Appendix D

Cost Engineering

FINAL
COST ENGINEERING
CAÑO MARTÍN PEÑA
ECOSYSTEM RESTORATION PROJECT
SAN JUAN, PUERTO RICO

Prepared for:

PROYECTO ENLACE DEL CAÑO MARTÍN PEÑA

Corporación del Proyecto ENLACE del Caño Martín Peña
Apartado Postal 41308
San Juan, Puerto Rico 00940-1308

February 2016

Appendix D

D-1 Planning Level Cost Estimate

Planning Level Cost Estimate
Caño Martín Peña Ecosystem Restoration Project
San Juan, Puerto Rico **23-Jul-15**

Number	Description	Alternative				
		75' X 10' PAVED BOTTOM	100' x 10'	125' x 10'	150' x 10'	200' x 10'
01	LANDS & DAMAGES					
01 01	REAL ESTATE REPORTS					
	Real Estate Cost Operations	$176,000	$176,000	$176,000	$176,000	$176,000
02	RELOCATIONS					
02 03	UTILITIES					
	Utility Terminations - Water Mains	$35,000	$35,000	$35,000	$35,000	$35,000
	Utility Terminations - Sanitary Sewers	$50,000	$50,000	$50,000	$50,000	$50,000
02 04	RELOCATION COST TO OWNER/TENANT					
	Acquisition by Local Sponsor	$1,695,100	$1,695,100	$1,695,100	$1,695,100	$1,695,100
	Condemnations by Local Sponsor	$1,935,000	$1,935,000	$1,935,000	$1,935,000	$1,935,000
	Appraisals by Local Sponsor	$847,500	$847,500	$847,500	$847,500	$847,500
	Real Estate Payments by Local Sponsor	$16,747,000	$16,747,000	$16,747,000	$16,747,000	$16,747,000
09	CHANNELS AND CANALS					
09 01	CHANNELS					
	Sediment and Erosion Control	$65,294	$64,233	$66,319	$66,319	$61,708
	Barrio Obrero Marina Temporary Dam	$3,696,350	$3,696,350	$3,696,350	$3,696,350	$3,696,350
	Western Bridges Turbidity Containment Temporary Dam	$710,400	$710,400	$710,400	$710,400	$710,400
	Utility Relocation - Rexach Trunk Sewer Demolition	$858,488	$858,488	$858,488	$858,488	$858,488
	Utility Relocation - Borinquen Water Transmission Demolition	$801,664	$801,664	$801,664	$801,664	$801,664
	Demolition	$2,206,790	$2,206,790	$2,206,790	$2,206,790	$2,206,790
	Clearing and Grubbing	$250,191	$250,191	$250,191	$250,191	$250,191
	Earthwork	$1,522,125	$1,336,500	$1,150,875	$965,250	$519,750
	Dredged Solid Waste Disposal	$1,931,864	$2,180,160	$2,513,240	$2,816,040	$3,512,480
	Dredged Sediments Disposal	$24,202,530	$27,313,200	$31,486,050	$35,279,550	$44,004,600
	PZ-22 30' Sheet Pile	$22,167,200	$22,167,200	$22,167,200	$22,167,200	$22,167,200
	PZ-27 30' Sheet Pile	$2,025,000	$2,025,000	$2,025,000	$2,025,000	$2,025,000
	PZ-22 40' Sheet Pile	$29,186,500	$29,186,500	$29,186,500	$29,186,500	$29,186,500
	PZ-27 40' Sheet Pile	$0	$0	$0	$0	$0
	Stormwater Management	$225,000	$225,000	$225,000	$225,000	$225,000
	Scour Protection - Western Bridges (Weir)	$1,792,065	$1,792,065	$1,792,065	$1,792,065	$1,792,065
	Scour Protection - Dr. Barbosa Avenue Bridge	$1,580,205	$1,580,205	$1,580,205	$1,580,205	$1,580,205
	Scour Protection - 75' wide channel bottom	$10,772,355	$0	$0	$0	$0
09 02	MITIGATION COST					
	Mangrove Restoration and Establishment	$340,440	$301,920	$261,480	$220,920	$139,320
14	RECREATION FACILITIES					
	Recreation Access Area - Water Plaza (9)	$2,279,990	$2,279,990	$2,279,990	$2,279,990	$2,279,990
	Recreation Park with out Boardwalk (6)	$391,198	$391,198	$391,198	$391,198	$391,198
	Recreation Park with Trail (6)	$817,027	$817,027	$817,027	$817,027	$817,027
	Linear Park (1,500 LF)	$3,233,497	$3,233,497	$3,233,497	$3,233,497	$3,233,497
	Park Mobilization and Demobilization	$447,911	$447,911	$447,911	$447,911	$447,911
	SUB TOTAL	**$132,989,685**	**$125,351,090**	**$129,633,041**	**$133,503,156**	**$142,392,935**
	CONTINGENCY (25%)	$33,247,421	$31,337,773	$32,408,260	$33,375,789	$35,598,234
30	PRE-CONSTRICTION ENGINEERING AND DESIGN (6%)	$7,979,381	$7,521,065	$7,777,982	$8,010,189	$8,543,576
31	CONSTRUCTION MANAGEMENT (5.5%)	$7,314,433	$6,894,310	$7,129,817	$7,342,674	$7,831,611
	GRAND TOTAL	**$181,530,921**	**$171,104,238**	**$176,949,101**	**$182,231,808**	**$194,366,356**
	YEARLY OPERATING & MAINTENANCE (1%)	$1,815,309	$1,711,042	$1,769,491	$1,822,318	$1,943,664

Appendix D

D-2 Project Cost Summary Estimate

Printed:1/26/2016

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

PROJECT: **Caño Martín Peña Ecosystem Restoration Project**
PROJECT NO: 354852
LOCATION: San Juan, Puerto Rico

DISTRICT: SAJ Jacksonville PREPARED: 1/7/2016
POC: CHIEF, COST ENGINEERING, Matthew W. Cunningham

This Estimate reflects the scope and schedule in report; Caño Martín Peña Ecosystem Restoration Project **SAN JOSÉ LAGOON DISPOSAL OPTION**
and is based on the Detailed cost estimate file 354852_CMP_Ecosystem_Restoration_Feasibility_2015_1027_Rev6Ver13

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)		
						Program Year (Budget EC): 2016 Effective Price Level Date: 1-Oct-15								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent To Date ($K)	TOTAL FIRST COST	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***	***M***	***N***	***O***
02	*RELOCATIONS (Cost to Date)*	*$270*								*$270*	*$ 270*			***$270***
02	**RELOCATIONS**	$9,179	$3,231	35.2%	$12,410	0.0%	$9,179	$3,231	**$12,410**		**$ 12,410**	$9,561	$3,365	**$12,926**
06	**FISH & WILDLIFEFACILITIES**	$8,489	$2,988	35.2%	$11,477	0.0%	$8,489	$2,988	**$11,477**		**$ 11,477**	$8,842	$3,112	**$11,954**
09	**CHANNEL & CANAL**	$37,900	$13,341	35.2%	$51,241	0.0%	$37,900	$13,341	**$51,241**		**$ 51,241**	$39,476	$13,895	**$53,371**
14	**RECREATION**	$7,258	$2,555	35.2%	$9,813	0.0%	$7,258	$2,555	**$9,813**		**$ 9,813**	$7,560	$2,661	**$10,221**
16	**BANK STABILIZATION**	$45,904	$16,158	35.2%	$62,062	0.0%	$45,904	$16,158	**$62,062**		**$ 62,062**	$47,812	$16,830	**$64,642**
18	**CULT RESOURTCE PRESERVATION**	$103	$36	35.2%	$139	0.0%	$103	$36	**$139**		**$ 139**	$107	$38	**$144**
	CONSTRUCTION ESTIMATE TOTALS:	$109,102	$38,309		$147,141	0.0%	$108,832	$38,309	$147,141	$270	$147,411	$113,356	$39,901	$153,528
01	**LANDS AND DAMAGES**	$38,847	$5,827	15.0%	$44,674	0.0%	$38,847	$5,827	**$44,674**		**$ 44,674**	$38,847	$5,827	**$44,674**
30	**PRECONST'N, ENGINEERING, DESIGN**	$9,795	$3,448	35.2%	$13,243	0.0%	$9,795	$3,448	**$13,243**		**$ 13,243**	$10,292	$3,623	**$13,915**
31	**CONSTRUCTION MANAGEMENT**	$6,530	$2,299	35.2%	$8,828	0.0%	$6,530	$2,299	**$8,828**		**$ 8,828**	$7,104	$2,501	**$9,605**
	PROJECT COST TOTALS:	$164,274	$49,882	30.4%	$214,156		$164,004	$49,882	**$213,886**	$270	**$214,156**	$169,600	$51,852	**$221,722**

ESTIMATED FEDERAL COST: 64.2% $142,366
ESTIMATED NON-FEDERAL COST: 35.8% $79,356
ESTIMATED TOTAL PROJECT COST: $221,722

CHIEF, COST ENGINEERING, Matthew W. Cunningham

PROJECT MANAGER, Jim Suggs

CHIEF, REAL ESTATE, Audrey Ormerod

CHIEF, PLANNING, Eric Summa, P SAJ

CHIEF, ENGINEERING, Laureen Borochaner

CHIEF, OPERATIONS, Jim Jeffords

CHIEF, CONSTRUCTION, Steve Duba

CHIEF, CONTRACTING, Carlos Clarke

CHIEF, PM-PB, xxxx

CHIEF, DPM,

Item	First Cost	Non-Federal Cost Share %	Non-Federal Cost*	Federal Cost
Ecosystem Restoration				
Construction, Construction Management, PED		35%	$13,050	$130,605
LERRDs		100%	$57,276	$0
LERRDs (Federal Admin)		35%	$679	$1,261
Subtotal - Ecosystem Restoration	**$202,871**		**$71,005**	**$131,866**
Recreation		50%		
Subtotal - Recreation	**$11,285**		**$5,642**	**$5,642**
Total First Cost	**$214,156**		**$76,647**	**$137,508**

Filename: 354852_CMP_TPCS_SJLagoon_Disposal_012516_Ver13g2 - MCX TEST.xlsx
TPCS, 39% Contingency

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

Printed:1/26/2016

**** CONTRACT COST SUMMARY ****

PROJECT: Caño Martín Peña Ecosystem Restoration Project
LOCATION: San Juan, Puerto Rico
This Estimate reflects the scope and schedule in report; Caño Martín Peña Ecosystem Restoration Project

DISTRICT: SAJ Jacksonville PREPARED: 1/7/2016
POC: CHIEF, COST ENGINEERING, Matthew W. Cunningham

354852_CMP_Ecosystem_Restoration_Feasibility_2015_1027_Rev6Ver13 FUTURE COST - COST TO COMPLETE ONLY

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
SAN JOSÉ LAGOON DISPOSAL		Estimate Prepared:			6-Jan-2016	Program Year (Budget EC):			2016					
		Effective Price Level:			1-Oct-2015	Effective Price Level Date:			1-Oct-15					
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*
02	RELOCATIONS	$9,179	$3,231	35.2%	$12,410	0.0%	$9,179	$3,231	$12,410	2018Q2	4.2%	$9,561	$3,365	$12,926
06	FISH & WILDLIFE FACILITIES	$8,489	$2,988	35.2%	$11,477	0.0%	$8,489	$2,988	$11,477	2018Q2	4.2%	$8,842	$3,112	$11,954
09	CHANNELS & CANALS	$37,900	$13,341	35.2%	$51,241	0.0%	$37,900	$13,341	$51,241	2018Q2	4.2%	$39,476	$13,895	$53,371
14	RECREATION FACILITIES	$7,258	$2,555	35.2%	$9,813	0.0%	$7,258	$2,555	$9,813	2018Q2	4.2%	$7,560	$2,661	$10,221
16	BANK STABILIZATION	$45,904	$16,158	35.2%	$62,062	0.0%	$45,904	$16,158	$62,062	2018Q2	4.2%	$47,812	$16,830	$64,642
18	CULTURAL RESOURCE PRESERVATION	$103	$36	35.2%	$139	0.0%	$103	$36	$139	2018Q2	4.2%	$107	$38	$144
	CONSTRUCTION ESTIMATE TOTALS:	$108,832	$38,309	35.2%	$147,141		$108,832	$38,309	$147,141			$113,356	$39,901	$153,258
01	LANDS AND DAMAGES	$38,847	$5,827	15.0%	$44,674	0.0%	$38,847	$5,827	$44,674	2016Q1	0.0%	$38,847	$5,827	$44,674
30	PRECONSTRUCTION, ENGINEERING, DESIGN													
0.5%	Project Management	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
1.0%	Planning & Environmental Compliance	$1,088	$383	35.2%	$1,471	0.0%	$1,088	$383	$1,471	2017Q2	4.6%	$1,139	$401	$1,539
5.0%	Engineering & Design	$5,442	$1,915	35.2%	$7,357	0.0%	$5,442	$1,915	$7,357	2017Q2	4.6%	$5,693	$2,004	$7,696
0.5%	Reviews, ATRs, IEPRs, VE	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
0.5%	Life Cycle Updates (cost, schedule, risks)	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
0.5%	Contracting & Reprographics	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
1.0%	Engineering During Construction	$1,088	$383	35.2%	$1,471	0.0%	$1,088	$383	$1,471	2018Q2	8.8%	$1,184	$417	$1,601
	Planning During Construction	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	Project Operations	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
31	CONSTRUCTION MANAGEMENT													
5.5%	Construction Management	$5,986	$2,107	35.2%	$8,093	0.0%	$5,986	$2,107	$8,093	2018Q2	8.8%	$6,512	$2,292	$8,805
	Project Operation:	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
0.5%	Project Management	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2018Q2	8.8%	$592	$208	$800
	CONTRACT COST TOTALS:	$164,004	$49,882		$213,886		$164,004	$49,882	**$213,886**			$169,600	$51,852	**$221,452**

Filename: 354852_CMP_TPCS_SJLagoon_Disposal_012516_Ver13g2 - MCX TEST.xlsx
TPCS, 39% Contingency

Appendix D

D-3 Cost and Schedule Risk Analysis

FINAL
COST & SCHEDULE RISK ANALYSIS
CAÑO MARTÍN PEÑA
ECOSYSTEM RESTORATION PROJECT
SAN JUAN, PUERTO RICO

Prepared for:

Corporación del Proyecto ENLACE del Caño Martín Peña
Apartado Postal 41308
San Juan, Puerto Rico 00940-1308

CŜōǊuary 2016

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

EXECUTIVE SUMMARY

The Project Development Team (PDT) has prepared the Risk Based Cost Analysis of the Caño Martín Peña (CMP) Ecosystem Restoration Project, which is based on the current estimate developed for the project, and has been performed to incorporate current and relevant risk and opportunities to the project to be used as a contingency amount. The experience of the entire PDT has been surveyed and considered in the development of the recommended contingency. Because of this, and in part due to the relatively small sample sizes, a single contingency factor has been developed for the design and construction portion of the project. This factor is based on the opportunities and risk identified by the PDT, assumed probabilities of occurrence, and impacts to the design and construction portion of the project for the individual items. Additional detail and explanation of specific considerations beyond the Cost & Schedule Risk Analysis Report may be found in the Project Risk Register and Crystal Ball Model for the management of the individual factors. The "Lands and Damages" portion of the project has been assigned a separate risk factor of 15%, based on the confidence in the cost estimates based on the recent lands and damages work already completed for the project.

The results of the design and construction probability run after these factors were evaluated and considered are shown in the following table. At an 80% level of confidence, the contingency level is approximately 35.2% of the estimate reviewed in the CSRA.

Table 1. Contingency Results
Design & Construction ($ in millions)

Most Likely Cost Estimate	$125.2	
Confidence Level	**Value**	**Contingency**
0%	$127.6	2.0%
10%	$146.9	17.4%
20%	$151.0	20.6%
30%	$154.1	23.2%
40%	$156.8	25.3%
50%	$159.4	27.4%
60%	$162.2	29.6%
70%	$165.2	32.0%
80%	$169.3	35.2%
90%	$174.5	39.4%
100%	$206.3	64.8%

Based on the Total Project Cost Summary (TPCS) revision for this estimate, the recommended contingency of 35.2% on all remaining project design and construction costs ($44.1 million), plus the 15% contingency on the lands and damages costs ($5.8 million), plus the base estimate of $164.0 million results in a present day estimate of $213.9 million, plus cost to date of $.3 million equals the "Project First Cost" of $214.2 million.

Table 2. Summary of "Project First Cost" in Program Year 2016 ($ in millions)

Base Cost Estimate	Contingency at 80%	Cost with Contingency	Cost to Date	Project First Cost Program Year 2016
$164.0	**$49.9***	**$213.9**	**$0.3**	**$214.2**

* Contingency includes $44.1 million for design and construction and $5.8 million for lands and damages.

The primary cost risk factors driving the recommended 35.2% contingency amount for design and construction are as follows (in order based on the impact on the cost variance in the model):

Included with each risk factor is the likelihood of occurrence and the range of potential impact ($ in millions). Additional detail can be found in the Crystal Ball Risk Model.

1. Risk CH-23: Concern is that the San Jose Lagoon pits may not be available; therefore, the spoils may have to be taken to upland disposal sites. Lack of pits availability could be due to uncontainable contamination levels or public opposition. Risk of going to upland sites is also the cost of containing any contaminated material.

   Likelihood of Occurrence: 100%; Range of impact, (Low, Likely, High) = $0; $0; $25.0

2. Risk PM-06: Potential for Change Orders during construction was considered by the team as a very likely risk that has a high potential range of impact. Considering the risk for unforeseen conditions and potential changes during construction, this is considered one of the greatest risks on the projects. Several smaller risks that were identified by the team are considered to be included in this risk total, such as the potential for items that could negatively impact the construction productivity. The range of results is an increase to the total project costs of from 5% at low end, 10% most likely, and up to 15% at the high end.

   Likelihood of Occurrence: 100%; Range of impact, (Low, Likely, High) = $6.3; $12.5; $18.8

3. Risk GE-01: Market conditions in Puerto Rico and in the construction industry may have a greater chance of increasing greater than historical escalation rates, and the PDT felt the costs could vary either higher or lower, although they have recently been stable. This includes the risk for potential fuel and steel cost variance, and for equipment and labor price variances at the time of bidding. The low end is based on a decrease of up to 10% to construction costs and the high end is based on an increase up to 10% of the construction costs.

   Likelihood of Occurrence: 100%; Range of impact, (Low, Likely, High) = $-12.5; $0; $12.5

4. Risk EA-4: Dredging Production Rates: The PDT considered that there could be a large variance in the dredging production rates from that included in the estimate. The potential for a lower production rate of up to 20% was modeled.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = $0; $0.0; $8.0

5. Risk EA-2: Sheet Pile Wall Quantities. There is some uncertainty with the exact quantity of sheet pile wall that will be required for the project. The PDT put the uncertainty from -2.5% to +10% from the current estimate.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = $-0.9; $0.0; $3.5

6. Risk CH-22: Disposal Material Quantity Variation. Quantity for special handling and disposal of dredged material. Based on borings taken, the estimate includes 10% of the dredged material that will have to be sorted and handled separately when containing solid waste. This risk is that this quantity could be greater than estimated.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = $0; $0; $4.0

The lands and damages contingency of 15% is lower than the design and construction contingency of 35.2% due to the confidence that the team has in the estimate pricing for this portion of the project. Over the past few years, a portion of the property acquisition and related relocations have taken place for the project. This has provided the team with confidence in the estimates of the work to be completed, resulting in the selection of the 15% for the lands and damages risks.

The schedule risks identified with the greatest contribution to variance in the model were the following:

1. Risk GE-04: Funding Constraints. This was the predominant schedule risk driver, as the Project is dependent on Water Resources Development Act authorization. Current local matching is 35% plus O&M and if no local share than the project could extend. Congress yearly appropriations could also impact phasing of the project.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 36

2. Risk PM-07: Project Closeout: Delays to closing out the project are considered a potential. These range from contract closeout to final inspections.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 5

3. Risk GE-09: Public Opposition: Could range from a demonstration to a lawsuit, but considered unlikely by the team.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 12

4. Risk RL-06: Relocation of Residents: Although considered unlikely by the PDT, there is some risk that a delay in the relocation of residents will delay the start of construction.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 6

5. Risk RL-04a: Utility relocations of the Borinquen Water Line & the Rexach Trunk Sewer: Work requires coordination with installation of CMP sheet pile walls. Delays could impact project schedule or require design modifications for future installation.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 3

6. Risk GE-02: Weather impacts: Weather was also considered to be a schedule risk, with the potential of weather events delaying construction.

   Likelihood of Occurrence: 100%: Range of impact, (Low, Likely, High) = 0, 0, 3

The schedule risks result in up to 20 months of potential delay at the 80% confidence level.

These are the major risks considered in the CSRA, and combined with other risks have made up the contingency amount noted for the CMP Ecosystem Restoration Project. These risks result in a Project First Cost of $214.2 million.

1.0 PURPOSE

The purpose of this risk based cost analysis was to study the potential impact on the cost and schedule of risks and opportunities that are specific to the Caño Martín Peña (CMP) Ecosystem Restoration Project (CMP-ERP) and which may cause cost and schedule overruns. Moreover it is to assess whether an appropriate contingency has been established and provide a basic outline for mitigation of the identified risks. The risks and opportunities have been studied from a probabilistic approach whereby the estimated cost is presented as a probability curve. The United States Army Corps of Engineers (USACE) recommends the contingency in the cost estimate be compared against the 80% value on the resultant probability curve.

This page intentionally left blank.

2.0 PROJECT BACKGROUND

The CMP is a natural tidal channel 3.75 miles long in metropolitan San Juan, Puerto Rico, south of Santurce and north of Hato Rey, dividing these two densely populated wards of the city. It is one of eight interconnected bodies of water within the San Juan Bay Estuary (SJBE), the only tropical estuary in the U.S. Environmental Protection Agency (EPA) National Estuary Program (NEP). The SJBE interior coastal lagoons and tidal channels are connected to the Atlantic Ocean at both ends. The drainage area of the CMP comprises about 2,500 acres. The drainage area of the canal is only about four square miles (2,500 acres) and is a tributary to the Rio Puerto Nuevo basin with a drainage area of about 25 square miles. Extending from east to west through eight densely populated impoverished communities in San Juan, the CMP connects the San Juan Bay with the San José and Los Corozos Lagoons, which are further connected by the Suárez Canal to La Torrecilla Lagoon and the Atlantic Ocean. A project location map is included as Figure 1.

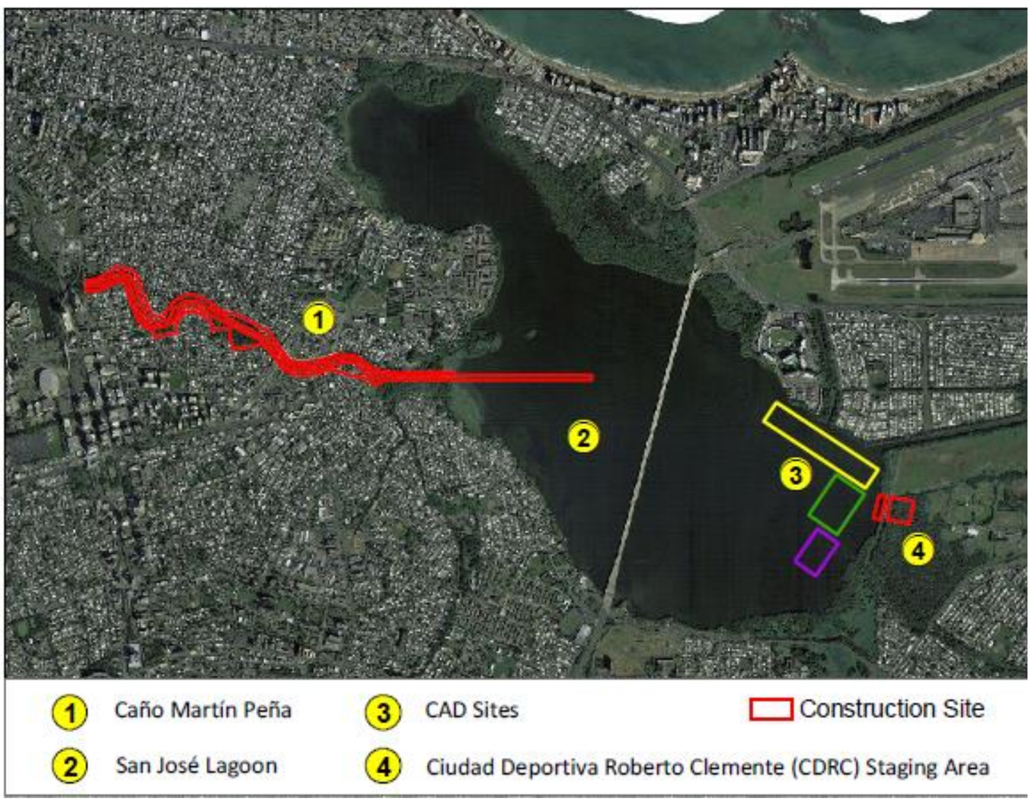


Figure 1. The Caño Martin Peña Ecosystem Restoration Project Area

Historically, the CMP had an average width of approximately 200 feet and provided tidal exchange between San Juan Bay and the San José Lagoon. Since the 1920s, the CMP channel and its associated wetlands began to be modified as a result of development pressures. Low-income migrants from rural Puerto Rico constructed housing structures throughout the wetlands. As the housing developments lacked basic utilities, such as storm and sanitary sewer systems, and adequate road infrastructure for a proper solid waste collection system, thousands of structures have discarded their refuse into the CMP for decades. Consequently, siltation, accumulation of household and construction debris, encroachment of housing and other structures, and sedimentation from urban runoff have almost completely blocked the CMP's ability to convey flows, thus affecting the habitat functional value and water quality in both the CMP and San José Lagoon. The main ecosystem restoration benefits will occur to benthic habitat within the 702-acre San José Lagoon. Habitat Units will be calculated for this area and, along with alternative plan costs and other criteria, used to compare and select an alternative plan.

The National Ecosystem Restoration Plan (NER Plan) consists of dredging the eastern segment of the channel (2.2 miles long) to restore the CMP and adjacent areas and increase tidal flushing of the San José Lagoon, restoring the benthic habitat and reducing the harmful salinity gradient and de-oxygenated areas that have become prevalent. Additionally, mangrove wetlands to the north and south of the CMP would be re-established, and, as ancillary benefits that were not quantified, reduce flooding within the CMP's eight adjacent communities. In addition, the CMP-ERP incorporates a recreation plan that will include the creation of recreation access parks that will formalize human interaction with the restored waterfront. The CMP-ERP would also allow for the potential of environmentally sound waterway transportation and promote recreation and tourism in the adjacent communities of Barrio Obrero Oeste and San Ciprian, Barrio Obrero Marina, Buena Vista Santurce, Israel-Bitumul, Buena Vista Hato Rey, Las Monjas and Parada 27 that make up the CMP Special Planning District (the District).

The Caño Martín Peña ENLACE Project Corporation (ENLACE) and the Commonwealth of Puerto Rico acting through the Department of Natural and Environmental Resources (DNER), are the non-Federal sponsors. ENLACE is the public entity within the Government of Puerto Rico that is legally designated with the coordination and implementation of the District Comprehensive Development Plan (DCDP). The DCDP includes the CMP Ecosystem Restoration Project, as well as a series of other improvements that ENLACE has been coordinating in preparation and are necessary for project success. These improvements include family relocations, the creation of sanitary sewer systems for the residences and business within the District, and the prevention of new development and fill in of the CMP.

3.0 REPORT SCOPE

3.1 Project Scope

The project scope as defined in Section 2 (Background). The approximate design stage is near 30%.

3.2 USACE Risk Analysis Process

In accordance with USACE Engineer Regulation 1110-2-1302, a formal risk analysis is required for any projects exceeding $40 million and which are going forward to Congress requesting funding. Due to the age of the prior analysis and estimate, (greater than 2 years) the Cost, Schedule, and Risk Analysis are indicated for review and updating. The CMP-ERP is subject to this requirement. Before beginning this analysis, the USACE provided a draft copy of its Cost and Schedule Risk Analysis Guidance document dated May 17, 2009. This document was utilized in the performance of the risk analysis and this update. The guidance document identifies the following key aspects of the risk analysis process:

- Uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software;
- Establishes reasonable contingencies reflective of an 80% confidence level;
- Provides project leadership with contingency information for scheduling, budgeting, and project control purposes;
- Provides tools to support decision making and risk management as the project progresses through planning and implementation; and
- Recognizes that to fully recognize its benefits, cost and schedule risk analyses 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.

This page intentionally left blank.

4.0 METHODOLOGY/PROCESS

For the purpose of performing the CMP-ERP risk analysis a team was assembled and lead by Atkins. The Project Development Team (PDT) comprised the following individuals:

- Mr. Carlos Rivera - USACE Jacksonville District
- Mr. Raymond Wimbrough – USACE Jacksonville District
- Mr. Alfred Walker – USACE Jacksonville District
- Ms. Katia Aviles Vazquez – ENLACE
- Mr. Carlos Muñiz – Pérez – ENLACE
- Mr. Webb Smith – ATKINS – Project Manager
- Mr. William Stevenson – ATKINS - Senior Estimator/Scheduler
- Mr. Dave Carter – ATKINS - Risk Analyst
- Mr. Donald Ator – ATKINS
- Mr. Francisco Perez – ATKINS
- Mr. Steven Pophal – ATKINS
- Mr. Don Deis – ATKINS

The PDT held its initial risk analysis workshop on Thursday, February 28, 2013. A copy of the agenda is provided in Appendix C along with the PowerPoint presentation orienting the PDT to the methodology and risk analysis process. In the workshop the team identified the risks and opportunities the project could experience, the likelihood of their occurrence and the potential impact both to cost and schedule. The information was captured in the risk register provided in Appendix D. With the input obtained from the team, the risk analysts then performed the market and Monte Carlo quantitative probability analysis on the cost estimate utilizing the Crystal Ball software. A follow-up call was held on Thursday, March 7, 2013 to review the risk register preliminary information and to discuss the probability assumptions. The team then agreed on an appropriate contingency to be used in the cost estimate. Once the team made the decision to utilize the "Ocean Disposal Site Work Plan", an update call was held on Wednesday, September 11, 2013. In this meeting the updated estimate was utilized in reviewing changes to the Risk Register resulting from using Ocean Disposal, and these changes were included in a previous CSRA draft report.

Once the Ocean Disposal Site Work Plan was rejected in 2014, the option of disposing dredged material in San Jose Lagoon (SJL) pits was developed. The PDT met via conference call on October 31, 2014, to discuss the risk impact of utilizing the SJL pits in lieu of ocean disposal. The current risk register and results in this report all are on the basis of the SJL pits disposal option. The project cost was updated for this report in January 2016.

In regard to the schedule, Appendix D is the current implementation schedule for the project showing a scheduled construction completion date for the project of September 2020. The team identified the risks that could impact the schedule, with the major risks identified that could have major impacts on the schedule. When a more detailed schedule is developed, a more comprehensive risk analysis can be performed.

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 any desired level of cost confidence. A parallel process is also used to determine the probability of various project schedule duration outcomes and quantify the required schedule contingency (float) needed in the schedule to achieve any desired level of schedule confidence.

In simple terms, contingency is an amount added to an estimate (cost or schedule) 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 Engineering DX guidance for cost and schedule risk analysis generally focuses on the 80% level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk adverse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50% would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level.

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. Because Crystal Ball is an Excel add-in, the schedules for each option are recreated in an Excel format from their native format. 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 would be provided in section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT are considered a qualitative process that results in establishing a risk register that serves as the document for the further 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.

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 in desirable and is considered.

Formal PDT meetings are held (include the name of the location in the report) for the purposes of identifying and assessing risk factors. The meetings (include the date) should include capable and qualified representatives from multiple project team disciplines and functions, for example:

- Project/program managers
- Contracting/acquisition
- Real Estate
- Relocations
- Environmental
- Civil, structural, geotechnical, and hydraulic design
- Cost and schedule engineers
- Construction
- Key sponsors

The initial formal meetings should focus primarily on risk factor identification using brainstorming techniques, but also include some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings should focus primarily on risk factor assessment and quantification.

Additionally, numerous conference calls and informal meetings are 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 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 involves multiple project team disciplines and functions; however, the quantification process relies more extensively on collaboration between cost engineering, designers, and risk analysis team members with lesser inputs from other functions and disciplines.

The following is an example of the PDT quantifying risk factor impacts by using an iterative, consensus-building approach to estimate the 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
- Affected cost estimate and schedule elements

In this example, the risk discussions focused on the various project features as presented within the USACE Civil Works Work Breakdown Structure for cost accounting purposes. It was recognized that the various features carry differing degrees of risk as related to cost, schedule, design complexity, and design progress. The example features under study are presented in table 3:

Table 3. Work Breakdown Structure by Feature

CODE	DESCRIPTION
01	LANDS AND DAMAGES
02	RELOCATIONS
09	CHANNELS & CANALS
14	RECREATION
16	BANK STABILIZATION
18	CULTURAL RESOURCES PRESERVATION
30	PLANNING, ENGINEERING & DESIGN
31	CONSTRUCTION MANAGEMENT

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

4.3 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 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 base 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.

For schedule contingency analysis, the option schedule contingency is calculated as the difference between the P80 option duration forecast and the base schedule duration. These contingencies are then used to calculate the time value of money impact of project delays that are included in the presentation of total cost contingency in section 6. The resulting time value of money, or added risk escalation, is then added into the contingency amount to reflect the USACE standard for presenting the “total project cost” for the fully funded project amount.

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 contingency analysis.

This page intentionally left blank.

5.0 KEY ASSUMPTIONS

The following are considered to be the key assumptions made by the PDT during the CSRA for the project.

- The project is at an approximate 30% design stage.
- The PDT has confidence in the design scope, particularly for the amount of subsurface information, including some soil borings along the channel walls.
- Disposal in San Jose Lagoon pits will be allowed for the dredged / filtered material. A risk is included for alternate disposal, should this not be allowed.
- There are no life cycle costs included in the risk analysis. All risk is related to design and construction time frames.
- Funding is considered to be a risk, with yearly funding appropriations from Congress and a 35% local match.
- Assumed that debris would be included in 10% to 20% of the dredged material, with 10% included in the cost estimate and an additional 10% in the risk amount.
- Have confidence in the cost estimate as it has been developed over a long term with good quantity and price information at this project stage.
- Assumed potential change orders during the construction stage could range from 2% at the low end to 15% at the high end, in addition to other risks identified for the project.
- Assumed dredging production rates could be 20% slower than included in the cost estimate.
- Assumed a risk that market conditions could impact the project costs to be lower or higher than currently estimated. This included potential volatility with equipment, materials (such as fuel and steel) and labor costs.
- Assumed potential delay and cost impact due to weather.
- Assumed a low chance that an earthquake could impact the project during construction.
- Did not include a catastrophic risk, as it was considered that these would completely stop the project and the future of the project.
- Assumed that HTRW materials would not be present within the project area in any significant volumes.

This page intentionally left blank.

6.0 RISK ANALYSIS RESULTS

Table 4 displays the results of the risk analysis for the Project First Cost for Program Year 2016:

Table 4. Project First Cost

CATEGORY	ESTIMATED COST (in millions)
Base Cost Estimate (design and construction)	$125.2
Risk Analysis Contingency Result (80% confidence)	$44.1
Base Cost Estimate (lands and damages)	$38.8
Contingency on lands and damages	$5.8
Subtotal Estimated Cost	**$213.9**
Cost-to-date (115-kV line)	$0.3
Total Project First Cost	**$214.2**

The major cost risks making up the contingency amount include the following (note that some of these risks are combined in the major risks related to the potential for changes and for varying market conditions):

- Potential for change orders during construction
- Market conditions in Puerto Rico and in the construction industry
- Increased quantities of dredged material requiring special handling and disposal
- The risk of steel cost variances for the sheet pile channel walls
- The potential of having to work through limestone on the eastern end of the CMP, which could require a king pile supported sheet pile wall in lieu of the cantilevered sheet pile wall estimated
- The potential for increased fuel costs
- The potential for an earthquake to damage the project
- The potential for vibrations from project construction to impact adjacent structures
- The potential for excess H_2S from project excavations
- Lower productivity of construction around existing bridges or damage to existing bridges
- Potential for alternate disposal (other than SJL pits disposal) being required
- Potential quantity variations of dredged material and sheet pile wall material
- Potential lower productivity than estimated, particularly for the dredging operation

Many of the cost risks also had schedule impact included with them. Other major schedule risks beyond the cost risks are the following:

- Funding Constraints
- Weather impacts
- Delays to dredging and disposal of material
- Delays due to identification of hazardous or potential human remains during the dredging
- Delay to completing and closing out the project

6.1 Risk Register

Provided in Appendix A is the Risk Register developed by the team. The risks were placed in the following categories. The corresponding USACE Civil Works project feature code is identified in the left column.

CODE	DESCRIPTION
	General and Economic
01	Lands and Damages
02	Relocations
09	Canals & Detention Ponds
14	Recreation Facilities
18	Cultural Preservation
	Estimating Assumptions
30 & 31	Project and Program Management

Cost and Schedule impacts, in terms of dollars, have been estimated for each of the risk factors, based on the estimated value of work that could potentially be affected by its occurrence.

The likelihood of occurrence was also identified and applied to the previously identified Cost and Schedule risks, in dollars, which yielded a most likely impact to the project for use in the Crystal Ball Model Analysis.

In accordance with USACE guidance, the level of risk was measured using the following criteria:

Table 5. Risk Level Assessment

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

Table 6 depicts a condensed version of the Risk Register showing the establishment of the risk level based on Table 5 above. The "Rough Order Impact" columns for cost and schedule impact are based on the most likely impacts as developed by the PDT. Note that the most likely result is typically no change to the current estimate, while the high end is typically used should a risk occur. For risks like scope changes and construction change orders, a likely result is included since there is no allowance in the current estimate for these risks.

Table 6. Condensed Risk Register

Caño Martín Peña Ecosystem Restoration Project									
Risk No.	Risk/Opportunity Event	Project Cost				Project Schedule			
		Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)									
GENERAL AND ECONOMIC RISKS									
GE-01	Market Conditions	Likely	Significant	HIGH	$0			LOW	
GE-02	Weather Impacts	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2
GE-03	Energy Costs	Likely	Significant	HIGH	$0			LOW	
GE-04	Funding Constraints	Likely	Critical	HIGH	$0	Likely	Critical	HIGH	24
GE-05	Availability of Skilled Resources	Very Unlikely	Marginal	LOW	$0			LOW	
GE-06	Project Reauthorization	Very Unlikely	Significant	LOW	$0			LOW	
GE-07	Steel Costs	Likely	Significant	HIGH	$0			LOW	
GE-08	Recreational Fishermen	Very Unlikely	Negligible	LOW	$0			LOW	
GE-9	Public Opposition	Very Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1
GE-10	Potential Earthquake	Unlikely	Crisis	HIGH	$0	Unlikely	Critical	HIGH	6
LANDS AND DAMAGES RISKS									
LD-01	Mitigation Cost	Very Unlikely		LOW	$0			LOW	
LD-02	Public Domain footprint	Very Unlikely		LOW	$0			LOW	
LD-03	Vibration Impacts	Very Likely	Significant	HIGH	$0			LOW	

Table 6, cont'd

Caño Martín Peña Ecosystem Restoration Project

Risk No.	Risk/Opportunity Event	Project Cost				Project Schedule			
		Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)
RELOCATIONS									
RL-01	Cost Variances	Very Unlikely	Negligible	LOW	$0			LOW	
RL-02	Condemnation	Very Unlikely		LOW	$0			LOW	
RL-03	Unknown Utilities	Very Unlikely		LOW	$0			LOW	
RL-04	Reduced project footprint	Very Unlikely	Marginal	LOW	$0			LOW	
RL-04a	Borinquen Water Line & Rexach Trunk Sewer	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2
RL-05	Air Quality	Very Likely	Significant	HIGH	$0			LOW	
RL-06	Relocation of residents	Unlikely	Negligible	LOW	$0	Unlikely	Significant	MODERATE	4
RL-07	Additional Relocations from Induced Flooding	Likely	Significant	HIGH		Unlikely	Marginal	LOW	0
CANALS AND DETENTION PONDS									
CH-01	Historic Finds	Unlikely	Marginal	LOW	$0			LOW	
CH-02	HTRW (Hazardous Material)	Unlikely	Significant	MODERATE	$0	Unlikely	Critical	HIGH	2
CH-03	Contaminated Material	Very Unlikely	Negligible	LOW	$0			LOW	
CH-04	Debris Removal and Sorting	Likely	Marginal	LOW	$0			LOW	
CH-05	Heavily Urbanized Area			LOW	$0			LOW	
CH-06	Work Hours / Site Access	Very Unlikely	Marginal	LOW	$0			LOW	
CH-07	Soil Conditions	Very Unlikely	Marginal	LOW	$0			LOW	

Table 6, cont'd

Caño Martín Peña Ecosystem Restoration Project									
		Project Cost				Project Schedule			
Risk No.	Risk/Opportunity Event	Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)
CH-08	Access Routes	Very Unlikely	Marginal	LOW	$0			LOW	
CH-09	Construction Sequencing	Very Unlikely	Negligible	LOW	$0			LOW	
CH-10	Sediment Containment	Very Unlikely	Negligible	LOW	$0			LOW	
CH-11	Sediment Contamination	Very Likely	Negligible	LOW	$0			LOW	
CH-12	Human remains	Very Likely	Marginal	MODERATE	$0		Marginal	MODERATE	0.5
CH-13	Equipment Access	Very Likely	Marginal	MODERATE	$0	Very Likely		LOW	
CH-14	Work under existing bridges	Very Likely	Significant	HIGH	$0			LOW	
CH-14a	Potential damage to existing bridges	Unlikely	Significant	MODERATE	$0	Unlikely	Significant	MODERATE	1.5
CH-14b	Additional Geotechnical information at Existing Bridges	Very Unlikely	Negligible	LOW	$0	Very Unlikely	Negligible	LOW	0
CH-15	Issues with Sediment Pumping	Very Unlikely	Negligible	LOW	$0	Very Unlikely	Negligible	LOW	
CH-16	Issues with Sediment Screening	Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1
CH-17	Coordination with PRPA	Very Unlikely	Negligible	LOW	$0			0	
CH-18	Operations interruption with AquaExpresso	Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1
CH-19	Weather and coordination impact to Barging of Disposal Material	Unlikely	Marginal	LOW	$0	Unlikely	Negligible	LOW	
CH-20	Trucking	Very Unlikely	Marginal	LOW	$0			LOW	
CH-21	Limestone in dredging	Likely	Marginal	LOW	$0	Likely	Significant	HIGH	3
CH-22	Disposal Material Quantity Variation	Very Likely	Critical	HIGH	$0	Likely	Significant	HIGH	3

Table 6, cont'd

Caño Martín Peña Ecosystem Restoration Project

Risk No.	Risk/Opportunity Event	Project Cost				Project Schedule			
		Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)
CH-23	Alternate Disposal Options	Unlikely	Critical	MODERATE	$0	Unlikely	Critical	MODERATE	
	OPPORTUNITIES								
CH-24	Source of Sand	Very Unlikely	Negligible	LOW	$0				
RECREATION									
RC-02	Variations in Design Concepts	Very Unlikely	Marginal	LOW	$0			LOW	
RC-03	Squatters	Very Unlikely	Marginal	LOW	$0			LOW	
CULTURAL PRESERVATION									
CP-01	Site Access	Very Unlikely	Marginal	LOW	$0			LOW	
CP-02	Encounter cultural conditions	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2
CP-03	Variations in Design Concepts	Very Unlikely	Marginal	LOW	$0			LOW	
ESTIMATING ASSUMPTIONS									
EA-1	Dredging Quantities	Very Likely	Marginal	MODERATE	$0	Very Unlikely	Marginal	LOW	
EA-2	Sheet Pile Wall Quantities	Very Likely	Marginal	MODERATE	$0	Very Unlikely	Marginal	LOW	
EA-3	Articulated Concrete Block Material Quantities	Very Likely	Marginal	MODERATE	$0	Likely	Marginal	MODERATE	
EA-4	Dredging Production Rates and Crews	Very Likely	Marginal	MODERATE	$0	Unlikely	Marginal	LOW	
EA-5	Sheet Pile Walls Production Rates and Crews	Very Likely	Marginal	MODERATE	$0	Unlikely	Marginal	LOW	
EA-6	Scope Changes	Very Unlikely	Marginal	LOW	$1,497,101	Unlikely	Marginal	LOW	

Table 6, cont'd

Caño Martín Peña Ecosystem Restoration Project									
Risk No.	Risk/Opportunity Event	Project Cost				Project Schedule			
		Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)
PROJECT & PROGRAM MGMT									
PM-03	Rights of Entry	Very Unlikely	Marginal	LOW	$0			LOW	
PM-05	Program Management Resources	Very Unlikely	Marginal	LOW	$0			LOW	
PM-06	Change Management	Very Likely	Critical	HIGH	$7,485,506			LOW	
PM-07	Project Closeout	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2
PM-07a	Wetlands Impact			0	$0			0	
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)									
PR-1				0				0	
PR-2				0				0	
PR-3				0				0	
PR-4				0				0	
PR-5				0				0	
PR-6				0				0	
PR-7				0				0	

The condensed Risk Register shows the determination of those risks that were considered to have a "High" impact on the project, and the resulting cost/schedule impact. There were relatively few opportunities identified and modeled to reduce the project costs or reduce the schedule duration.

6.2 Combined Cost and Schedule Contingency Results

Table 7 shows the results of the contingency analysis for the design and construction portion of the project, demonstrating that at the 80% confidence level, the contingency is made up of approximately $41.7 million in cost related risks and $2.4 million in schedule related risks. Table 7 also demonstrates that the potential range of contingency from a very low confidence level to near 100% confidence is from $2.4 million to over $80 million. These extremes are highly unlikely, but do demonstrate the high potential variability with the project costs and the opportunity for risk mitigation.

For those risk noted in the previous list, the following "Sensitivity Charts" (Figures 2 and 3) show the results of the impact of the major risks on the contingency results.

Table 7. Contingency Results Breakdown ($ in Millions)

Confidence Level	Cost Contingency	Schedule Contingency	Total Contingency	Contingency %
0%	$2.3	$0.1	$2.4	2.0%
5%	$17.9	$0.4	$18.3	14.7%
10%	$21.3	$0.5	$21.8	17.4%
15%	$23.4	$0.6	$24.0	19.2%
20%	$25.2	$0.7	$25.8	20.6%
25%	$26.7	$0.8	$27.5	21.9%
30%	$28.2	$0.8	$29.0	23.2%
35%	$29.4	$0.9	$30.3	24.2%
40%	$30.6	$1.0	$31.6	25.3%
45%	$31.9	$1.0	$33.0	26.3%
50%	$33.1	$1.1	$34.3	27.4%
55%	$34.4	$1.3	$35.7	28.5%
60%	$35.7	$1.4	$37.1	29.6%
65%	$36.9	$1.6	$38.5	30.8%
70%	$38.3	$1.8	$40.1	32.0%
75%	$39.9	$2.1	$42.0	33.6%
80%	$41.7	$2.4	$44.1	35.2%
85%	$43.6	$2.8	$46.4	37.1%
90%	$46.0	$3.3	$49.3	39.4%
95%	$49.6	$3.8	$53.5	42.7%
100%	$75.0	$6.1	$81.1	64.8%

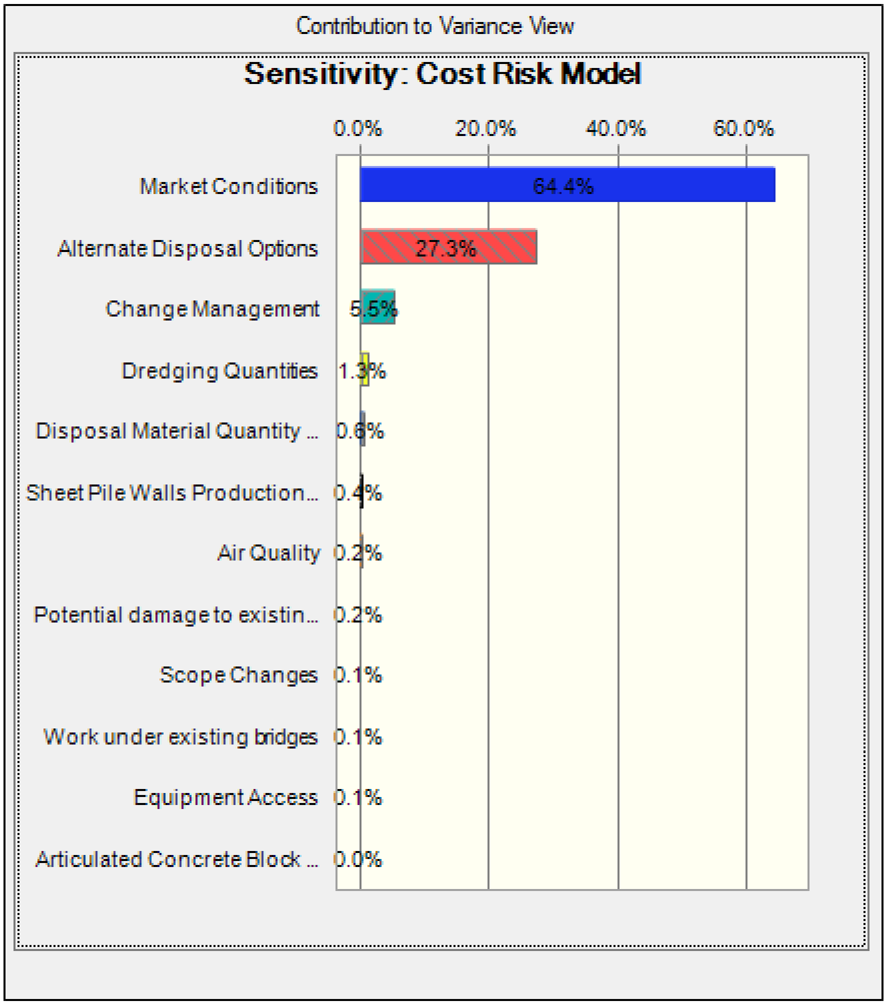


Figure 2. Cost Sensitivity Chart

Figure 2 demonstrates the potential impact of the risks related to dredging disposal, market conditions, dredging production rates and change management during construction have on the project. It also demonstrates that many of the risks with the greatest contribution to the risk variance are risks that the PDT has the ability to manage and mitigate during the final design and construction process.

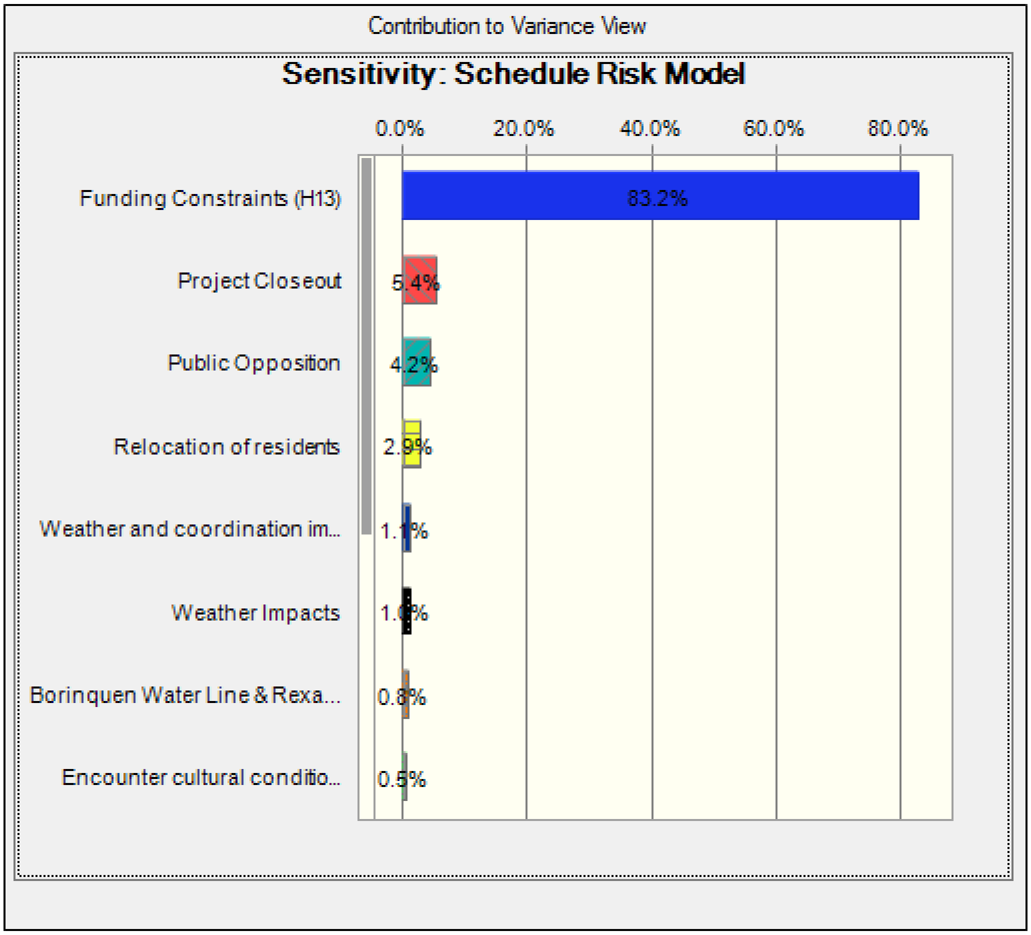
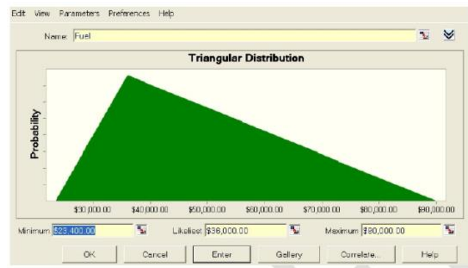


Figure 3. Schedule Sensitivity Chart

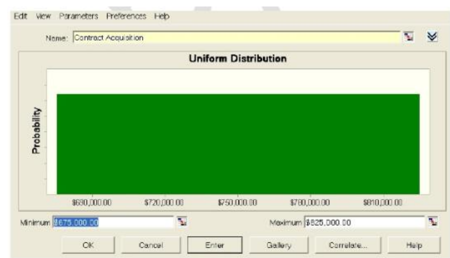
Figure 3 demonstrates that the potential for funding constraints has the greatest contribution to the schedule risk variance on the project, at over 80%. Other schedule risk impacts include a delay to project closeout, delay related to public opposition, delay to relocating residents prior to construction, and delay to utility relocations are risks that can be managed and mitigated by the PDT.

7.0 QUANTITATIVE RISK ANALYSIS

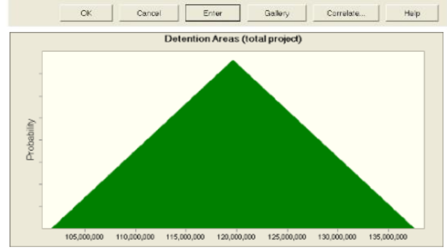
The quantitative risk analysis involved applying probability curves to the appropriate cost items of the current cost estimate based on the risks identified by the team. The probability curves were initially proposed by the risk analysts and then reviewed with the project development team. The probability curves were developed based on the risks documented in the risk register. It should be noted that in general, the risks were determined to be relatively low with the exception of those impacting the excavation and hauling of the excavated material from detention ponds. Also, the risks were found to be consistent across the major construction elements, and in order to reduce the need to correlate the probability curves the risk analysts applied the curves at the summary level of the cost estimate. The input probability assumptions the team made are provided in Appendix D.



In accordance with the USACE guidelines, the team used only the triangular and uniform distributions curves. These curves are described as follows. The triangular distribution establishes a best case, most likely and worst case value. This distribution is recommended for the risk events that impact discreet areas or where one cost value is more likely to occur than another value.



The uniform distribution is used when any value between the best case and worst case are equally likely to occur. This distribution is recommended when the risk events are more global to the project and a most likely occurrence cannot be established.



The key distribution curve was the modeling of the risks and opportunities associated with the costs to excavate and haul away the material from the detention ponds. For this probability assumption the team used the following model. This model is slightly more conservative than used in the previous study, related to concern over current market conditions resulting in price inflation for these costs.

The cost contingency was then analyzed using the Crystal Ball software and a Monte Carlo simulation was performed. The results are provided in the following section.

This page intentionally left blank.

8.0 MAJOR FINDINGS/OBSERVATIONS

The PDT review of the CMP-ERP had the following major findings / observations during the study:

The project scope is well-defined and the limits of construction are established. Many risks have been mitigated through the current design process. This minimizes the risk of expanded scope on the project. Many risks were identified during the PDT review, with those having the highest potential impact as follows:

Summarized from the detail provided earlier in the report, the major cost risks making up the contingency amount include the following:

- Alternate Disposal Options for the dredged material (other than San Jose Lagoon pits disposal)
- Market conditions in Puerto Rico and in the construction industry
- Variance in dredging productions rates due to field conditions
- Potential for change orders during construction
- The risk of quantity variances for the sheet pile channel walls
- Increased quantities of dredged material requiring special handling and disposal

The major schedule risks beyond the cost risks are the following:

- Funding Constraints
- Delay to completing and closing out the project
- Delays to dredging and disposal of material
- Delays to the start of the project for Public Opposition
- Delays to the relocation of residents impacting construction
- Weather impacts

The PDT analyzed these and other potential risks to the project and worked to determine the best likelihood of the risk occuring and the potential impact to the project should the risk occur. Multiple potential changes to specific project activities were noted, with multiple risks have a potential cost impact to the project, with dredging and disposal of material and other construction change orders being the largest risks during construction. Market conditions can also be an impact that should be closely followed by the PDT as the construction bid approaches. Funding constraints was the greatest schedule risk identified by the PDT, with the potential for lengthy delays should funding needs not be met.

The results of the probability run using the risks identified results in a range of the potential total costs of the project, based on a contingency that varies based on the risks. At the low confidence levels (lower chance that results will be below these values), the contingency is relatively low showing that most major risks have been mitigated. At the higher confidence levels (higher chance that results will be below these values), the contingency is greater showing that more of the major risks have occurred and had a cost or schedule impact on the project.

The following table (Table 8) summarizes these confidence levels and contingency results:

Table 8. Project Contingencies and Total Project Estimated Costs ($ in millions)

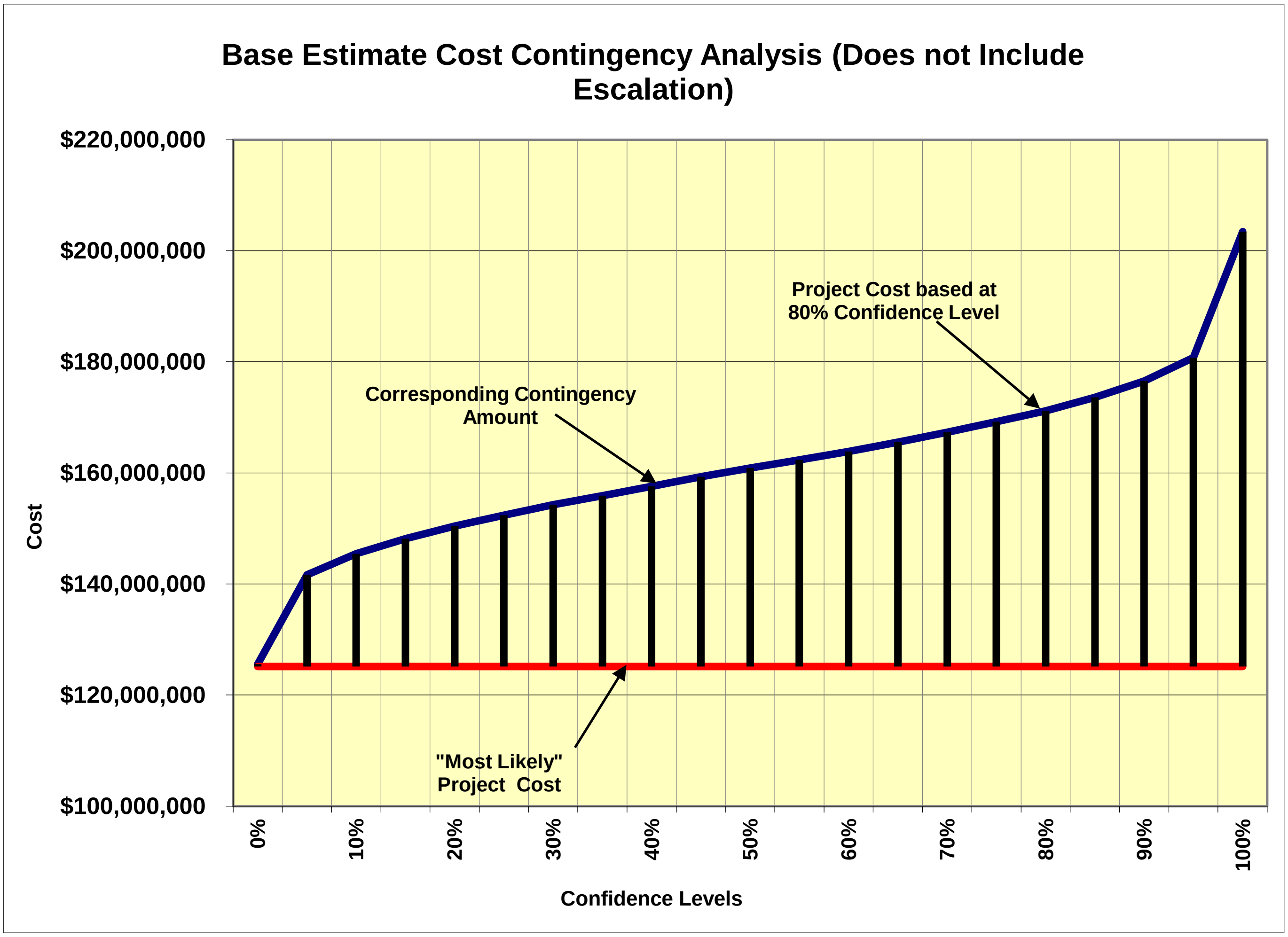
Project Design and Construction Costs

Confidence Level	Project Cost (Base plus Contingencies)*	Total Contingency	Contingency %
0%	$127.6	$2.4	2.0%
10%	$146.9	$21.8	17.4%
20%	$151.0	$25.8	20.6%
30%	$154.1	$29.0	23.2%
40%	$156.8	$31.6	25.3%
50%	$159.4	$34.3	27.4%
60%	$162.2	$37.1	29.6%
70%	$165.2	$40.1	32.0%
80%	$169.3	$44.1	35.2%
90%	$174.5	$49.3	39.4%
100%	$206.3	$81.1	64.8%

* Excludes Lands and Damages costs

Table 8 denotes the risk based contingency level and percentage based on the confidence levels resulting from the probability runs. Table 9 shows this in graphical form with the 80% confidence at $169.3 million. This amount combined with the Lands and Damages estimate of $38.8 million and associated contingency of $5.8 million results in the 2016 program year cost of $213.9 million. Including the $0.3 million of costs to date results in the Project First Cost of $214.2 million.

Table 9. Confidence Levels of Project Design & Construction Estimated Costs



This page intentionally left blank.

9.0 MITIGATION RECOMMENDATIONS

The PDT now has a risk register that compiles the risks on the project. As the project moves forward, mitigation approaches need to be determined for each of the risks, with assigned project personnel to evaluate these risks. Those risks with the most significant potential that can be managed, such as the funding constraints, should have the greatest focus.

The PDT in providing input on the risk register was able to identify and begin discussions on possible mitigating strategies for managing the risks. Some of these strategies included:

- Additional subsurface testing of the area to be dredged to further determine content and risk definition;
- Improved criteria for the final design stage to manage elements that could have scope changes;
- Continued analysis of the industry to determine the price trends for the major labor, equipment and materials required for the CMP project;
- Continued determination of future project funding;
- Input from construction industry on potential productivity issues for the project; and
- Focus on management of the construction contract to address issues and minimize change orders

The recommendation is that the current risk register continue to be utilized by the project team moving forward to document and manage the risks on the project.

This page intentionally left blank.

Appendix A

Total Project Cost Summary

**** TOTAL PROJECT COST SUMMARY **** Printed:1/26/2016

PROJECT: **Caño Martín Peña Ecosystem Restoration Project**
PROJECT NO: 354852
LOCATION: San Juan, Puerto Rico

DISTRICT: SAJ Jacksonville PREPARED: 1/7/2016
POC: CHIEF, COST ENGINEERING, Matthew W. Cunningham

This Estimate reflects the scope and schedule in report; Caño Martín Peña Ecosystem Restoration Project
and is based on the Detailed cost estimate file 354852_CMP_Ecosystem_Restoration_Feasibility_2015_1027_Rev6Ver13

SAN JOSÉ LAGOON DISPOSAL OPTION

Program Year (Budget EC): **2016**
Effective Price Level Date: 1-Oct-15

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)		
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent To Date ($K)	TOTAL FIRST COST	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*
02	*RELOCATIONS (Cost to Date)*	*$270*								*$270*	*$ 270*			***$270***
02	**RELOCATIONS**	$9,179	$3,231	35.2%	$12,410	0.0%	$9,179	$3,231	**$12,410**		**$ 12,410**	$9,561	$3,365	**$12,926**
06	**FISH & WILDLIFEFACILITIES**	$8,489	$2,988	35.2%	$11,477	0.0%	$8,489	$2,988	**$11,477**		**$ 11,477**	$8,842	$3,112	**$11,954**
09	**CHANNEL & CANAL**	$37,900	$13,341	35.2%	$51,241	0.0%	$37,900	$13,341	**$51,241**		**$ 51,241**	$39,476	$13,895	**$53,371**
14	**RECREATION**	$7,258	$2,555	35.2%	$9,813	0.0%	$7,258	$2,555	**$9,813**		**$ 9,813**	$7,560	$2,661	**$10,221**
16	**BANK STABILIZATION**	$45,904	$16,158	35.2%	$62,062	0.0%	$45,904	$16,158	**$62,062**		**$ 62,062**	$47,812	$16,830	**$64,642**
18	**CULT RESOURTCE PRESERVATION**	$103	$36	35.2%	$139	0.0%	$103	$36	**$139**		**$ 139**	$107	$38	**$144**
	CONSTRUCTION ESTIMATE TOTALS:	$109,102	$38,309		$147,141	0.0%	$108,832	$38,309	$147,141	$270	$147,411	$113,356	$39,901	$153,528
01	**LANDS AND DAMAGES**	$38,847	$5,827	15.0%	$44,674	0.0%	$38,847	$5,827	**$44,674**		**$ 44,674**	$38,847	$5,827	**$44,674**
30	**PRECONST'N, ENGINEERING, DESIGN**	$9,795	$3,448	35.2%	$13,243	0.0%	$9,795	$3,448	**$13,243**		**$ 13,243**	$10,292	$3,623	**$13,915**
31	**CONSTRUCTION MANAGEMENT**	$6,530	$2,299	35.2%	$8,828	0.0%	$6,530	$2,299	**$8,828**		**$ 8,828**	$7,104	$2,501	**$9,605**
	PROJECT COST TOTALS:	$164,274	$49,882	30.4%	$214,156		$164,004	$49,882	**$213,886**	$270	**$214,156**	$169,600	$51,852	**$221,722**

ESTIMATED FEDERAL COST: 64.2% $142,366
ESTIMATED NON-FEDERAL COST: 35.8% $79,356
ESTIMATED TOTAL PROJECT COST: $221,722

CHIEF, COST ENGINEERING, Matthew W. Cunningham

PROJECT MANAGER, Jim Suggs

CHIEF, REAL ESTATE, Audrey Ormerod

CHIEF, PLANNING, Eric Summa, P SAJ

CHIEF, ENGINEERING, Laureen Borochaner

CHIEF, OPERATIONS, Jim Jeffords

CHIEF, CONSTRUCTION, Steve Duba

CHIEF, CONTRACTING, Carlos Clarke

CHIEF, PM-PB, xxxx

CHIEF, DPM,

Item	First Cost	Non-Federal Cost Share %	Non-Federal Cost*	Federal Cost
Ecosystem Restoration				
Construction, Construction Management, PED		35%	$13,050	$130,605
LERRDs		100%	$57,276	$0
LERRDs (Federal Admin)		35%	$679	$1,261
Subtotal - Ecosystem Restoration	**$202,871**		**$71,005**	**$131,866**
Recreation		50%		
Subtotal - Recreation	**$11,285**		**$5,642**	**$5,642**
Total First Cost	**$214,156**		**$76,647**	**$137,508**

Filename: 354852_CMP_TPCS_SJLagoon_Disposal_012516_Ver13g2 - MCX TEST.xlsx
TPCS, 39% Contingency

Printed:1/26/2016

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

**** CONTRACT COST SUMMARY ****

PROJECT: Caño Martín Peña Ecosystem Restoration Project
LOCATION: San Juan, Puerto Rico
This Estimate reflects the scope and schedule in report; Caño Martín Peña Ecosystem Restoration Project

DISTRICT: SAJ Jacksonville PREPARED: 1/7/2016
POC: CHIEF, COST ENGINEERING, Matthew W. Cunningham

354852_CMP_Ecosystem_Restoration_Feasibility_2015_1027_Rev6Ver13

FUTURE COST - COST TO COMPLETE ONLY

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
SAN JOSÉ LAGOON DISPOSAL		Estimate Prepared:			6-Jan-2016	Program Year (Budget EC):			2016					
		Effective Price Level:			1-Oct-2015	Effective Price Level Date:			1-Oct-15					
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*
02	RELOCATIONS	$9,179	$3,231	35.2%	$12,410	0.0%	$9,179	$3,231	$12,410	2018Q2	4.2%	$9,561	$3,365	$12,926
06	FISH & WILDLIFE FACILITIES	$8,489	$2,988	35.2%	$11,477	0.0%	$8,489	$2,988	$11,477	2018Q2	4.2%	$8,842	$3,112	$11,954
09	CHANNELS & CANALS	$37,900	$13,341	35.2%	$51,241	0.0%	$37,900	$13,341	$51,241	2018Q2	4.2%	$39,476	$13,895	$53,371
14	RECREATION FACILITIES	$7,258	$2,555	35.2%	$9,813	0.0%	$7,258	$2,555	$9,813	2018Q2	4.2%	$7,560	$2,661	$10,221
16	BANK STABILIZATION	$45,904	$16,158	35.2%	$62,062	0.0%	$45,904	$16,158	$62,062	2018Q2	4.2%	$47,812	$16,830	$64,642
18	CULTURAL RESOURCE PRESERVATION	$103	$36	35.2%	$139	0.0%	$103	$36	$139	2018Q2	4.2%	$107	$38	$144
	CONSTRUCTION ESTIMATE TOTALS:	$108,832	$38,309	35.2%	$147,141		$108,832	$38,309	$147,141			$113,356	$39,901	$153,258
01	LANDS AND DAMAGES	$38,847	$5,827	15.0%	$44,674	0.0%	$38,847	$5,827	$44,674	2016Q1	0.0%	$38,847	$5,827	$44,674
30	PRECONSTRUCTION, ENGINEERING, DESIGN													
0.5%	Project Management	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
1.0%	Planning & Environmental Compliance	$1,088	$383	35.2%	$1,471	0.0%	$1,088	$383	$1,471	2017Q2	4.6%	$1,139	$401	$1,539
5.0%	Engineering & Design	$5,442	$1,915	35.2%	$7,357	0.0%	$5,442	$1,915	$7,357	2017Q2	4.6%	$5,693	$2,004	$7,696
0.5%	Reviews, ATRs, IEPRs, VE	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
0.5%	Life Cycle Updates (cost, schedule, risks)	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
0.5%	Contracting & Reprographics	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2017Q2	4.6%	$569	$200	$770
1.0%	Engineering During Construction	$1,088	$383	35.2%	$1,471	0.0%	$1,088	$383	$1,471	2018Q2	8.8%	$1,184	$417	$1,601
	Planning During Construction	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	Project Operations	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
31	CONSTRUCTION MANAGEMENT													
5.5%	Construction Management	$5,986	$2,107	35.2%	$8,093	0.0%	$5,986	$2,107	$8,093	2018Q2	8.8%	$6,512	$2,292	$8,805
	Project Operation:	$0	$0	35.2%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
0.5%	Project Management	$544	$192	35.2%	$736	0.0%	$544	$192	$736	2018Q2	8.8%	$592	$208	$800
	CONTRACT COST TOTALS:	$164,004	$49,882		$213,886		$164,004	$49,882	**$213,886**			$169,600	$51,852	**$221,452**

Filename: 354852_CMP_TPCS_SJLagoon_Disposal_012516_Ver13g2 - MCX TEST.xlsx
TPCS, 39% Contingency

Appendix B

Risk Workshop Agenda and Presentation

ATKINS

Cano Martin Pena
Ecosystem Restoration Project

Cost & Schedule Risk Analysis (CSRA)
CSRA Workshop

February 28, 2013

U.S. Army
Corps of Engineers

Plan Design Enable

CSRA Workshop Agenda

ATKINS

- Introductions
- Overview of Process (including CSRA checklist)
- Overview of Current Project Cost Estimate
- Identification and development of Risk items
  - Real estate acquisition and relocations
  - Cultural Preservation
  - Water Quality and Fisheries
  - Potential design changes prior to construction
  - Construction
  - Schedule
  - Other
  - Final review of checklist
- Next Steps

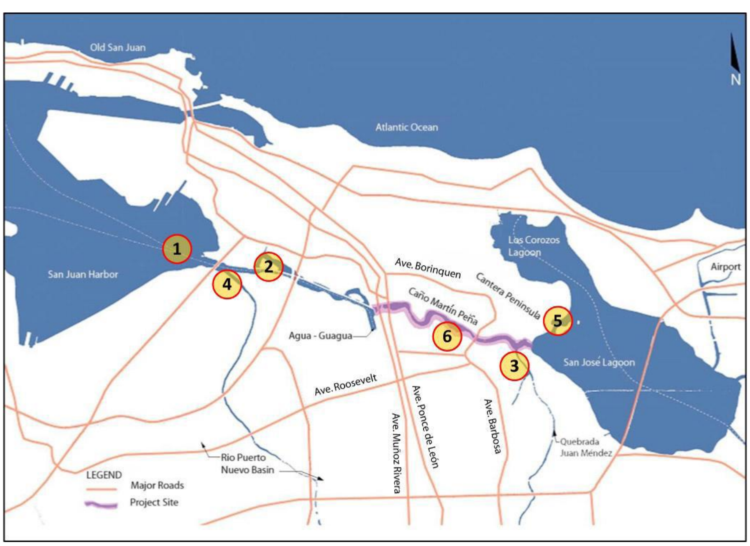
2

Project Overview

- 4-mile long tidal canal
- Connects the San Juan Bay with the San Jose Lagoon and Los Corozos Lagoon in San Juan, Puerto Rico
- Dredging ~ 2.2 miles of the canal
- Main channel with structurally supported rectangular cross section
- Preliminary estimate: $267.1 million (excludes contingency and escalation)

3

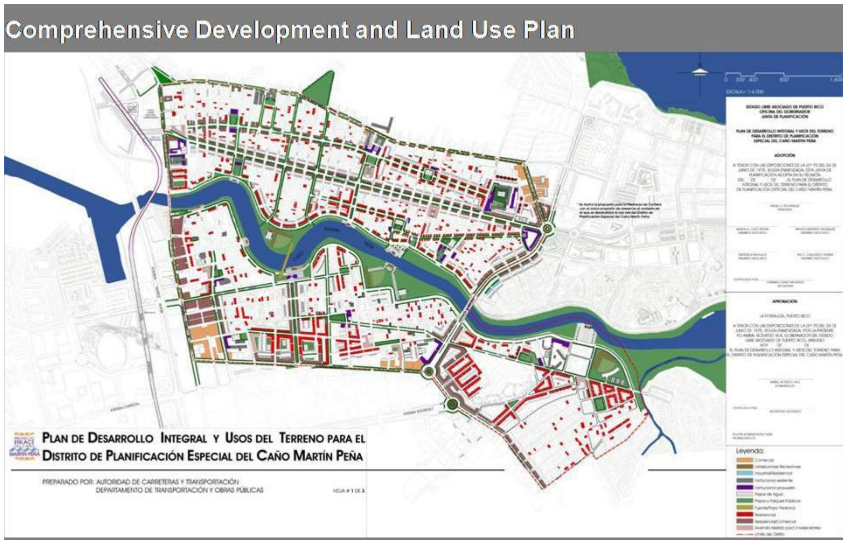
Project Location Map



4

Comprehensive Devt. & Land Use Plan

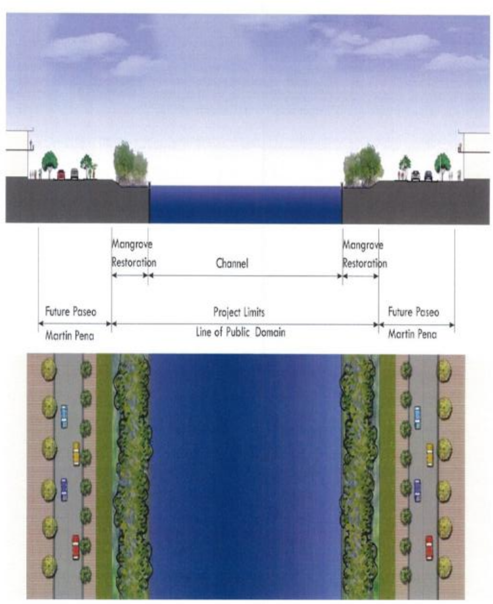
ATKINS



5

Channel Plan and Section

ATKINS



6

Risk Workshop Outline

- Overview & key goal
- Key Concepts
- Performed on total construction cost
- PDT – Project Development Team
- Identification of Risks & Opportunities
- Risk Assessment – Qualitative
- Risk Analysis – Quantitative
- Updating and tracking requirements

7

Overview and Key Goal

- Key Goal: Define an appropriate contingency
- Risk analysis done on current cost estimate without contingency or escalation

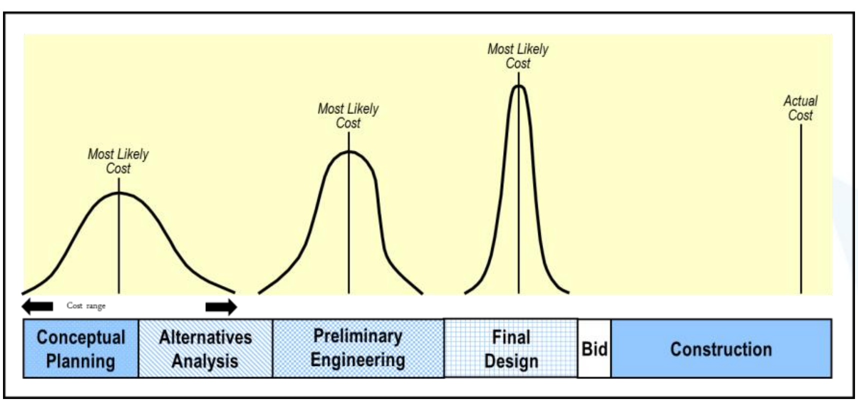
8

Key Concepts: Risk and Probability

- Risk:
  - the possibility of suffering harm or loss; danger
- Probability:
  - a measure of how likely it is that some event will occur

9

Key Concepts: Risk and Probability over Time



10

Key Concepts:
Components of Risk Analysis

- Identification
- Assessment
- Documentation
- Monitoring

Risk No.	PDT-developed Risk/Opportunity Event (logic by feature, contract, responsibility)	PDT Event Concerns (include all to archive)	PDT Discussions (support the likelihood and impact)
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere			
PROJECT & PROGRAM MGMT			
PPM-1	Contracting Plan	Contracting Plan may not be fully develpoed for the projects. Some uncertainty of	
PPM-1	Local Government	Local Sponsor influences on the design and scope of the project	
PPM-2	Legal Issues	Ongoing lawsuit may influence the design criteria and design plans for the project	
	OPPORTUNITIES		
OP-1	Bidding Climate	With many contractors searching for work nationally, large scale contratcrors may	
GENERAL AND ECONOMIC RISKS			
GE-1	Availablity of Resources	Capable contractors may be working outside of the local area reducing the qualified	
GE-2	Inflation / Esclation	Material pricing may rise as a result of inflation and other market economy factors.	
Feature Code 01 - LANDS & DAMAGES			
LD-1	Real Estate Recovery	Real Estate recovery may continue to affect fair market pricing	
LD-2	Acquisition Costs	Individual land owners may be unwilling to cooperate with acquisition plan.	

11

Qualitative Risk Assessment

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

12

Determining Risk

ATKINS

Collaborative Process that incorporate feedback from all members of the Project Delivery Team (PDT) to form a comprehensive picture of the probable project risks to cost AND schedule.

- Planning director
- Designer
- ROW
- Hydraulics
- Environmental
- Construction
- Cost Estimator
- Risk Analyst

13

Total Project Cost

ATKINS

The Risk Analysis builds on the Total Estimated Project Cost to determine an appropriate Contingency for each Feature Code.

- (01) Lands and Damages
- (02) Relocations
- (09) Channels and Canals
- (15) Detention Basins – Flood Control
- (30) Planning, Engineering and Design
- (31) Construction Management

14

Steps to Identify Risk

ATKINS

- Identify Risk (or Opportunity)
- Describe Risk
- Analyze Qualitatively
- Analyze Quantitatively
- Develop Risk Response Plan
- Establish Risk Monitoring and Control Plan
- Establish estimated cost for response and avoidance

15

Documenting Risk: The Risk Register

ATKINS

- Identify Risk (or Opportunity)
- Describe Risk
- Analyze Qualitatively and Quantitatively
- See CSRA guidance, Appendix A

Contract Acquisition Risks

- ❑ Undefined acquisition strategy
- ❑ Lack of acquisition planning support/involvement
- ❑ Preference to SDB and 8(a) contracts
- ❑ Acquisition planning to accommodate funding stream or anticipated strategy
- ❑ Numerous separate contracts
- ❑ Acquisition strategy decreasing competition
- ❑ Acquisition strategy results in higher scope risk (Design Build)

16

Quantitative Analysis of Risk

ATKINS

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

← Qualitative Analysis

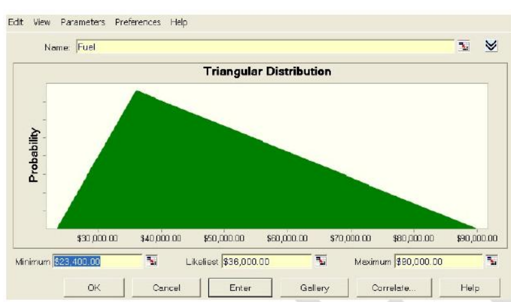
- **Likelihood of Occurrence (Y axis)**
  - Measured in percentage chance of occurrence
  - Example: Highly Unlikely = 10% chance
- **Impact or Consequence of Occurrence (X axis)**
  - Measured in $ impact to current project estimate
  - Include low, most likely and high assessment of impact with variance distributions

17

Variance Distributions

ATKINS

- Triangular Distribution



The triangular distribution (figure 3) is commonly used when the market research has established the best case, most likely, and worst cases: three distinct points, measured in dollars or percent. By definition, the most likely estimate has established what is most likely to occur. This distribution is recommended for the risks events that impact discreet areas or details of the estimate where one can determine that one cost value is more likely to occur than another value.

18

Variance Distributions

ATKINS

- Uniform Distribution

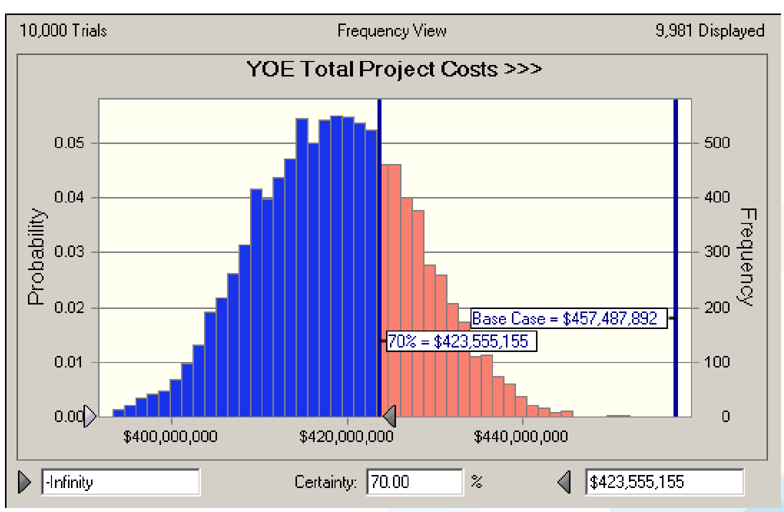
The uniform distribution (figure 4) is used when any value between the best case and worst case are equally likely to occur. In these instances, only two points are needed, the best and the worse case. This distribution is recommended when the risk events are more global to the project and a most likely occurrence cannot be established. Within the model, the best case is assigned a value equal-to/or less-than the most likely (cost estimate) value and the worst case is assigned a value equal-to/or greater-than the most likely (cost estimate) value.

19

Variance Distributions - Outcome

ATKINS

- Monte Carlo Analysis



20

Evaluation of Contingency

ATKINS

Most Likely Cost Estimate	$	283,798,120
Confidence Level	**Value**	**Contingency**
0%	$196,251,351	-30.85%
5%	$265,301,883	-6.52%
10%	$278,356,727	-1.92%
15%	$287,628,329	1.35%
20%	$294,426,931	3.75%
25%	$300,576,519	5.91%
30%	$306,044,712	7.84%
35%	$311,348,193	9.71%
40%	$316,463,923	11.51%
45%	$321,561,018	13.31%
50%	$325,920,859	14.84%
55%	$330,801,756	16.56%
60%	$335,990,370	18.39%
65%	$340,890,506	20.12%
70%	$346,028,517	21.93%
75%	$351,266,705	23.77%
80%	$357,691,114	26.04%
85%	$365,347,118	28.73%
90%	$373,567,089	31.63%
95%	$385,963,837	36.00%
100%	$455,670,837	60.56%

21

Reporting

ATKINS

22

Updating and Tracking

- CSRA Guidance suggests:
  - conducting periodic risk review meetings
  - revisit risks from original identification
  - continually refine the analysis and responses

23

Questions?

24

Appendix C

Risk Register

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)															
GENERAL AND ECONOMIC RISKS															
GE-01	Market Conditions	Labor costs are likely declining in PR, as unemployment has been increasing. There is still some risk with material costs and equipment costs that are combined in this risk.	The team considers cost risk related to the impact of construction market conditions on the project (labor, materials and equipment). Current market conditions in Puerto Rico show low construction volume, indicating likely high competition and lower prices. A low end market conditions impact of 10% was modeled for this opportunity. The risk of market conditions changing, with potential greater construction volume, would likely reduce competition and increase construction costs of the project by up to 15%. This also includes the impact of market conditions on the cost of fuel for the equipment, steel sheet pile and other larger cost elements on the project.	Likely	Significant	HIGH	$0			LOW		Triangular	GE-03; GE-07		
GE-02	Weather Impacts	Construction will span multiple Hurricane Seasons	3 months of potential schedule risk is included in the CSRA for the potential of weather impacts to the project that would be granted to the contractor as non-compensable time. The 3 months has been modeled as a 100% probability, with no impact at the low and most likely results, and the 3 months impact as the high result.	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2	Triangular	GE-10		
GE-03	Energy Costs	Fuel Costs continue to hedge upward	The intent of the Market Conditions risk (GE-01) is to account for any large increases in the cost of labor, materials or equipment due to market conditions. Therefore, GE-01 includes the potential impact on the project costs for a large increase in the cost of fuel during construction.	Likely	Significant	HIGH	$0			LOW		Triangular	GE-01		
GE-04	Funding Constraints	Inavailability of Sponsor funds to match Federal Assistance	Project is dependent on Water Resources Devt Act authorization. Current local matching is 35% plus O&M. Congress yearly appropriations may impact phasing of the project. If no local share, then the project could extend up to 7 years. Considering there will likely be local share, used a potential extended construction duration from 1 to 3 years, with a uniform distribution. Only costs considered are additional project extension related costs in the schedule risks.	Likely	Critical	HIGH	$0	Likely	Critical	HIGH	24	Triangular			
GE-05	Availability of Skilled Resources	Will the skilled resources be available locally? For example, will qualified and capable dredging companies, trucking companies, barging companies be available locally within Puerto Rico.	Surplus of skilled resources at this time. There is some concern that the work in an urban environment will pose challenges to the contractors. June 2014 update: this risk considered low as unemployment is high in Puerto Rico and it is very likely skilled workers will be available for the project.	Very Unlikely	Marginal	LOW	$0			LOW					
GE-06	Project Reauthorization	All alternative plans, including the recommended plan, exceeds 902 cost limitations and must be reauthorized prior to construction. Reauthorizataion timeline is uncertain, but assumed to occur prior to planned 2016 start of construction.	Authorizing legislation has become less regular and predictable in occurance. Delays may result in additional cost inflation. If no reauthorization, then there would be no Federal participation.	Very Unlikely	Significant	LOW	$0			LOW					

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
GE-07	Steel Costs	Fluctuating cost of steel could effect the cost of the sheet pile	The intent of the Market Conditions risk (GE-01) is to account for any large increases in the cost of labor, materials or equipment due to market conditions. Therefore, GE-01 includes the potential impact on the project costs for a large increase in the cost of steel for the sheet pile to be utilized during construction.	Likely	Significant	HIGH	$0			LOW		Triangular	GE-01		
GE-08	Recreational Fishermen	Recreational fishermen strongly oppose the disposal of dredged sediments in San Jose Lagoon.	The potential to have to compensate recreational fisherman was initially a concern, however, the PDT reduced the potential to a negligible cost impact due to minimal true impact to the fishermen. Therefore, this item was not modeled as a risk.	Very Unlikely	Negligible	LOW	$0			LOW		Triangular			
GE-9	Public Opposition	Public may attempt to stop the start of construction	The PDT considered that public opposition to the project is highly unlikely, and therefore, this item was not modeled as a risk.	Very Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1	Triangular	RL-04, RL-06		
GE-10	Potential Earthquake	Puerto Rico lies in a zone of active seismicity. Area of CMP is considered a concern for liquefaction of the soils should a powerful event occur. June 2014 update: discussed that if a major catastrophic earthquake occurs, the entire project would likely be changed and the landscape would be changed. Agreed to consider a moderate earthquake that would impact the project, but non-catastrophic	The PDT determined that an earthquake would likely be catastrophic and fundamentally change the project. Therefore, this risk was not modeled.	Unlikely	Crisis	HIGH	$0	Unlikely	Critical	HIGH	6	Triangular			
LANDS AND DAMAGES RISKS															
LD-01	Mitigation Cost	Incomplete design and analysis of Mitigation	The PDT determined that the mitigation cost is not expected to vary from what is included in the estimate. Therefore, this risk was not modeled. Also, Lands and Damages contingency is separate from this evaluation and included in the Total Project Cost Summary (TPCS)	Very Unlikely		LOW	$0			LOW					
LD-02	Public Domain footprint	More detailed surveys may indicate a smaller footprint for which the project can be implemented. UPDATE: The project footprint is not subject to change. Limits have been set, and surveys have confirmed the limits.	Footprint not subject to change. Lands and Damages contingency is separate from this evaluation and included in the Total Project Cost Summary (TPCS).	Very Unlikely		LOW	$0			LOW					

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
LD-03	Vibration Impacts	Heavily populated area with structures on fill dirt adjacent to the project area	Previous construction efforts on the island have resulted in structural damage to adjacent residences and structures as a result of vibrations from construction equipment, thus causing liquefication of underlying soils; (Carlos Muniz): some projects have impact on structures: 1) Cantera project in 2010 impacted structures from constr vibration for compaction of the roadbed. Concern that future construction could similarly impact adjacent structures. Will be 90' separation between sheet pile and existing structures. Most adjacent structures do not have proper foundations. Some structures will be removed in the ROW for the Paseo construction, some prior to the channel construction. All relocations and structures are included in the estimated related to the project footprint. Note: Lands and Damages contingency is separate from this evaluation and included in the Total Project Cost Summary (TPCS)	Very Likely	Significant	HIGH	$0			LOW		Triangular			
RELOCATIONS															
RL-01	Cost Variances	Major Public Utility Relocations	6-14 update: currently the only utility costs for major public utilities are the demolition of the Boriquen Water Line and Rexach Trunk Sewer (Risk RL-04a), so this risk no longer applies)	Very Unlikely	Negligible	LOW	$0			LOW					
RL-02	Condemnation	Necessity for Condemnation to acquire property	Condemnation may result in delays and additional administrative cost. Condemnation is planned on 55 of 371 structures; have not had to condemn unless cannot locate the owner (limited). Proportion is consistent with experience. The 55 condemnations are included in the project cost and schedule, and there is negligible risk of additional condemnations that could impact the project. December 2015 update: Condemnation may result in delays and additional administrative cost. Condemnation is planned on 97 of 393 structures; have not had to condemn unless cannot locate the owner (limited). Proportion is consistent with experience. The 97 condemnations are included in the project cost and schedule, and there is negligible risk of additional condemnations that could impact the project	Very Unlikely		LOW	$0			LOW					
RL-03	Unknown Utilities	Impacts to cost and schedule from unknown and unmapped utilities	June 2014 update: The only major utilities on the project are modeled in risk RL-04a. There are no additional impacts anticipated from utilities, as the other utilities are no longer included in the project.	Very Unlikely		LOW	$0			LOW					
RL-04	Reduced project footprint	Relocations as part of the Federal project may be diminished	If the public lands available for the project are recuced, then less relocations will be an element of the cost estimate; UPDATE: footprint and relocation will remain as estimated.	Very Unlikely	Marginal	LOW	$0			LOW					

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
RL-04a	Borinquen Water Line & Rexach Trunk Sewer	Timing of Major Public Utility Relocations	Work requires coordination with installation of CMP sheet pile walls. Delays could impact project schedule or require design modifications for future installation. UPDATE: 11-2015: Relocations are designed and coordinated with CMP plan. Previous relocations have come under budget, so high end riks is considered at 5% above budget	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2	Uniform			
RL-05	Air Quality	H2S concentrations have been identified as a concern (lethal concentrations), but the detailed analysis was perceived as "non-realistic" because it considered that the H2S would be realeased at the same time.	Preliminary control measures are recommended in the FR. Once construction begins, monitoring is highly recommended. If monitoring conditions exceed standards then evacuation could occur. There have been no documented events of H2S evacuations in open atmosphere by the USACE. Consider that H2S will be a nuisance, and will not be to evacuation standards. The "nuisance" may require temporary relocations. Mitigation measures have been included in the cost estimate that reduce the chance of this occurrence. Sound barriers also help mitigate this issue, and these are being considered for the project. Sept 13 Update: with the ocean disposal the area of impact has expanded. Thought is that the H2S will not be dissipated by the time the material is on the barge (barge area has large potential residential impact). Increase likelihood by 10% and potential impact by 20% to account for this.	Very Likely	Significant	HIGH	$0			LOW		Triangular			
RL-06	Relocation of residents	Relocation of families may take longer than anticipated schedule and could delay the start of construction	There is a potential that the relocation of residents could delay the start of the project. This is only a schedule impact risk.	Unlikely	Negligible	LOW	$0	Unlikely	Significant	MODERATE	4	Uniform			

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
RL-07	Additional Relocations from Induced Flooding	Additional Relocations could occur as a result of induced flooidng related to construction of the channel.	Tidal amplitude within the CMP and San José Lagoon would increase as a result of construction of the channel. The lagoon's tide range is expected to increase 1.28 feet after construction, which would equate to a 0.64-foot increase in average monthly water levels. The water surface rise may affect extremely low-lying structures around San José Lagoon and Los Corozos Lagoon. Preliminary analysis indicates that there are four areas adjacent to San José Lagoon and Los Corozos Lagoon where approximately 18 urban structures may be affected from the restoration of tidal activity upon completion of the CMP-ERP. In addition, storm sewers from the airport, at the north of the Suarez Canal, outfall into the SJL. The airport has been present for decades and presumably operating prior to the filling of the CMP. The airport is higher than its outfalls and thus may be able to build up a hydraulic head in its conduit to offset these monthly events. Nevertheless, a storm water management investigation will be conducted to determine any potential impact to the effectiveness of the airport's existing storm water sewers with the completion of the CMP-ERP.	Likely	Significant	HIGH		Unlikely	Marginal	LOW	0	Triangular			
CANALS AND DETENTION PONDS															
CH-01	Historic Finds	As Excavation work progresses archeological finds may be uncovered delaying progress or causing need for redesign	Should historic finds be discovered, the likely impact would be an extended duration on the project. This duration extension is combined with the HTRW item (CH-02) with a 3 month high for a project delay. Should any of the delay be considered reimbursable under the contract, this cost increase is included in PM-06, Change Management. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as Historic Finds.	Unlikely	Marginal	LOW	$0			LOW					
CH-02	HTRW (Hazardous Material)	The spoils may contain some degree of HTRW that would need to be contained and disposed of	Based on testing performed, the PDT determined there is a low likelihood of hazardous materials being encountered on site. Should there be, the estimate is a maximum cost in the range of $500K would be required for the cleanup, and with likely extended time as well. The time was modeled with a maximum of 3 months. The risk for potential cost increase is included in PM-06, Change Management. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as Hazardous Materials	Unlikely	Significant	MODERATE	$0	Unlikely	Critical	HIGH	2	Triangular			

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
CH-03	Contaminated Material	Spoils may included contaminated material that needs to be contained, including a sand cap to help prevent leaching of any contaminants.	The PDT considered that the risk of costs increasing for additional containment of contaminated material is very low. Considering this, any impact from this risk is included in PM-06, Change Management. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as containment of Contaminated Materials.	Very Unlikely	Negligible	LOW	$0			LOW					
CH-04	Debris Removal and Sorting	Excavated material, in addition to Cultural Finds are expected to contain household debris from adjacent areas	This risk is included in CH-22, which considers the potential additional handling of dredged material for items including household debris	Likely	Marginal	LOW	$0			LOW					
CH-05	Heavily Urbanized Area		Discussed through other items related to potential temporary relocations			LOW	$0			LOW					
CH-06	Work Hours / Site Access	Given proximity to residential properties, restrictions on work hours and activities may be required.	Strict noise regulations, particularly at night. Daylight operations only. Recent local study shows amended noise requirements for 60 db in residential areas in daylight (50 db at night). Sept 13 update: The pumps will run for 12 hours, 2 hours to clean sediment from lines. This is in compliance with the ordinance for 12 hours per day of construction.	Very Unlikely	Marginal	LOW	$0			LOW					
CH-07	Soil Conditions	Soil conditions and site conditions may vary from expectations and plans, requiring additional surveys and analysis and potentially higher construction costs.	Numerous existing boring data were used in feasibility, however, additional boring data and other geotech analyses during PED may not confirm existing data and inputs for the feasibility phase. Recent borings in area show limestone at 20' depth in some areas. The PDT considers impact from this risk very unlikely to occur.	Very Unlikely	Marginal	LOW	$0			LOW					
CH-08	Access Routes	Work will progress linearly down the channel	Work is expected to begin nearest the San Jose Lagoon and move to Open Water. Recreational fisherman will not be allowed in channel during construction. May be small delays to clear residential fisherman when beginning to work (considered minor resovled in less than a day).	Very Unlikely	Marginal	LOW	$0			LOW					
CH-09	Construction Sequencing	Impact that a delay in the start of one element of the overall project could impact other elements.	Based on the Dredge Material Management Plan (DMMP), several phases of work will be undertaken with each reliant upon the other for sequencing. The DMMP assumed a 16 hour work day. Sept 13 update: the current schedule is based on a 12 hour work day. Other risks related to dredging (risks CH-12,14a,15,16) have already covered the impact of the potential schedule delay.	Very Unlikely	Negligible	LOW	$0			LOW					
CH-10	Sediment Containment	Additional sediment containment may be required for turbidity	Installation of turbidity curtains is contained in the estimate, both at the excavation site and disposal site. Installation of turbidity curtain is in estimate at excavation site. Estimate also included sheet pile wall and turbidity curtain at San Jose Lagoon disposal site. Any risk impact from the sediment containment is considered very unlikely	Very Unlikely	Negligible	LOW	$0			LOW					

Caño Martín Peña Ecosystem Restoration Project

Risk Level

Likelihood of Occurrence					
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
	Negligible	Marginal	Significant	Critical	Crisis

Impact or Consequence of Occurrence

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
CH-11	Sediment Contamination	Sediment and trash may contain unexpected and/or extreme levels of contaminants	A bioassay will be completed during PED, the results of which could significantly impact mitigation efforts to deal with the issue, or restrict/prevent placement in the San Jose Lagoon pits. June 2014 update; indications are that contaminants are at a low level, and this risk was not modeled.	Very Likely	Negligible	LOW	$0			LOW					
CH-12	Human remains	The CMP is purported to have been a place for the disposal of human remains	There is a likelihood that human remains could be encountered during the dredging operations. Whether the remains are of cultural significance or needing to be processed as part of police investigations is unclear. Time frame for investigations are considered to be in days (not months). A high end delay of 1 month was modeled for this risk. Any cost impact is considered included in PM-06; Construction Change Orders. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as encountering human remains.	Very Likely	Marginal	MODERATE	$0		Marginal	MODERATE	0.5	Triangular	RC-02		
CH-13	Equipment Access	Difficulty of access of dredging and other equipment for construction to the CMP	There could be difficulty of access. Some of these costs are included in the estimate. The impact is considered on the mobilization costs of approximately $3 million, and a high end impact of $750K is included in the model.	Very Likely	Marginal	MODERATE	$0	Very Likely		LOW		Triangular			
CH-14	Work under existing bridges	Difficulty of access and work under 3 existing bridges on the West end of the project	Could impact the cost of construction in this area of the project. Approximately 500' of construction. Likely 50% to 70% more difficult to work in this area than in the remainder of the project.	Very Likely	Significant	HIGH	$0			LOW		Triangular			
CH-14a	Potential damage to existing bridges	There is a low probability chance that one of the existing bridges could be damaged when the operations are occuring in close proximity to the bridges.	Low probabilty of damage. The cost of repair could be high if this does occur, and the higher end was modeled.	Unlikely	Significant	MODERATE	$0	Unlikely	Significant	MODERATE	1.5	Triangular			

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
CH-14b	Additional Geotechnical information at Existing Bridges	The impact of additional cost related to unknown geotechnical information at existing bridges is considered by the PDT to be a very unlikely probability and negligible potential cost impact.	A determination is needed related to the depths of the piles supporting the Ponce de Leon and Luis Munoz Rivera Avenue bridge foundations. It is also recommended that a detailed structural conditions analysis be conducted for these two bridges and the existing Linear Park pedestrian bridge. Since as-built plans of the bridges were unavailable, the feasibility study was conducted without accurate information of the bridge pile cap elevations. Dredging under the bridges may not exceed the original construction depths. Otherwise, the bridge structures would become exposed and possibly require fortification. The additional studies would determine as-built pile cap elevations by performing non-destructive excavations (test pits and borings) to expose the bridge pile caps. Should it be determined that the preliminary plan for the channel under the bridges would expose bridge foundations, the proposed channel would be reconfigured around these structures and scour protection provided for their protection. It is anticipated that reconfiguration may widen the channel and adjust the channel invert in a manner that would maintain the cross sectional area required for the weir to function.	Very Unlikely	Negligible	LOW	$0	Very Unlikely	Negligible	LOW	0	Triangular			
CH-15	Issues with Sediment Pumping	While pumping sediment issues could occur that would include the possible breakdown of the pumps or lines: November 2014 update - this risk is no longer valid as San Jose Lagoon pits are the disposal option moving forward	Pumping from the dredge area to the W end of project (2 mile length of project) and then barging the material an additional 3.2 miles to end of harbor and then 1.6 miles to disposal site. Schedule has 2 hours per day of time for maintenance of line. With the potential makeup of the material, it is anticipated there will be clogging and other issues with the pumps and pipe. Critical element is the screening at the dredge site prior to pumping, which makes the impact marginal. This risk is no longer valid as SJL pits are the disposal option moving forward.	Very Unlikely	Negligible	LOW	$0	Very Unlikely	Negligible	LOW		Triangular			
CH-16	Issues with Sediment Screening	Sediment screening could be slowed down by items that are not easily separated by the screening process.	The PDT discussed that the screening operation has some "trial and error" flexibility to resolve issues and expected to have only marginal impact to the schedule. This was modeled as having a potential 1-1/2 month delay impact to the schedule.	Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1	Triangular			
CH-17	Coordination with PRPA	Coordination of maintenance dredging of the Western end of the CMP canal and the scheduling of this portion with Ferrys and Barges	Need to coordinate with the PR Ports Authority related to maintenance dredging for a portion of the W portion of the CMP channel that could restrict barge traffic and the use of the waterways under the PRPA. The maintenance dredging item is being investigated for potential impact. Item being followed up with PRPA for dredge maintenance and the Maritime Transport Authority channel coordination. After further discussion determined that this is negligible since it is outside of the project limits and would not impact barges ability to navigate the channel.	Very Unlikely	Negligible	LOW	$0			0					

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
CH-18	Operations interruption with AquaExpresso	There is some concern that the AquaExpresso boats for the new "Downtown" are could conflict with and delay the barge traffic.	ENLACE will meet with ATM to work an agreement to decrease/limit transit on that area of the CMP. There is also discussion that much of the barge traffic can be move to night time movements that would minimize this potential conflict. Used a 30% chance of occurrence, with a most likely impact to the project schedule of 1 month.	Unlikely	Marginal	LOW	$0	Unlikely	Marginal	LOW	1	Triangular			
CH-19	Weather and coordination impact to Barging of Disposal Material	Recent history has demonstrated that weather can delay barge traffic	Will now be using shallow draft barges since operating only in the San Jose Lagoon. Therefore, the risk of weather and coordination impact in less than ocean disposal. The dredging duration is ~ 19 months of the project.	Unlikely	Marginal	LOW	$0	Unlikely	Negligible	LOW		Triangular			
CH-20	Trucking	10% of the total volume of dredged material is estimated to be debris slated for sorting, collection and hauling to a landfill. Sand will also be brought in by truck for the encapsulation of material.	The PDT determined that there are good artery roads to truck spoils away that are considered adequate. May have to improve some interior roads to accommodate the trucking. This risk is considered minimal and is covered in the estimate.	Very Unlikely	Marginal	LOW	$0			LOW					
CH-21	Limestone in dredging	Risk associated with having to work though limestone on eastern end of the CMP for sheet pile and channel dredging. Assumption is additional installation costs for approximately 800 lf of king pile supported wall in lieu of cantilevered wall.	The risk of encountering limestone during the dredging operation has been noted for the eastern end of the CMP, where a king pile wall installation may be required in lieu of the cantilevered wall. This risk is considered low, and any potential cost impact is included in PM-06; Construction Change Orders. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as encountering limestone during the dredging operation.	Likely	Marginal	LOW	$0	Likely	Significant	HIGH	3	Triangular			
CH-22	Disposal Material Quantity Variation	Risk associated with the potential for additional amounts of the dredging material having to be handled and disposed of separately due to trash content	Estimate assumes approximately 10% of the dredged quantity will include trash that has to be handled and disposed of separately. High end of risk includes 76,200 CY additional in channels; 4,687 CY additional under bridges; and 13,500 CY additional with the earthwork. Used estimate rate of $37.15 for handling and disposing of this material.	Very Likely	Critical	HIGH	$0	Likely	Significant	HIGH	3	Uniform			
CH-23	Alternate Disposal Options	Concern is that the SJL pits may not be available; the spoils may have to be taken to upland disposal sites	Concern is that the SJL pits may not be available; the spoils may have to be taken to upland disposal sites. Lack of pits availability could be due to uncontainable contamination levels or public opposition. Risk of going to upland sites is also the cost of containing the contaminated material.	Unlikely	Critical	MODERATE	$0	Unlikely	Critical	MODERATE					
OPPORTUNITIES															
CH-24	Source of Sand	Contractor may be able to find a less costly source of capping material	The PDT determined that the potential opportunity for higher cost sand material for capping is very unlikely, and therefore, this risk was not modeled. Sand could be also gathered from adjacent carea in the San Jose Lagoon, or from dredging of San Jose Pits 1 and 2.	Very Unlikely	Negligible	LOW	$0					Triangular			
RECREATION															

Caño Martín Peña Ecosystem Restoration Project

Risk Level

Likelihood of Occurrence					
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
	Negligible	Marginal	Significant	Critical	Crisis

Impact or Consequence of Occurrence

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Project Cost: Rough Order Impact ($)	Project Schedule: Likelihood*	Project Schedule: Impact*	Project Schedule: Risk Level*	Project Schedule: Rough Order Impact (mo)	Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
RC-02	Variations in Design Concepts	Variations in Rec Feature sizing	The estimate was based on a smaller Recreation feature design and scaled up to approximate the requirements of the local sponsor in the MCACES. Size of features are set by the Comprehensive Devt Plan. May require additional wetlands in a mitigation plan, but this was considered very unlikely by the PDT.	Very Unlikely	Marginal	LOW	$0			LOW					
RC-03	Squatters	The area is currently largely occupied by residents with no titles because of the high cost fo land and the convenient location in San Juan. Once the relocations are completed, how can it be assured that the area will not be reoccupied during construction or following completion of construction?	The estimate was based on reoccupation by squatters not being a problem during construction or following completion of construction. UPDATE: completed features will mitigate this issue (returning squatters).	Very Unlikely	Marginal	LOW	$0			LOW					
CULTURAL PRESERVATION															
CP-01	Site Access	Site access limitations	Limited site access limitations; access will be limited to walkers along the cano. Ensuring existing residents are informed of all construction to not have site access being a concern.	Very Unlikely	Marginal	LOW	$0			LOW					
CP-02	Encounter cultural conditions	Encountering cultural conditions during construction that delay construction	There is the potential to encounter items during the dredging/construction that would be have to be addressed and could delay construction. This will likely be more of a documenting situation with the dredged material. Any cost impact not related to schedule is considered to be covered in the risk PM-06, Change Orders during construction. PM-06 includes increased costs for changes on the project of 3% at the low end, 6% most likely, and 15% at the high end to account for the risk of changes such as encountering cultural conditions during the dredging operation.	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2	Triangular			
CP-03	Variations in Design Concepts	Variations in Rec Feature sizing	The estimate was based on a smaller Recreation feature design and scaled up to approximate the requirements of the local sponsor in the MCACES. Size of features are set by the Comprehensive Devt Plan. May require additional wetlands in a mitigation plan if recreation areas increase. UPDATE: These costs have been included in the esitmate for mitigation and additional increases are very unlikely	Very Unlikely	Marginal	LOW	$0			LOW		Triangular			
ESTIMATING ASSUMPTIONS															
EA-1	Dredging Quantities	Actual dredging quantities may vary from estimate, Actual side slopes may not be as stable as estimated and additional quantities may be required.	PDT does not see much reason for the dredging to vary. It is considered a simple template, and the dredging operation will initially dredge, place excess material on the bank, install the sheet pile, and then backfill with the material. This process will minimize any quantity variance. A plus 5% or minus 2.5% quanitity variance is included	Very Likely	Marginal	MODERATE	$0	Very Unlikely	Marginal	LOW					

Caño Martín Peña Ecosystem Restoration Project

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

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
EA-2	Sheet Pile Wall Quantities	Actual sheet pile wall quantities could increase based on the required driving depth. Some concern that the design for a cantilevered wall may not be effective.	PDT noted that the Sheet Pile Wall design was based on substantial core boring information that provided reliable geotech information. Therefore, the length and strength of the sheet pile walls are considered to only have minor variance. A plus 10% or minus 5% quantity variance is included.	Very Likely	Marginal	MODERATE	$0	Very Unlikely	Marginal	LOW					
EA-3	Articulated Concrete Block Material Quantities	Potential quantity variation witth ACBM material.	PDT considered that the ACBM Quantities will not vary much. However, there is a risk that ACBM base material may have to be replaced if existing material is found to be unsuitable. The risk is related to over 2 acres of area with a maximum of 2' depth	Very Likely	Marginal	MODERATE	$0	Likely	Marginal	MODERATE					
EA-4	Dredging Production Rates and Crews	Possibility that the estimated dredging production rate may not be able to achieved.	PDT considered there is an equal chance that the dredging prodcutivity could be increase as it could decrease. The 200 CY per hour production estimated was considered to vary plus or minus 20% depending on conditions. To be conservative, only the potential higher end of the productivity range was modeled.	Very Likely	Marginal	MODERATE	$0	Unlikely	Marginal	LOW					
EA-5	Sheet Pile Walls Production Rates and Crews	Possibility that the estimated sheet pile wall installation production rate may not be able to achieved.	PDT considered that the sheet pile wall productivity could be lower than the 60 lf per hour estimated. This variance was considered to be 10%.	Very Likely	Marginal	MODERATE	$0	Unlikely	Marginal	LOW					
EA-6	Scope Changes	Possibility that scope changes will occur during the final design of the project.	The PDT considered that scope changes during the design stage are covered in the other risks identified. However, an additional risk of 2% has been included for unknown scope changes that could occur during the design completion.	Very Unlikely	Marginal	LOW	$1,251,569	Unlikely	Marginal	LOW					
PROJECT & PROGRAM MGMT															
PM-03	Rights of Entry	ROE may be held up or delayed due to unknown circumstances and situations.	Item not likely to occur	Very Unlikely	Marginal	LOW	$0			LOW					
PM-05	Program Management Resources	Program Management and Construction Management Resources may be limited	Risk very unlikely to occur	Very Unlikely	Marginal	LOW	$0			LOW					
PM-06	Change Management	Change Orders during Construction	The Change Management Risk has been modeled with a 100% probability that construction changes will impact the costs, with a 5% low end, a 10% most likely and a 15% high end. These change amounts are very conservative, considering the amount of information available for the project, and the amount of detail in the cost estimate. However, considering the high end going to a potential 15% increase appears to be a high end level, considering that this risk is included to cover multiple smaller potential construction risks on the project, primarily related to what is uncovered in the dredging operations.	Very Likely	Critical	HIGH	$12,500,000			LOW		Triangular			
PM-07	Project Closeout	Contract Closeout, Government Inspection, and Project Turnover may experience interruptions or delays creating the need for additional repairs.	Delay could likely occur during the project closeout that should have minimal impact on the project costs. This is modeled in the schedule delay. Any potential moderate cost increase is included in PM-06, change orders during construction.	Likely	Marginal	MODERATE	$0	Likely	Significant	HIGH	2	Triangular			
PM-07a	Wetlands Impact	Project location may impact wetlands areas requiring additional mitigation efforts and costs	Included in RC-03: Variations in Design Concepts			0	$0			0					

Caño Martín Peña Ecosystem Restoration Project

Risk Level

Likelihood of Occurrence					
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
	Negligible	Marginal	Significant	Critical	Crisis

Impact or Consequence of Occurrence

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)															
PR-1						0				0					
PR-2						0				0					
PR-3						0				0					
PR-4						0				0					
PR-5						0				0					
PR-6						0				0					
PR-7						0				0					

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact **Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.
6. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular or normal distribution. A risk item for which the PDT has little data or probability of modeling with respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.
7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

Appendix D

Project Schedule

The following schedules outline the remaining planning, PED, and construction tasks required to implement the National Ecosystem Restoration and Recommended Plan, and the CMP-ERP Construction Schedule, respectively.

Milestone	Schedule
Request PED Funding	January 2016
Final Report Approval (end of feasibility)	April 2016
Request Construction Funding	May 2016
Execute Cost Sharing Agreement for PED	October 2016
Begin Preconstruction Engineering and Design	October 2016
Execute Project Partnership Agreement (PPA)	April 2017
Start baseline monitoring	October 2017
Complete Design Documentation Report	April 2018
Complete Plans and Specifications	April 2018
Advertise Construction	May 2018
Award the contract	June 2018
Complete Real Estate Acquisition	August 2018
Start construction	October 2018
Complete Construction	December 2020
Turn Over Project to Local Sponsor	2020
Initiate Monitoring and Adaptive Management	January 2021
Complete Monitoring and Adaptive Management	2026

CMP-ERP Construction Schedule

Dredge/ Disposal Event	Details	Operational Duration (Days)	Operational Start (No. Days From NTP)	Operational Finish (No. Days from NTP)	Calendar Finish Date (Month)
Start Construction		0	0	0	0
Channels and Canals	Mobilization & Site Preparation	150	0	150	5
Channels and Canals	Clearing and Grubbing	213	150	363	13
Channels and Canals	Dredge Excavation and enlarge SJ1 & SJ2 pits	350	163	513	18
Channels and Canals	Dredge, separate solid wastes and haul to Humacao Landfill	520	163	683	23
Channels and Canals	Dredge sediments and place in SJ1 & SJ2 pits	520	163	683	23
Channels and Canals	Upland Excavation and Earthwork	248	193	441	15
Channels and Canals	Install Weir	122	283	405	14
Channels and Canals	Prepare mangrove beds and plant mangroves	90	575	665	23
Recreation	Recreation Structures	720	0	720	24
Bank Stabilization	Sheet Piling	382	283	665	23
Cultural Resource Preservation	Ongoing	810	0	810	27
Complete Construction	Final Inspection, Demob. and Acceptance	90	720	810	27

Appendix E

Adaptive Management Plan

FINAL
ADAPTIVE MANAGEMENT PLAN
CAÑO MARTÍN PEÑA
ECOSYSTEM RESTORATION PROJECT
SAN JUAN, PUERTO RICO

Prepared for:

PROYECTO ENLACE DEL CAÑO MARTÍN PEÑA

Corporación del Proyecto ENLACE del Caño Martín Peña
Apartado Postal 41308
San Juan, Puerto Rico 00940-1308

February 2016

Contents

Figures

Page

Tables

Executive Summary

The Caño Martín Peña Ecosystem Restoration Project (CMP-ERP) is an urban ecosystem restoration project to restore the Caño Martín Peña (CMP) and surrounding areas of the San Juan Bay Estuary (SJBE). Restoration of the CMP would re-establish the tidal connection between the San José Lagoon and the San Juan Bay, which would improve dissolved oxygen levels and reduce salinity stratification, increase biodiversity by restoring fish habitat and benthic conditions, and improve the functional value of mangrove habitat within the estuary.

The CMP is a 3.75-mile-long tidal channel in metropolitan San Juan, Puerto Rico. It is an integral part of the SJBE, the only tropical estuary included in the U.S. Environmental Protection Agency (USEPA) National Estuary Program (NEP). The SJBE's watershed covers 97 square miles. It is heavily urbanized, with a population density of over 5,000 people per square-mile. The SJBE includes over 33 percent of the mangrove forests on the island with over 124 species of fish and 160 species of birds. The eastern half of the CMP, historically between 200 and 400 feet wide and navigable, currently ranges in depth from 3.94 feet to 0 foot towards San José Lagoon. Due to years of encroachment and fill of the mangrove swamps along the CMP, the channel no longer serves as a functional connection between San Juan Bay and San José Lagoon. Sedimentation rates within the CMP are nearly two orders of magnitude higher than in other parts of the SJBE. Open waters in areas closer to the San José Lagoon have been lost, as the area has started transitioning into a wetland. A combination of sediment and solid waste is found in the CMP, of which the solid waste accounts for approximately 10 percent of its composition. In some sites, the solid waste extends to depths 10 feet below the sediment surface.

The conditions within the eastern side of CMP (the immediate Project Area), have led to degradation within the entire estuary. Connectivity of the ecosystem has been severed and the biodiversity within the lagoons has been compromised, as more individuals of a reduced number of species are found when compared with other lagoons throughout the SJBE. The decreases in biodiversity in turn have reduced the ability of fish and invertebrates to respond to natural changes, disease and other factors, resulting in a depletion of fish stock, biodiversity, and losses of economic and recreational resources.

The current condition of the CMP has resulted in the degradation of the environmental condition within areas of SJBE around the CMP. Water residence time in the San José Lagoon is approximately 17 days. The lack of tidal flushing causes strong salinity stratification and in turn leads to low oxygen or no oxygen levels in the 702 acres of lagoons with depth below 4 to 6 feet, severely affecting benthic habitats. Mangrove habitat, extremely important for native aquatic invertebrates, has been severely impacted, reducing habitat where important commercial fish species spend their juvenile life stages.

A conceptual ecological model was developed for the Caño Martín Peña. This model was used to develop hypotheses about relationships within the system and to assist in understanding changes brought about by planned project elements. The planning objectives for the Caño Martín Peña Feasibility Study include:

1. Improve fish habitat in the SJBE system by increasing connectivity and tidal access to estuarine areas;
2. Restore benthic habitat in San José Lagoon by increasing dissolved oxygen in bottom waters and improving the salinity regime to levels that support native estuarine benthic species; and
3. Increase the distribution and population density and diversity of native fish and aquatic invertebrates in the mangrove community by improving hydrologic conditions in the SJBE system.

After many considerations, it was determined that dredging the CMP could provide a way of reconnecting eastern and western segments of the SJBE system, as they were several decades ago. The plan formulation process built directly upon previous planning and design efforts. Structural management measures for the channel dredging, erosion control, dredged material disposal, mangrove planting and construction, recreation, as well as non-structural measures were identified and screened. An initial array of alternatives consisting of rectangular channel cross sections ranging between 75 to 200 feet widths and either 10 or 15 feet depths was developed and evaluated. Screening criteria such as completeness, acceptability, cost effectiveness, and secondary effects on adjacent communities, were then used to eliminate unfavorable plans and develop a final array of alternatives. The final array of alternatives consisted of four alternative plans ranging from no action to a 125 foot-wide by 10-foot-deep natural bottom channel. All constructed alternatives include an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour.

Performance measures for Benthic Habitat, Fish Habitat, and Mangrove Habitat were developed to measure alternative output, and ecosystem restoration measure benefits were calculated for each alternative. A cost effectiveness and incremental cost analysis (CE/ICA) was conducted based on a project life of 50 years and a Federal Discount Rate of 3.5 percent and a base year of 2019. Each alternative was considered to be independent and not combinable with the other alternative. Due to weir restrictions to prevent erosion at bridges and other structures for all three action alternatives, average annual habitat units (AAHUs) would be nearly identical among alternatives, totaling 6,133 AAHUs per alternative. As a result, Alternative 2, with a slightly less average annual equivalent cost when compared to Alternatives 1 and 3, was determined to be cost effective and the best buy.

Alternative 2, the National Ecosystem Restoration (NER) and recommended plan consists of a 100-foot-wide by 10-foot-deep natural bottom channel; the elongated weir described above; dredging approximately 762,000 cy of mixed materials along 2.2 miles of the eastern CMP; and construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands; and restoration of 25.57 acres of open water and 34.48 acres of wetland. This represents a net increase of approximately 18.17 acres of open water and 1.02 acres of mangroves.

The NER and recommended plan provides a complete solution to the problems identified for the study. It is also the most effective plan and meets the project objectives. The NER and recommended plan is acceptable and has been determined to be in the national and public interest and can be constructed while protecting the human environment from unacceptable impacts.

The CMP-ERP is a project that has a low uncertainty and high confidence that, once the project is constructed, the anticipated benefits will be observable and measureable, as demonstrated by the dredging of the western half of the CMP. In addition, other similar projects involving tidal and water flow restoration have resulted in improved water quality. Furthermore, several modeling efforts, specific to restoring tidal connectivity along the SJBE, have predicted improvements in water quality with concomitant benefits to habitats and fish and wildlife resources.

This Adaptive Management Plan (AMP) addresses the planning objectives, described above, that are directly related to water quality and ecosystem benefits obtained from tidal flow connectivity improvements across the SJBE, and mainly, between the San Juan Bay and San José Lagoon through the CMP.

This AMP includes those actions and measures that would be carried out:

- During project planning: Provide new knowledge to better define anticipated ecological responses.
- Before project implementation: Tidal flow, water quality, benthic and mangrove roots community characterization studies, fish censuses (including indicator species of ecosystem wellness) to be performed (or reviewed if they exist) at established stations to provide baseline information.
- During project construction: Monitoring and assessment of tidal/flow, water quality, benthic and mangrove roots community. Management measures would be implemented to avoid or reduce temporary impacts.
- After its implementation: Monitoring and assessment of tidal flow, water quality, benthic and mangrove roots communities, fish (including indicator species of ecosystem wellness). Management measures would be implemented, or existing ones would be adapted (adaptive management), to achieve goals and objectives. Adaptive management measures currently proposed and that would be implemented, if needed, would include planting mangrove trees along the new channel to promote wetland habitat restoration. In addition, conduct maintenance dredging at both of its ends to address any sedimentation and its effects on water flow.

These adaptive management activities would be refined during future phases of CMP-ERP, and the AMP would be updated accordingly. At such time, more baseline data and lessons learned would be available from the project itself as well as from other monitoring programs and restoration projects.

Given the new knowledge and data regarding Project's benefits, the adaptive management strategies and options proposed in this AMP may need enhancement.

This AMP addresses the requirements of the United States Army Corps of Engineers (USACE) Implementation Guidance for Section 2039—Monitoring Ecosystem Restoration, Memorandum (CECW-PB) dated 31 August 2009 (Guidance for Section 2039 of Water Resources Development Act 07) (USACE, 2009).

Acronyms and Abbreviations

AAHU	Average Annual Habitat Units
ACM	Articulated Concrete Mat
AMP	Adaptive Management Plan
BI	Benthic Index
BMPs	Best Management Practices
CCMP	Comprehensive Conservation & Management Plan for the San Juan Bay Estuary
CDRC	Ciudad Deportiva Roberto Clemente
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CEM	Conceptual Ecological Model
CH3D-WES	Curvilinear Hydrodynamics in 3-Dimensions-Waterways Experiment Station model
CMP	Caño Martín Peña
CMP-ERP	Caño Martín Peña Ecosystem Restoration Project
cy	cubic yard
DO	dissolved oxygen
EC	Engineering Circular
ECO-PCX	USACE Ecosystem Restoration Planning Center of Expertise
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENLACE	Corporación del Proyecto ENLACE del Caño Martín Peña
ENLACE Project	Caño Martín Peña ENLACE Project
ER	Engineering Regulation
ERDC	USACE Engineer Research and Development Center
ERP	Ecosystem Restoration Project
FR	Feasibility Report
FRM	Flood Risk Management
ft^2	square feet
ft/s	feet per second
ft/y	feet per year
g	grams
H&H	Hydrodynamic and Hydrologic
HU	Habitat Unit
GIS	Geographic Information System
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
mi^2	square mile
mL	milliliter
MLLW	mean low low water
mm/yr	millimeters per year
mph	miles per hour
MTZ-CMP	Public Domain lands within the Caño Martín Peña Maritime Terrestrial Zone
NED	National Economic Development Account
NEP	USEPA's National Estuary Program
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and Maintenance
ODMDS	San Juan Bay Ocean Dredged Material Disposal Site
P&G	United States Water Resources Council Principles and Guidelines
PED	Planning, Engineering and Design
PMP	Project Management Plan
PPA	Project Partnership Agreement
ppm	parts per million
PR	Commonwealth of Puerto Rico
PREQB	Puerto Rico Environmental Quality Board
PRHTA	Puerto Rico Highway and Transportation Authority
Project Channel	2.2 miles of the Eastern CMP associated with the CMP-ERP
PRWQSR	Puerto Rico Water Quality Standards Regulation
SJBE	San Juan Bay Estuary
SJBEP	San Juan Bay Estuary Program
SJHP	San Juan Bay Harbor
T&E	Threatened and Endangered Species
µg/g	micrograms per gram
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WQC	Water Quality Certification

1.0 INTRODUCTION

1.1 BACKGROUND

The Caño Martín Peña (CMP) is a 3.75-mile-long tidal channel in metropolitan San Juan, Puerto Rico. It is part of the San Juan Bay Estuary (SJBE), the only tropical estuary included in the U.S. Environmental Protection Agency (USEPA) National Estuary Program (NEP). The SJBE and its associated marine ecosystems are considered the “Study Area,” because the proposed CMP-ERP is expected to have direct, indirect, and cumulative beneficial effects on this whole region (Figure 1). The “Project Area,” which mostly lays out the construction footprint, has been defined as the Project Channel, where dredging would take place, and the adjacent delimitation of the public domain lands within the Public Domain lands within the Caño Martín Peña Maritime Terrestrial Zone (MTZ-CMP) where relocations are scheduled to occur. Also included in the Project Area is the 2-acre dredged material staging area adjacent to the Martín Peña bridge (Las Piedritas), 6-acre dredged material staging area within the 35-acre Ciudad Deportiva Roberto Clemente (CDRC) site, the boating routes from the eastern limit of the CMP to the CDRC and the nearby San José Lagoon pits, and the five pits in San José Lagoon (Figure 2).

Figure 1. The San Juan Bay Estuary Study Area

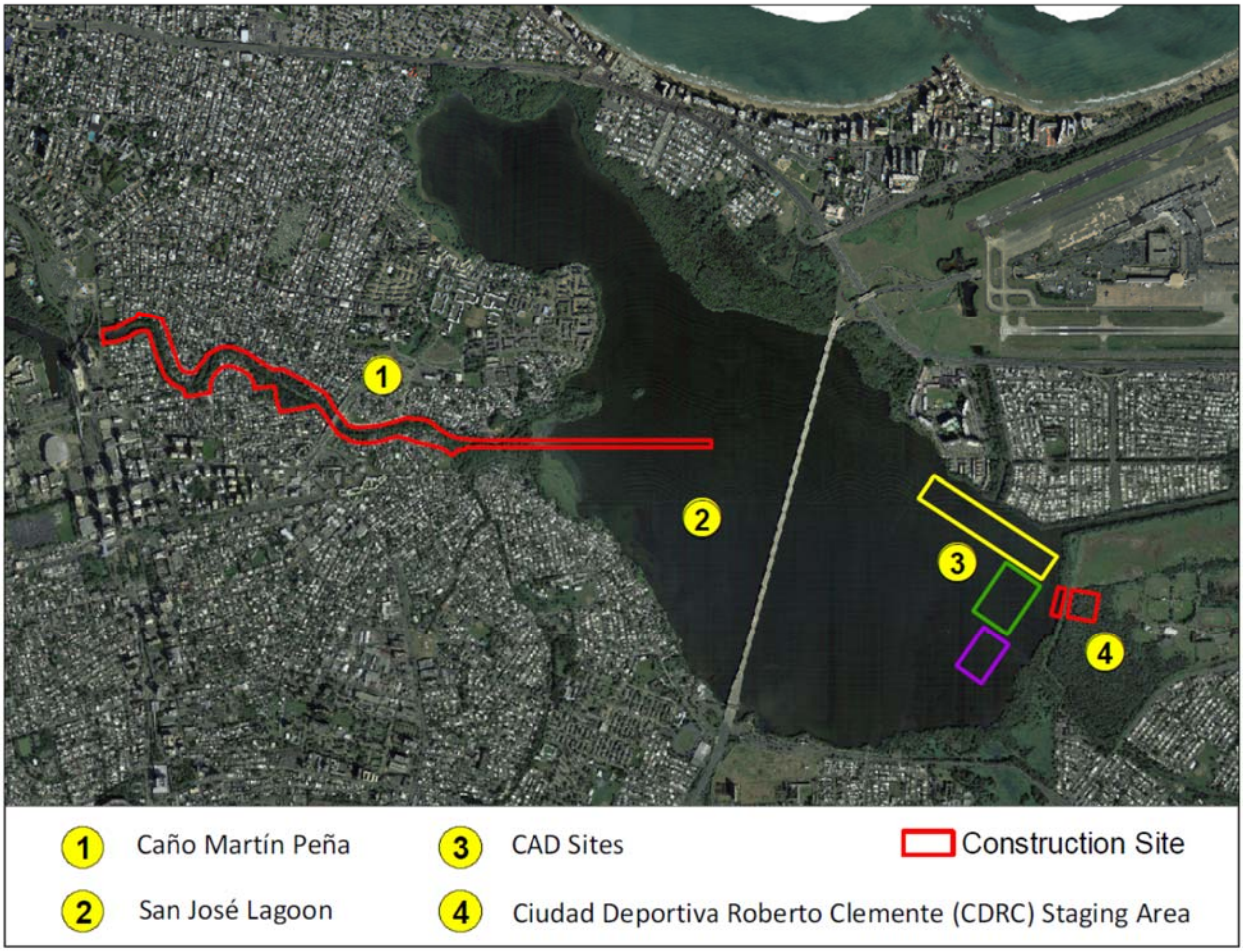


Figure 2. The Caño Martín Peña Ecosystem Restoration Project Area

The SJBE, along the northern coast of Puerto Rico, is the largest system of its kind on the island. Located within the largest urbanized and most densely populated region in Puerto Rico, the SJBE's watershed includes the municipalities of Toa Baja, Cataño, Bayamón, San Juan, Guaynabo, Carolina, Loíza, and Trujillo Alto. The system is characterized by a network of lagoons, channels, man-made canals, permanently and seasonally flooded woody and herbaceous wetlands, and the San Juan Bay, which is home to Puerto Rico's busiest port. In spite of its urbanized setting, the SJBE includes over 33 percent of the mangrove forests on the island with over 124 species of fish and 160 species of birds.

The SJBE and its associated marine ecosystems are considered the "Study Area," since the proposed Caño Martín Peña Ecosystem Restoration Project (CMP-ERP) is expected to have direct, indirect, and cumulative beneficial effects on this whole region (Figure 1). The SJBE includes the San Juan Bay, the Condado Lagoon, the San José Lagoon (including its northwestern section known as Los Corozos Lagoon), La Torrecilla Lagoon, and the Piñones Lagoon, the interconnecting Caño Martín Peña (CMP), San Antonio Channel, and the Suárez Canal, as well as the Piñones mangrove forest and Las

Chucharillas Swamp. Fresh water flows into the system from the creeks and rivers flowing mostly north from its watershed, covering approximately 97 square miles (Figure 1). These include the Río Piedras (Puerto Nuevo) River, Juan Méndez Creek, San Antón Creek, Blasina Creek, and the Malaria Canal. During medium to extreme flood events, fresh water is also received from the Río Grande de Loíza River, located east of the Piñones State Forest. Several flood control pump stations, as well as storm water sewers, discharge fresh water into the system. Ocean water enters the SJBE through three openings or outlets: Boca del Morro at the San Juan Bay, El Boquerón at the Condado Lagoon, and Boca de Cangrejos at La Torrecilla Lagoon. The Puerto Nuevo River, whose drainage area is of about 25 square miles, flows into the western end of the CMP, close to the San Juan Bay. The western half of the CMP was dredged during the 1980s as part of a waterway transportation project. This portion of the CMP is navigable and has a channel width and depth of 200 feet and 10 feet, respectively. The total drainage area of the CMP is about 4 square miles (2,500 acres).

The water quality of the SJBE has been significantly altered from its natural state not only by land-use activities, but also by the modification of its hydraulic properties through the dredging and filling of many of its water bodies. Water quality within both the Caño Martín Peña and San José Lagoon has been previously documented as being degraded [Kennedy et al. 1996, Webb and Gomez-Gomez 1998, San Juan Bay Estuary Program 2000, Puerto Rico Environmental Quality Board (PREQB) 2008] and data suggest that the Caño Martín Peña is a source of turbidity and bacteria to the waters of San José Lagoon; however, the CMP does not appear to be a source of nutrients for the San José Lagoon (Atkins, 2011a).

Impacts to the water quality of the CMP and San José Lagoon include prior on-ongoing inflows from combined storm sewer overflows, inflows from areas lacking sanitary sewers, untreated industrial discharges, surface runoff and subsurface seepage over areas with household waste, and from direct dumping of household waste. While water quality concerns remain within both the CMP and San José Lagoon, there is ample evidence of substantial improvements in water quality within San José Lagoon in recent decades, due mostly to improvements in the collection and treatment of wastewater loads in the San Juan Bay region (Webb and Gomez-Gomez, 1996 and 1998; Webb et al. 1998). In western San José Lagoon, in the part of the Lagoon closest to the CMP, phosphorus concentrations have decreased more than 50 percent since the late 1970s to early 1980s, and water clarity (as measured by Secchi disk depth) has doubled since the early 1980s (Atkins, 2011a).

The recent trends of improved water quality in much of the San Juan Bay Estuary have been achieved only after the investment of substantial time and resources. Since the late 1980s alone, the USEPA has awarded in excess of $650 million to the Commonwealth of Puerto Rico via the Clean Water State Revolving Fund program (Caribbean Business Journal 2012). As a result of these and other coordinated actions, there is an obvious trend of improving water quality in the San José Lagoon, as outlined in the report “Technical Memorandum for Task 2.6 – Water and Sediment Quality Studies” (Atkins, 2010b). Similar findings of improving water quality in the greater San Juan Bay estuary system have been previously reported by Webb and Gomez-Gomez (1996 and 1998) and by Webb et al. (1998). Webb and Gomez-Gomez (1998) concluded that "these records document the improved water quality that has resulted from implementing pollution control measures established in the 1970s."

The ongoing and reduced ecological integrity of the San José Lagoon, despite substantial reductions in pollutant loads, appears to be mostly due to salinity stratification and the development of hypoxic conditions (low levels of dissolved oxygen) in waters deeper than 4 to 6 feet (Atkins, 2011b). Model results lead to the conclusion that restoration of the tidal exchange capacity of the CMP would increase salinity in the surface waters of the San José Lagoon, which would decrease salinity stratification and thus reduce the spatial extent and severity of hypoxic conditions (Atkins, 2011b). Although acceptable levels of dissolved oxygen exist in those portions of the San José Lagoon that are shallower than approximately 4 feet, hypoxic to anoxic conditions are encountered throughout approximately 700 acres of the Lagoon where the water depths are greater than 4 feet. One of the most severe water quality problem in the CMP is levels of dissolved oxygen. Also, Webb and Gomez-Gomez (1998) found ammonia concentrations up to 2.3 milligrams per liter (mg/L) (as nitrogen) and orthophosphate concentrations of 0.22 mg/L (as phosphorus) as well as anoxic conditions within the CMP water column. Also in the Caño Martín Peña, recent studies have documented from 2,000,000 to 6,000,000 fecal coliform bacteria colonies per 100 milliliters (ml) well above guidance criteria of 200 colonies per 100 ml (SJBEP, 2012). Additionally, levels as high as 1,200,000 for Enterococci bacteria colonies per 100 ml, where the guidance criteria of 35 colonies per 100 ml (SJBEP, 2012).

The existing high sedimentation rates, presence of contaminants within the sediments, low dissolved oxygen levels, and salinity stratification within the CMP and/or the San José lagoon do not provide a healthy ecosystem for benthic organisms (e.g., infauna, meiofauna, epifauna) or organisms relying upon the estuarine water column (e.g., fish and invertebrates; Kennedy et al. 1996, Otero, 2002, SJBEP 2000, PREQB 2008). Benthic habitats in and around the Project Channel area are highly degraded due to the contaminant loads and reduced tidal flushing present, which result in limited light penetration, poor water quality, and anoxic, highly organic sediments.

Soft bottoms in these shallow areas, the mangrove roots that line the lagoons, seawalls, rip-rap and other surfaces at these depths are covered with a thriving community dominated by mussels. Rivera (2005) estimated 66.7 acres of this mussel reef within the San José lagoon, which he hypothesized, is a "large source of food for the Lagoon" and provides a water filtering function "which must help maintain the water quality."

Species abundance and diversity (important indicators of healthy habitats) of the encrusting community of red mangrove prop roots is higher in the La Torrecilla Lagoon (closest to the Atlantic Ocean), becomes less diverse and less abundant within the San José Lagoon (farthest from the flushing source), and is non-existent or limited (severely limited flushing) within the CMP. This could be related to dissolved oxygen and salinity concentrations.

This macrofauna follows a general pattern of reduced diversity and abundance along a gradient from La Torrecilla Lagoon to Suárez Canal, to the San José Lagoon to the CMP. In general, sponges, crabs, worms and mussels become less abundant to absent along a gradient from the eastern end of Suárez Canal, along San José Lagoon and into the CMP.

In summary, the results of the benthic habitat survey in the shallow portions of San José Lagoon indicate that diverse and healthy biological communities are restricted to the shallowest (less than four feet water depth) regions, where salinity stratification does not occur, and where sufficient levels of dissolved oxygen exist. These are the conditions that support a healthy benthic habitat, that type that would support sustenance and recreational fishery in the Lagoons; however, at the minimal dissolved oxygen conditions found in the approximately 700 acres of waters deeper than four feet water depth in San José Lagoon, the presence of hydrogen sulfide in the sediments is a strong indicator that the water layer above the sediments is also hydrogen sulfide laden. Therefore, these areas of the bottom of the lagoons cannot sustain a benthic habitat.

Some of the 124 fish species that have been documented in the SJBE system have been locally identified as important target species for both recreational and commercial fisheries. The important target species of common snook (*Centropomus undecimalis*) and tarpon (*Megalops atlanticus*) are caught within San José Lagoon itself (Yoshiura and Lilyestrom 1999). The commercially important offshore fishery for mutton snapper (*L. analis*) is dependent, in part, on the maintenance of a healthy inshore, lower-salinity mangrove habitat for post-larval and juvenile phases (Faunce et al. 2007). Out of the 124 species of fish documented within the SJBE system, fifteen of these are also found within the 84 managed species included in the Caribbean Fishery Management Council's Fisheries Management Program (FMP) (Yoshiura and Lilyestrom 1999).

Due to the current clogging of the eastern CMP, there is essentially no tidal exchange between San Juan Bay and the San José Lagoon. As a result, fish within San Juan Bay cannot directly access the mangroves, seagrass meadows, and open water habitats of San José Lagoon, Los Corozos Lagoon, the Suarez Canal, La Torrecilla Lagoon, and Piñones Lagoon, just as fish within those waterbodies cannot directly access the habitats afforded by San Juan Bay.

There are still some mangrove wetlands, albeit of extremely low functional quality, along the CMP. If the CMP was dredged, much of these wetlands would be within the construction area and impacted by the project. In order to maintain a mangrove fringe of wetlands along the CMP for habitat, nutrient reduction, water quality, and other wetland functions, mangrove wetlands could be re-established in areas along a dredged canal. This measure would provide immediate restoration within the project area, as the existing low quality mangrove areas would be removed along the CMP channel for construction purposes and replaced by high functioning mangrove wetlands. The north and south slopes of the channel above the sheet pile would be graded to receive tidal influence and then planted with appropriate mangrove species. Microtopography would be added to diversify habitat for mangroves, with higher contours being available over time as sea level change occurs.

The CMP-ERP is an urban ecosystem restoration project to restore the CMP and surrounding areas of the SJBE. Restoration of the CMP would re-establish the tidal connection across the SJBE, substantially improving the water quality of the entire SJBE and promoting the establishment of more diverse and healthy fish and wildlife habitats (USACE, 2004). This means helping to reduce water renewal time in the San José Lagoon and its salinity stratification, as well as to improve dissolved oxygen levels, fish and benthic habitat, and thus biodiversity, including the functional value of mangrove habitat within this system (Atkins, 2015).

Several modeling efforts have been conducted to further assess the effectiveness of the proposed project on the hydrology and hydrodynamics of the SJBE, and its possible effects on fish and wildlife resources. In 2000, the USACE's Research and Development Center published the report titled Hydrodynamic and Water Quality Model Study of the San Juan Bay Estuary (SJBE). This study was performed for the SJBE Program (Bunch et al. 2000). The researchers used a three-dimensional, coupled, hydrodynamic and water quality model of the SJBE system that was calibrated using field observations in order to estimate the effectiveness of various alternatives to increase flushing and reduce loadings for improving water quality. Dredging the CMP to 150 feet wide and 9 feet deep, in order to improve water flow along this water body was one of the scenarios modeled, showing improvements in the channel's water conveyance capacity and that of the San José Lagoon.

The CH3D-WES hydrodynamic model was used to quantify the improvement (decrease) in residence time in the San José Lagoon and improved connectivity between this water body and the San Juan Bay as a result of increasing the cross-sectional area and thus, the water flow capacity of the CMP within the Project Area. It was also used to predict ecological improvement for various parameters, such as dissolved oxygen and salinity. The output on residence time was combined with data from a recently developed Benthic Index (BI) for the SJBE (PBS&J, 2009). The relationship between residence time and benthic community health in the San José Lagoon was found to be significant. It was determined, as a result, that restoring tidal flow through the CMP would improve the lagoon's circulation, helping to decrease water stratification and thus, hypoxic to anoxic conditions affecting its waters and associated submerged habitats (Atkins, 2011a; 2011b; 2015; Bunch et al, 2000; PBS&J, 2009).

Preliminary hydrologic modeling for different channel configurations indicated that if the channel dredging measure was implemented, erosion control features would be necessary to protect the CMP channel from scouring, and to protect existing bridges and shoreline stabilization structures in the western CMP such as sheet piles. Three erosion control features were formulated, evaluated, and retained for these purposes. These erosion control features are all dependent on dredging of the existing CMP channel. First, articulated concrete mats (ACMs) would be required to provide scour protection for any high velocity dredged channel configurations. The soils in the CMP Project Channel are predominantly hard silts and clays at a depth of 10 to 15 feet below the existing bottom, and these soils could be subject to scour at velocities greater than approximately 4.0 feet per second. Table 1 provides within-channel bottom velocities that could be produced by the different channel dimensions. Those indicated in red would require ACM to prevent channel scouring. The other configurations are considered wide enough to slow within-channel velocities to an acceptable rate, and a 100-foot wide channel would be the most marginal that could be acceptable.

Table 1. Maximum Bottom Velocities
within the CMP Project Channel

Channel Dimensions (feet wide x feet deep)	CMP Bottom Velocity (ft/s)
(75 x 10)	4.22
(100 x 10)	4.09
(125 x 10)	3.95
(125 x 15)	3.45
(150 x 10)	3.85
(150 x 15)	3.13
(200 x 10)	3.13

Second, riprap would be a necessary feature for protection along any structures such as bridges. Lastly, initial hydrologic analysis for the project determined that a weir would be necessary to slow velocities in the western portion of the CMP above channel dimensions greater than 75 x 10 feet.

Two main project constraints for the proposed project is that the plan should not damage the shoreline and sheet pile structures in the downstream western CMP, and that the foundations of the existing four bridges in the western portion of the Project Channel must be protected. During recent years, three bridges and shoreline stabilization projects have been constructed in the western CMP, and these structures were not designed with a wider, higher velocity CMP channel in mind. Preventing erosion is essential to maintaining a functional project as any effects to the structures in the western CMP could require major construction and cost for repairs in the future, thus impacting funding for general channel maintenance. To evaluate this constraint, western CMP velocities were calculated and evaluated for the potential to damage bridges and sheet pile structures (Table 2). With the exception of the 75-x-10-foot channel, every other channel dimension would be considered unacceptable.

Table 2. Maximum Bottom Velocities within
the CMP and the Adjacent Western Channel

Channel Dimensions (feet wide x feet deep)	Western CMP Bottom Velocity (ft/s)
(75 x 10)	2.20
(100 x 10)	2.80
(125 x 10)	3.25
(150 x 10)	3.65
(200 x 10)	4.09

Because a 75-foot-wide by 10-foot-deep channel was the only dimension that resulted in a bottom velocity that was low enough to prevent unacceptable scour in the western CMP, every larger channel dimension that was modeled (e.g., 100-, 125-, 150-, and 200-foot widths) must include a design component to reduce water flow at the western end of the Project Channel consistent with the model output for the 75-x-10-foot channel if they were to be retained as viable, feasible dimensions. The inclusion of a weir (115 feet wide by 6.5 feet deep by 800 feet long) would enable the larger channels to replicate the cross-sectional area of the smaller 75-x-10-foot channel, and, in turn, maintain the same flow characteristics. With such a weir in place, the potential for unacceptable scour in the western CMP would be resolved while accommodating wider channel widths in the rest of the Project Channel.

In order to protect the structural integrity of the four bridges in the western portion of the Project Channel, it was recommended that channel depths in their vicinity do not extend below 6.5 feet in depth, which is consistent with the weir depth; however, in light of this depth restriction around the bridges, the 75-x-10-foot channel must also include the 115-x-6.5-foot weir. Thus, the inclusion of the weir in the 75-x-10-foot channel is in response to the protection of the existing bridges, not because of the need to reduce water flows to an acceptable bottom velocity in the western CMP, as is the case with the 100-, 125-, 150-, and 200-foot-wide channels.

Although the western and eastern CMP channel segments have different cross-sectional areas and bottom elevations, water flow through a tidal system such as the CMP is, and would continue to be, restricted by the smallest cross-sectional area. More specifically, the water flow characteristics of potential wider channel configurations with the weir would be not significantly different than those associated with that narrower channel configuration of 75 feet.

Benefits for the CMP-ERP are directly related to water flow, which controls differences in residence time and tidal range. With respect to benefits derived from the various channel alternatives, there is a significant benefit to the San José Lagoon (based on the benthic index score) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100, 125, 150, and 200 feet would progressively result in additional, albeit marginal, benefits as a result of the increased water flows and reduced water residence times.

After many considerations, it was determined that dredging the CMP could provide a way of reconnecting eastern and western segments of the SJBE system, as they were several decades ago. The plan formulation process built directly upon previous planning and design efforts. Structural management measures for the channel dredging, erosion control, dredged material disposal, mangrove planting and construction, recreation, as well as non-structural measures were identified and screened. An initial array of alternatives consisting of rectangular channel cross sections ranging between 75- to 200-foot widths and either 10- or 15-foot depths was developed and evaluated. Screening criteria such as completeness, acceptability, cost effectiveness, and secondary effects on adjacent communities, were then used to eliminate unfavorable plans and develop a final array of alternatives. The final array of alternatives consisted of four alternative plans ranging from no action to a 125-foot-wide by 10-foot-deep natural bottom channel. All constructed alternatives include an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour.

The CMP-ERP is a project that has a low uncertainty and high confidence that, once the project is constructed, the anticipated benefits will be observable and measureable. The western half section (approximately 2 miles long) was dredged to 200 feet wide by 10 feet deep to allow inland navigation (Acuaexpreso). In 2004, the USACE carried out a reconnaissance of the western side of the CMP and stated that "mangrove had established along both sides of the channel and flow, as well as water quality in this area, has slightly improved" (USACE, 2004). In addition, other reference or similar tidal restoration projects, (i.e., reestablishment of historical tidal connections) have shown improvements in water quality, benthic community health and fish abundance/diversity over time (Atkins, 2015).

This page intentionally left blank.

2.0 CMP-ERP OBJECTIVES: IDENTIFICATION OF PROBLEMS AND OPPORTUNITIES

The health of the SJBE has been compromised by the lack of tidal interchange between the San Juan Bay and the San José Lagoon, resulting from habitat destruction and the near-complete blockage of the CMP. The fragmented estuary has functionally been divided in half, which can cause such severe ecological effects as crowding, increased competition, and loss of population density and species diversity. The habitat fragmentation leaves the ecosystem extremely susceptible to changes in climate or shifts in available resources, which can have devastating effects on the community and can alter the overall species composition of the estuary.

The SJBE, being in an area of relatively low tidal amplitude, now suffers from a lack of tidal flushing that has led to decreases in dissolved oxygen and adverse changes in salinity stratification. The poor water quality conditions cause disruptions to the normal levels of species evenness and richness, leading to poor benthic habitat. These conditions have also led to poor species distribution and populations density within the mangrove root community. Research within the estuary has indicated that the mangrove root habitat decreased in overall quality with closer proximity to the CMP. Specifically, the current conditions within the Caño Martín Peña have led to the following problems:

1. Aquatic habitat in the SJBE has been fragmented due to the near complete obstruction of the CMP, eliminating connectivity throughout the entire estuary.
2. Severe hypoxic/anoxic bottom water conditions and poor salinity stratification exist in the San José lagoon due to a lack of tidal flushing and resulting in decreased habitat for benthic species in the estuary.
3. Mangrove wetland habitat in the CMP, the San José lagoon, and the Suárez Canal has been adversely impacted due to the lack of tidal flow and the subsequent reduction in density of native species that use this habitat.

Atkins (2010) developed a conceptual ecological model to better understand the relationship between stressors within the system and their effects on the ecosystem. Another conceptual ecological model was later developed by the USACE during their review process. The models worked by the technical teams were combined into one Conceptual Ecological Model featured in Figure 3.

The following opportunities were identified:

1. Increase tidal flushing, and in turn reduce sedimentation rates, in the SJBE by restoring the historic connectivity through the eastern CMP;
2. Reconnect surrounding estuarine areas and increase biodiversity and fish and wildlife populations by restoring access to historic habitats ;

3. Increase dissolved oxygen levels and reduce salinity stratification (enhance existing conditions) in the CMP and the San José Lagoon.
4. Improve mangrove and benthic habitats in the SJBE, especially within the CMP and San José Lagoon.

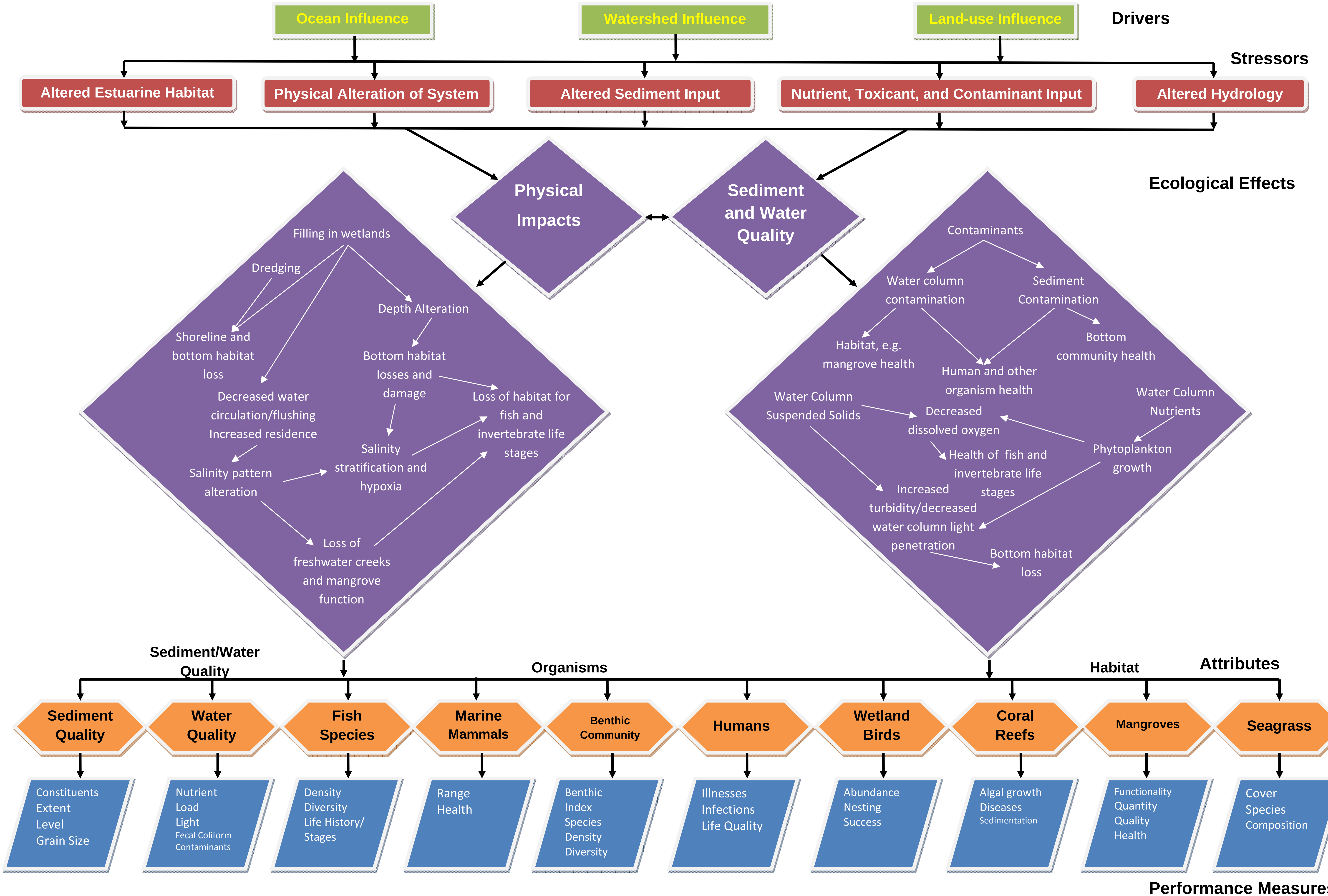
Subsequently, objectives were produced to address those problems and opportunities that have been identified. These describe the desired results of the planning process by solving these and taking advantage of the opportunities identified. The planning objectives must be directly related to the problems and opportunities identified for the project and would be used for the formulation and evaluation of plans. Objectives must be clearly defined and provide information on the desired effect (quantified, if possible), the subject of the objective (what would be changed by accomplishing the objective), the location where the expected result would occur, the timing of the effect (when would the effect occur) and the duration of the effect.

The following objectives have been developed for the CMP-ERP.

1. Improve fisheries in the San Juan Bay Estuary system by increasing connectivity and tidal access to estuarine areas;
2. Restore benthic habitat in San José and Los Corozos lagoons by increasing dissolved oxygen in bottom waters and improving the salinity regime to levels that support native estuarine benthic species; and
3. Increase the distribution and population density and diversity of native aquatic fish and invertebrates in the mangrove community by improving hydrologic conditions in the SJBE system.

The timing and duration for the objectives would occur over the period of analysis, beginning with project implementation in year 2019 and continuing for 50 years.

According to the Monitoring Plan (MP) prepared for the CMP-ERP, there are some metrics that would be assessed before project construction (pre-construction) and others that would be monitored after project construction (post-construction), in order to evaluate project success. Table 4 includes those metrics, as well as the adaptive management actions needed in the case monitoring data shows that Project is not complying with objectives and goals set forth according to those metrics.



Ocean Influence
Watershed Influence
Land-use Influence
Drivers
Stressors
Altered Estuarine Habitat
Physical Alteration of System
Altered Sediment Input
Nutrient, Toxicant, and Contaminant Input
Altered Hydrology
Ecological Effects
Physical Impacts
Sediment and Water Quality
Filling in wetlands
Dredging
Depth Alteration
Shoreline and bottom habitat loss
Bottom habitat losses and damage
Loss of habitat for fish and invertebrate life stages
Decreased water circulation/flushing Increased residence
Salinity stratification and hypoxia
Salinity pattern alteration
Loss of freshwater creeks and mangrove function
Contaminants
Water column contamination
Sediment Contamination
Habitat, e.g. mangrove health
Bottom community health
Human and other organism health
Water Column Suspended Solids
Decreased dissolved oxygen
Water Column Nutrients
Phytoplankton growth
Health of fish and invertebrate life stages
Increased turbidity/decreased water column light penetration
Bottom habitat loss
Sediment/Water Quality
Organisms
Habitat
Attributes
Sediment Quality
Water Quality
Fish Species
Marine Mammals
Benthic Community
Humans
Wetland Birds
Coral Reefs
Mangroves
Seagrass
Constituents Extent Level Grain Size
Nutrient Load Light Fecal Coliform Contaminants
Density Diversity Life History/ Stages
Range Health
Benthic Index Species Density Diversity
Illnesses Infections Life Quality
Abundance Nesting Success
Algal growth Diseases Sedimentation
Functionality Quantity Quality Health
Cover Species Composition
Performance Measures

This page intentionally left blank.

3.0 ADAPTIVE MANAGEMENT PROGRAM DEVELOPMENT

Ecosystem restoration is one of the primary missions of the USACE Civil Works program. The USACE objective in ecosystem restoration planning is to contribute to national ecosystem restoration. Contributions to national ecosystem restoration, or NER outputs, are increases in the net quantity and/or quality of desired ecosystem resources. Measurement of NER is based on changes in ecological resource quality as a function of improvement in habitat quality and/or quantity and expressed quantitatively in physical units or indexes (but not monetary units). These net changes are measured in the planning area and in the rest of the Nation.

With respect to benefits to the SJBE derived from the various channel alternatives, modeling concludes that there is a significant benefit to the San José Lagoon (based on the benthic index score, explained below) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100 and 125 feet would progressively result in additional, albeit marginal, benefit as a result of the increased water flows and reduced water residence times. Although the western and eastern segments of the Project Channel have different cross-sectional areas and bottom elevations for the 100- and 125-foot alternatives with the weir, water flow through a tidal system such as the CMP is, and would continue to be, restricted by the smallest cross-sectional area. Accordingly, once the weir is included in the larger channel configurations, there is no further benefit to residence time in San José Lagoon with channel widths wider than 75 feet, and thus no additional national ecosystem restoration benefits. Therefore, the NER benefits related to ecological uplift for all alternatives would be the same as the 75-foot channel alternative. The only difference would be the variation in habitat scores as it related to open water and mangrove habitat within the Project Channel.

The performance metrics/models for the benefits analysis were mostly based on assessments developed from existing efforts and from the relationships and hypotheses developed in the Conceptual Ecological Model (CEM) (Figure 3) contained in the NER Benefits Evaluation Appendix (Atkins, 2015). These prior efforts include a hydrodynamic model originally produced for San Juan Bay by Bunch et al. (2000), which was recreated with various potential tidal reestablishment scenarios by Atkins (2011a). The hydrodynamic model used was the Curvilinear-grid Hydro-dynamics model in 3-Dimensions, developed by USACE researchers from the Waterways Experimental Station model (i.e., Curvilinear Hydrodynamics in 3 Dimensions, WES version = CH3D-WES). The physical boundaries of the hydrodynamic model (Bunch et al. 2000) are consistent with the physical boundaries of the estuary and nearshore waters used by the San Juan Bay Estuary Program in developing its various resource management programs. The hydrodynamic model is an approved model by USACE Headquarters, and the habitat models have been evaluated by the USACE Ecosystem Restoration Planning Center of Expertise (ECO-PCX) and approved for single-use by the Model Certification Team, USACE HQ.

In order to calculate habitat units, performance metrics were developed from project planning documents, and relationships and hypotheses developed in the CEM. The CEM displays relationships demonstrating that the planned CMP-ERP would result in:

1. Improved fish habitat in the SJBE system by increasing connectivity and tidal access to estuarine areas;
2. Restored benthic habitat in San José and Los Corozos lagoons by increasing dissolved oxygen in bottom waters and improving the salinity regime to levels that support native estuarine benthic species; and
3. Increased distribution and population density and diversity of native aquatic fish and invertebrates in the mangrove community by improving hydrologic conditions in the SJBE system.

3.1 FISH HABITAT MODEL

The restoration of the inter-connectedness of mangrove forests, seagrass meadows, open water and coral reefs as the “seascape” is essential to improving the health, viability and number of fish within the SJBE. Currently, fish within San Juan Bay cannot directly access the mangroves, seagrass meadows, and open water habitats of San José Lagoon, the Suarez Canal, La Torrecilla Lagoon and Piñones Lagoon, just as fish within those waterbodies cannot directly access the habitats afforded by San Juan Bay (located to the west of the western end of the CMP). Due to the current condition of the CMP, there is essentially no tidal exchange between San Juan Bay and the San José Lagoon, i.e. the eastern and western sides of San Juan Bay Estuary system, creating essentially two estuary systems connected independently to the ocean waters by inlets.

The restoration of the CMP is not only expected to benefit water quality and fish habitat within the Caño Martín Peña, San José Lagoon, and Los Corozos Lagoon (Atkins, 2011a), it would benefit fisheries outside of these water bodies by allowing easier access to the variety of fish habitat (i.e., open water, seagrass meadows, hard bottom, mangrove fringes) found throughout the newly inter-connected waters of San Juan Bay, San José Lagoon, the Suarez Canal, La Torrecilla Lagoon and Piñones Lagoon (i.e., the entire San Juan Bay Estuary system).

The construction of the CMP-ERP would result in the eventual benefit to open water and reef habitat of additional net habitat units based upon the scaling factors and the proposed Caño Martín Peña channel alternatives (5,154.0 HUs for the 75-foot Alternative; 5.159.2 HUs for the 100-foot Alternative with weir; and 5,164.6 HUs for the 125-foot Alternative with weir). The net average annual Habitat Units (AAHUs) for the Fish Habitat Model varies between the proposed Caño Martín Peña channel alternatives (Table 3) (5,050.9 AAHUs for the 75-foot Alternative; 5,056.0 AAHUs for the 100-foot Alternative with weir; and 5,061.3 AAHUs for the 125-foot Alternative with weir) and is based upon the recovery time of 3 years (linearly from the existing condition to the predicted, modeled score) and a project period of 50 years.

Table 3
Average Annual Habitat Unit Lift for the project alternatives

Project Condition	Residence Time (days)	Benthic Index[1]	Benthic Index Project Perfor-mance	Benthic Index Habitat Units (HU)[2]	Benthic Index Net HU	Net Benthic Index Net Average Annual HU[3]	Fish Habitat Model Net HU[4]	Fish Habitat Model Net Average Annual HU[3]	Mangrove Habitat Model Net HU[4]	Mangrove Habitat Model Net Average Annual HU[3]	Total Net Habitat Units	Total Net Average Annual HU[5]
No Action	16.9	1.55	51.70%	362.95	0	0	0	0	0	0	0	0
75-ft-wide Alternative	3.9	2.84	94.56%	663.81	300.86	294.54	5,154.01	5,050.93	803.77	787.69	6,258.64	6,133.16
100-ft-wide Alternative with weir (NER Plan)	3.9	2.84	94.56%	663.81	300.86	294.54	5,159.16	5,055.98	798.63	782.66	6,258.65	6,133.17
125-ft-wide Alternative with weir	3.9	2.84	94.56%	663.81	300.86	294.54	5,164.56	5,061.27	793.23	777.37	6,258.65	6,133.17

[1] Based upon a maximum Benthic Index Score of 3.0 (see text for further explanation).

[2] Based upon an expected area to benefit = those regions between -4 and -6 feet in water depth within San José Lagoon (= 702 acres maximum).

[3] Average annual habitat unit lift from existing condition based upon a 3-year recovery time after project construction.

[4] See text for explanation.

[5] Combined Benthic Index Average Annual HU lift, Fish Habitat Model Average Annual HU lift and Mangrove Habitat Model HU lift based upon a 3-year recovery time after project construction [Columns F + H + J = K].

3.2 BENTHIC INDEX MODEL

Benthic habitat is evaluated using an index originally developed for the SJBE Program to report on the status and trends of the health of the SJBE and its individual component water bodies. The technique is consistent with the wider body of literature on how such indices should be constructed, and it is consistent with guidance provided by USEPA (2008) on the requirements of a benthic index which is a refinement of the standard diversity index for SJBE. The index combines information on benthic community diversity, the presence or absence of pollution-tolerant benthic taxa, and the presence or absence of pollution-sensitive taxa (PBS&J 2009). The Benthic index is designed to increase as beneficial factors (i.e., species richness [number of species present], species evenness [number of individuals present from each species is not dominated by one species in particular], and presence of pollution-sensitive taxa) increase. Conversely, if species richness and/or evenness decline and the proportion of pollution-tolerant taxa increases, the Benthic Index will decline. An extensive database on benthic species composition by Riviera (2005) was used to produce benthic index scores throughout SJBE. In the original report (PBS&J 2009), it was determined that benthic index scores were lowest in SJBE in the Caño Martín Peña, followed by the San José Lagoon and that distance from the Atlantic Ocean, used as a surrogate for tidal influence, was a better predictor of benthic index scores than water depth.

Output from the hydrodynamic model was used to determine whether the correlation between benthic index scores and distance from the Atlantic Ocean could be replicated with residence time. The model variables used for the linked hydrodynamic-Benthic Index Model are the hydrodynamic model (CH3D-WES) output of residence time (as an independent variable) and benthic index scores (as a potentially statistically significant independent response variable). The model assumptions are that residence time affects benthic index scores, and the derived mathematical equation reveals the direction of the relationship, the variability associated with the derived relationship, and the statistical significance of the relationship. The Benthic Index Model was properly associated with the residence time within San José Lagoon because the benthic index improvement in San José Lagoon depends upon the water within the Lagoon turning over with the reduced residence time and increased dissolved oxygen levels are anticipated in bottom waters of San José Lagoon as a function of decreased salinity stratification (which is currently occurring in the lagoon), brought about through increasing the exchange of more saline surface waters. Larger, deeper waterbodies like San Juan Bay proper will not experience a significant reduction in residence time with the opening of the CMP; whereas, smaller, fairly shallow waterbodies like San José Lagoon will experience significant reductions in residence time.

To estimate the spatial extent of benthic communities expected to benefit, with regard to the benthic index model, the water quality surveys conducted in the Hydrodynamic and Water Quality Modeling Effort (Atkins. 2011a) were examined in greater detail. A close examination of the water column profiles contained in that report shows that salinity stratification and bottom water hypoxia/anoxia occurs at depths greater than about 4 feet. Waters shallower than 4 feet do not show evidence of salinity stratification. There are a number of deep dredge pits in the San José Lagoon, mostly in the southeastern portion of the lagoon. The deep waters of these dredge pits grade down to depths in excess of 20 feet from a more typical depth within the lagoon of approximately 6 feet. It was thus concluded that waters shallower than 4 feet would not likely benefit from enhanced tidal circulation, as they are too shallow to exhibit hypoxia/anoxia brought about by salinity stratification. Those bottom areas associated with deep dredge pits which will likely continue to be problematic in terms of hypoxia and anoxia.

Those portions of San José Lagoon that are between 4 and 6 feet in depth represent the portions of the lagoon that are anticipated to have improved benthic index scores upon restoration of the historical tidal connection between San Juan Bay and San José Lagoon. The spatial extent of the bay bottom to benefit in this manner is quantified at 702 acres.

The performance of the Benthic Index Model is based on achieving a Benthic Index value of 3.0, which would be approximately the maximum predicted value for the Benthic Index in San José Lagoon after restoring the CMP to its original width and depth of an estimated 200 feet by 10 feet. The Habitat Unit score is based upon the project performance and the maximum spatial extent of the area of San José Lagoon that would benefit from the opening of the CMP (702 acres). The net AAHUs (294.5 Habitat Units) for the Benthic Index Model is based upon the recovery of the area in San José Lagoon to the predicted, modeled Benthic Index HUs (663.8) starting from no action (363.0 Habitat Units) with the expected time of recovery of 3 years (linearly from the existing condition to the predicted, modeled score) and the project period of 50.

3.3 MANGROVE HABITAT MODEL

The Sport Fisheries Study (Atkins, 2011b) includes an assessment of the red mangrove prop root community within the CMP and within zones in designated distances away from the CMP. It was found that the numbers and diversity of the attached (e.g., mussels and oysters) and mobile (e.g., crabs) organisms found on the roots increased from the CMP and western San José Lagoon out to La Torrecilla Lagoon, thus providing an indicator of water quality improvement that would likely respond to the improvements provided by the opening of the CMP. Through this preliminary study, a significant relationship was found between the number of crabs found on mangrove prop roots and distance from the CMP. This relationship uses the connectivity of habitat described above for fish habitat and may be expanded to further species individuals and groups or overall density and diversity of organisms with further data collection.

The net HUs would be those HUs (803.8 HUs for the 75-foot Alternative; 798.6 HUs for the 100-foot Alternative with weir; and 793.2 HUs for the 125-foot Alternative with weir) gained with each project alternative above the no action alternative. The net AAHUs for the Mangrove Habitat Model (787.7 for the 75-foot Alternative; 782.7 for the 100-foot Alternative with weir; and 777.4 for the 125-foot Alternative with weir) is based upon the recovery time of 3 years (linearly from the existing condition to the predicted, modeled score) and a project period of 50 years.

3.4 PROJECT PLAN ALTERNATIVE SELECTION

Pursuant to the calculation of habitat units, planning level cost estimates were developed for the Final Array. A cost effective analysis was conducted to determine which plans reasonably maximize ecosystem restoration benefits compared to costs. A cost effectiveness and incremental cost analysis (CE/ICA) was conducted based on a project life of 50 years and a Federal Discount Rate of 3.5 percent and a base year of 2019. Each alternative was considered to be independent and not combinable with the other alternative. Due to weir restrictions to prevent erosion at bridges and other structures for all three action alternatives, average annual habitat units (AAHUs) would be nearly identical among alternatives, totaling 6,133 AAHUs per alternative (see Table 3). As a result, Alternative 2, with a slightly less average annual equivalent cost when compared to Alternatives 1 and 3 was determined to be cost effective and best buy.

For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected and designated as the NER Plan. The NER plan must be shown to be cost effective and justified to achieve the desired level of output. Alternative Plan 2, the 100-x-10-foot channel, was selected as the NER plan as it reasonably maximizes the amount of environmental restoration compared to costs. This alternative is an economically viable solution to the problems identified for the proposed project and would produce significant and meaningful improvements to the natural environment of the SJBE.

Alternative 2 is the NER and recommended plan for the CMP-ERP. Alternative 2 consists of a 100-foot-wide by 10-foot-deep natural bottom channel; the elongated weir described above; dredging approximately 762,000 cy of mixed materials along 2.2 miles of the eastern CMP; and construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands; and restoration of 25.57 acres of open water and 34.48 acres of wetland, representing a net increase of approximately 18.17 acres of open water and 1.02 acres of mangroves. This plan would meet all three of the project objectives and would not violate any project constraints. The NER and recommended plan is both cost effective and a best buy, and has been demonstrated to be acceptable to state and local agencies as well as the public. The plan is also compatible with all applicable laws and policies.

Fish habitat within the SJBE would be restored with populations more resilient to change through increased genetic diversity. Commercial, recreational, and subsistence fishing would be improved as populations of native fish recover from currently degraded environmental conditions. The restoration of mangrove habitat will serve to provide increased habitat for juvenile fish, while increasing populations of native crabs and other invertebrates. Benthic habitat within the San José and Los Corozos Lagoons would be restored, with corresponding improvements to species such as wading birds that utilize the area for foraging grounds.

3.5 ADAPTIVE MANAGEMENT PROCESS

August 2009 guidance from USACE headquarters, implementing Section 2039 of WRDA 2007, requires that ecosystem restoration projects include plans for monitoring success and adaptively managing ecosystem restoration projects. The aspects of the guidance pertinent to the CMP-ERP are summarized in the following.

- The Adaptive Management Plan (AMP) should be appropriately scoped to the project scale and monitoring efforts.
- AMPs should discuss the uncertainty of achieving desired outputs.
- Monitoring should be tied to key parameters, desired outcomes and management decisions.
- The nature and costs of monitoring and potential adaptive management adjustments should be explicitly described in the plan.

The basic stages of the adaptive management process are planning, implementation, and monitoring. The more detailed steps are illustrated in Figure 4 and include:

1. Planning a program or project, including the development of an AMP;
2. Designing the corresponding project;
3. Building the project (construction/implementation);
4. Operating and maintaining the project;
5. Monitoring selected parameters to measure project performance; and
6. Assessing the results of monitoring, which will lead to decisions to:
7. Continuing project monitoring with no adjustment; or
8. Adjusting the project if goals and objectives are not being achieved; or
9. Determining whether the project has successfully produced the desired outcomes and is complete.

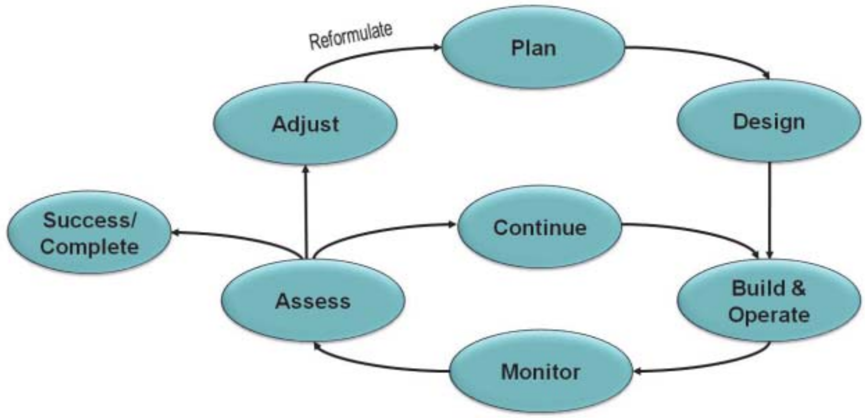


Figure 4. Steps in adaptive management (taken from Fischenich, et al. 2012)

According to Guidance for Section 2039 of WRDA 07 (USACE, 2009), "Monitoring includes the systemic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits."

Mangrove restoration success and water flow through the Eastern CMP are the two major uncertainties that would be addressed by several actions proposed as part of the AM plan. The AMP components selected for monitoring and assessment target these uncertainties.

This AMP is currently in the planning stage of development. The next stages (design and implementation) will include further refinement and implementation of the AMP. Periodic assessments are performed using monitoring data, which would be reported to the USACE and the Caño Martín Peña Ecosystem Restoration Adaptive Management Planning Team (ERAMPT). The ERAMPT would be made up of the representatives from member agencies and entities of the ENLACE Technical Advisory Committee. This team would review the assessment reports and make recommendations to ENLACE (non-Federal sponsor) and the USACE for adaptive management actions.

4.0 ADAPTIVE MANAGEMENT PROGRAM COMPONENTS

4.1 EXPECTED LOCALIZED BENEFITS

Mangrove area restoration: The NER and recommended plan includes the restoration of 34.48 acres of mangrove forested wetland or habitat fringing the Eastern CMP channel would be the expected localized benefits resulting from the CMP-ERP. Mangrove forest restoration would be considered successful if 85 percent or more of all red mangrove propagules are able to survive and develop within 5 years after planting. If seedling survival falls below 85 percent, adaptive management measures would be triggered, assuming that under foreseeable worst case circumstances, no less than 70 percent of all planted propagules would survive.

Two adaptive management actions have been proposed to restore propagule or tree numbers in order to reach an amount equal to 85 percent of that originally planted. These would be implemented after first assessing and identifying those factors (natural or man-made) responsible for propagule mortality. If seedling mortality is determined to have been caused by natural conditions (e.g. propagule unviability), new propagules would be planted to replace those lost.

If the topographic relief of the planting beds is found to be unsuitable to allow periodic tidal flow and soil saturation, two actions would be considered in order to select the one that is most effective and efficient in improving the area's hydrologic regime. These include the following.

- The area of the inlets (windows) in the sheet pile walls could be increased by 50 percent. The proposal would require cutting 252 15-inch by 72-inch windows into the upper most panels of the sheet pile.

- Minor grading of the planting bed could be performed. This would be done either by raising or lowering the planting bed by 12 inches. Raising the planting bed would require the importation of suitable fill material, spreading and replanting the mangroves. The imported fill would be placed utilizing a long-reach excavator placed on adjacent uplands and hand spreading into the mangrove beds. Lowering the planting bed would require stripping and disposing topsoil and replanting with new mangroves. It is anticipated that the excavated material would be removed with a small dozer and the material spread along the embankments. Under a worst case scenario, it is assumed that the area that could require minor grading would not exceed 10 percent (3.5 acres) of the total planting bed area. It is estimated that an approximate volume of 4,078 cubic yards would be handled, respectively, under any of the two grading works proposed.

Replacement of those propagules lost would then be conducted after new "windows" and or grading works have been completed.

4.2 PROJECTED BENEFITS WITHIN THE SAN JUAN BAY ESTUARY

Physical, water quality and habitat attributes: The CMP-ERP is anticipated to restore and improve tidal flow between the eastern and western portions of the SJBE, which is considered one of the major stressors, i.e. altered hydrology, responsible for water and habitat quality in the project and study areas. The dredging of the channel will increase bottom water velocity throughout the eastern CMP. Tidal flow will be initiated between San Juan Bay and San José Lagoon. This will lead to a reduction in water residence time at the San José Lagoon and variation in tidal flow in the areas of SJBE around the CMP.

The success of the project will be determined by initial physical changes in the system and eventual chemical and biological changes. The physical changes in the SJBE system, e.g. water velocity, tidal amplitude, should be measureable almost immediately after construction. As indicated in the background section, the hydrodynamic modeling indicates that the bottom channel velocity in the NER and recommended plan within the eastern CMP will be approximately 4 ft/s and the weir at the western end of the CMP will reduce that to less than 2.5 ft/s. Essentially, the NER and recommended plan is designed to move sediment through the newly constructed eastern CMP, preventing sedimentation from occurring faster than anticipated, and prevent scour in the existing western CMP and around the existing bridges. Hydrodynamic modeling also indicates that the tidal amplitude in San José Lagoon will increase from a change of approximately 10 cm to 40 cm with the opening of the CMP. Using these measurements, the changes in residence time can be calculated showing the decrease from about 17 days to between 3 and 4 days. These performance metrics are very measureable and can be compared to the anticipated results of the hydrodynamic modeling. AM measures for tidal flow, bottom channel velocities and residence time would be triggered if (1) the tidal amplitude is 20 percent less than the anticipated modeled increase; (2) bottom velocity in the Eastern CMP are less than 3 ft/s making them conducive to its sedimentation; and (3) the bottom velocity in the western CMP is greater 3 ft/s resulting in scouring of the channel.

These physical changes would result in the improvement of water quality in San José Lagoon. It is anticipated that the opening of the CMP will result in the elimination of the salinity stratification occurring at water depths greater -4 ft in the shallow waters of San José Lagoon. The dredged pits in San José Lagoon will remain stratified below the bottom depth of the lagoon. This would mean that we would anticipate the bottom water quality values (i.e., temperature, salinity, dissolved oxygen, pH, and turbidity) to be equivalent to the surface water quality values, i.e. equivalence throughout the water column profile. AM measures that will considered if the anticipated results do not occur are the same as those AM measures for the anticipated physical changes.

Several AM measures will be considered and implemented if these physical changes do not occur as the models predicted. A one-time early dredging would be performed to remove sediment that has accumulated in the eastern end of the CMP at its confluence with the Juan Méndez Creek prior to its scheduled maintenance 5-year cycle dredging. This one-time dredging work would be conducted to provide a sump to store additional sedimentation as an adaptive management measure, and thus, to restore tidal flow conditions in the channel and in the San José Lagoon to those conditions anticipated immediately after project construction. It would also serve to restore water residence time in the lagoon and other physical changes anticipated post construction. The total volume of material that is expected to be removed under a worst case scenario would be that equivalent to the annual estimated accumulation of 35,000 cubic yards (cy) times 2.5, or 87,500 cy. This management action would also help to offset any shortcomings related to salinity stratification that were not expected from the CMP-ERP.

Boulders, rip rap, and/or other appropriate concrete structure would be placed at those sites that may scour in the Eastern CMP if flow velocities are stronger than expected. Scour is most likely to occur, if at all, in any of the outside bends of the channel (6 bends in total) and limited to an area from the face of the sheet pile wall to approximately 30 feet into the channel. A layer of riprap, 30 feet wide with an average stone size of 3 feet (spherical) would be placed in any of the bends affected; and monitored to determine if the scour has been abated. A total volume of 12,600 tons of riprap could be used if it is needed to intervene at all of the six channel's bends. The riprap would be placed from both sides of the channel by employing a long reach loader.

If this measure proves insufficient, additional boulders, rip rap and/or other appropriate concrete structure would be placed on either side of the weir's channel to constrict flow. A low wall of rip rap, 3.4 ft. high by 11 ft. wide by 40 ft. deep, could project into the channel from each side. This would effectively reduce the cross sectional area by 10 percent and slow the velocity in the channel accordingly. Rip-rap with an average size of 3 feet (spherical) with a combined weight of 17 tons would be required and placed with a long-reach loader.

The beneficial effects that the construction of the CMP would have on tidal flow, residence time and water quality are also going to improve overall ambient conditions for benthic habitat, mangrove prop-root communities and open water column habitat, leading to an increase in the diversity and abundance of associated organisms (e.g. macroinvertebrates and fish). The changes in these communities will take more time to realize than the physical and water quality changes. Monitoring measures will be in place and AM measures can be implanted; however, it is anticipated that the AM measures that may be implemented for the physical and water quality parameters would be sufficient to ensure that the anticipated organism changes will occur over time. Efforts to eliminate or reduce watershed based loadings from point and nonpoint sources of pollution would be encouraged as a mean to improve water quality, and overall habitat conditions in the event that adaptive actions to improve tidal flow and reduce water residence time prove to be insufficient to achieve expected targets or performance measures. These would be coordinated with the corresponding government agencies in charge of their implementation.

This page intentionally left blank.

5.0 IMPLEMENTATION

The components of the AM plan are summarized in Table 4. Adaptive management provides a structured course for lowering risk, increasing certainty and informing decisions. It is successful only if its actions/strategies are implemented during the entire project-life cycle: from first steps of planning through all aspects of monitoring, engineering, design, construction, operations, and maintenance components. In addition, mechanisms must be in place to collect, manage, analyze, synthesize, coordinate, and integrate new information into management decisions. Figure 5 shows the implementation phase of adaptive management (Fischenich, et al. 2012).

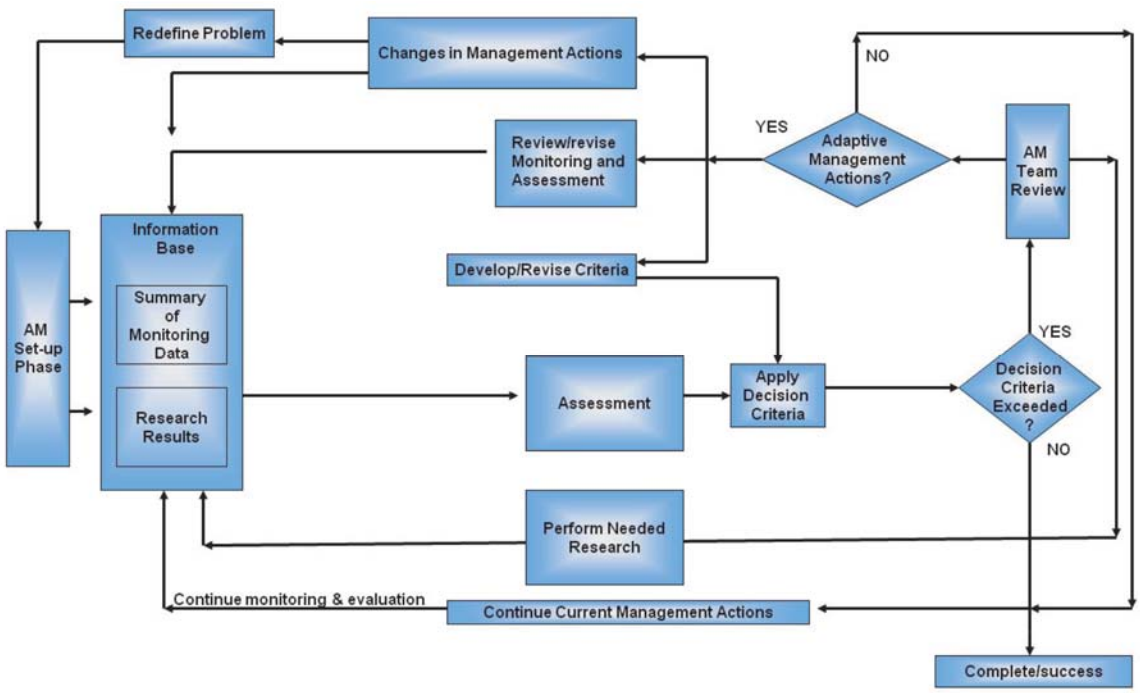


Figure 5. Implementation phase of adaptive management (Fischenich, et al. 2012)

The CMP-ERP's AM plan must be recognized as a "living" document that would be improved and fine-tuned through the incorporation of new data and information that as it becomes available as part of proposed monitoring activities. In particular, as each project component is implemented, specific adaptive management strategies and monitoring should be reviewed and adjusted as necessary. Table 5 shows the implementation schedule for the different AMP phases.

Table 4
Management Options Matrix for the CMP-ERP

Attribute/ Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action	Management Action Option 1	Management Action Option 2	Management Action Option 3
Mangrove habitat	Increase in the mangrove forest canopy cover within the monitoring plots over the 34.48 acres of planted mangrove wetland area after two years of project construction.	A mortality exceeding 15% of planted mangrove trees	Assess if mortality is due to natural causes (e.g. herbivores) or improper hydro period.	Replace dead mangrove propagules in order to increase up to 85% the number of trees initially planted.	Improve hydroperiod conditions either by removing the uppermost panels of the sheet piles or by conducting minor topographic grading.
Tidal Amplitude in San José Lagoon	Increase in tidal flow resulting in an increased tidal amplitude in San José Lagoon (immediately after Construction Phase ends).	Significant (an average of 20% or more) decrease in anticipated tidal amplitude between San Juan Bay and the San José Lagoon.*	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP.	N/A	N/A
CMP Bottom Velocity	Achieve existing bottom velocities to approximately 4.0 ft/s within the CMP and less than 2.5 ft/s at the western end of the CMP (immediately after Construction Phase ends).	Bottom velocities conducive to sedimentation within the eastern CMP (less than 3 ft/s).	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP.	Adopt best management practices to reduce erosion and sedimentation within San José Lagoon and the CMP watershed.	N/A
		Bottom velocities conducive to scouring within the western CMP (greater than 3 ft/s).	Placement of boulders, rip rap, and/or appropriate concrete structure at areas being scoured.	Placement of rip-rap on either side of weir's channel to constrict flow.	N/A
Residence Time	Reduction in residence time from approximately 17 days to between 3 and 4 days (immediately after Construction Phase ends).	Residence time greater than 4 days.*	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP.	N/A	N/A

Table 4, cont'd

Attribute/ Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action	Management Action Option 1	Management Action Option 2	Management Action Option 3
Field Parameter: Dissolved Oxygen	The bottom dissolved oxygen values are not equal to the surface values in shallow waters of San José Lagoon, i.e. an equivalent profile, not in the dredged pits (1-2 years).	Concentration of dissolved oxygen does not increase within timeframe or stays as observed during pre-construction monitoring	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow and water quality.	Elimination/reduction of raw sewage and polluted storm water discharges, coordination with related agencies.	N/A
Field Parameter: Salinity	The bottom salinity values are not equal to the surface values in shallow waters of San José Lagoon, i.e. an equivalent profile, not in the dredged pits (1-2 years). (1-2 years).	Salinity stratification is found in areas shallower than 4 feet deep and/or is spatially more frequent.	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow and water quality.	N/A	N/A
Sedimentation	No variation in channel depth	20% reduction in cross-sectional area in channel.	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow.	Adopt best management practices to reduce erosion and sedimentation within San José Lagoon and the CMP watershed.	N/A
Benthic Habitats: Bottom/Sediment Communities	Achieve a benthic index score of 3.0 in the CMP and the San José Lagoon (2-3 years).	The lack of improvement in the benthic index score from pre-construction values.**	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow and water quality.	Elimination/reduction of raw sewage and polluted storm water discharges, coordination with related agencies.	N/A

Table 4, cont'd

Attribute/ Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action	Management Action Option 1	Management Action Option 2	Management Action Option 3
Benthic Habitats: Red Mangrove (*Rhizophora mangle*) Prop Root Community	The colonization and diversity of fish, crustaceans, snails, and encrusting species would be within 10% in numbers and diversity across the zones (2-3 years).	A greater than 10% reduction of existing functional values (cover, species diversity, etc.)/habitat units. Increase in pollution-tolerant species (or reduction in pollution-sensitive species).**	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow and water quality.	Elimination/reduction of raw sewage and polluted storm water discharges, coordination with related agencies.	N/A
Open Water Column Habitat	Increase in fish populations and diversity, as well as other nekton groups with the numbers and kinds of fish nearly equal throughout SJBE (2-3 years).	Reduction of existing fish populations and diversity from pre-construction estimates. Increase in pollutant-tolerant species (or reduction in pollution-sensitive species).**	A one-time early dredging would be performed to remove sediment that has accumulated at the eastern end of the CMP leading to improvements in water flow and water quality.	Elimination/reduction of raw sewage and polluted storm water discharges, coordination with related agencies.	N/A

*Based on Atkins (2011a).

** Based on Atkins (2015).

Table 5
Adaptive Management and Monitoring Plan Implementation Schedule

Milestone	Schedule
Draft Adaptive Management Plan	During FR/EIS preparation
Finalize Adaptive Management Plan	During PED
Initiate Implementation of Adaptive Management and Monitoring Plan	At the beginning of project construction
Complete Adaptive Management and Monitoring Plan Implementation	5 years after project construction has been completed

This page intentionally left blank.

6.0 COSTS

Table 6
Management Options Estimated Costs

Management Actions	Costs
One-time early dredging	$5,371,800
Placement of boulders, rip rap, and/or concrete structures in scoured areas	$1,325,843
Placement of rip-rap on either side of weir's channel to constrict flow	$13,258
Increase size of inlets within sheet piles	$3,859
Elevate mangrove planting bed relief	$130,076
Lower mangrove planting bed relief	$12,512
Replanting of mangrove planting bed	$56,393
Total	$6,913,741

Assumptions:

One-time early dredging would be performed as an adaptive management action. Subsequent dredging (annual dredging) is included in the O&M costs.

Mangrove re-planting would be carried out to replace dead mangroves propagules in order to increase up to 85% the number of trees initially planted.

Actions related to the implementation of best management practices to reduce erosion and sedimentation within San José Lagoon and the CMP watershed and eliminating/reducing raw sewage and polluted storm water discharges in coordination with related agencies would be funded by existing or future government watershed management programs.

Grading of mangrove planting beds could require either elevating or lowering its topography, or combining a limited scope of both actions. As such, total costs would be lower than those shown under any of these two cases for the total expenses related to the implementation of proposed management measures.

This page intentionally left blank.

7.0 REFERENCES AND LITERATURE CITED

Atkins. 2010b. Water and Sediment Quality Studies. Technical Memorandum for ENLACE – Caño Martín Peña Restoration Project. San Juan, Puerto Rico. 42 pp.

———. 2010. Review of Existing Studies Report Caño Martín Peña Ecosystem Restoration Project San Juan, Puerto Rico. Corporación del Proyecto ENLACE del Caño Martín Peña. Chapter 25. Environmental Benefits Analysis. 8 p.

———. 2011a. Technical Memorandum, Task 6.0 – Hydrodynamic and Water Quality Modeling Efforts, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March, 2011.

———. 2011b. Technical Memorandum, Task 3.3 – Sport Fisheries Studies, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March, 2011.

———. 2011g. Technical Memorandum, Task 2.11 Section 404(b)(1) Evaluation, Including Functional Value of Wetlands and Delineation, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. October, 2011.

———. 2012e. Technical Memorandum, Task 2.03 Hydrologic and Hydraulic Evaluation Rev 1, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March 2012.

———. 2015. *National Ecosystem Restoration Benefits Evaluation. An Assessment of the Ecological Uplift Associated with the Restoration of the Caño Martín Peña, Focusing on Benefits to the Study Area.* Caño Martín Peña (CMP) Ecosystem Restoration Project (ERP), San Juan, Puerto Rico. Prepared for ENLACE. May 2015.

Bunch, B.W., C.F. Cerco, M.S. Dortch, B.H. Johnson, and K.W. Kim. 2000. Hydrodynamic and Water Quality Model Study of San Juan Bay Estuary. ERDC TR-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Caribbean Business Journal. 2012. EPA: $46M for PR clean water projects. Article published October 17, 2012.

Cerco, C., B. Bunch, M. Dortch, B. Johnson, and K. Kim. 2003. Eutrophication and pathogen abatement in the San Juan Bay Estuary. *Journal of Environmental Engineering* 129(4): 318–327.

Faunce. 2007. Ecological Connectivity among Tropical Coastal Ecosystems. Print.

Fischenich, C., C. Vogt, et al. 2012. *The application of Adaptive Management to ecosystem restoration projects*. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-10. Vicksburg, MS: U.S. Army Engineer Research and Development Center. www.wes.army.mil/el/emrrp.

Kennedy, R.H., J.J. Hains, and W.A. Boyd. 1996. "San Juan Bay and Estuary Study: Water Quality Data Collection," R.H. Kennedy, J.J. Hains, W.A. Boyd, USACE, WES, September 1996.

Livingston, Robert J. 2006. *Restoration of Aquatic Systems*. CRC Press. Taylor & Francis Group, LLC. 6000 Brokend Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742.

Moffatt & Nichol Engineers. 2003. "Caño Martín Peña Waterway Improvements" Final Report. Prepared for UNIPRO Architects, Engineers and Planners, San Juan, Puerto Rico. September 2003.

Nybaken, James W. 1982. *Marine Biology: An Ecological Approach.* Harper & Row, Publishers, Inc. 10 East 53d Street, New York, NY 10022.

Otero, E. 2002. Environmental Indicators on the San Juan Bay Estuary. Draft Document 5-8-02.

PBS&J. 2009. Development of the Benthic Index for San Juan Bay Estuary System. Final Report submitted to the San Juan Bay Estuary Program. 30 pp + appendices.

Puerto Rico Environmental Quality Board (PREQB), 2008. 305(b) and 303(d) Integrated Report. Water Quality Area.

Rivera J.A. 2005. Finding of the Benthic Assessment of the San Juan Bay Estuary, Puerto Rico. Final Report. NOAA-EPA Interagency Agreement #DW 1394 1778-01. 83 pp.

SJBEP. 2000. Comprehensive Conservation and Management Plan. San Juan Bay Estuary Program, San Juan, Puerto Rico, August 2000.

U.S. Army Corps of Engineers (USACE). Jacksonville District. June 2004. Reconnaissance Report, Section 905(b) (WRDA 86) Analysis, Caño Martín Peña, Puerto Rico, Ecosystem Restoration. 22 pp.

———. 2009. Implementation Guidance for Section 2039 – Monitoring Ecosystem Restoration, Memorandum (CECW-PB), 31 August 2009.

United States Environmental Protection Agency (USEPA). 2008. Indicator Development for Estuaries. United States Environmental Protection Agency. Washington, D.C. 138 pp.

Webb, R., and F. Gomez-Gomez. 1996. Trends in bottom-sediment quality and water quality in the San Juan Bay Estuary System, Puerto Rico. U.S. Geological Survey, San Juan, Puerto Rico: pp. 5.

Webb, R.M.T. and F. Gómez-Gómez. 1998. *Synoptic Survey of Water Quality and Bottom Sediments, San Juan Bay Estuary System, Puerto Rico, December 1994 – July 1995.* U.S. Geological Survey, Water Resources Investigations Report 97-4144, San Juan, PR.

Webb, R., F. Gomez-Gomez, and S. McIntyre. 1998. Contaminants in sediments deposited in the San Juan Bay Estuary System (1925-95). American Water Resources Association.

Yoshiura, L.M. and C. Lilyestrom, 1999. San José and La Torrecilla Lagoons Creel Survey. Report from Department of Natural and Environmental Resources, Marine Resources Division. 16 pp.

Appendix F

Monitoring Plan

FINAL
MONITORING PLAN
CAÑO MARTÍN PEÑA
ECOSYSTEM RESTORATION PROJECT
SAN JUAN, PUERTO RICO

Prepared for:

PROYECTO ENLACE DEL CAÑO MARTÍN PEÑA

Corporación del Proyecto ENLACE del Caño Martín Peña
Apartado Postal 41308
San Juan, Puerto Rico 00940-1308

February 2016

Contents

Page

Figures

Tables

This page intentionally left blank.

Executive Summary

The Caño Martín Peña Ecosystem Restoration Project (CMP-ERP) is an urban ecosystem restoration project to restore the Caño Martín Peña (CMP) and surrounding areas of the San Juan Bay Estuary (SJBE). Restoration of the CMP would reestablish the tidal connection between the San José Lagoon and the San Juan Bay, which would improve dissolved oxygen levels and reduce salinity stratification, increase biodiversity by restoring fish habitat and benthic conditions, and improve the functional value of mangrove habitat within the estuary.

The CMP is a 3.75-mile-long tidal channel in metropolitan San Juan, Puerto Rico. It is an integral part of the SJBE, the only tropical estuary included in the U.S. Environmental Protection Agency (USEPA) National Estuary Program (NEP). The SJBE's watershed covers 97 square miles. It is heavily urbanized, with a population density of over 5,000 people per square mile. The SJBE includes over 33 percent of the mangrove forests on the island with over 124 species of fish and 160 species of birds. The eastern half of the CMP, historically between 200 and 400 feet wide and navigable, currently ranges in depth from 3.94 feet to 0 foot towards San José Lagoon. Due to years of encroachment and fill of the mangrove swamps along the CMP, the channel no longer serves as a functional connection between San Juan Bay and San José Lagoon. Sedimentation rates within the CMP are nearly two orders of magnitude higher than in other parts of the SJBE. Open waters in areas closer to the San José Lagoon have been lost, as the area has started transitioning into a wetland. A combination of sediment and solid waste is found in the CMP, of which the solid waste accounts for approximately 10 percent of its composition. In some sites, the solid waste extends to depths 10 feet below the sediment surface.

The conditions within the eastern side of the CMP Project Channel have led to degradation within the entire estuary. Connectivity of the ecosystem has been severed and the biodiversity within the lagoons has been compromised, as more individuals of a reduced number of species are found when compared with other lagoons throughout the SJBE. The decreases in biodiversity in turn have reduced the ability of fish and invertebrates to respond to natural changes, disease and other factors, resulting in a depletion of fish stock, biodiversity, and losses of economic and recreational resources.

The current condition of the CMP has resulted in the degradation of the environmental condition within areas of SJBE around the CMP. Water residence time in the San José Lagoon is approximately 17 days. The lack of tidal flushing causes strong salinity stratification and in turn leads to low oxygen or no oxygen levels in the 702 acres of lagoons with depth below 4 to 6 feet, severely affecting benthic habitats. Mangrove habitat, extremely important for native aquatic invertebrates, has been severely impacted, reducing habitat where important commercial fish species spend their juvenile life stages.

A conceptual ecological model was developed for the Caño Martín Peña. This model was used to develop hypotheses about relationships within the system and to assist in understanding changes brought about by planned project elements. The planning objectives for the Caño Martín Peña Feasibility Study include:

1. Improve fish habitat in the SJBE system by increasing connectivity and tidal access to estuarine areas;
2. Restore benthic habitat in San José Lagoon by increasing dissolved oxygen in bottom waters and improving the salinity regime to levels that support native estuarine benthic species; and
3. Increase the distribution and population density and diversity of native fish and aquatic invertebrates in the mangrove community by improving hydrologic conditions in the SJBE system.

After many considerations, it was determined that dredging the CMP could provide a way of reconnecting eastern and western segments of the SJBE system, as they were several decades ago. The plan formulation process built directly upon previous planning and design efforts. Structural management measures for the channel dredging, erosion control, dredged material disposal, mangrove planting and construction, recreation, as well as non-structural measures were identified and screened. An initial array of alternatives consisting of rectangular channel cross sections ranging between 75- and 200-foot widths and either 10- or 15-foot depths was developed and evaluated. Screening criteria such as completeness, acceptability, cost effectiveness, and secondary effects on adjacent communities, were then used to eliminate unfavorable plans and develop a final array of alternatives. The final array of alternatives consisted of four alternative plans ranging from no action to a 125-foot-wide by 10-foot-deep natural bottom channel. All constructed alternatives include an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour.

Performance measures for Benthic Habitat, Fish Habitat, and Mangrove Habitat were developed to measure alternative output, and ecosystem restoration measure benefits were calculated for each alternative. A cost effectiveness and incremental cost analysis (CE/ICA) was conducted based on a project life of 50 years and a Federal Discount Rate of 3.5 percent and a base year of 2019. Each alternative was considered to be independent and not combinable with the other alternative. Due to weir restrictions to prevent erosion at bridges and other structures for all three action alternatives, average annual habitat units (AAHUs) would be nearly identical among alternatives, totaling 6,133 AAHUs per alternative. As a result, Alternative 2, with a slightly less average annual equivalent cost when compared to Alternatives 1 and 3 was determined to be cost effective and the best buy.

Alternative 2, the National Ecosystem Restoration (NER) and recommended plan consists of a 100-foot-wide by 10-foot-deep natural bottom channel; the elongated weir described above; dredging approximately 762,000 cy of mixed materials along 2.2 miles of the eastern CMP; and construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands;

and restoration of 25.57 acres of open water and 34.48 acres of wetland. This represents a net increase of approximately 18.17 acres of open water and 1.02 acres of mangroves.

The NER and recommended plan provides a complete solution to the problems identified for the study. It is also the most effective plan and meets the project objectives. The NER and recommended plan is acceptable and has been determined to be in the national and public interest and can be constructed while protecting the human environment from unacceptable impacts.

This monitoring plan (MP) includes those actions and measures associated to the Adaptive Management (AM) Plan that has been prepared for the Project. These actions and measures are listed below:

- During project planning: Provide new knowledge to better define anticipated ecological responses.
- Before project implementation: Tidal/flow velocity, water quality, benthic and mangrove roots community characterization studies, fish and bird censuses (including indicator species of ecosystem wellness) to be performed (or reviewed if they exist) at established stations to provide baseline information.
- During project construction: Monitoring and assessment of tidal/flow velocity, water quality, benthic and mangrove roots community. Management measures would be implemented to avoid or reduce temporary impacts.
- After its implementation: Monitoring and assessment of tidal flow, water quality, benthic and mangrove roots communities, and fish (including indicator species of ecosystem wellness). Management measures would be implemented, or existing ones would be adapted (adaptive management), in order to achieve goals and objectives. Adaptive management measures currently proposed, and that would be implemented, if needed, include planting mangrove trees along the new channel to promote wetland habitat restoration. In addition, conduct maintenance dredging at both of the CMP ends to address any sedimentation and its effects on water flow.

This MP address the requirements of the U.S. Army Corps of Engineers (USACE) Implementation Guidance for Section 2039—Monitoring Ecosystem Restoration, Memorandum (CECW-PB) dated 31 August 2009 (Guidance for Section 2039 of Water Resources Development Act 07).

This page intentionally left blank.

Acronyms and Abbreviations

AAHU	Average Annual Habitat Units
ACM	Articulated Concrete Mat
BI	Benthic Index
BMPs	Best Management Practices
CCMP	Comprehensive Conservation & Management Plan for the San Juan Bay Estuary
CDRC	Ciudad Deportiva Roberto Clemente
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CEM	Conceptual Ecological Model
CH3D-WES	Curvilinear Hydrodynamics in 3-Dimensions-Waterways Experiment Station model
CMP	Caño Martín Peña
CMP-ERP	Caño Martín Peña Ecosystem Restoration Project
cy	cubic yard
DO	dissolved oxygen
EC	Engineering Circular
ECO-PCX	USACE Ecosystem Restoration Planning Center of Expertise
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENLACE	Corporación del Proyecto ENLACE del Caño Martín Peña
ENLACE Project	Caño Martín Peña ENLACE Project
ER	Engineering Regulation
ERDC	USACE Engineer Research and Development Center
ERP	Ecosystem Restoration Project
FR	Feasibility Report
FRM	Flood Risk Management
ft^2	square feet
ft/s	feet per second
ft/y	feet per year
g	grams
HU	Habitat Unit
GIS	Geographic Information System
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mi^2	square mile
mL	milliliter

MLLW	mean low low water
mm/yr	millimeters per year
mph	miles per hour
MP	Monitoring Plan
MTZ-CMP	Public Domain lands within the Caño Martín Peña Maritime Terrestrial Zone
NED	National Economic Development
NEP	USEPA's National Estuary Program
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
O&M	Operation and Maintenance
ODMDS	San Juan Bay Ocean Dredged Material Disposal Site
P&G	U.S. Water Resources Council Principles and Guidelines
PED	Preconstruction, Engineering and Design
PMP	Project Management Plan
PPA	Project Partnership Agreement
ppm	parts per million
PR	Commonwealth of Puerto Rico
PREQB	Puerto Rico Environmental Quality Board
PRHTA	Puerto Rico Highway and Transportation Authority
Project Channel	2.2 miles of the Eastern CMP associated with the CMP-ERP
PRWQSR	Puerto Rico Water Quality Standards Regulation
SJBE	San Juan Bay Estuary
SJBEP	San Juan Bay Estuary Program
SJHP	San Juan Bay Harbor Project
T&E	Threatened and Endangered Species
µg/g	micrograms per gram
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WQC	Water Quality Certification

1.0 BACKGROUND AND INTRODUCTION

The Caño Martín Peña (CMP) is a 3.75-mile-long tidal channel in metropolitan San Juan, Puerto Rico. It is part of the San Juan Bay Estuary (SJBE), the only tropical estuary included in the U.S. Environmental Protection Agency (USEPA) National Estuary Program (NEP). The SJBE and its associated marine ecosystems are considered the "Study Area," because the proposed CMP-ERP is expected to have direct, indirect, and cumulative beneficial effects on this whole region (Figure 1). The "Project Area," which mostly lays out the construction footprint, has been defined as the Project Channel, where dredging would take place, and the adjacent delimitation of the public domain lands within the Public Domain lands within the Caño Martín Peña Maritime Terrestrial Zone (MTZ-CMP) where relocations are scheduled to occur. Also included in the Project Area is the 2-acre dredged material staging area adjacent to the Martín Peña bridge (Las Piedritas), the 6-acre dredged material staging area within the 35-acre Ciudad Deportiva Roberto Clemente (CDRC) site, the boating routes from the eastern limit of the CMP to the CDRC and the nearby five pits in San José Lagoon (Figure 2).

Figure 1. The San Juan Bay Estuary Study Area

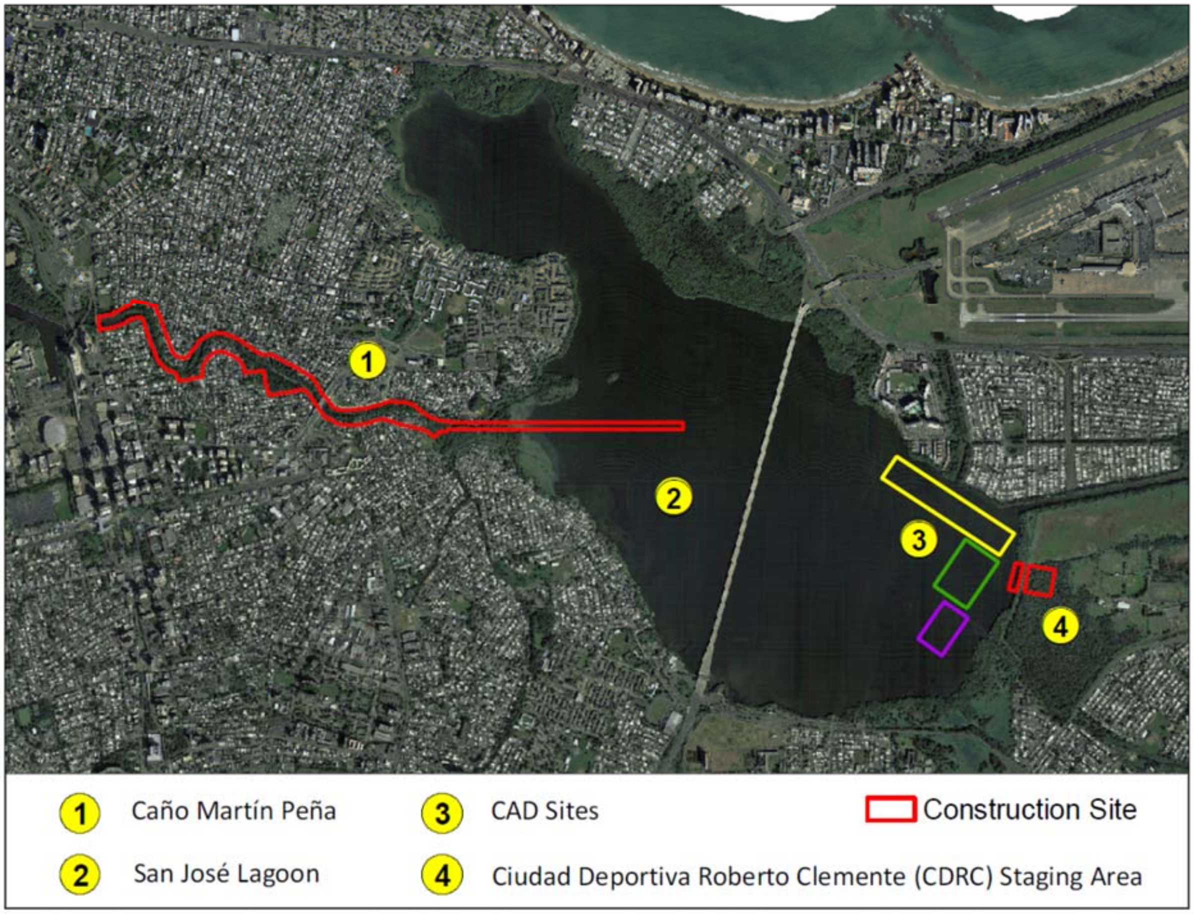


Figure 2. The Caño Martín Peña Ecosystem Restoration Project Area

The SJBE, along the northern coast of Puerto Rico, is the largest system of its kind on the island. Located within the largest urbanized and most densely populated region in Puerto Rico, the SJBE's watershed includes the municipalities of Toa Baja, Cataño, Bayamón, San Juan, Guaynabo, Carolina, Loíza, and Trujillo Alto. The system is characterized by a network of lagoons, channels, man-made canals, permanently and seasonally flooded woody and herbaceous wetlands, and the San Juan Bay, which is home to Puerto Rico's busiest port. In spite of its urbanized setting, the SJBE includes over 33% of the mangrove forests on the island with over 124 species of fish and 160 species of birds.

The SJBE and its associated marine ecosystems are considered the "Study Area," since the proposed Caño Martín Peña Ecosystem Restoration Project (CMP-ERP) is expected to have direct, indirect, and cumulative beneficial effects on this whole region (Figure 1). The SJBE includes the San Juan Bay, the Condado Lagoon, the San José Lagoon (including its northwestern section known as Los Corozos Lagoon), La Torrecilla Lagoon, and the Piñones Lagoon, the interconnecting Caño Martín Peña (CMP), San Antonio Channel, and the Suárez Canal, as well as the Piñones mangrove forest and Las Chucharillas Swamp. Fresh water flows into the system from the creeks and rivers flowing mostly north from its watershed, covering approximately 97 square miles (Figure 1). These include the Río Piedras (Puerto Nuevo) River, Juan Méndez Creek, San Antón Creek, Blasina Creek, and the Malaria

Canal. During medium to extreme flood events, fresh water is also received from the Río Grande de Loíza River, located east of the Piñones State Forest. Several flood control pump stations, as well as storm water sewers, discharge fresh water into the system. Ocean water enters the SJBE through three openings or outlets: Boca del Morro at the San Juan Bay, El Boquerón at the Condado Lagoon, and Boca de Cangrejos at La Torrecilla Lagoon. The Puerto Nuevo River, whose drainage area is of about 25 square miles, flows into the western end of the CMP, close to the San Juan Bay. The western half of the CMP was dredged during the 1980s as part of a waterway transportation project. This portion of the CMP is navigable and has a channel width and depth of 200 feet and 10 feet, respectively. The total drainage area of the CMP is about 4 square miles (2,500 acres).

The water quality of the SJBE has been significantly altered from its natural state not only by land-use activities, but also by the modification of its hydraulic properties through the dredging and filling of many of its water bodies. Water quality within both the Caño Martín Peña and San José Lagoon has been previously documented as being degraded [Kennedy et al. 1996, Webb and Gomez-Gomez 1998, SJBEP 2000, Puerto Rico Environmental Quality Board (PREQB) 2008] and data suggest that the Caño Martín Peña is a source of turbidity and bacteria to the waters of San José Lagoon; however, the Caño Martín Peña does not appear to be a source of nutrients for the San José Lagoon (Atkins 2011a).

Impacts to the water quality of the Caño Martín Peña and San José Lagoon include prior ongoing inflows from combined storm sewer overflows, inflows from areas lacking sanitary sewers, untreated industrial discharges, surface runoff and subsurface seepage over areas with household waste, and from direct dumping of household waste. While water quality concerns remain within both the Caño Martín Peña and San José Lagoon, there is ample evidence of substantial improvements in water quality within San José Lagoon in recent decades, due mostly to improvements in the collection and treatment of wastewater loads in the San Juan Bay region (Webb and Gomez-Gomez 1996 and 1998; Webb et al. 1998). In western San José Lagoon, in the part of the Lagoon closest to the Caño Martín Peña, phosphorus concentrations have decreased more than 50 percent since the late 1970s to early 1980s, and water clarity (as measured by Secchi disk depth) has doubled since the early 1980s (Atkins 2011a).

The recent trends of improved water quality in much of the San Juan Bay Estuary have been achieved only after the investment of substantial time and resources. Since the late 1980s alone, the USEPA has awarded in excess of $650 million to the Commonwealth of Puerto Rico via the Clean Water State Revolving Fund program (Caribbean Business Journal 2012). As a result of these and other coordinated actions, there is an obvious trend of improving water quality in the San José Lagoon, as outlined in the report "Technical Memorandum for Task 2.6 – Water and Sediment Quality Studies" (Atkins 2010b). Similar findings of improving water quality in the greater San Juan Bay estuary system have been previously reported by Webb and Gomez-Gomez (1996 and 1998) and by Webb et al. (1998). Webb and Gomez-Gomez (1998) concluded that "these records document the improved water quality that has resulted from implementing pollution control measures established in the 1970s."

The ongoing and reduced ecological integrity of the San José Lagoon, despite substantial reductions in pollutant loads, appears to be mostly due to salinity stratification and the development of hypoxic conditions (low levels of dissolved oxygen) in waters deeper than 4 to 6 feet (Atkins 2011b). Model results lead to the conclusion that restoration of the tidal exchange capacity of the Caño Martín Peña would increase salinity in the surface waters of the San José Lagoon, which would decrease salinity stratification and thus reduce the spatial extent and severity of hypoxic conditions (Atkins 2011b). Although acceptable levels of dissolved oxygen exist in those portions of the San José Lagoon that are shallower than approximately 4 feet, hypoxic to anoxic conditions are encountered throughout approximately 700 acres of the Lagoon where the water depths are greater than 4 feet. One of the most severe water quality problem in the Caño Martín Peña is levels of dissolved oxygen. Also, Webb and Gomez-Gomez (1998) found ammonia concentrations up to 2.3 milligrams per liter (mg/L) (as nitrogen) and orthophosphate concentrations of 0.22 mg/L (as phosphorus) as well as anoxic conditions within the Caño Martín Peña water column. Also in the Caño Martín Peña, recent studies have documented from 2,000,000 to 6,000,000 fecal coliform bacteria colonies per 100 milliliters (ml) well above guidance criteria of 200 colonies per 100 ml (SJBEP 2012). Additionally, levels as high as 1,200,000 for Enterococci bacteria colonies per 100 ml, where the guidance criteria of 35 colonies per 100 ml (SJBEP 2012).

The existing high sedimentation rates, presence of contaminants within the sediments, low dissolved oxygen levels, and salinity stratification within the CMP and/or the San José lagoon do not provide a healthy ecosystem for benthic organisms (e.g., infauna, meiofauna, epifauna) or organisms relying upon the estuarine water column (e.g., fish and invertebrates; Kennedy et al. 1996, Otero 2002, SJBEP 2000, PREQB 2008). Benthic habitats in and around the Project Channel area are highly degraded due to the contaminant loads and reduced tidal flushing present, which result in limited light penetration, poor water quality, and anoxic, highly organic sediments.

Soft bottoms in these shallow areas, the mangrove roots that line the lagoons, seawalls, rip-rap and other surfaces at these depths are covered with a thriving community dominated by mussels. Rivera (2005) estimated 66.7 acres of this mussel reef within the San José lagoon, which he hypothesized, is a "large source of food for the Lagoon" and provides a water filtering function "which must help maintain the water quality."

Species abundance and diversity (important indicators of healthy habitats) of the encrusting community of red mangrove prop roots is higher in the La Torrecilla Lagoon (closest to the Atlantic Ocean), becomes less diverse and less abundant within the San José Lagoon (farthest from the flushing source), and is non-existent or limited (severely limited flushing) within the CMP. This could be related to dissolved oxygen and salinity concentrations.

This macrofauna follows a general pattern of reduced diversity and abundance along a gradient from La Torrecilla Lagoon to Suárez Canal, to the San José Lagoon to the CMP. In general, sponges, crabs, worms and mussels become less abundant to absent along a gradient from the eastern end of Suárez Canal, along San José Lagoon and into the CMP.

In summary, the results of the benthic habitat survey in the shallow portions of San José Lagoon indicate that diverse and healthy biological communities are restricted to the shallowest (less than 4 feet) regions, where salinity stratification does not occur, and where sufficient levels of dissolved oxygen exist. These are the conditions that support a healthy benthic habitat, that type that would support sustenance and recreational fishery in the Lagoons; however, at the minimal dissolved oxygen conditions found in 702 acres of waters deeper than 4 feet in San José lagoon, the presence of hydrogen sulfide in the sediments is a strong indicator that the water layer above the sediments is also hydrogen sulfide laden. Therefore, these areas of the bottom of the lagoons cannot sustain a benthic habitat.

Some of the 124 species that have been documented in the SJBE system have been locally identified as important target species for both recreational and commercial fisheries. The important target species of common snook (*Centropomus undecimalis*) and tarpon (*Megalops atlanticus*) are caught within San José Lagoon itself (Yoshiura and Lilyestrom 1999). The commercially important offshore fishery for mutton snapper (*L. analis*) is dependent, in part, on the maintenance of a healthy inshore, lower-salinity mangrove habitat for post-larval and juvenile phases (Faunce et al. 2007). Out of the 124 species of fish documented within the SJBE system, 15 of these are also found within the 84 managed species included in the Caribbean Fishery Management Council's Fisheries Management Program (FMP) (Yoshiura and Lilyestrom 1999).

Due to the current clogging of the eastern CMP, there is essentially no tidal exchange between San Juan Bay and the San José Lagoon. As a result, fish within San Juan Bay cannot directly access the mangroves, seagrass meadows, and open water habitats of San José Lagoon, Los Corozos Lagoon, the Suárez Canal, La Torrecilla Lagoon, and Piñones Lagoon, just as fish within those waterbodies cannot directly access the habitats afforded by San Juan Bay.

There are still some mangrove wetlands, albeit of extremely low functional quality, along the CMP. If the CMP was dredged, much of these wetlands would be within the construction area and impacted by the project. In order to maintain a mangrove fringe of wetlands along the CMP for habitat, nutrient reduction, water quality, and other wetland functions, mangrove wetlands could be reestablished in areas along a dredged canal. This measure would provide immediate restoration within the project area, as the existing low quality mangrove areas would be removed along the CMP channel for construction purposes and replaced by high functioning mangrove wetlands. The north and south slopes of the channel above the sheet pile would be graded to receive tidal influence and then planted with appropriate mangrove species. Microtopography would be added to diversity habitat.

The CMP-ERP is an urban ecosystem restoration project to restore the Caño Martín Peña and surrounding areas of the SJBE. Restoration of the CMP would reestablish the tidal connection across the SJBE, substantially improving the water quality of the entire SJBE and promoting the establishment of more diverse and healthy fish and wildlife habitats (USACE 2004). This means helping to reduce water renewal time in the San José Lagoon and its salinity stratification, as well as to improve dissolved oxygen levels, fish and benthic habitat, and thus biodiversity, including the functional value of mangrove habitat within this system (Atkins 2015).

Several modeling efforts have been conducted to further assess the effectiveness of the proposed project on the hydrology and hydrodynamics of the SJBE, and its possible effects on fish and wildlife resources. In 2000, the USACE's Research and Development Center published the report titled Hydrodynamic and Water Quality Model Study of the San Juan Bay Estuary (SJBE). This study was performed for the SJBE Program (Bunch et al. 2000). The researchers used a three-dimensional, coupled, hydrodynamic and water quality model of the SJBE system that was calibrated using field observations in order to estimate the effectiveness of various alternatives to increase flushing and reduce loadings for improving water quality. Dredging the Caño Martín Peña (CMP) to 150 feet wide and 9 feet deep, in order to improve water flow along this water body was one of the scenarios modeled, showing improvements in the channel's water conveyance capacity and that of the San José Lagoon.

The CH3D-WES hydrodynamic model was used to quantify the improvement (decrease) in residence time in the San José Lagoon and improved connectivity between this water body and the San Juan Bay as a result of increasing the cross-sectional area and thus, the water flow capacity of the CMP within the Project Area. It was also used to predict ecological improvement for various parameters, such as dissolved oxygen and salinity. The output on residence time was combined with data from a recently developed Benthic Index (BI) for the SJBE (PBS&J 2009). The relationship between residence time and benthic community health in the San José Lagoon was found to be significant. It was determined, as a result, that restoring tidal flow through the CMP would improve the lagoon's circulation, helping to decrease water stratification and thus, hypoxic to anoxic conditions affecting its waters and associated submerged habitats (Atkins 2011a; 2011b; 2015; Bunch et al. 2000; PBS&J 2009).

Preliminary hydrologic modeling for different channel configurations indicated that if the channel dredging measure was implemented, erosion control features would be necessary to protect the CMP channel from scouring, and to protect existing bridges and shoreline stabilization structures in the western CMP such as sheet piles. Three erosion control features were formulated, evaluated, and retained for these purposes. These erosion control features are all dependent on dredging of the existing CMP channel. First, articulated concrete mats (ACMs) would be required to provide scour protection for any high velocity dredged channel configurations. The soils in the CMP Project Channel are predominantly hard silts and clays at a depth of 10 to 15 feet below the existing bottom, and these soils could be subject to scour at velocities greater than approximately 4.0 feet per second. Table 1 provides within-channel bottom velocities that could be produced by the different channel dimensions. Those indicated in red would require ACM to prevent channel scouring. The other configurations are considered wide enough to slow within-channel velocities to an acceptable rate, and a 100-foot-wide channel would be the most marginal that could be acceptable.

Table 1. Maximum Bottom Velocities
Within the CMP Project Channel

Channel Dimensions (feet wide x feet deep)	CMP Bottom Velocity (ft/s)
(75 x 10)	4.22
(100 x 10)	4.09
(125 x 10)	3.95
(125 x 15)	3.45
(150 x 10)	3.85
(150 x 15)	3.13
(200 x 10)	3.13

Second, riprap would be a necessary feature for protection along any structures such as bridges. Lastly, initial hydrologic analysis for the project determined that a weir would be necessary to slow velocities in the western portion of the CMP above channel dimensions greater than 75 x 10 feet.

Two main project constraints for the proposed project is that the plan should not damage the shoreline and sheet pile structures in the downstream western CMP, and that the foundations of the existing four bridges in the western portion of the Project Channel must be protected. During recent years, three bridges and shoreline stabilization projects have been constructed in the western CMP, and these structures were not designed with a wider, higher velocity CMP channel in mind. Preventing erosion is essential to maintaining a functional project as any effects to the structures in the western CMP could require major construction and cost for repairs in the future, thus impacting funding for general channel maintenance. To evaluate this constraint, western CMP velocities were calculated and evaluated for the potential to damage bridges and sheet pile structures (Table 2). With the exception of the 75-x-10-foot channel, every other channel dimension would be considered unacceptable.

Table 2. Maximum Bottom Velocities within
the CMP and the Adjacent Western Channel

Channel Dimensions (feet wide x feet deep)	Western CMP Bottom Velocity (ft/s)
(75 x 10)	2.20
(100 x 10)	2.80
(125 x 10)	3.25
(150 x 10)	3.65
(200 x 10)	4.09

Because a 75-foot-wide by 10-foot-deep channel was the only dimension that resulted in a bottom velocity that was low enough to prevent unacceptable scour in the western CMP, every larger channel dimension that was modeled (e.g., 100-, 125-, 150-, and 200-foot widths) must include a design component to reduce water flow at the western end of the Project Channel consistent with the model output for the 75-x-10-foot channel if they were to be retained as viable, feasible dimensions. The inclusion of a weir (115 feet wide by 6.5 feet deep by 800 feet long) would enable the larger channels to replicate the cross-sectional area of the smaller 75-x-10-foot channel, and, in turn, maintain the same flow characteristics. With such a weir in place, the potential for unacceptable scour in the western CMP would be resolved while accommodating wider channel widths in the rest of the Project Channel.

In order to protect the structural integrity of the four bridges in the western portion of the Project Channel, it was recommended that channel depths in their vicinity do not extend below 6.5 feet in depth, which is consistent with the weir depth; however, in light of this depth restriction around the bridges, the 75-x-10-foot channel must also include the 115-x-6.5-foot weir. Thus, the inclusion of the weir in the 75-x-10-foot channel is in response to the protection of the existing bridges, not because of the need to reduce water flows to an acceptable bottom velocity in the western CMP, as is the case with the 100, 125, 150, and 200-foot wide channels.

Although the western and eastern CMP channel segments have different cross-sectional areas and bottom elevations, water flow through a tidal system such as the CMP is, and would continue to be, restricted by the smallest cross-sectional area. More specifically, the water flow characteristics of potential wider channel configurations with the weir would be not significantly different than those associated with that narrower channel configuration of 75 feet.

Benefits for the CMP-ERP are directly related to water flow, which controls differences in residence time and tidal range. With respect to benefits derived from the various channel alternatives, there is a significant benefit to the San José Lagoon (based on the benthic index score) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100, 125, 150, and 200 feet would progressively result in additional, albeit marginal, benefits as a result of the increased water flows and reduced water residence times.

After many considerations, it was determined that dredging the CMP could provide a way of reconnecting eastern and western segments of the SJBE system, as they were several decades ago. The plan formulation process built directly upon previous planning and design efforts. Structural management measures for the channel dredging, erosion control, dredged material disposal, mangrove planting and construction, recreation, as well as non-structural measures were identified and screened. An initial array of alternatives consisting of rectangular channel cross sections ranging between 75- and 200-foot widths and either 10- or 15-foot depths was developed and evaluated. Screening criteria such as completeness, acceptability, cost effectiveness, and secondary effects on adjacent communities, were then used to eliminate unfavorable plans and develop a final array of alternatives. The final array of alternatives consisted of four alternative plans ranging from no action to a 125 foot-wide by 10-foot-deep natural bottom channel. All constructed alternatives include an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour.

The main goal of the proposed project is to restore water flow through the CMP and connectivity within the SJBE system by dredging and removing artificial fill deposited during past decades. These would lead to the restoration of open water and forested wetlands, the enhancement of benthic habitats, fish habitats and fisheries.

According to Guidance for Section 2039 of WRDA 07 (USACE 2009), "Monitoring includes the systemic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits."

Periodic assessments are performed using monitoring data, which would be reported to the Caño Martín Peña Ecosystem Restoration Adaptive Management Planning Team (ERAMPT). The ERAMPT would be made up of the representatives from member agencies and entities of the ENLACE Technical Advisory Committee. This team would review the assessment reports and make recommendations to ENLACE (non-federal cost sharing partner) and the USACE for adaptive management actions.

The following sections describe the key components of the Monitoring Plan for the CMP-ERP.

This page intentionally left blank.

2.0 MONITORING PLAN

The Implementation Guidance for Section 2039 of the Water Resources Act of 2007 – Monitoring Ecosystem Restoration (USACE 2009) states that monitoring includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits. Development of a monitoring plan… should focus on key indicators of project performance.

A monitoring plan is fundamental to evaluate the success of the CMP-ERP by measuring different physical, chemical, ecological and biological parameters. Important baseline data and concepts have been produced in some of the documents used to produce the Feasibility Study and the Environmental Impact Statement. Studies such as *The Sport Fisheries Study* (Atkins 2011b), the *Existing Wildlife Habitat* (Atkins 2011c), *Hydrodynamic and Water Quality Modeling Efforts* (Atkins 2011a), *Benthic Index within San José Lagoon and San Juan Bay* (PBS&J 2009; Atkins 2011b), *National Ecosystem Restoration Benefit Evaluation* (Atkins 2015), and SJBE Program, Volunteer-Based Monitoring Program, among others, provide useful baseline information to be compared with post-construction monitoring data to assess Project's performance.

The performance metrics/models for the benefits analysis were mostly based on assessments developed from existing efforts and from the relationships and hypotheses developed in the Conceptual Ecological Model (CEM) (Figure 3) contained in the NER Benefits Evaluation Appendix (Atkins 2015). These prior efforts include a hydrodynamic model originally produced for San Juan Bay by Bunch et al. (2000), which was recreated with various potential tidal reestablishment scenarios by Atkins (2011a). The hydrodynamic model used was the Curvilinear-grid Hydro-dynamics model in 3-Dimensions, developed by USACE researchers from the Waterways Experimental Station model (i.e., Curvilinear Hydrodynamics in 3 Dimensions, WES version = CH3D-WES). The physical boundaries of the hydrodynamic model (Bunch et al. 2000) are consistent with the physical boundaries of the estuary and nearshore waters used by the SJBE Program in developing its various resource management programs. The hydrodynamic model is an approved model by USACE Headquarters, and the habitat models have been evaluated by the USACE Ecosystem Restoration Planning Center of Expertise (ECO-PCX) and approved for single-use by the Model Certification Team, USACE HQ.

In order to calculate habitat units, performance metrics were developed from project planning documents, and relationships and hypotheses developed in the CEM. The CEM displays relationships demonstrating that the planned CMP-ERP would result in:

1. Improved fish habitat in the SJBE system by increasing connectivity and tidal access to estuarine areas;

2. Restored benthic habitat in San José and Los Corozos lagoons by increasing dissolved oxygen in bottom waters and improving the salinity regime to levels that support native estuarine benthic species; and
3. Increased the distribution and population density and diversity of native aquatic fish and invertebrates in the mangrove community by improving hydrologic conditions in the SJBE system.

The performance measures are described in detail in *National Ecosystem Restoration Benefit Evaluation* (Atkins 2015) and in the Adaptive Management Plan. Three models were developed to address the relationships described above.

1. A fish habitat model describing the benefits accrued from construction of the project through the interconnectedness of mangrove forests, seagrass meadows, open water and coral reefs as the "seascape," which is essential to improving the health, viability and number of fish within the SJBE.
2. A benthic index model which is associated with the decrease in residence time within San José Lagoon. Those portions of San José Lagoon that are between 4 and 6 feet in water depth represent the portions of the lagoon that are anticipated to have improved benthic index scores upon restoration of the historical tidal connection between San Juan Bay and San José Lagoon. The spatial extent of the bay bottom to benefit in this manner is quantified at 702 acres.
3. A mangrove habitat model describing the benefits to mangrove habitat accrued from the construction of the project to increased numbers and diversity of organisms found on and within the mangrove root community.

The basic elements of the program include the following components:

1. Mangrove restoration – Ten 1,000 m^2 plots would be established along the restored CMP channel to assess mangrove seedling survival and growth.
2. Tidal fluctuation/water quality stations – Four tidal fluctuation/water quality stations are proposed. The tidal stations would measure tidal fluctuations for translation into tidal exchange and residence time and collect water quality parameters such as temperature, salinity/conductivity, dissolved oxygen, and pH.
3. Water quality profiles – Ten water quality profiles are proposed to be monitored on a monthly basis. Parameters to be measured would be temperature, salinity/conductivity, dissolved oxygen, and pH.
4. Benthic sampling stations – Thirty stations would be sampled (three grabs per station); and the organisms sorted and identified sufficient to create Benthic Index scores yearly at each station. The stations would be spaced through the San Juan Bay Estuary system with samples intensified within the 702 acres between –4 and –6 foot depth within San José Lagoon.
5. Mangrove prop root community study – Sampling of the stations in and around the Project Area to evaluate the encrusting community diversity and juvenile fish diversity.

6. Post-construction sedimentation rate – Bathymetric surveys to determine post-construction sedimentation rates and maintenance dredging requirements within the CMP.

The monitoring parameters have been selected to assess the Project's success, as well as to determine whether adaptive management actions are required in the event that established thresholds are reached and detected. These parameters are related to localized, as well as system-wide expected benefits.

2.1 EXPECTED LOCALIZED BENEFITS

The difference between the evaluated project alternatives is the width of the channel of the eastern portion of the CMP and the resulting amount of open water in the channel versus the constructed mangrove habitat along the channel edges. The NER and recommended plan includes the restoration of 34.48 acres of mangrove forested wetland or habitat fringing the Eastern CMP channel would be the expected localized benefits resulting from the CMP-ERP. Failure of areas of the mangroves planted along the Eastern CMP will most likely occur early in the restoration project from improper flooding or ponding of water behind the retaining walls or improper elevation from settling or redistribution of sediment. Mangrove establishment is highly dependent on tidal influence, and thus, hydric soils, which at the same time helps to exclude other potentially invasive plant species from growing in this type of habitat. The monitoring program will identify problems in the ability of tidal water to access the planting areas or elevation problems that may result in other plant species entering the planting areas, or the failure of the planted mangroves.

The thresholds that trigger management actions for each metric or parameter related to expected localized benefits (i.e., mangrove restoration along Eastern CMP) are included in Table 3.

Table 3. Threshold for management actions to expected localized benefits
(i.e., mangrove restoration along Eastern CMP)

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Mangrove habitat	Increase in mangrove forest canopy cover within the monitoring plots, over the 34.48 acres of planted area, 2 years after project construction.	A mortality exceeding 15% of planted mangrove trees

2.2 EXPECTED SYSTEM-WIDE BENEFITS

2.2.1 Physical Attributes

The proposed project seeks to restore and improve tidal flow between the eastern and western portions of the SJBE system, which is considered one of the major stressors responsible for water and habitat quality (and its current degraded state) in the project and study areas. In order to determine whether the project goals are accomplished, flow velocity would be measured in the CMP and the Suárez Canal, as well as tidal amplitude, to determine the trend towards equalization of tides and tidal velocities with eastern and western SJBE system and shorter water residence time in the San José Lagoon. Table 4 includes the thresholds that trigger management actions for each metric or parameter related to the physical attributes.

Table 4. Thresholds for management actions for each measured parameter
(i.e., physical attributes) related to expected system-wide benefits.

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Tidal Amplitude in San José Lagoon	Increase in tidal flow and amplitude (immediately after Construction Phase ends).	Significant (an average of 20% or more) decrease in tidal oscillation between San Juan Bay and the San José Lagoon.*
CMP Bottom Velocity	Achieve existing bottom velocities to approximately 4.0 ft/s within the CMP and less than 2.5 ft/s at the western end of the CMP (immediately after Construction Phase ends).	Bottom velocities conducive to sedimentation within the eastern CMP (less than 3 ft/s). Bottom velocities conducive to scouring within the western CMP (greater than 3 ft/s).
Residence Time	Reduction in residence time from approximately 17 days to between 3 and 4 days (immediately after Construction Phase ends).	Residence time greater than 4 days.*
Sedimentation	No variation in channel depth	20% reduction in cross-sectional area in channel.

*Based on Atkins (2011a)

2.2.2 Water Quality Attributes

The physical changes are anticipated to effect the water quality predicted to occur in San José Lagoon. It is anticipated that the opening of the CMP will result in the elimination of the salinity stratification occurring at water depths greater –4 feet in the shallow waters of San José Lagoon. The dredged pits in San José Lagoon will remain stratified below the bottom depth of the lagoon. This would mean that we would anticipate the bottom water quality values (i.e., temperature, salinity, dissolved oxygen, pH, and turbidity) to be equivalent to the surface water quality values, i.e., equivalence throughout the water column profile. Table 5 includes the thresholds that trigger management actions for each metric or parameter related to the water quality attributes.

Table 5. Thresholds for management actions for each measured parameter (i.e., water quality attributes) related to expected system wide benefits.

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Field Parameter: Dissolved Oxygen	The bottom dissolved oxygen values are not equal to the surface values in shallow waters of San José Lagoon, i.e. an equivalent profile, not in the dredged pits (1–2 years).	Concentration of dissolved oxygen does not increase within timeframe or stays as observed during pre-construction monitoring
Field Parameter: Salinity	The bottom salinity values are not equal to the surface values in shallow waters of San José Lagoon, i.e., an equivalent profile, not in the dredged pits (1–2 years).	Salinity stratification is found in depths shallower than 4 feet and/or is spatially more frequent.

2.2.3 Habitat Attributes

The beneficial effects that the construction of the CMP would have on tidal flow, residence time and water quality are also going to improve overall ambient conditions for benthic habitat, mangrove prop-root communities and open water column habitat, leading to an increase in the diversity and abundance of associated organisms (e.g., macroinvertebrates and fish). The changes in these communities will take more time to realize than the physical and water quality changes.

Benthic Habitat

Benthic habitat is evaluated using an index originally developed for the SJBEP to report on the status and trends of the health of the SJBE and its individual component water bodies. The Benthic Index (BI) combines information on benthic community diversity, the presence or absence of pollution-tolerant benthic taxa, and the presence or absence of pollution-sensitive taxa (PBS&J 2009). The BI is designed to increase as beneficial factors increase (e.g., species richness, species evenness, and presence of pollution-sensitive taxa). Conversely, if species richness and/or evenness decline and the proportion of pollution-tolerant taxa increases, the BI would decline. The performance of the BI Model is based on achieving a BI value of 3.0, which would be the approximate maximum predicted value for the BI in the San José Lagoon after restoring flow through the CMP.

Benthic habitat in those areas shallower than –4 to –6 feet deep in the San José Lagoon are expected to improve as a result of the proposed project. This would be verified by sampling for an increase in diversity and abundance of benthic pollution-sensitive species (e.g., invertebrates). The data that would be collected would be employed in the BI model in order to determine that a benthic index score of 3.0 has at least been achieved. Table 6 includes the thresholds that trigger management actions for each metric or parameter related to benthic habitat attributes.

Table 6. Thresholds for management actions for each measured parameter (i.e., benthic habitat attributes) related to expected system wide benefits.

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Benthic Habitats: Bottom/Sediment Communities	Achieve a benthic index score of 3.0 in San José Lagoon (2–3 years).	The lack of improvement in the benthic index score from pre-construction values.*

* Based on Atkins (2015)

Mangrove Prop Root Habitat

The Sport Fisheries Study (Atkins 2011b) includes an assessment of the red mangrove prop root community within the CMP, and within six zones in designated distances away from the CMP (see Figure 3). It was found that the numbers and diversity of the attached (e.g., mussels and oysters) and mobile (e.g., crabs) organisms found on the roots increased from the CMP and western San José Lagoon out to La Torrecilla Lagoon, thus providing an indicator of water quality improvement that would likely respond to the improvements that will be provided by the opening of the CMP (see Figure 4). Through this preliminary study, a significant relationship was found between the number of crabs found on mangrove prop roots and its distance from the CMP (Atkins 2015).

Monitoring activities would document the numbers and diversity of attached mobile organisms within the mangrove prop root community to determine whether an increase leading to habitat uplift similar to those conditions presently found in the Suárez Canal (Zone D) has been achieved as a result of the project. Table 7 includes the thresholds that trigger management actions for each metric or parameter related to mangrove prop root habitat attributes.

Table 7. Thresholds for management actions for each measured parameter (i.e., mangrove prop root habitat attributes) related to expected system wide benefits.

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Red Mangrove (*Rhizophora mangle*) Prop Root Community	The colonization and diversity of fish, crustaceans, snails, and encrusting species would be within 10% in numbers and diversity across the zones (2–3 years).	A greater than 10% reduction of existing functional values (cover, species diversity, etc.)/habitat units. Increase in pollution-tolerant species (or reduction in pollution-sensitive species).*

* Based on Atkins (2015)

Figure 3. Mangrove prop root habitat sampling segments (Atkins 2011b)

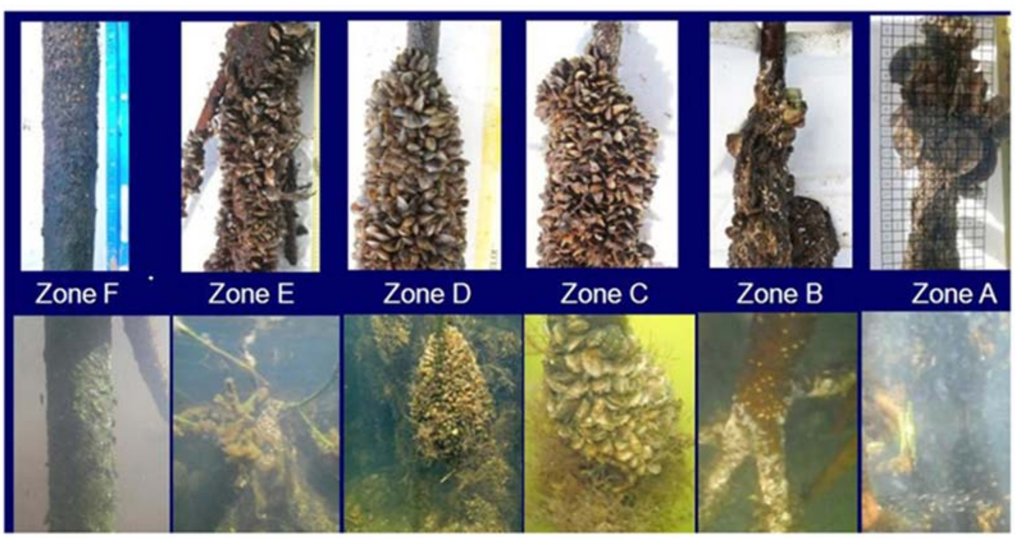


Figure 4. Mangrove prop root habitat fouling community
in various portions of the SJBE (Atkins 2011b)

Open Water Column Habitat

Existing fish populations and diversity would be assessed in San José Lagoon and the CMP as part of the pre-construction baseline data sampling in order to compare said data with that resulting from the post-construction monitoring activities. Table 8 includes the thresholds that trigger management actions for each metric or parameter related to fish diversity and abundance attributes.

Table 8. Thresholds for management actions for each measured parameter (i.e., fish diversity and abundance) related to expected system wide benefits.

Attribute/Performance Metric	Target or Performance Measure (Timeframe)	Trigger/Threshold for Management Action
Open Water Fish Habitat	Increase in fish populations and diversity, as well as other nekton groups with the numbers and kinds of fish nearly equal throughout SJBE (2–3 years).	Reduction of existing fish populations and diversity from pre-construction estimates. Increase in pollutant-tolerant species (or reduction in pollution-sensitive species).*

* Based on Atkins (2014)

Implementation of a pre-project monitoring plan would be necessary to establish baseline data of those metrics that are not available prior to construction. It would be carried out by in-house agency resources or via contracts with CMP-ERP partner agencies and/or contracted universities or consultants to most efficiently and effectively execute the pre-construction monitoring efforts. Table 9 includes the monitoring plan matrix, which contains the parameters to be measured, methods, monitoring period and frequency, as well as proposed monitoring sites.

Table 9. Monitoring Plan Matrix

Metric	Specific Property to be Monitored	Method	Monitoring Period	Frequency of Monitoring	Monitoring Site/Station
Tidal Fluctuation/ Water Velocity	Tidal oscillation between the SJB, and the San José and Los Corozos lagoons. Current velocity at ends and within the CMP and other locations as needed to calculate residence time.	Acoustic Doppler Current Profilers (ADCP); appropriate tide gauge stations	Post-construction	Digital recording at appropriate intervals throughout tidal cycles	See Figure 3
Field Parameters (Dissolved oxygen, salinity, temperature, turbidity, pH, and Secchi disk depth)	Dissolved oxygen (mg/L), salinity (psu), temperature (C°), turbidity (ntu), and Secchi disk depth (meters) at water surface, mid-depth and bottom.	Multi parameter sensors	Pre-construction, post-construction	Pre-construction: existing data, pre-construction baseline study of water column profiles and continuous monitoring stations. Post-construction both monthly profiles and continuous monitoring stations.	See Figure 3
Benthic Habitats: Bottom/Sediment Communities	Presence of bottom/sediment species and bottom sediment composition.	Petite Ponar Grab sampling	Pre-construction, post-construction	Pre-construction baseline study. Post-construction: twice yearly	See Figure 3
Benthic Habitats: Mangrove/wetland	Sampling density, survival rate, diversity, overall condition/health, wildlife utilization.	Plot (quadrat) establishment.	Post-construction	Post-construction: twice yearly, first 3 years. Annually: next 2years	Mangrove restoration areas

Table 9, concluded

Metric	Specific Property to be Monitored	Method	Monitoring Period	Frequency of Monitoring	Monitoring Site/Station
Red Mangrove (*Rhizophora mangle*) Prop root community	Presence, diversity of organisms, including fish.	*In situ* characterization, optical methods; sampling for attached and cryptic organisms	Pre-construction, post-construction	Pre-construction: existing data. Post-construction: twice a year	Mangroves in CMP, Suárez Canal, San José and Los Corozos lagoons
Open water habitat	Fish species density, diversity.	Creel surveys	Pre-construction, post-construction	Pre-construction: existing data. Post-construction: sport fisheries data/creel surveys, twice a year	Along CMP, and San José and Los Corozos lagoons
Sedimentation at CMP	Sedimentation rate.	Multibeam Bathymetry Survey System (MBSS)	Post-construction	Yearly	Along CMP

These parameters would be monitored at specific site or stations, as shown in Figure 5.

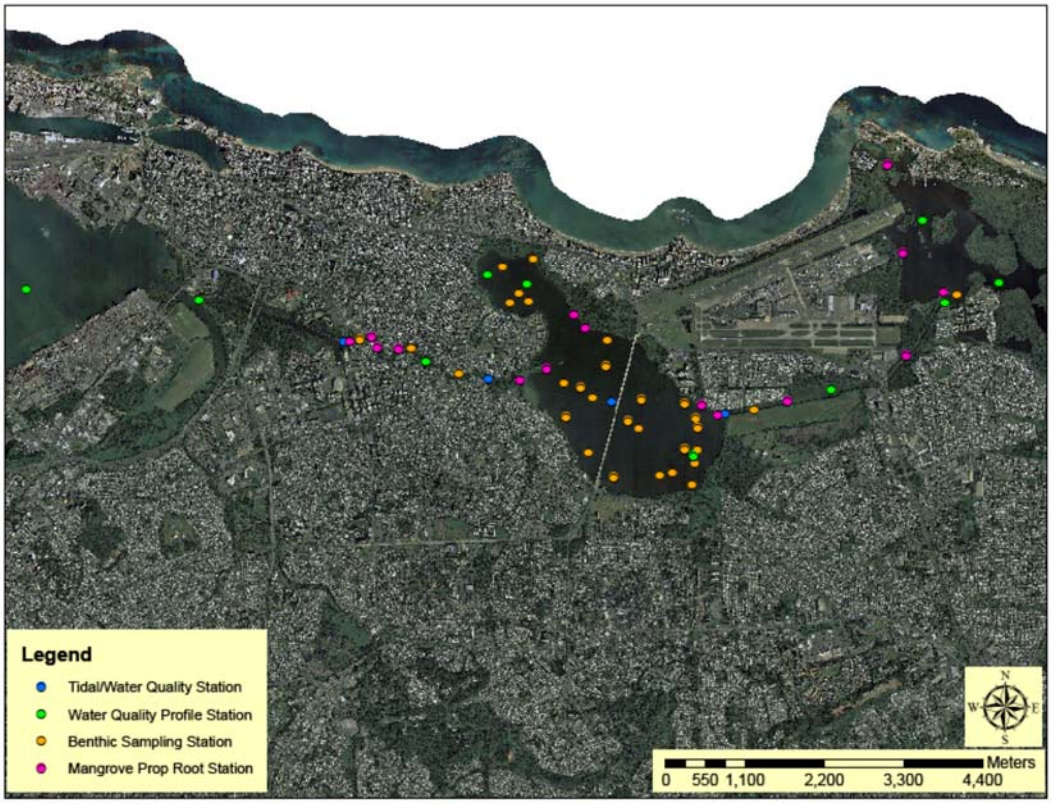


Figure 5. Proposed monitoring stations (mangrove planting sampling stations not shown)

2.3 MONITORING METHODS

The following sections describe the pre-construction and post-construction methodology that would be employed to monitor the established metrics.

2.3.1 Pre-Construction Monitoring

Pre-construction baseline data would be collected to document the condition for several parameters related to the expected benefits of the project system-wide. Pre-construction data consists of a combination of pre-construction field sampling and the use of existing data from long-term studies and site specific studies. Some of the proposed monitoring sites would be located within stations that were previously or currently used in these studies. The proposed approach is also comparable to the methods used in these previous or existing studies. Therefore, pre-construction data would be suitable for comparison with post-construction monitoring.

Physical Attributes – Tidal Fluctuation/Residence Time

Improvement of tidal exchange is crucial metric the CMP-ERP acting to decrease salinity stratification (among other benefits) and thus improve the ecological health of San José Lagoon and the rest of the SJBE (Atkins 2011a). Existing tidal volume residence time within San José Lagoon has been estimated at an average of approximately 17 days. This data would be used as the pre-construction existing condition; therefore, no additional sampling of tidal velocity to translate it to residence time is necessary before project begins. Tidal gauge stations and velocity meters would be used tom record post-construction changes and provide the data needed to calculate post-construction residence times. The velocity meters would be used to record and understand the current velocity within and around the CMP.

Physical Attributes – Water Quality

Field parameters such as dissolved oxygen (mg/L), salinity (psu), temperature (C°), turbidity (ntu) and pH would be sampled using a multi parameter sensor. This methodology (*in situ* measurement) is likely to be more accurate and precise than measurements made in samples removed from their source (Gibs 2007). A Secchi Disk would be used to measure water transparency (depth, meters). Dissolved oxygen, salinity, temperature, turbidity and pH are intrinsically related to water quality.

Existing field parameters data, sampled by the SJBEP or others, is useful as pre-construction baseline data. The SJBE Water Quality Volunteer Monitoring Program samples water quality parameters every month. Some of the proposed sampling stations are placed within the same location as the SJEBP water quality sampling stations. Monitoring would consist of permanent fixed stations and water column profile stations.

Habitats: Benthic, Mangrove Prop Roots, and Open Water Column Communities

Thirty benthic monitoring stations are proposed. A petite ponar type grab sampler would be employed to sample bottom/sediment communities such as mussel reefs and other soft-bottom macro-invertebrate communities in the 30 sampling stations. Sampling methodology would follow the *Standard Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing and for Selection of Samplers Used to Collect Benthic Invertebrates* (ASTM E1391-03). The data produced during benthic sampling would be analyzed and also uploaded into a Geographical Information System (GIS) to produce a map of benthic communities within Project area before construction begins. The BI would be calculated for each station during each sampling period.

Mangrove prop root community monitoring methodology would include *in situ* characterization and observations, as well as optical methods (video and still camera documentation). Optical equipment would include a scale system or grid to determine percent coverage. If any species cannot be identified in the field, a sample would be taken to the laboratory for further identification.

Pre-construction fish monitoring would be conducted through creel surveys combining roving and access points components (Wilberg and Humphrey 2008). Also, meetings and interviews of anglers would be performed. Angler interviews and questionnaires would be prepared and administered to receptive anglers at nearby marinas, access points (including shoreline and boat ramps) and boat to boat. These methods are valuable tools to get information about the effort, harvest, and size distribution of several important species of fish (Malvestuto 1996).

2.3.2 Post-Construction Monitoring

Localized Project Benefits – Mangrove Restoration

The CMP-ERP includes the restoration of approximately 34.48 acres of forested wetlands. After the restoration area has been constructed, ten (1,000 m^2) permanent plots within mangrove restoration areas would be established randomly (five at each side of the restored CMP channel). In these plots a time-zero or restoration area post-construction monitoring would be carried out to:

- Establish the density of planted propagules;
- Evaluate hydroperiod within restoration site; and
- Document wildlife utilization (simple observation for information purposes only).

The first two bullets would serve as the baseline data to compare tree density in future monitoring events.

Subsequent monitoring of wetland restoration area would be performed twice yearly during the first 3 years, and annually in the last 2 years (5 years in total). These monitoring events would include:

- Determination of tree density;
- Determination of survival rate of planted trees;
- Species diversity;
- Overall condition/health of planted trees;
- Determination of a functional hydroperiod; and
- Wildlife utilization (simple observation of presence of species from different trophic levels for information purposes only).

Project success would be achieved if:

- At least 85% of planted trees are alive;
- 85% of vegetative cover is composed of native, desirable species;
- Hydroperiod (hydrological connectedness and frequency of inundation/saturation) is correct for planted species; and
- An observed increase of wildlife utilization.

These are standard monitoring methods required in restoration and mitigation projects approved by the USACE.

Project Benefits for the San Juan Bay Estuary

Given that post-construction information would be obtained using similar methodologies as the ones used for pre-construction data production, both data sets may be compared to evaluate project success.

Physical Attributes – Tidal Fluctuation/Residence Time

Tidal velocity would be monitored using an Acoustic Doppler Current Profiler (ADCP). ADCPs would be permanently deployed in four stations along the CMP and the San José Lagoon (see Figure 5). Tidal amplitude will be measured at tide gauge stations located with San José Lagoon. Tidal amplitude and flow would be translated into the calculation of residence time within San José Lagoon. Monitoring of tidal flow would take place automatically on a timed basis sufficient to understand the tidal velocity through tidal cycles. The tide gauges will be automatic recording gauges with sufficient timing to understand tidal cycle changes. Also, these stations would collect water quality parameters, such as dissolved oxygen, conductivity/salinity, temperature and pH. This represents four additional stations, besides the proposed ten water quality stations (see below) to collect water quality parameters. At sufficient intervals to understand the changes in water quality through tidal cycles.

Sedimentation rates would be monitored along the CMP using a Multibeam Bathymetry Surveying System (MBSS). The MBSS measures bottom elevation identifying changes (erosion or accumulation) of sediment between survey intervals. This method, in combination with the proposed tide and current stations would identify any degradation in tide or current, indicating that the CMP channel is potentially filling in, or that flow is being restricted near the Quebrada Juan Méndez confluence with the CMP. The MBSS surveys would be conducted on a yearly basis.

Physical Attributes – Water Quality

Project success would be achieved if water quality parameters (temperature, DO, salinity, and pH) become equal throughout the water column in areas shallower than 6 feet when compared with pre-construction data. The project related water quality sampling program would consist of a series of permanent continuously monitoring stations and stations where the water column profile is measured on a monthly basis. To augment the project related program, field parameters also could be monitored on a monthly basis by a volunteer program, such as the San Juan Bay Estuary Water Quality Volunteer Monitoring Program. Sampling would follow the *Standard Operating Procedures for Water Quality Monitoring*, prepared by the San Juan Bay Estuary Water Quality Volunteer Monitoring Program (2008).

Habitats: Benthic, Mangrove Prop Roots, and Open Water Column Communities

Post-construction monitoring to determine project success regarding benthic, mangrove prop roots, and open water column communities would follow the same methods as those described for pre-construction monitoring. Post-construction monitoring for these habitat attributes would occur twice yearly for the 5-year monitoring period.

To augment the project related program, other metrics may be monitored by volunteer programs, such as the SJBE Program Volunteer-Based Monitoring Program. These metrics would include the monitoring of water quality lab parameters (Ammonia, BOD, chlorophyll a, fecal coliforms, enterococcus, nitrate + mitrite, total nitrogen Kjeldahl (TKN), oil & grease, total organic carbon (TOC) and total phosphorus.), non-native invasive and native nuisance flora/fauna species, as well as avifauna species density and diversity.

This page intentionally left blank.

3.0 IMPLEMENTATION

Monitoring and assessment of data is a fundamental step of adaptive management. It provides a structured course for lowering risk, increasing certainty and informing decisions. It is successful only if its actions/strategies are implemented during the entire project-life cycle: from first steps of planning through all aspects of monitoring, engineering, design, construction, operations, and maintenance components. In addition, mechanisms must be in place to collect, manage, analyze, synthesize, coordinate, and integrate new information into management decisions. The Adaptive Management Plan outlines the steps for the use of monitoring data in this process.

A five (5) year monitoring plan is proposed; however, if ecological success is determined earlier (prior to 4 years post-construction), for some of the monitored parameters, these would cease to be measured; associated costs would be reduced accordingly. For those parameters that would be measured on continuously (data recorders) or monthly basis, monitoring would cease once these meet target or performance measures for a continuous period of a whole year. Those parameters that would be measured quarterly or biannually would cease to be monitored once these meet target or performance measures for a continuous period of two years. Sedimentation rate is the only parameter that would be measured for the whole post-construction monitoring period of four years.

Table 10 shows the implementation schedule for the different Monitoring Plan phases.

Table 10. Monitoring Plan Implementation Schedule

Milestone	Schedule
Draft Monitoring Plan	During FR/EIS preparation
Finalize Monitoring Plan	During preconstruction engineering and design
Pre-construction Baseline Study	Within 1 year before construction begins
Initiate Implementation of Monitoring Plan	At the beginning of project construction
Complete Monitoring Plan Implementation	5 years after project construction has been completed

This page intentionally left blank.

4.0 COSTS

The total cost for all monitoring activities proposed for a 5-year period has been estimated at $1,673,750, considering a 3% inflation rate.

Table 11. Monitoring Plan Estimated Costs

Monitoring Plan Element	Estimated Equipment Cost	Estimated Annual Maintenance, Monitoring, and Reporting	Total Estimated Maintenance/ Monitoring/ Reporting	Source of Cost Estimate
Preconstruction baseline studies and mapping	$15,000	$60,000[1]	$60,000	Coll Rivera Environmental / NOAA
Four permanent tidal/water quality stations	$40,000	$34,000[2]	$170,000	Atkins
Inspection and bathymetric survey	–	$23,000[3]	$115,000	Atkins
Ten water quality profile stations (Lab/field)	$10,000	$20,000[2]	$100,000	Atkins and consultation with SJBEP
Thirty benthic sampling stations	$10,000	$80,000[2]	$400,000	Atkins
Mangrove prop root community monitoring	–	$50,000[2]	$250,000	Atkins
Creel survey	$5,000	$10,000	$50,000	Coll Rivera Environmental
End of monitoring period benthic mapping	–	$60,000[1]	$60,000	Coll Rivera Environmental / NOAA
Data Analysis Evaluation and Assessment	–	$50,000[2]	$250,000	Coll Rivera Environmental
Equipment maintenance/ transportation	–	$8,000[2]	$40,000	Atkins, Coll Rivera Environmental
SUBTOTALS	**$80,000**	**$395,000**		
		Total Equipment and 5-Year Cost	**$1,575,000**	
		Total 5-Year Cost with 3% Inflation	**$1,622,250**	

[1]Single time cost / [2]Five year monitoring period / [3]1st. year for initial survey, $25,000; following 5 years, $18,000. Total of $115,000, or an annual average of $23,000.00.

This page intentionally left blank.

5.0 REFERENCES

American Society for Testing and Materials, Annual Book of ASTM Standards. *ASTM E1391-03 Standard Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing and for Selection of Samplers Used to Collect Benthic Invertebrates.*

Atkins. 2010a. Review of Existing Studies Report Caño Martín Peña Ecosystem Restoration Project San Juan, Puerto Rico. Corporación del Proyecto ENLACE del Caño Martín Peña. Chapter 25. Environmental Benefits Analysis. 8 p.

———. 2010b. Water and Sediment Quality Studies. Technical Memorandum for ENLACE – Caño Martín Peña Restoration Project. San Juan, Puerto Rico. 42 pp.

———. 2011a. Technical Memorandum, Task 6.0 – Hydrodynamic and Water Quality Modeling Efforts, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March 2011. 44 p.

———. 2011b. Technical Memorandum, Task 3.3 – Sport Fisheries Studies, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March 2011. 54 p.

———. 2011c. Technical Memorandum, Task 3.7 (a & b) Existing Wildlife Habitat and Threatened or Endangered Species Identification, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. March 2011.

———. 2011g. Technical Memorandum, Task 2.11 Section 404(b)(1) Evaluation, Including Functional Value of Wetlands and Delineation, CMP-ERP, San Juan, Puerto Rico. Prepared for ENLACE. October 2011.

———. 2015. *National Ecosystem Restoration Benefits Evaluation. An Assessment of the Ecological Uplift Associated with the Restoration of the Caño Martín Peña, Focusing on Benefits to the Study Area.* Caño Martín Peña (CMP) Ecosystem Restoration Project (ERP), San Juan, Puerto Rico. Prepared for ENLACE. May 2015.

Bunch, B.W., C.F. Cerco, M.S. Dortch, B.H. Johnson, and K.W. Kim. 2000. Hydrodynamic and Water Quality Model Study of San Juan Bay Estuary. ERDC TR-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Caribbean Business Journal. 2012. EPA: $46M for PR clean water projects. Article published October 17, 2012.

Cerco, C., B. Bunch, M. Dortch, B. Johnson, and K. Kim. 2003. Eutrophication and pathogen abatement in the San Juan Bay Estuary. *Journal of Environmental Engineering* 129(4): 318–327.

Faunce et al. 2007. Ecological Connectivity among Tropical Coastal Ecosystems. Print.

Fischenich, C., C. Vogt, et al. 2012. *The application of Adaptive Management to ecosystem restoration projects*. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-10. Vicksburg, MS: U.S. Army Engineer Research and Development Center. www.wes.army.mil/el/emrrp.

Gibs, Jacob, Wilde, F.D. , and Heckatorn, H.A. 2007. *Use of multiparameter instruments for routine field measurements (ver. 1.0): U.S. Geological Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.8, August.* Available only online at http://water.usgs.gov/owq/FieldManual/Chapter6/6.8.html.

Kennedy, R.H., J.J. Hains, and W.A. Boyd. 1996. "San Juan Bay and Estuary Study: Water Quality Data Collection," USACE, WES, September 1996.

Livingston, Robert J. 2006. *Restoration of Aquatic Systems*. CRC Press. Taylor & Francis Group, LLC. 6000 Brokend Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742.

Malvestuto, S. P. 1996. *Sampling the recreational creel*. Pages 591–623 in B. R. Murphy and D. W. Wouldis editors. Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda, Maryland.

Moffatt & Nichol Engineers. 2003. "Caño Martín Peña Waterway Improvements" Final Report. Prepared for UNIPRO Architects, Engineers and Planners, San Juan, Puerto Rico. September 2003.

Nybakken, James W. 1982. *Marine Biology: An Ecological Approach.* Harper & Row, Publishers, Inc. 10 East 53d Street, New York, NY 10022.

Otero, E. 2002. Environmental Indicators on the San Juan Bay Estuary. Draft Document 5-8-02.

PBS&J. 2009. Development of the Benthic Index for San Juan Bay Estuary System. Final Report submitted to the San Juan Bay Estuary Program. 30 pp + appendices.

Puerto Rico Environmental Quality Board (PREQB), 2008. 305(b) and 303(d) Integrated Report. Water Quality Area.

Rivera J.A. 2005. Finding of the Benthic Assessment of the San Juan Bay Estuary, Puerto Rico. Final Report. NOAA-EPA Interagency Agreement #DW 1394 1778-01. 83 pp.

SJBEP. 2000. Comprehensive Conservation and Management Plan. San Juan Bay Estuary Program, San Juan, Puerto Rico, August 2000.

———. 2008. *Standard Operating Procedures*. Water Quality Monitoring Volunteer Program. San Juan Bay Estuary Program. San Juan, Puerto Rico. 15 pp plus attachments.

———. 2008a. Quality Assurance Project Plan. The San Juan Bay Estuary Water Quality Volunteer Monitoring Program. San Juan Bay Estuary Program. San Juan, Puerto Rico. 38 pp plus appendices.

U.S. Army Corps of Engineers (USACE). 2004. Reconnaissance Report. Section 905(b) (WRDA 86) Analysis. Caño Martín Peña, Puerto Rico, Ecosystem Restoration.

———. 2009. Implementation Guidance for Section 2039 – Monitoring Ecosystem Restoration, Memorandum (CECW-PB), 31 August 2009.

Webb, R., and F. Gomez-Gomez. 1996. Trends in bottom-sediment quality and water quality in the San Juan Bay Estuary System, Puerto Rico. U.S. Geological Survey, San Juan, Puerto Rico: pp. 5.

Webb, R.M.T., and F. Gómez-Gómez. 1998. *Synoptic Survey of Water Quality and Bottom Sediments, San Juan Bay Estuary System, Puerto Rico, December 1994 – July 1995.* U.S. Geological Survey, Water Resources Investigations Report 97-4144, San Juan, PR.

Webb, R., F. Gomez-Gomez, and S. McIntyre. 1998. Contaminants in sediments deposited in the San Juan Bay Estuary System (1925–95). American Water Resources Association.

Wilberg, M., J. Humphrey. 2008. *Progress Report to Maryland Department of Natural Resources on A Creel Survey for Early Spring Fisheries of Maryland's Chesapeake Bay Tributaries.* University of Maryland Center for Environmental Science. Chesapeake Biological Laboratory. P.O. Box 38, Solomons, MD 20688.

Yoshiura, L.M., and C. Lilyestrom. 1999. San José and La Torrecilla Lagoons Creel Survey. Report from Department of Natural and Environmental Resources, Marine Resources Division. 16 pp.

5-4

This page intentionally left blank.