NEW YORK-NEW JERSEY HARBOR AND TRIBUTARIES

NEW YORK DISTRICT

Interim Report Cost Appendix

US Army Corps of Engineers

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

NEW YORK STATE Department of Environmental Conservation

NYC Mayor's Office of Recovery & Resiliency

US Army Corps
of Engineers®
New York District

INTERIM REPORT

New York – New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study

Interim Report Cost Appendix

February 2019

US Army Corps of Engineers
NY District - Cost Engineering
USACE-NAN-EN-C

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1 INTRODUCTION

The NY-NJ Harbor & Tributaries Feasibility Study (HATS) for coastal protection against storm surge investigates four alternative flood risk mitigation systems ranging from large transect storm surge barriers (SSB's) paired with the necessary on-land tie-in features (alternative 2) to an entirely on-land, perimeter solution of shoreline-based measures (SBM's) throughout the study area (alternative 5). Additional alternatives consider different combinations of intermediate SSB's and the corresponding SBM's for shoreline left exposed outside of the protection of the SSB's (alternatives 3A, 3B & 4). See the summary of alternatives table below for major cost drivers alongside descriptions of the corresponding areas to be benefitted by those features.

1.0.1 Cost Appendix Table 1: Summary of Major Features by Alternative

Alt	Major Features driving Cost of Alternative	Areas Benefited by Alternative
1	None	None
2	Sandy Hook – Breezy Point, Throgs Neck & Pelham barriers.	Nearly all of the study area
3.a	Jamaica Bay, Arthur Kill, Verrazano, Throgs Neck & Pelham barriers.	Much of the study area
3.b	Jamaica Bay, Arthur Kill, KVK & Pelham barriers + Hudson and East Rivers shoreline based measures & smaller inlet barriers	Inland NJ areas (including port, oil terminals and Newark airport) and backside of SI by barrier, high risk areas of NJ & upstate NY along HR & NYC
4	Jamaica Bay, Pelham & Hackensack barriers + shoreline based measures and smaller inlet barriers	Only relatively higher risk sections of shoreline or smaller tributary basins in study area.
5	Shoreline based measures throughout study area. No transect barriers.	Only relatively higher risk sections of shoreline or smaller tributary basins in study area.

2 BASIS OF COST ESTIMATE

Details of the parametric approach to cost engineering on this study are detailed in the Methodology section, but to summarize: All proposed measures for the four alternatives under consideration fall within the two categories of Storm Surge Barriers (SSB's) and Shoreline-Based Measures (SBM's). Each measure is assigned a unit cost based on type while design dimensions are estimated based on preliminary layout informed by available topography/bathymetry and development data.

SSB's include a range of features (mostly dynamic such as navigable gates and auxiliary flow openings) constructed to transect existing bodies of water. Their design is meant to permit the maximum flow of / minimum interruption to existing fluvial and tidal flow while retaining the capacity to close and block the advance of a high surge associated with a large coastal storm.

SBM's include a range of features (mostly static ones like levees and floodwalls) constructed along the coast to impede rising waters associated with fluvial or storm surge flood events. Their design is meant to integrate as smoothly as possible with current coastal land use while providing elevated mitigation against flood risk. Natural and Nature Based Features (NNBF) costs will be integrated into cost estimates upon greater design with public feedback for NNBF integration.

For this study, the large size of—and the design uncertainties associated with—the SSB's under consideration drive the cost engineering approach. The proportional weight of these measures upon the ultimate construction costs and durations of whichever alternative is selected has meant that the bulk of the cost engineering effort thus far has focused on development of a cost model which is both sufficiently sensitive to the limited design decisions available at this phase and well-grounded in the limited reference data available.[1] The Army Corps' greater experience with SBM's, paired with research into estimates compiled by study partners with experience in higher density applications, informs the unit costs applied for perimeter features. For both SSB's and SBM's the unit costs published in the NACCS report[2] were taken as a starting point and refined based on the need for greater site-specific design dependency and improved modeling based on additional available information.

Operations and Maintenance costs are treated as a function of construction costs and durations are estimated based on engineering judgment informed by experience and, in the case of SSB's, based on analysis of construction durations for reference barriers studied.

Project costs for the alternatives studied are expressed in present (2019) value dollars to be compared against the corresponding benefits and against the no action Alternative 1.

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[1] Fewer than twenty SSB's of comparable size to those considered on this project have been constructed around the world.

[2] North Atlantic Coast Comprehensive Study, USACE – North Atlantic Division, January 2015

3 STORM SURGE BARRIER COST METHODOLOGY

Previously USACE-referenced models[3] for estimating the construction cost of Storm Surge Barriers (SSB's) have not incorporated the full range of available reference data or design considerations most pertinent to the costs of proposed barriers. This study expands the field of variables to investigate for influence upon cost. Through application of autocorrelation tests and regression analysis, this study identifies and employs an improved cost model for estimating the costs of SSB's. The same methodology is also used to develop a model for estimating construction duration.

The applicable cost information and dimensional information for seventeen (17) reference SSB's from Europe and the East- and Gulf-Coasts of the United States is published in Cost Appendix Table 6 (Oversized). The sixteen columns shown (other than the barrier name, cost and duration) constitute the common variables of interest identified by various studies of SSB costs.

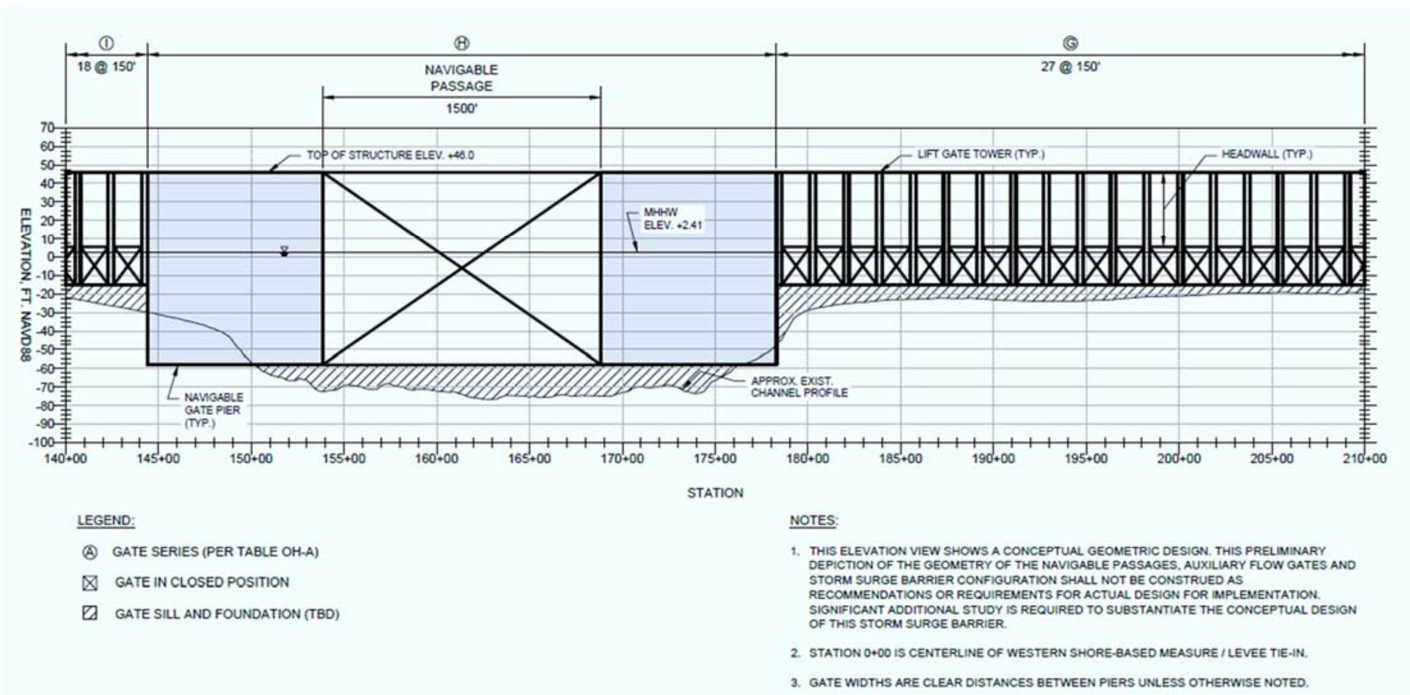
The lengths of barrier span separated out as Navigable, Auxiliary and Dam Lengths refer, respectively, to: barrier sections which can be opened for vessel traffic, those which can be opened for flow but not navigation and those which permanently close off flow. The first two are categories of "Dynamic" barriers and the latter is sometimes also referred to as "Static" or "Embankment structure". The "Area" variables refer to the total area along the barrier respective to that type. Typically, these parameters are calculated by taking the product of the average barrier height for a given section and the length of that section.

The important attribute of the Area parameters is that both height and length of given barrier sections are incorporated into models which incorporate them (as opposed to those models which only consider linear distances). In the case of Auxiliary or Navigable Area, the adjacent structures which facilitate the function of such gates (e.g., gate housing, frame support structures, etc.) are included in such calculations. Dam Area captures only that area which is associated with static features of the barrier.

Without abundantly available detailed plans for all reference barriers, some have been excluded for lack of complete information. The seventeen (17) barriers analyzed were selected for their general applicability (size, function) and completeness of data. With more research, some additional barriers may be incorporated into future studies and some measurements may be refined for those reference barriers incorporated here. For all the corroborative research performed to "check out" the accuracy of the cost, duration and physically-dimensional values summarized in the Table 6, one should note the risk associated with the incompleteness of some of the underlying data. In general, one may characterize the data as moderately precise. For that reason, the model formulae published in Results & Analysis below never incorporate more than two (2) significant figures.

[3] See "North Atlantic Coast Comprehensive Study" and Mooyart & Jonkman in References

3.0.1 Cost Appendix Figure 1: Sample Preliminary Storm Surge Barrier Drawing



Preliminary drawings for a navigable passageway and auxiliary flow gates for a proposed barrier in the NY Harbor. Such drawings represent a higher than average level of design effort than can be expected for a plan-selection phase of a feasibility study. Auxiliary and Navigable Area can be preliminarily derived from such drawings and should be incorporated into a corresponding cost-benefit analysis. Drawing provided by Moffatt & Nichol.

The models analyzed in this study were generated based on linear regression analysis (with log-transformed data also analyzed). Before multiple variables were to be considered in combination, two separate methods—one conceptual and one statistical —were employed to identify which variables carried the greatest weight toward approximating a given barrier’s construction cost or duration.

Conceptually, upon review of the existing relevant literature and consideration of the problem, one can reasonably judge from the available data which variables might contribute greater weight to the overall construction cost or duration of a storm surge barrier. The variables shown in Table 6 were selected in part for their conceptual importance in assembling a cost estimate grounded in likely design criteria. In addition to the variables previously considered and analyzed for their influence on cost, we additionally consider refinement of variables to reflect more of the design criteria which can be known at this phase (such as barrier area by barrier component type).

The selected model meets three criteria. The dependent variables modeled (cost or duration) must:

1) Be informed by and sensitive to adjustments to the major design composition and dimensions which can be anticipated with moderate precision, even at a feasibility study level of design effort. Such details include:

    a. approximate breakdown of barrier by component type (navigable and auxiliary openings versus static dam components)

    b. height and length (and therefore area) of barrier (overall and by component type)

    c. design deployment conditions and target operation decisions (including head differential and regularity of deployment)

    d. Land-based tie-in requirements

    Planning decisions, environmental factors and engineering judgment which would inform such details include:

    a. Natural, commercial and recreational water use such as might require greater incorporation of auxiliary and/or navigable gate structures.

    b. Flood frequency analysis, sea level rise or other factors informing design water level or frequency of operation.

    c. Local topography and bathymetry to inform barrier component height and area or tie-in dimensions.

2) Be grounded in statistical analysis of the best available data.

3) Be reasonable and consistent with sound engineering judgment. E.g., Cost or duration should not be negatively correlated with a larger barrier and should not depend more heavily on less complex components.

The regression analysis to develop cost and duration models was performed using commonly available regression analysis software, corroborated across platforms (R, Excel formulas, Excel user-built). By first separating out dependence on individual variables and then pursuing combinations of variables which meet the first criteria above, the study progressed to identify as preferred models those which additionally met the 2nd and 3rd criteria defined above.

3.1 Results & Analysis

The cost study applied regression analysis to the sixteen (16) chosen independent[4] variables and the two (2) dependent variables—construction cost escalated/converted to 2019 US Dollars and construction duration in days. Unsurprisingly, we see strong correlation between area and length measurements of given barrier component types or that the highest correlation is observed between

[4] "Independent" is used here strictly to identify the variables thought to inform cost and duration (our target *dependent* variables). Not all are truly independent. For example, one cannot consider, for example, barrier area to be independent of barrier length since Area = Length x Height.

total length and dynamic length (with the exception of only a couple barriers out of the seventeen, the span of most barriers constructed are dominated by their dynamic components). Also of note was a very high correlation between cost and number of gates and the very low correlation between Total Height (TH) and Head Differential (H).

Strong correlation between Number of Gates (NG) and cost introduces the possible use of such a metric in the common "back of the envelope" estimate which up until now has depended only upon the Dynamic Length measurement.[5] Of course, "Number of Gates" contains within itself various assumptions about the dimensions and types of such gates. Furthermore, the purpose of this study is to generate models which depend on greater information, not less.

Low correlation between Total Height (TH) and Head Differential (H) is of interest for different reasons: the NACCS study and Mooyart & Jonkman investigated cost as proportional to the product of Dynamic Length, Head Differential and Average Barrier Height. Possible objections among study engineers included the concern that the latter two variables were not in truth independent and therefore such a model might see inflated costs associated with any barriers which require extrapolation outside of the range of values present in the reference data. This low correlation statistic may alleviate such concerns. The extrapolation risk remains because of the model's dependence on a product of variables (effectively requiring a logarithmic transformation to fit within the family of Generalized Linear Models).

The most significant take-away from the single-variable regression analysis among target variables is the sufficiently low correlation between our variables of interest: navigable, auxiliary and dam lengths and areas. These low correlations allow us to safely proceed with various combinations of these variables of interest. The first model investigated confirms the simple models already published.

Previously identified dependence of cost upon length of dynamic components within barriers is confirmed. Mooyart & Jonkman published their finding that overall cost can be estimated at 2.2M€ (2013 Euros) per linear meter of dynamic barrier component (auxiliary flow gates and navigable gates, taken together). This matches closely to the corresponding model developed in this study: Cost (in 2019 US Dollars) estimated at $1M per linear foot of dynamic length.

The inclusion of additional variables of interest produce models with improved conceptual strength and usable cost models are selected which offer reasonable elasticity for each of the variables. For construction cost and duration, the following models are recommended:

Cost = $19,000 x Navigable Area + $14,000 x Auxiliary Area + $3,000 Dam Area

Where, all areas are measured in Square Feet and Cost, in 2019 U.S. Dollars.

Duration = 2 Years + 10 months / 100FT of Navigable Span + 7 weeks/ 100FT of Auxiliary Flow Span + 5 Days / 100FT of Dam

[5] Mooyart & Jonkman, NACCS

Each coefficient passes the "reasonability test" for sign and relative size to each other. Also, a t-test to compare the size of each coefficient to its variance demonstrates that each variable presented is indeed statistically relevant to the formula (i.e. the values are statistically different from zero).

See Cost Appendix Figure 2 (Oversized) for actual versus modeled costs of the reference SSB's plotted along with modeled costs for a representative set of SSB's considered in this study (shown as vertical, orange lines).

3.2 Application

Application of this model to the NY/NJ Harbor & Tributaries Study is based on preliminary dimensions and alignment decisions for proposed features (SSB's and SBM's), provided by Moffatt Nichol engineers. These dimensions are likely to change with refinement but the current values are a reasonable estimate for the eventual dimensions and types applied for any plans selected for further study.

The Cost and Duration models identified above were applied to the preliminary designs and alignments for the sixteen barriers proposed for various alternatives on this study. The costs and durations shown in the table below do not reflect any additional contingencies. Various combinations of these proposed barriers figure into each of the alternatives with none appearing the SBM-only alternative (Alternative 5).

3.2.1 Cost Appendix Table 2: Estimated Construction Costs and Durations for proposed Storm Surge Barriers

Proposed Barrier	Construction Cost (No Contingency) [$, 2019Q1]	Duration of Construction [Years]
Throgs Neck	$ 3,640,000,000	10
Sandy Hook - Breezy Point	$ 36,455,000,000	25*
Verrazzano Narrows	$ 8,469,000,000	18
Arthur Kill	$ 1,671,000,000	7
Kill Van Kull	$ 3,574,000,000	8
Jamaica Bay	$ 2,378,000,000	9
Hackensack River	$ 719,000,000	4
Gowanus Canal	$ 85,000,000	2
Newtown Creek	$ 170,000,000	3
Flushing Creek	$ 200,000,000	3
Gerritson Creek	$ 98,000,000	2
Sheepshead Bay	$ 343,000,000	3
Coney Island Creek	$ 187,000,000	3
Bronx River	$ 150,000,000	3
Westchester Creek	$ 170,000,000	3
Pelham Barrier	$ 318,000,000	4

*SH-BP Barrier construction duration is estimated with the same reference-based parametric duration model as the others, but assumes that the total span will be constructed in 3 parts, concurrently.

4 SHORELINE BASED MEASURES METHODOLOGY

As discussed above, the corresponding methodology for developing unit costs for Shoreline Based Measures (SBM's) depends on local experience and cost engineering judgment rather than statistical analysis. The SBM's currently proposed for at least one alternative on this study include Floodwalls, Levees, Seawalls, Operable Floodgates, Elevated Promenades, Dunes/Buried Seawalls and Tide Gates. Each type has a unit cost (per linear foot) which corresponds with three categories of anticipated accessibility: very limited, limited and unlimited.

Accessibility stands in as a catch-all categorization tool for various anticipated cost drivers which include local geotechnical factors as well as development density and site access conditions. The unit costs for each as currently used[6] are summarized in Table 3, below:

4.0.1 Cost Appendix Table 3: Shoreline Based Measure Costs (per LF)

	"ACCESSIBILITY" METRIC		
MEASURE TYPES	**Very Limited**	**Limited**	**Unlimited**
Floodwall	$ 37,500	$ 11,250	$ 6,000
Levee	$ 9,000	$ 3,750	$ 2,000
Seawall	$ 11,500	$ 4,500	$ 3,000
Operable Flood Gate	$ 75,000	$ 30,000	$ 16,500
Elevated Promenade	$ 45,000	$ 15,000	$ 7,500
Burried Seawall/Dune	$ 15,000	$ 6,000	$ 3,000
Tide Gate	$ 75,000	$ 30,000	$ 16,500

Determination of Feature and Access limitations by segment of shoreline is preliminary but reflects reasonable engineering judgment given the overall scope of the project area and length of shoreline studied.

[6] January, 2019: for the Interim Report (pre-TSP)

5 CONTINGENCY

Without greater detail incorporated into the preliminary designs for the alternatives, a 40% contingency is applied to the baseline construction cost estimates developed for each measure. Due to the differences in anticipated construction duration, this does not work out to a direct scaling of each present value cost (longer duration items compound their higher costs in the form of benefits not yet accrued) but also does not fully incorporate reasonable judgment to be applied in the form of a fuller cost and schedule risk analysis.

The value of 40% for design and cost contingency is chosen on the bases of average historical contingencies developed through Cost and Schedule Risk Analysis.

6 COSTS & DURATIONS BY SEPARABLE ELEMENT

In the table below, construction costs for each separable element are shown. A 'separable element' refers to a system of features which work in concert to provide flood risk mitigation. For example, the large Sandy Hook-Breezy Point barrier alone does not constitute a separable element because it does not mitigate against flood risk unless paired with a barrier at Throgs Neck. Smaller examples might include a network of levees and floodwalls protecting a stretch of low lying coastal development.

6.0.1 Cost Appendix Table 4: Major Cost Drivers by Separable Element

Separable Element	Construction Cost (w/ Contingency, PED & S&A)	Interest During Construction	Present Value of 50 Years of OMRR
	($B)	($B)	($B)
Combined - Sandy Hook & Throgs Neck Barriers	$ 69.980	$ 36.140	11.4
Combined - Arthur Kill, Verrazano & Throgs Barriers	$ 23.780	$ 7.290	5.0
Combined - Arthur Kill & Kill Van Kull Barriers	$ 9.350	$ 1.590	2.4
Hackensack River Barrier	$ 1.630	$ 0.180	0.5
Jamaica Bay Barrier	$ 6.750	$ 1.310	1.7
New Jersey along Hudson River SBM	$ 1.960	$ 0.150	0.6
Flushing Creek Barrier	$ 0.820	$ 0.080	0.2
Hackensack Perimeter Upper Area - Polygon	$ 0.700	$ 0.090	0.0
Newtown Creek Barrier	$ 0.840	$ 0.080	0.3
Bronx River Westchester Creek Barrier	$ 1.500	$ 0.160	0.4
New York City West Side SBM	$ 1.810	$ 0.110	0.6
East Harlem SBM	$ 1.620	$ 0.150	0.5
Pelham Barrier	$ 0.670	$ 0.070	0.2
Hackensack Perimeter Lower Area - Polygon	$ 0.130	$ 0.010	0.1
Long Island City Astoria SBM	$ 1.120	$ 0.180	0.3
Gowanus Canal Barrier	$ 0.460	$ 0.040	0.1
Hackensack Perimeter Middle Area - Polygon	$ 0.110	$ 0.010	0.0
Astoria SBM	$ 1.380	$ 0.270	0.4
Tarrytown SBM	$ 0.210	$ 0.020	0.1
Yonkers North SBM	$ 0.270	$ 0.020	0.1
Yonkers South SBM	$ 0.270	$ 0.020	0.1
Stony Point Perimeter - Polygon	$ 0.100	$ 0.010	0.0
Stony Point SBM	$ 0.100	$ 0.010	0.0
Ossining SBM	$ 0.060	$ 0.010	0.0

7 OPERATIONS AND MAINTENANCE

Costs associated with Operations, Maintenance, Repair and Rehabilitation (OMRR) are calculated as a function of construction costs and applied at the appropriate years, after construction is complete.

Operations: All features are treated as if functional/deployed at a rate of once every two years at the start of the 50-year period of analysis, growing to three-times every two years at the end of the period of analysis. The per-operation cost is calculated at 0.3% of the cost of construction.

Maintenance: Annual maintenance costs are calculated at 0.3% of construction costs, to be applied annually once the feature is constructed. Five-year maintenance costs are calculated at 0.6% of construction costs and applied every five years.

Repair: Repair costs are calculated at 6% of construction costs, to be applied every ten years once the feature is constructed.

Rehabilitation: Rehabilitation costs are calculated at 27.5% of initial construction cost and applied twice within the period of analysis: at the 25 year mark and at the 50 year mark.

The various percentages used above to calculate OMRR costs as a function of construction costs are grounded in engineering judgment. Research of small barriers in the NY/NJ region as well as larger barriers from the international set referenced (such as the Thames Barrier) indicated comparable Operations and Maintenance costs as related to Constructions Costs.

8 TOTAL COST AND DURATION ESTIMATES BY ALTERNATIVE

In the table below, construction costs and durations for each alternative are summarized. The 40% contingency is included within the cost and no contingency is applied to the durations. Additional costs shown are separately tallied into the total costs for each alternative. Total costs and construction durations for Cost-Benefit Analysis are shown in the two right-most columns.

Total Project Cost Summary tables for each Alternative are provided separately at the end of this Cost Appendix.

8.0.1 Cost Appendix Table 5: Costs of Alternatives 2-5 (2019 US Dollars, Discount Rate: 2.875%)

ALTERNATIVE	First Cost (w/ 40% contingency)	Environmental and Cultural Mitigation	Real Estate	IDC	PED	S&A	OMRR (50 Years)	Total	Constr. Duration
	($B)	($B)	($B)	($B)	($B)	($B)	($B)	($B)	(Years)
2	$57.9	$0.27	$0.03	$36.21	$6.96	$5.80	$11.6	$118.8	25
3a	$25.6	$0.24	$0.11	$8.67	$3.08	$2.57	$6.9	$47.1	18
3b	$23.9	$1.27	$0.27	$4.28	$2.93	$2.48	$7.9	$43.0	9
4	$17.6	$1.27	$0.27	$2.87	$2.17	$1.85	$6.0	$32.0	9
5	$8.0	$1.38	$0.15	$1.06	$1.00	$0.86	$2.7	$15.1	9

9 REFERENCES

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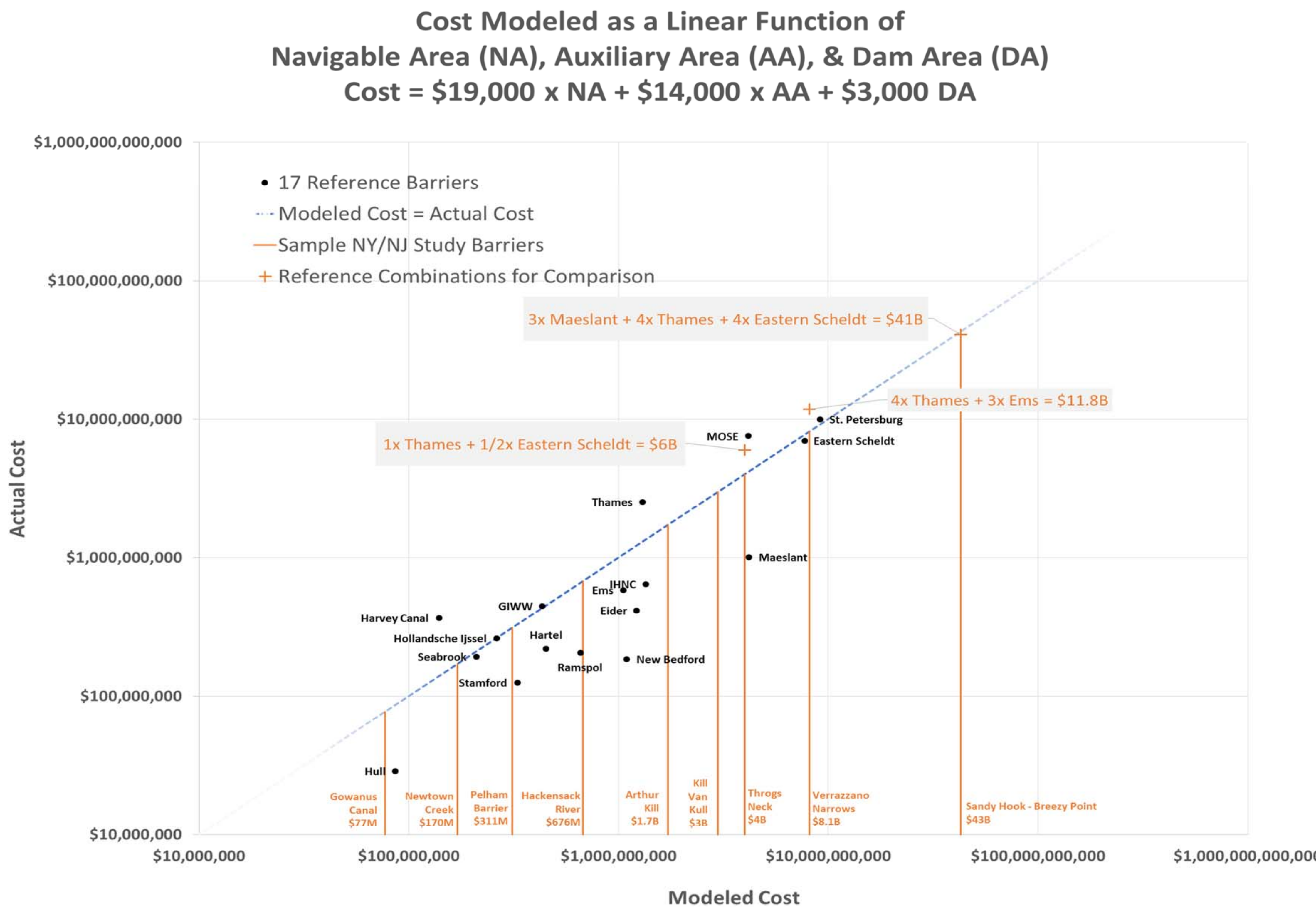
10 OVERSIZED TABLES

10.0.1 Cost Appendix Table 6: 17 Reference Barriers with analyzed data

Storm Surge Barrier	Midpoint of Construction	Dutch/German = 1	No. of Gates	Total Length	Navigable Length	Auxiliary Length	Dam Length	Dynamic Length	Total Height	Head	Navigable Area	Auxiliary Area	Dam Area	Dynamic Area	Avg Water Depth	NACCS "Volume"	2019 Cost	Construction Period
Hollandsche Ijssel	1957	1	2	400.0	400.0	0.0	20.0	400.0	36.1	14.8	13611.0	0.0	517.0	13611.0	20.6	212915.7	$ 262,000,000	1460
New Bedford	1965	0	1	4495.0	361.0	0.0	4134.0	361.0	60.0	16.1	21667.8	0.0	227850.0	21667.8	39.4	348333.3	$ 185,000,000	1460
Stamford	1968	0	1	2854.0	98.0	0.0	2756.0	98.0	32.8	14.8	3229.2	0.0	90417.0	3229.2	18.0	47674.8	$ 126,000,000	1460
Eider	1971	1	5	16076.0	49.0	797.0	15230.0	846.0	21.8	6.6	1049.5	17001.6	324779.0	18051.1	14.8	121178.7	$ 416,000,000	2190
Hull	1979	0	1	134.0	134.0	0.0	7.0	134.0	33.5	19.4	4468.5	0.0	220.0	4468.5	15.8	86497.1	$ 29,000,000	1095
Thames	1979	0	10	1718.0	1193.0	525.0	85.0	1718.0	41.2	22.6	59575.4	11022.2	1791.0	70597.6	19.5	1603108.3	$ 2,521,000,000	2920
Eastern Scheldt	1977	1	62	25853.0	52.0	9154.0	16647.0	9206.0	44.0	18.0	2307.8	394669.5	731855.0	396977.3	25.6	7303150.8	$ 6,960,000,000	6205
Maeslant	1994	1	2	2789.0	2789.0	0.0	138.0	2789.0	77.8	22.0	216839.0	0.0	10714.0	216839.0	59.6	4766473.5	$ 1,010,000,000	2920
Hartel	1996	1	2	820.0	763.0	0.0	57.0	763.0	30.5	22.0	23274.3	0.0	1752.0	23274.3	8.5	511606.2	$ 219,000,000	1460
Ramspol	2000	1	3	1348.0	715.0	0.0	633.0	715.0	26.9	11.6	33981.7	0.0	2295.0	33981.7	15.3	224106.2	$ 206,000,000	1825
Ems	2001	1	7	2100.0	425.0	1091.0	584.0	1516.0	43.3	21.0	19405.2	43480.8	25674.0	62886.0	21.2	1378323.0	$ 585,000,000	1095
St. Petersburg	1998	0	66	76280.0	2008.0	5531.0	68741.0	7539.0	52.7	14.9	123748.4	148961.8	1589976.0	272710.2	9.5	5925660.4	$ 9,948,000,000	9855
IHNC	2010	0	3	9449.0	502.0	210.0	8737.0	712.0	37.7	21.7	18512.8	7922.2	298407.0	26435.1	12.7	581643.2	$ 643,000,000	1095
Seabrook	2010	0	3	469.0	226.0	98.0	144.0	324.0	27.9	16.1	7724.2	3358.3	4926.0	11082.5	18.0	145614.7	$ 192,000,000	1095
Harvey Canal	2010	0	1	394.0	282.0	0.0	112.0	282.0	24.3	8.2	6846.5	0.0	2708.0	6846.5	16.1	56185.6	$ 368,000,000	1095
GIWW	2011	0	1	1706.0	230.0	295.0	1181.0	525.0	32.0	15.9	15994.1	19192.9	37781.0	35187.0	26.9	267190.8	$ 446,000,000	1460
MOSE	2013	0	79	5184.0	3871.0	1312.0	230.0	5183.0	45.1	9.8	172437.8	60277.9	6781.0	232715.7	36.4	2301633.4	$ 7,540,000,000	6935

10.0.2 Cost Appendix Figure 2: Actual versus Modeled Costs of Reference Barriers



11 COST ASSUMPTIONS

- Site-based specific designs for all features, particularly for transect Storm Surge Barriers, will be needed for lower-contingency, bottom-up estimates.
- Dataset of reference barriers reflects small population size of storm surge barriers around the world (high susceptibility to data errors).
- Cost data available for reference SSB's is susceptible to large differences in escalation and currency adjustment as well as the accuracy of available original cost information. This study uses the cost data used by Mooyart & Jonkman.
- No material, labor or equipment estimates incorporated into or corroborated against parametric cost models.
- Same OMRRR formula applied to all features
- Features associated with high frequency risk mitigation (i.e. not covered by SSB's with limited deployment) not incorporated within this estimate.
- 40% contingency applies equally to all alternatives and features. Could/should be refined to reflect relative certainties associated with different feature types and alignments/locations.
- Duration estimates for SSB's are not bottom up schedules. They are based on parametric models developed through regression analysis of reference data and are not sensitive to market capacity, contracting structures, restrictions on availability of funds and any number of other considerations.
- Designs and costs do not reflect features to cope with the likelihood of flooding induced by project features into areas adjacent to the work study.
- Costs associated with port interruptions during construction are not incorporated into this cost estimate.

PROJECT: **NY/NJ Harbor & Tributaries Study**
ALTERNATIVE: 2
LOCATION: NY/NJ Harbor & Tributaries

DISTRICT: NAN **PREPARED: 1/29/2019**
POC: Cost Engineering, Chris Dols

This Estimate reflects the scope and schedule in report;

Civil Works Work Breakdown Structure		ESTIMATED COST (Nominal Dollars: 2019)				PROJECT FIRST COST (Constant Dollar Basis: 2022 Chiefs Report) Program Year (Budget EC): 2022; Effective Price Level Date: 1 JULY 2022					
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($B) *C*	CNTG ($B) *D*	CNTG (%) *E*	TOTAL ($B) *F*	ESC (%) *G*	COST ($B) *H*	CNTG ($B) *I*	**TOTAL ($B)** *J*	Spent Thru: **10/1/2018** ($B)	**TOTAL FIRST COST ($B)**
11	LEVEES & FLOODWALLS	$0	0	40.00%	$0	11.2%	$0.00	$0	$0	$0	**$0**
12	NAVIGATION PORTS & HARBORS	$41,350	$ 16,540	40.00%	$57,890	11.2%	$45,981.20	$18,392	$64,374	$0	**$64,374**
	CONSTRUCTION ESTIMATE TOTALS:	$41,350	$16,540		$57,890	11.2%	$45,981	$18,392	$64,374	$0	**$64,374**
01	LANDS AND DAMAGES	$22	$ -	0.00%	$21.97	11.2%	$24.43	$0	$24	$0	**$24**
30	PLANNING, ENGINEERING & DESIGN	$4,971	$ 1,988.57	40.00%	$6,960.00	11.2%	$5,528.23	$2,211	$7,740	$0	**$7,740**
31	CONSTRUCTION MANAGEMENT	$4,143	$ 1,657.14	40.00%	$5,800.00	11.2%	$4,606.86	$1,843	$6,450	$0	**$6,450**
	PROJECT COST TOTALS:	$50,486	$20,186	39.98%	$70,672		$56,141	$22,447	**$78,587**	$0	**$78,587**

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PROJECT: **NY/NJ Harbor & Tributaries Study**
ALTERNATIVE: 3A
LOCATION: NY/NJ Harbor & Tributaries

DISTRICT: NAN **PREPARED: 1/29/2019**
POC: Cost Engineering, Chris Dols

This Estimate reflects the scope and schedule in report;

Civil Works Work Breakdown Structure		ESTIMATED COST (Nominal Dollars: 2019)				PROJECT FIRST COST (Constant Dollar Basis: 2022 Chiefs Report)					
						Program Year (Budget EC): 2022 Effective Price Level Date: 1 JULY 2022				Spent Thru:	
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($B)	CNTG ($B)	CNTG (%)	TOTAL ($B)	ESC (%)	COST ($B)	CNTG ($B)	**TOTAL ($B)**	**10/1/2018** ($B)	**TOTAL FIRST COST ($B)**
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		
11	LEVEES & FLOODWALLS	$0	0	40.00%	$0	11.2%	$0.00	$0	$0	$0	**$0**
12	NAVIGATION PORTS & HARBORS	$18,250	$ 7,300	40.00%	$25,550	11.2%	$20,294.00	$8,118	$28,412	$0	**$28,412**
	CONSTRUCTION ESTIMATE TOTALS:	$18,250	$7,300		$25,550	11.2%	$20,294	$8,118	$28,412	$0	**$28,412**
01	LANDS AND DAMAGES	$78	$ -	0.00%	$78.12	11.2%	$86.87	$0	$87	$0	**$87**
30	PLANNING, ENGINEERING & DESIGN	$2,200	$ 880.00	40.00%	$3,080.00	11.2%	$2,446.40	$979	$3,425	$0	**$3,425**
31	CONSTRUCTION MANAGEMENT	$1,836	$ 734.29	40.00%	$2,570.00	11.2%	$2,041.31	$817	$2,858	$0	**$2,858**
	PROJECT COST TOTALS:	$22,364	$8,914	39.86%	$31,278		$24,869	$9,913	**$34,781**	$0	**$34,781**

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PROJECT: **NY/NJ Harbor & Tributaries Study**
ALTERNATIVE: 3B
LOCATION: NY/NJ Harbor & Tributaries

DISTRICT: NAN **PREPARED: 1/29/2019**
POC: Cost Engineering, Chris Dols

This Estimate reflects the scope and schedule in report;

Civil Works Work Breakdown Structure		**ESTIMATED COST (Nominal Dollars: 2019)**				**PROJECT FIRST COST (Constant Dollar Basis: 2022 Chiefs Report)**					
						Program Year (Budget EC): 2022 Effective Price Level Date: 1 JULY 2022				Spent Thru:	
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($B)	CNTG ($B)	CNTG (%)	TOTAL ($B)	ESC (%)	COST ($B)	CNTG ($B)	**TOTAL ($B)**	**10/1/2018** ($B)	**TOTAL FIRST COST ($B)**
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		
11	LEVEES & FLOODWALLS	$5,157	2062.85714	40.00%	$7,220	11.2%	$5,734.74	$231	$5,966	$0	**$5,966**
12	NAVIGATION PORTS & HARBORS	$11,900	$ 4,760	40.00%	$16,660	11.2%	$13,232.80	$5,293	$18,526	$0	**$18,526**
	CONSTRUCTION ESTIMATE TOTALS:	$17,057	$6,823		$23,880	2.6%	$18,968	$5,524	$24,492	$0	**$24,492**
01	LANDS AND DAMAGES	$194	$ -	0.00%	$193.73	11.2%	$215.43	$0	$215	$0	**$215**
30	PLANNING, ENGINEERING & DESIGN	$2,093	$ 837.14	40.00%	$2,930.00	11.2%	$2,327.26	$931	$3,258	$0	**$3,258**
31	CONSTRUCTION MANAGEMENT	$1,771	$ 708.57	40.00%	$2,480.00	11.2%	$1,969.83	$788	$2,758	$0	**$2,758**
	PROJECT COST TOTALS:	$21,115	$8,369	39.63%	$29,484		$23,480	$7,243	**$30,723**	$0	**$30,723**

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PROJECT: **NY/NJ Harbor & Tributaries Study** **DISTRICT: NAN** **PREPARED: 1/29/2019**
ALTERNATIVE: 4 **POC: Cost Engineering, Chris Dols**
LOCATION: NY/NJ Harbor & Tributaries

This Estimate reflects the scope and schedule in report;

Civil Works Work Breakdown Structure		**ESTIMATED COST (Nominal Dollars: 2019)**				**PROJECT FIRST COST (Constant Dollar Basis: 2022 Chiefs Report)**					
						Program Year (Budget EC): 2022 Effective Price Level Date: 1 JULY 2022				Spent Thru:	
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($B) *C*	CNTG ($B) *D*	CNTG (%) *E*	TOTAL ($B) *F*	ESC (%) *G*	COST ($B) *H*	CNTG ($B) *I*	**TOTAL ($B)** ***J***	**10/1/2018** ($B)	**TOTAL FIRST COST ($B)**
11	LEVEES & FLOODWALLS	$5,157	2062.85714	40.00%	$7,220	11.2%	$5,734.74	$231	$5,966	$0	**$5,966**
12	NAVIGATION PORTS & HARBORS	$7,379	$ 2,951	40.00%	$10,330	11.2%	$8,204.97	$3,282	$11,487	$0	**$11,487**
	CONSTRUCTION ESTIMATE TOTALS:	$12,536	$5,014		$17,550	-0.6%	$13,940	$3,513	$17,453	$0	**$17,453**
01	LANDS AND DAMAGES	$191	$ -	0.00%	$190.86	11.2%	$212.23	$0	$212	$0	**$212**
30	PLANNING, ENGINEERING & DESIGN	$1,550	$ 620.00	40.00%	$2,170.00	11.2%	$1,723.60	$689	$2,413	$0	**$2,413**
31	CONSTRUCTION MANAGEMENT	$1,321	$ 528.57	40.00%	$1,850.00	11.2%	$1,469.43	$588	$2,057	$0	**$2,057**
	PROJECT COST TOTALS:	$15,598	$6,163	39.51%	$21,761		$17,345	$4,790	**$22,135**	$0	**$22,135**

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PROJECT: **NY/NJ Harbor & Tributaries Study** **DISTRICT: NAN** **PREPARED: 1/29/2019**
ALTERNATIVE: 5 **POC: Cost Engineering, Chris Dols**
LOCATION: NY/NJ Harbor & Tributaries

This Estimate reflects the scope and schedule in report;

Civil Works Work Breakdown Structure		ESTIMATED COST (Nominal Dollars: 2019)				PROJECT FIRST COST (Constant Dollar Basis: 2022 Chiefs Report)					
						Program Year (Budget EC): 2022; Effective Price Level Date: 1 JULY 2022				Spent Thru:	
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($B)	CNTG ($B)	CNTG (%)	TOTAL ($B)	ESC (%)	COST ($B)	CNTG ($B)	**TOTAL ($B)**	**10/1/2018** ($B)	**TOTAL FIRST COST ($B)**
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		
11	LEVEES & FLOODWALLS	$5,700	2280	40.00%	$7,980	11.2%	$6,338.40	$255	$6,594	$0	**$6,594**
12	NAVIGATION PORTS & HARBORS	$0	$ -	40.00%	$0	11.2%	$0.00	$0	$0	$0	**$0**
	CONSTRUCTION ESTIMATE TOTALS:	$5,700	$2,280		$7,980	-17.4%	$6,338	$255	$6,594	$0	**$6,594**
01	LANDS AND DAMAGES	$104	$ -	0.00%	$104.29	11.2%	$115.97	$0	$116	$0	**$116**
30	PLANNING, ENGINEERING & DESIGN	$657	$ 262.86	40.00%	$920.00	11.2%	$730.74	$292	$1,023	$0	**$1,023**
31	CONSTRUCTION MANAGEMENT	$564	$ 225.71	40.00%	$790.00	11.2%	$627.49	$251	$878	$0	**$878**
	PROJECT COST TOTALS:	$7,026	$2,769	39.41%	$9,794		$7,813	$799	**$8,611**	$0	**$8,611**

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