ENGINEERING
APPENDIX

NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT
FEASIBILITY STUDY

PHILADELPHIA, PENNSYLVANIA

APPENDIX B

March 2019

U.S. Army Corps of Engineers
Philadelphia District

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U.S. Army Corps of Engineers
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NJBB

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Introduction

The North Atlantic Coast Comprehensive Study (NACCS) was conducted to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps. The New Jersey Back Bays (NJBB) area was identified as a “focus area” within the NACCS study. This Civil Engineering Appendix discusses the engineering and design work conducted to layout and evaluate potential structural, non-structural and natural & nature-based (NNBF) solutions for protection against flooding in the New Jersey Back Bays Region. Two structural flood control solution types were evaluated; perimeter plans and storm surge barriers. Both solutions were evaluated separately for initial screening analysis, but components of each will be combined to determine a focused array of alternatives that will be further evaluated during the next phase of the study.

The NACCS Tier 1 Screening provided pre-compiled reference data for initial screening of alternatives. Designs from other USACE District studies were also analyzed for suitability of incorporating these features as measures in this study. Parametric data from each were utilized for determination of with-project costs.

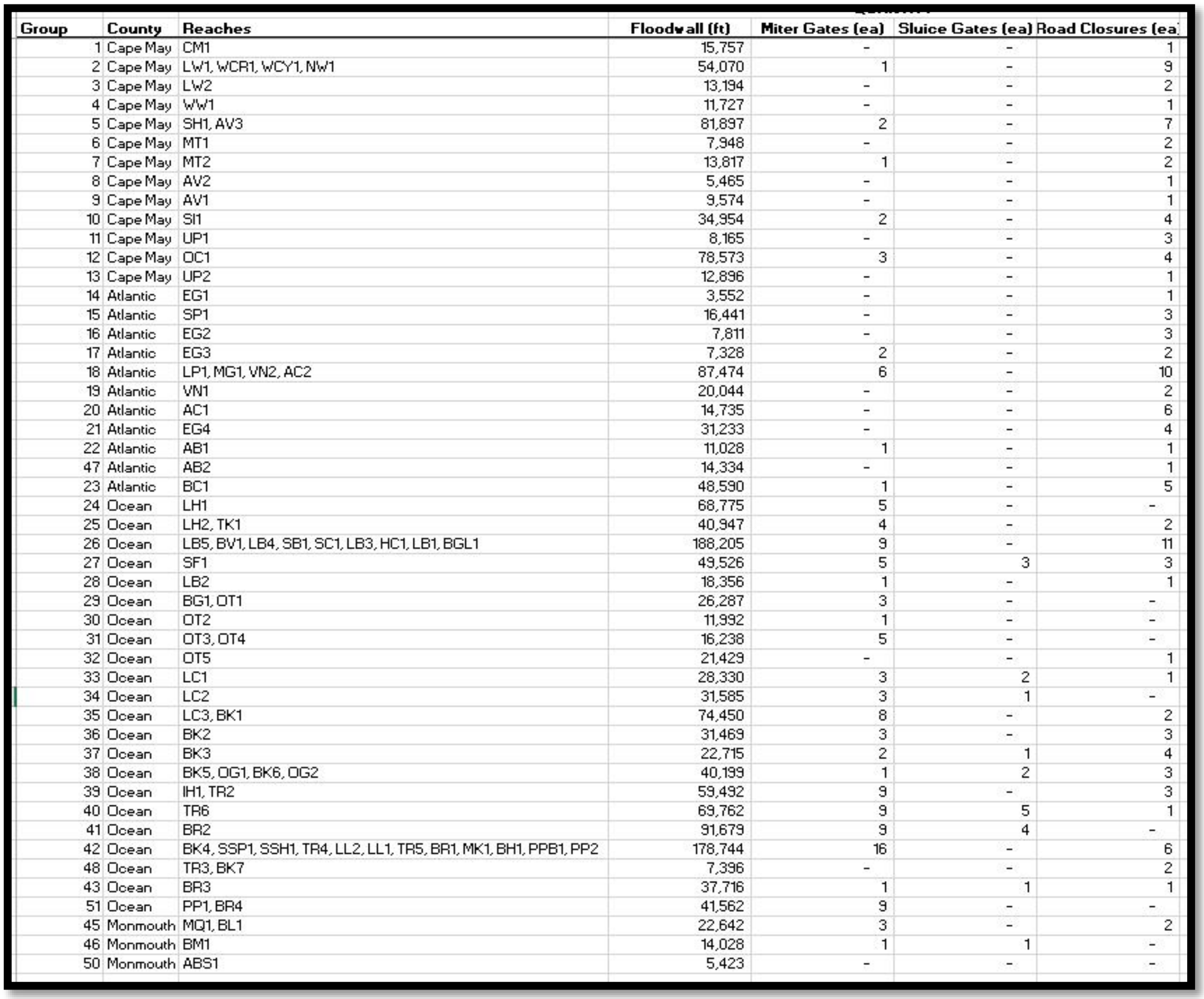
Perimeter Plan Screening Level Analysis

Perimeter Plan Cycle 1 Screening

The entire back bays perimeter area was divided into economic reaches by county and municipality. Reaches were then combined into groups based upon geographical conditions (municipalities on a barrier island, etc.) or hydraulic connectivity (small island off the barrier) resulting in 50 groups. Google Earth mapping was utilized to enclose each reach within a polygon for economic analysis. The economic model, HEC-FDA, was used to determine the benefit pool for the reach and the Average Annual Net Benefits (AANB) were determined (See Appendix C for Economic Analysis). A preliminary line of protection was laid out for each group (completed also in Google Earth) along the bay frontage of the polygon or at other suitable locations.

Ground above the FEMA 500 year flood zone was considered high ground and used to determine where to terminate the line of protection. At this stage of the study, it was assumed the performance of the existing USACE CSRM projects along the ocean shorelines would be compatible as a tie-in point for storm surge barrier and perimeter plan alternatives. It is acknowledged that there is variability in the design dune dimensions and performance of the existing CSRM projects up and down the coast. In the next phase of the study, the performance and compatibility of the existing CSRM projects as a tie-in point will be investigated further. This preliminary layout did not consider the best horizontal placement of the line but did approximate the existing shoreline or exposed perimeter. The linear foot length of the line of protection for each group is shown in Table 1 below.

Table 1: Cycle 1 Reaches & Quantities of Floodwalls, Miter Gates and Road Closure Structure by Group



Group	County	Reaches	Floodwall (ft)	Miter Gates (ea)	Sluice Gates (ea)	Road Closures (ea
1	Cape May	CM1	15,757	-	-	1
2	Cape May	LW1, WCR1, WCY1, NW1	54,070	1	-	9
3	Cape May	LW2	13,194	-	-	2
4	Cape May	WW1	11,727	-	-	1
5	Cape May	SH1, AV3	81,897	2	-	7
6	Cape May	MT1	7,948	-	-	2
7	Cape May	MT2	13,817	1	-	2
8	Cape May	AV2	5,465	-	-	1
9	Cape May	AV1	9,574	-	-	1
10	Cape May	SI1	34,954	2	-	4
11	Cape May	UP1	8,165	-	-	3
12	Cape May	OC1	78,573	3	-	4
13	Cape May	UP2	12,896	-	-	1
14	Atlantic	EG1	3,552	-	-	1
15	Atlantic	SP1	16,441	-	-	3
16	Atlantic	EG2	7,811	-	-	3
17	Atlantic	EG3	7,328	2	-	2
18	Atlantic	LP1, MG1, VN2, AC2	87,474	6	-	10
19	Atlantic	VN1	20,044	-	-	2
20	Atlantic	AC1	14,735	-	-	6
21	Atlantic	EG4	31,233	-	-	4
22	Atlantic	AB1	11,028	1	-	1
47	Atlantic	AB2	14,334	-	-	1
23	Atlantic	BC1	48,590	1	-	5
24	Ocean	LH1	68,775	5	-	-
25	Ocean	LH2, TK1	40,947	4	-	2
26	Ocean	LB5, BV1, LB4, SB1, SC1, LB3, HC1, LB1, BGL1	188,205	9	-	11
27	Ocean	SF1	49,526	5	3	3
28	Ocean	LB2	18,356	1	-	1
29	Ocean	BG1, OT1	26,287	3	-	-
30	Ocean	OT2	11,992	1	-	-
31	Ocean	OT3, OT4	16,238	5	-	-
32	Ocean	OT5	21,429	-	-	1
33	Ocean	LC1	28,330	3	2	1
34	Ocean	LC2	31,585	3	1	-
35	Ocean	LC3, BK1	74,450	8	-	2
36	Ocean	BK2	31,469	3	-	3
37	Ocean	BK3	22,715	2	1	4
38	Ocean	BK5, OG1, BK6, OG2	40,199	1	2	3
39	Ocean	IH1, TR2	59,492	9	-	3
40	Ocean	TR6	69,762	9	5	1
41	Ocean	BR2	91,679	9	4	-
42	Ocean	BK4, SSP1, SSH1, TR4, LL2, LL1, TR5, BR1, MK1, BH1, PPB1, PP2	178,744	16	-	6
48	Ocean	TR3, BK7	7,396	-	-	2
43	Ocean	BR3	37,716	1	1	1
51	Ocean	PP1, BR4	41,562	9	-	-
45	Monmouth	MQ1, BL1	22,642	3	-	2
46	Monmouth	BM1	14,028	1	1	-
50	Monmouth	ABS1	5,423	-	-	-

As an initial screening measure the NACCS Tier 1 floodwall was assumed for the line of protection to generate with-project quantities. The NACCS floodwall is a pile supported, reinforced concrete T-Wall, with an unsupported stem height of 10 feet above ground and 2.5 foot thickness. Rows of piles spaced every 7 feet at lengths between 15 and 50 feet, depending on the soil conditions, form the foundation of the structure, although these are not shown in the graphic (See Figure 1 below). The linear foot parametric cost of the wall includes drainage gates/outlet structures every 400 feet along the length of the floodwall. Additional structures (miter gates, sluice gates, and road closure structures) necessary to complete the continuous line of protection were also included to determine with-project quantities. Miter gates, 65 feet wide, were used to close off navigable canals or channels. Sluice gates, 60 feet wide, were used to maintain flow in areas where the floodwall will cut off flow to a small stream, tidal wetland or marsh, and where navigation is not required. Road closure structures (roller gate type) were used to close the line of protection during flooding events while allowing use of the roadway or municipal boat ramp during non-flood conditions. One road closure will accommodate two lanes of standard traffic; two road closures were used at locations with four lanes of traffic.

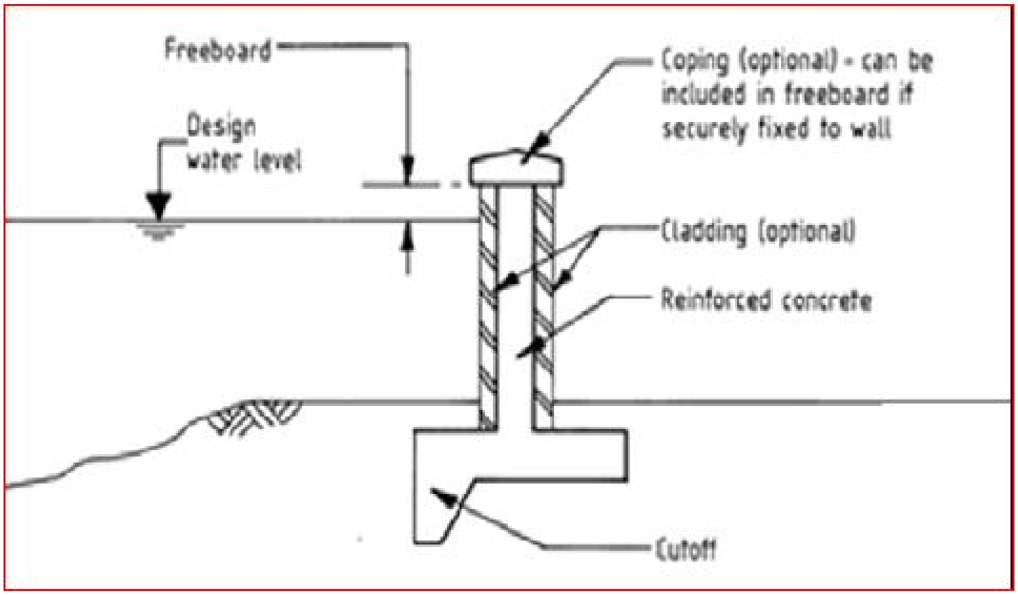


Figure 1: Representative NACCS Floodwall Cross Section (T-Wall)

Benefit-Cost Ratio results for the Cycle 1 Screening of potential Perimeter Plan alternative locations resulted in 12 Groups considered "Favorable" (BCR above 2.0), 12 Groups considered "Possible" (BCR between 1.0 and 2.0), and 25 Groups considered "Screened Out" (BCR below 1.0). A further cycle of screening (Cycle 2) was applied to the 12 groups that received a “favorable” status.

Perimeter Plan Cycle 2 Screening

A more detailed evaluation of the proposed preliminary line of protection was ultimately completed for a total of 13 groups for Perimeter Plan Cycle 2 Screening. The 13 groups included the 12 groups that advanced from the Perimeter Plan Cycle 1 Screening analysis (with some changes) and one additional group added to the analysis that had been overlooked in Cycle 1. Previous group compositions were revised to reorganize reaches for economic evaluation purposes, or to combine reaches differently due to hydraulic or structural reasons. The Perimeter Plan Cycle 2 Screening process applied to the 13 groups included refinement of the location of the line of protection, selection of a proposed structure type based upon preliminary consideration of existing conditions where it was to be placed, and computation of quantities based upon the updated layout and typical flood protection sections. Google Earth with elevation tools, the FEMA 500 Year Flood Plain Mapping, and NOAA Navigation Charts as an underlay were used to determine approximate nearshore conditions.

The back bays shoreline ranges from coastal marshland to emergent beachhead to hard structure armoring (typically bulkhead) in areas of high density development. Typical flood protection levee and floodwall sections were generated for the Perimeter Plan Cycle 2 Screening analysis based on these general conditions assumed along the proposed line of protection. The design crest elevation of the protection (feet NAVD88) was computed using still water elevation (SWEL) with required freeboard and anticipated relative sea level change (RSLC) in order to prevent wave overtopping during the design storm event. Crest elevations for floodwalls or earthen levees are similar if the levee includes a rubble slope on the flood side for wave armoring. Approximate maximum required crest elevations are 13 feet NAVD88 everywhere except within Barnegat Bay, where the crest elevations are closer to 10 feet NAVD88. For this level of screening the quantities assumed a maximum of 13 feet NAVD88 for all locations. The three typical sections used in this analysis were a levee section (Type A), a floodwall section to be constructed in areas below water level (Type B), and a floodwall section to be constructed in areas above the mean tide zone (Type C). Typical Sections of each type are shown in Figure 2 through 4.

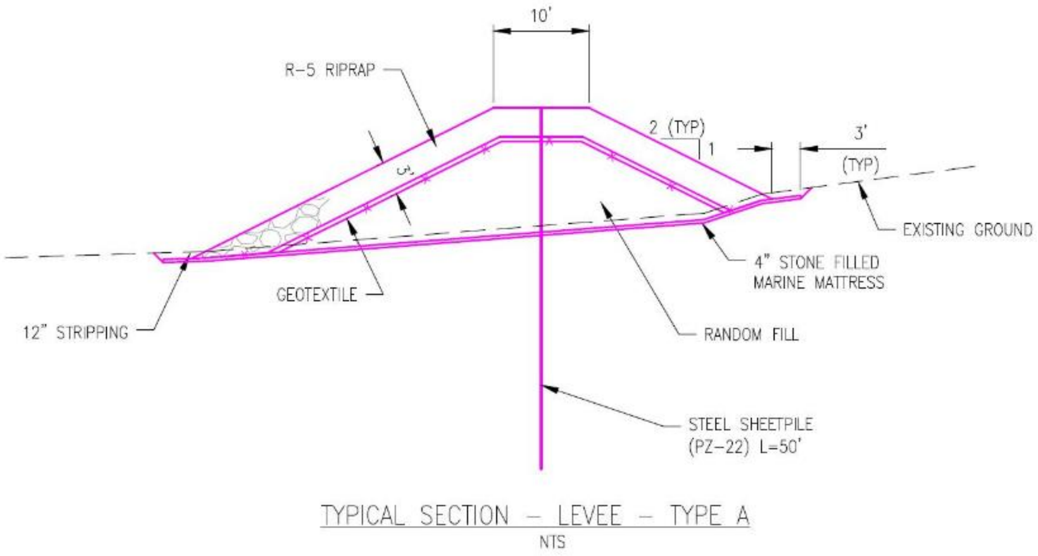


Figure 2: Typical Section - Levee - Type A

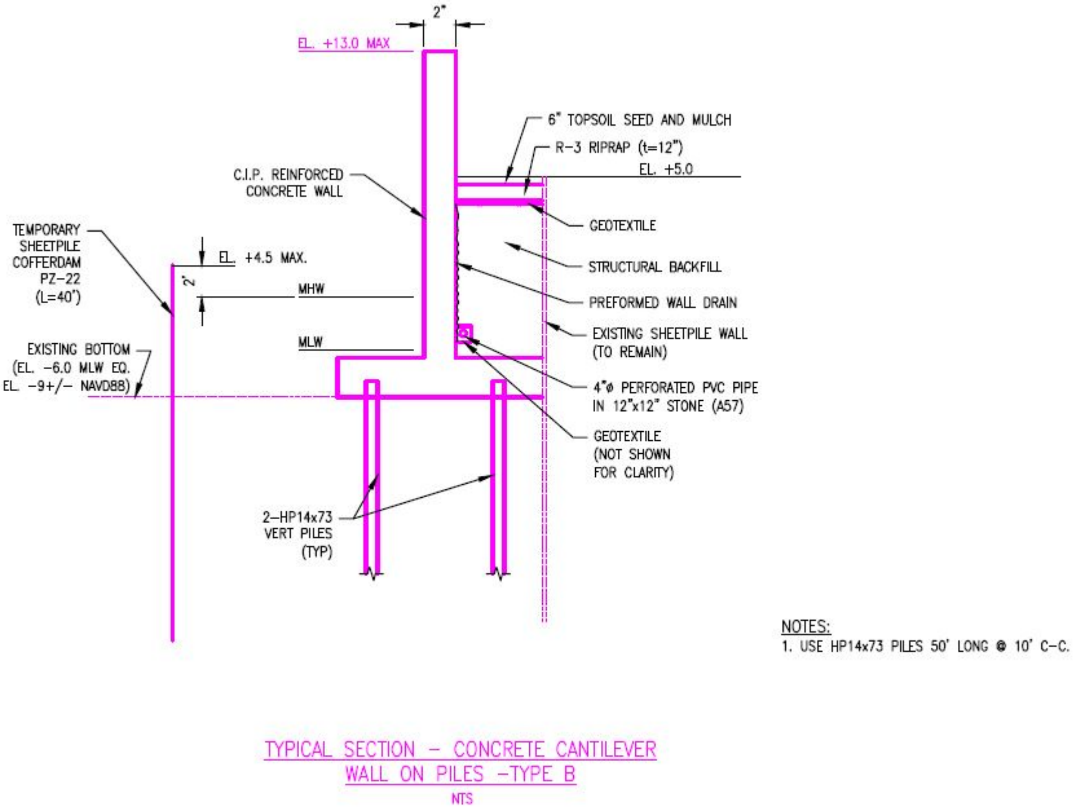


Figure 3: Typical Section - Concrete Cantilever Wall on Piles - Type B

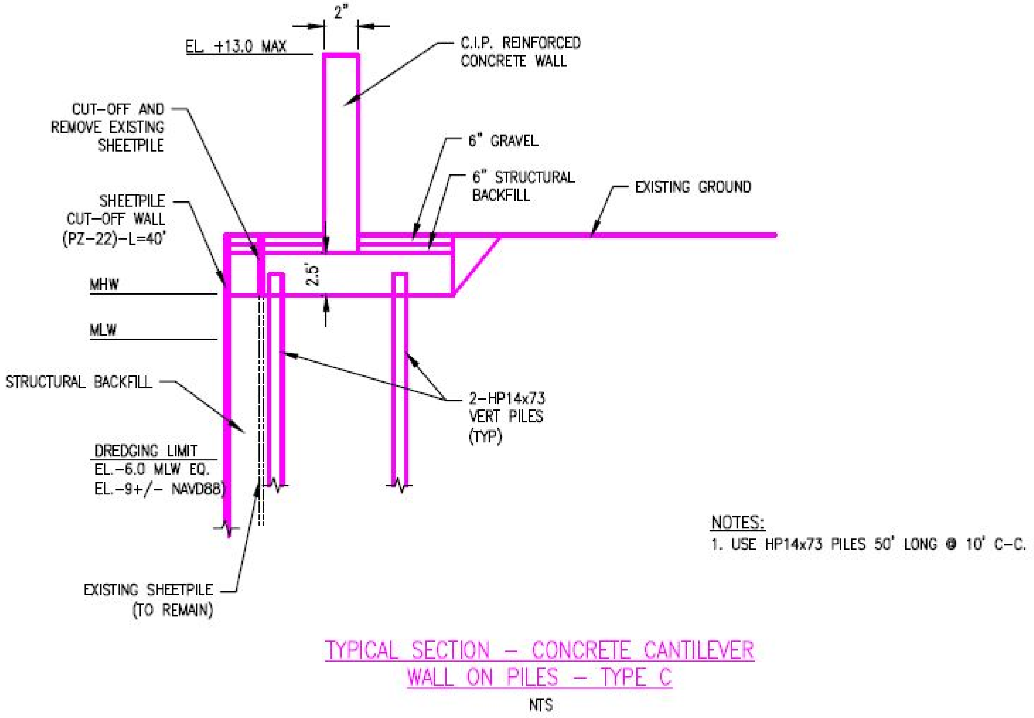


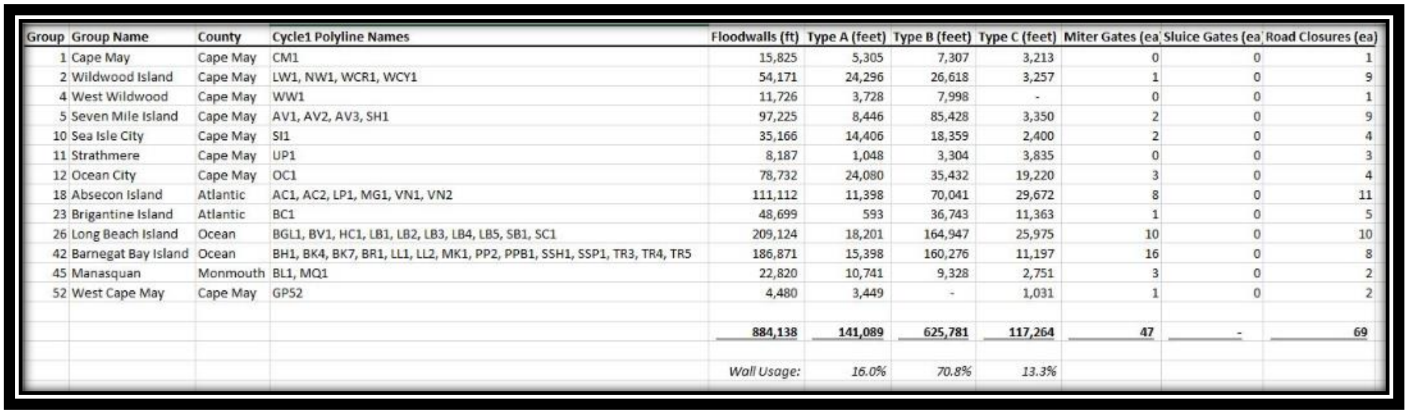
Figure 4: Typical Section - Concrete Cantilever Wall - Type C

Levee sections were used in open space areas that transitioned from beach to water, or from undeveloped property to marshland, but generally avoided areas of coastal marsh or maritime forest for placement of the full levee section to minimize environmental impacts to these resources. If the alignment for the line of protection could not substantially avoid an environmentally sensitive area one of the floodwall types was utilized since its footprint is much smaller than the levee. Very short sections of levee between floodwalls were also avoided for the sake of continuity at the screening level. Layout assumed a landward toe tie-in to existing ground higher than mean high water (MHW), with a sloped bottom extending to the flood side toe at an approximate depth of mean low water (MLW). The levee section, 10' crest width with 2H:1V side slopes, includes a 3 foot thick layer of riprap placed above a random fill interior. The riprap will protect the structure from, and reduce run-up by, wave action, and protect against erosion during overtopping. At the center of the levee section is a sheetpile wall to provide impermeability of the structure, and for cut-off protection against underseepage. Sections will be constructed on top of 4" thick, stone-filled marine mattresses with geotextile along the base to provide foundation support at the soil interface. Quantities include a 2 foot overbuild for expected settlement of the structure.

Both floodwalls Type B and Type C are assumed to be similar in composition but different in size, location of placement, and means and methods needed for construction. Both floodwalls are reinforced concrete T-Walls, with a stem thickness of 2 feet, base thickness of 2.5 feet, supported by (2) 50 foot long HP14x73 piles spaced at 10 feet longitudinally. Construction of the Type B wall assumes placement just bayward of an existing bulkhead structure that will remain in place and provide support of excavation. The base of the Type B wall will extend down to a bed elevation of approximately 9 feet NAVD88, which is the expected maximum dredging depth for the New Jersey Intracoastal Waterway (NJICWW). A temporary cofferdam is required for construction of the wall which will be completed using water-based methods. The Type C wall will be constructed from land at a base depth above or close to the tidal zone. The wall dimensions are based upon constructing the concrete base above the lowest MHW level in the bay (0 feet +/- NAVD88) which results in a stem height of 10.5 feet. The unsupported stem height is estimated to be as high as 9.5 feet. The Type C wall assumes construction behind an existing bulkhead (condition unknown) or at the land edge. In either case, the installation of a sheetpile cut-off wall in front of the structure is assumed to be required for protection of soil below and beyond the base from scour. The depth, number, or size and spacing of piles for either of the floodwalls was not analyzed at this screening level, however, selection of these elements and their parameters was based upon other walls of similar type proposed in other studies.

Floodwall placement in the vicinity of finger canals and other waterfront communities that included alternating lanes of bulkheaded waterway with developed or residential property was considered from an economic point of view. Perimeter floodwall placement would need to follow the existing bulkhead alignment, resulting in long linear foot lengths of structure and, thus, substantial with-project costs for these areas. A miter gate, therefore, was used across the opening of a waterway lane if it would eliminate 3000 feet or more of floodwall. This limit was determined by dividing the cost of a typical miter gate by the linear foot cost of floodwall. The linear foot lengths of the line of protection for each group is shown in Table 2 below.

Table 2: Cycle 2 Reaches & Quantities of Floodwalls, Miter Gates and Road Closure Structure by Group



Group	Group Name	County	Cycle1 Polyline Names	Floodwalls (ft)	Type A (feet)	Type B (feet)	Type C (feet)	Miter Gates (ea	Sluice Gates (ea	Road Closures (ea)
1	Cape May	Cape May	CM1	15,825	5,305	7,307	3,213	0	0	1
2	Wildwood Island	Cape May	LW1, NW1, WCR1, WCY1	54,171	24,296	26,618	3,257	1	0	9
4	West Wildwood	Cape May	WW1	11,726	3,728	7,998	-	0	0	1
5	Seven Mile Island	Cape May	AV1, AV2, AV3, SH1	97,225	8,446	85,428	3,350	2	0	9
10	Sea Isle City	Cape May	SI1	35,166	14,406	18,359	2,400	2	0	4
11	Strathmere	Cape May	UP1	8,187	1,048	3,304	3,835	0	0	3
12	Ocean City	Cape May	OC1	78,732	24,080	35,432	19,220	3	0	4
18	Absecon Island	Atlantic	AC1, AC2, LP1, MG1, VN1, VN2	111,112	11,398	70,041	29,672	8	0	11
23	Brigantine Island	Atlantic	BC1	48,699	593	36,743	11,363	1	0	5
26	Long Beach Island	Ocean	BGL1, BV1, HC1, LB1, LB2, LB3, LB4, LB5, SB1, SC1	209,124	18,201	164,947	25,975	10	0	10
42	Barnegat Bay Island	Ocean	BH1, BK4, BK7, BR1, LL1, LL2, MK1, PP2, PPB1, SSH1, SSP1, TR3, TR4, TR5	186,871	15,398	160,276	11,197	16	0	8
45	Manasquan	Monmouth	BL1, MQ1	22,820	10,741	9,328	2,751	3	0	2
52	West Cape May	Cape May	GP52	4,480	3,449	-	1,031	1	0	2
				884,138	**141,089**	**625,781**	**117,264**	**47**	**-**	**69**
				Wall Usage:	*16.0%*	*70.8%*	*13.3%*			

Storm Surge Barrier Screening Level Analysis

Background

A screening level analysis was performed to investigate potential storm surge barrier (SSB) options that would protect NJBB from coastal storm damages. USACE Engineering Research and Development Center (ERDC) performed three iterations of SSB modeling throughout the study area. The first iteration modeled a SSB at each individual inlet (one at a time). The second iteration modeled 15 alternatives, comprised of inlet and bay closures, to see how a system of barriers would reduce water levels. The third iteration modeled 8 alternatives with a larger storm set to establish hazard curves used for the HEC-FDA economic model. Based on the ERDC models, 11 inlets and 8 bay closures were identified for screening level analysis. Preliminary alignments of SSB components were estimated in AutoCAD for each location. Quantities were then estimated at each location (see Tables 3 and 4) and were provided to Cost Engineering which then estimated construction costs for each SSB. Construction costs were then used in the HEC-FDA economic model to determine the National Economic Development (NED) benefits for each barrier. Barriers with low NED benefits were screened out while barriers with high NED benefits were added to a focused array of alternatives. The focused array will be investigated in more detail as the feasibility study continues in order to reach a tentatively selected plan. The following section outlines the process for determining SSB alignments and quantities for all 11 inlets and 8 bay closures.

Table 3: Inlet Storm Surge Barrier Screening Level Analysis Quantities

Barrier Components	Inlet Storm Surge Barrier Locations										
	Cape May Canal	Cape May Inlet	Hereford Inlet	Townsends Inlet	Corsons Inlet	Great Egg Harbor Inlet	Absecon Inlet	Brigantine & Little Egg Inlet	Barnegat Inlet	Manasquan Inlet	Shark River Inlet
Navigable Gate Length (FT)	253	885	211	211	253	253	885	422	675	569	232
Navigable Gate Average Height (FT)[1]	34	55	65	58	50	70	74	62	45	39	55
Navigable Gate Area (SF)[2]	8609	48692	13704	12229	12651	17736	65456	26347	30133	22232	12755
Aux. Flow Gate Length (FT)	344	0	516	430	516	4214	774	4128	774	0	0
Aux. Flow Gate Average Height (FT)[1]	26	0	29	43	28	31	31	40	36	0	0
Aux. Flow Gate Area (SF)[2]	9021	0	15015	18587	14464	130296	23958	163787	28228	0	0
Impermeable Barrier Length (FT)	65	0	5112	1641	1124	1293	307	1927	174	0	165
Impermeable Barrier Average Height (FT)[1]	21	0	20	20	20	24	21	24	23	0	14
Impermeable Barrier Area (SF)[3]	1358	0	100313	33460	22668	31373	6331	46434	4071	0	2340
Levee Length (FT)	2159	2435	0	0	0	0	0	0	1054	0	0
Seawall Length (FT)	0	302	1837	2516	2839	474	2567	48742	192	7833	0

Notes:

1. Navigable Gate Average Height, Auxiliary Flow Gate Average Height, and Impermeable Barrier Average Height is the average height from the existing bathymetry to a design height of 20' NAVD88 for the bay closure locations (see H&H Appendix for design height calculations).
2. Gate area is the cross sectional surface area of the dynamic (openable) span of barrier plus the cross sectional surface are of the housing structure associated with the gate.
3. The Impermeable Barrier Area is the cross sectional surface area of the impermeable barrier.

Table 4: Bay Closure Screening Level Analysis Quantities

Barrier Components	Bay Closure Locations							
	Wildwood Blvd Bay Closure	Stone Harbor Blvd Bay Closure	Sea Isle Blvd Bay Closure	South Ocean City Bay Closure	Absecon Blvd Bay Closure	North Point Bay Closure	Holgate Bay Closure	Point Pleasant Canal Bay Closure
Navigable Gate Length (FT)	253	253	253	253	253	253	253	253
Navigable Gate Average Height (FT)[1]	38	38	37	25	38	35	43	38
Navigable Gate Area (SF)[2]	9613	9611	9360	6324	9613	8910	10878	9613
Aux. Flow Gate Length (FT)	258	344	0	0	0	2666	3010	0
Aux. Flow Gate Average Height (FT)[1]	42	28	0	0	0	21	24	0
Aux. Flow Gate Area (SF)[2]	10793	9515	0	0	0	55961	73029	0
Impermeable Barrier Length (FT)	562	431	158	0	150	16331	10075	0
Impermeable Barrier Average Height (FT)[1]	13	14	16	0	17	13	12	0
Impermeable Barrier Area (SF)[3]	7073	5927	2488	0	2593	206342	118965	0
Levee Length (FT)	15585	20620	13096	9558	25733	15810	18074	0
Seawall Length (FT)	0	0	0	0	0	3953	9658	0
Floodwall - In the Wet (FT)	0	17546	1911	1205	9746	0	0	0
Floodwall - In the Dry (FT)	0	0	2400	2919	5503	0	0	0
Miter Gate (EA)	2	1	0	1	5	1	8	0
Sluice Gate (EA)	2	1	2	1	1	7	6	0
Road Closure (EA)	2	4	1	0	3	0	1	0

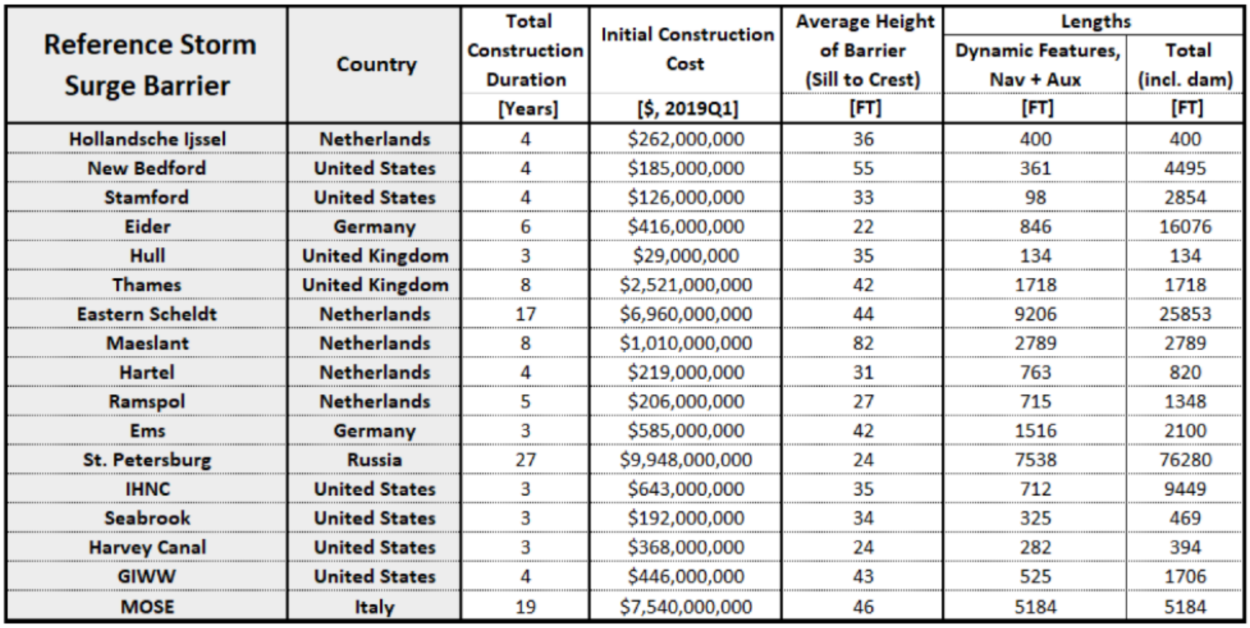
Notes:

1. Navigable Gate Average Height, Auxiliary Flow Gate Average Height, and Impermeable Barrier Average Height is the average height from the existing bathymetry to a design height of 13' NAVD88 for the bay closure locations (see H&H Appendix for design height calculations).
2. Gate area is the cross sectional surface area of the dynamic (openable) span of barrier plus the cross sectional surface are of the housing structure associated with the gate.
3. The Impermeable Barrier Area is the cross sectional surface area of the impermeable barrier.

Storm Surge Barrier Parametric Cost Model

The cost model used in this study was developed by USACE New York District and is based on statistical data and major design considerations. Design considerations include barrier crest elevations, lengths, depths and proportion of navigable and auxiliary flow features versus static elements. As seen in Table 5, cost engineers assembled a dataset of seventeen reference SSBs from around the world (Mooyart & Jonkman, 2017). As the study continues, this data set can be improved and expanded upon.

Table 5: Reference Set of Storm Surge Barriers



Reference Storm Surge Barrier	Country	Total Construction Duration	Initial Construction Cost	Average Height of Barrier (Sill to Crest)	Lengths	
					Dynamic Features, Nav + Aux	Total (incl. dam)
		[Years]	[$, 2019Q1]	[FT]	[FT]	[FT]
Hollandsche Ijssel	**Netherlands**	4	$262,000,000	36	400	400
New Bedford	**United States**	4	$185,000,000	55	361	4495
Stamford	**United States**	4	$126,000,000	33	98	2854
Eider	**Germany**	6	$416,000,000	22	846	16076
Hull	**United Kingdom**	3	$29,000,000	35	134	134
Thames	**United Kingdom**	8	$2,521,000,000	42	1718	1718
Eastern Scheldt	**Netherlands**	17	$6,960,000,000	44	9206	25853
Maeslant	**Netherlands**	8	$1,010,000,000	82	2789	2789
Hartel	**Netherlands**	4	$219,000,000	31	763	820
Ramspol	**Netherlands**	5	$206,000,000	27	715	1348
Ems	**Germany**	3	$585,000,000	42	1516	2100
St. Petersburg	**Russia**	27	$9,948,000,000	24	7538	76280
IHNC	**United States**	3	$643,000,000	35	712	9449
Seabrook	**United States**	3	$192,000,000	34	325	469
Harvey Canal	**United States**	3	$368,000,000	24	282	394
GIWW	**United States**	4	$446,000,000	43	525	1706
MOSE	**Italy**	19	$7,540,000,000	46	5184	5184

The parametric cost model equation differentiates barrier components into three categories; navigable gate area (NA), auxiliary flow gate area (AA), and impermeable barrier/dam area (DA). Length or area of “dynamic” span of storm surge barriers refers to those portions of a barrier system which can be opened either to allow flow for navigation or auxiliary flow. The values include both the width/area of the openings and the structures associated with operation and housing of such features. By contrast, length and area of “static” span refers to that of the closed off wall or dam portions of barrier systems.

The model estimates construction costs at a specified % confidence interval based on available reference data for existing barriers all over the world. An example of the 50% confidence interval parametric cost equation is as follows:

$$Construction\ Cost_{50\%} = (\$19{,}200 * NA) + (\$13{,}900 * AA) + (\$3{,}000 * DA)$$

The construction cost is a function of the cross sectional area of each barrier component. Barrier widths were not analyzed as part of the screening level analysis and will need to be investigated as the study continues. The SSB design heights were selected to be 20’ NAVD88 at the inlets and 13’ NAVD88 along the bay closures. Since bay closure locations are not as exposed to ocean waves and storm surge, the design heights do not need to be as high.

Navigable and Auxiliary Flow Gates

A navigable gate was analyzed at every inlet and bay closure to provide a navigable opening with an unlimited height restriction. At this stage of the analysis, navigable gates were assumed to be sector gates due to their prevalence not only in the United States but all over the world. A sector gate contains two dynamic gates and two static gate housing structures. The dynamic gates remain in their housing structures, providing an open channel for navigation. The dynamic sector gates are horizontally closed during significant storm events. Due to the parametric cost model, the specific type of navigable gate does not affect the total construction cost. The parametric cost model references construction costs for a variety of navigable gate types. The specific type of navigable gate will need to be further evaluated and refined as the study continues.

Along bay closure alignments, sector gates were positioned across the NJIWW. At the inlets, sector gates were placed at federal navigation channels. To ensure channels were not restricted, the dynamic span of the sector gates were sized to provide a 10 foot buffer on either side of the NJIWW or federal navigation channel. The size of each dynamic gate and static housing structure was scaled off an existing SSB site in the United States, the Seabrook Flood Complex in New Orleans, LA (see Figure 5). Not all inlets or bay closures have a federal navigation channel or NJIWW. In these instances, sector gates were positioned along the deepest portion of the waterway in order to promote tidal flow during open conditions. Some inlets, such as Townsends Inlet, have no Federal Navigation Channel but do have existing bridges with drawbridges. Sector gates were aligned directly in front of these drawbridges to support large vessel navigation.

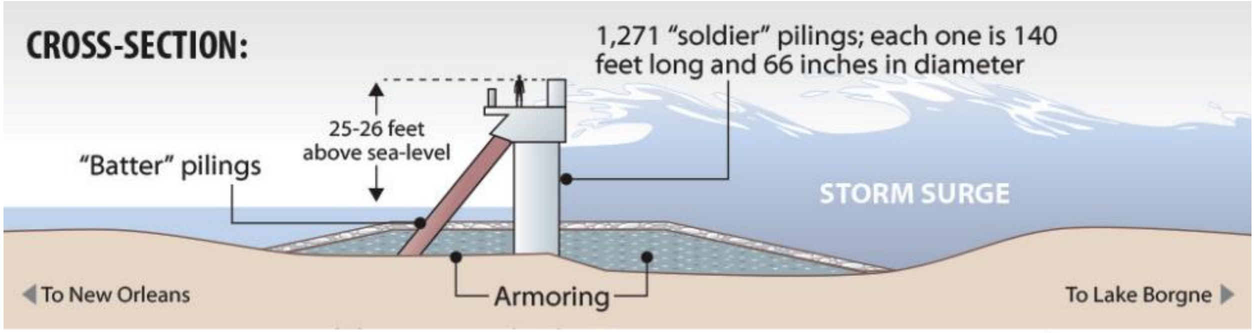
Figure 5: Seabrook Floodgate Complex in New Orleans, LA

Auxiliary flow gates were positioned adjacent to navigable gates and throughout bay closures to maintain tidal flow. Auxiliary flow gates were placed throughout water depths that were deemed constructible and practical. For example, an area with water depths of only a foot may not generate enough flow in and out of a channel to justify the cost of an auxiliary flow gate. The minimum flow gate depth will need to be further investigated as the study continues. Auxiliary flow gates were assumed to be vertical lift gates because they are one of the more prevalent SSB gate types seen in the United States as well as overseas. Due to the parametric cost model, the specific type of auxiliary flow gate does not affect the total construction cost. The parametric cost model references construction costs for a variety of auxiliary flow gates including, but not limited to, vertical lift gates, segment gates, flap gates, and inflatable gates. The specific type of auxiliary flow gate will be further evaluated and refined as the study continues. The Seabrook Flood Complex (see Figure 5) was used as a template to initially size the vertical lift gates for this study. The dynamic portion of the gate is approximately 50 feet long, flanked by two housing structures that are each approximately 18 feet long. The length of movable gate will need to be refined as the study continues as it directly impacts the flow restriction of the inlet. Vertical lift gates have limited vertical clearance but are capable of providing recreational navigation. For example, the Bayou Bienvenue vertical lift gate in New Orleans, LA (see Figure 6) has enough vertical clearance to allow recreational boats to pass to and from Lake Borgne.

Figure 6: Bayou Bienvenue Vertical Lift Gate in New Orleans, LA

Impermeable Barriers

Impermeable barriers flank the dynamic SSB components in order to tie the barrier into the upland. Impermeable barriers were also positioned along portions of low lying marsh land across bay closure alignments. The parametric cost equation does not estimate construction costs for a specific type of impermeable barrier, it applies a cost factor to a cross sectional area of static wall based on reference data for seventeen existing SSB sites (Table 5). A site specific impermeable barrier type has not been selected at this stage but will be further investigated as the study continues. Figure 7 shows one example of an existing impermeable barrier at Lake Borgne in New Orleans, LA.



Dan Swenson, NOLA.com | The Times-Picayune

Figure 7: Lake Borgne Impermeable Barrier in New Orleans, LA

Levees, Floodwalls and Seawalls

In areas that are not in open water or on open marsh land, levees, floodwalls and seawalls were used to tie barriers into high ground or existing adjacent oceanfront projects. Type A - levees were used in areas with little to no exposure to wave forcing. Type B and C - floodwalls were used in areas where the SSBs tie into the Perimeter Plan. In-water floodwalls were not used along low lying open marsh areas through bay closure alignments. The in-water floodwall design assumes there are adjacent existing sheet piles with backfill. To be conservative, impermeable barriers were selected for these areas. A more detailed wall design will be investigated for low lying open marsh areas as the study continues. Seawalls were selected for low lying areas, such as beaches, that are still susceptible to waves and erosion but may not need a structure as robust as an impermeable barrier. As the study continues, beach and dune restoration measures will be investigated for these areas as well. Estimated seawall costs were scaled off construction costs for the Absecon Seawall in Atlantic City, NJ (see Figure 8).

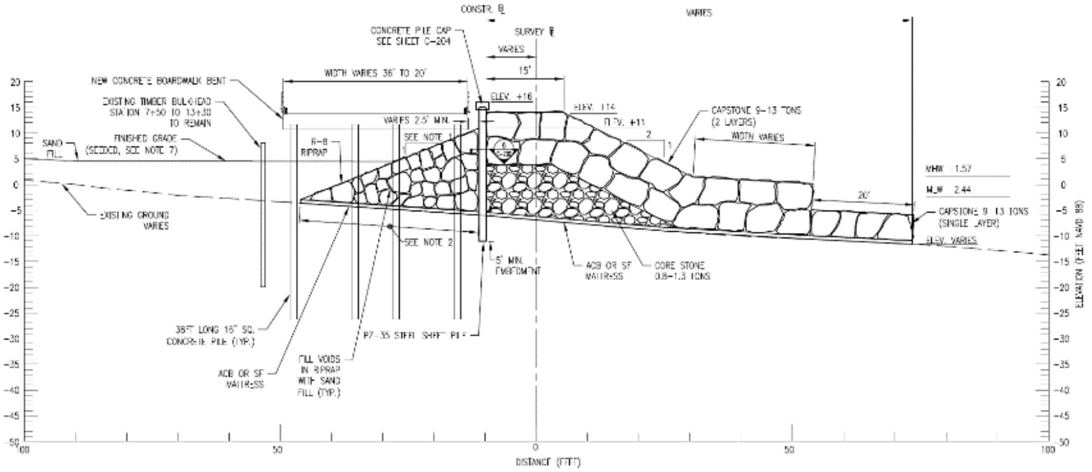


Figure 8: Typical Section - Absecon Seawall Structure 1

Perimeter Plan Drawings

Detailed perimeter plan drawings in Section B-5. Perimeter Plan and Storm Surge Barrier Drawings.

Storm Surge Barrier Drawings

Detailed storm surge barrier drawings in Section B-5. Perimeter Plan and Storm Surge Barrier Drawings.

Existing Data

Existing bathymetry and topography data was obtained from the U.S. Geological Survey's (USGS) Topobathymetric Model for New Jersey and Delaware. In response to storm damages induced from Hurricane Sandy, the USGS Coastal and Marine Geology Program in collaboration with the USGS National Geospatial Program (NGP) and National Oceanic and Atmospheric Administration (NOAA) developed three-dimensional 1-meter topobathymetric elevation models for the New Jersey/Delaware sub-region. The temporal range of input topography and bathymetry ranges from 1880 to 2014 and is referenced to NAVD88. USGS topobathymetric data was cross referenced against available USACE NAP bathymetric surveys which ranged from 2015-2018. The bathymetry data was used to estimate the total cross sectional area for each SSB component. The topographic data was used to tie SSBs into high ground. High ground was selected to be at approximately 13' NAVD88 or at an existing adjacent ocean front project. Not all ocean front projects were designed or maintained to a 13' NAVD88 elevation. Improving existing ocean front projects will need to be further evaluated as the study continues. Additional survey data will also be collected, as the study continues, to establish more accurate and representative site conditions.

Non-Structural

Non-structural solutions are being considered for the entire study area, especially the 12 Groups considered "Possible" (BCR between 1.0 and 2.0), and 25 Groups considered "Screened Out" (BCR below 1.0) from the initial perimeter plan screening. Raising structures (primarily residential) to elevate the first floor above the design flood level was the only non-structural solution considered for this phase of the screening process. Figure 5 below shows a graphic representation of this alternative. Refer to the Economic Technical Appendix for information on the analysis. Future alternative analyses will consider other non-structural measures such as flood proofing, deployable flood walls, ring levees/floodwalls, etc.

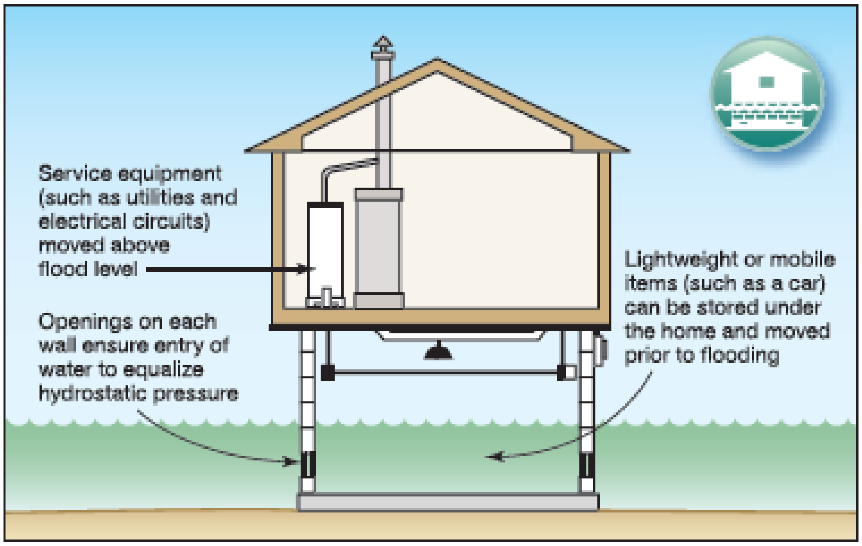


Figure 9: Non-Structural Flood Control Solution

Natural and Nature-Based Features (NNBF)

A qualitative screening effort was completed to identify perimeter plan and SSB areas for possible NNBF sites and measures. As a result the array of measures was screened down to focus primarily on living shorelines and EWN (Engineering with Nature) modifications. Refer to the Environmental and Cultural Appendix for information on the screening analysis. Living shorelines may be created in areas where protection incorporates a dune and beach fill or along a levee frontage. EWN features, such as textured concrete, habitat benches, and ecologically enhanced revetments, can be incorporated into the design of floodwall and levee structures. Preliminary costs of these items are considered to be within the contingency values for construction of the flood control feature.

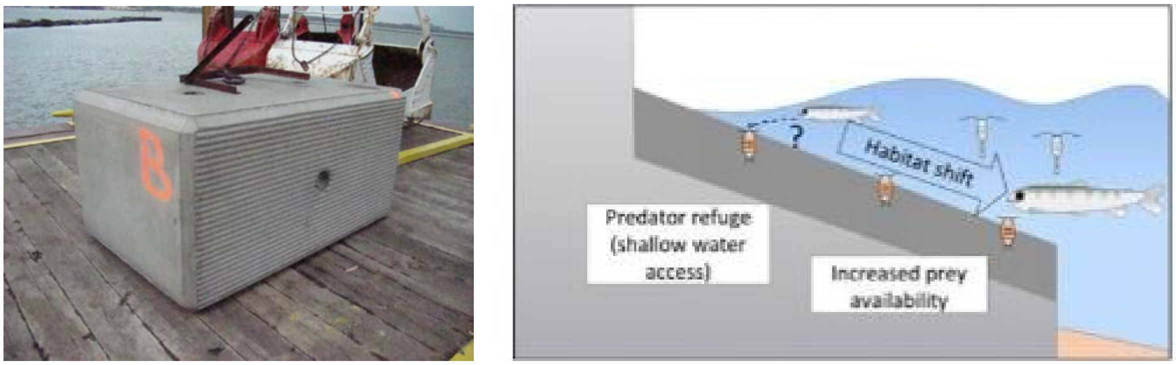


Figure 10: NNBF Measures

Real Estate

Real Estate costs for the perimeter plan and SSB screening were estimated as a percentage of construction costs. Future analyses will include quantification of permanent easement acreages based upon the proposed structure footprint and interior drainage modifications including required maintenance access, and temporary easement based upon required access during construction.

B-1) GEOTECHNICAL

Geotechnical Subsurface Explorations

The purpose of the geotechnical subsurface explorations is to determine soil type, properties, and strength characteristics of the subsurface materials for the feasibility of preliminary design alternatives. In a preliminary overview of the NJBB Study Area, a search of existing subsurface data from previous geotechnical investigations was conducted. Existing subsurface investigation data consisting of field boring logs and laboratory testing was obtained from USACE archive data, specifically from the N.J. Inlets and Beaches project. Existing subsurface investigation data consisting of boring location plans and borings logs was also obtained from NJDOT Geotechnical Data Management System (GDMS) data base. The following sections detail the relevance of the existing subsurface investigations used from each source.

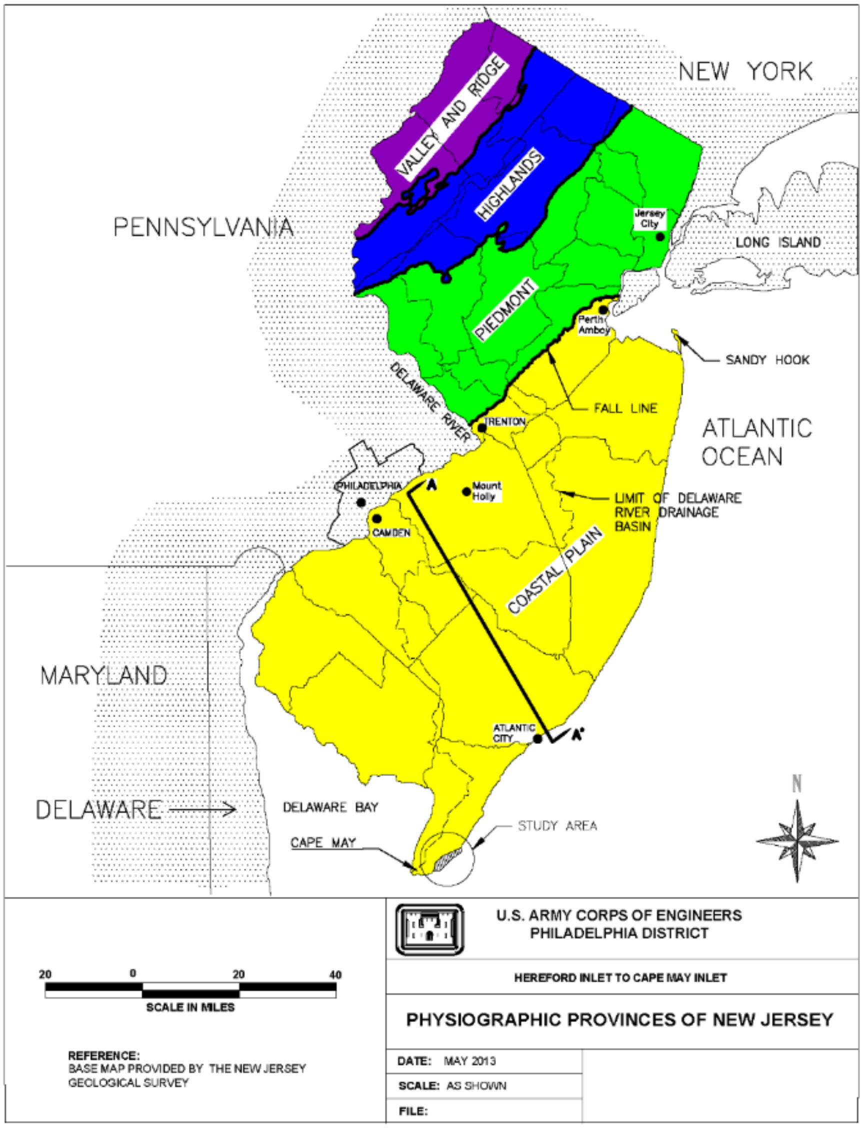
The geotechnical investigations conducted as part of the N.J. Inlets and Beaches were performed in 1964 in the following areas: Corson’s Inlet between Strathmere and Ocean City, NJ, Townsends Inlet between Avalon and Sea Isle City, NJ, and Hereford Inlet between Wildwood and Stone Harbor, NJ. The boring location plans with the exact locations of the existing borings are not available; however, the approximate investigation areas are known. The subsurface profile generally consisted of (in descending order): 1) granular soils with intermittent fine-grained soils and with organics, 2) organic fine-grained soils, and 3) granular soils. The soils encountered are in general agreement with the published geologic data.

The subsurface investigation data obtained from NJDOT GDMS data base contained boring location plans and boring logs from various NJDOT projects spanning Ocean City to Manasquan in relative close proximity to the major NJBB CSRM Feasibility Study alternative structures. The projects included bridge, approach, and state route structure subsurface investigations. Representative borings based on their respective locations and depths were included in the subsurface data gathering. The representative borings were drilled as recent as 2002 and as far back as 1973. The subsurface profile generally consisted of (in descending order): 1) granular soils with intermittent fine-grained soils and with organics, 2) organic fine-grained soils, and 3) granular soils. The soils encountered are in general agreement with the published geologic data.

The proposed geotechnical subsurface explorations will include Standard Penetration Test (SPT) borings with laboratory testing and Cone Penetrometer Test (CPT) Soundings. The purpose for the SPT boring explorations and laboratory testing is to obtain subsurface soil classification and strength data for the preliminary design to be used in determining the feasibility of proposed bay closure structures and storm surge barrier gate structures. The boring data should fill in the gaps of the existing soil data gathered. An SPT boring schedule and laboratory testing program have been developed. The purpose for the CPT soundings is to develop a reliable profile of the subsurface material along the back bays for the various floodwall structures. The CPT method will allow for a high quantity of sounding locations at significant depths along the 3,400 miles of coastline in the study area. The CPT data will be reviewed and a determination can be made for the feasibility of the floodwall structures as well as specific target areas for future testing and investigation. A CPT sounding schedule has been developed.

Geomorphology

The study area is situated along the New Jersey coast, which is located within the New Jersey section of the Coastal Plain Physiographic Province of Eastern North America. In New Jersey, the Coastal Plain Province extends from the southern terminus of the Piedmont Physiographic Province southeastward for approximately 155 miles to the edge of the Continental Shelf. The boundary between the rock units of the Piedmont and unconsolidated sediments of the Coastal Plain Physiographic Provinces is known as the Fall Line, which extends southwest across the state from Perth Amboy through Princeton Junction to Trenton. It is termed the Fall Line due to its linearity and the distinct elevation change that occurs across this border between the more rugged, generally higher rock terrain of the Piedmont and generally lower terrain of the soil materials comprising the Coastal Plain. The locations of the Physiographic Provinces in New Jersey and Fall Line are shown below:



REFERENCE:
BASE MAP PROVIDED BY THE NEW JERSEY GEOLOGICAL SURVEY

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

HEREFORD INLET TO CAPE MAY INLET

PHYSIOGRAPHIC PROVINCES OF NEW JERSEY

DATE: MAY 2013
SCALE: AS SHOWN
FILE:

The Coastal Plain Province, lying southeast of the Fall Line, is part of the Atlantic Coastal Plain that extends along the entire eastern Atlantic Ocean coastline from Newfoundland to Florida. The Coastal Plain is the largest physiographic province in the state and covers approximately sixty percent of the surface area of New Jersey. This province encompasses an area of approximately 4,667 square miles, almost 3 million acres. More than half of the land area in the Coastal Plain is below an elevation of 50 feet above sea level (NGVD). The terrestrial portion of the Coastal Plain Province is bounded on the west and southwest by the Delaware River and Delaware Bay, on the north by the Fall Line and on the northeast by the Raritan Bay and Staten Island. The remaining portions of the Coastal Plain Province in New Jersey are bordered by the Atlantic Ocean. The Atlantic Coastal Plain has been further differentiated into the Inner and Outer Coastal Plain regions. The Inner Coastal Plain consists of lowlands and rolling hills underlain by Cretaceous deposits and is border to the north by the Piedmont Province. The Outer Coastal Plain is a region of low altitude where low-relief terraces are bounded by subtle erosional scarps, and consists of the unconsolidated Tertiary deposits of sand, silt and gravels. The eastern boundary of the Coastal Plain includes many barrier bars, bays, estuaries, marshes and meadowlands along the Atlantic coast extending from Sandy Hook in the north to Cape May Point at the southern tip of New Jersey.

Physiography

The New Jersey shoreline, which is included in the Coastal Lowlands can be divided into those sections where the sea meets the mainland, at the northern and extreme southern ends of the State, and where the sea meets the barrier islands, in the central to southern portion of the State. The Coastal Lowlands include as many as three scarp-bounded terraces, which are underlain by marine and estuarine deposits. The outer margin of the terraces are surrounded by the tidal marshes, bays and the barrier islands. The barrier islands extend from Bay Head, down the coast for approximately 90 miles, to just north of Cape May Inlet and are generally continuous, except for the interruption by 10 inlets.

Barrier Islands

The New Jersey barrier islands, which include the study area, belong to a land form susceptible to comparatively rapid changes. The barrier islands range in width from around 1000 feet to 5,000 feet. Landward of the barrier beaches and inlets along the barrier islands are tidal bays, which range from 1 to 4 miles in width. These bays have been filled by natural processes until much of their area has been covered with tidal marshes. The remaining water area landward of the barrier islands consists of smaller bays connected by water courses called thorofares. Four geologic processes are considered to be responsible for the detritus (or loose material) in the bay area: (1) stream sedimentation, which contributes a small amount of upland material; (2) waves washing over the barrier islands during storms; (3) direct wind action blowing beach and dune sand into the lagoon; and (4) the work of tidal currents, which normally bring in more sediments in suspension from the ocean on flood tide than they remove on ebb tide. The vegetation of the lagoons, both in marshland and bays, serves to trap and retain the sediments.

Drainage of the Coastal Plain

The land surface in the Coastal Plain of New Jersey is divided into drainage basins, based on the area that contributes runoff to streams and their tributaries in a particular region. A drainage divide marks the topographic boundary between adjacent drainage basins. A major drainage divide in the Coastal Plain separates streams flowing to the Delaware River on the west and to the Atlantic

Ocean on the east and southeast. **Figure X** illustrates the surficial geology that is present within the study area.

The surficial drainage system of the New Jersey Coastal Plain was developed at a time when sea level was lower than at present. The subsequent rise in sea level has drowned the mouth of coastal streams where tidal action takes place. This tidal effect extends up the Delaware River to Trenton, New Jersey, a distance of 139 miles. The formation of the barrier islands removed all direct stream connection with the ocean between Barnegat Bay and Cape May Inlet. These streams now flow into the lagoons formed in the back of these barrier beaches and their waters reach the Atlantic Ocean by way of the thorofares and inlets, discussed above. The significance of these features to the drainage system in the study area is that the Coastal Plain streams, whose upper courses carry little sediment, lose that little sediment in their estuaries, and in the lagoons, and supply virtually no beach nourishment to the ocean front areas.

The material present within the coastal lagoons and tidal marshes consists primarily of alluvium, and salt-marsh deposits. The alluvium, which was deposited was derived from weathered upland soils of the Bridgeton and Cohansey Formations, consists of gray and brown sand, silt, pebble gravel, cobbles, minor peat and shells. The salt-marsh deposits, which are comprised of organic muck and peat, silt clay and sand. Black, brown and gray organic muck includes remains of salt-tolerant grasses. Silt and sand occur as deposits along tidal creek margins. These salt-marsh deposits were deposited largely as suspended sediment in turbid bays or rivers during high tides.

Regional Geology

The New Jersey Coastal Plain Physiographic Province consists of sedimentary formations overlying crystalline bedrock known as the "basement complex." From well drilling logs, it is known that the basement surface slopes at about 155 feet per mile to a depth of more than 5,000 to 6,000 feet near the coast. Geophysical investigations have corroborated well-log findings and have permitted determination of the profile seaward to the edge of the continental shelf. A short distance offshore, the basement surface drops abruptly but rises again gradually near the edge of the continental shelf. Overlying the basement are semi-consolidated sedimentary formations of Lower to Middle Cretaceous sediments. The beds vary greatly in thickness, increasing seaward to a maximum thickness of 2.5 miles then decreasing to 1.5 miles near the edge of the continental shelf. On top of the semi-consolidated beds lie unconsolidated sediments of Upper Cretaceous and Tertiary formations. These sediments range from relatively thin beds along the northwestern margin at the Fall Line, to around 4,500 feet beneath Atlantic City to over 40,000 feet in the area of the Baltimore Canyon Trough located around 50 miles offshore of Atlantic City.

Based on information provided by the New Jersey Geological Survey (NJGS) and United States Geological Survey (USGS), the wedge shaped mass of unconsolidated sediments that comprise the New Jersey Coastal Plain discussed above are composed of sand, gravel, silt and clay. The wedge thins to a featheredge along the Fall Line and attains a thickness of over 6,500 feet in the southern part of Cape May County, New Jersey. The system is comprised of relatively highly permeable sand and gravel layers separated by semi-permeable to impermeable silt and clay interlayers that form confining layers and restrict the vertical flow of groundwater. These sediments range in age from Cretaceous to Upper Tertiary (i.e. Miocene - 144 to 5 Ma) (Ma = mega annum = million years ago), and can be classified as continental, coastal or marine deposits. The Cretaceous and Tertiary age sediments generally strike on a northeast-southwest direction and dip gently to the southeast from ten to sixty feet per mile. The Coastal Plain is mantled by discontinuous deposits of Late Tertiary to Quaternary (geologically recent) sediments, which, where present are basically flat lying. The unconsolidated Coastal Plain deposits, are unconformably underlain by a Pre-Cretaceous crystalline basement bedrock complex, which consists primarily of Precambrian and early Paleozoic age (>540 Ma to 400 Ma) rocks. Locally, along the Fall Line in Mercer and Middlesex Counties, Triassic age (circa 225 Ma) rocks overlie the crystalline basement rocks and underlie the unconsolidated sediments.

Surficial Geology

As indicated above, the Coastal Plain of New Jersey consists of beds of gravel, sand, silt and clay, which dip gently towards the southeast. Fossil evidence indicates that these sediments range from the Cretaceous to Quaternary Period, with some more recent glacial period Quaternary sediments mantling the surface. The older and lower layers outcrop at the surface along the northwest margin of the Coastal Plain and pass beneath successively younger strata in the direction of their dip. Since the formations dip toward the southeast, this results in a series of successive generally parallel outcrops with a northeast-southwest strike, with successively younger layers outcropping at the surface towards the southeast and progressing southward along the shore.

The sea successfully advanced and retreated across the 155 mile width of the Coastal Plain during the Cretaceous through Quaternary Periods (144 Ma to present). Many sedimentary formations were deposited, exposed to erosion, submerged again and buried by younger sediments. The types of sorting, the stratification, and the fossil types in the deposits indicate that deposition took place offshore as well as in lagoons and estuaries, and on beaches and bars. Considerable changes in sea level continued to take place during Pleistocene time. Glacial periods brought a lowering in sea level as water was locked up in the large terrestrial ice masses. As the sea level fell to a beach line thousands of feet seaward of the present shoreline, Pleistocene sediments were deposited in valleys cut into older formations. The water released through glacial melt during interglacial periods brought a rising of sea level and beaches were formed far inland of the present shore.

Between Bay Head and Cape May City, the coastal lagoons, tidal marshes and barrier beaches that fringe the coast have contributed to the sands of the present beaches. During Quaternary time, changes in sea level caused the streams alternately to spread deposits of sand and gravel along drainage outlets and later to remove, rework, and redeposit the material over considerable areas, concealing earlier marine formations. One of these, the Cape May Formation consisting largely of sand and gravel, was deposited during the last interglacial stage, when the sea level stood 33 to 46 feet higher than at present. The material was deposited along valley bottoms, grading into the estuarine and marine deposits of the former shoreline. In most places along the New Jersey coast, there is a capping of a few feet of Cape May Formation. This capping is of irregular thickness and distribution, but generally forms a terrace about 25 to 35 feet above sea level. The barrier beaches, being of relatively recent origin, are generally composed of the same material as that found on the offshore bottom.

Throughout the feasibility study phase, USACE will continue researching and collecting its own archival and relevant project data, as well as subsurface data from other state and local databases to develop a thorough and complete geotechnical database for the New Jersey Back Bay Coastal Storm Risk Management Feasibility Study project. Existing data collection will be a continuous process and used to supplement the proposed geotechnical subsurface explorations.

Geotechnical Subsurface Information

Additional geotechnical subsurface information including drilling logs and grain size gradation curves is located in Section B-6. Geotechnical Subsurface Information.

Geo-Environmental – Hazardous, Toxic and Radioactive waste Concerns

A desktop overview of the NJBB Study area was combined with District and personnel knowledge of the area to develop information regarding the potential for HTRW issues. This review was revised following receipt of the initial planned line of protection for the study.

For the barrier islands portion of the study area, these are predominately populated with residences, township supporting infrastructure (including water treatment plants), commercial, amusement parks/piers and some light industrial/marina-related facilities. There are fuel storage tanks related to the non-residential structures and marinas. Marinas may have pump out facilities with onsite temporary storage. Residential and most other facilities are likely heated using natural gas. There are small parks or natural areas within some townships on the barrier islands. The study area includes a number of public-owned facilities that would be the sites of protective measures.

There are some larger natural areas, mostly in the southern portions of the study area (e.g., Island Beach State Park, E.B. Forsythe National Wildlife Refuge and the Cape May National Wildlife Refuge). Little to no protective structures are anticipated for these areas. These areas may also have storage tanks supporting facility structure and/or vehicles. There are limited heavy industrial facilities, including power plants, on the barrier islands. The Atlantic City area is heavily populated and has more industrial-type facilities. Atlantic City and Ocean City have airport facilities.

The need for environmental data reviews (Phase I) and field investigation work (Phase II) will be highly dependent upon the locations and type(s) of flood management structures that are carried forward in the study. Review of the initial lines of protection and structures have refined the major areas of interest for HTRW issues to approximately 13 areas, excluding the marinas, several of which are quasi-public areas (e.g., recycling center, airports, fire department building) and getting access for sample collection should not constitute a large problem. In areas where a floodwall is planned for construction in the water, sediment sampling from shore (if access is permitted) or from a small boat (if access is problematic) will be conducted. Phase I reports for these areas will be obtained and reviewed. A sampling and analysis program for soils and sediments is being developed and will be implemented based on the results of the Phase I reports.

B-2) HYDROLOGY, HYDRAULICS AND COASTAL

Introduction

This appendix presents the results of the Hydraulic, Hydrology and Coastal (HH&C) engineering evaluation and analysis for the New Jersey Back Bays (NJBB) Coastal Storm Risk Management (CSRM) Study. The NJBB study area is shown in Figure 111. This report will discuss in detail all the existing information that was reviewed and how that information was used in the HH&C engineering evaluation and analysis to come up with the contribution of the elements to get to the TSP-IPR Milestone and Focused Array for the study.

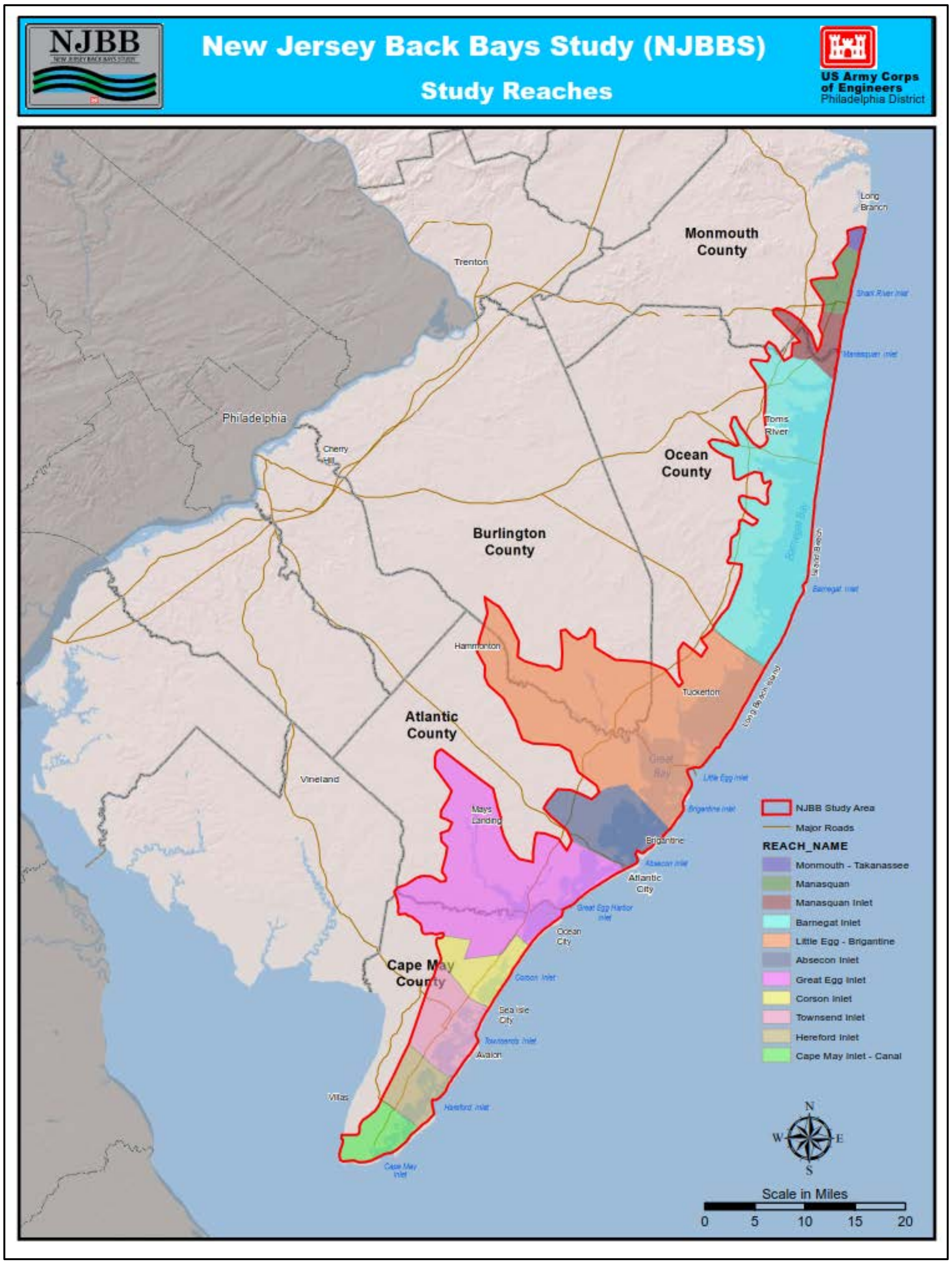


Figure 11: Study Area and Hydraulic Reaches

Vertical Datum

In accordance with ER 1110-2-8160 the NJBB Feasibility Study is designed to North American Vertical Datum of 1988 (NAVD88), the current orthometric vertical reference datum within the National Spatial Reference System (NSRS) in CONUS. The study area is subject to tidal influence and is directly referenced to National Water Level Observation Network (NWLON) tidal gages and coastal hydrodynamic tidal models established and maintained by the U.S. Department of Commerce (NOAA). The current NWLON National Tidal Datum Epoch (NTDE) is 1983-2001.

More than one NWLON tidal gage is required to reference tidal water levels to NAVD88 due to the vast size of the study area. Four NWLON tidal stations within the study area are as presented in Table 6. The location of NOAA tidal stations is shown in Figure 12. The local NAVD88-MSL relationship at locations between gages is estimated using NOAA VDatum models of the project region (EM 1110-2-6056).

Table 6: NOAA Tidal Gage Datum Relationships

Datum[1]	**Cape May**	**Atlantic City**	**Barnegat Inlet**	**Sandy Hook**
	(Feet)	**(Feet)**	**(Feet)**	**(Feet)**
MHHW	2.42	1.99	1.33	2.41
MHW	1.99	1.58	1.10	2.09
NAVD88	0.00	0.00	0.00	0.00
MSL	-0.45	-0.40	-0.02	-0.23
MLW	-2.86	-2.44	-1.06	-2.62
MLLW	-3.02	-2.61	-1.18	-2.81
MN[2]	4.85	4.02	2.16	4.71

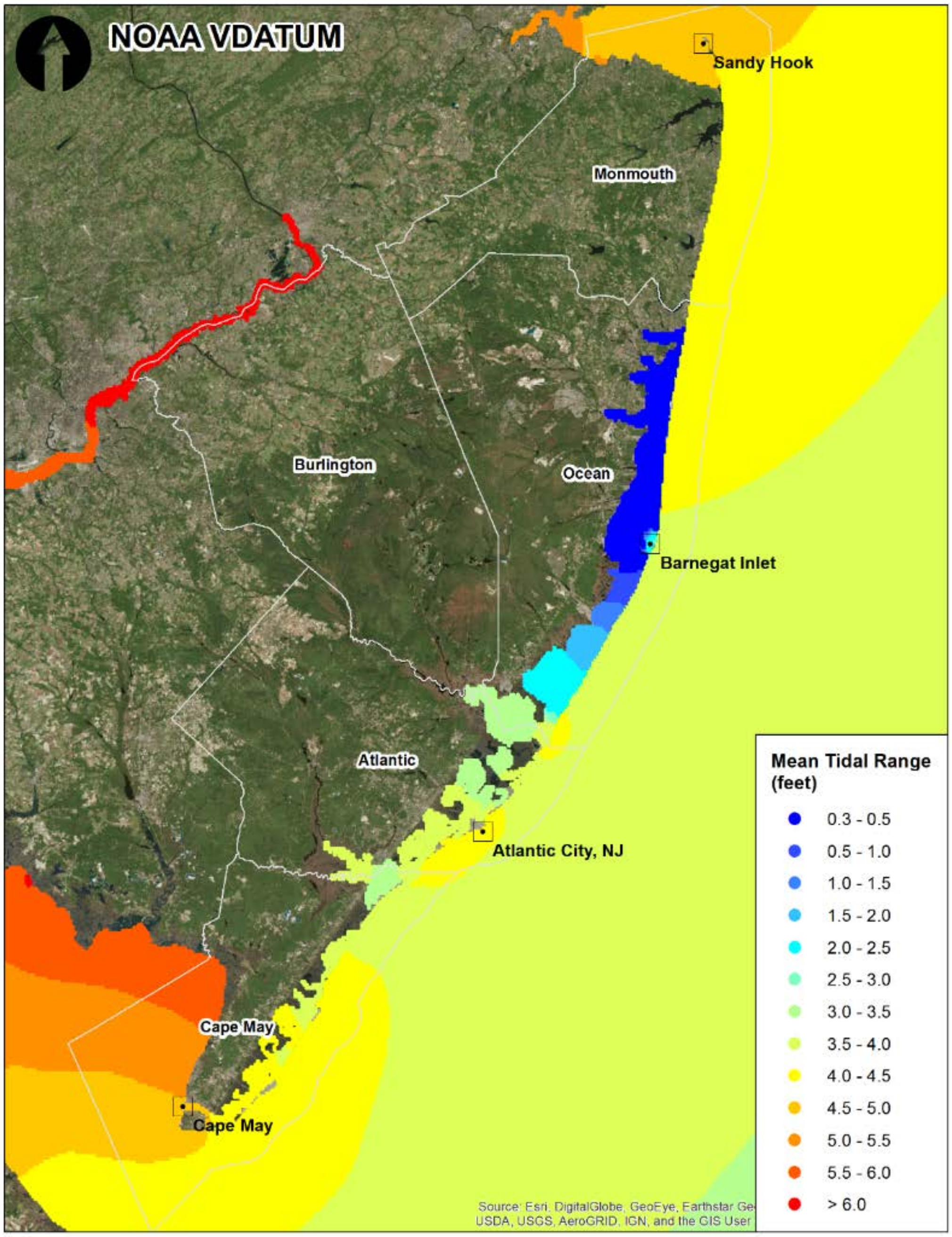
Notes: [1]Tidal datums based on 1983-2001 Tidal Epoch
[2]Mean Tidal Range (MHW-MLW)

Hydrodynamic modeling completed for this study was performed in meters, MSL in the current NTDE. Water elevations are converted to feet, NAVD88 using NOAA VDatum. VDatum is a vertical datum transformation software tool, that provides conversions between various tidal datums fields and mean sea level as well as between mean sea level and North American Vertical Datum of 1988 (NAVD88). The tidal datums fields (MHHW, MHW, MSL, MLW, MLLW) are derived from hydrodynamic simulations using the hydrodynamic model, ADCIRC (Yang et al. 2008). NOAA ADCIRC model results were validated by comparing with observations water level stations maintained by the NOAA’s Center for Operational Oceanographic Products and Services (CO-OPS). Figure 12 presents the mean tidal range (MHW - MLW) for the study area. Table 7 presents the NOAA VDatum results for MHHW and mean tidal range (MN) at the four NOAA tidal stations. Comparison of the values in in Table 6 and Table 7 show that the VDatum results are in agreement with the NOAA tidal stations.

Table 7: NOAA VDatum Tidal Datum Relationships

Datum[1]	**Cape May**	**Atlantic City**	**Barnegat Inlet**	**Sandy Hook**
MHHW	2.42	1.99	1.34	2.40
MN[2]	4.85	4.02	2.14	4.66

Notes: [1] Tidal datums based on 1983-2001 Tidal Epoch
[2] Mean Tidal Range (MHW-MLW)



Source: Esri, DigitalGlobe, GeoEye, Earthstar Ge
USDA, USGS, AeroGRID, IGN, and the GIS User

Figure 12: Mean Tidal Range in Study Area

Sea Level Change

Background on SLC

Global sea level change (SLC) is often caused by the global change in the volume of water in the world's oceans in response to three climatological processes: 1) ocean mass change associated with long-term forcing of the ice ages ultimately caused by small variations in the orbit of the earth around the sun; 2) density changes from total salinity; and most recently, 3) changes in the heat content of the world's ocean, which recent literature suggests may be accelerating due to global warming. Global SLC can also be caused by basin changes through such processes as seafloor spreading. Thus, global sea level, also sometimes referred to as global mean sea level, is the average height of all the world's oceans.

Relative (local) SLC is the local change in sea level relative to the elevation of the land at a specific point on the coast. Relative SLC is a combination of both global and local SLC caused by changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns (often caused by changes in regional atmospheric patterns), hydrologic cycles (river flow), and local and/or regional vertical land motion (subsidence or uplift).

Historical SLC

Historical RSLC for this study (4.07 mm/yr) is based on NOAA tidal records at Atlantic City, NJ. Additional historic RSLC rates within the study area are available at Cape May, NJ (4.55 mm/yr) and Sandy Hook, NJ (4.05 mm/yr). Figure 13 shows historical RSLC at Atlantic City from 1992 to 2019. Several metrics for sea level are presented, the monthly mean sea level (light blue), 5-year moving average (orange), and 19-year moving average (dark blue). It is apparent that over long time scales (19 years) mean sea level is steadily increasing. However, over shorter time scales mean sea level may increase or decrease.

The monthly mean sea level, light blue line in Figure 13, appears to go up and down every year in Figure 13 capturing the seasonal cycle in mean sea level. The 5-year moving average, orange line in Figure 13 captures the interannual variation (2 or more years) of sea level.

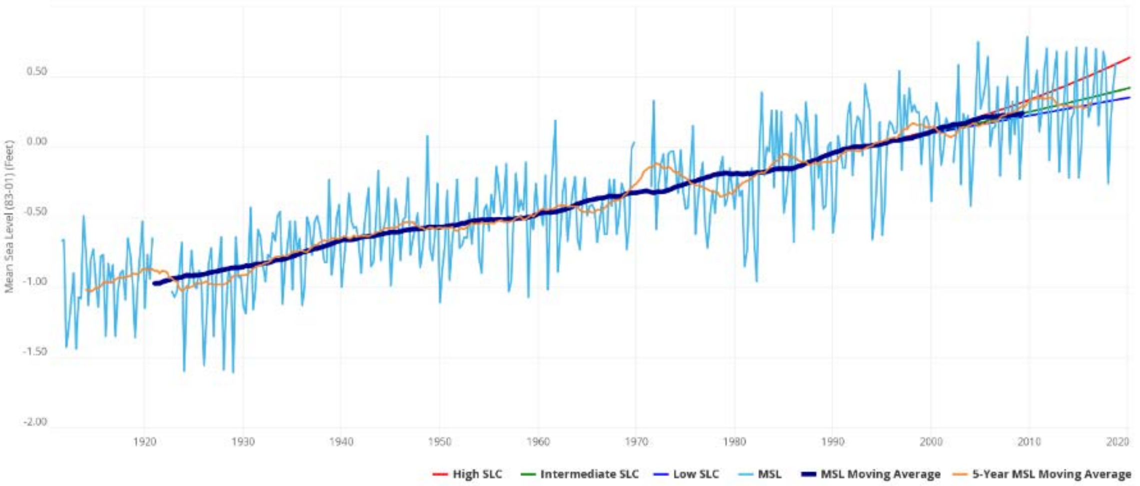


Figure 13: Historical Relative Sea Level Change at Atlantic City, NJ

USACE SLC Scenarios

USACE low, intermediate, and high SLC scenarios over the 100-yr planning horizon at Atlantic City, NJ are presented in Table 8 and Figure 14. Water level elevations at year 2030 are expected to be between 0.5 and 1.0 feet higher than the current NTDE. Water elevations at year 2080 are expected to be between 1.15 and 4.02 feet higher than the current NTDE.

Hydrodynamic modeling performed for this study was completed in the current NTDE. Therefore, the modeled water levels represent MSL in 1992. Future water levels are determined by adding the SLC values in Table 8. For example, a water level elevation of 10 feet NAVD88 based on the current National Tidal Datum Epoch (1983-2001), will have an elevation in the year 2080 of 11.15, 11.84, and 14.02 feet NAVD88 under the USACE low, intermediate, and high SLC scenario respectively.

Table 8: USACE Sea Level Change Scenarios (Derived from Atlantic City, NJ)

Year	USACE – Low (ft, MSL[1])	USACE - Int (ft, MSL[1])	USACE – High (ft, MSL[1])
1992	0.00	0.00	0.00
2000	0.11	0.11	0.13
2019	0.35	0.42	0.62
2030	0.50	0.63	1.03
2050	0.76	1.06	2.01
2080	1.15	1.84	4.02
2100	1.41	2.54	5.74
2130	1.81	3.50	8.87

[1]Mean Sea Level based on National Tidal Datum Epoch (NTDE) of 1983-2001

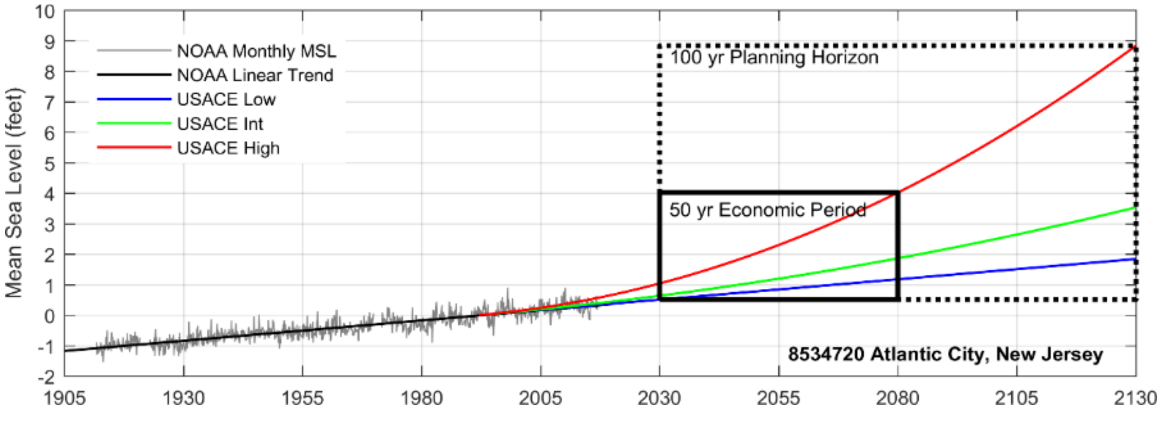


Figure 14: Relative Sea Level Change Projections at Atlantic City, NJ

USACE Guidance

In accordance with ER 1100-2-8162, potential effects of relative sea level change (RSLC) were analyzed over a 50-yr economic analysis period and a 100-yr planning horizon. Research by climate science experts predict continued or accelerated climate change for the 21st century and possibly beyond, which would cause a continued or accelerated rise in global mean sea level. ER 1100-2-8162 states that planning studies will formulate alternatives over a range of possible future rates of SLC and consider how sensitive and adaptable the alternatives are to SLC.

ER 1100-2-8162 requires planning studies and engineering designs consider three future sea level change scenarios: low, intermediate, and high. The historic rate of SLC represents the “low” rate. The “intermediate” rate of SLC is estimated using the modified National Research Council (NRC) Curve I. The “high” rate of SLC is estimated using the modified NRC Curve III. The “high” rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate the potential rapid loss of ice from Antarctica and Greenland, but it is within the range of values published in peer-reviewed articles since that time.

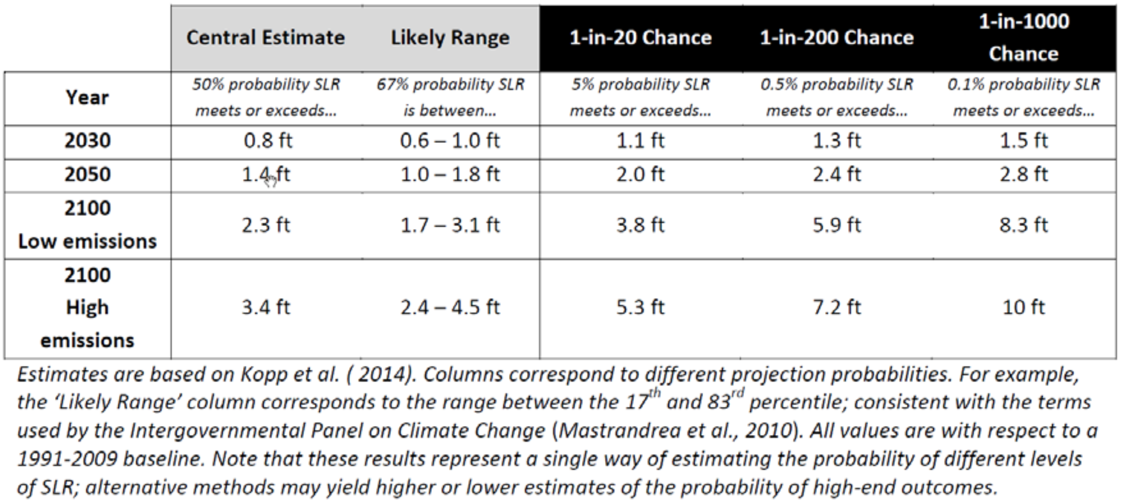
NJ Climate Adaption Alliance

NJ Climate Adaptation Alliance (NJCAA) convened a Science and Technical Advisory Panel (STAP) to identify and evaluate the most current science on sea level rise projections and changing coastal storms, consider the implications for the practices and policies of local and regional stakeholders, and provide practical options for stakeholders to incorporate science into risk-based decision processes. The report titled “Assessing New Jersey’s Exposure to Sea-Level Rise and Coastal Storms: Report of the New Jersey Climate Adaption Alliance Science and Technical Advisory Panel” (Kopp et al. 2016) contains a detailed description of the basis for the STAP’s projected SLR estimates. The following is an excerpt from the Executive Summary:

> *The STAP concluded that practitioners should use a range of SLR estimates, given the range of future exposures and vulnerabilities that exist among people, places, and assets in New Jersey communities. The majority of practitioners indicated it would be practical to use two or three SLR scenarios for most of their work. Certain applications require more detailed analysis that considers the full range of projections. The SLR values in Table 9 represent projections under continued fossil-fuel-intensive global economic growth through 2050 because differences in SLR projections between emissions scenarios are minor in the first half of the century (with low-emissions projections for 2050 being about 0.1 feet lower than high-emissions projections). Differences in projections related to greenhouse gas emissions are only germane for those practitioners with planning horizons that extend beyond 2050.*

NJCAA Projected SLC Estimates, Table 9, are with respect to mean sea level from 1991-2009, with a midpoint of 2000. USACE SLC estimates are based on mean sea level over the current National Tidal Datum Epoch (1983-2001) with a midpoint of 1992. The NJCAA central estimate falls between the USACE intermediate and high scenarios. The NJCAA 1-in-20 chance estimate is very similar to the USACE high scenarios. USACE guidance does not preclude feasibility studies from applying or formulating to SLC scenarios other than three USACE scenarios. In the next phase of the study consideration will be given to also evaluating the NJCAA SLC estimates.

Table 9: NJCAA Projected SLC Estimates for New Jersey



	Central Estimate	**Likely Range**	**1-in-20 Chance**	**1-in-200 Chance**	**1-in-1000 Chance**
Year	*50% probability SLR meets or exceeds…*	*67% probability SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*	*0.1% probability SLR meets or exceeds…*
2030	0.8 ft	0.6 – 1.0 ft	1.1 ft	1.3 ft	1.5 ft
2050	1.4 ft	1.0 – 1.8 ft	2.0 ft	2.4 ft	2.8 ft
2100 Low emissions	2.3 ft	1.7 – 3.1 ft	3.8 ft	5.9 ft	8.3 ft
2100 High emissions	3.4 ft	2.4 – 4.5 ft	5.3 ft	7.2 ft	10 ft

Estimates are based on Kopp et al. (2014). Columns correspond to different projection probabilities. For example, the 'Likely Range' column corresponds to the range between the 17th and 83rd percentile; consistent with the terms used by the Intergovernmental Panel on Climate Change (Mastrandrea et al., 2010). All values are with respect to a 1991-2009 baseline. Note that these results represent a single way of estimating the probability of different levels of SLR; alternative methods may yield higher or lower estimates of the probability of high-end outcomes.

Storm Probability

Storm events are often defined according to their likelihood of occurring in any given year at a specific location. The most commonly used definition is the "100-year storm". This refers to a storm with a "recurrence interval" or "return period" of 100 years and is equivalent to a storm that has a 1 in 100, or 1-percent chance of being equaled or exceeded in any year (i.e., 1-percent "annual exceedance probability").

A common misinterpretation is that a 100-year storm is likely to occur only once in a 100-year period. In fact, a second 100-year storm could occur a year or even a week after the first one. The term only means that the average interval between storms greater than the 100-year storm over a very long period (say 1,000 years) will be 100 years. However, the actual interval between storms greater than this magnitude will vary considerably.

The probability of exceedance describes the likelihood of a specified flood or storm event being exceeded in a given year. There are several ways to express the annual chance of exceedance (ACE) or annual exceedance probability. The ACE is expressed as a percentage. An event having a one in 100 chance of occurring in any single year would be described as the one percent ACE event. This is the current accepted scientific terminology for expressing chance of exceedance. The annual recurrence interval, or return period, has historically been used by engineers to express probability of exceedance.

In addition, the probability of a certain storm occurring will increase for a longer period of time. For example, over the life of an average 30-year mortgage, a home located within the 100-year flood zone has a 26-percent chance of being flooded at least once. Even more significantly, a house in a 10- year flood zone is almost certain to be flooded at least once (96-percent chance) in the same 30-year mortgage cycle. The probability (P) that one or more of a certain-size flood occurring during any period will exceed a given flood threshold can be estimated as

$$P = 1 - \left[1 - \frac{1}{T}\right]^{n}$$

where T is the return period of a given storm (e.g., 100 years, 50 years, 25 years) and n is the number of years in the period. The probability of storms of various return periods in any given year and over the life of a 30-year mortgage is summarized in Table 10.

Table 10: Storm Frequency Examples

Return Period (Years)	**Annual Chance Event**	**Chance of Storm Occurring During 30-Year Mortgage**
10	1 in 10 (10%)	96%
50	1 in 50 (2%)	46%
100	1 in 100 (1%)	26%
500	1 in 500 (0.2%)	6%

Existing Conditions

Astronomical Tide

Daily tidal fluctuations at the project site are semi-diurnal, with a full tidal period that averages 12 hours and 25 minutes; hence there are nearly two full tidal cycles per day. The mean tidal range in the ocean is 4.0 feet at Atlantic City. The rise and fall of the tide in the ocean leads to tidal flow through the inlets that causes a corresponding rise and fall of water levels in the back bays. Figure 12 shows the mean tidal range for the study area.

The southern half of the study area, from Little Egg Harbor Inlet south to Cape May Inlet, experiences a mean tide range that is only slightly reduced relative to the mean range in the open ocean at Atlantic City, typically in the 3.5 to 4.0 foot mean range. This is due to the relatively shorter distance along the coast between inlets, and the relatively short distances from the open ocean, through the inlets, to the inland extent of the bays.

North of Little Egg Harbor Inlet the mean tide range in the back bays gradually decreases such that at Mantoloking, near the head of Barnegat bay, the mean range is about 0.9 feet. The reduction in mean tide range is due to the long, narrow, and shallow geometry of Barnegat Bay and the relatively greater distances between inlets; it is about 24 miles from Manasquan Inlet south to Barnegat Inlet, and then an additional 21 miles south to Little Egg Harbor Inlet.

Seasonal and Interannual Fluctuations in Sea Level

The average seasonal cycle of mean sea level, shown in Figure 15, is caused by regular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents and on average causes a 0.5 foot difference in sea level from September (highest) to January (lowest).

Interannual (2 or more years) variations in sea level, shown in Figure 16, are caused by irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents (El Niño).

Seasonal and interannual fluctuations in sea level are significant in the study area and will be incorporated in design water elevations in subsequent phases of the feasibility study.

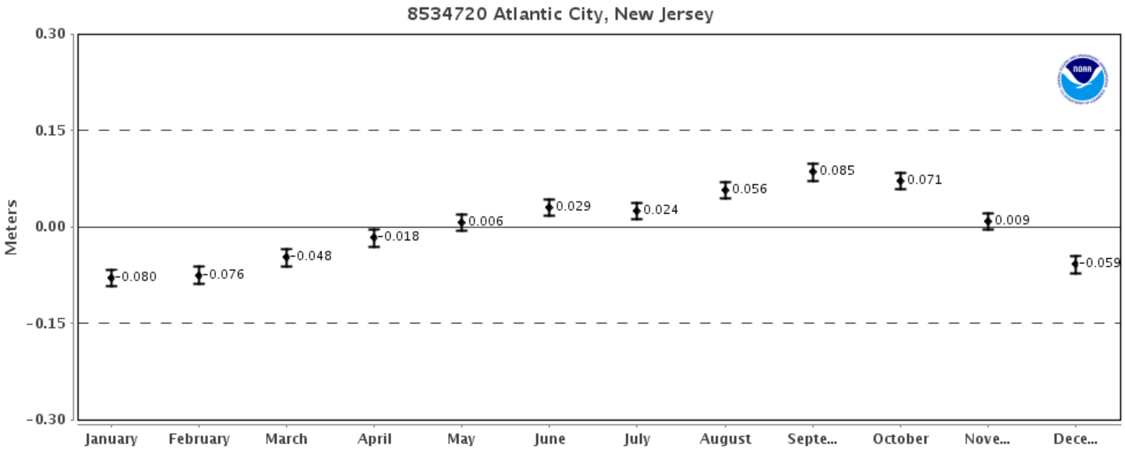


Figure 15: Average Seasonal Cycle in Sea Level at Atlantic City, NJ

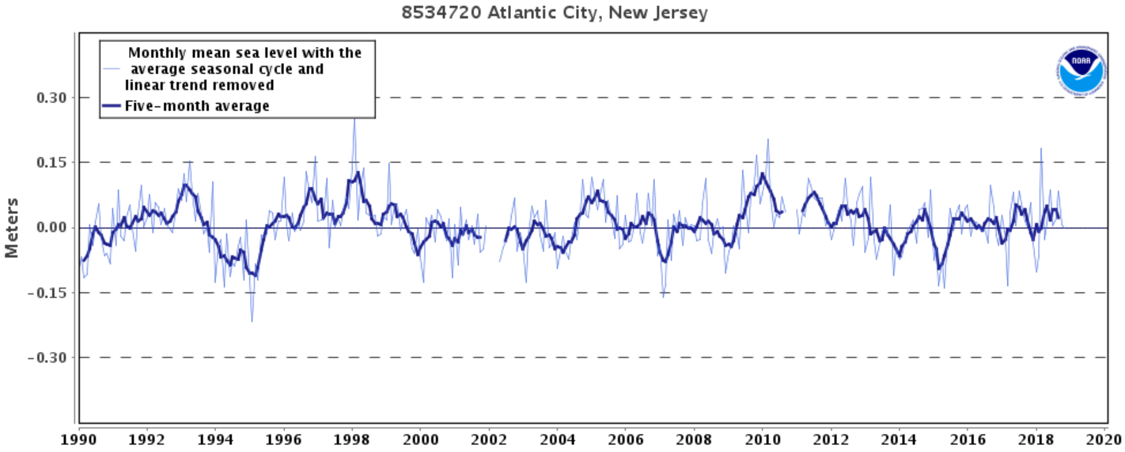


Figure 16: Interannual Variation in Sea Level at Atlantic City, NJ

Storm Surge

Storm surge is the increased water level above the predicted astronomical tide due to storm winds over the ocean and the resultant wind stress on the ocean surface. The principal factor that creates flood risk for the study area is storm surge that propagates into the back bays through the twelve inlets distributed along the New Jersey coast. The magnitude of the storm surge is calculated as the difference between the predicted astronomic tidal elevation and the actual water surface elevation at any time. Wind blowing over the ocean surface is capable of generating storm surge. However, the largest and most damaging storm surges develop as a result of either tropical cyclones (hurricanes and tropical storms) or extra-tropical cyclones ("nor'easters"). Although the meteorological origins of the two types of storms differ, both can generate large, low-pressure atmospheric systems with intense wind fields that rotate counter-clockwise (in the northern hemisphere). The relatively broad and shallow continental shelf along the east coast allows the generation of larger storm surge values than are typically experience on the US Pacific coast.

Storm surge propagation into the back bays broadly mirror the tidal propagation, with storm surge in the southern portions of the study area in similar magnitude to the ocean coastline and attenuated storm surge in Barnegat Bay. However, storm surge in Barnegat Bay is highly dependent on wind speed and direction. Strong winds are capable of “pushing” accumulated storm surge from either the southern end or northern end of the Little Egg Harbor-Barnegat Bay system in the direction that the wind is blowing. The effect of the wind is that storm surges at the southern or northern ends of the Little Egg Harbor-Barnegat Bay system may be similar in elevation to storm surge elevations on the ocean even though tidal amplitudes in the bay are muted relative to the ocean. Storm surge elevations along the middle of the bay are lowest, and generally less than the ocean, because the wind effects are less signficant.

Waves

Wave conditions in the NJBB study area are fetch-limited and generated by local wind conditions. In fetch-limited conditions, wave heights are limited by the distance of open water in which the waves are able to grow. Wave conditions throughout the bay are also affected by the shallow water depths, marshes and orientation relative to the wind directions. The 100-year wave conditions in the back bays are generally between 3 and 4 feet with a peak wave period of 3 to 4 seconds. At some back bay locations wave conditions may be dominated vessel wakes.

The ocean coastline and inlets are exposed to significantly greater wave energy associated with the ocean. Wave conditions offshore may exceed 30 feet during 100-year wave conditions with peak wave periods between 9 and 16 seconds. Wave conditions inside the inlets are affected by complex wave transformation process (wave refraction, shoaling, breaking, diffraction, reflection, and wave-current interactions) associated with the dynamic bathymetry and ebb shoals and rubble mound structures (jetties).

Historical Storms

The study area has experienced flooding from both tropical cyclones and extratropical cyclones. Table 11 displays the top ten historical storms at Cape May, Atlantic City, and Sandy Hook NOAA tidal stations. Note that the historical water levels have not been adjusted for sea level rise.

Table 11: Historical Peak Water Levels at NOAA Stations

Cape May, NJ (since 1965)			Atlantic City, NJ (since 1911)			Sandy Hook, NJ (since 1932)		
Date	**Type**	**Feet NAVD88**	**Date**	**Type**	**Feet NAVD88**	**Date**	**Type**	**Feet NAVD88**
23-Jan-2016	E	5.96	11-Dec-1992	E	6.37	29-Oct-2012	T	10.42
29-Oct-2012	T	5.87	14-Sep-1944	T	6.23	12-Sep-1960	T	7.27
27-Sep-1985	T	5.79	29-Oct-2012	T	6.15	11-Dec-1992	E	7.26
29-Oct-2011	E	5.67	27-Sep-1985	T	5.96	28-Aug-2011	T	6.95
25-Oct-1980	E	5.64	31-Oct-1991	E	5.85	7-Nov-1953	E	6.87
11-Dec-1992	E	5.53	6-Mar-1962	E	5.83	6-Mar-1962	E	6.57
4-Jan-1992	E	5.52	9-Aug-1976	T	5.83	14-Sep-1944	T	6.57
3-Mar-1994	E	5.50	25-Nov-1950	E	5.63	13-Mar-2010	E	6.21
28-Aug-2011	T	5.37	29-Mar-1984	E	5.38	25-Nov-1950	E	6.17
14-Oct-1977	T	5.25	23-Jan-2016	E	5.23	12-Nov-1968	E	5.99

High-Frequency Flooding

High-frequency flooding, also known as nuisance flooding, recurrent flooding, or sunny-day flooding, are flood events caused by tides and/or minor storm surge that occur more than once per year. High-frequency flooding mostly affects low-lying and exposed assets or infrastructure, such as roads, public storm-, waste- and fresh-water systems (Sweet et. al 2018) and is likely more disruptive (a nuisance) than damaging. However, the cumulative effects of high-frequency flooding may be a serious problem to residents who live and work in these low-lying areas. The number of high-frequency flood days is accelerating in the study area in response to RSLC.

Flooding from rainfall and inadequate stormwater systems are closely related to high-frequency flooding but are treated separated in this study. It is common for municipalities in the study area to have gravity based stormwater systems that are unable to drain water when tidal level exceeds the elevation of the storm drain. When this happens, water starts ponding around the drain and may flood many of the same low-lying areas as high-frequency flooding. The frequency and impact of rainfall flooding will increase as the probability of the tide level exceeding storm drains will increases in response to RSLC. Some municipalities are addressing this problem by installing pump stations that are capable of draining water during elevated water levels.

The primary focus of the NJBB study is managing risk to severe storm surge events (i.e. Hurricane Sandy), not flooding associated with inadequate storm sewer systems and/or high-frequency flooding. It is USACE policy (ER 1165-2-21) that stormwater systems are a local non-Federal responsibility. While flooding from high frequency flooding and inadequate stormwater systems is not the focus of the NJBB study, it is acknowledged that nonstructural and storm surge barrier measures may not provide any relief from these problems. Therefore, complementary measures to address these problems will be investigated and may be recommended as part of a comprehensive Federal project or recommended for implementation at the local non-federal level.

National Weather Service Flood Stages

The National Weather Service (NWS) with the help of NOAA and USGS provide real time flood status of stream gages and tidal stations (Figure 17). The National Weather Service (NWS) has established three coastal flood severity thresholds: minor, moderate, and major flood stages. The NWS minor and moderate flood stages are the most representative of high-frequency flooding events right now. However, all three flood stages will be evaluated here since NWS major flood stage could eventually occur at frequency consistent with high-frequency flooding in the future in response to RSLC.

The definition of minor, moderate, and major flooding is provided herein by NWS. The definitions are taken from the NWS website for Atlantic City, NJ so that impacts are specific to Ocean and Atlantic County. However, impacts experienced described at this station are generally representative of the entire study area.

> **Minor Flooding** - Minimal or no property damage, but possibly some public threat;
>
> **Moderate Flooding** - widespread flooding of roadways begins due to high water and/or wave action with many roads becoming impassable in the coastal communities of Ocean County and Atlantic County. Lives may be at risk when people put themselves in harm's way. Some damage to vulnerable structures may begin to occur;
>
> **Major Flooding** - flooding starts to become severe enough to begin causing structural damage along with widespread flooding of roadways in the coastal communities of Ocean County and Atlantic County. Vulnerable homes and businesses may be severely damaged or destroyed as water levels rise further above this threshold. Numerous roads become impassable and some neighborhoods may be isolated. The flood waters become a danger to anyone who attempts to cross on foot or in a vehicle.

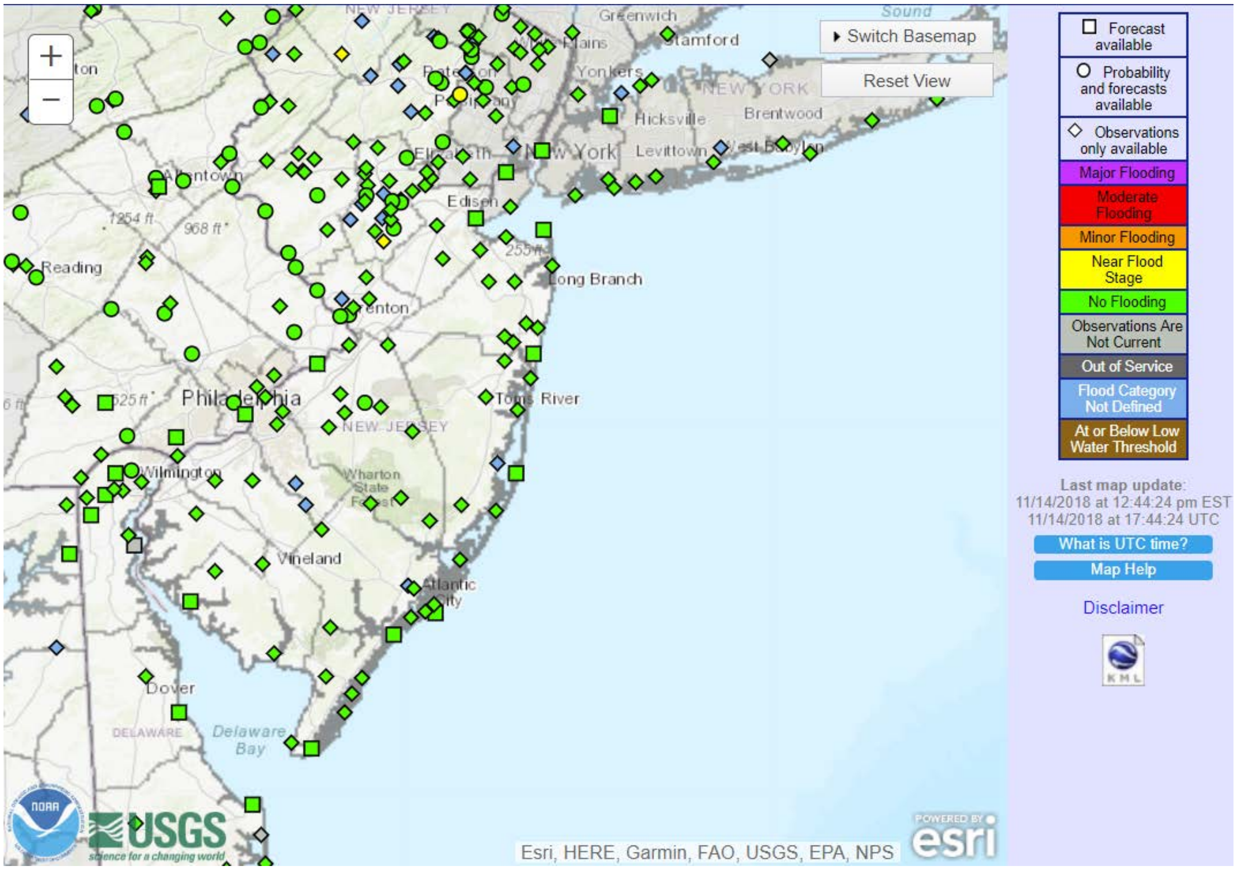


Figure 17: NWS Real-Time Flood Monitoring Network

An example of the flood inundation area associated with the three NWS Flood stages is shown in Figure 18, Figure 19, and Figure 20 at Atlantic City, Wildwood, and Cape May. The impact of minor flooding can be seen to be very limited to a few particularly low-lying areas. The impact of moderate flooding is more widespread impacting some streets and properties and major flooding is widespread impacting several streets and blocks near the bay shoreline.

There are 17 NWS stations in the study area with documented flood stages. The flood stages are reported on the NWS website in feet MLWW:

https://water.weather.gov/ahps/region.php?state=nj

The NWS flood stages are converted to feet NAVD88 in Table 12 for floodplain mapping. NWS minor flood stages are typically 1 to 1.5 feet above MHHW. Moderate and major flood stages are an additional 1 and 2 feet, respectively, above the minor flood stage. The NWS minor flood stage elevations are pretty consistent across the study area, 3.2 to 3.7 feet NAVD88, with the exception of Barnegat Bay where the tidal range is smaller.

Table 12: NWS Flood Stages

Location	Gage	Minor	Moderate	Major
			NAVD88	
Belmar	BLMN4	3.7	4.7	5.7
Manasquan	MSNN4	3.2	4.2	5.2

Mantaloking	MTLN4	1.4	2.4	3.4
Bayshore	BASN4	1.4	2.4	3.4
Barnegat Light	BGLN4	2.3	3.3	4.3
Ship Bottom	SBTN4	2.1	3.1	4.1
Tuckerton	TKTN4	2.6	3.6	4.6
Atlantic City Marina	ATLN4	3.3	4.3	5.3
Atlantic City	ALCN4	3.5	4.5	5.5
Atlantic City (ocean front)	ACYN4	3.4	4.4	5.4
Margate	MGTN4	3.3	4.3	5.3
Ocean City	ONCN4	3.2	4.2	5.2
Sea Isle City	SICN4	3.3	4.3	5.3
Avalon	AVLN4	3.5	4.5	5.5
Stone Harbor	SHBN4	3.4	4.4	5.4
Cape May	CMAN4	3.7	4.7	5.7
Cape May Harbor	CAPN4	3.4	4.4	5.4

Note: Locations are sorted from North to South. Grey-shaded locations are in Barnegat Bay.

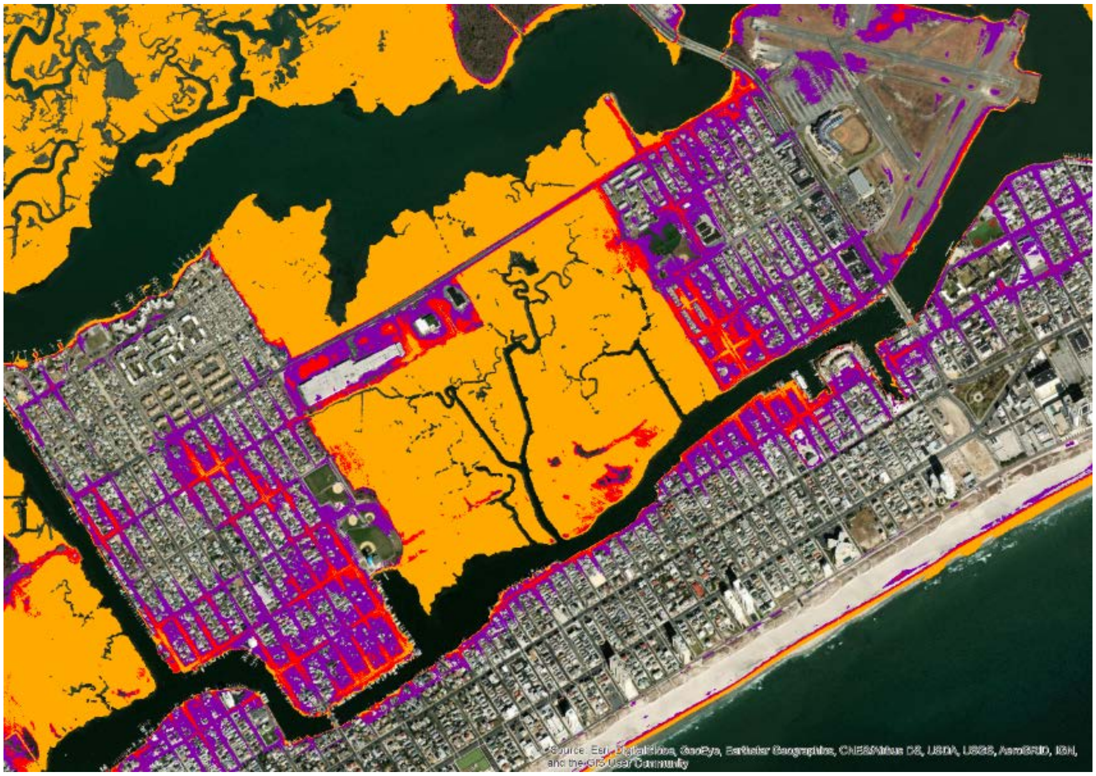


Figure 18: Floodplain associated with NWS Stages at Atlantic City, NJ

Figure 19: Floodplain associated with NWS Stages at Wildwood, NJ

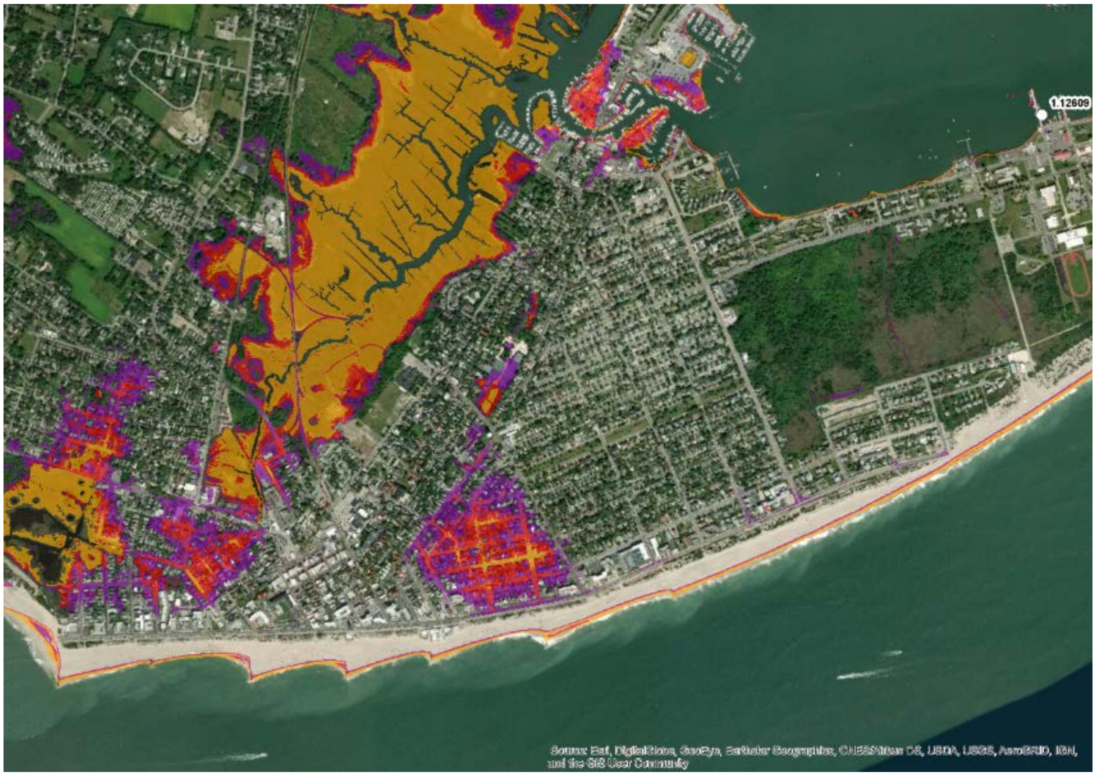


Figure 20: Floodplain associated with NWS Stages at Cape May, NJ

Historical High-Frequency Flooding at Atlantic City, NJ

Atlantic City, NJ has the longest tidal record (1911-Present) out of any of NOAA or USGS stations and is therefore best suited for investigating how often high-frequency flooding has occurred in the past and how rate of flooding has been affected by historic RSLC. Hourly verified data from NOAA CO-OPS station at Atlantic City, NJ was downloaded from 1911-2018. The number of days in which the daily maximum water level equaled or exceeded the NWS flood stages was calculated. The top panel of Figure 21 shows historic record of water levels and a dot for any day in which the NWS flood stages were exceeded. The bottom panel of Figure 21 shows a histogram of the total number of days in a given year that the NWS flood stages were exceeded. It is readily observed from Figure 21 that annual rate of NWS minor flooding has increased over time, with a dramatic increase in the 1990’s. The annual rate of NWS moderate flooding has a seen a small but visible increase and with little or no increase in NWS major flooding.

To isolate the impact of historic RSLC on the frequency of flooding, the analysis was repeated with the historic SLR trend removed so that the mean sea level remained the same as in 1910 over the period of record. Figure 22 shows that if no RSLC had occurred since 1910, the frequency of NWS minor flooding would be still be a couple times per year, significantly lower than today, and that primary driver of the increase in high-frequency flooding over the last 100 years has been RSLC not changes in the tidal range or meteorological conditions.

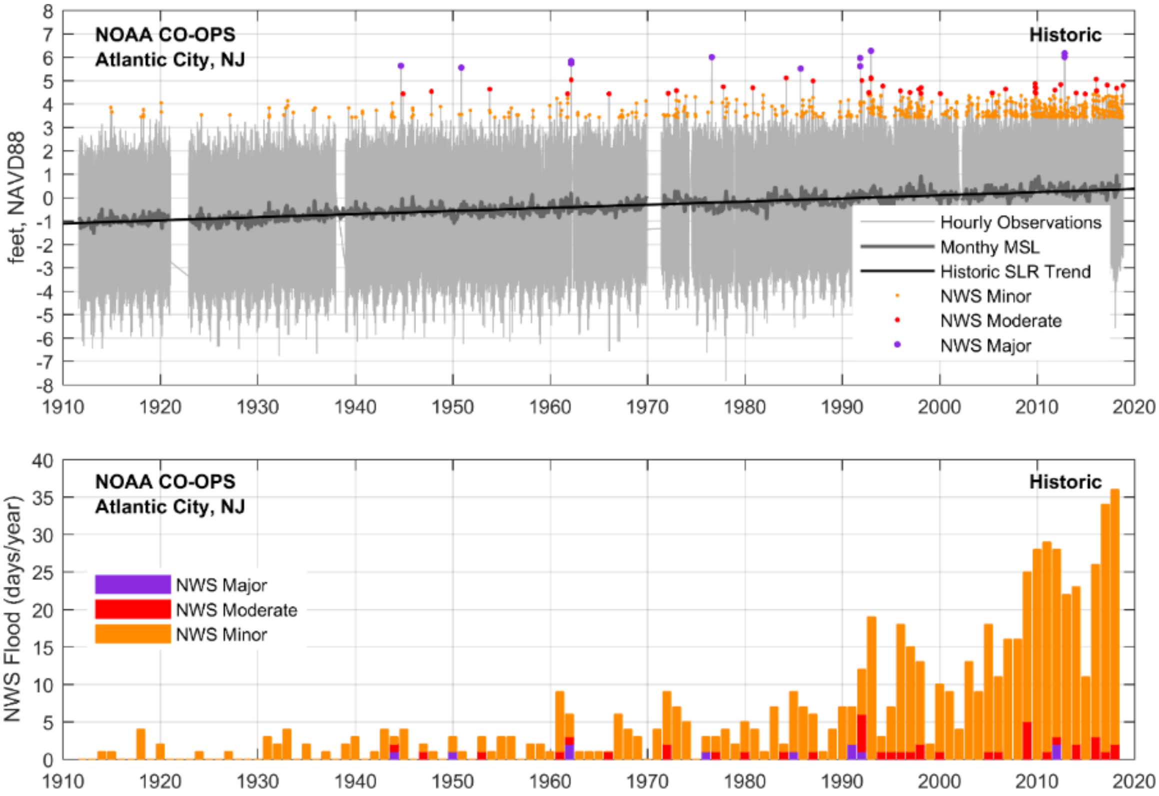


Figure 21: Historic High-Frequency Flooding at Atlantic City, NJ

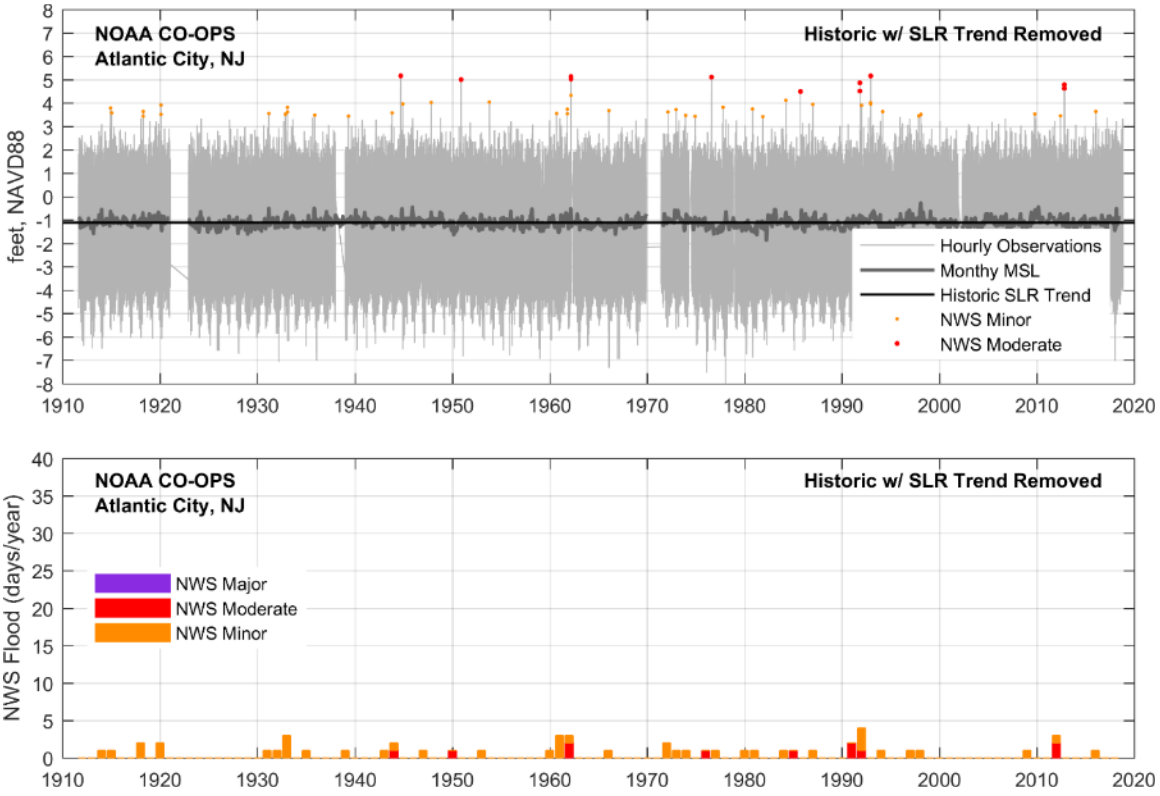


Figure 22: Impact of SLC on Historic High-Frequency Flooding

Future High-Frequency Flooding at Atlantic City, NJ

The previous section showed the dramatic impact RSLC has had on frequency of flooding over the last 100 years. This section shows how the rate of high-frequency flooding will be affected by future RSLC. To complete this analysis the last 25 years of the NOAA tidal record (1992-2017, skipping 2002 which had data gaps) was assumed to repeat over and over again until 2130. However, the three USACE SLC projections were added to the observed water levels. The top panel of Figure 23 shows the hourly water level observations and future projections with the USACE-Low SLC scenario applied and a dot for any day in which the NWS flood stages were exceeded. The middle and bottom panel of Figure 23 shows a histogram of the total number of days in a given year that the NWS flood stages were exceeded. The bottom panel shows the same information as the middle panel, but zooms in on NWS flood days (per year) between 0 and 40. The results in Figure 23 show that Atlantic City is experiencing an acceleration in NWS minor flood days that will only get worse in the future. It also indicates that the increase already underway in NWS minor flooding will begin to occur in the future for the NWS moderate and major flooding. A significant increase in NWS moderate and major flooding appears to occur after 2030 and 2080 respectively.

The same analysis was repeated for the USACE-Intermediate and USACE-High RSLC scenarios in Figure 24 and Figure 25. Annual NWS flood days from the analyses are tabulated in Table 13. It is difficult to say or know what the tipping point (days per year) for NWS minor, moderate, and major flooding before the impacts to roads and infrastructure are unacceptable. However, the analysis shows that major investments in high frequency flood measures and stormwater systems are likely to be required in the future for the portions of the study area that could become uninhabitable otherwise.

Table 13: High-Frequency Flood Occurrences (Per Year)

Year	NWS Minor Flood			NWS Moderate Flood			NWS Major Flood		
	Low	**Int**	**High**	**Low**	**Int**	**High**	**Low**	**Int**	**High**
1930	1.1			0.0			0.0		
1955	1.7			0.2			0.1		
1980	3.6			0.5			0.2		
2005	14.5			0.7			0.0		
2015	26.5			2.2			0.5		
2030	54.7	73.2	139.8	4.7	5.9	21.1	0.1	0.3	1.0
2055	98.0	164.5	325.8	9.5	25.5	191.6	0.5	2.1	37.7
2080	153.8	282.6	356.2	23.1	100.9	349.9	1.5	11.1	298.3
2105	218.6	342.0	356.3	50.1	243.2	356.3	4.4	69.6	356.3
2130	258.5	350.6	352.3	78.1	327.3	352.3	5.8	182.3	352.3

Note: 10-year running mean filter applied to determine annual flood occurrences

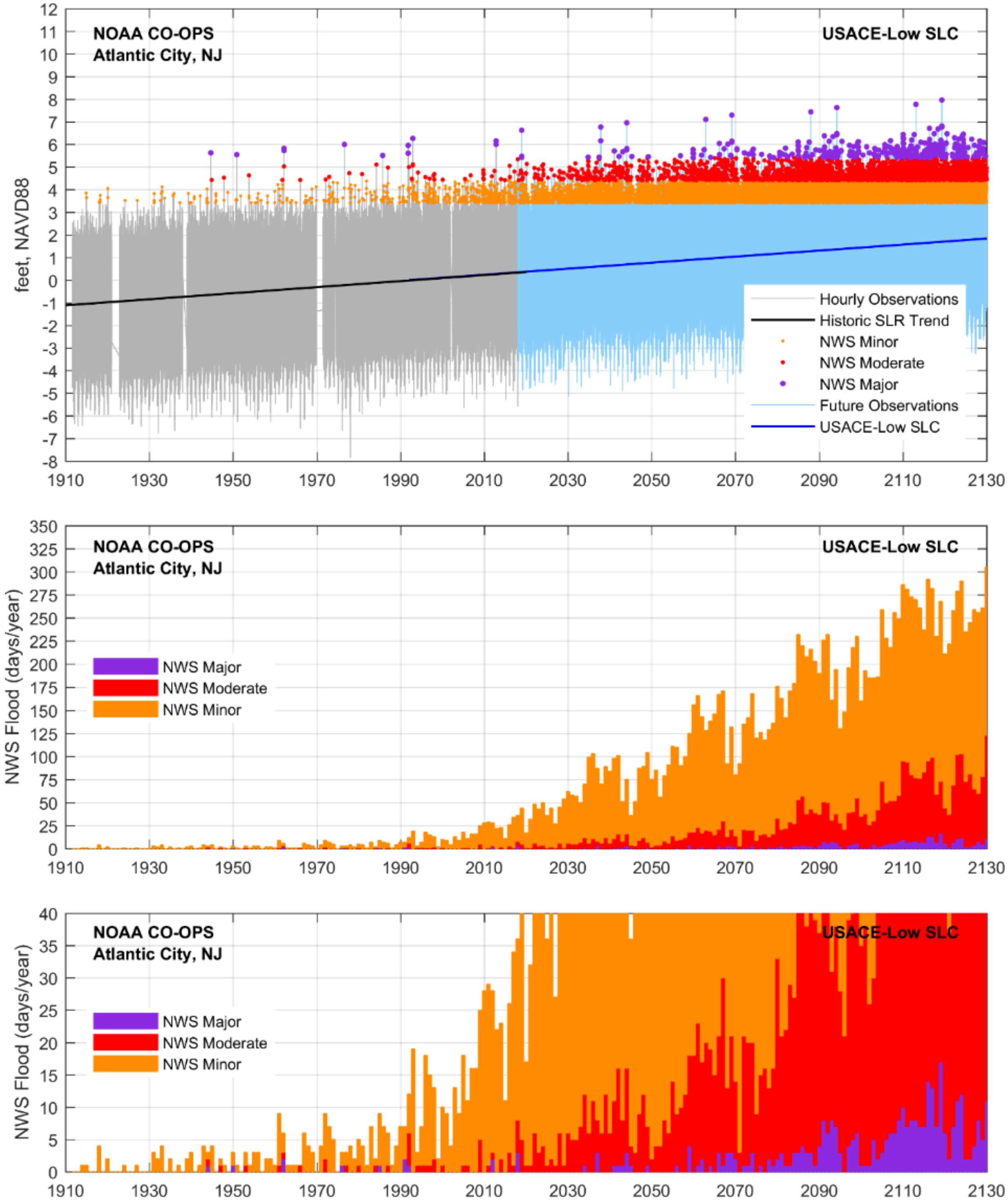


Figure 23: Future High-Frequency Flooding – USACE-Low SLC

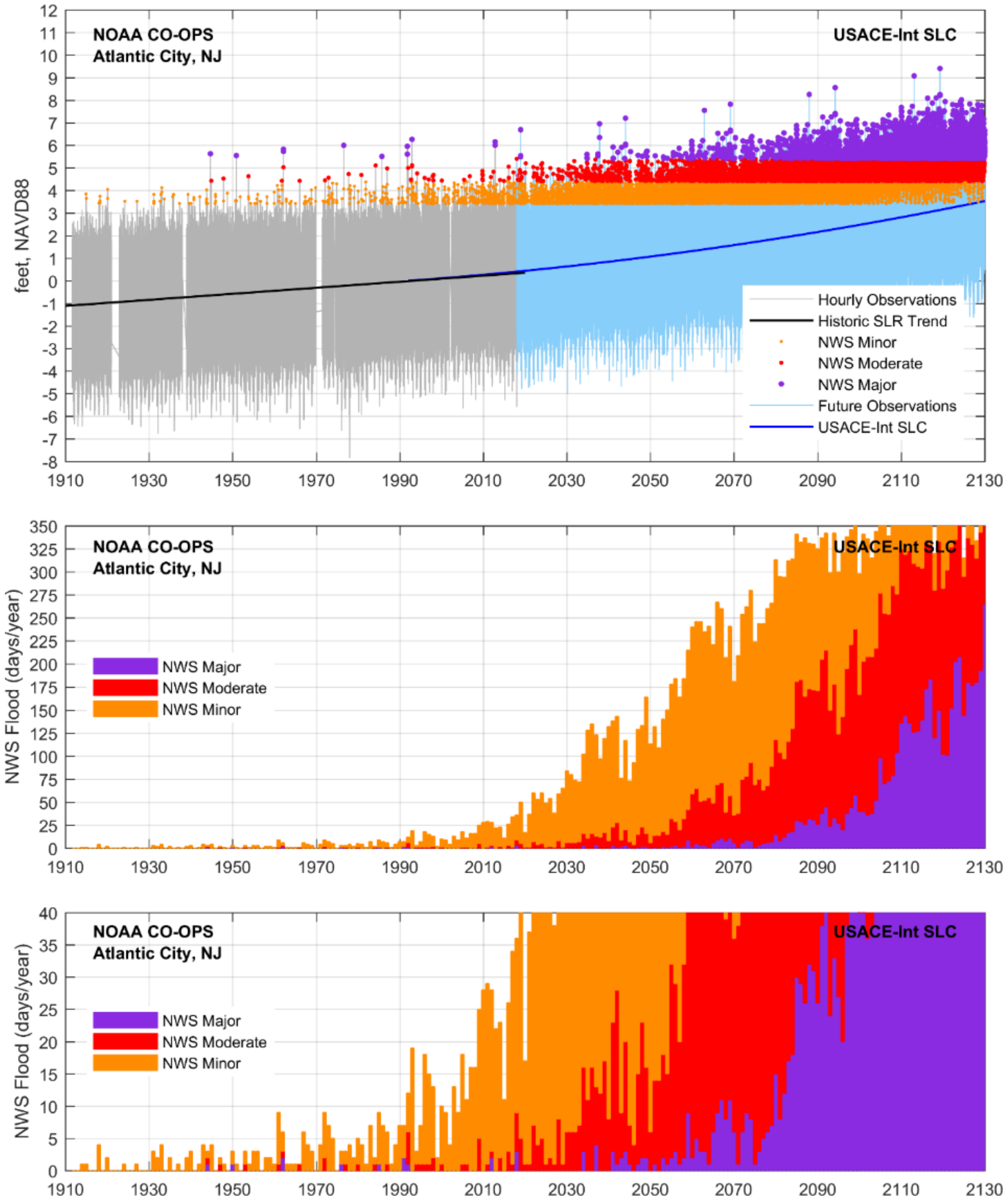


Figure 24: Future High-Frequency Flooding – USACE-Intermediate SLC

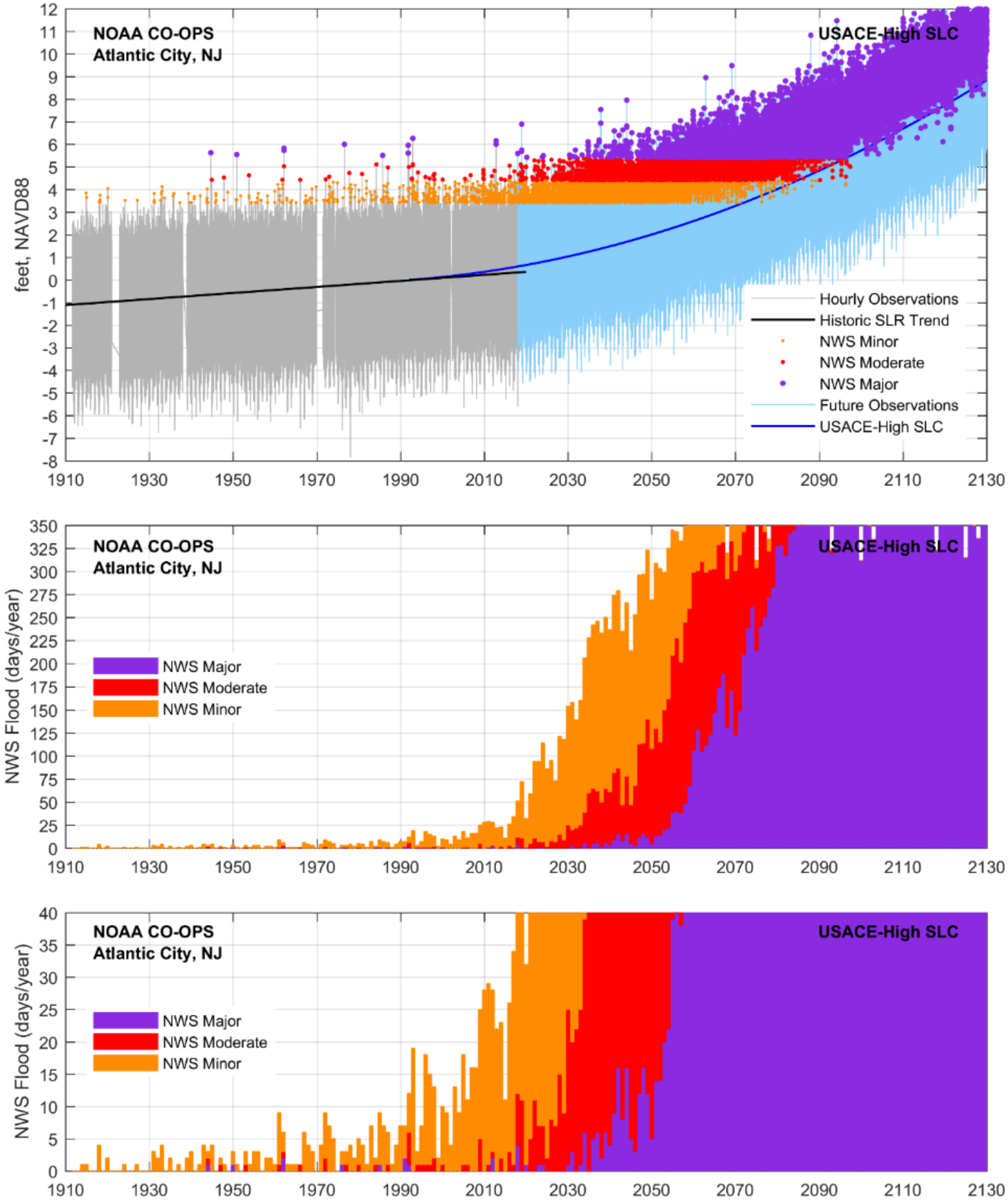


Figure 25: Future High-Frequency Flooding – USACE-High SLC

Storm Surge Modeling

NACCS

The North Atlantic Coast Comprehensive Study (NACCS) was authorized under the Disaster Relief Appropriations Act, PL 113-2, in response to Superstorm Sandy. The Act provided the USACE up to $20 Million to conduct a study with the goal to (1) reduce flood risk to vulnerable coastal populations, and (2) promote resilient coastal communities to ensure a sustainable and robust coastal landscape system, considering future sea level change and climate change scenarios.

As part of the NACCS, the US Army Engineer Research and Development Center (ERDC) completed a coastal storm wave and water level modeling effort for the U.S. North Atlantic Coast. This modeling study provides nearshore wind, wave, and water level estimates and the associated marginal and joint probabilities critical for effective coastal storm risk management. This modeling effort involved the application of a suite of high-fidelity numerical models within the Coastal Storm Modeling System (CSTORM-MS) to 1050 synthetic tropical storms and 100 historical extra-tropical storms. Documentation of the numerical modeling effort is provided in Cialone et al. 2015 and documentation of the statistical evaluation is proved in Nadal-Caraballo et al. 2015. Products of the study are available for viewing and download on the Coastal Hazards System (CHS) website: https://chs.erdc.dren.mil/.

Modifications for NJBB

The USACE Engineer Research and Development Center (ERDC), Coastal and Hydraulics Lab (CHL) conducted a numerical modeling study to evaluate the effectiveness of storm surge barriers in reducing water levels in the study area. As part of this numerical modeling study the existing condition water levels in the study area were updated to ensure that the existing and with-project water levels were consistent and derived from a common model, set of storms, and statistical evaluation. A detailed discussion of the ERDC numerical modeling report is provided in the Draft Interim Report.

The ERDC numerical modeling study reused the CSTORM-MS developed for NACCS. While the original mesh boundary was maintained, Chesapeake Bay and coastal Long Island in the NACCS grid were subject to a “de-refining” procedure, which locally reduces a mesh resolution in areas that are distant from the area of interest. The model bathymetry was only updated to raise the barrier islands elevations from Manasquan to Lower Cape May Meadows to represent 2018 existing conditions with the recent construction of several USACE beach restoration projects that were not captured in the original NACCS model.

A total of 1050 synthetic tropical cyclones were designed and simulated in the NACCS. However, not all of these storms affect the NJBB region. Using Gaussian process metamodeling (GPM) and a design of experiments (DoE) approach, CHL selected subset of the NACCS synthetic tropical cyclones to maximize coverage of the storm parameter and probability spaces and produce storm surges across the NJBB region while reducing the hydrodynamic modeling requirements. A set of approximately 60 tropical cyclones was selected for modeling in order to complete the frequency distributions of response for both the with- and without-project conditions. Although the subset of storms does not include extratropical storms (nor’easters) the combined frequency distributions for both tropical and extratropical storms is generated by CHL using GPM.

Modeling results are applied throughout the NJBB study to define wave and water level Annual Chance Events (ACE) . The water level ACE are based on the “Base + Linear superposition of 96 random tides” simulations and the mean confidence interval. The wave height ACE are based on the “Base Conditions + 1 random tide” simulations and the mean confidence interval. The water levels represent the peak water level observed during a storm due to the combination of storm surge, astronomical tide, wave-setup, currents, and winds. The water levels are computed stillwater levels, which do not include individual wave crests that could increase the instantaneous water surface.

Model Validation

ADCIRC Model Validation

The NACCS model validation procedure, documented in Cialone et al. (2015), included a harmonic analysis to ensure that the model is responding correctly to astronomical forcing 143 NOAA gage locations, 3 of which are in the study area: Sandy Hook, NJ; Atlantic City, NJ, and Cape May, NJ. In addition a comparison of model to measurements for seven storm conditions to ensure that the model is responding to meteorological forcing. The seven storms are Hurricanes Sandy, Irene, Isabel, Josephine, and Gloria and extratropical storms ET070 (North American Blizzard of 1996) and ET073. Cialone et al. (2015) concluded that “consistency in the model’s ability to predict water levels for the seven validation storm events provided a level of confidence in what can be expected from the model”, and “from the harmonic analysis conducted for the long-term simulation, it was determined that the model accurately predicts response to tidal forcing”.

Since model validation conducted for the NACCS study focused on the available NOAA gage locations, which are located in the Atlantic Ocean, the Philadelphia District asked ERDC-CHL to perform an additional analyses for USGS gages located in the back bays (Figure 27). The additional model validation analyses compared observed water levels to modeled (ADCRIC) water levels for all seven of the validation storm events and at any USGS gage that were active during the storm events. Figure 26 compares the observed and modeled peak water levels. For water levels above 6 feet NAVD88 the ADCIRC model may be biased and over-predict water levels in the study area. It was concluded from the model validation that the model was acceptable for a planning study, but that the mean water level values, rather than a higher confidence interval, should be used for design.

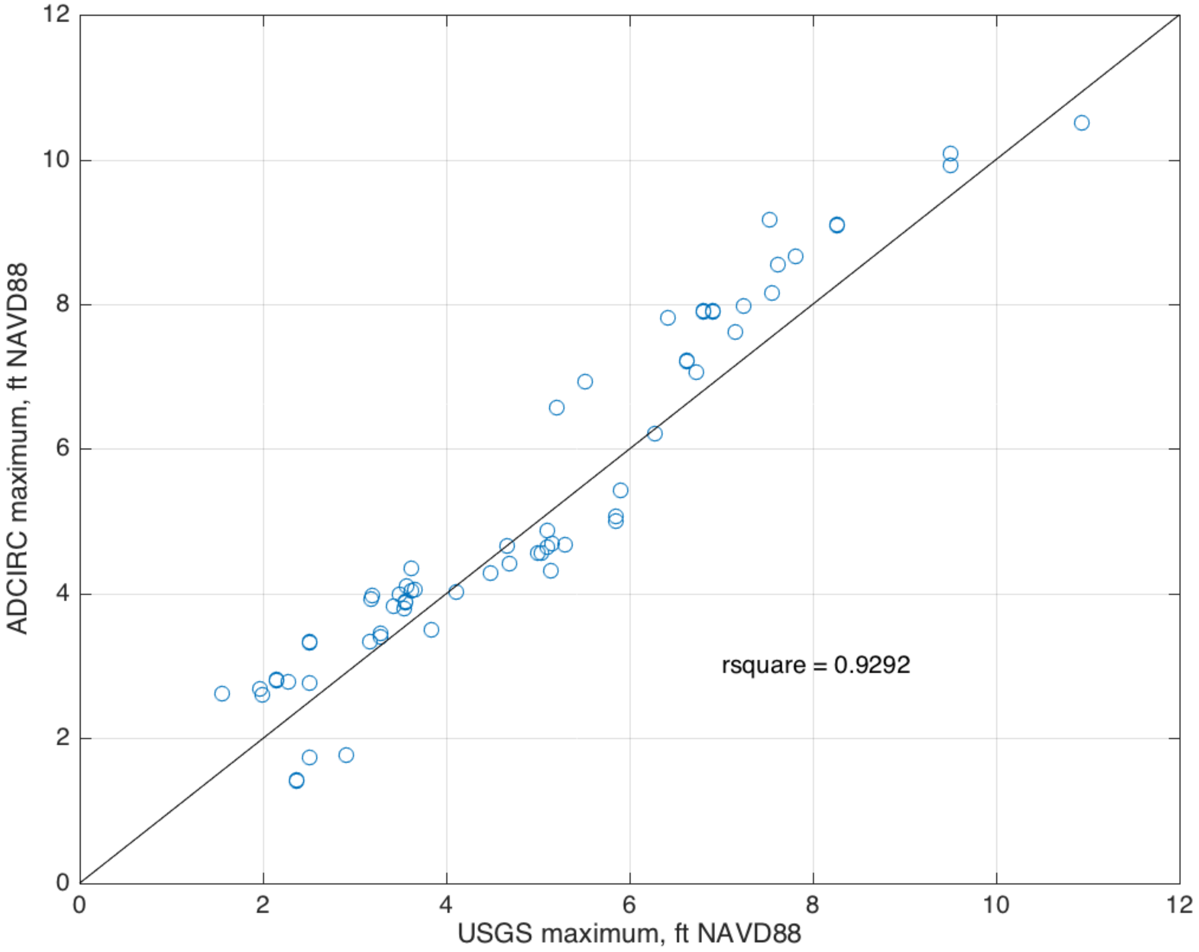


Figure 26: NACCS Model Validation at USGS Gages

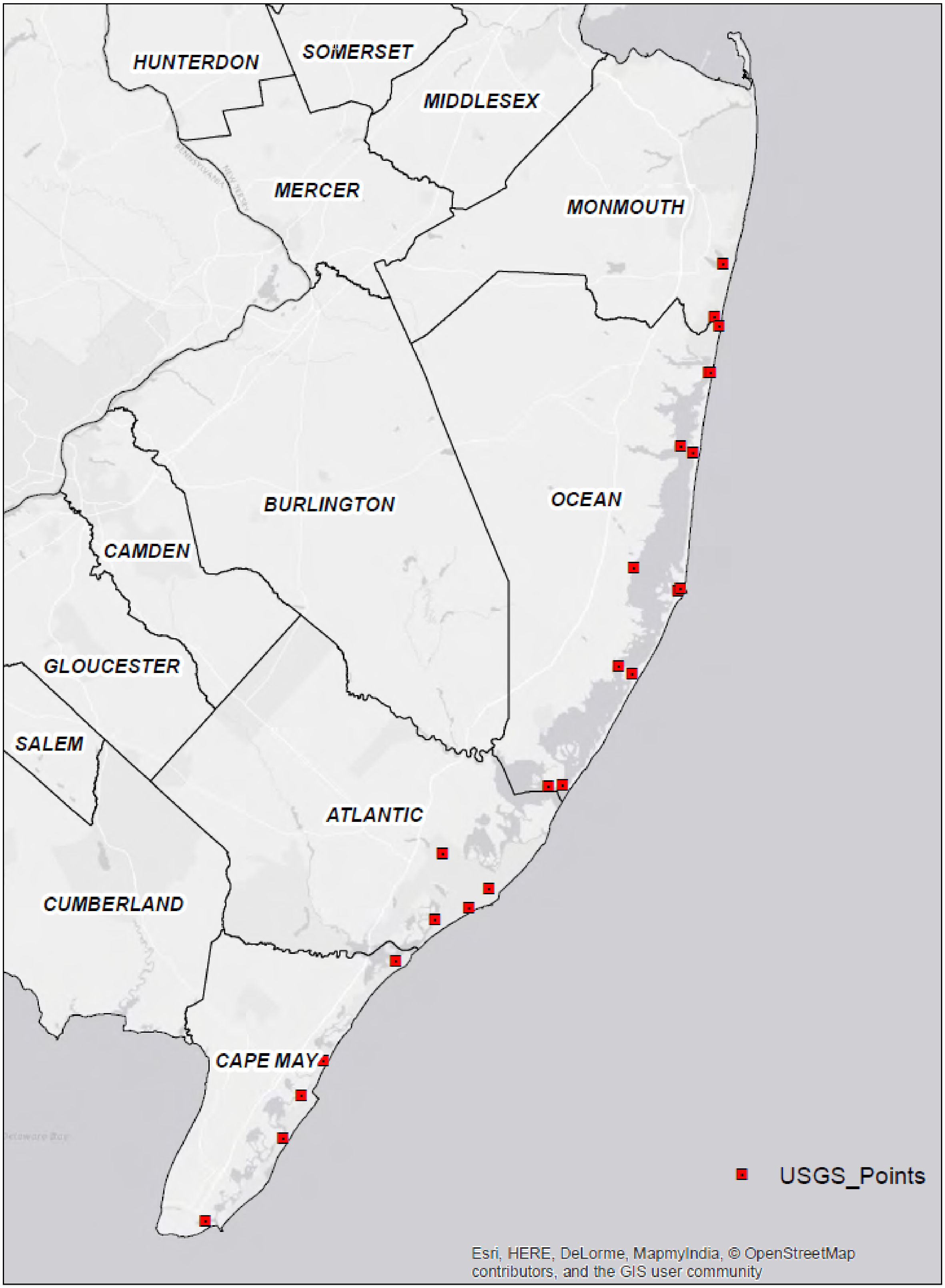


Figure 27: USGS Model Validation Gages

NACCS vs. FEMA

NACCS and the FEMA Region II study are based on the Joint Probability Method (JPM). The JPM was adopted by federal agencies for the critical post-Katrina determinations of hurricane surge frequencies. In standard JPM implementations, it is necessary to consider a very large number of combinations of storm parameters, and each such combination (or synthetic storm) requires the simulation of wind, waves, and surge. The JPM is a very robust methodology, and it is also very complex. The complexity arises from the fact that it has multiple components and probabilistic models that could be executed in different ways, or different developers could choose to use different models.

The results of the NACCS and FEMA water level frequencies for the 1% ACE are shown side by side in Figure 28 to give a visual understanding of the differences. Figure 29 shows a scatter plot comparison of the NACCS save points and FEMA save points. With the exception of a few save points, the NACCS and FEMA 1% annual chance water levels are within 2 feet of each other. The NACCS values tend to be a higher, especially south of Little Egg Inlet. The purpose of comparing FEMA and NACCS is to provide some context of how the NACCS data compares to the FEMA BFE which may be more familiar to stakeholders and the public.

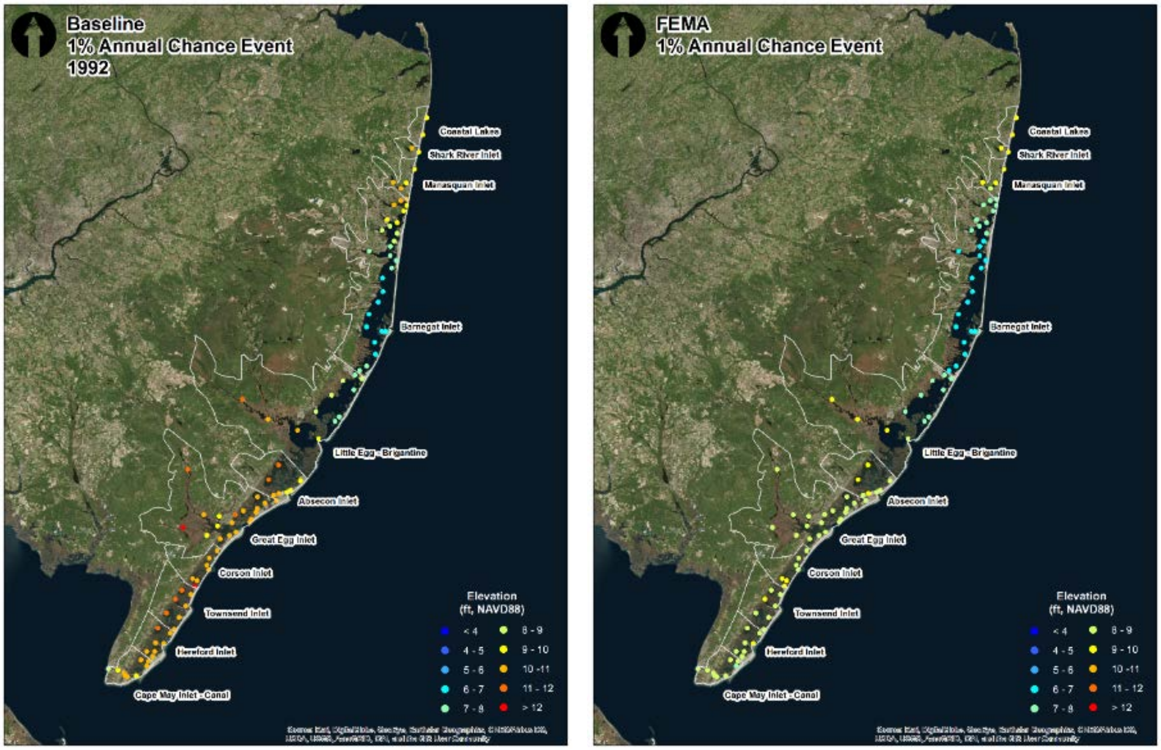


Figure 28: NACCS and FEMA 1% ACE Peak Water Level

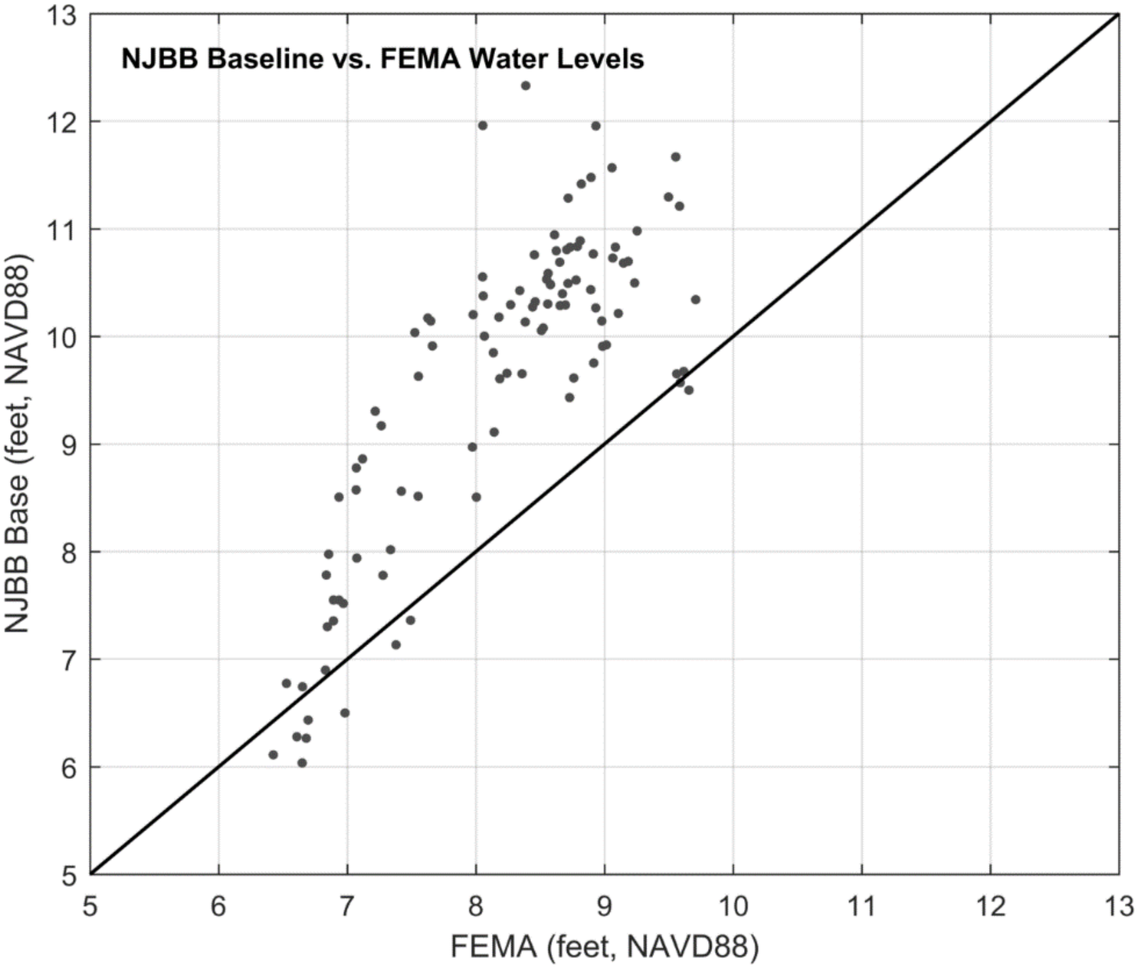


Figure 29: FEMA and Base 1% ACE Water Levels

Historical Tide Gauge Analysis vs. Numerical Modeling

There have been discussion in the past about computing frequency water levels from a historical tide gauge analysis versus numerical modeling (in this case the NACCS modeling). The historical record at the NOAA stations primarily reflects maximum water levels from nor'easters, tropical storms, or Category 1 type storms. The historical maximum water levels are approximately equal to a 10 to 100-year event. A statistical gauge analysis of the historical record may suggest that what has occurred in the past will occur in the future, thus may underestimate the risk. Modeling, such as performed for the NACCS, provides an opportunity to evaluate impacts from stronger hypothetical storms that may not have occurred on record, but could occur.

Table 14: NOAA Extreme Water Level Analysis

Return Period (years)	ACE	Cape May	Atlantic City	Barnegat Inlet	Sandy Hook
		feet, NAVD88			
1	100.0%	3.8	3.6	N/A	4.0
2	50.0%	4.7	4.4	N/A	5.0
10	10.0%	5.4	5.3	N/A	6.4
100	1.0%	6.0	6.8	N/A	9.2

Note: All elevations are in feet NAVD88, relative to NTDE (1983-2001)

Baseline Water Levels

NOAA (Ocean) Stations

An overview of the NACCS 1% ACE water levels at the four NOAA tidal stations in the study area is presented in Table 15.

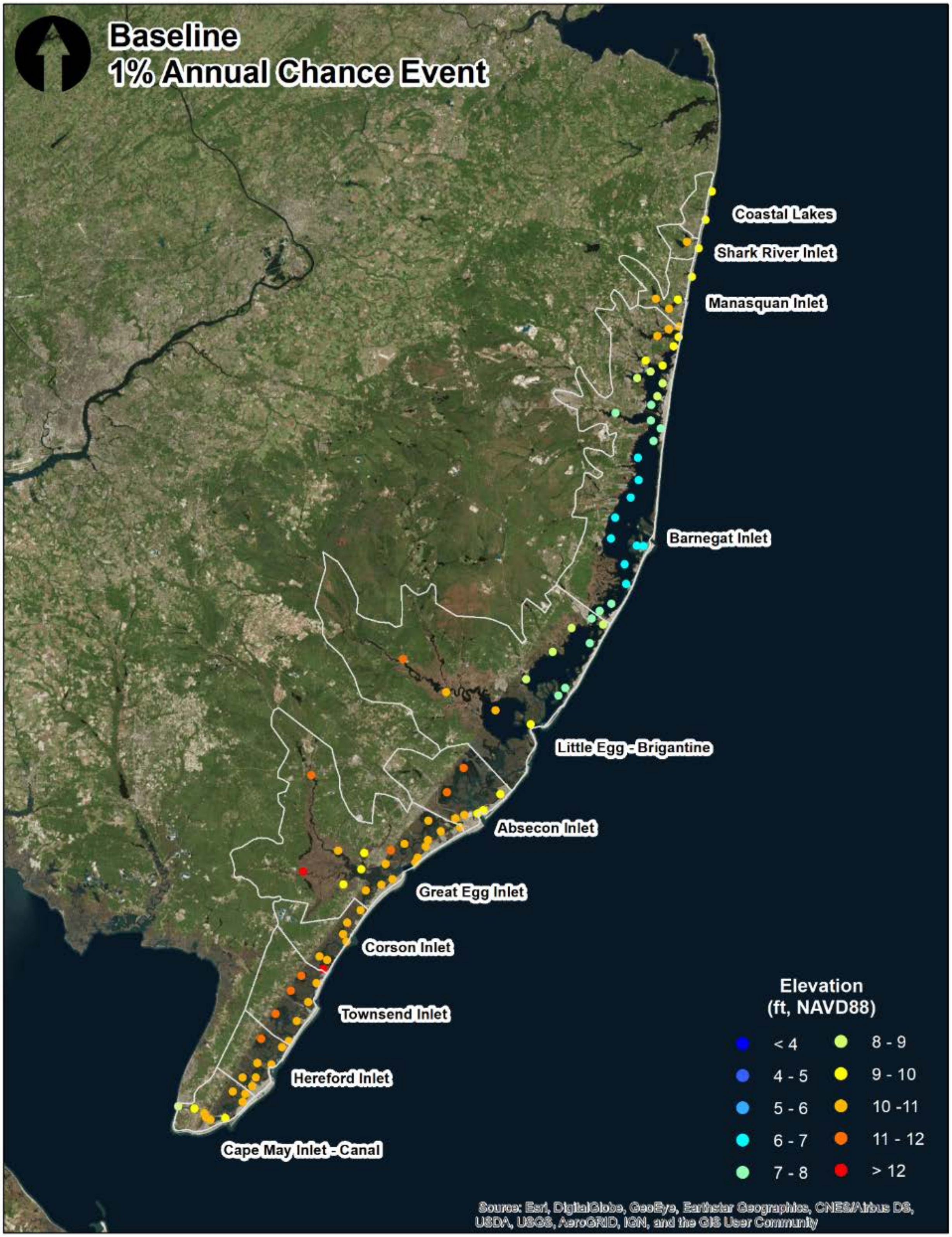
Table 15: NACCS Water Level ACE at NOAA Stations

Return Period (years)	ACE	Cape May	Atlantic City	Barnegat Inlet	Sandy Hook
		feet, NAVD88			
1	100.0%	3.0	3.6	3.1	4.2
2	50.0%	4.4	4.4	3.8	5.0
5	20.0%	5.4	5.4	4.6	6.1
10	10.0%	5.9	6.1	5.1	7.0
20	5.0%	6.3	6.9	5.5	7.9
50	2.0%	6.9	8.5	6.1	9.2
100	1.0%	8.0	9.9	6.5	10.6
200	0.5%	8.9	11.3	7.0	12.2
500	0.2%	10.0	13.2	7.6	14.3

Note: All elevations are in feet NAVD88, relative to NTDE (1983-2001)

Save Points

Model save points are locations inside the modeling domain where detailed numerical modeling output from the simulations is saved and water level frequency distributions (ACE water levels) were calculated. A reduced set of 182, out of a possible 772, NACCS save points was selected to represent the ACE water levels in the economic model HEC-FDA.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 30 shows the subset of 182 NACCS save points. The reduced set of 182 points was selected by first removing points that appeared to be outliers relative to nearby points and then selecting a save point about every half-mile along the coastline, prioritizing open water save points and save points that seemed to best represent the nearby points. A smaller subset of save points would likely have been possible to characterize the FWOP conditions due to the homogeneity in water levels, but it is anticipated that there will be more variability in the water levels for the storm surge barrier alternatives. Sharp gradients in the water levels may occur between adjacent inlets when one inlet is closed and the other is open. Each save point is assigned to a specific reach and damage elements (i.e. structures) in HEC-FDA based on its location. The same set of save points and reaches is used in the FWOP and With Project HEC-FDA model simulations.

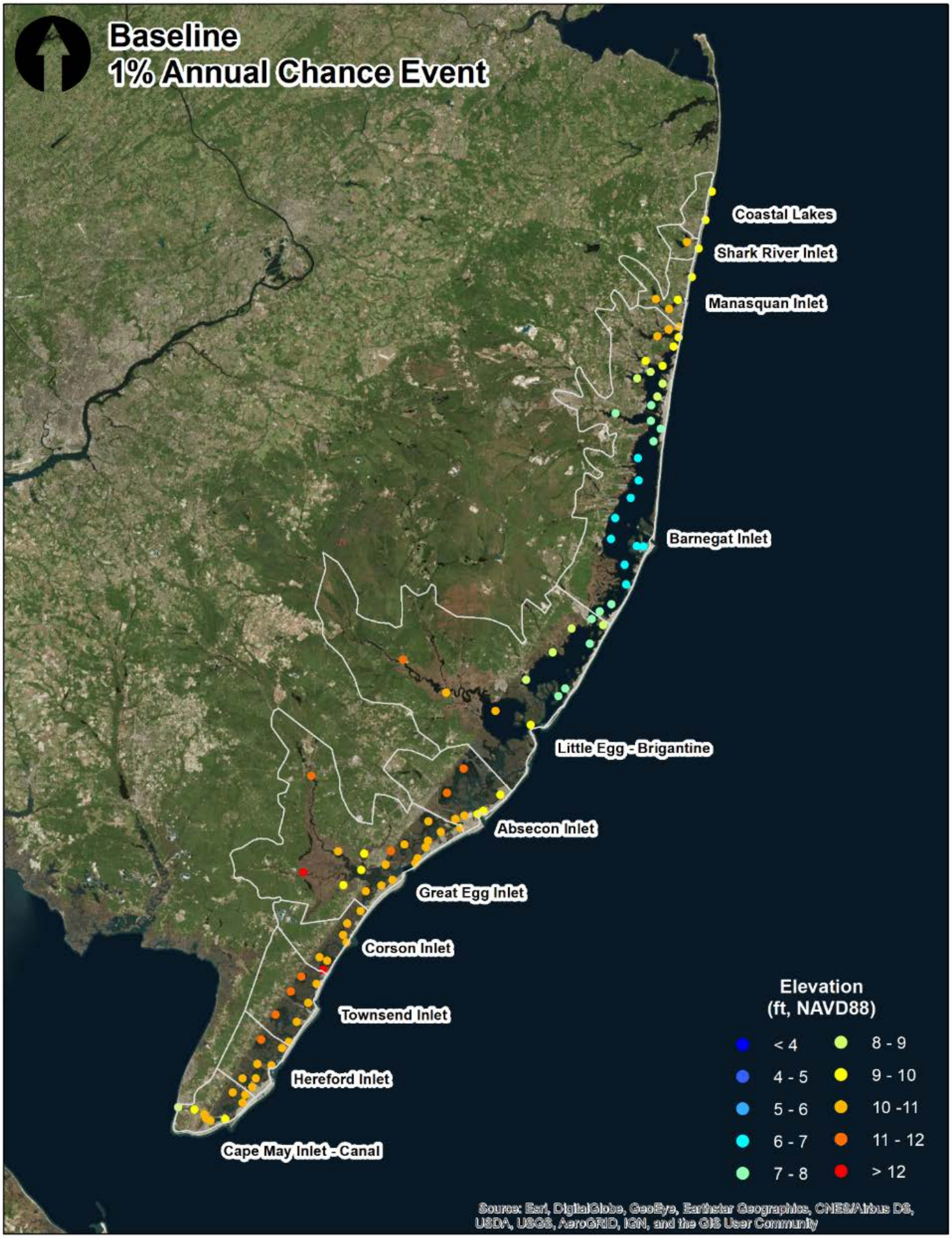
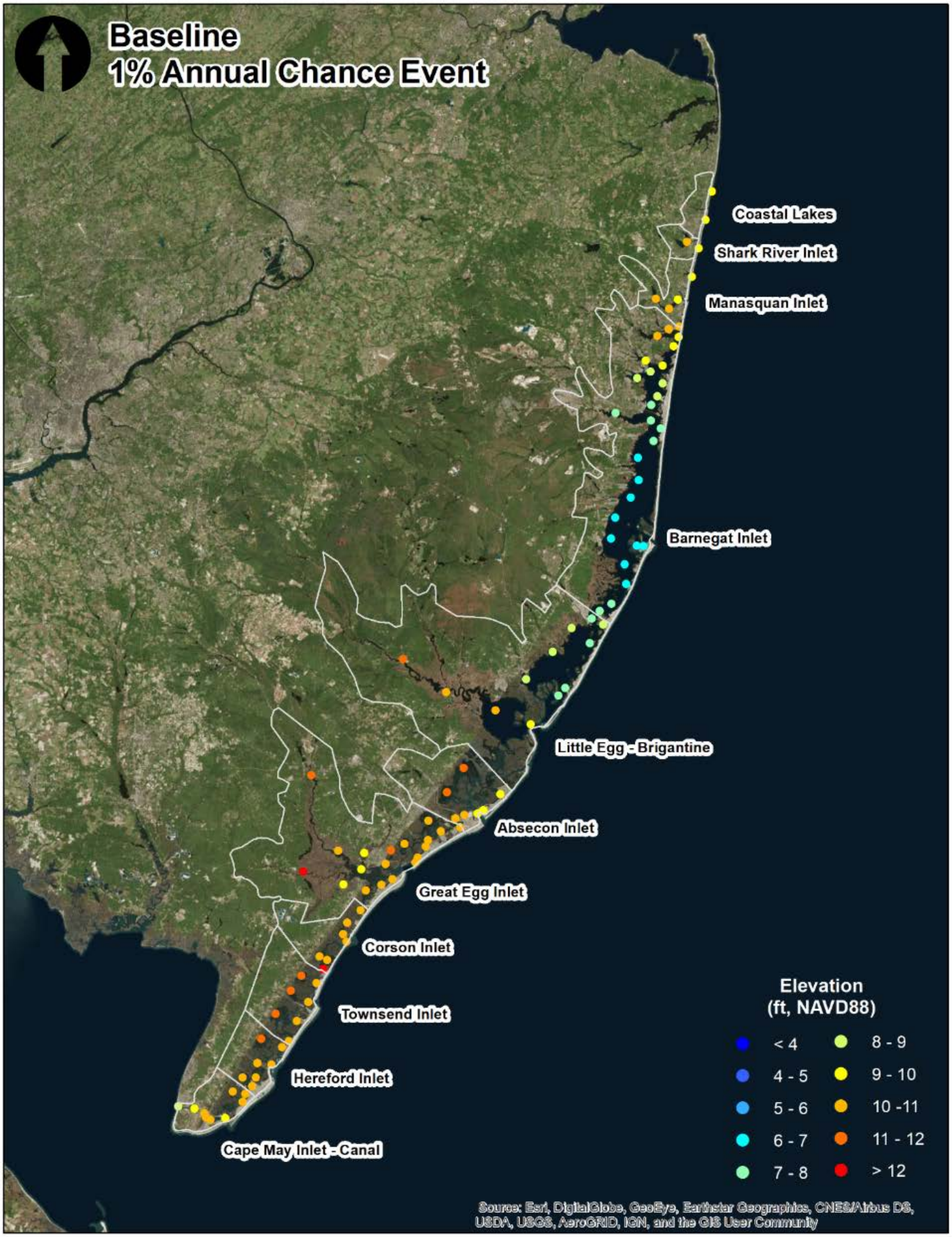


Figure 30: NACCS 1% ACE Water Level at HEC-FDA Stations

Hydraulic Reaches

The ACE water levels throughout the study area separated by Hydraulic Reach (shown Figure 11) and represented by a typical station in Table 16. The variability in water levels within hydraulic reaches is captured by


Baseline
1% Annual Chance Event

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure *30*, which shows a map of the 1% ACE water levels, and Figure 31 and Figure 32 which show the ACE curves at all of the 182 save points within each hydraulic reach, as well as the station listed in Table 16 in red. It is apparent from these tables and figures that the back bay ACE water levels are relatively homogenous, except for Barnegat Bay where the ACE water levels are 1 to 3 feet lower.

Table 16: Water Level ACE at Hydraulic Reaches

Location	**Save Point**	**Hydraulic Reach**	**Return Period (years)**					
			1	**10**	**20**	**50**	**100**	**500**
			Annual Chance Event					
			100%	**10%**	**5%**	**2%**	**1%**	**0.2%**
Cape May	15566	Cape May Inlet - Canal	3.9	7.1	7.9	9.2	10.4	12.9
Wildwood	11282	Hereford Inlet	4.0	7.4	8.1	9.2	10.5	13.5
Avalon	13470	Townsend Inlet	3.9	6.9	7.7	9.2	10.6	14.0
Strathmere	7531	Corson Inlet	4.1	7.0	7.8	9.2	10.4	13.9
Ocean City	11309	Great Egg Inlet	4.2	6.9	7.7	9.2	10.3	13.2
Atlantic City	11356	Absecon Inlet	4.1	6.9	7.7	9.1	10.3	12.8
Mystic Island	11273	Little Egg-Brigantine	4.2	7.0	7.9	9.3	10.7	13.4
Lavallette	13694	Barnegat Inlet	2.9	5.2	6.1	7.6	8.8	11.2
Point Pleasant	13716	Manasquan Inlet	4.0	6.4	7.2	8.7	9.9	12.0
Belmar	13721	Shark River Inlet	4.3	7.2	8.1	9.3	10.3	12.3
Asbury Park	3742	Coastal Lakes	4.0	6.6	7.3	8.4	9.6	12.6

Note: All elevations are in feet NAVD88, relative to NTDE (1983-2001)

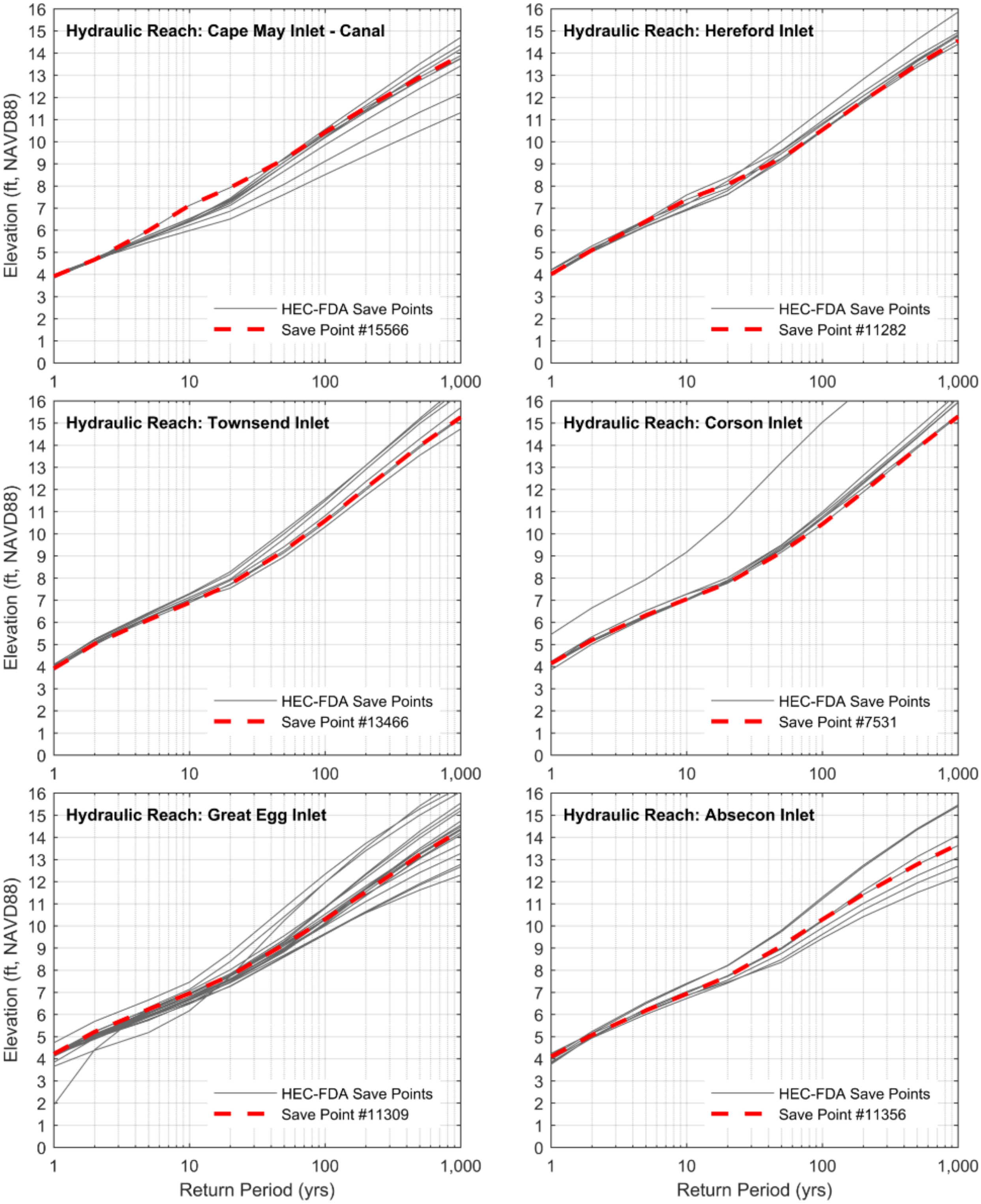


Figure 31: NACCS: Cape May Inlet to Absecon Inlet

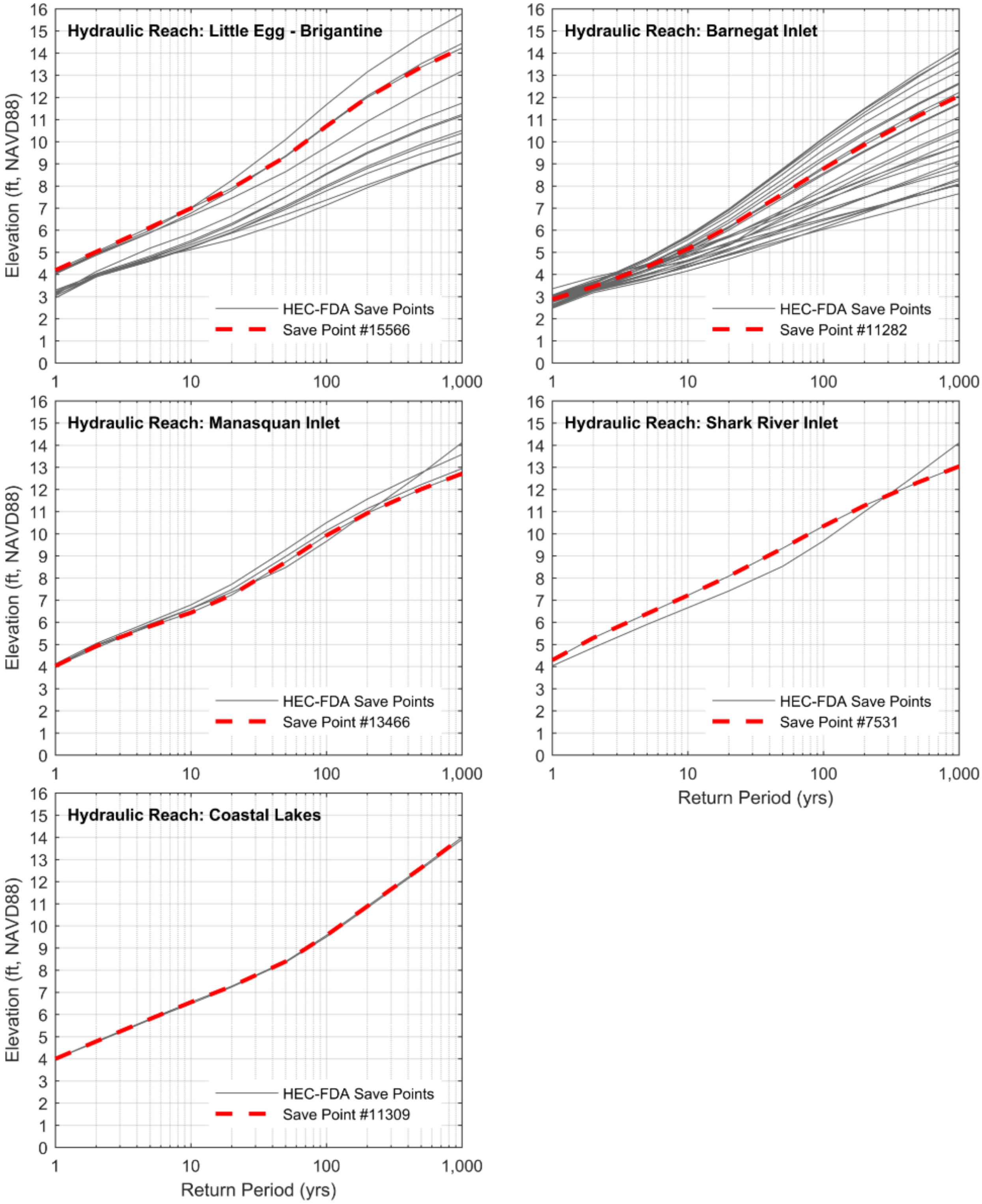


Figure 32: NACCS: Little Egg to Coastal Lakes

Storm Surge Barrier Modeling

Approach to Storm Surge Barrier Modeling

Due to the complex network of inlets and bays that control the flow of water between the ocean and back bays, NAP requested assistance from ERDC-CHL in evaluating the effectiveness of inlet closures in reducing water levels in the NJBB study area. More specifically, NAP wanted help determining how much inlet closures reduce back-bay flooding? How effective inlet closures are at reducing water levels if other inlets are open and if multiple inlet closures could work as system? To answer these questions ERDC-CHL leveraged the existing NACCS CSTORM-MS. The Draft Interim Report provides a detailed description of the storm surge modeling effort and discussion of the modeling results.

An iterative modeling approach was devised that would allow a large number of inlet closures and potential inlet closure combinations to be considered before converging on a smaller final set of inlet closure alternatives. The iterative modeling approach begins with model simulations of one inlet closure at a time to improve understanding of the hydraulic influence of each inlet. The second iteration evaluated a large number of possible inlet closure combinations, before moving on to the final iteration of a smaller final set of alternatives. Model simulations for the final set of alternatives is used to develop frequency distributions of peak water levels that may be applied in economic analyses of flood damages. The iterative modeling approach is made feasible by utilizing a very small subset of 10 extreme cyclones for Iterations 1 and 2. A more robust set of 60 tropical cyclones was selected for Iteration 3 in order to develop the frequency distributions.

Iteration 1 - Model the hydraulic influence of each barrier island inlet by modeling one inlet at a time.

Iteration 2 - Model the effectiveness of large set of possible inlet closure combinations.

Iteration 3 - Model the effectives of final set of inlet closure alternatives and develop frequency distributions of peak water levels.

Workshops with the CHL, the NJBB Project Delivery Team (PDT), and non-Federal sponsor (NJDEP) were held on January 31, 2018 and April 13, to review the model results from Iteration 1 and Iteration 2 and selected the closure configurations to be brought forward in the study. Many of the closure configurations for Iteration 2 are designed around leaving the most environmentally sensitive inlets open: Little Egg/Brigantine, Corson, and Hereford. Closures across the interior bays “bay closures” are added to several configurations to reduce water levels where environmental sensitive inlets open. The study area was also broken up into 3 regions (north, central, and south) based on the relative hydraulic independence of the configurations identified for these regions. Since many of the configurations are designed around leaving Little Egg and Corson inlets open, these two inlets were natural boundaries for the three regions.

Summary of Storm Surge Barrier Model Results

A detailed discussion of the storm surge barrier modeling results is provided in Draft Interim Report. Only a summary of modeling results is provided here.

Iteration 1 focused on the ability of individual surge barriers to alter maximum water levels compared to a base condition with no closures in place. It was found that individual closures can reduce back bay flooding, mainly in the bays closest to the closure location, but adjacent inlets may allow flow into the bay then water level reductions can be less significant. Individual storm surge barriers at Great Egg Inlet, Barnegat Inlet, and Shark River Inlet were most effective. Individual storm surge barriers from Cape May to Corson Inlet were not as effective and would perform better as part of system of storm surge barriers. A storm surge barrier at Manasquan Inlet was effective for storms where the predominate wind direction was south, however, storms with winds from the south could push storm surge north into Barnegat Bay and Manasquan limiting the barriers effectiveness.

Iteration 2 focused on evaluating systems (multiple) of storm surge barriers including cross-bay storm surge barriers ("bay closures"). Many of the storm barrier alternatives were designed around leaving the most environmentally sensitive inlets open: Little Egg/Brigantine, Corson, and Hereford. The numerical modeling results show that many of the Iteration 2 alternatives are effective at reducing back bay water levels. However, some of the alternatives such as All Closures Less 2 showed considerable sensitivity to the storm and wind directions and it was unclear what the impact would be on the hazard curve. Iteration 2 also showed that many of the bay closures have the potential to increase surge on the unprotected side of the closure as wind-blown water piles up against the closure. Increases in surge were not limited to the immediate vicinity of the closure and significant impacts may be felt 5 to 10 miles away.

Figure 33, Figure 34, and Figure 35 show the modeling results for three storm surge barrier alternatives, All Closures and All Closures Less 2, and C3, respectively. The All Closures Less 2 alternative has storm surge barriers at all the inlets except Little Egg and Corson inlets. C3 has storm surge barriers at Great Egg Inlet, Absecon Inlet, and a bay closure north of Brigantine.

Iteration 3 focused on the 8 alternatives identified during the April 13, 2018 workshop with the CHL, the NJBB Project Delivery Team (PDT), and non-Federal sponsor (NJDEP). These 8 alternatives were selected based on their ability to generate the greatest NED benefits (flood damages reduce minus project costs) and be environmentally acceptable. Several alternatives were included that are not likely to be environmentally acceptable to ensure that alternatives were not eliminated too early before a more thorough plan formulation evaluation is applied.

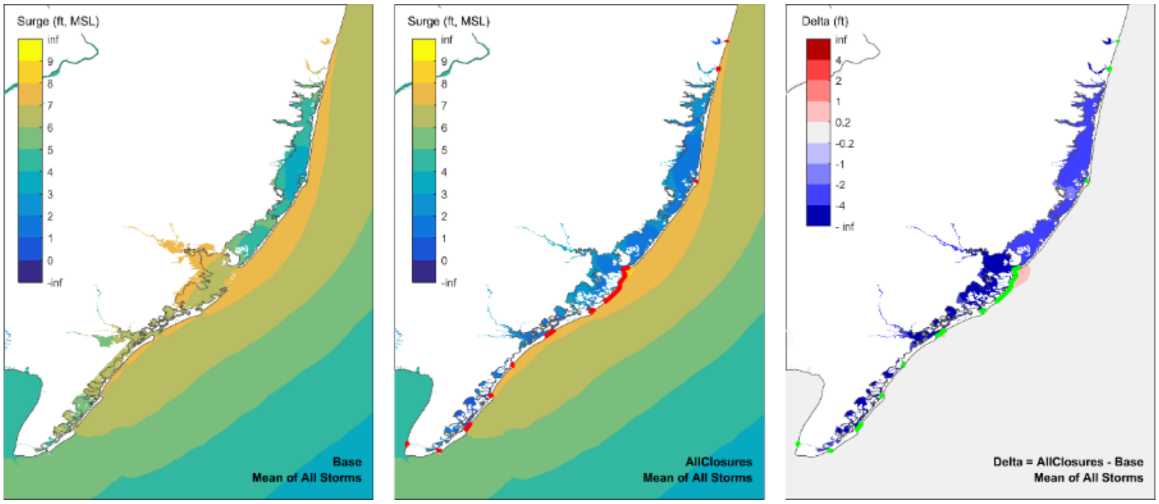


Figure 33: CSTORM Model Results – All Closures

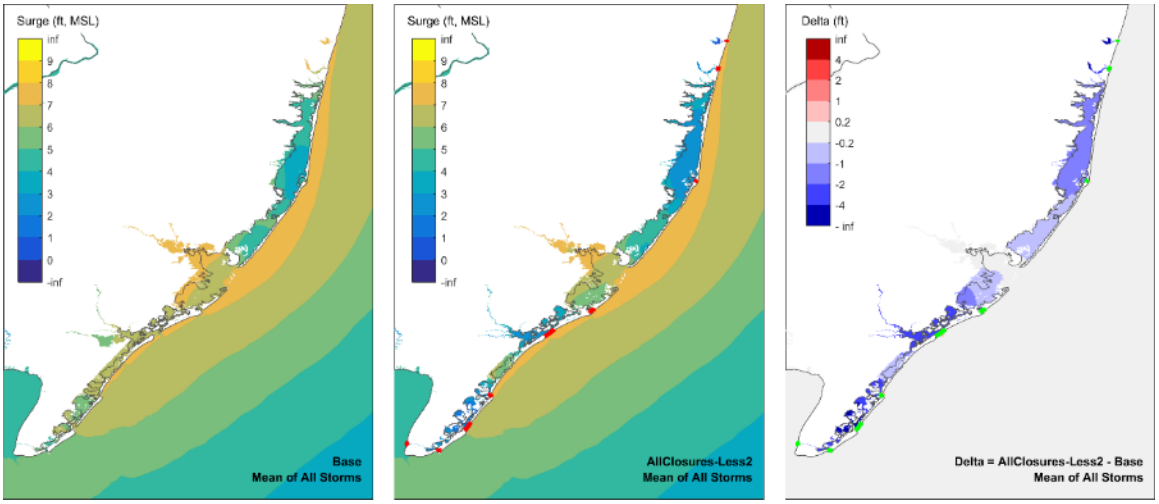


Figure 34: CSTORM Model Results – All Closures Less 2

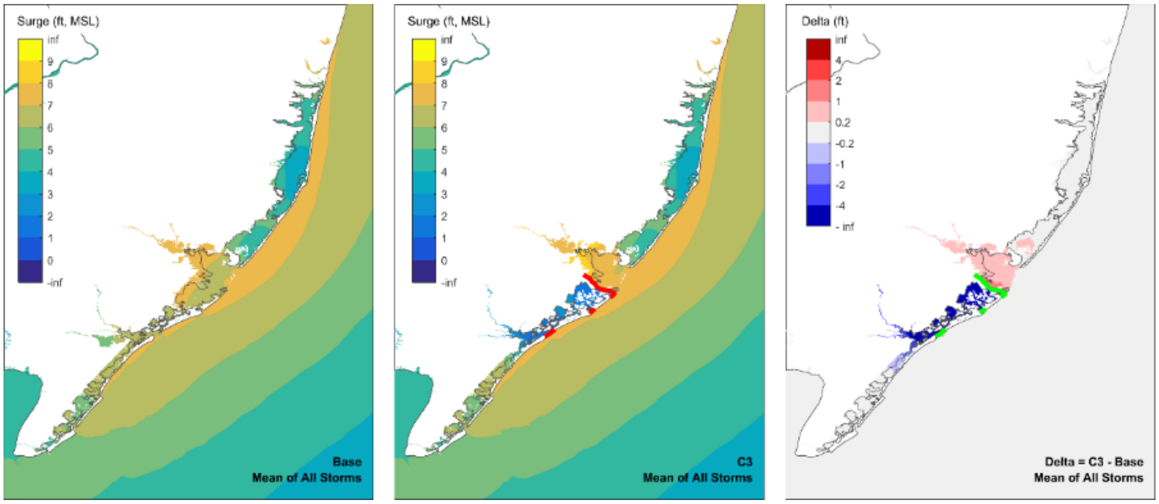


Figure 35: CSTORM Model Results – C3

Hazard curves were generated for the Iteration 3 alternatives based on simulations for storm suite of 60 tropical cyclones. An example of the hazard curves at three locations (Figure 36) for Baseline, All Closures, and All Closures Less 2 alternatives is provided in Figure 37. The Baseline and All Closures hazard curves may thought of as bracketing the possible performance of other storm surge barrier alternatives. Less effective storms surge barrier alternatives have hazard curves close to the Baseline curve and more effective storm surge barrier alternatives have hazard curves close to the All Closures curve. Figure 37 shows that the performance of All Closures Less 2 varies within the study area. At some locations like Ocean City the performance of All Closures Less 2 is similar to All Closed, and other areas like Lavallette, closer to open inlets, the performance is more similar to the Baseline conditions.

A 1 or 2 foot reduction in storm surge may not seem significant, but a 2 foot reduction in storm surge at Lavallette may be the difference in a 6 foot (NAVD88) storm surge event being a 100-year event versus a 20-year event. It is unclear until the economic model is completed if a 1 or 2 foot reduction in water level in places like Barnegat Bay will translate into a significant reduction in damages. The purpose of Iteration 3 was to generate the water level hazard curves that may be applied in HEC-FDA to calculate benefits.

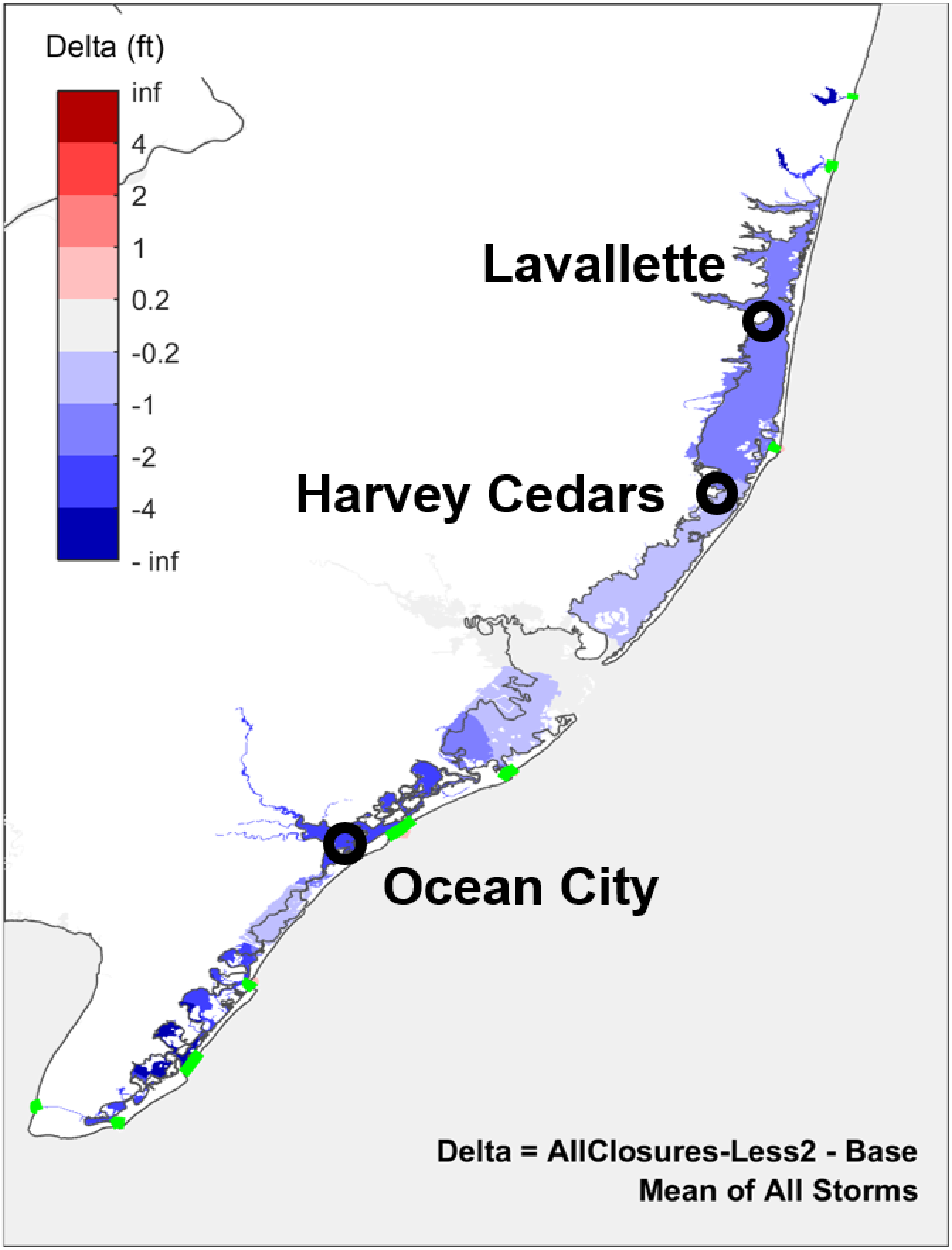


Figure 36: CSTORM Model Results – All Closures Less 2 (Delta)

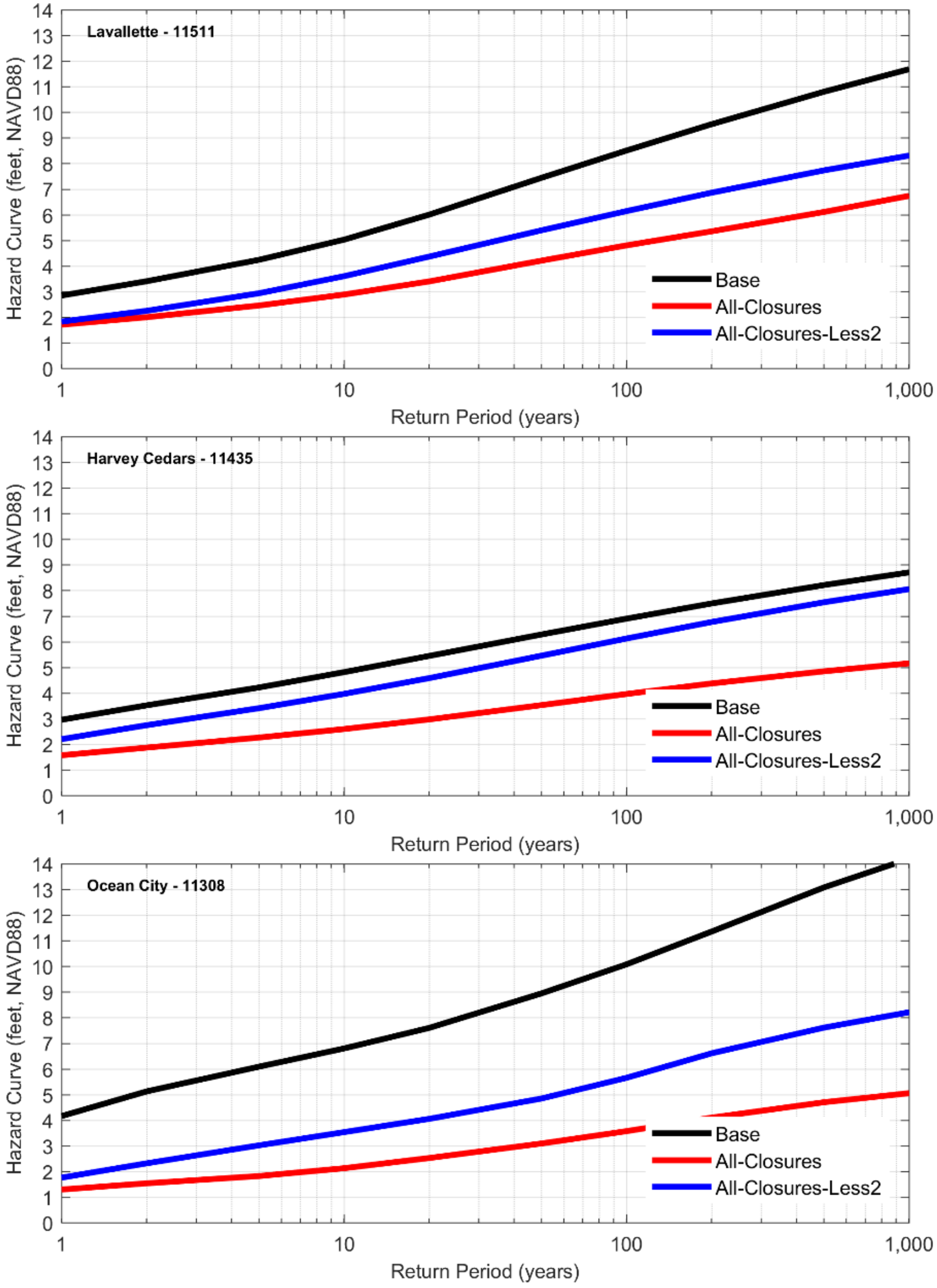


Figure 37: Hazard Curves

Impact of Storm Surge Barriers on Ocean-Facing Beaches

Modeling results show that the storm surge barriers may cause an increase in water levels in the immediate vicinity of the storm surge barrier. Beyond a distance of 1 mile of the storm surge barrier no discernable (less than 1 inch) increase in water levels was observed. Figure 38 shows a comparison of the peak surge in the baseline conditions, All Closures Less 2 alternative, and the difference between All Closures Less 2 and the baseline conditions. An increase in ocean water levels of 6 to 12 inches is observed at the storm surge barrier, and increase of 2 to 6 inches within ½ mile of the barrier, and 1 to 2 inches within 1 mile of the barrier. It is noted that the values reported here and shown in Figure 38 are based on mean of all 10 tropical storms in NJBB Iteration 1 and 2 storm suites, and increase, proportionally, with stronger storms. Further investigation of the impact of the storm surge barriers on ocean-facing beaches will be performed in the next phase of the study.

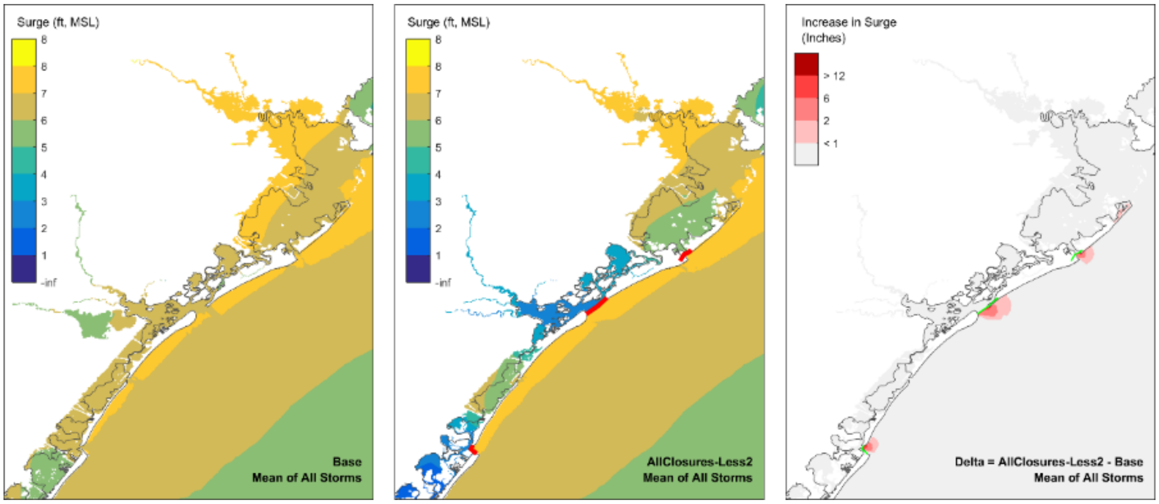


Figure 38: Impact of Storm Surge Barrier on Ocean-Facing Beaches

Wave Overtopping

Overview

Wave overtopping is of principal concern for structures constructed for flood risk management. The design crest elevation of flood risk management structure is often determined by the design still water level and required freeboard, height above still water level, to prevent wave overtopping from damaging the structure during the design storm event.

EurOtop (2016) describes wave overtopping as:

> *Overtopping discharge occurs because of waves running up the face of a seawall or dike. If wave run-up levels are high enough water will reach and pass over the crest of the structure. This defines the 'green water' overtopping case where a continuous sheet of water passes over the crest. In cases where the structure is vertical, the wave may impact against the wall and send a vertical plume of water of the crest. A second form of overtopping occurs when waves break on the seaward face of the structure and produce significant volumes of splash 'whitewater'. These droplets may then be carried over the wall either under their*

own momentum or as a consequence of an onshore wind.

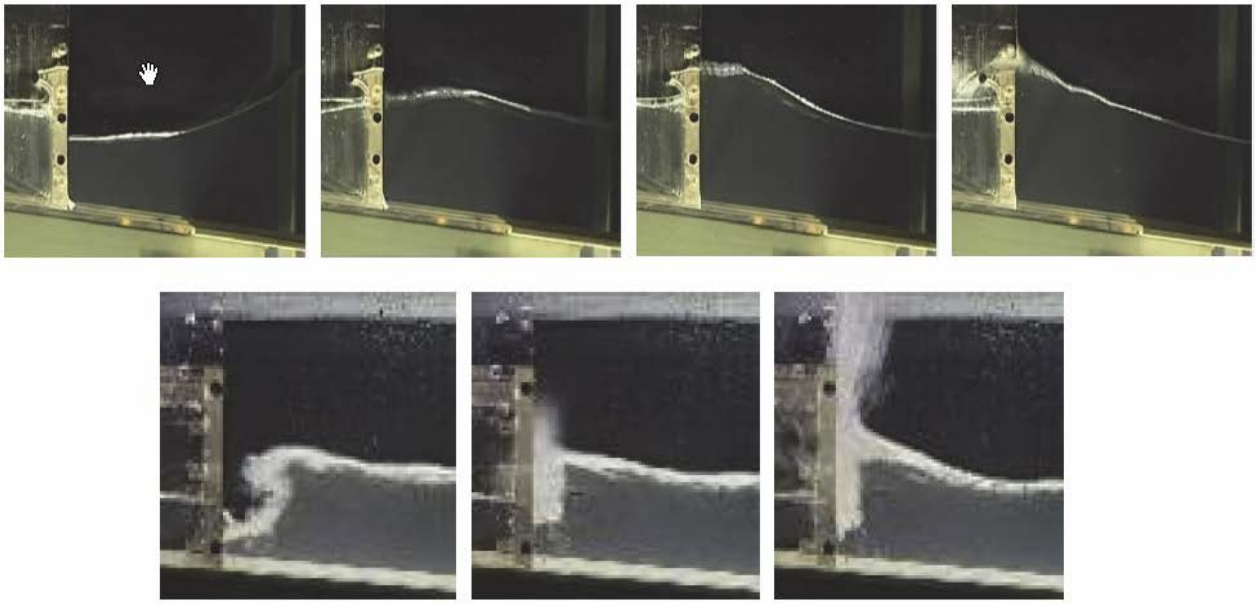


Figure 39: Wave Overtopping at Vertical Wall (EurOtop, 2016)

The top panel and bottom panel of Figure 39 show an example ‘green water’ and ‘white water’ overtopping at a vertical structure respectively.

The wave overtopping rate, q, reported in this study is the mean overtopping discharge (liters/s/m). In actuality wave overtopping occurs in sporadic short pulses and is not constant over time. It is coastal engineering practice to use mean wave overtopping rates in engineering applications since available design formulas are based on the mean overtopping rate due to its ability to be easily measured in laboratory studies.

Wave Conditions

Wave conditions in the NJBB study area are fetch-limited waves generated by local wind conditions. In fetch-limited conditions, wave heights are limited by the distance of open water in which the waves are able to grow. Wave conditions throughout the bay are also affected by the shallow water depths, marshes and orientation relative to the wind directions. A sampling of the 100-year wave conditions at 11 representative locations throughout the study area is provided in Table 17.

In the design or assessment of coastal structures with respect to wave overtopping, the two primary hydraulic parameters (water level and wave height and wave period) may be derived from a joint probability analysis (EurOtop, 2016). If both water level and wave height are determined for a certain return period, then the wave overtopping discharge for the combination of these extreme conditions will be larger than the actual wave overtopping occurring with the return period (EurOtop, 2016). This is caused by the fact that the combination of these two extreme values will have a lower probability of occurrence if the two are not fully correlated (EurOtop, 2016).

The “H_{m0} – Joint” and “Tp – Joint” columns in Table 17 represent the joint probability or most likely wave height and wave period associated with the 1% ACE water level event. The joint probability of the wave height and water levels was determined from time series of NACCS model results at each of the representative stations. The maximum wave height within 1 hour of the maximum water level was identified from the time series. Scatter plots showing the relationship between the peak water level and wave height is presented in Figure 41 to Figure 43. These figures also show the relationship between the wave height and wave period associated with the peak water levels. A 2nd order polynomial curve was fit to the scatter data to obtain the joint probability relationship. The still water elevations applied in the wave overtopping analysis are based on the original NACCS model results, which were available at the time of the wave overtopping analysis, before the storm surge modeling modifications for NJBB.

Table 17: Representative Wave Conditions, Joint Probability for 1% ACE

Station	**ID**	**SWEL (ft, NAVD88)**	**H_{m0} (ft)**	**H_{m0}-Joint (ft)**	**Tp-Joint (s)**
Cape May	15566	9.0	3.8	3.0	3.1
Wildwood	11282	9.1	3.5	2.7	3.7
Ocean City	11309	9.4	3.6	2.2	3.2
Somers	11230	9.5	3.7	3.1	3.4
Atlantic City	13554	8.8	3.5	2.1	3.2
Beach Haven	11399	7.2	4.2	2.7	3.4
Tuckerton	11444	7.5	4.7	3.8	4.2
Lavallette	11511	7.2	3.3	2.0	3.3
Island Heights	13684	7.0	3.5	1.9	3.4
Mantoloking	13706	8.0	3.4	1.7	2.8
Manasquan	13711	9.2	3.4	1.9	2.7

Notes: Still Water Elevation (SWEL), Joint probabilities values shown based on curve fit. SWEL values are from the original NACCS model results.

A joint probability analysis was not conducted at the storm surge barrier locations at inlets, as it is assumed at this stage of the study that the 1% ACE water level and wave event occur simultaneously. A representative design wave height of 12 feet and wave period of 12 seconds is used in the analysis based on available NACCS wave data near the location of the storm surge barriers at inlets. A single representative wave condition is applied to all the inlet closures at this phase of the study, however detailed modeling will be performed in subsequent phases of the modeling to determine the design wave conditions at each storm surge barrier location.

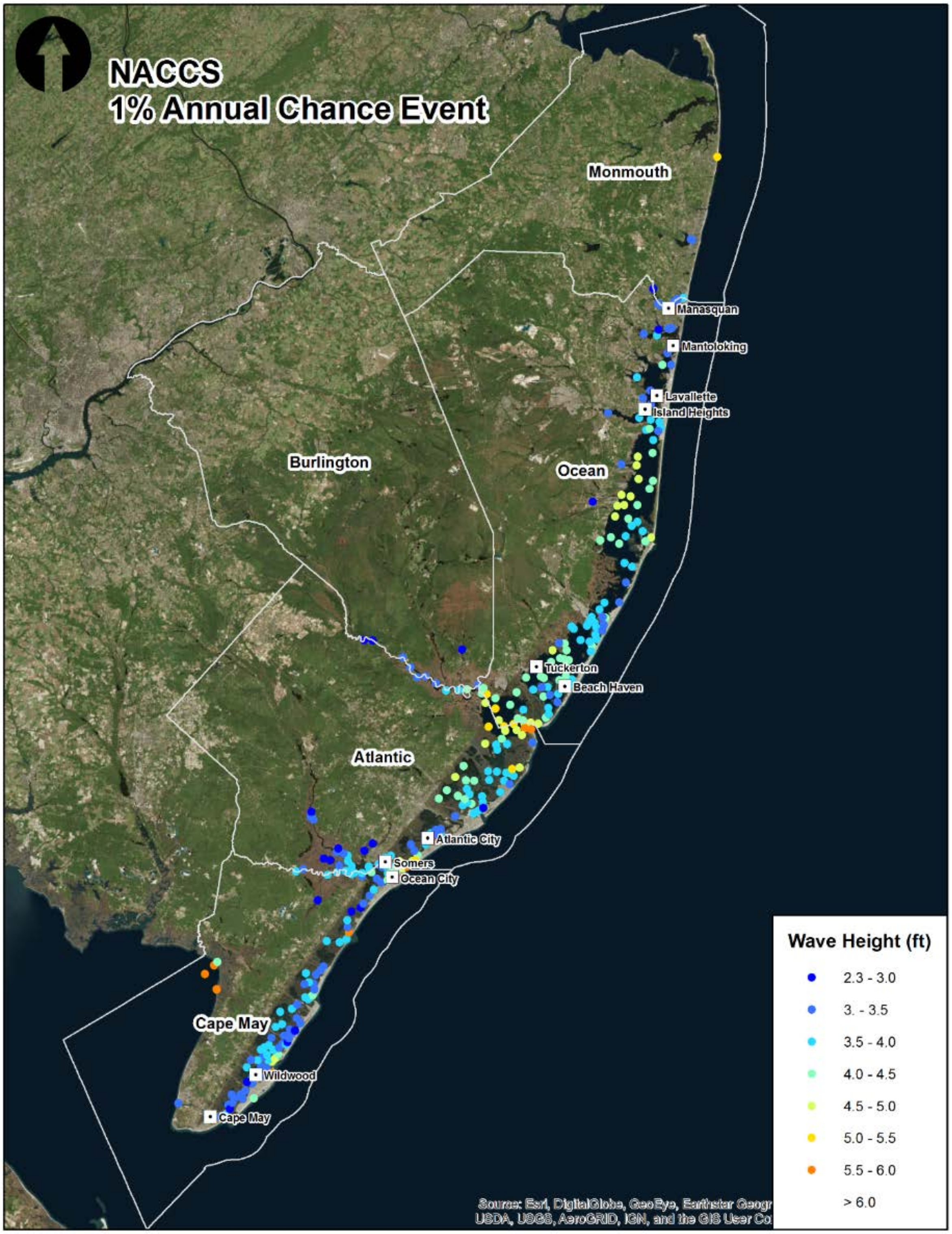


Figure 40: NACCS 1% ACE Peak Wave Height and Representative Stations

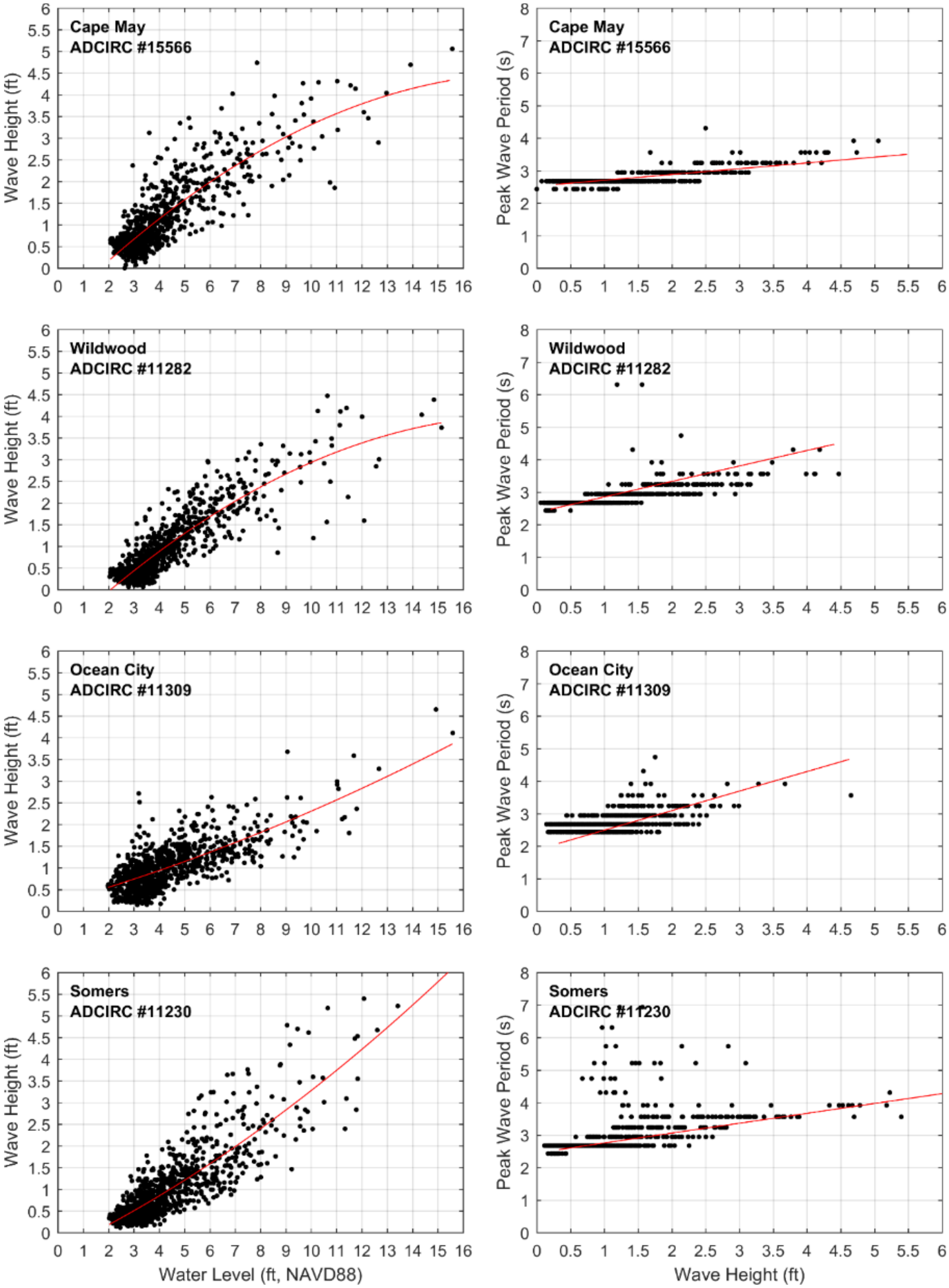


Figure 41: Joint Wave Probability, Cape May to Somers

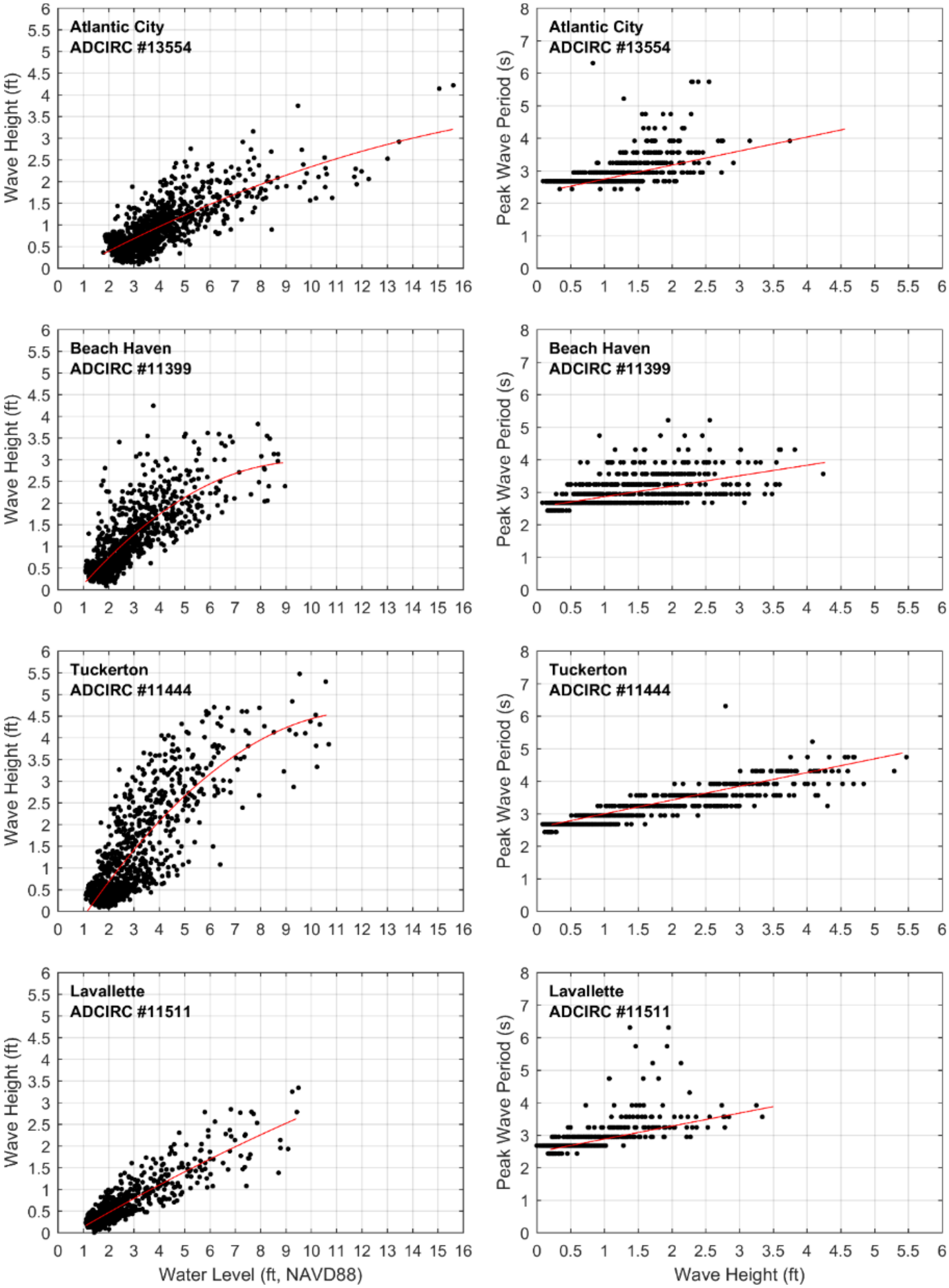


Figure 42: Joint Wave Probability, Atlantic City to Lavallette

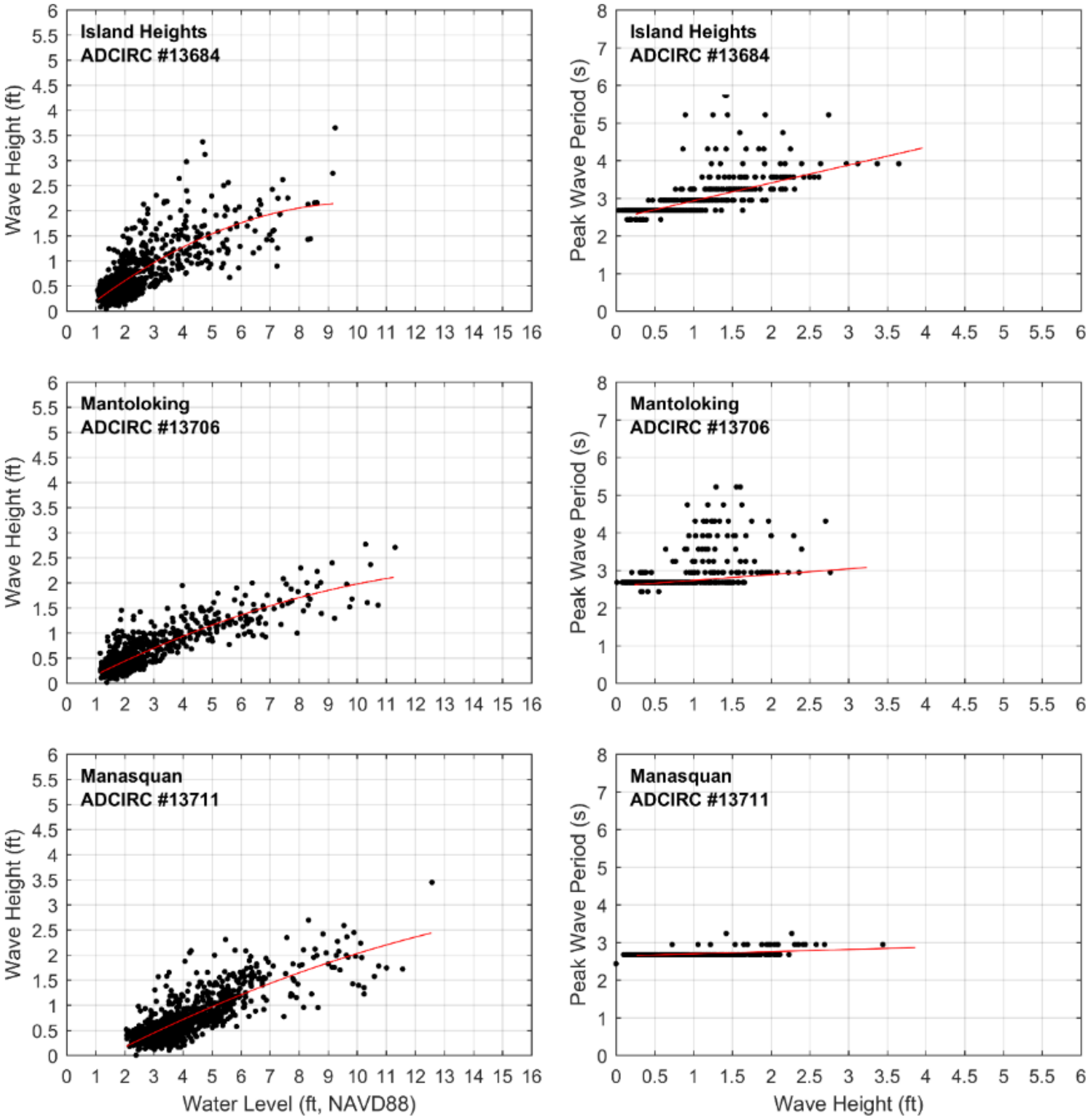
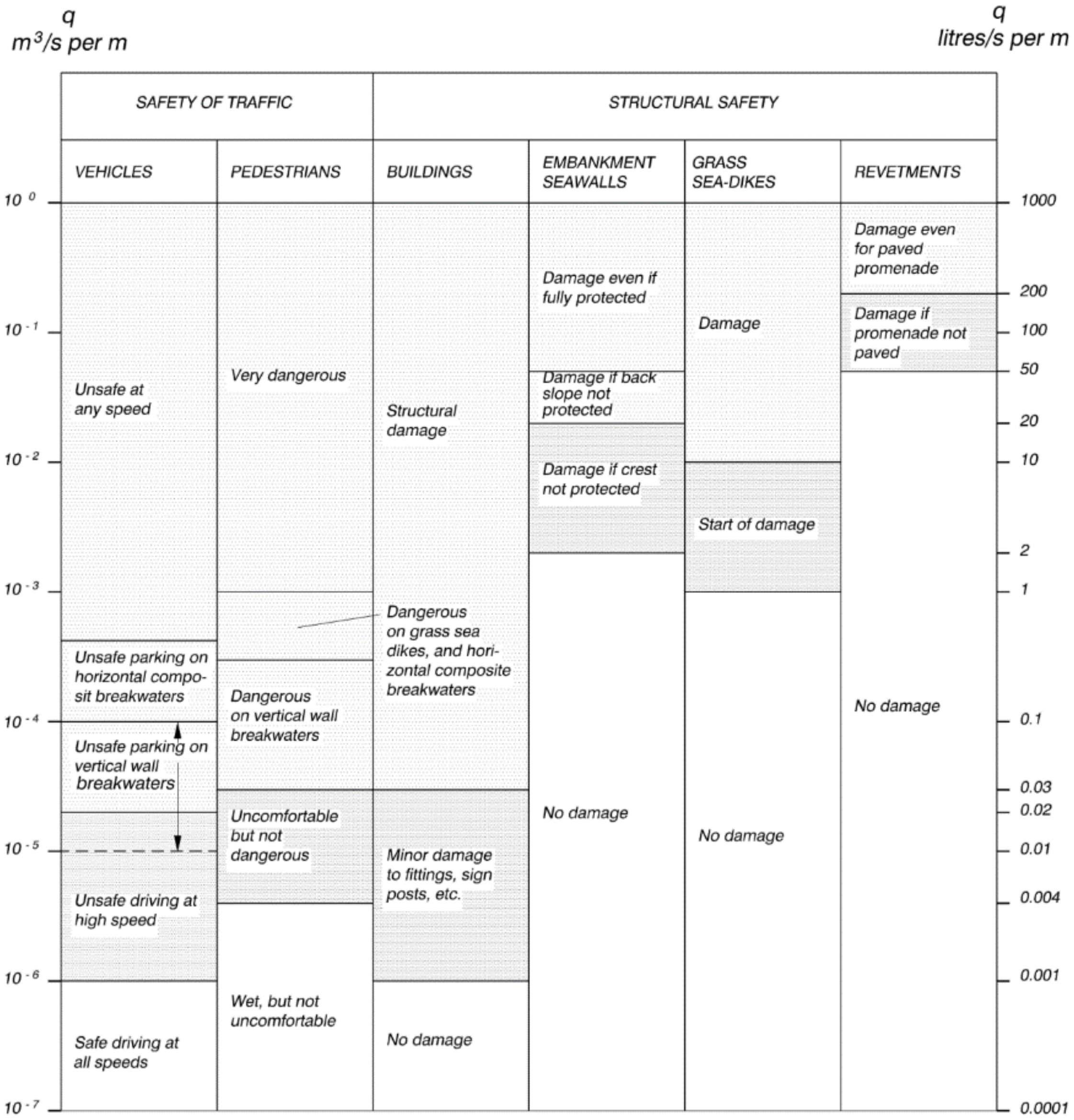


Figure 43: Joint Wave Probability, Island Heights to Manasquan

Tolerable Wave Overtopping Rates

Floodwalls that are exposed to heavy wave overtopping for many hours are susceptible to structural failure (Goda, 2000). Therefore, floodwalls are often designed to limit wave overtopping below a tolerable overtopping rate based on the structure type, property and operation, and people and vehicles. EM 1110-2-1100 provides guidelines for critical mean wave overtopping rates of several structure types before the structure begins to exhibit damage which may eventually lead to structural failure. Based on available literature including European and United States reference documents including Table 18, a tolerable mean wave overtopping rate of 50 liters/s/m is selected for floodwalls, rubble slopes (armored levees), and bay closures in the NJBB study. A tolerable mean wave overtopping rate of 200 liters/s/m is selected for storm surge barriers located at inlets. During the next phase of the study the tolerable wave overtopping rate for structures adjacent infrastructure and buildings will be revaluated, and possibly lowered, to reduce the potential for localized damage and safety hazards associated with wave overtopping.

Table 18: Tolerable Values of Mean Wave Overtopping (EM 1110-2-1100)



EurOtop (2016) and EM 1110-2-1100 highlight the importance of peak wave overtopping from a single wave on tolerable wave overtopping values. Overtopping discharge from a single wave can be more than 100 times the mean overtopping discharge during the storm peak (EM 1110-2-1100) and is often responsible for structural damages. Peak wave overtopping volumes have been shown to be strongly dependent on the wave height (EurOtop, 2016). For a given mean overtopping discharge, small waves only give small overtopping volumes, whereas large waves may give a much larger overtopping volumes for a single wave (EurOtop, 2016). In that sense mean tolerable overtopping rates should also be coupled to the wave height (EurOtop, 2016). Since the design wave conditions in the NJBB study area are relatively small the tolerable mean wave overtopping rate selected for this study should be considered conservative relative to higher wave energy environments.

Overtopping Formulas

Vertical Wall

Mean wave overtopping rates are calculated for vertical walls using empirical formulas provided by EurOtop (2016). Results from EurOtop are compared to Franco and Franco (1999) as described in EM 1110-2-1100 and Ward and Ahrens (1992). The primary parameters in all of these wave overtopping formulas are the crest freeboard (R_c) and wave height (H_{m0}) as shown in Figure 44. The water depth (h), slope of foreshore (1:m), and wave period are important parameters in shallow water.

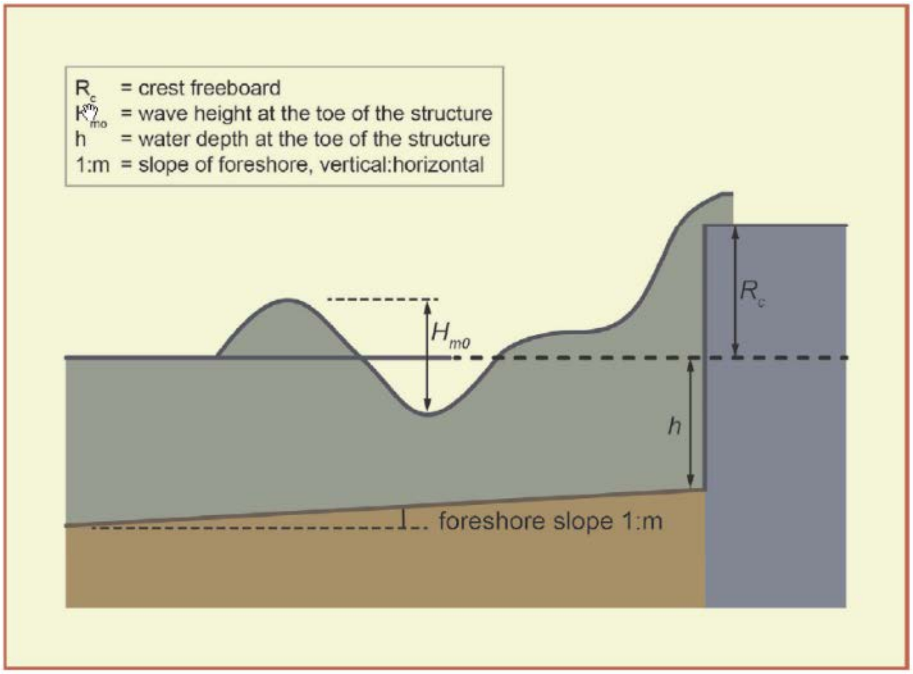


Figure 44: Wave Overtopping Parameters (EurOtop, 2016)

The five wave overtopping formulas for vertical walls evaluated here are:

- EurOtop equations 7.1 and 7.2 for non-impulsive wave conditions;
- EurOtop equations 7.5 and 7.6 for non-impulsive wave conditions with an influencing foreshore;
- EurOtop equations 7.6, 7.8, 7.9, and 7.10 for impulsive wave conditions;
- Franco & Franco (1999), Table VI-5-13 in EM 1110-2-1100;
- Ward & Ahrens (1992), Group 1 Seawalls.

The general equation for the empirical formulas are

$$Q = a\, exp[-(bR)^c]$$

where Q and R are the non-dimensional representation of the mean wave overtopping rate, *q*, and freeboard, R_c,

$$Q = \frac{q}{\sqrt{gH_{m0}^3}}\,, \qquad R = \frac{R_c}{H_{m0}}$$

and *a*, *b*, and *c* are constants. This general equation is used by Franco & Franco (1999) and the EurOtop formulas for non-impulsive (i.e. non-breaking) wave conditions. The empirical formulas for Ward and Ahrens (1992) and EurOtop formula for impulsive wave conditions follow this general form but also include parameters based on the water depth, slope of foreshore, and wave period. A comparison of three EurOtop formulas are shown in Figure 45, where the strong dependence of wave overtopping on the relative freeboard is shown. It is apparent from Figure 45 that under small relative freeboard conditions, $R_c/H_{m0} < 1$, the three wave overtopping formulas produce similar results. As the relative freeboard increases the impulsive wave (breaking wave) conditions produce higher rates of wave overtopping and the impact of the foreshore becomes more significant.

The EurOtop Manual provides two sets of formulas, the “Mean value approach” and “Design or assessment approach”. The mean value approach should be used to predict or compare with test data and the design or assessment approach includes a partial safety factor with one standard deviation above the mean value approach. The difference between the approaches is shown in Figure 46 for non-impulsive wave conditions.

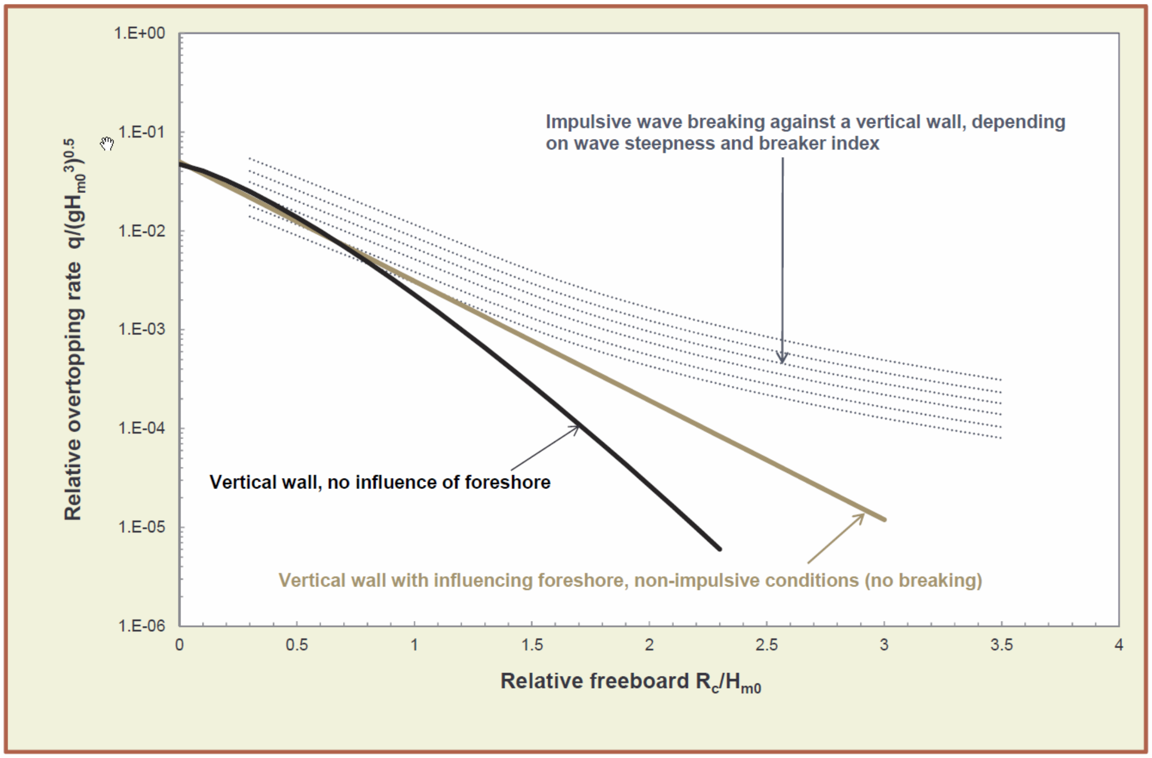


Figure 45: Non-dimensional Overtopping and Freeboard (EurOtop, 2016)

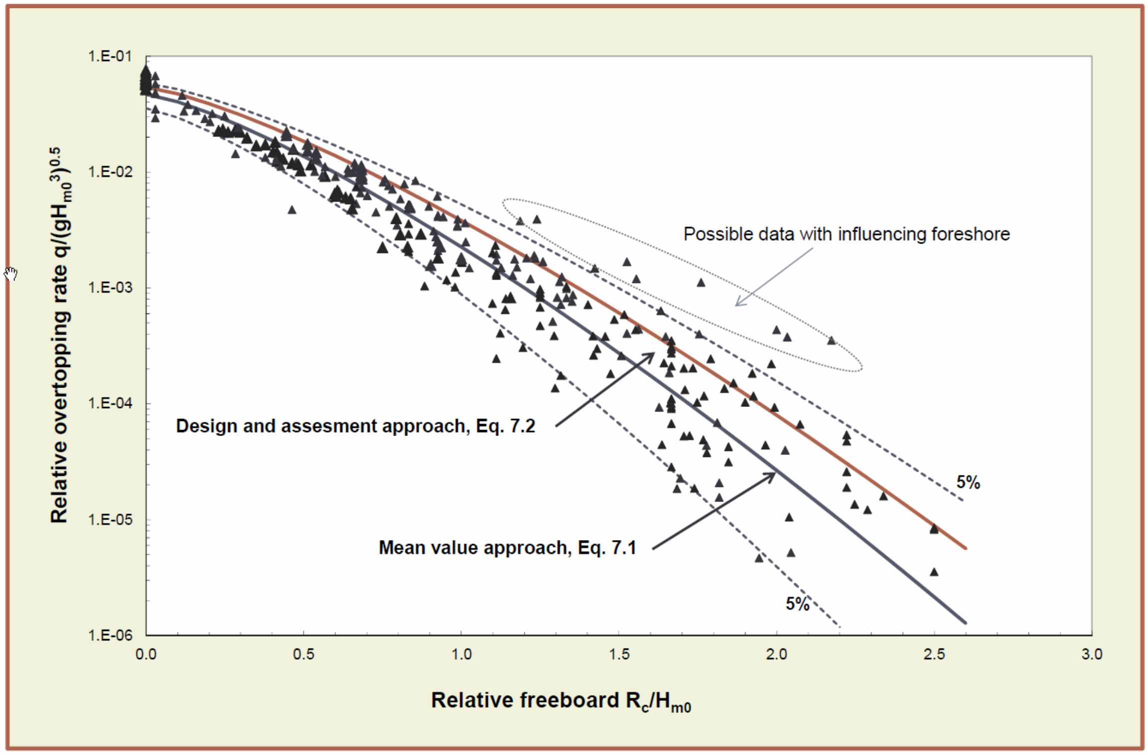


Figure 46: Mean Value and Design Approaches (EurOtop, 2016)

Rubble Slope

The primary focus of the wave overtopping analysis is on vertical walls (i.e. floodwalls) since they are the primary measure under consideration in the Perimeter Plan. However, there are some locations where a rubble slope (i.e. armored levee) is more appropriate and economical. Mean wave overtopping rates are calculated for rubble slopes using empirical formulas provided by EurOtop (2016). The general formula for the rubble slope is the same as the vertical wall with other influence factors that account for roughness associated with the armor stone, oblique wave attack, crest berm, composite slopes, and wave wall at crest. EurOtop (2016) provides a formula for the “Mean value approach” and “Design or assessment approach”.

Comparison of Formulas

Due to the size of the study area, there will be considerable variability in the local site conditions, such as the wave conditions, water depth, and foreshore slope. Rather than perform a detailed analysis at every site, several representative sites are selected throughout the study area and the sensitivity to the wave overtopping formulas is evaluated. This approach provides confidence in the results and a deeper understanding of the most important parameters governing wave overtopping in the study area.

Three sets of wave conditions are evaluated:

- Wave Height = 1 m, Wave Period = 4 s, Water Depth = 3m;
- Wave Height = 2 m, Wave Period = 8 s, Water Depth = 3m;
- Wave Height = 4 m, Wave Period = 12 s, Water Depth = 10m;

The first set of wave conditions are fairly representative of the design wave conditions found in the NJBB study area. The second set of wave conditions are included to illustrate how the results are affected by the wave conditions. The third set of wave conditions is representative of the conditions at the storm surge barriers located inside the tidal inlets. Figure 47 and presents the wave overtopping results on a vertical wall for the first two wave conditions over a range of freeboard heights in terms of the relative wave overtopping and relative freeboard. Figure 48 presents the wave overtopping results for the third wave condition, representative of the wave conditions at the storm surge barriers.

In order to provide context to the non-dimensional figures, the tolerable wave overtopping rate of 50 liters/s/m, as well as 5 liters/s/m, is plotted in Figure 47. The intersection of the wave overtopping formulas and tolerable rate of wave overtopping represents the relative freeboard, R_c/H_{m0}, required to limit wave overtopping below this tolerable rate. For the 1 meter wave height conditions, a relative freeboard of about 0.5 is required to limit wave overtopping below 50 liters/s/m for all the formulas except Ward & Ahrens, which requires a higher freeboard. Said differently, the freeboard must be equal to or greater than one half the wave height. For the 2 meter wave height conditions a relative freeboard of 0.8 is required to limit wave overtopping below the tolerable rate.

It is apparent from this analysis that the required relative freeboard for a vertical wall is not very sensitive to the wave overtopping formula, especially in the 1 meter waves, with the exception of Ward & Ahrens. Ward & Ahrens based their formula on physical lab experiments with impulsive wave conditions with wave heights generally greater than 2m and wave periods between 8 and

12 seconds. Therefore, the Ward & Ahrens formula is better suited for larger wave conditions not found within the NJBB study area. It can be seen from Figure 47 that Ward & Ahrens produce similar results to the impulsive EurOtop formulas for the 2 meter wave conditions within the 50/liter/s/m to 5/liters/s/m overtopping range.

Wave overtopping for the rubble slope (solid blue line) is very similar to vertical walls and it is expected that the required relative freeboard will be similar between the vertical wall and rubble slope.

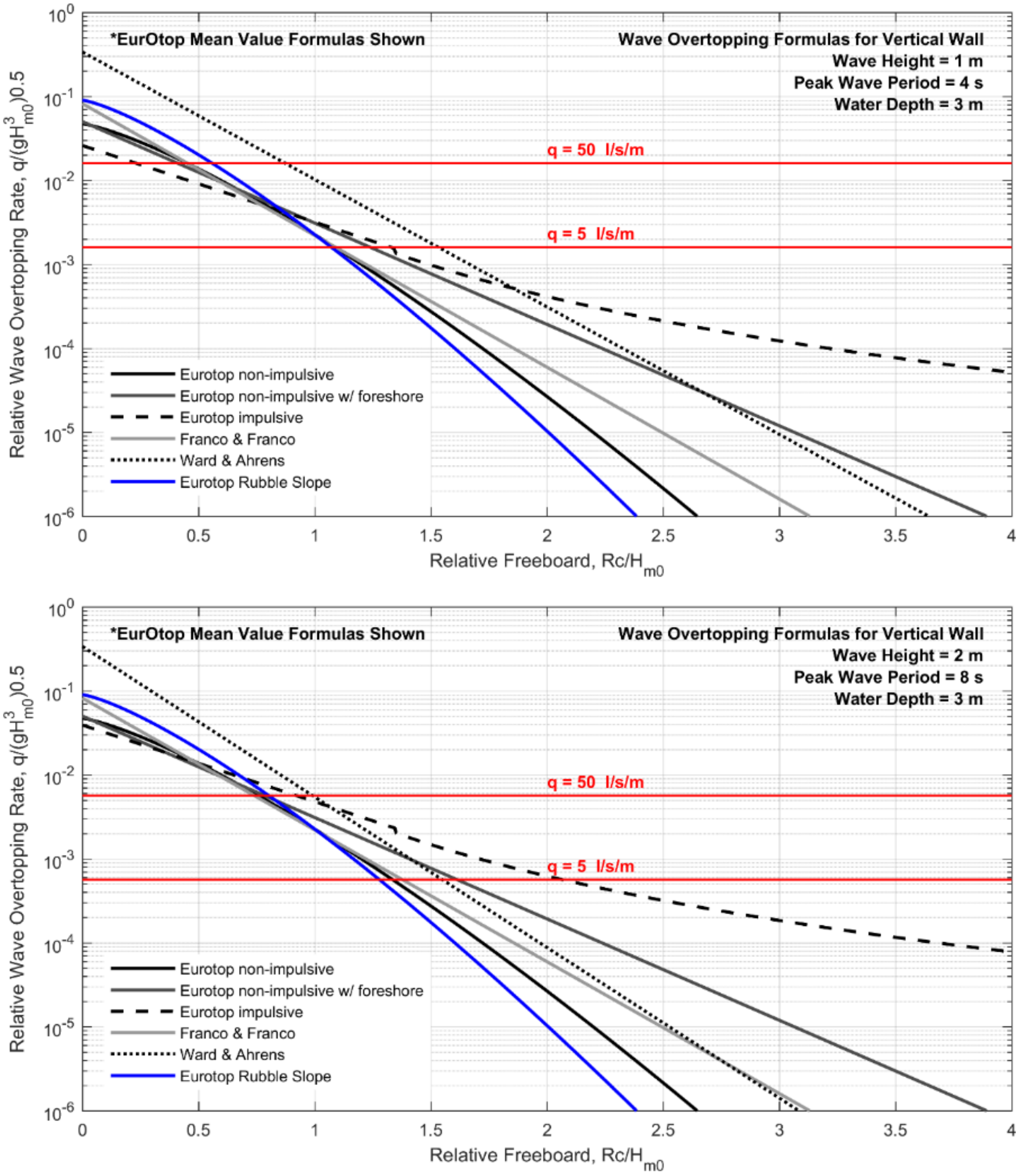


Figure 47: Wave Overtopping Formulas for Vertical Wall

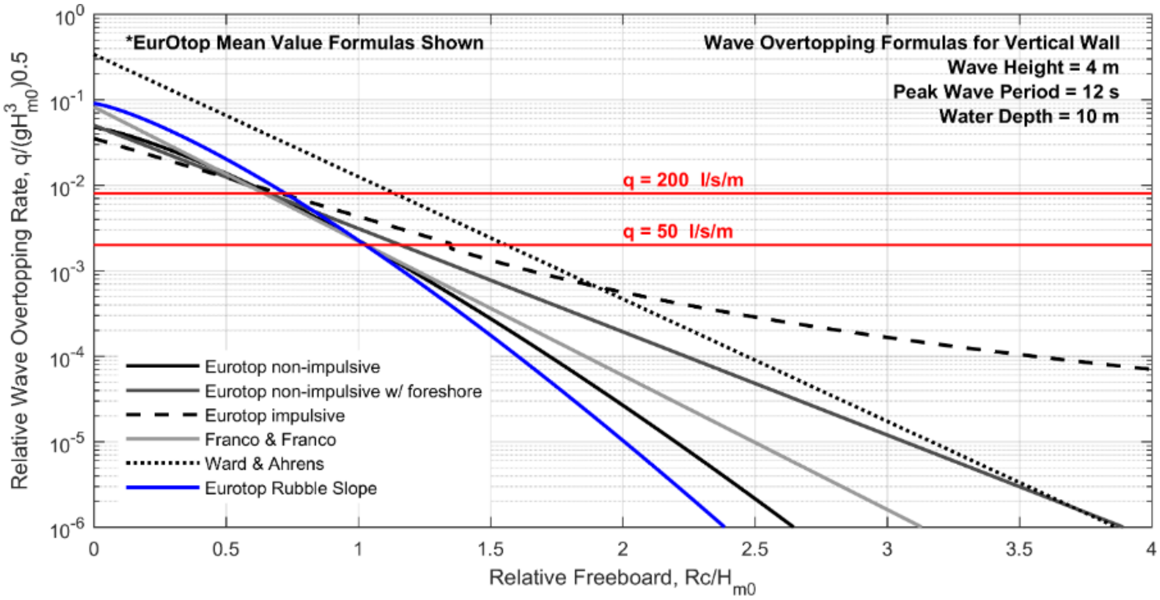


Figure 48: Wave Overtopping Formulas Applied to Storm Surge Barriers

Overtopping Results

Vertical Wall

The results from the wave overtopping analysis at the 11 representative locations are presented in Table 19. The required relative freeboard, R_c/H_{m0}, and freeboard height, R_c, to keep wave overtopping below the tolerable threshold, 50 liters/s/m, are given. The results in Table 19 are based on the EurOtop equation for non-impulsive conditions with an influencing foreshore. The more conservative "design approach" formula was applied. The required relative freeboard increases with wave height and varies between 0.2 in northern Barnegat Bay where the wave conditions are the smallest, to 0.6 at Tuckerton where the wave conditions are the largest. The actual freeboard height varies between 0.3 and 2.3 feet, with all but Tuckerton below 1.5 feet.

Table 19: Wave Overtopping Results at Vertical Wall, Relative Freeboard

Station	**ID**	**SWEL (ft, NAVD88)**	**H_{m0}-Joint (ft)**	**Tp-Joint (s)**	**R_C/H_{m0} (-)**	**Rc (ft)**
Cape May	15566	9.0	3.0	3.1	0.5	1.4
Wildwood	11282	9.1	2.7	3.7	0.4	1.1
Ocean City	11309	9.4	2.2	3.2	0.3	0.6
Somers	11230	9.5	3.1	3.4	0.5	1.5
Atlantic City	13554	8.8	2.1	3.2	0.3	0.6
Beach Haven	11399	7.2	2.7	3.4	0.4	1.1
Tuckerton	11444	7.5	3.8	4.2	0.6	2.3
Lavallette	11511	7.2	2.0	3.3	0.3	0.5

Island Heights	13684	7.0	1.9	3.4	0.2	0.4
Mantoloking	13706	8.0	1.7	2.8	0.2	0.3
Manasquan	13711	9.2	1.9	2.7	0.2	0.4

The sensitivity of the relative freeboard height to EurOtop “mean value” and “design approach”, as well as the Franco & Franco equation, are presented in

Table 20. Differences between the three equations are relatively small and the EurOtop “design approach” generally requires the greatest relative freeboard. Results for Ward & Ahrens are not presented here because the wave conditions in the NJBB are smaller than the range of values used in their laboratory experiment. The EurOtop impulsive wave conditions actually produces smaller required freeboard elevations for these wave conditions and is not presented here. It is more likely that the wave conditions will be non-impulsive during the design conditions considering the small wave periods, small wave heights, and water depths during the 1% ACE.

Table 20: Relative Freeboard Sensitivity, Vertical Wall

Station	**ID**	**EurOtop w/ Foreshore Mean Value Approach**	**EurOtop w/ Foreshore Design Approach**	**Franco & Franco**
Cape May	15566	0.37	0.48	0.43
Wildwood	11282	0.31	0.40	0.38
Ocean City	11309	0.18	0.29	0.29
Somers	11230	0.38	0.49	0.43
Atlantic City	13554	0.19	0.28	0.28
Beach Haven	11399	0.31	0.41	0.38
Tuckerton	11444	0.49	0.60	0.51
Lavallette	11511	0.16	0.26	0.26
Island Heights	13684	0.14	0.22	0.24
Mantoloking	13706	0.06	0.15	0.19
Manasquan	13711	0.12	0.21	0.23

Rubble Slope

The results from the wave overtopping analysis at the 11 representative locations are presented in Table 21. The required relative freeboard, R_c/H_{m0}, and freeboard height, R_c, to keep wave overtopping below the tolerable threshold, 50 liters/s/m, are given. The results in Table 21 are based on the EurOtop equation for rubble slopes using the more conservative “design approach” formula. The required relative freeboard increases with wave height and varies between 0.4 in northern Barnegat Bay where the wave conditions are the smallest, to 0.7 at Tuckerton where the wave conditions are the largest. The actual freeboard height varies between 0.7 and 2.7 feet, with all but Tuckerton below 2.0 feet.

Table 21: Wave Overtopping Results at Rubble Slope, Relative Freeboard

Station	**ID**	**SWEL (ft, NAVD88)**	**H_{m0}-Joint (ft)**	**Tp-Joint (s)**	**R_C/H_{m0} (-)**	**Rc (ft)**
Cape May	15566	9.0	3.0	3.1	0.6	1.9
Wildwood	11282	9.1	2.7	3.7	0.6	1.5
Ocean City	11309	9.4	2.2	3.2	0.5	1.0
Somers	11230	9.5	3.1	3.4	0.6	2.0
Atlantic City	13554	8.8	2.1	3.2	0.5	1.0
Beach Haven	11399	7.2	2.7	3.4	0.6	1.6
Tuckerton	11444	7.5	3.8	4.2	0.7	2.7
Lavallette	11511	7.2	2.0	3.3	0.5	1.0
Island Heights	13684	7.0	1.9	3.4	0.4	0.9
Mantoloking	13706	8.0	1.7	2.8	0.4	0.7
Manasquan	13711	9.2	1.9	2.7	0.4	0.8

Storm Surge Barriers

The results from the wave overtopping analysis at the 1 representative storm surge barrier locations are presented in Table 22. The required relative freeboard, R_c/H_{m0}, and freeboard height, R_c, to keep wave overtopping below the tolerable threshold, 200 liters/s/m, are given. The results in Table 22 are based on the EurOtop equation for non-impulsive conditions with an influencing foreshore. The more conservative “design approach” formula was applied.

Table 22: Wave Overtopping at Storm Surge Barriers, Relative Freeboard

Station	**SWEL (ft, NAVD88)**	**H_{m0}-Joint (ft)**	**Tp-Joint (s)**	**R_C/H_{m0} (-)**	**Rc (ft)**
Storm Surge Barriers	9.0	12.0	12.0	0.75	9.0

The required freeboard at storm surge barriers at the cross-bay closures, is the equal to the results provided for the vertical floodwalls and rubble slopes inside the bays. The wave conditions and tolerable wave overtopping rate of 50 liters/s/m for the bay closures are within the range of values evaluated for the vertical walls and rubble slopes located inside the back bays.

Total Water Level and Crest Elevations

Total Water Level Components

The total water level component analysis identifies all the contributions to the water surface elevation applied in the design structural crest elevations. The significant water level components for the NJBB study area are shown below:

Mean Sea Level

- Mean Sea Level (MSL) is a tidal datum, is mean or average sea level computed over a 19-year period, known as the National Tidal Datum Epoch (NTDE). The present 19-year reference period used by NOAA is the 1983-2001 NTDE.
- Relative Sea Level Change (RSLC) is a combination of both global and local SLC including local vertical land motion (subsidence or uplift).

Astronomical Tide is the semi-diurnal (twice daily) periodic rise and fall of a body of water resulting from gravitational interactions between Sun, Moon, and Earth.

Non-Tidal Residuals

- Seasonal variations in sea level from regular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents.
- Interannual variations in sea level from irregular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents (El Niño).
- Storm Surge is the increased water level due to storm winds over the ocean and the resultant wind stress on the ocean surface.

Wave-induced Components

- Wave Setup is the increase in water level from wave breaking in the nearshore.
- Freeboard is additional height of a structure (i.e. levee, floodwall) above the still water level required to limit wave overtopping below a tolerable discharge. On sloped structures such as levees the freeboard height is related to wave runup.

Design Crest Elevations

Preliminary crest elevations for structural measures (Floodwalls, Levees, Storm Surge Barriers) are based on the 1% annual chance water level with 50% assurance provided in the NACCS hazard curves. The 50% assurance implies that the there is 50% chance, or coin flip, that the 1% ACE will have a water level greater. The preliminary design water levels are equal to the 4% ACE water level with a 90% assurance.

It is emphasized that there is no policy requirement that USACE projects be designed to the 1% annual chance water level or any minimum performance standard. In subsequent phases of the NJBB Feasibility Study the performance of the measures will be optimized to maximize NED benefits, which could result in higher or lower performance. The decision to design structures to the 1% ACE water level at this stage of the study is consistent with the parametric designs in NACCS and ECB 2013-33 that required all Sandy rebuilding projects receiving funds for construction under the Sandy supplemental (Public Law 113-2) be meet a flood risk reduction standard of one foot above the best available and most recent base flood elevation. The 1% ACE water levels used for design are equal to or greater than observed water levels during Hurricane Sandy.

The relative contribution of the each respective total water level component at three representative structure locations is provided in Table 23. A total water elevation relative to the NAVD88 vertical datum is based on MSL or the combined contribution from the NACCS hazard curve (shaded in grey), all other components are reported are added to MSL or the NACCS hazard curve. Conceptual design of floodwalls, levees, and storm surge barriers across the bay (bay closures) are based on a crest elevation of 13 feet NAVD88. Conceptual design of storm surge barriers at inlets are based on a crest elevation of 20 feet NAVD88. Additional refinement and granularity will be included in design crest elevations in subsequent phases of the Feasibility Study.

Table 23: Total Water Level Components

Component	**Ocean City (feet)**		**Lavallette (feet)**		**Storm Surge Barrier (feet)**	
MSL (feet, NAVD88)	-0.40	9.4[2]	0.0	7.2[2]	-.40	9.0[2]
Astronomical Tide	1.6[1]		1.1[1]		1.6[1]	
Storm Surge	8.0		5.9		7.2	
Wave Setup	0.2		0.2		0.6	
RSLC	2.0		2.0		2.0	
Seasonal Variations	0.3		0.3		0.3	
Interannual Variations	0.3		0.3		0.3	
Freeboard	0.6[3]		0.5[3]		9.0[3]	
Total Water Level (feet, NAVD88)	**12.6**		**10.3**		**20.6**	

Notes: [1]MHW shown; [2]Value from NACCS hazard curve in feet, NAVD88; [3]Freeboard based on wave overtopping of vertical wall.

The NACCS numerical modeling results and water level hazard curves include several of the total water level components: MSL, astronomical tide, storm surge, and wave setup. The water level hazard curves represent the join probability of all the components combined and the exact relative contribution of each component is not well defined. However, the relative contribution of each component is estimated here based on the well-known tidal amplitudes (MHW) and approximate estimates of wave setup based on the wave heights.

Relative SLC is included by adding 2 feet, rounded value of the USACE Intermediate SLC scenario in 2080. The required freeboard for each structure was determined based on wave overtopping calculations and tolerable overtopping rate. Seasonal variations in sea level are included based on average seasonal fluctuation during peak hurricane season (August, September, October) observed NOAA tidal gage at Atlantic City. Interannual variations in sea level are included based on a typical peaks observed at Atlantic City over the last 20 years. In subsequent phases of the NJBB Feasibility Study the performance of the measures will be revisited and optimized to maximize NED benefits, which could result in higher or lower crest elevations. The performance and adaptability of the measures to all three SLC scenarios will be incorporated in the optimization process.

Interior Drainage

Any perimeter plan with-project (WP) conditions implemented in the study area would require upgrades to existing stormwater infrastructure. Given the large study area, and initial phase of screening, detailed assessment for each reach (e.g. determination of runoff, storage, pipe sizing, minimum facilities, pump sizing, etc.) was infeasible. As such, a conservative assumption was made that all necessary stormwater management upgrades would be in the form of pump stations. Following Cycle 1 screening of the perimeter plan, a desktop assessment was performed to estimate the number of pump stations required in each reach of the proposed perimeter plan. This desktop effort focused on reaches determined most feasible in Cycle 1. Figure 49 depicts a flow chart describing the desktop process developed for this assessment. In general, a distinction was made between areas with existing bulkhead, which currently prohibits stormwater runoff from flow toward the bay (where perimeter plan was assumed to have no impact), and areas without existing bulkhead (where perimeter plan was assumed to have an impact that would be address through installation of pump station(s)). The subsequent process is described in step-wise, bullet-point fashion, below:

- Estimated percentage of existing shoreline that had bulkhead greater than 2ft height above grade, using available aerial photography and existing DEM data
  - Less than 2 ft height categorized as unprotected
- Assumed if existing bulkhead greater than 2ft height => no WP impact anticipated; if existing bulkhead less than 2ft (or unprotected) => WP will have impact, pump stations required
- Determined percentage of assumed impacted shoreline (e.g. length of unprotected shoreline (or less than 2 ft bulkhead) / total shoreline length)
- Obtained drainage area to each reach of perimeter plan
  - Used NJDEP HUC14 watershed boundaries, follow identifiable breakpoint in DEM between drainage to oceanside/bayside
- Applied percentage of assumed impacted shoreline to drainage area
- Assumed pump station required for every 60 acres of adjusted drainage area
  - Based on previous USACE and NJDOT studies (Chelsea Heights FRM Feasibility, NJDOT Seaside Park Route 35 Stormwater Improvements)
- Applied area reduction factor of 50% to any contiguous areas dissimilar to majority of study area (i.e. any areas that were noticeably NOT long and narrow typical of a barrier island),

assuming less pump stations would be necessary to treat same land area shaped differently

- Applied reduction factor of 25% globally to account for likelihood that a portion of the identified pump station locations have existing available storage/may not be economically justified
- Calculated additional metrics for back check
  - Above method averages approximately 3 pump stations per municipality
    - NJDOT Seaside Park Improvements included 3 pump stations for one municipality
  - Above method averages approximately 1,200 ft shoreline spacing between pump stations/outfalls
    - Oceanside outfall spacing is approximately 1450 ft on average (outfalls on bayside difficult to visually identify)
  - Back checks appear reasonable

Results of the assessment and calculations are shown in Table 24. Given the coarse desktop nature of this assessment, it is expected that with additional analysis, including available storage (on streets, open areas, pipe systems), actual increase in flooding/damages, assessment of minimum facilities, etc.; some of the identified pump stations may not be economically justified. As such, this is likely a conservative estimate, appropriate for, and consistent with, this phase of screening.

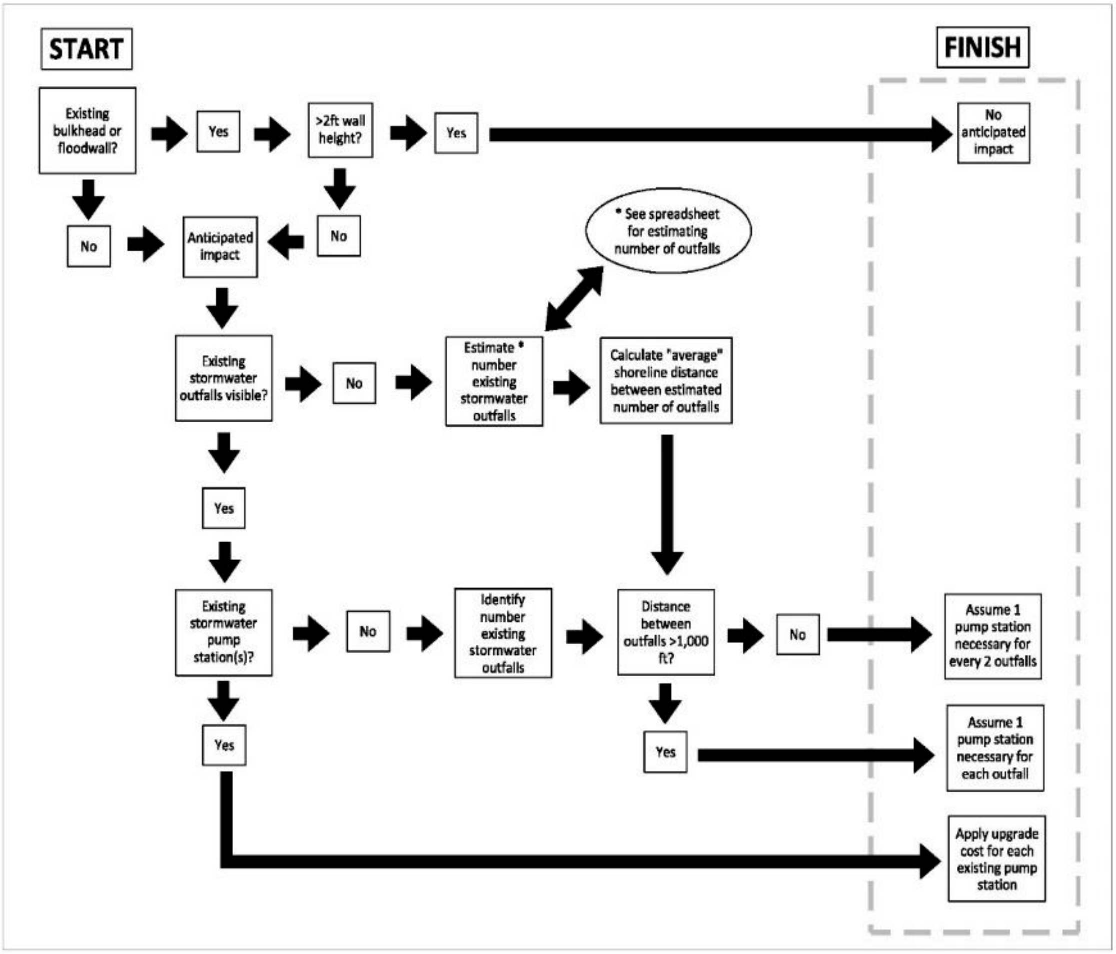


Figure 49: Flow chart for pump station assessment

Table 24: Summary of Estimated Number of Pump Stations by Reach

Group Number	Reach	Total Floodwall Length (ft)	Approx. shoreline Length with Existing Bulkhead > 2ft Height (ft)	Total Baseline Length (ft)	Ratio of Baseline to Total Length	% of Shoreline with Existing Bulkhead > 2 ft	Approx. Drainage Area to BB (ac)	Approx. Drainage Area to BB Factored (ac)	Number of Proposed Pump Stations
1	CM1	15757	0	10000	0.63	0	490	367.5	6
2	LW1	9312	0	30750	0.57	63	1340	1005	6
2	NW1	21841	11150						
2	WCR1	7255	7255						
2	WCY1	15662	15662						
4	WW1	11727	6950	5000	0.43	59	113	84.75	1
5	AV3	50997	36397	33500	0.41	73	892	669	3
5	SH1	30900	23400						
9	AV1	9574	0	3700	0.39	0	56	42	1
10	SI1	34954	9200	20000	0.57	26	473	354.75	4
12	OC1	78573	52000	37100	0.47	66	1807	1355.25	9
18	AC2	43263	30263	44000	0.50	75	3083	2312.25	15
18	LP1	10016	10016						
18	MG1	19953	18953						
18	VN2	14242	6242						
23	BC1	48590	39390	19500	0.40	81	1244	933	3
26	BGL1	12565	0	97000	0.52	45	2301	1725.75	17
26	BV1	21691	13441						
26	HC1	28070	26570						
26	LB1	23056	0						
26	LB3	10349	0						
26	LB4	44084	29074						
26	LB5	17438	3144						
26	SB1	17445	0						
26	SC1	13507	11807						
42	BH1	12786	2878	75000	0.42	9	3581	2067	32
42	BK4	6990	0						
42	BR1	22767	0						
42	LL1	10047	0						
42	LL2	11698	0						
42	MK1	18712	7015						
42	PP2	4471	0						
42	PPB1	10976	0						
42	SSH1	7259	0						
42	SSP1	19253	5988						
42	TR4	15486	0						
42	TR5	38299	0						
45	BL1	7638	0	10500	0.46	0	949.875	949.875	16
45	MQ1	15004	0						
52	GP52	-----	-----	-----	-----	-----	-----	-----	1

Existing Beach/Dune Conditions

A map of existing USACE CSRM projects in New Jersey, Figure 50, shows that nearly the entire Atlantic Ocean facing shoreline, from Cape May to Sandy Hook, is part of an existing USACE CSRM project. The only exception is Island Beach State Park and few sand spits or shorelines adjacent to inlets where there is little infrastructure at risk. Several of the USACE CSRM projects were authorized but unconstructed until Hurricane Sandy in October of 2012. Following Hurricane Sandy, nearly all of the projects have been constructed or are currently under construction.

Feasibility studies for each of the USACE CSRM projects were completed independently of each other and determined design dune and berm conditions by optimizing NED benefits within each respective study area. Due to unique nature of each study area the optimization resulted in variability in the design dune dimensions up and down the coast. There is even variability in the design dune heights in some of the projects and two projects don't have an authorized dune as part of the project. A summary of the existing USACE-CSRM projects authorized design dune/seawall heights is provided in Table 25. These studies optimized the dune and berm dimensions *with* the understanding that back-bay flooding could still occur during storm events, thus limiting the potential flood inundation benefits provided by dunes along the ocean. Therefore, it is possible that the risk of back-bay flooding constrained the optimized dune heights in some studies.

Table 25: Existing USACE CSRM Projects in Study Area

Project	Location	Authorized Crest Elevation (ft, NAVD88)
Manasquan Inlet to Barnegat Inlet	Northern Point Pleasant Beach and Seaside Heights	18
Manasquan Inlet to Barnegat Inlet	Rest of Project Area	22
Barnegat Inlet to Little Egg Inlet	Long Beach Island	22
Brigantine Island	Brigantine Island	10
Absecon Island	Absecon Seawall	16
Absecon Island	Atlantic City	14.75
Absecon Island	Ventnor, Margate, Longport	12.75
Great Egg Harbor Inlet & Peck Beach	Ocean City - North	n/a
Great Egg Harbor Inlet to Townsends Inlet	Ocean City - South	12.8
Great Egg Harbor Inlet to Townsends Inlet	Strathmere and Sea Isle City	14.8
Townsends Inlet to Cape May Inlet	Townsends Seawall	11.7
Townsends Inlet to Cape May Inlet	Avalon	14.75
Townsends Inlet to Cape May Inlet	Stone Harbor	14.75
Townsends Inlet to Cape May Inlet	Hereford Seawall	11.7
Hereford Inlet to Cape May Inlet	Wildwood	16
Cape May Inlet to Lower Township	Cape May	n/a
Lower Cape May Meadows	Cape May Meadows	16.75

Notes: Grey-shaded rows are Seawalls, not dunes

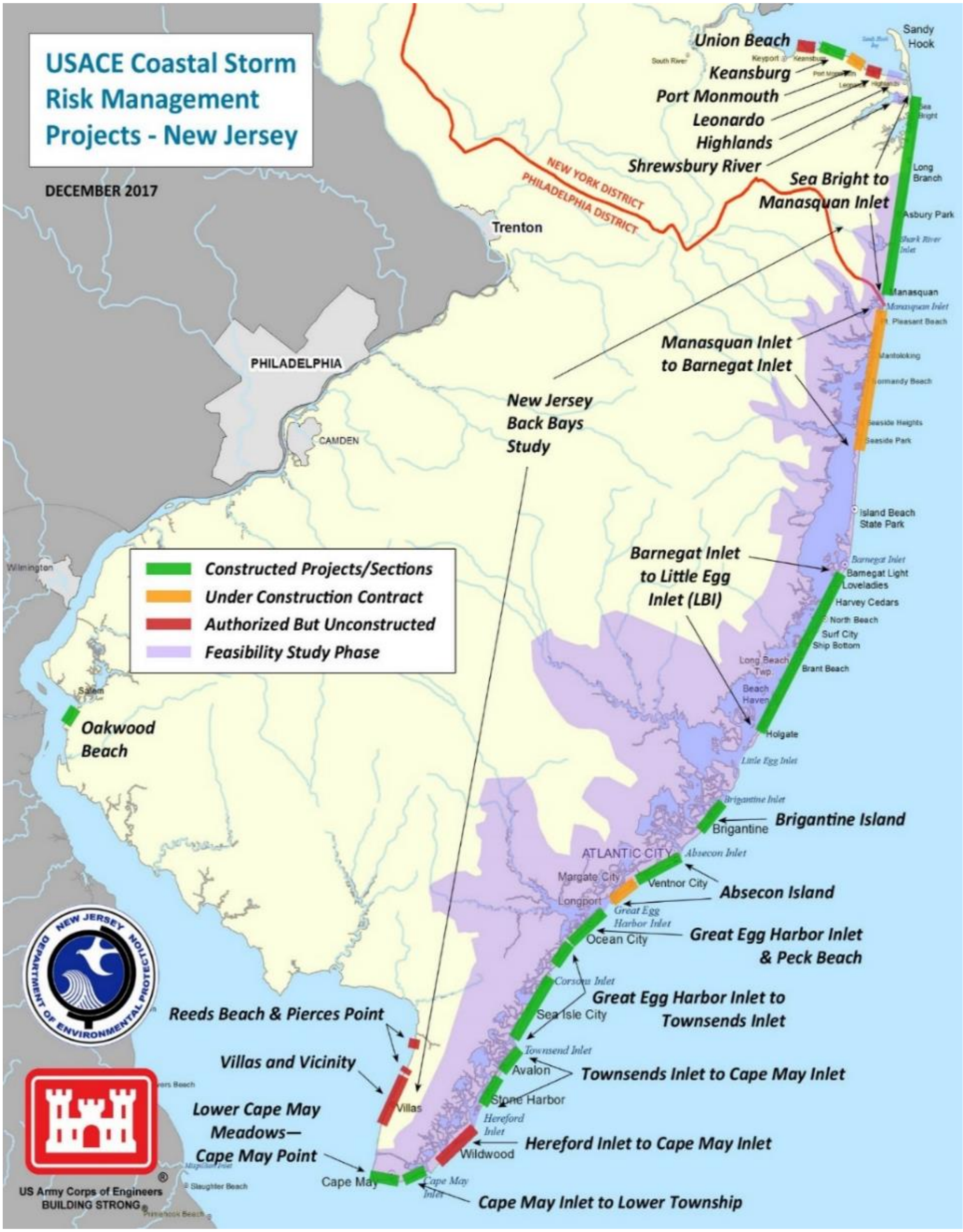


Figure 50: USACE CSRM Projects along Ocean Shorelines

On November 13th, 2018 Philadelphia District coastal engineers and coastal planners, familiar with the existing USACE CSRM projects, got together to discuss how these existing projects would mesh with the NJBB CSRM alternatives. Since the beginning of the NJBB study there have been questions about whether the existing USACE CSRM projects dunes are robust and reliable enough to be part of NJBB storm surge barrier alternative or bay shoreline floodwall alternative (i.e. perimeter plan). The purpose of the November 13th meeting was to discuss the complexities of answering this question and identifying a path forward for evaluating the interaction between the ocean dunes and NJBB alternatives.

During the meeting it was pointed out that it is unlikely that a storm surge barrier alternative would need to maintain an uninterrupted line of impregnable dunes along the shoreline. Dune erosion and overtopping would allow more water into the bay and increase bay water levels, however it is not an “all or nothing situation” where any dune failure would completely negate the benefits of the storm surge barriers. It was also noted during the meeting that ocean shoreline is exposed to significantly larger waves than the bay and therefore design crest elevations for CSRM measures along the bay are likely to be lower than ocean for the same design level.

Another important discussion during the meeting was that the existing CSRM projects along the ocean may provide a practical upper limit to the design level on NJBB bay alternatives. If a NJBB alternative did require modifications to the existing CSRM projects, such as higher dunes, the cost associated with these modifications would extend well beyond the additional sand required to construct the dune. Increasing the dune height would increase the footprint of the dune and push the design profile further seaward, increasing fill quantities and periodic nourishment quantities/frequency. In some erosion hot spots it may be difficult to maintain the expanded design profile between periodic nourishment operations. Modifying the dune height may also require obtaining new easements, since the existing easements are based on specific dune crest elevation. Despite these complexities, it was noted during the meeting that an evaluation would need to be completed to determine if costly dune modifications would be offset by a reduction in damages and still be part of an optimized NED plan.

The path forward identified during the meeting was to first get a better understanding of the sensitivity of back-bay water levels to the dune conditions and the performance of the NJBB alternatives without any modifications to the existing USACE CSRM projects. To complete this analyses ADCIRC simulations will be completed for three dune conditions: (1) Existing/authorized dune heights, (2) Partially eroded, 50% of dune height removed, and (3) No dune. The ADCIRC simulations will be performed for a small subset of representative storms.

The second step is to improve our understanding of how likely the existing USACE CSRM projects are to become eroded during storm events. This will be accomplished by running SBEACH simulations for the existing/authorized dune heights for a small subset of representative storms.

The third step, if necessary, is to develop designs and cost estimates for modifications to the existing USACE CSRM projects.

Recommendations

The following is a list of analyses recommended in subsequent phases of the NJBB study:

- Evaluate impact of storm surge barriers on tidal exchange, salinity, residence time, and water quality.
- Evaluate impact of storm surge barriers on sediment transport and inlet morphodynamics.
- Refine storm surge modeling with most-recent bathymetric measurements and evaluate sensitivity of modeling results to NNBF, breaches in barrier islands, and overwash.
- Refine pump station analysis after identifying the TSP.
- Calculate wave overtopping, structure reliability, fragility, and assurance using more advanced joint probability methods such as StormSim

References

Cialone, M. A., T. C. Massey, M. E. Anderson, A. S. Grzegorzewski, R. E. Jensen, A. Cialone, D. J. Mark, K. C. Pevey, B. L. Gunkel, T. O. McAlpin, N. C. Nadal-Caraballo, J. A. Melby, J. J. Ratcliff, 2015. North Atlantic Coast Comprehensive Study (NACCS) Coastal Storm Model Simulations: Waves and Water Levels. ERDC/CHL TR-15-14. Vicksburg, MS: U.S. Army Engineer Research and Development Center.ECB 2013-33

EM 1110-2-1100. *Coastal Engineering Manual*. Department of the Army, U.S. Army Corps of Engineers, Washington, DC 20314-1000.

EM 1110-2-6056. *Standsards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums*. December 31, 2010. Department of the Army, USACE, Washington DC.

ER 1110-2-8160. *Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums*. March 1, 2009. Department of the Army, USACE, Washington DC.

ER 1100-2-8162. *Incorporating Sea Level Change in Civil Works Programs*. December 31, 2013. Department of the Army, USACE, Washington DC.

EurOtop, 2016. *Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application*. Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., www.overtopping-manual.com.

Franco, C. & Franco, L. 1999 *Overtopping formulae for caisson breakwaters with non-breaking 3-d waves*. Journal of Waterway, Port, Coastal & Ocean Engineering, Vol 125, No 2, pp 98-107, ASCE, New York.

Goda, Y. (2000). *Random Seas and Design of Maritime Structures*. World Scientific: New Jersey.

Kopp, R.E., A. Broccoli, B. Horton, D. Kreeger, R. Leichenko, J.A. Miller, J.K. Miller, P. Orton, A. Parris, D. Robinson, C.P.Weaver, M. Campo, M. Kaplan, M. Buchanan, J. Herb, L. Auermuller and C. Andrews. 2016. *Assessing New Jersey's Exposure to Sea-Level Rise and Coastal Storms: Report of the New Jersey Climate Adaptation Alliance Science and*

Technical Advisory Panel. Prepared for the New Jersey Climate Adaptation Alliance. New Brunswick, New Jersey.

Nadal-Caraballo, N. C., J. A. Melby, V. M. Gonzalez, and A. T. Cox, 2015. *North Atlantic Coast Comprehensive Study (NACCS) Coastal Storm Hazards from Virginia to Maine*. ERDC/CHL TR-15-5. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

New Jersey Climate Adaption Alliance, http://njadapt.rutgers.edu/

NOAA VDATUM, https://vdatum.noaa.gov/about.html

NWS Flood Stages, https://water.weather.gov/ahps/region.php?state=nj

Sweet, W. V., Dusek, G., Obeysekera, J., Marra, J. J., 2018. Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold. NOAA Technical Report NOS CO-OPS 086. Silver Spring, Maryland.

USACE-NAO, 2017. *City of Norfolk Coastal Storm Risk Management Study, Hydraulics, Hydrology, & Coastal Sub-Appendix*. Norfolk Virginia, October 2017.

Ward., D. L., Ahrens, J. P., 1992. Overtopping Rates for Seawalls. Miscellaneous Paper CERC-92-3. Department of the Army. Waterways Experiment Stations, Corps of Engineers, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199.

Yang Z., Myers E. P., Wong A. M., and White S. A., 2008. *VDATUM for Chesapeake Bay, Delaware Bay and Adjacent Coastal Water Areas: Tidal Datums and Sea Surface Topography*. NOAA Technical Memorandum NOS CS 15, Silver Spring, Maryland.

B-3) COST ENGINEERING

Cycle 1 Perimeter Plan Strategy Screening

General

This section presents Cycle 1 screening cost estimates for forty nine alternative plans resulting in total and annualized project costs for flood risk management. Table 26 shows the forty nine perimeter locations with the green shaded alternatives carried forward to Cycle 2 as a result of BCRs $\geq$ 1.0.

Basis of Cycle 1 Cost

Cost estimates presented herein for the Cycle 1 analysis are based on December 2017 price level. Perimeter costs were adapted from the North Atlantic Coast Comprehensive Study (NACCS). Cost estimates included $8,000 per linear foot of floodwall with additional costs added for miter gates, sluice gates, and road closures where applicable. The costs also include 25% contingency, 12% for PED, 10% for S&A and 3% mobilization, demobilization and preparatory work all based on the markups used in the NACCS Report. The PDT anticipated that the NACCS costs were likely an underestimate of the actual construction costs, however, at this early stage of the screening, the decision was made to use lower than anticipated cost estimates to capture the largest number of justified perimeter plan locations. Other unit prices used in the screening cost estimate were developed from similar COE flood protection studies and are shown in Table 27 highlighted in green.

Table 26: Cycle 1 Perimeter Plan Screening

	UOM	Total Unit Cost
Floodwall	LF	$8,000
Miter Gate	Ea	$13,507,000
Sluice Gate	Ea	$9,800,000
Road Closure	Ea	$3,421,000

Includes 25% Contingency, 12% PED and 10% S&A. O&M not included. See folder '1% Design Unit Costs'.

Price Level: Oct 17

			QUANTITY				**Cost**					
Alternative	**County**	**Reaches**	**Flood-wall (ft)**	**Miter Gates (ea)**	**Sluice Gates (ea)**	**Road Closures (ea)**	**Floodwalls**	**Miter Gates**	**Sluice Gates**	**Road Closures**	**Mob, Demob & Prep Work (@ 3%)**	**Total Cost**
🟩 1	Cape May	CM1	15,757	-	-	1	$126,056,000	$0	$0	$3,421,000	$3,884,310	$133,361,310
🟩 2	Cape May	LW1, WCR1, WCY1, NW1	54,070	1	-	9	$432,560,000	$13,507,000	$0	$30,789,000	$14,305,680	$491,161,680
🟥 3	Cape May	LW2	13,194	-	-	2	$105,552,000	$0	$0	$6,842,000	$3,371,820	$115,765,820
🟩 4	Cape May	WW1	11,727	-	-	1	$93,816,000	$0	$0	$3,421,000	$2,917,110	$100,154,110
🟩 5	Cape May	SH1, AV3	81,897	2	-	7	$655,176,000	$27,014,000	$0	$23,947,000	$21,184,110	$727,321,110
🟨 6	Cape May	MT1	7,948	-	-	2	$63,584,000	$0	$0	$6,842,000	$2,112,780	$72,538,780
🟥 7	Cape May	MT2	13,817	1	-	2	$110,536,000	$13,507,000	$0	$6,842,000	$3,926,550	$134,811,550
🟨 8	Cape May	AV2	5,465	-	-	1	$43,720,000	$0	$0	$3,421,000	$1,414,230	$48,555,230
🟩 9	Cape May	AV1	9,574	-	-	1	$76,592,000	$0	$0	$3,421,000	$2,400,390	$82,413,390
🟩 10	Cape May	SI1	34,954	2	-	4	$279,632,000	$27,014,000	$0	$13,684,000	$9,609,900	$329,939,900
🟩 11	Cape May	UP1	8,165	-	-	3	$65,320,000	$0	$0	$10,263,000	$2,267,490	$77,850,490
🟩 12	Cape May	OC1	78,573	3	-	4	$628,584,000	$40,521,000	$0	$13,684,000	$20,483,670	$703,272,670
🟥 13	Cape May	UP2	12,896	-	-	1	$103,168,000	$0	$0	$3,421,000	$3,197,670	$109,786,670
🟥 14	Atlantic	EG1	3,552	-	-	1	$28,416,000	$0	$0	$3,421,000	$955,110	$32,792,110
🟥 15	Atlantic	SP1	16,441	-	-	3	$131,528,000	$0	$0	$10,263,000	$4,253,730	$146,044,730
🟥 16	Atlantic	EG2	7,811	-	-	3	$62,488,000	$0	$0	$10,263,000	$2,182,530	$74,933,530
🟥 17	Atlantic	EG3	7,328	2	-	2	$58,624,000	$27,014,000	$0	$6,842,000	$2,774,400	$95,254,400
🟩 18	Atlantic	LP1, MG1, VN2, AC2	87,474	6	-	10	$699,792,000	$81,042,000	$0	$34,210,000	$24,451,320	$839,495,320
🟨 19	Atlantic	VN1	20,044	-	-	2	$160,352,000	$0	$0	$6,842,000	$5,015,820	$172,209,820
🟨 20	Atlantic	AC1	14,735	-	-	6	$117,880,000	$0	$0	$20,526,000	$4,152,180	$142,558,180
🟥 21	Atlantic	EG4	31,233	-	-	4	$249,864,000	$0	$0	$13,684,000	$7,906,440	$271,454,440
🟥 22	Atlantic	AB1	11,028	1	-	1	$88,224,000	$13,507,000	$0	$3,421,000	$3,154,560	$108,306,560
🟥 47	Atlantic	AB2	14,334	-	-	1	$114,672,000	$0	$0	$3,421,000	$3,542,790	$121,635,790
🟩 23	Atlantic	BC1	48,590	1	-	5	$388,720,000	$13,507,000	$0	$17,105,000	$12,579,960	$431,911,960
🟨 24	Ocean	LH1	68,775	5	-	-	$550,200,000	$67,535,000	$0	$0	$18,532,050	$636,267,050
🟥 25	Ocean	LH2, TK1	40,947	4	-	2	$327,576,000	$54,028,000	$0	$6,842,000	$11,653,380	$400,099,380
🟩 26	Ocean	LB5, BV1, LB4, SB1, SC1, LB3, HC1, LB1, BGL1	188,205	9	-	11	$1,505,640,000	$121,563,000	$0	$37,631,000	$49,945,020	$1,714,779,020
🟨 27	Ocean	SF1	49,526	5	3	3	$396,208,000	$67,535,000	$29,400,000	$10,263,000	$15,102,180	$518,508,180
🟨 28	Ocean	LB2	18,356	1	-	1	$146,848,000	$13,507,000	$0	$3,421,000	$4,913,280	$168,689,280
🟥 29	Ocean	BG1, OT1	26,287	3	-	-	$210,296,000	$40,521,000	$0	$0	$7,524,510	$258,341,510
🟥 30	Ocean	OT2	11,992	1	-	-	$95,936,000	$13,507,000	$0	$0	$3,283,290	$112,726,290
🟥 31	Ocean	OT3, OT4	16,238	5	-	-	$129,904,000	$67,535,000	$0	$0	$5,923,170	$203,362,170
🟥 32	Ocean	OT5	21,429	-	-	1	$171,432,000	$0	$0	$3,421,000	$5,245,590	$180,098,590
🟥 33	Ocean	LC1	28,330	3	2	1	$226,640,000	$40,521,000	$19,600,000	$3,421,000	$8,705,460	$298,887,460
🟥 34	Ocean	LC2	31,585	3	1	-	$252,680,000	$40,521,000	$9,800,000	$0	$9,090,030	$312,091,030
🟥 35	Ocean	LC3, BK1	74,450	8	-	2	$595,600,000	$108,056,000	$0	$6,842,000	$21,314,940	$731,812,940
🟥 36	Ocean	BK2	31,469	3	-	3	$251,752,000	$40,521,000	$0	$10,263,000	$9,076,080	$311,612,080
🟥 37	Ocean	BK3	22,715	2	1	4	$181,720,000	$27,014,000	$9,800,000	$13,684,000	$6,966,540	$239,184,540
🟥 38	Ocean	BK5, OG1, BK6, OG2	40,199	1	2	3	$321,592,000	$13,507,000	$19,600,000	$10,263,000	$10,948,860	$375,910,860
🟨 39	Ocean	IH1, TR2	59,492	9	-	3	$475,936,000	$121,563,000	$0	$10,263,000	$18,232,860	$625,994,860
🟥 40	Ocean	TR6	69,762	9	5	1	$558,096,000	$121,563,000	$49,000,000	$3,421,000	$21,962,400	$754,042,400
🟥 41	Ocean	BR2	91,679	9	4	-	$733,432,000	$121,563,000	$39,200,000	$0	$26,825,850	$921,020,850
🟩 42	Ocean	BK4, SSP1, SSH1, TR4, LL2, LL1, TR5, BR1, MK1, BH1, PPB1, PP2	178,744	16	-	6	$1,429,952,000	$216,112,000	$0	$20,526,000	$49,997,700	$1,716,587,700
🟨 48	Ocean	TR3, BK7	7,396	-	-	2	$59,168,000	$0	$0	$6,842,000	$1,980,300	$67,990,300
🟥 43	Ocean	BR3	37,716	1	1	1	$301,728,000	$13,507,000	$9,800,000	$3,421,000	$9,853,680	$338,309,680
🟨 51	Ocean	PP1, BR4	41,562	9	-	-	$332,496,000	$121,563,000	$0	$0	$13,621,770	$467,680,770
🟩 45	Monmouth	MQ1, BL1	22,642	3	-	2	$181,136,000	$40,521,000	$0	$6,842,000	$6,854,970	$235,353,970
🟥 46	Monmouth	BM1	14,028	1	1	-	$112,224,000	$13,507,000	$9,800,000	$0	$4,065,930	$139,596,930
🟨 50	Monmouth	ABS1	5,423	-	-	-	$43,384,000	$0	$0	$0	$1,301,520	$44,685,520
			1,809,554	129	20	122	**$14,476,432,000**	**$1,742,403,000**	**$196,000,000**	**$417,362,000**	**$504,965,910**	**$17,337,162,910**

Table 27: NJBB CSRM 5% Design Unit Costs

							Price Level:	Dec 17									
ACCOUNT NUMBER	DESCRIPTION OF ITEM	QUANTITY	UOM	ORIGINAL UNIT COST	SOURCE OR STUDY - LOCATION	ORIGINAL PRICE LEVEL (OPL)	OPL FACTOR	CURRENT PRICE LEVEL (CPL)	CPL FACTOR	ESCA-LATION	AREA FACTOR	DEC 17 UNIT COST	CONTIN-GENCY	E&D	S&A	TOTAL UNIT COST	NOTES
													40.00%	12.00%	10.00%	(ROUNDED)	
01.	Lands and Damages	1	Job	LS													
06.	Fish and Wildlife Facilities																
10.	Breakwaters and Seawalls																
10.00.46	Breakwaters																
10.00.47	Seawalls																
10.00.47.02	Storm Surge Barrier (SSB)																
10.00.47.02.01	Impermeable Barrier	1	SF	$3,000	NAN Parametric Cost Model	Oct 19	861.94	Dec 17	839.63	0.97	1.00	$2,922	$1,169	$490.95	$409.13	$5,000	Includes mob/demob costs.
10.00.47.02.02	Levee	1	LF	$6,221	NJBB	Oct 17	839.63	Dec 17	839.63	1.00	1.00	$6,221	$2,488	$1,045.13	$870.94	$10,700	Mob/demob costs not included.
10.00.47.02.03	Seawall	1	LF	$10,600	Absecon Inlet CSDRS, Atlantic City, NJ IFB W912BU-14-B-0004	Oct 14	797.85	Dec 17	839.63	1.05	1.00	$11,155	$4,462	$1,874.05	$1,561.71	$19,100	Mob/demob costs not included.
10.00.47.05.01	Navigable Gates	1	SF	$19,200	NAN Parametric Cost Model	Oct 19	861.94	Dec 17	839.63	0.97	1.00	$18,703	$7,481	$3,142.11	$2,618.43	$32,000	Includes mob/demob costs.
10.00.47.05.02	Auxilliary Flow Gates	1	SF	$13,900	NAN Parametric Cost Model	Oct 19	861.94	Dec 17	839.63	0.97	1.00	$13,540	$5,416	$2,274.76	$1,895.63	$23,200	Includes mob/demob costs.
11.	Levees and Floodwalls																
11.01	Levees																
11.02	Floodwalls																
11.02.01	T-Wall Floodwall (NACCS)	1	LF	$4,900	NACCS - Hoboken, NJ	Apr 13	789.56	Dec 17	839.63	1.06	0.99	$5,142	$2,057	$863.94	$719.95	$8,800	Includes mob/demob and drainage outlets costs.
11.02.99.02.06	Clearing and Grubbing - light trees	1	Acre	$6,214	NJBB Study -MII file: NJBB PP_2018May14.mlp	Oct 17	839.63	Dec 17	839.63	1.00	1.00	$6,214	$2,486	$1,043.99	$870.00	$10,700	
11.01.04.02.01	Clearing and Grubbing - heavy trees	1	Acre	$13,355	Delaware Comprehensive, NJ - Gibbstown, NJ	May 13	789.56	Dec 17	839.63	1.06	0.99	$14,016	$5,606	$2,354.66	$1,962.22	$24,000	
11.01.04.02.12	4' Marine Mattress	1	SF	$8.09	Absecon Inlet CSDRS, Atlantic City, NJ IFB W912BU-14-B-0004	Oct 14	797.85	Dec 17	839.63	1.05	1.00	$8.51	$3	$1.43	$1.19	$100	
13.	Pumping Stations																
	Galveston Island 1 Pump Sta.	1	CFS	$16,000	GCCPRD - Galveston, TX	Mar 15	801.94	Dec 17	839.63	1.05	1.34	$22,402	$8,961	$3,764	$3,136.29	$38,300	Add pump station frontal protection as needed.
	Flat Creek, NJ 250 cfs Pump Sta.	1	Ea	$3,719,197	Raritan & Sandy Hook FRM Project,Monmouth Co, NJ	May 13	789.56	Dec 17	839.63	1.06	1.00	$3,955,050	$1,582,020	$664,448	$553,707.02	$6,755,300	Add pump station frontal protection as needed.
	East Creek, NJ 100 cfs Pump Sta.	1	Ea	$3,032,364	Raritan & Sandy Hook FRM Project,Monmouth Co, NJ	May 13	789.56	Dec 17	839.63	1.06	1.00	$3,224,662	$1,289,865	$541,743	$451,452.62	$5,507,800	Add pump station frontal protection as needed.
	Chingarora Creek, NJ 40 cfs Pump Sta.	1	Ea	$2,879,022	Raritan & Sandy Hook FRM Project,Monmouth Co, NJ	May 13	789.56	Dec 17	839.63	1.06	1.00	$3,061,595	$1,224,638	$514,348	$428,623.35	$5,229,300	Add pump station frontal protection as needed.
15.	Floodway Control and Diversion Structures																
15.01	Storm Gate (Navigation) Structures																
15.01.01	Miter Gates (Toe of foundation El. -8 Ft. & top of gate El. +13.5 Ft. NAVD88)																
15.01.01.01	Miter Gate - 1,398 SF	1	Ea	$6,573,938	Norfolk CSRM Feasibility - Norfolk, VA	May 17	831.74	Dec 17	839.63	1.01	1.32	$8,770,782	$3,508,313	$1,473,491	$1,227,909	$14,980,500	Add closure floodwalls at ends as needed.
15.02	Roadway Closure Structures																
15.02.01.01	Roller Gate Type Closure Structure - 440 SF	1	Ea	$1,664,926	Norfolk CSRM Feasibility - Norfolk, VA	May 17	831.74	Dec 17	839.63	1.01	1.32	$2,221,302	$888,521	$373,179	$310,982	$3,794,000	46.5'w x 9.5'h ≈ 440 SF
15.03	Drainage (Flood Gate) Structures																
15.03.01.01	60 Ft Sluice Gate	1	Ea	$4,769,732	Norfolk CSRM Feasibility - Norfolk, VA	May 17	831.74	Dec 17	839.63	1.01	1.32	$6,363,656	$2,545,462	$1,069,094	$890,912	$10,869,200	
16.	Bank Stabilization																

Cycle 2 Design Considerations, Process and Assumptions

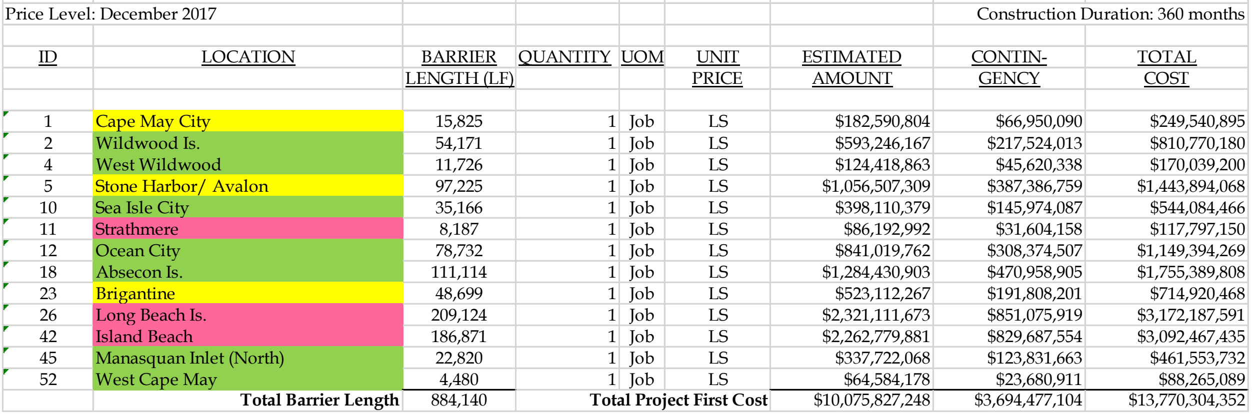
General

Cost estimates were updated with modifications to perimeter barrier placement and lengths as well as efforts to improve accuracy with changes to cost per linear foot and contingencies. Table 28 shows the Cycle 2 perimeter plan screening with the green shaded alternatives carried forward to Cycle 3 as a result of BCRs $\geq$ 1.0.

Basis of Cycle 2 Cost

Cost estimates presented herein for the Cycle 2 analysis are based on December 2017 price level. Perimeter barrier costs were developed based on parametric unit costs and design quantities for 3 types of barriers: Type A, earthen levee; Type B, concrete T-wall constructed from the water side; and Type C, concrete T-wall constructed from the land side. Additional costs for pump stations, miter gates, sluice gates, road closures, relocation of dock structures, and cultural mitigation were added where applicable. Real estate costs of 10% of the project cost was included since obtaining actual real estate costs for the 183,000 structures in the study area would have been time consuming. Environmental mitigation costs of 5% of the project cost was included since discussions with the permitting agencies had not yet occurred due to the preliminary stage of the study. The costs also include 40% contingency, 12% for PED, 10% for S&A and 3% mobilization, demobilization and preparatory work The PDT anticipated that the contingency amount was likely an underestimate of the actual contingency based on guidance in ER 1110-2-1302, however, at this early stage of the screening, the decision was made to use lower than anticipated contingency estimates to capture the largest number of justified perimeter locations. Other unit prices used in the screening cost estimate were developed from similar COE flood protection studies and are shown in Table 27 highlighted in green.

Table 28: Cycle 2 Perimeter Plan Screening



Price Level: December 2017								Construction Duration: 360 months
ID	LOCATION	BARRIER LENGTH (LF)	QUANTITY	UOM	UNIT PRICE	ESTIMATED AMOUNT	CONTIN-GENCY	TOTAL COST
1	Cape May City	15,825	1	Job	LS	$182,590,804	$66,950,090	$249,540,895
2	Wildwood Is.	54,171	1	Job	LS	$593,246,167	$217,524,013	$810,770,180
4	West Wildwood	11,726	1	Job	LS	$124,418,863	$45,620,338	$170,039,200
5	Stone Harbor/ Avalon	97,225	1	Job	LS	$1,056,507,309	$387,386,759	$1,443,894,068
10	Sea Isle City	35,166	1	Job	LS	$398,110,379	$145,974,087	$544,084,466
11	Strathmere	8,187	1	Job	LS	$86,192,992	$31,604,158	$117,797,150
12	Ocean City	78,732	1	Job	LS	$841,019,762	$308,374,507	$1,149,394,269
18	Absecon Is.	111,114	1	Job	LS	$1,284,430,903	$470,958,905	$1,755,389,808
23	Brigantine	48,699	1	Job	LS	$523,112,267	$191,808,201	$714,920,468
26	Long Beach Is.	209,124	1	Job	LS	$2,321,111,673	$851,075,919	$3,172,187,591
42	Island Beach	186,871	1	Job	LS	$2,262,779,881	$829,687,554	$3,092,467,435
45	Manasquan Inlet (North)	22,820	1	Job	LS	$337,722,068	$123,831,663	$461,553,732
52	West Cape May	4,480	1	Job	LS	$64,584,178	$23,680,911	$88,265,089
	Total Barrier Length	884,140			**Total Project First Cost**	$10,075,827,248	$3,694,477,104	$13,770,304,352

Note – Contingency amount includes 30% for lands and damages; 40% for construction, 25% for PE&D and 25% for S&A.

Cycle 3 Storm Surge Barrier Measures

General

Cost estimates were calculated for eleven storm surge barrier (SSB) inlet closures and eight bay closures. Designs are based on barriers with navigable sector gates and vertical lift gates to allow tidal flow outside of storm events. Table 29 shows the Cycle 3 storm surge barriers and bay closures screening.

Basis of Cycle 3 Cost

Cost estimates presented herein for the Cycle 3 analysis are based on December 2017 price level. Storm surge barrier costs were developed based on parametric unit costs developed in Appendix A: Tables of Parametric Cost Engineering Models for Storm Surge Barriers from Report Summary New York-New Jersey Harbor and Tributaries (NYNJHAT) Coastal Storm Risk Management Feasibility Study. Additional costs for impermeable barrier, levee, seawall, and cultural mitigation were added where applicable. Real estate costs and mobilization, demobilization and preparatory work were already included in the seawall unit costs. Environmental mitigation costs of 5% of the project cost was included since discussions with the permitting agencies had not yet occurred due to the preliminary stage of the study. The costs also include 40% contingency, 12% for PED and 10% for S&A. The PDT anticipated that the contingency amount was likely an underestimate of the actual contingency based on guidance in ER 1110-2-1302, however, at this early stage of the screening, the decision was made to use lower than anticipated contingency estimates to capture the largest number of justified storm surge barriers and bay closures. Other unit prices used in the screening cost estimate were developed from similar COE flood protection studies and are shown in Table 27 highlighted in green.

Table 29: Cycle 3 Storm Surge Barrier and Bay Closure Screening

REGION	DESCRIPTION OF ITEM	QUANTITY	UOM	UNIT PRICE	CONSTRUCTION COST FOR OMRR&R	ESTIMATED AMOUNT	CONTIN-GENCY	TOTAL COST	CONSTRUC-TION DURATION (Mo.)
Price Level: December 2017							Construction Duration: 175 months		
	Storm Surge Barrier (SSB)								
South	Cape May Canal SSB	1	Job	LS	$420,895,061	$389,412,444	$145,231,690	$534,644,135	55
South	Cape May Inlet SSB	1	Job	LS	$1,301,019,558	$1,203,162,981	$448,720,620	$1,651,883,601	113
South	Hereford Inlet SSB	1	Job	LS	$1,082,770,438	$1,001,372,963	$373,462,867	$1,374,835,830	66
South	Townsends Inlet SSB	1	Job	LS	$848,866,691	$785,108,900	$292,807,008	$1,077,915,908	56
Boundary	Corson Inlet SSB	1	Job	LS	$742,645,318	$686,898,136	$256,179,223	$943,077,358	61
Central	Great Egg Harbor SSB	1	Job	LS	$3,070,152,978	$2,838,878,469	$1,058,762,052	$3,897,640,520	126
Central	Absecon Inlet SSB	1	Job	LS	$2,234,147,936	$2,065,920,149	$770,486,613	$2,836,406,762	127
Boundary	Brigantine to Little Egg Inlet SSB	1	Job	LS	$4,748,276,776	$4,390,447,759	$1,637,421,090	$6,027,868,849	143
North	Barnegat Inlet SSB	1	Job	LS	$1,353,007,544	$1,251,230,331	$466,647,378	$1,717,877,708	105
North	Manasquan Inlet SSB	1	Job	LS	$654,720,530	$605,604,133	$225,860,558	$831,464,691	81
Shark Rive	Shark River Inlet SSB	1	Job	LS	$465,563,610	$430,712,347	$160,634,523	$591,346,869	48
	Bay Closure								
Central	Absecon Blvd Bay Closure	1	Job	LS	$733,749,440	$720,765,348	$265,805,135	$986,570,483	50
South	Sea Isle Blvd Bay Closure	1	Job	LS	$443,482,829	$426,965,947	$158,037,499	$585,003,446	50
North	Holgate Bay Closure	1	Job	LS	$2,629,724,757	$2,459,847,347	$915,349,338	$3,375,196,685	125
Central	North Point Bay Closure	1	Job	LS	$2,419,926,956	$2,256,893,769	$840,312,553	$3,097,206,322	133
South	Wildwood Blvd Bay Closure	1	Job	LS	$675,926,594	$641,899,400	$238,182,663	$880,082,063	55
South	Stone Harbor Blvd Bay Closure	1	Job	LS	$856,239,570	$828,572,333	$306,461,250	$1,135,033,583	56
North	Point Pleasant Canal Closure	1	Job	LS	$251,716,102	$233,064,269	$86,919,429	$319,983,698	49
Central	52 Street Bay Closure	1	Job	LS	$318,050,043	$307,798,287	$113,821,634	$421,619,920	49
	Partial Perimeter Plan (Cycle 2B)								
Central	(Partial) Ocean City PP (Cycle 2B)	1	Job	LS	same as PP screening	$289,686,158	$106,218,462	$395,904,620	33
North	(Partial) Southern LBI PP (Cycle 2B)	1	Job	LS	same as PP screening	$1,071,608,318	$392,923,807	$1,464,532,125	111
					Total Project First Cost	$24,885,849,788	$9,260,245,391	$34,146,095,179	

Note – Contingency amount includes 30% for lands and damages; 40% for construction, 25% for PE&D and 25% for S&A.

Focused Array of Alternative Plans

General

Cost estimates were calculated for 20 alternative plans with perimeter plan alternatives prevalent in the South and Central Regions and storm surge barrier alternatives in the North and Central Regions. Combinations of perimeter plans and storm surge barriers that minimize environmental impact or maximize social benefits, including other objectives will be calculated by aggregating one alternative from each Region. Table 30 shows the Focused Array of Alternatives Plans screening.

Basis of Focused Array of Alternative Plans Costs

Cost estimates presented herein for the Focused Array of Alternatives Plans analysis are based on December 2017 price level. Perimeter plan costs were developed based on criteria discussed in paragraph Basis of Cycle 2 Cost and storm surge barrier costs were developed based on criteria discussed in paragraph Basis of Cycle 3 Cost with additional costs added for non-structural (raising of structures only) construction where applicable. Other unit prices used in the screening cost estimate were developed from similar COE flood protection studies and are shown in Table 2 highlighted in green.

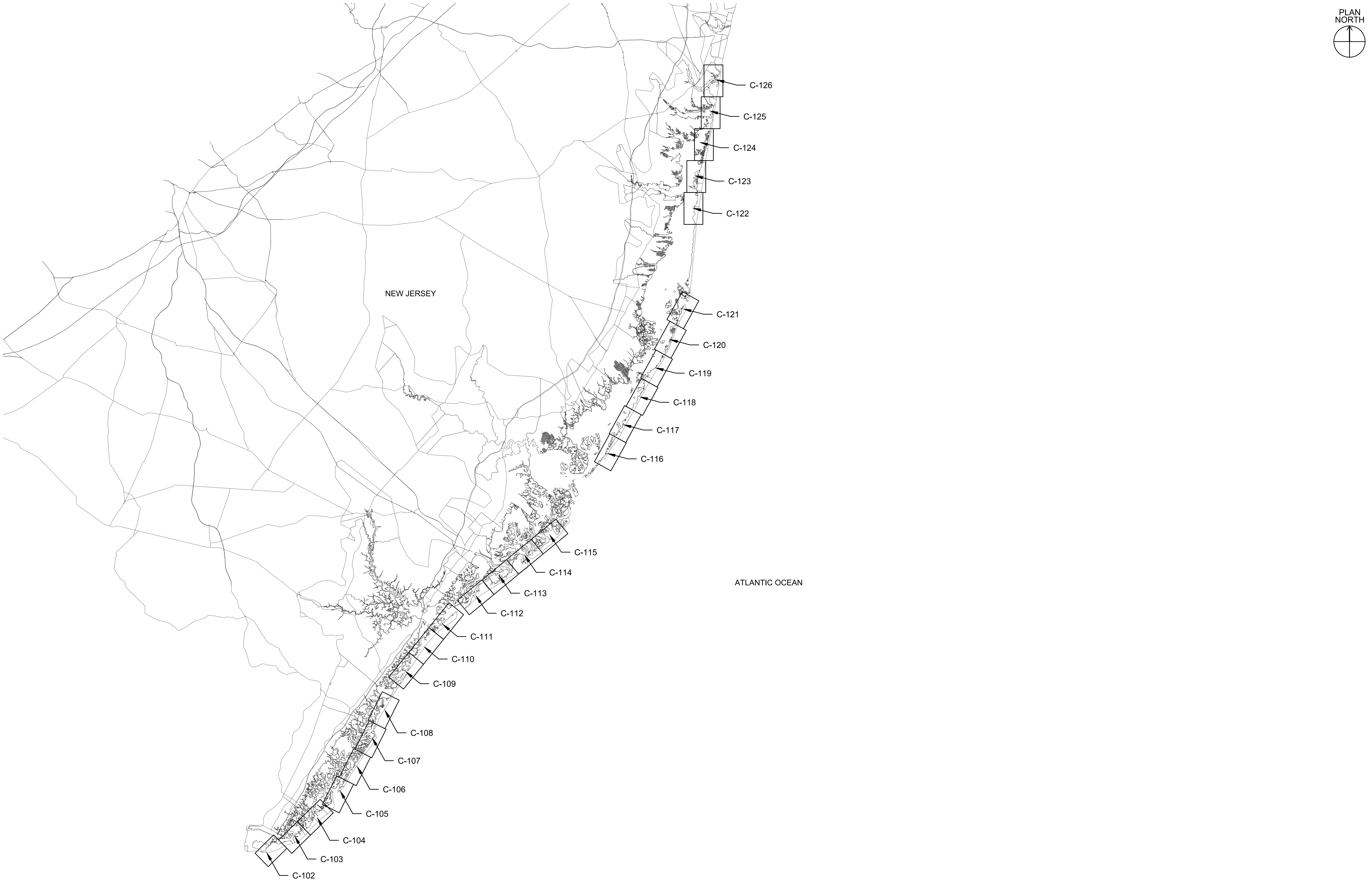
Operation, maintenance, repair, rehabilitation and replacement (OMRR&R) costs of 1.96% of the construction cost were included for the storm surge barrier features and 1.0% of the project cost for the perimeter plan features for each year of the 50-year project life. OMRR&R costs for the storm surge barriers are based on the work performed in the NYNJHAT Coastal Storm Risk Management Feasibility Study and 2 storm surge barrier closure operations per year.

Table 30: Focused Array Screening of Alternative Plans

Price Level: December 2017							Construction Duration: 180 months	
ALTER-NATIVE #	DESCRIPTION OF ITEM	QUANTITY	UOM	UNIT PRICE	ESTIMATED AMOUNT	CONTIN-GENCY	TOTAL COST	CONSTRUC-TION DURATION (Mo.)
Shark River Region:								
2A	See Focused Array Map	1	Job	LS	$16,746,211	$6,140,289	$22,886,500	36
North Region:								
3A	See Focused Array Map	1	Job	LS	$2,655,433,949	$973,660,989	$3,629,094,938	96
3D	See Focused Array Map	1	Job	LS	$2,852,642,816	$1,045,971,046	$3,898,613,862	96
3E-2	See Focused Array Map	1	Job	LS	$2,799,509,731	$1,038,152,945	$3,837,662,677	105
3E-3	See Focused Array Map	1	Job	LS	$3,531,721,731	$1,306,631,196	$4,838,352,927	105
Central Region:								
4A	See Focused Array Map	1	Job	LS	$1,430,214,019	$524,412,817	$1,954,626,835	54
4D-1	See Focused Array Map	1	Job	LS	$2,441,643,247	$895,270,914	$3,336,914,161	86
4D-2	See Focused Array Map	1	Job	LS	$2,796,679,073	$1,025,450,968	$3,822,130,041	108
4E-2	See Focused Array Map	1	Job	LS	$5,202,357,036	$1,938,350,375	$7,140,707,411	127
4E-3	See Focused Array Map	1	Job	LS	$5,223,641,575	$1,946,154,721	$7,169,796,296	127
4E-4	See Focused Array Map	1	Job	LS	$5,225,838,626	$1,947,922,353	$7,173,760,979	127
4G-5	See Focused Array Map	1	Job	LS	$3,740,960,788	$1,391,048,577	$5,132,009,365	126
4G-6	See Focused Array Map	1	Job	LS	$4,025,277,484	$1,495,298,234	$5,520,575,718	126
4G-7	See Focused Array Map	1	Job	LS	$4,046,562,022	$1,503,102,579	$5,549,664,602	126
4G-8	See Focused Array Map	1	Job	LS	$4,048,759,074	$1,504,870,211	$5,553,629,286	126
4G-9	See Focused Array Map	1	Job	LS	$4,095,996,614	$1,521,228,631	$5,617,225,246	126
4G-10	See Focused Array Map	1	Job	LS	$4,380,313,312	$1,625,478,288	$6,005,791,599	126
4G-11	See Focused Array Map	1	Job	LS	$4,401,597,850	$1,633,282,633	$6,034,880,483	126
4G-12	See Focused Array Map	1	Job	LS	$4,403,794,902	$1,635,050,265	$6,038,845,167	126
Southern Region:								
5A	See Focused Array Map	1	Job	LS	$1,073,489,369	$393,613,527	$1,467,102,896	72
5D-1	See Focused Array Map	1	Job	LS	$1,673,283,750	$613,538,556	$2,286,822,307	69
SD-2	See Focused Array Map	1	Job	LS	$2,508,695,372	$919,856,741	$3,428,552,113	99
		Total Project First Cost			$72,575,158,552	$26,884,486,856	$99,459,645,408	

Note – Contingency amount includes 30% for lands and damages; 40% for construction, 25% for PE&D and 25% for S&A.

B-5) Perimeter Plan and Storm Surge Barrier Drawings



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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
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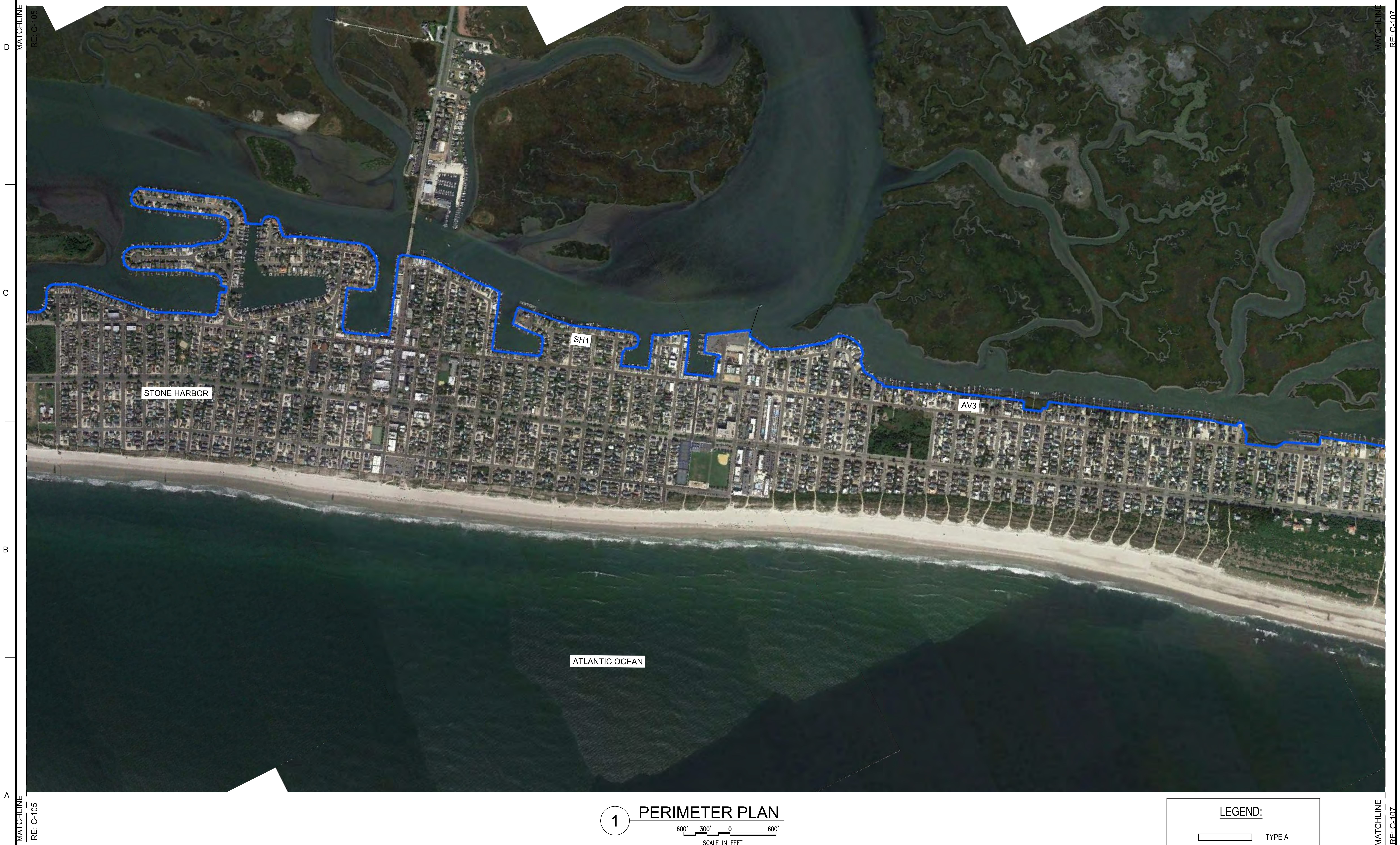

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COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
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NEW JERSEY BACK BAY
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PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-109

1 PERIMETER PLAN

LEGEND:

☐	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA
DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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DWN BY: EMC
DES BY: MKP
ISSUE/SUBMITTAL DATE: INTERIM REPORT
CKD BY: DAN
REVIEWED BY: GMG
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-110

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

☐	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER
C-111

1 PERIMETER PLAN

LEGEND:

▭	TYPE A
▬	TYPE B
▬	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

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DES BY: MKP
REVIEWED BY: GMG
DWN BY: EMC
CKD BY: DAN
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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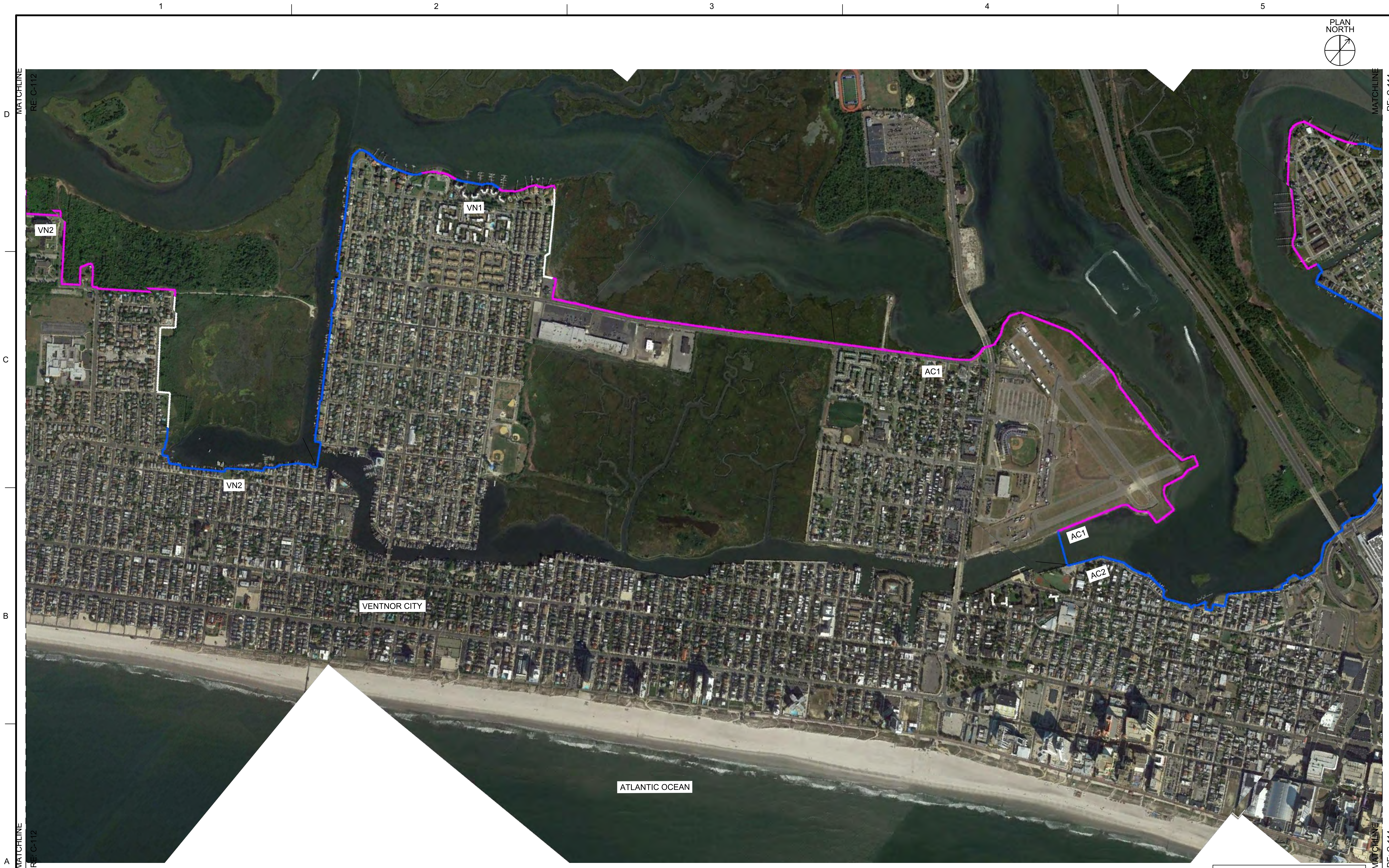
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-112



1 PERIMETER PLAN

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-113

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭ TYPE A
▬ TYPE B
▬ TYPE C

US Army Corps ® of Engineers
PHILADELPHIA
DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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ISSUE/SUBMITTAL DATE: INTERIM REPORT
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
DES BY: MKP
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DWN BY: EMC
CKD BY: DAN
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-114

PLAN NORTH

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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ISSUE/SUBMITTAL DATE: INTERIM REPORT
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CONTRACT NUMBER: -
DWN BY: EMC
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REVIEWED BY: GMG
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER
C-115

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER
C-116

PLAN NORTH

① PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

☐	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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ISSUE/SUBMITTAL DATE: INTERIM REPORT
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FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-117

① PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT
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DWN BY: EMC
DES BY: MKP
CKD BY: DAN
REVIEWED BY: GMG
ISSUE/SUBMITTAL DATE: INTERIM REPORT
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-118

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps ®
of Engineers
PHILADELPHIA
DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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DWN BY: EMC
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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-119

① PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers®
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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ISSUE/SUBMITTAL DATE: INTERIM REPORT
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
DES BY: MKP
DWN BY: EMC
CKD BY: DAN
REVIEWED BY: GMG
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER
C-120

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers®
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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ISSUE/SUBMITTAL DATE: INTERIM REPORT
DWN BY: EMC
DES BY: MKP
CKD BY: DAN
REVIEWED BY: GMG
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-121

PLAN
NORTH

MATCHLINE
RE: C-123

MATCHLINE
RE: C-123

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭ TYPE A
🟦 TYPE B
🟪 TYPE C

US Army Corps of Engineers®
PHILADELPHIA
DISTRICT

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DWN BY: EMC
DES BY: MKP
CKD BY: DAN
REVIEWED BY: GMG
ISSUE/SUBMITTAL DATE: INTERIM REPORT
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER
C-122

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

☐	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps ®
of Engineers
PHILADELPHIA
DISTRICT

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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
DES BY: MKP
DWN BY: EMC
CKD BY: DAN
REVIEWED BY: GMG
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-123

PLAN NORTH

1 PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

▭	TYPE A
🟦	TYPE B
🟪	TYPE C

US Army Corps of Engineers
PHILADELPHIA
DISTRICT

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ISSUE/SUBMITTAL DATE: INTERIM REPORT
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CKD BY: DAN
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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
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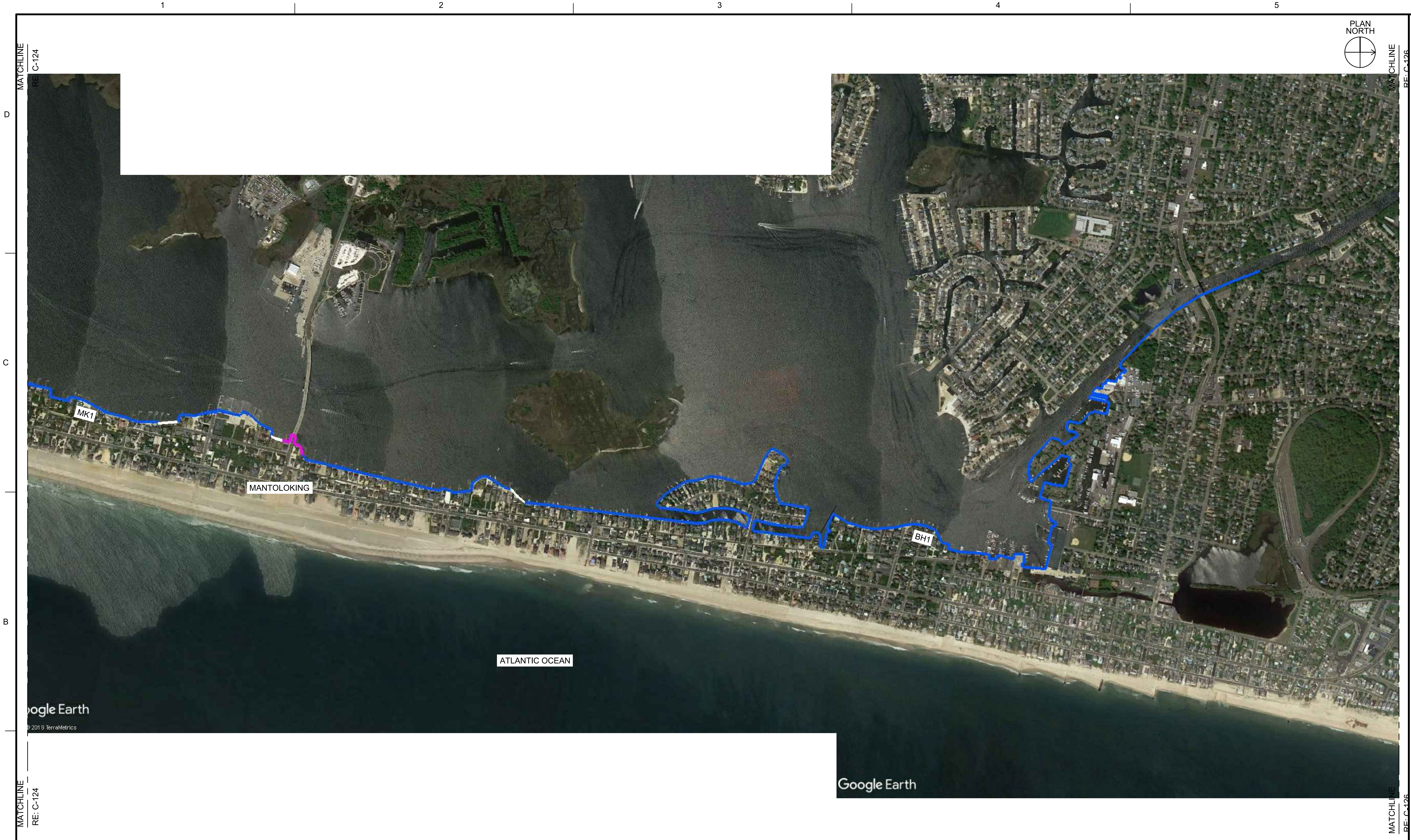
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-124



① PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

US Army Corps of Engineers
PHILADELPHIA
DISTRICT

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CKD BY: DAN
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

PERIMETER PLAN

SHEET NUMBER

C-125

① PERIMETER PLAN

600' 300' 0 600'
SCALE IN FEET

LEGEND:

☐	TYPE A
▬	TYPE B
▬	TYPE C

US Army Corps of Engineers
PHILADELPHIA DISTRICT

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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
DWN BY: EMC
DES BY: MKP
CKD BY: DAN
REVIEWED BY: GMG
PLOT SCALE: 1"=600'
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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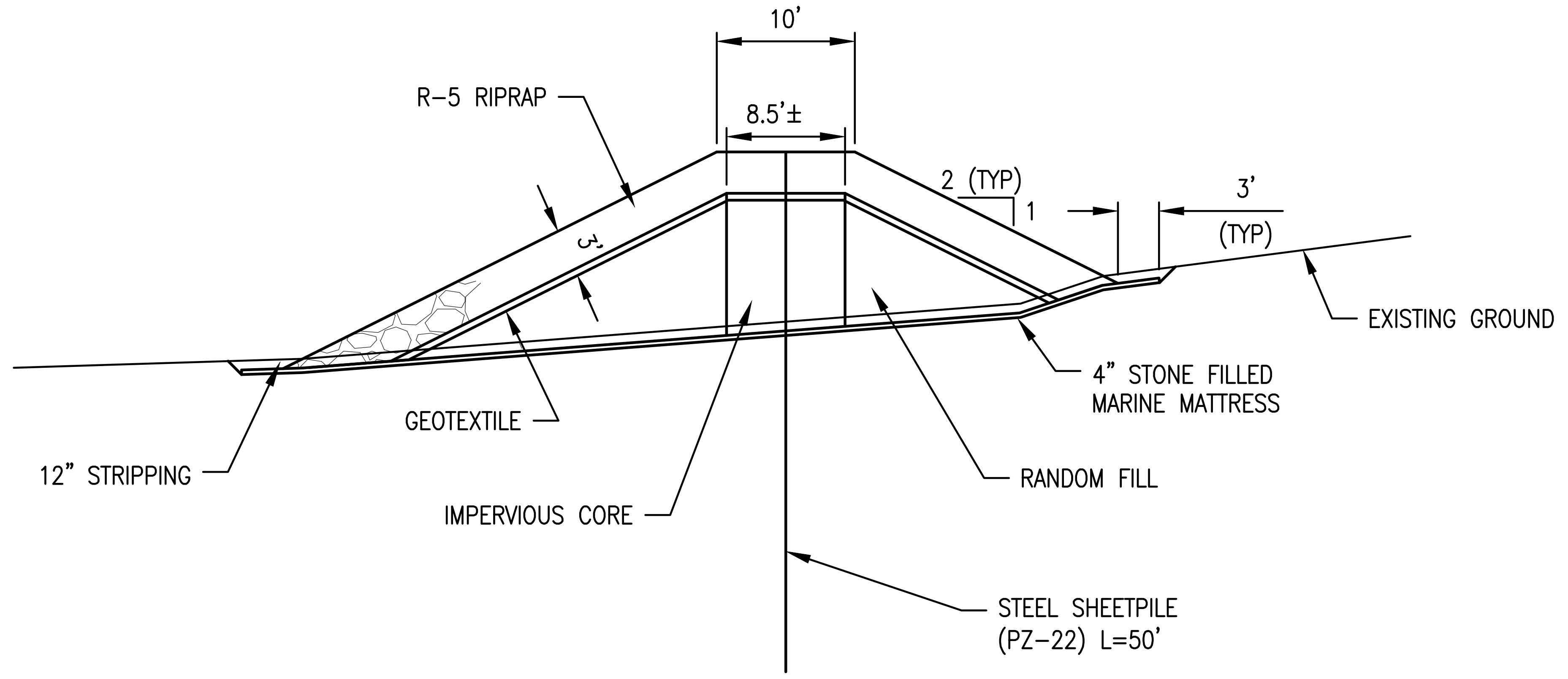
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

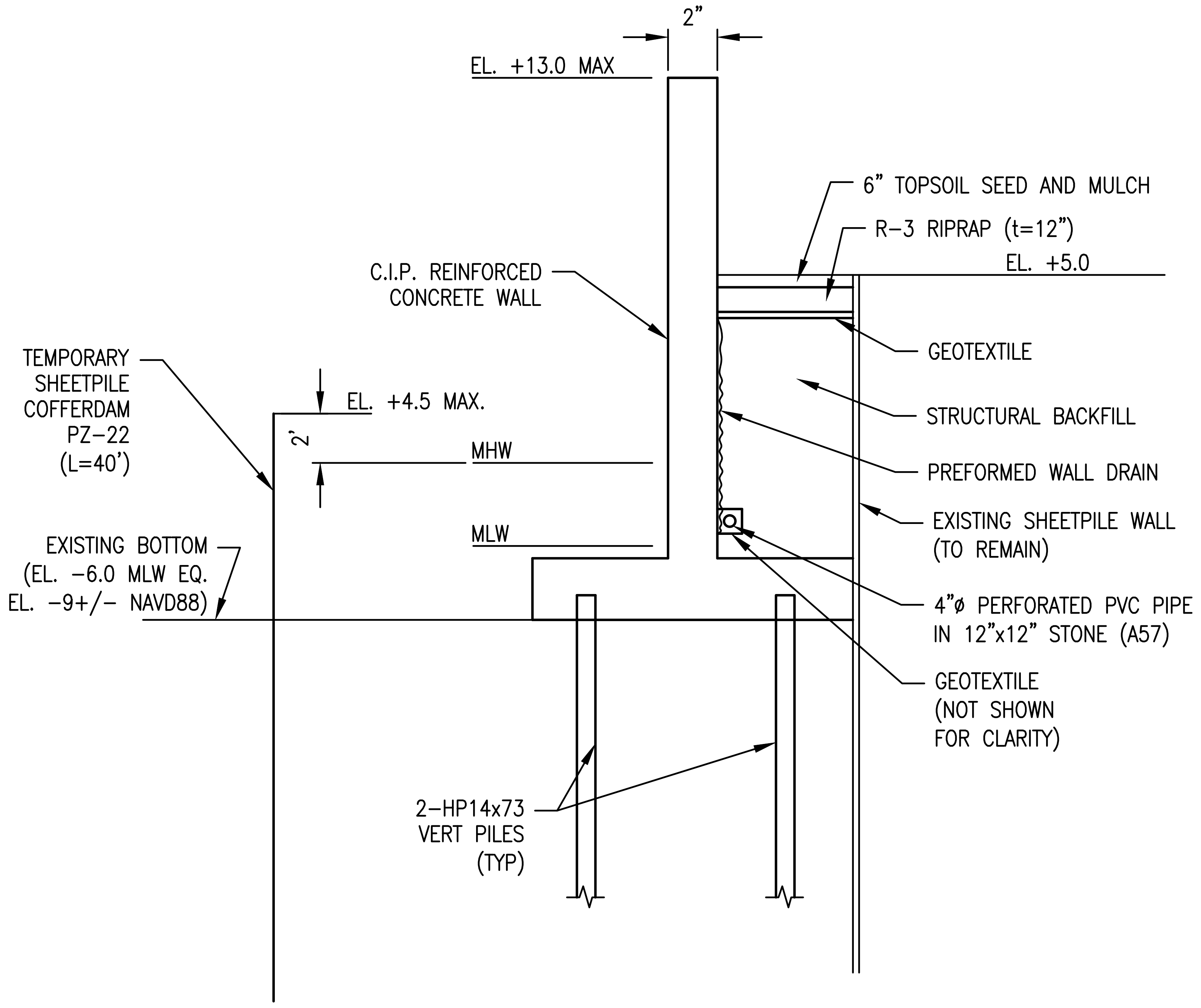
PERIMETER PLAN

SHEET NUMBER
C-126



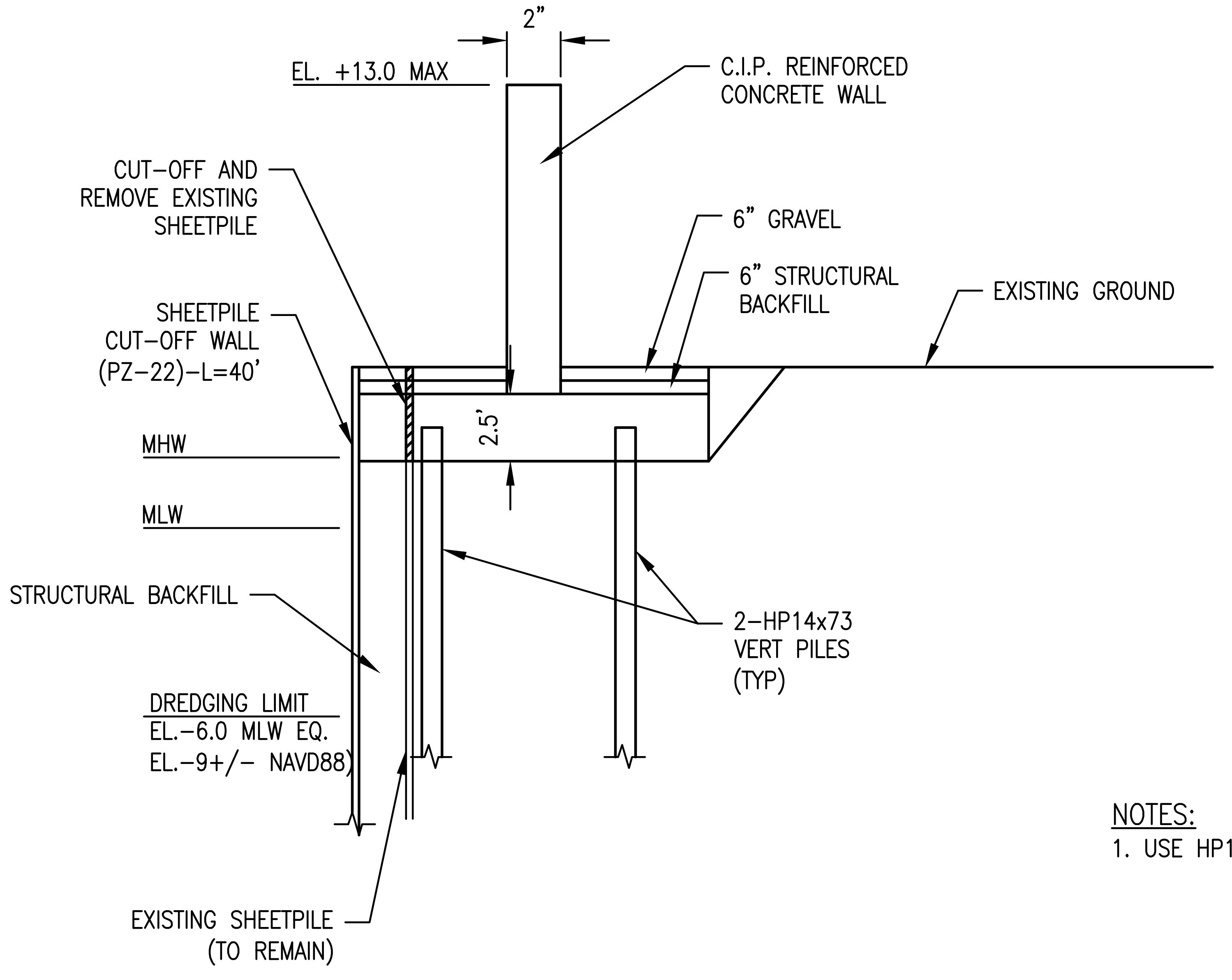
1 TYPICAL SECTION - TYPE A WALL

10' 5' 0 10'
SCALE IN FEET



2 TYPICAL SECTION - TYPE B WALL

10' 5' 0 10'
SCALE IN FEET



NOTES:
1. USE HP14x73 PILES 50' LONG @ 10' C-C.

3 TYPICAL SECTION - TYPE C WALL

5' 0 5'
SCALE IN FEET

NOTES:
1. WALL TYPES B AND C ARE CONCRETE CANTILEVER WALLS ON PILES.
2. FOR WALL TYPES B AND C, USE HP14X73 PILES 50' LONG @ 10' C-C.

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE: -
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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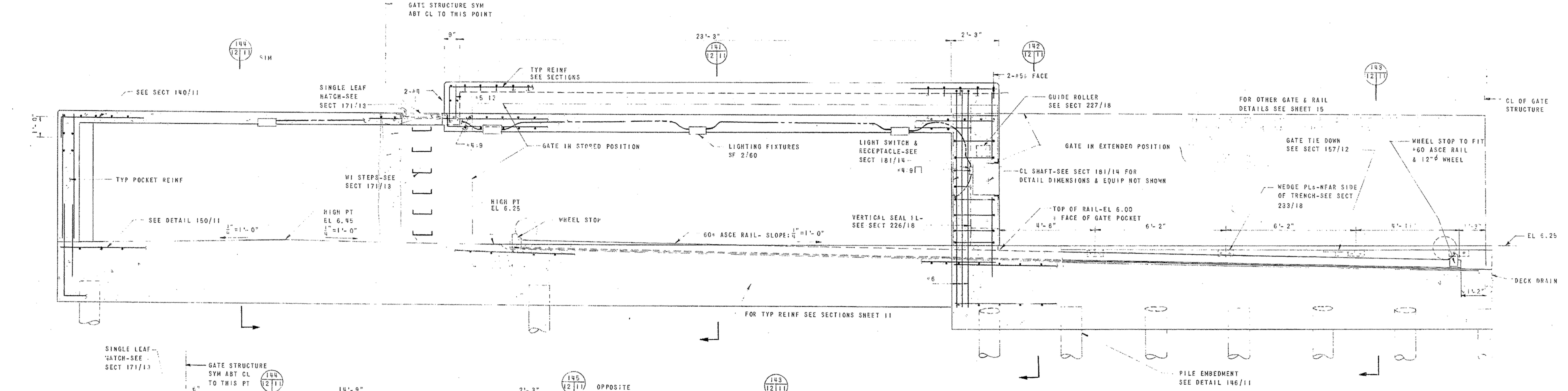
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

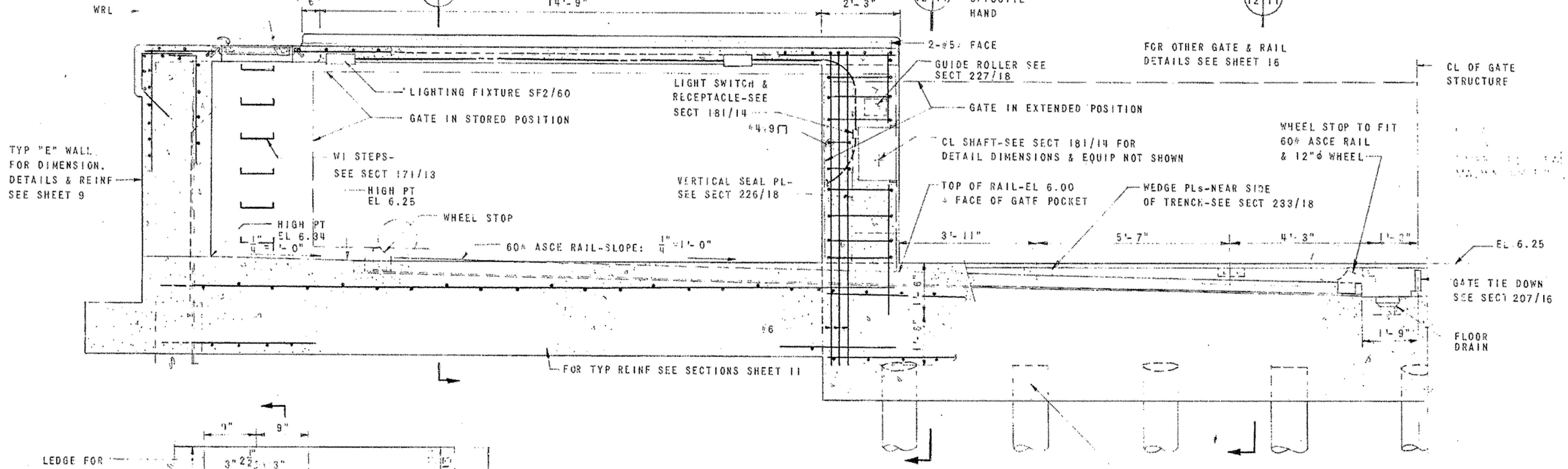
PERIMETER PLAN
SCREENING ANALYSIS

FLOOD PROTECTION STRUCTURES
TYPICAL SECTIONS

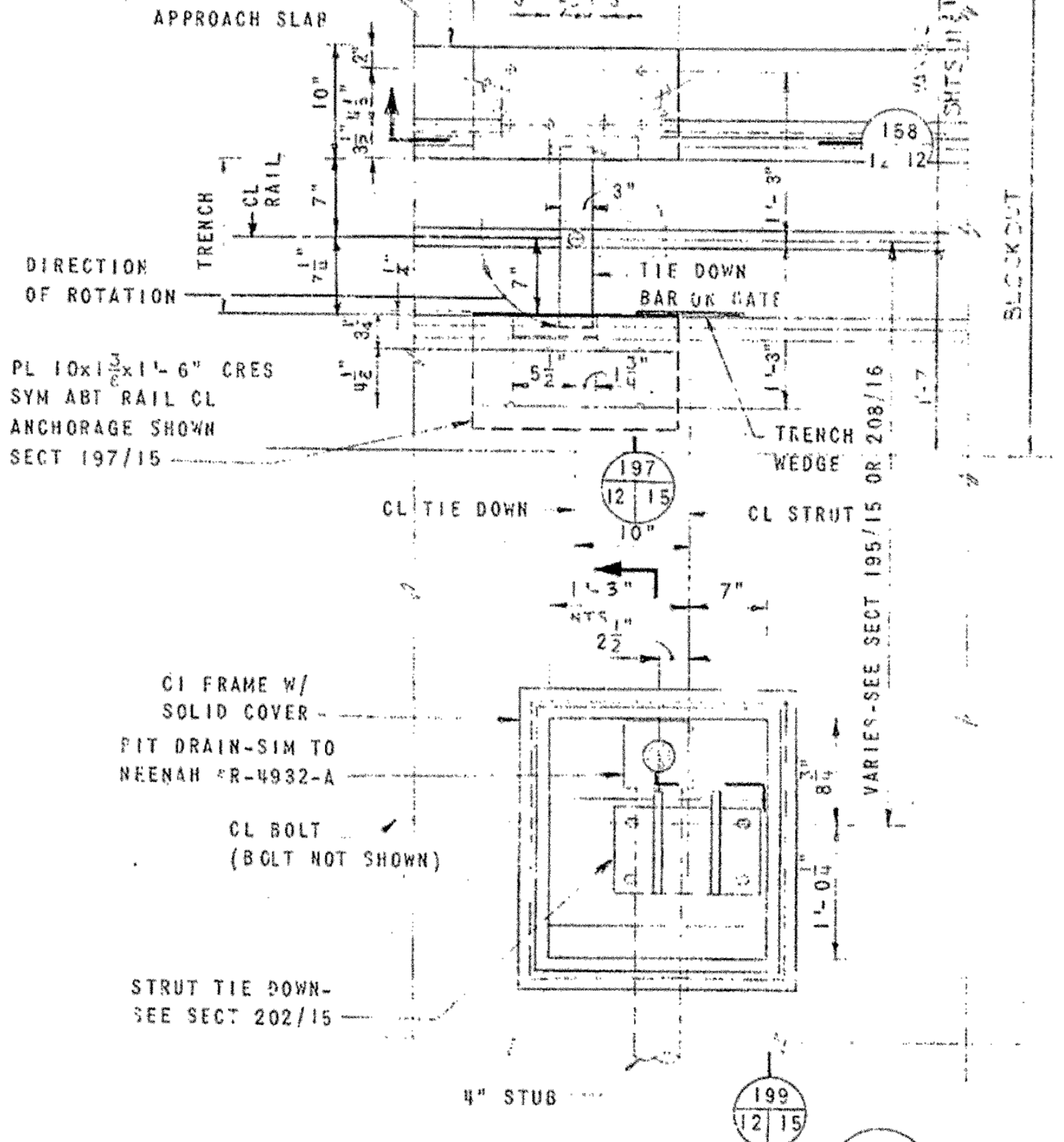
SHEET NUMBER
C-301



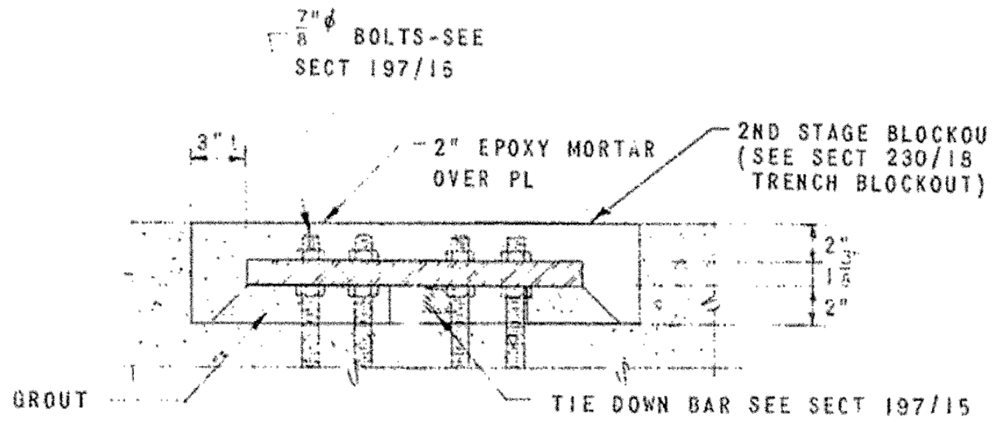
SECTION 155 11|12
SCALE: 1/2"=1'-0"



SECTION 156 11|12
SCALE: 1/2"=1'-0"



PLAN SECTION 157 11|12
SCALE: 1"=1'-0"



SECTION 158 12|12
SCALE: 1 1/2"=1'-0"

NOTE:
GATE AND STRUT TIE DOWN SHOWN SECT 157/12 APPLIES AS SHOWN AND OPPOSITE HAND TO THE MAIN ST. GATE. THE STRUT TIE DOWN AS SHOWN WILL BE SIMILAR FOR THE RAMP "G" GATE. THE GATE TIE DOWN AS SHOWN WILL BE SIMILAR FOR THE NORTH SERVICE ROAD GATE.

GRAPHIC SCALES
1 1/2"=1'-0" 0 3" 6" 9" 1' 2'
1/2"=1'-0" 0 1' 2' 3' 6'

NOTES:
1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.
2. ALL VERTICAL TIMBER PILES SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 4a.
3. ALL BATTERED TIMBER PILES SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 4b.
4. ALL ELECTRICAL WORK AND LIGHTING SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 9.
5. EXCEPT AS OTHERWISE NOTED OR INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID UNDER CONTRACT PAYMENT ITEM 1.
6. GATE AND STRUT TIE DOWN SHOWN SECT 157/12 APPLIES AS SHOWN AND OPPOSITE HAND TO THE MAIN ST. GATE. THE STRUT TIE DOWN AS SHOWN WILL BE SIMILAR FOR THE RAMP "G" GATE. THE GATE TIE DOWN AS SHOWN WILL BE SIMILAR FOR THE NORTH SERVICE ROAD GATE.

US Army Corps of Engineers®
PHILADELPHIA DISTRICT

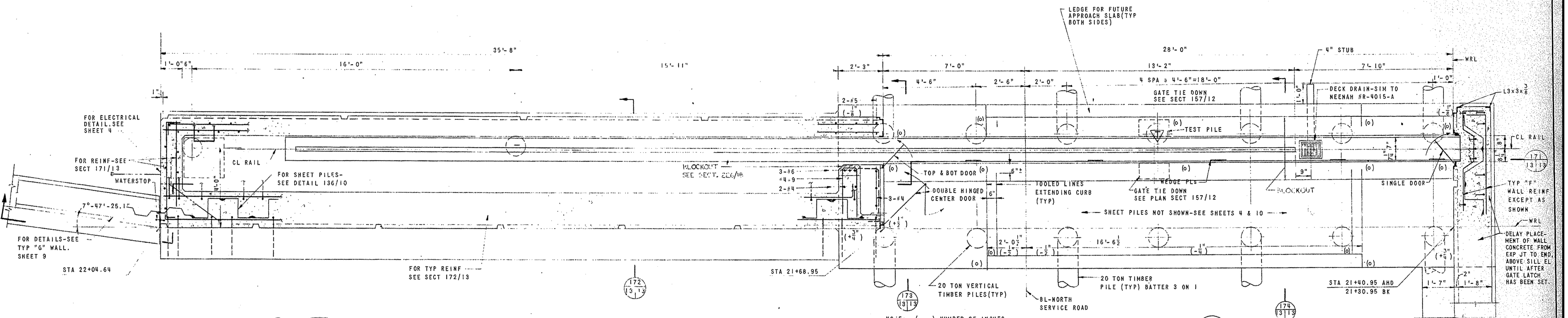
MARK	ACTION	DESCRIPTION	DATE	BY

DWN BY:
DES BY:
ISSUE/SUBMITTAL DATE: INTERIM REPORT
CKD BY:
REVIEWED BY:
SOLICITATION NUMBER:
CONTRACT NUMBER:
PLOT SCALE:
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

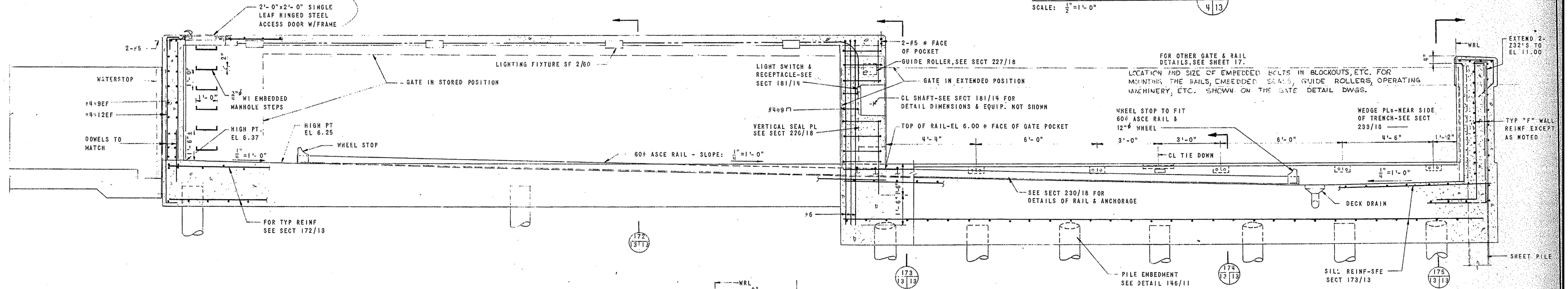
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY
PERIMETER PLAN
SCREENING ANALYSIS
TYPICAL ROAD CLOSURE
MAIN ST. & RAMP "G" GATE STRUCTURE - SECTIONS

SHEET NUMBER
P-101



PLAN SECTION 170 4|13

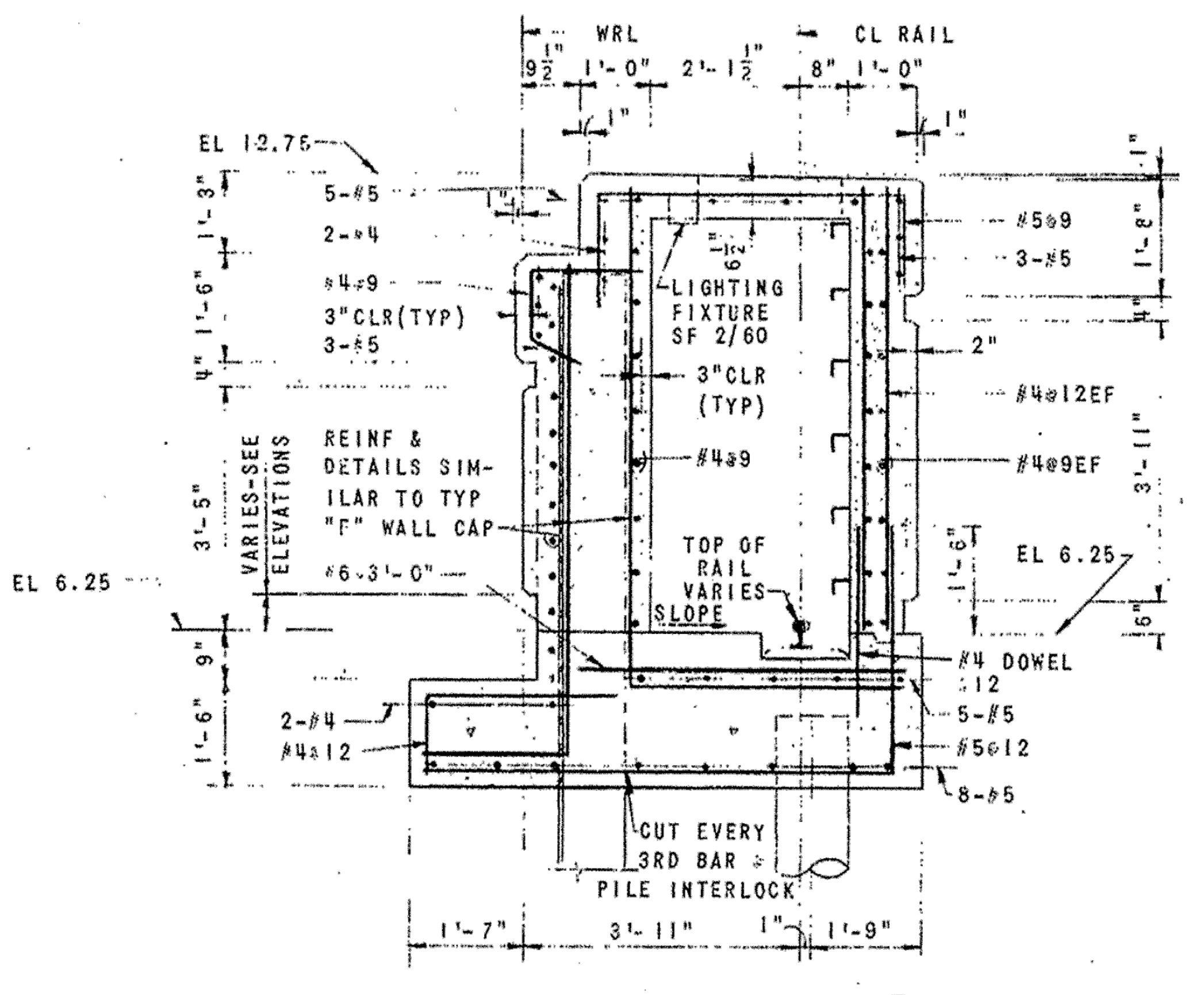
SCALE: 1/2"=1'-0"



NOTE: FOR SLEEVES SEE SHEET 4.

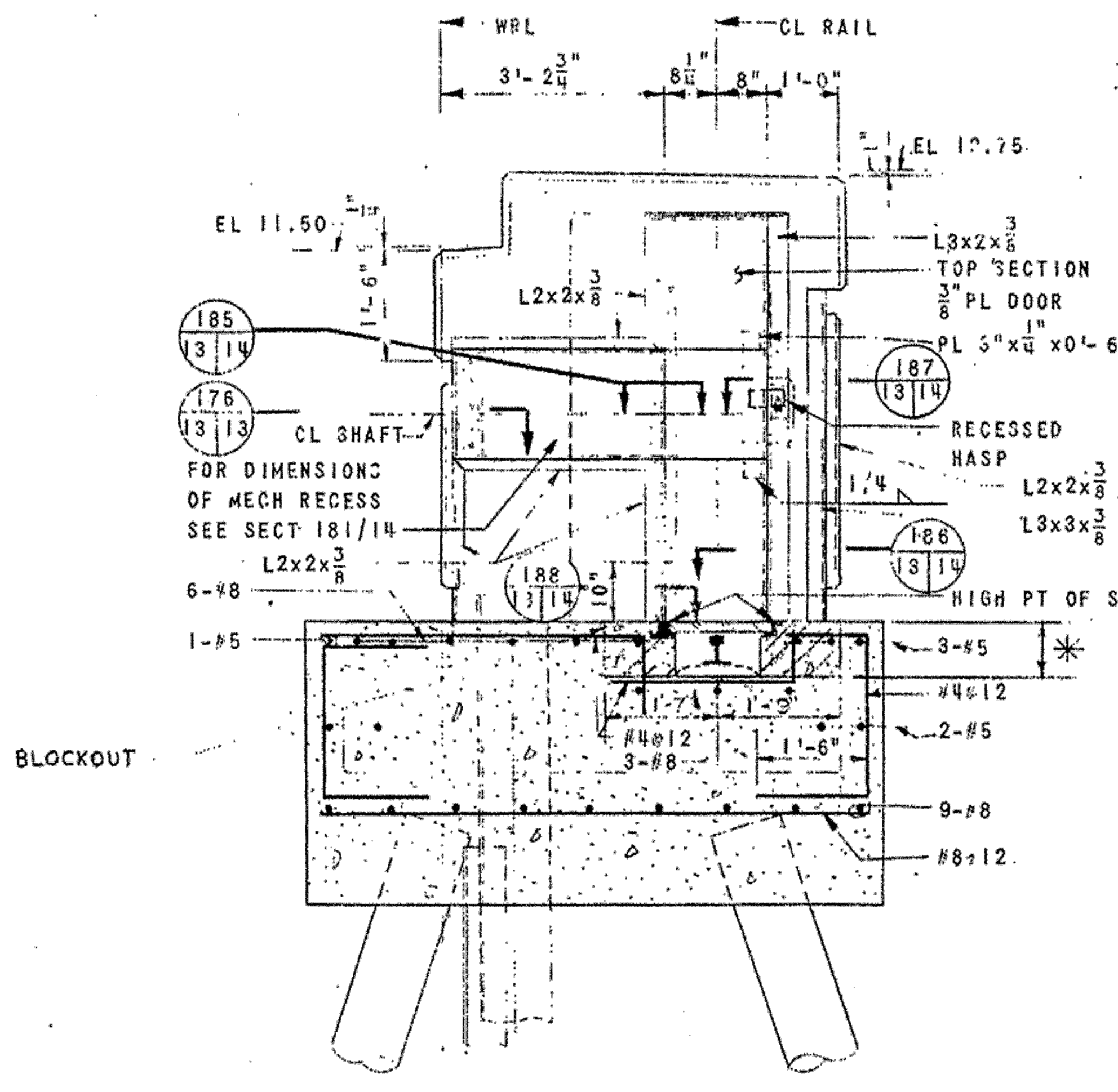
SECTION 171 13|13

SCALE: 1/2"=1'-0"



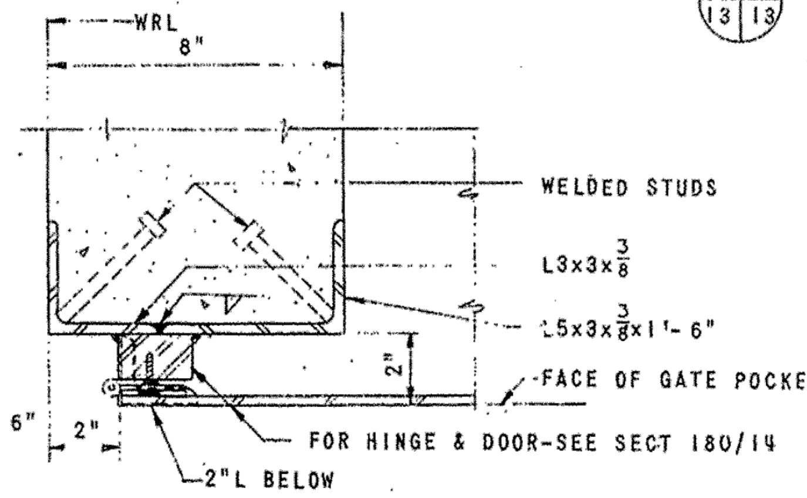
SECTION 172 13|13

SCALE: 1/2"=1'-0"



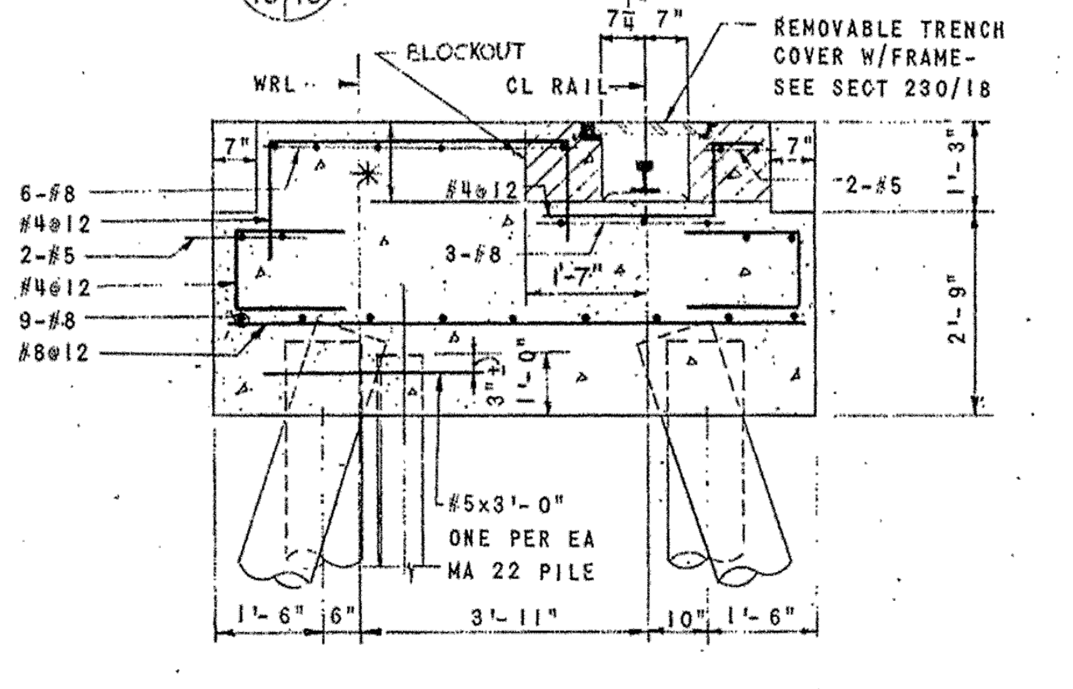
SECTION 173 13|13

SCALE: 1/2"=1'-0"



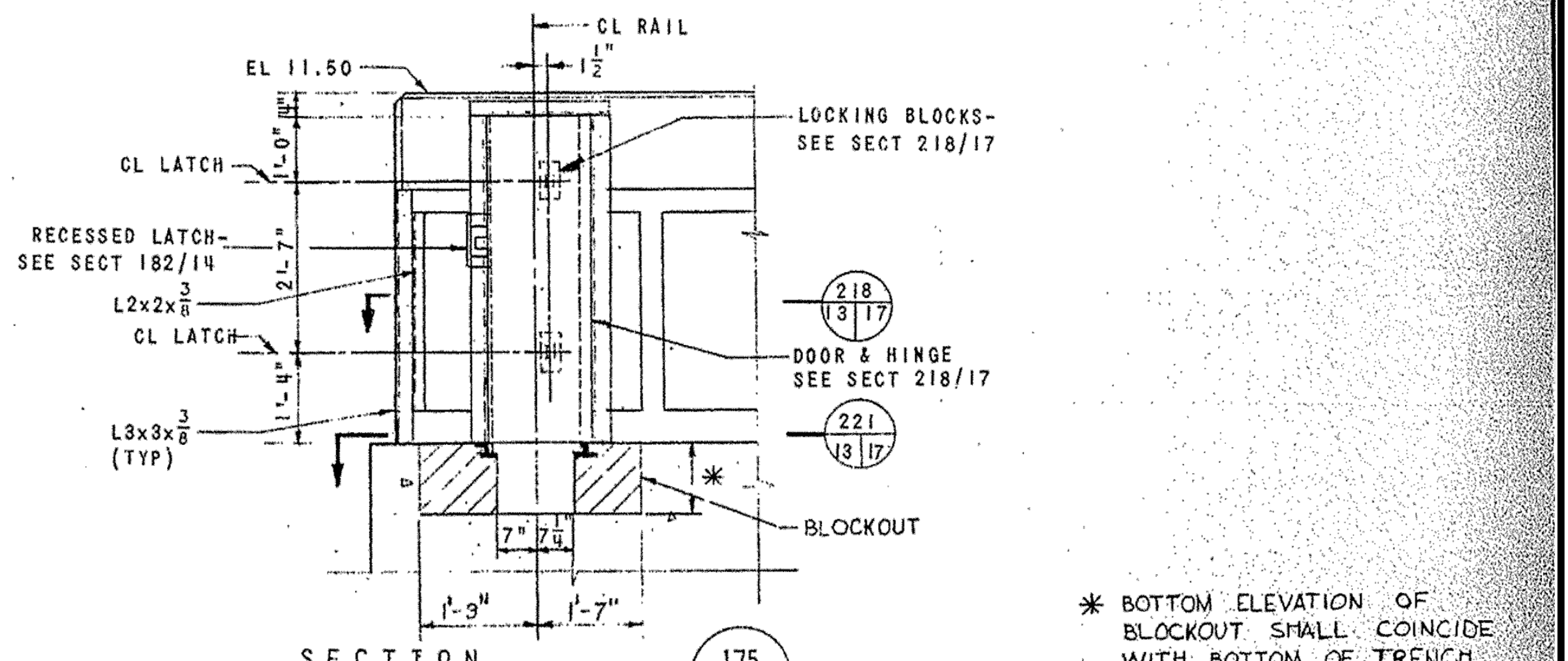
SECTION 176 13|13

SCALE: 3"=1'-0"



SECTION 174 13|13

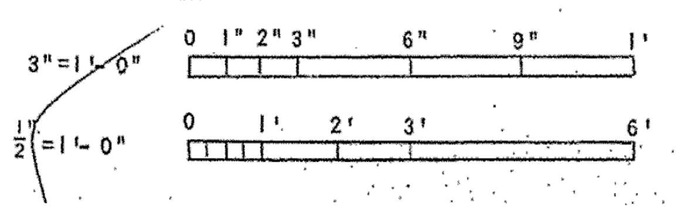
SCALE: 1/2"=1'-0"



SECTION 175 13|13

SCALE: 1/2"=1'-0"

GRAPHIC SCALES



NOTES:

1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.
2. ALL VERTICAL TIMBER PILES SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 4a.
3. ALL BATTERED TIMBER PILES SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 4b.
4. TEST PILE LOADING WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 4c.
5. ALL ELECTRICAL WORK AND LIGHTING SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM 9.
6. EXCEPT AS OTHERWISE NOTED OR INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID UNDER CONTRACT PAYMENT ITEM 1.

US Army Corps of Engineers®
PHILADELPHIA DISTRICT

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DWN BY:
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CONTRACT NUMBER:
PLOT SCALE:
FILE NAME:
DWG. SIZE: 22"x34" ANSI D
FN

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

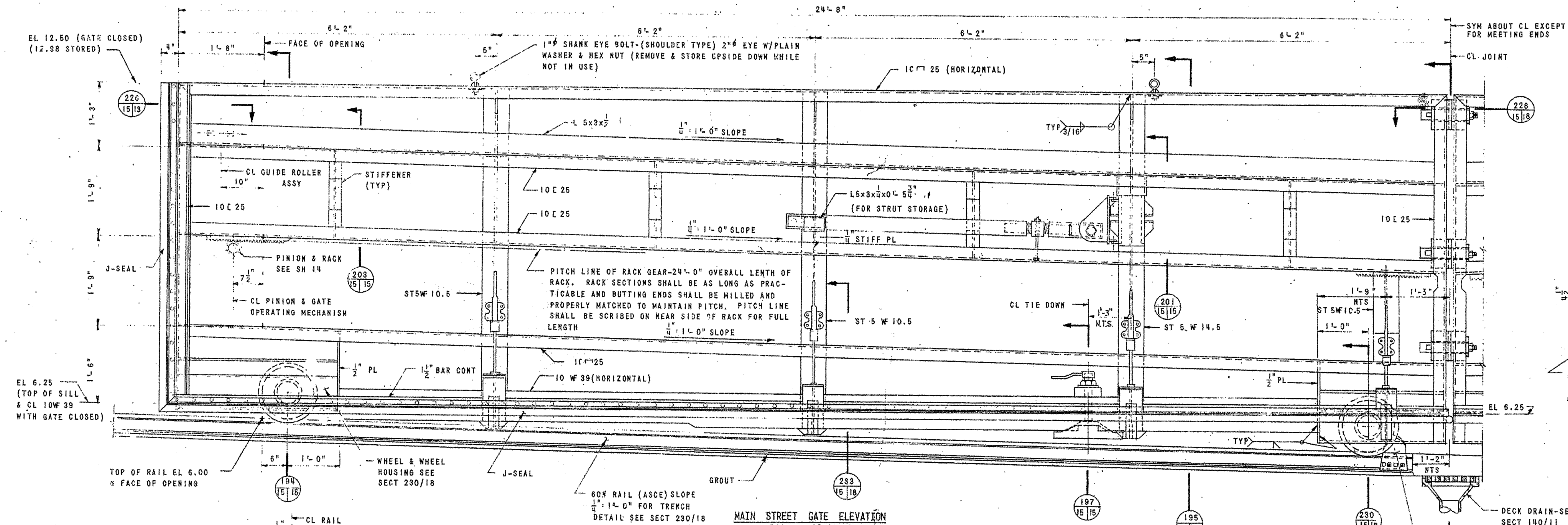
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

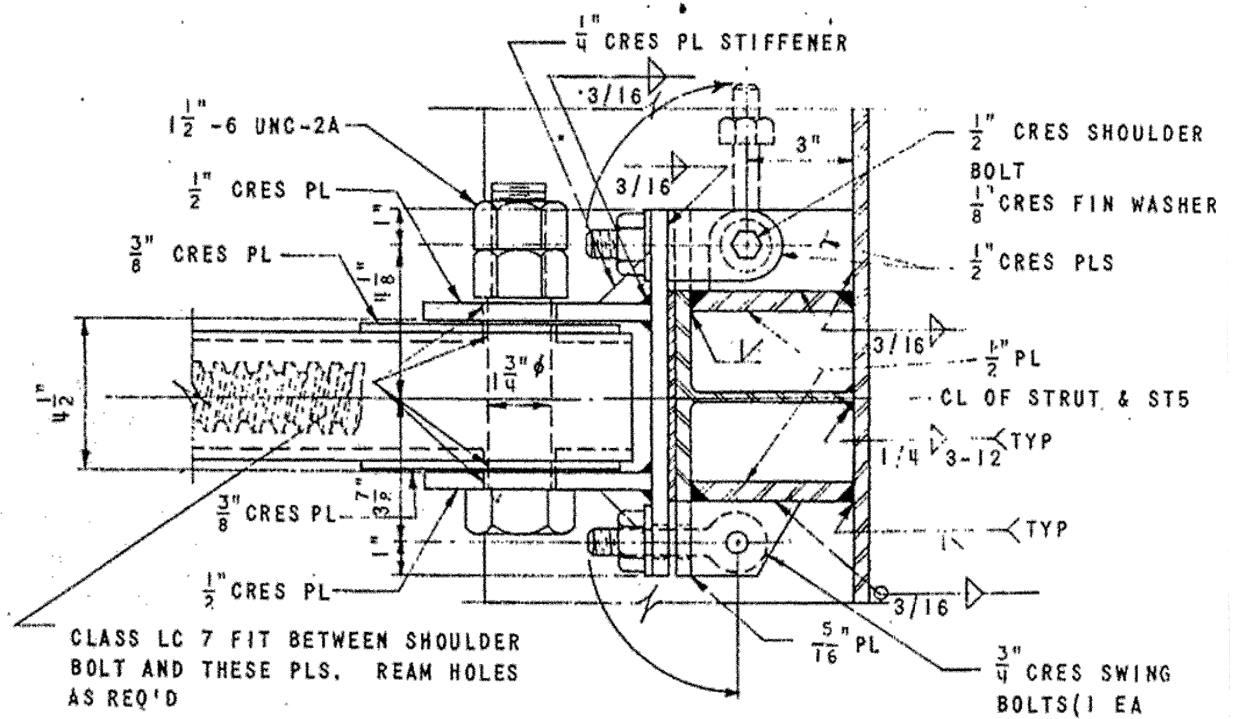
TYPICAL ROAD CLOSURE
NORTH SERVICE ROAD GATE ELEVATION

SHEET NUMBER

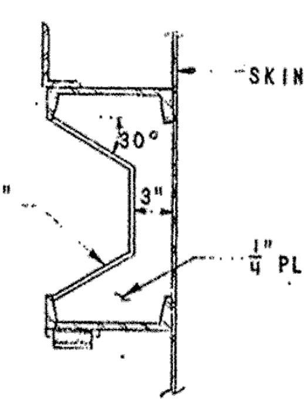
P-102



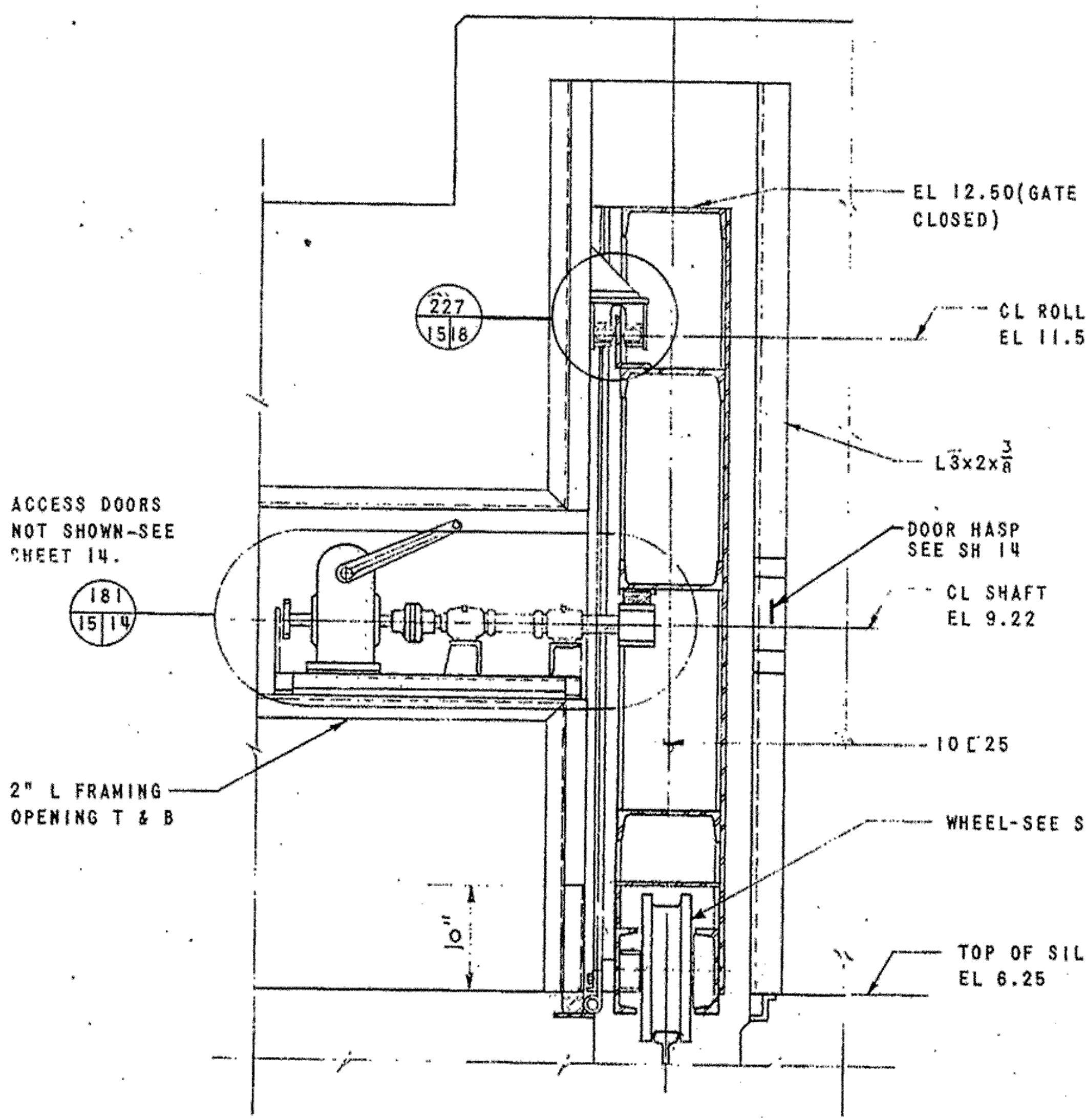
MAIN STREET GATE ELEVATION
SCALE: 1"=1'-0"
(PROTECTED SIDE VIEW SHOWING SOUTH(LEFT) LEAF, NORTH LEAF OPPOSITE HAND AND SIMILAR)



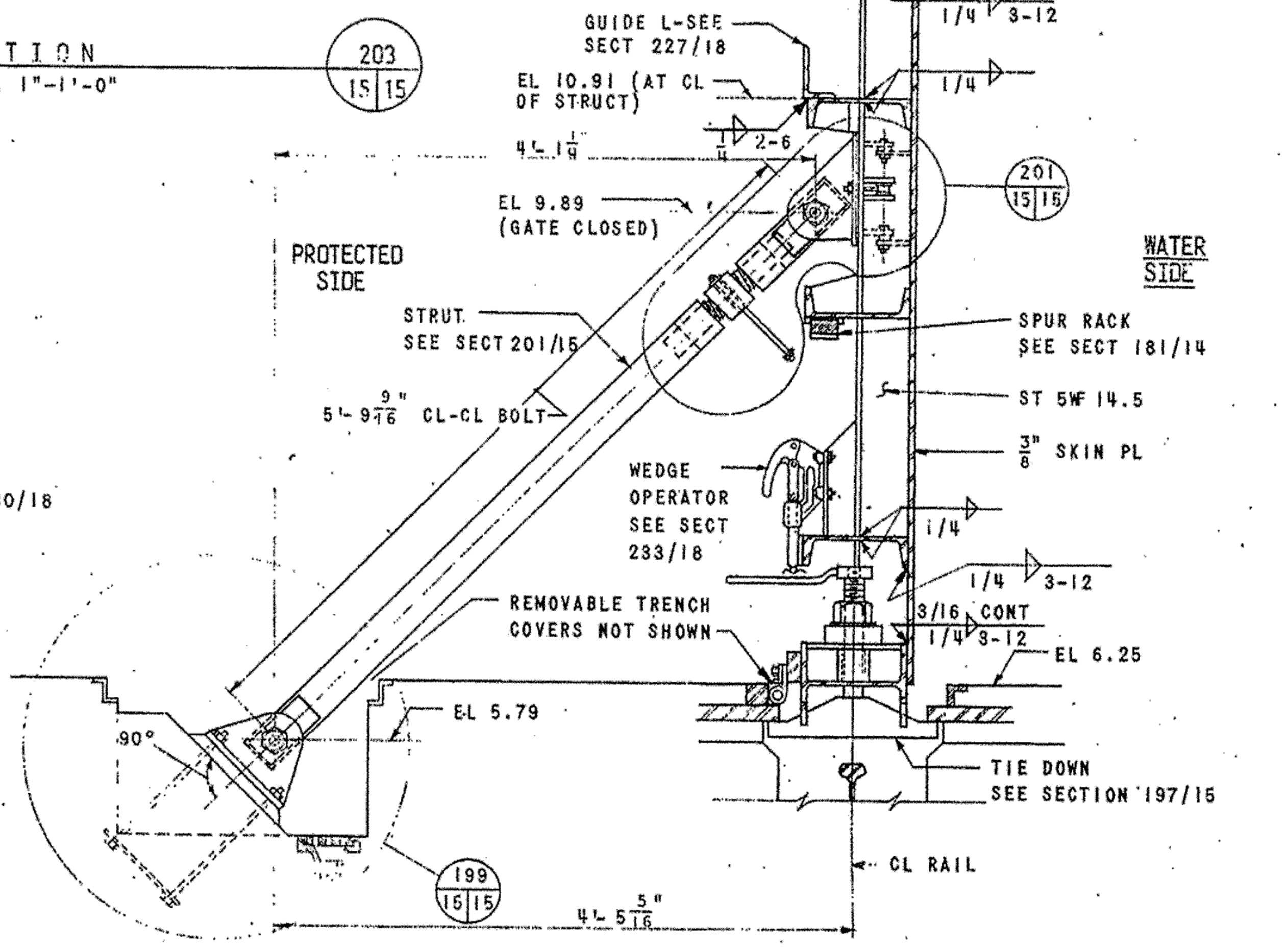
SECTION 200 15|15
SCALE: 3"=1'-0"



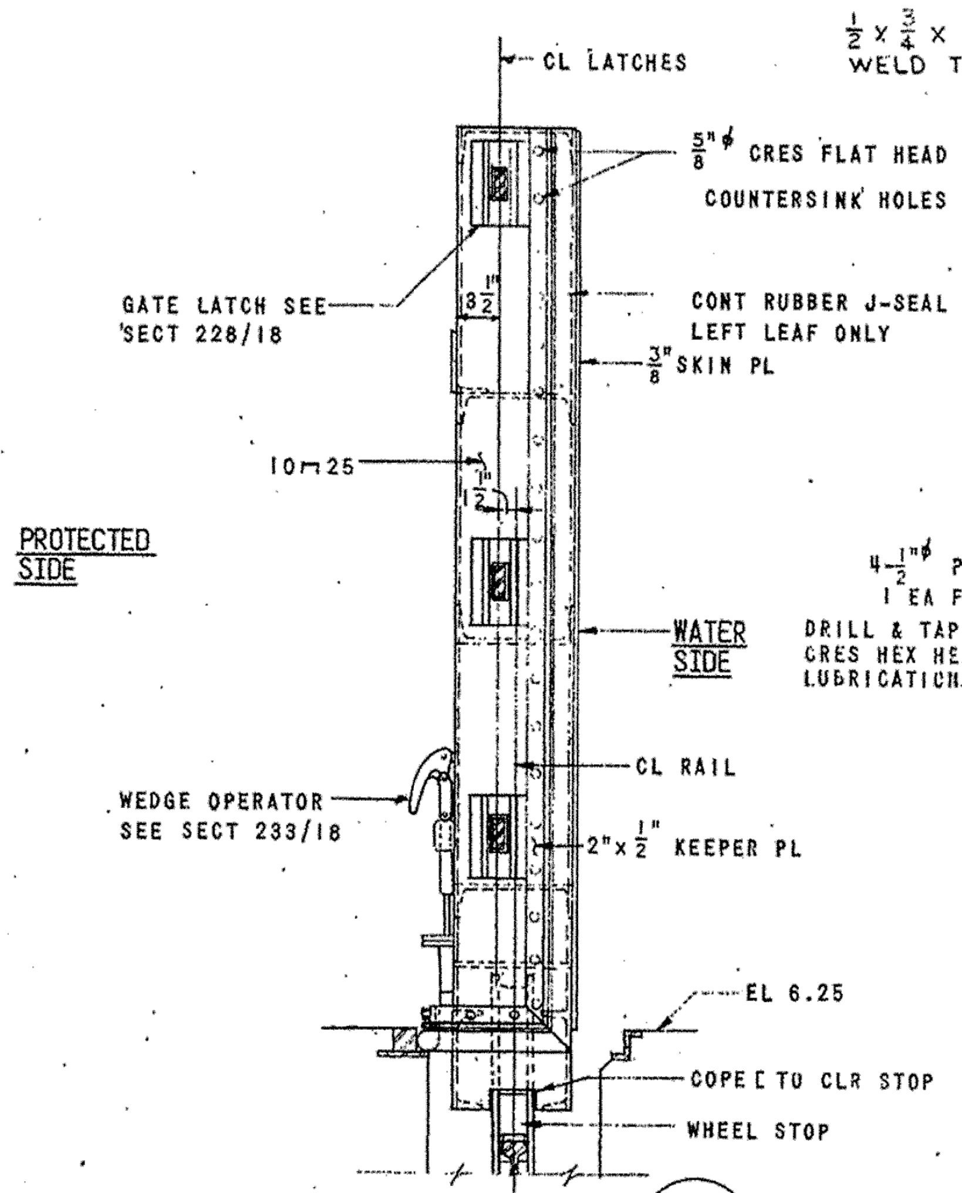
SECTION 203 15|15
SCALE: 1"=1'-0"



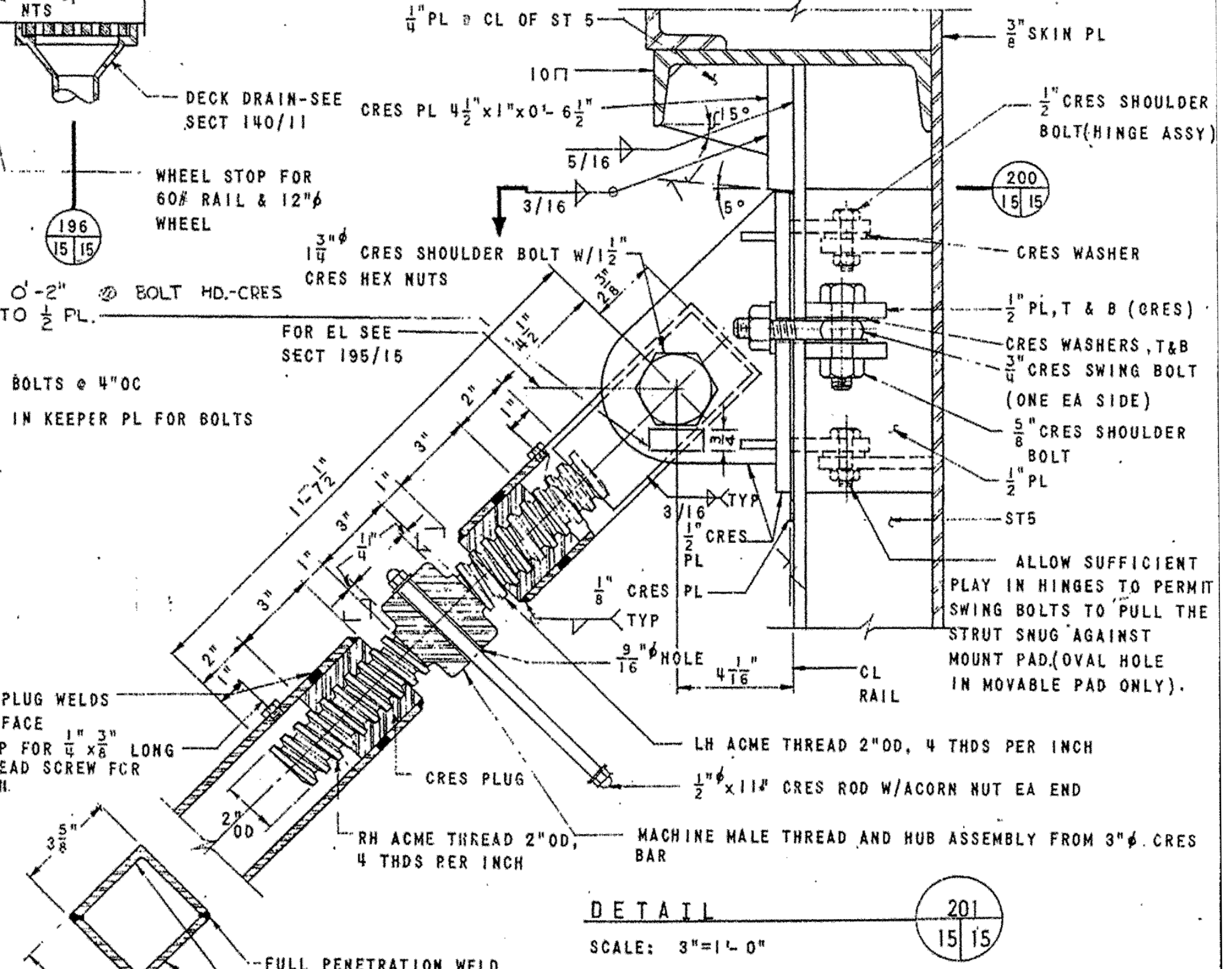
SECTION 194 15|15
SCALE: 1"=1'-0"



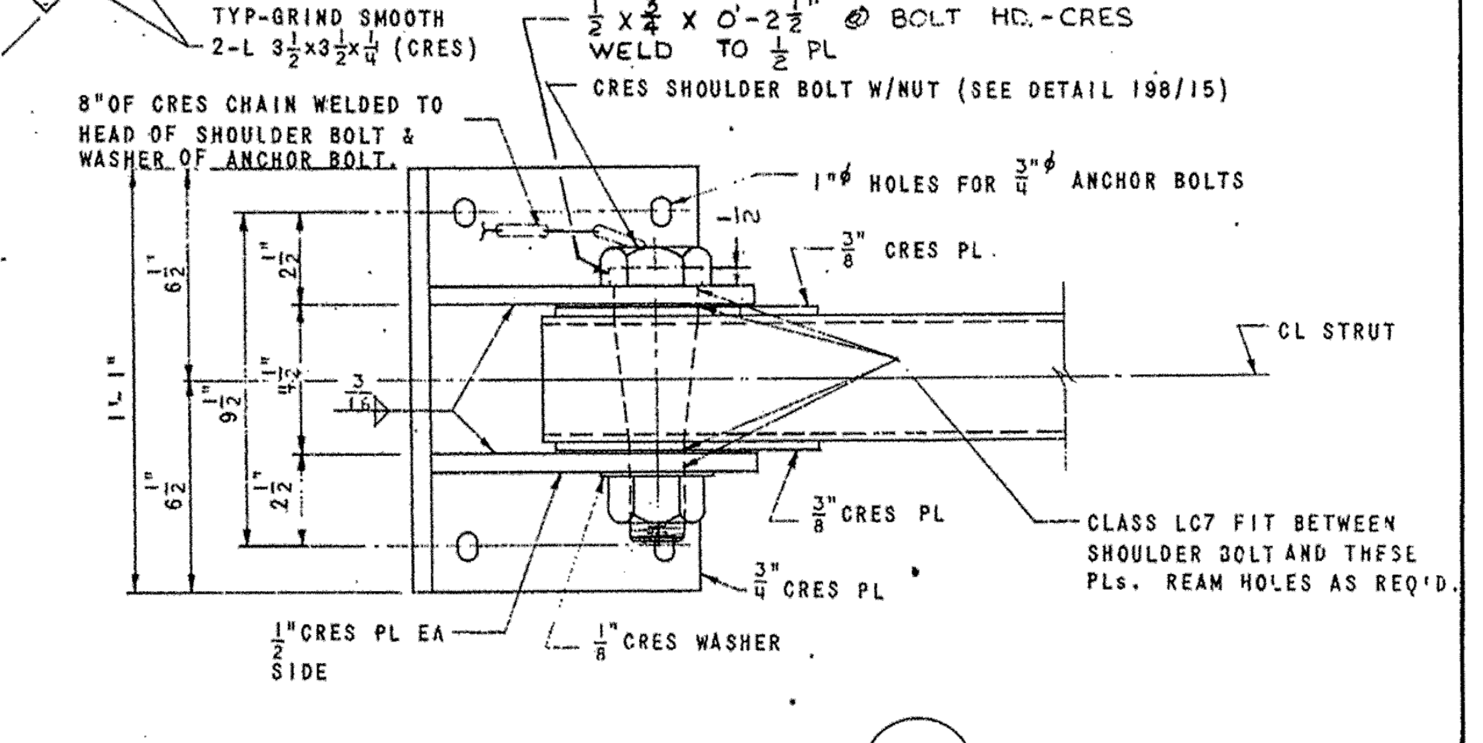
SECTION 195 15|15
SCALE: 1"=1'-0"



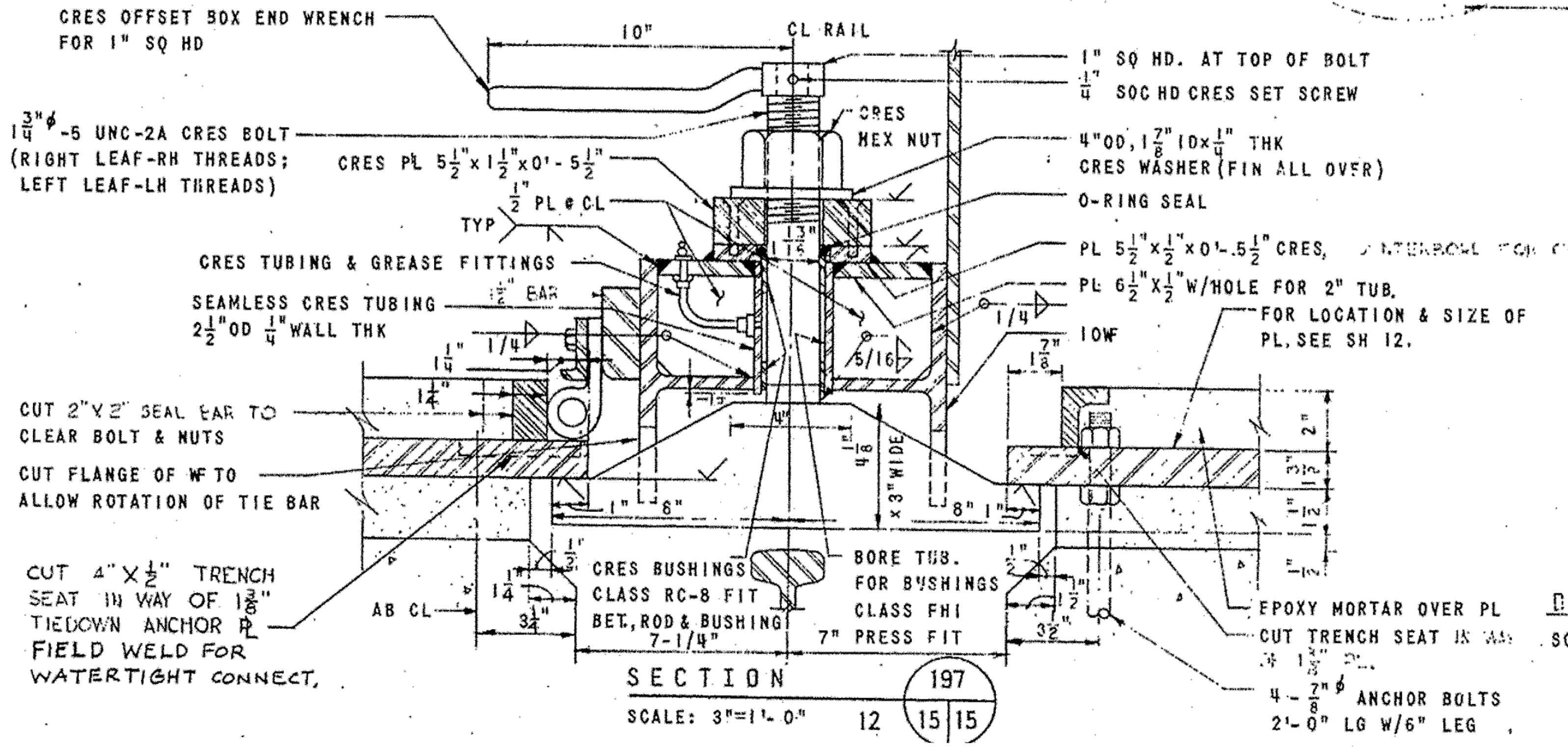
SECTION 196 15|15
SCALE: 1"=1'-0"



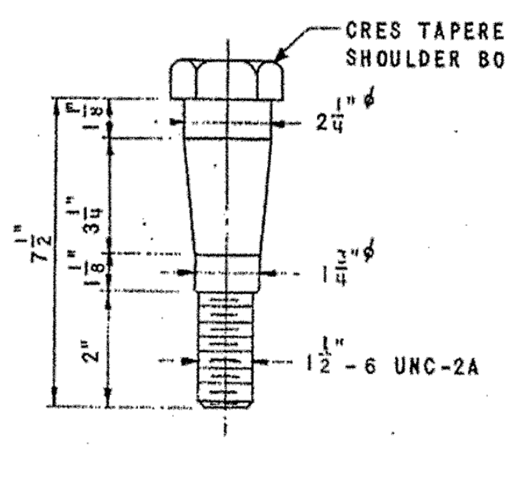
DETAIL 201 15|15
SCALE: 3"=1'-0"



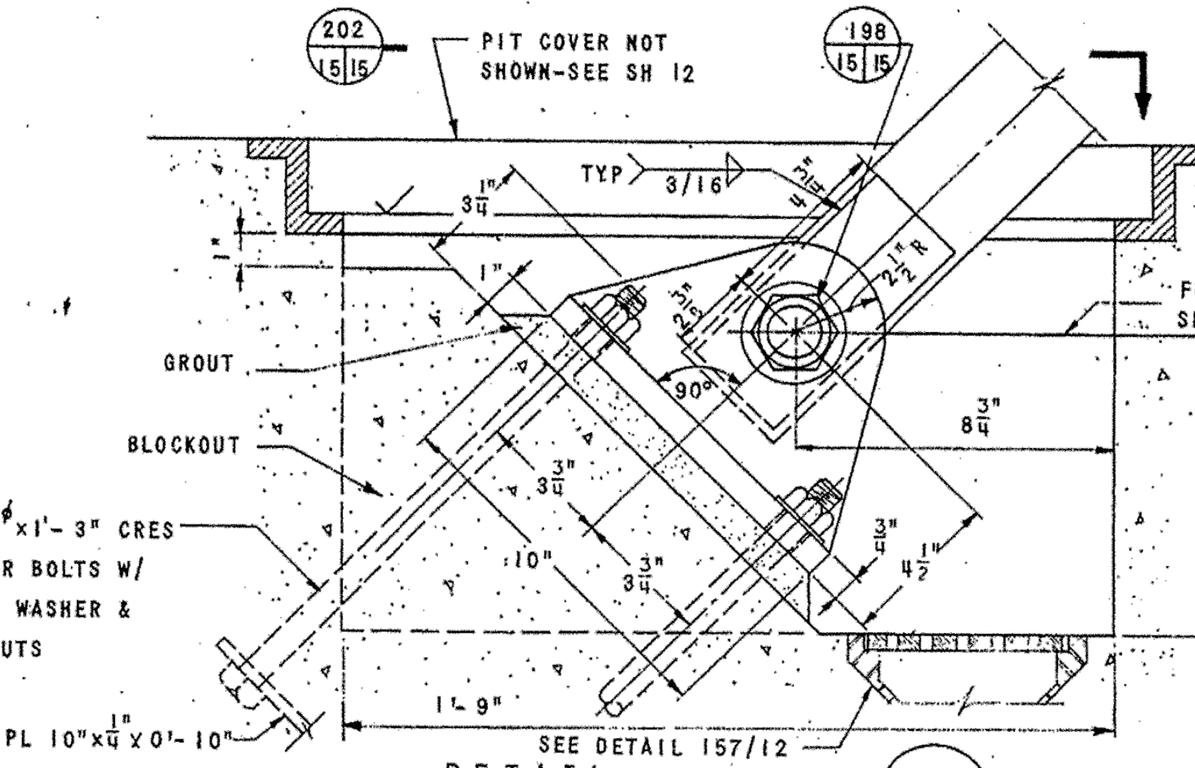
SECTION 202 15|15
SCALE: 3"=1'-0"



SECTION 197 15|15
SCALE: 3"=1'-0" 12

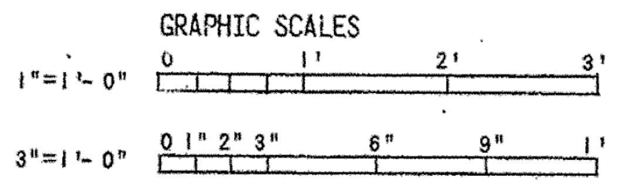


DETAIL 198 15|15
SCALE: 3"=1'-0"



DETAIL 199 15|15
SCALE: 3"=1'-0" 12

NOTE: EXCEPT AS OTHERWISE INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID FOR UNDER CONTRACT PAYMENT ITEM ①.



NOTES:
1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.
2. EXCEPT AS OTHERWISE NOTED OR INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID UNDER CONTRACT PAYMENT ITEM 1.

US Army Corps of Engineers
PHILADELPHIA DISTRICT

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PLOT SCALE:		CONTRACT NUMBER:
DWG. SIZE: 22"x34" ANSI D	FILE NAME: FN	

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

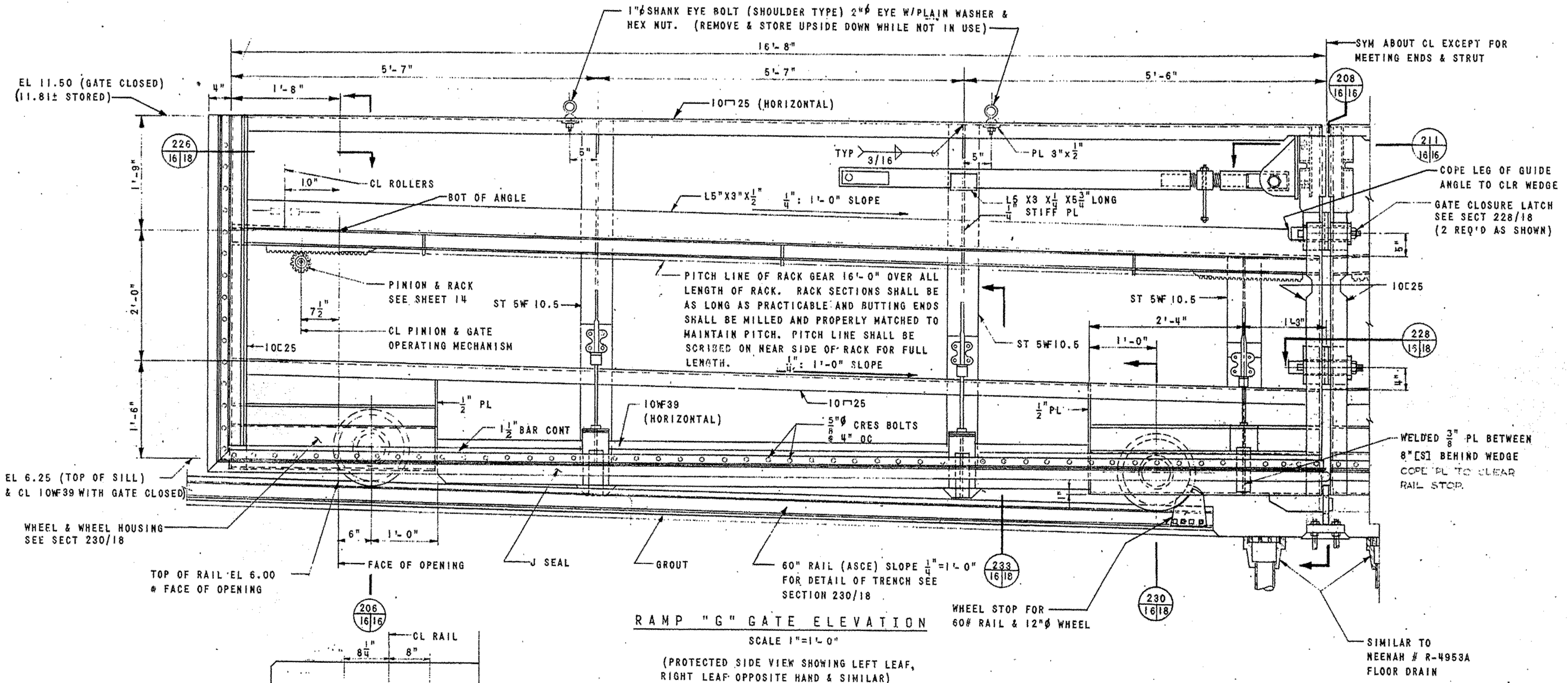
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

TYPICAL ROAD CLOSURE
MAIN STREET GATE ELEVATION

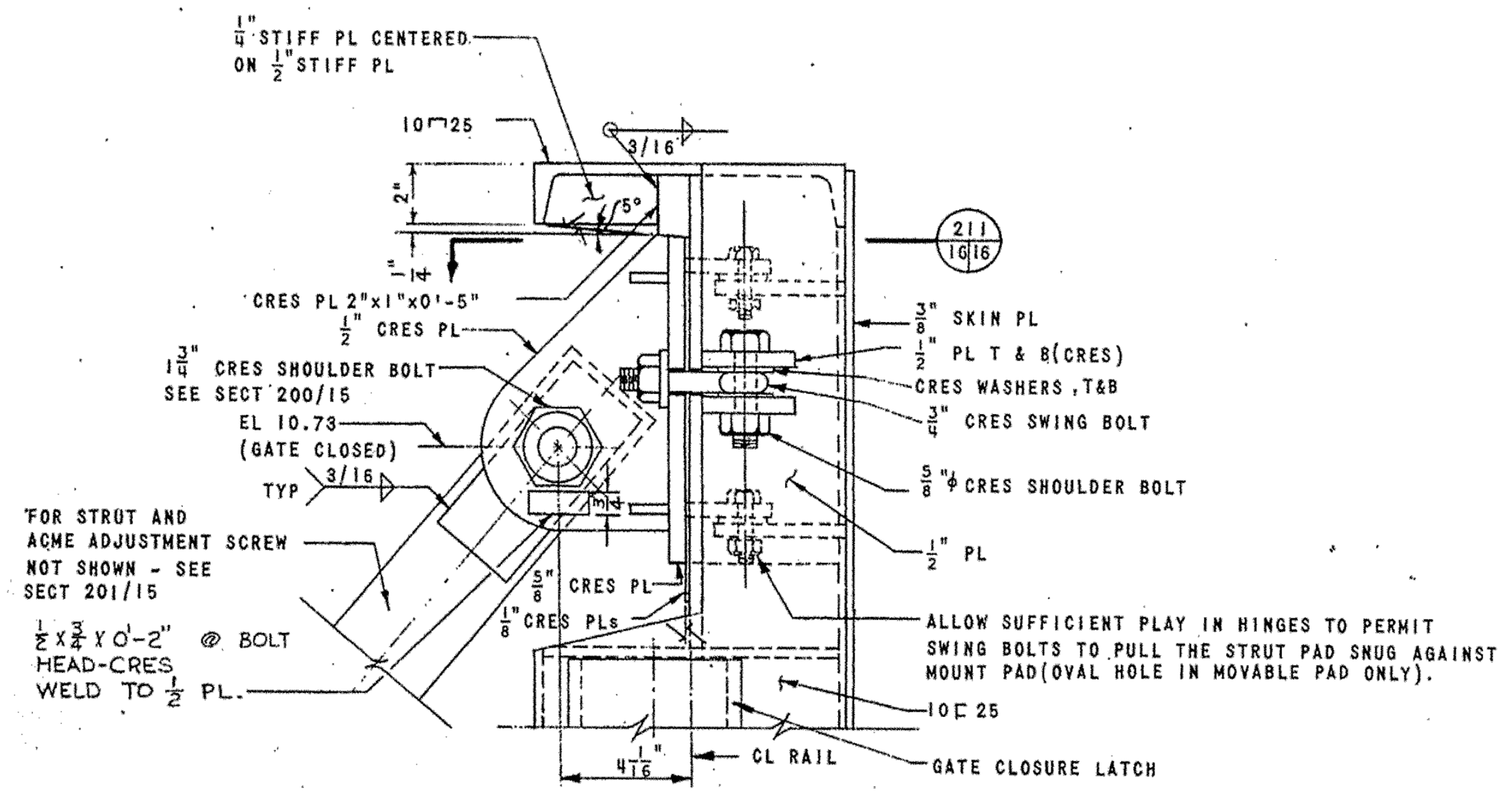
SHEET NUMBER

P-103



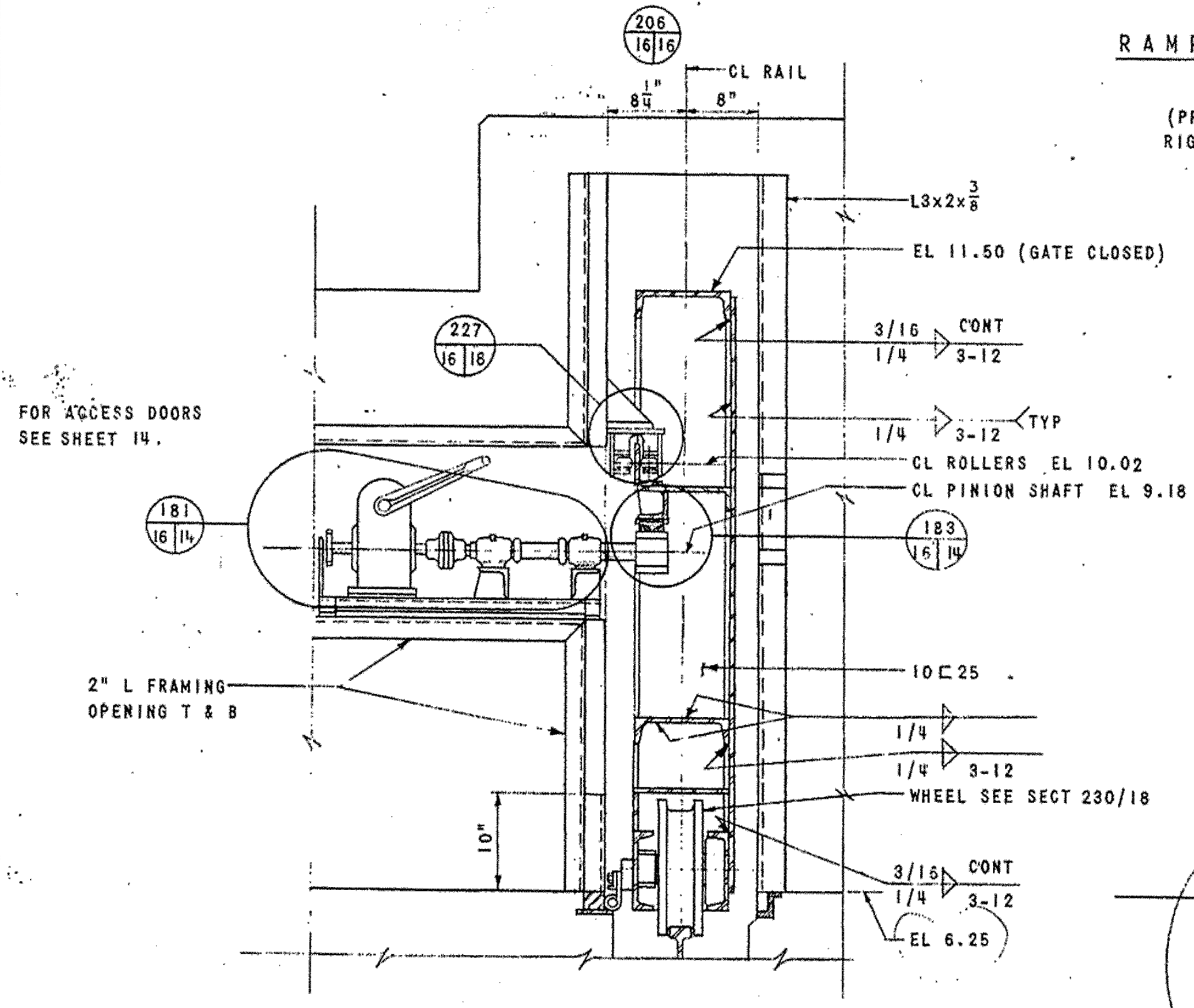
RAMP "G" GATE ELEVATION
SCALE 1"=1'-0"

(PROTECTED SIDE VIEW SHOWING LEFT LEAF, RIGHT LEAF OPPOSITE HAND & SIMILAR)

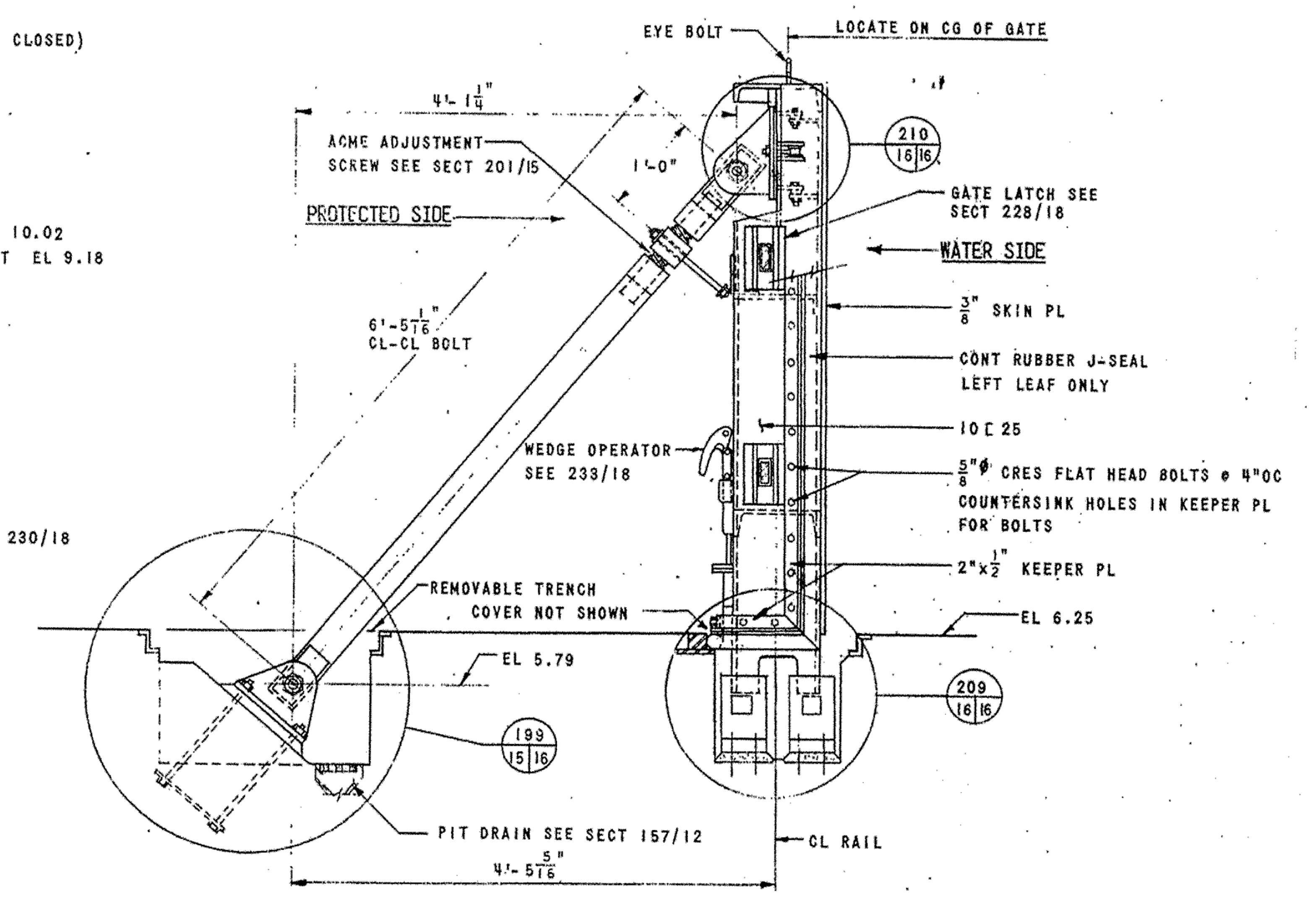


DETAIL 210 16|16
SCALE 3"=1'-0"

NOTE:
DETAIL SIMILAR TO DETAIL 200/15



SECTION 206 16|16
SCALE 1"=1'-0"

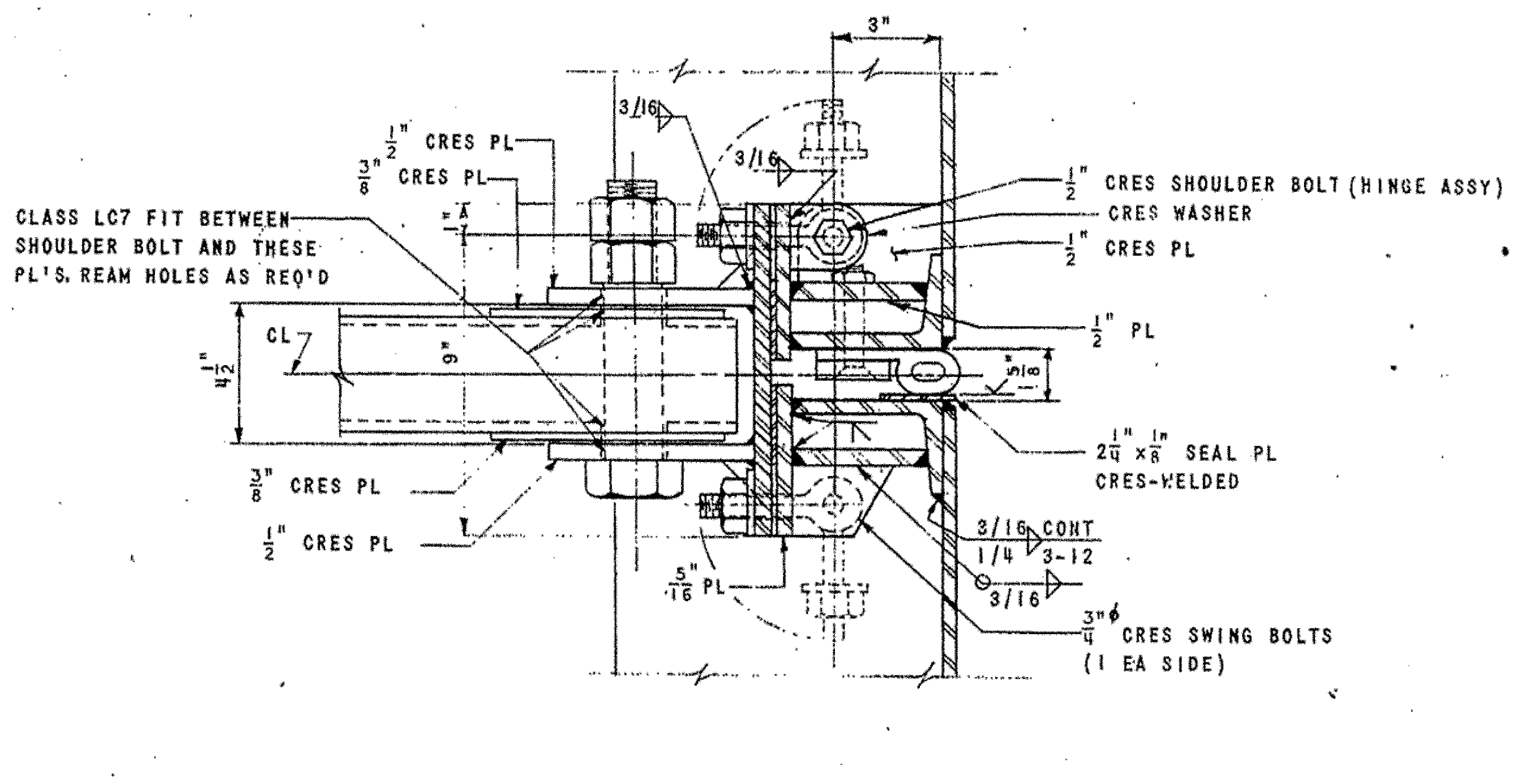


SECTION 208 16|16
SCALE 1"=1'-0"

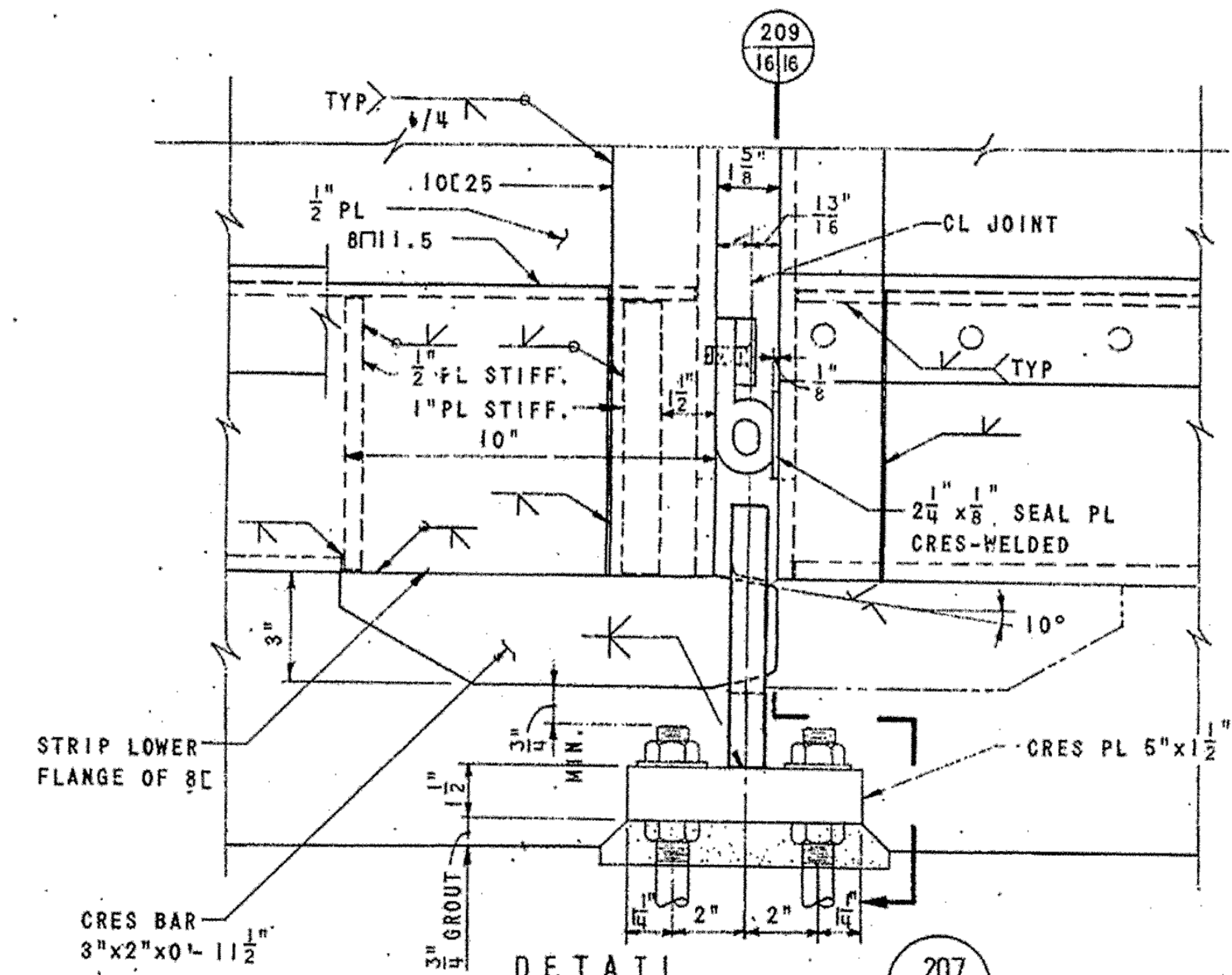
2-0
1-9
1-6
5 3

6.25
5.25
11.50   11.83   11'-11
11'-6"   - 11'-10"

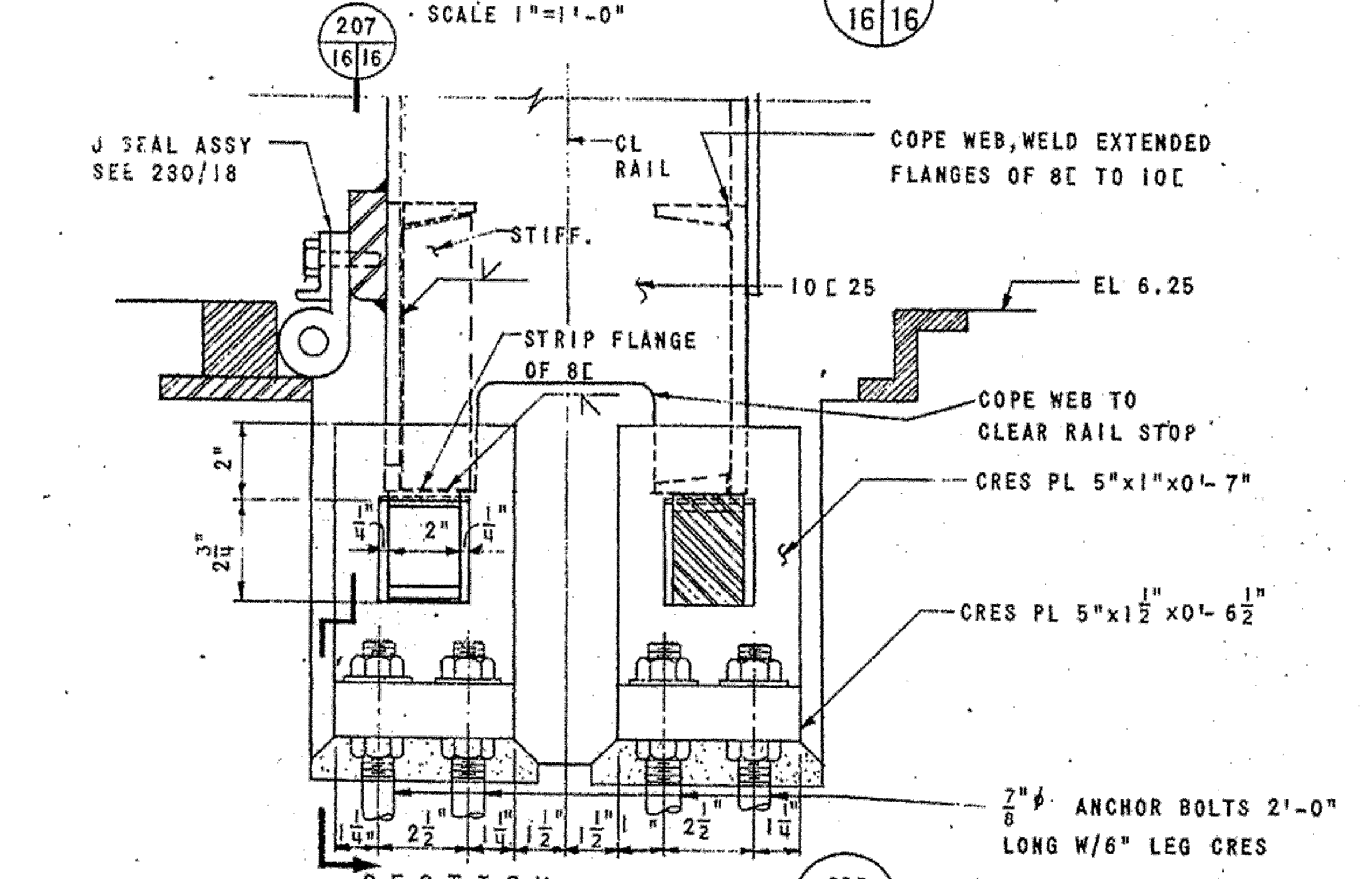
11-11
11-~~11~~ 3/8
(1 1/8)



SECTION 211 16|16
SCALE 3"=1'-0"



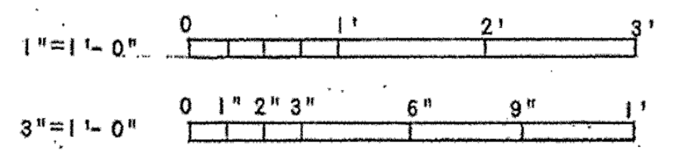
DETAIL 207 16|16
SCALE 3"=1'-0"



SECTION 209 16|16
SCALE 3"=1'-0"

NOTES:
1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.
2. EXCEPT AS OTHERWISE NOTED OR INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID UNDER CONTRACT PAYMENT ITEM 1.

GRAPHIC SCALES



US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY
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U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA
DISTRICT

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#

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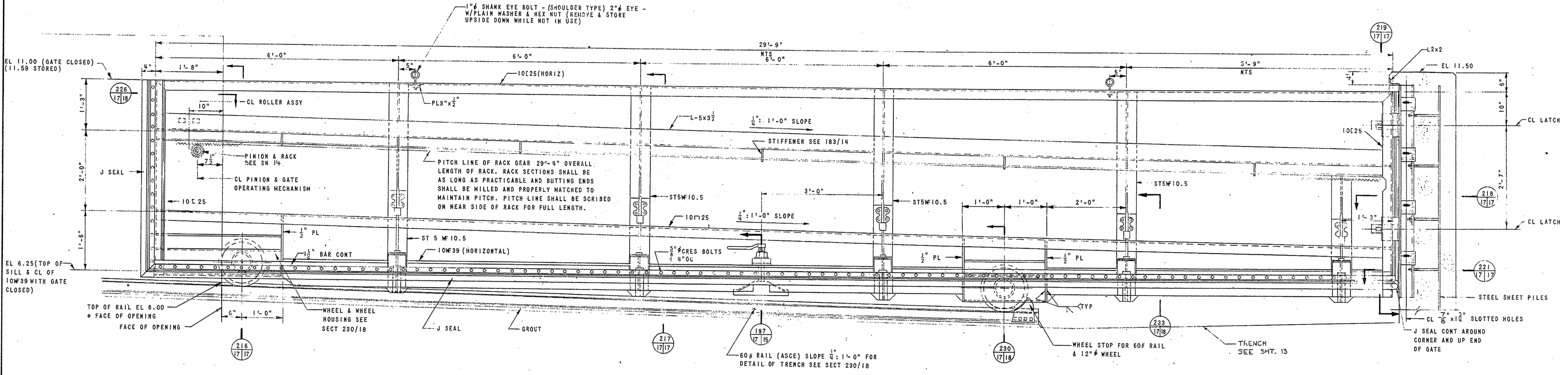
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
PLOT SCALE:
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

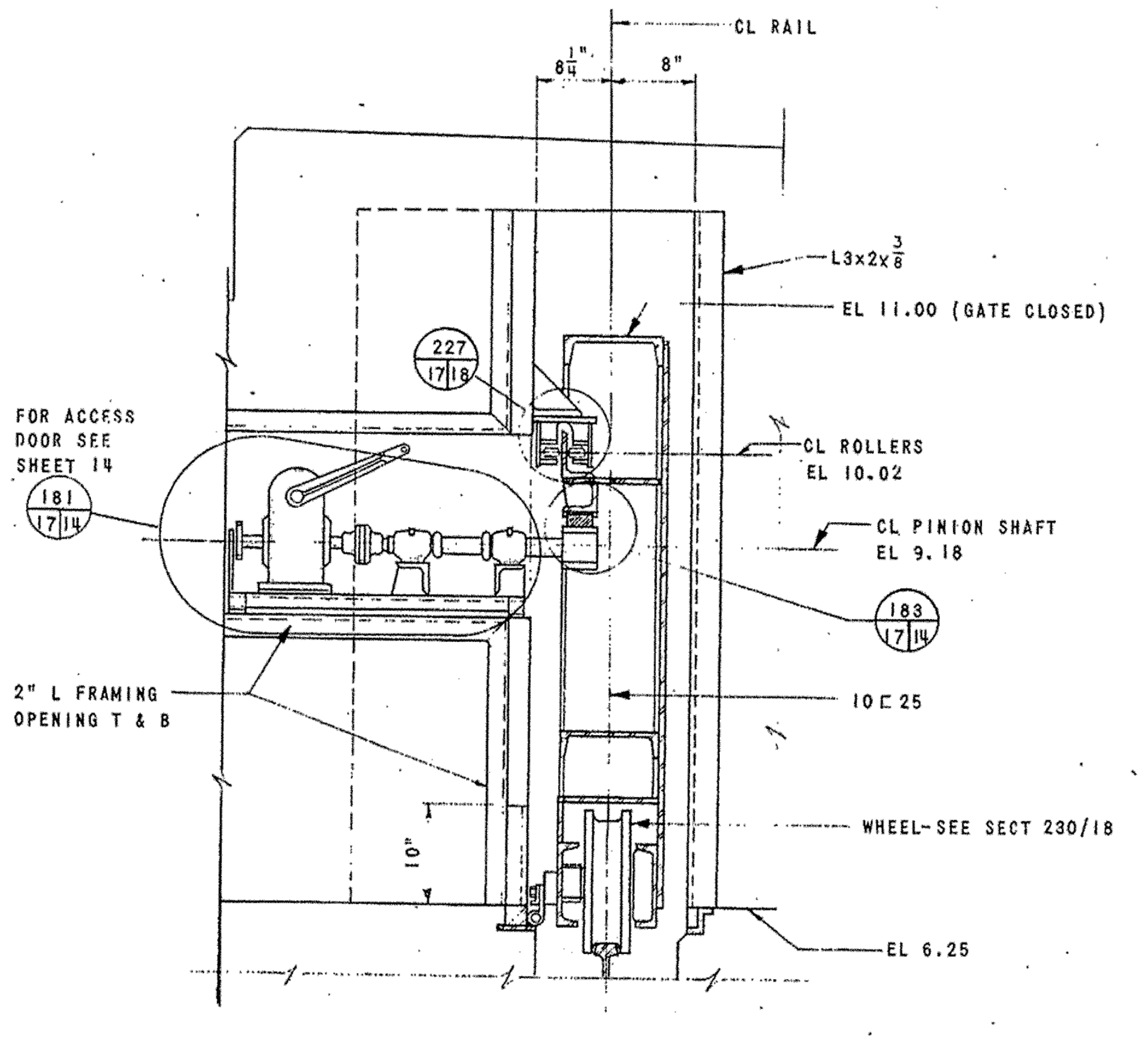
PERIMETER PLAN
SCREENING ANALYSIS

TYPICAL ROAD CLOSURE
RAMP "G" GATE ELEVATION

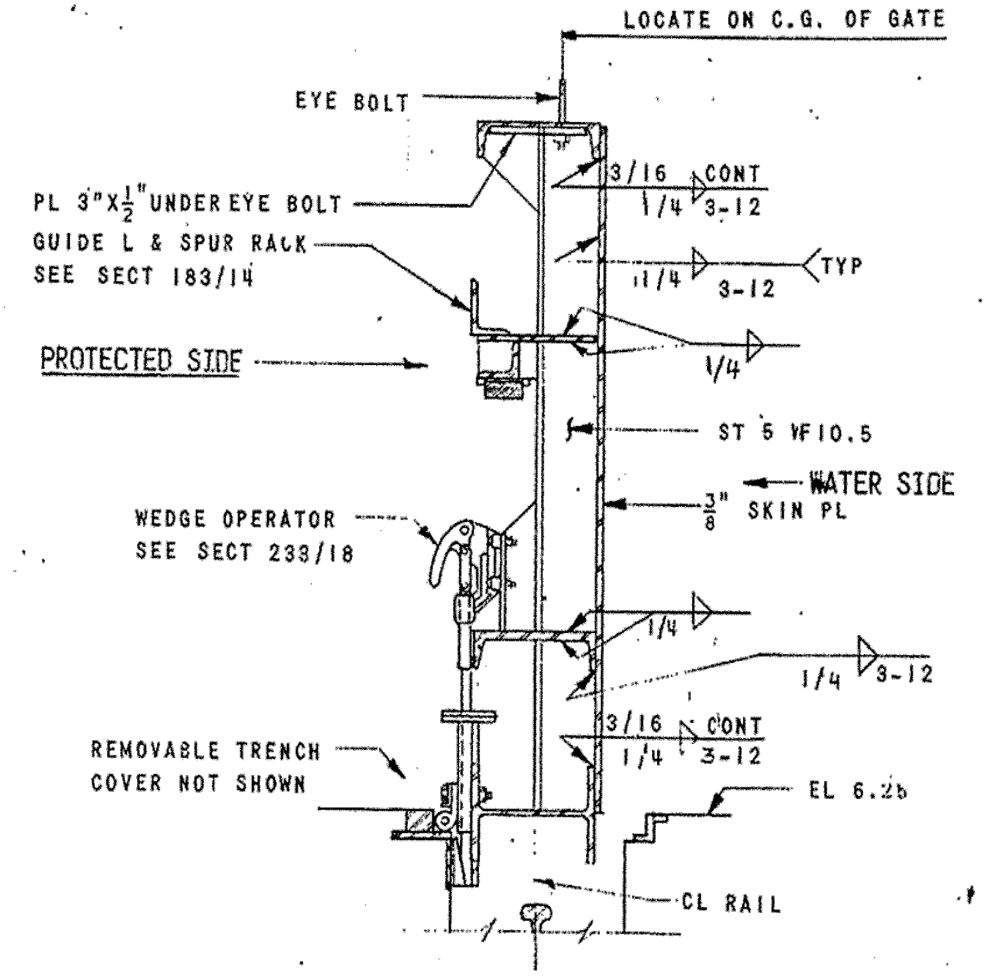
SHEET NUMBER
P-104

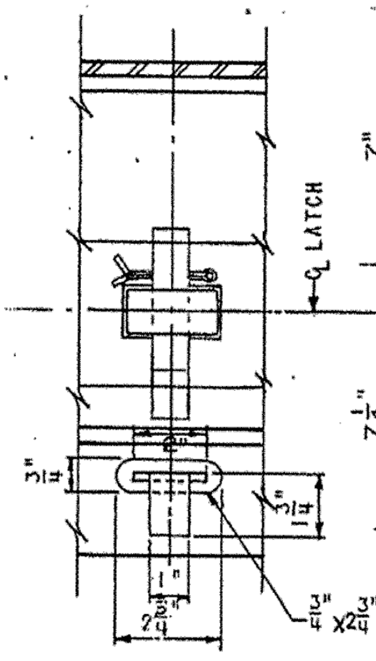


NORTH SERVICE ROAD GATE ELEVATION
SCALE 1"=1'-0"
(PROTECTED SIDE VIEW)



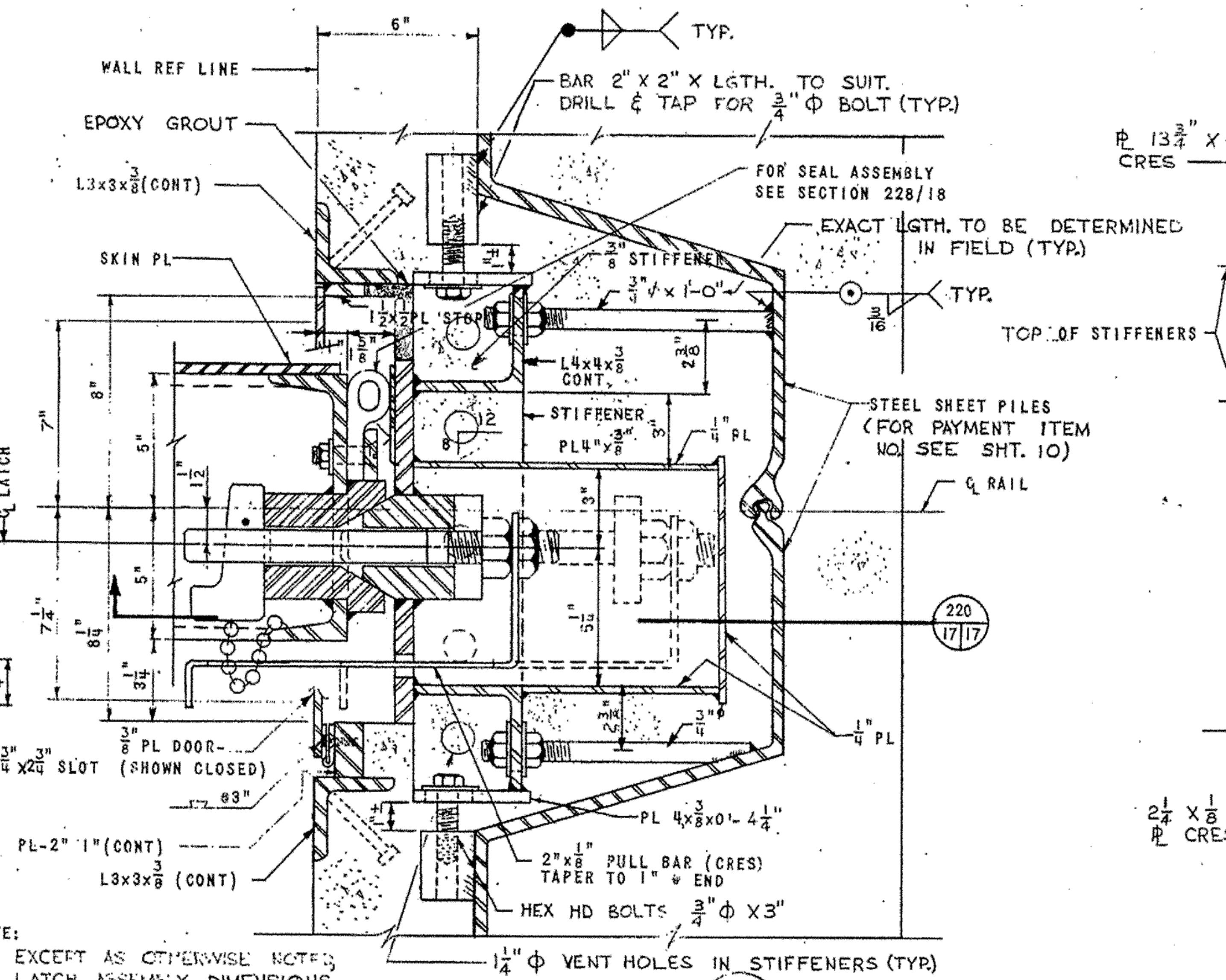
SECTION 216 17|17
SCALE 1"=1'-0"





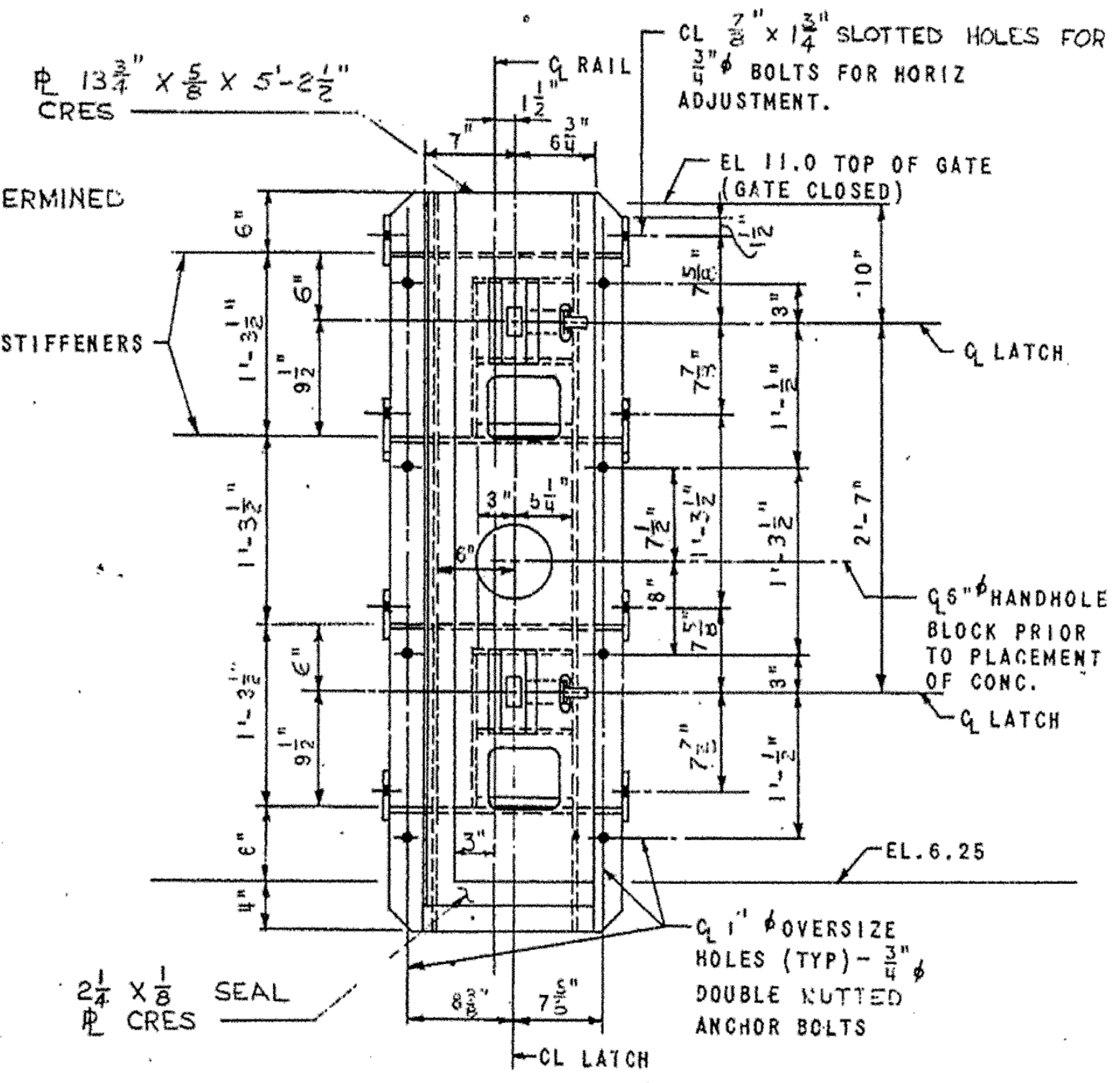
DEVELOPED VIEW OF WEDGE & PULL BAR

INSTALLATION NOTE: LIMITED INSTALLATION CLEARANCE MAY REQUIRE REMOVAL OF RUBBER J-SEALS BEFORE INSTALLING THIS GATE LEAF.

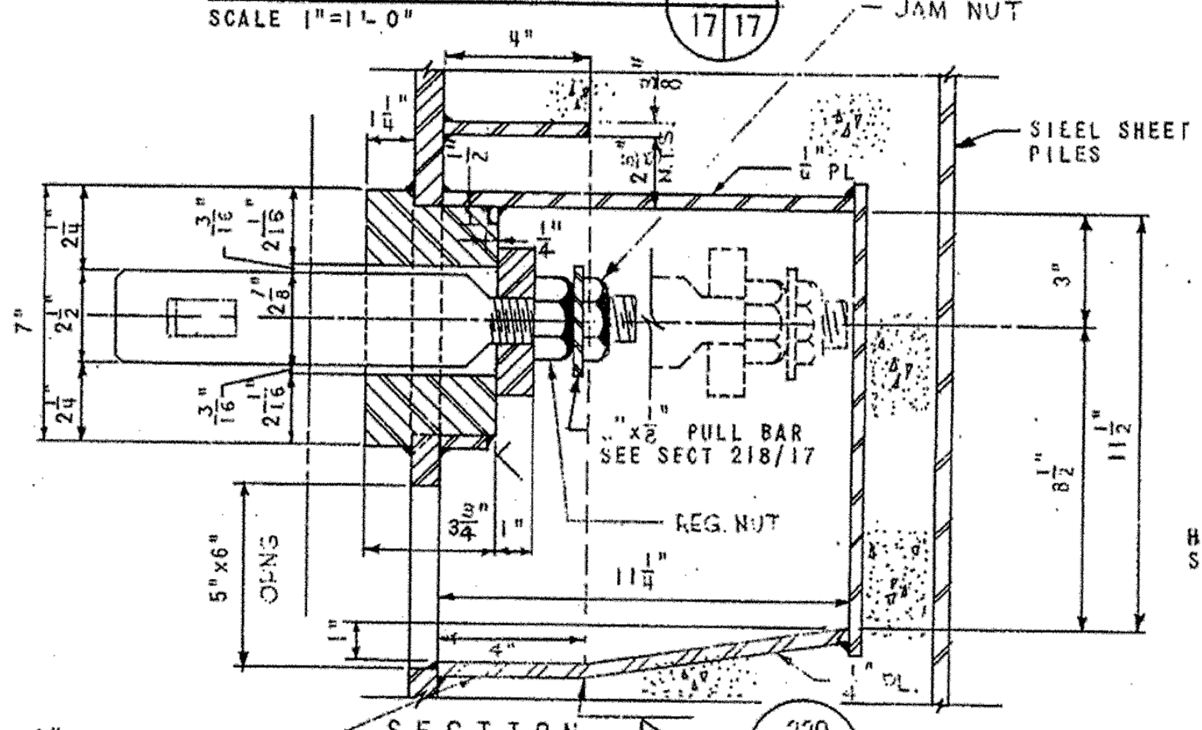


NOTE:
EXCEPT AS OTHERWISE NOTED LATCH ASSEMBLY DIMENSIONS AND MATERIALS SHALL CONFORM TO SECT. 228/18.

SECTION 218
SCALE 3"=1'-0" 13 17|17

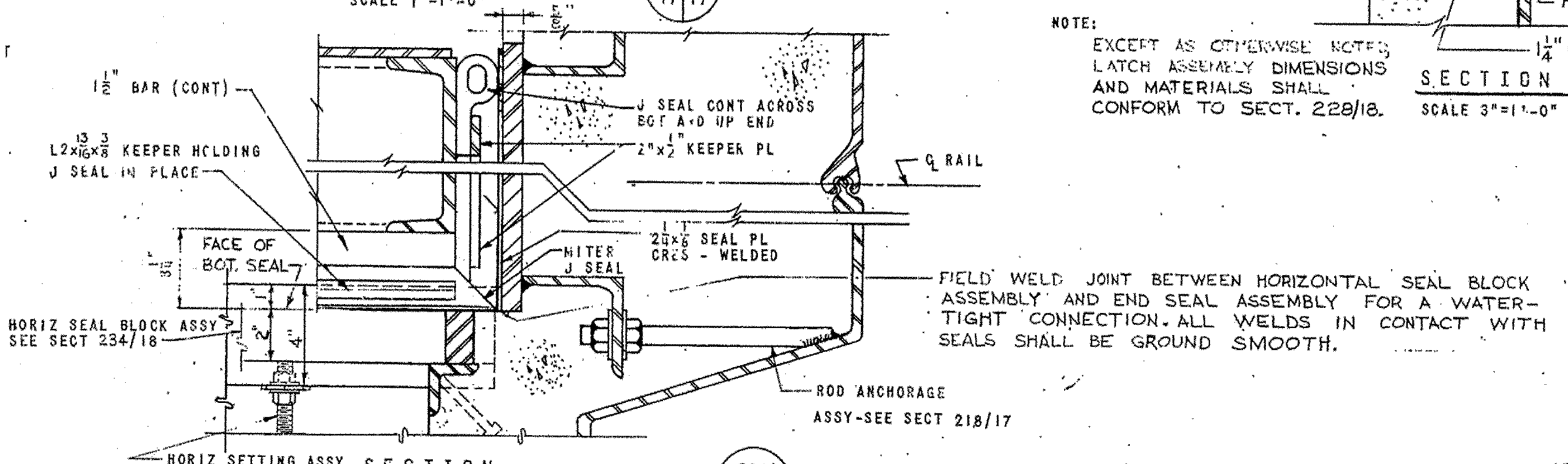


SECTION 219
SCALE: 1"=1'-0" 17|17



⅜" STIFFENER OMIT 1½" ϕ VENT HOLES IN WAY OF LATCH ENCLOSURE.

SECTION 220
SCALE 3"=1'-0" 17|17

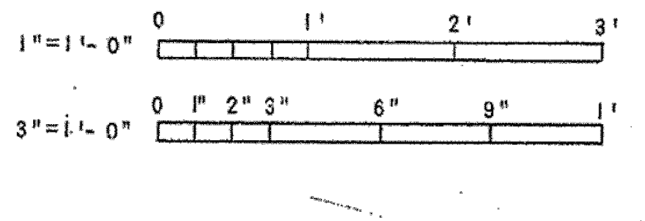


FIELD WELD JOINT BETWEEN HORIZONTAL SEAL BLOCK ASSEMBLY AND END SEAL ASSEMBLY FOR A WATER-TIGHT CONNECTION. ALL WELDS IN CONTACT WITH SEALS SHALL BE GROUND SMOOTH.

SECTION 221
SCALE: 3"=1'-0" 13 17|17

NOTES:
1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.
2. EXCEPT AS OTHERWISE NOTED OR INDICATED, ALL WORK SHOWN ON THIS SHEET WILL BE PAID UNDER CONTRACT PAYMENT ITEM 1.

GRAPHIC SCALES



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PHILADELPHIA DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY
PERIMETER PLAN
SCREENING ANALYSIS
TYPICAL ROAD CLOSURE
NORTH SERVICE ROAD GATE ELEVATION

SHEET NUMBER
P-105

PRELIMINARY STREET CLOSURES
NORFOLK CSRM 10% DESIGN

No.	Gate No.	Location	Station	Sill Height	Top of Gate	Height	Width	
1	PL-1	Crossing shore drive	56+00	7.0	13.5	6.5	130 ft	
2	LR-1	Gleneagle Road	3+00	8.0	13.5	5.5	60 ft	
3	LR-2	North Shore Road	5+00	8.0	13.5	5.5	45 ft	
4	LR-3	Elizabeth River Trail Norfolk Yacht	6+50	8.0	13.5	5.5	45 ft	
5	LR-4	Helena Ave	11+00	8.0	13.5	5.5	50 ft	
6	LR-5	Pasadena	13+00	8.0	13.5	5.5	45 ft	
7	LR-6	Claudin Ave	15+00	8.0	13.5	5.5	40 ft	
8	LR-7	across Hampton Blvd@ft of bridge	18+50	8.0	13.5	5.5	50 ft	
9	LR-8	North Fair water Dr	39+00	8.0	13.5	5.5	40 ft	
10	LR-9	Escadrile Dr	40+00	6.0	13.5	7.5	60 ft	
11	LR-10	South Fairwater Dr	41+50	6.0	13.5	7.5	65 ft	
12	LR-11	Lexan Dr (Library)	47+50	4.0	13.5	9.5	60 ft	
13	LR-12	Bedford Ave	50+00	5.0	13.5	8.5	40 ft	
14	LR-13	Manchester Ave	53+00	5.0	13.5	8.5	45 ft	
15	LR-14	Hanover/Richmond Cresc Ave	56+00	5.0	13.5	8.5	60 ft	
16	LR-15	Surrey Crescent	61+50	4.0	13.5	9.5	40 ft	
17	LR-16	Larchmont Crescent	64+00	3.0	13.5	10.5	40 ft	
18	LR-17	Magnolia Ave	67+00	5.0	13.5	8.5	50 ft	
19	LR-18	Rockbridge Ave	70+00	6.0	13.5	7.5	40 ft	
20	LR-19	Westmoreland Ave -1	72+00	6.5	13.5	7.0	70 ft	
21	BR-1	Gresham Dr - 1	10+50	9.0	13.5	4.5	30 ft	
22	BR-2	Colley Ave	18+50	9.0	13.5	4.5	130 ft	
23	FR-1	NOAA West York Ave	43+50	6.0	13.5	7.5	40 ft	
24	FR-2	West Freemason	50+75	5.5	13.5	8.0	15 ft	
25	FR-3	Yarmouth/College Cross	61+00	6.0	13.5	7.5	25 ft	
26	FR-4	Harbor St	63+00	5.0	13.5	8.5	35 ft	
27	FR-5	Duke St	65+50	6.5	13.5	7.0	55 ft	
28	FR-7	Brooke Ave	70+00	4.0	13.5	9.5	30 ft	
29	FR-8	Nauticus	75+00	4.0	13.5	9.5	25 ft	
30	FR-8	Main street	79+00	5.0	13.5	8.5	50 ft	
31	FR-9	Waterside Bend/Park	79+50	4.0	13.5	9.5	30 ft	

PRELIMINARY STREET CLOSURES
NORFOLK CSRM 10% DESIGN

32	WS-1	Waterside 1	86+00	7.5	13.5	6.0	65 ft	
33	WS-2	Waterside 2	93+00	8.0	13.5	5.5	25 ft	
34	WS-3	Waterside 3 / Roanoke Ave	96+00	8.0	13.5	5.5	120 ft	
35	WS-4	E Water St	102+00	6.0	13.5	7.5	200 ft	
36	HP-1	West of Harbor Park @ pier	126+00	4.0	13.5	9.5	20 ft	
37	HP-2	East of Harbor Park @ Helopad	134+50	6.0	13.5	7.5	25 ft	
38	NS-1	Norfolk Southern Closure	141+00	10.0	13.5	3.5	60 ft	
39	SUB-1	Substation location - Parking Lot	155+50	7.0	13.5	6.5	60 ft	
40	SUB-2	Substation location -Reeves Rd	158+50	8.0	13.5	5.5	40 ft	
41	SUB-3	across Brown Ave	161+00	6.0	13.5	7.5	40 ft	
42	SUB-4	across Willoughby Ave	164+50	10.0	13.5	3.5	30 ft	
43	SUB-5	across Claiborne Ave	168+25	8.0	13.5	5.5	30 ft	
44	CF-1	across Hydro Street	189+25	6.0	13.5	7.5	20 ft	
45	CF-2	across Jacobs Street	195+50	6.0	13.5	7.5	25 ft	
46	CF-3	across Kimball Terrace	205+25	5.0	13.5	8.5	35 ft	
47	CF-4	across Grandy Village Canoe	253+25	6.5	13.5	7.0	25 ft	
48	CF-5	across East End Ave	271+00	7.0	13.5	6.5	50 ft	
49	BC-1	across Corporate Blvd	76+00	9.5	13.5	4.0	50 ft	
50	BC-2	across Michelle V. Bell Park'g lot	80+00	8.0	13.5	5.5	40 ft	
51	BC-3	across park'g lot south of Michelle Bell	84+00	8	13.5	5.5	35 ft	possibly not needed
52	BC-4	across park'g lot bldg west of Military Hwy	90+00	9.0	13.5	4.5	60 ft	
53	BC-5	across Orion Ave	92+25	10.0	13.5	3.5	30 ft	
54	BC-6	across Corporate Blvd	102+00	11.0	13.5	2.5	245 ft	
55	CA-1	across Fauquier St	5+50	7.0	13.5	6.5	80 ft	
56	CA-2	across parking south of Fauquier St	9+00	7.0	13.5	6.5	50 ft	
58	CA-3	across shipyard parking lot along E.Indian River	21+00	11	13.5	2.5	70 ft	

2

PRELIMINARY STREET CLOSURES
NORFOLK CSRM 10% DESIGN

		Front Street Alignment					
	FS-1	across Colley Ave	3+50	8	13.5	5.5	50 ft
	FS-2	across Third St	8+00	8	13.5	5.5	30 ft
	FS-3	across Second St	12+25	8	13.5	5.5	30 ft

Stationing is from alignments along each reach of wall.

LEGEND	
PL	PRETTY LAKE
LR	LAFAYETTE RIVER
BR	BRAMBLETON
WS	WATERSIDE
HP	HARBOR PARK
NS	NORFOLK SOUTHERN
SUB	SUBSTATION
CF	CHESTERFIELD
BC	BROAD CREEK
CA	CAMPOSTELLA
FS	FRONT STREET

3

NOTES:
1. TYPICAL ROAD CLOSURE PLANS ARE FROM A NORFOLK DISTRICT COSTAL STORM RISK MANAGEMENT (CSRM) STUDY.

US Army Corps ®
of Engineers
PHILADELPHIA
DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
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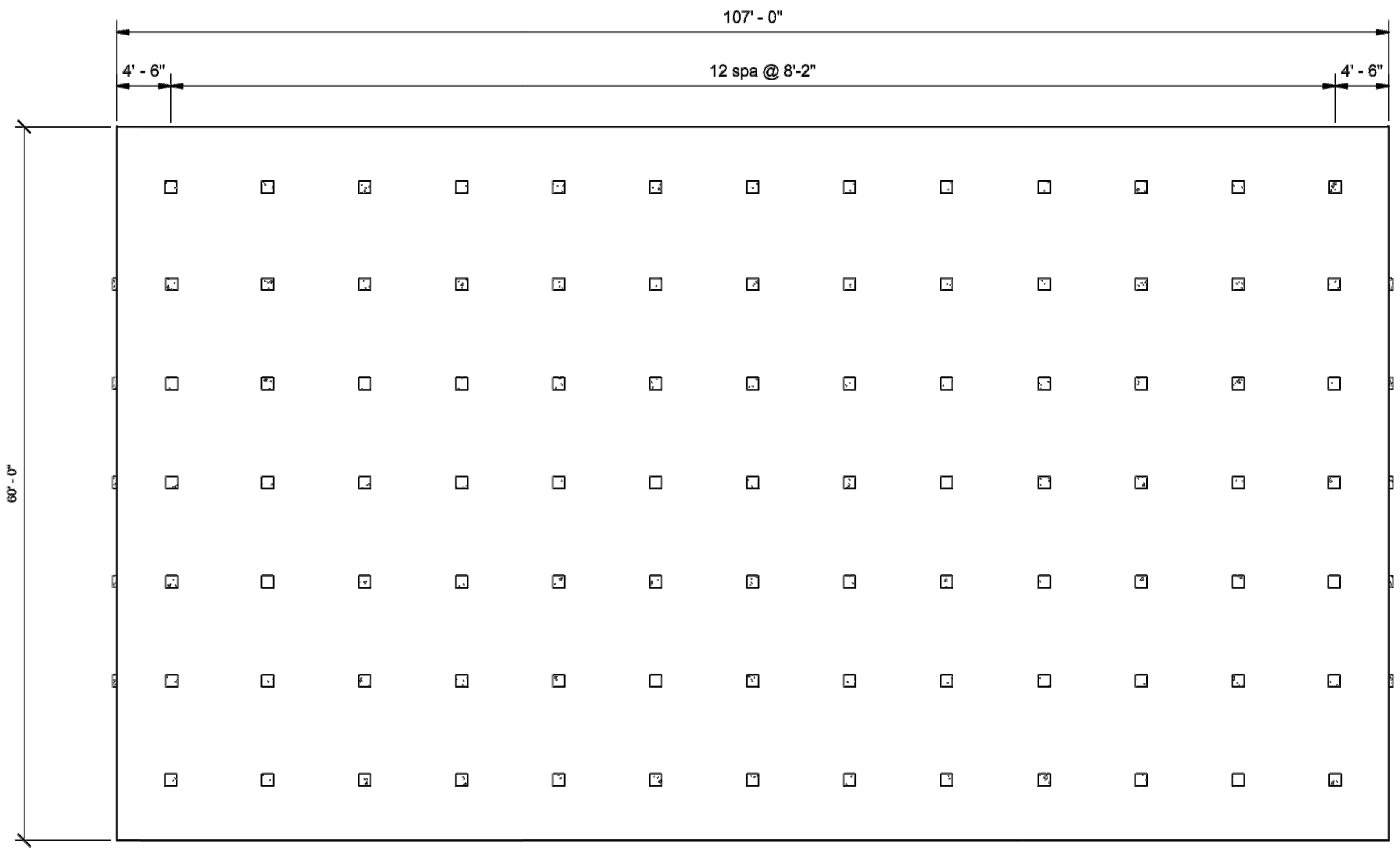
NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

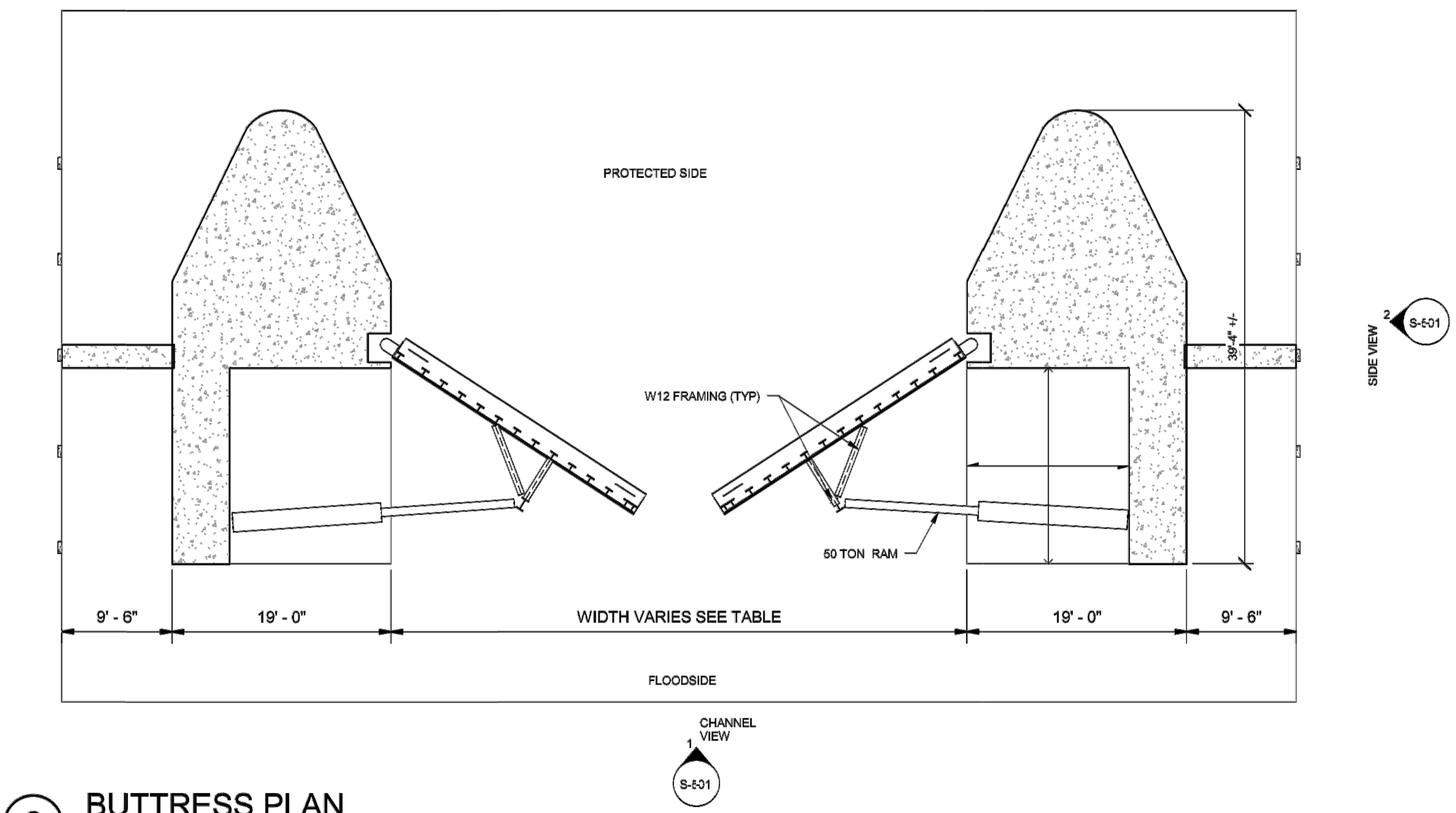
TYPICAL ROAD CLOSURE
GATE STATIONS AND DIMENSIONS

SHEET NUMBER
P-106



① SINGLE TIDE GATE FOUNDATION PLAN

1/8" = 1'-0"



② BUTTRESS PLAN

1/8" = 1'-0"

US Army Corps of Engineers
PHILADELPHIA DISTRICT

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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

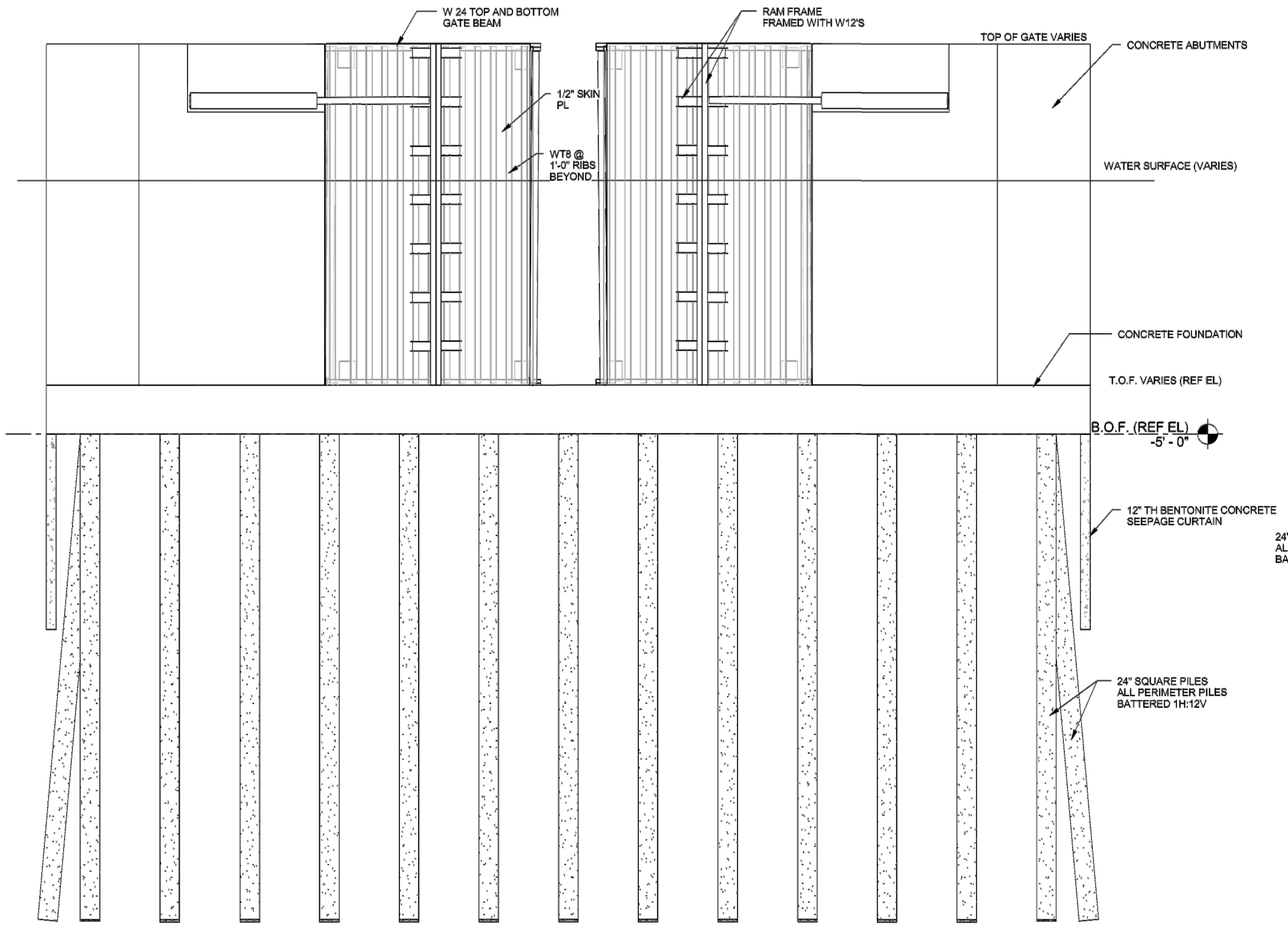
PERIMETER PLAN
SCREENING ANALYSIS

MITER TIDE GATE
PLAN VIEW

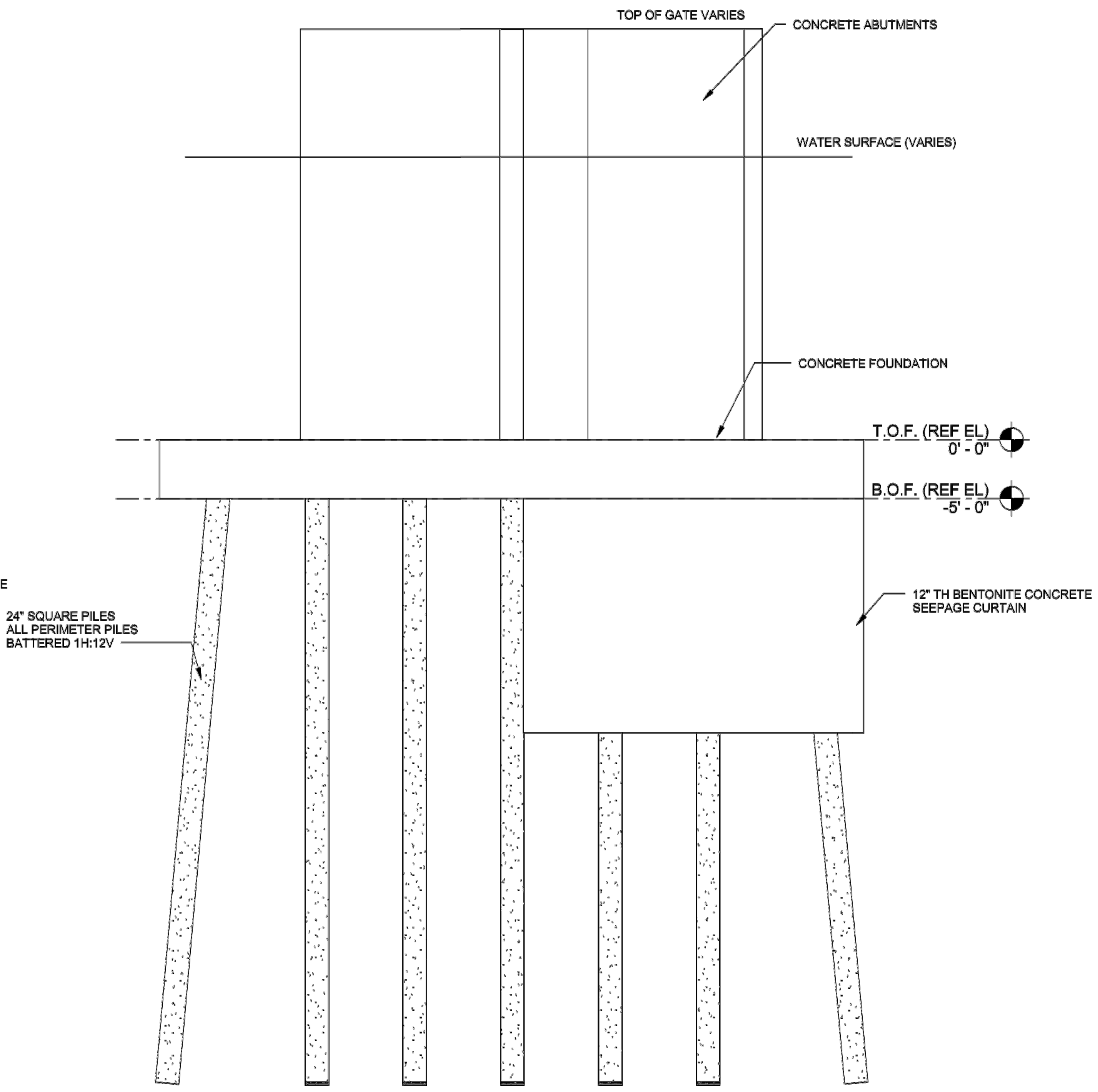
SHEET NUMBER

P-107

ALL ELEVATIONS ARE NAVD 88



① CHANNEL VIEW
1/8" = 1'-0"



② SIDE VIEW
1/8" = 1'-0"

LOCATION	NO. OF GATES	ELEVATION T.O.F.	ELEVATION TOP OF GATES	WIDTH OF GATES	LENGTH OF PILES
LR-1 OUTERMOST ALIGNMENT AT MOUTH OF RIVER	9	3 @ -10.0 3 @ -15.0 3 @ -20.0	13.5	ALL @ 70'-0"	65'-0"
HAGUE	2	-9.5	13.5	65'-0"	50'-0"
BROAD CREEK	6	0.0	13.5	65'-0"	60'-0"
PRETTY LAKE	1	-8.0	13.5	65'-0"	55'-0"

ALL ELEVATIONS IN THE CHART ARE NAVD 88

US Army Corps of Engineers
PHILADELPHIA DISTRICT

MARK	ACTION	DESCRIPTION	DATE	BY

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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAY
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PERIMETER PLAN
SCREENING ANALYSIS

MITER TIDE GATE
ELEVATIONS

SHEET NUMBER

P-108

US Army Corps of Engineers
DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

CAPE MAY CANAL SSB
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SHEET NUMBER

C-101

1 CAPE MAY INLET SSB

US Army Corps of Engineers ®
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

CAPE MAY INLET SSB
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SHEET NUMBER

C-102

1 HEREFORD INLET SSB

US Army Corps of Engineers
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

HEREFORD INLET - SSB
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SHEET NUMBER

C-103

US Army Corps of Engineers
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

TOWNSENDS INLET SSB
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SHEET NUMBER

C-104

CORSON INLET SSB

US Army Corps of Engineers
- DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

CORSON INLET SSB
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SHEET NUMBER
C-105

1 GREAT EGG HARBOR INLET

US Army Corps
of Engineers
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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

GREAT EGG HARBOR INLET SSB
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SHEET NUMBER
C-106

1 ABSECON INLET SSB

US Army Corps of Engineers
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DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

ABSECON INLET SSB
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SHEET NUMBER
C-107

1 BRIGANTINE AND LITTLE EGG INLET SSB

US Army Corps of Engineers
DISTRICT

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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

BRIGANTINE AND LITTLE EGG INLET SSB
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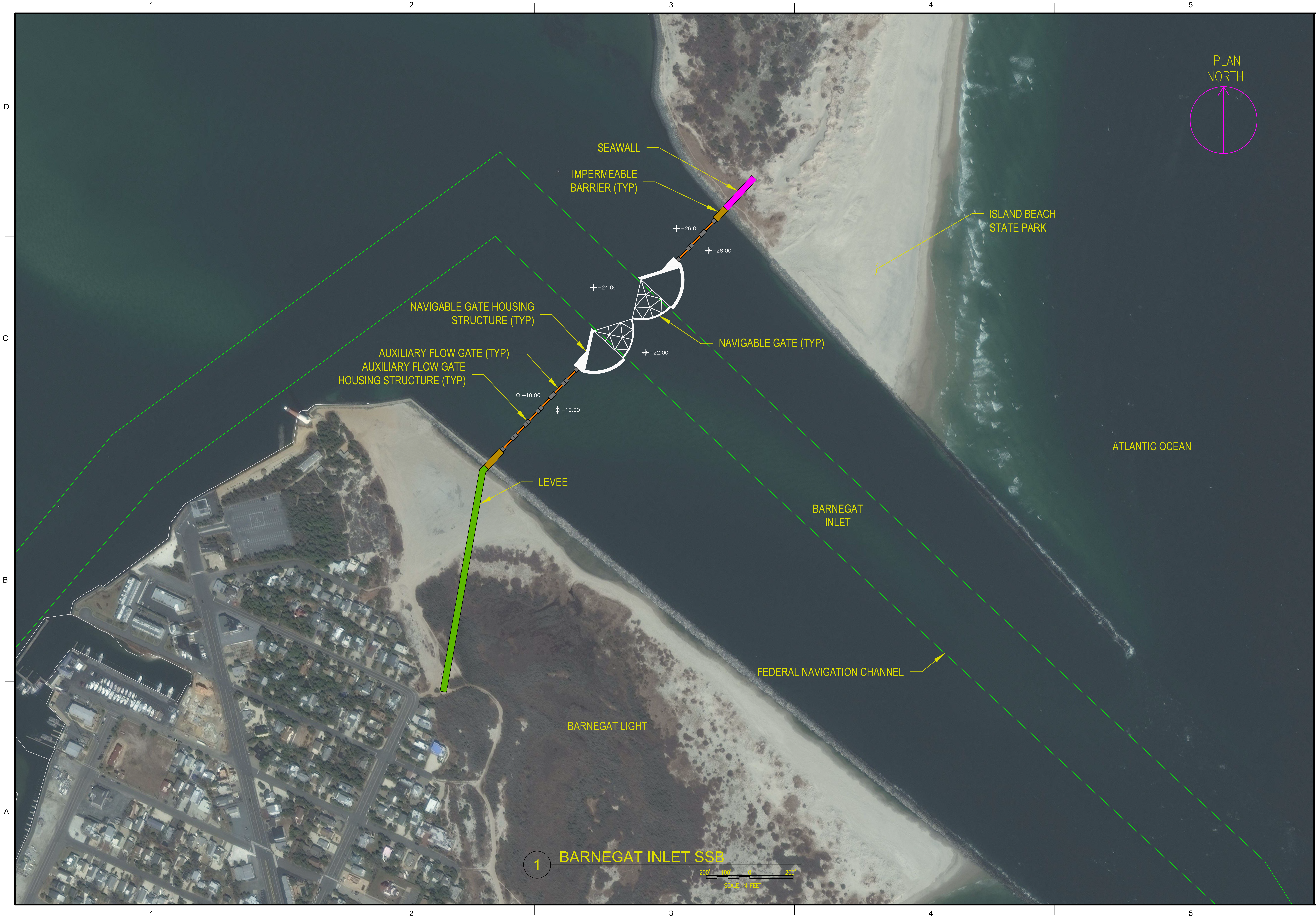
SHEET NUMBER

C-108



1 BARNEGAT INLET SSB

US Army Corps of Engineers ®
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

BARNEGAT INLET SSB
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SHEET NUMBER

C-109

1 MANASQUAN INLET SSB

US Army Corps of Engineers ®
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

MANASQUAN INLET SSB
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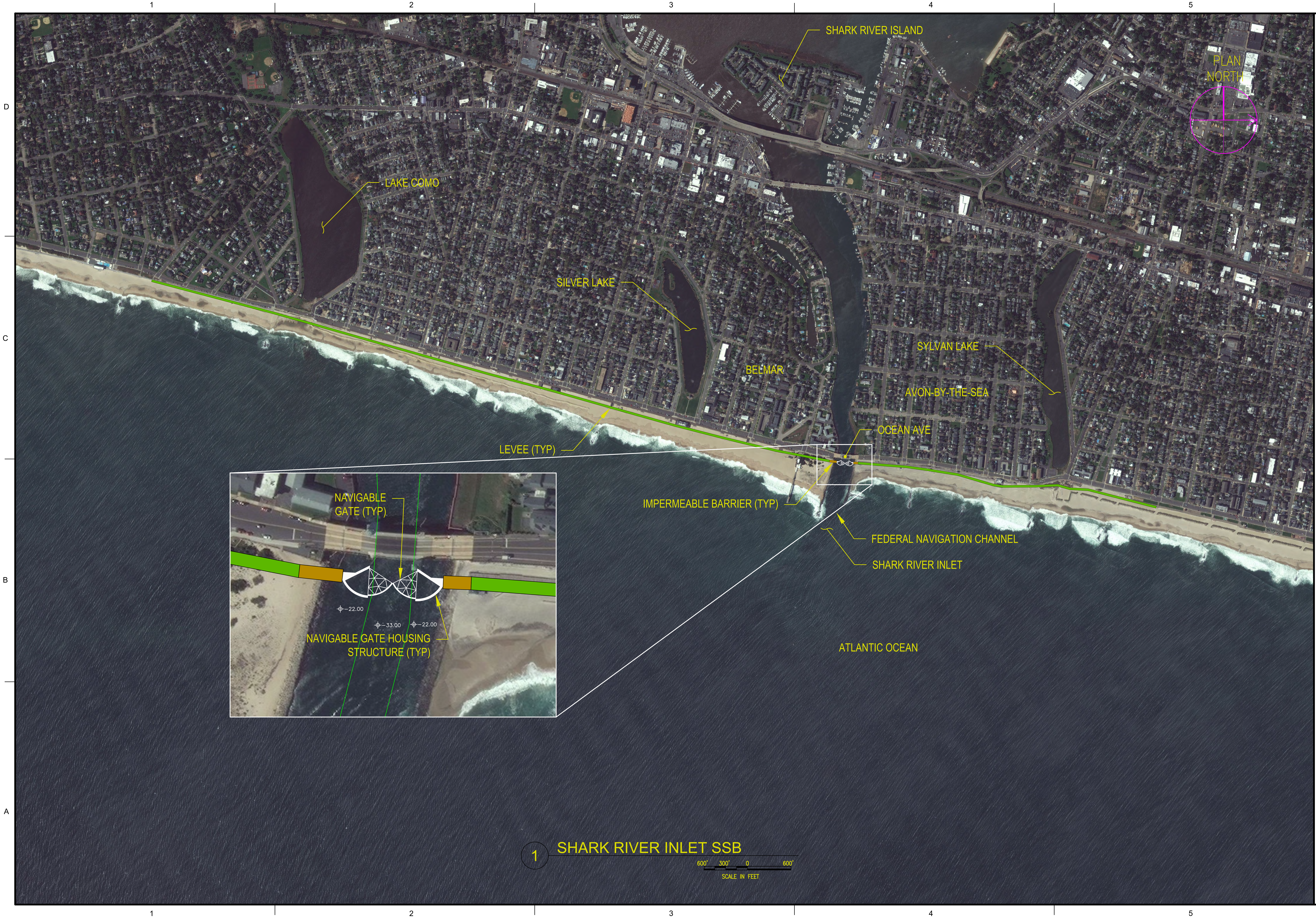

1 SHARK RIVER INLET SSB

US Army Corps of Engineers®
DISTRICT

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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

SHARK RIVER INLET SSB
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SHEET NUMBER

C-111

1 WILDWOOD BLVD BAY CLOSURE

US Army Corps of Engineers
DISTRICT

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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

WILDWOOD BLVD BAY CLOSURE
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SHEET NUMBER
C-112

1 STONE HARBOR BLVD BAY CLOSURE

US Army Corps ® of Engineers
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

STONE HARBOR BLVD BAY CLOSURE
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SHEET NUMBER

C-113

1 SEA ISLE BLVD BAY CLOSURE

US Army Corps of Engineers ®
DISTRICT

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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

SEA ISLE BLVD BAY CLOSURE
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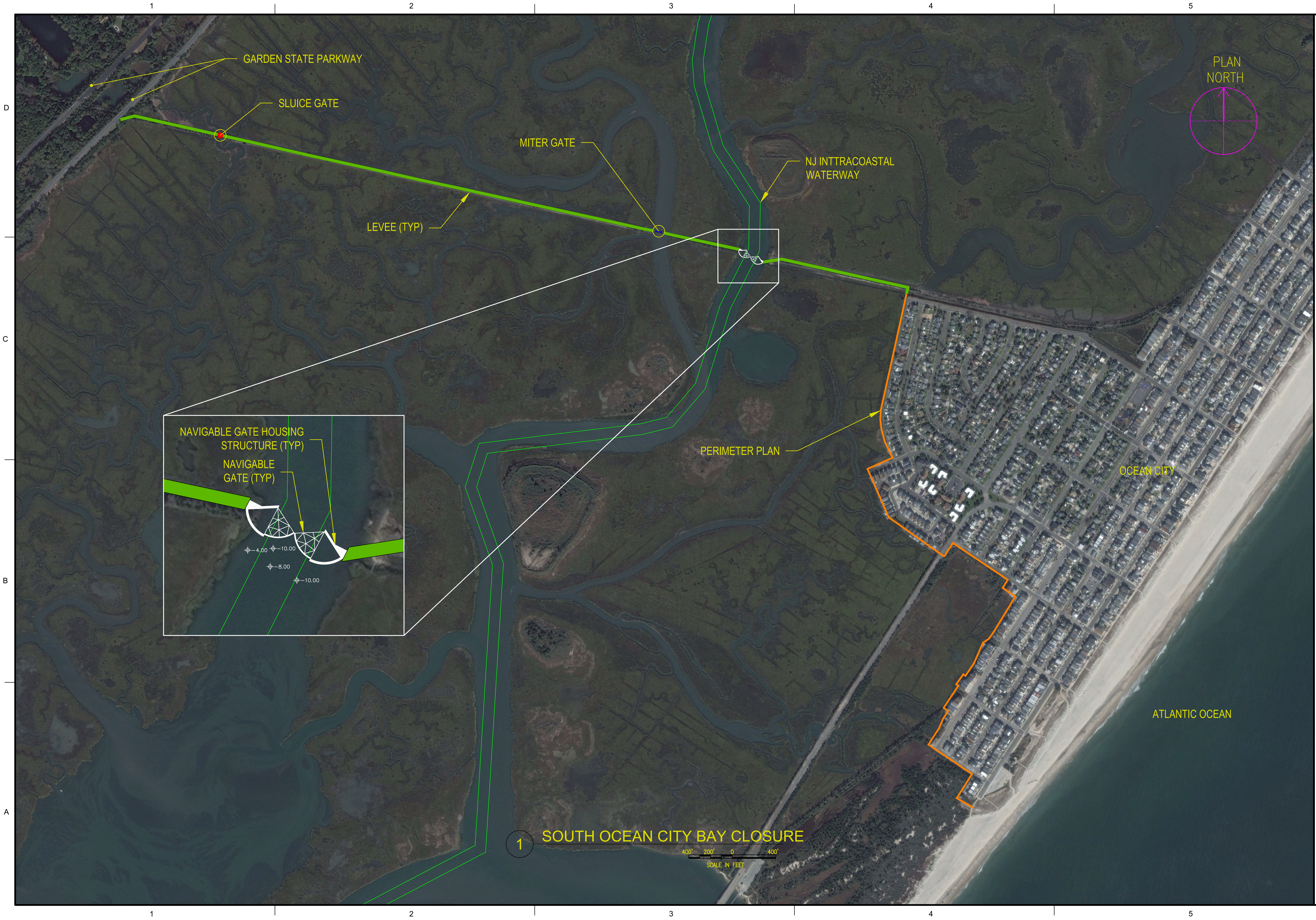
SHEET NUMBER
C-114



1 SOUTH OCEAN CITY BAY CLOSURE

US Army Corps of Engineers®
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

SOUTH OCEAN CITY BAY CLOSURE
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SHEET NUMBER

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1 ABSECON BLVD - BAY CLOSURE

US Army Corps of Engineers
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

ABSECON BLVD BAY CLOSURE
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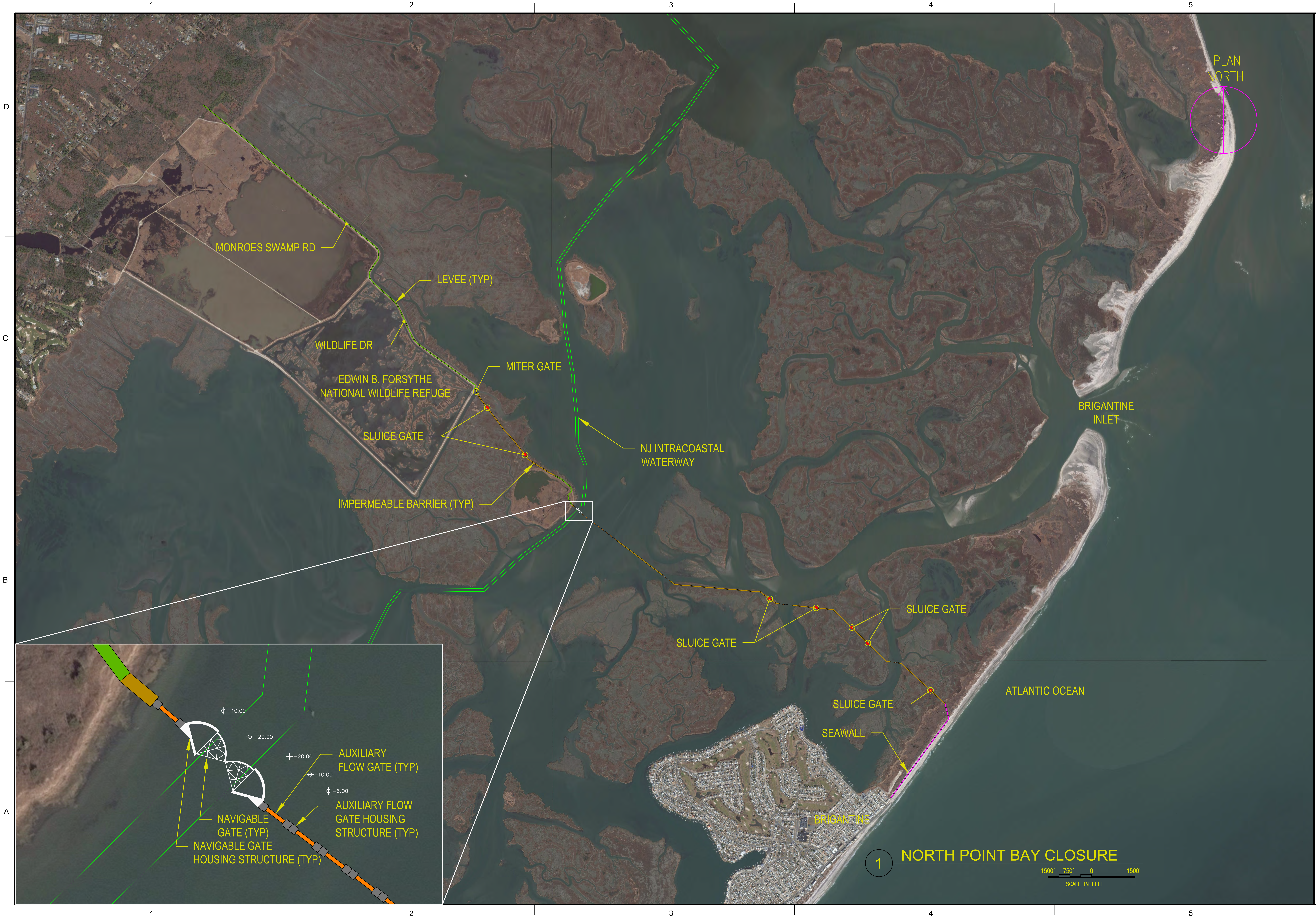
C-116



1 NORTH POINT BAY CLOSURE

US Army Corps of Engineers
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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

NORTH POINT BAY CLOSURE
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SHEET NUMBER
C-117

1 HOLGATE BAY CLOSURE

US Army Corps of Engineers
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U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

STORM SURGE BARRIER
SCREENING ANALYSIS

HOLGATE BAY CLOSURE
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SHEET NUMBER

C-118

1 POINT PLEASANT CANAL BAY CLOSURE

US Army Corps of Engineers
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ISSUE/SUBMITTAL DATE: -
SOLICITATION NUMBER: -
CONTRACT NUMBER: -
DWN BY: SJW
DES BY: SJW
CKD BY: DAN
REVIEWED BY: GMG
PLOT SCALE: AS SHOWN
DWG. SIZE: 22"x34" ANSI D
FILE NAME: FN

U.S. ARMY CORPS OF ENGINEERS
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NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

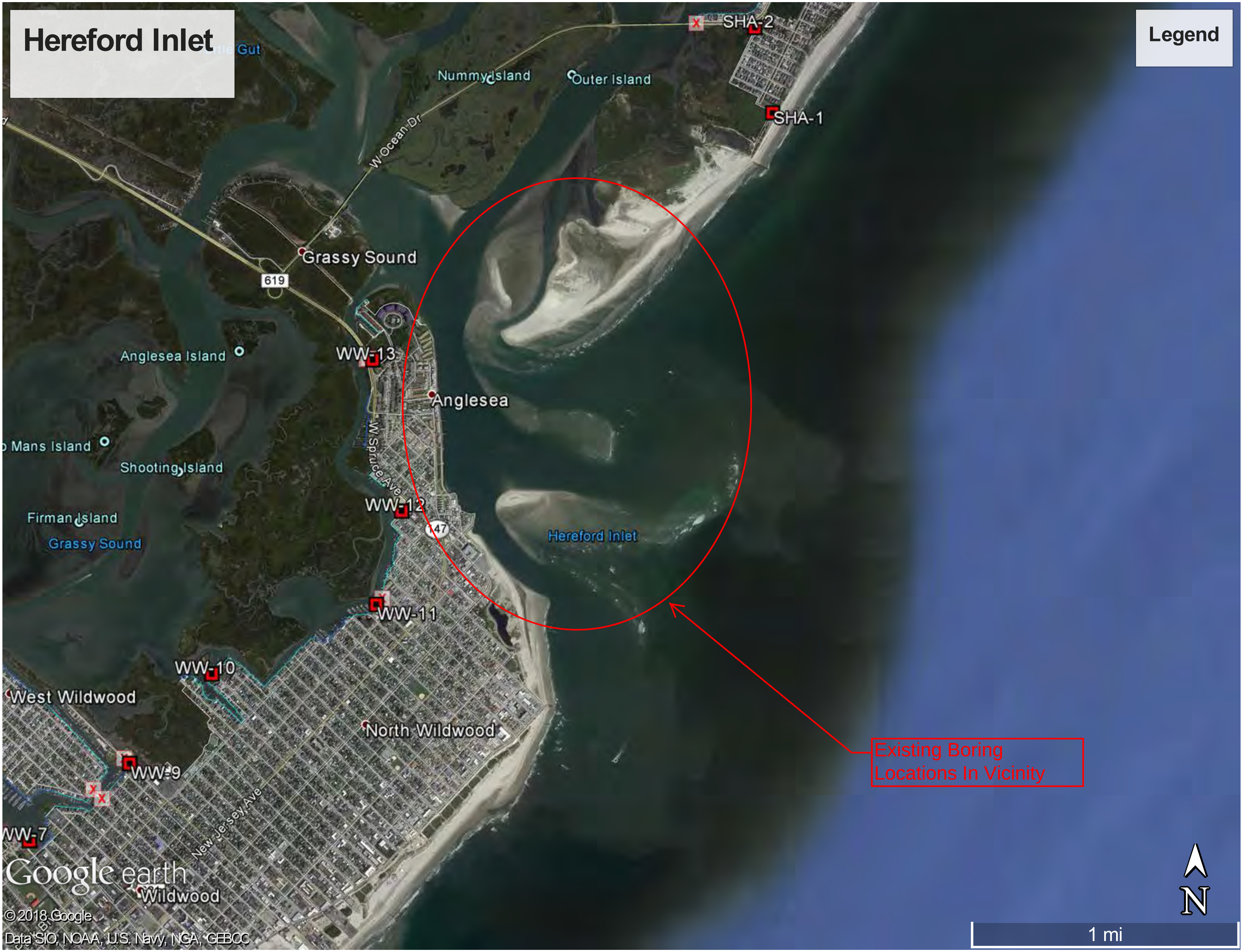
STORM SURGE BARRIER
SCREENING ANALYSIS

POINT PLEASANT CANAL BAY CLOSURE
-

SHEET NUMBER
C-119

B-6) Geotechnical Subsurface Information

Hereford Inlet



Existing Boring Locations In Vicinity

HOLE NO. ANHB - 1

DEPARTMENT OF THE ARMY

DIVISION NAD

INSTALLATION Philadelphia District Office

DRILLING LOG

1. PROJECT N.J INLETS & BEACHES

SHEET 1 OF 1

2. LOCATION (Coordinates or Station) HEREFORD Inlet - N. Wildwood

3. DRILLING AGENCY Giles Drilling Corporation

4. HOLE NO. (As shown on drawing title and file no.) ANHB - 1

5. NAME OF DRILLER Frank Derby

6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL ——

7. THICKNESS OF OVERBURDEN ——

8. DEPTH DRILLED INTO ROCK ——

9. TOTAL DEPTH OF HOLE 40'

10. SIZE AND TYPE OF BIT 2" I.D. split spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL T-2 Tractor w/ Tripod

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED ——

14. TOTAL NO. CORE BOXES ——

15. ELEV. GROUND WATER +4.3

16. DATE HOLE STARTED 0800 14 AUGUST 64 COMPLETED 1245 14 AUGUST 64

17. ELEV. TOP OF HOLE +6.4

18. TOTAL CORE RECOVERY FOR BORING (%) ——

19. SIGNATURE OF INSPECTOR R. W. Wright

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY Blows per 6"	BOX OR SAMPLE NO. SYMBOL	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0	1	Lt tan f. uniform SAND (dry)	1 1 3 3	SP	Unless otherwise noted, samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches Descriptive adjectives used silty or sandy = 30-50% some = 12-30% trace = 5-12% slight trace = less than 5% marine life = shells etc
	5	2	Same (damp)	3 12 10 13	SP	
	10	3	Gray f. uniform SAND (wet)	16 26 29 24	SP	
	15	4	Gray f. SAND (wet)	9 12 16 19	SP	
	20	5	Gray f. SAND w/ slight trace of marine life	8 11 14 12	SP	
	25	6	Gray f. SAND w/ slight trace of coarse sand & fine gravel & marine life. [organic odor]	7 9 15 20	SP	Sample (6) - slight organic odor due to decayed marine life.
	30	7	DK gray f SAND w/ trace of black silt & slight trace of marine life [organic odor]	2 2 5 3	SP	(34'-35') - Gray f. sand w/ occasional trace of black silt IN wash water
	35	8	DK grey f. SAND w/ trace of marine life & slight trace of black silt [slight organic odor]	4 2 1 8	SP	
	40	9	DK gray f. SAND w/ trace of marine life & slight trace of m. sand & silt [slight organic odor]	11 16 17 12	SP	
			Bottom of hole El. -33.6'			Ground water level @ 2.1' depth on 14 August 64 @ 1300 hrs High Tide

ENG FORM 1 MAR 61 1836 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J INLETS & Beaches Hereford Inlet HOLE NO. ANHB-1

HOLE NO. ANHB-2

DEPARTMENT OF THE ARMY

DIVISION N.A.D.

INSTALLATION Phila. Dist Office

DRILLING LOG

1. PROJECT N.J. Inlets & Beaches

SHEET OF

2. LOCATION (Coordinates or Station) Hereford Inlet N.J

3. DRILLING AGENCY Warren Gilles Drilling Corp

4. HOLE NO. (As shown on drawing title and file no.) ANHB-2

5. NAME OF DRILLER Jacob Harris

6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 44'

10. SIZE AND TYPE OF BIT 2" I.D. Split Spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL Acker

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 12 UNDISTURBED -

14. TOTAL NO. CORE BOXES —

15. ELEV. GROUND WATER 2.2

16. DATE HOLE STARTED 13Aug64 COMPLETED 14Aug64

17. ELEV. TOP OF HOLE +7.70

18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR J. J. Ucciferro

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
+7.70	0					
		1	Brn to gray f-uniform SAND dry	2 4 3 4	SP	Samples taken with 2" I.D. Split Spoon & 140 lb hammer dropped 30 inches
	5	2	Brn.to blK. f-uniform SAND damp	10 15 14 10	SP	Casing is 2½" I.D. began 0900 hrs. sample 2 - recovery 15%
	10	3	BlK- f uniform SAND very strong odor, trace of decaying organic matter damp	11 16 21 25	SP	at 34', small pcs of silt appeared in wash
	15	4	Gray f uniform SAND wet	19 26 28 30	SP	Sample 8 - silt occurred in clusters
	20	5	Same as above	30 36 40 49	SP	
	25	6	Same as above	15 25 27 28	SP	Spoon appeared To leave region of Clay @ 42' Completed hole 1300 hrs 14 Aug 64
	30	7	same as above	8 16 18 23	SP	
	35	8	DK. gry f-uniform SAND w/ tr silt (strong odor)	25 64 46 26	SP	
		9a	Gray f-m SAND w/ tr. shell frag. (Very wet)		SP	
		9b	Brn. org. SILT	4 5 6 5	OL	
	40	9c	Gray CLAY w/ tr of decaying org. matter		CH	
		10	Gray f-m SAND w/ tr. clay	11 23 29 29	SP	
	45		(Bottom of hole EL.- 36.3)			

ENG FORM 1 MAR 61 1836 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J. Inlets & Beaches HOLE NO. ANHB-2

HOLE NO. ANHB-3

DEPARTMENT OF THE ARMY

DIVISION N.A.D

INSTALLATION Phila. DisT. Office

DRILLING LOG

1. PROJECT N.J. InleTs & Beaches

SHEET 1 OF 1

2. LOCATION (Coordinates or Station) Hereford InleT N.J

3. DRILLING AGENCY Warren Giles Drilling Corp.

4. HOLE NO. (As shown on drawing title and file no.) ANHB-3

5. NAME OF DRILLER Jacob Harris

6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 40'

10. SIZE AND TYPE OF BIT 2" I.D. SpliT Spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL AcKer

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 10 UNDISTURBED

14. TOTAL NO. CORE BOXES —

15. ELEV. GROUND WATER 3.35

16. DATE HOLE STARTED 17 Aug 64 COMPLETED 17 Aug 64

17. ELEV. TOP OF HOLE 7.75

18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR J. J. Ucciferro

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY Blow CounT	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
~~7.75~~	~~0~~	1	Brn-gray f-uniform SAND dry	1 2 5 6		Samples were taken with 2" I.D. SpliT Spoon & 140 lb hammer dropped 30 inches Casing is 2½" I.D.
	5	2	Brn-gray f-uniform SAND damp	9 24 29 35	SP	Word began 1000 hrs
	10	3	Dk-gray f-uniform SAND	6 8 7 7	SP	
	15	4	DK-black silt. Low plasticity STrong odor, organic	17 2 1 3	OL	
	20	5a	BIK. f-uniform SAND trace of organic silt		SP-SM	Samples (5-6) Sand & silt occur in Layers of about 4 To 6 inches.
		5b	BIK. organic SILT. trace of decaying vegeTaTion, also trace of f-sand	1 2 1 1	OL	
	25	6	BIK. SILT w/ layers of f-uniform SAND (strong odor)	2 5 7 10	OL & SP	Sample 7 - This SAND firsT appeared IN wash aT 27.5'
	30	7	Gray f-uniform SAND	24 25 16 28	SP	from 37'-38' m-sand was washed from casing.
	35	8	same as above	36 84 151 223	SP	Completed 1330 hrs
	40	9	Gray f-SAND, few pcs. of c & f gravel	28 30 28 35	SP	
			BoTT. of hole el. -32.25			

ENG FORM 1836 1 MAR 61 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J. InleTs & Beaches HOLE NO. ANHB-3

HOLE NO. ANHB-4

DEPARTMENT OF THE ARMY

DIVISION NAD

INSTALLATION Philadelphia District Office

DRILLING LOG

1. PROJECT N.J. INLETS & BEACHES

SHEET 1 OF 1

2. LOCATION (Coordinates or Station) HEREFORD INLET - No Wildwood

3. DRILLING AGENCY Giles Drilling Corporation

4. HOLE NO. (As shown on drawing title and file no.) ANHB - 4

5. NAME OF DRILLER Frank Derby

6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 40'

10. SIZE AND TYPE OF BIT 2" I.D. split spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL T-2 Tractor w/ Tripod

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED —

14. TOTAL NO. CORE BOXES —

15. ELEV. GROUND WATER +2.4

16. DATE HOLE STARTED 1800 17 August 64 COMPLETED 1500 17 AUGUST 64

17. ELEV. TOP OF HOLE +6.90

18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR R. W. Wright

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
				Blows per 6"	SYMBOL	
	0	1	Lt tan f. SAND w/ trace of crs sand & f. gravel (dry)	1 2 3 4	SP	Unless other wise noted Samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches
	5	2	Brownish-gray f. SAND w/ slight trace of f. gravel & marine life.	3 6 4 6	SP	Descriptive adjectives used Silty or sandy = 30-50% Some = 12-30% Trace = 5-12% slight trace = less than 5% marine life - shells etc.
	10	3	Gray f. SAND w/ slight trace of marine life, & blk silt (organic odor)	2 1 4 3	SP	(12'-15') - Wash water appeared to be a black silty f. SAND (SM)
	15	4	Gray f. SAND	9 19 21 25	SP	
	20	5	Gray f. SAND w/ slight trace of black silt. Stiff & compact.	11 18 25 32	SP	
	25	6	Gray f. SAND (stiff)	7 12 15 19	SP	
	30	7	Lt. gray c-f SAND w/ trace of marine life	8 21 39 13	SW	
	35	8	Tan & gray c-f SAND w/ trace of silt & decayed marine life & f. gravel [organic odor]	11 17 22 25	SP-SM	
	40	9	Gray c-f SAND w/ some f. gravel & slight trace of silt & marine life	10 16 17 17	SP	Ground water level @ 4.5' depth on 17 August 1964 @ 1500 hrs Medium Tide

Bottom of Hole El-33.1'

ENG FORM 1 MAR 61 1836 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J. INLETS & BEACHES HEREFORDS INLET HOLE NO. ANHB-4

HOLE NO. ANHB-5

DEPARTMENT OF THE ARMY

DIVISION N.A.D

INSTALLATION Phila. Dist. Office

DRILLING LOG

1. PROJECT N.J. Inlets & Beaches

SHEET 1 OF 1

2. LOCATION (Coordinates or Station) Hereford Inlet

3. DRILLING AGENCY Giles Drilling Corp.

4. HOLE NO. (As shown on drawing title and file no.) ANHB-5

5. NAME OF DRILLER Frank Derby

6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 40'

10. SIZE AND TYPE OF BIT 2" I.D. Split Spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL Acker (Modified)

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED

14. TOTAL NO. CORE BOXES —

15. ELEV. GROUND WATER 5.40

16. DATE HOLE STARTED 18 Aug 64 COMPLETED 19 Aug 64

17. ELEV. TOP OF HOLE + 6.65

18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR J.J. Ucciferro

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description) Blow Count ↘	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
6.65	0	1	Brn-gray f-uniform SAND dry	1 2 4 4	SP	Samples Taken with 2" I.D. Split Spoon & 140 lb. hammer dropped 30 inches
	5	2	alternating brn & gray seams of f-uniform SAND, very small trace of shell frags, damp	6 9 14 12	SP	work began 1500 hrs
	10	3	Gray f-uniform SAND wet	3 5 6 6	SP	
	15	4	Same as above	7 9 9 8	SP	recovery about 5%
	20	5	DK-gray f-uniform SAND	4 7 8 9	SP	work stopped at 1700 hrs, 18 Aug @ depth of 20' work began 1100 hrs 19 Aug
	25	6	Brn. f-uniform SAND	11 21 28 23	SP	Work completed 1400 hrs 19 Aug
	30	7	Gray f-uniform SAND	6 6 10 12	SP	
	35	8	Gray f SAND, Trace of decaying wood	7 9 10 12	SP	
	40	9	Brn & gray f-uniform SAND. One or two small pcs. of decaying wood	21 16 28 41	SP	
			Bottom of hole el -33.35			

ENG FORM 1 MAR 61 1836 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT NJ Inlets & Beaches HOLE NO. ANHB-5

OLE NO. ANHB-6

DEPARTMENT OF THE ARMY

DIVISION N.A.D

INSTALLATION Phila Dist. Office

DRILLING LOG

1. PROJECT N.J. Inlets & Beaches

SHEET OF

2. LOCATION (Coordinates or Station) Hereford Inlet N.J.

3. DRILLING AGENCY Warren Giles Drilling Corp.

4. HOLE NO. (As shown on drawing title and file no.) ANHB-6

5. NAME OF DRILLER Jacob Harris

6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 40'

10. SIZE AND TYPE OF BIT 2" I.D. Split Spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) U.S.E.D

12. MANUFACTURER'S DESIGNATION OF DRILL Acker (Modified)

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED —

14. TOTAL NO. CORE BOXES —

15. ELEV. GROUND WATER —

16. DATE HOLE STARTED 11 Aug 64 COMPLETED 11 Aug 64

17. ELEV. TOP OF HOLE el. -1.0'

18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR J. J. Ucciferro

ELEVATION	ELEVATION ~~DEPTH~~	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0		Ground el. -1.0	Blows	Symbl	Samples taken with 2" I.D. split Spoon & 140 lb. hammer dropped 30 inches
		1	dk-gray f-uniform SAND trace of decaying organic matter	3 3 4 5	SP	
	5					Casing - 2½" I.D.
		2	Gray f-uniform SAND	4 3 2 1	SP	Work began 1200 Work finished 1700
	10					
		3	same as above	7 11 11 13	SP	
	15					
		4	same as above, but with very slight trace of decaying organic matter	9 15 19 25	SP	@ 35', clay first appeared in wash
	20					
		5	Gray f-uniform SAND	11 20 21 26	SP	
	25					Sample 8b Approx. 40% CLAY 30% gravel 30% Sand
		6	Same as above	6 12 12 16	SP	
	30					
		7	Gray very-f-uniform SAND	22 32 23 20	SP	
	35					
		8a	Gray, highly plastic CLAY Some silt, trace of m-f sand	27 22 24 33	CH	
	40	8b	Gray f-gravelly c-f sandy ClAY		CL	
			Bottom of hole el. -40			

ENG FORM 1836 1 MAR 61 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J. Inlets & Beach HOLE NO. ANHB-6

HOLE NO. ANHB-7

DEPARTMENT OF THE ARMY
DIVISION N.A.D
INSTALLATION Phila. Dist. Off

DRILLING LOG

1. PROJECT N.J. Inlets & Beaches
SHEET 1 OF 1
2. LOCATION (Coordinates or Station) Hereford Inlet N.J.
3. DRILLING AGENCY Warren Gilles Drilling Corp.
4. HOLE NO. (As shown on drawing title and file no.) ANHB-7
5. NAME OF DRILLER Jacob Harris
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL
7. THICKNESS OF OVERBURDEN —
8. DEPTH DRILLED INTO ROCK —
9. TOTAL DEPTH OF HOLE 40'
10. SIZE AND TYPE OF BIT 2" I.D. Split Spoon
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL Acker
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED
14. TOTAL NO. CORE BOXES —
15. ELEV. GROUND WATER —
16. DATE HOLE STARTED 10 Aug 64 COMPLETED 10 Aug 64
17. ELEV. TOP OF HOLE Water Hole (-3)
18. TOTAL CORE RECOVERY FOR BORING (%)
19. SIGNATURE OF INSPECTOR J. J. Ucciferro

ELEVATION	~~DEPTH~~ ELEVATION	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0		Water	Blow Count		Samples taken with 2" I.D. Split spoon & 140 lb. hammer dropped 30 inches. Casing is 2½ I.D. Began 1100 Completed 1600
			Ground el. -3.0'			
	5	1	Black silty SAND highly organic	6 6 5 6	SM	
	10	2	DK-gray to black silty f-SAND, very strong odor, Trace of decaying organic matter	4 3 2 4	SM	
	15	3	DK-gray f-uniform SAND	7 12 10 12	SP	
	20	4	Lt-gray f-uniform SAND	3 1 8 7	SP	
	25	5	Same as above	8 8 9 11	SP	
	30	6	Same as above	7 11 12 14	SP	
		7A	Gray CLAY, highly plastic, w/ trace of gravel	14 21 42 130	CH	
	35	7B	Gray CLAY w/ some c-f sand, tr f. gravel		CH	
	40	8	Gray f-gravely c-f SAND	18 27 30 74	SP	
			Bottom of hole el. -40			

ENG FORM 1836 (EM 1110-1-1801) PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.
1 MAR 61 TRANSLUCENT

PROJECT N.J. Inlets & Beaches HOLE NO. ANHB-7

Existing Boring Locations In Vicinity

Hole No. ANTB - 1

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N. J. INLETS & BEACHES
2. LOCATION *(Coordinates or Station)*: TOWNSENDS INLET - AVALON
3. DRILLING AGENCY: Giles Drilling Corporation
4. HOLE NO. *(As shown on drawing title and file number)*: ANTB - 1
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ——— DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: ——
8. DEPTH DRILLED INTO ROCK: ——
9. TOTAL DEPTH OF HOLE: 50.0'
10. SIZE AND TYPE OF BIT: 2" I.D. Split spoon
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: J-3 Willey 4-wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 12 UNDISTURBED ——
14. TOTAL NUMBER CORE BOXES: ——
15. ELEVATION GROUND WATER: + 5.33
16. DATE HOLE: STARTED 1000 hrs 6 August 64 COMPLETED 1630 hrs 6 August 64
17. ELEVATION TOP OF HOLE: + 8.5
18. TOTAL CORE RECOVERY FOR BORING: —— %
19. SIGNATURE OF INSPECTOR: R. W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blows per 6" e	~~BOX OR SAMPLE NO.~~ SYMbol f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	0	1	Lt. tan & black f. uniform SAND (dry)	1 1 2 4	SP	Unless otherwise noted Samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 in Descriptive adjectives used silty or sandy = 30% - 50% some = 12 - 30% trace = 5 - 12% slight trace = less than 5%
	5	2	Tan f. uniform SAND (dry)	9 12 25 26	SP	
	10	3	Gray f. slightly micaceous uniform SAND (wet)	11 18 23 34	SP	
	15	4	Gray m-f SAND w/ slight trace of marine life.	24 36 45 61	SP	
	20	5	Gray f SAND	17 28 37 60	SP	
	25	6	Gray f. SAND w/ trace of m sand & marine life	13 22 36 39	SP	Ground water level @ 3.17' depth on 6 August 64 @ 1700 hrs Medium tide
	30	7	Gray f. SAND w/ slight trace of marine life	9 ~~15~~ 14 16 22	SP	
	35	8	Gray m-f SAND w/ slight trace c-s sand, f. gravel & marine life	22 36 49 59	SP	(37'-40') - Wash water brought up slight traces of black SILT
	40	9 A	A (40'-40.5) Gray m-f SAND w/ some silt & slight trace of marine life	4 6	SP	(42'-43') - Mostly sand - Wash water brought up traces of black silt
		9 B	B (40.5-42) - Gray silty m-f SAND w/ slight trace of marine life	3 7	SM	(43'-45') - Wash water turned dark brown w/ pieces of black & brown silt & sand [Mostly sand & probably org pockets]
	45	10	Gray m-f SAND w/ small pockets of black organic matter & trace of marine life	10 13 24 24	SP	[47'-48'] - Decayed frags of wood, but mostly c-f sand
	50	11	Brown or tan m-f SAND changing in bottom of shoe to gray c-f sand w/ some f. gravel	11 38 56 132	SP	Bottom of hole @ 50' depth Hole completed 6 August 64 @ 1630 hrs

ENG FORM 1836
1 APR 63

PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)*

☆ GPO 1963 : OF—712-275

PROJECT: N.J INLETS & Beaches Townsends Inlet

HOLE NO. ANTB - 1

Bottom of hole EL. - 41.5

HOLE NO. ANTB-2

DEPARTMENT OF THE ARMY
DIVISION NAD
INSTALLATION Philadelphia District office

DRILLING LOG

1. PROJECT N.J. INLETS & Beaches
SHEET 1 OF 1
2. LOCATION (Coordinates or Station) TOWNSENDS INLET - AVALON
3. DRILLING AGENCY Giles Drilling Corporation
4. HOLE NO. (As shown on drawing title and file no.) ANTB-2
5. NAME OF DRILLER Frank Derby
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL
7. THICKNESS OF OVERBURDEN —
8. DEPTH DRILLED INTO ROCK —
9. TOTAL DEPTH OF HOLE 30'
10. SIZE AND TYPE OF BIT 2" I.D. split spoon
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL T-2 Tractor w/ Tripod
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 7 UNDISTURBED —
14. TOTAL NO. CORE BOXES —
15. ELEV. GROUND WATER +2.49
16. DATE HOLE STARTED 1400 12 August 64 COMPLETED 1630 12 August
17. ELEV. TOP OF HOLE +4.29
18. TOTAL CORE RECOVERY FOR BORING (%) —
19. SIGNATURE OF INSPECTOR R. W. Wright

ELEVATION	DEPTH	~~LEGEND~~	CLASSIFICATION OF MATERIALS (Description)	~~% CORE RECOVERY~~ Blows per 6"	BOX OR SAMPLE ~~NO.~~ SYMBOL	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0	1	Lt tan f. uniform SAND	2 4 5 5	SP	Unless otherwise noted samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches
	5	2	Gray f. SAND w/ trace of organic silt & root matter	12 13 22 25	SP	Descriptive adjectives used Silty or sandy = 30-50% Some = 12-30% trace = 5-12% slight trace = less than 5% marine life = shells, etc
	10	3	Gray f. SAND	7 6 8 11	SP	(2'-5') Wash water was f. SAND W/ some seams of f. sandy silt from 4' to 5'
	15	4	Gray f. SAND w/ slight trace of marine life	8 16 15 20	SP	Samples #2 & 3 had an oily smell about them Sample #4 - oily smell
	20	5	Gray m-f SAND w/ some marine life & trace of Coarse sand	10 39 30 17	SP	Sample #5 - oily smell
	25	6	Gray f SAND w/ some c-m sand & f. gravel & slight trace of marine life	8 10 17 19	SP	
	30	7	Gray c-f SAND w/ slight trace of marine life	10 14 29 23	SP	
	35					Low Tide 0900 hrs, Ground water level @ 1.8' depth on 13 August 64 ANTB-2 - Location is 23' towards inlet [Note change on orginal Boring sheet - Exact location fell on stone bulkhead.]

Bottom of hole El. -25.71'

ENG FORM 1836 1 MAR 61 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT N.J. INLETS & Beaches Townsends Inlet HOLE NO. ANTB-2

Hole No. ANTB-3

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. INLETS & BEACHES
2. LOCATION *(Coordinates or Station)*: Townsends Inlet - Avalon
3. DRILLING AGENCY: Giles Drilling Corporation
4. HOLE NO. *(As shown on drawing title and file number)*: ANTB-3
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: —
8. DEPTH DRILLED INTO ROCK: —
9. TOTAL DEPTH OF HOLE: 30.0 Ft
10. SIZE AND TYPE OF BIT: 2" I.D. split spoon
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: T-2 Tractor W/ Tripod
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 7 UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: 4.85'
16. DATE HOLE: STARTED 0800 11 August 64 COMPLETED 1200 11 August 64
17. ELEVATION TOP OF HOLE: +7.85
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: R.W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blows per 6" e	~~BOX OR SAMPLE NO.~~ SYMBOL f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		1	Lt. tan f. uniform SAND W/slight trace of charred wood (dry)	1 1 2 2	SP	Unless otherwise noted Samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 IN
	5	2	Gray-brown f. SAND w/slight trace of black silt (wet)	11 14 10 9	SP	Descriptive adjectives used silty or sandy = 30 - 50% some = 12 - 30% trace = 5 - 12% slight trace = less than 5% marine life = shells, etc
	10	3	Gray f. SAND w/ slight trace of marine life.	3 1 6 11	SP	(12'-19.5') - Wash water - was f. SAND w/some f. sandy SILT seams
	15	4	Black organic SILT w/ trace of f. sand	P P P 2	OH	(17'-19') - Black organic silt w/ some fine sand
	20	5	Gray f. SAND	9 11 12 13	SP	
	25	6	Same	9 17 18 24	SP	Sample 7 - (28'-30')
	30	7	Same	9 18 19 30	SP	
			Bottom of Hole El. -22.15'			Hole completed @ depth 30 FT on 11 August 64 @ 1200 hrs Ground water level @ 3.0' depth ON 11 August 1964 @ 1600 hrs Low Tide

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)

☆ GPO 1963 : OF—712-275

PROJECT: N.J. INLETS & BEACHES Townsends Inlet

HOLE NO. ANTB-3

Hole No. ANTB-4

DRILLING LOG

DIVISION NAD	**INSTALLATION** Philadelphia District Office	**SHEET** 1 **OF** 1 **SHEETS**	
1. PROJECT N.J Inlets & Beaches	10. SIZE AND TYPE OF BIT 2" ID split spoon		
2. LOCATION *(Coordinates or Station)* Townsends Inlet	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* IWWD		
3. DRILLING AGENCY Giles Drilling Corporation	12. MANUFACTURER'S DESIGNATION OF DRILL J-3 Willey 4-wheel Drive		
4. HOLE NO. *(As shown on drawing title and file number)* ANTB - 4	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 9	UNDISTURBED —
5. NAME OF DRILLER Frank Derby	14. TOTAL NUMBER CORE BOXES —		
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER + 4.5'		
	16. DATE HOLE	STARTED 1030 3 August 64	COMPLETED 0935 4 August 64
7. THICKNESS OF OVERBURDEN —	17. ELEVATION TOP OF HOLE + 7.28'		
8. DEPTH DRILLED INTO ROCK —	18. TOTAL CORE RECOVERY FOR BORING — %		
9. TOTAL DEPTH OF HOLE 42.0'	19. SIGNATURE OF INSPECTOR R. W. Wright		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blows per 6"	~~BOX OR SAMPLE NO.~~ SYMBOL	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	0	1	LT. tan f. SAND w/slight trace of drift wood (dry)	1 2 2 1	SP	Unless otherwise noted Samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches
	5	2	Lt tan to gray f. SAND w/ trace of marine life & slight trace of f. gravel (moist)	9 12 15 20	SP	
	10	3	Gray f SAND w/a zone .15' long @ 10.8' of black f. sand. Trace of marine life thru-out entire sample (moist)	8 13 21 23	SP	
	15	4	Gray m-f micaceous SAND w/ some marine life. (moist)	23 48 50 44	SP	
	20	5	Gray m-f SAND w/ some marine life. (moist)	12 19 29 28	SP	
	25	6	Gray f. SAND w/ slight trace of m. sand & marine life (moist)	8 11 12 15	SP	1130 hrs - Driving rain, wind & sandstorm persisted thru-out entire day
	30	7	Lt. tan & gray-black f. SAND w/slight trace of f. gravel, m-sand & marine life	7 8 8 10	SP	Forced to quite due to incoming tide approaching hole Work stopped 3 August 64 @ 1930 hrs @ depth 32' Work started @ 0800 hrs on 4 August 64 @ 32'
	35	8	Gray f. SAND w/slight trace of crs. sand & trace of marine life	8 9 8 11	SP	Note: Sample were obtained w/o inspector present R. W. Wright was employed setting a buoy for hole ANCB-3 - Absecon Inlet
	40	9	Gray m-f SAND w/ some marine life & slight trace of crs sand	12 10 10 12	SP	Hole completed @ 0935 hr 4 August 64
			Bottom of hole El. -34.72			
	45					Water depth 2.8' @ 4 August 64 @ 1000 hr Low tide

ENG FORM 1836
1 APR 63

PREVIOUS EDITIONS MAY BE USED (*EM 1110-1-1801*)

☆ GPO 1963 : OF—712-275

PROJECT N.J Inlets & Beaches Townsends Inlet

HOLE NO. ANTB-4

Hole No. ANTB-5

DRILLING LOG

DIVISION NAD

INSTALLATION Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT N. J. INLETS & BEACHES
2. LOCATION (Coordinates or Station) TOWNSENDS INLET
3. DRILLING AGENCY Giles Drilling Corporation
4. HOLE NO. (As shown on drawing title and file number) ANTB-5
5. NAME OF DRILLER Frank Derby
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN ——
8. DEPTH DRILLED INTO ROCK ——
9. TOTAL DEPTH OF HOLE 40.0'
10. SIZE AND TYPE OF BIT 2" I.D. Split spoon
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL J-3 Willey 4-wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 10 UNDISTURBED ——
14. TOTAL NUMBER CORE BOXES ——
15. ELEVATION GROUND WATER + 5.27'
16. DATE HOLE STARTED 1100 hrs 4 August 64 COMPLETED 1400 hrs 4 August 64
17. ELEVATION TOP OF HOLE + 7.27'
18. TOTAL CORE RECOVERY FOR BORING —— %
19. SIGNATURE OF INSPECTOR R. W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	~~% CORE RECOVERY~~ Blows e	~~BOX OR~~ SAMPLE ~~NO.~~ f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0	1	Lt. tan f. SAND (dry)	per 6" P 2 2 2	SYMBOL SP	Unless otherwise noted samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches
	5	2	Lt tan to gray f SAND w/ trace of m.-sand & slight trace of marine life (wet)	10 12 15 19	SP	
	10	3	Dk. gray f SAND grading down to a m-f SAND w/ trace of marine life & slight trace of crs. sand (wet)	12 13 21 21	SP	Sample 3 - Marine life (shells) increased w/ increase in depth
	15	4	Dk. gray f. SAND w/ trace of marine life & slight trace of m-c sand (wet)	11 15 15 20	SP	
	20	5	Gray c-f SAND w/ trace of marine life & slight trace of f. gravel (just over 1/4" size)	12 17 25 28	SP	
	25	6	Gray f. SAND w/ some marine life & slight trace of m. sand	10 11 17 19	SP	Wash water @ 24.5' to Approx 24.8' turned black & brought up (m-c Sand & f. gravel size particles) of graphite or coal
	30	7	Gray f. SAND w/ trace of marine life	5 6 9 15	SP	
	35	8	Gray m-f SAND w/ trace of marine life & slight trace of f. gravel	9 9 10 7	SP	Wash water from 37'-38' appeared to be f sand
		9 A	BIK. f. sandy SILT	10 6	ML	
	40	B	BIK. silty, c-f sandy, fine GRAVEL	15 19	GP	Hole completed 4 August 1964 @ 1400 hrs
			Bottom of hole El. -32.73'			Water table 2' depth on 4 August 64 @ Low tide

ENG FORM 1 APR 63 **1836** PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)

★ GPO 1963 : OF—712-275

PROJECT N.J Inlets & Beaches TOWNSENDS INLET

HOLE NO. ANTB-5

HOLE NO. ANTB-6

DEPARTMENT OF THE ARMY

DIVISION N.A.D.

INSTALLATION Phila. DisT. Office

DRILLING LOG

1. PROJECT N.J. InleTs & Beaches

SHEET 1 OF 1

2. LOCATION (Coordinates or Station) Townsend's InleT N.J

3. DRILLING AGENCY Warren Giles Drilling Co.

4. HOLE NO. (As shown on drawing title and file No.) ANTB-6

5. NAME OF DRILLER Frank Derby

6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED DEGREES WITH VERTICAL —

7. THICKNESS OF OVERBURDEN —

8. DEPTH DRILLED INTO ROCK —

9. TOTAL DEPTH OF HOLE 43'

10. SIZE AND TYPE OF BIT 2"ID SpliT Spoon

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) IWWD

12. MANUFACTURER'S DESIGNATION OF DRILL J-3 Willeys 4-Wheel DrivE

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 11 UNDISTURBED —

14. TOTAL NO. CORE BOXES 0

15. ELEV. GROUND WATER +4.9

16. DATE HOLE STARTED 4Aug 64 COMPLETED 5 August 64

17. ELEV. TOP OF HOLE +7.6'

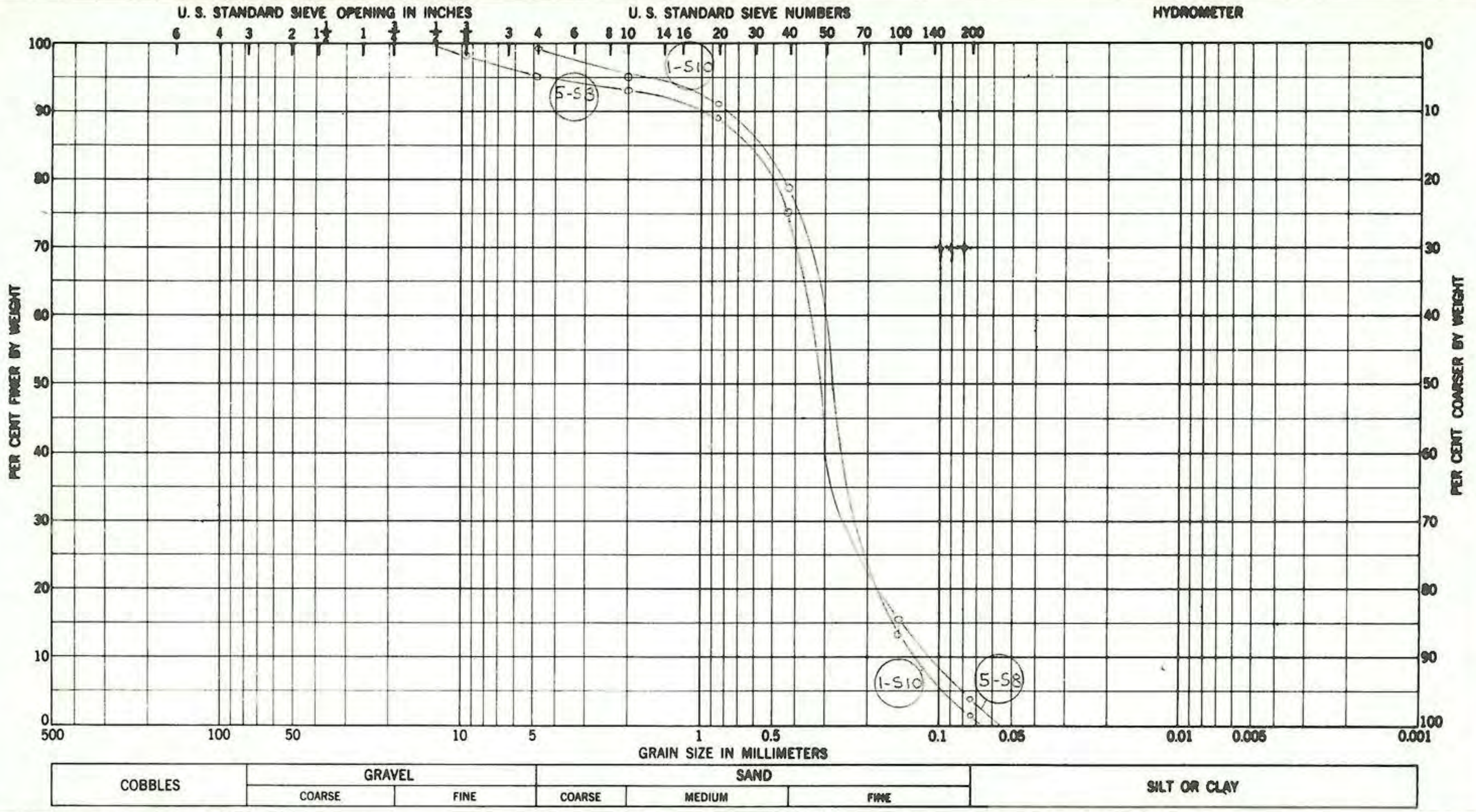
18. TOTAL CORE RECOVERY FOR BORING (%) —

19. SIGNATURE OF INSPECTOR Joseph J. Ucciferro

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0	1	grayish-brn - f uniform SAND	BLOWS 1 1 2 2	SP	Unless otherwise noted Samples were taken with 2" I.D split spoon & 140# hammer dropping 30"
	5	2	gray f-uniform SAND	9 15 17 15	SP	
	10	3	gray f-m SAND, a small Trace of shell fragmenTs, WeT	18 23 29 39	SP	med. Sand occured in small clusTers held Together by a small amt of silt
	15	4	Gray c-f SAND w/ some marine life (shell) & slight trace of f. gravel & black silt	23 34 44 47	SP	Samples 4 & 5 - Inspector R. W. Wright
	20	5	Gray m-f SAND w/ trace of crs sand & marine life	13 30 52 52	SP	Work stopped 4 Aug 64 @ 1700hrs @ depth 22' Work started 5 Aug 64 @ 0800 hrs @ depth 22'
	25	6	Lt tan f SAND w/ trace of m sand & slight trace of marine life	19 38 58 75	SP	Inspector - R. W. Wright Note: sample (6) gotten @ 1100 hrs due to lack of hose to reach water supply @ extremely Low Tide period
	30	7	Tan m-f SAND w/ slight trace of crs. sand & marine life	27 53 55 57	SP	Sample (7) - Lost Sample went down again and retrieved it
	35	8	Lt gray m-f SAND w/ slight trace of crs sand & marine life	9 7 8 13	SP	Driller lost approx. 3 hrs working time @ Low tide stage due to lack of hose to reach water.
		9A	(38.0 - 38.5) - Gray m-f SAND w/ trace organic silt, crs Sand & marine life		SP	
	40	9B	(38.5 - 40.0) - Greenish - gray-yel organic SILT w/ some f. sand (dry & compact)	23 9 7 7	OL	
		10	Yellowish - brown to dark gray, [org. Silty] c-f SAND w/ some f. gravel. [crs sand & f. gravel also appeared in 1" seams thru-out sample]	8 8 9 9	SM	Hole completed 5 August 64 @ 1700 hrs
	45		Bottom of hole El. - 35.4			Water table 2.7' depth ON 6 August 64 @ 0830 hrs - medium tide

ENG FORM 1836 1 MAR 61 (EM 1110-1-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED.

PROJECT Townsends Inlet HOLE NO. ANTB-6



Sample No.	~~Elev~~ or Depth	Classification	Nat w %	LL	PL	PI
1 - S 10	45-47	Dk.gry. c.-f. SAND	23.8			
5 - S 8	35-37	Lt. gry. c.-f. SAND	19.5			

Project
Inlets and Beaches

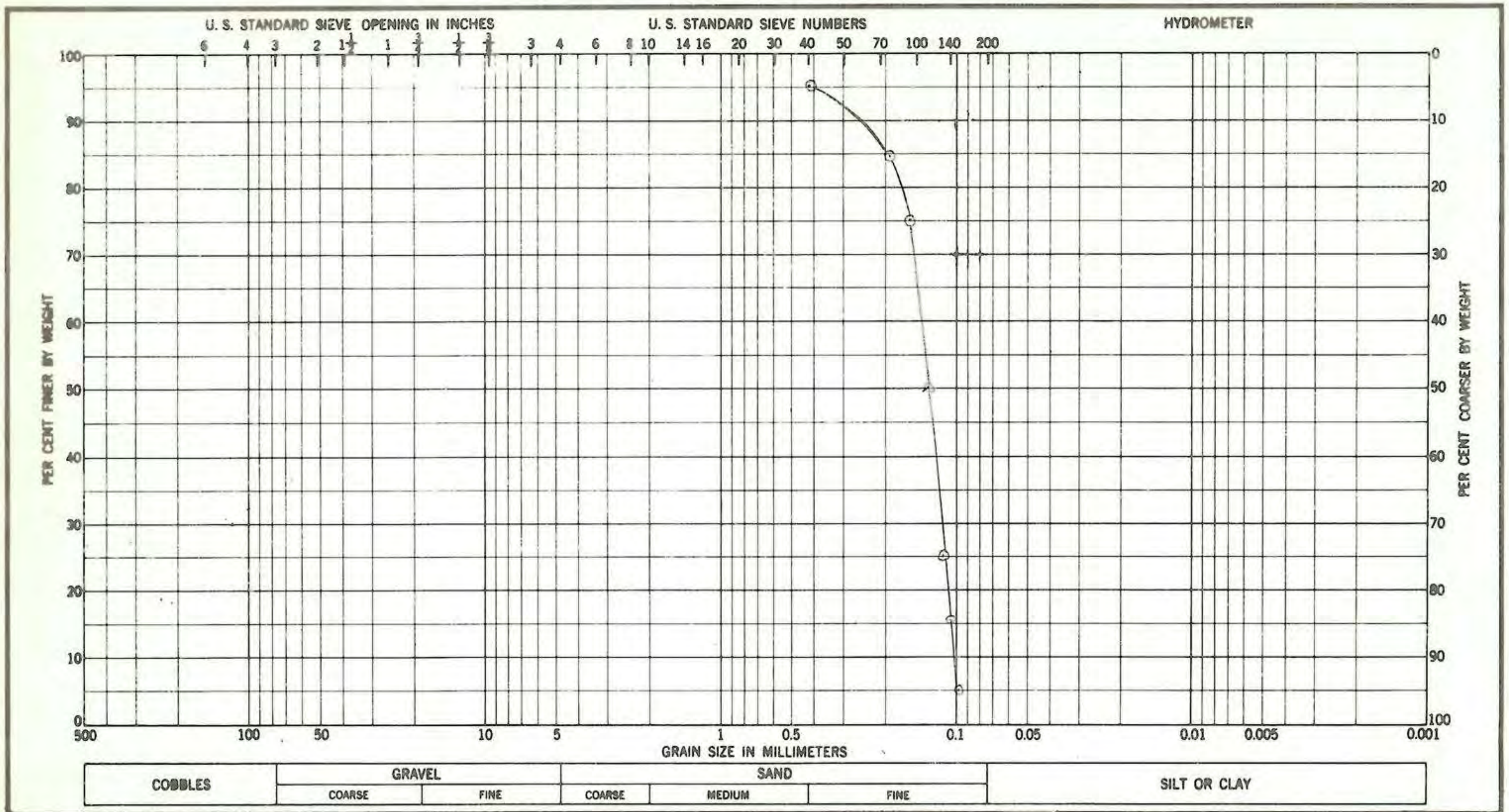
Area N. J.

Boring No. ANTB

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*



Sample No.	Elev or ~~Depth~~	Classification	Nat w %	LL	PL	PI
5 - S3	-2.7 - 4.7	Dark gray f. SAND	23			

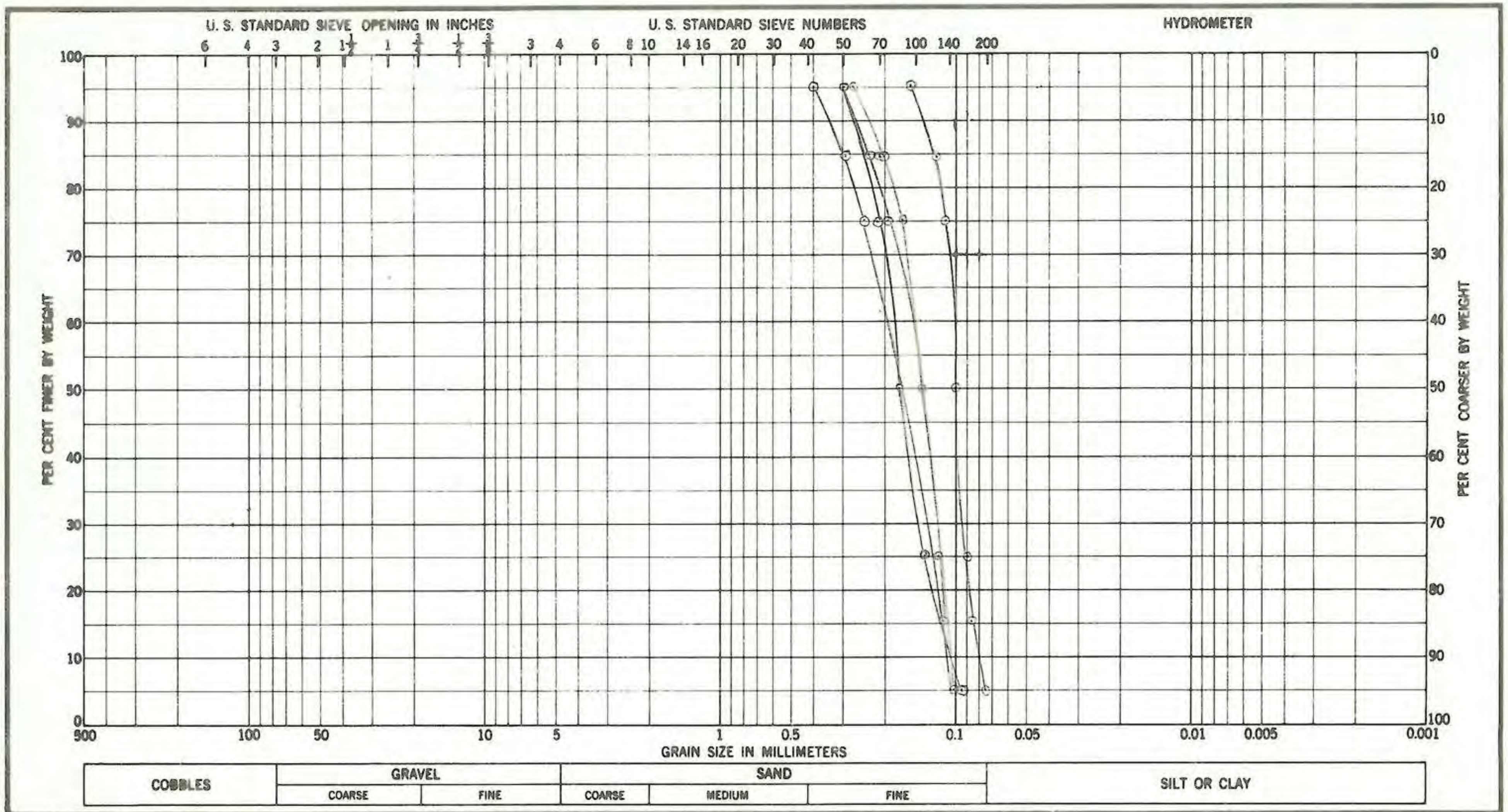
Project Inlets and Beaches

Area N.J.

Boring No. ANTB

Date

GRADATION CURVES



Sample No.	Elev or ~~Depth~~	Classification	Nat w %	LL	PL	PI
1 – S3	–1.5 – 3.5	Gray f. SAND	22.4			
1 – S5	–11.5 – 13.5	Gray f. SAND	25.2			
2 – S3	– 5.7 – 7.7	Gray f. SAND	20.1			
3 – S3	– 2.1 – 4.1	Gray f. SAND	24.5			
3 – S5	– 12.1 – 14.1	Gray f. SAND	19.6			

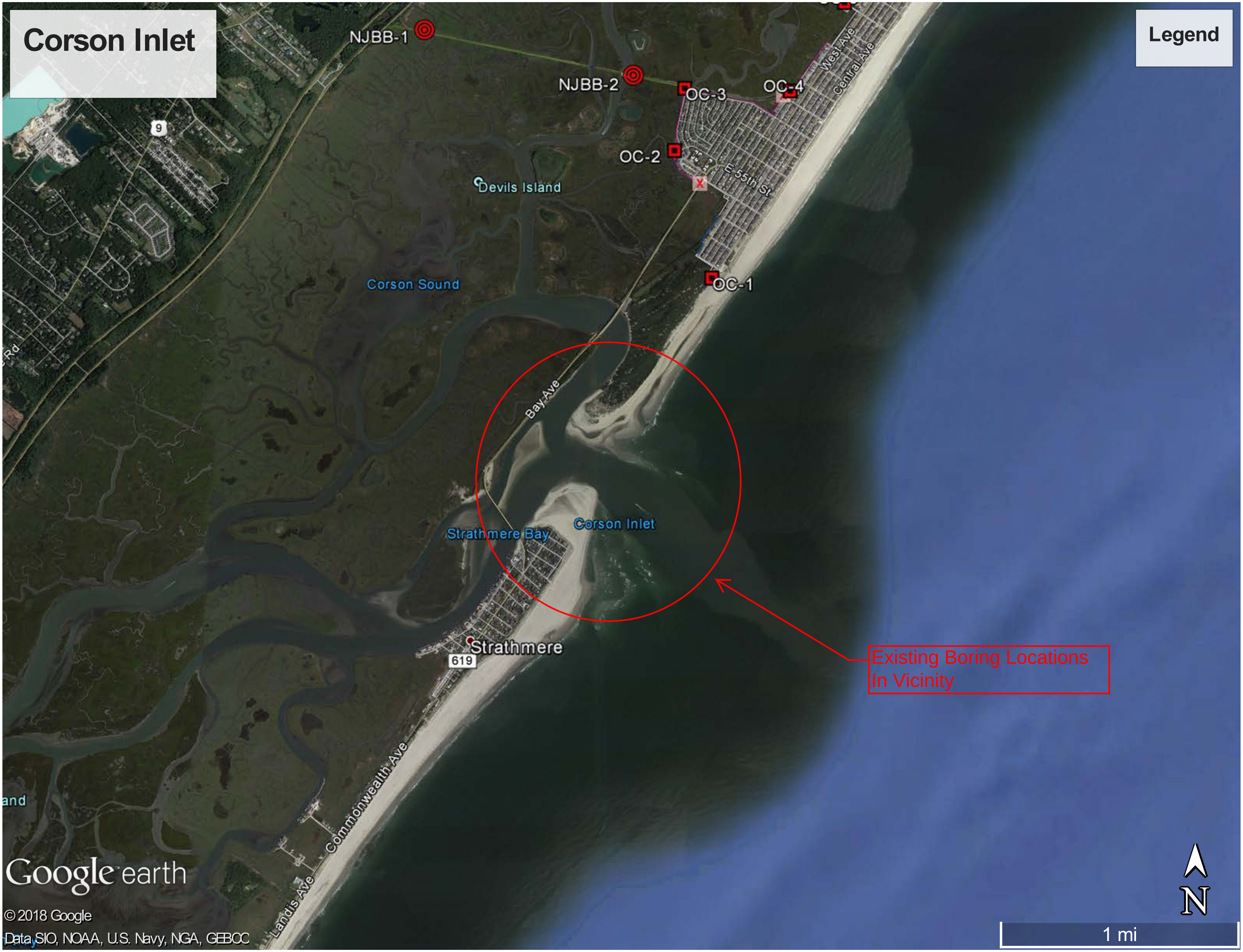
GRADATION CURVES

Project Inlets and Beaches

Area N. J.

Boring No. ANTB

Date


Corson Inlet
Legend
NJBB-1
NJBB-2
OC-3
OC-4
OC-2
OC-1
West Ave
Central Ave
E 55th St
Devils Island
Corson Sound
Bay Ave
Strathmere Bay
Corson Inlet
Strathmere
619
9
Commonwealth Ave
Landis Ave
Existing Boring Locations In Vicinity
N
1 mi
Google earth
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Hole No. ANCB-1

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. INLETS & BEACHES - CORSON
2. LOCATION *(Coordinates or Station)*: Corson's Inlet
3. DRILLING AGENCY: Giles Drilling Corp.
4. HOLE NO. *(As shown on drawing title and file number)*: ANCB - 1
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: —
8. DEPTH DRILLED INTO ROCK: 0.0
9. TOTAL DEPTH OF HOLE: 42.0'
10. SIZE AND TYPE OF BIT: 2" ID split spoon
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: J-3 Willey 4-Wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 9 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: + 2.66
16. DATE HOLE: STARTED 1120 29 July 64 COMPLETED 1700 29 July 64
17. ELEVATION TOP OF HOLE: + 4.66
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: R. W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE~~ RECOVERY BLOWS per 6" e	~~BOX OR SAMPLE NO.~~ SYMbol f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	0	1	LT. brown to yellowish brown f. SAND (clean) moist	3 6 7 8	SP	Unless otherwise noted samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 IN.
	5	2	Lt brown to yellowish brown changing to gray f. SAND w/ slight trace of marine life (wet)	7 10 15 22	SP	Hole was advanced between samples by washing with split spoon
	10	3	Gray f. SAND grading into a grey c-f SAND w/slight trace of marine life (wet)	12 24 23 25	SP	
	15	4	Browish-gray f. SAND w/ trace of m. SAND & slight trace of marine life (wet)	9 15 17 24	SP	
	20	5	Gray m-f SAND w/ trace of marine life (wet)	12 19 20 21	SP	
					OL	At approximately 24.0' depth wash water brought up black organic silt, & stopped around 24.5' [NOT enough sample for testing purposes]
	25	6	Gray f. SAND w/ slight trace of marine life (wet)	8 14 15 20	SP	
	30	7	Gray m-f SAND w/ slight trace of marine life (wet)	6 6 5 8	SP	(27'-30') - did not detect any silt in wash
	35	8	Gray f SAND w/ trace of marine life	31 9 11 11	SP	
	40	9	Gray c-f SAND w/ trace of f. gravel	29 64 67 73	SW	
			Bottom of hole El. -37.34'			
						Water Table Depth @ 2.0' on 29 July 64 @ 1645 hrs - Low Tide

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)*

☆ GPO 1963 : OF—712-275

PROJECT: N.J Inlets & Beaches Corson's Inlet

HOLE NO. ANCB

Hole No. ANCB-2

DRILLING LOG

DIVISION: N.A.D.

INSTALLATION: Phila. Dist. Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. Inlets & Beaches
2. LOCATION *(Coordinates or Station)*: Curson's Inlet N.J.
3. DRILLING AGENCY: Warren Giles Drilling Co.
4. HOLE NO. *(As shown on drawing title and file number)*: ANCB-2
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: ______
8. DEPTH DRILLED INTO ROCK: ______
9. TOTAL DEPTH OF HOLE: 42'
10. SIZE AND TYPE OF BIT: 2" I.D. Split Spoon
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: J-3 Willeys 4-Wheel drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 9 UNDISTURBED ______
14. TOTAL NUMBER CORE BOXES: ______
15. ELEVATION GROUND WATER: +2'-3" 1100 hrs
16. DATE HOLE: STARTED 30 July 64 COMPLETED 31 July 64
17. ELEVATION TOP OF HOLE: +4.5'
18. TOTAL CORE RECOVERY FOR BORING: ______ %
19. SIGNATURE OF INSPECTOR: J.J. Ucciferro

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blows e	BOX OR SAMPLE NO. SYMBOL	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	0	1	Lt. Brn. f-uniform SAND damp	P 2 3 5		Samples were taken with 2" I.D. split spoon & 140 lb. hammer dropped 30 inches
	5	2	Brn-Gray f-uniform SAND moist	8 8 11 18		2 ½ inch I.D. casing
	10	3	gray f-uniform SAND moist	16 22 30 36		after spoon was pounded down and the blow count recorded, the rod was raised and dropped several times to insure a sufficient sample recovery.
	15	4	same as above	15 24 32 37	SP	See back of this sheet for location of this hole
	20	5	gray f-uniform SAND many pieces of small shell fragments. Also a very small trace of decaying organic matter.	7 9 8 16		
	25	6	Gray f-uniform SAND	10 10 11 13		
	30	7	same as above	8 10 13 18		Work stopped on 30 July at 1700 hrs at depth of 30' Work continued 800 hrs. 31 July
	35	8	gray f-m SAND many pieces of shell fragments ranging up to ½" in size	7 8 9 9		
	40	9	gray f-c SAND with a trace of fine gravel. Also some silt, dark gray in color	12 30 49 88	SP-SM	Sample 9 - Silt appeared in thin seams or layers
			el. Bott. of hole -37.5'			completed 1100 hrs 31 July 64

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)*

☆ GPO 1963 : OF—712-275

PROJECT: N.J. Inlets & Beaches HOLE NO. ANCB-2

Hole No. ANCB-3

DRILLING LOG

DIVISION: N.A.D.

INSTALLATION: Phila. Dist. Office

SHEET OF SHEETS

1. PROJECT: N.J. Inlets & Beaches
2. LOCATION (Coordinates or Station): Corson's Inlet N.J.
3. DRILLING AGENCY: Warren Giles Drilling Co.
4. HOLE NO. (As shown on drawing title and file number): ANCB-3
5. NAME OF DRILLER: Jacob Harris
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: ——
8. DEPTH DRILLED INTO ROCK: ——
9. TOTAL DEPTH OF HOLE: 40'
10. SIZE AND TYPE OF BIT: 2" I.D. Split Spoon
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: Acker
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED ——
14. TOTAL NUMBER CORE BOXES: ——
15. ELEVATION GROUND WATER: ——
16. DATE HOLE: STARTED 5 Aug 64; COMPLETED 5 Aug 64
17. ELEVATION TOP OF HOLE: Water Hole! -1.7'
18. TOTAL CORE RECOVERY FOR BORING: —— %
19. SIGNATURE OF INSPECTOR: J. J. Ucciferro

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	~~% CORE RECOVERY~~ Blows e	BOX OR SAMPLE NO. SYMBOL	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		——— Water			Drilling began 800 hrs, 5 Aug64
			Ground el. -1.7'			
		1	Brn. f-uniform SAND very small trace of shell fragments.	3 6 8 13		Samples were taken with 2" I.D. Split spoon & 140lb hammer dropped 30 inches.
	5					
		2	gray f-uniform SAND	70 23 36 50		Sample #2 - Casing dropped 6" when taking sample with 140lb hammer. - No recovery when spoon was brought up for 1st time. Spoon was again dropped to same depth and with an up & down motion of rod, sample was obtained.
	10					
		3	Same as above	34 31 34 23		
	15				SP	
		4	Same as above, but grain size slightly larger. also small trace of fine shell frag.	19 17 20 20		
	20					
		5	gray f-uniform SAND	23 13 17 17		When washing out 14'-17' fine gravel appeared.
	25					
		6	Same as above	6 7 6 8		
	30					
		7	Same as above, but small trace of shell frag.	6 15 19 16		
	35					
		8	gray c-f SAND trace of shell frag	8 29 39 24		
	40		Bott of hole, el. -40'			Completed 1400 hrs

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)

☆ GPO 1963 : OF—712-275

PROJECT: N.J. Inlets & Beaches

HOLE NO. ANCB-3

Hole No. ANCB-4

DRILLING LOG

DIVISION: N.A.D.

INSTALLATION: Phila. Dist. Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. Inlets & Beaches
2. LOCATION (*Coordinates or Station*): Corson's Inlet N.J.
3. DRILLING AGENCY: Warren Giles Drilling Co.
4. HOLE NO. (*As shown on drawing title and file number*): ANCB-4
5. NAME OF DRILLER: Jacob Harris
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: ______
8. DEPTH DRILLED INTO ROCK: ______
9. TOTAL DEPTH OF HOLE: 40'-0"
10. SIZE AND TYPE OF BIT: 2" I.D. Split Spoon
11. DATUM FOR ELEVATION SHOWN (*TBM or MSL*): IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: acker modified Rig
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 6 | UNDISTURBED ______
14. TOTAL NUMBER CORE BOXES: ______
15. ELEVATION GROUND WATER: ______
16. DATE HOLE: STARTED 29 July 64 | COMPLETED 29 July 64
17. ELEVATION TOP OF HOLE: - 12.00'
18. TOTAL CORE RECOVERY FOR BORING: ______ %
19. SIGNATURE OF INSPECTOR: J.J. Ucciferro

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (*Description*) d	~~% CORE RECOVERY~~ e	BOX OR SAMPLE NO. f	REMARKS (*Drilling time, water loss, depth of weathering, etc., if significant*) g
	0			BLOW COUNT		Samples were Taken with 2" I.D. split spoon & 140 lb hammer dropped 30 inches
	5		Water			2½ inch I.D. Casing
	10		Ground EL.-12.00			
		1	LT. Brn. f-uniform SAND WeT	2 P 2 4		No recovery on first attempt. Rag was inserted in spoon to catch sample on next Try.
	15					
		2	Gray f-uniform SAND WeT	9 13 21 25		25% recovery
	20					
		3	Same as above	15 13 40 24		25% recovery
	25				SP	
		4	Same as above	14 16 22 14		15% recovery
	30					
		5	Same as above	19 13 21 18		25% recovery
	35					
		6	Same as above	17 24 21 17		25% recovery
	40		BoTT. of hole, el. -40'0"			Completed 1645 hrs.

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED (*EM 1110-1-1801*) ☆ GPO 1963 : OF-712-275

PROJECT: NJ. INLETS & Beaches | HOLE NO. ANCB-4

1.1

Hole No. ANCB - 5

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. INLETS & BEACHES
2. LOCATION *(Coordinates or Station)*: CORSONS INLET
3. DRILLING AGENCY: Giles Drilling Corporation
4. HOLE NO. *(As shown on drawing title and file number)*: ANCB - 5
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: ——
8. DEPTH DRILLED INTO ROCK: ——
9. TOTAL DEPTH OF HOLE: 42.0'
10. SIZE AND TYPE OF BIT: 2" I.D. Split spoon
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: J-3 Willey 4-wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 11 | UNDISTURBED ——
14. TOTAL NUMBER CORE BOXES: ——
15. ELEVATION GROUND WATER: + 3.5
16. DATE HOLE: STARTED 0830 30 July 64 | COMPLETED 1215 30 July 64
17. ELEVATION TOP OF HOLE: + 4.60
18. TOTAL CORE RECOVERY FOR BORING: —— %
19. SIGNATURE OF INSPECTOR: R. W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blows per 6" e	~~BOX OR SAMPLE NO.~~ Symbol f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	0	1	Dark gray f SAND w/ some swamp matter & surface vegetation	2 3 4 5	SP	Unless otherwise noted samples were taken with 2" I.D. split spoon & 140# hammer dropping 30 inches
	5	2	Dark gray f. SAND - (slight organic or oily smell)	6 6 4 2	SP	Hole was advanced between samples by washing with split spoon
			Gray-blK silty f. SAND		SM	
			Gray-blK. f. sandy org. SILT		OH	
	10	3	Gray f. SAND (clean)	2 1 1 2	SP	Sample 3 - No Recovery installed rag in conjunction with basket & tried again
	15	4 A	Dark-brownish-blK f. sandy PEAT w/ some sea shell or marine life	2 6	PT	Note: Wash water appeared to be a silty f SAND from 7' to 8.5' & changing a f. sandy org. SILT from 8.5' to 9.5'
		4 B	Brownish-gry f. SAND w/ some organic matter	11 8		
	20	5	Lt. tan f. SAND w/ some m-Sand	4 4 5 6	SP	(13'-15') - Wash water brought up dark brown silty Peat (17'-20') - Wash water brought up few thin 1/16" to 1/8" seams of gray & brown f sandy org. SILT
	25	6	Dark gray organic SILT w/ some swamp matter & Vegetation (sample in 2-jars)	P P 1 1	OH	(22'-24') - Wash water brought up f SAND (24'-25') - Wash water brought up f sandy org SILT
	30	7 A	Dark gray organic SILT w/ some swamp matter & Peat	1 3	OH	(27'-30') - Wash water brought up dk. gray org SILT
		7 B	Lt. tan m-f SAND w/ slight trace of silt	9 12	SP	
	35	8	Dark gray silty f. SAND w/ some c-m sand (organic smell)	7 8 7 7	SM	(37'-40') - Wash water brought up gray silty c-m SAND
	40	9	Lt gray & white c-f SAND w/ some f gravel (just over 1/4")	12 19 40 56	SW	
			Bottom of hole El. -37.4			Water Table Depth @ 1.1' on 30 July 64 @ 1245 hrs

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)*

☆ GPO 1963 : OF—712-275

PROJECT: N.J. Inlets & Beaches Corson's Inlet

HOLE NO. ANCB-5

Hole No. ANCB-6

DRILLING LOG

DIVISION NAD

INSTALLATION Phila. District Office

SHEET 1 OF 1 SHEETS

1. PROJECT N.J. Inlets & Beaches
2. LOCATION *(Coordinates or Station)* Corson's Inlet
3. DRILLING AGENCY Giles Drilling Corp.
4. HOLE NO. *(As shown on drawing title and file number)* ANCB-6
5. NAME OF DRILLER Frank Derby
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 42.0
8. DEPTH DRILLED INTO ROCK 0.0
9. TOTAL DEPTH OF HOLE 42.0
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL J-3 Willey 4 Wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 10 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES —
15. ELEVATION GROUND WATER +3.09
16. DATE HOLE STARTED 23 July '64 COMPLETED 23 July '64
17. ELEVATION TOP OF HOLE + 6.09
18. TOTAL CORE RECOVERY FOR BORING — %
19. SIGNATURE OF INSPECTOR J. L. Vecifurro & J. D. Kane

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	~~% CORE RECOVERY~~ Blow count e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
6.09	0	1	Lt. gry. f. uniform SAND. Damp to moist. Micaceous	Push 2 2 4	SP	Unless otherwise noted samples were taken with 2" I.D. split spoon & 140 lb hammer dropping 30 inches.
	5	2	Same as above. Wet (Sample recovery 60%) Contains few sea shell pcs. (Turns to gry. due to moisture content)	27 54 60 19		Hole was advanced between samples by lowering split spoon repeatedly & washing out loosened material.
	10	3	Same as above. Wet Contains small pcs. of shells	11 29 37 40	SP	Casing diameter is 2½" I.D.
	15	4	Same as above	9 16 18 26		
	20	5	Gry. med-f. micaceous SAND w/few small pcs. of shells	9 12 11 12		
	25	6	Dk. gry organic CLAY w/many pcs of decaying vegetation. Highly plastic. Some odor wet.	1 2 1 1	OH	From 25 to 30.5 OH material
	30	7a		9 16 25 17		
		7b	Brn.-gry micaceous med-f SAND. Wet		SP	
	35	8	Dk. gry. CLAY w/many seams of f. SAND.	23 16 22 13	CL-SC	
	40	9	Lt. gry f-to C. SAND w/few pcs. of f. to m. GRAVEL	29 75 160 152	SW	Completed @ 1510 on 23 July 64
			Bottom of Hole @ El. -35.91			Water Table Depth @ 3.0' on 23 July @ 1500.

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)* ☆ GPO 1963 : OF—712-275

PROJECT N.J. Inlets & Beaches Corson's Inlet

HOLE NO. ANCB-6

Hole No. ANCB-7

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: N.J. Inlets & Beaches
2. LOCATION *(Coordinates or Station)*: Corson's Inlet
3. DRILLING AGENCY: Warren Giles Drilling Corp.
4. HOLE NO. *(As shown on drawing title and file number)*: ANCB-7
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 39.0
8. DEPTH DRILLED INTO ROCK: 0.0
9. TOTAL DEPTH OF HOLE: 39.0
10. SIZE AND TYPE OF BIT: 2" I.D. SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: Willey's 4-Wheel Drive
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 8 UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: +3.17
16. DATE HOLE: STARTED 24 July '64 COMPLETED 24 July '64
17. ELEVATION TOP OF HOLE: + 5.92
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: J.D. Kane

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
+5.92	0		Lt. gry. uniform fine SAND. Dry & loose.			Unless otherwise noted, samples were taken with a 2" I.D. split spoon & a 140 lb. hammer dropped 30 inches.
	5	1	Lt. to dk. gry f. micaceous SAND. Moist to wet. Contains few med pcs of SAND.	5 6 10 16		Hole was advanced between samples by slightly dropping split spoon repeatedly & washing out loosened material.
	10	2	Dk. gry. micaceous fine SAND w/ many pcs of sea shell fragments. Wet (60% sample recovery) slight odor.	21 21 27 35	SP	Casing ϕ is 2½" I.D.
	15	3	Gry. mica. fine SAND, slightly coarser than above. Wet Contains many small pcs of shells.	14 21 25 35		
	20	4	Same as above	9 8 8 9		
	25		No Recovery except for many small pcs of shells.	11 8 9 11	SW	No Recovery From 25.0 to 27.0
		5	From 27.0 to 28.0, lt. gry c. to f. SAND changing @ 28.0 to dk. gry f. SAND. wet. Some small pcs of gravel	7 8 11 12		
	30		No Recovery	4 3 10 18		No Recovery From 30.0 to 32.0
		6	Brn-gry. m-f. SAND w/ small pellets of brn. organic matter. Wet	23 203 63 54		w/300 lb hammer
	35		Gry m-f SAND. Wet. Mica.		SP	
		7a	Dk. gry. f. sandy CLAY. Slight odor	12 12 13 24	CL	Ground Water Depth @ 2'-9" on 24 July '64 @ 1330.
		7b				
	40		Bottom of hole @ El. -33.08			Completed ANCB-7 @ 1340
	45					

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED *(EM 1110-1-1801)*

☆ GPO 1963 : OF—712-275

PROJECT: N.J. Inlets & Beaches Corson's Inlet

HOLE NO.: ANCB-7

Hole No. ANCB 8

DRILLING LOG

DIVISION: NAD

INSTALLATION: Philadelphia District Office

SHEET 1 OF 1 SHEETS

1. PROJECT: CORSON'S INLET
2. LOCATION (*Coordinates or Station*)
3. DRILLING AGENCY: GILES DRILLING CORPORATION
4. HOLE NO. (*As shown on drawing title and file number*): ANCB 8
5. NAME OF DRILLER: Frank Derby
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: —
8. DEPTH DRILLED INTO ROCK: —
9. TOTAL DEPTH OF HOLE: 42.0'
10. SIZE AND TYPE OF BIT: 2" I.D. split spoon
11. DATUM FOR ELEVATION SHOWN (*TBM or MSL*): IWWD
12. MANUFACTURER'S DESIGNATION OF DRILL: J-3 Willey 4-wheel Drive - Home made Rig
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 12 UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: + 3.2
16. DATE HOLE: STARTED 0800 hrs 28 July 64 COMPLETED 1500 hrs 28 July 64
17. ELEVATION TOP OF HOLE: 4.8'
18. TOTAL CORE RECOVERY FOR BORING: %
19. SIGNATURE OF INSPECTOR: Robert W. Wright

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (*Description*) d	% CORE RECOVERY e	BOX OR SAMPLE NO. SYMBOL	REMARKS (*Drilling time, water loss, depth of weathering, etc., if significant*) g
	0 2	1	Brown f. SAND w/ very slight trace of shell or marine life.	P 6 6 9	SP	Work started @ 0800 hrs 28 July 64 - Encountered faulty engine trouble @ start.
	4					? El. top of ground is 1.1' lower than marking @ 4.8' - Possibly somebody pulled stake out of ground? or true el is 3.7' due to shifting sand?
	6 8	2	Gray f. micaceous SAND w/ trace marine life	5 6 8 6	SP	Descriptive adjectives silty or sandy = 30-50% some - 12-30% trace - 5-12% slight trace - less 5%
	10 12	3	Gray f. micaceous SAND w/ some (15%) marine life	4 3 5 7	SP	
	14 16 18	4	Dark gray f. micaceous SAND w/ trace of marine life	9 15 21 23	SP	Sample 4 had a slight oily or organic smell
	20	5A	Dark gry. f. micaceous SAND w/ trace m. sand, blk silt & marine life	3 5		
	22 24	5B	Black organic fiberous SILT w/ slight trace of fine sand & marine life.	1 1	OH	
	26	6A	(6-A) (25'-26.4') - Same	P 1	OH	Sample 6B - had slight oily or organic smell
	28	6B	(6-B) (26.4'-27') - Dark Gray f. micaceous SAND w/ trace of black silt	9 12	SP-SM	
	30 32	7	Light gray m-f SAND (Clean)	4 7 10 10	SP	
	34		Multicolored c-f SAND w/ some f. gravel			Sample 8 - Put in two Jars 8A - SAND 8B - SILT
		8A	(35.5'-36.2') - Zone of f. sandy org. SILT w/ some c-m Sand	12	SW	
	36	8B		9	OL	
		8A	Multicolored c-f SAND w/ some f. gravel.	9 17	SW	A & slight trace of silt
	38 40 42	9	Brown & gray m-f SAND w/ some f. gravel & trace f. sand	13 41 98 210	SP	Sample 9 - (40'-42') Brown sand changing to gray @ 41.0'

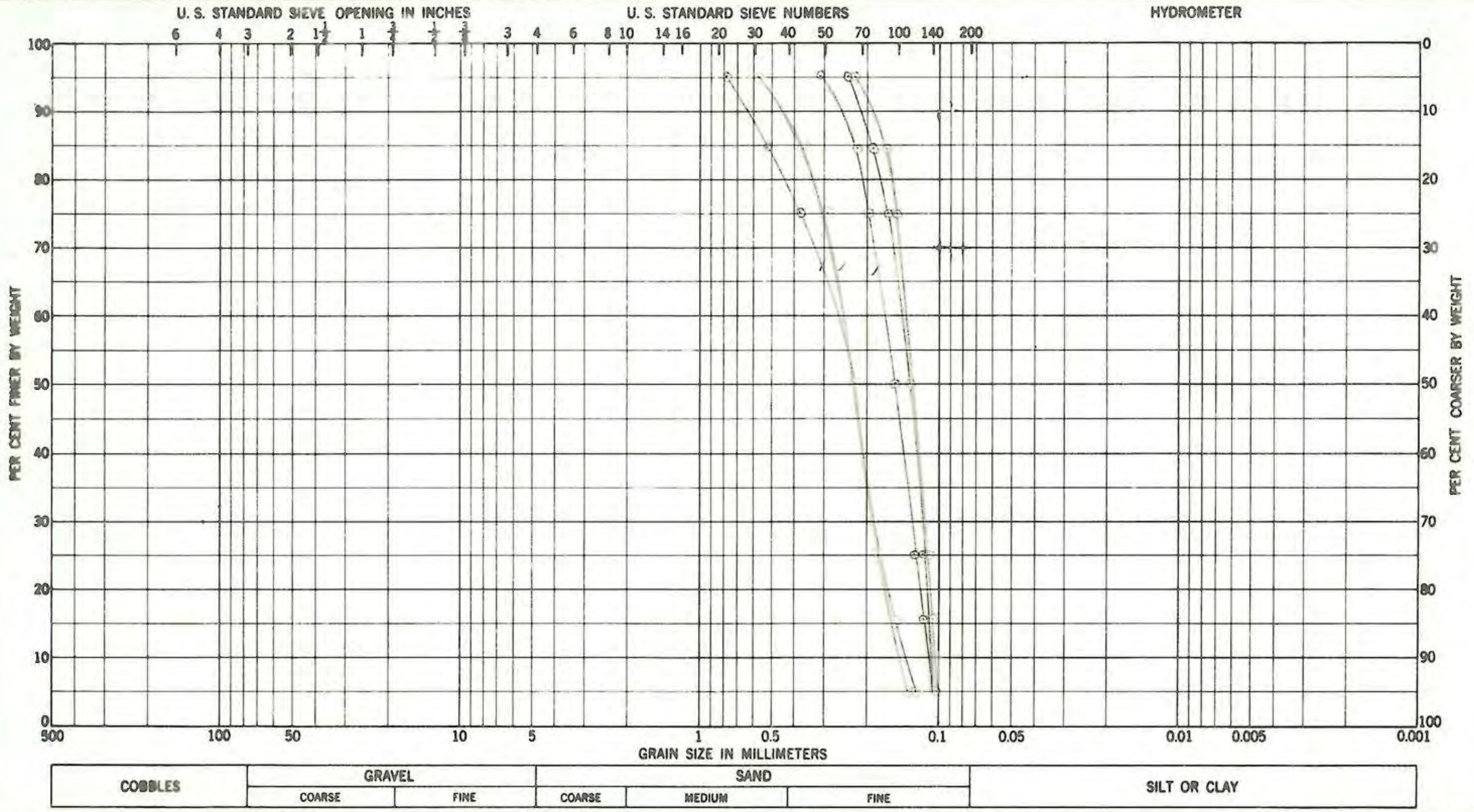
ENG FORM 1 APR 63 **1836** PREVIOUS EDITIONS MAY BE USED (*EM 1110-1-1801*)

☆ GPO 1963 : OF—712-275

PROJECT

HOLE NO. ANCB 8

Bottom of hole EL-37.2'



Sample No.	– Elev or ~~Depth~~	Classification	Nat w %	LL	PL	PI
1 - S4	-10.3 - 12.3	Br. - gry. f. SAND w/ tr. m. sand	19.6			
1 - S6	-20.3 - 22.3	Gray f. SAND	24.4			
3 - S7	- 32.0 - 34.0	Gray f. SAND w/ some m. sand	14.5			
4 - S3	- 22.0 - 24.0	Gray f. SAND	26.6			
5 - S3	- 5.4 - 7.4	Gray f. SAND	24.9			

GRADATION CURVES

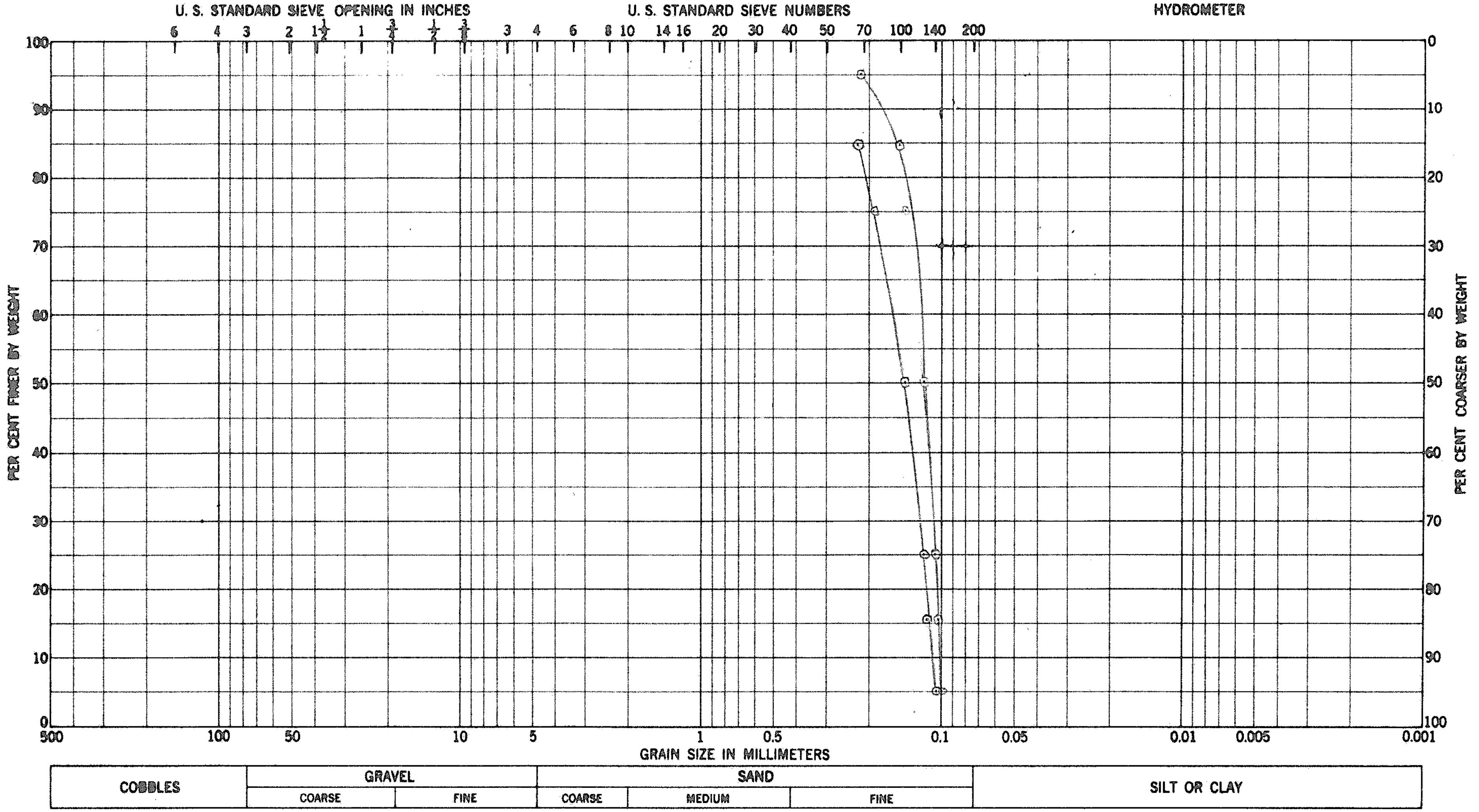
Project Inlets and Beaches

Area N. J

Boring No. ANCB

Date

ENG FORM 1 MAY 63 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*



Sample No.	– Elev or ~~Depth~~	Classification	Nat w %	LL	PL	PI
7 – S3	–19.1 – 11.1	Gray f. SAND	22.3			
8 – S2	– 0.9 – 2.9	Gray f SAND	23.2			

Project
Inlets and Beaches

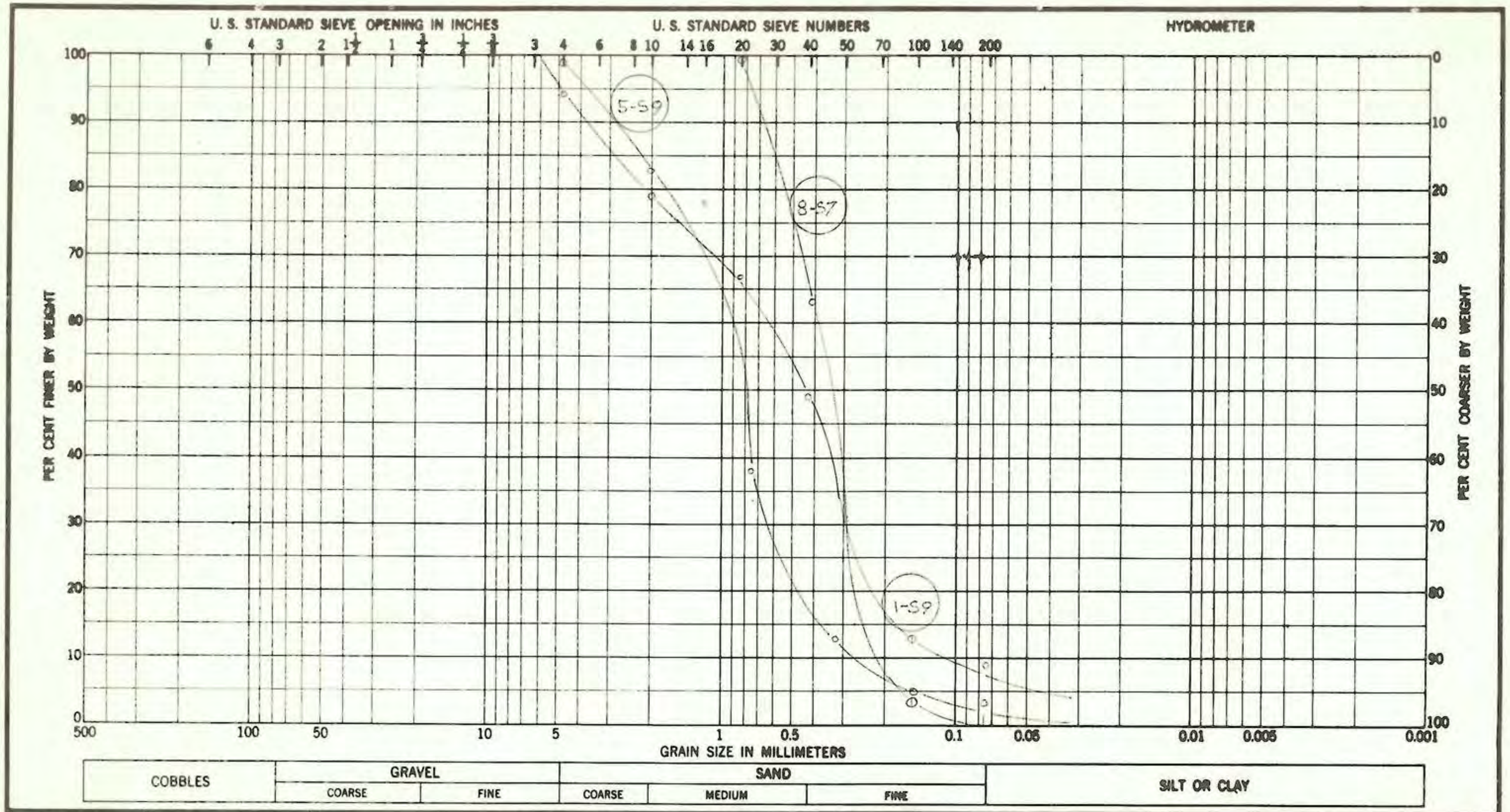
Area N. J.

Boring No. ANCB

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*



Sample No.	~~Elev- or~~ Depth	Classification	Nat w %	LL	PL	PI
1-S9	40-42	Tan c-f. SAND w. trace of silt	10			
5-S9	40-42	Tan c-f. SAND	13.3			
8-S7	30-32	Lt. gry. med-f. SAND	19.4			

Project Inlets and Beaches

Area N. J.

Boring No. ANCB

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*

B51831

Station ANCB-1 S-4

Jar #4

Date 25 Aug 64 Time 1500

Tube ______ Temp. 24.5 °C

Date analyzed 27 Aug 64

Remarks

W.C. 19.6%

SIZE DISTRIBUTION

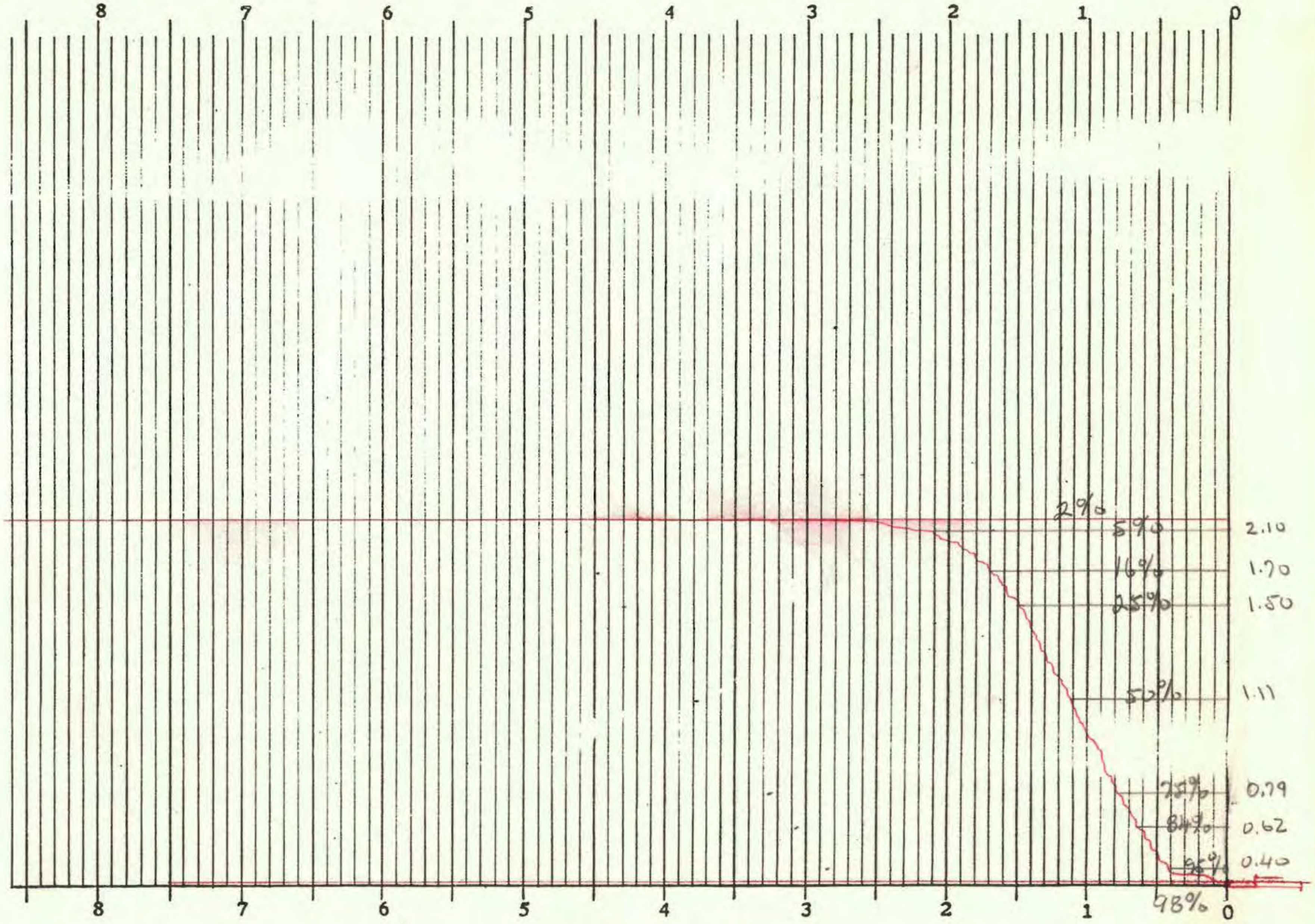
Percent Finer by wt	Diameter (microns)
5	.142
16	164
25	178 179
50	226 227
75	299 298
84	374
95	586 585

% Fines 2% ~~%CaCO3~~ % + No 18 2%

M_ϕ .248 σ_ϕ ______

Chart speed 2.020 in/min.

CERC — FORM 24



Station ANCB-1 S-6

Jar #1

Date 25 Aug 64 Time 1500

Tube Temp. 25.7 °C

Date analyzed 26 Aug 64

Remarks

W.C. 24.4 %

SIZE DISTRIBUTION

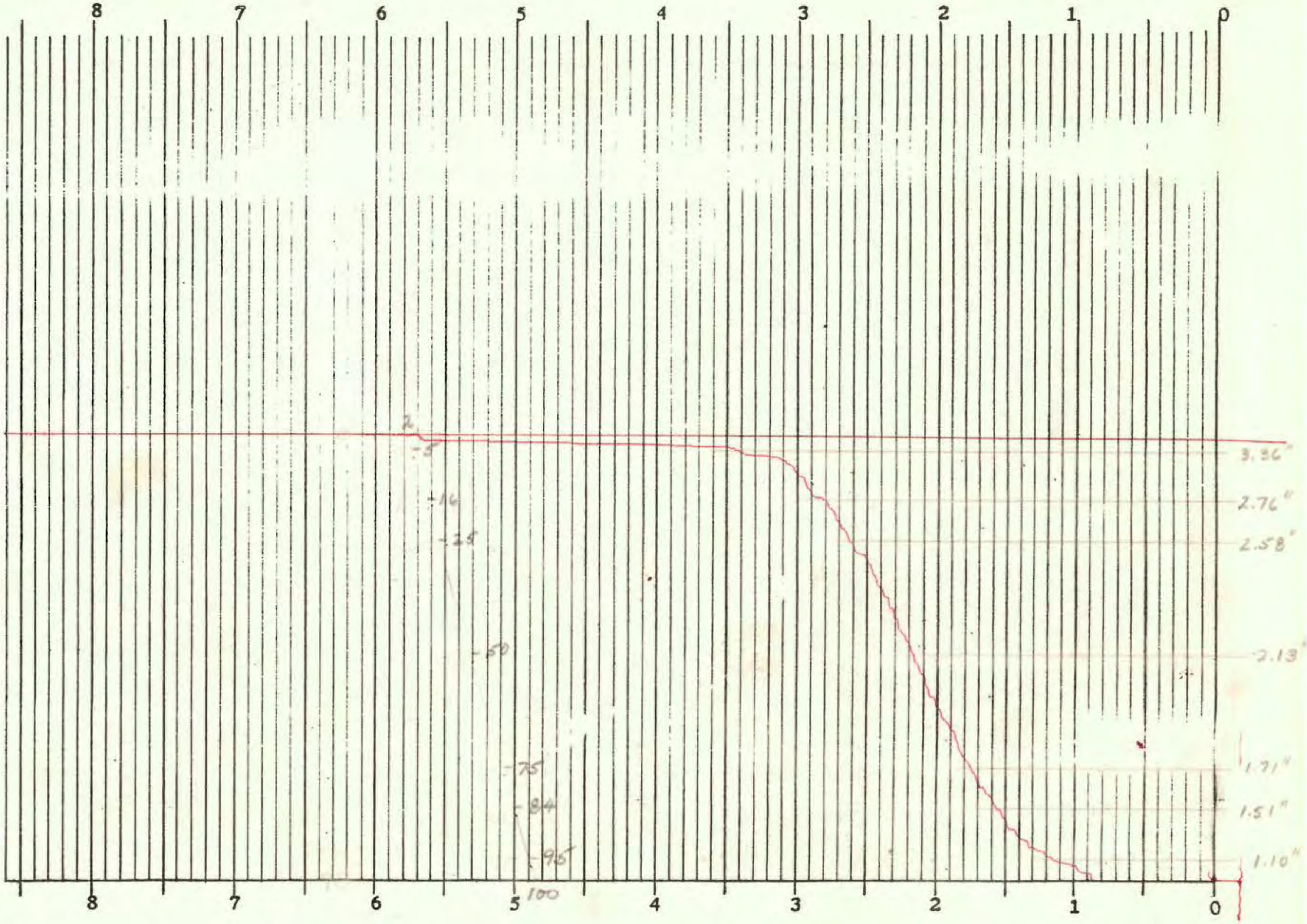
Percent	Diameter (microns)
5	102 ✓
16	116 ✓
25	122 ✓
50	138 ✓
75	~~161~~ 162
84	176 ✓
95	~~224~~ 225

% Fines 2% %CaCO3 % (+No.18) 0 %

$M_\phi = \sqrt{(\phi 16\%)(\phi 84)}$ σ_ϕ $\sqrt{\frac{\phi 16}{\phi 84}}$

Chart speed 2.020 in/min.

CERC — FORM 24
Nov. 7, 1963



Station ANCB-3 S-7

Jar #7

Date 25 Aug 64 Time 1500

Tube 27 Aug 64 Temp. 24.9 °C

Date analyzed

Remarks

W.C : 14.5%

SIZE DISTRIBUTION

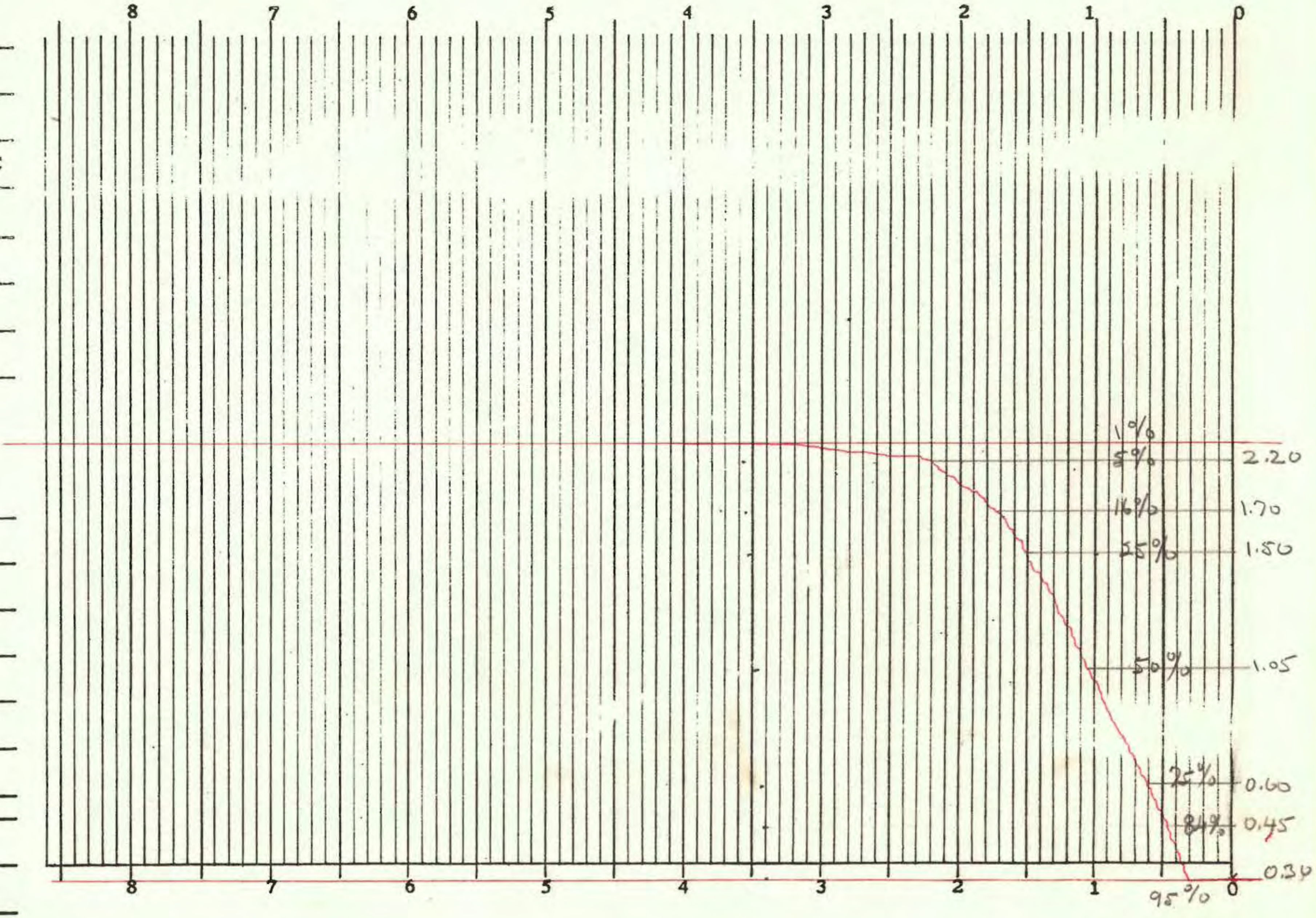
Percent	Diameter (microns)
5	136 ✓
16	163 ✓
25	178 ✓
50	233 ✓
75	385 ✓
84	518 ✓
95	788 ✓

% Fines 1% %CaCO3 +18 5%

M_ϕ σ_ϕ

Chart speed 2.020 in/min.

CERC — FORM 24



Station ANCB-4 S-3

Jar #6

Date 25Aug64 Time 1500

Tube [illegible] Temp. 24.8 °C

Date analyzed 27 Aug 64

Remarks

W.C. 26.6%

SIZE DISTRIBUTION

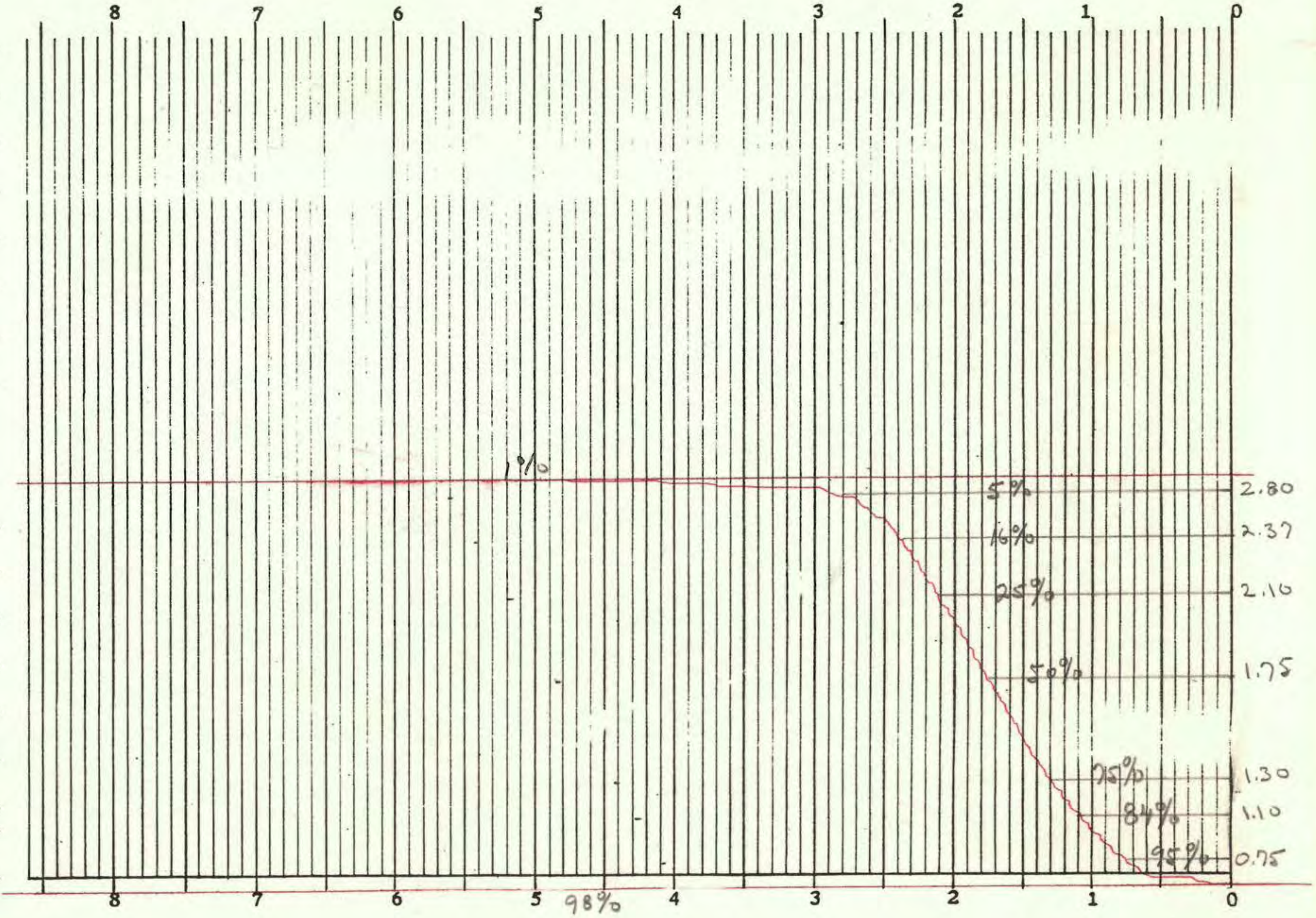
Percent	Diameter (microns)
5	116 ✓
16	129 ✓
25	141 ✓
50	160 ✓
75	198 ✓
84	226 ✓
95	312 ✓

% Fines 1% ~~%CaCO3~~ % +No 18 2%

M_ϕ σ_ϕ

Chart speed 2.020 in/min.

CERC — FORM 24



Station ANCB-5 S-3

Jar #13

Date 25 Aug 64 Time 1500

Tube ______ Temp. 25.8 °C

Date analyzed 27 Aug 64

Remarks

W.C. 24.9%

SIZE DISTRIBUTION

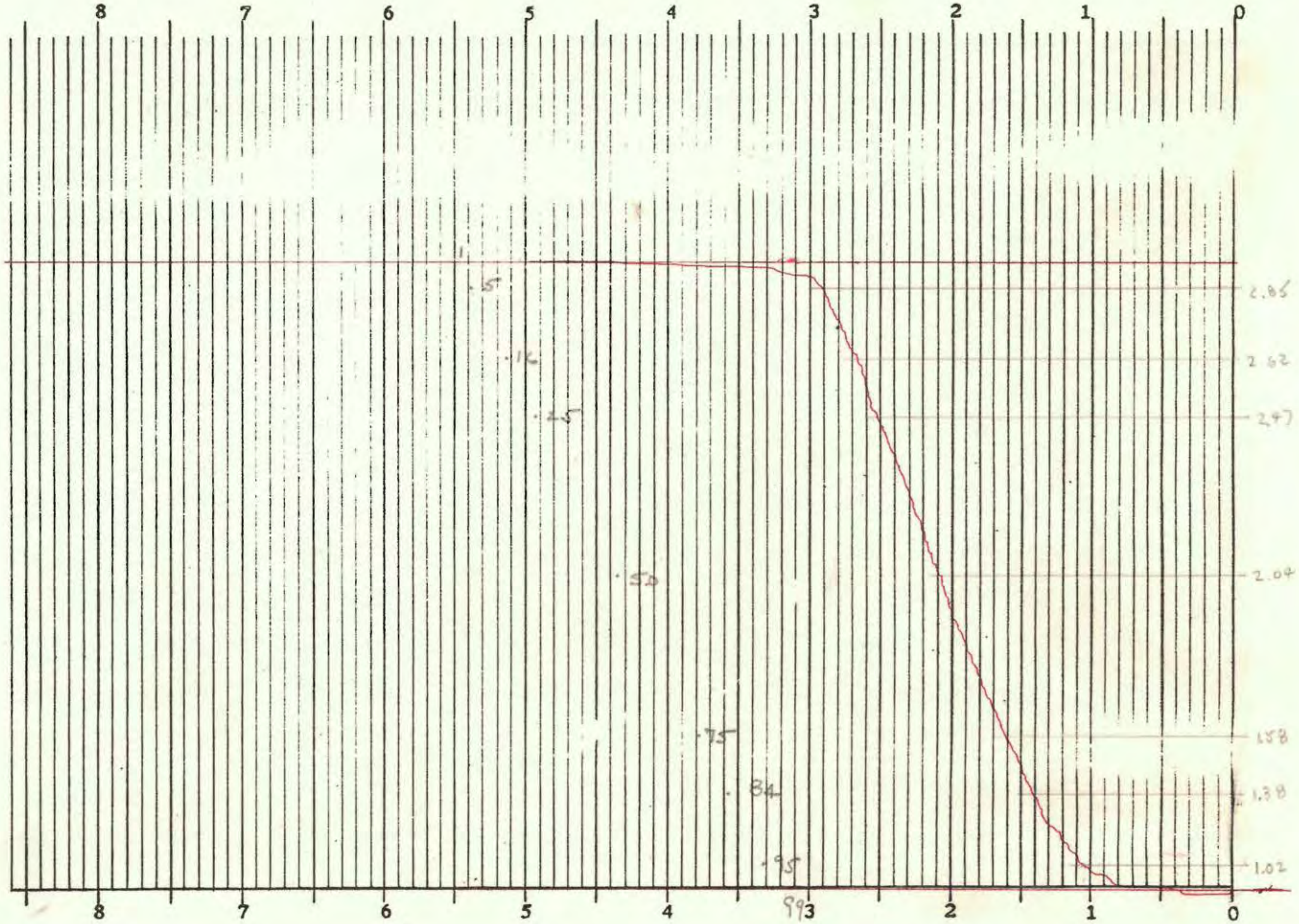
Percent	Diameter (microns)
5	114
16	121
25	125
50	142
75	171
84	~~188~~ 189
95	~~237~~ 238

% Fines 1% ~~%CaCO3~~ % +No 18 1%

M_ϕ ______ σ_ϕ ______

Chart speed 2.020 in/min.

CERC — FORM 24



Station ANCB-7 S-3

Jar #10

Date 25 Aug 64 Time 1500

Tube ______ Temp. 24.6 °C

Date analyzed 27 Aug 64

Remarks

W.C. 22.3%

SIZE DISTRIBUTION

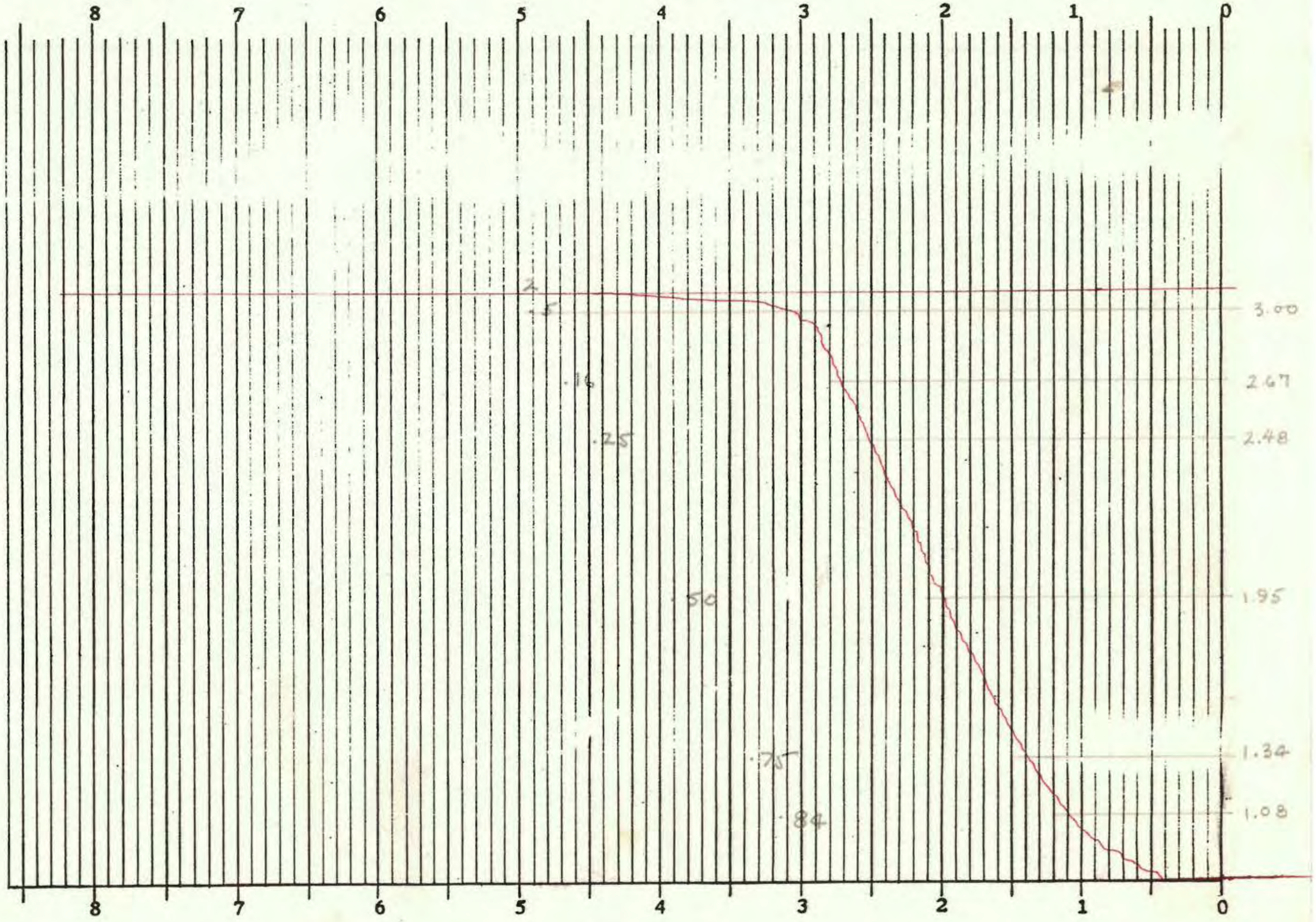
Percent	Diameter (microns)
5	111 ✓
16	120 ✓
25	125 ✓
50	149 ✓
75	195 ✓
84	226 ✓
95	—

% Fines 2% ~~%CaCO3~~ %+No 18 6%

M_ϕ ______ σ_ϕ ______

Chart speed 2.020 in/min.

CERC — FORM 24



Station ANCB-8 S-2

Jar #8

Date 25Aug64 Time 1500

Tube ______ Temp. 24.7 °C

Date analyzed 27Aug64

Remarks

W.C. 232%

SIZE DISTRIBUTION

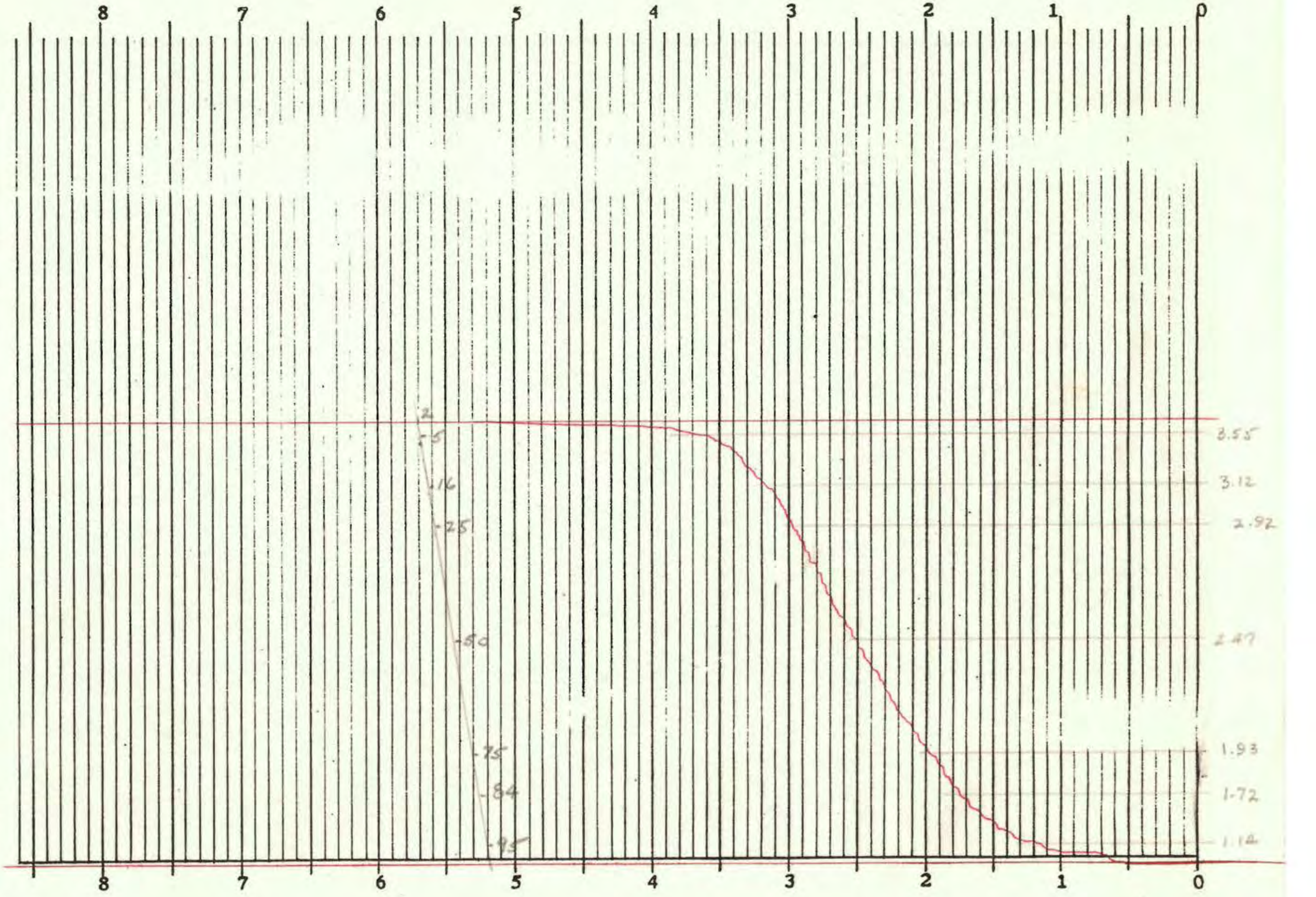
Percent	Diameter (microns)
5	99 ✓
16	108 ✓
25	113 ✓
50	126 ✓
75	149 ✓
84	161 ✓
95	220 ✓

% Fines 2% ~~%CaCO3~~ %+No18 1%

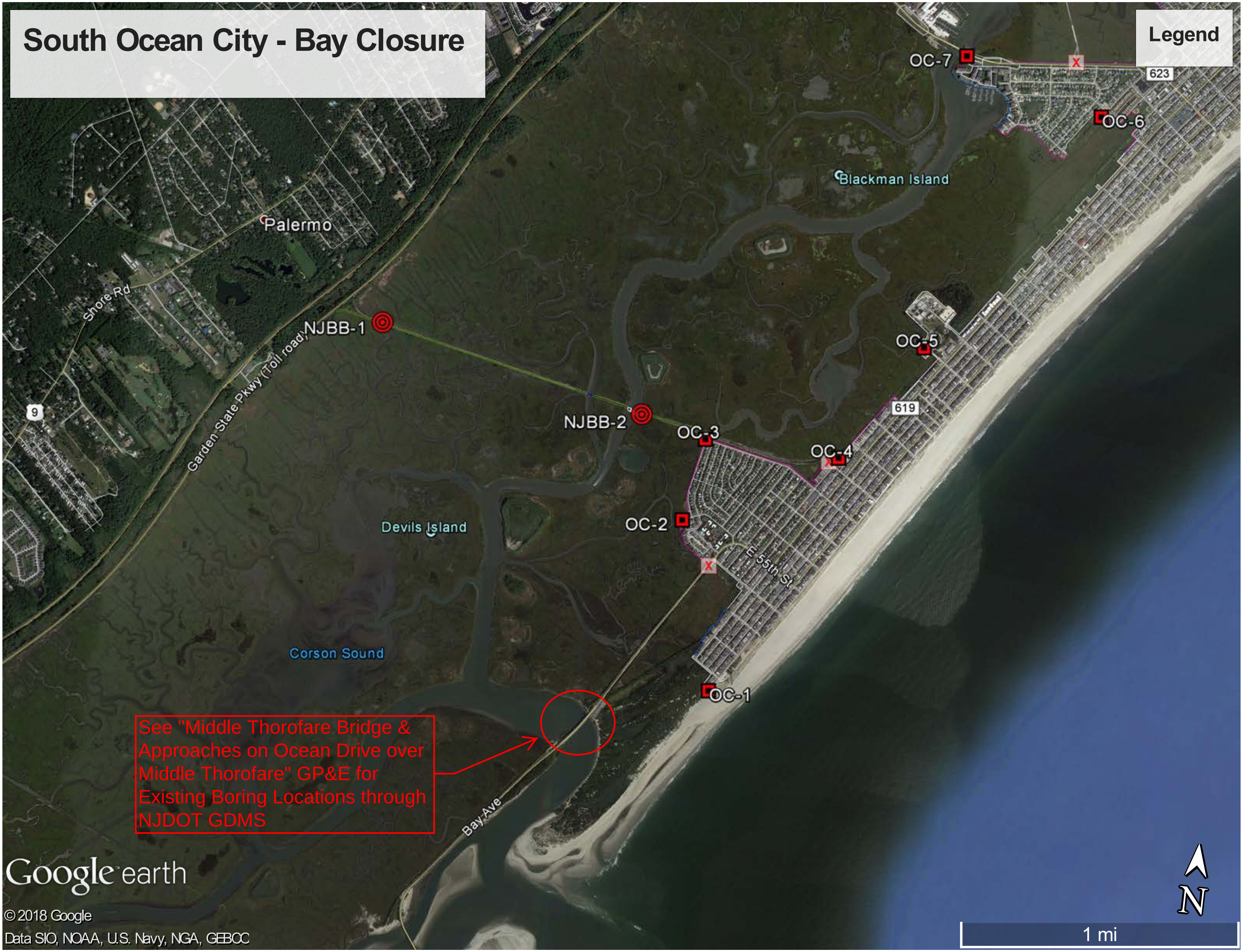
M_ϕ ______ σ_ϕ ______

Chart speed 2.020 in/min.

CERC — FORM 24



South Ocean City - Bay Closure



See "Middle Thorofare Bridge & Approaches on Ocean Drive over Middle Thorofare" GP&E for Existing Boring Locations through NJDOT GDMS

FED. ROAD DIV. NO.	FED. AID PROJECT NO.	STATE	FISCAL YEAR	SHEET NO.	TOTAL SHEETS

STRUCTURE NO.

PLAN

ELEVATION

30' 20' 10' 0' 30' 60'

SUMMARY OF QUANTITIES

~~ITEM~~				UNIT	CONTRACT QUANTITY	AS-BUILT QUANTITY	~~ITEM~~				UNIT	CONTRACT QUANTITY	AS-BUILT QUANTITY
BORING	STATION	OFFSET	GRND. EL.				BORING	STATION	OFFSET	GRND. EL.			
421W-1	363+05	31' RT.	+ 6.6'				421W-10	351+50	35' RT.	+ 2.3'			
421W-2A	361+54	22' RT.	+ 8.6'				421W-11	352+45	00	+ 9.7'			
421W-2B	360+51	5' RT.	+ 8.1'				421W-12	353+25	3' LT.	+ 7.9'			
421W-3	360+02	9' RT.	+ 4.8'				421W-14	356+45	20' RT.	-21.9'			
421W-4	358+55	7' LT.	- 5.1'				421W-15	358+00	20' RT.	- 13.4'			
421W-5	357+02	9' LT.	-17.8'				421W-16	359+65	20' RT.	+ 2.1'			
421W-6	355+51	19' LT.	-17.5'				421W-17	360+18	15' LT.	+ 6.8'			
421W-7	354+00	17' LT.	+ 7.8'				421W-18	360+30	17' RT.	+ 6.3'			
421W-8	352+99	48' LT.	+ 8.1'				421W-19	360+78	22' LT.	+ 9.1'			
421W-9	352+00	27' LT.	+ 9.0'				421W-20	361+00	35' RT.	+ 8.4'			

INDEX OF DRAWINGS

DWG. NO.	TITLE	DWG. NO.	TITLE
B-1	GENERAL PLAN AND ELEVATION		
B-2	SECTION AND PROFILE		

STATE OF NEW JERSEY
DEPARTMENT OF TRANSPORTATION

MIDDLE THOROFARE BRIDGE & APPROACHES
ON OCEAN DRIVE
OVER MIDDLE THOROFARE

OCEAN CITY
UPPER TOWNSHIP
CAPE MAY COUNTY

NEIL O.CLARKE, P.E. COUNTY ENGINEER

GENERAL PLAN AND ELEVATION

A.G. LICHTENSTEIN AND ASSOCIATES
CONSULTING ENGINEERS
NEW YORK, N.Y. FAIR LAWN, N.J. LANGHORNE, PA.

SCALE	DATE	DWG. NO. 35 OF	B-1
AS SHOWN			

421W-1 TO 20

DESIGNED BY: GZ
DRAWN BY: JW
CHECKED BY:
IN CHARGE OF:
JOB NO 851

Form SO-2 2/79

NEW JERSEY DEPARTMENT OF TRANSPORTATION Sheet 1 of 2

ROUTE:
LOCAL NAME: Structure Boring
TEST HOLE NO. 421W-16
SECTION: Middle Thorofare Bridge FAUS M-5305(001)
STATION: 359+65 OFFSET: 20' Rt. REFERENCE LINE: Constr. BL GROUND LINE ELEVATION: +2.1'
BORINGS MADE BY: Bronston DATE STARTED: 9-23-85
INSPECTOR: Lord DATE COMPLETED: 10-9-85

Elevation G.W.T.
0 Hr. Tidal Date:
24 Hr. Tidal Date:
ft. P.P. Installed Date:

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0-6	6-12	12-18	REC.	Sample ID and Profile Change	
	29	S-1	0.0'	1.5'	5	7	7	0.5'	Light Brown CF(+)SAND, trace(-)Silt.	
	27									
	20									
	16									
5	18									
	17	S-2	5.0'	6.5'	3	2	2	1.0'	Light Gray F SAND, trace(-)Silt.	
	19	S-3	6.5'	8.0'	2	5	8	0.2'	Light Gray F SAND, trace Silt, trace F Gravel.	
	20									
	21	S-4	8.0'	9.5'	4	4	6	1.0'	Gray F SAND, trace Silt.	
10	23	S-5	9.5'	11.0'	1	3	3	0.4'	Gray F SAND, trace Silt, trace(-)F Gravel.	
	23									
	28	S-6	11.0'	12.5'	4	11	13	0.5'	Gray F SAND, trace Silt.	
	34	S-7	12.5'	14.0'	7	13	15	0.3'	SAME.	
	44									
15	50	S-8	14.0'	15.5'	13	15	14	0.2'	Gray F SAND, trace(+)Silt, trace(-)Fibers.	
	42	S-9	15.5'	17.0'	11	16	19	0.7'	Gray F SAND, trace(-)Silt.	
	37									
	40	S-10	17.0'	18.5'	7	11	9	0.3'	Gray F SAND, trace Silt, trace(-)F Gravel.	
	40	S-11	18.5'	20.0'	15	16	18	1.1'	Gray CF(+)SAND, trace Silt, trace F Gravel.	
20	42									
	45	S-12	20.0'	21.5'	6	2	2	0.2'	Gray CF(+)SAND, trace Silt, little(-)Shell Fragments.	21.5'
	48	S-13	21.5'	23.0'	1	1	1	1.5'	Dark Gray Organic CLAY and SILT, trace(-) Fibers.	
	44									
	50	S-14	23.0'	24.5'	1	1	2	1.5'	SAME.	
25	39	S-15	24.5'	26.0'	1	1	1	1.5'	Dark Gray Organic CLAY and SILT, trace F Sand, trace Fibers. (Slightly Micaceous).	
	36									
	37	S-16	26.0'	27.5'	1	1	1	1.5'	Dark Gray Organic CLAY and SILT, trace(-)Fibers. (Slightly Micaceous)	
	42	S-17	27.5'	29.0'	1	1	1	1.5'	SAME.	
	39									
30	60	S-18	29.0'	30.5'	1	2	1	1.5'	SAME.	
	47	S-19	30.5'	32.0'	2	2	3	1.5'	Dark Gray Organic CLAY and SILT, little(-) Shell Fragments,trace CF Sand, trace(-)Fibers.	
	49									
	57	S-20	32.0'	33.5'	1	1	2	1.5'	Dark Gray Organic CLAY and SILT, trace(-)Fibers.	
	69	S-21	33.5'	35.0'	2	2	21	1.5'	(Micaceous).	
35	65								Gray CLAY and SILT, some MF(+)Gravel, trace CF Sand.	35.0'
	45									
	86	S-22	35.0'	36.5'	58	46	42	0.3'	Gray CF GRAVEL, trace(-)Silt, trace(+)CF Sand.	
	113									
	185									
40	202									

Nominal I.D. of Drive Pipe	2½" xxx
Nominal I.D. of Split Barrel Sampler	1½"
Weight of hammer on Drive Pipe	300 lbs.
Weight of hammer on Split Barrel Sampler	140 lbs.
Drop of hammer on Drive Pipe	24"
Drop of hammer on Split Barrel Sampler	30"

Core Dia.

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey Department of Transportation

Bureau of Geotechnical Engineering

Approximate Change in Strata

Inferred Change in Strata - - - - - - - -

Form SO-2 2/79 **NEW JERSEY DEPARTMENT OF TRANSPORTATION** Sheet 2 of 2

ROUTE: **LOCAL NAME:** Structure Boring **TEST HOLE NO.** 421W-16

SECTION: Middle Thorofare Bridge FAUS M-5305(001)

STATION: 359+65 **OFFSET:** 20' Rt. **REFERENCE LINE:** Constr. BL **GROUND LINE ELEVATION:** +2.1'

BORINGS MADE BY: Bronston **DATE STARTED:** 9-23-85

INSPECTOR: Lord **DATE COMPLETED:** 10-9-85

Elevation G.W.T.

0 Hr. Tidal **Date:**

24 Hr. Tidal **Date:**

_______ **ft. P.P. Installed** **Date:**

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	Sample ID and Profile Change	
	101	S-23	40.0'	40.8'	66	120	/.3'	0.3'	Light Gray F GRAVEL, trace(-)Silt, some CF	
	179								Sand.	
	197									
	282									
5	349									
	140	S-24	45.0'	46.0'	52	122	-	0.5'	SAME.	
	254									
	535									
	384									
10	286									
	330	S-25	50.0'	51.0'	76	121	-	0.4'	Tan CF SAND, trace(-)Silt, some(-)F Gravel.	
	422									
	561									
	236									
15	115									
	227	S-26	55.0'	56.5'	36	48	74	0.3'	Tan CF SAND, trace(-)Silt, little(-)F Gravel.	
	382									
	370									
	391									
20	418									
	320	S-27	60.0'	61.3'	30	84	120/	0.3'	Tan and Gray MF(+)GRAVEL, trace(-)Silt, little	
	401						.3'		(+)CF Sand.	
		S-28	62.0'	62.7'	69	120	/.2'	0.4'	Tan CF SAND, trace(-)Silt, trace(+)F Gravel.	62.7'
									Bottom of Hole	
25										
30										
35										
40										

Nominal I.D. of Drive Pipe 2½"	4" ~~XXX~~
Nominal I.D. of Split Barrel Sampler 1½"	
Weight of hammer on Drive Pipe 300 lbs.	
Weight of hammer on Split Barrel Sampler 140 lbs.	
Drop of hammer on Drive Pipe 24"	
Drop of hammer on Split Barrel Sampler 30"	

Core Dia. _______________

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

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New Jersey Department of Transportation

Bureau of Geotechnical Engineering

Approximate Change in Strata _______________

Inferred Change in Strata ‒ ‒ ‒ ‒ ‒ ‒ ‒ ‒ ‒ ‒

Form SO-2 2/79 **NEW JERSEY DEPARTMENT OF TRANSPORTATION** Sheet 1 of 2

ROUTE: **LOCAL NAME:** Structure Boring **TEST HOLE NO.** 421W-18

SECTION: Middle Thorofare Bridge FAUS #BR-M-5305(001)

STATION: 360+30 **OFFSET:** 17' Rt. **REFERENCE LINE:** Constr. BL **GROUND LINE ELEVATION:** +6.3'

BORINGS MADE BY: Augustine **DATE STARTED:** 9-17-85

INSPECTOR: Lord **DATE COMPLETED:** 10-11-85

Elevation G.W.T.

0 Hr. +2.1' **Date:** 10-11-85

24 Hr. +1.9' **Date:** 10-15-85

______ **ft. P.P. Installed** **Date:**

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	Sample ID and Profile Change	
	13	S-1	0.0'	1.5'	11	16	19	1.0'	FILL-Brown and Yellow CF GRAVEL, trace(-)Silt,	
	18								little(+)CF Sand.	
	51	S-2	1.5'	3.0'	8	13	7	1.2'	Black MF GRAVEL, trace(-)Silt, some(-)CF Sand.	
	37	S-3	3.0'	4.5'	5	7	7	0.8'	SAME. (Coal & Cinders)	
5	43									
	60	S-4	4.5'	6.0'	8	12	13	1.5'	SAME.	
	85	S-5	6.0'	7.5'	17	27	29	1.5'	Top 1' SAME. Bottom of Fill	7.0'
	90								Bottom 0.5' - Gray F SAND, trace Silt.	
	65	S-6	7.5'	9.0'	15	15	9	1.2'	Gray F SAND, trace Silt.	
10	52									9.5'
	37	S-7	10.0'	11.5'	6	3	3	1.2'	Dark Gray Fibrous Organic SILT, M.P.I.	
	43									
	61	U-1	11.5'	13.0'	PRESSED			0.8'		
	59	S-8	13.0'	14.5'	1	2	1	0.5'	Gray Fibrous Organic SILT, L.P.I.	
15	68									
	47	U-2	15.0'	16.5'	PRESSED			0.5'		15.5'
	51									
	60	S-9	16.5'	18.0'	12	14	14	1.5'	Gray F SAND, little Silt, trace(-)Fibers.	
	108									
20	104									
	61	S-10	20.0'	21.5'	11	18	26	1.0'	Gray F SAND, trace(+)Silt.	
	76									
	84									
	158									23.5'
25	110									
	91	S-11	25.0'	26.5'	2	2	2	1.5'	Dark Gray Fibrous Organic SILT, M.P.I.	
	100									
	117	U-3	26.5'	28.0'	PRESSED			1.5'		
	121	S-12	28.0'	29.5'	2	2	3	1.5'	SAME.	
30	137									
	92	U-4	30.0'	31.5'	PRESSED			0.1'	In Jar.	
	84									
	102	S-13	31.5'	33.0'	1	2	2	1.5'	SAME.	
	97									
35	98									35.0'
	109	S-14	35.0'	36.5'	9	12	17	1.5'	Gray MF(+)SAND, little Silt.	
	116									
	141									
	113									
40	116									

Nominal I.D. of Drive Pipe ~~2½~~ 4"

Nominal I.D. of Split Barrel Sampler 1½"

Weight of hammer on Drive Pipe 300 lbs.

Weight of hammer on Split Barrel Sampler 140 lbs.

Drop of hammer on Drive Pipe 24"

Drop of hammer on Split Barrel Sampler 30"

Core Dia. ______

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The Information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey Department of Transportation

Bureau of Geotechnical Engineering

Approximate Change in Strata ______

Inferred Change in Strata - - - - - - - -

Form SO-2 2/79 **NEW JERSEY DEPARTMENT OF TRANSPORTATION** Sheet 2 of 2

ROUTE:

LOCAL NAME: Structure Boring

TEST HOLE NO. 421W-18

SECTION: Middle Thorofare Bridge FAUS #BR-M-5305(001)

STATION: 360+30 OFFSET: 17' Rt. REFERENCE LINE: Constr. BL

GROUND LINE ELEVATION: +6.3'

BORINGS MADE BY: Augustine DATE STARTED: 9-17-85

INSPECTOR: Lord DATE COMPLETED: 10-11-85

Elevation G.W.T.

0 Hr. +2.1' Date: 10-11-85

24 Hr. +1.9' Date: 10-15-85

______ ft. P.P. Installed Date:

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon			REC.	Sample ID and Profile Change	
					0 / 6	6 / 12	12 / 18			
	121	S-15	40.0'	41.5'	16	26	33	0.2'	Gray CF SAND, little Silt, little Shell Fragments.	
	164									
	500									
	860									
5	1312									
	319	S-16	45.0'	46.0'	56	113	-	0.3'	Gray F SAND, trace(+)Silt.	
	1402									
	1671									
	2091									
10	2140									
	916	S-17	50.0'	51.0'	81	150	-	0.5'	Gray F SAND, little Silt.	
	1363									
	1571									
	2114									
15	2396									
		S-18	55.0'	56.5'	59	96	112	0.5'	Gray CF SAND, trace Silt, trace(+)F Gravel.	56.5'
									Bottom of Hole	

Nominal I.D. of Drive Pipe	~~2½"~~ 4"
Nominal I.D. of Split Barrel Sampler	1½"
Weight of hammer on Drive Pipe	300 lbs.
Weight of hammer on Split Barrel Sampler	140 lbs.
Drop of hammer on Drive Pipe	24"
Drop of hammer on Split Barrel Sampler	30"

Core Dia. ______

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

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Approximate Change in Strata ______

Inferred Change in Strata - - - - - - - -

Form SO-2 2/79 **NEW JERSEY DEPARTMENT OF TRANSPORTATION** Sheet 1 of 2

ROUTE:
LOCAL NAME: Structure Boring
TEST HOLE NO. 421W-19
SECTION: Middle Thorofare Bridge FAUS #BR-M-5305(001)
STATION: 360+78 **OFFSET:** 22' Lt. **REFERENCE LINE:** Constr. BL
GROUND LINE ELEVATION: +9.1'
BORINGS MADE BY: Augustine **DATE STARTED:** 8-9-85
INSPECTOR: Lord **DATE COMPLETED:** 8-29-85

Elevation G.W.T.
0 Hr. +1.3' Filled In Dry **Date:** 8-29-85
24 Hr. SAME **Date:** 9-3-85
________ **ft. P.P. Installed** **Date:**

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon			REC.	Sample ID and Profile Change	
					0/6	6/12	12/18			
	4	S-1	0.0'	1.5'	7	6	10	1.5'	Brown CF SAND, trace(-)Silt, trace(+)F Gravel.	
	7									
	11	S-2	1.5'	3.0'	8	11	11	1.5'	Light Brown F SAND, trace(-)Silt.	
	12	S-3	3.0'	4.5'	11	10	9	1.2'	SAME.	
5	10									
	14	S-4	4.5'	6.0'	5	7	7	1.5'	SAME.	
	11	S-5	6.0'	7.5'	7	8	8	1.5'	SAME.	
	13								Gray CF SAND, trace (-) Silt, some (+) F	
	10	S-6	7.5'	9.0'	5	7	6	1.2'	Gravel.	
10	6	S-7	9.0'	10.5'	5	4	4	1.5'	Gray & Black F SAND, trace(+)Silt.	
	20									
	32	S-8	10.5'	12.0'	2	1	2	1.0'	Gray & Brown CF(+)SAND, trace Silt.	
	33	S-9	12.0'	13.5'	2	2	2	0.8'	Top - 2" - Gray F SAND, trace(+)Silt.	12.5'
	32								Bottom - 6" - Gray Fibrous Organic CLAY & SILT, some(-)F Sand.	
15	34	S-10	13.5'	15.0'	1	1	2	1.2'	SAME.	
	39	U-1	15.0'	16.5'		PRESS		0		
	35									
	68	S-11	16.5'	18.0'	2	1	2	1.0'	Dark Gray Organic CLAY & SILT, little(+)F	
	51								Sand, trace Shell Fragments, trace(-)Fibers.	
20	51									20.0'
	61	U-2	20.0'	21.5'		PRESS		1.5'		
	62								Gray F SAND, trace Silt, little (+) Shell	
	68	S-12	21.5'	23.0'	7	11	11	1.2'	Fragments.	23.0'
	84									
25	89									
	67	S-13	25.0'	26.5'	2	2	1	1.5'	Gray Fibrous Organic CLAY & SILT, trace(+)F	
	71								Sand, trace Shell Fragments.	
	80	U-3	26.5'	28.0'		PRESS		1.5'		
	82									
30	76	S-14	28.0'	29.5'	1	1	2	1.2'	Gray Fibrous Organic CLAY & SILT in jar.	
	80	U-4	30.0'	31.5'		PRESS		0.5'*		
	80									31.5'
	99	S-15	31.5'	33.0'	2	3	10	1.5'	Gray MF SAND, trace(+)Silt, trace Shell	
	149								Fragments.	
35	164									
	94	S-16	35.0'	36.5'	13	11	10	0.8'	Gray CF SAND, trace Silt, some(+)Shell	
	154								Fragments.	
	158									
	150									38.5'
40	146									

Nominal I.D. of Drive Pipe	~~2½"~~ 4"
Nominal I.D. of Split Barrel Sampler	1½"
Weight of hammer on Drive Pipe	300 lbs.
Weight of hammer on Split Barrel Sampler	140 lbs.
Drop of hammer on Drive Pipe	24"
Drop of hammer on Split Barrel Sampler	30"

Core Dia. ____________

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The Information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey Department of Transportation

Bureau of Geotechnical Engineering

Approximate Change in Strata ____________

Inferred Change in Strata — — — — — —

Form SO-2 2/79 **NEW JERSEY DEPARTMENT OF TRANSPORTATION** Sheet 2 of 2

ROUTE: **LOCAL NAME:** Structure Boring **TEST HOLE NO.** 421W-19

SECTION: Middle Thorofare Bridge FAUS #BR-M-5305(001)

STATION: 360+78 **OFFSET:** 22' Lt. **REFERENCE LINE:** Constr. BL **GROUND LINE ELEVATION:** +9.1'

BORINGS MADE BY: Augustine **DATE STARTED:** 8-9-85

INSPECTOR: Lord **DATE COMPLETED:** 8-29-85

	Elevation G.W.T.	Date
0 Hr.	+1.3' Filled in Dry	8-29-85
24 Hr.	SAME	9-3-85
	ft. P.P. Installed	

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	Sample ID and Profile Change	
	143	S-17	40.0'	41.5'	5	11	11	1.5'	Gray Silty CLAY, some(-)C(+)F SAND, trace(+)F	
	159								Gravel.	
	194									42.5'
	172									
5	200									
	168	S-18	45.0'	46.5'	38	65	106	0.2'	Light Gray MF(+)SAND, trace(-)Silt.	
	243									
	358									
	367									
10	385									
	184	S-19	50.0'	51.5'	24	65	121	0.2'	Light Brown CF(+)SAND, trace(-)Silt, trace	
	289								Wood Fibers(Lignitic), trace(-)F Gravel.	
	343									
	634									
15	1180									
		S-20	55.0'	55.5'	169	-	-	0.2'	Tan F SAND, trace(-)Silt.	55.5'
									Bottom of Hole	

*NOTE: Sample removed from tube and placed in jar.

20

25

30

35

40

Nominal I.D. of Drive Pipe	~~2½"~~ 4"
Nominal I.D. of Split Barrel Sampler	1½"
Weight of hammer on Drive Pipe	300 lbs.
Weight of hammer on Split Barrel Sampler	140 lbs.
Drop of hammer on Drive Pipe	24"
Drop of hammer on Split Barrel Sampler	30"

Core Dia. ______

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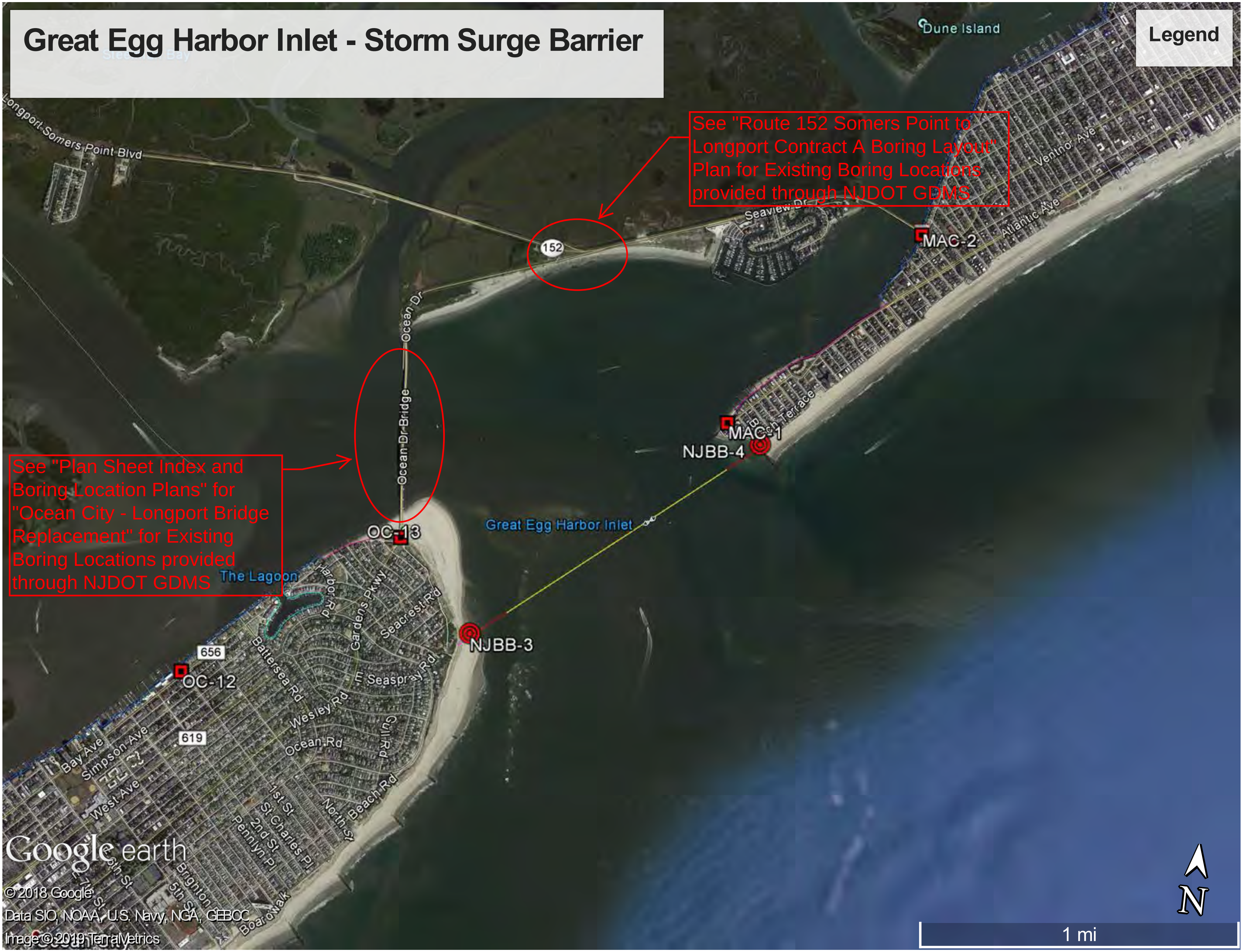
New Jersey Department of Transportation

Bureau of Geotechnical Engineering

Approximate Change in Strata ______

Inferred Change in Strata — — — — —

Great Egg Harbor Inlet - Storm Surge Barrier



See "Route 152 Somers Point to Longport Contract A Boring Layout" Plan for Existing Boring Locations provided through NJDOT GDMS

See "Plan Sheet Index and Boring Location Plans" for "Ocean City - Longport Bridge Replacement" for Existing Boring Locations provided through NJDOT GDMS

For Boring Notes See Sh. No. 1

AS BUILT

SHEET NO. 4

NEW JERSEY DEPARTMENT OF TRANSPORTATION

ROUTE 152
SOMERS POINT TO LONGPORT
ATLANTIC COUNTY

CONTRACT A
BORING LAYOUT

DATE: Jan. 15, 1973
SCALE: 1" = 200'

E. LIONEL PAVLO ENGINEERING COMPANY
NEW YORK NEW YORK

Form SO-2 5/73

E. Lionel Pavlo Engineering Co. Sheet 1 of 3

ROUTE: 152 LOCAL NAME: Somers Point to Longport Blvd. TEST HOLE NO. D-36 (Water)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International Inc.

STATION: 140+47 OFFSET: 30 Lt. REFERENCE LINE Survey BL Rte 152 GROUND LINE ELEVATION: - 1.5

BORINGS MADE BY: L. Anthony DATE STARTED: 9/17/73

INSPECTOR: J. R. Dowdy DATE COMPLETED: 9/21/73

Elevation G.W.T.		
0 Hr.	TIDAL	Date:
24 Hr.	+2.6 to - 1.5	Date:
ft. P.P. Installed		Date:

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon			REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	0.0
					0/6	6/12	12/18			
	3	S-1	0	2'	P	P	P	7"	Brownish Gray mf SAND, trace(-) Silt, trace Shell fragments	
	2									
	0									
	4									
5	2									
	5	S-2	5	6'-6"	5	6	6	16"	Dark Gray f SAND, little(+) Silt trace Shell fragments, 1-1/2" layer organic Silt, tr. Fibers	
	5									
	20									
9/17	31									
10	49									
	23	S-3	10	11'-6"	62	62	100/5"	5"	Gray f SAND, trace Silt, trace Fibers See Note #1	
	39									
	40									
	41									
15	40									
	35	S-4	15	16'-6"	6	9	6	4"	Gray f SAND, little(+) Silt	
	52									
	62									
	63									
20	80									
	7	S-5	20	21'-6"	12	24	24	10"	Gray f SAND, trace(-) Silt	
	10									
	11									
	43									
25	68									
	105	S-6	25	26'-6"	13	40	90	14"	Gray f SAND, trace(+) Silt	
	100									
	99									
9/18	101									
30	98									
	65	S-7	30	31'-6"	7	9	18	2"	Gray f SAND, trace(-) Silt	
	70									
	95									
	83									
35	90									
	55	S-8	35	36'-6"	6	10	10	8"	Gray mf SAND, trace(-) Silt	
	67									
	67									
	71									
40	96									

Nominal I.D. of Casing	4"	2½ "
Nominal I.D. of Spoon		1 3/8 "
Weight of hammer on Casing	500 lbs	300 lbs.
Weight of hammer on Spoon		140 lbs.
Drop of hammer on Casing		24 "
Drop of hammer on Spoon		30 "

Core Dia. ....

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

E. Lionel Pavlo Engineering Co.

Approximate Change in Strata ....

Inferred Change in Strata ....

Form 50-2 5-73

E. Lionel Pavlo Engineering Co.

Sheet 2 of 3

ROUTE: 152 LOCAL NAME: Somers Point to Longport Blvd. TEST HOLE NO. D-36 (Water)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International Inc.

STATION: 140+47 OFFSET: 30' Lt. REFERENCE LINE Survey BL Rte 152 GROUND LINE ELEVATION: -1.5

BORINGS MADE BY: L. Anthony DATE STARTED: 9/17/73

INSPECTOR: J. R. Dowdy DATE COMPLETED: 9/21/73

Elevation G.W.T.		
0 Hr.	TIDAL	Date:
24 Hr.	+2.6 to - 1.5	Date:
ft. P.P. Installed		Date:

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	
40	101	S-9	40	41'-6"	4	5	9	0"	See Note # 1	
	105									
	50	S-10	42	44'	13	8	10	0"	" " "	
	57									
45	72	S-11	44	46'	5	5	6	0"	Gray c-f SAND, trace(-) Shells See Note # 2	
	60									
	53									
	80									
	131	A							A. Gray c-m-f SAND, trace(+) mf Gravel, trace organic Silt 1-1/2" seam organic Clayey Silt	
50	100	S-12	49	50'-6"	14	7	6	7"		
	127	B								
	130								B. Gray organic SILT, trace c-f Sand	
	146									
9/19	92									
55	81	S-13	54	55'-6"	8	9	16	9"	Gray c-f SAND, little organic Silt, trace m-f Gravel	
	84									
	76									
	85									
	83									
60	77	S-14	59	60'-6"	21	17	27	17"	Gray c-f SAND, little(-) Silt, trace m-f Gravel, 3" ALTERNATING 1/4" to 1/2" layers of Gray Silt, Tr. c-f SAND & c-f Sand, little(-) Silt	
	61									
	86									
	101									
	113									
65	130	S-15	64	65'-6"	26	49	97	4"	Gray c-f SAND, trace(+) Silt, trace f Gravel, several 1/4" layers of Gray Silt, trace m-f Gravel	
	146									
	179									
	230									
	200									69'
70	175	S-16	69	70'-6"	11	28	41	7"	Gray organic SILT & CLAY, several 1/2" layers, Gray m-f Sand, little Silt	
	186									
	185									72'
	190									
	204									
75	125	S-17	74	75'-6"	59	87	95	6"	Brown and Gray m-f SAND, trace Silt, trace Silt, tr. c Sand	
	183									
	204									
	285									
	197								Gray c-f SAND, trace Silt, trace(-) f Gravel	
80	185	S-18	79	80'-6"	71	79	89	4"		

Nominal I.D. of Casing	X" 2½"
Nominal I.D. of Spoon	1 3/8"
Weight of hammer on Casing	XOO 1XS 300 lbs.
Weight of hammer on Spoon	140 lbs.
Drop of hammer on Casing	24"
Drop of hammer on Spoon	30"

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The Information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

E. Lionel Pavlo Engineering Co.

Core Dia. ____________

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

Approximate Change in Strata ____________

Inferred Change in Strata ____________

Form SO-2 5-73

E. Lionel Pavlo Engineering Co.

Sheet 3 of 3

ROUTE: 152 LOCAL NAME: Somers Point to Longport Blvd. TEST HOLE NO. D-36 (Water)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International Inc.

STATION: 140+47 OFFSET: 30' Lt. REFERENCE LINE Survey BL Rte 152 GROUND LINE ELEVATION: - 1.5

BORINGS MADE BY: L. Anthony DATE STARTED: 9/17/73

INSPECTOR: J. R. Dowdy DATE COMPLETED: 9/19/73

Elevation G.W.T.
0 Hr. TIDAL Date:
24 Hr. +2.6 to - 1.5 Date:
ft. P.P. Installed Date:

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	
80										
	240									
See Note	745									
# 3	90									
9/20	93									
9/21 85	117	S-19	84	85'-6'	53	72	83	6"	Gray cmf SAND, trace Silt, trace(-) f Gravel	
	145									
	190									
	205									
	403									
90		S-20	89	90'	53	125		12"		90'
				Bottom of Hole @ 90.0 El. - 91.5						
95										
100										
105										
110										
115										
120										

Completed @ 3:00 9/21/73

Note # 1 & 2 - Made 3 attempts
0" Rec. @ 40'-41'-6"
Made 7 attempts
0" Rec. @ 42'- 44'
Made 3 attempts
0" Rec. @ 44'- 46'. Recovered wash sample @ 44'-46' for classification minus silt content.

Note # 3 - Washed ahead of casing @ 82'

Nominal I.D. of Casing	~~4"~~ 2½"
Nominal I.D. of Spoon	1 3/8"
Weight of hammer on Casing	~~500 lbs~~ 300 lbs.
Weight of hammer on Spoon	140 lbs.
Drop of hammer on Casing	24"
Drop of hammer on Spoon	30"

Core Dia. ______

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The Information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

E. Lionel Pavlo Engineering Co.

Approximate Change in Strata ______

Inferred Change in Strata ______

E. Lionel Pavlo Engineering Co. Sheet 1 Of 3

ROUTE: 152 **LOCAL NAME:** Somers Point to Longport Blvd. **TEST HOLE NO.** D-37 (Land)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International, Inc.

STATION: 140+83 **OFFSET:** 74' Lt. **REFERENCE LINE** Survey BL Rte 152 **GROUND LINE ELEVATION:** +3.3

BORINGS MADE BY: L. Anthony **DATE STARTED:** 9/24/73

INSPECTOR: J. R. Dowdy **DATE COMPLETED:** 10/1/73

Elevation G.W.T.

0 Hr. TIDAL Date:

24 Hr. Date:

ft. P.P. Installed Date:

	CASING BLOWS	SAMPLE NO.	DEPTH		Blows on Spoon 0/6	6/12	12/18	REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	0.0
	1	S-1	0	1'-6"	1	1	2	17"	Light brown f SAND, trace (-) Silt	
	3									
	7									
	7									
5	9									
	9	S-2	5'	6'-6"	2	2	3	13"	Same	
	12									
	8									
	16									
10	17									
	10	S-3	10'	11'-6"	9	11	7	9"	Brown f. SAND, trace (-) Silt	
	16									
	33									
	49									
15	40									
9/24	48	S-4	15'	16'-6"	10	14	11	8"	Grey f SAND, trace (-) Silt	
9/25	51									
	71									
	74									
20	42									
	55	S-5	20'	21'-6"	28	20	20	10"	Same	
3" Casing	50									
	65									
	83									
25	58									
	56	S-6	25'	26'-6"	24	20	25	16"	Same	
	62									
	67									
	82									
30	58									
	63	S-7	30'	31'-6"	4	9	19	9"	Same	
	60									
	53									
	64									
35	50									
	75	S-8	35'	36'-6"	13	7	11	10"	Same	
	57									
	57									
	53									
40	51									

Nominal I.D. of Casing	3"	~~4"~~	~~2½"~~
Nominal I.D. of Spoon			1 3/8"
Weight of hammer on Casing			XXXXXs 300 lbs.
Weight of hammer on Spoon			140 lbs.
Drop of hammer on Casing			24"
Drop of hammer on Spoon			30"

Core Dia. ____________ ____________

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

E. Lionel Pavlo Engineering Co.

Approximate Change in Strata ....

Inferred Change in Strata ....

E. Lionel Pavlo Engineering Co. Sheet No. 2 of 3

ROUTE: 152 **LOCAL NAME:** Somers Point to Longport Blvd. **TEST HOLE NO.** D-37 (Land)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International, Inc.

STATION: 140+83 **OFFSET:** 74' Lt. **REFERENCE LINE** Survey BL Rte 152 **GROUND LINE ELEVATION:** +3.3

BORINGS MADE BY: L. Anthony **DATE STARTED:** 9/24/73

INSPECTOR: J. R. Dowdy **DATE COMPLETED:** 10/1/73

Elevation G.W.T.		
0 Hr.	TIDAL	Date:
24 Hr.		Date:
ft. P.P. Installed		Date:

	CASING BLOWS	SAMPLE NO.	DEPTH		Blows on Spoon 0/6	6/12	12/18	REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	
40	70	S-9	40'	41'-6"	22	14	14	7"	Same	
	60									
	67									
	69									
	56									
45	71	S-10	45'	46'-6"	24	14	14	7"	Grey f SAND, trace (-) Silt, little f Gravel, trace (-) Shells	
	68									
	61									
	58									48'
	61									
50	75	S-11	50'	51'-6"	12	7	7	11"	Grey m-f GRAVEL, some c-f Sand, trace Silt, (slight organic odor) (Loose)	
	78									
	100									
	86									
	47									
55	51	S-12	55'	56'-6"	27	31	29	7"	Same	
	55									
	58									
	61									58'
	71									
60	97	S-13	60'	61'-6"	39	49	53	15"	Light and dark brown c-f SAND, trace Silt, trace f Gravel	
	85									
3" Casing	82									
	79									
	90									
65	95	S-14	65'	66'-6"	50	48	39	18"	Grey c-f SAND, trace (+) Silt, trace f Gravel	
	90									
	112									
	180									
	235									
70 /28	117	S-15	70'	71'-6"	78	86	113	7"	Light brown c-f SAND and (-) m-f (+) Gravel, trace Silt	
	218									
	101									
	92									
	102									
75	89	S-16	75'	76'-6"	36	47	52	14"	Grey cmf SAND, trace Silt, trace (-) f Gravel, occ. 1/4" pockets of Grey Silt (slight organic odor)	
	96									
	92									
	121									
80	140									

Nominal I.D. of Casing	3"	~~4~~"	~~2~~"
Nominal I.D. of Spoon			1 3/8"
Weight of hammer on Casing		~~[illegible] lbs~~	300 lbs.
Weight of hammer on Spoon			140 lbs.
Drop of hammer on Casing			24"
Drop of hammer on Spoon			30"

Core Dia. ______________

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

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E. Lionel Pavlo Engineering Co.

Approximate Change in Strata ....

Sheet 3 of 3

ROUTE: 152 **LOCAL NAME:** Somers Point to Longport Blvd. **TEST HOLE NO.** D-37 (Land)

SECTION: JFK Bridge to Shore Road Contractor: Raymond International, Inc.

STATION: 140+83 **OFFSET:** 74' Lt. **REFERENCE LINE** Survey BL Rte 152 **GROUND LINE ELEVATION:** +3.3

BORINGS MADE BY: L. Anthony **DATE STARTED:** 9/24/73

INSPECTOR: J. R. Dowdy **DATE COMPLETED:** 10/1/73

Elevation G.W.T.

0 Hr. TIDAL Date:

24 Hr. +2.3 to -1.6 Date:

ft. P.P. Installed Date:

3" Casing

	CASING BLOWS	SAMPLE NO. DEPTH			Blows on Spoon 0/6	6/12	12/18	REC.	SAMPLE IDENTIFICATION AND PROFILE CHANGE	
80	141	S-17	80'	81'-6"	41	53	66	4"	Grey c-f SAND, trace Silt, trace m-f Gravel	
	163									
	294									
	410									
85	450									
	72	S-18	85'	86'-6"	35	89	113	13"	Grey and brown c-f SAND, trace Silt, some (+) m-f Gravel	
	120									
	271									
	308									
90	240									
		S-19	90'	91'-6"	24	190	156	11"	Grey cmf SAND, trace Silt, little m-f Gravel, slight organic odor	91'-6
									Completed hole 10:30 AM 10/1/73 Depth 91'-6" El. - -88.2	
95										
100										
105										
110										
115										
120										

Nominal I.D. of Casing	3"	~~4"~~	~~2½"~~
Nominal I.D. of Spoon			1 3/8"
Weight of hammer on Casing		~~300 lbs~~	300 lbs.
Weight of hammer on Spoon			140 lbs.
Drop of hammer on Casing			24"
Drop of hammer on Spoon			30"

Core Dia. ______

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

The Contractor shall make his own subsurface investigations in order to satisfy himself of the actual subsurface conditions. The Information contained on this log is not warranted to show the actual subsurface conditions. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

E. Lionel Pavlo Engineering Co.

Approximate Change in Strata ______

Inferred Change in Strata ......

STATE	FEDERAL PROJECT NO.
N.J.	DPB - 0007 (003)

LEGEND

SHEET C - CONSTRUCTION PLANS

G - GRADING AND DRAINAGE

⊕ - EXISTING BORING (DRILLED IN 1994)

● - EXISTING BORING (DRILLED IN 1992)

SCALE IN FEET

100' 50' 0 100' 200'

PSI-1 / PSI-3

NEW JERSEY DEPARTMENT OF TRANSPORTATION

PLAN SHEET INDEX AND
BORING LOCATION PLANS

OCEAN CITY - LONGPORT BRIDGE REPLACEMENT
AND UPGRADE OF OCEAN DRIVE (C.R. 656)

PARSONS BRINCKERHOFF-FG, INC.

THEODORE J. FISCHER
N.J. P.E. LIC. NO. 13927

7

PARSONS BRINCKERHOFF CADD DATA

OPERATOR	Schaible
PLOT DATE	08-MAR-1999 14:52
PENTABLE	ehx.tbl
DESIGN FILE	f:\200143\ln01.dgn

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-5

BORING LOG

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
CONTRACTOR: Warren George, Inc.
DRILLER: Rob Danielson
TYPE RIG: ATV - CME - 550
INSPECTOR: A. Reed

GROUND ELEVATION: +5.70 ft
STATION: 7+25
DRILLING START TIME: 3:30 PM
DRILLING FINISH TIME: 1:50 PM

BASELINE: Proposed Bridge Baseline
OFFSET: 0 ft
DATE: 10 / 26 / 94
DATE: 10 / 28 / 94

DEPTHS	METHOD(S) OF DRILLING
0 - 95.2 ft	Rotary Drilling

BOREHOLE WATER LEVEL DATA

DEPTH	HOUR	DATE	REMARKS

TYPE OF SAMPLE

SS SPLIT SPOON
O.D.: 2 in
I.D.: 1-3/8 in
LENGTH: 24 in
HAMMER WEIGHT: 140 lbs
HAMMER FALL: 30 in

UNDISTURBED

U SHELBY TUBE
O.D.:
I.D.:
I.L.:

D DENISON
O.D.:
I.D.:
I.L.:

C CORE
BARREL TYPE:
O.D.:
I.D.:

P PISTON
O.D.:
I.D.:
I.L.:

CASING

O.D.: 4 in
I.D.: 3-1/4 in
WEIGHT OF HAMMER: 300 lbs
HAMMER FALL: 24 in

Notes:

1. The subsurface information shown hereon was obtained for the design and estimate purposes for our Client. It is made available to authorized users only that they may have access to the same information available to our Client. It is presented in good faith, but is not intended as a substitute for investigations, interpretations or judgment of such authorized users.
2. Field identification of soil samples is based on Burmister Soil Identification System.
3. pp = Unconfined compression strength from Pocket Penetrometer (tsf)
4. WOH = Weight of Hammer; WOR = Weight of Rod

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE DEPTH (ft)	ROCK CORING INFORMATION: RUN (in) / SOIL SAMPLING (Blows per 6 inches): 0-6	REC. (in) / 6-12	REC. (%) / 12-18	L > 4" (in) / 18-24	RQD (%) / REC. (in)	FIELD IDENTIFICATION OF SOIL / ROCK
	7	SS	1	0-2	1	1	2	2	12	Brown f SAND, trace (-) Silt
	7									
	19									
	30									
5	29									
	65	SS	2	5-7	3	4	4	7	10	Same as SS-1
	70									
	125									
	68									
10	77									
	91	SS	3	10-12	16	7	8	11	12	Gray f SAND, trace (+) Silt
15										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-5

BORING LOG (continued)

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: A. Reed

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	4	15-17	6	18	21	29	12	Gray f SAND, trace (+) Silt
20										
		SS	5	20-22	8	10	12	14	12	Same as SS-4
25										
		SS	6	25-27	13	17	20	19	10	Same as SS-4
30										
		SS	7	30-32	9	13	15	15	14	Same as SS-4
35										
		SS	8	35-37	12	12	21	28	16	Same as SS-4
40										
		SS	9	40-42	14	15	18	20	18	Same as SS-4
45										

PARSONS BRINCKERHOFF-FG, INC.

BORING LOG (continued)

BORING NUMBER: PB-5

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: A. Reed

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	10	45-47	13	16	17	19	10	Gray f SAND, trace (+) Silt
50										
		SS	11	50-52	13	19	20	14	7	Same as SS-10
55										
		SS	12	55-57	12	12	19	23	12	Gray mf SAND, little (-) Silt, trace (-) mf Gravel
60										
		SS	13	60-62	1	1	1	1	19	Gray Clayey SILT, some (+) f Sand, trace mf Gravel (pp = 0.25)
65										
		SS	14	65-67	4	3	3	5	20	Gray Clayey SILT, some (+) f Sand (pp = 0.5)
70										
		SS	15	70-70.3	100/4"				3	Gray cf SAND, little (+) mf Gravel, trace Silt
75										

BORING NUMBER: PB-5

BORING LOG (continued)

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: A. Reed

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	16	75-75.4	100/5"				3	Gray cf SAND, little Silt, trace (-)f Gravel
80										
		SS	17	80-80.2	100/3"				3	Same as SS-16
85										
		SS	18	85-85.5	100/6"				2	Same as SS-16
90										
		SS	19	90-90.5	100/6"				2	Same as SS-16
95										
		SS	20	95-95.2	100/3"				2	Same as SS-16
										End of Boring @ 95.2 ft
100										
105										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-6

BORING LOG

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
CONTRACTOR: Warren George, Inc.
DRILLER: Rob Danielson
TYPE RIG: ATV - CME - 550
INSPECTOR: A. Reed & K. Ro

GROUND ELEVATION: +3.0 ft
STATION: 8+12
DRILLING START TIME: 3:00 PM
DRILLING FINISH TIME: 1:40 PM

BASELINE: Proposed Bridge Baseline
OFFSET: 18 ft RT
DATE: 10 / 28 / 94
DATE: 10 / 31 / 94

DEPTHS	METHOD(S) OF DRILLING
0 - 95.5 ft	Rotary Drilling

BOREHOLE WATER LEVEL DATA

DEPTH	HOUR	DATE	REMARKS

TYPE OF SAMPLE

SS SPLIT SPOON
O.D.: 2 in
I.D.: 1-3/8 in
LENGTH: 24 in
HAMMER WEIGHT: 140 lbs
HAMMER FALL: 30 in

UNDISTURBED

U SHELBY TUBE
O.D.:
I.D.:
I.L.:

D DENISON
O.D.:
I.D.:
I.L.:

C CORE
BARREL TYPE:
O.D.:
I.D.:

P PISTON
O.D.:
I.D.:
I.L.:

CASING

O.D.: 4 in
I.D.: 3-1/4 in
WEIGHT OF HAMMER: 300 lbs
HAMMER FALL: 24 in

Notes:

1. The subsurface information shown hereon was obtained for the design and estimate purposes for our Client. It is made available to authorized users only that they may have access to the same information available to our Client. It is presented in good faith, but is not intended as a substitute for investigations, interpretations or judgment of such authorized users.
2. Field identification of soil samples is based on Burmister Soil Identification System.
3. pp = Unconfined compression strength from Pocket Penetrometer (tsf)
4. WOH = Weight of Hammer; WOR = Weight of Rod

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE DEPTH (ft)	ROCK CORING INFORMATION: RUN (in) / SOIL SAMPLING (Blows per 6 inches): 0-6	REC. (in) / 6-12	REC. (%) / 12-18	L > 4" (in) / 18-24	RQD (%) / REC. (in)	FIELD IDENTIFICATION OF SOIL / ROCK
	Casing	SS	1	0-2	3	2	5	11	12	Gray f SAND, little (-) Silt
5										
		SS	2	5-7	13	30	29	34	10	Same as SS-1
10										
		SS	3	10-12	4	4	10	11	15	Gray f SAND, little (+) Silt
15										

BORING NUMBER: PB-6

BORING LOG (continued)

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: A. Reed & K. Ro

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	4	15-17	9	9	9	13	15	Gray f SAND, little (+) Silt, trace (-) f Gravel
20										
		SS	5	20-22	4	4	5	6	10	Same as SS-4
25										
		SS	6	25-27	6	8	13	14	12	Same as SS-4
30										
		SS	7	30-32	7	8	10	11	14	Same as SS-4
35										
		SS	8	35-37	8	9	11	10	14	Same as SS-4
40										
		SS	9	40-42	9	12	12	15	11	Same as SS-4
45										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-6

BORING LOG (continued)

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: K. Ro

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
					RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
		TYPE	NUMBER	DEPTH (ft)	0-6	6-12	12-18	18-24	REC. (in)	
		SS	10	45-47	10	13	18	19	13	Gray f SAND, little (+) Silt, trace (-) f Gravel
50										
		SS	11	50-52	13	15	15	25	12	Same as SS-10
55										
		SS	12	55-57	3	4	3	5	13	Gray Clayey SILT, little f Sand, trace (-) f Gravel
60										
		SS	13	60-62	4	6	6	15	14	Gray f SAND, some (-) Clayey Silt
65										
		SS	14	65-67	3	5	5	30	16	Same as SS-13
										Gray mf SAND, little Silt
70										
		SS	15	70-70.2	100/3"				2	Brown cf SAND, little (-) Silt, trace f Gravel
75										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-6

BORING LOG (continued)

PROJECT: Ocean City - Longport Bridge
LOCATION: Ocean City, NJ
INSPECTOR: K. Ro

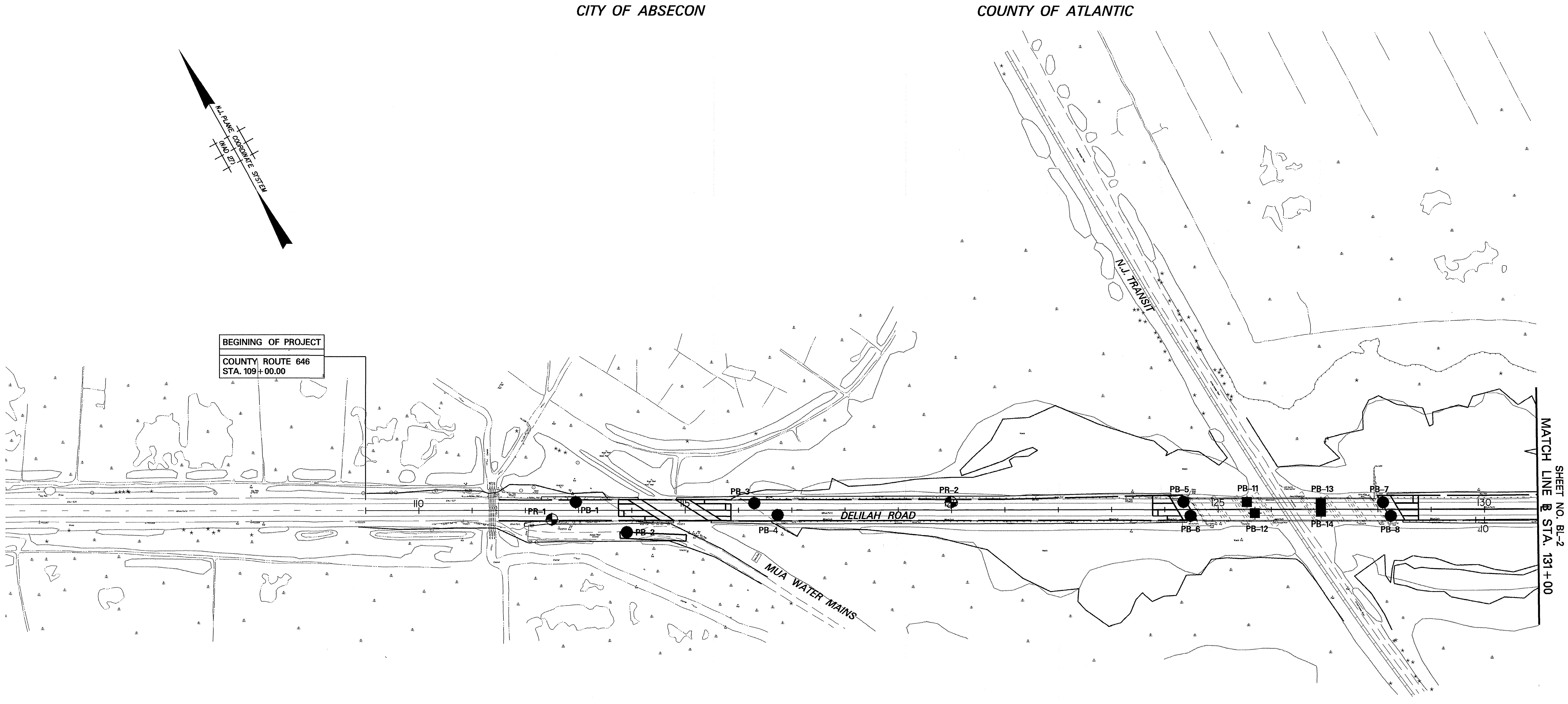
DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	16	75-75.3	100/4"				3	Brown cf SAND, little (-) Silt, trace (-) f Gravel
80										
		SS	17	80-80.4	100/5"				4	Same as SS-16
85										
		SS	18	85-85.5	100/6"				4	Same as SS-16
90										
		SS	19	90-90.2	100/3"				3	Same as SS-16
95										
		SS	20	95-95.5	100/6"				6	Yellow/Brown cf SAND, little Silt, trace (+) f Gravel
										End of Boring @ 95.5 ft
100										
105										

Absecon Blvd - Bay Closure

See "Boring Location Plan" Sheets 9 and 10 from "Delilah Road Bridges" for Existing Boring Locations provided through NJDOT GDMS

See "Soil Borings" Plan from "Routes 30 & 87" for Existing Boring Locations provided through NJDOT GDMS

STATE	FEDERAL PROJECT NO.
N.J.	BR-0190 (101)



SCALE IN FEET
100′ 50′ 0 100′ 200′

BL-1 / BL-2

LEGEND

- ◧ BORINGS DRILLED IN 1986
- ◑ ROADWAY BORINGS DRILLED IN 2002
- ◉ ROADWAY BORING WITH GROUND WATER OBSERVATION WELL DRILLED IN 2002
- ● BRIDGE BORINGS DRILLED IN 2002
- ⊕ ROADWAY BORING DRILLED IN 2004
- ■ BRIDGE BORINGS DRILLED IN 2004
- ▣ BRIDGE BORING WITH GROUND WATER OBSERVATION WELL DRILLED IN 2004
- ◉ PAVEMENT CORES DRILLED IN 2004

NEW JERSEY DEPARTMENT OF TRANSPORTATION

BORING LOCATION PLAN

DELILAH ROAD BRIDGES
CONTRACT NO. 054983230

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
CERTIFICATION OF AUTHORIZATION NO. 24GA28029800
Michael D. Helmlinger 3-3-06
MICHAEL D. HELMLINGER
NEW JERSEY PROFESSIONAL ENGINEER LICENSE NO. 38121

FIGURE 2A

9

PARSONS BRINCKERHOFF CADD DATA

OPERATOR	Runk	QUEUE	\\PRIPLOT\Oce_M
PLOT DATE	02-MAR-2006 15:23		
PENTABLE	ehx.tbl		
DESIGN FILE	U:\100297\bl02.dgn		

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-2

BORING LOG

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
CONTRACTOR: Craig Test Boring
DRILLER: Gary McAneny
TYPE RIG: CME-750
INSPECTOR: Z. Liu

GROUND ELEVATION: 2.00
BASELINE: Delilah Road
STATION: 113+90.71
OFFSET: 41.51 RT
DRILLING START TIME: 12:05 PM
DATE: June 10, 2002
DRILLING FINISH TIME: 6:25 PM
DATE: June 10, 2002

DEPTHS	METHOD(S) OF DRILLING
0-85'	Mud Rotary

BOREHOLE WATER LEVEL DATA

DEPTH	HOUR	DATE	REMARKS
			Drilling Mud Used

TYPE OF SAMPLE

SS SPLIT SPOON
O.D.: 2"
I.D.: 1-3/8"
LENGTH: 24"
HAMMER WEIGHT: 140 lbs
HAMMER FALL: 30"

UNDISTURBED

U SHELBY TUBE
O.D.: 3"
I.D.: 2-7/8"
I.L.: 24"

D DENISON
O.D.:
I.D.:
I.L.:

C CORE
BARREL TYPE:
O.D.:
I.D.:

P PISTON
O.D.:
I.D.:
I.L.:

CASING

O.D.:
I.D.:
WEIGHT OF HAMMER: 300 lbs
HAMMER FALL: 24"

Notes:

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2. Field identification of soil samples is based on Burmister Soil Identification System.
3. pp = Unconfined compression strength from Pocket Penetrometer (tsf)
4. WOH = Weight of Hammer; WOR = Weight of Rod

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE DEPTH (ft)	RUN (in) / 0-6	REC. (in) / 6-12	REC. (%) / 12-18	L > 4" (in) / 18-24	RQD (%) / REC. (in)	FIELD IDENTIFICATION OF SOIL / ROCK
	PUSH	SS	1	0-2	18	21	22	20	8	White / Brown cf **SAND**, little cf Gravel, trace Silt
		SS	2	2-4	11	8	7	5	13	Yellowish Brown cf **SAND**, little mf Gravel, trace Silt
5		SS	3	4-6	3	2	1	2	17	Yellowish / Dark Brown cf **SAND**, trace mf Gravel, trace Silt
		SS	4	6-8	1	1	1	1	13	Tan / Light Gray cm **SAND**, little$^{(+)}$ Silt, little$^{(-)}$ mf Gravel with Roots
		SS	5	8-10	1	1	1	1	9	Yellowish Brown cf **SAND**, little Silt
10										
		SS	6	10-12	WOH	0	0	0	13	Gray cm **SAND**, some Organic Silt, little f Gravel
15	↓									

PARSONS BRINCKERHOFF-FG, INC.

BORING LOG (continued)

BORING NUMBER: PB-2

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
INSPECTOR: Z. Liu

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
	↓	SS	7	15-17	1	0	1	0	8	Drak Gray **Organic SILT**, some$^{(+)}$ m Gravel, trace mf$^{(+)}$ Sand, pp = 0.2
20										
		SS	8	20-22	WOH	0	2	6	17	Brown **Organic SILT** with Peat, pp = 0.25
										Bottom 1" Gray cf **SAND**, little Silt
25										
		SS	9	25-27	7	10	15	17	12	Gray cf **SAND**, little Silt, trace f Gravel
30										
		SS	10	30-32	1	0	1	0	9	Gray **Organic SILT**, pp = 0.4
35										
		SS	11	35-37	1	0	1	2	22	Same as SS-10, pp=0.75
		U	1	37-39					23	Gray **Organic SILT**, trace(-) f Sand
40		SS	12	39-41	1	0	0	0	2	Same as SS-10
45										

BORING NUMBER: PB-2

BORING LOG (continued)

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
INSPECTOR: Z. Liu

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	13	45-47	31	35	38	26	9	Brown cf **SAND**, little mf Gravel, trace Silt
50										
		SS	14	50-52	21	22	20	21	11	Tan / Light Gray / Gray cm$^{(+)}$f **SAND**, trace$^{(+)}$ Silt, trace$^{(-)}$ f Gravel
55										
		SS	15	55-57	9	12	15	17	9	Same as SS-14
60										
		SS	16	60-62	9	12	13	10	10	Brown cf **SAND**, little Silt
65										
		SS	17	65-67	13	18	20	23	13	Brown cf **SAND**, little Silt, trace f Gravel
70										
		SS	18	70-72	15	15	16	19	15	Reddish Brown / Yellowish Brown cf **SAND**, little Silt
75										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PB-2

BORING LOG (continued)

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, N J
INSPECTOR: Z. Liu

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	19	75-77	9	8	15	18	15	Tan / Orange Brown **CLAY**, pp=2.5 (mottled)
										Bottom 2" Brown cf **SAND**, little Silt
80										
		SS	20	80-82	11	13	17	15	10	Brown mf **SAND**, little Silt
85										
		SS	21	85-87	15	18	20	22	11	Brown mf **SAND**, little Silt
										End of Boring at 87' Borehole bentonite sealed upon completion.
90										
95										
100										
105										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PR-3

BORING LOG

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
CONTRACTOR: Craig Test Boring
DRILLER: Gary McAneny
TYPE RIG: CME-750
INSPECTOR: Z. Liu

GROUND ELEVATION: 20.72
BASELINE: Delilah Road
STATION: 131+49.85
OFFSET: 15.50 LT
DRILLING START TIME: 7:10 AM
DATE: June 17, 2002
DRILLING FINISH TIME: 8:40 AM
DATE: June 17, 2002

DEPTHS	METHOD(S) OF DRILLING
0 – 45	Mud Rotary

BOREHOLE WATER LEVEL DATA

DEPTH	HOUR	DATE	REMARKS
			Drilling Mud Used

TYPE OF SAMPLE

SS SPLIT SPOON
O.D.: 2"
I.D.: 1-3/8"
LENGTH: 24"
HAMMER WEIGHT: 140 lbs
HAMMER FALL: 30"

UNDISTURBED

U SHELBY TUBE
O.D.:
I.D.:
I.L.:

D DENISON
O.D.:
I.D.:
I.L.:

C CORE
BARREL TYPE:
O.D.:
I.D.:

P PISTON
O.D.:
I.D.:
I.L.:

CASING
O.D.:
I.D.:
WEIGHT OF HAMMER: 300 lbs
HAMMER FALL: 24"

Notes:
1. The subsurface information shown hereon was obtained for the design and estimate purposes for our Client. It is made available to authorized users only that they may have access to the same information available to our Client. It is presented in good faith, but is not intended as a substitute for investigations, interpretations or judgment of such authorized users.
2. Field identification of soil samples is based on Burmister Soil Identification System.
3. pp = Unconfined compression strength from Pocket Penetrometer (tsf)
4. WOH = Weight of Hammer; WOR = Weight of Rod

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
					RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
		TYPE	NUMBER	DEPTH (ft)	0-6	6-12	12-18	18-24	REC. (in)	
		SS	1	0-2	Drill	Drill	15	33	10	Top 7.5" Asphalt
										Brown cf **SAND**, little mf Gravel, little Silt
		SS	2	2-4	19	19	20	25	9	Same as SS-1
5		SS	3	4-6	4	5	7	7	6	Brown cf **SAND**, little Silt, trace f Gravel
		SS	4	6-8	7	5	5	4	9	Brown cf **SAND**, little mf$^{(+)}$ Gravel, little$^{(-)}$ Silt
		SS	5	8-10	6	5	4	4	6	Brown cf **SAND**, little Silt, trace mf Gravel
10										
		SS	6	10-12	4	4	6	4	7	Brown cf **SAND**, little mf Gravel, little Silt
15										

PARSONS BRINCKERHOFF-FG, INC.

BORING LOG (continued)

BORING NUMBER: PR-3

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
INSPECTOR: Z. Liu

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	7	15-17	2	2	2	3	7	Brown mf **SAND**, little Silt
20										
		SS	8	20-22	2	3	3	3	5	Same as SS-7
25										
		SS	9	25-27	3	4	4	5	4	Brown cf **SAND**, little mf Gravel, little Silt
30										
		SS	10	30-32	3	3	4	6	4	Tan m$^{(+)}$f **GRAVEL**, some$^{(+)}$ cmf Sand, trace Silt
35										
		SS	11	35-37	WOH	0	0	0	15	Dark Gray **Organic SILT**, trace f Sand, pp = 0.25
40										
		SS	12	40-42	WOH	0	0	0	13	Gray **Organic SILT,** trace f Sand with white Shell Fragments, pp = 0.1
45										

PARSONS BRINCKERHOFF-FG, INC.

BORING NUMBER: PR-3

BORING LOG (continued)

PROJECT: Delilah Road Bridge Replacements
LOCATION: Absecon and Pleasantville, NJ
INSPECTOR: Z. Liu

DEPTH BELOW GROUND SURFACE (ft)	BLOWS ON CASING	SAMPLE			ROCK CORING INFORMATION					FIELD IDENTIFICATION OF SOIL / ROCK
		TYPE	NUMBER	DEPTH (ft)	RUN (in)	REC. (in)	REC. (%)	L > 4" (in)	RQD (%)	
					SOIL SAMPLING (Blows per 6 inches)					
					0-6	6-12	12-18	18-24	REC. (in)	
		SS	13	45-47	7	15	20	21	8	Brown m$^{(+)}$f **SAND**, little Silt, trace f Gravel
										End of Boring at 47 ft Borehole bentonite sealed upon completion.
50										
55										
60										
65										
70										
75										

STATE	FEDERAL PROJECT NO.
N.J.	BR-0190 (101)

BL-2 / BL-2

NEW JERSEY DEPARTMENT OF TRANSPORTATION

BORING LOCATION PLAN

DELILAH ROAD BRIDGES
CONTRACT NO. 054983230

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
CERTIFICATION OF AUTHORIZATION NO. 24GA28029800
Michael D. Helmlinger 3-3-06
MICHAEL D. HELMLINGER
NEW JERSEY PROFESSIONAL ENGINEER LICENSE NO. 38121

FIGURE 2B

10

LEGEND

BORINGS DRILLED IN 1986	⊕ ROADWAY BORING DRILLED IN 2004
ROADWAY BORINGS DRILLED IN 2002	■ BRIDGE BORINGS DRILLED IN 2004
ROADWAY BORING WITH GROUND WATER OBSERVATION WELL DRILLED IN 2002	BRIDGE BORING WITH GROUND WATER OBSERVATION WELL DRILLED IN 2004
● BRIDGE BORINGS DRILLED IN 2002	PAVEMENT CORES DRILLED IN 2004

PARSONS BRINCKERHOFF CADD DATA

OPERATOR	Runk	QUEUE	\\PRIPLOT\Oce_M
PLOT DATE	02-MAR-2006 15:23		
PENTABLE	ehx.tbl		
DESIGN FILE	U:\100297\bl01.dgn		

BORING LOG

BORING NO.	B-61
CONTRACT NO.	3

PROJECT ATLANTIC CITY APPROACH ROADWAYS
LOCATION ATLANTIC COUNTY, NEW JERSEY
CLIENT NEW JERSEY DEPT. OF TRANSPORTATION
GROUND ELEVATION ~~[illegible]~~
CONTRACTOR LIPPINCOTT ENGINEERING ASSOCIATES
STATION 414+00 OFFSET 17'L
DRILLER H. Doron INSPECTOR J.J. Hartman
DRILLING START TIME 9:05 DATE 9/10/86
EQUIPMENT Mobile B-40L Truck Rig
DRILLING FINISH TIME 4:15 DATE 9/10/86

CONTRACT QUANTITIES

ITEM	2.5" land boring	3.5" land boring	3.5" water boring	tube samples	denison samples	gw obs well	addnl. s.p.t.
UNIT	✓ lf	lf	lf	ea	ea	lf	ea
QTY	85.0	0	0	1	0	0	0

GROUNDWATER OBSERVATIONS

DATE	TIME	DEPTH	REMARKS
9/10/86	11:00	15.0ft	30 min, b.o.h. 40.0ft.
— bore	hole	backfilled upon	completion —
—	for	safety	reasons —

PURPOSE: Delilah Road Bridge Approach Fill (4.15)

SAMPLERS

DISTURBED

S SPLIT SPOON
O.D. 2"
I.D. 1 3/8"
I.L. 24"
HAMMER 140#
DROP 30"

R RING-LINED SAMPLER
O.D. —
I.D. —
I.L. —
HAMMER —
DROP —

UNDISTURBED

T THIN-WALL TUBE (shelby or piston)
O.D. 3"
I.D. 2 7/8"
I.L. 30"

D DENISON OR PITCHER
O.D. —
I.D. —
I.L. —

C CORE BARREL
I.D. — LEN. —
TYPE

DRILLING METHOD

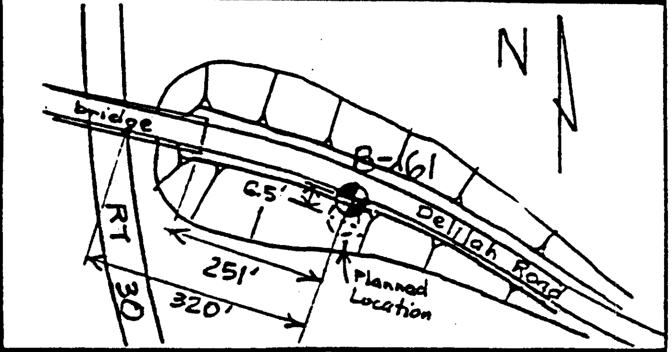
✓ HOLLOW STEM AUGER
I.D. 3 1/4"
PC. LEN. 63 1/4"
BIT LEN. 5 1/2"

MUD STABILIZED ROTARY
BIT O.D.
BIT LEN.
MUD

DRIVE OR SPIN CASING
I.D.
BIT LEN.
WT/DROP

DOUBLE WALLED DRIVE PIPE
I.D.
O.D.
HAMMER

LOCATION SKETCH (NTS)



DEPTH	BLOWS ON CASING	SAMPLES TYPE	SAMPLES NO.	SAMPLES DEPTH	SOILS 0-6 / ROCK RUN	SOILS 6-12 / ROCK REC	SOILS 12-18 / ROCK 4"+	SOILS REC / ROCK %R	SOILS N / ROCK RQD	SAMPLE DESCRIPTION	DRILLING NOTES
					auger	1.5	ft.			0.7' Bituminous paving	(0.7')
		S	1	1.5 / 3.0	15	9	9	1.1'	18	Black to brown MF SAND, little MF Gravel, little Silt.	
5		S	2	4.0' / 5.5	8	8	8	1.1'	16	Brown to light brown F SAND, trace Silt.	Fill 0'-20'
					bailed	7"	plug.				
10		S	3	8. / 10.2	3	3	2	1.2'	5	Brown to light brown M(-)F SAND, trace Silt, trace F Gravel.	
15		S	4	14.0 / 15.5	4	6	8	1.2'	14	Brown MF SAND, trace Silt, trace F Gravel.	Soil in S-4 saturated.

SHEET 1 OF 4

BORING LOG

PROJECT ATLANTIC CITY APPROACH ROADWAYS
BORING NUMBER B-61
LOCATION ATLANTIC COUNTY, NEW JERSEY
INSPECTOR J.J. Hartman

DEPTH	BLOWS ON CASING	SAMPLES			SOILS					SAMPLE DESCRIPTION	DRILLING NOTES
		TYPE	NO.	DEPTH	0 6	6 12	12 18	REC	N		
					ROCK						
					RUN	REC	4"+	%R	ROD		
											Fill 0'-20'
20'		S	5	18.5' 20.0	2	4	4	1.2'	8	0.6' Gray MF SAND little Silt 0.05' Gray SILTY CLAY 0.55' Gray MF SAND, little Silt	(19.0') (19.05')
25'		S	6	23.5 25.0	3	2	3	1.2'	5	0.7' Same. 0.05' Gray SILTY CLAY 0.45' Gray MF SAND, little Silt	(24.5') (24.55')
30'					bailed	12"	plug.				
		S	7	29.5 31.5	1	1	1	0.8'	2	Gray C(-)F SAND, trace Silt, trace F Gravel	
					1						(32.0')
35'		S	8	33.7 35.2	2	2	2	1.2'	4	0.3' Same. 0.9' Dark gray ORGANIC SILT, medium plasticity.	PP= 1000 psf (H & V)
					clean with tube – u-x					0.8' Dark gray and brown ORGANIC SILT and Plant Fibers, low plasticity	(38.3')
		u	x	38.3	Shelby Tube Push 20"					0.6' Whitish gray MF(+) SAND, trace Silt. 0.5' Greenish gray ORGANIC SILT, trace Plant Fibers, medium plasticity.	(38.9') (39.4')
40'		U	1	40.0	Rec 20"		Save 13"			0.6' Dark Brown PLANT FIBERS and Organic Silt, low plasticity.	(40.3')
		S	9	40.0 41.5	5	16	23	1.2'	39	0.3' Same 0.9' Dark brown to brown MF SAND, some Silt, trace Organic Silt, trace F Gravel, slightly plastic.	(42.0')
45'		S	10	43.5 45.0	5	12	32	1.2'	44	0.6' Dark brown ORGANIC SILT, some Plant Fibers, medium plasticity 0.1' Gray CF SAND, some Silt 0.3' Gray SILTY CLAY. 0.2' Gray CF SAND, trace MF Gravel little Silt.	~~PP= 450 psf (H)~~ PP= 2000 psf (H), 3000 psf (V)

PRELIMINARY

SHEET 2 OF 4

PARSONS BRINCKERHOFF - FG, INC.
BORING LOG

BORING NUMBER B-61

PROJECT ATLANTIC CITY APPROACH ROADWAYS

LOCATION ATLANTIC COUNTY, NEW JERSEY

INSPECTOR J. J. Hartman

DEPTH	BLOWS ON CASING	SAMPLES TYPE	SAMPLES NO.	SAMPLES DEPTH	SOILS 0-6 / ROCK RUN	SOILS 6-12 / ROCK REC	SOILS 12-18 / ROCK 4"+	SOILS REC / ROCK %R	SOILS N / ROCK RQD	SAMPLE DESCRIPTION	DRILLING NOTES
50		S	11	48.8/50.3	10	22	54	1.5'	76	Gray CF SAND, little F Gravel trace Silt.	
55		S	12	54.1/55.6	36	36	56	1.0'	92	Whitish gray MF SAND, trace to little Silt.	
60'		S	13	58.5/60.0	31	63	78	0.8'	141	Gray to brownish gray MF SAND, little Silt.	
					bailed	40"	plug				
65'		S	14	63.9/65.4	22	28	50	1.4'	78	Brownish gray to gray CF SAND, trace MF Gravel, trace Silt.	Gravel subrounded
					bailed	48"	plug.				
70'		S	15	68.5/70.0	13	19	24	1.0	43	Brown MF SAND, trace(+) Silt.	
					washed	60"	plug				
75'		S	16.	73.5/75.0	11	14	24		38	Same.	

SHEET 3 OF 4

P SONS BRINCKERHOFF – FG C.

BORING LOG

PROJECT ATLANTIC CITY APPROACH ROADWAYS
BORING NUMBER B-61
LOCATION ATLANTIC COUNTY, NEW JERSEY
INSPECTOR J. J. Hartman

DEPTH	BLOWS ON CASING	SAMPLES TYPE	SAMPLES NO.	SAMPLES DEPTH	SOILS 0-6 / ROCK RUN	SOILS 6-12 / ROCK REC	SOILS 12-18 / ROCK 4"+	SOILS REC / ROCK %R	SOILS N / ROCK RQD	SAMPLE DESCRIPTION	DRILLING NOTES
										— — — — —	— — (76.0')
					washed		48"	plug			
80'		S	17	78.5 80.0	9	11	16	1.3'	27	Varves (1/8" to 1/4") Orangish brown F SAND some Clayey Silt / Gray SILT & CLAY; low to medium plasticity.	PP = 3500psf H PP = 4500 psf V
										— — — — —	— — (82.0')
		S	18	83.5 85.0	35	56	49	1.3'	105	Orangish brown to brown CM(+)F SAND, trace Silt.	(85.0')
										Bottom of hole - 85.0 ft	

SHEET 4 OF 4

PARS[illegible]S BRINCKERHOFF - FG, [illegible]

BORING LOG

BORING NO. B-71
CONTRACT NO. 3

PROJECT ATLANTIC CITY APPROACH ROADWAYS
OCATION ATLANTIC COUNTY, NEW JERSEY
LIENT NEW JERSEY DEPT. OF TRANSPORTATION
CONTRACTOR LIPPINCOTT ENGINEERING ASSOCIATES
RILLER Wm Shinn INSPECTOR J J Hartman
QUIPMENT Diedrich D-50 Truck Mt.

GROUND ELEVATION 6.6
STATION 227+95± OFFSET 35R+/-
DRILLING START TIME 9:42 DATE 8/5/86
DRILLING FINISH TIME 4:10 DATE 8/5/86

CONTRACT QUANTITIES

TEM	2.5" land boring	3.5" land boring	3.5" water boring	tube samples	denison samples	gw obs well	addnl. s.p.t.
UNIT	lf	lf	lf	ea	ea	lf	ea
TY	0	71.5	0	2	0	0	0

GROUNDWATER OBSERVATIONS

DATE	TIME	DEPTH	REMARKS
8/5/86	4:45	5'6"	35 mins, b.o.h. 71.5 ft

SAMPLERS

DISTURBED

S SPLIT SPOON
O.D. 2"
I.D. 1 3/8"
I.L. 24"
HAMMER 140#
DROP 30"

R RING-LINED SAMPLER
O.D. –
I.D. –
I.L. –
HAMMER –
DROP –

UNDISTURBED

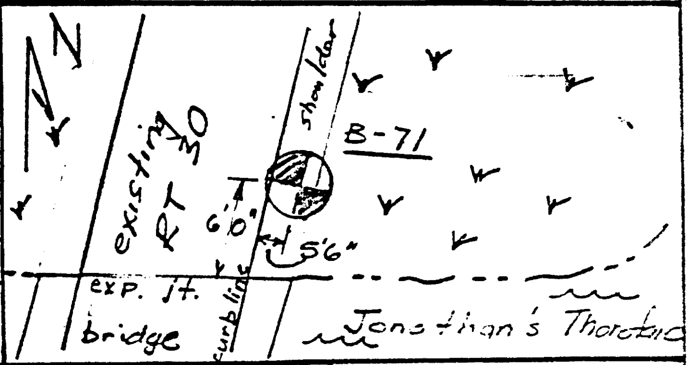
T THIN-WALL TUBE (shelby or piston)
O.D. 3"
I.D. 2 7/8"
I.L. 30"

D DENISON OR PITCHER
O.D. –
I.D. –
I.L. –

C CORE BARREL
I.D. – LEN. –
TYPE –

PURPOSE: Bridge 155-Jonathan's Thorofare

LOCATION SKETCH



DRILLING METHOD

HOLLOW STEM AUGER
I.D. 3 1/4"
PC. LEN. 62 1/4"
BIT LEN. 5 1/2"

MUD STABILIZED ROTARY
BIT O.D.
BIT LEN.
MUD

DRIVE OR SPIN CASING
I.D.
BIT LEN.
WT/DROP

DOUBLE WALLED DRIVE PIPE
I.D.
O.D.
HAMMER

DEPTH	BLOWS ON CASING	SAMPLES TYPE	SAMPLES NO.	SAMPLES DEPTH		SOILS 0-6 / ROCK RUN	SOILS 6-12 / ROCK REC	SOILS 12-18 / ROCK 4"+	SOILS REC / ROCK %R	SOILS N / ROCK RQD	SAMPLE DESCRIPTION	DRILLING NOTES
						auger	12	"			10" bituminous paving	
		S	1	1'	2'	3	10	×	1.0	20	18" Brown CF SAND and MF GRAVEL	
		S	2	2'		10	12	8	1.5	20	Brown CF SAND, some MF Gravel	Gravel
					4'	8						
5		S	3	4'		3	3	3	1.5	6	Same	Fill 0' to 10'
					6'	4						
		S	4	6'		3	2	3	1.3'	5	Brown and gray CF SAND, some MF Gravel.	Extra SPT's, 24" drives at contractors option S-2 thru S-5.
					8'	3						
		S	5	8'		3	5	2	1.2'	7	Gray CF SAND, little Silt, trace Clay, little MF Gravel	Traces of Black Organic Silt In Spoon tip, S-5 (10'6")
10					10'	1						
		S	6	11'		W	O	H	1.5	0	Dark gray Organic SILT, med plastic	PP = 300 psf H&V
					11'6"							U-X by Shelby Tube
		U	X	13'		P	US	H	2.0'		Same	U-X no recovery.
15					15	RE	C		0			Obtained representive Same with spoon-saved jar

SHEET 1 OF 3

PA[illegible]ONS BRINCKERHOFF – FG, [illegible]

BORING LOG

BORING NUMBER B-71

PROJECT ATLANTIC CITY APPROACH ROADWAYS

LOCATION ATLANTIC COUNTY, NEW JERSEY **INSPECTOR** J. J. Hartman

DEPTH	BLOWS ON CASING	SAMPLES TYPE	SAMPLES NO.	SAMPLES DEPTH	SOILS 0-6 / ROCK RUN	SOILS 6-12 / ROCK REC	SOILS 12-18 / ROCK 4"+	SOILS REC / ROCK %R	SOILS N / ROCK RQD	SAMPLE DESCRIPTION	DRILLING NOTES
		U	1	15' 17'	PUSH REC			2.0' 2.0		Dark gray organic SILT, med plastic, trace plant fibers	Traces gray F Sand in bottom 1" of T-1.
		S	7	17' 1'0" 18'6"	WOH			1.7	0	10" Gray MF SAND, some clayey Silt, 10" Gray ORGANIC SILT, fibrous, medium plastic, H2S Odor	T-1 by Sta. Piston pp= 250psf H&V
20		S	8	18'6" 1'4" 20'	WOH		2	0.8'	2	Same, little shell fragments	pp= 150 psf H&V
		U	2	22'6" 1'1" 24'6"	PUSH			2.0		Same, trace brown fibers, trace shell fragments	pp= 450 psf V T-2 by Sta. Piston
25		S	9	24'6" 26'	WOH	1	1	1.3	2	6" Same 10" Brown fibrous PEAT, Strong H2S Odor.	
30										4" Same ———	——— (30'4")
		S	10	30' 32'	9	6	7	1.2	13	6" Gray MF SAND, trace Silt	
35		S	11	34'6" 36'	7	8	9	0.7	17	Gray F SAND, little Silt	
										———	——— (38')
40		S	12	39'6" 41	2	4	3	0.8	7	Green, CLAY and SILT, little F Sand, trace Shells, trace black mottling	pp= 3000psf H&V
45											

SHEET 2 OF 3

BORING LOG

PROJECT ATLANTIC CITY APPROACH ROADWAYS

BORING NUMBER B-71

LOCATION ATLANTIC COUNTY, NEW JERSEY

INSPECTOR J. J. Hartman

DEPTH	BLOWS ON CASING	SAMPLES			SOILS					SAMPLE DESCRIPTION	DRILLING NOTES
					0-6	6-12	12-18	REC	N		
					ROCK						
		TYPE	NO.	DEPTH	RUN	REC	4"+	%R	RQD		
		S	13	44'6" 46'	3	3	4	1.3'	7	Green CLAY and SILT, trace black mottling, ~~[illegible]~~	pp= 2500 psf H&V (47')
											10 min water refill delay 2:50-3:00pm, 8/5/86 @ 44'6", 200 gals.
50'				49'6"	bailed	12"	plug				
		S	14	51'	8	22	42	1.0'	64	Gray and brown CF SAND, little F Gravel	S-14 Gravel subr to subang quar
55'				54'6"	bailed	12"	plug				
		S	15	56	15	23	28		46	Same.	
60'				59'6"	bailed	6"	plug				
		S	16	61	15	16	14	1.0'	30	Brown MF SAND, trace Silt.	trace reddish brown streaks, trace white clay, S-16.
65'											
		S	X	65'6" 67	8	11	16	0	27	no recovery	finger retainer striped of 14 of 16 fingers — no recovery S-X. Replaced retainer. Check valve ok.
										(69')	
70											FC SAND, little FM Gravel in spoon tip, S-17
		S	17	70 71'6"	12	9	11	1.3	20	Gray CLAY & SILT ~~plastic~~	pp = 4000 psf
										bottom of hole - 71'6"	

SHEET 3 OF 3

3/29/84	2.	ADDITION OF OVERHEAD SIGN BORING LOCATIONS
3/8/84	1.	REVISED STRUCTURE BORING LOCATIONS
DATE.	NO.	REVISIONS

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

STATE OF NEW JERSEY
DEPARTMENT OF TRANSPORTATION
SOIL BORINGS
ROUTES 30&87 **SECTION**

CITY OF ATLANTIC CITY COUNTY OF ATLANTIC

SCALE: 1"= 200' PLATE 2
CONTRACT BORINGS

LOG of BORING No. 0-1

DATE 4/17/84 SURFACE ELEVATION 7.3 LOCATION

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0		41	Bituminous Pavement (4") Concrete (8")	6.1				
		19	Very dense brown and black medium to fine sand, trace gravel	4.3				
10		4 1	Very dense, becoming loose gray silty fine sand, slight sulfur odor	-0.7				
		33	Very soft dark brown silty clay with plant matter; sulfur odor	-3.7				
		27	Very dense gray silty fine sand	-10.7				
20		WOH WOH	Very soft dark gray fine sandy silty clay	-23.2				
30		13 6	Medium dense dark gray silty fine sand, becoming loose dark gray medium to fine sand	-31.7				
40		105 8	Very dense light gray medium to fine sand, trace coarse sand	-38.7				
50		100/6"	Firm dark gray silty clay, trace fine sand	-39.7				
60 70		93 113 102 161	Very dense gray medium to fine sand, trace coarse sand and gravel	-64.2				
80								

Completion Depth 71.5 Feet Water Depth N/A Feet Date 4/17/84

Project Name Marina District Highway Improvements Project Number 84C2056

Woodward-Clyde Consultants

Absecon Inlet - Storm Surge Barrier

See "Boring Locations" Plan from "Route 87 Section 1-B, Huron Ave. to East Side Absecon Inlet" for Existing Boring Locations provided through NJ GDMS

New Jersey
State Highway Department

PLAN

Route 87 Section 1-B
Huron Ave. to East Side Absecon Inlet
Cities of Atlantic City & Brigantine Atlantic County
BORING LOCATIONS
Scale 1" = 50' November 9, 1966

2/2

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NEW JERSEY STATE HIGHWAY DEPARTMENT
Bureau of Soils

Sheet 1 of 2

TEST BORING DATA

TEST HOLE NO. 28

Route: 87 Section 1-B Local Name: Absecon Inlet

Station: 80+00 Offset: 25 Rt. Reference Line: Proposed BL Rt. 87 Ground Line Elevation: +7.7'

Borings made by: Sprague & Henwood Date Started: 5-2-67 El. G.W.T. +6.1 Date: 5-4-67

Inspector: Winkler Date Completed: 5-3-67 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No. Depth			Blows on Spoon			Rec.	Sample Identification and Profile Change	
					0/6	6/12	12/18			
	4	S-1	0.0	1.5	3	4	6	14"	Brown CF SAND, t. (-) Organic Silt, ?PI, l. (-) MF Gravel. (Fill from existing road.)	
	13									
	9									
	7									
5	9									
	17	S-2	5.0	6.5	4	6	9	15"	Same	
	10									
	10									
	8									8.0
10	9	S-3	9.0	10.5	1	1	1	18"	Brown PEAT, l. Organic Silt, ?PI, trace MF Gravel	
	10									
	11									
	12									
	12									13.0
15	17	S-4	14.0	15.5	8	7	7	5"	Gray F SAND, trace (-) Organic Silt? PI, t. (-) Shells.	
	15									
	16									
	12									
	13									
20	23	S-5	19.0	20.5	4	4	6	6"	Gray F SAND, trace Organic Silt, ? PI	
	20									
	22									
	19									
	21									
25	16	S-6	24.0	25.5	3	6	5	12"	Gray F SAND, t. Organic Silt,: PI, trace (-) Shells.	
	16									
	19									
	18									
	15									
30	23	S-7	29.0	30.5	7	8	11	18"	Gray MF SAND, t. (-) Organic Silt, ? PI, t. (-) Shells.	
	31									
	27									
	22									
	20	S-8	33.0	34.5	1	3	3	6"	Gray MF SAND, t. (+) Organic Silt, ? PI, t. (-) Shells.	
35	36									
	42									
	49									
	43									
	35	S-9	38.0	39.5	5	10	10	12"	Greyish Brown CF SAND, t. Organic Silt, ? PI, Little MF Gravel.	
40	36									

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300 lbs
" " " " Spoon	140 lbs
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

The information contained on this log is not warranted to show the actual subsurface condition. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey State Highway Dept.
Soils Bureau

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NEW JERSEY STATE HIGHWAY DEPARTMENT
Bureau of Soils

Sheet 2 of 2

TEST BORING DATA

TEST HOLE NO. 28

Route: 87
Section 1-B
Local Name: Absecon Inlet
Station: 80+00
Offset: 25 Rt.
Reference Line: Proposed BL Rt. 87
Ground Line Elevation: +7.7'
Borings made by: Sprague & Henwood
Date Started: 5-2-67
El. G.W.T. +6.1'
Date: 5-4-67
Inspector: Winkler
Date Completed: 5-3-67
El. G.W.T. (Auger):
Date:

Depth in Feet	Casing Blows	Sample No. Depth			Blows on Spoon			Rec.	Sample Identification and Profile Change	
					0/6	6/12	12/18			
	37									
	29									
	28									
	19	S-10	43.0	44.5	4	5	5	11"	Grayish Brown CM+F SAND, t.(-)Silt,t. (+) MF Gravel	
5	32									
	36									
	54									
	45	S-11	47.0	48.5	7	12	15	12"	Light Gray MF SAND, trace (-) Silt, t. (-) F Gravel	
	42									
10	37									
	41									
	41									
	52	S-12	52.0	53.5	3	4	12	13"	Light Gray CF SAND, t. Silt, t. (+) MF Gravel.	
	115									
15	108									
	103									
	112									
	65	S-13	57.0	58.5	12	34	52	8"	Light Gray MF SAND, trace Silt, t. (-) MF Gravel	
	91									
20	125									
	224									
	343									
		S-14	62.0	63.5	110	205		10"	Light Gray CF SAND, trace (-) Silt, t. F Gravel	63.0
									BOTTOM OF HOLE	
25										
30										
35										
40										

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300 lbs
" " " " Spoon	140 lbs
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill
Core Diameter

The information contained on this log is not warranted to show the actual subsurface condition. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey State Highway Dept.
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NEW JERSEY STATE HIGHWAY DEPARTMENT
Bureau of Soils

Sheet 1 of 2

TEST BORING DATA

TEST HOLE NO. 29

Route: 87 Section 1-B Local Name: Absecon Inlet

Station: 82+00 Offset: 10 Rt. Reference Line:

Ground Line Elevation: +9.3'

Borings made by: Sprague & Henwood Date Started: 5-4-67 El. G.W.T. Date: 5-5-67

Inspector: Winkler Date Completed: 5-5-67 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No. Depth			Blows on Spoon 0/6	6/12	12/18	Rec.	Sample Identification and Profile Change	
	0	S-1	0.0	1.0	3	5		12"	Brown CF SAND, t. Organic Silt?PI,t.(-)F Gravel, (-) Fibe	1.0'
	0								Concrete from Existing Road	1.66
	18	S-2	2.0	3.5	10	19	15	10"	Brown CF Sand, and CF Gravel, trace Organic Silt?PI, (fill from existing road)	
	23									
5	20									
	16	S-3	5.0	6.5	8	8	12	7"	Gray and Brown CF SAND, t. Organic Silt ?PI, l. (+) CF Gravel (fill from existing road)	
	19									
	20									
	12									8.0
10	10	S-4	9.0	10.5	1	1	1	18"	Brown PEAT, l. Organic Silt,?PI, t. (-) MF Sand.	
	12									
	15									
	17									
	19									
15	8	S-5	14.0	15.5	1	1	1	18"	Gray Organic SILT, M PI	14.0
	18									
	31									16.0
	28									
	16									
20	11	S-6	19.0	20.5	8	4	3	7"	Gray F SAND, t. Organic Silt, ?PI, t. (-) Shells.	
	14									
	22									
	21									
	17									
25	13	S-7	24.0	25.5	4	3	7	18"	Gray F SAND, trace (-) Organic Silt,?PI,t. (-) Shells.	
	22									
	26									
	26									
	18									
30	15	S-8	29.0	39.5	4	11	13	12"	Same	
	31									
	32									
	32									
	28									
35	21	S-9A	34.0	35.0	2	1		12"	Gray MF SAND, trace (-) Organic Silt?PI,t. (-) Shells.	
	31	S-9B	35.0	35.5			1	12"	Gray Organic SILT, M+PI, trace (+) Fibers	35.0
	36									
	36									
	33									38.0
40	30	S-10	39.0	40.5	8	12	24	17"	Brown CM+F SAND, t. (-) Organic Silt ? PI, trace (-) Fine Gravel	

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300 lbs
" " " " Spoon	140 lbs
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

The information contained on this log is not warranted to show the actual subsurface condition. The Contractor agrees that he will make no claims against the State if he finds that the actual conditions do not conform to those indicated by this log.

New Jersey State Highway Dept.
Soils Bureau

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NEW JERSEY STATE HIGHWAY DEPARTMENT
Bureau of Soils

Sheet 2 of 2

TEST BORING DATA

TEST HOLE NO. 29

Route: 87 Section 1-B Local Name: Absecon Inlet

Station: 82+00 Offset: 10 Rt. Reference Line: Proposed BL Rt. 87 Ground Line Elevation: +9.3'

Borings made by: Sprague & Henwood Date Started: 5-4-67 El. G.W.T. Date: 5-5-67

Inspector: Winkler Date Completed: 5-5-67 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No.	Depth		Blows on Spoon 0/6	6/12	12/18	Rec.	Sample Identification and Profile Change	
	44									
	58									
	59									
	52									
5	52	S-11	44.0	45.5	7	12	15	12"	Light Gray CF SAND, trace (-) Organic Silt? PI, little (-) MF Gravel	
	56									
	50									
	47									
	47									
10	50	S-12	49.0	50.5	6	13	13	10"	Light Gray CF SAND, trace (-) Organic Silt? PI, trace (-) F Gravel	
	51									
	55									
	59									
	46	S-13	53.0	54.5	8	13	18	18"	Gray CF SAND, trace (-) Organic Silt, trace (-) F Gravel	
15	66									
	81									
	95									
	56	S-14	57.0	58.5	15	10	29	6"	Light Gray CF SAND, trace Silt, little F Gravel (2-1/8" layers Silt in sample)	
	89									
20	186									
	213									
		S-15	61.0	62.5	95	50	53	4"	Light Gray CF SAND, trace (-) Silt, trace (+) F Gravel	
										62.5
25									BOTTOM OF HOLE	
30										
35										
40										

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300 lbs
" " " " Spoon	140 lbs
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

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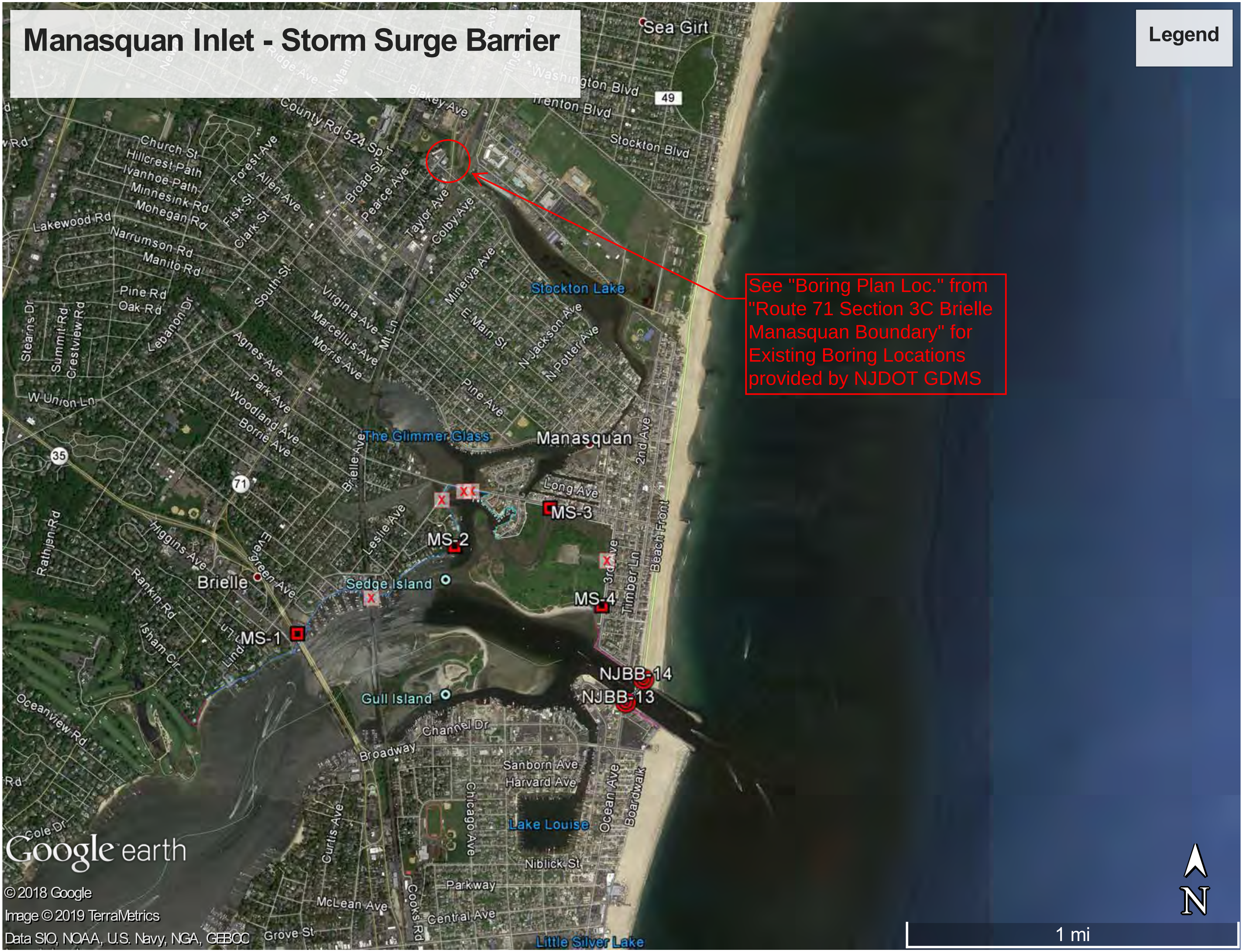
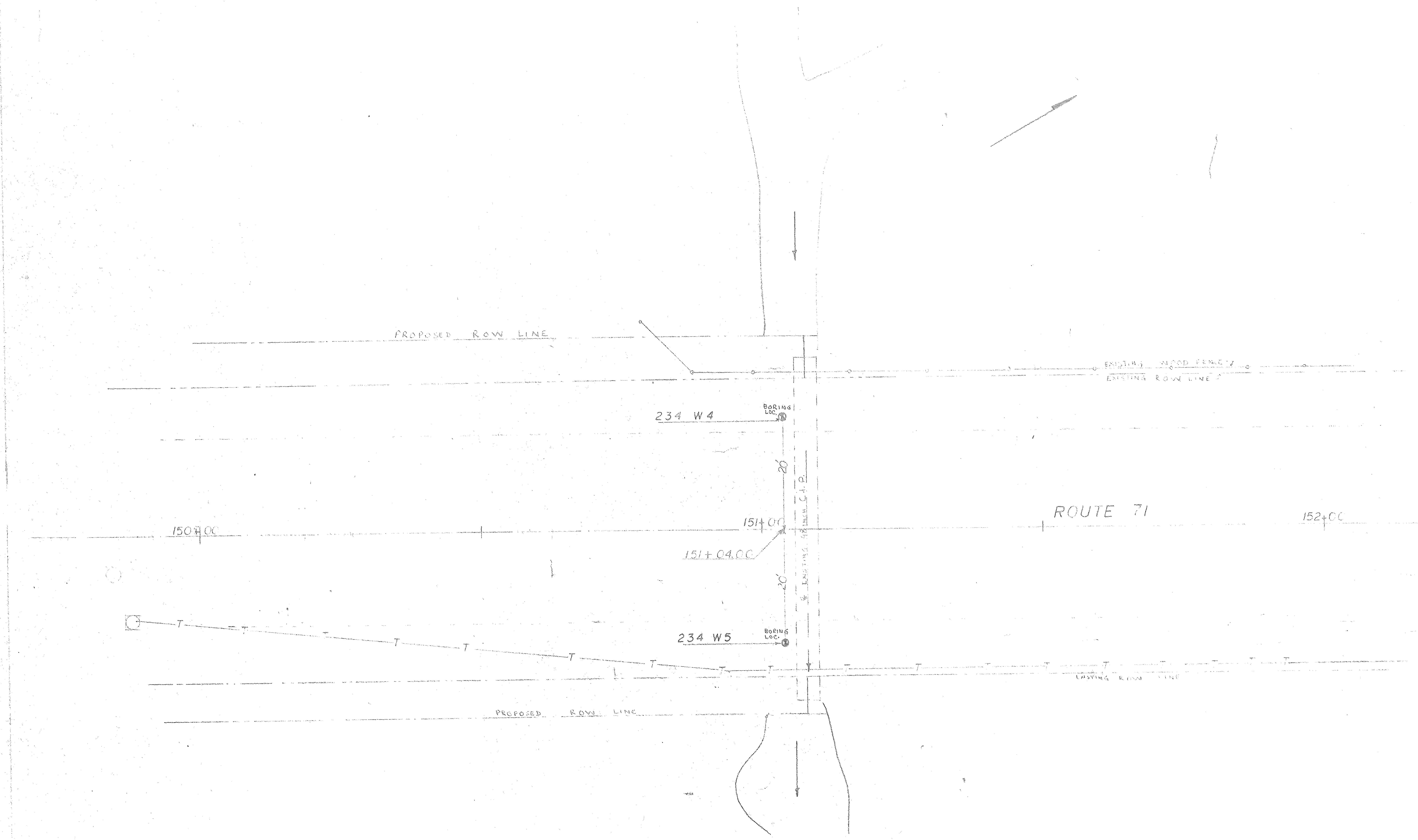
New Jersey State Highway Dept.
Soils Bureau

Manasquan Inlet - Storm Surge Barrier





BORING REQUEST		
BORING NO	STATION	OFFSET
234 W4	151+04.00	20' RIGHT
234 W5	151+04.00	20' LEFT

Approx. bottom Ftg El. -4.0

ROUT 71 SECTION 3C
BRIELLE MANASQUAN BOUNDARY
CONTROL SECTION 1320

BORING PLAN LOC.

SCALE 1" = 10'

WIDENING & RESURFACING OFROM
UNION LANE TO THE BOUNDARY OF
BRIELLE_MANASQUAN, BOROUGHOF
BRIELLE, MONMOUTH COUNTY
BRIDGE CULVERT DESIGN

Form SO-2
Rev. 6/27/68

NEW JERSEY DEPARTMENT OF TRANSPORTATION

Bureau of Soils

Sheet #1 of 1

Route: 71 Local Name: Culvert TEST HOLE NO. 234W-4

Section: Rt. 35 Brielle to Rt. 35 So. Belmar.

Station: 151+04 Offset: 20'Rt. Reference Line: CL Proposed Rt. 71. Ground Line Elevation: +8.0'

Borings made by: Patykula Date Started: 1-7-69 El. G.W.T. +7.0' (UNCASED) Date: 1-10-69

Inspector: Mahaney & Winkler Date Completed: 1-9-69 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No. Depth			Blows on Spoon			Rec.	Sample Identification and Profile Change	
					0/6	6/12	12/18			
	8									
	5	S-1	0.0	1.5	20	13	5	9"	Brown CF SAND, little Silt, little MF Gravel.	
	4									
	2									
5	1									
	1									
	4									
	50	S-2	7.0	8.5	6	3	2	12"	Dark Brown CF Sand, and CF Gravel, trace (+) Silt.	
	53									
10	59									
	73									
	113								Light Gray MF SAND, trace (-) Silt, trace (-)	
	37	S-3	12.0	13.5	38	64	188	9"	MF Gravel.	
	80	S-4	13.5	15.0	37	39	53	8"	Brown MF SAND, trace Silt, trace (-) F Gravel.	
15	252									
	375									
	601									
	149									
	297									
20	130									
	190									
	130	S-5	21.0	22.5	59	48	27	6"	Gray & Brown F SAND, trace (+) Silt, trace (-) F Gravel. (One ¼" layer Dark Gray Silt & Clay.)	
	102									
	198									
25	86									
	116									
	150									
	99									28.0
	86	S-6	28.0	29.5	7	11	10	18"	Dark Gray CLAY & SILT. (Few 1/8-¼" layers Gray F Sand.)	
30	101									
	108									
	153									
	213									
	175									
35	136									
		S-7	35.0	36.5	11	41	48	18"	Gray CF SAND, little Silt, some MF Gravel.	36.5
									BOTTOM OF HOLE	
40										

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300#
" " " " Spoon	140#
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

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NEW JERSEY DEPT. OF TRANS.
Soils Bureau

Form SO-2
Rev. 6/27/68

NEW JERSEY DEPARTMENT OF TRANSPORTATION

Bureau of Soils

Sheet #1 of 2

Route: 71 Local Name: Culvert TEST HOLE NO. 234W-5

Section: Rt. #35 Brielle to Rt. 35 So. Belmar.

Station: 151+04 Offset: 20'Lt. Reference Line: CL Proposed Rt.71. Ground Line Elevation: +8.0'

Borings made by: Patykula Date Started: 1-2-69 El. G.W.T. +5.0' (UNCASED) Date: 1-8-69

Inspector: Mahaney-Winkler Date Completed: 1-7-69 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No.	Depth		Blows on Spoon 0/6	6/12	12/18	Rec.	Sample Identification and Profile Change	
	20	S-1	0.0	1.5	9	7	5	18"	Brown CF SAND, and MF Gravel, little Silt,	
	10								trace (-) Fibers.	
	6									
	2									
5	2									
	5									
	6									
	25	S-2	7.0	8.5	1	1	1	18"	Brown CF SAND, little Silt, little (+) MF Gravel.	
	40									
10	55									
	91									
	94	S-3	12.0	13.5	6	21	15	18"	Orange Brown CM + F SAND, trace Silt.	
	21									
	66	S-4	13.5	15.0	18	34	56	18"	Orange Brown MF SAND, trace Silt.	
15	97									
	135									
	187									
	165									
	140									
20	103									
	69									21.0
	101	S-5	21.0	22.5	24	40	76	12"	Dark Gray SILT & CLAY.	
	92									
	81									
25	90									
	73									
	82									
	66									
	161	S-6	28.0	29.5	28	13	15	18"	Dark Gray Silty CLAY.	
30	100									30.0
	321									
	264									
	219									
	178									
35	93									
	152	S-7	35.0	36.5	19	24	26	18"	Gray F SAND, trace (+) Silt. (Few ¼" layers Gray	
	128								Silty CLAY.)	
	178									
	156									
40	148									

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300 LB.
" " " " Spoon	140 LB.
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

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NEW JERSEY DEPT. OF TRANS.
Soils Bureau

Form SO-2
Rev. 6/27/68

NEW JERSEY DEPARTMENT OF TRANSPORTATION

Bureau of Soils

Sheet #2 of 2

Route: 71 Local Name: Culvert TEST HOLE NO. 234W-5

Section: Rt. 35 Brielle to Rt. 35 So. Belmar.

Station: 151+04 Offset: 20'Lt. Reference Line: CL Proposed Rt. 71 Ground Line Elevation: +8.0'

Borings made by: Patykula Date Started: 1-2-69 El. G.W.T. +5.0' (UNCASED) Date: 1-8-69

Inspector: Mahaney-Winkler Date Completed: 1-7-69 El. G.W.T. (Auger): Date:

Depth in Feet	Casing Blows	Sample No. Depth			Blows on Spoon 0/6	6/12	12/18	Rec.	Sample Identification and Profile Change	
	115									
	104									
	84	S-8	42.0	43.5	19	31	41	15"	Gray F SAND, little Silt.	
	78									
45	115									
	141									
	103									
	109									
	136									
50 10		S-9	49.0	50.5	26	52	101	16"	Dark Gray & Brown F SAND, some (+) Silt.	50.5
									BOTTOM OF HOLE	
15										
20										
25										
30										
35										
40										

Inside Dia. of Casing	2½"
" " " Spoon	1½"
Weight of Hammer on Casing	300#
" " " " Spoon	140#
Drop of Hammer on Casing	24"
" " " " Spoon	30"

Type of Core Drill

Core Diameter

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NEW JERSEY DEPT. OF TRANS.
Soils Bureau

B-7) USACE ERDC Draft Report “Storm Surge Comparison for Proposed New Jersey Back Bays Inlet Closures”

Draft Report – February 27, 2019

Storm Surge Comparison for Proposed New Jersey Back Bays Inlet Closures

Gregory Slusarczyk, Mary A. Cialone, Norberto C. Nadal-Caraballo, and Robert W. Hampson

US Army Corps of Engineers
Engineer Research & Development Center
Coastal & Hydraulics Lab
3909 Halls Ferry Road
Vicksburg, MS 39180

Abstract

The U.S. Army Corps of Engineers (USACE) Philadelphia District (NAP) and the New Jersey Department of Environmental Protection (NJDEP) are currently engaged in the New Jersey Back Bays (NJBB) Coastal Storm Risk Management CSRM Feasibility Study. The USACE Engineer Research and Development Center (ERDC), Coastal and Hydraulics Lab (CHL) conducted a numerical modeling study to evaluate the effectiveness of storm surge barriers in reducing water levels in the NJBBs. The numerical modeling study included the computation of water levels and a comparison of water surface elevations between existing conditions and six final project alternatives. Results from that numerical study are presented herein.

Section 1.1-- Background

The U.S. Army Corps of Engineers (USACE) Philadelphia District (NAP) and the non-federal sponsor, New Jersey Department of Environmental Protection (NJDEP), are currently engaged in the New Jersey Back Bays (NJBB) Coastal Storm Risk Management CSRM Feasibility Study. The NJBB study area is one of nine focus areas identified in the North Atlantic Coast Comprehensive Study (NACCS) for additional analyses by USACE to address coastal flood risk.

The North Atlantic Coast Comprehensive Study (NACCS) was authorized under the Disaster Relief Appropriations Act, PL 113-2, in response to Hurricane Sandy. The Act provided the USACE up to $20 Million to conduct a study with the goal to (1) reduce flood risk to vulnerable coastal populations, and (2) promote resilient coastal communities to ensure a sustainable and robust coastal landscape system, considering future sea level change and climate change scenarios.

As part of the NACCS, the US Army Engineer Research and Development Center (ERDC) completed a coastal storm wave and water level modeling effort for the U.S. North Atlantic Coast. This modeling study provides nearshore wind, wave, and water level estimates and the associated marginal and joint probabilities critical for effective coastal storm risk management. This modeling effort involved the application of a suite of high-fidelity numerical models within the Coastal Storm Modeling System (CSTORM-MS) to 1050 synthetic tropical storms and 100 historical extra-tropical storms. Documentation of the numerical modeling effort is provided in Cialone et al. 2015 and documentation of the statistical evaluation is proved in Nadal Caraballo et al. 2015. Products of the study are available for viewing and download on the Coastal Hazards System (CHS) website: https://chs.erdc.dren.mil/.

The NJBB study area, Figure 1, extends along 110 miles of the New Jersey and encompasses 950 square miles of land, wetlands, open water, and coastal lakes across parts of five counties and 90 municipalities. There are approximately 235,000 structures and a permanent population of about 700,000 within the study area. Twelve inlets provide hydraulic connections between the Atlantic Ocean and the back bays, making all of the back bays susceptible to flooding from the ocean. During coastal storms, elevated ocean water levels propagate through the inlets into the back bays, causing flood damage proportional to the geographic extent, duration, and height of the ocean storm surge. Hurricane Sandy in 2012 demonstrated that in addition to the coastal flood risk posed to public and private infrastructure, there is a significant life-safety risk posed by coastal storms and the flooding that they cause.

The objective of the NJBB CSRM Study is to investigate CSRM problems and solutions to reduce damages from coastal flooding that affects population, critical infrastructure, critical facilities, property, and ecosystems. CSRM measures under consideration include Non Structural, Structural, and Natural and Nature Based Features (NNBF). One Structural measure under consideration are inlet closures, constructed at one or more inlets in the study area. Due to the complex network of inlets and bays that control the flow of water between the ocean and back bays, NAP requested assistance from ERDC-CHL in evaluating the effectiveness of inlet closures in reducing water levels in the NJBB study area. More specifically, NAP wanted help determining how much inlet closures reduce back-bay flooding? How effective inlet closures are at reducing water levels if other inlets are open and if multiple inlet closures could work as system? To answer these questions ERDC-CHL leveraged the existing NACCS CSTORM-MS.

Figure 1: NJBB Study Area.

Section 1.2 – Project Objectives

The objective of this numerical modeling study is to evaluate the effectiveness of inlet closures in reducing water levels in the NJBB study area. An iterative modeling approach was devised that would allow a large number of inlet closures and potential inlet closure combinations to be considered before converging on a smaller final set of inlet closure alternatives.

The iterative modeling approach begins with model simulations of one inlet closure at a time to improve understanding of the hydraulic influence of each inlet. The second iteration evaluated a large number of possible inlet closure combinations, before moving on to the 3rd iteration of a smaller final set of alternatives. Model simulations for the final set of alternatives is used to develop frequency distributions of peak water levels that may be applied in economic analyses of flood damages and benefits.

- Iteration 1: Model the hydraulic influence of each barrier island inlet by modeling one inlet at a time.
- Iteration 2: Model the effectiveness of large set of possible inlet closure combinations.
- Iteration 3: Model the effectives of final set of inlet closure alternatives and develop frequency distributions of peak water levels.

The iterative modeling approach is made feasible by utilizing a very small subset of 10 extreme cyclones for Iterations 1 and 2. A more robust set of 60 tropical cyclones was selected for Iteration 3 in order to develop the frequency distributions.

To achieve the project objectives the NACCS Coastal Storm Modeling System will be applied with modifications to ADCRIC mesh, ADCIRC bathymetry, and storm suite as presented herein.

Section 2 -- Storm Selections

The New Jersey Back Bays (NJBB) feasibility study sought the evaluation of the with-project alternatives discussed in Section 3. The NJBB study made use of existing still water level (SWL) data from the North Atlantic Coast Comprehensive Study (NACCS) (Nadal-Caraballo et al. 2015; Cialone et al. 2015). ERDC-CHL's probabilistic coastal hazard analysis (PCHA) framework for the North Atlantic region requires the simulation of both TC and XC storm sets in order to estimate TC, XC, and combined cyclones (CCs) hazard curves. The NACCS full storm suite (FSS) consists of 1,050 synthetic tropical cyclones (TCs) and 100 historical extratropical cyclones (XCs).

The process of reconstructing FSS SWL hazard curves for NJBB began with the selection of reduced storm sets (RSS) using design of experiments (DoE) approach. For initial phase of the NJBB study, two RSS of 10 and 60 TCs, respectively, were identified. The 10-TC RSS was used in sensitivity analyses for initial screening of with-project alternatives (iteration 1 and 2). For iteration 3 alternatives, storm surge-only ADCIRC simulations of the 60-TC RSS were performed. A key component in the reconstruction of hazard curves is the use of surrogate modeling or metamodeling techniques (e.g., Jia and Taflanidis 2013; Kim et al. 2015) for the estimation of the FSS with-project water levels. More specifically, this study relied of the use of a Gaussian process metamodel (GPM) trained with results derived from the 60-TC RSS.

The methodology for the reconstruction of NJBB hazard curves at each save point is summarized as follows:

1. Tropical cyclone (TC) storm surge hazard curves
    1.1 Since NJBB simulations of the 60-TC RSS were storm surge-only, in order to estimate and add wave setup, fit linear regression model to NACCS storm surge results with waves (Y) and without waves (X).
    1.2 Add wave setup to NJBB storm surge results through linear correction.
    1.3 Compute the ratio of NJBB storm surge to NACCS storm surge.
    1.4 Train and validate a GPM using the NJBB to NACCS storm surge ratios.
    1.5 Use GPM results to estimate the NJBB to NACCS storm surge ratios for the remaining of FSS (i.e., 1050 TCs – 60 TCs = 990 TCs).
    1.6 Compute TC storm surge hazard curves using PCHA.
2. Extratropical cyclone (XC) storm surge hazard curves
    2.1 Fit a linear regression model to establish the relationship between NJBB TC storm surge (Y) and NACCS (X) TC storm surge; this will provide an estimate of surge attenuation or amplification (Y) as a function of initial surge (X), at each NJBB save point.
    2.2 Use linear correction to estimate the XC storm surge for NJBB from previous NACCS results for 70 XCs.
    2.3 Compute XC storm surge hazard curves using PCHA.
3. Combined cyclone (CC) storm surge hazard curves – use the TC and XC hazard curves developed in steps 1 and 2, respectively, to compute CC storm surge hazard curves.

In this chapter, examples of the results are presented for five NJBB save points. The IDs and coordinates of these save points are given in Table 1; their location is illustrated in Figure 2.

Table 1: IDs and coordinates for select NJBB save points.

NJBB Save Point	NACCS Save Point	Lat (deg N)	Lon (deg W)	Depth (m, MSL)
36	11276	39.3698	74.4076	5.84
2	5380	39.3806	74.419	5.08
57	11360	39.3912	74.4302	4.98
50	11316	39.4103	74.4746	0.66
29	11249	39.4246	74.4857	-0.5

Figure 2: Location of five select NJBB save points.

Section 2.1 -- Selection of Reduced Storm Sets

For the initial phase of the New Jersey Back Bays (NJBB) feasibility study, two RSS of 10 and 60 TCs, respectively, were sought. The storm selection process was performed using the design of experiments (DoE) approach described in details in Taflanidis et al. (2017, 2018). The number of storms to be sampled was dictated by budget and/or schedule constraints. Then, the goal of storm selection, as implemented in this study, was to find the optimal combination of storms given a predetermined number of storms to be sampled (e.g., 60 TCs). In other words: out of a 1050-TC FSS, which storms should be sampled to constitute the 60-TC RSS?

The DoE compares the storm surge or SWL hazard curves derived from the RSS to "benchmark" hazards curves corresponding to the FSS at a given number of save points. The difference between the RSS hazard curves and FSS benchmark curves is minimized by initially finding an optimal small subset of TCs (e.g., 10) and then iteratively adding additional TCs (e.g., 10 by 10, as needed). The locations (or save points) where the hazard curve optimization will take place must be provided by the user. The number of required save points typically ranges from 50 to 200.

In summary, the general steps in this DoE approach for selection a subset of storms are:

1. Identify a set of save points critical to project or study area, where optimization will be performed.
2. Develop hazard curves for the FSS.
3. Select number of storms to be sampled.
4. Develop hazard curves for the RSS.
5. Choose the range of probabilities for which hazard curves will be compared. Differences can be computed along the entire hazard curves, or prioritizing a specific segment of the curves, e.g., 50 to 500 years.
6. Compute errors between RSS and FSS hazard curves.
7. An iterative sensitivity analysis is performed to evaluate the benefits of increasing storm subset size.
8. Once an appropriate number of storms is met, e.g. 60, another optimization is performed to compare RSS chosen interactively (10 by 10) vs. RSS of 60 TCs sampled at once; finalize storms selection.

The selected storms (60-TC RSS) were simulated in ADCIRC and results were used to reconstruct hazard curves for NJBB without- and with-project conditions.

Section 2.2.1 -- Reconstruction of Water Lever Hazard Curves for Base (Without-Project) Condition

The 60-TC RSS was used to estimate the storm surge hazard for different NJBB alternatives based on results from the 1,050 TCs and 100 XCs in the original NACCS FSS. The processes for developing the TC and XC hazard curves are discussed in Section 2.2.2 -- Tropical Cyclones and Section 2.2.3 -- Extratropical Cyclones.

Section 2.2.2 -- Tropical Cyclones

Since the hydrodynamic simulations of the 60 TCs selected for NJBB were surge-only and did not include waves or wave setup, the first step in the hazard curve reconstruction was to estimate the wave setup at the 180 NJBB save points by first comparing NACCS storm surges with and without wave setup. These are shown in Figure 3 and Figure 4 for save points 36 and 29, respectively.

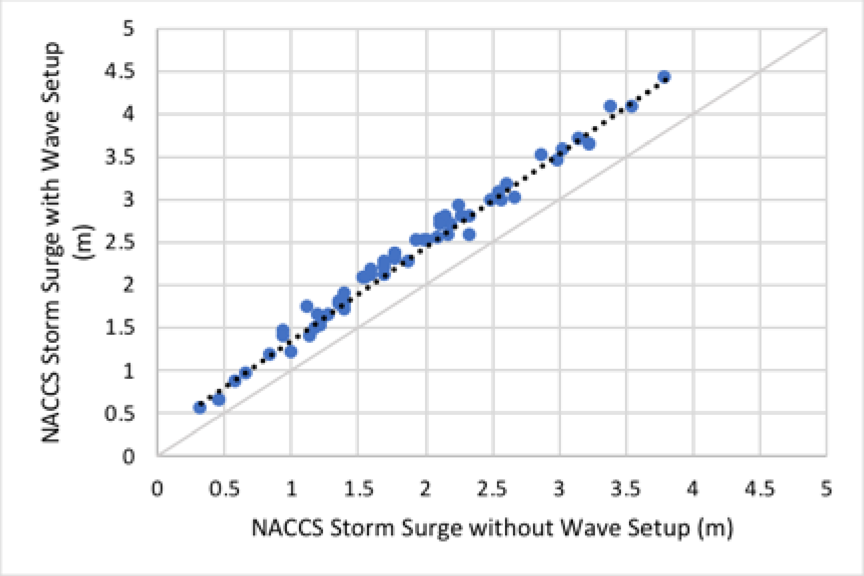


Figure 3: TC storm surge with and without wave setup for NJBB SP 36 (base condition).

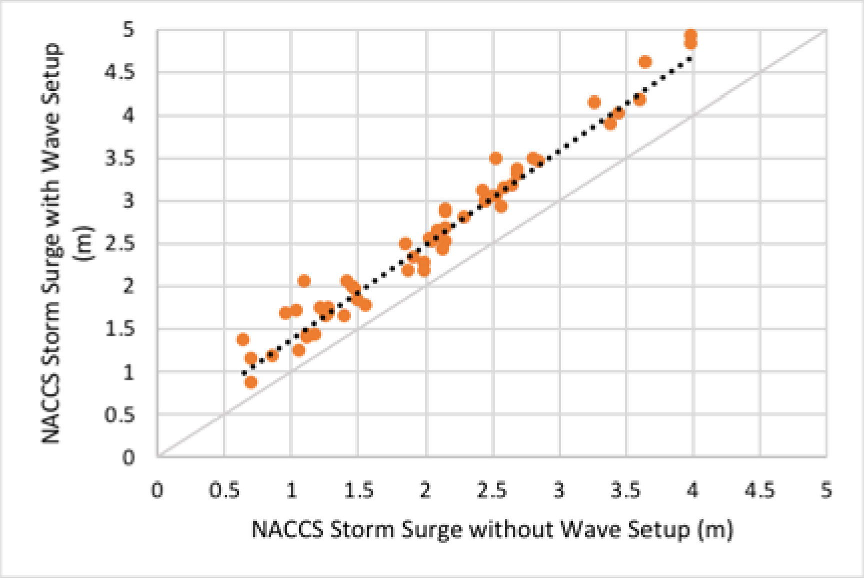


Figure 4: TC storm surge with and without wave setup for NJBB SP 29 (base condition).

As seen from Figure 3 and Figure 4, the storm surge with wave setup plotted as a function of surge without setup follows a linear trend. Therefore, wave setup was implicitly estimated at each NJBB save point by comparing NACCS FSS storm surge results with and without wave set up, and fitting a linear regression model of the form:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

Where: Y = NACCS storm surge with wave setup (dependent variable); X = NACCS storm surge without wave setup (independent variable); β_0= intercept; β_1= slope; and ε = aleatory error.

The linear regression coefficients and coefficients of determination, R2, a goodness-of-fit metric, are presented in Table 2.

Table 2: Linear regression coefficients for TC wave-setup correction (base condition).

NJBB Save Point	β_0 (m)	β_1	R^2
36	0.2659	1.0856	0.9853
2	0.1821	1.1644	0.9745
57	0.0957	1.2363	0.9725
50	0.2135	1.1511	0.9727
29	0.2534	1.1104	0.9653

The linear regressions are then used to correct the NJBB simulation results by adding wave setup to the surge-only values. In this phase of the study, the aleatory error (ε) component was not accounted for in the wave-setup correction process. The NJBB storm surge results including wave setup are presented in Figure 5 and Figure 6 for save points 36 and 29.

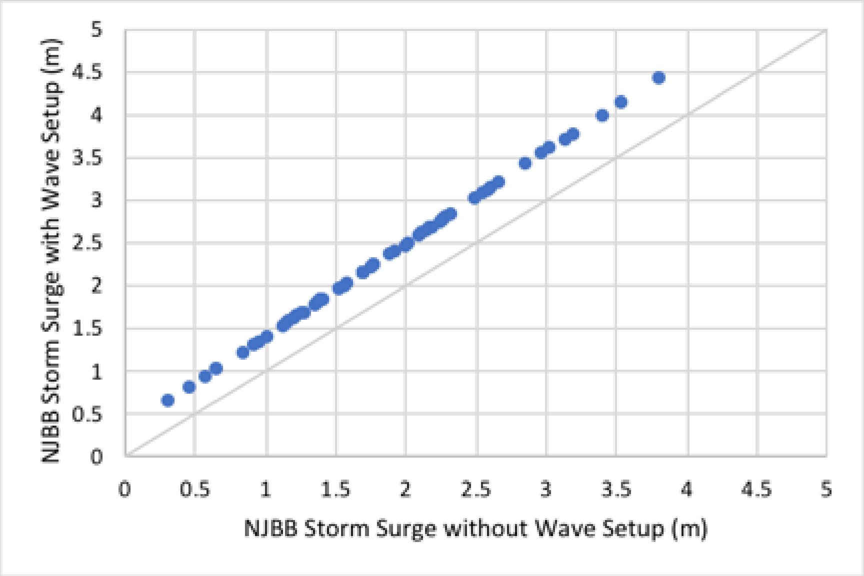


Figure 5: TC wave setup correction for NJBB SP 36 (base condition).

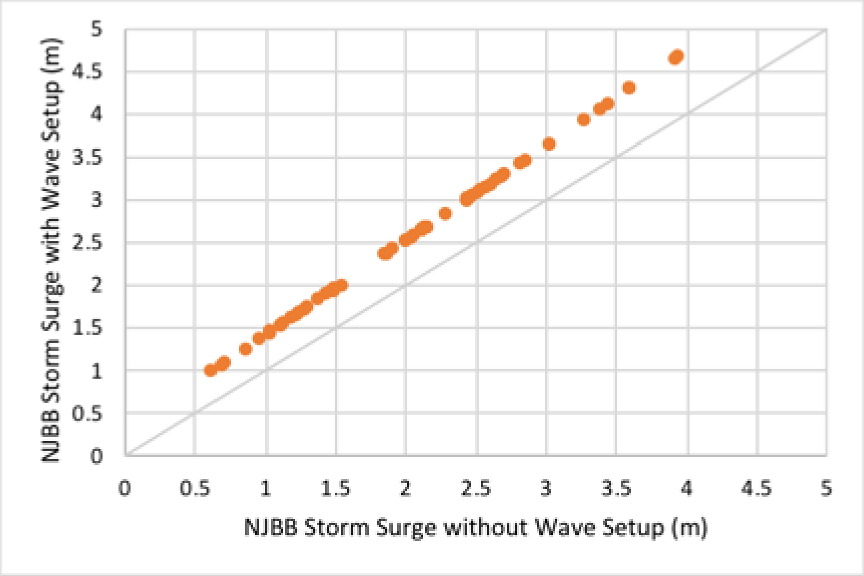


Figure 6: TC wave setup correction for NJBB SP 29 (base condition).

After correcting the NJBB simulations by adding wave setup, the next step is to compute the NJBB storm surge to NACCS storm surge ratios for the 60-TC RSS (plotted in Figure 7 and Figure 8). As observed in these figures, there is a nonlinear relationship between the NJBB to NACCS storm surge ratios (Y) and the NACCS storm surge (X). Therefore, instead of fitting linear regression models, the storm surge ratios are used to train the GPM.

Training and validation of the GPM is discussed in details in Taflanidis et al. (2014); Jia et al. (2015); Taflanidis et al. (2017); and Zhang et al. (2018).

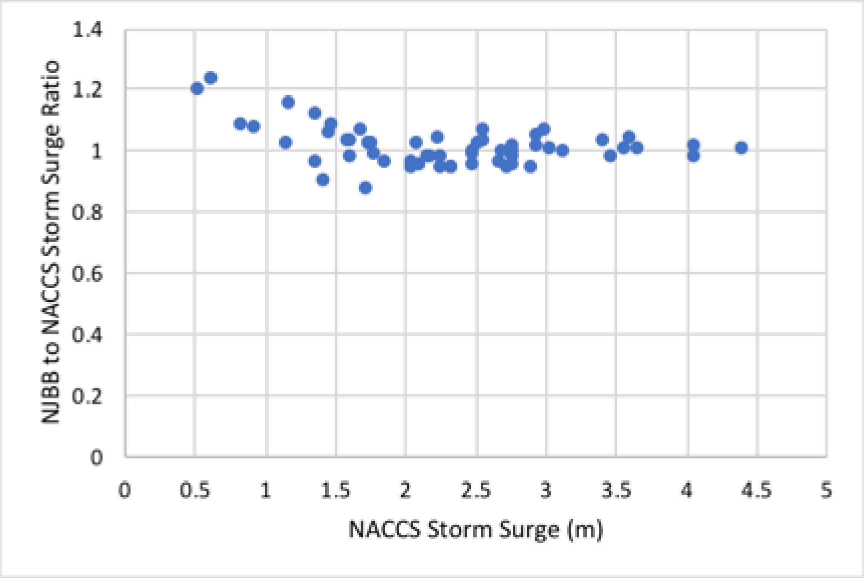


Figure 7: NJBB to NACCS TC storm surge ratios for SP 36 (base condition).

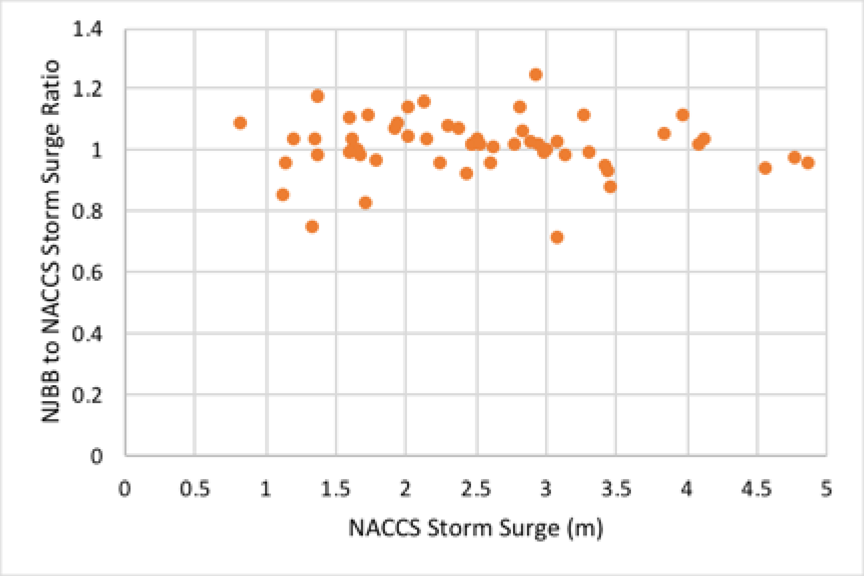
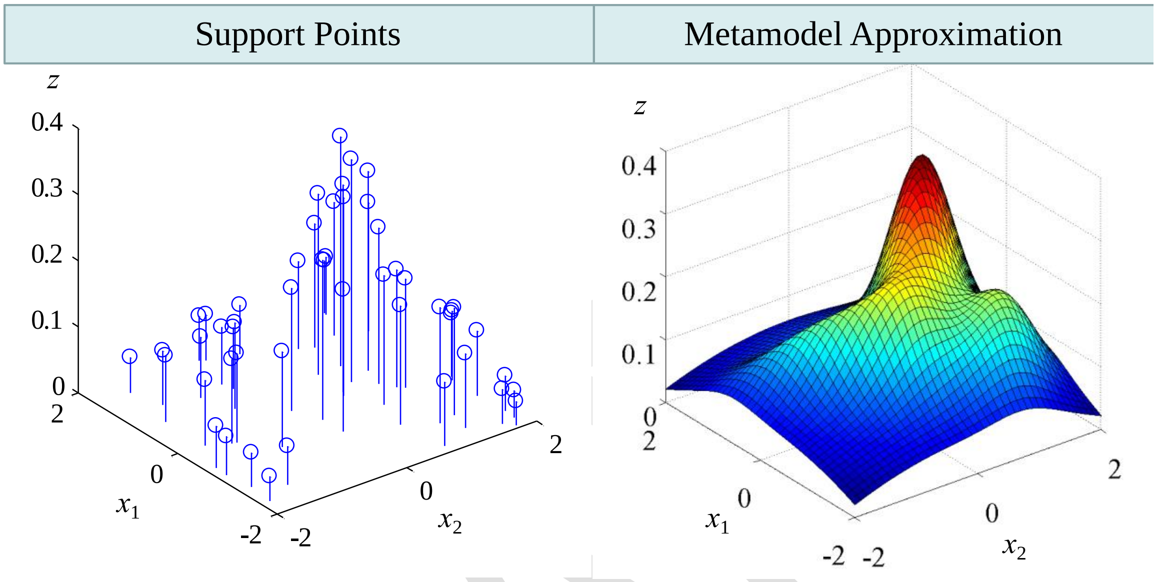


Figure 8: NJBB to NACCS TC storm surge ratios for SP 29 (base condition).

The GPM is a mathematical approximation for the input/output (x/z) relationship of a complex numerical model. It is formulated based on a database of simulations for complex process such as hurricane storm surge. This database is frequently referenced as experiments or support points. The basis for the metamodeling framework used in this study is the TC parameterization done as part of the Joint Probability Method (JPM) (Nadal-

Caraballo et al. 2015). The NACCS synthetic TCs were generated utilizing JPM and constitute the GPM input (x). The GPM output (z) are the storm surge simulation results.



Support Points

Metamodel Approximation

Figure 9: GPM input/output relationship.

Synthetic TCs are developed considering the historical climatology and characteristic storms of a specific region, and reflect likely combinations of storm intensity and size, track and landfalling location. Specifically, the input vector (x) is composed of:

- Landfalling or bypassing reference location, x_0
- Heading direction, θ
- Central pressure deficit, Δp
- Radius of maximum winds, R_m
- Forward speed, v_f

The validation metrics for the GPM employed in this study were: coefficient of determination (R2), mean absolute error (ME), and correlation coefficient (CC). Validation results for select NJBB save points and global validation values are given in Table 3.

Table 3: GPM validation for NJBB to NACCS TC storm surge ratios (base condition).

NJBB Save Point	R^2	ME (m)	CC
36	0.8781	0.0172	0.9606
2	0.9179	0.0135	0.9695
57	0.8952	0.0167	0.964
50	0.8943	0.023	0.9634
29	0.6712	0.103	0.9427
All	0.8781	0.0172	0.9606

The GPM validation metrics for all 180 NJBB save points are plotted in Figure 10. Once trained, the GPM are used to estimate the storm surge response. Storm surge hazard curves for TCs were developed as described in Nadal-Caraballo et al. (2015).

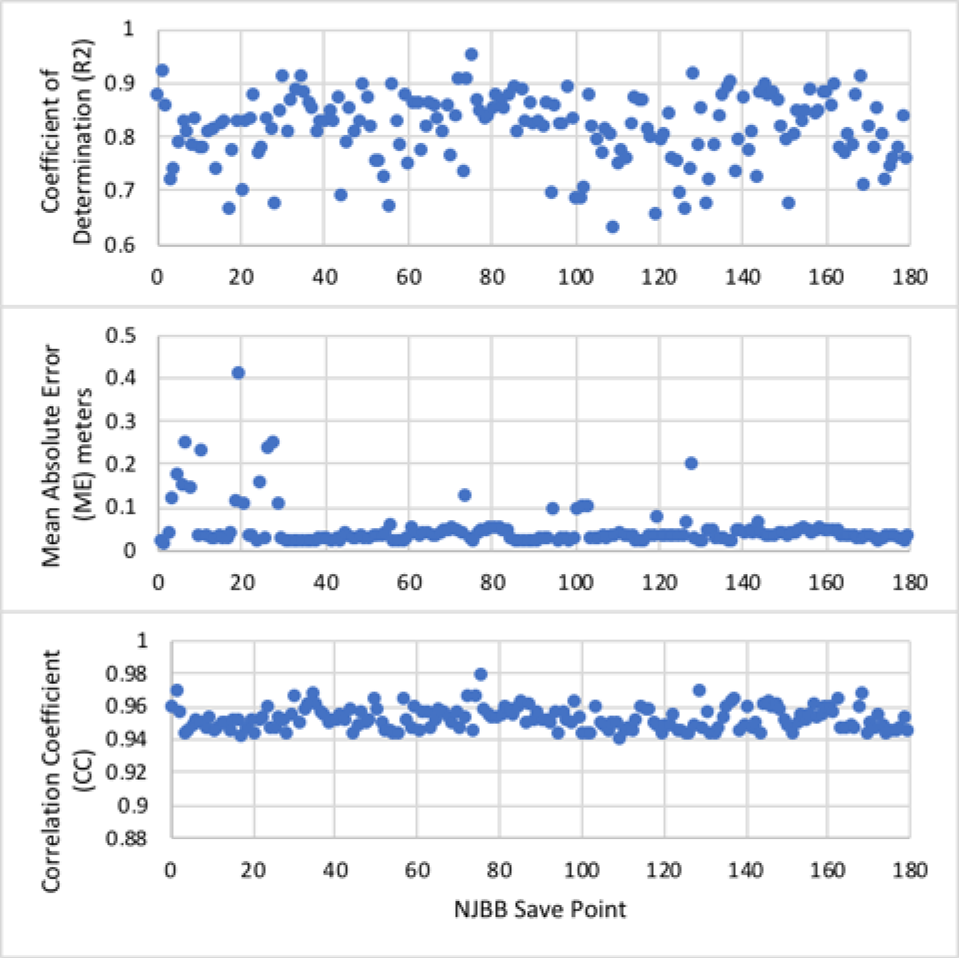


Figure 10: GPM validation metrics for TC storm surge at all NJBB save points (base condition).

Section 2.2.3 -- Extratropical Cyclones

The standard of practice for assessment of XC storm surge hazard does not require these storms to be parametrized. Without a parametrization scheme, training of a GPM is unfeasible. Therefore, a linear regression models is used to establish estimate the relationship between NJBB and NACCS storm surge, regardless of storm forcing. This allows the estimation of XC storm surge for NJBB from previous NACCS results for 100 XCs. The NJBB vs. NACCS storm surges at save points 36 and 29 are shown in Figure 11 and Figure 12, respectively. The coefficients and goodness-of-fit metrics for the linear regression models are presented in Table 4

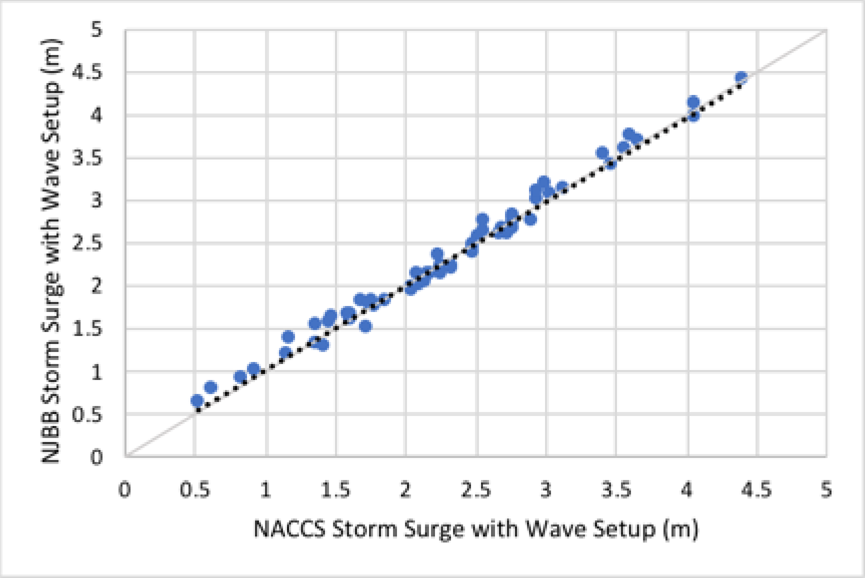


Figure 11: NJBB vs. NACCS TC storm surge for NJBB SP 36 (base condition).

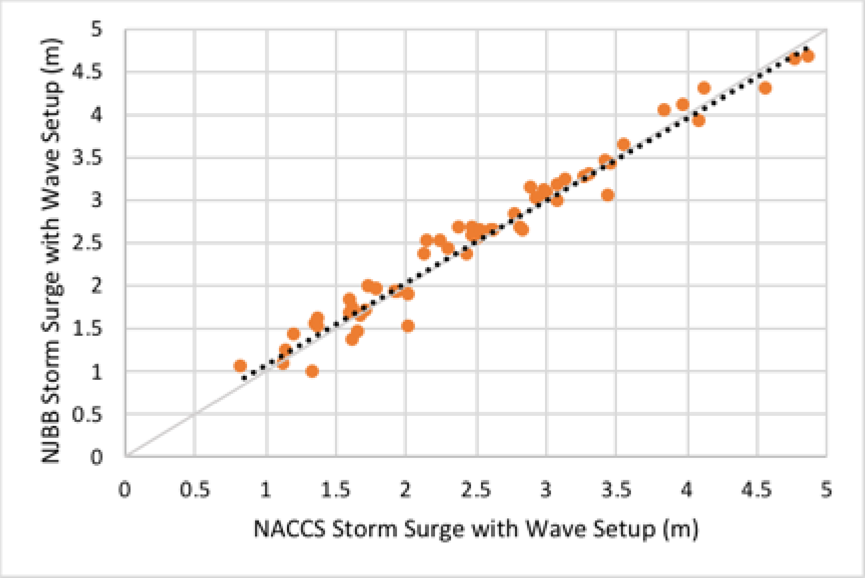


Figure 12: NJBB vs. NACCS TC storm surge for NJBB SP 29 (base condition).

Table 4: Linear regression coefficients for estimation of NJBB XC storm surge (base condition).

NJBB Save Point	β_0 (m)	β_1	R^2
36	0.0369	0.9828	0.9864
2	0.0987	0.9433	0.9782
57	0.0847	0.9555	0.9727
50	0.0815	0.9627	0.9705
29	0.1018	0.958	0.9647

The estimated NJBB XC storm surge, as a function of NACCS XC storm surge, are depicted in Figure 13 and Figure 14 for save points 36 and 29, respectively. Storm surge hazard curves for XCs and CC hazard curves were developed as described in Nadal-Caraballo et al. (2015).

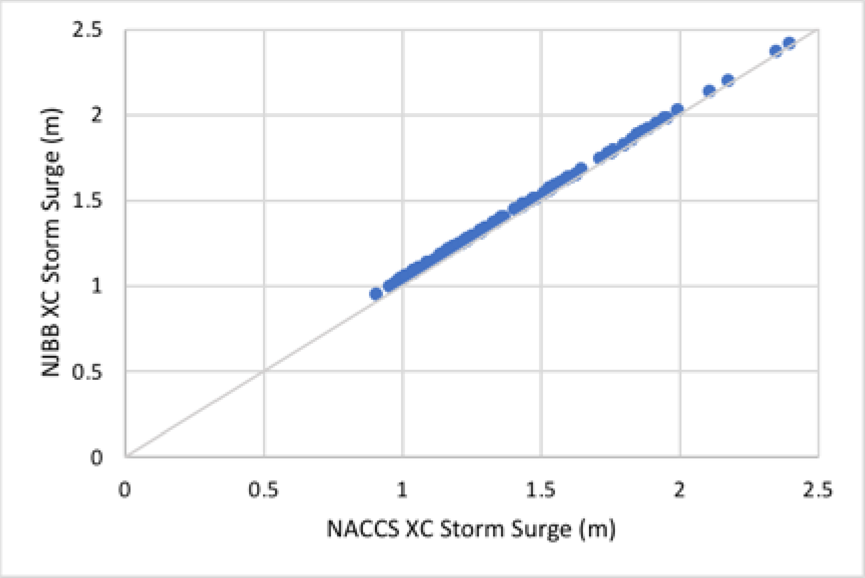


Figure 13: Estimated XC storm surge NJBB SP 36 (base condition).

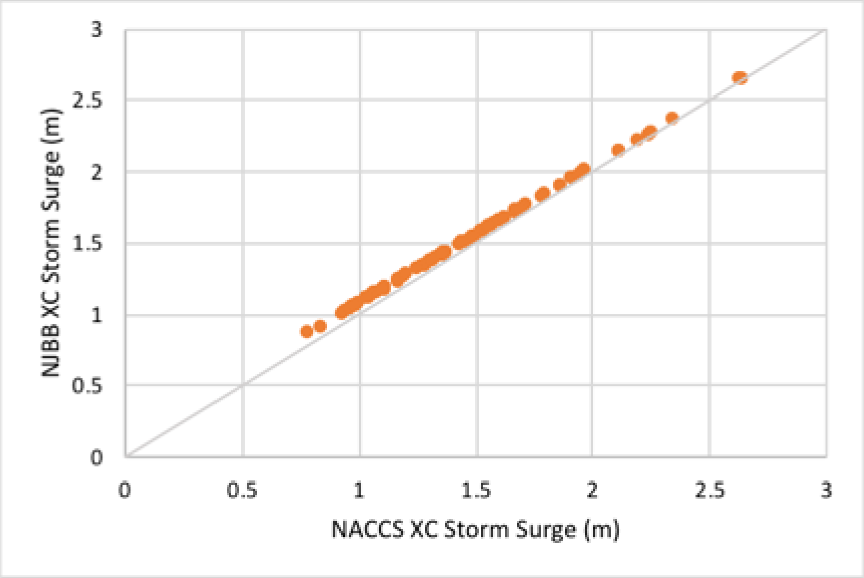


Figure 14: Estimated XC storm surge NJBB SP 29 (base condition)

Section 2.3 -- Estimation of Water Lever Hazard Curves for With-Project Alternatives

In this section the evaluation of with-project alternatives is discussed. Results for the All-Closed and All-Closed-Less-2 alternatives are presented as examples.

Section 2.3.1 -- Tropical Cyclones

Training the GPM and developing FSS hazard curves for with-project alternatives is similar to the process discussed in Section 2.2.2 -- Tropical Cyclones. First, NJBB storm surge is corrected by adding wave setup. Second, NJBB storm surge to NACCS storm surge ratios for the 60-TC RSS are computed. Third, the storm surge ratios are used to train the GPM. The ratios for the All-Closed alternative are depicted in Figure 15 and Figure 16 for NJBB save points 36 and 29.

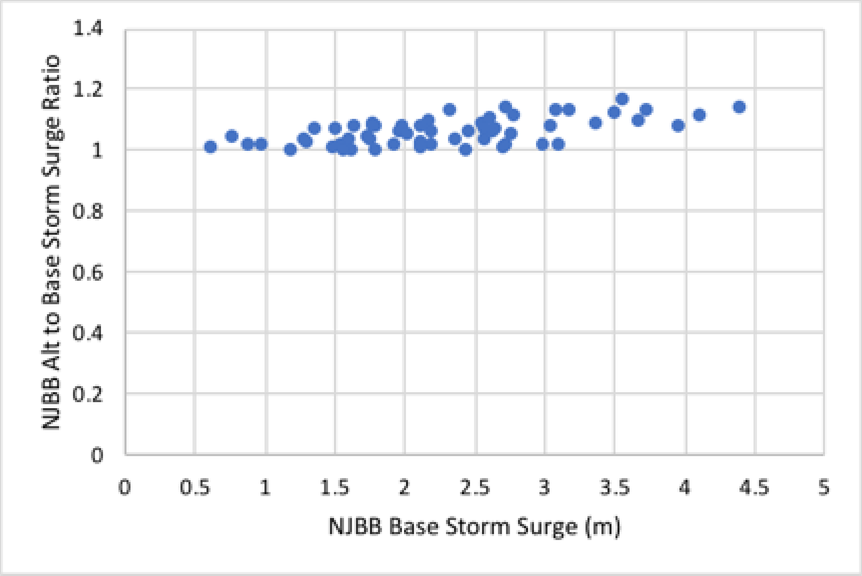


Figure 15: NJBB All-Closed to base condition storm surge ratios for SP 36.

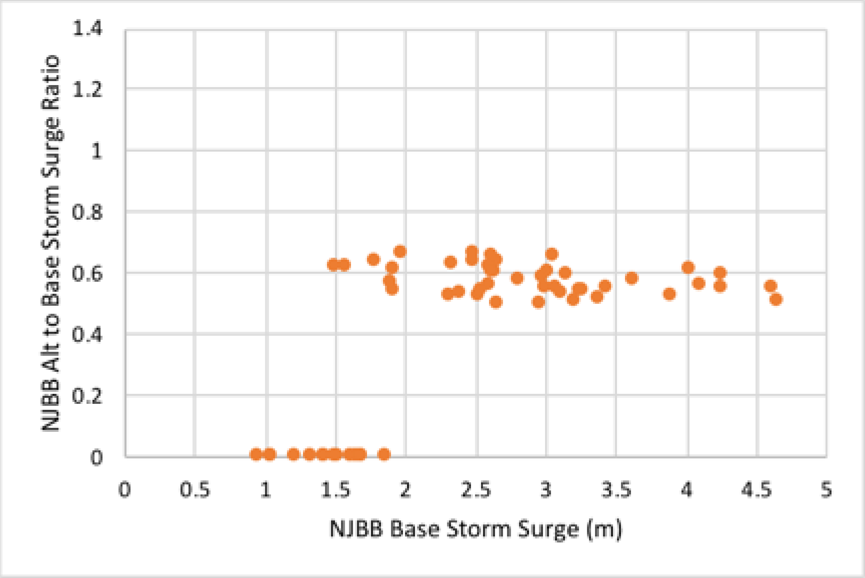


Figure 16: NJBB All-Closed to base condition TC storm surge ratios for SP 29.

The validation metrics (R2, ME, and CC) for the GPM trained for the All-Closed alternative are shown in Table 5 for select NJBB save points and global validation values are given in Table 6.

Table 5: GPM validation for All-Closed to base condition TC storm surge ratios.

NJBB Save Point	R^2	ME (m)	CC
36	0.8859	0.0053	0.9615
2	0.9691	0.0649	0.9872
57	0.9599	0.079	0.984
50	0.924	0.0326	0.9758
29	0.776	0.2095	0.9377
All	0.8652	0.1354	0.9582

The All-Closed GPM validation metrics for all 180 NJBB save points are plotted in Figure 17.

All-Closed storm surge hazard curves for TCs were developed as described in Nadal-Caraballo et al. (2015).

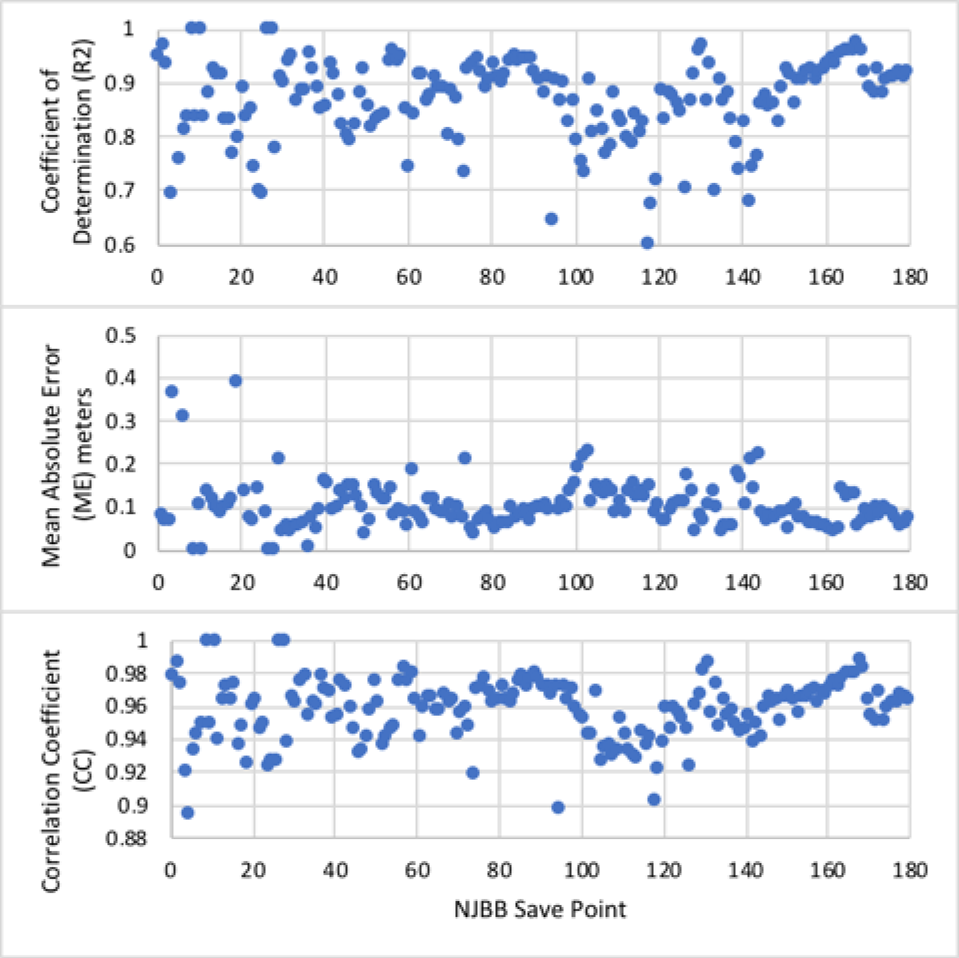


Figure 17: GPM validation metrics for TC storm surge at all NJBB save points (All-Closed).

NJBB storm surge to NACCS storm surge ratios for the All-Closed-Less-2 alternative are depicted in Figure 18 and Figure 19 for NJBB save points 36 and 29.

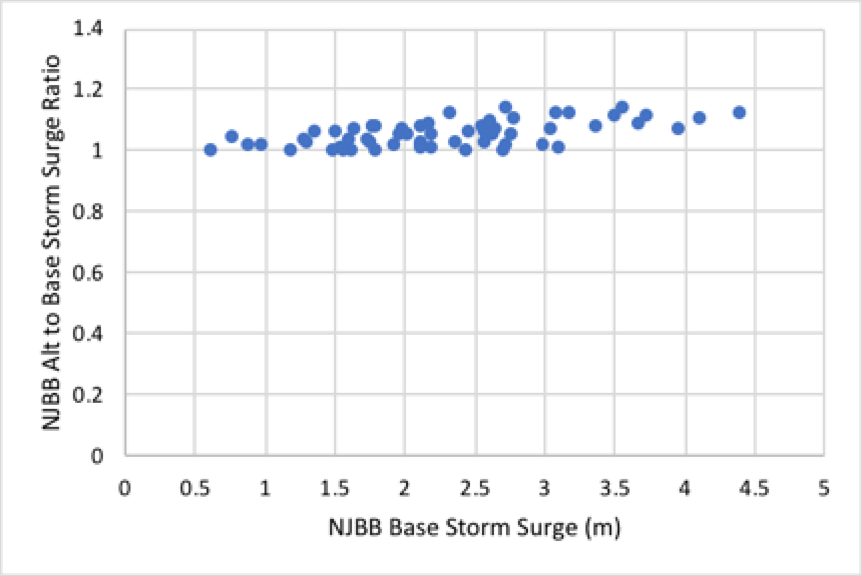


Figure 18: NJBB All-Closed-Less-2 to base condition storm surge ratios for SP 36.

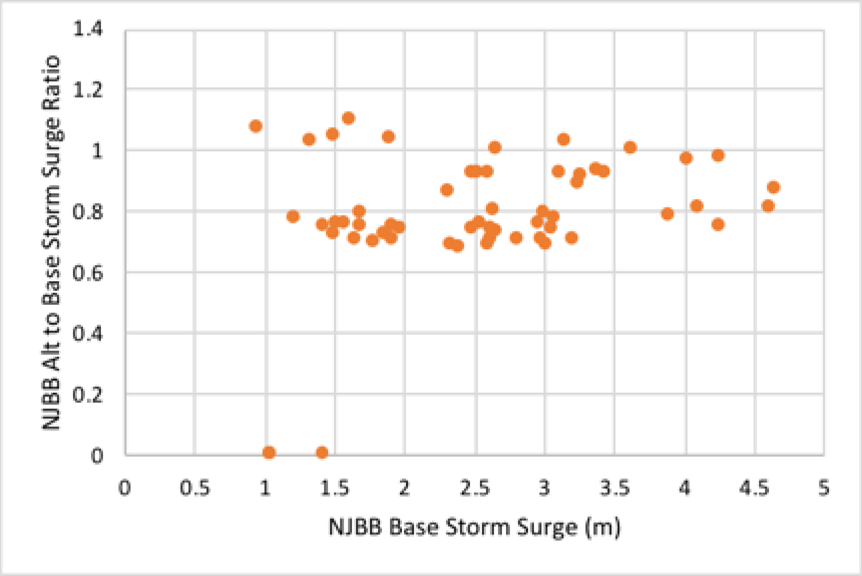


Figure 19: NJBB All-Closed-Less-2 to base condition storm surge ratios for SP 29.

The validation metrics (R2, ME, and CC) for the GPM trained for the All-Closed-Less-2 alternative are shown in Table 5 for select NJBB save points and global validation values are given in Table 6.

Table 6: GPM validation for All-Closed-Less-2 to base condition TC storm surge ratios.

NJBB Save Point	R^2	ME (m)	CC
36	0.8816	0.0052	0.9605
2	0.9653	0.0516	0.9847
57	0.9708	0.0467	0.9869
50	0.9352	0.0393	0.9746
29	0.7461	0.1375	0.9456
All	0.8622	0.0956	0.9596

The All-Closed-Less- 2GPM validation metrics for all 180 NJBB save points are plotted in Figure 20. All-Closed-Less-2 storm surge hazard curves for TCs were developed as described in Nadal-Caraballo et al. (2015).

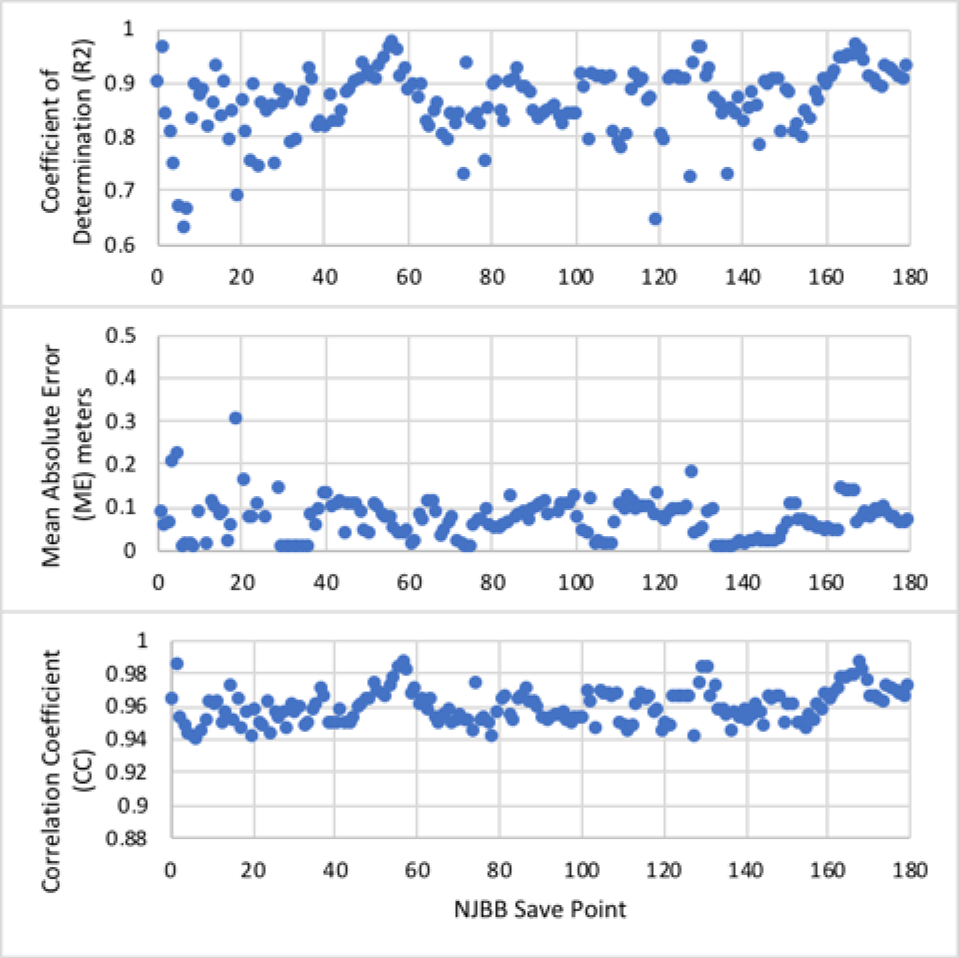


Figure 20: GPM validation metrics for TC storm surge at all NJBB save points (All-Closed-Less-2).

Section 2.3.2 -- Extratropical Cyclones

As discussed in Section 2.2.3 -- Extratropical Cyclones, there XCs are not parameterized. Thus, instead of utilizing the GPM, the reconstruction of XC storm surge hazard curve relies on a linear regression model to the relationship, first, between NJBB and NACCS storm surge for base condition and, subsequently, the relationship between NJBB with-project alternatives and base condition. This is an additional step not required when reconstructing the NJBB XC storm surge hazard curves for base condition.

The NJBB All-Closed storm surge vs. base condition storm surge are shown in Figure 21 and Figure 22 for save points 36 and 29, respectively. The coefficients and goodness-of-fit metrics for the linear regression models are presented in Table 7.

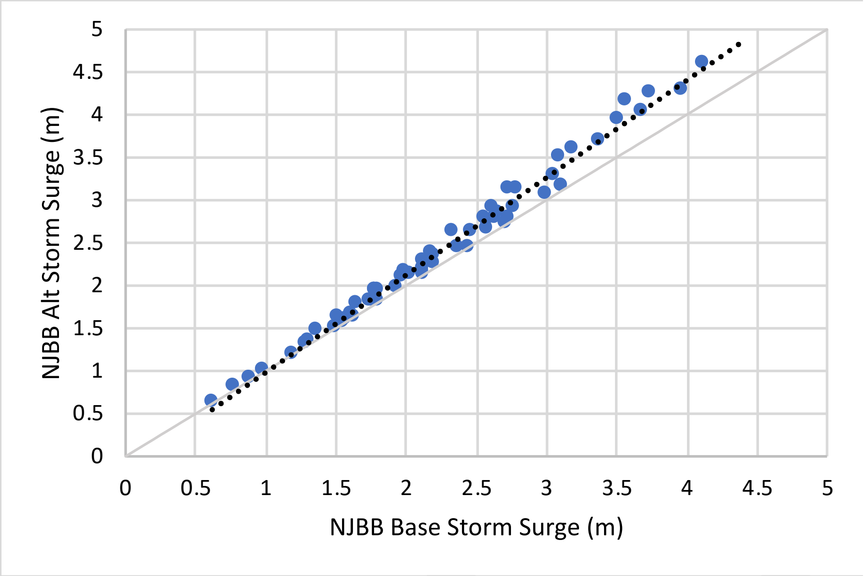


Figure 21: NJBB All-Closed vs. base condition storm surge for SP 36.

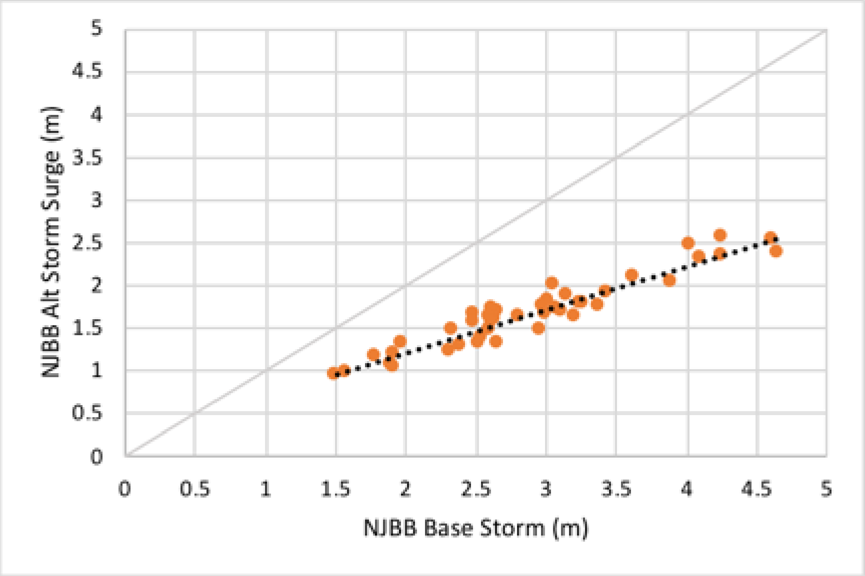


Figure 22: NJBB All-Closed vs. base condition storm surge for SP 29.

Table 7: Linear regression coefficients for estimation of NJBB XC storm surge (All-Closed).

NJBB Save Point	β_0 (m)	β_1	R^2	Elevation Threshold (m)
36	-0.1825	1.1432	0.9898	–
2	0.4907	0.1299	0.0802	–
57	0.3535	0.1615	0.145	–
50	0.1298	0.4234	0.8713	–
29	0.1846	0.5069	0.908	1.42

In the case of the All-Closed alternative, save point 29 remained dry until the storm surge reached an elevation of 1.42 m. This occurrence is recorded in Table 7 as elevation threshold. When estimating NJBB XC storm surge for the All-Closed alternative, NACCS XC storm surge values less than this threshold are set to zero.

The estimated NJBB XC storm surge for the All-Closed alternative as a function of NACCS XC storm surge are shown in Figure 23 and Figure 24 for save points 36 and 29, respectively. All-Closed storm surge hazard curves for XCs and CC hazard curves were developed as described in Nadal-Caraballo et al. (2015).

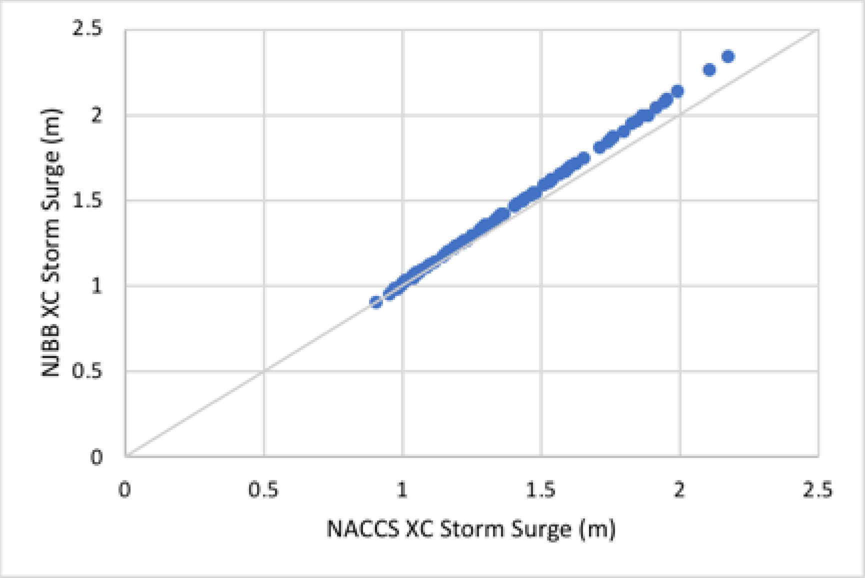


Figure 23: Estimated XC storm surge NJBB SP 36 (All-Closed).

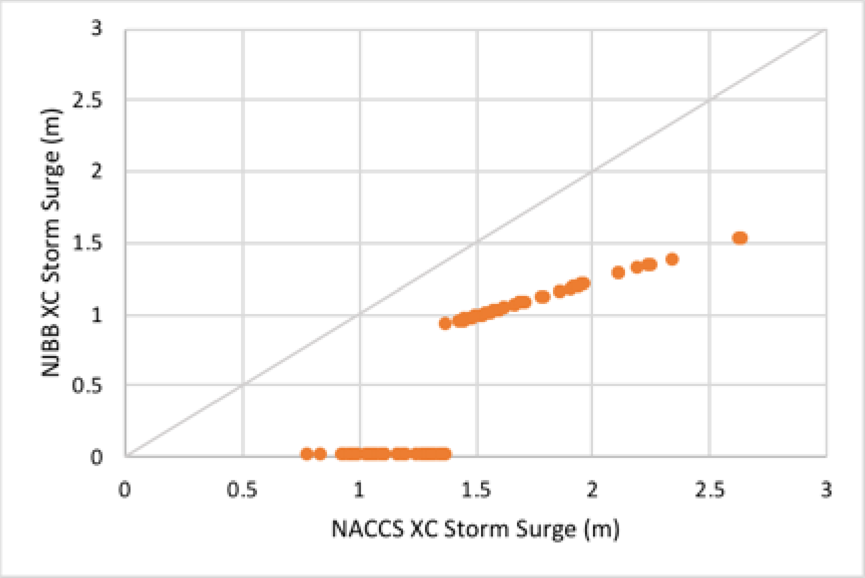


Figure 24: Estimated XC storm surge NJBB SP 29 (All-Closed).

The NJBB All-Closed-Less-2 storm surge vs. base condition storm surge for save points 36 and 29 are shown in Figure 25 and Figure 26, respectively. The coefficients and goodness-of-fit metrics for the linear regression models are presented in Table 8.

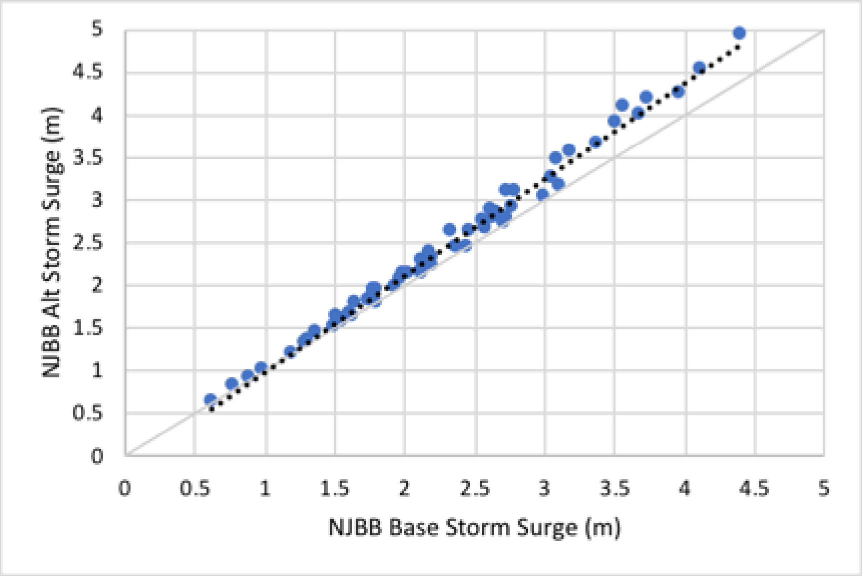


Figure 25: NJBB All-Closed-Less-2 vs. base condition storm surge for SP 36.

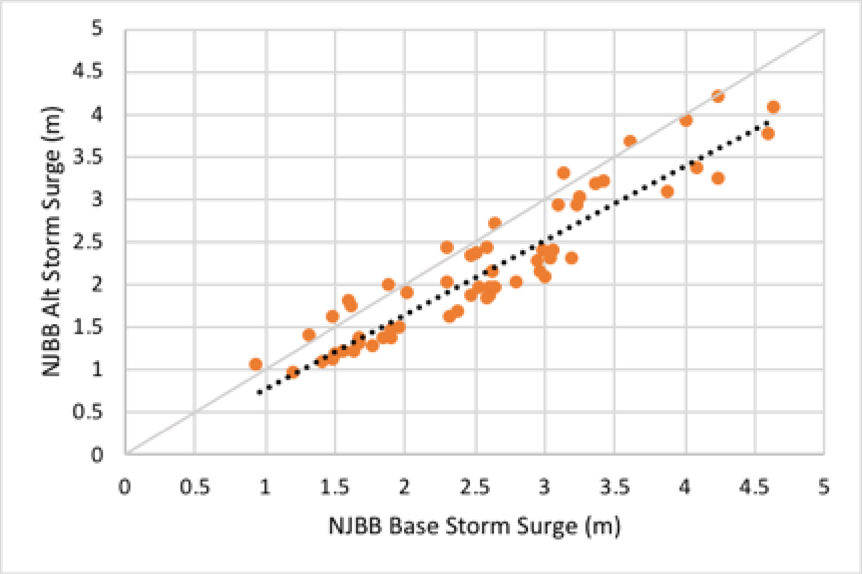


Figure 26: NJBB All-Closed-Less-2 vs. base condition storm surge for SP 29.

Table 8: Linear regression coefficients for estimation of NJBB XC storm surge (All-Closed-Less-2).

NJBB Save Point	β_0 (m)	β_1	R^2	Elevation Threshold (m)
36	-0.1593	1.1261	0.9911	–
2	0.1536	0.6603	0.3778	–
57	-0.144	0.808	0.5538	–
50	-0.1779	0.8664	0.8437	–
29	-0.1436	0.8831	0.8778	–

The estimated NJBB XC storm surge for the All-Closed-Less-2 alternative as a function of NACCS XC storm surge are shown in Figure 27 and Figure 28 for save points 36 and 29, respectively. All-Closed-Less-2 storm surge hazard curves for XCs and CC hazard curves were developed as described in Nadal-Caraballo et al. (2015).

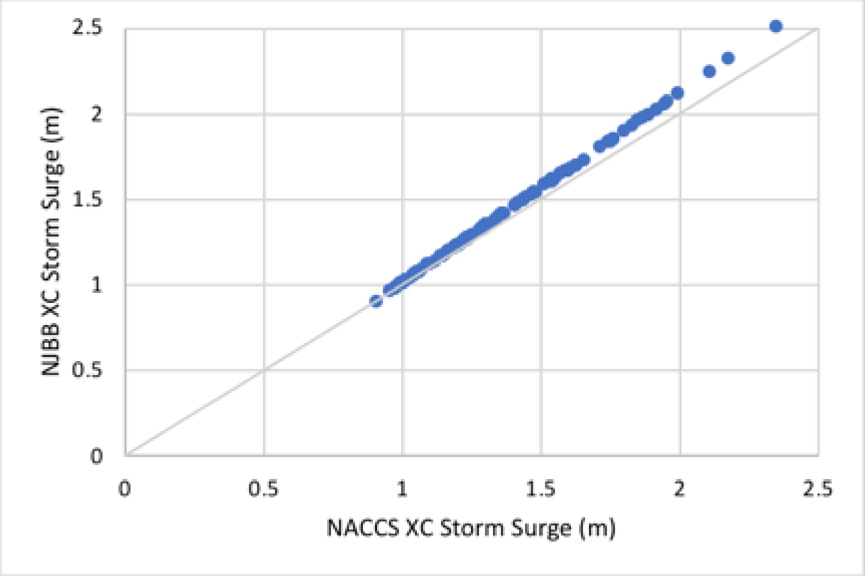


Figure 27: Estimated XC storm surge NJBB SP 36 (All-Closes-Less-2).

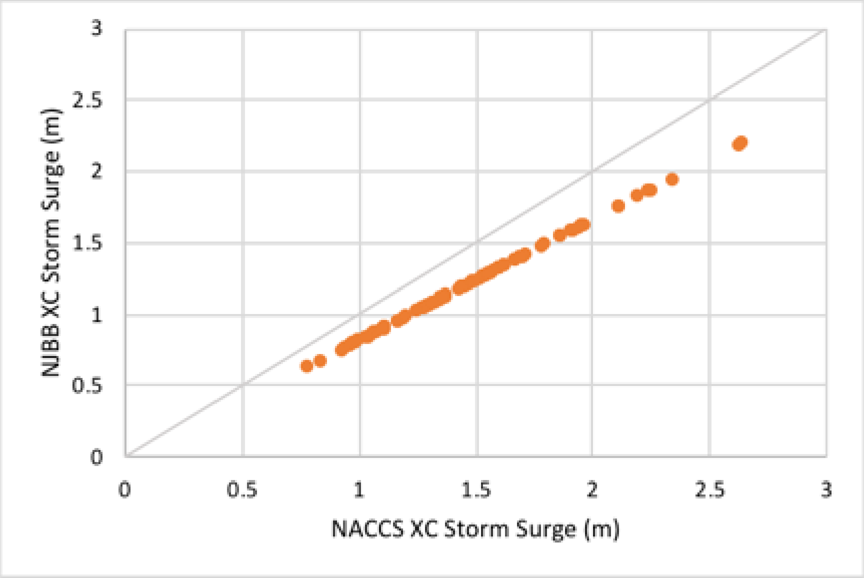


Figure 28: Estimated XC storm surge NJBB SP 29 (All-Closed-Less-2).

Section 3 -- ADCIRC Mesh Grid Details and Model parameters

The computational domain for NJBB study, shown in Figure 29 was derived from the North Atlantic Coast Comprehensive Study (NACCS) ADCIRC mesh and covers the North Atlantic Coasts, the Gulf of Mexico, and the Caribbean Sea (Cialone et al. 2015). Figure 30 shows the New Jersey ADCIRC coast line.

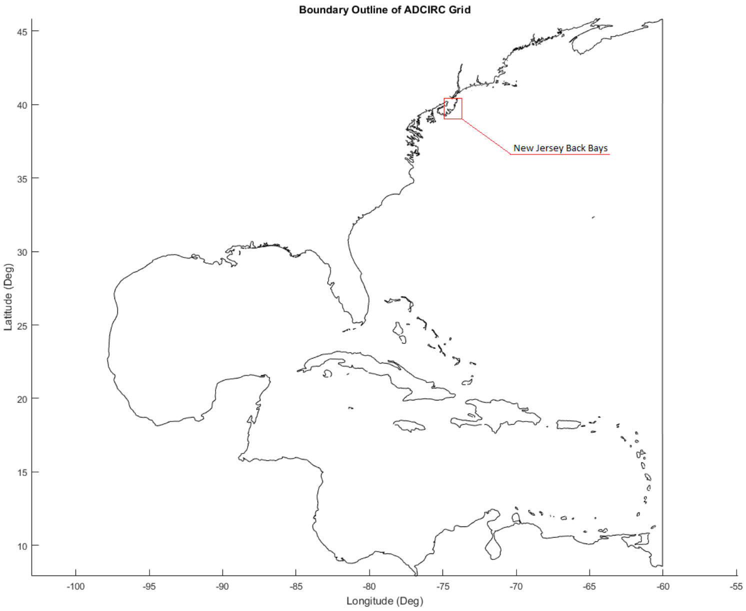


Figure 29: Outline plot showing the boundary of the ADCIRC mesh.

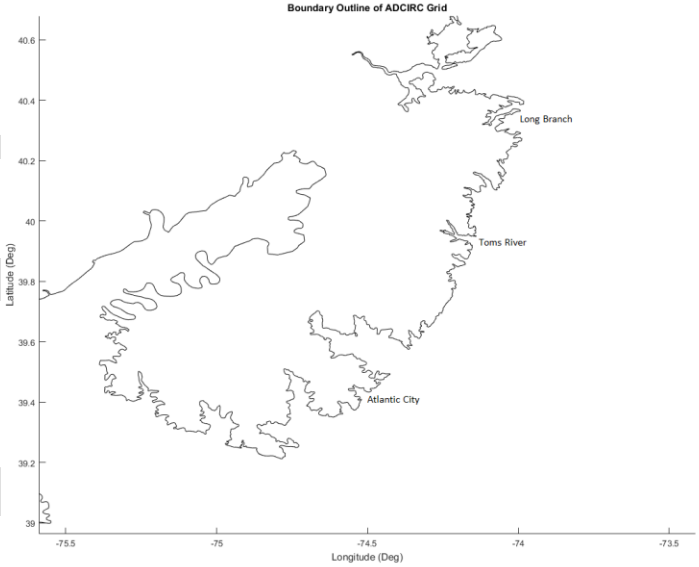


Figure 30: Boundary of ADCIRC mesh showing New Jersey coast.

While the original mesh boundary was maintained, Chesapeake Bay and coastal Long Island in the NACCS grid were subject to a "de-refining" procedure, which locally reduces a mesh resolution in areas that are distant from the area of interest. (Figure 31 and Figure 32 show grid resolution before and after de-refining in Chesapeake Bay and coastal Long Island regions, respectively). The de-refining is performed in order to reduce model simulation times, while maintaining the flow volume exchange from the distant locations to and from the area of interest. The total number of 3.12 million nodes in NACCS grid was reduced to 2.38 million (approximately a 24% reduction) in the NJBB grid due to the de-refining.

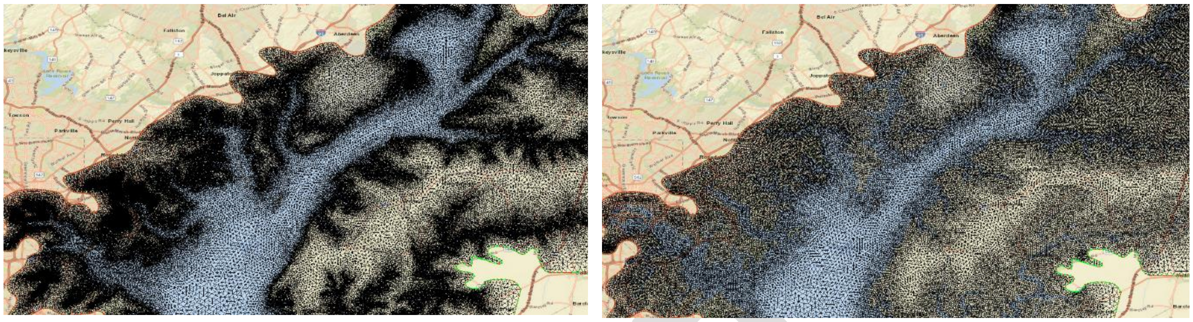


Figure 31: Chesapeake Bay before (left) and after (right) de-refining

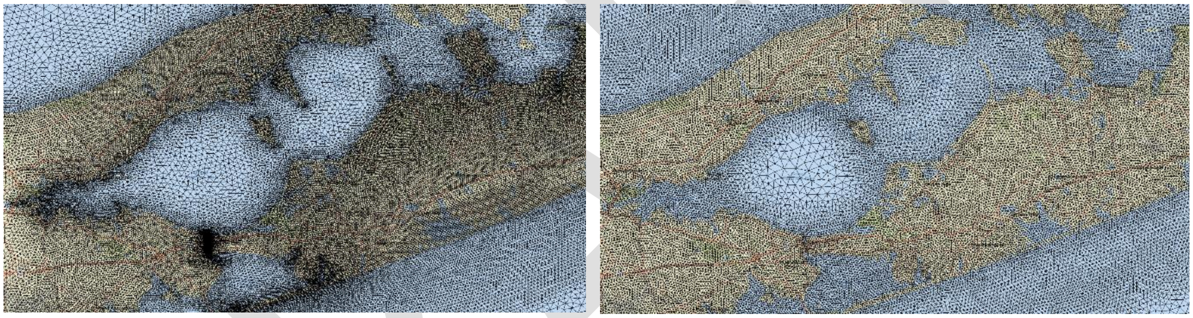


Figure 32: Long Island before (left) and after (right) de-refining

In order to show that the de-refining procedure did not significantly alter the model output in the region of the interest, a comparison of water surface elevations from NJBB grid and NACCS grids was made for 59 safe points (the locations of the save points are displayed in and Figure 34). The results of this comparison for selected save points is shown in Table 9. The average absolute difference for maximum water level elevation was ~0.02 meters and the corresponding average relative difference was 1.02%. The maximum difference in maximum water level elevation was observed at safe point # 56 (0.06 m, 3.64%).

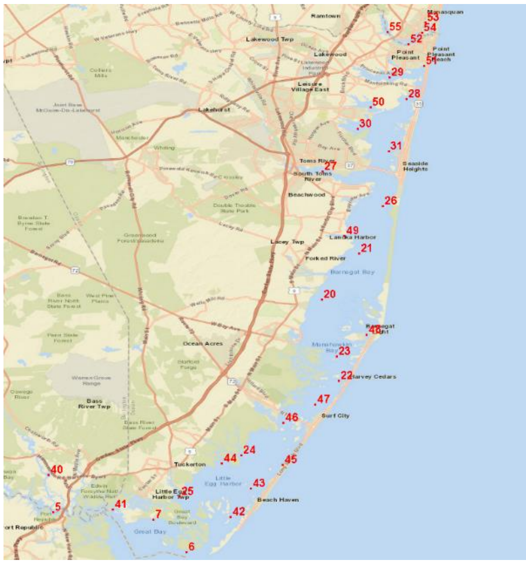


Figure 33: NJBB safe points (North)

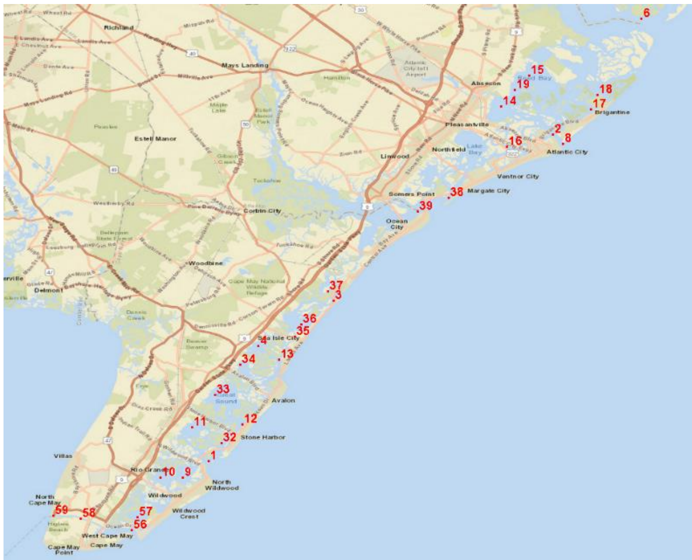
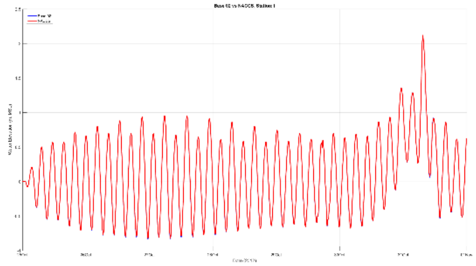
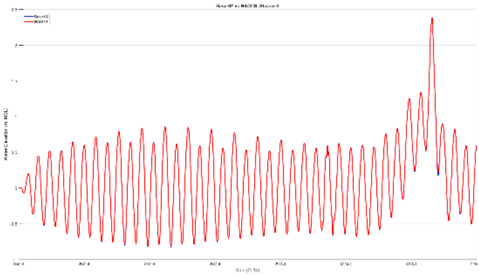
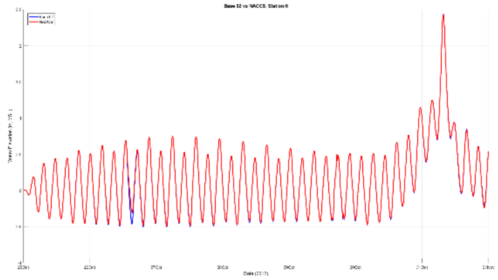
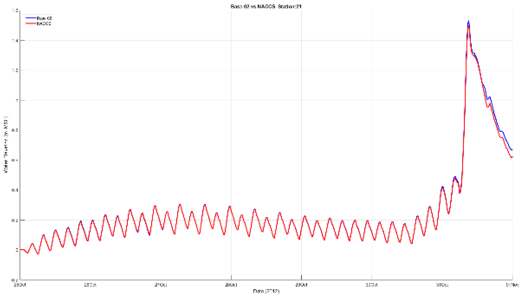
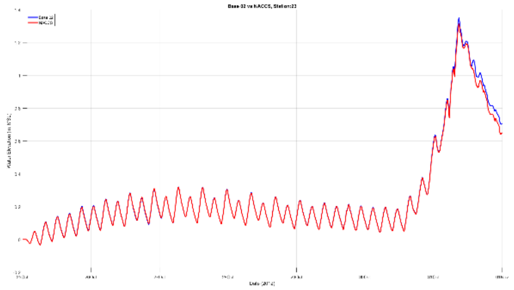
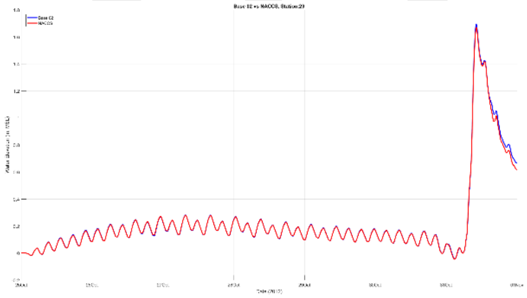
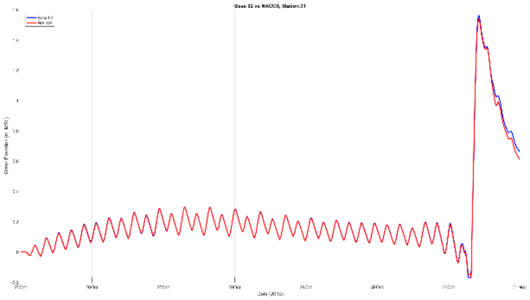
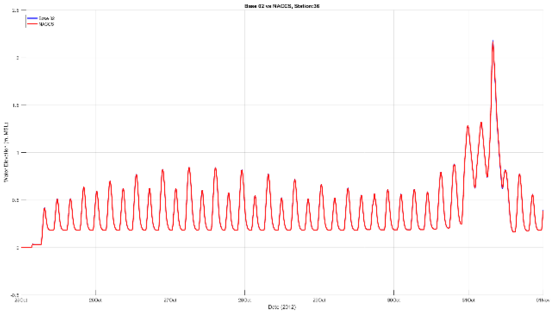
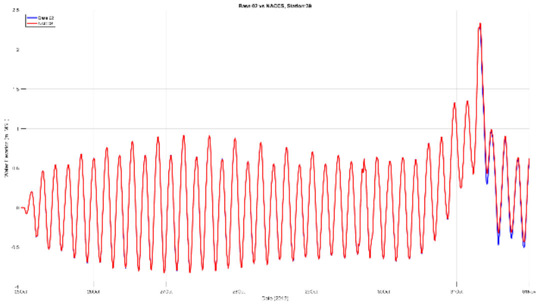
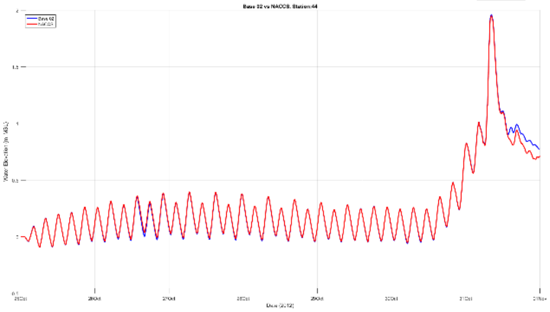
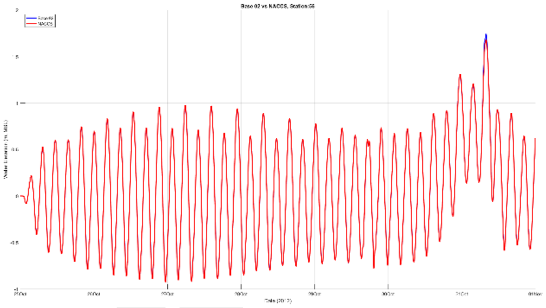


Figure 34: NJBB safe points (South)

Table 9: Time series plots for water surface elevation: NACCS (red) vs NJBB (blue), max difference for the peak surge in meters (col 2) and in percent (col 3).

Save point	Water surface elevation [m, MSL]: NACCS (red) vs NJBB (blue) between October 25 and November 1, 2012	Max diff for the peak surge [m]	Max diff for the peak surge [%]
1		0.00012	0.005663
2		0.001527	0.06409

6		0.002166	0.089133
21		0.032815	2.192233
23		0.036887	2.802876
29		0.025455	1.525335
31		0.021779	1.41494

36		0.012211	0.563921
39		0.055168	2.363608
44		0.011737	0.601841
56		0.061138	3.639444

The final step in creating the “without-project condition” NJBB grid (further in this text referred to as the “Base Grid”) was to raise the barrier islands elevations from Manasquan to Lower Cape May Meadows to represent 2018 existing conditions with the recent construction of several USACE beach restoration projects (10-22 ft., NAVD88). Table 10 gives a detail description of the updated barrier islands elevations. All subsequent “surge barrier alternative” grids were constructed from the Base Grid. The NJBB Base Grid has a spatial resolution (element size) varying approximately from 10 to 1000 m and MSL as a vertical datum.

Table 10: Elevation updates for New Jersey barrier island dunes to meet 2018 existing conditions.

Project	**Location**	**Dune Height (ft, NAVD88)**
Manasquan Inlet to Barnegat Inlet	northern Point Pleasant Beach and Seaside Heights	18
Manasquan Inlet to Barnegat Inlet	Rest of Project Area	22
Barnegat Inlet to Little Egg Inlet	Long Beach Island	22
Brigantine Inlet to Great Egg Harbor Inlet	Brigantine Island	10
Brigantine Inlet to Great Egg Harbor Inlet	Atlantic City	14.75
Brigantine Inlet to Great Egg Harbor Inlet	Ventnor, Margate, Longport	12.75
Great Egg Harbor Inlet & Peck Beach	northern Ocean City	-
Great Egg Harbor Inlet to Townsends Inlet	southern Ocean City	12.8
Great Egg Harbor Inlet to Townsends Inlet	Strathmere and Sea Isle City	14.8
Townsends Inlet to Cape May Inlet	Avalon	14.75
Townsends Inlet to Cape May Inlet	Stone Harbor	14.75
Hereford Inlet to Cape May Inlet	Wildwood	16
Cape May to Lower Township	Cape May	-
Lower Cape May Meadows	Cape May Meadows	16.75
	Absecon Seawall	16
	Townsends Seawall	11.7
	Hereford Seawall	11.7

The NACCS ADCIRC depth grid with exception of the raised elevations of the barrier islands, mentioned in the preceding paragraph, was used as a topo-bathymetric data source. The source of the data used for modifying the barrier islands was the authorized dune and seawall heights for NAP projects.

Section 3.1 -- Iteration 1

Iteration 1 began with model simulations of one inlet closure at a time to improve understanding of the hydraulic influence of each inlet and inform the development of multiple closure alternatives. One additional simulation was included in Iteration 1, All

Closures Less 2, at the request of NAP. This alternative provided an early look at how leaving two of the most environmentally sensitive inlets, Little Egg/Brigantine and Corson, might limit the effectiveness of reducing water levels in the study area. A schematic of the study areas tidal inlets and bay systems is shown in Figure 35.

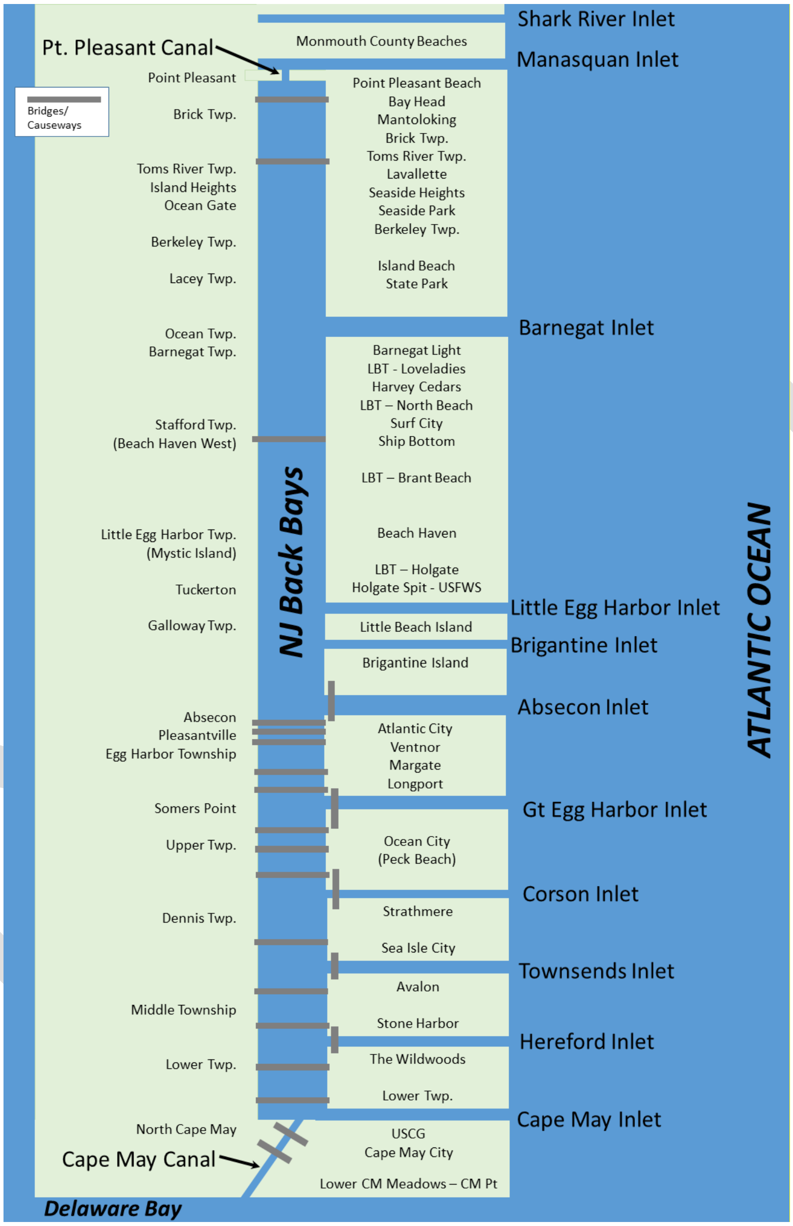


Figure 35: Schematic of NJBB Study Area

Section 3.1.1 -- Configurations of proposed structures

Iteration 1 included the following closure configurations:

1. Base Conditions
2. Cape May Canal
3. Cape May Inlet
4. Hereford
5. Townsends
6. Corson
7. Great Egg
8. Absecon
9. Little Egg / Brigantine
10. Barnegat
11. Manasquan
12. Shark River
13. All Closures Less 2

A schematic of All Closures Less 2 is provided in Figure 36, where the red lines represent closures.

Figure 36: Schematic of All Closures Less 2

Section 3.1.2 -- Grids

A total of twelve proposed design structure layouts were modeled in addition to the existing conditions (Base Conditions) case for Iteration 1. The process of the grid modification to implement a proposed closure was the same for all twelve structures, that is, the Base Grid was altered in the vicinity of the structure by adding "weir-pairs" to represent a storm surge barrier. This local modification of the Base Grid minimized the mesh changes between the different alternatives. All weir-pair structures were set to +20 ft MSL in Iteration 1. Implementing weir-pairs in ADCIRC improves the stability of the model since sub-grid scale formulation for weir-pairs prevents the model from transitioning from sub to supercritical flows during the course of the simulation in the event that the water elevation is high enough to overtop the structure. Figure 37 and Figure 38 show the same region of the ADCIRC mesh before and after implementation of the weir-pairs, respectively.

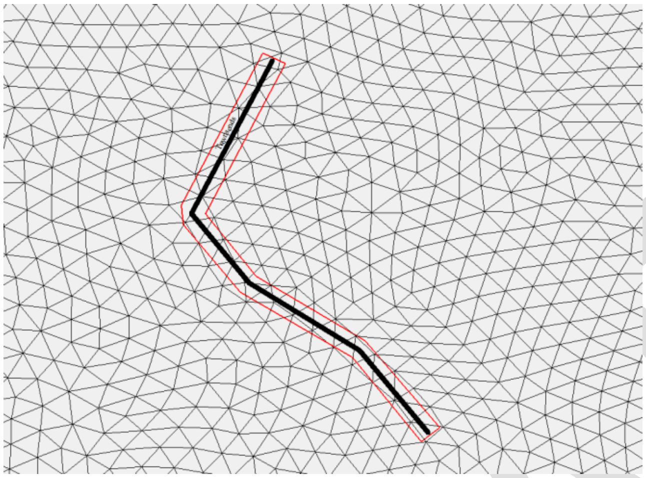


Figure 37: Base Grid before implementing Townsends Inlet closure. The red contour indicates the position of the future weir-pairs, the black line is the centerline of the structure.

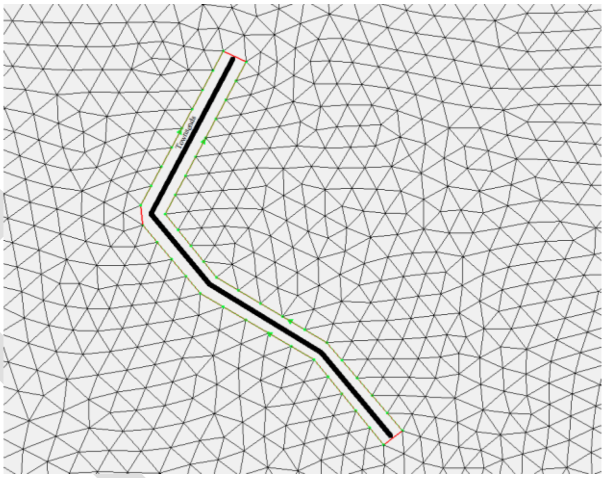


Figure 38: The ADCIRC mesh implementing Townsends Inlet closure. The green contour shows the weir-pairs, the black line is the centerline of the structure

Section 3.2 -- Iteration 2

A workshop with the CHL and the NJBB Project Delivery Team (PDT) was held on January 31, 2018 to review the model results from Iteration 1 and identify various closure configurations for Iteration 2. The PDT is an interdisciplinary group including project planners, biologist, hydraulic engineer, civil engineer, cost engineer, and project manager.

Many of the closure configurations for Iteration 2 are designed around leaving the most environmentally sensitive inlets open: Little Egg/Brigantine, Corson, and Hereford. Closures across the interior bays “bay closures” are added to several configurations to reduce water levels in instances where environmental sensitive inlets remain open. The study area was also broken up into 3 regions (north, central, and south) based on the relative hydraulic independence of the configurations identified for these regions. Since many of the configurations are designed around leaving Little Egg and Corson inlets open, these two inlets were natural boundaries for the three regions.

Model results from Iteration 1 indicated that the north and south configurations could be combined into a single ADCIRC simulation without the results for the north or south configurations impacting each other. Combining the north and south configurations reduced the total number of simulations required and HPC demand.

A few of the closure configurations are intended as sensitivity runs to help determine if certain closures may be omitted from configurations without significantly reducing the configurations effectiveness.

Section 3.2.1 -- Configurations of proposed structures

Iteration 2 included the following closure configurations:

1. All Closed (Figure 39)
2. All Closed Less 2 - Simulated during Iteration 1 (Figure 40)
3. N3 + S3 (Figure 41)
4. N4 + S4 (Figure 42)
5. N5 + S5 (Figure 43)
6. N6 + S6 (Figure 44)
7. N7 + S7 (Figure 45)
8. S8 (Figure 46)
9. S9 (Figure 47)
10. S10 (Figure 48)
11. C3 (Figure 49)
12. C4 (Figure 50)
13. C5 (Figure 51)
14. C6 (Figure 52)
15. C7 (Figure 53)

A schematic of the closure alternatives are provided in Figure 39 to Figure 53, where the red lines represent closures.

Figure 39: Schematic of All Closures

Figure 40: Schematic of All Closures Less 2

Figure 41: Schematic of N3S3

Figure 42: Schematic of N4S4

Figure 43: Schematic of N5S5

Figure 44: Schematic of N6S6

Figure 45: Schematic of N7S7

Figure 46: Schematic of S8

Figure 47: Schematic of S9

Figure 48: Schematic of S10

Figure 49: Schematic of C3

Figure 50: Schematic of C4

Figure 51: Schematic of C5

Figure 52: Schematic of C6

Figure 53: Schematic of C7

Section 3.2.2 -- Grids

The grid development procedure was the same as in 3.1.2, however, this time multiple structures were implemented on a specific mesh.

Section 3.3 -- Iteration 3

A second workshop with the CHL, NJBB PDT, and non-Federal sponsor (NJDEP) was held on April 13, 2018 to review the model results from Iteration 2 and identify the final set of configurations for Iteration 3. The focus of this workshop was identifying the configurations that meet the NJBB study objectives and constraints, or the configurations likely to generate the greatest NED benefits (flood damages reduce minus project costs) and be environmentally acceptable. Several configurations are still included that are not likely to be environmentally acceptable (All Closed, N3, C3, and majority of southern alternatives) to ensure that configurations are not eliminated too early before a more thorough plan formulation approach is applied.

Section 3.3.1 -- Configurations of proposed structures

Iteration 3 included the following closure configurations:

1. All Closed (Figure 54)
2. All Closed Less 2 (Figure 55)
3. N3 + S3 (Figure 56)
4. N7 + S4 (Figure 57)
5. C3 (Figure 58)
6. C4 (Figure 59)

All of the Iteration 3 configurations were evaluated in Iteration 2. Only one configuration, N7S4, is a different combination of previously evaluated north and south configurations. A schematic of the Iteration 3 alternatives is provided in Figure 54 to Figure 59 where the red lines represent closures.

Figure 54: Schematic of All Closed

Figure 55: Schematic of All Closed Less 2

Figure 56: Schematic of N3S3

Figure 57: Schematic of N7S4

Figure 58: Schematic of C3

Figure 59: Schematic of C4

Section 3.3.2 -- Grids

The grid development procedure was the same as in 3.1.2, however, this time multiple structures were implemented on a specific mesh.

Section 4.1 -- Maximum Storm Surge Results – Iteration 1

The Iteration 1 numerical modeling task consisted of the evaluation of the impact of 1) individuals inlet closures, 2) all inlets closed except Little Egg/Brigantine and Corson Inlet, and 3) all inlets closed, on water levels in New Jersey back bays for 10 storm events. (The storm selection process was described in Section 2 -- Storm Selections) The following section describes the effect of closure configurations on maximum water level in the New Jersey back bays. The evaluation was made by analyzing the maximum water level in the overall project area as well as specific hydraulic reaches (shown in Figure 60). The first stage of the analysis was based on differences in the maximum water level for the entire project area. Secondly, maximum water levels for the base condition at specific points in a hydraulic reach were compared to maximum water levels with a closure in place. These comparisons were referred to as "dot plots", where each dot color represents one of the 10 storms. Lastly, water level time series plots at specific points in the hydraulic reach were generated showing a comparison between the base condition and closure conditions. For the brevity of this document, only Barnegat Inlet Closed and Townsend Inlet Closed cases (Iteration 1) are furnished with the above three types of plots. The complete set of maximum water level plots, difference plots, dot plots, and time series plots can be found in the Appendix.

Figure 60: NJBB Hydraulic Reaches.

Shark River Inlet Closed versus Base Condition

Closure of Shark River Inlet individually (eliminated all surge) had no impact on maximum water level for each of the 10 simulated storms, beyond the immediate area behind (landward) of the closure location.

Manasquan Inlet Closed versus Base Condition

Closure of Manasquan Inlet individually had mixed results. For some storm events that closure was effective at reducing water levels. During other storm events that closure had little impact on maximum water levels and in a few instances resulted in higher water levels. The closure at Manasquan had no impact on Barnegat Bay. Results indicate that a standalone closure at Manasquan Inlet may not be effective.

Barnegat Inlet Closed versus Base Condition

Moving southward, the next inlet is Barnegat Inlet, which is hydraulically connected to Barnegat Bay, Manahawkin Bay, and Little Egg Harbor. Maximum water level reductions with Barnegat Inlet closed are most significant in the northern section of the bay (0.32 to 0.67 m), moderate in Manahawkin Bay, and negligible in Little Egg Harbor (0.07-0.26 m). This finding is due to the opening at Little Egg/Brigantine Inlet allowing surge into the bay from the south for most storms and minimizing water level reduction with Barnegat Inlet closed. Water levels in the southern portion of the bay are dominated by flow through Egg/Brigantine Inlet, except for Storm 636, which shows the greatest average reduction in Manahawkin Bay due to strong north-to-south winds. For the Base condition, Storm 636 surge propagating through Barnegat Inlet is directed southward into Manahawkin Bay, but with Barnegat Inlet closed, the volume of water entering Barnegat Bay is reduced resulting in less water/lower water levels propagating southward into Manahawkin Bay.

Figure 61 and Figure 62 show maximum water elevation for the Base Grid (left), maximum water elevation for Barnegat Inlet closed (center), and the difference in maximum water elevations between Barnegat Inlet closed and the Base Grid (right) for tropical synthetic storms 434 and 636, respectively.

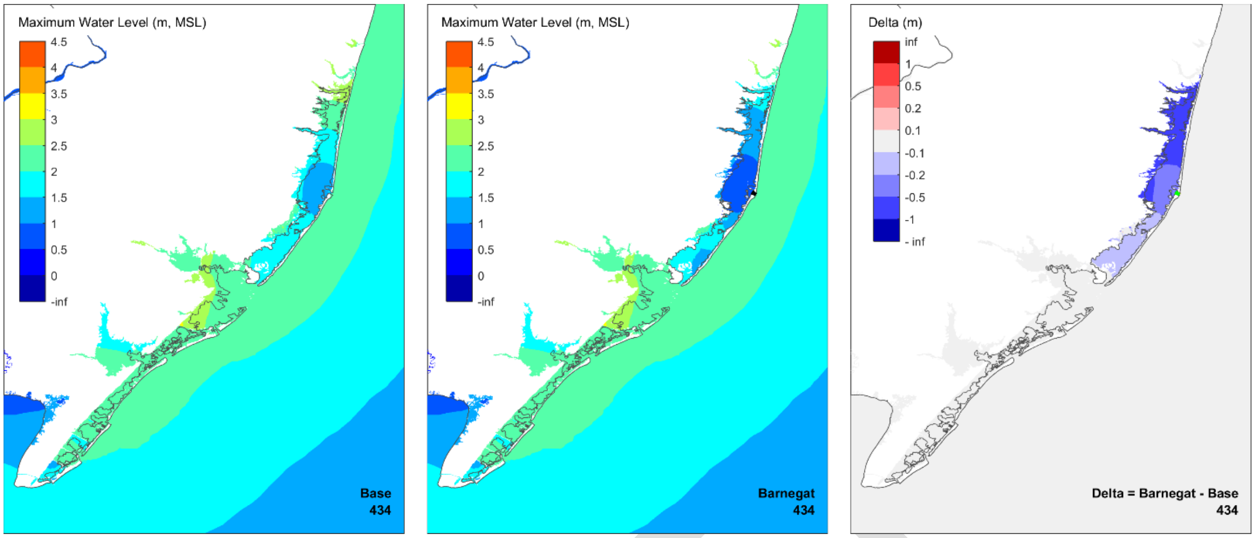


Figure 61: Maximum water elevation for Synthetic Storm 434: Base Grid (left), Barnegat Inlet Closed (center), and difference between Barnegat and Base (right)

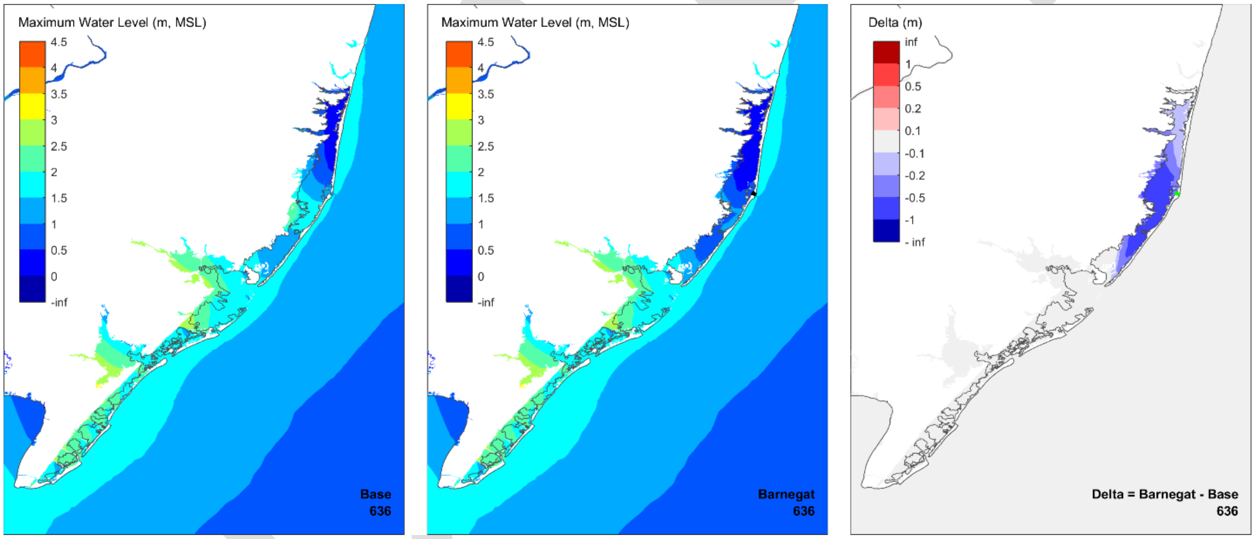


Figure 62: Maximum water elevation for Synthetic Storm 636: Base Grid (left), Barnegat Inlet Closed (center), and difference between Barnegat and Base (right)

Figure 63 shows maximum water levels for the Base condition vs maximum water levels with Barnegat Inlet closed, referred to as a dot plot. Values below the 45 degree line indicate a reduction in maximum water level attributable to the closure. For this particular configuration the average reduction in maximum water level was 30% due to Barnegat Inlet being closed.

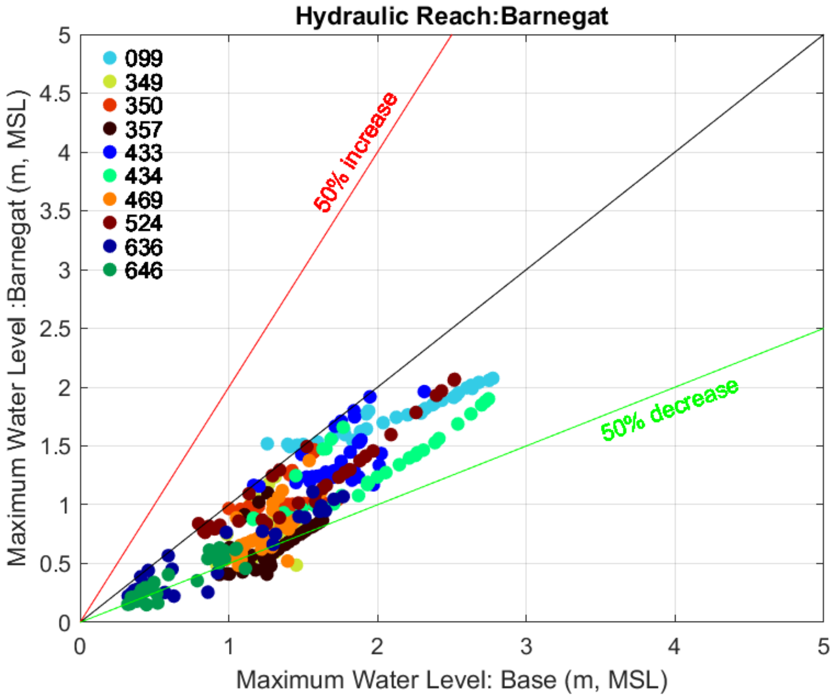


Figure 63: Dot plot: maximum water level for the Base condition vs maximum water level with Barnegat Inlet closed

Figure 64 shows the locations of save points in Barnegat Bay used in time series plots.

Figures 64 -67 show time series plots of water elevation at selected stations (save points) for tropical synthetic storm 434. The red line shows the Base Grid time series, the blue line shows the time series with Barnegat Inlet closed, the black line – the time series for All Closures Closed less2, and the green line – the time series for All Closures Closed.

Figure 64: Selected save points in Barnegat Bay for time series plots

Figure 65 depicts the time series at the southernmost save point (station 139), which indicates that this region only experiences a significant reduction in water level with all inlets closed. This region is greatly influenced by Little Egg/Brigantine Inlet. Moving northward, Figure 66 (station 68) indicates that this location is still influenced by Little Egg/Brigantine Inlet and only experiences significant reduction with all inlets closed. There is a significant reduction in water surface elevation at station 152 (Figure 67) for all three closure configurations due to its proximity to the Barnegat Inlet closure. The initial reduction in water level in the Base Grid (Figure 68, station 156) is attributed to north-to-south winds transporting water southward away from this region. When the wind shifts, water accumulates in this region with the most significant accumulation for the base condition.

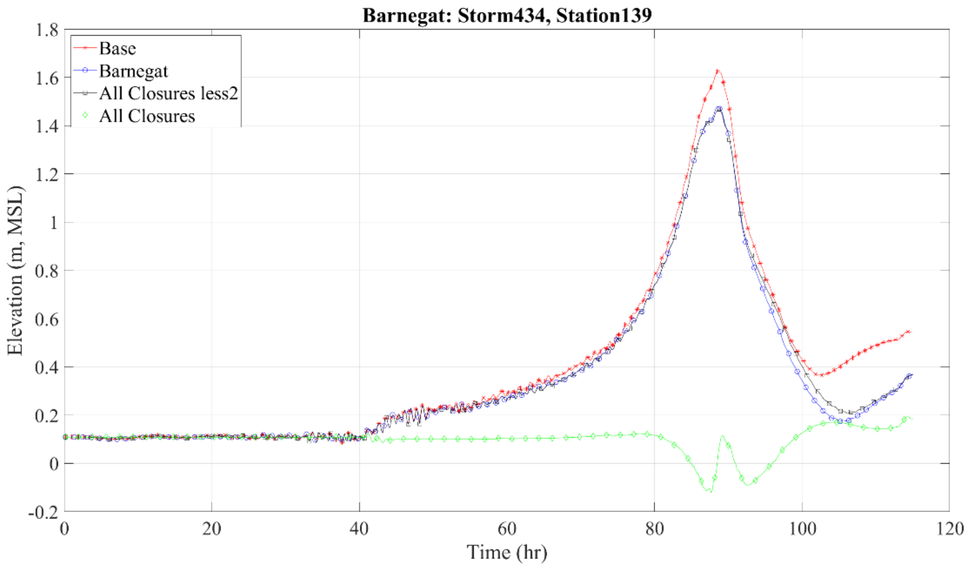


Figure 65: Storm 434: Time series plots for station (save point) 139.

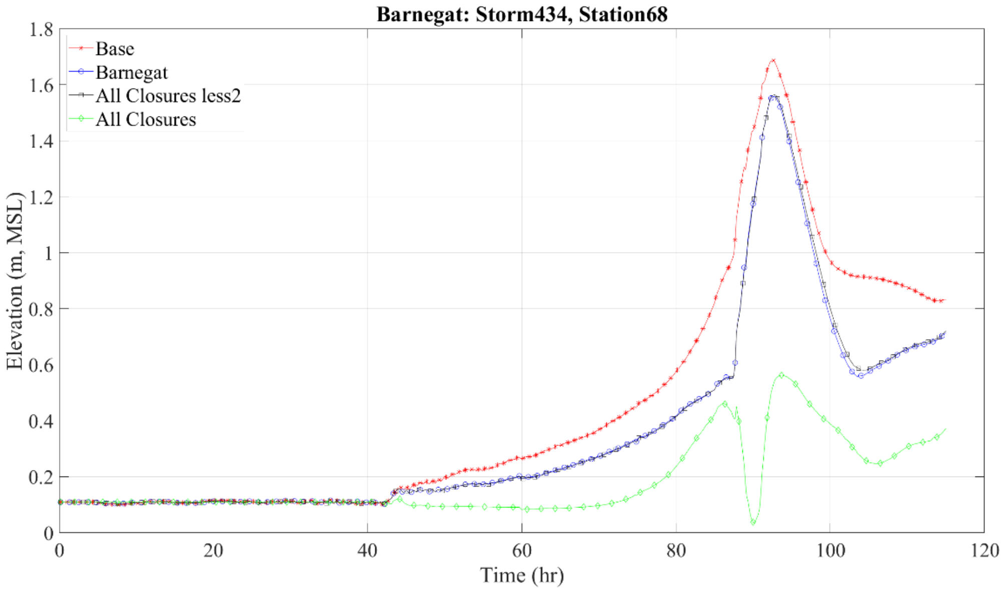


Figure 66: Storm 434: Time series plots for station (save point) 68.

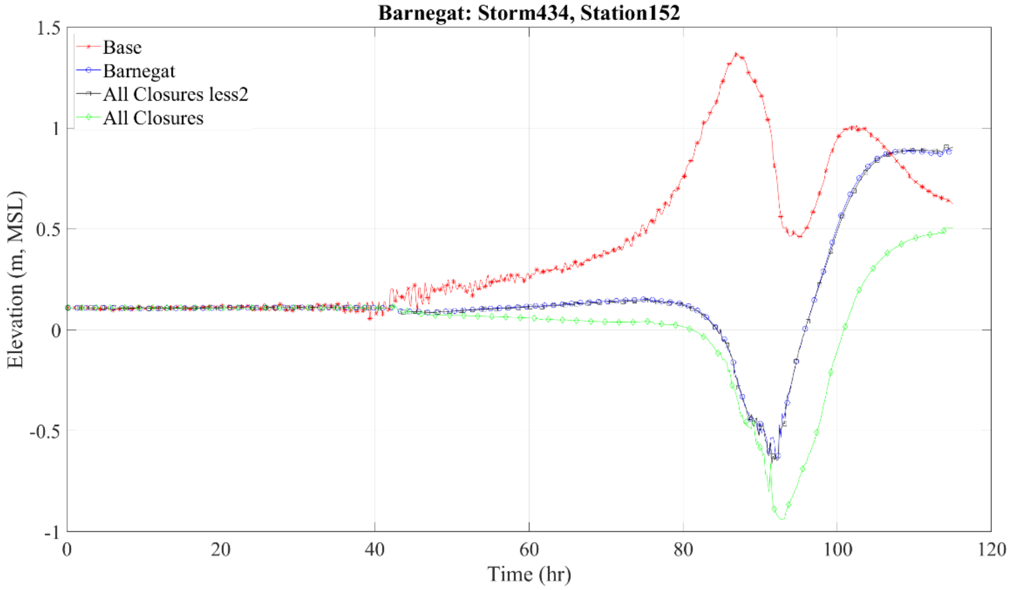


Figure 67: Storm 434: Time series plots for station (save point) 152.

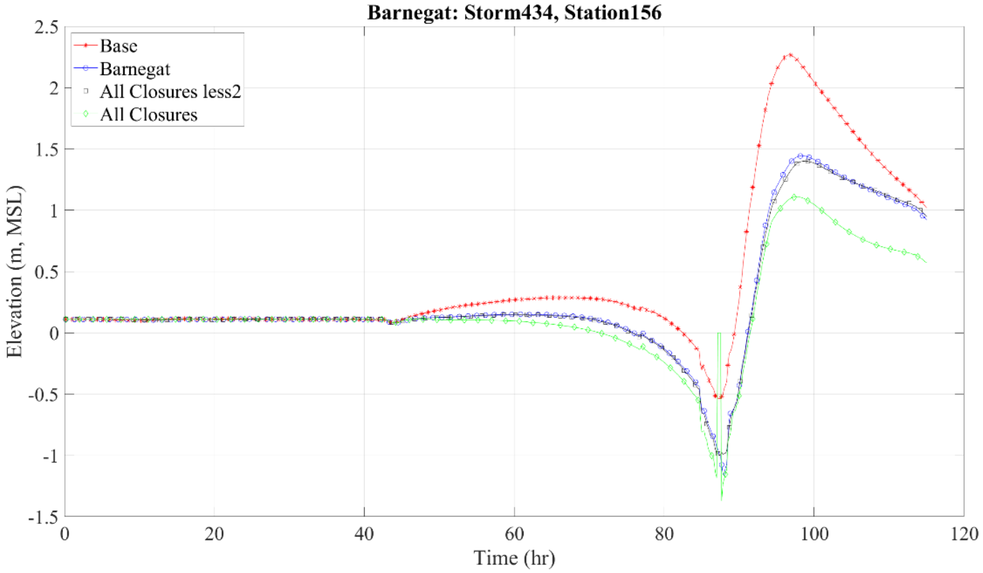


Figure 68: Storm 434: Time series plots for station (save point) 156

Figures 68 -71 show the time series plots of water elevation for selected stations (save points) for tropical synthetic storm 636. The red line shows the Base Grid time series, the blue line shows the time series with Barnegat Inlet closed, the black line – the time series of All Closures Closed less2, and the green line – the time series of All Closures Closed.

Figure 69 depicts the time series at the southernmost save point (station 139), which indicates that this region experiences an initial reduction in water level with all inlets closed followed by an increase in water level due to seiching. However the water level with all inlets closed is still lower compared to the water levels for the other closure configurations. Moving northward, Figure 70 (station 68) indicates that this location is still influenced by Little Egg/Brigantine Inlet as well as exposure to north-to-south winds. Therefore the water level response initially indicates convergence in the phasing of the peak response. After the peak, all configurations except All Closures Closed allow water to escape through Little Egg/Brigantine Inlet. Conversely, the trapped water with All Closures Closed elevates the water level 0.2 to 0.4 m above the base condition water level. At station 152 (Figure 71) the peak water level is less extreme due to its location in the bay and north-to-south winds.

The initial reduction in water level for all four configurations (Figure 72, station 156) is attributed to strong north-to-south winds transporting water southward away from this region. When the wind shifts, water accumulates in this region with the most significant accumulation for the All Closures Closed condition due to seiching of the trapped water. In real operation of the closures, the gates may be opened following the storm allowing the accumulated water to flow back into the ocean.

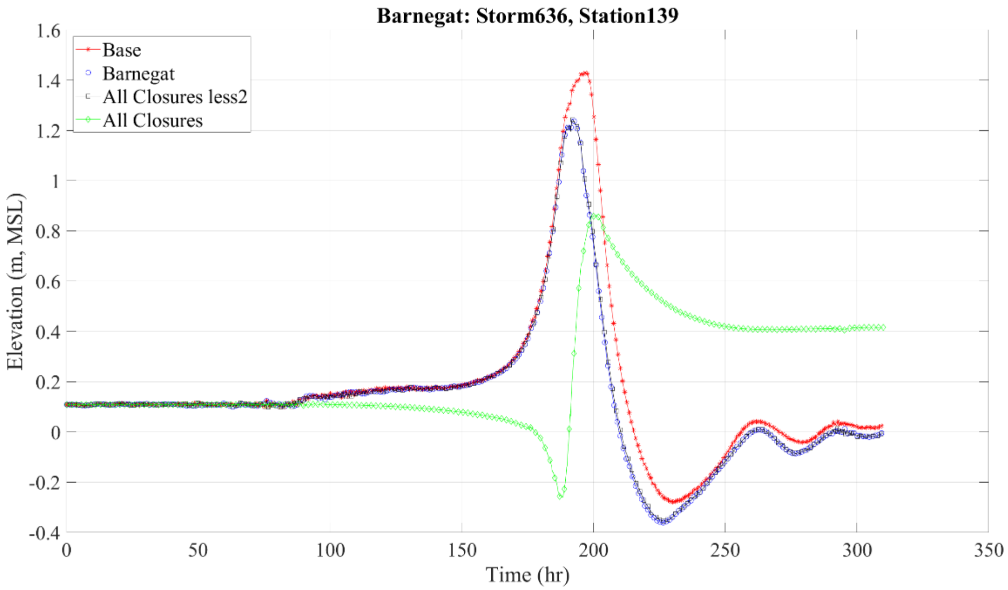


Figure 69: Storm 636: Time series plots for station (save point) 139

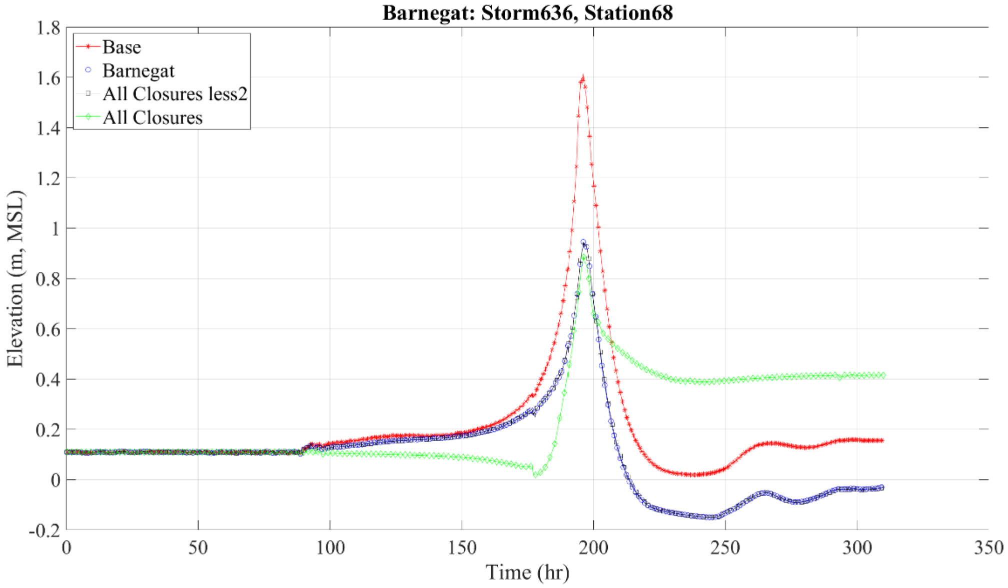


Figure 70: Storm 636: Time series plots for station (save point) 68

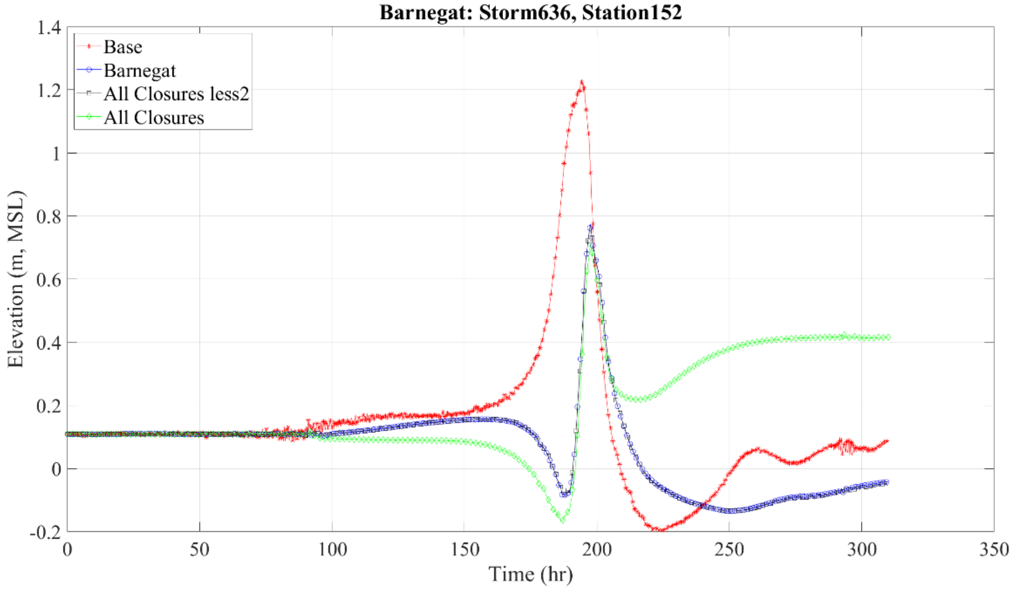


Figure 71: Storm 636: Time series plots for station (save point) 152

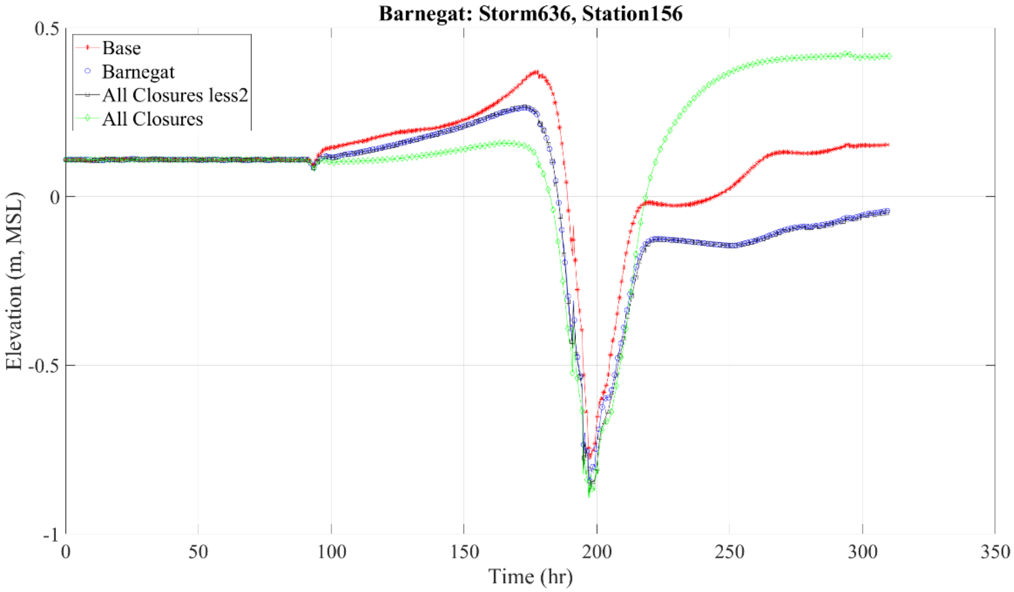


Figure 72: Storm 636: Time series plots for station (save point) 156

Little Egg/Brigantine Inlet

The implementation of a 15 km closure in the ADCIRC grid across Little Egg Inlet and Brigantine Island to inhibit surge propagation into the back bay areas was the most extensive closure evaluated in this study. The impact of the Little Egg/Brigantine closure was corresponding extensive, with reductions in peak water level extending to the northernmost part of Barnegat Bay to Great Egg Inlet. The average reduction in Great Bay (bayward of the closure) was 1.3 m for all storms.

Absecon Inlet Closed versus Base Condition

Absecon Inlet is the first inlet south of the large opening at Little Egg/Brigantine, therefore the closure at Absecon Inlet can be influenced by flow through Little Egg/Brigantine. As such, closing Absecon Inlet can locally reduce water levels in Absecon Bay and vicinity, can be of no consequence to water levels, or can actually cause increased water levels, depending on the direction of storm winds. No change in water level with the closure in place is the result of water entering through Little Egg/Brigantine Inlet and propagating southward into Absecon Bay, thereby eliminating any positive impact of the closure. Increased water levels in the bay with the inlet closures in place are caused by surge entering through Little Egg/Brigantine Inlet, propagating southward into Absecon Bay, then as the winds shift, surge cannot exit the bay due to the Absecon Inlet closure resulting in elevated water levels in the “protected” bay. This demonstrates the importance of considering multiple means of flow propagation into an embayment as well as the operation/timing of surge barrier closures.

Great Egg Harbor Inlet

Closing Great Egg Harbor Inlet can potentially have reductions in water level spanning northward to the bays near Atlantic City, southward to the bays near Sea Isle City, and eastward to the Great Egg Harbor River watershed, depending on the characteristics of the storm. The greatest reductions are in Great Egg Harbor, as expected.

Corson Inlet

Closing Corson Inlet can potentially have reductions in water level spanning northward to the bay near Ocean City/Great Egg Harbor Inlet and southward to the bay near Hereford Inlet. The greatest reductions are in Strathmere Bay near Corson Inlet, as expected

Townsend Inlet

Closing Townsend Inlet can potentially have reductions in water level spanning northward to Corson Inlet and southward to Cape May Harbor, depending on the storm characteristics (intensity, forward speed, direction, etc.). The greatest reductions are in Stites and Townsend Sound which are closest to the closure at Townsends Inlet, as expected.

Figure 73 and Figure 74 show maximum water elevation for the Base Grid (left), maximum water elevation for Townsend Inlet closed (center), and the difference in maximum water elevations between Townsend Inlet closed and the Base Grid (right) for tropical synthetic storms 99 and 636, respectively.

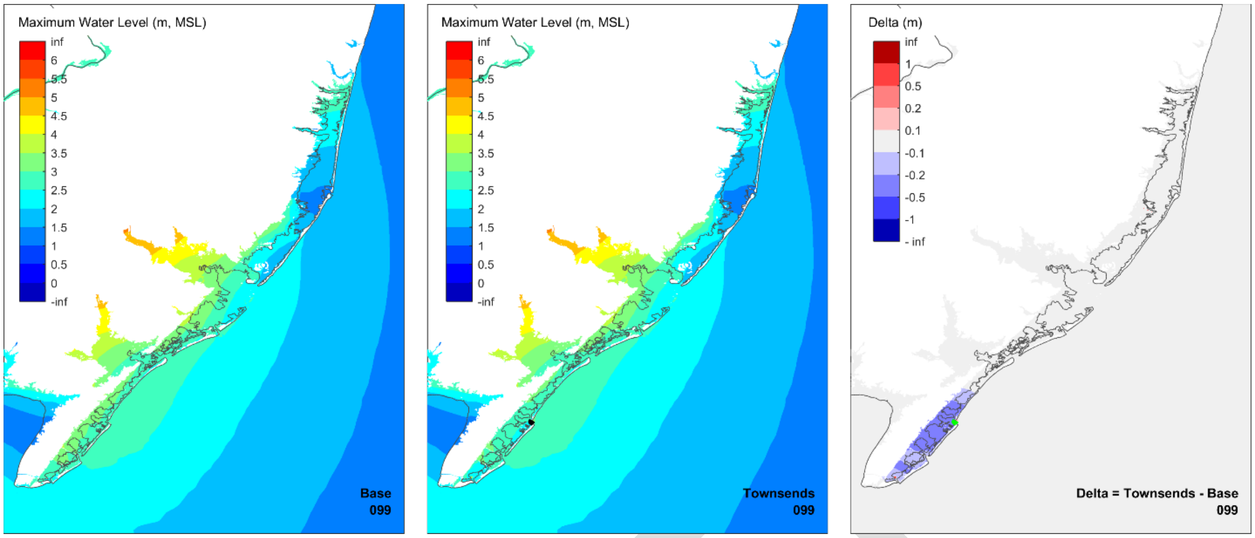


Figure 73: Maximum water elevation for Synthetic Storm 99: Base Grid (left), Townsend Inlet Closed (center), and difference between Townsend and Base (right)

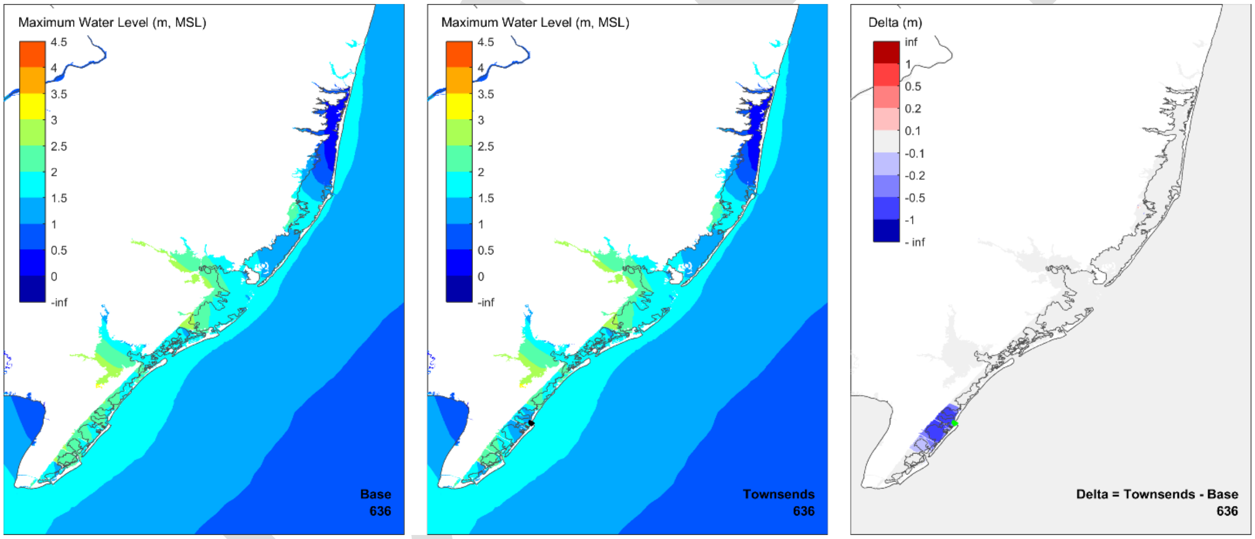


Figure 74: Maximum water elevation for Synthetic Storm 636: Base Grid (left), Townsend Inlet Closed (center), and difference between Townsend and Base (right)

Figure 75 shows maximum water levels for the Base condition vs maximum water levels with Townsend Inlet closed, referred to as a dot plot. Values below the 45 degree line indicate a reduction in maximum water level attributable to the closure. For this particular configuration the average reduction in maximum water level was26% due to Townsend Inlet being closed.

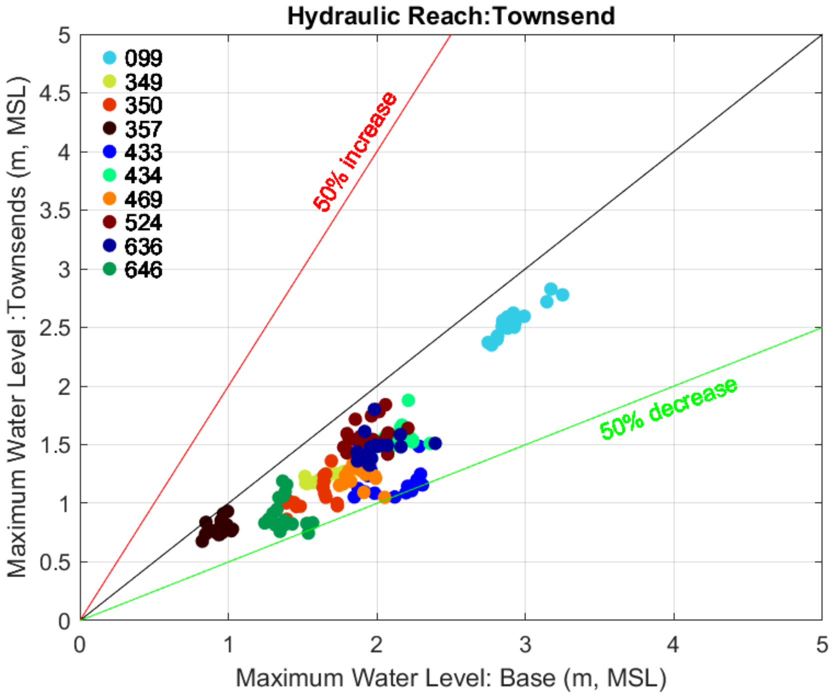


Figure 75: Dot plot: maximum water level for the Base condition vs maximum water level with Townsend Inlet closed

Figure 76 shows the locations of the save points used to evaluate the Townsend closure with the time series plots.

Figure 77 and Figure 78 show time series plots of water elevation at selected stations (save points) for tropical synthetic storm 99. The red line shows the Base Grid time series, the blue line shows the time series with Townsend Inlet closed, the black line – the time series for All Closures Closed less2, and the green line – the time series for All Closures Closed.

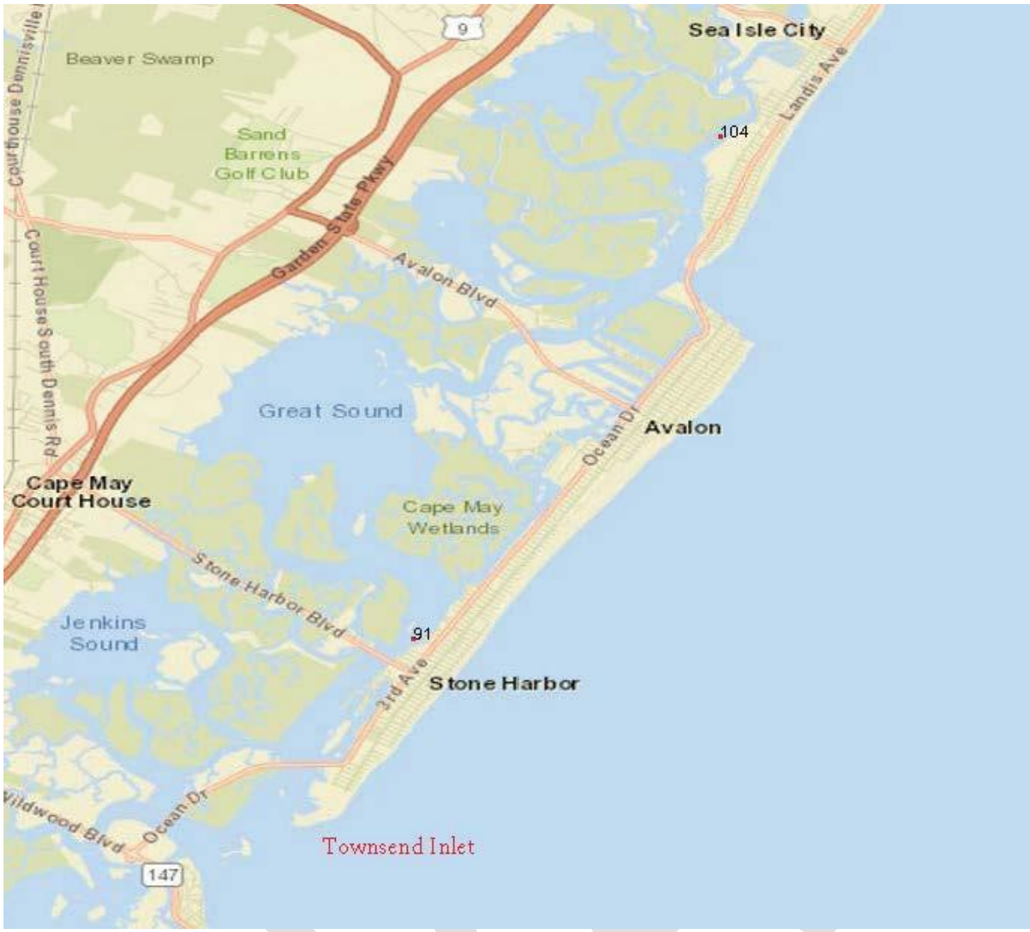


Figure 76: locations of the save points used for evaluation of the Townsend closure with the time series plots

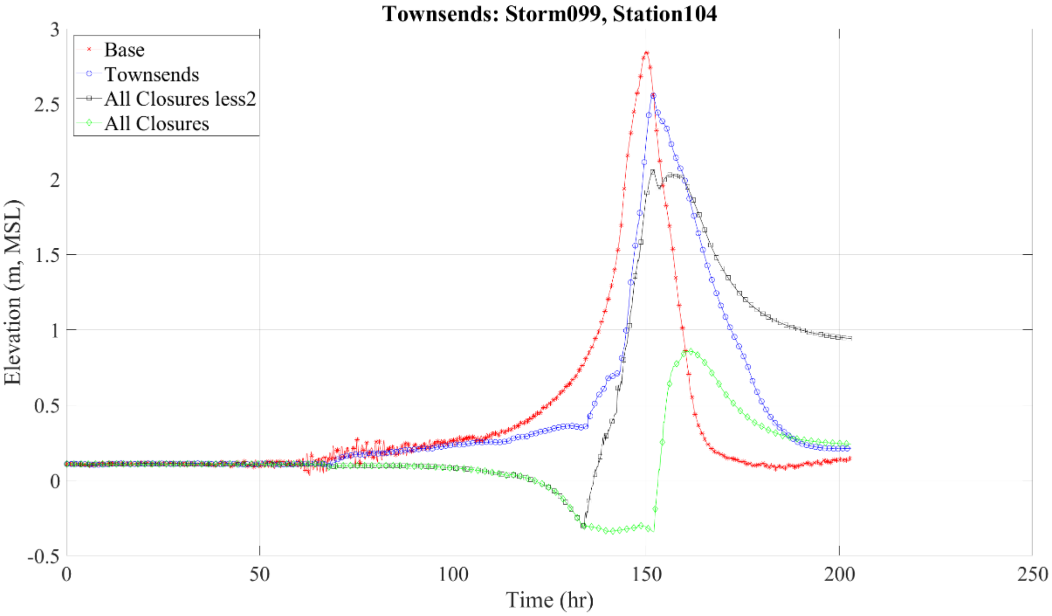


Figure 77: Storm 99: Time series plots for station (save point) 104

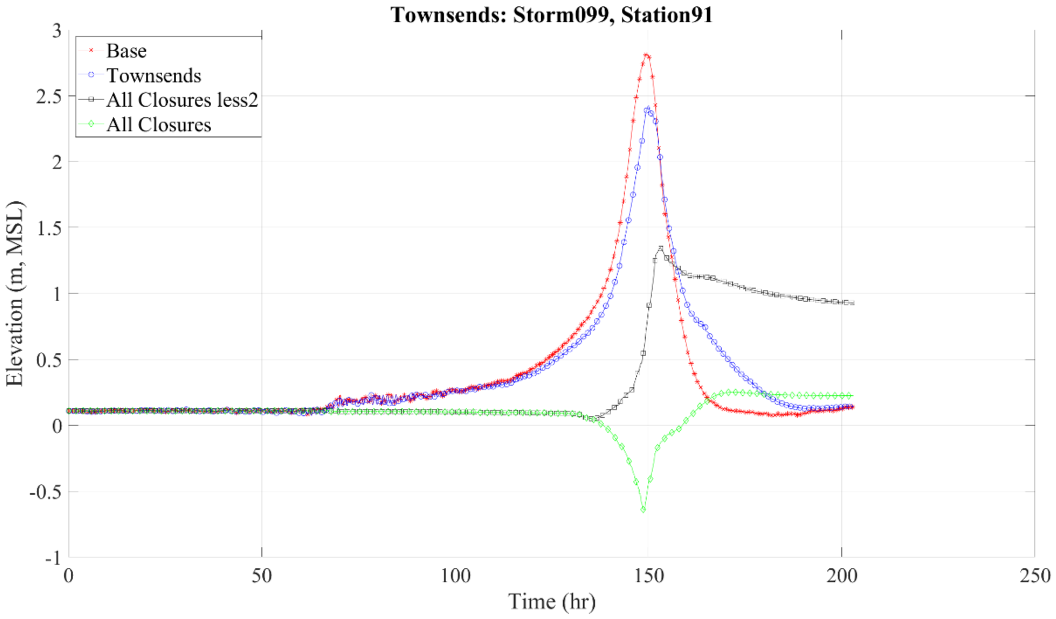


Figure 78: Storm 99: Time series plots for station (save point) 91

Figure 79 and Figure 80 show time series plots of water elevation at selected stations (save points) for tropical synthetic storm 636. The red line shows the Base Grid time series, the blue line shows the time series with Townsend Inlet closed, the black line – the time series for All Closures Closed less2, and the green line – the time series for All Closures Closed.

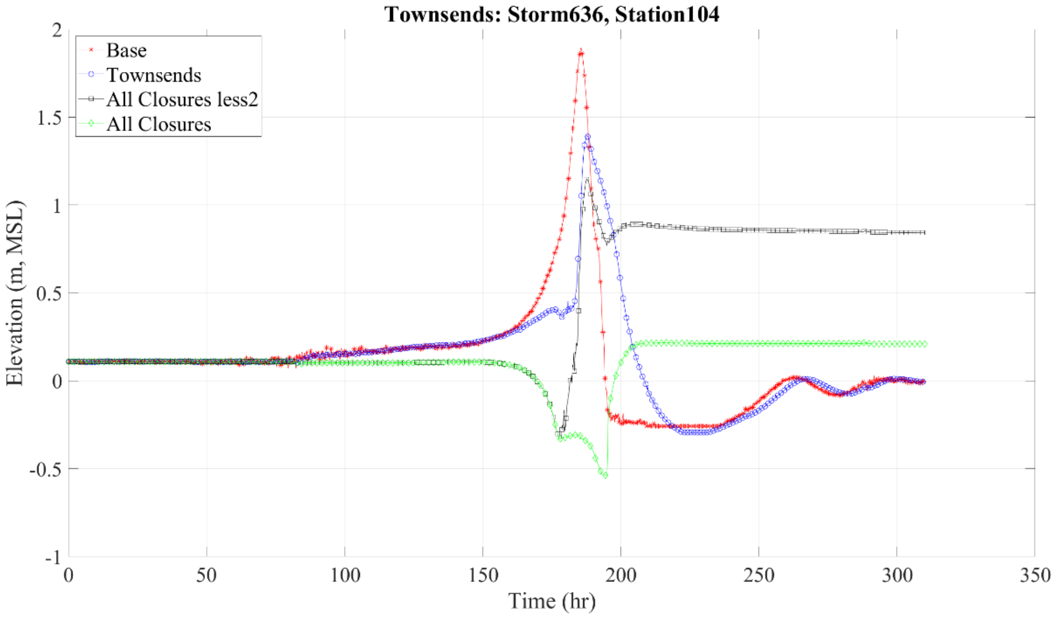


Figure 79: Storm 636: Time series plots for station (save point) 104

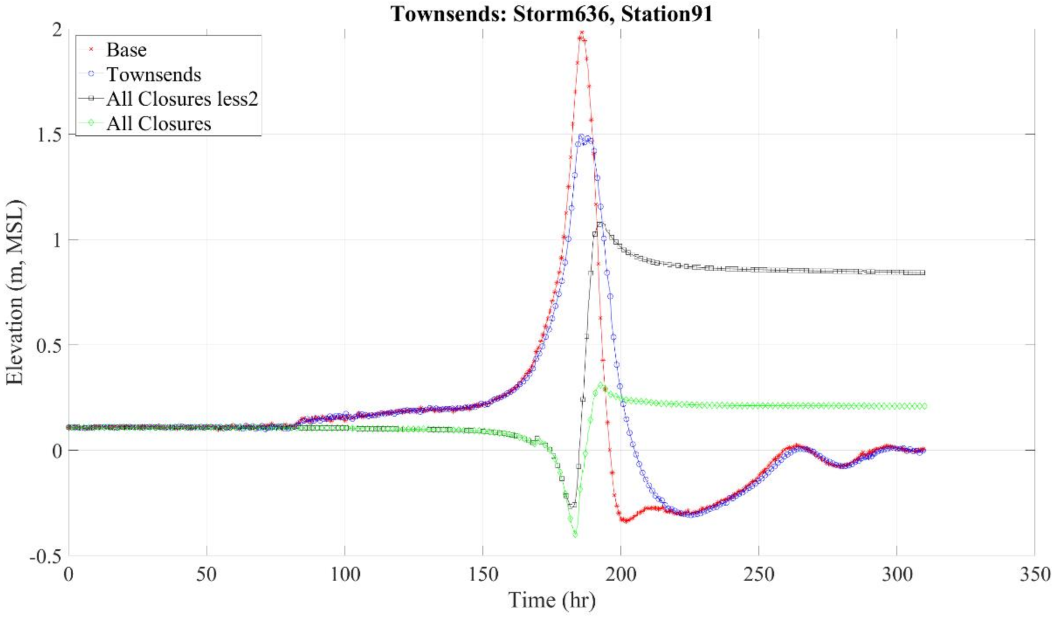


Figure 80: Storm 636: Time series plots for station (save point) 91

Hereford Inlet

Closing Hereford Inlet can potentially have reductions in water level spanning northward to the bay near Corson Inlet and southward to the Cape May Harbor. The greatest reductions are in Jenkins Sound and Grassy Sound near Hereford Inlet, as expected.

Cape May Inlet

Similar to Absecon Inlet, closing Cape May Inlet can cause a reduction or an increase in maximum water levels, depending on the direction of storm winds and corresponding flows. Water entering Hereford Inlet or Cape May Canal could potentially be directed towards the Cape May Inlet closure and become trapped leading to elevated water levels. Other storms showed a reduction in water level in Cape May Harbor when flows entering nearby inlets were not directed to Cape May Harbor.

Cape May Canal

Closing Cape May canal only had a null or detrimental effect on maximum water levels for the 10 storms simulated with this closure in place. Flow entering through Cape May Inlet and Hereford Inlet could potentially lose the ability to flush through the canal, resulting in elevated water levels as was observed for Storm 99, 524, and 636.

AllClosedLess2 versus Base Condition

With all of the inlets closed except Corson Inlet and Little Egg/Brigantine Inlet, the reduction in maximum water level compared to the base condition with all the inlets open is significant in most of the New Jersey back bays, except in the vicinities of the open inlet areas. One notable exception is again, Storm 636 as was described in the evaluation of the Absecon Inlet closure. Surge entering Little Egg/Brigantine Inlet propagates southward into Absecon Bay, then becomes trapped from exiting the Absecon Inlet due to the closure, again demonstrating the importance of closure operations/timing and taking in to consideration multiple points of entry.

In summary, the analysis of Iteration 1 maximum surge envelope focused on the evaluation of the ability of individual surge barriers to alter maximum water levels compared to a base condition with no closures in place. It was found that individual closures can reduce back bay flooding significantly, mainly in the bays closest to the closure location, but if other mechanisms allow flow into the bay then water level reductions can be less significant and closures can also trap water and prevent return flow out of the bays.

Section 4.2 -- Maximum Storm Surge Results – Iteration 2

All Closed versus Base Condition

Closing all 11 inlets with surge barriers dramatically reduces maximum water levels in New Jersey Back Bays, most notably during Storm 99 (Figure 81), with an average reduction of 2.11 m over the entire NJBB system Inlet and an average reduction for all storms of 1.27 m. Closing Little Egg/Brigantine Inlet dramatically reduced the potential for surge propagation into the Little Egg/Manahawkin/Barnegat Bay region. The overall average reduction for those regions doubled from 0.37 m to 0.74 m, with the greatest change (0.59 m ADDITIONAL average reduction) in the Little Egg Harbor with all inlets closed. Maximum reductions are in the central portion of the study area because of the extremely large Little Egg/Brigantine closure length. The average reduction in Great Bay with all inlets closed was 1.31 m.

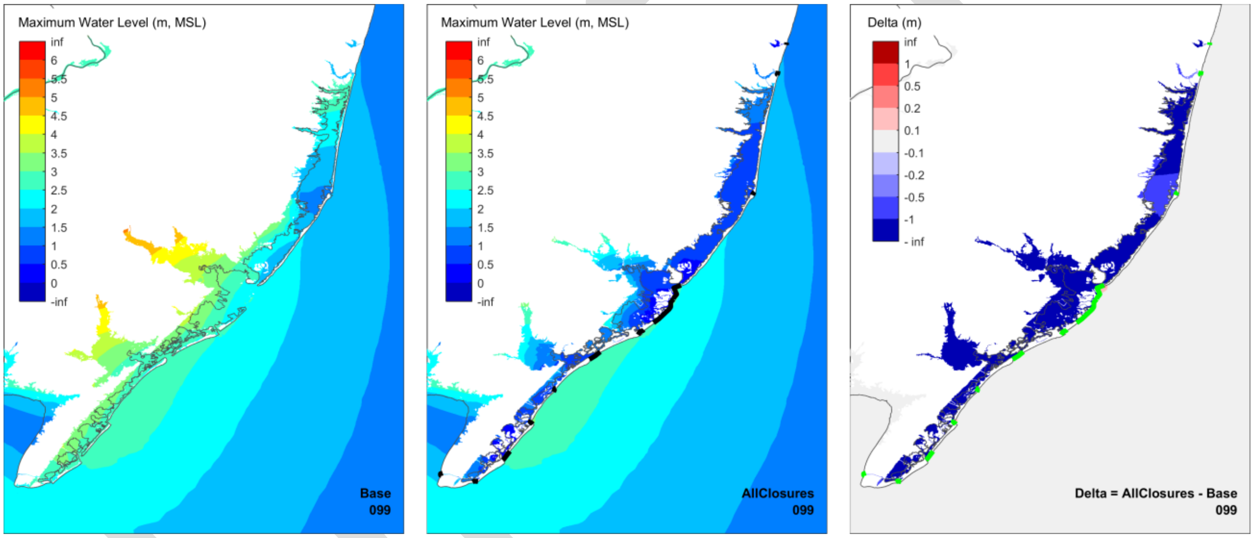


Figure 81: Maximum water elevation for Synthetic Storm 99: Base Grid (left), All Closed (center), and difference between All Closed and Base (right)

N3S3

The closures at Barnegat Inlet, Manasquan, and Holgate generally reduce water levels in Barnegat Bay for all 10 storms. The average reduction in maximum water level for this region is 0.67 m. Some storms, such as 434 and 469 have a more uniform reduction in water level, whereas other storms such as 99, 636, and 646 have a gradation in water level reduction due to a combination of wind direction over the bay, seiching, and barrier island overtopping.

For one of the storms (Storm 99, Figure 82), water level in the bay with the inlet closed is actually higher in the region of the bay immediately inside (bay side) of Barnegat Inlet. For this particular storm and closure configuration, overtopping of the barrier island near

Barnegat Inlet elevates the maximum water level in the small region near the overtopping location.

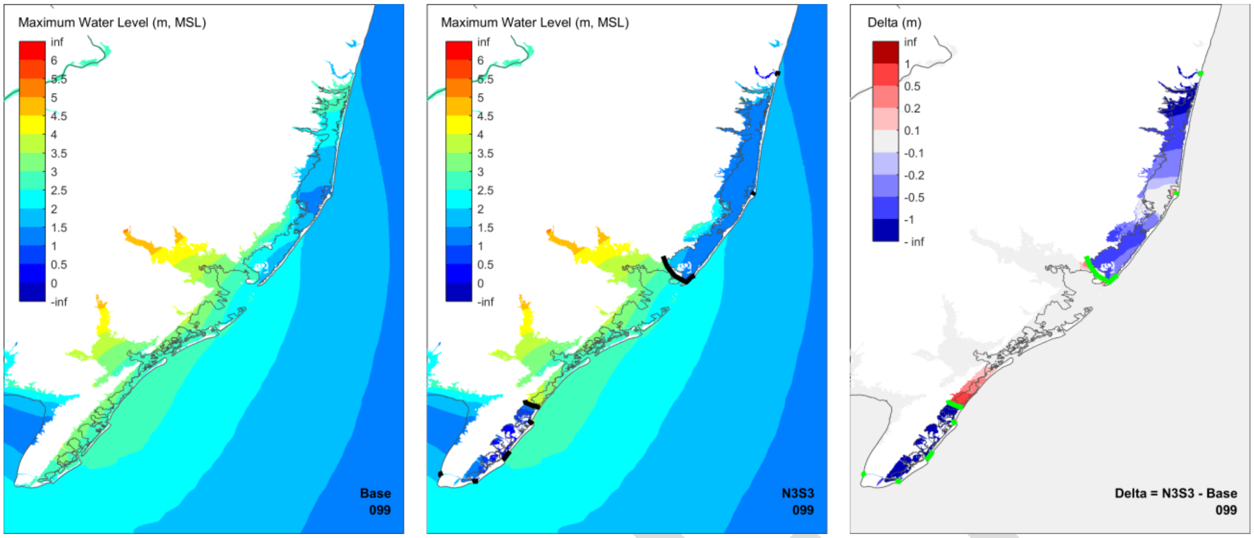


Figure 82: Maximum water elevation for Synthetic Storm 99: Base Grid (left), N3S3 (center), and difference between N3S3 and Base (right)

Storm 636 (Figure 83) shows little change in the north part of the bay from the base condition to the closure condition and the greatest reduction in Manahawkin Bay due to the north to south winds transporting flow into this region for the base condition and a smaller volume of water being transported into this region with the inlet closed. In addition, water levels are elevated inside the bay near the Holgate barrier due to the north to south winds and the Holgate barrier trapping water in the bay (behind the barrier).

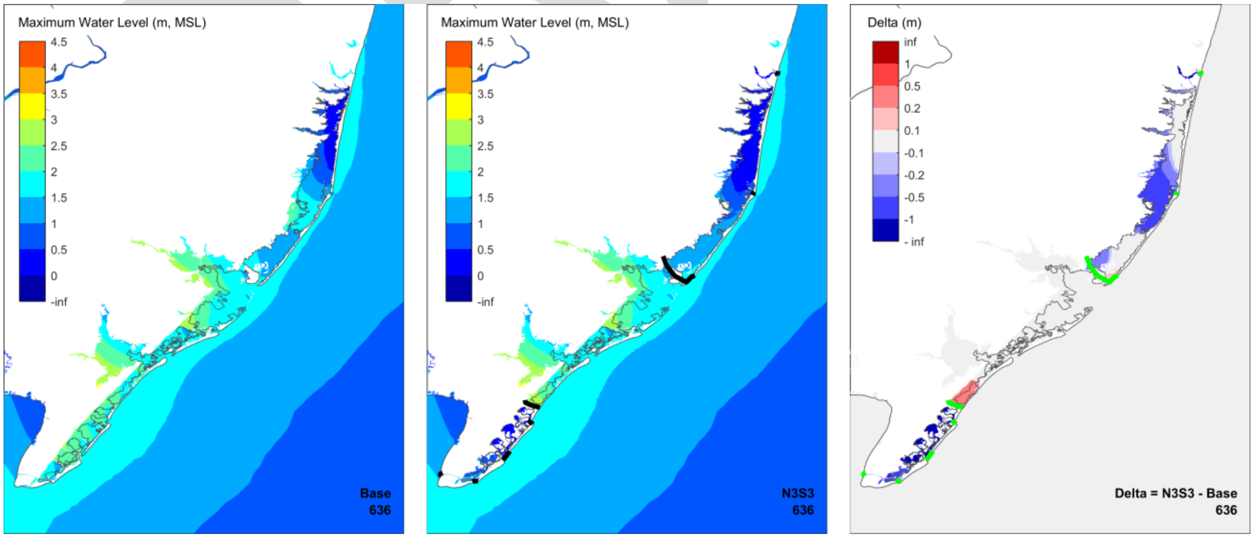


Figure 83: Maximum water elevation for Synthetic Storm 636: Base Grid (left), N3S3 (center), and difference between N3S3 and Base (right)

Even though the direction of Storm 646 is similar to Storm 636, it follows a path that is more seaward of Storm 636 and the resulting winds over Barnegat Bay are less intense. This results in more uniform water level reduction for the N3S3 configuration for this storm compared to the base condition as opposed to the large gradation in response for Storm 636.

In the south (S3) region, all inlets south of Sea Isle Blvd (Townsends, Hereford, Cape May, and Cape May Canal) are closed along with Sea Isle Blvd. Maximum water levels south of Sea Isle Blvd are greatly reduced (average reduction of 1.5 m), which is more uniform and more effective than the reduction in the northern region. The region north of Sea Isle Blvd experiences an increase in maximum water level due to wind direction trying to push water into this region, but the Sea Isle Blvd barrier blocks entry. However this surge buildup at Sea Isle Blvd is not present for Storms 433, 349, and 524 (Figure 84) due to several factors. The fast forward speed of Storms 349 and 433 resulted in a short duration of strong winds over the bay and therefore insufficient wind forcing towards the Sea Isle Blvd closure. Though Storms 349 and 433 differed greatly in intensity, the short duration of winds over the bay for both storms led to similar impacts at the Sea Isle Blvd closure. For Storm 524, the storm track resulted in the major wind direction over the bay being from south to north, therefore water does not pile up on the Sea Isle Blvd closure as was observed for many of the other storms.

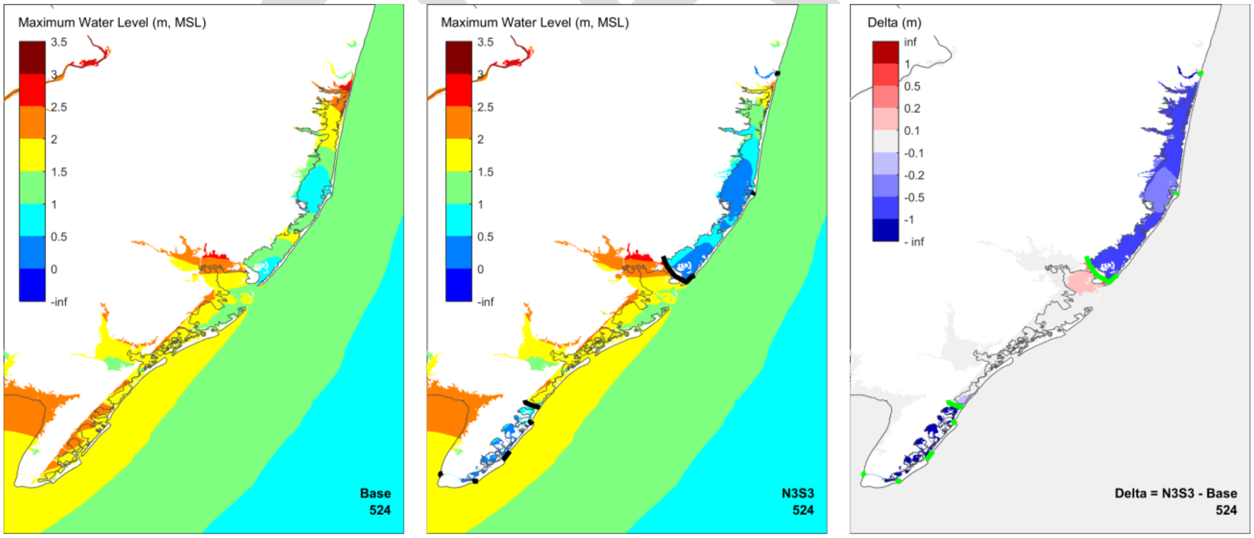


Figure 84: Maximum water elevation for Synthetic Storm 524: Base Grid (left), N3S3 (center), and difference between N3S3 and Base (right)

N4S4

For all storms, there is an increase in water level near the Rte 72 closure. Due to the wind direction, Storms 99, 469, 434 (Figure 85), and 524 experience accumulation of water on the south of the Rte 72 closure, whereas Storms 636 and 646 experience accumulation inside the protected area (adjacent to the Rte 72 closure on the north side). Other storms (357, 350, 433, and 349) experience accumulation on both sides of the Rte 72 closure, due to seiching along the major North-South axis of Barnegat Bay. The Rte 72 closure reduces the fetch length, thereby limiting the seiche amplitude.

In the southern portion of the study area (S4), generally with the bay closures in place, there is a consistent decrease in maximum water level in all protected areas. In addition, the Sea Isle Blvd barrier prevents water from entering from the north, which leads to accumulation north of the Sea Isle Blvd barrier for most storms. As was previously described, Storms 349, 433, and 524 do not show accumulation at the Sea Isle Blvd barrier due mainly to the forward speed of the storm and wind direction over the bay.

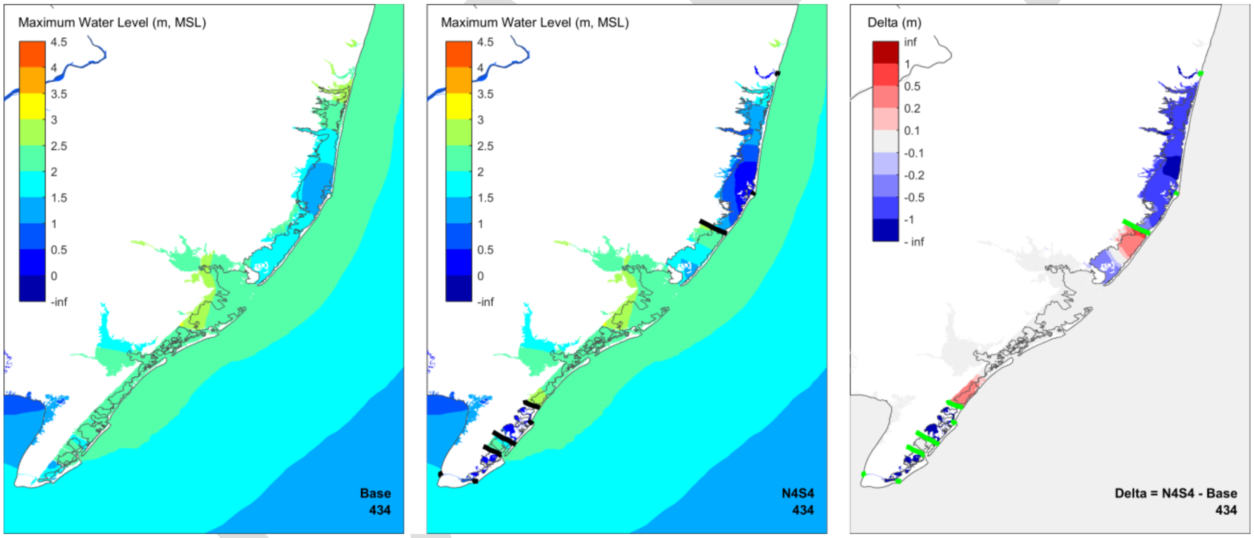


Figure 85: Maximum water elevation for Synthetic Storm 434: Base Grid (left), N4S4 (center), and difference between N4S4 and Base (right)

N5S5

Most storms show a decrease in water level north of the Berkeley barrier and an increase in water level south of the Berkeley barrier (Figure 86). However, the response is reversed for Storm 636 (Figure 87) and 646 due to the wind direction from north to south over the bay for these two storms leading to increased water level north of the barrier and decreased water level south of the barrier. The S5 closure configuration is effective at reducing water level in the southern region. The average reduction in water level is 0.99 m.

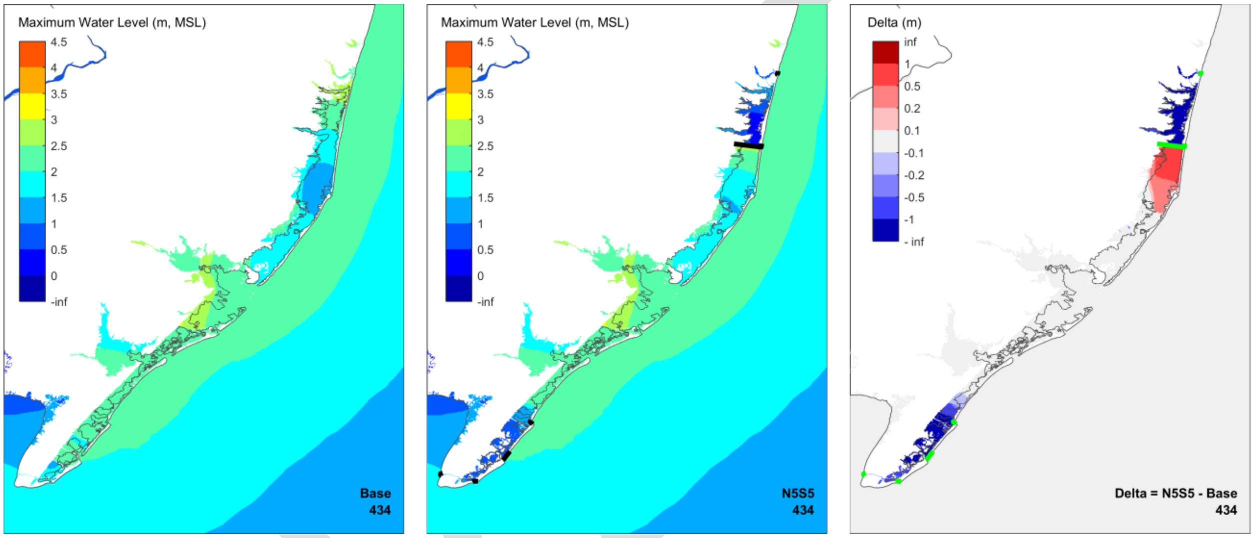


Figure 86: Maximum water elevation for Synthetic Storm 434: Base Grid (left), N5S5 (center), and difference between N5S5 and Base (right)

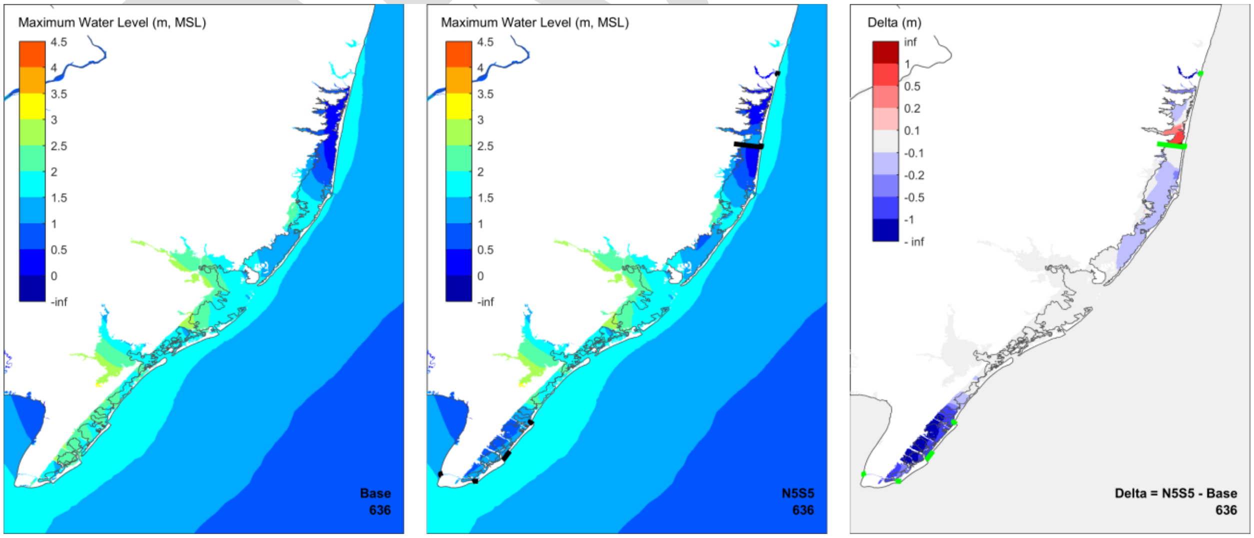


Figure 87: Maximum water elevation for Synthetic Storm 636: Base Grid (left), N5S5 (center), and difference between N5S5 and Base (right)

N6S6

The northern section of this closure configuration behaves like the N5S5 configuration because of the presence of the Berkeley barrier in both cases. The primary difference is without a closure at Manasquan Inlet, storm surge in Manasquan River is effectively the same as the base condition (Figure 88). The results of N6S6 also show that a closure at Manasquan Inlet has relatively little impact on storm surge in Barnegat Bay and is not essential to configurations with closures at Barnegat Inlet. For the southern section, there is a great reduction in water level in the bays with the closures in place for most storms. One exception is Storm 357 which shows that the closures are less effective (not as necessary to be implemented) because this storm is distant from these closure locations and maximum surge levels were not significant even for the base condition with the inlets open.

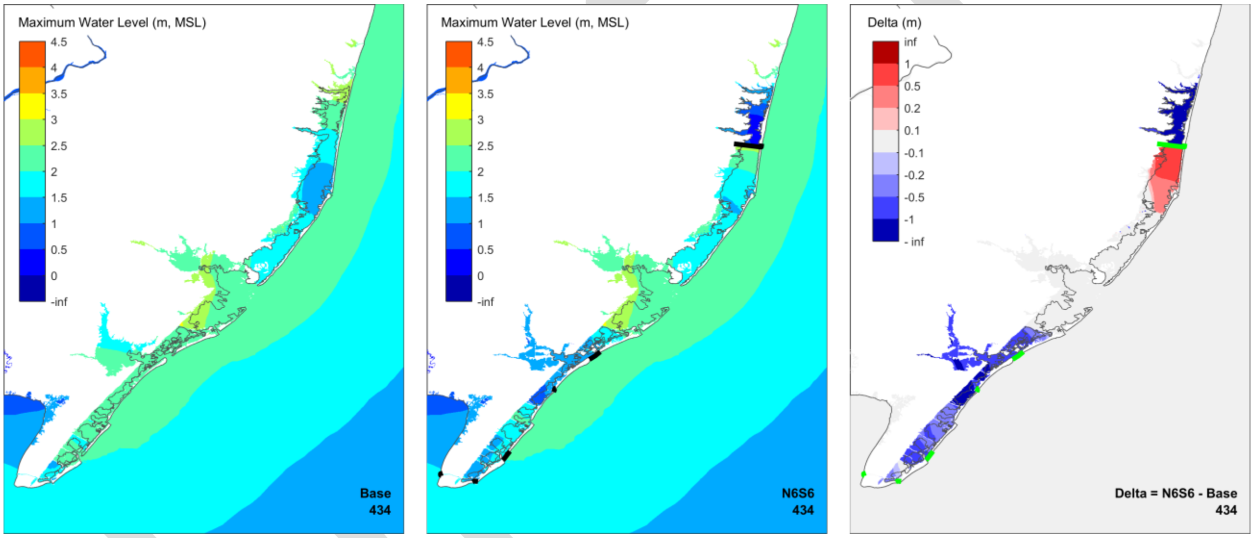


Figure 88: Maximum water elevation for Synthetic Storm 434: Base Grid (left), N6S6 (center), and difference between N6S6 and Base (right)

N7S7

Manasquan Inlet and Point Pleasant Canal closures only reduce water levels in a very limited region behind (bayward) of these closures (Figure 89). The southern region has two basic responses: (1) widespread reduction in peak water level due to the closures in place and 2) an increase in maximum water level in the Cape May area for a few storms (350 and 636, Figure 90) due to wind direction and slower storm speeds allowing flow entering from the open area bayward of Hereford Inlet and transmitting that flow southward towards Cape May. With Cape Inlet closed, the water is entrapped and maximum water levels increase in this region.

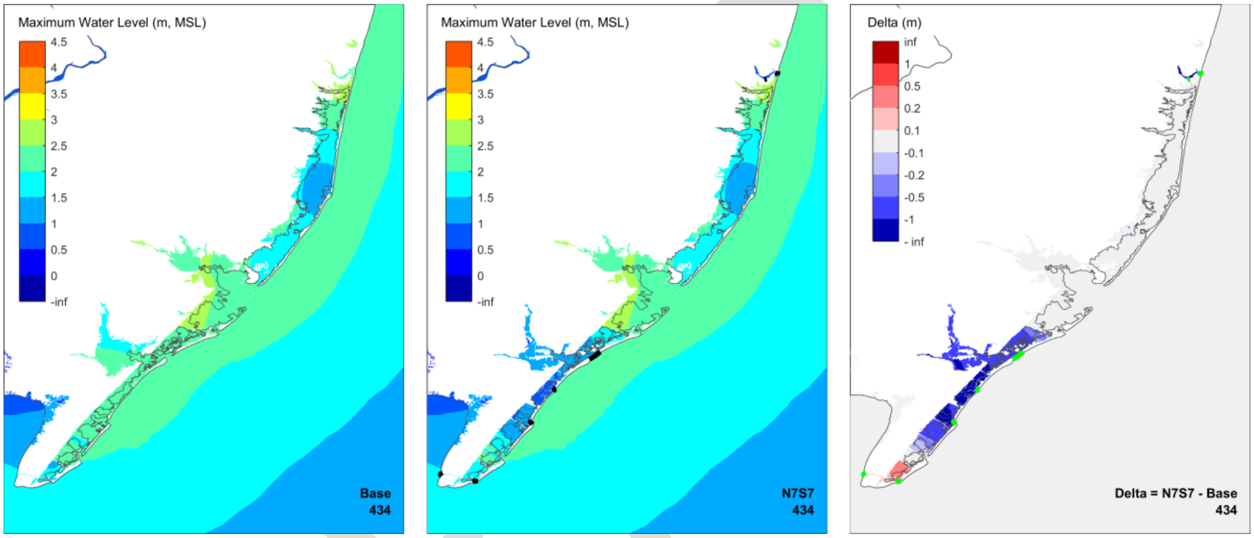


Figure 89: Maximum water elevation for Synthetic Storm 434: Base Grid (left), N7S7 (center), and difference between N7S7 and Base (right)

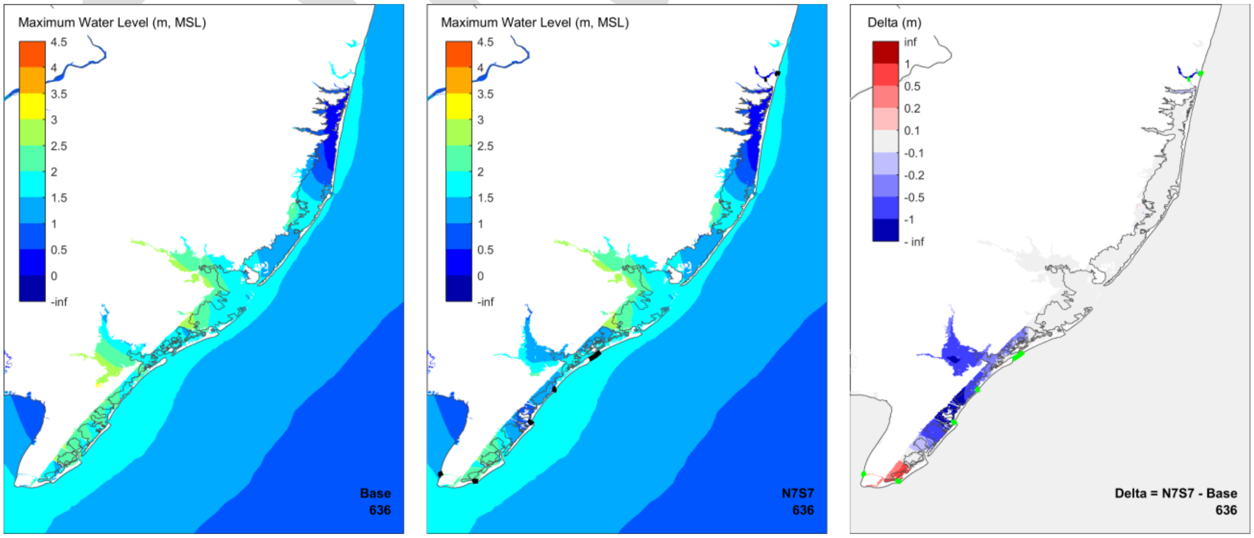


Figure 90: Maximum water elevation for Synthetic Storm 636: Base Grid (left), N7S7 (center), and difference between N7S7 and Base (right)

S8 and S9

These two configurations result in water level responses that are similar to N7S7 for all areas north of Hereford Inlet. There is significant reduction in water level in all south bay areas. It is interesting to note the difference in water level response for N7S7 versus S8 (Figure 91) and S9 (Figure 92) near Cape May for Storms 99, 350, 357, and 636 due to the opening at Hereford for N737, Cape May Inlet for S8, and Cape May Canal for S9. For N7S7, the volume of water entering Hereford Inlet is pushed southward towards Cape May, where it is trapped by the Cape May Inlet and Cape May Canal closures. For S8 and S9, the supply of water from the Hereford Inlet region is eliminated by the Hereford Inlet closure, which reduces the volume of water that can be transported southward during these storms. In addition, the Cape May Inlet (S8) and Cape May Canal (S9) openings allow water to escape rather than build up as was observed for N7S7. Water levels seaward of the closures increase by approximately 0.25 m for the most intense storm (Storm 433).

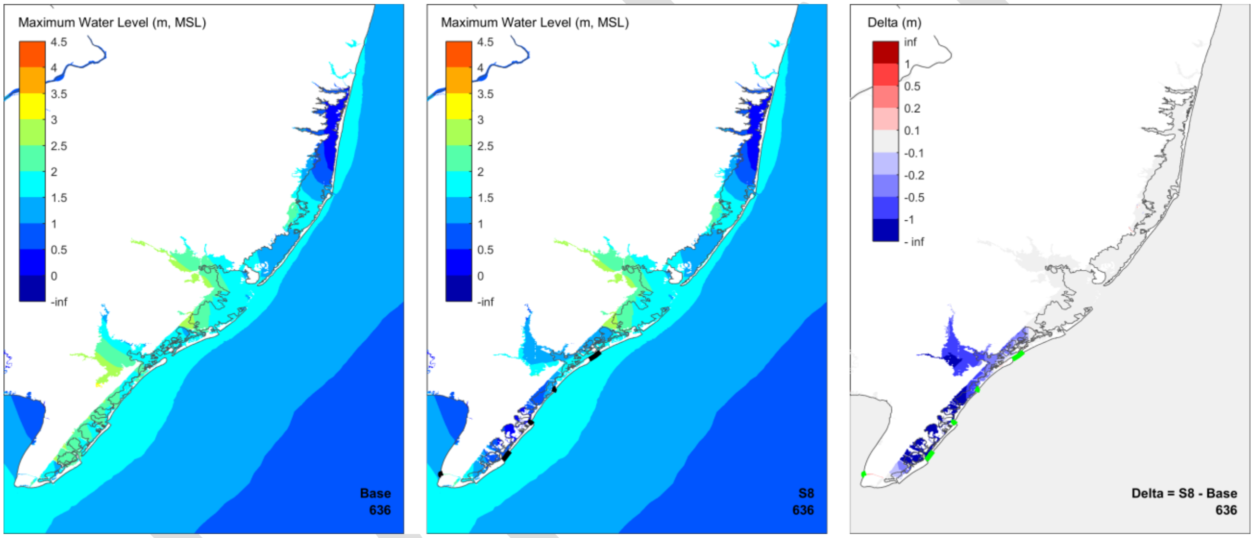


Figure 91: Maximum water elevation for Synthetic Storm 636: Base Grid (left), S8 (center), and difference between S8 and Base (right)

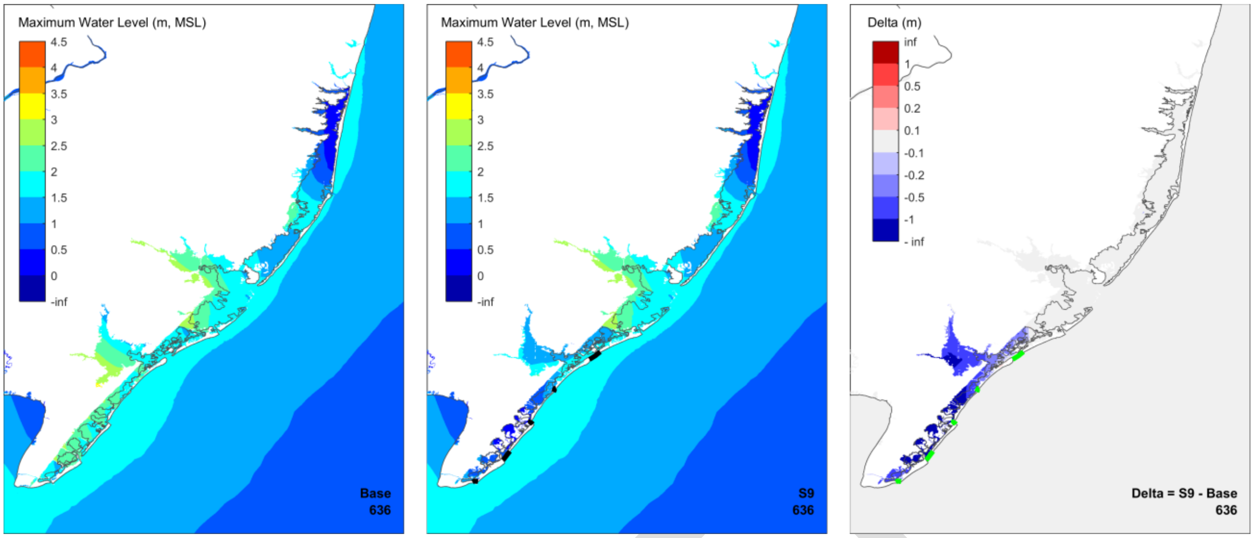


Figure 92: Maximum water elevation for Synthetic Storm 636: Base Grid (left), S9 (center), and difference between S9 and Base (right)

S10

For all storm events, there is significant reduction in peak water level for the protected areas (Figure 93). One interesting observation for this configuration is that leaving Great Egg Inlet open allows an escape route (flushing) of flow entering from other areas, rather than building up behind a closure. Also for Storm 433, allowing flow to enter the bays reduces the surge buildup on the barrier island side, seaward of the bays for this configuration.

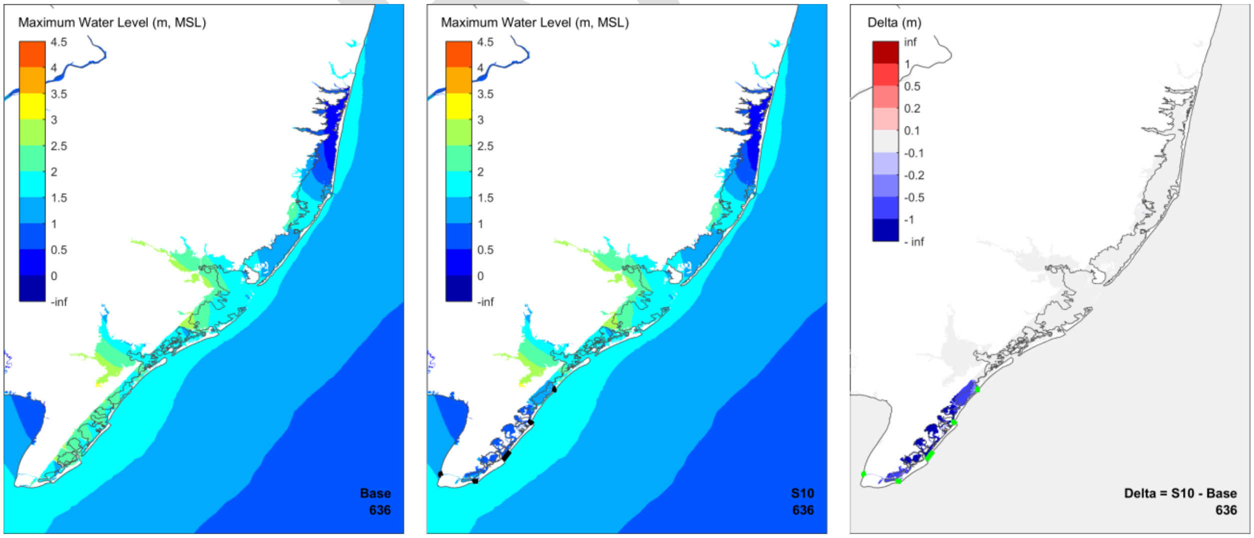


Figure 93: Maximum water elevation for Synthetic Storm 636: Base Grid (left), S10 (center), and difference between S10 and Base (right)

C3

This configuration generally led to a reduction in peak water level compared to the base condition for bay areas behind Absecon and Great Egg Inlets and an increase in peak water level north of North Point (Figure 94). One exception is Storm 524 (Figure 95) which did not show an increase in peak water level north of North Point due to wind direction. The greatest reduction in peak water level was observed for Storms 99, 350, 434, and 636 due to the slow forward speed of these events and Storm 433 due to its great intensity. All other storms showed a reduction in peak water level in the protected areas, however the reduction was less significant than the previously mentioned storms.

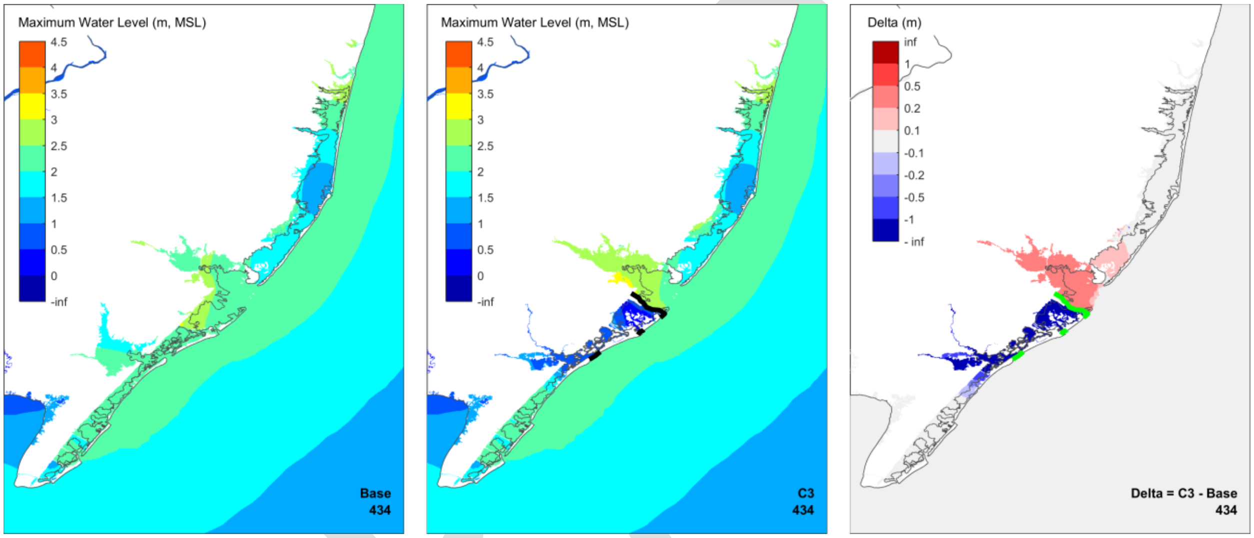


Figure 94: Maximum water elevation for Synthetic Storm 434: Base Grid (left), C3 (center), and difference between C3 and Base (right)

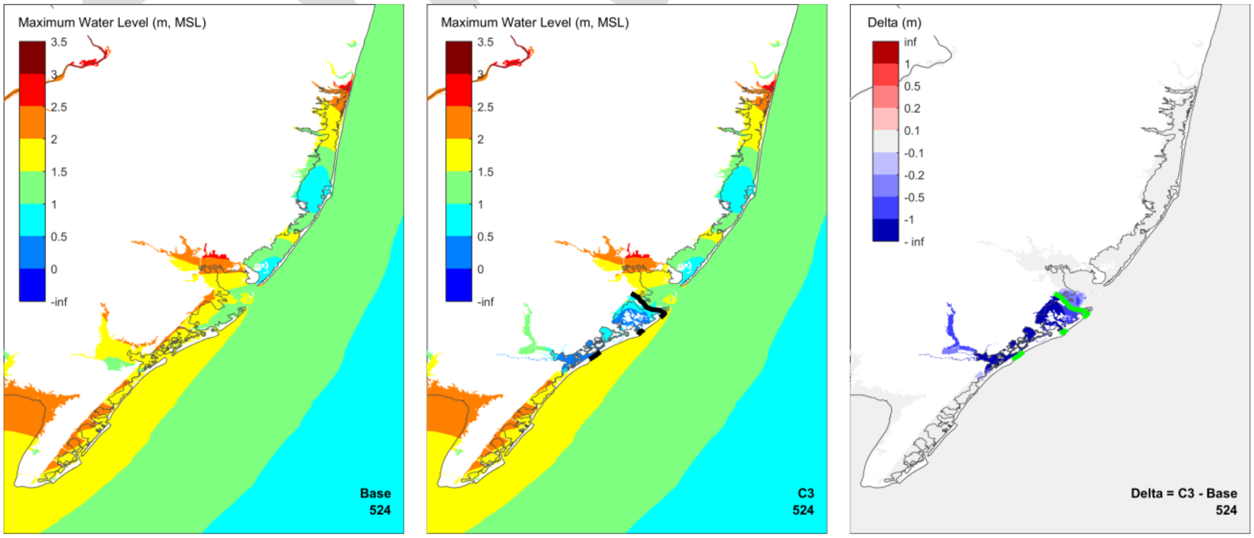


Figure 95: Maximum water elevation for Synthetic Storm 524: Base Grid (left), C3 (center), and difference between C3 and Base (right)

C4

This configuration responds similar to the C3 response, the primary difference is that an increase in peak water levels are observed at Brigantine since the bay closure is moved south to Absecon Blvd (Figure 96 and Figure 97).

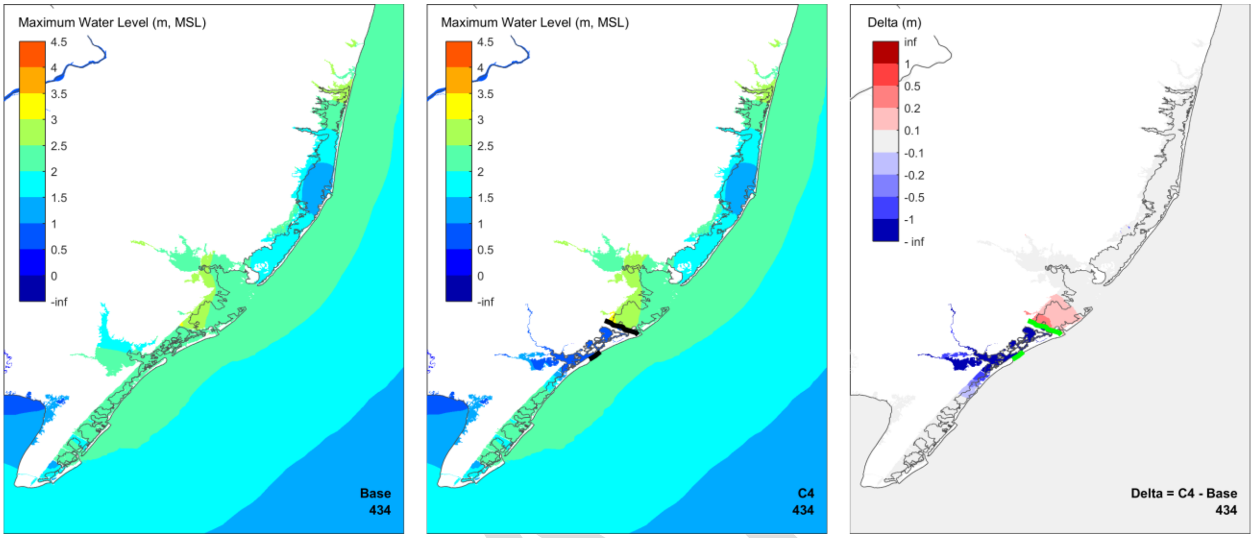


Figure 96: Maximum water elevation for Synthetic Storm 434: Base Grid (left), C4 (center), and difference between C4 and Base (right)

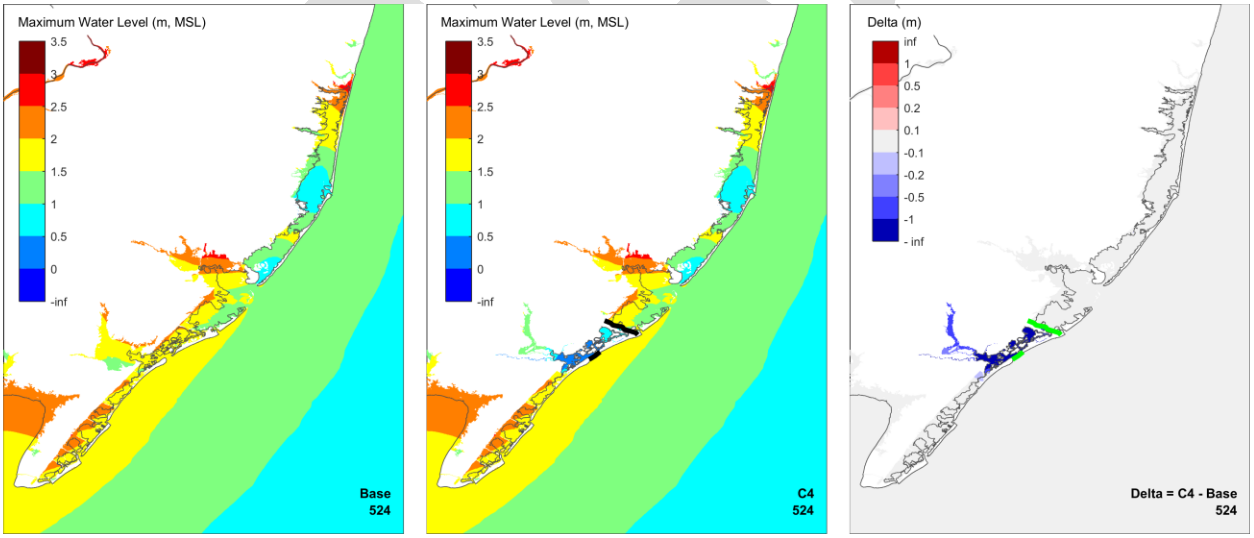


Figure 97: Maximum water elevation for Synthetic Storm 524: Base Grid (left), C4 (center), and difference between C4 and Base (right)

C5

In general, water levels are reduced within the bounds of the closures at Absecon Blvd, Great Egg, and 52nd St and water levels increase north of this region due to wind direction (Figure 98). Storm 433 results in increased accumulation seaward of the closures for this high intensity storm. Storms 349 and 524 (Figure 99) show increased accumulation on the south side of the enclosed region due to the south to north wind direction over the bay for these storms. Storm 357 shows no closure-induced accumulation external to the closures because this storm made landfall distant from the C5 area.

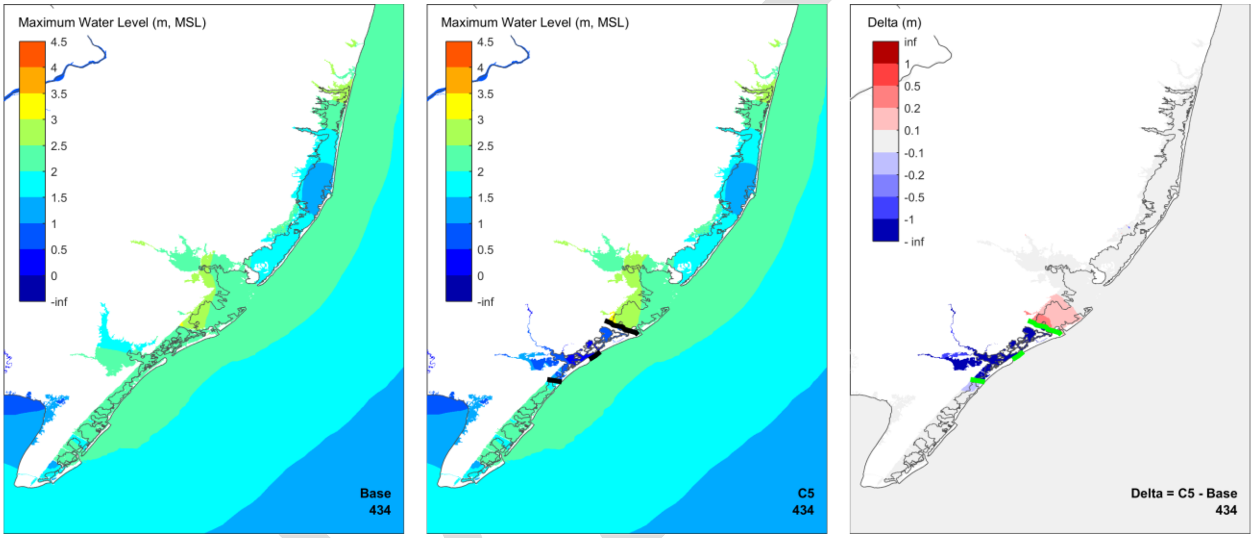


Figure 98: Maximum water elevation for Synthetic Storm 434: Base Grid (left), C5 (center), and difference between C5 and Base (right)

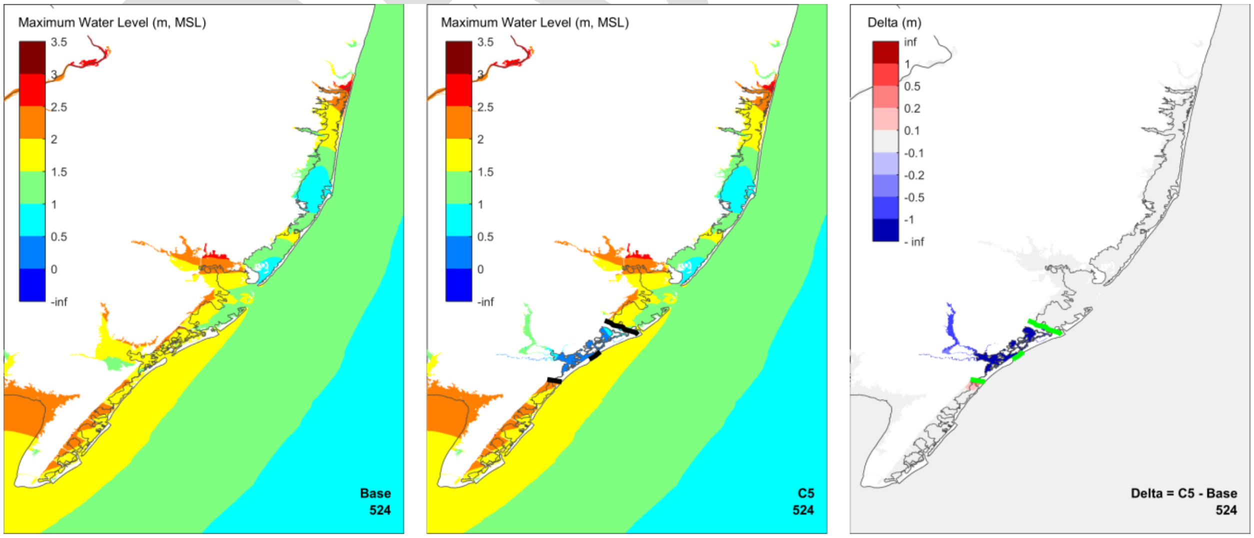


Figure 99: Maximum water elevation for Synthetic Storm 524: Base Grid (left), C5 (center), and difference between C5 and Base (right)

C6

In general, a very small section of the bay between Absecon Blvd and Somers Longport Blvd experiences a reduction in peak water level between these closures and areas north of Absecon Blvd experience an increase in water level (Figure 100), except for Storm 349 which experiences an increase in water level on the south (Somers Longport Blvd) side of the closure due to wind direction. For Storm 433, there is an increase in water level external to the closures on both the north and south ends of the region due to the storms intensity. For Storm 99, there is an increase north of Absecon Blvd and reduction in water level south of Somers Longport Blvd. This is due to the wind direction. Normally water would pass north to south, however with the closures in place, the supply of water from the north is prevented from reaching the southern region, therefore resulting in a reduction in water level south of Somers Longport Blvd.

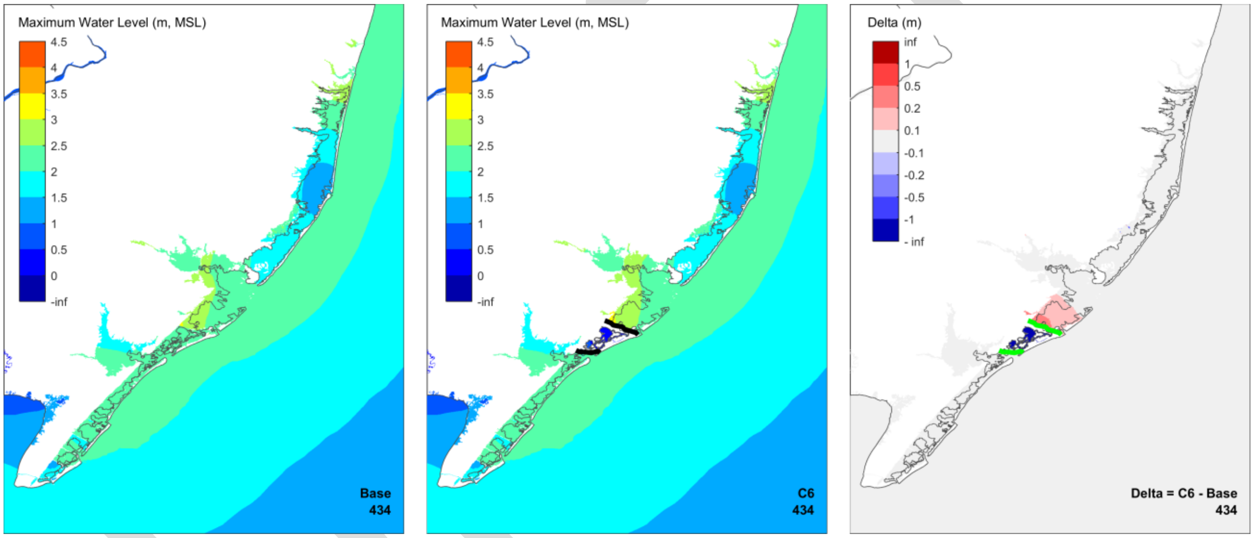


Figure 100: Maximum water elevation for Synthetic Storm 434: Base Grid (left), C6 (center), and difference between C6 and Base (right)

C7

This configuration responds similar to many of the other "C" configuration, with reduction in peak water level internal to the closures and an increase in peak water level external north of the Absecon Blvd closure, dependent on wind direction. The purpose of this configuration was to determine how a closure at Corson Inlet would impact peak water levels, north of the closure, at the southern end of Ocean City. Comparison of the results for C4 and C7 shows that the impact of Corson Inlet is limited to a relatively small area north of the inlet and doesn't significantly impact water levels in Great South Bay.

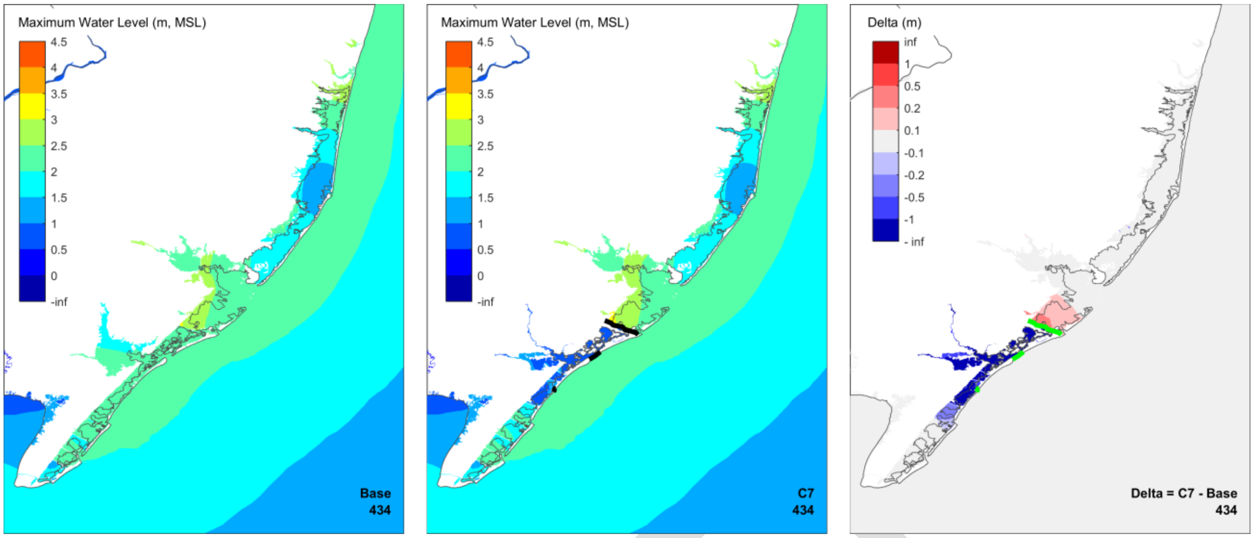


Figure 101: Maximum water elevation for Synthetic Storm 434: Base Grid (left), C7 (center), and difference between C7 and Base (right)

Section 4.3 -- Maximum Storm Surge Results – Iteration 3

Shark River Region

The Iteration 3 model results for the All Closed Configuration confirmed earlier observations that a closure at Shark River is effective at reducing peak water levels inside the inlet. The still water level (SWL) hazard curve for both the baseline and All Closed configurations, Figure 102, shows that a closure at Shark River effectively blocks storm surge from entering Shark River, with the 100-year SWL reduced from 3.2 m (MSL) in the baseline configuration to 1.0 m (MSL) in the All Closed configuration. Shark River Inlet is independent of all the other inlets so only one configuration, All Closed, is evaluated.

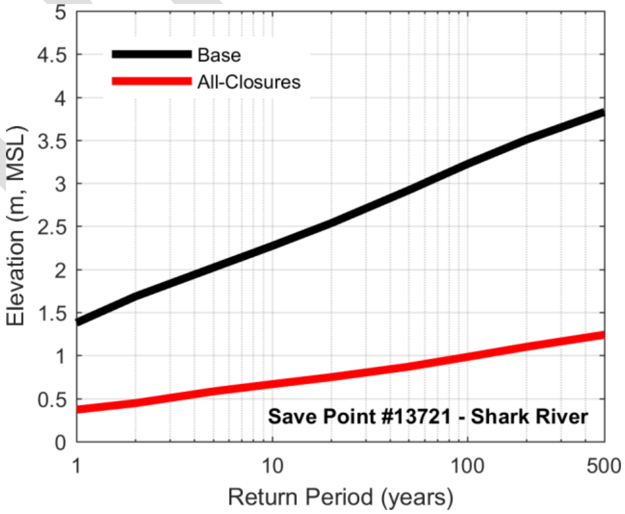


Figure 102: Shark River SWL Hazard Curves

North Region

Four configurations (All Closed, All Closed Less 2, N3S3, and N7S4) plus the baseline configuration are evaluated in Iteration 3. The performance of the four configurations is characterized in this section by presenting the SWL hazard curves (Figure 104) at six locations throughout the North Region (Figure 103).

All Closed is generally the most effective configuration with significant reductions in SWL across the region. The hazard curves for Baseline and All Closed generally bracket the performance of all other configurations. Configurations with hazard curves closer to All Closed are more effective at reducing peak SWLs. As noted during Iteration 2, even though all the inlets are closed, the potential for elevated SWL is not eliminated since overwash may occur at a couple locations along Long Beach Island and winds are capable of generating seiches in the bay.

All Closed Less 2, closures at Manasquan Inlet and Barnegat Inlet, is nearly as effective as All Closed from Barnegat Light to Manasquan with significant reductions in SWL. However, peak SWLs from Surf City to Mystic Island are closer to the baseline condition, confirming an earlier observation that peak SWLs in lower Barnegat Bay are dominated by flow from Little Egg Inlet.

N3, closures at Manasquan Inlet, Barnegat Inlet, and a bay closure at Holgate, is similar in performance to All Closed Less and All Closed Less 2 from Barnegat Light to Manasquan, with significant reductions in peak SWLs. The bay closure at Holgate significantly reduces peak SWLs along Long Beach Island, as observed in the Beach Haven and Surf City hazard curves. However, the potential for seiching and wind piling up storm surge near the bay closure limits the effectives of the bay closure at the southern end of Long Beach Island (Beach Haven).

N7, closures at Manasquan Inlet and a bay closure at Point Pleasant Canal, is effective at reducing peak SWLs in Manasquan, with little or no effect on water levels in Barnegat Bay. It is noted that Point Pleasant, shoreline between Manasquan Inlet and Barnegat Bay, is still vulnerable to flooding from elevated water levels in Barnegat Bay.

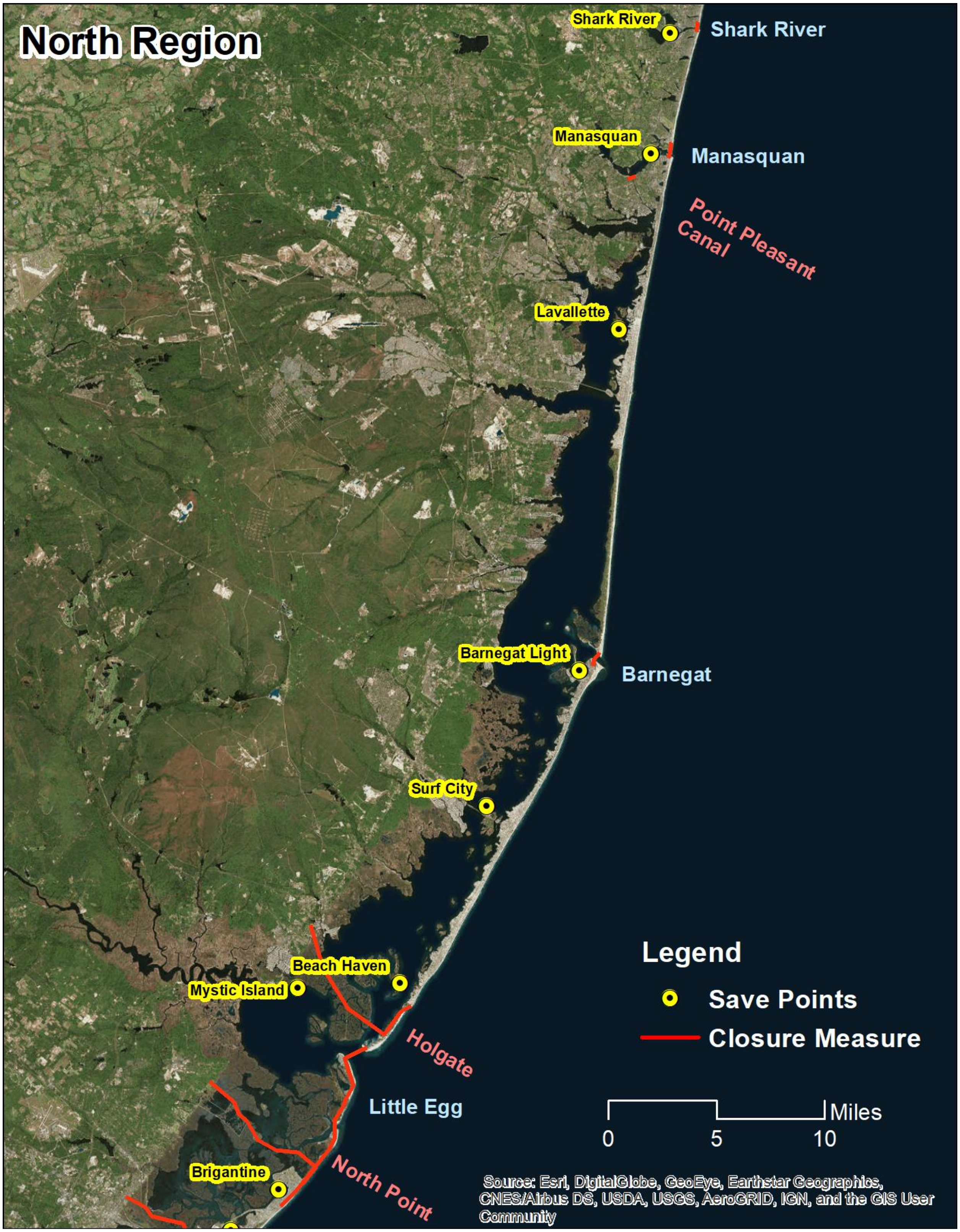


Figure 103: North Region and Save Points

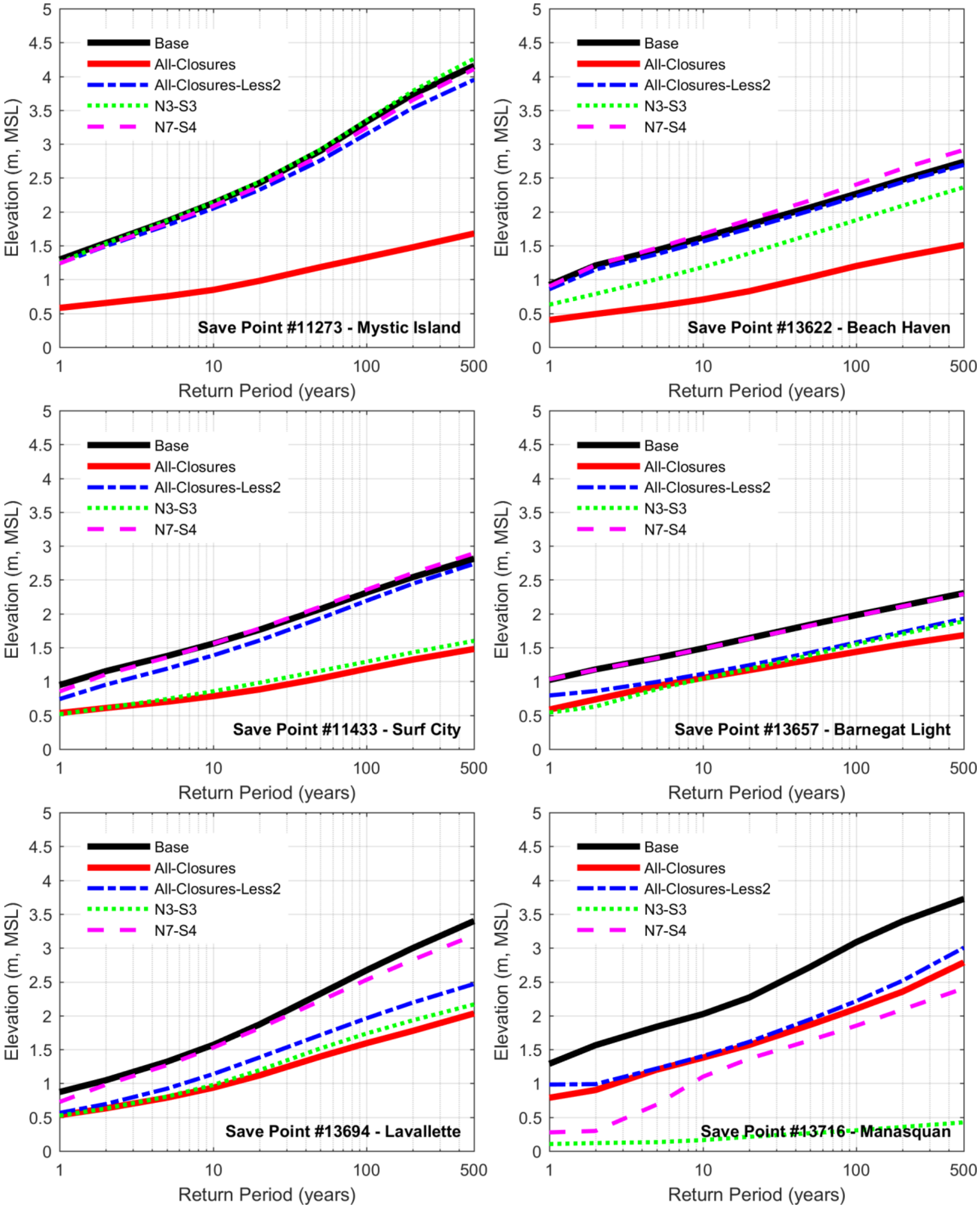


Figure 104: North Configurations SWL Hazard Curves

Central Region

Four configurations (All Closed, All Closed Less 2, C3, and C4) plus the baseline configuration are evaluated in Iteration 3. The performance of the four configurations is characterized in this section by presenting the SWL hazard curves at six locations (Figure 106).throughout the Central Region (Figure 105)

All Closed is generally the most effective configuration with significant reductions in SWL across the region. The hazard curves for Baseline and All Closed generally bracket the performance of all other configurations. Configurations with hazard closer to All Closed are more effective at reducing peak SWLs. As noted during Iteration 2, even though all the inlets are closed, the potential for elevated SWL is not eliminated since winds are capable of generating wind setup and seiches in the bay.

All Closed Less 2, closures at Absecon Inlet and Great Egg Inlet, has peak SWLs that are about halfway between the Baseline and All Closed. All Closed Less 2 is most effective in immediate vicinity of Great Egg Inlet (Ocean City 4th St.) and less effective near Corson Inlet (Ocean City 43rd Street) and Little Egg Inlet (Brigantine) where peak SWLs are affected by flow from the open inlets.

C3, closures at Absecon Inlet, Great Egg Inlet, and a bay closure at North Point, is more effective than All Closed at Brigantine and Absecon Inlet since the bay closure at North Point blocks the flow of storm surge from Little Egg Inlet. The North Point bay closure also reduces the potential for wind setup and large seiches associated with Barnegat Bay. Peak SWLs at Atlantic City and Ocean City 4th St. are also lower than All Closed Less 2, and nearly equal to All Closed. Further south at Ocean City 43rd St, the peak SWLs are nearly the same as All Closed Less 2 with storm surge from Corson Inlet reducing the effectiveness of C3.

C4, closures at Great Egg Inlet and a bay closure at Absecon Blvd, does not improve peak SWLs at Mystic Island, Brigantine, or Absecon Inlet, and has the potential to increase peak SWLs at these locations. South of Absecon Blvd, at Atlantic City and Ocean City and inside Great Egg Harbor, C4 is effective at reducing peak SWLs with hazard curves that closely match C3.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 105: Central Region and Save Points

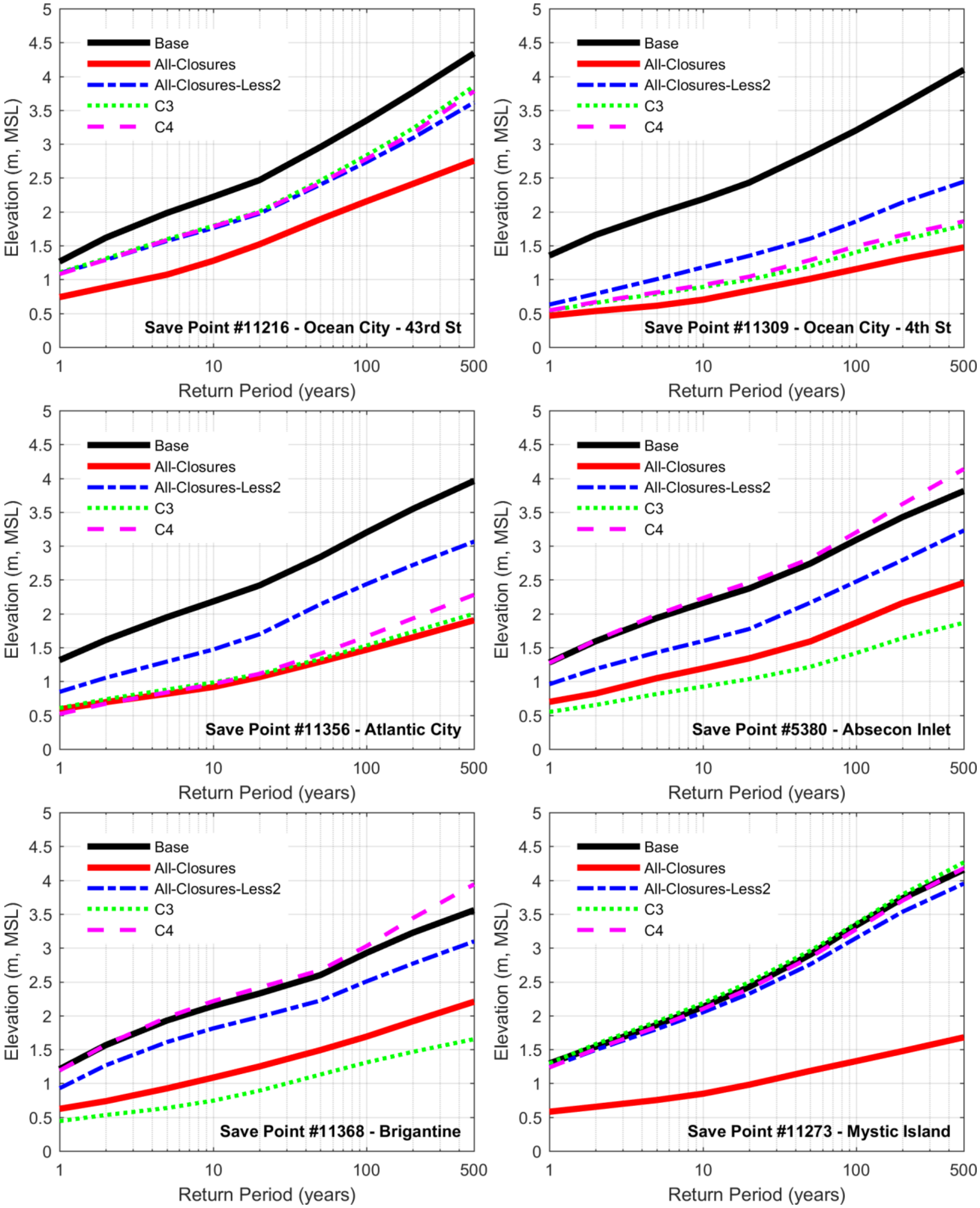


Figure 106: Central Configurations SWL Hazard Curves

South Region

Four configurations (All Closed, All Closed Less 2, S3, and S4) plus the baseline configuration are evaluated in Iteration 3. The performance of the four configurations is characterized in this section by presenting the SWL hazard curves (Figure 108) at six locations throughout the South Region (Figure 107).

All Closed is generally the most effective configuration with significant reductions in SWL across the region. The hazard curves for Baseline and All Closed generally bracket the performance of all other configurations. Configurations with hazard closer to All Closed are more effective at reducing peak SWLs. As noted during Iteration 2, even though all the inlets are closed, the potential for elevated SWL is not eliminated since winds are capable of generating wind setup and seiches in the bay.

All Closed Less 2, closures at Townsends Inlet, Hereford Inlet, Cape May Inlet, and Cape May Canal, is effective at reducing peak SWLs for the majority of the South Region. Elevated peak SWLs are observed at Ludlam Bay due to proximity to Corsons Inlet (open) as well as at Cape May, where wind setup and seiching limit the effectiveness of even the All Closed configuration. Peak SWLs at Wildwood are reduced from approximately 3.3 m (MSL) to 1.3 m (MSL) at the 100-year return period. Similar reductions are observed at Stone Harbor, Mayville, and Sea Isle City.

S3, closures at Townsends Inlet, Herford Inlet, Cape May Inlet, Cape May Canal, and a bay closure at Sea Isle Blvd, is similar in performance to All Closed Less 2 except with a notable improvement at Sea Isle City. The bay closure at Sea Isle Blvd reduces peak SWLs south of the closure (Sea Isle City), but has the potential to increase peak SWLs in Ludlam Bay.

S4, closures at Townsends Inlet, Cape May Inlet, Cape May Canal, and three bay closures at Sea Isle Blvd, Stone Harbor Blvd. and N. Wildwood Blvd, is designed to reduce peak SWLs in the South Region without a closure at Hereford Inlet which may be environmentally untenable. The three bay closures allow Hereford Inlet and Corson Inlet to remain open and block storm surge from propagating into the majority of the bays in the South Region. S4 is the most effective configuration at Cape May, with peak SWLs below the All Closed configuration. At other locations, Wildwood, Stone Harbor, Sea Isle City, peak SWLs are similar to All Closed. The bay closures have the potential to increase peak SWLs on the exterior side of the closures, as observed at Mayville and Ludlam Bay.

Figure 107: South Region and Save Points

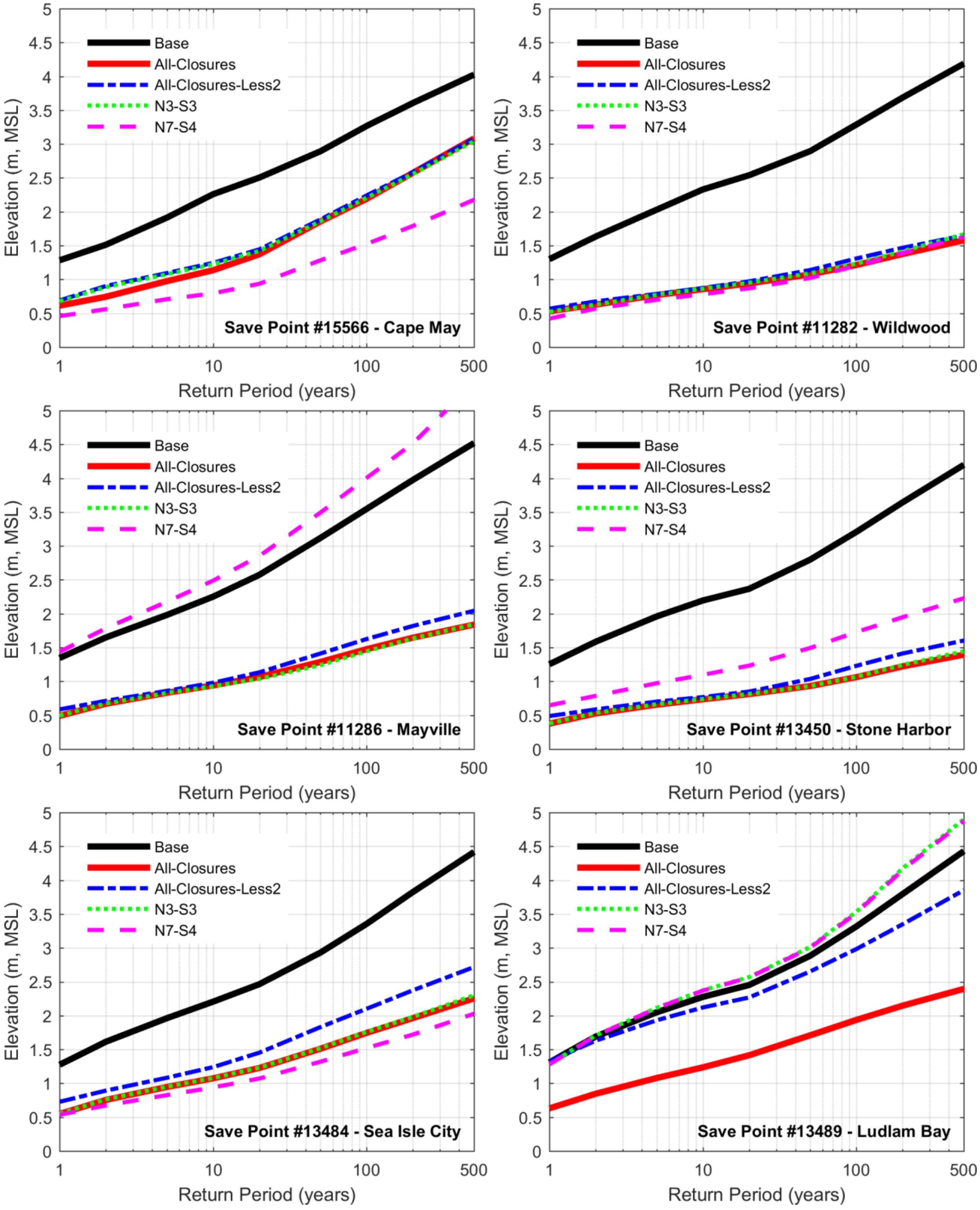


Figure 108: South Configurations SWL Hazard Curves

Section 5 -- Conclusions

The USACE Engineer Research and Development Center (ERDC), Coastal and Hydraulics Lab (CHL) conducted a numerical modeling study to evaluate the effectiveness of storm surge barriers in reducing water levels in the study area. ERDC-CHL leveraged the existing NACCS CSTORM-MS complete the numerical modeling study. As part of this numerical modeling study the existing condition water levels in the study area were updated from NACCS to ensure that the existing and with-project water levels were consistent and derived from a common model, set of storms, and statistical evaluation.

An iterative modeling approach was devised that would allow a large number of inlet closures and potential inlet closure combinations to be considered before converging on a smaller final set of inlet closure alternatives.

Iteration 1 focused on the ability of individual closures to alter maximum water levels compared to a base condition with no closures in place. It was found that individual closures can reduce back bay flooding, mainly in the bays closest to the closure location, but adjacent inlets may allow flow into the bay then water level reductions can be less significant. Individual closures at Great Egg Inlet, Barnegat Inlet, and Shark River Inlet were most effective. Individual closures from Cape May to Corson Inlet were not as effective and may perform better as part of system of closures. A closure at Manasquan Inlet was effective for storms where the predominant wind direction from the north, however, storms with winds from the south could push storm surge up into northern Barnegat Bay and Manasquan limiting the closure's effectiveness.

Iteration 2 focused on evaluating systems (multiple) of closures including cross-bay closures ("bay closures"). Many of the configurations were designed around leaving the most environmentally sensitive inlets open: Little Egg/Brigantine, Corson, and Hereford. The numerical modeling results show that many of the Iteration 2 configurations are effective at reducing back bay water levels. However, some of the configurations such as All Closures Less 2 showed considerable sensitivity to the storm and wind directions and it was unclear what the impact would be on the hazard curve. Iteration 2 also showed that many of the bay closures have the potential to increase surge on the unprotected side of the closure as wind-blown water piles up against the closure.

Iteration 3 focused on the 6 configurations selected based on their ability to generate the greatest NED benefits (flood damages reduce minus project costs) and be environmentally acceptable. Using Gaussian process metamodeling (GPM) and a design of experiments (DoE) approach, CHL completed the frequency distributions of response for both the baseline and alternative configurations. An evaluation of the Iteration 3 hazards curves indicate that several of the configurations are effective at reducing peak still water levels and have the potential to generate significant economic benefits.

Section 6 -- References

Cialone, Mary A., Massey, T. Chris , Anderson, Mary E. , Grzegorzewski, Alison S. , Jensen, Robert E. , Cialone, Alan , Mark, David J. , Pevey, Kimberly C. , Gunkel, Brittany L. , McAlpin, Tate O. , Nadal-Caraballo, Norberto , Melby, Jeffrey A. , and Ratcliff, Jay J. (2015) “North Atlantic Coast Comprehensive Study (NACCS) coastal storm model simulations: Waves and water levels”. U.S. Army Engineer Research and Development Center, ERDC/CHL TR-15-14.

Jia, G., and Taflanidis, A.A. (2013) “Kriging metamodeling for approximation of high-dimensional wave and surge responses in real-time storm/hurricane risk assessment”. Computer Methods in Applied Mechanics and Engineering, vol. 261-262, pp. 24-38.

Jia, G., Taflanidis, A.A., Nadal-Caraballo, N.C., Melby, J.A., Kennedy, A.B., and Smith, J.M. (2015) “Surrogate modeling for peak or time-dependent storm surge prediction over an extended coastal region using existing database of synthetic storms”. Natural Hazards, 81(2): 909-938.

Kim, S.W., Melby, J.A., Nadal-Caraballo, N.C., and Ratcliff, J. (2015) “A time- dependent surrogate model for storm surge prediction based on an artificial neural network using high-fidelity synthetic hurricane modeling”. Natural Hazards, 76(1): 565-585.

Nadal-Caraballo, N.C., Melby, J.A., Gonzalez, V.M., and Cox, A.T. (2015) “North Atlantic Coast Comprehensive Study – Coastal Storm Hazards from Virginia to Maine”. Vicksburg, MS: U.S. Army Engineer Research and Development Center, ERDC/CHL TR-15-5.

Taflanidis A.A., Jia, G., Nadal-Caraballo, N., Kennedy, A., Melby J., and Smith, J. (2014) “Development of Real-Time Tools for Hurricane Risk Assessment”. In Vulnerability, Uncertainty, and Risk. M. Beer, S.K. Au, and J.W. Hall, ed. (Liverpool, UK, ASCE) 1341-1350.

Taflanidis, A.A., Zhang, J., Nadal-Caraballo, N.C., and Melby, J.A. (2017) “Advances in surrogate modeling for hurricane risk assessment: storm selection and climate change impact”. In proceedings of 12th International Conference on Structural Safety & Reliability, August 6-10, Vienna, Austria.

Zhang, J., Taflanidis, A.A., Nadal-Caraballo, N.C., Melby, J.A., Diop, F. (2018) “Advances in surrogate modeling for storm surge prediction: storm selection and addressing characteristics related to climate change”. Natural Hazards, 94(3): 1225-1253.

APPENDIX