US Army Corps
of Engineers®
New York District

FINAL

Integrated Hurricane Sandy
General Reevaluation Report
and
Environmental Impact Statement

Atlantic Coast of New York

East Rockaway Inlet to
Rockaway Inlet and Jamaica Bay

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July 2019

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1 INTRODUCTION

This Atlantic Coast of New York, East Rockaway Inlet to Rockaway Inlet Hurricane Sandy General Revaluation Report Cost Engineering Appendix summarizes the cost engineering methods used to calculate project costs for features for each planning reach within the study area. There were initially three reaches within the study area, but one reach, Motts Basin North was removed during the Recommended Plan as its benefit-to-cost ratio dropped below 1.0. The remaining two reaches within the study area: 1) the Atlantic Shorefront and 2) Jamaica Bay. Since each planning reach is exposed to different risk mechanisms, two engineering appendices are included within this GRR/EIS: Appendix A1 - Shorefront Engineering and Design Appendix, and Appendix A2 - Jamaica Bay High Frequency Flood Risk Reduction Features Engineering and Design Appendix.

This Cost Engineering Appendix provides an overview of the cost analyses supporting both the development of the High Frequency Flood Risk Reduction Features (HFFRRF) for Jamaica Bay and the shorefront reach. This appendix describes the development of MII Cost Estimate for the Recommended Plan for these two reaches. Lastly, this appendix details the cost and schedule risk analysis (CSRA), with the recommended contingency value for the MII estimate and Total Project Cost Summary (TPCS) determined from the CSRA analysis.

The initial study was initially limited to the Atlantic Ocean Shoreline Planning Reach and was conducted as a legacy study. The engineering analyses were conducted to satisfy a more rigorous design level and the Atlantic Ocean shorefront summary engineering documents were written to satisfy those study requirements. The Jamaica Bay Planning Reach analysis was added following Hurricane Sandy and was conducted to broaden the recommended plan to the entire authorized study area and was conducted under SMART planning guidelines.

As a result of the Agency Decision Milestone, the storm surge barrier component of the Tentatively Selected Plan was moved into the New York and New Jersey Harbor and Tributaries Study for further study and possible recommendation. Without the barrier, the communities surrounding Jamaica Bay still experience substantial risk for coastal flooding. Therefore, the study team sought to identify stand-alone features that could complement a potential future storm surge barrier, but also be economically justified on their own. Residents in many parts of the Back-Bay experience regular flooding due to rainfall events and high tides that occur frequently. Since the proposed barrier would not be closed at every high tide or rainfall event, there is an opportunity to recommend features to mitigate flood risk for high frequency flooding events where the proposed storm surge barrier would remain open yet inundation still occurs.

2 PROJECT DESCRIPTION

2.1 Location

Please refer to Figure 2-4 in the HFFRRF Engineering Appendix A2 and Figure 1-1 of the Shorefront Engineering Appendix A1 for details relating to the project location.

2.2 Feature Descriptions

The high frequency flood risk reduction features are detailed in Section 4 of the Engineering Appendix (A2), including typical sections for all features. The alternative development options for the shorefront are detailed in Section 7 of the Shorefront Appendix (A1).

3 RECOMMENDED PLAN FOR EAST ROCKAWAY INLET TO ROCKAWAY INLET AND JAMAICA BAY

3.1 Introduction

The Recommended Plan (RP) for the East Rockaway inlet to Rockaway inlet and Jamaica Bay includes the shorefront sections along Rockaway beach that feature beach fill, groin construction and composite seawall construction. Typical sections and plan views are included in Sub Appendix A1-C of the shorefront Engineering Appendix. The Jamaica Bay section of the project includes various features to reduce flooding in the area including berms, bulkheads, and floodwalls. The Jamaica Bay reach consists of two HFFRRF sites: Mid-Rockaway and Cedarhurst Lawrence. Costs for these areas were developed in MCACES II (MII) in accordance with USACE guidelines and contingency was calculated via the cost and schedule risk analysis using Crystal Ball software.

All labor is assumed to be from prevailing wage rates for New York City and equipment rates estimated from published Blue Book Rates for equipment and supplemented with USACE Region 1 equipment data.

3.2 HFFRRF for Jamaica Bay

The HFFRRF for Jamaica Bay recommended plan initially included three locations, Mid-Rockaway, Motts Basin North, and Cedarhurst Lawrence. However, during the recommended plan phase, increases to the costs of the Motts Basin North location without any corresponding increases in the benefits caused its benefit-to-cost ratio to drop below 1.0, removing it from the recommended plan. The recommended plan described below consists only of Mid-Rockaway and Cedarhurst Lawrence.

3.2.1 Description of Tasks

3.2.1.1 01 – Lands & Damages

Real Estate costs have been provided by the USACE for this project.

3.2.1.2 11 – Floodwalls

Floodwalls were designed using steel sheet pile walls with a concrete cap, with excavation of material and fill material compacted on site. It was assumed that pavement demolition was required, as well as utility relocations, although no location information for utilities was provided. Three different heights of floodwalls were considered, low, medium, and high, but they all contain the same construction features and materials, just varying quantities of each. All steel shapes were assumed to be shapes that are domestically supplied. A description of the individual elements are included in the MII estimate.

3.2.1.1 13 - Pump Stations

Pump stations were estimated using pump cost curves for the New York Metropolitan area. Costs are estimated based off of the size and number of pumps in a given HFFRRF site. Please refer to Sub-appendix G for further information on pump cost development.

3.2.1.2 18 – Cultural Resource Preservation

Costs for the cultural resource preservation were estimated using data provided by the USACE on November 20, 2018. These costs include Phase 1 and Phase II surveys, historic structure documentation and Phase II data recovery efforts. The Phase III data recovery costs do not exceed the 1% threshold.

3.2.2 30 - Planning, Engineering, and Design

Code of Account 30, Planning, Engineering, and Design (PED) was estimated at 12% of construction costs for the Jamaica Bay sections that require additional survey, utility location, and further site specific design.

3.2.3 31 - Construction Management

Code of Account 31, Construction management costs were estimated using the USACE Supervision and Administration cost formula [% = 17 – 2.1 * log (subtotal / 1000) / 100]. This calculated to a 6.11% construction management percentage for the Jamaica Bay project.

3.2.4 Cost Summary

The Summary of costs for the Jamaica Bay portion of the project including the 28.36% contingency calculated in the CSRA (see section 4) are included in Tables 3-1 and 3-2 below.

Table 3-1: Mid-Rockaway HFFRRF Costs

****** CONTRACT COST SUMMARY ******

PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
LOCATION: Queens, NY
This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			**20-Aug-18**	Program Year (Budget EC):			2019					
		Effective Price Level:			1-Oct-17	Effective Price Level Date:			1 OCT 18					
				RISK BASED										
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*
	Mid-Rockaway													
02	RELOCATIONS	$4,155	$1,178	28.4%	$5,333	2.1%	$4,240	$1,203	$5,443	2020Q4	3.5%	$4,390	$1,245	$5,636
11	LEVEES & FLOODWALLS	$91,240	$25,876	28.4%	$117,116	2.1%	$93,113	$26,407	$119,519	2022Q2	6.7%	$99,309	$28,164	$127,473
13	PUMPING PLANT	$33,824	$9,592	28.4%	$43,416	2.1%	$34,518	$9,789	$44,307	2022Q2	6.7%	$36,815	$10,441	$47,256
18	CULTURAL RESOURCE PRESERVATION	$1,250	$355	28.4%	$1,605	2.1%	$1,276	$362	$1,637	2022Q2	6.7%	$1,361	$386	$1,746
	CONSTRUCTION ESTIMATE TOTALS:	$130,469	$37,001	28.4%	**$167,470**		$133,146	$37,760	$170,907			$141,875	$40,236	$182,111
01	LANDS AND DAMAGES	$28,649	$5,730	20.0%	$34,379	2.1%	$29,237	$5,847	$35,084	2020Q4	3.5%	$30,272	$6,054	$36,327
30	PLANNING, ENGINEERING & DESIGN													
1.0%	Project Management	$1,305	$370	28.4%	$1,675	3.9%	$1,355	$384	$1,739	2019Q3	2.1%	$1,383	$392	$1,775
0.5%	Planning & Environmental Compliance	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2019Q3	2.1%	$691	$196	$888
6.0%	Engineering & Design	$7,828	$2,220	28.4%	$10,048	3.9%	$8,130	$2,306	$10,436	2019Q3	2.1%	$8,297	$2,353	$10,650
0.5%	Reviews, ATRs, IEPRs, VE	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2019Q3	2.1%	$691	$196	$888
0.5%	Life Cycle Updates (cost, schedule, risks)	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2019Q3	2.1%	$691	$196	$888
0.5%	Contracting & Reprographics	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2019Q3	2.1%	$691	$196	$888
1.0%	Engineering During Construction	$1,305	$370	28.4%	$1,675	3.9%	$1,355	$384	$1,739	2022Q2	14.0%	$1,545	$438	$1,984
1.0%	Planning During Construction	$1,305	$370	28.4%	$1,675	3.9%	$1,355	$384	$1,739	2022Q2	14.0%	$1,545	$438	$1,984
0.5%	Adaptive Management & Monitoring	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2022Q2	14.0%	$773	$219	$992
0.5%	Project Operations	$652	$185	28.4%	$837	3.9%	$677	$192	$870	2019Q3	2.1%	$691	$196	$888
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$5,219	$1,480	28.4%	$6,699	3.9%	$5,420	$1,537	$6,957	2022Q2	14.0%	$6,181	$1,753	$7,934
1.0%	Project Operation:	$1,305	$370	28.4%	$1,675	3.9%	$1,355	$384	$1,739	2022Q2	14.0%	$1,545	$438	$1,984
1.1%	Project Management	$1,448	$411	28.4%	$1,859	3.9%	$1,504	$427	$1,931	2022Q2	14.0%	$1,715	$486	$2,202
	CONTRACT COST TOTALS:	$182,746	$49,432		$232,178		$186,922	$50,567	**$237,489**			$198,589	$53,789	**$252,378**

Table 3-2: Cedarhurst Lawrence HFFRRF Costs

****** CONTRACT COST SUMMARY ******

PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
LOCATION: Queens, NY
This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 20-Aug-18				Program Year (Budget EC): 2019								
		Effective Price Level: 1-Oct-17				Effective Price Level Date: 1 OCT 18								
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*
	Cedarhurst Lawrence													
02	RELOCATIONS	$175	$50	28.4%	$225	2.1%	$179	$51	$230	2020Q4	3.5%	$185	$53	$238
11	LEVEES & FLOODWALLS	$6,694	$1,898	28.4%	$8,592	2.1%	$6,831	$1,937	$8,768	2021Q3	5.1%	$7,178	$2,036	$9,214
13	PUMPING PLANT	$2,753	$781	28.4%	$3,534	2.1%	$2,809	$797	$3,606	2021Q4	5.6%	$2,967	$841	$3,809
18	CULTURAL RESOURCE PRESERVATION	$750	$213	28.4%	$963	2.1%	$765	$217	$982	2021Q3	5.1%	$804	$228	$1,032
	CONSTRUCTION ESTIMATE TOTALS:	$10,372	$2,941	28.4%	**$13,314**		$10,585	$3,002	$13,587			$11,135	$3,158	$14,293
01	LANDS AND DAMAGES	$725	$145	20.0%	$870	2.1%	$740	$148	$888	2020Q3	3.0%	$762	$152	$915
30	PLANNING, ENGINEERING & DESIGN													
1.0%	Project Management	$104	$29	28.4%	$133	3.9%	$108	$31	$138	2019Q3	2.1%	$110	$31	$141
0.5%	Planning & Environmental Compliance	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2019Q3	2.1%	$55	$16	$71
6.0%	Engineering & Design	$622	$176	28.4%	$799	3.9%	$646	$183	$830	2019Q3	2.1%	$660	$187	$847
0.5%	Reviews, ATRs, IEPRs, VE	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2019Q3	2.1%	$55	$16	$71
0.5%	Life Cycle Updates (cost, schedule, risks)	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2019Q3	2.1%	$55	$16	$71
0.5%	Contracting & Reprographics	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2019Q3	2.1%	$55	$16	$71
1.0%	Engineering During Construction	$104	$29	28.4%	$133	3.9%	$108	$31	$138	2021Q3	10.7%	$119	$34	$153
1.0%	Planning During Construction	$104	$29	28.4%	$133	3.9%	$108	$31	$138	2021Q3	10.7%	$119	$34	$153
0.5%	Adaptive Management & Monitoring	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2021Q3	10.7%	$60	$17	$77
0.5%	Project Operations	$52	$15	28.4%	$67	3.9%	$54	$15	$69	2019Q3	2.1%	$55	$16	$71
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$415	$118	28.4%	$533	3.9%	$431	$122	$553	2021Q3	10.7%	$477	$135	$612
1.0%	Project Operation:	$104	$29	28.4%	$133	3.9%	$108	$31	$138	2021Q3	10.7%	$119	$34	$153
1.1%	Project Management	$115	$33	28.4%	$148	3.9%	$120	$34	$153	2021Q3	10.7%	$132	$38	$170
	CONTRACT COST TOTALS:	$12,975	$3,619		**$16,595**		$13,276	$3,703	**$16,979**			$13,968	$3,898	**$17,866**

3.2.5 MII Estimate

The MII Estimate for Jamaica Bay is included in Sub-Appendix A.

3.2.6 Schedule

The Project Schedule is included in Sub-Appendix B.

3.3 Rockaway Shorefront

3.3.1 Description of Tasks

Beach fill is planned for construction starting in December 2019. Since it is impossible to predict the exact shoreline position for the point in time that construction is to start, beach fill quantities required for initial construction are estimated based on the expected shoreline position in December 2019. The unknown quantities are due to the fact that wave conditions vary from year to year and affect shoreline change rates. The assumptions utilized in the quantity estimate are detailed in the Shorefront Engineering and Design Appendix (Appendix A1).

3.3.1.1 17 - Beach Fill

Beach fill was estimated by a USACE provided CEDEP estimate for this project using a hydraulic cutterhead dredge. Mobilization and Demobilization for this dredge was also provided by the USACE using a CEDEP.

3.3.1.2 10 - Groin Extensions

Five groins in Reaches 5 & 6 have been proposed to be extended to reduce erosion and improve overall project performance. These groins will have a layer of bedding stone that is 30 – 130 lbs. The core layer of the groin will be the same size, with a larger layer of underlayer stone that will serve as a dividing layer between the armor and the core stone. The underlayer stone is proposed as 500 – 1500 lbs stone. The top layer of armor stone is estimated as 7-10 tons in weight. A diagram showing the cross section of the groin extensions is located on Sheet CS-407 of Sub-Appendix C of Appendix A1, the Shorefront Engineering Appendix (A1).

3.3.1.3 10 - New Groin Construction

16 total groins are to be constructed in addition to the five groin extensions discussion previously. These groins range from 298 feet - 498 feet long. These groins have the same design as the groin extensions with a layer of bedding stone, core stone, underlayer stone, and armor stone on top. A typical section of the new groin construction is located in Figure 7-6 of the Shorefront Engineering Appendix (A1). The new groin construction had the same components as the groin extensions, and are described below.

3.3.1.4 10 - Composite Seawall

Construction of a 32,450 foot composite wall has been proposed along the beach to protect the boardwalk and residential homes adjacent to the beach, including a taper to connect the seawall with other flood protection features. The composite wall consists of steel sheet piles with a concrete cap. The wall is then protected using large armor stone with an underlayer stone to separate the armor from the sand beneath. A significant amount of sand must also be excavated for the placement of the underlayer and armor stone.

3.3.2 Markups

Markups for the shorefront work included sales tax on materials and overtime. It was assumed that the composite wall was constructed 6 days a week, with a single shift per day. This resulted in an 8.875% markup in the MII file. Profit was estimated at 10.0% using the USACE profit weighted guidelines.

3.3.3 18 – Cultural Resource Preservation

Costs for the cultural resource preservation were estimated using data provided by the USACE on November 20, 2018. These costs include Phase 1 and Phase II surveys, historic structure documentation and Phase II data recovery efforts. The Phase III data recovery costs do not exceed the 1% threshold.

3.3.4 30 - Planning, Engineering, and Design

Code of Account 30, Planning, Engineering, and Design (PED) was estimated at 8% for the shorefront portions, with detailed survey and further refinement required for the design near the boardwalk.

3.3.5 31 - Construction Management

Code of Account 31, Construction management costs were estimated using the USACE Supervision and Administration cost formula [% = 17 – 2.1 * log (subtotal / 1000) / 100]. This calculated to a 5.8% construction management percentage for the shorefront project.

3.3.6 Cost Summary

The summary of costs for the shorefront including the 28.36% contingency calculated from the CSRA (See section 4) is included in Table 3-3 below. The additional costs for the beach replenishment over the 50 year life cycle is included in Tables 3-4 & 3-5 below.

Table 3-3: Shorefront Costs

****** CONTRACT COST SUMMARY ******

PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
LOCATION: Queens, NY
This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			**20-Aug-18**	Program Year (Budget EC):			2019	FULLY FUNDED PROJECT ESTIMATE				
		Effective Price Level:			1-Oct-17	Effective Price Level Date:			1 OCT 18					
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***
	Shorefront													
10	BREAKWATER & SEAWALLS	$187,704	$53,233	28.4%	$240,936	2.1%	$191,556	$54,325	$245,881	2022Q1	6.1%	$203,281	$57,650	$260,931
17	BEACH REPLENISHMENT	$26,966	$7,648	28.4%	$34,614	2.1%	$27,519	$7,804	$35,324	2020Q3	3.0%	$28,353	$8,041	$36,393
18	CULTURAL RESOURCE PRESERVATION	$10,000	$2,836	28.4%	$12,836	2.1%	$10,205	$2,894	$13,099	2021Q3	5.1%	$10,724	$3,041	$13,766
	CONSTRUCTION ESTIMATE TOTALS:	$224,670	$63,716	28.4%	**$288,386**		$229,280	$65,024	$294,304			$242,358	$68,733	$311,090
01	LANDS AND DAMAGES	$528	$106	20.0%	$634	2.1%	$539	$108	$647	2019Q3	1.0%	$545	$109	$654
30	PLANNING, ENGINEERING & DESIGN													
1.0%	Project Management	$2,247	$637	28.4%	$2,884	3.9%	$2,333	$662	$2,995	2019Q1	0.0%	$2,333	$662	$2,995
0.5%	Planning & Environmental Compliance	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q1	0.0%	$1,167	$331	$1,498
2.0%	Engineering & Design	$4,493	$1,274	28.4%	$5,768	3.9%	$4,667	$1,323	$5,990	2019Q1	0.0%	$4,667	$1,323	$5,990
0.5%	Reviews, ATRs, IEPRs, VE	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q1	0.0%	$1,167	$331	$1,498
0.5%	Life Cycle Updates (cost, schedule, risks)	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q1	0.0%	$1,167	$331	$1,498
0.5%	Contracting & Reprographics	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q1	0.0%	$1,167	$331	$1,498
1.0%	Engineering During Construction	$2,247	$637	28.4%	$2,884	3.9%	$2,333	$662	$2,995	2022Q1	12.9%	$2,635	$747	$3,382
1.0%	Planning During Construction	$2,247	$637	28.4%	$2,884	3.9%	$2,333	$662	$2,995	2022Q1	12.9%	$2,635	$747	$3,382
0.5%	Adaptive Management & Monitoring	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q3	2.1%	$1,191	$338	$1,528
0.5%	Project Operations	$1,123	$319	28.4%	$1,442	3.9%	$1,167	$331	$1,498	2019Q1	0.0%	$1,167	$331	$1,498
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$8,987	$2,549	28.4%	$11,535	3.9%	$9,333	$2,647	$11,980	2022Q1	12.9%	$10,539	$2,989	$13,528
1.0%	Project Operation:	$2,247	$637	28.4%	$2,884	3.9%	$2,333	$662	$2,995	2022Q1	12.9%	$2,635	$747	$3,382
0.8%	Project Management	$1,797	$510	28.4%	$2,307	3.9%	$1,867	$529	$2,396	2022Q1	12.9%	$2,108	$598	$2,706
	CONTRACT COST TOTALS:	$256,202	$72,615		**$328,817**		$262,019	$74,264	**$336,282**			$277,478	$78,647	**$356,125**

Table 3-4: Shorefront Beach Replenishment Costs

**** CONTRACT COST SUMMARY ****

PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
LOCATION: Queens, NY
This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 20-Aug-18 Effective Price Level: 1-Oct-17				Program Year (Budget EC): 2019 Effective Price Level Date: 1 OCT 18				FULLY FUNDED PROJECT ESTIMATE				
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*
	RENOURISHMENT COSTS (EVERY 4 YRS)													
17	BEACH REPLENISHMENT - CYCLE 1	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2024Q3	11.5%	$21,932	$6,220	$28,152
17	BEACH REPLENISHMENT - CYCLE 2	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2028Q3	20.7%	$23,740	$6,733	$30,473
17	BEACH REPLENISHMENT - CYCLE 3	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2032Q3	30.7%	$25,697	$7,288	$32,984
17	BEACH REPLENISHMENT - CYCLE 4	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2036Q3	41.4%	$27,815	$7,888	$35,703
17	BEACH REPLENISHMENT - CYCLE 5	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2040Q3	53.1%	$30,108	$8,539	$38,646
17	BEACH REPLENISHMENT - CYCLE 6	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2044Q3	65.7%	$32,590	$9,242	$41,832
17	BEACH REPLENISHMENT - CYCLE 7	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2048Q3	79.4%	$35,276	$10,004	$45,281
17	BEACH REPLENISHMENT - CYCLE 8	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2052Q3	94.2%	$38,184	$10,829	$49,013
17	BEACH REPLENISHMENT - CYCLE 9	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2056Q3	110.2%	$41,332	$11,722	$53,053
17	BEACH REPLENISHMENT - CYCLE 10	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2060Q3	127.5%	$44,739	$12,688	$57,426
17	BEACH REPLENISHMENT - CYCLE 11	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2064Q3	146.2%	$48,427	$13,734	$62,160
17	BEACH REPLENISHMENT - CYCLE 12	$19,271	$5,465	28.4%	$24,736	2.1%	$19,666	$5,577	$25,244	2068Q3	166.5%	$52,419	$14,866	$67,285
	CONSTRUCTION ESTIMATE TOTALS:	$231,251	$65,583	28.4%	$296,833		$235,995	$66,928	$302,923			$422,257	$119,752	$542,009
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2023Q3	20.0%	$2,401	$681	$3,082
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2027Q3	42.1%	$2,843	$806	$3,650
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2031Q3	70.0%	$3,402	$965	$4,367
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2035Q3	105.6%	$4,115	$1,167	$5,282
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2039Q3	151.2%	$5,028	$1,426	$6,454
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2043Q3	207.7%	$6,158	$1,747	$7,905
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2047Q3	276.9%	$7,543	$2,139	$9,682
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2051Q3	361.6%	$9,238	$2,620	$11,858
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2055Q3	465.4%	$11,315	$3,209	$14,524
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2059Q3	592.4%	$13,859	$3,930	$17,789
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	2063Q3	748.1%	$16,974	$4,814	$21,788
30	PLANNING, ENGINEERING & DESIGN	$1,927	$547	28.4%	$2,474	3.9%	$2,001	$568	$2,569	19270.8838	938.8%	$20,789	$5,896	$26,685
	PLANNING, ENGINEERING & DESIGN TOTAL	$23,125	$6,558	28.4%	$29,683		$24,017	$6,811	$30,828			$103,666	$29,400	$133,066
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2024Q3	25.0%	$1,451	$412	$1,863
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2028Q3	48.5%	$1,723	$489	$2,212
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2032Q3	78.0%	$2,067	$586	$2,653
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2036Q3	115.9%	$2,507	$711	$3,218
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2040Q3	164.3%	$3,068	$870	$3,938
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2044Q3	223.7%	$3,758	$1,066	$4,823
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2048Q3	296.5%	$4,602	$1,305	$5,907
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2052Q3	385.6%	$5,637	$1,599	$7,235
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2056Q3	494.8%	$6,904	$1,958	$8,862
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2060Q3	628.5%	$8,456	$2,398	$10,854
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2064Q3	792.2%	$10,357	$2,937	$13,294
31	CONSTRUCTION MANAGEMENT	$1,118	$317	28.4%	$1,435	3.9%	$1,161	$329	$1,490	2068Q3	992.8%	$12,685	$3,597	$16,282
	CONSTRUCTION MANAGEMENT TOTAL	$13,413	$3,804	28.4%	$17,216		$13,930	$3,950	$17,880			$63,214	$17,928	$81,142
	CONTRACT COST TOTALS:	$267,788	$75,945		$343,733		$273,941	$77,690	$351,631			$589,137	$167,079	$756,217

Table 3-5: Shorefront Beach Replenishment Monitoring Costs

****** CONTRACT COST SUMMARY ******

PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
LOCATION: Queens, NY
This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 20-Aug-18 Effective Price Level: 1-Oct-17				Program Year (Budget EC): 2019 Effective Price Level Date: 1 OCT 18				FULLY FUNDED PROJECT ESTIMATE				
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*
	ENVIRONMENTAL MONITORING (EVERY 4 YRS)													
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2024Q3	11.5%	$1,406	$399	$1,804
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2028Q3	20.7%	$1,521	$431	$1,953
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2032Q3	30.7%	$1,647	$467	$2,114
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2036Q3	41.4%	$1,783	$506	$2,288
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2040Q3	53.1%	$1,930	$547	$2,477
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2044Q3	65.7%	$2,089	$592	$2,681
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2048Q3	79.4%	$2,261	$641	$2,902
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2052Q3	94.2%	$2,447	$694	$3,141
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2056Q3	110.2%	$2,649	$751	$3,400
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2060Q3	127.5%	$2,867	$813	$3,680
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2064Q3	146.2%	$3,104	$880	$3,984
06	FISH & WILDLIFE FACILITIES	$1,235	$350	28.4%	$1,585	2.1%	$1,260	$357	$1,618	2068Q3	166.5%	$3,359	$953	$4,312
	CONSTRUCTION ESTIMATE TOTALS:	$14,820	$4,203	28.4%	**$19,023**		$15,124	$4,289	$19,413			$27,061	$7,675	$34,736
	CONTRACT COST TOTALS:	$14,820	$4,203		**$19,023**		$15,124	$4,289	**$19,413**			$27,061	$7,675	**$34,736**

3.3.7 MII Estimate

The MII Estimate for the Rockaway Shorefront is included in Sub-Appendix C.

3.3.8 Schedule

The Project Schedule is included in Sub-Appendix B.

3.4 Recommended Plan Cost Summary

A summary table showing the total cost without contingency and with the calculated 28.36% contingency for both the Shorefront and Jamaica Bay project locations is included below in Table 3-6. In addition, Table 3-6 displays the Total Project Cost Summary (TPCS) sheet for the project based on the anticipated Project Schedule as shown in Appendix B.

Table 3-6: TPCS for East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

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

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PROJECT: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay
PROJECT NO: P2 403429
LOCATION: Queens, NY

DISTRICT: NY District
POC: CHIEF, COST ENGINEERING, Mukesh Kumar

PREPARED: 6/20/2019

This Estimate reflects the scope and schedule in report; East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2019; Effective Price Level Date: 1 OCT 18				Spent Thru: 1-Oct-17	TOTAL FIRST COST				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	($K)	($K)	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		*K*	*L*	*M*	*N*	*O*
02	RELOCATIONS	$4,330	$1,228	28.4%	$5,559	2.1%	$4,419	$1,253	$5,673	$0	$5,673	3.5%	$4,576	$1,298	$5,874
10	BREAKWATER & SEAWALLS	$187,704	$53,233	28.4%	$240,936	2.1%	$191,556	$54,325	$245,881	$0	$245,881	6.1%	$203,281	$57,650	$260,931
11	LEVEES & FLOODWALLS	$97,934	$27,774	28.4%	$125,707	2.1%	$99,944	$28,344	$128,288	$0	$128,288	6.5%	$106,487	$30,200	$136,687
13	PUMPING PLANT	$36,577	$10,373	28.4%	$46,950	2.1%	$37,327	$10,586	$47,913	$0	$47,913	6.6%	$39,783	$11,282	$51,065
17	BEACH REPLENISHMENT	$26,966	$7,648	28.4%	$34,614	2.1%	$27,519	$7,804	$35,324	$0	$35,324	3.0%	$28,353	$8,041	$36,393
18	CULTURAL RESOURCE PRESERVATION	$12,000	$3,403	28.4%	$15,403	2.1%	$12,246	$3,473	$15,719	$0	$15,719	5.3%	$12,889	$3,655	$16,545
	CONSTRUCTION ESTIMATE TOTALS:	$365,511	$103,659		$469,169	2.1%	$373,011	$105,786	$478,797	$0	$478,797	6.0%	$395,368	$112,126	$507,495
01	LANDS AND DAMAGES	$29,903	$5,981	20.0%	$35,883	2.1%	$30,516	$6,103	$36,619	$0	$36,619	3.5%	$31,579	$6,316	$37,895
30	PLANNING, ENGINEERING & DESIGN	$34,874	$9,890	28.4%	$44,765	3.9%	$36,219	$10,272	$46,491	$0	$46,491	3.9%	$37,636	$10,673.57	$48,310
31	CONSTRUCTION MANAGEMENT	$21,636	$6,136	28.4%	$27,772	3.9%	$22,470	$6,373	$28,843	$0	$28,843	13.3%	$25,452	$7,218	$32,670
	PROJECT COST TOTALS:	$451,924	$125,666	27.8%	$577,590		$462,217	$128,534	**$590,750**	$0	**$590,750**	6.0%	$490,035	$136,334	$626,369
	Renourishment/Monitoring/Breach Closure Costs														
06	FISH & WILDLIFE FACILITIES	$14,820	$4,203	28.4%	$19,023	2.1%	$15,124	$4,289	$19,413	$0	$19,413	78.9%	$27,061	$7,675	$34,736
17	BEACH REPLENISHMENT	$231,251	$65,583	28.4%	$296,833	2.1%	$235,995	$66,928	$302,923	$0	$302,923	78.9%	$422,257	$119,752	$542,009
		$246,071	$69,786		$315,856	2.1%	$251,119	$71,217	$322,336	$0	$322,336	78.9%	$449,318	$127,427	$576,745
	E&D AND S&A														
30	PLANNING, ENGINEERING & DESIGN	$23,125	$6,558	28.4%	$29,683	3.9%	$24,017	$6,811	$30,828	$0	$30,828	331.6%	$103,666	$29,400	$133,066
31	CONSTRUCTION MANAGEMENT	$13,413	$3,804	28.4%	$17,216	3.9%	$13,930	$3,950	$17,880	$0	$17,880	353.8%	$63,214	$17,928	$81,142
	RENOURISHMENT COST TOTALS:	$282,608	$80,148	28.4%	$362,756		$289,065	$81,979	**$371,044**	$0	**$371,044**	113.2%	$616,198	$174,754	$790,952
	PROJECT COST TOTALS	$734,532	$205,813	28.0%	$940,345		$751,282	$210,512	**$961,794**	$0	**$961,794**	47.4%	**$1,106,234**	**$311,088**	**$1,417,321**

CHIEF, COST ENGINEERING, Mukesh Kumar

PROJECT MANAGER, Daniel Falt

CHIEF, REAL ESTATE, xxx

ESTIMATED TOTAL PROJECT COST: **$626,369**

ESTIMATED RENOURISHMENT PROJECT COST: **$790,952**

ESTIMATED TOTAL PROJECT COST: **$1,417,321**

3.4.1 Operations and Maintenance (O&M) Costs

Operations and maintenance costs were estimated as $19 / linear foot of feature per year. The vehicular gates were estimated separately at 0.5% of the initial gate cost, and pump stations were assumed to have an O&M cost of 2% of the initial construction cost. These values were estimated from other flood protection and pump cost data for the NYC metropolitan area.

3.5 Interest During Construction

The interest during construction calculated for the project based on the project schedule and project first costs are included below in Table 3-7: Interest During Construction.

Table 3-7: Interest During Construction

Recommended Plan Component	Project First Costs	Duration (Months)	Interest During Construction
Shorefront Element	336,282,000	44	20,147,000
Mid-Rockaway HFFRRF	237,489,000	41	15,055,000
Cedarhurst-Lawrence HFFRRF	16,979,000	12	293,000
TOTAL			**35,495,000**

3.6 Beach Renourishment

Renourishment of the shorefront is anticipated to be placed at 4-year cycles subsequent to commencement of construction and throughout the 50-year economic life. The renourishment beach fill cost has been estimated by the USACE using CEDEP and is assumed to be placed in the same manner as the beach fill for the main contracts; with a 30” cutterhead dredge pumping the fill onto the shore, and a shore crew placing the material. Annualized renourishment costs, including environmental monitoring have been included in the annualized costs included for the Shorefront in Table 3-8.

3.7 Annualized Costs

The annualized costs for the Shorefront, Cedarhurst-Lawrence, and Mid-Rockaway Components are shown in Table 3-8: Annualized Project Costs below.

Table 3-8: Annualized Project Costs

Recommended Plan Component	Annual Project Costs
Shorefront Element (First Costs)	23,010,000
Shorefront (Beach Renourishment)	7,598,000
Mid-Rockaway HFFRRF	10,737,000
Cedarhurst-Lawrence HFFRRF	744,000
TOTAL	**42,089,000**

4 COST AND SCHEDULE RISK ANALYSIS

4.1 Introduction

The United States Army Corps of Engineers (USACE) requires a risk analysis for projects over $40 million. Preliminary estimates for the East Rockaway to Rockaway Inlet and Jamaica Bay Project is over $400 million, exceeding the $40 million limit, requiring this risk analysis to be completed.

4.2 Background

The project's cost estimate is prepared using MCACES MII software in accordance with USACE policy and can be found in Sub-Appendix A and Sub-Appendix C. MII uses existing or custom unit cost databases and allows contingency, taxes, insurance, and profit to be added to each item as needed to create an accurate construction cost estimate. Dredging unit costs were created using USACE's CEDEP spreadsheets and provided by the USACE NY District. Low, middle, and high unit costs were evaluated and a median unit cost was typically selected for the cost estimate.

4.3 Report Scope

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes as mandated by 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.

4.4 USACE Risk Analysis Process

The risk analysis process follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Directory of Expertise for Civil Works (Cost Engineering DX). The risk analysis process uses probabilistic cost and schedule risk analysis methods within the framework of the *Crystal Ball* software. The risk analysis results are intended to serve several functions, one being the establishment of reasonable contingencies reflective of an 80 percent confidence level to successfully accomplish the project work within that established contingency amount. 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 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 analyses should be considered as an ongoing process conducted concurrent to, and along 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, the risk analysis is performed to meet the recommendations of the following documents and sources:

- ER 1110-2-1150, Engineering and Design for Civil Works Projects.
- ER 1110-2-1302, Civil Works Cost Engineering.
- ETL 1110-2-573, Construction Cost Estimating Guide for Civil Works.
- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering DX.

4.5 Methodology / Process

The purpose of the risk analysis process is to determine what can be expected for the project as a whole, allowing variation within the individual project components. Natural variation allows the simulation to mimic real-world scenarios more closely, accounting for unforeseen changes that could affect a project, but within reason for the given distributions.

As recommended in the above references, *Crystal Ball* Risk Analysis Software was selected to run the risk analysis for the project. *Crystal Ball* uses a mathematical modeling technique called a Monte Carlo Simulation that takes distributions of assumed unit costs, quantities and production rates and runs thousands of trials, taking one input from each distribution in each simulation, adding in natural variation when selecting the points. The input data was based on the Risk Register, MII Cost Estimate, Project schedule, and PDT involvement.

Crystal Ball allows multiple trials, 5,000 trials were used for the analysis, in order to model the distribution given to that assumption. All of the individual assumptions (i.e. cost, volumes, etc.) are then summed for each trial and plotted to show cost and schedule versus probability. The median is the most likely project cost/schedule and, based on USACE policy, the 80% confidence value is the probable upper bound cost/schedule. The software is also used to create sensitivity plots that show which risk items have the greatest impacts in the overall project cost distribution.

4.5.1 Identify and Assess Risk Factors

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.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and is considered. Identifying the risk factors is considered a qualitative process that results in establishing a list of risks that serves as the document for the further study using the Crystal Ball risk software.

The risk analysis process, for this project, began by gathering input from the PDT. The PDT identified potential risks associated with each part of the project and designated each risk. In accordance with the current *Cost and Schedule Risk Analysis Guidance* (May 2009), all risks were then identified as low, moderate, or high risks based on their respective likelihoods and overall effects, as defined in the risk matrix shown below (Figure 4-1: Risk Level Matrix). These were used to identify what the PDT considered to be the key risks of the project and the degree that these risks might affect the final cost and schedule.

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

Impact or Consequence of Occurrence

Figure 4-1: Risk Level Matrix

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 are meant to support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.5.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans are analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts are 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. For each of the risks identified, quantifying risk factor impacts were determined to include:

- 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.
- Affected cost estimate and schedule elements.

The resulting risk register includes discussion of the above.

4.5.3 Analyze Cost Estimate 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 risks identified.

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the base cost estimate. P80 is the value that with 80% confidence one can conclude the project cost will not exceed, or 80% of the Monte Carlo simulations were less than or equal to that number. 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.

Schedule contingency is calculated as the difference between the P80 option duration forecast and the base schedule duration.

Schedule contingency is analyzed only on the basis of each option and not allocated to specific tasks. Based on Cost Engineering DX guidance, only critical path and near critical path tasks are considered to be uncertain for the purposes of schedule contingency analysis.

4.6 RISK ANALYSIS RESULTS

This section discusses the major components of the risk register, data used to develop the distributions for the risk analysis and results.

4.6.1 Risk Register – Cost Risk Analysis

During development of the risk register, risk items were discussed and evaluated by the PDT. A risk register is a tool commonly used in project planning and risk analysis and serves as the basis for the risk studies and *Crystal Ball* risk models. The risk register reflects the results of risk factor identification and assessment, risk factor quantification, and contingency analysis. From this process, 16 items were determined by the PDT to warrant inclusion in the final risk register for the cost risk analysis. Each of the risks was then evaluated in detail to determine the variability and distribution in quantities, cost and schedule so they could be evaluated in *Crystal Ball*. The detailed risk register is provided in Sub-Appendix D to this report and summarized in Table 4-1 below.

Table 4-1: Key Cost Risks Identified

Risk No.	PDT-Developed Risk/Opportunity Event
PM-3	Project Scope Definition
CA-1	Beach Fill Bidding Climate
CA-3	Rock Source for Groin Construction
CA-5	Composite Wall Rock Source
TL-4	Additional Groins Added to Project
TL-9	Design of Pumps for Saltwater
TL-15	Armor Stone Required for Floodwalls
TL-18	Drainage Improvements for Bulkheads
TL-19	Additional Fill for Bulkheads
TL-21	Baffle Wall Repairs / Replacement
LD-1	Additional Real Estate Relocations Required
CO-6	Additional Utility Relocations Required
ET-1	Beach Fill Bidding Climate
PR-1	Extreme Weather
PR-3	Quarry Monopoly
PR-4	Similar Projects Reducing Contractor Supply
PR-5	Stakeholders Requesting Mechanical Cleaning of Trash Racks

Based on the above, 21 different variables were used in the Crystal Ball Cost Risk analysis to model the above risks, with 14 variables for unit costs and 7 for quantities. These assumptions consider values from the MII cost estimate, historical data and PDT recommendations on individual risk items.

Following is a discussion of the more significant risks shown above, and assumptions used in developing the analysis. Crystal ball reports show details on ranges and distributions.

PM-3. Project Scope Definition

Some of the non-federal sponsors are not in favor of adding pump stations, as they increase maintenance costs for the local jurisdictions. This is expected to add $7 million to the project on the high end if a significant amount of resources must be utilized to review alternatives to appease the non-federal sponsors.

CA-1. Beach Fill Bidding Climate

An additional 25% cost was added for the high end to account for a bidding climate where only one contractor bids on a beach fill contract. 10% was reduced on the low end to account for a highly competitive bidding environment.

CA-3 Rock Source for Groin Construction

The low rock material cost was reduced 10% to account for new quarries opening up that could increase competition. A 50% increase was included for the high end to account for only one quarry having the capability to supply the project and having to spend a considerable amount of resources to produce the correct size armor stone.

CA-5 Composite Seawall Rock Source

The low rock material cost was reduced 10% to account for new quarries opening up that could increase competition. A 50% increase was included for the high end to account for only one quarry having the capability to supply the project and having to spend a considerable amount of resources to produce the correct size armor stone.

TL-4 Additional Groins Required

No change in the low cost of the groins was considered. The weight of the rock was increased by 19,700 tons to account for additional groins being required.

TL-9 Pumps Designed for Saltwater

A $5 million fee was associated with providing all pumps with parts designed for pumping saltwater. No change in low prices to the pump stations was considered.

TL-15 Armor Stone Required for Floodwalls

The high quantity for armor stone was calculated assuming a 7’ wide, 1’ deep section of stone on the protected side of the floodwalls was required. No change in low quantity was considered, as the current design does not have stone on the floodwalls.

TL-18 Drainage Improvements for Bulkheads

High costs for drainage improvements increased by $1.5 million to account for additional improvements needed in the tight areas near many of the bulkheads.

TL-19 Additional Fill Required for Bulkheads

The uneven nature of the existing bulkheads may require that the proposed bulkhead be a few feet away from some of the existing bulkheads, requiring fill. Additional volume assumes 18 square feet of additional fill per foot of bulkhead.

TL-21 Baffle Wall Repairs / Replacement

The existing baffle wall may require repairs and / or upgrades. Although no known issues existing for the wall, any repairs or replacement would add a critical amount of cost to the project. A unit cost of $4,500 / lf was estimated for full replacement of the wall on the high end. No cost was assumed for the low end.

LD-1 Real Estate

Real estate is a significant unknown for this project. Low prices were reduced 50%, while high prices were increased 300%.

CO-6 Utility Relocations

Utilities have not been located and are a significant unknown for the project. A 50% decrease was considered for the low end and a 500% increase for the high end.

ET-1 Beach Fill Bidding Climate

Mobilization price decreased by $1.3 million to $2 million on the low end and increased $1.8 million to $5.1 million on the high end. These limits were determined from historical beach fill bids in the area.

PR-1 Weather Issues

Weather impacts can cause quantities of sand and groin rock to increase as a storm erodes away the existing materials. A 20% increase was considered in quantities on the high end.

PR-3 Quarry Monopoly

Some of the quarries in the area have been purchased by the same company. If this trend continues, an increase of 25% higher was considered to account for this lack of competition.

PR-4 Other Similar Projects

Since there are other coastal storm risk management (CSRM) projects in the area, it may be possible that the quarries and contractors do not have enough supply to complete this project with the other work going on. To account for this, the profit was considered to be as high as 18% (instead of 10%), or as low as 6%.

PR-5 NFS Request Mechanical Cleaning Trash Racks

An additional cost of $1 million was included to account for the potential of the mechanical cleaning trash racks on the drainage structures.

Distributions

For this analysis, most quantities were assumed to be triangular distributions since minimum, maximum, and expected quantities have been determined. Unit costs were typically modeled as triangular functions. The triangular distribution was used as expected, low, and high values were known for all major variables. However, some items were modeled as uniform if the expected value was not a confidence value and the range of possible outcomes was broad. The Crystal Ball Software Output contains all of the assumptions and distributions used for each element in the analysis, as well as descriptive statistics for the distributions.

The full risk register and Crystal Ball reports are included in Sub-Appendix D, E, and F and contain additional details.

4.6.1 Risk Register – Schedule Risk Analysis

Although this schedule risk register was completed at the same time for both the cost and schedule risk analysis, the key risks are displayed separately, as different risks impact the cost and schedule differently. Below in Table 4-2 is the list of key schedule risks determined for the project.

Table 4-2: Key Schedule Risks Identified

Risk No.	PDT-Developed Risk/Opportunity Event
PM-2	Groin Scope Growth
PM-4	Coordination of Plan with NFS
PM-5	Timely Response from NFS
PM-6	Local Agency / Permit Issues
PM-7	NFS Priorities Change
CA-4	Composite Wall Construction Access
TL-1	Beach fill – Quantity Changes
TL-4	Additional Groins Added
TL-7	Energy Dissipation may impact wetlands
TL-15	Riprap Required for Floodwalls
LD-1	Delays in Real Estate
LD-2	Additional RW Access Needed
LD-4	Relocation Delays
CO-2	Beach fill – Equipment Availability
ET-2	Groin Construction Methods
ET-3	Groin and Seawall Construction Timing
ET-5	Groin Extensions Turn into Rebuilds

Based on the above risks, 14 different variables were used in the *Crystal Ball* Schedule Risk analysis to model the identified risks.

Following is a discussion of the more significant risks shown above, and assumptions used in developing the analysis. Crystal ball reports show details on ranges and distributions.

PM-2. Groin Scope Growth

An additional 40 days was added to the schedule to account for the possibility of additional groins added to the project.

PM-4. Coordination of Plan with NFS

An additional 120 days was added to coordinate with NFS.

PM-5 Timely Response from NFS

The 120 days included in PM-4 addressed this delay as well.

PM-6 Local Agency / Permit Issues

An additional 120 days was added to the Notice to Proceed of the project to account for permit delays.

PM-7 NFS Priorities Change

The 120 days included in PM-4 addressed this delay as well.

CA-4 Composite Wall Construction Access

An additional 40 days was added to the composite wall construction duration to account for potential delays due to limited construction access.

TL-1 Beach fill – Quantity Changes

A 20% increase in days was added on the high end and a decrease of 10% was added to the low end to account for volume changes since the survey utilized for this project quantity calculations.

TL-4 Additional Groins Added

60 days was added on the high end construction duration o account for construction of the additional groins.

TL-7 Energy Dissipation may impact wetlands

The notice to proceed duration high value was increased by 80 days to account for mitigation delays.

TL-15 Riprap Required for Floodwalls

An additional 30 days was added to the floodwall construction high value to account for the riprap.

LD-1 Delays in Real Estate

The notice to proceed duration high value duration was increased by 260 days to account for mitigation delays.

LD-2 Additional RW Access Needed

The notice to proceed duration high value duration was increased by 180 days to account for RW access delays.

LD-4 Relocation Delays

The notice to proceed duration high value duration was increased by 180 days to account for utility relocation delays.

CO-2 Beach fill – Equipment Availability

An additional 120 days was added on the high value for the beach fill construction duration to account for a delay in mobilization.

ET-2 Groin Construction Methods

An additional 50 days on the high end construction duration was added to account for slower construction methods.

ET-3 Groin and Seawall Construction Timing

An additional 80 days was added to the high value construction duration to account for summer windows when the local cities may not want limitations on the beach access.

ET-5 Groin Extensions Turn into Rebuilds

An additional 60 days on the high end construction duration was added to account for the additional quantities required to rebuild the groins instead of only extending them.

4.7 Cost Risk Analysis - Cost Contingency Results

Using an initial base cost of $355.8 million (not including beach renourishment, real estate, engineering, or construction management) a distribution of costs was calculated in *Crystal Ball*. Based on the *Crystal Ball* Analysis of the 100% Design Estimate, the most probable project cost (50 percentile) is $435.5 million. The project cost at the 80% confidence interval is $456.8 million. The confidence interval and total project distribution are shown in Figure 4-2 below. Detailed figures and statistical analysis from the simulation are contained in Sub-Appendix E. The range from the minimum total cost to the maximum cost is approximately $157.6 million and the range from the 80% upper limit to the minimum value is approximately $102.4 million. Please note that these are not Project First Costs or Total Project Costs as this analysis is done on the expected costs without contingency.

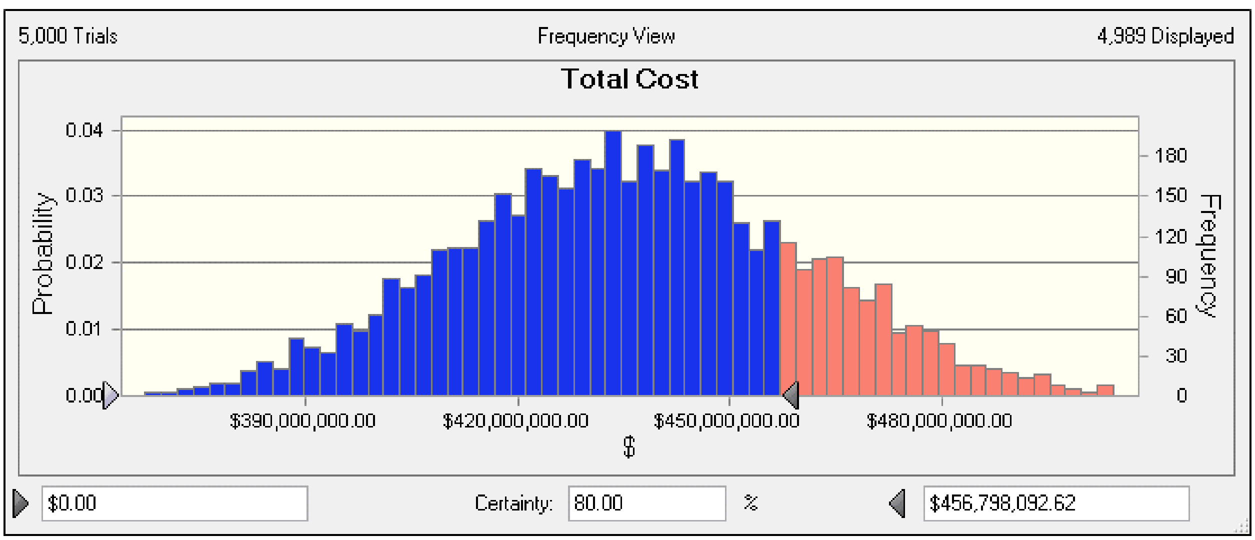

Figure 4-2: Cost Distribution with the 80% Confidence Interval Shown

A sensitivity analysis was conducted to determine which items cause the greatest change in overall project cost. The results are displayed in Figure 4-3 below. The two most significant items were the real estate costs and the limited competition of contractors, which both represented approximately 26% of the cost variance and is a significant unknown for the project. These are identified in risks LD1 and PR-4, respectively. The third major risk is the quarry competition relating to rock supply and availability at the time of the job (Risks CA-5 and PR-3). It represents approximately 21% of the variation in the project. Two other risks represented about 10% of the total project variation, the baffle wall repairs / replacement along the shorefront and the utilities, relating to risks TL-21 and CO, respectively. Those items have significant unknowns at this time and will be narrowed down in final design.

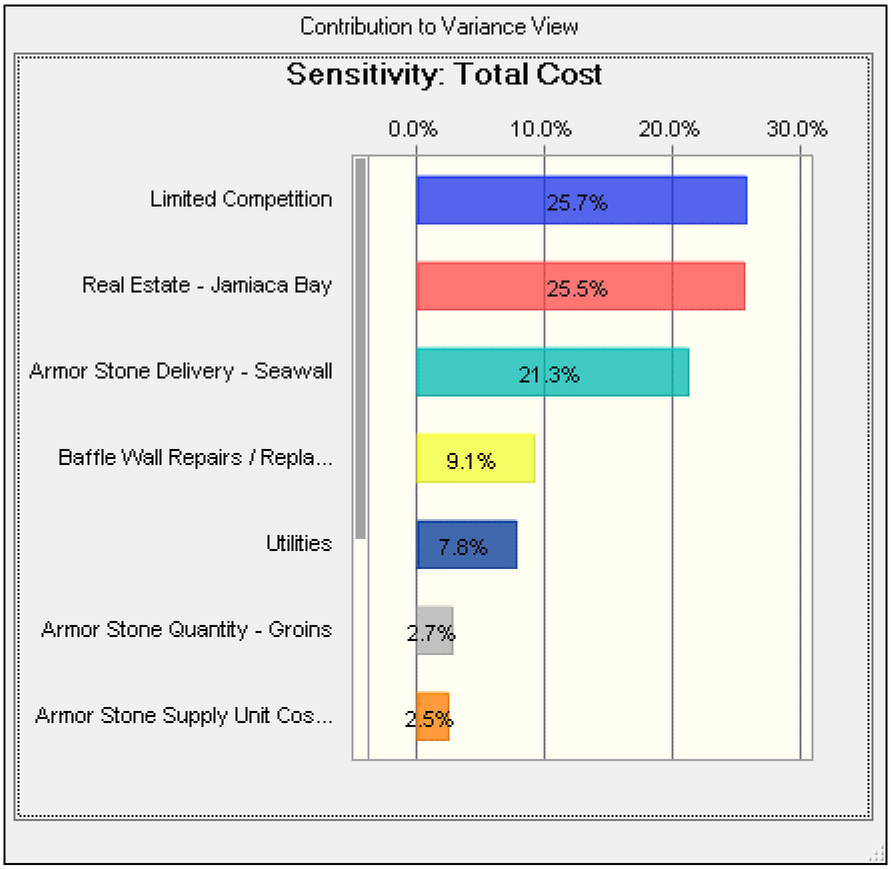

Figure 4-3: Sensitivity Analysis for Cost Risk

Note that these results reflect only those contingencies established from the cost risk analysis.

Table 4-3: Confidence Table of Total Cost

Percentiles:	Forecast values ($)
0%	$354,392,835.80
10%	$404,101,189.97
20%	$414,924,691.45
30%	$422,372,011.90
40%	$429,329,968.13
50%	$435,488,722.73
60%	$441,691,565.03
70%	$448,323,726.59
80%	$456,798,092.62
90%	$467,933,686.11
100%	$512,055,589.86

The cost risk analysis determined that a 28.36% contingency (calculated as the difference from the 80% to the base case divided by the base case of $355.8 million) should be expected for the project as a whole. This percentage represents the funds that should be allocated to complete this project based on the risks developed by the PDT. Table 4-4: Project Contingencies (Base Cost Plus Cost and Contingencies) shows the change in contingency with different confidence levels of the cost estimate.

Table 4-4: Project Contingencies (Base Cost Plus Cost and Contingencies)

Confidence Level	Project Cost ($)	Contingency ($)	Contingency (%)
P0	$354,392,835.80	($1,472,540.62)	-0.41%
P10	$404,101,189.97	$48,235,813.56	13.55%
P20	$414,924,691.45	$59,059,315.04	16.60%
P30	$422,372,011.90	$66,506,635.49	18.69%
P40	$429,329,968.13	$73,464,591.72	20.64%
P50	$435,488,722.73	$79,623,346.32	22.37%
P60	$441,691,565.03	$85,826,188.62	24.12%
P70	$448,323,726.59	$92,458,350.18	25.98%
P80	**$456,798,092.62**	**$100,932,716.21**	**28.36%**
P90	$467,933,686.11	$112,068,309.70	31.49%
P100	$512,055,589.86	$156,190,213.45	43.89%

5 SCHEDULE RISK ANALYSIS

The schedule risk analysis was very dependent on many issues relating to getting the construction started, including permitting, real estate acquisitions, and coordination with local sponsors. The results are included below.

5.1 Results

The Monte Carlo Simulation results indicate to an 80% certainty that it would be unlikely for the project delay to exceed 630 working days, a delay of approximately 2.4 years. The results are shown in Figure 5-1 below.

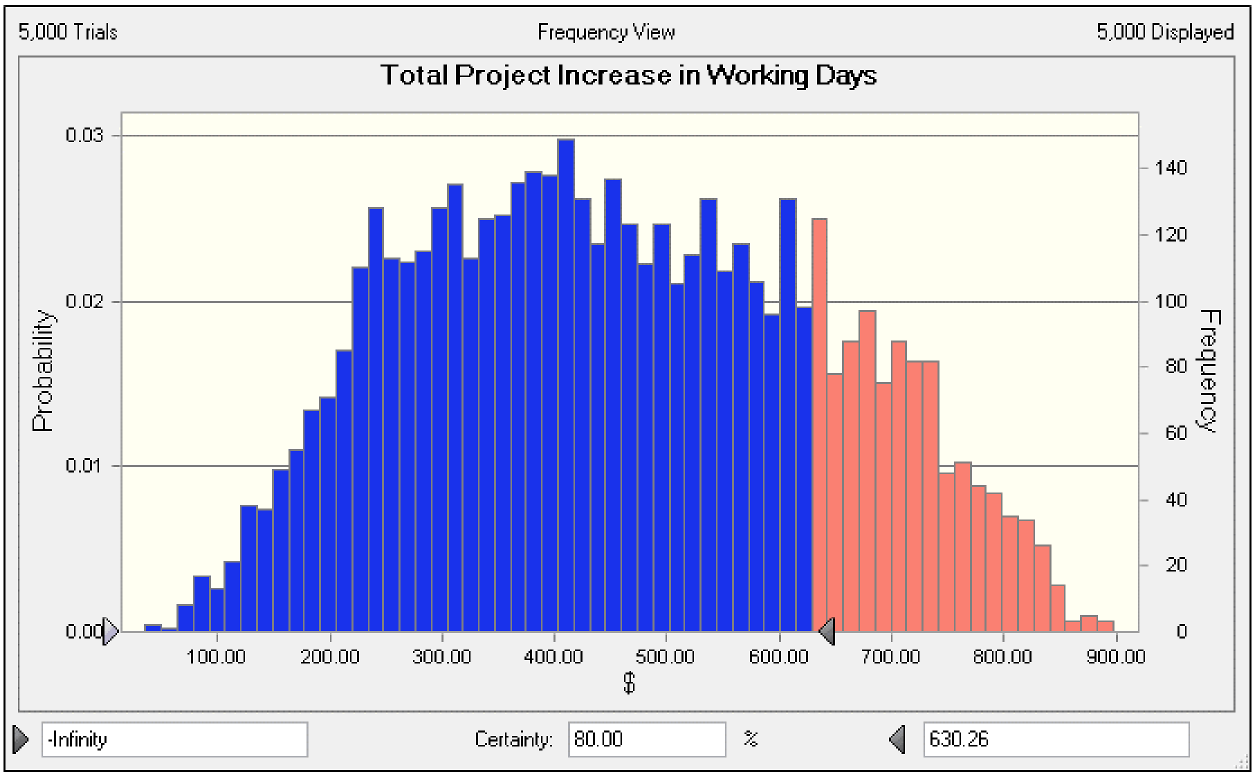

Figure 5-1: Schedule Risk Analysis Results

A sensitivity analysis was also completed for the schedule risk analysis and included in Figure 5-2. It indicated that issuing the notice to proceed for the construction contracts in Arverne, and Edgemere were the most important factors relating to the schedule by a significant margin. These are relating to delays with regards to permitting, utilities, real estimate, and non-federal sponsors identified in risks PM4, PM5, PM6, PM7, TL7, LD1, LD2 and LD4 of the risk register.

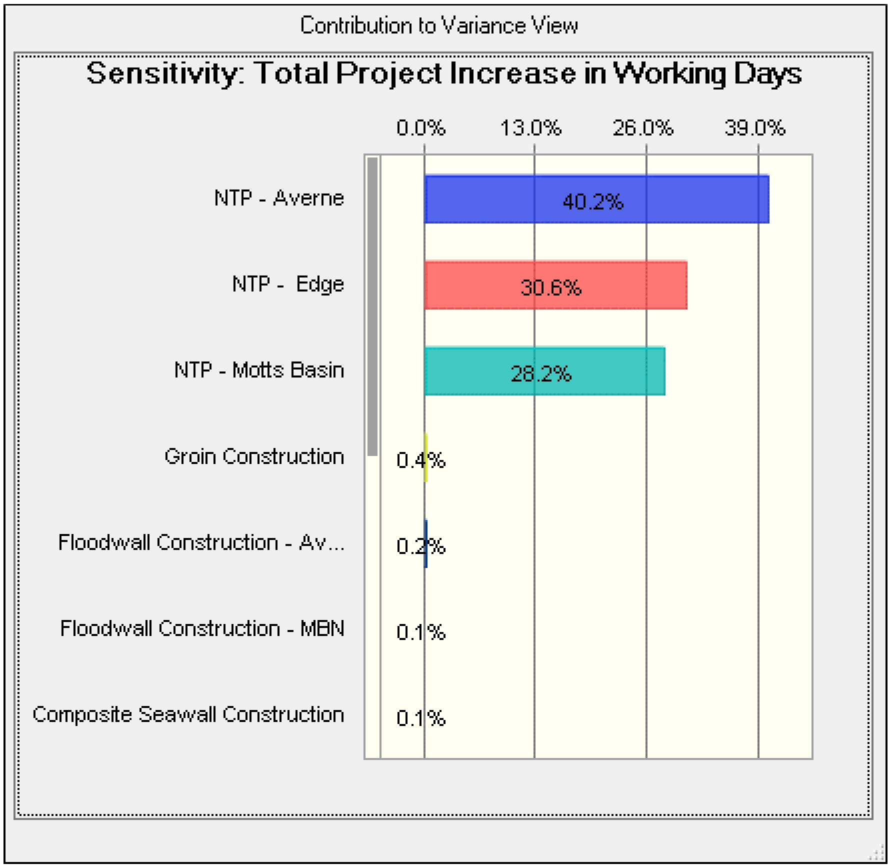

Figure 5-2: Schedule Risk Analysis Sensitivity

6 MAJOR FINDINGS/OBSERVATIONS

Based on analysis of the 100% design, the most probable project cost is currently estimated to be $435.5 million with an 80% confidence interval for the cost to not exceed $456.8 million. These are for the project first costs and do not include costs for the beach renourishment costs. This means the contingency to be utilized for the project is 28.36%. The project schedule is anticipated to be completed in approximately 3.5 years based upon the expected schedule, but is likely to be delayed due to permitting and other relocation issues, with an 80% confidence that the project schedule will be completed within 2.4 years of the expected completion date. The total project schedule duration is expected to be approximately 5.9 years instead of 3.5 years due to these delays, although this may not impact the duration of actual construction, as many of the key risks are to the notice to proceed for construction and not relating to construction activities' durations themselves.

7 RECOMMENDATIONS

The identified risks for the project may be unavoidable, but identifying ways to mitigate their effect on the final project cost is essential to the success of the project and has been pursued through project development by the PDT. Efforts to reduce risk continue as described below.

Contractor Outreach – An extensive contractor outreach program is recommended to maintain interest in the projects, especially with potential armor stone suppliers so that they can prepare for the large volumes of stone required for the project.

Coordination with State and NFS – A significant amount of delays are anticipated due to not getting the NTP issued, which can be mitigated if the NFS and other state agencies are in support of the project.

A. SUB-APPENDIX A: MII ESTIMATE – JAMAICA BAY

The MII Estimate for the Jamaica Bay section of the project.

B. SUB-APPENDIX B: PROJECT SCHEDULE

The anticipated schedule for the project.

C. SUB-APPENDIX C: MII ESTIMATE - SHOREFRONT

The MII Estimate for the Shorefront section of the project.

D. SUB-APPENDIX D: RISK REGISTER

The Risk Register was developed during the risk workshop on June 13, 2018.

E. SUB-APPENDIX E: COST RISK ANALYSIS

F. SUB-APPENDIX F: SCHEDULE RISK ANALYSIS

G. SUB-APPENDIX G: PUMP COST CURVE