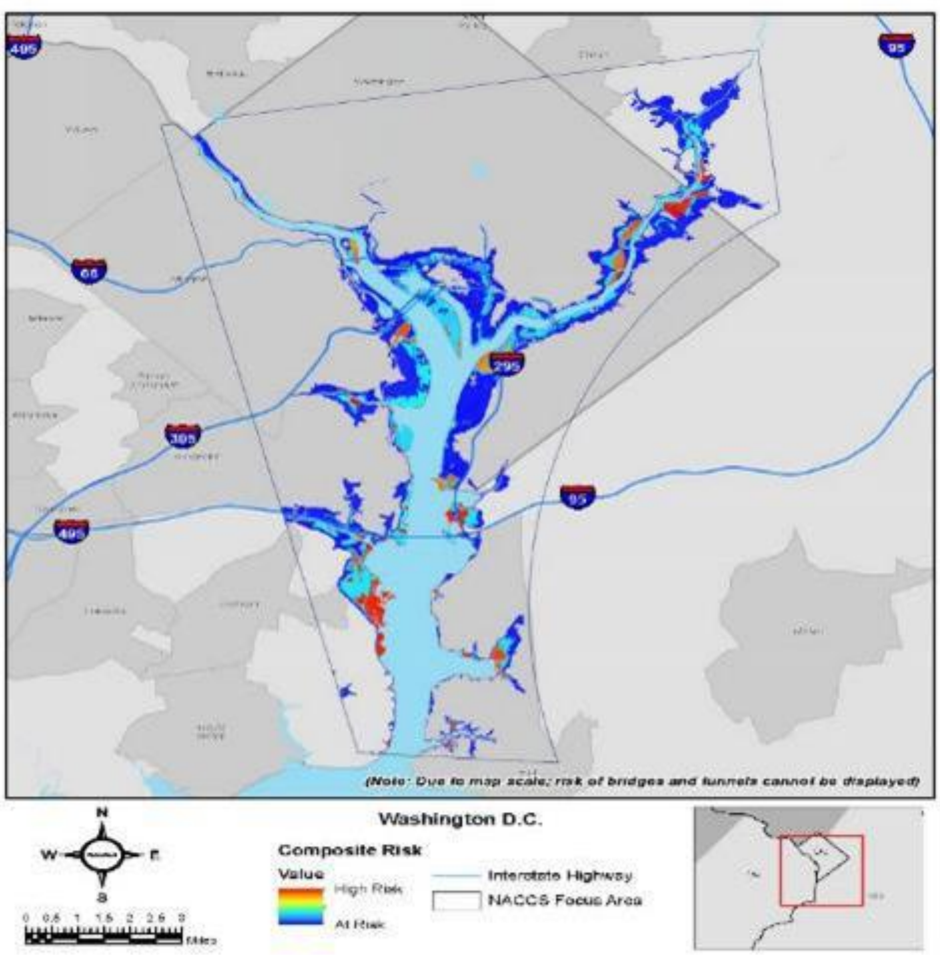
METROPOLITAN WASHINGTON DISTRICT OF COLUMBIA COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

COST ENGINEERING APPENDIX



WALLA WALLA COST ENGINEERING MANDATORY CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW CERTIFICATION STATEMENT

For Project No. 497631

NAB – Metropolitan Washington District of Columbia Coastal Storm Risk Management

The Metropolitan Washington District of Columbia Coastal Storm Risk Management study as presented by Baltimore District, has undergone a successful Cost Agency Technical Review (Cost ATR), performed by the Walla Walla District Cost Engineering Mandatory Center of Expertise (Cost MCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

As of December 21, 2023, the Cost MCX certifies the estimated total project cost:

FY24 Project First Cost:	$15,230,000
Fully Funded Total Project Cost:	$16,690,000

It remains the responsibility of the District to correctly reflect these cost values within the Final Report and to implement effective project management controls and implementation procedures including risk management through the period of Federal participation.

FOR: Michael P. Jacobs, PE, CCE
Chief, Cost Engineering MCX
Walla Walla District

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **NoVA DC Coastal Storm Risk Management Structural Plan**
PROJECT NO: P2 497631
LOCATION: DC and VA

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 12/11/2023

This Estimate reflects the scope and schedule in report; METRO WASHINGTON, DC COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

Program Year (Budget EC): 2024
Effective Price Level Date: 1 OCT 23

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-22** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
02	RELOCATIONS	$408	$143	35.0%	$551	0.0%	$408	$143	$551	$0	$551	11.7%	$456	$160	$616
11	LEVEES & FLOODWALLS	$3,670	$1,284	35.0%	$4,954	0.0%	$3,670	$1,284	$4,954	$0	$4,954	11.7%	$4,097	$1,434	$5,531
13	PUMPING PLANT	$0	$0 -		$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$415	$145	35.0%	$560	0.0%	$415	$145	$560	$0	$560	11.7%	$463	$162	$626
	CONSTRUCTION ESTIMATE TOTALS:	$4,493	$1,573		$6,066	0.0%	$4,493	$1,573	$6,066	$0	$6,066	11.7%	$5,017	$1,756	$6,773
01	LANDS AND DAMAGES	$886	$166	18.8%	$1,052	0.0%	$886	$166	$1,052	$0	$1,052	5.3%	$932	$175	$1,107
30	PLANNING, ENGINEERING & DESIGN	$4,569	$1,599	35.0%	$6,168	0.0%	$4,569	$1,599	$6,168	$0	$6,168	6.8%	$4,879	$1,708	$6,587
31	CONSTRUCTION MANAGEMENT	$1,440	$504	35.0%	$1,944	0.0%	$1,440	$504	$1,944	$0	$1,944	14.4%	$1,647	$576	$2,223
	PROJECT COST TOTALS:	$11,388	$3,842	33.7%	$15,230		$11,388	$3,842	**$15,230**	$0	**$15,230**	9.6%	$12,475	$4,215	$16,690

______________________ **CHIEF, Estimating and Specs Section, Mark Buehn**

______________________ **PROJECT MANAGER, Christine Danaher**

______________________ **CHIEF, REAL ESTATE, Craig Homesley**

______________________ **CHIEF, PLANNING, Amy M. Guise**

______________________ **CHIEF, ENGINEERING, Mary P. Foutz**

______________________ **CHIEF, OPERATIONS, William Seib**

______________________ **CHIEF, CONSTRUCTION, Kevin Coleman**

______________________ **CHIEF, CONTRACTING, Paula M. Beck**

______________________ **CHIEF, PP-C, Justin Callahan**

______________________ **CHIEF, DPM, David B. Morrow**

ESTIMATED TOTAL PROJECT COST: $16,690

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: NoVA DC Coastal Storm Risk Management Structural Plan
LOCATION: DC and VA
This Estimate reflects the scope and schedule in report; METRO WASHINGTON, DC COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 12/11/2023

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			11-Dec-23	Program Year (Budget EC):			2024					
		Effective Price Level:			1-Oct-23	Effective Price Level Date:			1 OCT 23					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Four Mile Run Arlington WPCP													
02	RELOCATIONS	$408	$143	35.0%	$551	0.0%	$408	$143	$551	2028Q2	11.7%	$456	$160	$616
11	LEVEES & FLOODWALLS	$3,670	$1,284	35.0%	$4,954	0.0%	$3,670	$1,284	$4,954	2028Q2	11.7%	$4,097	$1,434	$5,531
13	PUMPING PLANT	$0	$0	35.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$415	$145	35.0%	$560	0.0%	$415	$145	$560	2028Q2	11.7%	$463	$162	$626
	CONSTRUCTION ESTIMATE TOTALS:	$4,493	$1,573	35.0%	**$6,066**		$4,493	$1,573	$6,066			$5,017	$1,756	$6,773
01	LANDS AND DAMAGES	$886	$166	18.8%	$1,052	0.0%	$886	$166	$1,052	2026Q1	5.3%	$932	$175	$1,107
30	PLANNING, ENGINEERING & DESIGN													
	Planning, Engineering & Design total	$4,569	$1,599	35.0%	$6,168	0.0%	$4,569	$1,599	$6,168	2026Q1	6.8%	$4,879	$1,708	$6,587
31	CONSTRUCTION MANAGEMENT													
	Construction Management total	$1,440	$504	35.0%	$1,944	0.0%	$1,440	$504	$1,944	2028Q2	14.4%	$1,647	$576	$2,223
	CONTRACT COST TOTALS:	$11,388	$3,842		$15,230		$11,388	$3,842	**$15,230**			$12,475	$4,215	**$16,690**

Design Maturity Determination for Cost Certification

Date: 12/12/23
P2 Designation/Project Name: 497631/Washington DC Metropolitan Coastal

The Chief of Engineering is responsible for the technical content and engineering sufficiency for all engineering products produced by the command. As such, I have performed the Management Control Evaluation per Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works Projects, Appendix H, Internal Management Control Review Checklist.

The current design DOES NOT require HQ approval (i.e., engineering waivers), requiring a deviation from mandatory requirements and mandatory standards, as defined in ERs, Engineering Manuals, Engineering Technical letters, and Engineering Circulars.

The current hydrology and hydraulics modeling is at 60+ % design maturity, per reference (h) below.

The current geotechnical data and subsurface investigations are at 10 % design maturity, per reference (h) below. Subsurface investigations shall also include investigations of potential borrow and spoil areas.

The current survey data is at 30 % design maturity, per reference (h) below.

Other major technical and/or scope assumptions and risks include the following, which will be refined as the design progresses.

The aggregate for all features is 15 % design maturity. Therefore, per the CECW-EC memorandum dated 05-June-2023, I certify that the design deliverables used to generate the cost products for this project and the estimate meet the requirements for a CLASS 3 estimate, as per reference (a) below. Design risks, impacts and remaining efforts are summarized on page 2.

Considering risks and assumptions noted above, along with all other concerns documented in the Risk Register, the Cost and Schedule Risk Analysis has developed a contingency of 35 % at the 80 % confidence level for the defined project scope.

Chief of Engineering

Mary P. Foutz, P.E.

Printed Name

FOUTZ.MARY.P.1229325082 Digitally signed by FOUTZ.MARY.P.1229325082 Date: 2023.12.20 17:02:38 -05'00'

Signature

Design Maturity Determination for Cost Certification, Remaining Work

If an engineering waiver is required, list the risks and remaining design work needed to mitigate this issue in the current design. Identify remaining effort to complete the design required for 100% design.

N/A

Identify remaining effort to complete geotechnical design effort required for 100% design. List the risks and cost and schedule impacts needed to mitigate this issue in the current design.

The geotechnical design effort that remains includes subsurface investigation as well as improving the seepage and stability design. There was existing geotechnical data along the alignment and nearby from a prior study with data dating 1978. The impacts from the lack of this information were mitigated by adjusting the parameters in the CSRA to account for larger structures and including additional filter material.

Identify remaining effort required to complete H&H required for 100% design. List the risks and cost and schedule impacts needed to mitigate this issue in the current design.

The H&H effort done thus far has determined the project's elevation as well as the loading parameters that affect the structural/geotechnical design and the interior drainage. The H&H specific aspects of this project did not require adjustments to mitigate the uncertainties. The advanced modeling has significantly reduced the risk for this aspect of the project.

Identify remaining effort needed to complete survey data required for 100% design. List the risks and cost and schedule impacts needed to mitigate this issue in the current design.

The data source for the modeling was the NACCS study where the data was in meters and mean sea level. This had to be converted to NAVD88. The proposed project features were overlaid on recent LIDAR with nearly the level of accuracy and precision that would be required to produce plans. Site walks have been performed to look for anomalies which were not found. GIS data was used for much of the interior drainage network which resulted in increasing the costs in the CSRA associated with all interior drainage features. Quantities for the structural components were not increased beyond what was already done for the geotechnical uncertainty.

If the project is anticipated to be executed in parts, provide a design assessment (percent complete) of each part/phase below.

N/A

References:

a. ER 1110-2-1302 – Civil Works Cost Engineering
b. CECW-EC memorandum dated 05-June-2023MFR, Guidance on Cost Engineering Products update for Civil Works Projects in accordance with Engineer Regulation 1110-2-1302 – Civil Works Cost Engineering
c. ER 1165-2-217 – Civil Works Review Policy
d. ER 1110-2-1150 – Engineering and Design for Civil Works Projects
e. ER 1110-3-12 – Quality Management
f. ER 1110-345-700 – Design Analysis, Drawings and Specifications
g. EM 5-1-11 – Project Delivery Business Process (PDBP)
h. Engineering and Construction Bulletin (ECB) 2023-9 – Civil Works Design Milestone Checklists

Design Maturity Determination for Cost Certification – Instructions

Paragraph 1 – Design Date: Use the drop-down menu to populate the date of the design.

Paragraph 1 – Project Information: Enter the P2 Project number and Project name.

Paragraph 3 – Engineering Waivers: Use the drop-down menu to populate this field with either "Does," or "Does not." If an engineering waiver is needed, or anticipated to be needed, provide the specific waiver required for the Project. A waiver is any deviation from current mandatory standards, as indicated.

Paragraph 4 – Hydrology and Hydraulics: Populate this field with the % design maturity.

Paragraph 5 – Geotechnical Information: Populate this field with the % design maturity.

Paragraph 6 – Survey Data: Populate this field with the % design maturity.

Paragraph 7 – Other Technical Assumptions and/or Scope: Enter any other major technical assumptions or scope assumptions here. Only include assumptions that pertain to design. Template discussion fields are provided as a courtesy. Please include additional pages as necessary.

Paragraph 8 – Signature: Print the name and title and provide the signature for the District's Chief of Engineering. This authority cannot be delegated; however, the Deputy Chief of Engineering and Design may sign the form in the absence of the Chief of Engineering. All fillable fields must be populated (use N/A if not applicable) in order for the document to be signed.

Page 2 – Remaining Work: Identify the current baseline design assumptions and the remaining design effort and risks to complete 100% design for the authorized project. If the project is to be broken into parts or phases, provide details on the aggregate design level of each phase and anticipated timeline for completion.

This form is required for all Civil Works projects for initial Cost Certification and Recertification, based on Policy Clarification MFR dated 05 June 2023, *Guidance on Cost Engineering Products update for Civil Works Projects in accordance with Engineer Regulation 1110-2-1302 – Civil Works Cost Engineering*.
The Point of Contact for this action is Mr. Mukesh Kumar, Cost Engineering Community of Practice Leader, CECW-EC, Mukesh.Kumar@usace.army.mil.
Version 1: 01 October 2023.

Discussion of Final Alternative Array:

The final array for the Metropolitan DC Coastal Feasibility Study includes 8 Alternatives, but only five (5) study areas with structural plan and a nonstructural plan for entire study area at different level of protection (20 years, 50 years, and 100 years) were further developed and evaluated with cost estimating and economic values. The structural alternatives include the following areas or planning units: Ronald Reagan Washington National Airport, Arlington Water Pollution Control Plant (WPCP), Four Mile Run, Belle Haven, and Old Town Alexandria. Selected structures were elevated roads, earthen levees, floodwalls, and aluminum stop log closures as a flood protection line. The following Table 2 shows final array of alternatives.

Table 2. Final Array of Alternatives

Alt.	Description	Screen/Retain
1	**No Action**	Retain
2	Comprehensive Coastal Surge Barrier	Screened Out
3	Upper Coastal Surge Barrier	Screened Out
4	Critical Infrastructure Plan (GWMP, Reagan, Arlington WPCP)	
4a	GWMP Floodwall	Screened Out
4b	Reagan National Airport Levee and Floodwall	Screened Out
4c	**Arlington WPCP Floodwall**	Retain
5	Floodwall/Levee Plan (Four Mile Run, Alexandria, Belle Haven)	
5a	Four Mile Run Floodwall	Screened Out
5b1	Alexandria Floodwall	Screened Out
5c	**Belle Haven Levee & Floodwall**	Retain
6	Non-Structural Plan (entire study area or components)	Screened Out
7	Alts 3 and 6 (Upper Coastal Barrier + Nonstructural downstream)	Screened Out
8	**Combinations of 4c and 5c**	Retain

Screened-Out Alternatives:

The cost for the Comprehensive Coastal Barrier (Alternative 2) was estimated by the consultant (CH2MHill, 2015) for rising sector gates (16) spanning a 4,000 feet wide channel, with a 4,400 feet earth/rock levee barrier. The capital costs in rough order of magnitude cost at the alternative selection for the barriers and gates were $7.4 billion. Given the magnitude of the total estimated cost for this alternative, it was immediately screened out from consideration.

The Upper Coastal Storm Surge Barrier (Alternative 3) was estimated by the same consultant for radial gates with a 1,000 feet wide channel, and 2,800 feet of an earth/rock levee barrier. The capital cost in rough order magnitude for the Upper Coastal Storm Surge Barrier was estimated to be $600 million for the barriers and gates. Following the alternative milestone meeting, the

PDT coordinated removal of storm surge barriers from further consideration in the study with USACE higher authorities. Consideration of barriers would have resulted in a substantial increase in the project scope (budget), by expanding the study area to include Maryland and Washington D.C., in addition to Northern Virginia. Additionally, the following preliminary considerations indicate that the barrier would not be acceptable to resource agencies or local jurisdictions including:

- Hydraulic constraints - riverine discharge, induced flooding impacts on either side of the barrier
- Cultural resource constraints - impacts to the George Washington Memorial Parkway and other cultural resources
- Environmental - water quality impacts, impacts to endangered species (e.g., Atlantic Sturgeon) and other anadromous fish

The study was descoped to include just the Northern Virginia area and based on this change in scope and the preliminary considerations listed, USACE removed surge barriers from further consideration.

Alternative 7 was also eliminated because it was a combination of the cost prohibitive Alternative 3 and a nonstructural plan for a downstream area. The combination of the two planning units makes it even more cost prohibitive.

As far as Alternative 4a, coordination with the National Park Service led to the elimination of the floodwall/levee measures along the GWMP dropping this alternative from consideration. During agency coordination meetings, NPS has voiced that they are very concerned with any impact to the parkway, which includes anything that detracts from the character or viewshed of the road and its' historic integrity. This includes changes to views of the river, disconnection from the natural landscape, alterations of other views, impact to the historical character of the road itself, impacts from induced flooding to trails or other NPS resources, and other cultural resource impacts. NPS has been negotiating with the Federal Highway Administration (FHWA) over a 7-inch raising of the wall along the parkway, and therefore there is little viability for a floodwall that would be significantly higher than what is currently under negotiation.

Alternative 5b1, Alexandria Deployable Floodwall, is further evaluated but is also eliminated due to low benefit cost ratio and also due to the fact that most benefits cannot be claimed if and when the City of Alexandria is implementing their own Waterfront Mitigation Plan to address nuisance flooding, including building a six foot bulkhead along their “core” waterfront area, from Duke Street to Queen Street. In 2021, $120 million in funding was approved for this project with planned implementation expected by 2025-2026. The City of Alexandria conducted extensive public outreach as part of their Waterfront Mitigation Plan development and following public feedback, it was determined that six feet was the maximum height that is acceptable by the community. Additionally, new construction along the waterfront has elevation requirements above the base flood elevation and a majority of new development sits well above the planned six feet bulkhead along the waterfront. If USACE will not be implementing flood protection along the waterfront, the project could not justify this feature through NED benefits, as no storm damage reduction would occur. Cost estimate for Alternative 5b1 is included in CSRA and TPCS for references only.

As a result, Alternatives 4b, 4c, 5a, 5c, 6, and 8 moved forward as for further consideration.

Further evaluation results in elimination of alternative 4b (Reagan National Airport Levee and Floodwall), 5a (Four Mile Run Floodwall), and alternative 6 (Non-Structural Plan for entire study area or components).

For alternative 4b, Reagan Airport, it was determined through coordination with MWCOG, MWAA, and FAA, that the runways would be shut down during any level of inundation. The FAA also identified engineering constraints during alternative development to include deployable floodwalls at the end of the runways. Due to the lack of structures at Reagan Airport and the fact that most structures are on high ground based on the G2CRM outputs, for damage reductions do not support flood protective system elements around, the structure inventory yielded low benefits results which is not reflective of the important nature of this critical facilities which includes electrical facilities, NAVAIDS, fuel farm, and runways. The PDT has worked to engage with MWAA since the Summer 2022 along with the help of MWCOG, but no additional information has been provided to improve the discussion and analysis of these facilities. Due to the nature of the feasibility planning process timeline and considering that this study has a set amount of supplemental funding and additional time per the 3x3x3 policy exception signed 05 February 2021, the PDT has determined that there is not enough information to justify an NED exception for the Reagan Airport alternative. Additionally, the proposed CSRM measures at Reagan Airport yielded negative average annualized net benefits of -$3,065,000 and a BCR of 0.02. Therefore, the Reagan Airport alternative was not carried forward as a component of the TSP.

Alternative 5a, Four Mile Run Levee and Floodwall, did not yield positive net benefits due to the performance of the elevated walkway along the shoreline. G2CRM outputs did not show inundation of structures until about the year 2080 which is the end of the 50-year period of economic life. The park to the west of the community also serves as natural flood storage during a high-water event. Evaluating for the high SLR curve, there may be some overtopping of the walkway prior to the year 2080, however due to the low benefits and limited structures getting inundated in the model, this was not evaluated further in this study.

Alternative 6, flood proofing and building elevation evaluation of all planning units, got eliminated for various reasons. This alternative was formulated based on neighborhood, building, and flooding characteristics using a GIS analysis, which identified structures appropriate for certain nonstructural measures. The non-structural plan included several clusters of structures throughout the study area, but the areas selected for further evaluation across the three flood scenarios were Old Town Alexandria, Belle Haven, and Occoquan Bay.

For City of Alexandria area in alternative 6, several structures that could be raised or floodproofed have already taken these measures to reduce their risk and new infrastructure has to follow strict building codes to raise them out of the 100-year floodplain. Many of the remaining structures in the 2-6ft inundation area are historic buildings which cannot be raised, or flood proofed without negatively impacting the integrity of the historic structure.

For Belle Haven area in alternative 6, the Greater Belle View neighborhood non-structural evaluation in yielded several properties seeing anywhere from 0-2ft and 2-6ft of inundation. There were also a few properties in low-lying areas that are in the 6-9ft category. USACE has been coordinating with the County of Fairfax for well over a decade to implement coastal storm risk measures to reduce risk to this community during a storm event. There has been significant public opposition to any proposed plan resulting in the original FPMS study being terminated. Non-structural measures would not eliminate the risk of inundation to vehicles, roadways and some businesses, but could reduce damages to some residential and commercial structures. The cost of non-structural measures is high due to the high number of apartment/condominium buildings. The other challenge with non-structural is that it would be a voluntary program and the same opposition to coastal storm risk measures that was shared during the original FPMS study has not changed over the past decade. USACE has received numerous negative comments and letters from the public and community organizations about USACE pursuing a project in this location. With a BCR under 0.2 for all non-structural scenarios and the high cost and voluntary nature of non-structural implementation, a non-structural plan was not carried forward for further evaluation at Belle Haven.

For Occoquan Bay area in alternative 6, evaluation for non-structural measures for the 1%, 2%, and 5% Annual Exceedance Probability (AEP) got eliminated with reduced benefits mainly because the community already has plans to implement coastal risk reduction measures. The 1% AEP identified 25 structures that could be elevated and 35 structures that could be flood-proofed to reduce coastal storm risk. This community has already started to raise critical infrastructure out of the 100-year floodplain and is in the process of removing some of the structures that could be impacted at the marina as sea levels rise. Accounting for the communities plans to address their coastal storm risk under the FWOP condition greatly reduced benefits that could be realized by this proposed plan (BCR range was 0.06-0.09). Due to the limited benefit a USACE project could offer in this location, further evaluation was not conducted for this planning unit.

The NNBF measures for the City of Alexandria were eliminated because the city recently completed a living shoreline project at Windmill Hill Park Waterfront in 2018.

The NNBF measures were evaluated and eliminated for the Belle Haven plan (SAVs, Wetland Restoration and Living Shoreline). Through coordination with NPS, it was determined that the alignment for Belle Haven would need to move further inland to avoid NPS property and there is no opportunity for SAVs, Wetland Restoration or Living Shorelines between the GWMP and Boulevardview Road. There is a very limited footprint for a project between NPS property and residences and businesses, so USACE has optimized the alignment to work within these constraints. Dyke Marsh could offer opportunity for NNBF; however, it is an on-going USACE project and has maximized FRM benefits with the current NNBF being implemented. Since none of the three NNBF measures evaluated could be constructed in the upland footprint on the west side of the GWMP to avoid NPS property, it was determined that SAVs, Wetland Restoration and Living Shoreline measures could not provide added benefit to the floodwall and levee measures.

The Tentative Selected Plan (TSP):

The Tentative Selected Plan is Alternative 8 which includes Alternative 4c, a floodwall and stop log closure alignment at the Arlington WPCP, and Alternative 5c, a levee and floodwall system with pump stations in Belle Haven. These combined alternatives were selected because they are viable, providing high benefit cost ratio.

The Recommended Plan:

On 4 November 2022, The TSP was endorsed as the Recommended Plan at the Agency Decision Milestone meeting. The Recommended Plan includes the two locations, Arlington WPCP and Belle Haven, within the study area where coastal flood risk measures could be implemented.

However, the Recommended Plan is further narrowed down to just Arlington WPCP due to rejection of the Belle Haven Plan by communities in Fairfax County, Virginia. The County of Fairfax, Virginia provided a letter on 29 March 2022 supporting the proposed levee and floodwall improvements in Belle Haven. Representatives of the County attended in-person and virtual public meetings in June 2002 during which community members expressed their views and opposition on the project in the Belle View neighborhood. Comments were also received and reviewed during the public comment period. After the public comment period, alternate options for alignment of the proposed coastal storm risk reduction features were explored. No substantially different alignment of proposed coastal storm risk reduction features was found to be acceptable. County of Fairfax representatives also engaged leaders of the affected community and elected officials in an outreach effort to gain support and promote flood risk management. Community opposition to the Recommended Plan remained consistent throughout this process. Therefore, as stated in an email received March 13, 2023, “Fairfax County will not support the project as proposed at the present time, and thus will not be providing the USACE with a letter of intent." Measures for coastal storm risk reduction in the Belle Haven community will not be pursued further through this feasibility study.

The following discussion is for the civil works feature accounts for the Recommended Plan:

- Account 01. Land and Damages. For structural features of work, real estate costs due to construction impacts are assessed and provided by Real Estate Division. Real estate cost for structural plan includes real estate administrative cost to provide easement and access to study areas. Real estate costs are accounted for in Total Project Cost Summaries.

- Account 02. Relocation. Relocation is likely but because of lack of utility survey, allowance costs based on experience of similar past studies were used. For structural plan, a budgetary allowance applied using ten (10) percent of construction accounts, accounts 11, 13, and 15. The estimating risk of this item is modeled in Cost and Schedule Risk Analysis.

- Account 11. Levees and Floodwalls. The proposed project alignment shows elements of Measures that include walls and levee constructions for multiple areas. T-walls are used as flood wall construction. Levees with typical cross section for different heights are also quantified and estimated. Length of wall and levees and typical cross section dimensions are from concept design by Baltimore District civil engineer. Quantity take-offs for the walls and levees based on averaged wall heights and typical cross section dimensions were conservatively estimated. The alignment is broken into multiple segments with same average elevation. Each segment of proposed lengths for walls or levees with same average elevation is assumed to have the same constant desired structural height. The project alignment is crossing many areas that may need traffic control, which is estimated by assuming that new traffic signals, vehicle barriers, and flagmen may be needed. Flap gates, sluice gates, and cured in place of existing 72 in drainage pipe are included in Baseline MII estimate to ensure adequate interior drainage. All costs in connection with construction of floodwalls were estimated using MII software, Cost Book Library 2022 as starting point updated with 2023 quotes for major materials, 2023 prevailing local labor wage rates, and latest fuel prices for Revision 2 of 2022 Equipment Region 02, escalated to 2023 price level for remaining items as applicable using CWCCIS Escalation Calculation dated 30 Sep 2022 for account 11 and 15.

- Account 15. Floodway Control - Diversion Structures. Stop log structure cost is parametrically estimated using historical $580/sf stop log cost in a DC project in quarter 1 of 2016 which is escalated to quarter 2 in 2023 for account 15. The square foot area is basically length times height of structure. It is not exact cost but should provide a close estimated cost of a stop log closure structure. The parametrical cost is assigned to subcontractor since the historical cost was done by a Prime contractor. Stop log closure structures are assumed in all areas because they are cheapest solution while providing a temporary sturdy structure, but they may require a lot of time to set up and install. Some sponsors may desire to have a quicker and more expensive temporary structure such as automatic pop-up structure that can be controlled afar with a push button. A final decision has not been made from the sponsors but a market survey for a compatible structure is done and has shown that an auto push- button pop-up structure could cost as much as 62% higher than a stop log structure. Risk analysis for this item includes estimated magnitude of cost impact.

- Account 30. Planning, Engineering, and Design. The team estimated the cost considering the typical tasks required during PED.

- Account 31. Construction Management. The team estimated the cost considering the typical tasks required for Construction Management.

Construction Cost Estimate:

The following methodology is used in the preparation of the cost estimate for Northern Virginia DC Coastal Storm Risk Management Project:

a. The estimate is in accordance with the guidance contained in ER 1110-2-1302, Civil Works Cost Engineering.

b. The estimate is presented in Civilworks Work Breakdown Structure.

c. The price level for the estimate is in second quarter of FY2024.

d. Construction costs developed by Estimating and Specifications Section, Engineering Division, Baltimore District are based on concept design developed by NAB Engineering team. Unit costs are developed using the M-CACES Second Generation (MII) software containing the 2022 English Cost Book Library which was used as a starting point. Historical cost data from similar projects are used as parametric estimate and updated with latest material costs. Material cost for major items were also updated with latest quotes. The estimate is documented with notes to explain the assumed construction methods, crews, productivity, and other specific information. The intent is to provide or convey a "fair and reasonable" estimate that which depicts the local market conditions.

e. Labor costs are based on the latest prevailing rates for DC VA areas.

f. Bid competition: No contracting plan is done at this point. Bidding competition is assumed to be unrestricted in the baseline estimate since the overall work is typical to the area and the massive size of the project will likely draw multiple national level large size contractors to bid on the project. However, unfavorable bidding environment such as low competition due to saturated work in the area could cause increase in bid costs. This assessment is reflected in the Cost and Schedule Risk Analysis.

g. Contract Acquisition Strategy: Acquisition strategy is not yet determined at this point. However, to reflect the historical market condition for this type of work, Prime Contractor is assumed to perform minimal work and will sub-contract out all remaining work.

h. Labor Shortages: It is assumed that there will be a normal labor market since the Recommended Plan is located in a largely populated metro area with available workers. In addition, planned civilwork study normally takes time for funding approval and authorization; by that time, a somewhat normal labor market can be expected. In addition, even though current labor shortage is happening almost everywhere, the cost impact due to labor shortage in construction cost for civil work projects appears to be minimal.

i. Materials: Most material costs are from the Cost Book Library. Vendor quotes were used for non-Cost Book items such as quotes of concrete and rebar for concrete walls, cured in place pipe quote for interior drainage, pump quote for the pump stations. Assumptions include:

1. Quoted delivery charge is included in the vendor's material cost.
2. Materials will be available from local nearest available sources.
3. Hauling: most hauling will be done by trucks. For trucking, it is assumed that the average speed is 30 mph factoring traffic hours in often congested major routes.

j. Equipment: Rates used are based on the latest USACE EP-1110-1-8, Region II. Adjustments are made for fuel and facility capital cost of money (FCCM). Judicious use of owned verses rental rates was considered based on typical contractor usage and local equipment availability. Full FCCM/Cost of Money rate is latest available; MII program takes EP recommended discount, no other adjustments have been made to the FCCM.

k. Fuels (gasoline, on and off-road diesel) were based on local market averages for on-road and off-road fuels in Mid Atlantic areas. Since fuels fluctuate irrationally, an average was used.

l. Major crew and productivity rates were developed and studied by senior USACE estimators familiar with the type of work. All the work is typical to the Baltimore District. The crews and productivities were checked by local NAB estimators, discussions with contractors and comparisons with historical cost data. Major crews include hauling, stonework, and planting.

m. Most crew work hours are assumed to be 8 hrs 5 days/week which is typical to the area. It is anticipated that no overtime is required for reasons such as time of year restriction because it is anticipated that there is none. At the Reagan Airport area, there will likely be off hour or nightly differential hours which may take place to avoid the interruption to the normal operations of the airport. Therefore, the construction estimate for levees and floodwalls at the airport includes ten (10) percent labor cost increase for nightly differential.

n. Mobilization and demobilization: Contractor mobilization and demobilization are assumed that most of the contractors will take about one 8 hrs day to mobilize and one 8 hrs day to demobilize.

o. Field Office Overhead: Typically, civil works project has field office overhead ranging from 9% to 12%. Since this project is a larger than the norm, 12% was used for Job Office Overhead. Overhead assumptions may include: Superintendent, office manager, pickups, periodic travel, costs, communications, temporary offices (contractor and government), office furniture, office supplies, computers and software, as-built drawings and minor designs, tool trailers, staging setup, camp and kitchen maintenance and utilities, utility service, toilets, safety equipment, security and fencing, small hand and power tools, project signs, traffic control, surveys, temp fuel tank station, generators, compressors, lighting, and minor miscellaneous.

p. Home Office Overhead: Typical percentage was used current market (7%) for HOOH. Subcontractor's HOOH is also at 7%. The rates are based upon estimating and negotiating experience, and consultation with local construction representatives. However, the HOOH rate could be higher if market and bidding condition is limited in competition or there is a labor shortage which forces construction companies to increase overhead to provide incentives to hire skill workers or professionals field management teams. This risk is captured as part of market risk and rated as high risk in the CSRA.

q. Profit: Since the Construction Cost Estimate is currently in a budgetary phase, profit is typically included at 10% for Prime Contractor. However, due to the size of project and because Prime is assumed to sub out most of the work, Prime's risk is reduced, 7% profit was used for Prime and Prime's Profit on Sub's work. Sub-contractors' profit is 10%. Sales Tax: Only State sales tax was applied. No local sales tax was included in the estimate.

r. Bond: Bond is calculated at 0.96% using Bond Table in MII for the Prime contractor.

s. Contingency: Contingency is based the outcome of the Cost and Schedule Risk Analysis for TSP milestone which was done in January 2021 initially and updated in Nov 2023 with updated costs.

t. Escalation: No escalation to midpoint of construction according to tentative construction start dates is included in the estimate but will be included in the Total Project Cost Summary (TPCS) to avoid duplicates.

u. HTRW: The estimate includes no costs for Hazardous, Toxic, and Radioactive Waste (HTRW) since there is no potential concern for HTRW where the levees, floodwalls, closure structures, and pump station expansion are proposed.

Cost and Schedule Risk Analysis

Cost and Schedule Risk Analysis (CSRA) was used in developing the cost and schedule contingencies for all alternatives. The CSRA was vigorous process which includes all key team members of the PDT to meet, discuss, provide evaluation of probability and impacts from various risks that could increase costs or delay the project from the baseline estimate and schedule. A CSRA report is generated and included as follows to provide evaluation of data and elaborate the entire process.

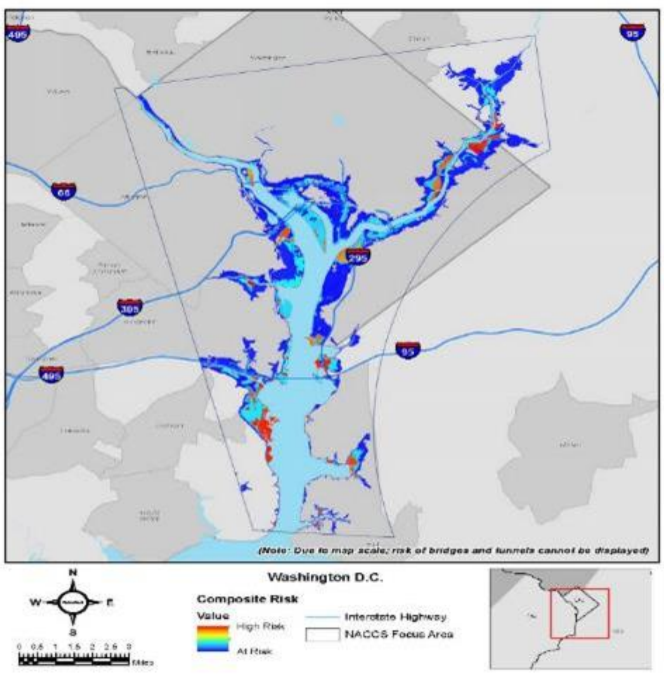
Prepared for:
U.S. Army Corps of Engineers
Baltimore District

US Army Corps of Engineers

Metropolitan Washington District of Columbia Coast Storm Risk Management Feasibility Study (DC Coastal)

DC, VA

Cost & Schedule Risk Analysis Report



Prepared by:
U.S. Army Corps of Engineers
Cost Engineering Baltimore District

December 2023

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Appendixes

Executive Summary

The US Army Corps of Engineers (USACE), Baltimore District, presents this cost and schedule risk analysis (CSRA) report regarding the risk findings and recommended contingencies for the Metropolitan Washington District of Columbia Coastal Storm Risk Management project. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated June 30, 2016, a *Monte-Carlo* based risk analysis was conducted by the Project Development Team (PDT) on remaining costs. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommended 80% confidence level of successful execution to project completion.

The Metropolitan Washington District of Columbia Coastal Storm Risk Management is proposed to include construction of levees or road raising, floodwalls, and flood closure structures for Arlington Water Pollution Control Plant.

The current study base cost for the Tentative Selected Plan is approximately $10.3 M for Arlington Water Pollution Control Plan excluding contingency and expressed in FY 2024 dollars. This CSRA study included all estimated construction costs, Planning, Engineering, Design and Construction Management costs. Based on the results of the analysis, the Estimating and Specifications Section in Baltimore District recommends a contingency value of $3.6 M or approximately 35% of base project cost for Arlington Water Pollution Control Plant at an 80% confidence level of successful execution.

Cost estimates fluctuate over time. During this period of study, minor cost fluctuations can and have occurred. For this reason, contingency reporting is based in cost and per cent values. Should cost vary to a slight degree with similar scope and risks, contingency percent values will be reported, cost values rounded.

Table 1. Cost Contingency Results for Arlington WPCP

Base Estimate		**$83,076,000**	
Confidence Level	**Cost w/ Contingencies ($)**	**Contingency (%)**	**Contingency ($)**
50%	$13,022,485	24%	$2,520,481
80%	**$14,177,705**	**35%**	**$3,675,701**
90%	$14,702,806	40%	$4,200,802

Table 2. Schedule Duration Contingency Results for Arlington WPCP

Base Schedule		**125 Months**	
Confidence Level	**Duration w/ Contingencies (Months)**	**Contingency (%)**	**Contingency (Months)**
50%	82.7 Months	62%	31.6 Months
80%	**99.5 Months**	**95%**	**48.5 Months**
90%	108.7 Months	113%	57.7 Months

KEY FINDINGS/OBSERVATIONS/ASSUMPTIONS & RECOMMENDATIONS

The PDT worked through the risk register in February 2022 and updated again in February 2023. For the Recommended plan, the key risk drivers identified through sensitivity analysis.

Cost Risks: From the Arlington Water Pollution Control Plant CSRA, the key or greater Cost Risk items of include:

- CA2 – Acquisition Plan – Estimate assumes substantial subcontracting and is generally conservative however there is the risk that the project is less than $4.5 mil which may lead to sole source acquisition.
- ES6 – Construction Productivity - Change in productivity can affect the estimate in positive and negative ways.
- EX3 – Storm Event During Construction - Typical risk of storms for the area - There may be a need for restrictions on the amount of teardown of exiting floodwall. Project schedule should include typical weather productivity effects. However, in a severe storm event, additional costs can come from standby time, EDC, cleanup effort, and Corps S&A.
- SD1 Foundation Design – Current geotech info is available to some degree. Conservative geotech assumption was made and deep foundations are not required. Current concept using T-Wall is conservative as far as foundation assumption goes. However, there could be moderate cost impact in later design.
- CV2 Scope Change - What is the likelihood of changing of the alignments, wall heights, closure sizes. Interior drainage is not done (not until PED). Current assumption and length of alignment seem to be conservative and less likely to be changed to larger measures. The deployable closure type may be a more high tech expensive type.
- ES1 – Utility Relocation - No utility data is available but there is a chance that utility relocation (communication, gas, and water) may be necessary. However, there is a conservative allowance cost included in the estimate. And based on geographical location, the utility relocation may be very few and may be worked out with utilities at minimum additional costs.

Schedule Risks: From the Arlington Water Pollution Control Plant CSRA, the key or greater Schedule Risk items include:

- EX2 – Time of Funding – Past experience on civil studies shows that authorization of funding to initiate the start of the design of the project is likely not the time the PDT anticipated. This risk concerns mostly the project schedule.

- LD3 – Acquisitions and Easements – The acquisitions need to be completed prior to construction so that the project can move forward. There may not be many issues of getting easements. Early involvement is usually applied and will minimize schedule risk, with exception to Non-Standard Estates which will require HQUSACE approval.

- LD2– County Discussion– Time to coordinate with the county could take longer than necessary to discuss a trail.

1. Purpose

Within the authority of the US Army Corps of Engineers (USACE), Baltimore District, this report presents the efforts and results of the cost and schedule risk analysis for the Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study. The report includes risk methodology, discussions, findings and recommendations regarding the identified risks and the necessary contingencies to confidently administer the project, presenting a cost and schedule contingency value with an 80% confidence level of successful execution.

2. Background

The Middle Potomac River watershed encompasses approximately 11,500 square miles, including a diverse landscape, with urban, rural, and natural areas in six different eco-regions and four states and the District of Columbia. The study area for the DC Coastal Feasibility Study encompasses approximately 76 square miles and includes the Northern Virginia jurisdictions within the Middle Potomac watershed boundary, from Arlington County south to include a portion of Prince William County within the study area, the Virginia side of the Potomac River contains approximately 135 miles of Potomac River shoreline. The population within the study area is approximately 155,000). The study area was further reduced to 4 main sections: Ronald Reagan Washington National Airport, Arlington Water Pollution Control Plant, Four Mile Run, and Belle Haven. Further analysis shows that only structural alternative for Arlington Water Pollution Control Plant is viable and acceptable to local sponsors. Many flood risk management structures were evaluated and through the project matrix elimination process. Selected structures were elevated roads, earthen levees, floodwalls, and aluminum stop log closures as a flood protection line.

3. Report Scope

The scope of the risk analysis report is to identify cost and schedule risks with a resulting recommendation for contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for construction features. The CSRA does not include consideration for life cycle costs.

3.1. Project Scope

The formal process included extensive involvement of the PDT for risk identification and the development of the risk register. The analysis process evaluated the Micro Computer Aided Cost Estimating System (MCACES) cost estimate, project schedule, and funding profiles using Crystal Ball software to conduct a *Monte Carlo* simulation and statistical sensitivity analysis, per the guidance in Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The project technical scope, estimates and schedules were developed and presented by the District. Consequently, these documents serve as the basis for the risk analysis.

The scope of this study addresses the identification of concerns, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

3.2. Risk Analysis Process

The risk analysis process for this study follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering MCX. The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering MCX.
- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated June 30, 2016.
- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

4. Methodology/Process

The Cost Engineering MCX performed the Cost and Schedule Risk Analysis, relying on local District staff to provide expertise and information gathering. The District PDT conducted initial risk identification via meetings in January 2021. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the draft framework for the risk analysis.

Participants in the risk identification updated meeting on November 14, 2023 are included in Table 3 below.

Table 3. Risk Identification Meeting Participants

Name	Office	Representing
Andrew Roach	USACE	Plan Formulator
Komla Jackatey	USACE	Lead Economist
Daniel Lovette	USACE	Civil Engineer
Amber Metallo	USACE	Study Manager
Kristina May	USACE	Environmental
Mike Fritzges	USACE	Geotechnical
CJ Ditsious	USACE	HTRW
Dennis Powers	USACE	HTRW
Ethan Bean	USACE	Archaeologist
Christine Danaher	USACE	PM
Jack Steketee	USACE	Support Economist
Robert Klara	USACE	Real Estate
La-Wanda Carter	USACE	Real Estate
Syed Qayum	USACE	H&H
Daniel Risley	USACE	Chief H&H
Andrew Orlovsky	USACE	Chief Civil
Alissa Albrecht	USACE	DA Intern H&H

Name	Office	Representing
Geoffrey Tapalu	USACE	Geographer
Luis Santiago	USACE	Geographer
Luan Ngo	USACE	Cost Engineer

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve the desired level of cost confidence. Per regulation and guidance, the P80 confidence level (80% confidence level) is the normal and accepted cost confidence level. District Management has the prerogative to select different confidence levels, pending approval from Headquarters, USACE.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions, or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost MCX guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses Monte Carlo techniques to determine probabilities and contingency. The Monte Carlo techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

4.1. Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

A formal PDT meeting was held with the District office and project owners for the purposes of identifying and assessing risk factors. The meeting included capable and qualified representatives from multiple project team disciplines and functions, including project management, cost engineering, design, environmental compliance, real estate, construction, contracting and representatives of the sponsoring agencies.

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Additionally, numerous conference calls and informal meetings were conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2. Quantify Risk Factor Impacts

The quantitative impacts (putting it to numbers of cost and time) of risk factors on project plans were analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts were quantified using probability distributions (density functions) because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines and functions. However, the quantification process relied more extensively on collaboration between cost engineering and risk analysis team members with lesser inputs from other functions and disciplines. This process used an iterative approach to estimate the following elements of each risk factor:

- Maximum possible value for the risk factor,
- Minimum possible value for the risk factor,
- Most likely value (the statistical mode), if applicable,
- Nature of the probability density function used to approximate risk factor uncertainty,
- Mathematical correlations between risk factors, and
- Affected cost estimate and schedule elements.

The resulting product from the PDT discussions is captured within a risk register as presented in Section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3. Analyze Cost and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. Monte Carlo simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high-level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by Monte Carlo simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5. Project Assumptions

The following data sources and assumptions were used in quantifying the costs associated with the project.

a. The District provided estimate files electronically. The files transmitted and resulting independent review, served as the basis for the final cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level of design.

c. Schedules are analyzed for impact to the project cost in terms of delayed funding, uncaptured escalation (variance from OMB factors and the local market) and unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay.

d. The Cost Engineering MCX guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

e. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation and reviewed at each project milestone to determine if they should be placed on the risk "watch list".

6. Results

The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1. Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in 0. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2. Cost Contingency and Sensitivity Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project cost at intervals of confidence (probability).

6.2.1. Sensitivity Analysis

Sensitivity analysis generally ranks the relative impact of each risk/opportunity as a percentage of total cost uncertainty. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the impact of each risk/opportunity contributing to variability of cost outcomes during Monte Carlo simulation.

Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept, or transfer key risks.

6.2.2. Sensitivity Analysis Results

The risks/opportunities considered as key or primary cost drivers and the respective value variance are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown fwith a positive sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to project cost.

Figure 1 presents a sensitivity analysis for cost growth risks of Structural Alternatives from the high-level cost risks identified in the risk register. Likewise, Figure 2 presents a sensitivity analysis for schedule growth risk from the high-level schedule risks identified in the risk register.

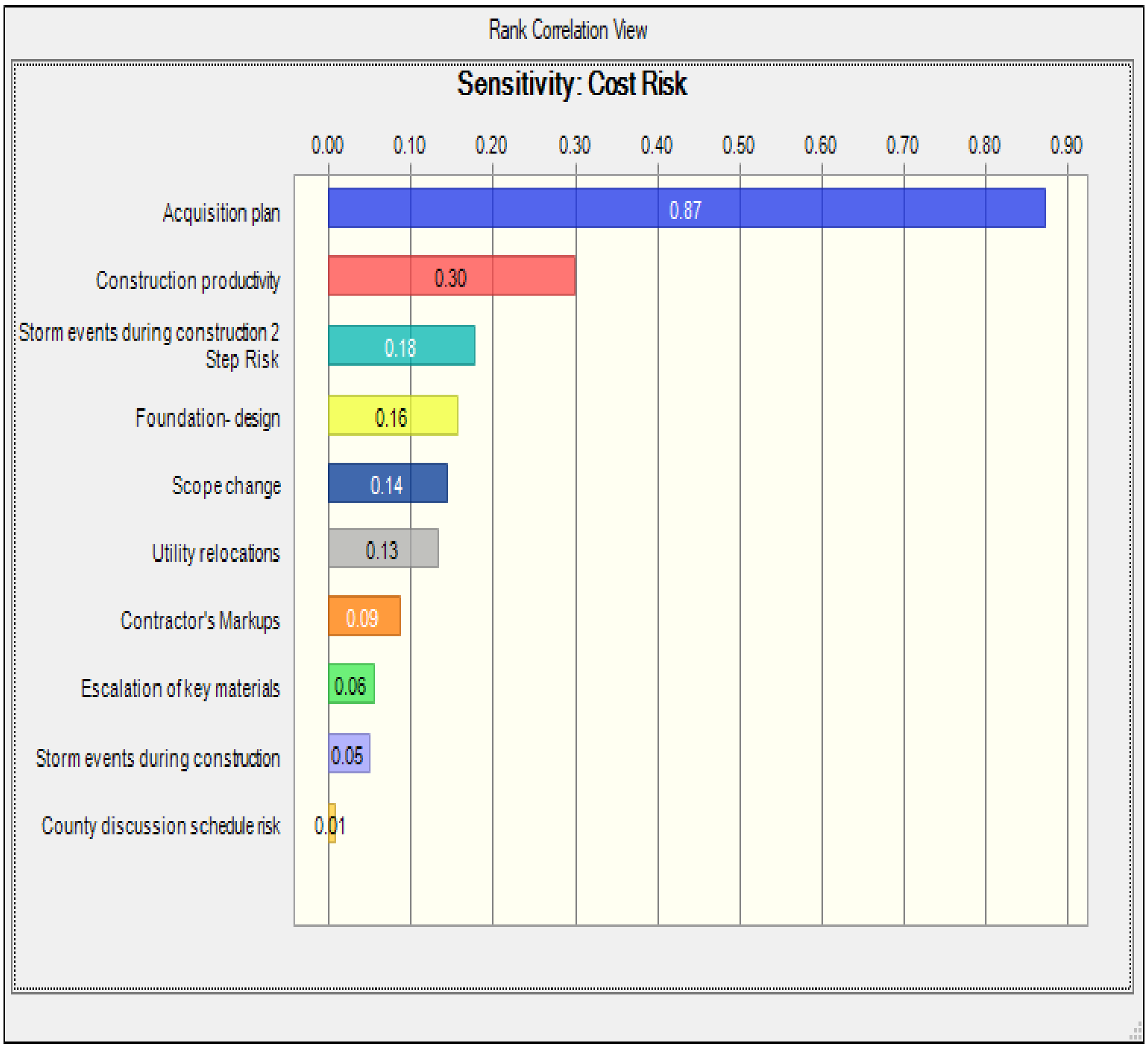


Figure 1. Cost Sensitivity Analysis

6.3. Schedule Contingency and Sensitivity Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project duration at intervals of confidence (probability).

The schedule contingencies were calculated by applying the high-level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based solely on projected residual fixed costs. Figure 1 presents a sensitivity analysis for cost growth risks of Structural Alternatives from the high-level schedule risks identified in the risk register.

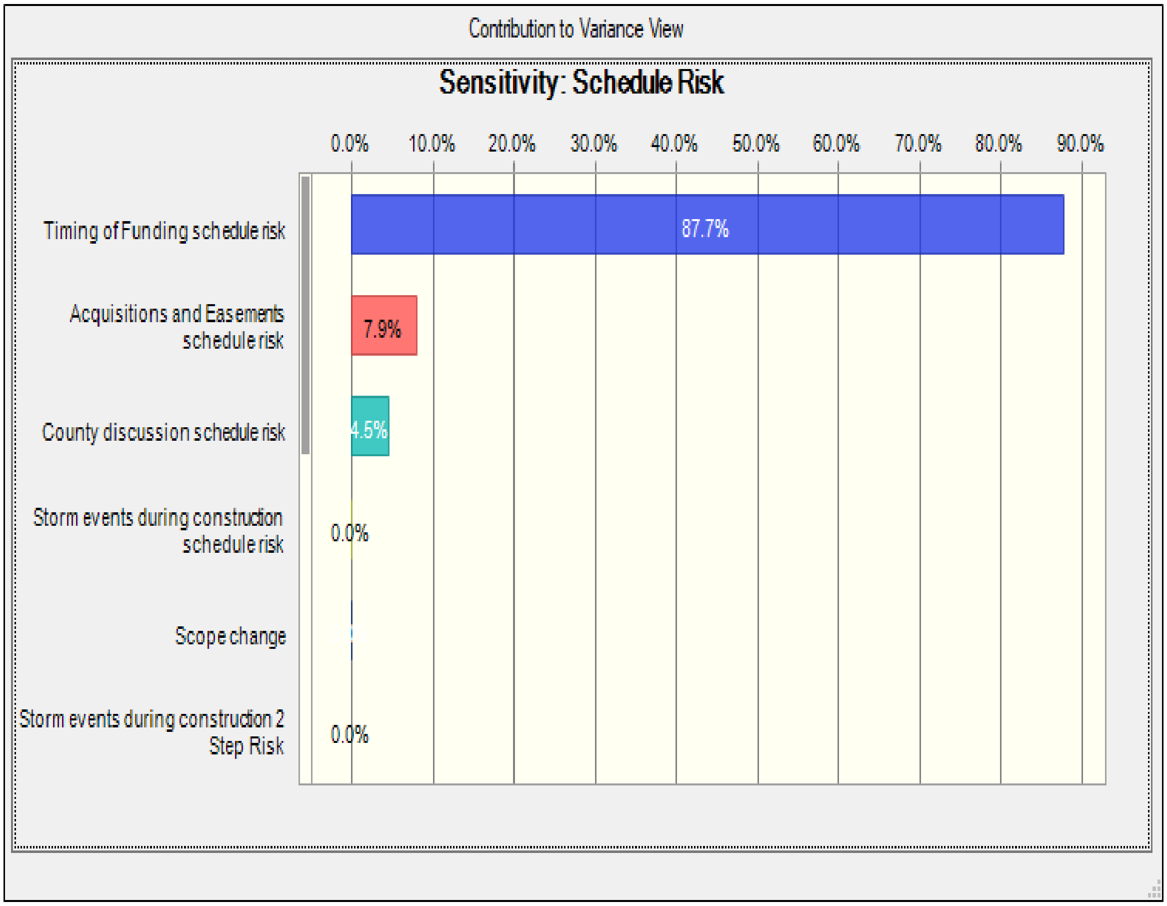


Figure 2. Schedule Sensitivity Analysis

6.4. Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *6th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

The CSRA study serves as a "road map" towards project improvements and reduced risks over time. The PDT should include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life cycle is important in support of remaining within an approved budget and appropriation.

6.4.1. Risk Management

Project leadership should use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings.

6.4.2. Risk Analysis Updates

Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

Sub Appendix A

Cost and Schedule Contingency Tables Supporting the CSRA

Contingency on Base Estimate		80% Confidence Project Cost
Base Estimate	$10,502,004	
Baseline Estimate Cost Contingency Amount ->	$3,675,701	35%
Baseline Estimate Construction Cost (80% Confidence) ->	$14,177,705	

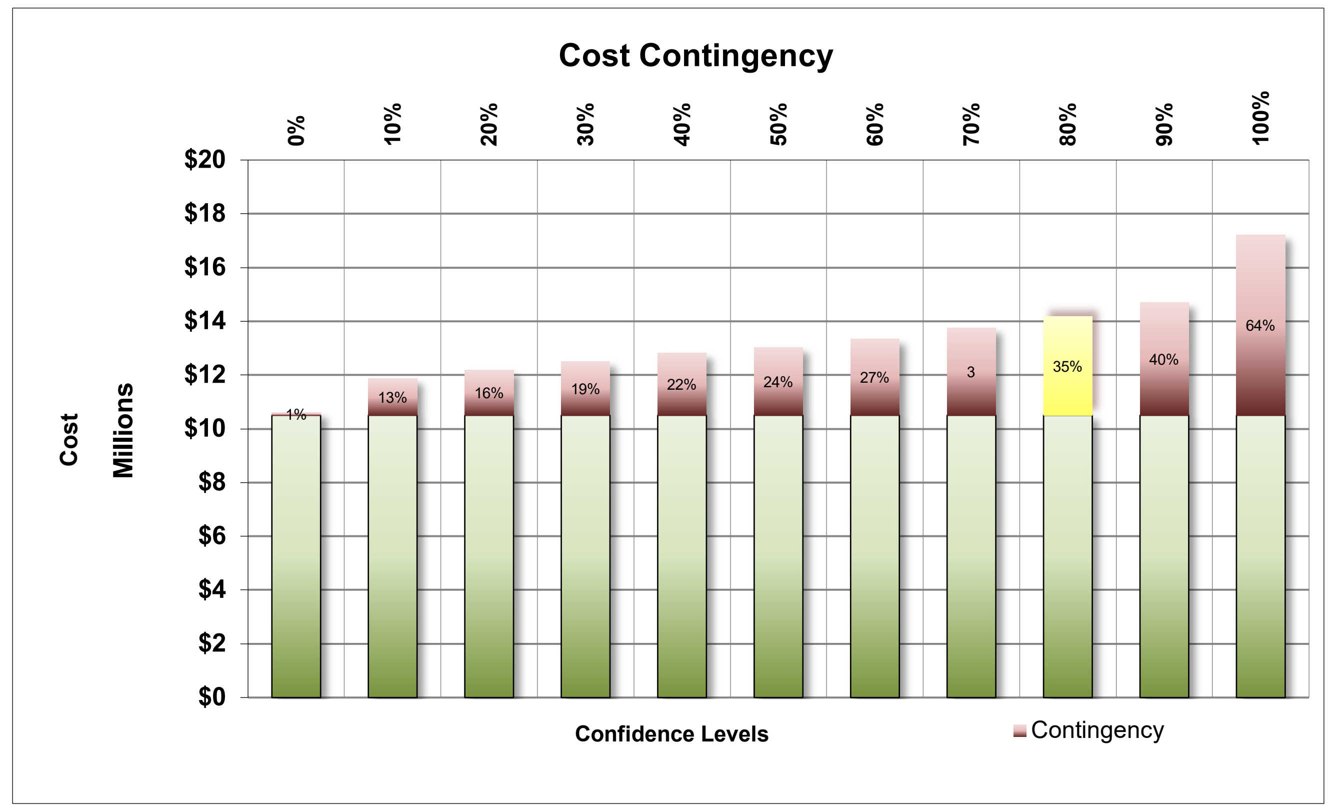
Contingency on Schedule		80% Confidence Project Schedule
Project Base Schedule Duration ->	51.0 Months	
Schedule Contingency Duration ->	48.5 Months	95%
Project Schedule Duration (80% Confidence) ->	99.5 Months	

Northern Virginia Coastal Storm Risk Management Feasability Study
14-Nov-23

- PROJECT CONTINGENCY DEVELOPMENT -

INITIAL CONSTRUCTION
Contingency Analysis

Base Case Estimate (Excluding 01)	$10,502,004	
Confidence Level	**Contingency Value**	**Contingency**
0%	105,020	1%
10%	1,365,261	13%
20%	1,680,321	16%
30%	1,995,381	19%
40%	2,310,441	22%
50%	2,520,481	24%
60%	2,835,541	27%
70%	3,255,621	31%
80%	3,675,701	35%
90%	4,200,802	40%
100%	6,721,283	64%

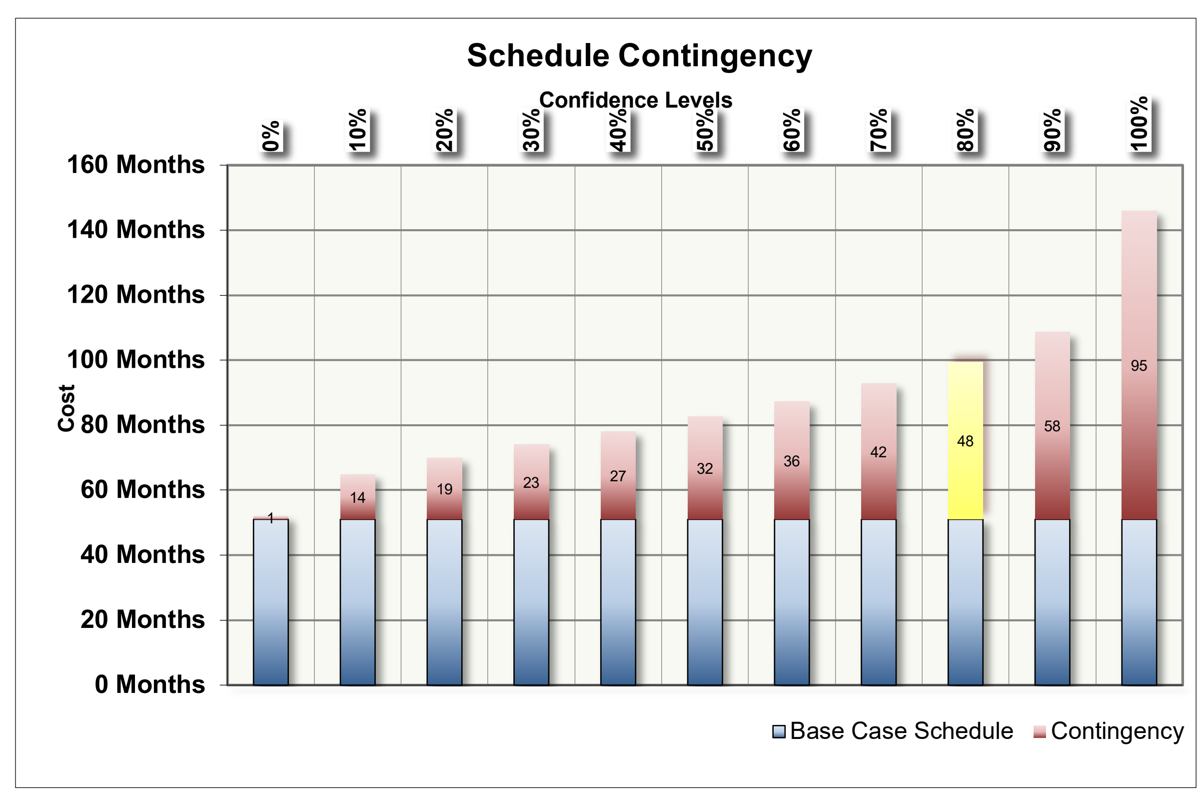


Northern Virginia Coastal Storm Risk Management Feasability Study
14-Nov-23

- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

Contingency Analysis

Base Case Schedule	51.0 Months	
Confidence Level	**Contingency Value**	**Contingency**
0%	1 Months	2%
10%	14 Months	27%
20%	19 Months	37%
30%	23 Months	45%
40%	27 Months	53%
50%	32 Months	62%
60%	36 Months	71%
70%	42 Months	82%
80%	48 Months	95%
90%	58 Months	113%
100%	95 Months	186%



Sub Appendix B

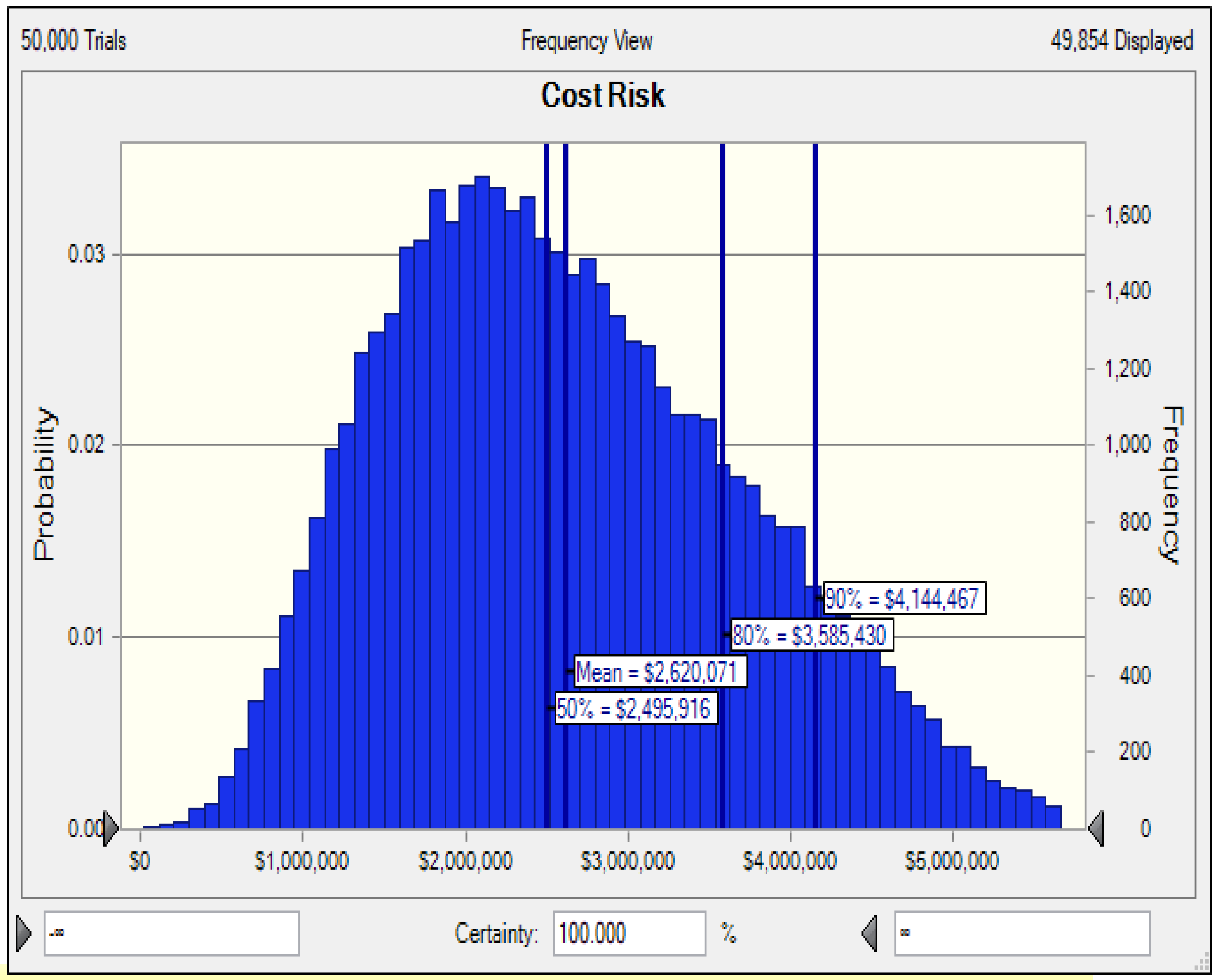
Cost and Schedule Sensitivity Charts Supporting the CSRA

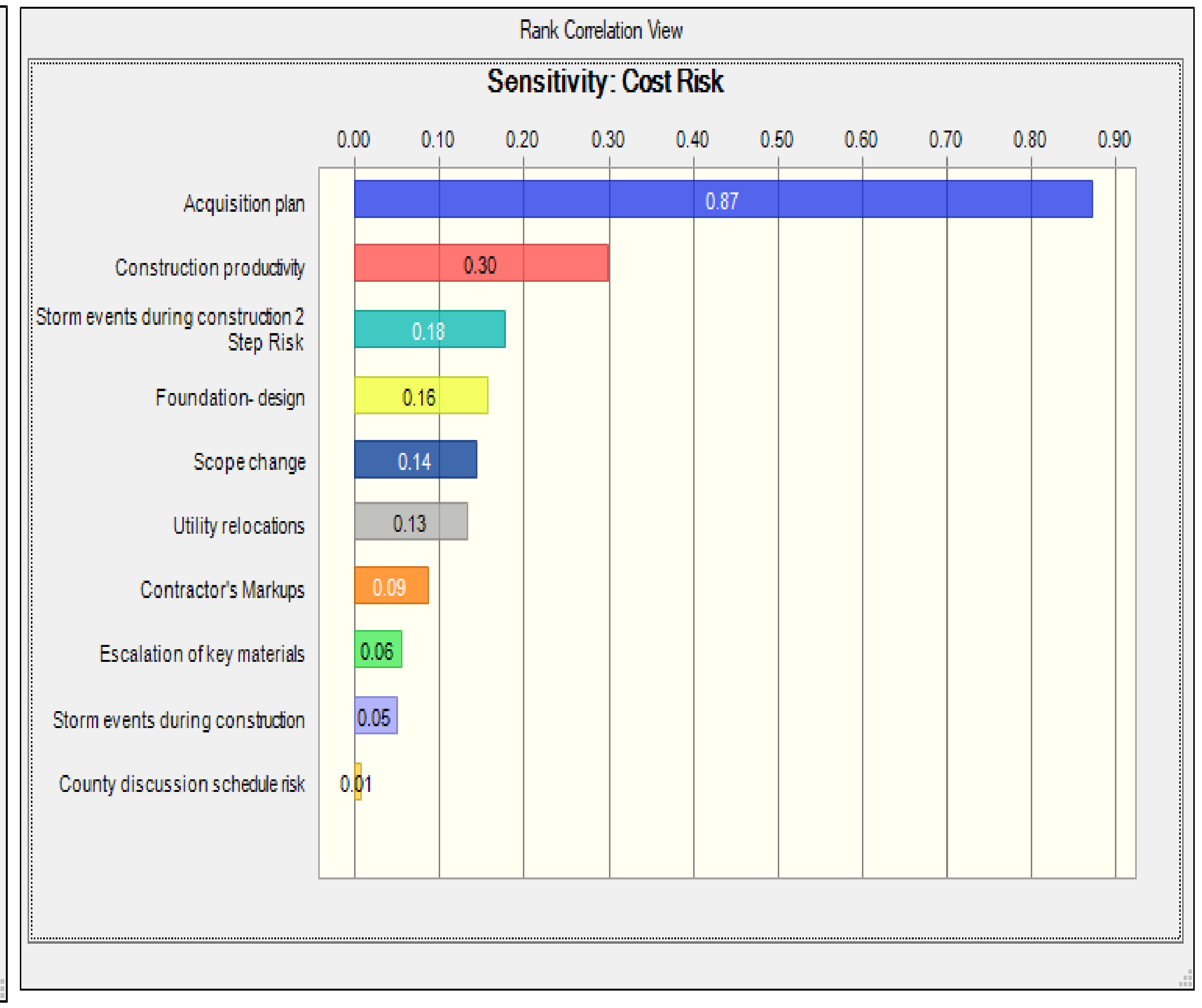
Contingency on Base Estimate		
Base Estimate	**$10,502,004**	**35%**
Baseline Estimate Cost Contingency Amount ->	$3,675,701	
Baseline Estimate Construction Cost (80% Confidence) ->	**$14,177,705**	

Contingency on Schedule		
Project Base Schedule Duration ->	**51.0 Months**	95%
Schedule Contingency Duration ->	48.5 Months	
Project Schedule Duration (80% Confidence) ->	**99.5 Months**	

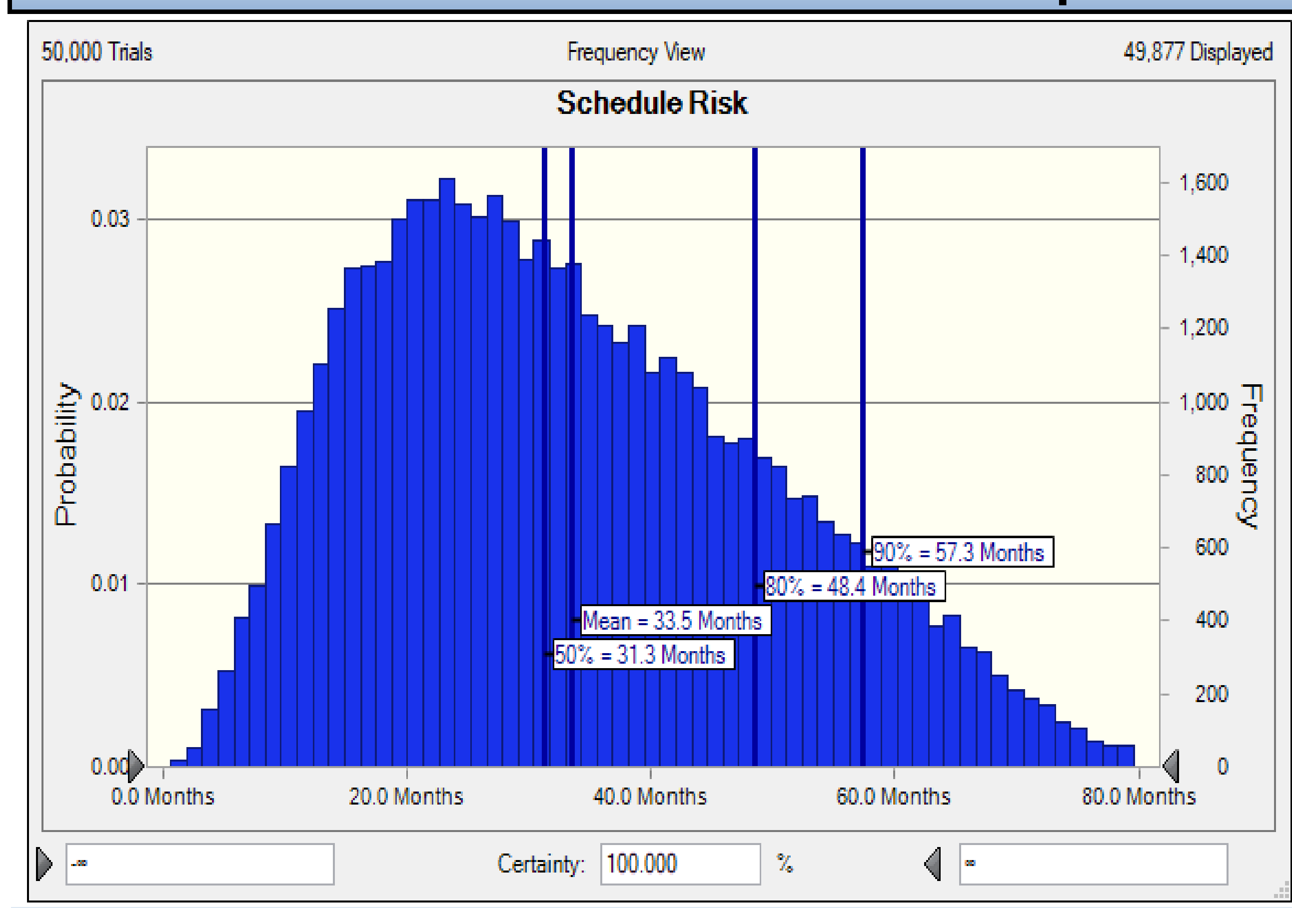
Northern Virginia Coastal Storm Risk Management Feasability Study
14-Nov-23

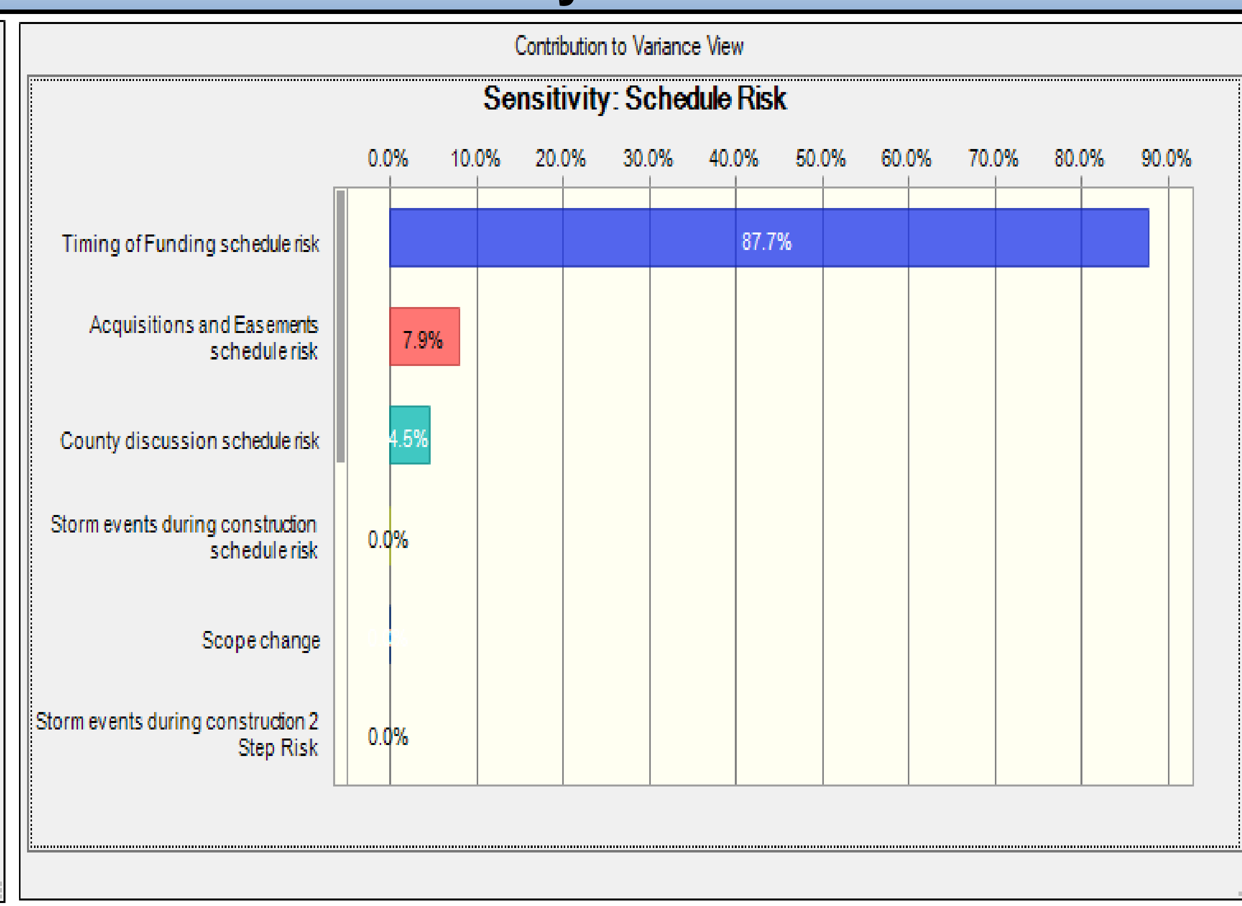
- Cost Outputs Distribution and Sensitivity -





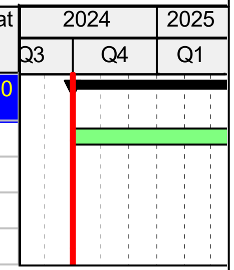
- Schedule Outputs Distribution and Sensitivity -





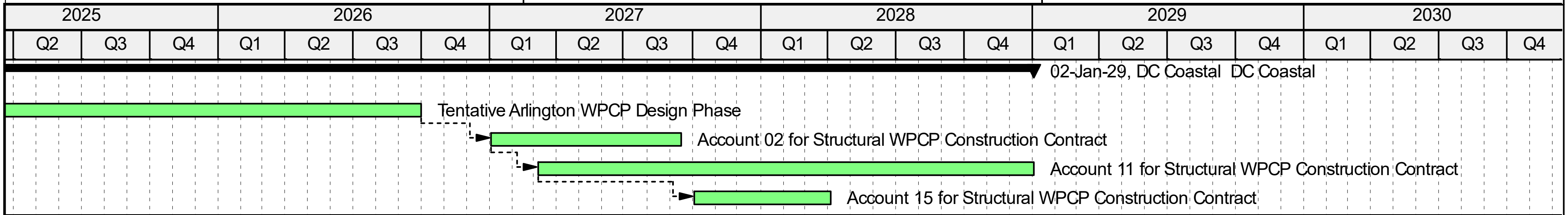
PROJECT SCHEDULE

Activity ID	Activity Name	Planned Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
DC Coastal	**DC Coastal**	1111	1111	0%	01-Oct-24	02-Jan-29	0
A1000	Tentative Arlington WPCP Design Phase	523	523	0%	01-Oct-24	01-Oct-26	
A1010	Account 02 for Structural WPCP Construction Contract	183	183	0%	04-Jan-27*	15-Sep-27	
A1020	Account 11 for Structural WPCP Construction Contract	477	477	0%	08-Mar-27*	02-Jan-29	
A1040	Account 15 for Structural WPCP Construction Contract	132	132	0%	04-Oct-27*	04-Apr-28	



Actual Level of Effort
Actual Work
Remaining Work
Critical Remainin...

TASK filter: All Activities



Actual Level of Effort
Remaining Work
Actual Work
Critical Remainin...

TASK filter: All Activities

Total Project Cost Summary
RECOMMENDED PLAN

FY2024 PRICE LEVEL

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **NoVA DC Coastal Storm Risk Management Structural Plan**
PROJECT NO: P2 497631
LOCATION: DC and VA

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 12/11/2023

This Estimate reflects the scope and schedule in report; METRO WASHINGTON, DC COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC): 2024 Effective Price Level Date: 1 OCT 23									
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-22** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
02	RELOCATIONS	$408	$143	35.0%	$551	0.0%	$408	$143	$551	$0	$551	11.7%	$456	$160	$616
11	LEVEES & FLOODWALLS	$3,670	$1,284	35.0%	$4,954	0.0%	$3,670	$1,284	$4,954	$0	$4,954	11.7%	$4,097	$1,434	$5,531
13	PUMPING PLANT	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$415	$145	35.0%	$560	0.0%	$415	$145	$560	$0	$560	11.7%	$463	$162	$626
	CONSTRUCTION ESTIMATE TOTALS:	$4,493	$1,573		$6,066	0.0%	$4,493	$1,573	$6,066	$0	$6,066	11.7%	$5,017	$1,756	$6,773
01	LANDS AND DAMAGES	$886	$166	18.8%	$1,052	0.0%	$886	$166	$1,052	$0	$1,052	5.3%	$932	$175	$1,107
30	PLANNING, ENGINEERING & DESIGN	$4,569	$1,599	35.0%	$6,168	0.0%	$4,569	$1,599	$6,168	$0	$6,168	6.8%	$4,879	$1,708	$6,587
31	CONSTRUCTION MANAGEMENT	$1,440	$504	35.0%	$1,944	0.0%	$1,440	$504	$1,944	$0	$1,944	14.4%	$1,647	$576	$2,223
	PROJECT COST TOTALS:	$11,388	$3,842	33.7%	$15,230		$11,388	$3,842	**$15,230**	$0	**$15,230**	9.6%	$12,475	$4,215	$16,690

ESTIMATED TOTAL PROJECT COST: $16,690

______________________________ **CHIEF, Estimating and Specs Section, Mark Buehn**

______________________________ **PROJECT MANAGER, Christine Danaher**

______________________________ **CHIEF, REAL ESTATE, Craig Homesley**

______________________________ **CHIEF, PLANNING, Amy M. Guise**

______________________________ **CHIEF, ENGINEERING, Mary P. Foutz**

______________________________ **CHIEF, OPERATIONS, William Seib**

______________________________ **CHIEF, CONSTRUCTION, Kevin Coleman**

______________________________ **CHIEF, CONTRACTING, Paula M. Beck**

______________________________ **CHIEF, PP-C, Justin Callahan**

______________________________ **CHIEF, DPM, David B. Morrow**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: NoVA DC Coastal Storm Risk Management Structural Plan
LOCATION: DC and VA
This Estimate reflects the scope and schedule in report; METRO WASHINGTON, DC COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 12/11/2023

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			**11-Dec-23**	Program Year (Budget EC):			2024					
		Effective Price Level:			1-Oct-23	Effective Price Level Date:			1 OCT 23					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	Four Mile Run Arlington WPCP													
02	RELOCATIONS	$408	$143	35.0%	$551	0.0%	$408	$143	$551	2028Q2	11.7%	$456	$160	$616
11	LEVEES & FLOODWALLS	$3,670	$1,284	35.0%	$4,954	0.0%	$3,670	$1,284	$4,954	2028Q2	11.7%	$4,097	$1,434	$5,531
13	PUMPING PLANT	$0	$0	35.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$415	$145	35.0%	$560	0.0%	$415	$145	$560	2028Q2	11.7%	$463	$162	$626
	CONSTRUCTION ESTIMATE TOTALS:	$4,493	$1,573	35.0%	**$6,066**		$4,493	$1,573	$6,066			$5,017	$1,756	$6,773
01	LANDS AND DAMAGES	$886	$166	18.8%	$1,052	0.0%	$886	$166	$1,052	2026Q1	5.3%	$932	$175	$1,107
30	PLANNING, ENGINEERING & DESIGN													
	Planning, Engineering & Design total	$4,569	$1,599	35.0%	$6,168	0.0%	$4,569	$1,599	$6,168	2026Q1	6.8%	$4,879	$1,708	$6,587
31	CONSTRUCTION MANAGEMENT													
	Construction Management total	$1,440	$504	35.0%	$1,944	0.0%	$1,440	$504	$1,944	2028Q2	14.4%	$1,647	$576	$2,223
	CONTRACT COST TOTALS:	$11,388	$3,842		$15,230		$11,388	$3,842	**$15,230**			$12,475	$4,215	**$16,690**

Backup MII Cost Estimate
RECOMMENDED PLAN

Estimating Basis of Assumptions:

This version of the estimate includes Recommended Plan which includes alignments of levees, floodwalls, and closure structures at Four Mile Run Arlington Water Polution Control Plant.

Per latest ATR structural comments, the following items were added:

- a 60 in flap gate and a 60 in sluice gate
- a 36 in flap gate
- a 24 in flap gate
- a 15 in flap gate
- At 72 in RCP outfall, add a cured in place pipe (CIPP) process to existing 72 in pipe
- temporary re-route waste water pipe while CIPP takes place.

PDT re-evaluated and found that the scope does not require the team to consider a pump station, as dictated by EM 1110-2-14-13, section 3-3, minimum facilities. Engineering and H&H have had multiple internal discussions about this (including NAD) and it will be up to the Non-federal Sponsor and not part of the federal scope of the project. The main reason is without project conditions it would require the Sponsor to take the required action.

Since labor and equipment unit costs are updated, material and sub bid costs for all minor unquoted 2022 miscellaneous items from Jan 2022 Cost Book needs escalation to bring it to current (Nov 2023). Latest ENR material indices provide 20.72% from Jan 2022 to Nov 2023.

No Planning Engineering Design (PED) account 30 and Construction Management (CM) are included b/c they are estimated by % of construction cost and are included in the TPCS.
No Design Contingency from CSRA is included because it will be included in the TPCS.

Estimated by CENAB-EN-DT
Designed by CENAB-EN
Prepared by Luan Ngo
Preparation Date 11/14/2023
Effective Date of Pricing 11/14/2023
Estimated Construction Time 730 Days

Description	Quantity	UOM	ContractCost
Cost Summary			**4,493,096.04**
1 Recommended Plan	**1.0000**	**EA**	**4,493,096.04**
1.1 Four Mile Run Arlington WPCP	**2,530.0000**	**LF**	**4,493,096.04**
1.1.1 Relocation	**1.0000**	**EA**	**408,463.28**
1.1.2 Floodwalls, Floodway Control	**1.0000**	**EA**	**4,084,632.76**