U.S. Army Corps of Engineers
Baltimore District

Baltimore Metropolitan
Coastal Storm Risk Management Feasibility Study

APPENDIX C

Cost Engineering

FINAL REPORT

May 2024

WALLA WALLA COST ENGINEERING MANDATORY CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

For Project No. 404561

NAB – Baltimore Coastal Storm Risk Management Feasibility Study

The Baltimore CSRM Feasibility 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 May 31, 2024, the Cost MCX certifies the estimated total project cost:

FY24 Project First Cost: $77,489,000
Fully Funded Amount: $87,337,000

Cost Certification assumes Efficient Implementation (Funding). 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.

®

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

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

PROJECT: **Baltimore City Storm Risk Management Structural Plan** **DISTRICT:** **NAB District** **PREPARED:** **5/25/2024**
PROJECT NO: 404561 **POC:** **CHIEF, Estimating and Specs Section, Mark Buehn**
LOCATION: MD

This Estimate reflects the scope and schedule in report; Baltimore City 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-21** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
02	RELOCATIONS	$782	$336	43.0%	$1,119	0.0%	$782	$336	$1,119	$0	$1,119	13.8%	$890	$383	$1,273
11	LEVEES & FLOODWALLS	$28,867	$12,413	43.0%	$41,280	0.0%	$28,867	$12,413	$41,280	$0	$41,280	14.2%	$32,968	$14,176	$47,144
13	PUMPING PLANT	$0	$0	0.0%	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRUCTURE	$6,355	$2,733	43.0%	$9,088	0.0%	$6,355	$2,733	$9,088	$0	$9,088	14.3%	$7,266	$3,124	$10,390
18	CULTURAL RESOURCE PRESERVATION	$360	$155	43.0%	$515	0.0%	$360	$155	$515	$0	$515	14.2%	$411	$177	$588
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0.0%	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$36,364	$15,637		$52,001	0.0%	$36,364	$15,637	$52,001	$0	$52,001	14.2%	$41,535	$17,860	$59,395
01	LANDS AND DAMAGES	$5,489	$150	2.7%	$5,638	0.0%	$5,489	$150	$5,638	$0	$5,638	5.3%	$5,778	$157	$5,935
30	PLANNING, ENGINEERING & DESIGN	$10,244	$4,405	43.0%	$14,649	0.0%	$10,244	$4,405	$14,649	$0	$14,649	8.5%	$11,116	$4,780	$15,896
31	CONSTRUCTION MANAGEMENT	$3,636	$1,564	43.0%	$5,200	0.0%	$3,636	$1,564	$5,200	$0	$5,200	17.5%	$4,274	$1,838	$6,111
	PROJECT COST TOTALS:	$55,734	$21,755	39.0%	$77,489		$55,734	$21,755	**$77,489**	$0	**$77,489**	12.7%	$62,702	$24,635	$87,337
	CONTRACT COST TOTALS:														

ESTIMATED TOTAL PROJECT COST: **$87,337**

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

______________________ **PROJECT MANAGER, Joseph Bieberich**

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

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

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

______________________ ' **CHIEF, OPERATIONS, William Seib**

______________________ **CHIEF, CONSTRUCTION, Jeff J. Werner**

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

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

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

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

**** CONTRACT COST SUMMARY ****

PROJECT: Baltimore City Storm Risk Management Structural Plan
LOCATION: MD
This Estimate reflects the scope and schedule in report; Baltimore City STORM RISK MANAGEMENT FEASIBILITY STUDY

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 5/25/2024

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			**5-Dec-23**	Program Year (Budget EC):			2024	FULLY FUNDED PROJECT ESTIMATE				
		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***
	Patapsco North Canton Ventilation Building [MA 8] and MA24 - I-895 Tunnel & Bulkheads													
02	RELOCATIONS	$782	$336	43.0%	$1,119	0.0%	$782	$336	$1,119	2029Q1	13.8%	$890	$383	$1,273
11	LEVEES & FLOODWALLS	$13,545	$5,824	43.0%	$19,369	0.0%	$13,545	$5,824	$19,369	2029Q1	13.8%	$15,415	$6,629	$22,044
13	PUMPING PLANT	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRUCTURE	$1,955	$841	43.0%	$2,795	0.0%	$1,955	$841	$2,795	2029Q1	13.8%	$2,225	$957	$3,182
18	CULTURAL RESOURCE PRESERVATION	$163	$70	43.0%	$233	0.0%	$163	$70	$233	2029Q1	13.8%	$185	$80	$265
	CONSTRUCTION ESTIMATE TOTALS:	$16,445	$7,071	43.0%	**$23,516**		$16,445	$7,071	$23,516			$18,716	$8,048	$26,763
01	LANDS AND DAMAGES	$2,814	$75	2.7%	$2,889	0.0%	$2,814	$75	$2,889	2026Q1	5.3%	$2,962	$79	$3,041
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$411	$177	43.0%	$588	0.0%	$411	$177	$588	2026Q1	6.8%	$439	$189	$628
2.0%	Planning & Environmental Compliance	$329	$141	43.0%	$470	0.0%	$329	$141	$470	2026Q1	6.8%	$351	$151	$502
15.5%	Engineering & Design	$2,594	$1,115	43.0%	$3,709	0.0%	$2,594	$1,115	$3,709	2026Q1	6.8%	$2,770	$1,191	$3,961
1.3%	Reviews, ATRs, IEPRs, VE	$206	$88	43.0%	$294	0.0%	$206	$88	$294	2026Q1	6.8%	$220	$94	$314
1.3%	Life Cycle Updates (cost, schedule, risks)	$214	$92	43.0%	$306	0.0%	$214	$92	$306	2026Q1	6.8%	$228	$98	$326
0.8%	Contracting & Reprographics	$123	$53	43.0%	$176	0.0%	$123	$53	$176	2026Q1	6.8%	$132	$57	$188
3.0%	Engineering During Construction	$493	$212	43.0%	$705	0.0%	$493	$212	$705	2029Q1	17.0%	$577	$248	$826
0.5%	Planning During Construction	$82	$35	43.0%	$118	0.0%	$82	$35	$118	2029Q1	17.0%	$96	$41	$138
1.0%	Adaptive Management & Monitoring	$164	$71	43.0%	$235	0.0%	$164	$71	$235	2029Q1	17.0%	$192	$83	$275
0.0%	Project Operations	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
31	CONSTRUCTION MANAGEMENT													
7.5%	Construction Management	$1,233	$530	43.0%	$1,764	0.0%	$1,233	$530	$1,764	2029Q1	17.0%	$1,443	$621	$2,064
0.0%	Project Operation:	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
2.5%	Project Management	$411	$177	43.0%	$588	0.0%	$411	$177	$588	2029Q1	17.0%	$481	$207	$688
	CONTRACT COST TOTALS:	$25,520	$9,838		**$35,358**		$25,520	$9,838	**$35,358**			$28,608	$11,106	**$39,715**

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

**** CONTRACT COST SUMMARY ****

PROJECT: Baltimore City Storm Risk Management Structural Plan
LOCATION: MD
This Estimate reflects the scope and schedule in report; Baltimore City STORM RISK MANAGEMENT FEASIBILITY STUDY

DISTRICT: NAB District
POC: CHIEF, Estimating and Specs Section, Mark Buehn
PREPARED: 5/25/2024

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			5-Dec-23	Program Year (Budget EC):			2024	FULLY FUNDED PROJECT ESTIMATE				
		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*
	Locus Point West Ventilation Building [MA 18] and MA 19 - aka I-95 Tunnel & Bulkheads													
02	RELOCATIONS	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
11	LEVEES & FLOODWALLS	$15,322	$6,589	43.0%	$21,911	0.0%	$15,322	$6,589	$21,911	2029Q2	14.6%	$17,552	$7,548	$25,100
13	PUMPING PLANT	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRUCTURE	$4,400	$1,892	43.0%	$6,292	0.0%	$4,400	$1,892	$6,292	2029Q2	14.6%	$5,041	$2,168	$7,208
18	CULTURAL RESOURCE PRESERVATION	$197	$85	43.0%	$282	0.0%	$197	$85	$282	2029Q2	14.6%	$226	$97	$323
	CONSTRUCTION ESTIMATE TOTALS:	$19,920	$8,565	43.0%	**$28,485**		$19,920	$8,565	$28,485			$22,819	$9,812	$32,632
01	LANDS AND DAMAGES	$2,675	$75	2.8%	$2,749	0.0%	$2,675	$75	$2,749	2026Q1	5.3%	$2,815	$79	$2,894
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$498	$214	43.0%	$712	0.0%	$498	$214	$712	2026Q1	6.8%	$532	$229	$760
2.0%	Planning & Environmental Compliance	$398	$171	43.0%	$570	0.0%	$398	$171	$570	2026Q1	6.8%	$425	$183	$608
15.5%	Engineering & Design	$3,178	$1,366	43.0%	$4,544	0.0%	$3,178	$1,366	$4,544	2026Q1	6.8%	$3,394	$1,459	$4,853
1.3%	Reviews, ATRs, IEPRs, VE	$249	$107	43.0%	$356	0.0%	$249	$107	$356	2026Q1	6.8%	$266	$114	$380
1.3%	Life Cycle Updates (cost, schedule, risks)	$259	$111	43.0%	$370	0.0%	$259	$111	$370	2026Q1	6.8%	$277	$119	$395
0.8%	Contracting & Reprographics	$149	$64	43.0%	$214	0.0%	$149	$64	$214	2026Q1	6.8%	$160	$69	$228
3.0%	Engineering During Construction	$598	$257	43.0%	$855	0.0%	$598	$257	$855	2029Q2	17.9%	$705	$303	$1,008
0.5%	Planning During Construction	$100	$43	43.0%	$142	0.0%	$100	$43	$142	2029Q2	17.9%	$117	$51	$168
1.0%	Adaptive Management & Monitoring	$199	$86	43.0%	$285	0.0%	$199	$86	$285	2029Q2	17.9%	$235	$101	$336
0.0%	Project Operations	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
31	CONSTRUCTION MANAGEMENT													
7.5%	Construction Management	$1,494	$642	43.0%	$2,136	0.0%	$1,494	$642	$2,136	2029Q2	17.9%	$1,762	$758	$2,519
0.0%	Project Operation:	$0	$0	43.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
2.5%	Project Management	$498	$214	43.0%	$712	0.0%	$498	$214	$712	2029Q2	17.9%	$587	$253	$840
	CONTRACT COST TOTALS:	$30,214	$11,917		**$42,131**		$30,214	$11,917	**$42,131**			$34,094	$13,528	**$47,622**

Design Maturity Determination for Cost Certification

Date: 4/26/24

P2 Designation/Project Name: 404561/Baltimore Metropolitan Area Coastal Storm Risk Management Feasibility Study

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 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 primary uncertainty with design maturity was related to the non-structural plan; that part of the plan was removed from the final version of the report which changed the overall design maturity, as well as, estimate class.

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 __________ 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 43 % at the 80 % confidence level for the defined project scope.

Chief of Engineering
Chief of Engineering

Mary P. Foutz, P.E.

Printed Name

FOUTZ.MARY.P.1229325082

Digitally signed by FOUTZ.MARY.P.1229325082
Date: 2024.04.29 10:54:49 -04'00'

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.

For the structural solutions in the recommended plan, there is sufficient design maturity for a class 3 estimate. The cost risk remaining for this work is primarily related to uncertainties in the geotechnical aspects of the design.

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.

Structural aspects of recommended plan: At present, the geotechnical information available is from nearby infrastructure projects and as-built drawings. Site specific subsurface information will be needed in order to progress with design. Not only are there large inherent risks with the lack of information, acquiring the site specific data will be challenging due to the locations where it is needed which will increase PED costs. The locations are in an urban environment and in some cases close by critical infrastructure which could require specialized equipment and permits from the sponsor. The impacts to the cost estimate from the lack of this information were mitigated by adjusting the parameters in the CSRA to account for larger structures with 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 has determined the project's elevation and 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.

Structural aspects of recommended plan: 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. The data set was validated using VRS GPS at key areas such as crossings and along the alignment to ensure the accuracy of the LIDAR information. There were no issues identified, but the LIDAR dataset was not modified since it would have little effect on the surface. Costs for temporary construction features were elevated in the CSRA to account for potential impacts in the highly confined area.

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.

BALTIMORE COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

Discussion of Final Alternative Arrays:

The Baltimore Coastal Feasibility Study includes multiple combinations of structural and nonstructural measures for multiple areas. The following Table 1 shows the final focus array of alternatives.

Table 1. Final Focused Array of Alternatives

	Description	Screen/Retain
4	Critical Infrastructure Plan	Not Selected
5	Critical Infrastructure & Nonstructural Measures Plan	Not Selected
5A (TSP)	Critical Infrastructure with Select Nonstructural Measures Plan	Selected as NED Plan
6	Critical Balanced Plan	Not Selected
7	Mid-Tier Balanced Plan	Not Selected

In the final array of alternatives, Alternative Plan 4 was optimized to include nonstructural measures (floodproofing) of critical infrastructure at Fort McHenry, the Patapsco Wastewater Treatment Plant, and at the Martin State Airport, in addition to the structural measures proposed at the I-895 and the I-95 tunnels and associated transportation critical facilities. Alternative Plan 5 includes the elements of Alternative Plan 4, with the addition of the nonstructural plan along the Inner Harbor and Locust Point planning units. The nonstructural plan consists solely of the use of nonstructural measures to reduce flood risk to structures. Floodproofing of structures was determined to be the most feasible nonstructural measures in the study area, due to the characteristics of the existing structures and limitations from presence of historic districts in the Inner Harbor planning unit. Alternative Plan 5A is an optimization of Alternative Plan 5. It also includes the critical infrastructure measures of Alternative Plan 4: the I-895 and I-95 tunnels and their support facilities. Alternative Plan 5A increases overall net benefits of the critical infrastructure and the nonstructural plan by creating focus areas for floodproofing. The focus areas under the Annual Exceedance Probabilities yield the highest net benefit, while improving the resiliency of these structures against coastal flood risk.

Alternative Plan 6 expands on Alternative Plan 5, to include the addition of a structural line-of-defense, in the form of an elevated bulkhead (or “sea curb”) along the shoreline of the Port of Baltimore’s Seagirt terminal. In Alternative Plan 7, structural lines of defense are proposed along vulnerable portions of the Inner Harbor, Canton, Fells Point and Locust Point areas, instead of nonstructural measures. These structural lines of defense would primarily be permanent floodwalls and could include elevated walkways and deployable floodwalls at certain locations. The floodwalls would generally be located along the shoreline and would include stoplog structures and permanent and temporary pump stations, where needed. A floodwall around the Wheelabrator Incinerator is also proposed under this alternative. The Wheelabrator Incinerator is a waste-to-energy facility that services Baltimore City and provides steam to the local heating loop and electricity to about 40,000 homes. In the MSA planning unit, this alternative proposes the creation of a levee via the elevation of Wilson Point Road, which would provide protection to the airport from flooding from Dark Head Cove and would ensure that residents of Wilson Point can safely evacuate or be reached by emergency responders. Alternative Plan 7 includes some limited floodproofing, specifically at the Patapsco Wastewater Treatment Plant and at the Martin State Airport. Alternative 7 structural measures include pump stations required for the structural components in the Inner Harbor and Locust Point planning units.

The final array of alternatives addresses the study objectives to reduce coastal storm risk and reduce damages and impacts from coastal inundation to people and critical infrastructure assets. All five alternatives meet the Principles & Guidelines for Federal Investments in Water Resources screening criteria. However, only alternative 5A provides net benefits while maintaining historic neighborhood character, access to water, and improving community resilience.

The Tentative Selected Plan:

The Tentative Selected Plan is identified as Alternative 5A – Critical Infrastructure Plan with Select Nonstructural Measures, which also has the highest comprehensive benefits across three out of the four accounts (National Economic Development, Environmental Quality, and Other Social Effects). It is noted that Alternative 7 has higher Regional Economic Development (RED) benefits, but also has a BCR below parity and negative net benefits and therefore is not selected for further evaluation.

The Recommended Plan

Following Agency Decision Milestone, Alternative 5A becomes the Recommended Plan, the Critical Infrastructure with Select Nonstructural Measures Plan, which incorporates floodwalls and closure structures at the I-95 and I-895 Tunnels and supporting infrastructure (Fort McHenry and Harbor Tunnels) as well as floodproofing of commercial and industrial properties in Fells Point, Inner Harbor, Riverside, and Locust Point areas. While the Nonstructural Plan which includes floodproofing of targeted commercial and industrial properties to help maximizing net benefits while maintaining historic neighborhood character, access to water, and enhancing community resilience, it is not currently approved due to insufficient design maturity.

Therefore, the only approved Recommended Plan to move forward is the Structural Plan that includes design and construction of floodwalls and closure structures at the I-95 and I-895 Tunnels and supporting infrastructure (Fort McHenry and Harbor Tunnels).

Summary of Scope of Work:

The Recommended Plan for the Baltimore Coastal Feasibility Study includes floodwalls and stoplog closure structures at the I-95 and I-895 Tunnels and supporting infrastructure (Fort McHenry and Harbor Tunnels). Estimated project costs are done in M-CACES Second Generation (MII) software for structural. The Recommended Plan for this Coastal Storm Risk Management Project includes the following civil works feature accounts for selected structures and associated work:

- Account 01. Land and Damages. For structural features of work, real estate costs due to construction impacts are assessed by and provided by Real Estate Division. Real estate cost for structural plan includes real estate administrative cost to provide easement and access to structural alignment as well land damage costs. Real estate costs are accounted for in Total Project Cost Summary.
- Account 02. Utilities Relocation. It is likely. Site visit and utilities data from sponsor helped the Baltimore District Engineering team to evaluate and come up with a scope for utilities relocation. From team's assessment, all utilities relocations appear to be associated with MA24 I-895 Baltimore Harbor Tunnel area. All other locations are not of much concern according to local sponsor. It should be noted that relocation cost in account 02 is not for relocating residents while construction is ongoing. It is meant for relocation of utilities and/or roads if needed as result of construction of floodwalls and stoplog structures.
- Account 11. Levees and Floodwalls. The proposed project alignment shows elements of Measures that include floodwall constructions for multiple areas. As far as flood wall construction goes, T-walls are used. No deep foundation such as steel piling was evaluated as necessary. Lengths and heights of flood walls and stoplog structures and assumed typical cross section dimensions were provided by the Project civil engineer and were verified on flood elevation maps, site visits, and civil concept drawings. Preliminary quantity take- offs for the walls and closure structure roller gates based on averaged wall heights and typical cross section dimensions were conservatively estimated. Each segment of proposed lengths for walls or levees are assumed to have the same averaged elevation with the same as the constant desired structure 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. Site visit and utilities data from sponsor helped the Baltimore District Engineering team to evaluate and come up with a scope for utilities crossings. All costs in connection with construction work for floodwalls and roller gates were estimated using MII software, Cost Book Library 2022 as starting point, updated with MD prevailing labor rates, and latest fuel prices for

2022 Equipment Region 02, and escalation to current material price level using ENR Material index for other minor miscellaneous items.

- Account 15. Floodway Control - Diversion Structures. Roller gates are selected based on Evaluation, Design, and Construction of Levees guidance EM 1110-2-1913. Roller gate closure structure cost is based on budgetary quote $/sf by Orange Flood Panel, LLC. The square foot area is basically length times height of roller gates. It is not exact cost but should provide a conservative estimated cost of a roller gate closure structure. The roller gate cost is assigned to Prime contractor since the quoted cost is a sub bid cost which includes the gate itself, installation of the gate, shipping to site, 2 winches for deployment and retraction, signage for the gate, full primed and painted finish, site visits for embed and rail placement observation/guidance, the rails/embeds, the gates (complete with all gaskets and latches). The gate foundation was based on Olyphant project. Team discussed that the closure structures are likely to be the same type of gates in later stage of design but may be with site specific design and dimensions. Risk analysis for this item includes estimated magnitude of cost impact.

- Account 18. Cultural Resource Preservation. The proposed project alignment has potential impacts on cultural resources that may require extensive archaeological mitigations. Since no surveys were done, areas that are currently considered as significant sites may potentially have extensive impacts or no impact. A conservative approach was taken to count as if most sites are high risk sites and will have substantial archaeological mitigations. The cost for archaeological mitigation was conservatively estimated and provided by a NAB archeologist.

- Account 30. Planning, Engineering, and Design. The team decided to use 27.8% of construction cost. It is noted that the Baltimore District team concurred that the use of the percentage is adequate for this effort.

- Account 31. Construction Management. The team decided to use 10% of construction cost. It is noted that the Baltimore District team concurred that the use of the percentage is adequate for this effort.

Construction Cost Estimate:

The following methodology is used in the preparation of the cost estimate for Baltimore 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 1st Quarter of FY2024.

d. Construction costs developed by Estimating and Specifications Section, Engineering Division, Baltimore District are based on a 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 for parametric estimate and updated with latest material quotes for major items. 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 latest MD prevailing wage rates.

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 (CSRA).

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: There is a labor shortage but bids on site work projects seem to indicate that there was minimal cost impact. CSRA includes labor shortage risk in case it gets worsen in future.

i. Materials: Most material costs are from the Cost Book Library. Vendor quotes were used for major items such as quotes for concrete, stones, rebar. 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.

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. However, at the MA24 I-895 tunnel area, construction work may have to be done during off hour or nightly differential hours which may take place to avoid the interruption to the normal operations of the sponsor. Therefore, the construction estimate for levees and floodwalls at the MA24 area includes overtime and ten (10) percent labor cost increase for nightly differential.

n. Mobilization and demobilization: Contractor mobilization and demobilization 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 projects can have field office overhead ranging from 8% to 20%. For project of this size, 10% 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: 15% was used for HOOH. Subcontractor's HOOH is varied between 5% and 10%. 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 one of the high risks in the CSRA.

q. Profit: Since the Construction Cost Estimate is currently in a budgetary phase, profit is varied between 8% to 10% for Prime Contractor. Sub-contractors' profit is also varied between 8% to 10%.

r. Sales Tax: Only State sales tax was applied. No local sales tax was included in the estimate.

s. Bond: Bond is varied between 1% to 2% in MII for the Prime contractor.

t. Contingency: Contingency is based the outcome of the Cost and Schedule Risk Analysis which was done in Feb 2022 and updated in Dec 2023 with latest 2024 costs.

u. 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.

v. 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 stations are proposed.

Cost and Schedule Risk Analysis

Cost and Schedule Risk Analysis (CSRA) was used in developing the cost and schedule contingencies for structural plan. 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

Baltimore Coastal Storm Risk Management Feasibility Study

Baltimore, MD

Project Cost & Schedule Risk Analysis Report

Prepared by:
U.S. Army Corps of Engineers
Baltimore District
January 2024

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Table of Contents

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 Baltimore Coastal Storm Risk Management Feasibility Study 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 Baltimore Coastal Feasibility Study includes four (4) main study areas or planning units: Inner Harbor, Patapsco, Locus Point, and Martin State Airport. Within these main areas, measuring area (MA) planning units are considered. Many flood risk management structures were evaluated and through the project matrix elimination process. Selected structures were floodwalls, elevated roads, earthen levees, and aluminum stop log closures as a flood protection line. For the Tentative Selected Plan, this study includes T-walls at Patapsco North I-895 Tunnel Bulkhead, Locust Point I-95 Tunnel Bulkhead and Tunnel Facility Bulkhead, Patapsco South I-895 Tunnel Bulkhead.

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.

KEY FINDINGS/OBSERVATIONS/ASSUMPTIONS & RECOMMENDATIONS

The PDT worked through the risk register initially in February 2022 and updated it in Dec 2023. The key risk drivers identified through sensitivity analysis suggest a cost contingency and schedule risks all at an 80% confidence level.

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 Baltimore 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 Baltimore Coastal Study Feasibility Cost Share Agreement (FCSA) was signed by USACE and the Maryland Department of Transportation (MDOT) on August 5, 2019. MDOT is the non-federal sponsor for the Baltimore Coastal Study.

The study authority is under the Baltimore Metropolitan Water Resources authority, which was adopted by a resolution of the Committee on Public Works and Transportation of the United States House of Representatives on April 30, 1992. This study authority was identified by the Baltimore District Office of Counsel (in a memorandum dated April 22, 2014) as the most recent authority that includes the study area, with the ability to investigate solutions to coastal flooding problems leading to a USACE recommendation for implementation. Although the study authority also identifies other purposes, this study will focus solely on CSRM. This draft IFR/EA will culminate in a Chief's Report on March 27, 2024, as an interim response to the authority.

The purpose of the study is to evaluate the feasibility of federal participation in implementing solutions to problems and opportunities associated with coastal storm damage to reduce coastal flood risk, risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources along the banks of the Patapsco River in the vicinity of Baltimore City including northern Anne Arundel County and eastern Baltimore County, Maryland and Martin State Airport (MSA) in Baltimore County, Maryland. Coastal storms have produced extensive property damage and loss of life resulting from storm surge and flooding in the recent past, particularly from Hurricane Isabel in 2003, which resulted in costs of $4.8 million to the City of Baltimore, up to $252 million in total damages in Southern Baltimore County, and one fatality.
The study area encompasses the portion of the City of Baltimore and surrounding metropolitan areas to the Francis Scott Key Bridge (I-695) and along the tidally influenced areas that were subject to flooding, storm surge, and damages because of Hurricane Sandy and other recent storms (Figure E-1). The study area was defined to also include assets of importance to MDOT, including MSA in Baltimore County. Within the study area, Baltimore City contains approximately 69 miles of Patapsco River shoreline. The Baltimore County study area contains approximately 4 miles of shoreline along Martin State Airport. The study area is in a densely populated urban setting with residential/mixed-use neighborhoods in areas further inland along Inner Harbor, and industrial facilities primarily serving the Port of Baltimore and associated facilities in the City of Baltimore. Notable historic resources include the Fells Point, Canton, Federal Hill, and Locust Point Historic Districts, the Baltimore Municipal Airport Harbor Field, the Baltimore Municipal Airport Air Station, the Western Electric Company/Point Breeze Historic District, the Canton Grain Elevator, and the Fort McHenry National Monument and Historic Shrine (Fort McHenry). Important cultural resources include the Star-Spangled Banner National Historic Trail and the Captain John Smith Chesapeake National Historic Trail.

The development and screening of measures and formulation of alternatives went through several iterations starting with an initial array of 10 alternatives in addition to the no action plan. These alternatives were screened to a final array of six alternatives including the no action alternatives and five action alternatives that propose structural measures to address CSRM impacts to critical infrastructure and mixed-use/ residential areas within the study area. Of these five action alternatives, three resulted in positive net benefits; Alternative 4: Critical Infrastructure Plan, Alternative 5: Critical Infrastructure and Nonstructural Measures Plan, and Alternative 5A: Critical Infrastructure with Select Nonstructural Measures Plan.

Alternative 5A: Critical Infrastructure with Select Nonstructural Measures Plan was identified as the NED Plan because it reasonably maximizes net benefits and is also identified as the plan that maximizes comprehensive benefits. The NED plan maintains historic neighborhood character, access to water, and enhances community resilience.

Due to insufficient design maturity of Nonstructural Plan, the NED plan or the Recommended Plan is later on finalized with the vertical team only includes structural plan which is the design and construction of floodwalls and closure structures at the Interstate (I)-95 and I-895 Tunnels and supporting transportation critical facilities (the Fort McHenry and Harbor Tunnels ventilation buildings).

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 with the Walla Walla Cost Engineering MCX facilitator 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 meeting are included in Table 1 below.

Table 1. Risk Identification Meeting Participants

Name	Office	Representing
Luis Santiago	USACE	Community Planner
Komla Jackety	USACE	Lead Economist
Damian Lebron	USACE	Civil Engineer
Vanessa Ciaramellano	USACE	Study Manager
Joseph Bieberich	USACE	Project Manager
Chun-Yi Kuo	USACE	Geotechnical
Eric Lamb	USACE	Real Estate
Syed Qayum	USACE	H&H
Andrew Roach	USACE	Planner
Narom Louis	USACE	Cost Engineer
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 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 criterion 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 Appendix C. 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 with 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.

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).

TSP alternative 5A on page 33 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P90 confidence levels are also provided for illustrative purposes.

These contingencies were used to calculate the projected residual fixed cost impact of project delays that are included in the TSP selected alternative 5A pg. 33-41 presentation of total cost contingency. 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.

Major Findings/Observations/Recommendations

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are 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 projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

6.4. Major Findings/Observations

Project cost and schedule comparison summaries are provided in the report's appendix**.** Additional major findings and observations of the risk analysis are listed below.

The PDT worked through the risk register in February 2022. The key risk drivers identified through sensitivity analysis suggest a cost contingency all at an 80% confidence level.

6.4.1. Cost Risks

From the CSRA, the key or greater Cost Risk items of include:

- Market/Bidding conditions - Typical various bids are due to local market and bidding conditions. Low bid competition can be from prequalification of bidders, saturation of market, and labor shortage.
- Acquisition plan - Estimate is not arranged by contracts and can miss out proper escalation. Market condition may be different if project is divided into more contracts. Executing contracts has minimal schedule delays.
- Construction productivity - Change in productivity can affect the estimate positive and negative ways.
- Gates and crossings (structural only) - Closure gates are necessary for road access. Roller gates are selected based on Evaluation, Design, and Construction of Levees guidance EM 1110-2-1913 and included in the Baseline MII estimate and they are likely to be the same type of gates later on. There might be site specific data that may alter the design later on.
- Contractor's Markups - There could be possible increase cost due to higher contractor's markups.
- Scope change (structural only) - Scope change may change once design is more developed with more data and analysis. Field investigations indicate that there might be some saving to length of wall at Ft. McHenry tunnel. Gate sizes might change somewhat.

6.4.2. Schedule Risks

From the CSRA, the key or greater Schedule Risk items include:

- Time of Funding – Large study such as Coast Storm Risk Management tends to have funding delay and other external factors that can prolong the project schedule.
- Acquisitions and Easements - Easements follow existing right of way, mostly, and may be difficult to avoid private property. Easements for private properties are complex. For structural measures, if the owner is not cooperative, condemnations are necessary. Condemnations are very time consuming.
- Schedule of Acquisitions - PDT and sponsors may delays in acquisition schedule.
- Agreement from sponsor on design - Sponsors may disagree on design for reasons such as impacts to tourist areas and normal traffic and pedestrian accesses.
- Overall project funding level - Cost share may be too high. Sponsor may delay decision making. Delay into identifying funding sources.
- H&H NACCS model (structural only) - H&H project conditions and effects on surrounding areas have not been analyzed or considered.
- Geotech modeling deferred (structural only) - There is uncertainty with foundation and sub surface condition. Some areas may require treatment for seepage issues. Cost impact may be moderate. Schedule may have marginal impact because contractors may be able to obtain so much steel materials in time for construction.

6.5. 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.

6.5.1. 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.

6.5.2. 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).

Cost & Schedule Risk Analysis Details

ALTERNATIVE 5A - RECOMMENDED PLAN

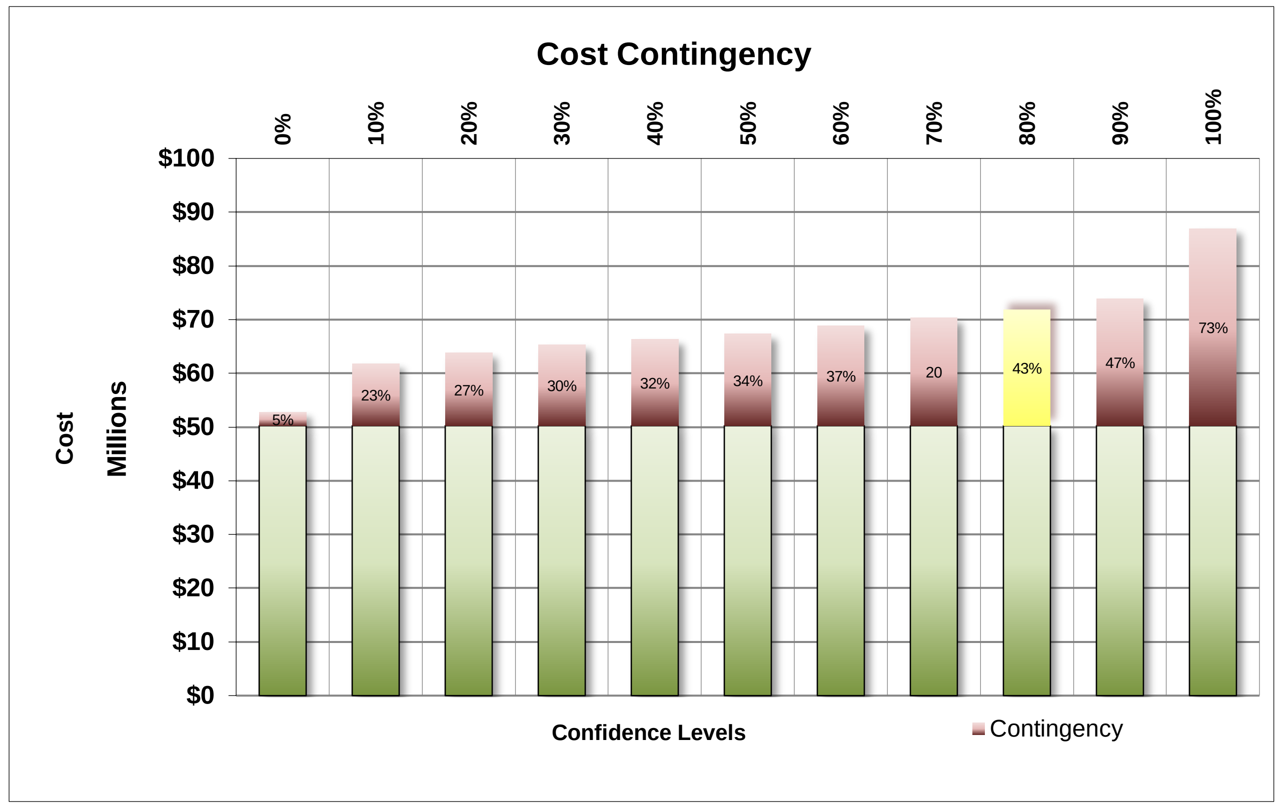
Cost and Schedule Risk Analysis for Structural Plan

Baltimore Coastal Storm Risk Management Feasability Study
24-May-24

- PROJECT CONTINGENCY DEVELOPMENT -

INITIAL CONSTRUCTION
Contingency Analysis

Base Case Estimate (Excluding 01)	$50,245,070	
Confidence Level	**Contingency Value**	**Contingency**
0%	2,512,253	5%
10%	11,556,366	23%
20%	13,566,169	27%
30%	15,073,521	30%
40%	16,078,422	32%
50%	17,083,324	34%
60%	18,590,676	37%
70%	20,098,028	40%
90%	23,615,183	47%
100%	36,678,901	73%

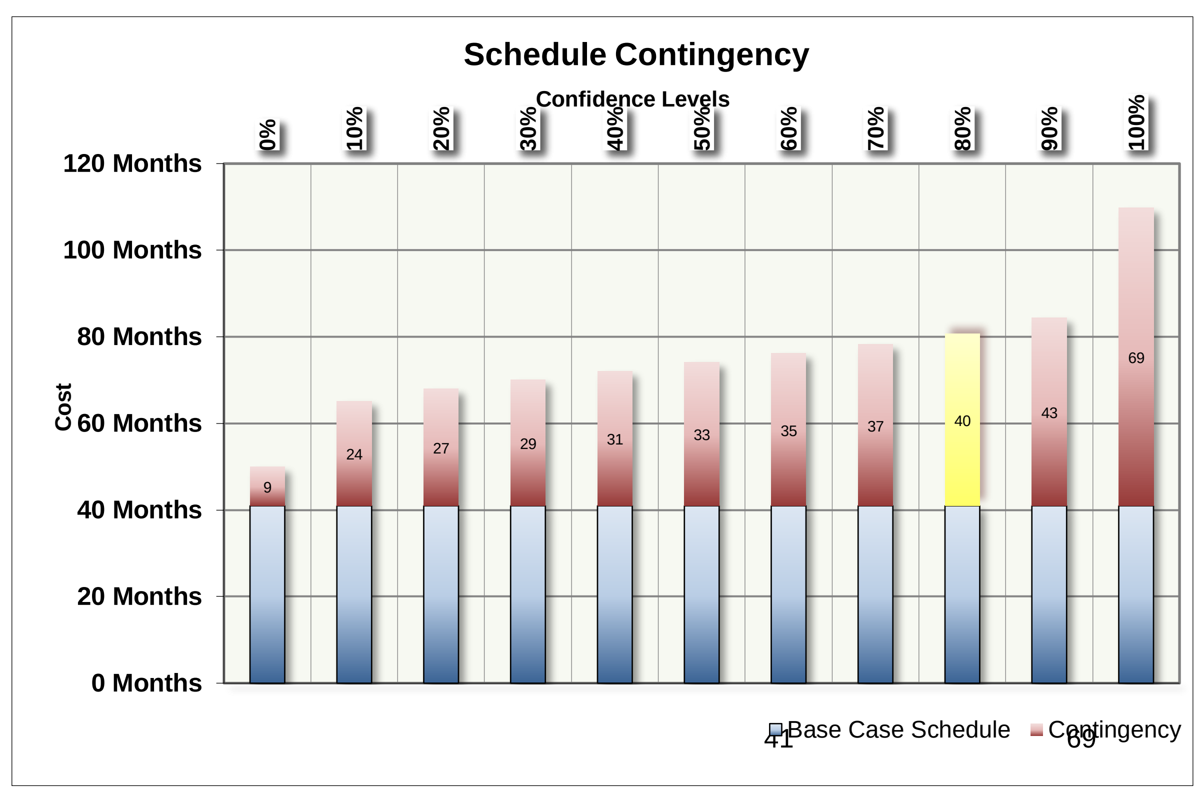


Baltimore Coastal Storm Risk Management Feasability Study

- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

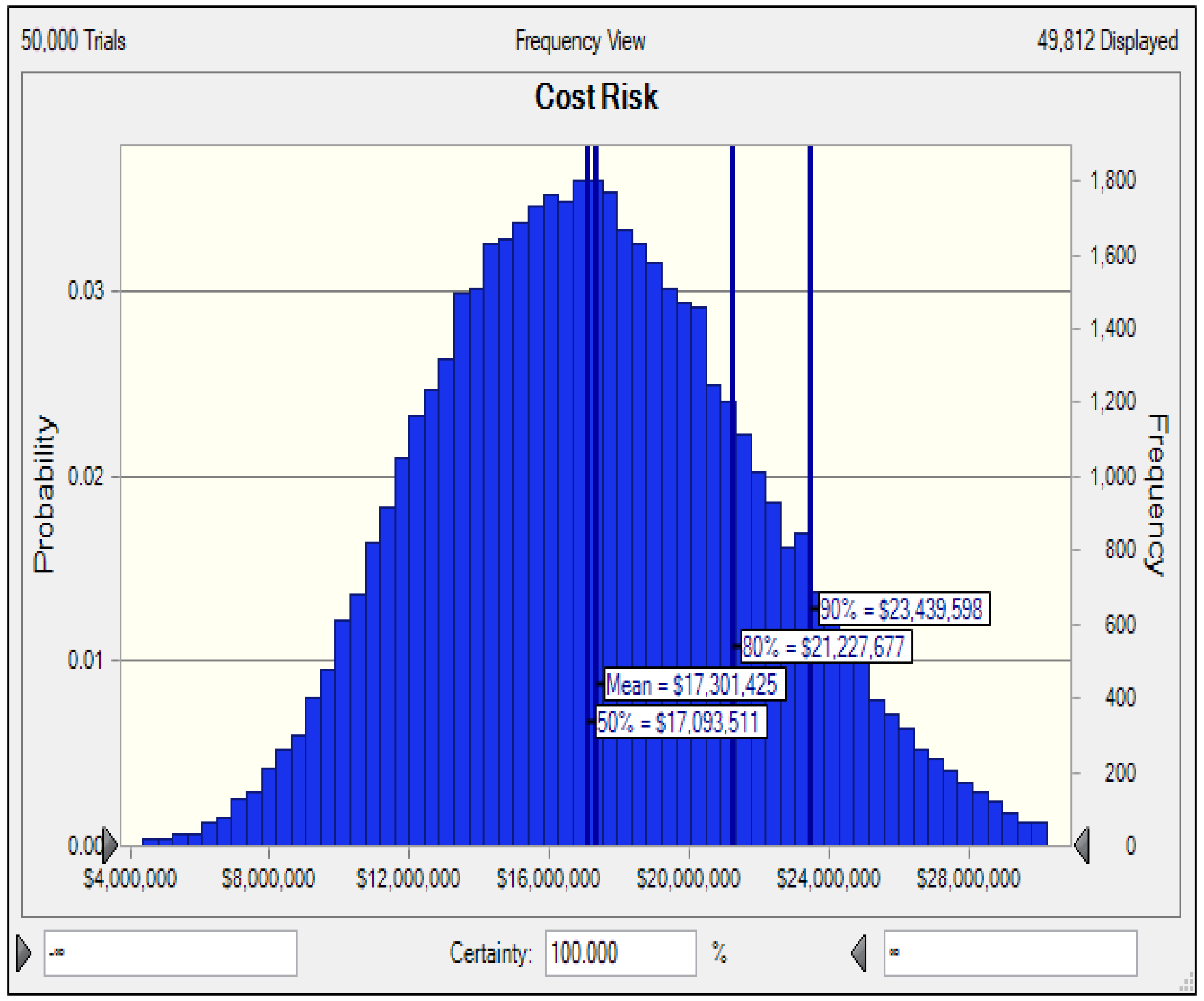
Contingency Analysis

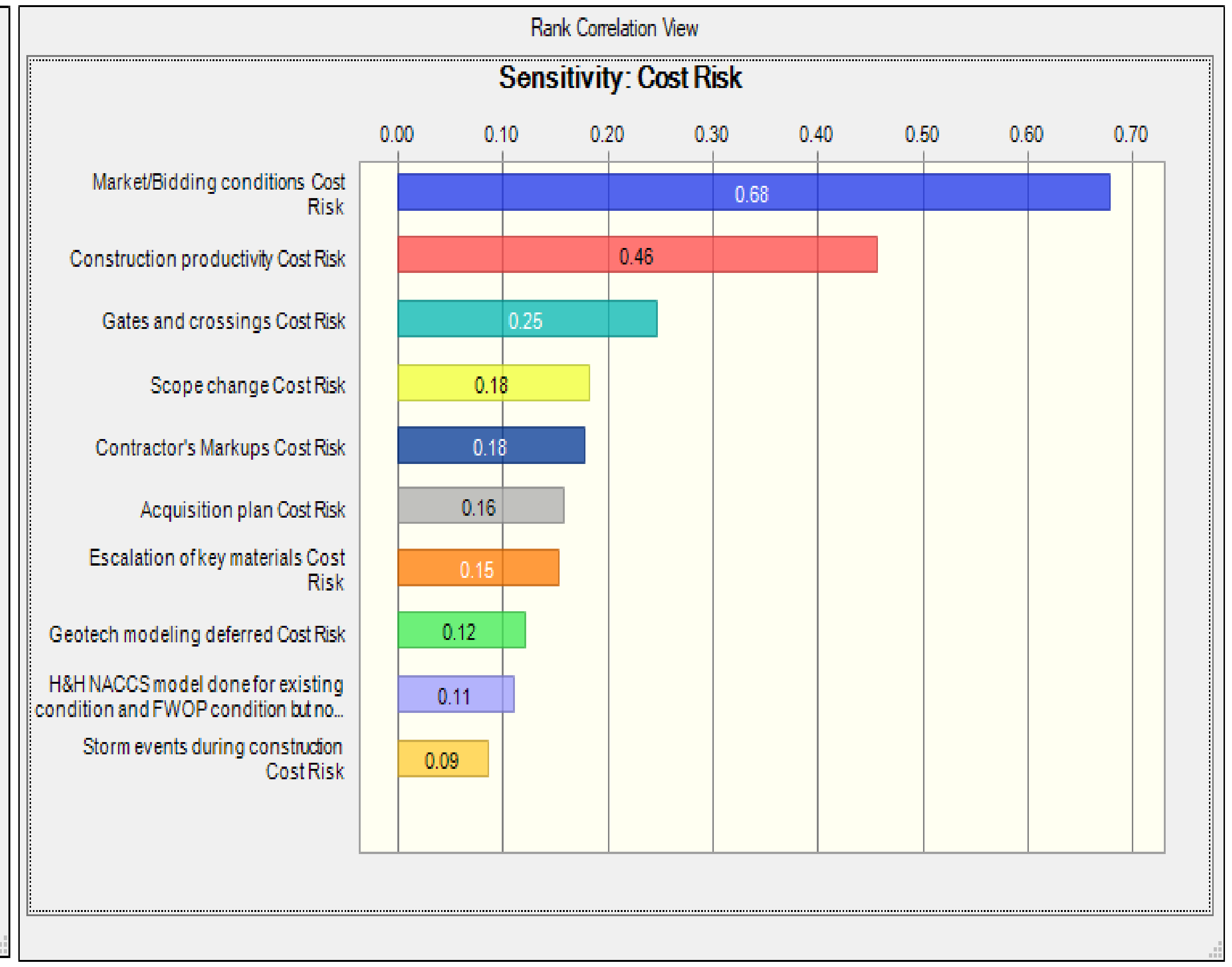
Base Case Schedule	41.0 Months	
Confidence Level	**Contingency Value**	**Contingency**
0%	9 Months	22%
10%	24 Months	59%
20%	27 Months	66%
30%	29 Months	71%
40%	31 Months	76%
50%	33 Months	81%
60%	35 Months	86%
70%	37 Months	91%
80%	**40 Months**	**97%**
90%	43 Months	106%
100%	69 Months	168%



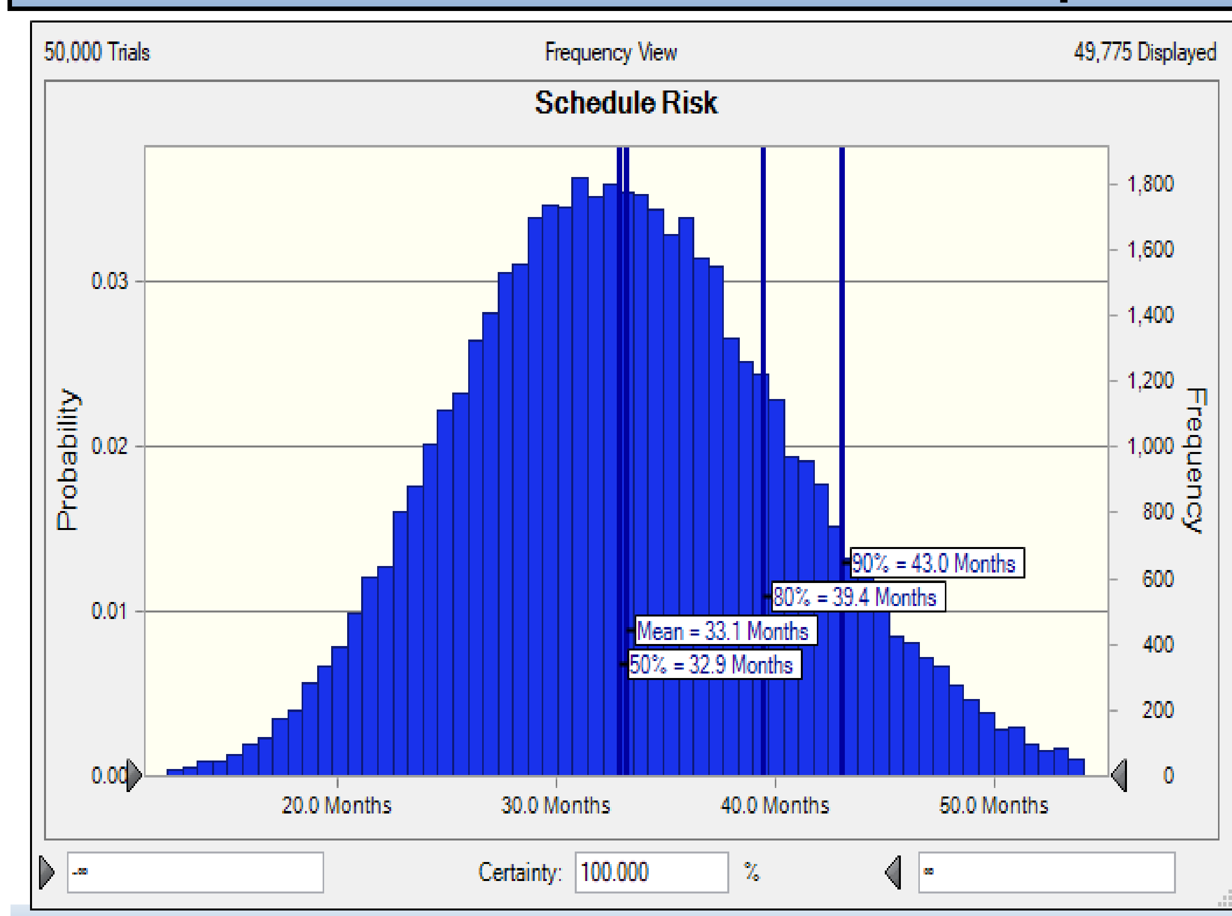
Baltimore Coastal Storm Risk Management Feasability Study
24-May-24

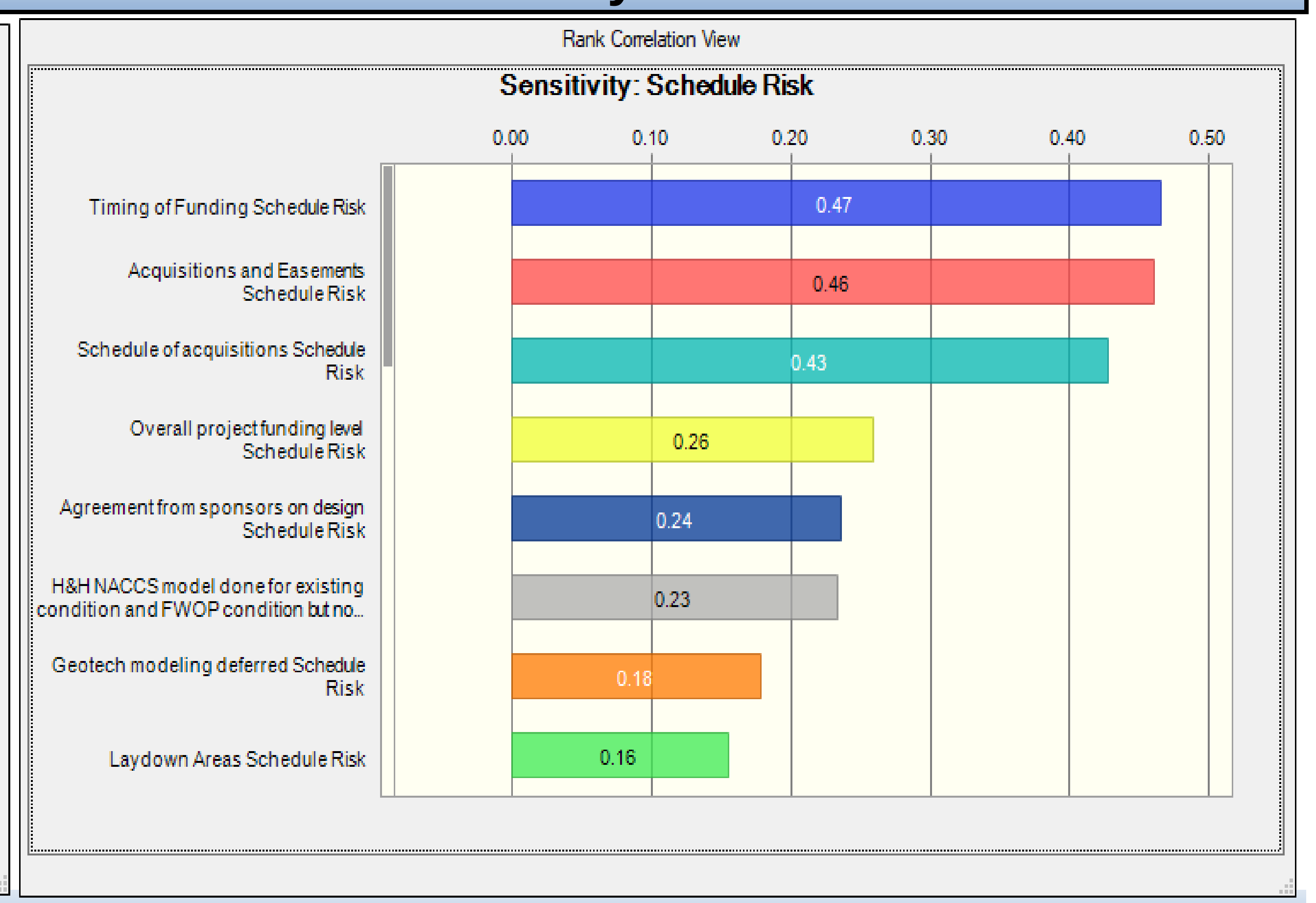
- Cost Outputs Distribution and Sensitivity -





- Schedule Outputs Distribution and Sensitivity -





ALTERNATIVE 5A -RECOMMENDED PLAN

Cost Development Backup for Structural Measures

Estimate Basis of Assumption

Update includes:

Rebar quote checked Nov 2023 Timothy Guinoo 410-263-9134

Structural Ready Mix Concrete - Vulcan Materials Nov 2023, 4000psi $170/cy (before tax) anticipating 2024 increase.

Aggregate base is assumed #57 stone, Vulcan Materials Havre de Grace 2023 price with projected 25% increase (same as 2023 increase) for 2024 projected pricing.

Wall quantities are revised due to a slight change in structural heights which were revised thru site visits and surveys in Sep 2023.

Closure structures are revised to Roller Gates from Stop Logs structures. Roller gates are selected based on Evaluation, Design, and Construction of Levees guidance EM 1110-2-1913. Gate foundation is based on 2001 Olyphant project as proof of concept.

Based on field investigation and data from local sponsor, Utilities Relocation occurs only at MA24 - I-895 Baltimore Harbor Tunnel Ventilation Bldg. The other locations are not of concern according to local sponsor.

There was no design for associated site work. Cost items were added based on visual inspection and field investigation.

No Planning Engineering Design (PED) account 30 and Construction Management (CM) are inlcuded 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.

Material Escalation Indices: Material Price Index History - As of Nov 2023

Nov 2023/Jan 2022 - 1 = 6144.21/ 5073.87 - 1 = 21.1 %

Estimated by CENAB-EN-DT
Designed by CENAB-EN
Prepared by Luan Ngo
Preparation Date 12/6/2023
Effective Date of Pricing 12/6/2023
Estimated Construction Time Days

Description	Quantity	UOM	ContractCost
Cost Summary			**36,004,236.83**
1 Alternative 5A (Recommended Plan)	**1.0000**	**EA**	*36,004,236.8326* **36,004,236.83**
1.1 Levees, Floodwalls, and Floodway Control	**1.0000**	**EA**	*36,004,236.8326* **36,004,236.83**
1.1.1 Relocation	**1.0000**	**EA**	*782,197.7056* **782,197.71**
1.1.1.1 Utility Relocation	**1.0000**	**EA**	*782,197.7056* **782,197.71**
1.1.1.1.1 Relocate Septic Tanks	**2.0000**	**EA**	*363,518.9449* **727,037.89**
1.1.1.1.2 Relocate Storm Drainage Inlets	**3.0000**	**EA**	*5,615.5495* **16,846.65**
1.1.1.1.3 Relocate Electric Pole	**1.0000**	**EA**	*13,128.8646* **13,128.86**
1.1.1.1.4 Relocate Oil Tank Near Emergency Garage Bldg	**1.0000**	**EA**	*10,492.2980* **10,492.30**
1.1.1.1.5 Relocate Manhole Close to Emergency Garage Bldg	**1.0000**	**EA**	*14,692.0046* **14,692.00**
1.1.2 Floodwalls	**11,297.0000**	**LF**	*2,555.2629* **28,866,805.01**
1.1.2.1 Floodwalls	**2,533.0000**	**LF**	*11,396.2910* **28,866,805.01**
1.1.2.1.1 5.5 ft T-Wall at MA8-Patapsco North - Canton Ventilation Bldg 1700+00 to 1709+71	**975.0000**	**LF**	*2,192.8443* **2,138,023.17**
1.1.2.1.2 4.5 ft T-Wall at MA18-Locust Point- McHenry Tunnel-West ventilation building 200+00 to 208+30	**835.0000**	**LF**	*2,952.8169* **2,465,602.07**
1.1.2.1.3 8.5 ft T-Wall at MA19-Locust Point-Ft McHenry Tunnel 100+00 to 142+83	**4,285.0000**	**LF**	*3,000.3486* **12,856,493.78**
1.1.2.1.4 7.5 ft T-Wall MA24-Patapsco South-Baltimore Harbor Tunnel Protection at 1400+00 to 1430+58	**3,060.0000**	**LF**	*3,727.6752* **11,406,685.99**
1.1.3 Floodway Control - Diversion Structures	**1.0000**	**EA**	*6,355,234.1141* **6,355,234.11**
1.1.3.1 MA8 New Closure at Ft. McHenry Tunnel- Canton Ventilation Building	**84.0000**	**SF**	*8,492.9501* **713,407.81**
1.1.3.1.1 Mob and Demob	**1.0000**	**EA**	*80,673.0334* **80,673.03**
1.1.3.1.2 Traffic Controls	**1.0000**	**EA**	*23,047.8987* **23,047.90**

Description	Quantity	UOM	ContractCost
1.1.3.1.3 Closure Structure	**84.0000**	**SF**	*7,258.1771* **609,686.88**
1.1.3.2 MA18 New Closure Structure at Ft. McHenry Tunnel- West Ventilation Vuilding	**56.0000**	**SF**	*12,358.4209* **692,071.57**
1.1.3.2.1 Mob and Demob	**1.0000**	**EA**	*109,948.9966* **109,949.00**
1.1.3.2.2 Traffic Controls	**1.0000**	**EA**	*24,745.4399* **24,745.44**
1.1.3.2.3 Closure Structure	**56.0000**	**SF**	*9,953.1631* **557,377.13**
1.1.3.3 MA19 New Closure Structures at Fort McHenry South Tunnel Approach	**638.0000**	**SF**	*5,812.3316* **3,708,267.55**
1.1.3.3.1 Mob and Demob	**1.0000**	**EA**	*119,009.6988* **119,009.70**
1.1.3.3.2 Traffic Controls	**3.0000**	**EA**	*26,226.7903* **78,680.37**
1.1.3.3.3 Closure Structure 1	**290.0000**	**SF**	*5,147.2298* **1,492,696.64**
1.1.3.3.4 Closure Structure 2	**174.0000**	**SF**	*5,798.5082* **1,008,940.42**
1.1.3.3.5 Closure Structure 3 (same as closure gate 2)	**174.0000**	**SF**	*5,798.5082* **1,008,940.42**
1.1.3.4 MA24 New Closure Structure at Patapsco South-Baltimore Harbor Tunnel	**174.0000**	**SF**	*7,134.9838* **1,241,487.19**
1.1.3.4.1 Mob and Demob	**1.0000**	**EA**	*112,939.0100* **112,939.01**
1.1.3.4.2 Traffic Controls	**1.0000**	**EA**	*28,897.5612* **28,897.56**
1.1.3.4.3 Closure Structure	**174.0000**	**SF**	*6,133.5768* **1,067,242.37**
1.1.3.4.4 Temporary Access - Detour	**6,000.0000**	**SF**	*5.4014* **32,408.25**

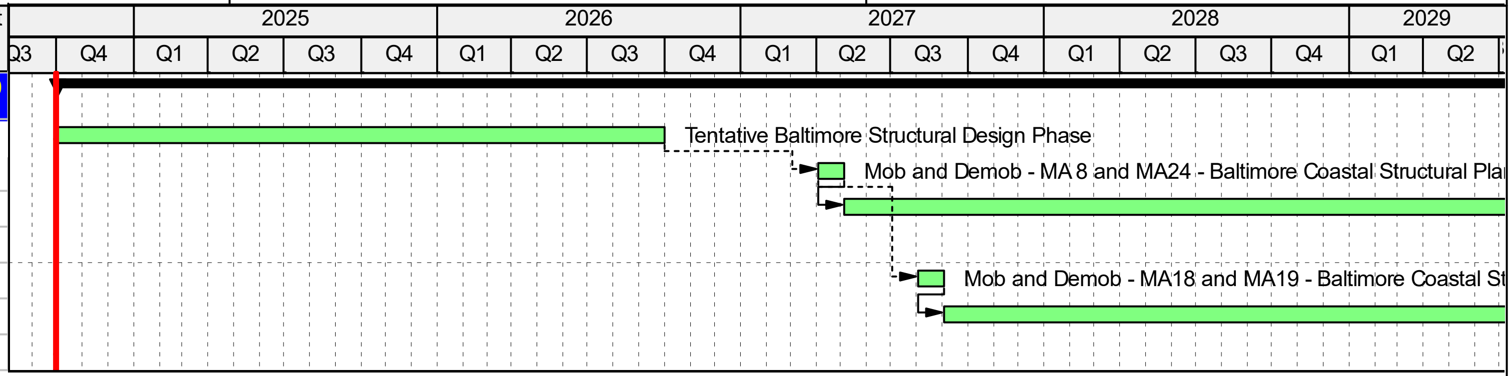
ALTERNATIVE 5A - RECOMMENDED PLAN
Schedule

Activity ID	Activity Name	Planned Duration	Remaining Duration	Schedule % Complete
Baltimore Coastal	**Baltimore Coastal**	1545	1545	0%
A1000	Tentative Baltimore Structural Design Phase	523	523	0%
A1005	Mob and Demob - MA 8 and MA24 - Baltimore Coastal Structural Plan Construction Contract	22	22	0%
A1010	MA 8 and MA24 - Baltimore Coastal Structural Plan Construction	763	763	0%
A1015	Site Close-out - MA 8 and MA24 - Baltimore Coastal Structural Plan Construction Contract	22	22	0%
A1020	Mob and Demob - MA18 and MA19 - Baltimore Coastal Structural Plan Construction Contract	23	23	0%
A1030	MA18 and MA 19 for Baltimore Coastal Structural Plan Construction	761	761	0%
A1040	Site Close-out - MA18 and MA19 - Baltimore Coastal Structural Plan Construction Contract	22	22	0%

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

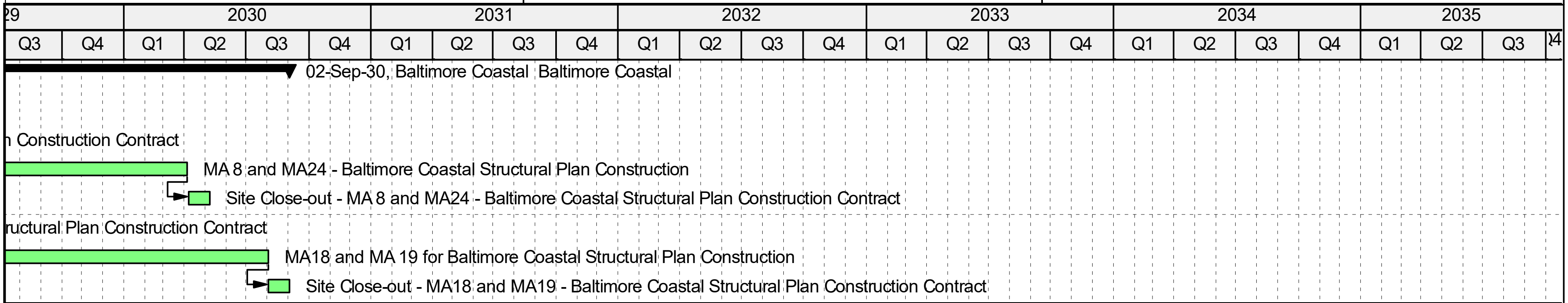
TASK filter: All Activities

e % lete	Start	Finish	Total Float
0%	01-Oct-24	02-Sep-30	0
0%	01-Oct-24	01-Oct-26	
0%	05-Apr-27*	04-May-27	
0%	05-May-27*	05-Apr-30	
0%	08-Apr-30*	07-May-30	
0%	02-Aug-27*	01-Sep-27	
0%	02-Sep-27*	01-Aug-30	
0%	02-Aug-30*	02-Sep-30	



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

TASK filter: All Activities



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

TASK filter: All Activities