is identified if the applied First Floor Elevation is lower than the 5% AEP event stage height for that reach (Year 2030). The 5% AEP event stage height was selected because it approximated maximizing potential nonstructural net benefits.

The Sea Level Change and Adaptive Capacity Section later in the Appendix addresses opportunities for nonstructural to adapt to varying SLC rates and retrofit structures over the entire course of the period of analysis as necessary to maintain project effectiveness. At this stage of analysis, the nonstructural component elevates / floodproofs only the structures vulnerable before the Base Year without any adaptive or precautionary plans to elevate / floodproof more structures after the Base Year.

To reiterate a major nonstructural analysis limitation, because compiling a fully comprehensive structure inventory is resource and time prohibitive, structures are only assigned the mean occupancy type foundation height as opposed to their actual foundation height. As such, the actual structures that are being recommended for elevation cannot be identified. Instead, the results more generally show a total number of structures in a given area that are expected to be good candidates for elevation. Because the feasibility study will never have perfect information regarding the foundation heights of the structures in the study area, this issue will not be resolved until the PE&D phase of the study.

The number of structures eligible for nonstructural and the average cost (shown in FY2021 dollars) for nonstructural by structure type are documented by occupancy type in Table 49.

Table 49: Number of Structures Recommended for Nonstructural by Occupancy Type

Occupancy Type	# Eligible	Total	% of Total Eligible	Methods Considered	Average Cost
APT	367	1,669	22.0%	Wet Floodproof, Elevate	3,302,758
COM	2,899	6,558	44.2%	Wet/Dry Floodproof, Elevate	530,033
HIGH	21	117	17.9%	Wet Floodproof, Elevate	3,302,758
IND	22	62	35.5%	Wet Floodproof, Elevate	3,302,758
PUB	349	1,051	33.2%	Elevate	1,027,753
SFR1-B	17,350	50,911	34.1%	Elevate	247,768
SFR1-M	3,891	23,560	16.5%	Elevate	247,768
SFRM-B	15,520	68,288	22.7%	Elevate	308,462
SFRM-M	2,342	20,772	11.3%	Elevate	308,462
TOTAL	**42,761**	**172,988**	**24.7%**	**-**	**-**

As the assigned mean foundation heights for the non-single-family structures are very low (all less than 1.5 feet) and very few of the PUB, COM, and IND structures are already elevated out of the floodplain, a larger relative percentage of them are considered eligible for nonstructural. Regardless, 91% of the structures recommended for nonstructural are single-family residential. Of the total number of single-family structures, 23.9% of them are good candidates for nonstructural based on this methodology.

More information regarding the creation of the nonstructural costs can be found in the Cost Engineering Section of the Engineering Appendix and the Nonstructural Appendix.

Future analysis will vary costs based on square footage, but currently, costs are fixed for both SFR1 and SFRM ($247,768 and $308,462 per structure, respectively). Because of the high amount of heterogeneity amongst PUB structures, using a single cost was considered prohibitively inaccurate. Currently, DRV is used to create a separating equilibrium—structures with a DRV under $1 million get a cost of $351,172 and structures over $1 million get a cost of $3,302,758. Future work will refine this methodology and give bespoke costs based on individual structure attributes. For HIGH, APT, and IND, costs are available for both wet floodproofing and elevation, but it was unclear if the structures in the inventory could be wet floodproofed and maintain project effectiveness; as such, to be conservative, only the higher elevation cost was used.

For COM, costs were based on the square footage of the structure. Square footage was known for 3,282 commercial structures. From these data, a linear model was constructed to predict the square footage for other commercial structures using improvement value. Once calculated, the model was used to assign square footages to the other commercial structures in the study area. These square footages were then used to assign per-structure nonstructural costs. The average of these costs can be seen in Table 49.

The Interest During Construction (IDC) and Average Annual Cost (AAC) are both calculated using the FY2021 Federal Discount Rate of 2.5%.

Future analysis will also evaluate different vertical thresholds for structural eligibility identification (e.g., 10% AEP event stage height, 2% AEP event stage height) and identify structures based on their contribution to net NED benefits. All methodologies will only estimate the number of structures of a given type in a given area that are promising candidates for nonstructural measures. As mentioned earlier, final selection is only possible during implementation once specific characteristics of individual structures are visually surveyed and documented.

C-11) TENTATIVELY SELECTED PLAN IDENTIFICATION

The Federal objective of the Project Delivery Team is to identify the Tentatively Selected Plan (TSP) and provide rationale and justification for the plan if it is not the NED plan in accordance with ER 1105-2-100 *Planning Guidance Notebook*. The NED Plan is the plan that reasonably maximizes contribution to National Economic Development consistent with protecting the Nation's environment, pursuant to national environmental statuses, applicable executive orders, and other Federal planning requirements.

The January 5th, 2021 Policy Directive "Comprehensive Documentation of Benefits in Decision Document" also directs the PDT to identify two other plans: one, a Nonstructural Plan, and two, a Net Total Benefit plan, which accounts for RED, OSE, and EQ benefits in addition to NED benefits.

This section will identify the aforementioned plans (TSP, NED, Total Benefits, and Nonstructural) as well as outline the use of a partial distribution of NED results by plan (lower quartile to upper quartile) and other decision metrics such as residual risk, long-term exceedance probability, SLC adaptability, reliability / fragility, and life safety risk to inform the identification of the TSP. Additionally, there remains the possibility that future optimizations and analysis of the identified TSP may actually reveal that the plan is also the true NED Plan. However, when solely using the current mean Average Annual Net Benefit (AANB) totals, the TSP is not the net NED benefit maximizing plan and, as such, the current NED Plan will also be provided alongside the TSP.

NED Results

As each of the four study regions are essentially independent, the NED Plan is the alternative in each region that reasonably maximizes AANBs. Table 50 below shows the summary breakdown of the current NED Plan, identified TSP, and Nonstructural-Only Plan under Intermediate SLC. Table 51 provides the results for the Low SLC curve and Table 52 provides the results for the High SLC curve.

Table 50: Comparison of TSP, NED, and Nonstructural Plans (Intermediate RSLC)

Tentatively Selected Plan (TSP) / Total Benefits Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$393,372,000
Total Reduced AAD	**$1,415,238,000**
Total Initial Construction	$16,067,536,000
OMRR&R	$195,710,000
Average Annual Cost (AAC)	**$803,107,000**
Average Annual Net Benefits	**$612,131,000**
Benefit-Cost Ratio	**1.8**
Residual Damages	21.7%
Eligible Nonstructural	18,800
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4G(8)**
South Region	**5A**

National Economic Development (NED) Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$417,176,000
Total Reduced AAD	**$1,391,434,000**
Total Initial Construction	$16,492,814,000
OMRR&R	$134,957,000
Average Annual Cost (AAC)	**$758,956,000**
Average Annual Net Benefits	**$632,478,000**
Benefit-Cost Ratio	**1.8**
Residual Damages	23.1%
Eligible Nonstructural	19,900
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4D(1)**
South Region	**5A**

Nonstructural Plan	
Future Without-Project AAD	$1,808,610,000
Future With-Project AAD	$710,695,000
Total Reduced AAD	**$1,097,915,000**
Total Initial Construction	$13,947,220,000
OMRR&R	$0
Average Annual Cost (AAC)	**$491,752,000**
Average Annual Net Benefits	**$606,163,000**
Benefit-Cost Ratio	**2.2**
Residual Damages	39.3%
Eligible Nonstructural	42,800
Shark River / Coastal Lakes	**2A**
North Region	**3A**
Central Region	**4A**
South Region	**5A**

Table 51: Comparison of TSP, NED, and Nonstructural Plans (Low RSLC)

Tentatively Selected Plan (TSP) / Total Benefits Plan	
Future Without-Project AAD	$1,437,190,000
Future With-Project AAD	$311,424,000
Total Reduced AAD	**$1,125,766,000**
Total Initial Construction	$16,067,536,000
OMRR&R	$195,710,000
Average Annual Cost (AAC)	**$803,107,000**
Average Annual Net Benefits	**$322,659,000**
Benefit-Cost Ratio	**1.4**
Residual Damages	21.7%
Eligible Nonstructural	18,800
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4G(8)**
South Region	**5A**

National Economic Development (NED) Plan	
Future Without-Project AAD	$1,437,190,000
Future With-Project AAD	$503,602,000
Total Reduced AAD	**$933,588,000**
Total Initial Construction	$13,324,776,000
OMRR&R	$73,279,000
Average Annual Cost (AAC)	**$559,106,000**
Average Annual Net Benefits	**$374,482,000**
Benefit-Cost Ratio	**1.7**
Residual Damages	35.0%
Eligible Nonstructural	28,500
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4A**
South Region	**5A**

Nonstructural Plan	
Future Without-Project AAD	$1,437,190,000
Future With-Project AAD	$577,117,000
Total Reduced AAD	**$860,073,000**
Total Initial Construction	$13,947,220,000
OMRR&R	$0
Average Annual Cost (AAC)	**$491,752,000**
Average Annual Net Benefits	**$368,321,000**
Benefit-Cost Ratio	**1.7**
Residual Damages	40.2%
Eligible Nonstructural	42,800
Shark River / Coastal Lakes	**2A**
North Region	**3A**
Central Region	**4A**
South Region	**5A**

Table 52: Comparison of TSP, NED, and Nonstructural Plans (High RSLC)

Tentatively Selected Plan (TSP) / Total Benefits Plan	
Future Without-Project AAD	$3,874,279,000
Future With-Project AAD	$1,196,560,000
Total Reduced AAD	**$2,677,719,000**
Total Initial Construction	$16,067,536,000
OMRR&R	$195,710,000
Average Annual Cost (AAC)	**$803,107,000**
Average Annual Net Benefits	**$1,874,612,000**
Benefit-Cost Ratio	**3.3**
Residual Damages	30.9%
Eligible Nonstructural	18,800
Shark River / Coastal Lakes	**2A**
North Region	**3E(2)**
Central Region	**4G(8)**
South Region	**5A**

National Economic Development (NED) Plan	
Future Without-Project AAD	$3,874,279,000
Future With-Project AAD	$1,121,338,000
Total Reduced AAD	**$2,752,941,000**
Total Initial Construction	$18,701,058,000
OMRR&R	$101,769,000
Average Annual Cost (AAC)	**$793,933,000**
Average Annual Net Benefits	**$1,959,008,000**
Benefit-Cost Ratio	**3.5**
Residual Damages	28.9%
Eligible Nonstructural	28,000
Shark River / Coastal Lakes	**2A**
North Region	**3A**
Central Region	**4D(1)**
South Region	**5D(1)**

Nonstructural Plan	
Future Without-Project AAD	$3,874,279,000
Future With-Project AAD	$1,767,230,000
Total Reduced AAD	**$2,107,049,000**
Total Initial Construction	$13,947,220,000
OMRR&R	$0
Average Annual Cost (AAC)	**$491,752,000**
Average Annual Net Benefits	**$1,615,297,000**
Benefit-Cost Ratio	**4.3**
Residual Damages	45.6%
Eligible Nonstructural	42,800
Shark River / Coastal Lakes	**2A**
North Region	**3A**
Central Region	**4A**
South Region	**5A**

A summary of the alternatives selected for both the NED plans and the TSPs for each SLC rate can be found below in Table 53.

Table 53: TSP and NED Plan by SLC Rate

	Shark River		North Region		Central Region		South Region	
SLC Rate	**TSP**	**NED**	**TSP**	**NED**	**TSP**	**NED**	**TSP**	**NED**
Low (Historic)	2A	2A	3E(2)	3E(2)	4G(8)	4A	5A	5A
Intermediate	2A	2A	3E(2)	3E(2)	4G(8)	4D(1)	5A	5A
High	2A	2A	3E(2)	3A	4G(8)	4D(1)	5A	5D(1)

As Table 53 shows, the NED plan often depends on the SLC curve selected. The TSP, which was formulated under the Intermediate SLC curve and based on both Average Annual Net Benefits and other criteria, such as adaptive capacity, fragility, and life safety risk, does not change based on the SLC curve selected. A discussion of the additional selection criteria follows this Section. The increase or decrease of SLC increases or decreases the magnitude of AANBs, but only one plan—5D(2)—changes sign (it goes from negative AANBs to positive under the High curve—see Table 48). As such, the selection of SLC curve is not the determinant of economic viability for the project. There are two changes to the NED plan under the High curve in the North and the South regions, though, as well as a change to the NED plan under the Low curve in the Central region. For these, the NED plan switches from one economically justified plan to another economically justified plan.

In the North under the High Curve, the NED plan switches from 3E(2) (storm surge barrier and nonstructural) to 3A (nonstructural). This result, while surprising, is an artifact of how the storm surge barriers were modeled within HEC-FDA. In the face of higher SLC, there may be changes to closure frequency or increased nonstructural implementation that are not captured within the HEC-FDA analysis. These additional measures would likely make 3E(2) the NED plan, despite the HEC-FDA results suggesting that 3A is the NED plan. Future analysis will verify this, while a qualitative discussion of adaptability and sea level change can be found later in this Section.

In the South under the High curve, the NED plan switches from 5A (nonstructural) to 5D(1) (perimeter plus nonstructural). While it is true that perimeter measures prevent more damage as there is more sea level change, these results need to be considered in context. There are major limitations in using the results under the High SLC curve, as HEC-FDA is not a life cycle model and does not allow for inventory changes over time. As the sea level rises, some structures will begin to take high amounts of repetitive damage. In reality, some of these structures will be elevated or not be rebuilt, but within HEC-FDA, they are assumed to remain in the inventory and take damage until the end of the study timeframe. When HEC-FDA interfaces a static inventory with water levels that have been raised by SLC, the model may overestimate damages by assuming indefensible repetitive damages. Some of the damages reduced by the perimeter plan in the South under the High SLC curve are those repetitive damages; as such, it is possible that, even under the High curve, the nonstructural plan is still the NED plan. Future work will seek to remove erroneous repetitive damages to verify the NED plan for the South under the High curve.

As can be seen in Table 46, Table 47, and Table 48, the Average Annual Net Benefits between different plans for the same region are often similar. Due to high levels of uncertainty and modeling limitations, one alternative may have higher AANBs than another but still be well within the uncertainty bounds regarding whether that alternative is truly the NED alternative for the region.

The following section will describe the methodology for identifying the TSP and NED plans. In summary, the TSP's mean AANB is $20,347,000 (3.2%) less than that of the NED Plan, but the TSP provides an estimated 1.4% additional decrease in residual damages. Though the NED Plan's mean is higher, the distributions of the iteration results overlap extensively, suggesting that we cannot definitively show which alternative reasonably maximizes net AANBs.

As the two identified plans only differ in the Central Region, Figure 48 below shows the distribution in AANBs between alternative 4D(1) (NED Plan) and 4G(8) (TSP):

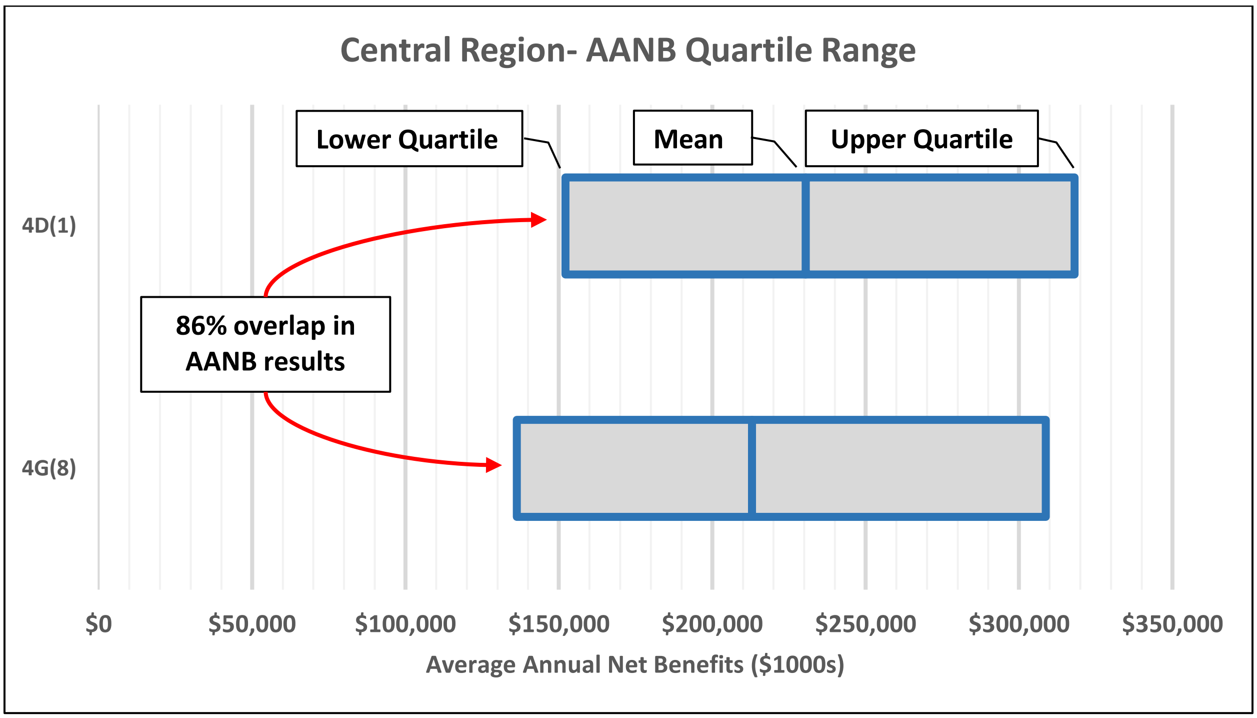


Figure 48: Central Region AANB Quartile Range

Figure 48 has key limitations that do not impact the overall validity of the comparison but can be improved with future evaluation and data. In particular, the distribution only provides data between the lower quartile and upper quartile and the uncertainty in AANBs shown is driven only by uncertainty in the HEC-FDA and non-HEC-FDA benefit streams while keeping AACs deterministic. Access to complete AAB results by iteration and a probability distribution of AACs will allow for more in-depth assessment of the full range of AANBs and the probability of economic justification per plan.

Given these limitations, it is still apparent that alternatives 4D(1) and 4G(8) have significant overlap in possible AANB results with fairly similar costs and project effectiveness.

The TSP also provides advances in other decision metrics including long-term exceedance probability, SLC adaptability, reliability / fragility, and life safety risk. While only addressed here semi-quantitatively or qualitatively, these metrics will be fully quantified during the study risk assessment effort in accordance with Planning Bulletin 2019-04 *Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies*.

Figure 49, Figure 50, and Figure 51 show the TSP, NED, and Nonstructural plans for the study area, respectively.

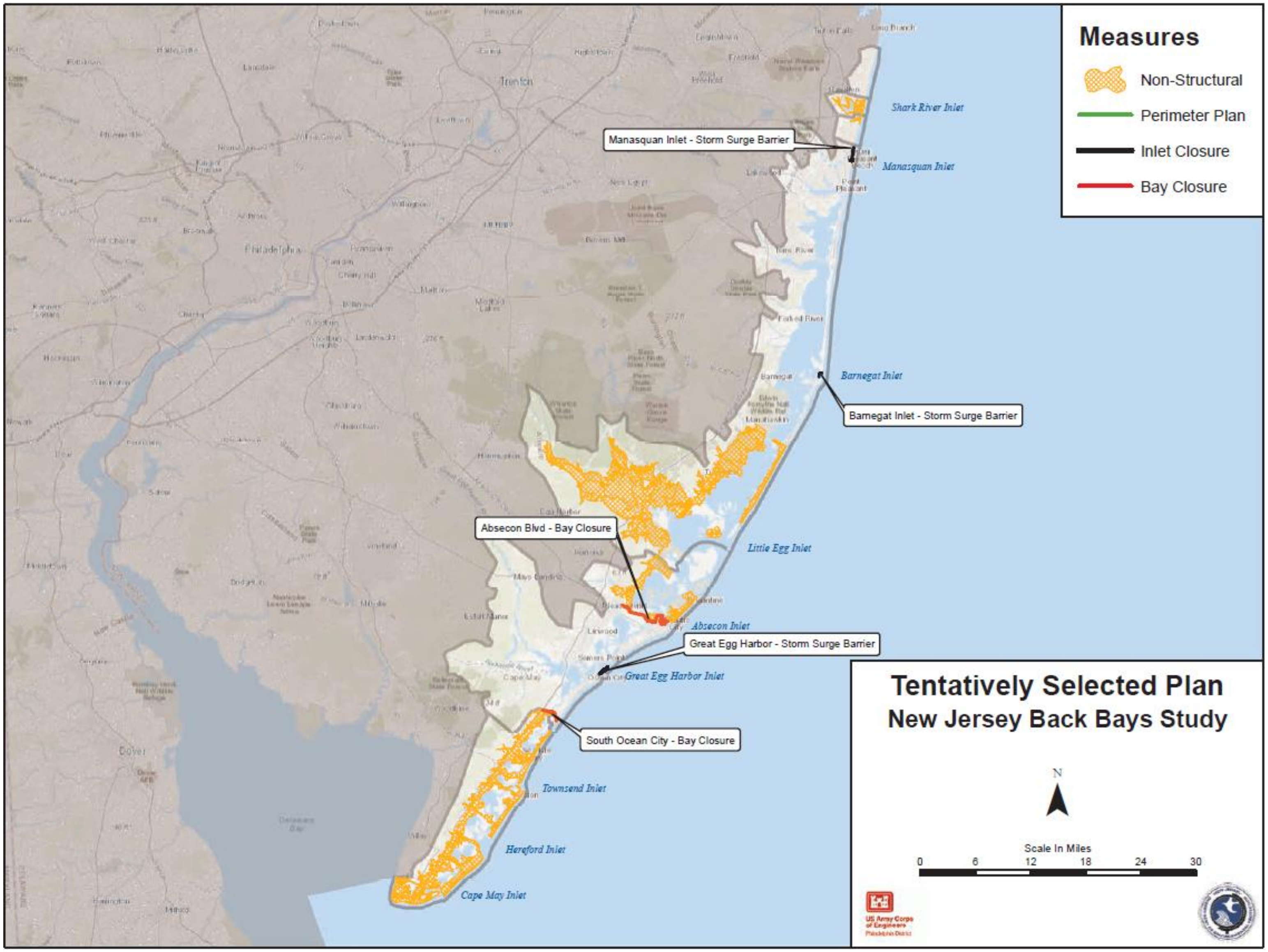


Figure 49: TSP for the Study Area

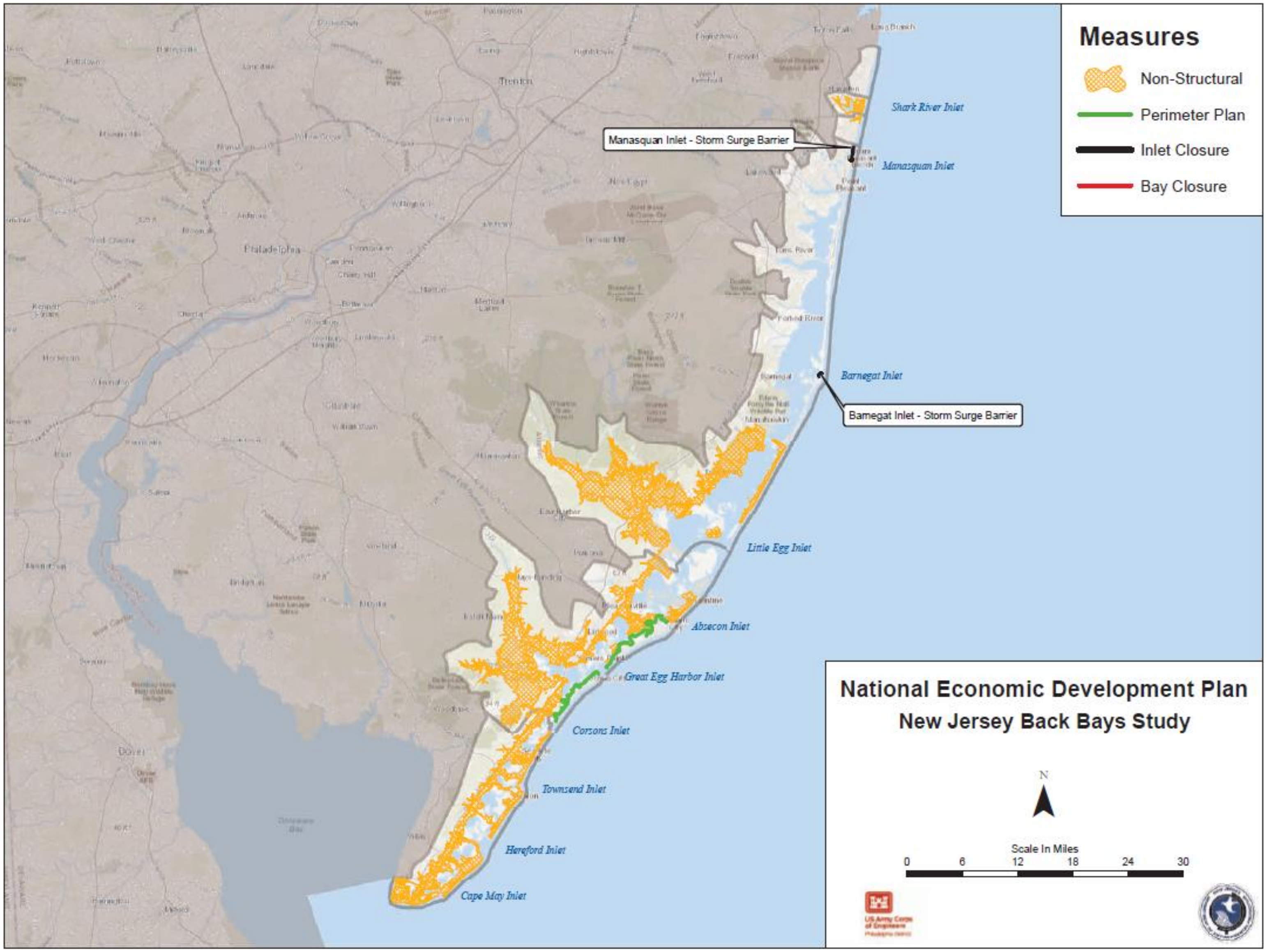


Figure 50: NED Plan for the Study Area

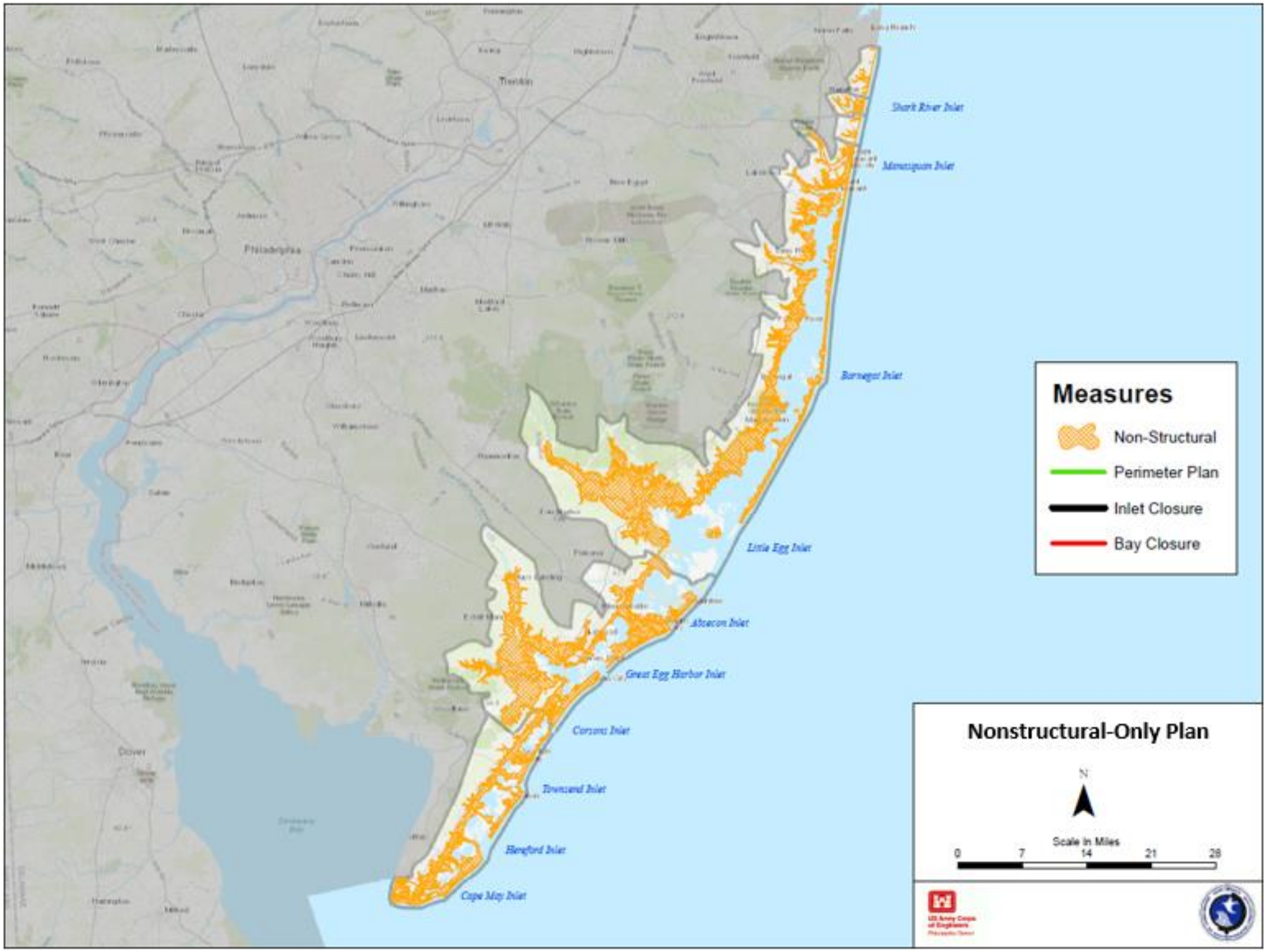


Figure 51: Nonstructural-Only Plan for the Study Area

Sea Level Change and Adaptive Capacity

ER 1110-2-8162 *Incorporating Sea Level Change In Civil Works Programs* requires the performance of alternatives to be evaluated under all three USACE SLC scenarios to determine the alternatives' overall potential performance. Not only is it possible that RSLC could be lower or greater than the USACE Intermediate SLC scenario, it is also possible that the plans will have a service life well beyond 50 years. Therefore, it is important to consider the sensitivity of the project performance to RSLC, the adaptive capacity of the alternatives, and performance over the 100-year planning horizon.

Perimeter structural alternatives, such as 4D(1), present certain project risks when accounting for SLC that are not found with storm surge barriers or adaptive nonstructural. For example, if a perimeter measure is designed and constructed to maintain project performance with a given SLC rate and that rate is exceeded during the life of the project, then the project may encounter a difficult choice between low project performance or requiring an expensive reconstruction to a higher design elevation. This risk can be mitigated in two ways, but both must be undertaken before the base year. This includes initially constructing the perimeter measure for the higher SLC rate (precautionary approach) or initially constructing the measure with certain design features, wider levee base or deeper floodwall piles, which allow for a future adaptation if the SLC rate is different than expected during formulation (managed adaptive approach).

Both methods present disadvantages. Constructing an initially larger perimeter feature mitigates the risk of reduced project performance due to SLC, but likely decreases net benefits and increases the risk of selecting an inefficient design. If a larger and more expensive design is constructed, there is the risk that SLC does not increase at the higher rate and a smaller, less expensive design would have maintained the desired project performance. The same risk is apparent if constructing an initially larger base or deeper piles for a SLC rate that does not come to fruition. Furthermore, the additional costs for these adaptability approaches must be incurred at the base year and can jeopardize economic viability.

The inherent adaptive capacity of the storm surge barrier structure is low, as it is not feasible to increase the height of vertical lift gate or sector gate; however, additional complementary nonstructural measures can be implemented over time in adjustment to the SLC rate being experienced without adding expensive adaptability costs to initial construction. Even under the High SLC curve, the initial storm surge barrier design proposed for the TSP can be adapted to maintain project performance over a 100-year planning horizon.

Figure 52 shows the LTEP (over a 25-year period) for perimeter / nonstructural measures and several storm surge barrier scenarios. Project performance at representative structures (i.e., FFE of 8ft NAVD88) is useful in evaluating how the performance is affected by RSLC and how adaptive actions could be taken to maintain performance over a 100-year period of analysis.

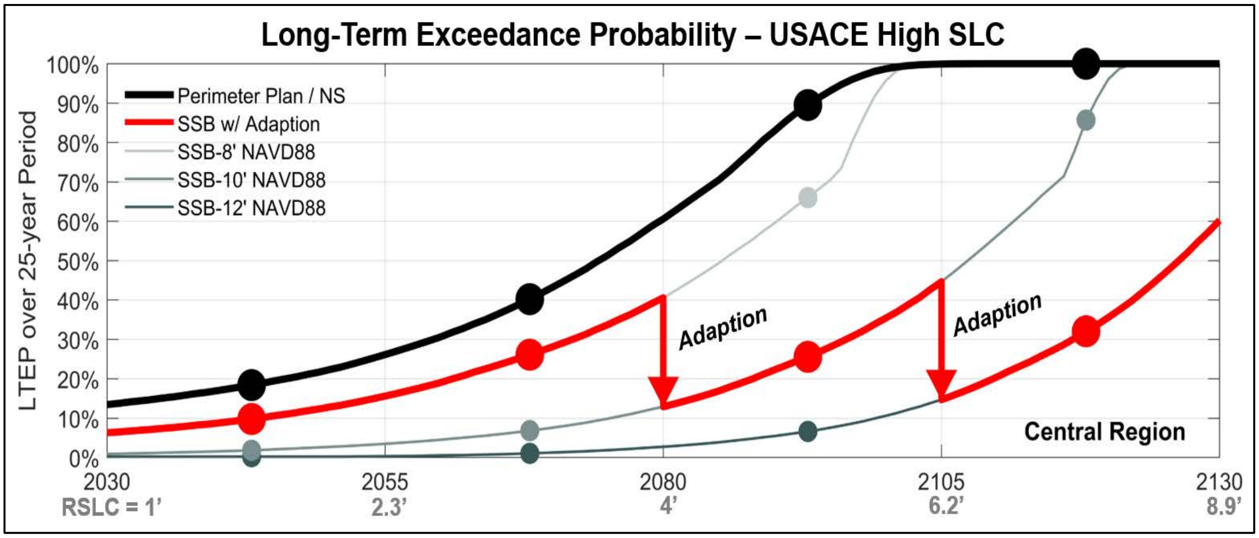


Figure 52: Long-Term Exceedance Probability for Perimeter and SSB

For the current perimeter measure formulated and designed using the Intermediate SLC curve, LTEP increases steadily over time until approaching 60% at the end of the 50-year period of analysis and 99.9% in Year 2105. This means any structure with a FFE less than the design elevation of the perimeter measure has between a 60% annual probability to a 99.9% annual probability of being inundated in the 25-year period following 2080. This LTEP risk can be mitigated but requires significant upfront costs to provide that adaptability.

For the current storm surge barrier measure formulated and designed using the Intermediate SLC curve, LTEP for a structure with a FFE at 8ft NAVD88 eclipses 40% in 2080. However, storm surge barriers can be adapted in several ways including adjusting the closure operation frequency or incrementally adding smaller complementary nonstructural measures throughout the period of analysis. Costs can be deferred past the base year and only implemented in the event of High SLC without any change to current design or formulation. Nonstructural measures can be incrementally added to the storm surge barrier measure throughout the 100-year planning horizon to maintain project performance under the High SLC curve without any additional upfront costs.

Essentially, the storm surge barrier measure allows for adaptation to High SLC rates while providing reduced vulnerability to coastal storm damage for the study area over the full 100-year planning horizon.

Reliability and Fragility

Storm surge barriers and perimeter measures also differ in their probability of failure and consequences of failure. While this section qualitatively addresses these distinctions, a comprehensive risk assessment is required to quantitatively compare the structural and life safety risks of the measures. The risk assessment will be completed before release of the final Feasibility Report.

For perimeter measures, the length and characteristics of the proposed design present potential failure modes and potential failure consequences not apparent for storm surge barriers. 4D(1) requires approximately 189,843 linear feet of hardened structure with 24 miter gates and/or road closures. The failure of any one section of floodwall or multiple scattered gates/closures could compromise the integrity and effectiveness of the entire perimeter network.

The lack of storage in the event of an overtopping or breach or gate failure, coupled with high flood depths and rapid rate of flooding, presents significant potential structural and life safety consequences. The risk from inundation is transformed from a moderate rate of flooding with days of warning time to a sudden catastrophic event with limited to no warning time.

Plan 4G(8) still requires the construction of some floodwall length, but considerably less than required in Plan 4D(1). There are certain potential failure modes unique to storm surge barriers not present with floodwalls or levees, but these failure points are centralized at the location of the barrier. As such, they are easier to mitigate and monitor for. Additionally, the high storage capacity afforded with storm surge barrier measures mitigates consequences of an overtopping or breach event by moderating the rate of flooding and extending the evacuation window.

HEC-FDA allows the introduction of floodwall fragility curves to properly assess the economic project performance of the proposed plans. While this will not provide insight on life safety concerns nor fully identify the economic risk for perimeter measures, it can partially quantify the risk to adjust estimated NED AANBs. The implementation of these fragility curves is planned for future work before release of the final Feasibility Report.

Life Safety Risk

Planning Bulletin 2019-04 requires plan formulation and evaluation to explicitly consider and incorporate risks to life safety. Evaluation must consider whether and how measures and alternatives change the risk to life safety in the future, including increases to the potential for life loss, risk transformation, and risk transfer. Quantified evaluation of the probability, consequences, and life safety risk for the proposed TSP and NED plan can only be accomplished with a complete risk assessment. Among the many assessment outputs will be an evaluation of the life safety risk and actions to reduce that risk.

While qualitative assessments of the measure types (discussed in Section C-9) suggest storm surge barriers have reduced life safety risk, which in turn has influenced the decision to propose 4G(8) for the Central Region as part of the TSP over other alternatives, the final decision for the Recommended Plan will only be reached once the quantitative risk assessment is completed.

Project Performance

In accordance with ER 1105-2-101 *Risk Assessment for Flood Risk Management Studies*, the following performance considerations for the measures included in the TSP and NED plans are provided in Table 54.

Table 54: Project Performance at Year 2080 (USACE Int. SLC)

Plan	AEP		LTEP			Assurance by Event				
	Expected	90% Assurance	10YR Period	30YR Period	50YR Period	10%	2%	1%	0.4%	0.2%
Nonstructural	0.91%	2.37%	8.8%	24.1%	36.8%	99.9%	85.0%	54.6%	17.9%	6.1%
Perimeter	0.91%	2.37%	8.8%	24.1%	36.8%	99.9%	85.0%	54.6%	17.9%	6.1%
SSB, FFE 14'	0.01%	0.01%	0.1%	0.3%	0.5%	99.9%	99.9%	99.9%	99.9%	99.9%
SSB, FFE 12'	0.01%	0.06%	0.1%	0.3%	0.5%	99.9%	99.9%	99.9%	99.9%	99.8%
SSB, FFE 10'	0.09%	0.27%	0.9%	2.8%	4.6%	99.9%	99.9%	99.9%	97.7%	80.2%
SSB, FFE 08'	0.48%	0.95%	4.7%	13.5%	21.5%	99.9%	99.9%	91.8%	38.9%	12.4%

Annual exceedance probability (AEP) is the probability that a certain threshold (crest elevation or first floor elevation) may be exceeded at a location in any given year considering the full range of possible storm events and project performance.

Long-term exceedance probability (LTEP) is the probability that a certain threshold (crest elevation or first floor elevation) is exceeded at least once during a specified period. For Table 54, the LTEP is calculated as if the water surface profile stage heights in Year 2080 with Intermediate SLC remained constant. The LTEP for the study 50-year period of analysis (Year 2030 to Year 2080) is actually lower than the LTEP specified in the table as every year before Year 2080 has lower mean stage heights.

Assurance is the probability that a target stage will not be exceeded during the occurrence of a flood of specified exceedance probability considering the full range of uncertainties.

Nonstructural and perimeter measures within the TSP and NED plans are both designed to meet the same project performance and therefore share the same AEP, LTEP, and Assurances. The expected AEP for either measure is 0.91%, or in other words, there is a 0.91% probability in any given year that the measure will be exceeded by a coastal storm event and any structures with a FFE less than the height of the perimeter measure will be inundated. At the 90% assurance level, this probability rises to 2.37%.

The LTEP over a 50-year period of analysis is 36.8% for the nonstructural and perimeter measures. This means there is an estimated 36.8% probability the measure will be exceeded at least once over the 50-years of analysis. The Assurance by Event shows when considering the uncertainties in the hydraulic variables, there is a 0.1% probability the measure will be exceeded by a 10% AEP event, but a 45.4% probability the measure will be exceeded by a 1% AEP event.

Evaluating the project performance of storm surge barriers is less straightforward compared to evaluating nonstructural and perimeter structural measures due to the differences in how the measures respond to storm events that exceed the design crest elevations. Perimeter structural measures are at risk of structural failure when wave overtopping exceeds the design standard and have limited storage capacity behind the measures to accommodate the water overtopping the wall before damages are incurred. Storm surge barriers, in contrast to perimeter structural measures, are not as susceptible to structural failure from wave overtopping and are able to disperse and store the water overtopping the barriers over a much larger area throughout the bays. This same fundamental difference in storage capacity will be a key determining factor in qualitatively assessing life safety consequences in the event of a measure failure.

To accurately compare the project performance of perimeter and storm surge barrier measures, the plans can be evaluated on how effectively they mitigate coastal storm risk for representative structures behind those measures. The SSB performance in Table 54 is based on the 4G(8) storm surge barrier alternative in the Central Region. Starting with a representative structure at a First Floor Elevation (FFE) of just 8ft NAVD88, there is a 0.48% annual probability that the structure will be inundated, but a 0.91% annual probability of inundation for the same structure behind a perimeter measure.

For that same representative structure at 8ft NAVD88, there is a 21.5% probability of being inundated behind a storm surge barrier at least once in a 50-year period of analysis compared to 36.8% probability for the same structure behind a perimeter measure. In terms of Assurance at a 1% AEP event, the representative structure has only an 8.2% probability of being inundated behind a storm surge barrier compared to the 45.4% probability behind a perimeter measure.

C-12) CONCLUSION

Using current figures, the TSP is expected to provide mean Average Annual Net Benefits of \$612,131,000 with a Benefit-to-Cost ratio of 1.8 and 21.7% in Residual Damages.

In accordance with ER 1105-2-100 *Planning Guidance Notebook*, the current NED Plan must also be identified. It provides estimated mean Average Annual Net Benefits of \$632,478,000 with a Benefit-to-Cost Ratio of 1.8 and 23.1% in Residual Damages.