DRAFT INTEGRATED GENERAL REEVALUATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

SAN FRANCISCO BAY TO STOCKTON, CALIFORNIA NAVIGATION STUDY

APPENDIX C: Cost Engineering and Risk Analysis

APRIL 2019

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

PROJECT: **SAN FRANCISCO BAY TO STOCKTON NAVIGATION IMPROVEMENT PROJECT,**
PROJECT NO: P2 xxxxxx
LOCATION: CONTRA COSTA COUNTY, CA

DISTRICT: SAN FRANCISCO
POC: CHIEF, COST ENGINEERING, Warren H. Tan

PREPARED: 2/1/2018

This Estimate reflects the scope and schedule in report; Report 2019

Program Year (Budget EC): 2020
Effective Price Level Date: 1 OCT 19

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	**TOTAL ($K) J**	Spent Thru: **1-Oct-18** ($K)	**TOTAL FIRST COST ($K) K**	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
12	NAVIGATION PORTS & HARBORS	$46,335	$9,267	20.0%	$55,602	2.6%	$47,512	$9,526	$57,038	$0	$57,038	11.7%	$53,079	$10,621	$63,699
	CONSTRUCTION ESTIMATE TOTALS:	$46,335	$9,267		$55,602	2.6%	$47,512	$9,526	$57,038	$0	$57,038	11.7%	$53,079	$10,621	$63,699
01	LANDS AND DAMAGES	$48	$2	5.0%	$50	2.5%	$49	$2	$51	$0	$51	10.1%	$54	$3	$56
30	PLANNING, ENGINEERING & DESIGN	$1,344	$269	20.0%	$1,612	3.9%	$1,396	$279	$1,675	$0	$1,675	14.3%	$1,595	$319	$1,914
31	CONSTRUCTION MANAGEMENT	$510	$102	20.0%	$612	3.9%	$529	$106	$635	$0	$635	14.8%	$608	$122	$730
	PROJECT COST TOTALS:	$48,236	$9,640	20.0%	$57,876		$49,486	$9,914	**$59,400**	$0	**$59,400**	11.8%	$55,336	$11,064	$66,400

ESTIMATED TOTAL PROJECT COST: $66,400

_________________________ **CHIEF, COST ENGINEERING, Warren H. Tan**

_________________________ **PROJECT MANAGER, Pamela G. Castens,**

_________________________ **CHIEF, REAL ESTATE, xxx**

_________________________ **CHIEF, PLANNING, xxx**

_________________________ **CHIEF, ENGINEERING, xxx**

_________________________ **CHIEF, OPERATIONS, xxx**

_________________________ **CHIEF, CONSTRUCTION, xxx**

_________________________ **CHIEF, CONTRACTING,xxx**

_________________________ **CHIEF, PM-PB, xxxx**

_________________________ **CHIEF, DPM, xxx**

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

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

PROJECT: SAN FRANCISCO BAY TO STOCKTON NAVIGATION IMPROVEMENT PROJECT,
LOCATION: CONTRA COSTA COUNTY, CA
This Estimate reflects the scope and schedule in report; Report 2019

DISTRICT: SAN FRANCISCO
POC: CHIEF, COST ENGINEERING, Warren H. Tan
PREPARED: 2/1/2018

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 1-Oct-18 Effective Price Level: 1-Oct-18				Program Year (Budget EC): 2020 Effective Price Level Date: 1 OCT 19								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED 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*
	PHASE 1 or CONTRACT 1													
12	NAVIGATION PORTS & HARBORS	$46,335	$9,267	20.0%	$55,602	2.5%	$47,512	$9,526	$57,038	2023Q4	11.7%	$53,079	$10,621	$63,699
	CONSTRUCTION ESTIMATE TOTALS:	$46,335	$9,267	20.0%	**$55,602**		$47,512	$9,526	$57,038			$53,079	$10,621	$63,699
01	LANDS AND DAMAGES	$48	$2	5.0%	$50	2.5%	$49	$2	$51	2023Q2	10.1%	$54	$3	$56
30	PLANNING, ENGINEERING & DESIGN													
0.1%	Project Management	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
0.1%	Planning & Environmental Compliance	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
0.2%	Engineering & Design	$93	$19	20.0%	$111	3.9%	$96	$19	$116	2023Q2	12.8%	$109	$22	$130
0.1%	Reviews, ATRs, IEPRs, VE	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
0.1%	Life Cycle Updates (cost, schedule, risks)	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
0.1%	Contracting & Reprographics	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
2.0%	Engineering During Construction	$927	$185	20.0%	$1,112	3.9%	$963	$193	$1,155	2023Q4	14.8%	$1,106	$221	$1,327
0.1%	Planning During Construction	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q4	14.8%	$55	$11	$66
0.1%	Project Operations	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q2	12.8%	$54	$11	$65
31	CONSTRUCTION MANAGEMENT													
0.1%	Construction Management	$46	$9	20.0%	$56	3.9%	$48	$10	$58	2023Q4	14.8%	$55	$11	$66
0.5%	Project Operation:	$232	$46	20.0%	$278	3.9%	$241	$48	$289	2023Q4	14.8%	$276	$55	$332
0.5%	Project Management	$232	$46	20.0%	$278	3.9%	$241	$48	$289	2023Q4	14.8%	$276	$55	$332
	CONTRACT COST TOTALS:	$48,236	$9,640		$57,876		$49,486	$9,914	**$59,400**			$55,336	$11,064	**$66,400**

Filename: San Francisco to Stockton Channel Improvement TPCS 1 Year Contract Jan 2019 v1CM.xlsx
TPCS

US Army Corps
of Engineers®

San Francisco Bay to Stockton General Reevaluation Report (GRR)

Project Cost and Schedule Risk Analysis Report

Prepared for:

U.S. Army Corps of Engineers,
San Francisco District

Prepared by:

Phillip C. Ohnstad, CPC, CCC
U.S. Army Corps of Engineers,
Walla Walla District

January 2019

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EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE), District, presents this cost and schedule risk analysis (CSRA) report regarding the risk findings and recommended contingencies for the San Francisco Bay to Stockton General Reevaluation Report (GRR). In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a *Monte-Carlo* based risk analysis was conducted by the Project Development Team (PDT) on remaining costs. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommended 80% confidence level of successful execution to project completion.

The San Francisco Bay to Stockton Federal Navigation Project was authorized by the 1965 Rivers and Harbor Act (RHA). The project includes the John F. Baldwin Ship Channel (consisting of the San Francisco Bar, Richmond Outer Harbor, West Richmond, Pinole Shoal, and Suisun Bay Channels), and the Stockton Deep Water Ship Channel (DWSC). The San Francisco Bar Channel (aka San Francisco Main Ship Channel) was deepened in 1975 to its authorized depth of -55 feet MLLW. Richmond Outer Harbor was deepened to its authorized depth of -45 feet MLLW in 1986. West Richmond, Pinole Shoal and Suisun Bay Channels were deepened to 35 feet MLLW in 1986; however, the authorized depth is at -45 feet MLLW. This reach (San Francisco Main Ship Channel to Suisun Bay Channels) of the ship channel is referred to as the Western Reach. The Stockton DWSC was deepened to its authorized depth of 35 feet MLLW in 1988 and is referred to as the Eastern Reach.

Subsequent to the 1965 authorization, Congress provided a separate study resolution via a House Resolution of the Committee on Transportation and Infrastructure (September 24, 1992) to determine if modifications to the 35 feet MLLW Stockton DWSC would be advisable for navigation and other purposes from the Carquinez Strait to Stockton. The Energy and Water Development Appropriation Act of 1998 included $100,000 for United States Army Corps of Engineers (USACE) to initiate a reconnaissance study for deepening the Stockton DWSC channel. At the request of the Port of Stockton and pursuant to section 905(b) of the Water Resources Development Act (WRDA) of 1986, the Sacramento District prepared a Reconnaissance Study in 1998 that concluded that there is sufficient federal interest to execute a FCSA and conduct feasibility studies for navigational improvements and ecosystem restoration in the Suisun Bay Channel, New York Slough Channel, and Stockton DWSC (i.e., Eastern Reach). The feasibility study to deepen the Stockton DWSC was incorporated into the San Francisco Bay to Stockton General Reevaluation Report (GRR).

Specific to the San Francisco Bay to Stockton General Reevaluation Report (GRR), the current project base cost estimate, pre-contingency, approximates $46M. This CSRA study excluded any spent costs, excludes contingencies and is expressed in FY 2018 dollars. Since the Real Estate office provided a separate 5% contingency for its real estate requirements, the Cost MCX performed study on the estimated remaining construction costs of $46M. Based on the results of the analysis, the Cost Engineering Mandatory Center of Expertise for Civil Works (MCX located in Walla Walla District) recommends a contingency value of $9M or approximately 20% of base project cost at an 80% confidence level of successful execution. This contingency includes a separate $2K for Real Estate, another $9M for the construction costs, and $360K for design and construction management.

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

Table ES-1. Construction Contingency Results

Base Case Construction Cost Estimate	**$46,335,000**	
Confidence Level	**Construction Value ($$) w/ Contingencies**	**Contingency (%)**
50%	$52,822,000	14%
80%	**$55,602,000**	**20%**
90%	$56,992,000	23%

KEY FINDINGS/OBSERVATIONS RECOMMENDATIONS

The PDT worked through the risk register on December 19, 2017 and the risk register was updated at a follow up meeting on December 18, 2018. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $9M and schedule risks adding another 0.5 months (10% risk), both at an 80% confidence level.

Cost Risks: From the CSRA, the key or greater Cost Risk items (top 5) include:

- ES2: Fuel Price – The volatility of fuel prices is a critical risk driver affecting cost.
- TR1: Change in Dredging Quantities – The quantities of material to be dredged could vary from the quantities that have been assumed based on newer and a greater number of cross-section surveys and underwater changes over time.
- CO1: Modifications and Claims During Construction – Changes and or Claims are always a possibility. Typical contract modifications on dredging contracts are 5% but can be expected to go as high as 10%.
- EX1: Market Conditions – Current market conditions could vary the dredging costs.
- TR5: Disposal site could be flooded – Weather conditions could flood disposal sites and limit capacity.

Schedule Risks: The moderate value of schedule risk indicates some uncertainty of key risk items, time duration growth that can translate into added costs. Over time, risks increase on those out-year contracts where there is a greater potential for change in new scope requirements, uncertain market conditions, and unexpected high inflation. The greatest risk is:

- TR1: Change in Dredging Quantities – The quantities of material to be dredged could vary from the quantities that have been assumed based on newer and a greater number of cross-section surveys and underwater changes over time.
- CO1: Modifications and Claims During Construction – Changes and or Claims are always a possibility. Typical contract modifications on dredging contracts are 5% but can be expected to go as high as 10%.

Recommendations: The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of the remaining project work within an approved budget and appropriation.

MAIN REPORT

1.0 PURPOSE

Within the authority of the US Army Corps of Engineers (USACE), San Francisco District, this report presents the efforts and results of the cost and schedule risk analysis for the San Francisco Bay to Stockton General Reevaluation Report (GRR). The report includes risk methodology, discussions, findings and recommendations regarding the identified risks and the necessary contingencies to confidently administer the project, presenting a cost and schedule contingency value with an 80% confidence level of successful execution.

2.0 BACKGROUND

As of January 2016, the GRR has successfully completed the Tentatively Selected Plan (TSP) milestone. Proposed phasing of the GRR into two separate studies (Phase I and Phase II) in an effort to comply with SMART Planning requirements was disapproved by HQ in response to a 3x3x3 exemption request meeting. The study was subsequently directed for transfer to South Atlantic Division by the Deputy Commanding General for Civil and Emergency Operations on 1 December 2016. This Project Management Plan (PMP) revision addresses the remaining scope, schedule and cost to complete the GRR in compliance with HQ direction that the scope of the study be reduced to address only opportunities in the western reach of the study area.

3.0 REPORT SCOPE

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

3.1 Project Scope

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

CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

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

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

3.2 USACE Risk Analysis Process

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

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

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

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering MCX.

- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008.

- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

4.0 METHODOLOGY / PROCESS

The Cost Engineering MCX performed the Cost and Schedule Risk Analysis, relying on local San Francisco District, Mobile District, and Jacksonville District Staff to provide expertise and information gathering. The team conducted initial risk identification via webinar/teleconference with the Walla Walla Cost Engineering MCX facilitator on December 19, 2017 and an update meeting was held on December 18, 2018. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the draft framework for the risk analysis.

Participants in the risk identification update meeting of December 18, 2018 included:

Attendance	Name	Office	Representing
Full	David Doak	CESPN	Civil
Full	Sherman Fong	CESPN	Cost Engineering
Full	Stacey Roth	CESAJ	Planning
Full	Stacie Auvenshine	CESAJ	Environmental
Full	Patrick Sing	CESPN	H&H
Full	Elizabeth Campbell	CESPN	Environmental
Full	Tu Nguyen	CESPN	Civil
Full	Bonievee Delapaz	CESPN	Real Estate
Full	Pam Castens	CESAW	Project Management

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

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

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

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

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

4.1 Identify and Assess Risk Factors

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

A formal PDT meeting was held with the PDT for the purposes of identifying and assessing risk from multiple project team disciplines and functions. The meeting included capable and qualified represent engineering, design, environmental compliance, and real estate.

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and location.

4.2 Quantify Risk Factor Impacts

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

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

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

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

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

5.0 PROJECT ASSUMPTIONS

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

a. The San Francisco District provided MII MCACES (Micro-Computer Aided Cost Estimating Software) and CEDEP files electronically. The MII and CEDEP files transmitted and downloaded on December 11, 2018 was the basis for the cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the preconstruction engineering and design (PED) level, most approximating a 10% design stage.

c. Schedules are analyzed for impact to the in terms of construction contract delays.

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

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

6.0 RESULTS

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

6.1 Risk Register

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

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

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.

- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Contingency and Sensitivity Analysis

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

Table 1 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P5, P50 and P90 confidence levels are also provided for illustrative purposes only.

Cost contingency for the Construction risks (including schedule impacts) was quantified as approximately $9 Million at the P80 confidence level (10% of the baseline construction cost estimate).

Table 1. Construction Cost Contingency Summary

Base Case Construction Cost Estimate	**$46,335,000**	
Confidence Level	**Construction Value ($$)**	**Contingency (%)**
50%	$52,822,000	13%
80%	**$55,602,000**	**20%**
90%	$56,992,000	23%

6.2.1 Sensitivity Analysis

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

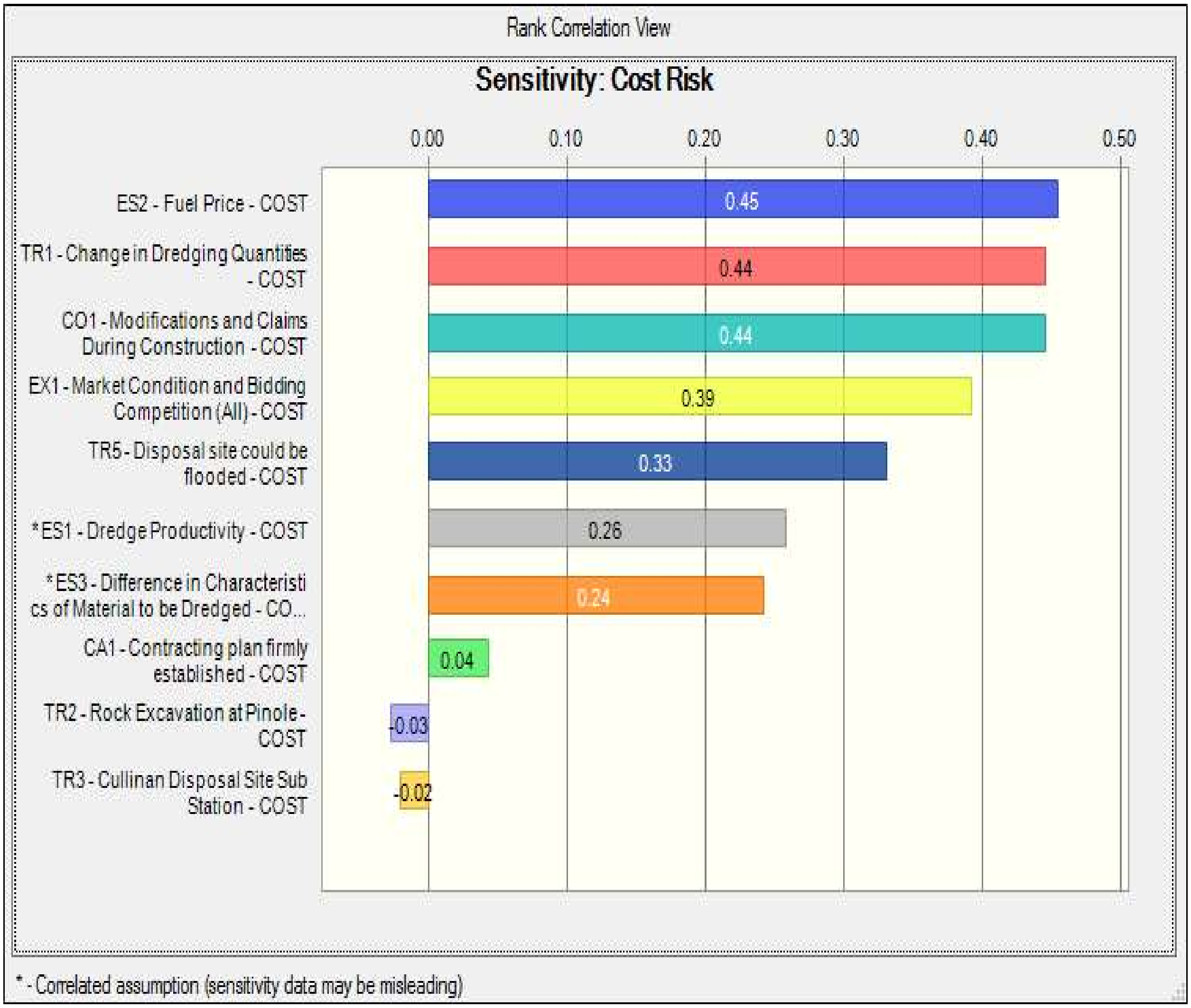
Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used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

6.2.2 Sensitivity Analysis Results

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

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

Figure 1. Cost Sensitivity Analysis



6.3 Schedule and Contingency Risk Analysis

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

Table 2 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P90 confidence levels are also provided for illustrative purposes.

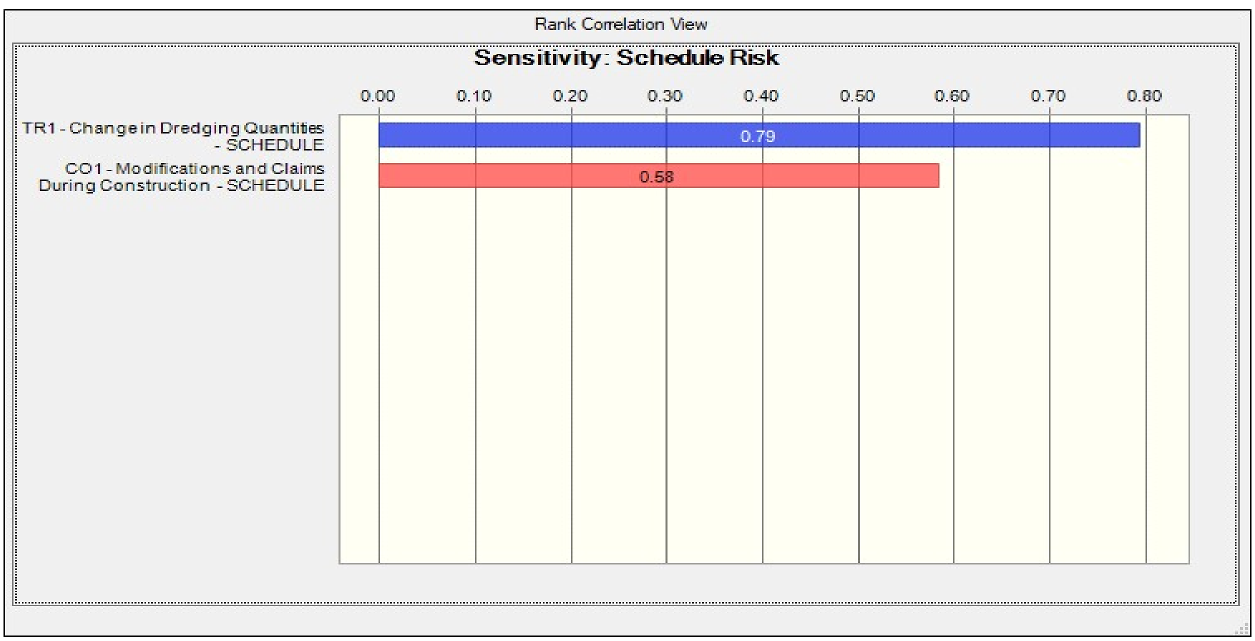
Schedule duration contingency was quantified as 58 months based on the P80 level of confidence. These contingencies were used to calculate the projected residual fixed cost impact of project delays that are included in the Table 1 presentation of total cost contingency. The schedule contingencies were calculated by applying the high level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based solely on projected residual fixed costs.

Table 2. Schedule Duration Contingency Summary

Risk Analysis Forecast (base schedule of 57 months)	Duration w/ Contingencies (months)	Contingency[1] (months)
50% Confidence	5.3	0.3
80% Confidence	5.5	0.5
90% Confidence	5.6	0.6

Figure 2. Schedule Sensitivity Analysis



7.0 MAJOR FINDINGS/OBSERVATIONS/RECOMMENDATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

7.1 Major Findings/Observations

Project cost and schedule comparison summaries are provided in Table 3 and Table 4 respectively. Additional major findings and observations of the risk analysis are listed below.

The PDT worked through the risk register on December 19, 2017. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $9M and schedule risks adding another 0.5 months, both at an 80% confidence level.

Cost Risks: From the CSRA, the key or greater Cost Risk items (top 5) include:

- ES2: Fuel Price – The volatility of fuel prices is a critical risk driver affecting cost.
- TR1: Change in Dredging Quantities – The quantities of material to be dredged could vary from the quantities that have been assumed based on newer and a greater number of cross-section surveys and underwater changes over time.
- CO1: Modifications and Claims During Construction – Changes and or Claims are always a possibility. Typical contract modifications on dredging contracts are 5% but can be expected to go as high as 10%.
- EX1: Market Conditions – Current market conditions could vary the dredging costs.
- TR5: Disposal site could be flooded – Weather conditions could flood disposal sites and limit capacity.

Schedule Risks: The moderate value of schedule risk indicates some uncertainty of key risk items, time duration growth that can translate into added costs. Over time, risks increase on those out-year contracts where there is a greater potential for change in new scope requirements, uncertain market conditions, and unexpected high inflation. The greatest risk is:

- TR1: Change in Dredging Quantities – The quantities of material to be dredged could vary from the quantities that have been assumed based on newer and a greater number of cross-section surveys and underwater changes over time.
- CO1: Modifications and Claims During Construction – Changes and or Claims are always a possibility. Typical contract modifications on dredging contracts are 5% but can be expected to go as high as 10%.

Table 3. Construction Cost Comparison Summary (Uncertainty Analysis)

INITIAL CONSTRUCTION
Contingency Analysis

Base Case Estimate (Excluding 01)	$46,335,013	
Confidence Level	Contingency Value	Contingency
0%	-4,633,501	-10%
10%	2,316,751	5%
20%	3,706,801	8%
30%	4,633,501	10%
40%	5,560,202	12%
50%	6,486,902	14%
60%	7,413,602	16%
70%	8,340,302	18%
80%	9,267,003	20%
90%	10,657,053	23%
100%	19,460,705	42%

Table 4. Construction Schedule Comparison Summary (Uncertainty Analysis)

Contingency Analysis

Base Case Schedule	5.0 Months	
Confidence Level	:ontingency Valu	Contingency
0%	0 Months	-9%
10%	0 Months	-2%
20%	0 Months	1%
30%	0 Months	3%
40%	0 Months	4%
50%	0 Months	5%
60%	0 Months	7%
70%	0 Months	8%
80%	1 Months	10%
90%	1 Months	12%
100%	1 Months	19%

7.2 Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

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

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

The CSRA study serves as a "road map" towards project improvements and reduced risks over time. Timely coordination and risk resolution between the Sponsor, Railroad, and USACE is needed in areas of ROW, mobile home relocations, site access and staging, and funding needs and updates as applicable. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

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

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

APPENDIX A

San Francisco Bay to Stockton Navigation Improvement Project (1 YEAR)									
				Project Cost			Project Schedule		
CREF	Risk/Opportunity Event	Risk Event Description	PDT Discussions on Impact and Likelihood	Likelihood ©	Impact ©	Risk Level ©	Likelihood (S)	Impact (S)	Risk Level (S)
Organizational and Project Management Risks (PM)									
PM1	Project Competing for Funding at the National Level	There is a risk that the project may not obtain funding in a timely manner due to other large projects competing for funds.	Inadequate funding will protract the project schedule. These will delay awarding the project but will not delay a contract once it is awarded and therefore is not modeled. Navigation is a high priority and is likely to be funded. Any funding delay (partial or full) is likely a full year delay.	Possible	Marginal	**Low**	Possible	Negligible	**Low**
PM2	Construction Timing	Construction and O&M work need to be coordinated and could delay the start of the construction contract.	Construction timing of deepening and O&M must occur in the summer of 2023 for Pinole Shoal. Any issues would delay the deepening construction to 2025. O&M will need be coordinated but is not a cost risk. Schedule will need to be coordinated but any delays would be 2 years. This is a programmatic risk and therefore is not modeled.	Unlikely	Marginal	**Low**	Unlikely	Negligible	**Low**
PM3	Project Partnership Agreement (PPA)	PPA agreement needs to be updated and could delay the contract.	Need to execute/modify a new PPA for cost sharing. This could lead to schedule delays. This is done prior to appropriations and could delay the deepening contract start. There is plenty of time in the schedule and unlikely.	Unlikely	Marginal	**Low**	Unlikely	Negligible	**Low**
PM4	CEQA	CEQA compliance during planning.	Failure to complete CEQA compliance prior to design could impact availability of non federal funding to proceed with the project as scheduled. Delays could be months to a year.	Unlikely	Marginal	**Low**	Possible	Moderate	**Medium**

Contract Acquisition Risks (CA)									
CA1	Contracting plan firmly established	Dredging costs are based on a firmly established procurement methodology.	The contracting plan for dredging contracts is normally IFB with full and open large business competition. Small business goals could lead to breaking the Suisun project into a smaller contract. Numerous contracts could lead to increased mob/demob costs. Small business impacts are unlikely but is possible to add a subcontract for offloading at Cullinan.	Possible	Moderate	**Medium**	Unlikely	Negligible	**Low**
CA2	Dredge Competition	Dredge shortage could lead to fewer and higher bids.	Corps studies have resulted in an expected dredge shortage as compared to the many anticipated projects in the region. Less competition is likely, resulting in higher bids. This is correlated to Market Conditions and therefore modeled in Market Conditions.	Possible	Marginal	**Low**	Unlikely	Negligible	**Low**
General Technical Risks (TR)									
TR1	Change in Dredging Quantities	The quantities of material to be dredged could vary from the quantities that have been assumed based on newer and a greater number of cross-section surveys and underwater changes over time.	Method of calculation of dredging quantities and surveying is well established from dredge history. Could be slight increase but PDT is confident in quantities.	Possible	Moderate	**Medium**	Unlikely	Negligible	**Low**

TR2	Rock Excavation at Pinole	Hard Rock at Pinole could add to excavation costs.	Work is assumed to be done with an excavator. Estimate assumes conservative case and the actual material could be easier to excavate and remove decreasing the costs.	Possible	Marginal	**Low**	Possible	Negligible	**Low**
TR3	Cullinan Disposal Site Sub Station	A Sub Station may be required.	If the environmental regulations do not allow diesel and needs an electrical substation. Additional costs for modifying the off loader and adding a substation to power the off loader at Cullinan. If costs at Cullinan were too high, disposal would be rerouted to Montezuma. Update 12/18/2018. Estimate includes costs to modify the Cullinan offloader to electrical.	Unlikely	Moderate	**Low**	Unlikely	Negligible	**Low**
TR4	Disposal site Capacity/Availability	If upland disposal sites do no have the capacity or are not available to receive material, it could lead to increased costs.	Capacity at both Montezuma and Cullinan. Need 6 months notice. 2 sites can receive material so risk of 2 not being available is low. In the unlikely event, material could be redirected to SF-DODS (until the end of Nov.).	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**
TR5	Disposal site could be flooded	Weather conditions could flood disposal sites and limit capacity.	If beneficial use sites cannot be dewatered, material may need to be redirected to SF-DODS. This would add to transportation costs and mitigation costs to offset the lost benefits. May need to purchase USFWS bank credits.	Possible	Moderate	**Medium**	Unlikely	Negligible	**Low**

TR6	Stiff Clays or rock encountered.	Stiff Clays or Rock could decrease productivity.	Minor risk of encountering stiff clay or rock that could decrease production. Sampling limits this risk and the impacts would be minor.	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**
TR7	Utility crossing in Pinole Shoal	Utility line conflicts could lead to increased costs.	Utility owner indicates there are no conflicts but there is a chance cables are buried higher and could cause a conflict. Hitting a utility could stop production and lead to schedule delays.	Unlikely	Negligible	**Low**	Possible	Marginal	**Low**
Equipment (EQ)									
EQ1	Equipment Availability	The availability and number of scows for this particular project is a concern.	2 clamshell dredges require 4 scows and they may not be available. If the optimum # of scows is not available at the time of the construction it could lead to inefficiencies with increase cost and schedule delays. PDT feels scow availability is not likely to be an issue.	Unlikely	Marginal	**Low**	Unlikely	Marginal	**Low**
Lands and Damages (LD)									

LD1	Real Estate Risk	Land and damages estimate scope is unclear.	Construction trailer, laydown yard, or site access costs for contractor assumed in estimate. Many contractors already have access to the dredging area and would not require land adjacent to the dredging area. The estimate and associated contingency is not part of the CSRA and therefore is not modeled.	Possible	Negligible	**Low**	Unlikely	Negligible	**Low**
LD2	Utility Relocations	Utility relocations not included in estimate.	Utility survey performed and no relocations are anticipated for this project.	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**
Regulatory Environmental Risks (RG)									
RG1	Sea Level Rise	The implementation of estimating sea level rise in the design life of all ACOE projects could affect the quantities and project cost.	This project is being constructed in 2023 and therefore the short term risk of sea level rise is low.	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**

RG2	SHPO	Possible sunken ship in work area.	Coordination with SHPO is underway and is not expected to adversely affect cultural resources. There is a possibility of a sunken ship in the dredging area (between Bulls Head and Pinole Shoal). Overlays have are being done with GIS data but will be done and the cost impacts are unlikely.	Possible	Negligible	**Low**	Unlikely	Negligible	**Low**
RG3	Environmental Clearances	ESA, MSA and MMPA consultations have been initiated with NMFS and USFWS but the final draft could be modified due to public/agency comment.	The timing of initiation of consultation is not expected to exceed typical consultation period of 135 days. Draft Biological Assessments and 404b analysis have been prepared to mitigate these effects. Project is designed to minimize impacts and the cost risk is minimal.	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**
RG4	CZMA	Bay Conservation and Development Commission may object to aspect of the recommended plan.	Bay Conservation and Development Commission (BCDC) is the entity responsible for reviewing consistency with California's Coastal Management Plan and may impose additional restrictions which could lead to additional cost and schedule delays. This is highly unlikely and they are anticipated to approve the plan.	Unlikely	Negligible	**Low**	Unlikely	Negligible	**Low**
RG5	Sediment Testing	Sediment testing of dredged material may indicate material is not suitable for disposal at the beneficial use site.	If testing of dredge materials during the PED phase indicate material is not suitable for disposal the beneficial use site, additional mitigation costs and/or dredge haul cost may be incurred. Montezuma accepts contaminated material but there is an additional cost of $30/CY so the SFDOD site may be utilized. Additional cost impacts would be marginal.	Possible	Marginal	**Low**	Unlikely	Negligible	**Low**

RG6	Emissions (NOX)	Emission could exceed the State standards.	If the emissions exceed the State standards, it could lead to requiring electrical equipment, breaking apart the dredging into 2 seasons, or purchasing mitigation offsets. Purchasing these offsets is not anticipated for this project. Multi season construction could add to mob/demob costs. Estimate assumes 2 clamshell dredges so additional dredging season could add 20% to costs. 1 or 2 year dredging will exceed the State standards. An exemption of State Override Concerns will be required for the project to move forward. This is a low risk item. Electrical offloading at Cullinan is planned and Montezuma is currently electric. Cost estimate includes the additional upgrades at Cullinan.	Possible	Marginal	**Low**	Unlikely	Negligible	**Low**
RG7	Salinity Intrusion	Other agencies may not agree that our salinity conclusions are the correct determination.	Modeling has been completed and impacts have been minimized. Other agencies may disagree and request additional modeling to demonstrate the location of the X2. This has a possibility to delay the project and impacts the construction schedule.	Unlikely	Negligible	**Low**	Possible	Marginal	**Low**
Construction Risks (CO)									

CO1	Modifications and Claims During Construction	Changes and or Claims are always a possibility. Typical contract modifications on dredging contracts are 5% but can be expected to go as high as 10%.	Due to the inherent unknowns related to physical conditions at all deepening locations there is always a possibility of unknowns; therefore, there is always a possibility that modifications and/or claims may occur. The physical impact of shoaling and placement area damage are usually paid for in separate emergency funded contracts. Direct cost to the O&M contracts would be limited to delay in mobilization or interruption of dredging. The risk level of "possible" seems reasonable in light of these historical facts. Testing and sampling during PED will minimize the possibility of claims during construction.	Possible	Moderate	**Medium**	Possible	Moderate	**Medium**
CO2	Navigation Traffic Conflicts	Traffic within the shipping channel could delay or halt construction.	A ship accident or oil spill within the channel could lead to standby costs and schedule delays.	Possible	Marginal	**Low**	Possible	Negligible	**Low**
CO3	Incompetent Contractor	Incompetent Contractor could lead to inefficiencies and schedule delays.	Incompetent contractor could lead to productivity problems and schedule delays. Contract termination would add mob/demob cost and schedule delays for a new solicitation.	Unlikely	Moderate	**Low**	Unlikely	Moderate	**Low**
Estimate and Schedule Risks (ES)									

ES1	Dredge Productivity	Dredging efficiencies could vary considerably depending on the size of the dredge plant used, characteristics of the material dredged, bank heights, haul distances.	Dredging efficiency affects cost and dredging time. This is not O&M dredging and productivity on deepening project may be less than anticipated due to encountering rock or silty material. New work has conservative production numbers and the PDT feels this will accurately represent the contract pricing. Actual jobsite dredging efficiency may increase and not lead to any contract savings but could affect the schedule.	Possible	Moderate	**Medium**	Possible	Moderate	**Medium**
ES2	Fuel Price	The volatility of fuel prices is a critical risk driver affecting cost.	Increases in the fuel price will increase construction costs. Historically, fuel cost has been the major contributor to cost growth on dredging jobs.	Likely	Significant	**High**	Unlikely	Negligible	**Low**
ES3	Difference in Characteristics of Material to be Dredged	The types and classifications of materials for the purposes of estimating could present a risk to the project costs and schedule. Since future dredging is in new work areas, there is some uncertainty about the types of material that will be encountered.	Material types affect dredging efficiency which drives the costs. Limited Geotechnical data of the dredged material may result in encountering unanticipated materials that could be more difficult to dredge that would impact productivity. Sediment testing done to 45' and includes the whole prism depth. Confirmatory testing will need to be done in PED phase. Challenged material cannot be used as cover at either Montezuma or Cullinan and could add to costs if we find elevated levels of metals. Test results could change disposal sites and add to costs. Characteristic of dredge material is directly related to the dredge productivity and therefore linked with a 50% correlation.	Possible	Moderate	**Medium**	Unlikely	Negligible	**Low**
ES4	Overflow of Material	If overflow is allowed it could decrease costs.	The estimate assumes no overflow. If material is limited in silty material, overflow will be allowed and decrease the construction dredging costs. The PDT feels the need for overflow quality monitoring will not be required for this project.	Possible	Marginal	**Low**	Possible	Marginal	**Low**
External Risks (EX)									

EX1	Market Condition and Bidding Competition (All)	Current market conditions could vary the dredging costs.	If competition is good, contractor bids could approach five percent lower or 10% higher than the government estimate of construction cost. USACE projects have experienced high values as much as 20% higher but the PDT feels the competition for this bay area work is very competitive and the risk to be lower than typical.	Likely	Significant	**High**	Unlikely	Negligible	**Low**
EX2	Severe Weather Impacts	Fog & heavy rain could lead to schedule delays.	Upland disposal sites could experience delays due to fog leading to schedule and standby costs. Costs are minimal due to anticipated days included in contract. Severe weather in other parts of the country could tie up contractors. Most storm support is pipeline and is not much of a factor for clamshell dredging.	Possible	Marginal	**Low**	Unlikely	Marginal	**Low**
EX3	Stakeholder/Sponsor	Stakeholder/Sponsor changes could add requirements or delays.	No changes or additions anticipated from stakeholder or sponsor. See PPM 3 for PPA agreement changes.	Unlikely	Negligible	**Low**	Unlikely	Marginal	**Low**
EX4	Incremental Funding	Incremental funding could delay the project.	Decreased or delayed funding would delay the start. A partial project is not anticipated. Delayed funding is not modeled.	Possible	Negligible	**Low**	Possible	Marginal	**Low**
EX5	Sponsor funding	Sponsor (Port of Stockton) funding could delay the project.	Non federal sponsor (Port of Stockton) may not have funding and could delay the project. Delayed funding is not modeled. Risk captured in Risk PM4 (CEQA).	Unlikely	Negligible	**Low**	Unlikely	Marginal	**Low**