APPENDIX F

HABITAT EVALUATION PROCEDURE

COST EFFECTIVENESS/INCREMENTAL COST ANALYSIS

White Paper
Revised Habitat Evaluation Procedures Outputs for the Delta Islands and Levees Feasibility Study Selected Plan

Background

The U.S. Army Corps of Engineers (USACE) initiated the Delta Study in 2006 at the request of the California Department of Water Resources (DWR), the non-Federal sponsor for the study. USACE and the DWR have identified a Federal interest in conducting an ecosystem restoration project to reverse subsidence and restore lost intertidal marsh habitat. The restoration work would involve placing dredged material into open water habitat over an estimated 10 year period and installing marsh vegetation. This proposal provides a unique opportunity to restore intertidal marsh, habitat which is now greatly reduced in this ecosystem of national significance. The proposed alternatives link the proposed ecosystem restoration actions to historic and ongoing USACE navigation projects, providing a cost effective mechanism to implement otherwise costly subsidence reversal. This results in restoration of habitat for multiple Federally listed species, notably salmonids and Delta smelt. The restored habitat would also benefit the millions of migratory fowl on the Pacific Flyway as they travel through the Delta.

Changes to the Selected Plan

A recommendation for plan selection was made by identifying the plan that reasonably maximizes environmental outputs relative to costs while meeting planning objectives and avoiding planning constraints. In May 2017 at the Agency Decision Milestone, the Tentatively Selected Plan presented to the vertical chain, involved a proposed 84 acres of intertidal marsh restoration over 10 years of direct placement of dredged material. Following approval at the milestone meeting, USACE initiated feasibility level design, in order to develop a greater level of detail for the recommended plan, as described in Appendix C of the Feasibility Report/Environmental Impact Statement (FS/EIS).

Two factors were of particular importance during design refinement.

- Additional data and information regarding the composition of dredged material to be used in the recommended plan indicates that the material will be sand, rather than silt as previously assumed. As a sandy material will form into mounds when placed via hydraulic dredging, the design of the recommended plan changed to incorporate the varying topography and interwoven channels.
- Building off of the change of substrate, designs of the recommended plan were refined using a more diverse, multi-species, ecosystem approach, which ultimately decreased the initial overall target elevations with a goal of providing habitat benefits to Federally listed fish species such as juvenile salmonids and Delta smelt. The channels will provide foraging habitat for fish species, in addition to spawning habitat for Delta smelt. Aquatic vegetation would provide a food source for fish species, as well as nesting habitat for marsh wren and foraging habitat for other migratory fowl. Additionally, this change in target elevation incorporated the lessons learned from

Donlon Island, which focused on a need to provide more water circulation through the site, and allowed for an improvement in aquatic habitat quality in addition to an increase in acreage of marsh wren habitat for the purpose of benefits calculation.

These two factors described above would apply to all alternatives under consideration in this study; therefore, previous plan formulation evaluations and comparisons of alternatives were not revisited.

These refined design characteristics resulted in an increase in the size of the restoration area from 84 acres to 340 acres due to the varying topography, interwoven channels, and decrease in target elevations, with the estimated total cost decreasing from $23M to $22.3M; and the annual cost per acre decreasing from $274,000 to $66,000. The revised project description is described in detail in Section 3.9 of the FR/EIS. Additional information is included in Chapter 8 of the FR/EIS. The purpose of this White Paper is to communicate the updated Habitat Evaluation Procedures (HEP) analysis in order to communicate the benefits of the refined Selected Plan.

Habitat Evaluation Procedures (HEP) Update

The purpose of the HEP is to provide a quantitative basis for identifying the habitat values which would be created by the construction of the proposed alternatives. The quantitative outcomes can then be used for decisions to select the most appropriate alternative plan. Initially, the HEP was applied to all of the final array of alternatives, and then the tentatively selected plan was chosen based on the most cost effective alternative. Design refinements have since occurred, as described above, that impact the benefits communicated in the initial HEP analysis. As a result, this updated HEP is intended to communicate the change in benefits on the Selected Plan.

The Habitat Suitability Models: Marsh Wren (U.S. Fish and Wildlife Service, 1987) was used to assess outputs of each alternative during plan formulation. The marsh wren requires emergent herbaceous vegetation, typically cattails and bulrushes for nesting and cover in water greater than 15 centimeters. The intertidal marsh habitat being proposed would meet typical marsh wren requirements and is a scarce habitat type within the Delta. This model was selected because it is an approved bluebook model that has been used in other projects in the area, is focused on the target habitat type, and has been coordinated with the USFWS. USACE planning guidelines require habitat suitability models which are certified through the USACE Ecosystem Restoration Planning Center of Expertise (Eco-PCX). The Marsh Wren model meets these guidelines in addition to providing measureable outputs to compare alternatives. The Eco-PCX confirmed that the model meets the approved guidelines.

Although the Marsh Wren model provided an appropriate indicator of relative ecosystem outputs for comparison of alternative sites, the Marsh Wren is not the only target species for intertidal marsh restoration. Marsh wrens require dense stands of emergent herbaceous vegetation, typically cattails *(Typha* spp.), and bulrushes *(Schoenoplectus* spp.) for nesting and cover. They prefer emergent vegetation in relatively deeper water; depths greater than 15 centimeters deep is considered optimum. The habitat variables established in the marsh wren HSI model are:

- Variable 1 – Growth form of emergent hydrophytes;
- Variable 2 – Canopy cover of emergent herbaceous vegetation;
- Variable 3 – Mean water depth; and,
- Variable 4 – Canopy cover of woody vegetation.

These habitat variables were assessed for the future condition of the selected plan by applying lessons learned from the Donlon Island reference site and through the expected future condition documented through the targets and success criteria identified in Appendix M of the FR/EIS, the Monitoring and Adaptive Management Plan.

The product of quantity (acres) versus quality (HSI) is comparable to "habitat value". This formula is expressed as a Habitat Unit (HU). The Average Annual Habitat Units (AAHUs) over the period of analysis can then be calculated and used to determine mitigation needs. Since it is not possible to empirically determine habitat quality and quantity for future years, future HSI values were projected. Four Target Years (TY) were projected over the period of analysis:

- TY0 is the baseline condition prior to restoration.
- TY1 through TY10 encompasses the estimated 10 year construction period, with aquatic plant installation beginning in TY2 and ending in TY11.
- TY13 represents the estimated end of the monitoring period, when established vegetation is anticipated to have met the success criteria based on the lessons learned at Donlon Island. This monitoring estimate is established in the Monitoring and Adaptive Management Plan, Appendix M of the FR/EIS.
- TY50 is 50 years following implementation, and is considered the end of the period of analysis.

Table 1. Habitat Suitability Index (HSI) Variables and Resulting Outputs for the Marsh Wren Model With-Project.

Target Year	Plantable Acreage	Planted Acreage	Estimated Natural Recruitment	Total Vegetated Acreage	Variables				Suitability Index				Output	Total Acres	HUs
					V1	V2	V3	V4	SI-V1	SI-V2	SI-V3	SI-V4	HSI		
TY0	0	0	0	0	Cat 4	0%	103.6 cm	0%	0.0	0.0	1.0	1.0	0.0	0	0
TY1	0	0	1.5	1.5	Cat 1	4%	99.1 cm	0%	1.0	0.01	1.0	1.0	0.20	34	6.8
TY2	9	0.09	3.5	3.59	Cat 1	5%	94.5 cm	0%	1.0	0.02	1.0	1.0	0.22	68	14.96
TY3	18	0.18	8.0	8.68	Cat 1	8.5%	89.9 cm	0%	1.0	0.03	1.0	1.0	0.26	102	26.52
TY4	27	0.27	16.5	16.77	Cat 1	12%	85.3 cm	0%	1.0	0.03	1.0	1.0	0.29	136	39.44
TY5	36	0.36	26.5	26.86	Cat 1	16%	80.8 cm	0%	1.0	0.04	1.0	1.0	0.32	170	54.4
TY6	45	0.45	37.0	37.45	Cat 1	18%	76.2 cm	0%	1.0	0.04	1.0	1.0	0.33	204	67.32
TY7	54	0.54	46.5	47.04	Cat 1	20%	70.1 cm	0%	1.0	0.04	1.0	1.0	0.34	238	80.92
TY8	63	0.63	56.5	57.13	Cat 1	21%	64.0 cm	0%	1.0	0.05	1.0	1.0	0.35	272	95.2
TY9	72	0.72	65.5	66.22	Cat 1	21.5%	57.9 cm	0%	1.0	0.05	1.0	1.0	0.35	306	107.1
TY10	81	0.81	75.0	75.81	Cat 1	22%	51.8 cm	0%	1.0	0.05	1.0	1.0	0.35	340	119
TY11	90	0.9	83.5	84.40	Cat 1	24%	51.8 cm	0%	1.0	0.05	1.0	1.0	0.36	340	122.4
TY13	90	0.9	85.0	85.9	Cat 1	25%	51.8 cm	0%	1.0	0.05	1.0	1.0	0.37	340	125.8
TY50	90	0.9	87.0	87.9	Cat 1	26%	51.8 cm	0%	1.0	0.05	1.0	1.0	0.37	340	125.8
$HSI = (SI\text{-}V1 \times SI\text{-}V2 \times SI\text{-}V3)^{1/3} \times SI\text{-}V4$															

The assumptions included in Table 1 for each variable are as follows:

- Variable 1: Preconstruction condition in TY 0 is unvegetated open water habitat, so no emergent hydrophytes are present. Donlon Island monitoring reports show that cattails began to repopulate within 1 year. Therefore, emergent hydrophytes would be present in limited quantities beginning in TY 1, with planting of additional emergent hydrophytes beginning in TY 2.
- Variable 2: Preconstruction condition in TY 0 is unvegetated open water habitat, so there is no canopy cover in the baseline condition. Each construction season would result in an estimated 9 acres of dredged material at elevations suitable for planting. Donlon Island monitoring reports show that cattails began to repopulate within 1 year. Therefore, an estimated acreage based on the results displayed in the Donlon Island monitoring reports was developed in limited quantities beginning in TY 1 in order to calculate the canopy cover. Beginning in TY 2, vegetation would be installed on 10% of the newly plantable area (0.9 acre) each year for the duration of the construction period. In addition, it is anticipated that natural recruitment would occur and would be aided by the additional plantings each year. An estimated acreage for annual natural recruitment was developed based on the results of monitoring at Donlon Island. The planted acreage combined with the estimated natural recruitment was compared to the overall acreage of the restoration site in each TY in order to develop the annual canopy cover.
- Variable 3: Baseline condition in the restoration site is a range of 3 to 4 feet mean tide level (MTL), which averaged to mean water depth of 103.6 centimeters (cm). Each year of dredged placement would raise the mean water depth slightly throughout the construction period. The change in mean water depth was estimated consistent with the proposed dredged material placement plan.
- Variable 4: Baseline condition is unvegetated open water habitat, so no woody vegetation is present. The proposed restoration site would not support growth of woody vegetation, therefore, none would remain present over the period of analysis.

Table 1 shows the results of the initial HEP analysis, with a total value of 125.8 Habitat Units (HUs) for the proposed restoration project. This data was calculated using the ECO-PCX certified marsh wren spreadsheet (Attachment 1). The data in Table 1 was then inputted into the ECO-PCX certified Institute for Water Resources (IWR) Planning Suite Version 2.0.9.1 to annualize the data and determine the average annual habitat units (AAHUs). The annualizer determined that over the period of analysis, the proposed restoration site would provide approximately 111.44 AAHUs. The outputs are shown in Figure 1 below.

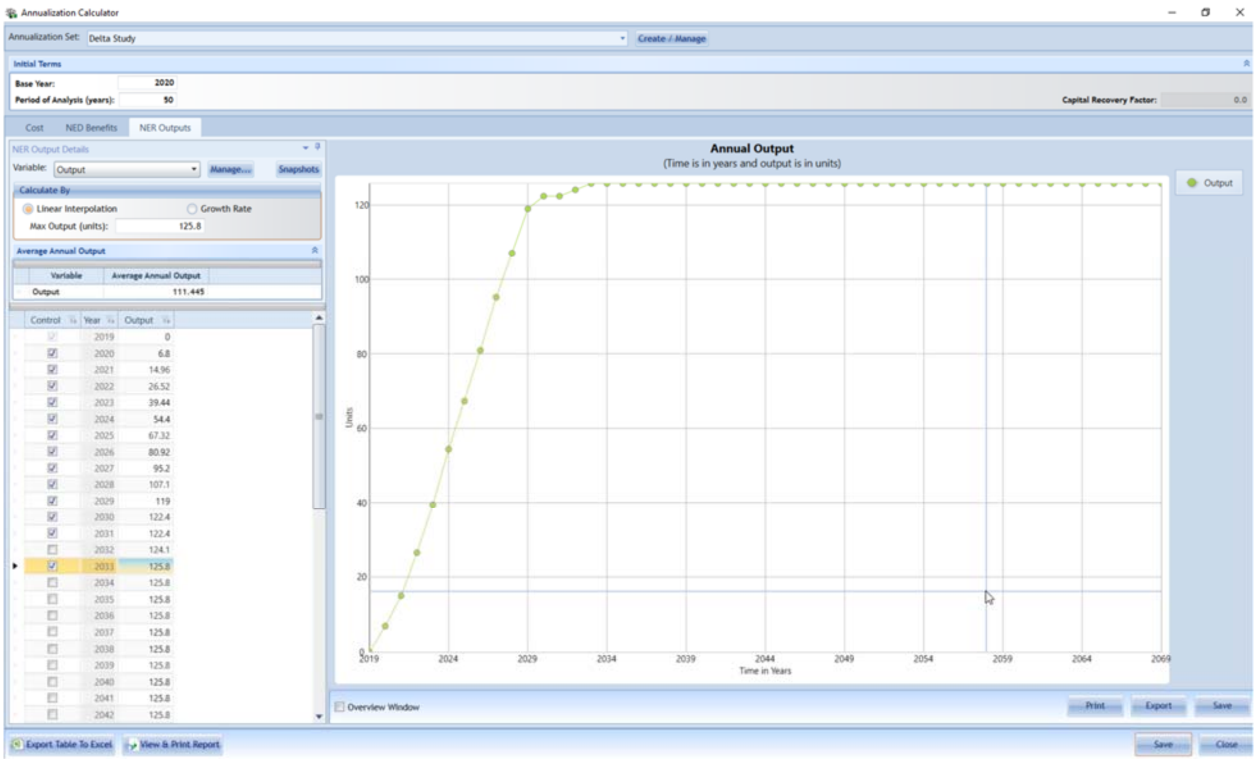


Figure 1. Annual Outputs for Proposed Delta Study Restoration.

Conclusion

This updated HEP analysis shows the updated HSI calculations, HUs, and AAHUs for the Delta Study selected plan and supersedes the results of the 2014 HEP Report, which is attached. The 2014 HEP Report's results are still applicable to the study as they are the basis for the Cost Effectiveness/Incremental Cost Analysis that was used for plan formulation and selection.

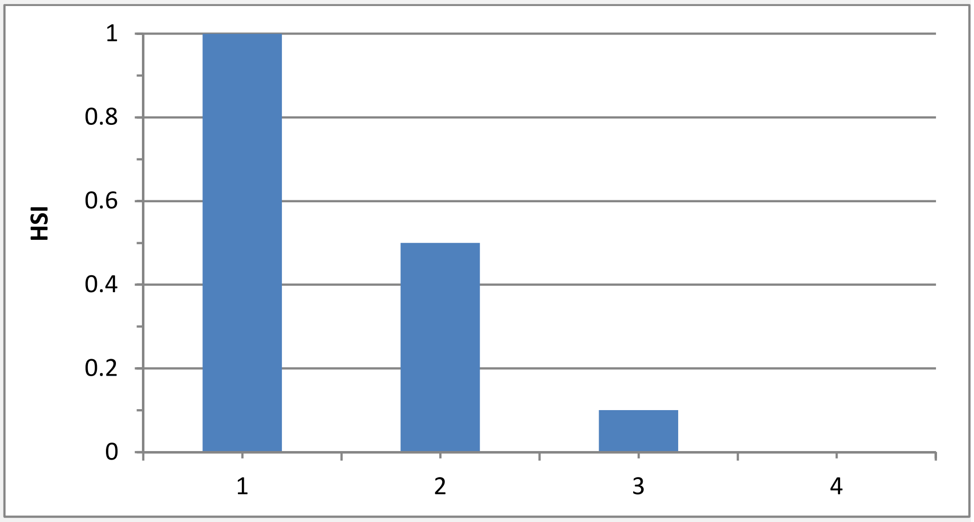
These updated results, as presented in this White Paper, are reflective of the analysis associated with feasibility level design for the selected plan. Should any of the assumptions in the selected plan change, then these calculations would also require further updating.

The proposed restoration would provide a total of 125.8 HUs, and 111.44 AAHUs based on the marsh wren model for evaluating intertidal marsh habitat.

HSI GRAPHS
This worksheet documents the equations created to match the suitability index graphs presented in the Marsh Wren Habitat Suitability Index Model.

V1 - Growth form of emergent hydrophytes

X	Y
1	1
2	0.5
3	0.1
4	0



1. Cattails, cordgrasses, bulrushes

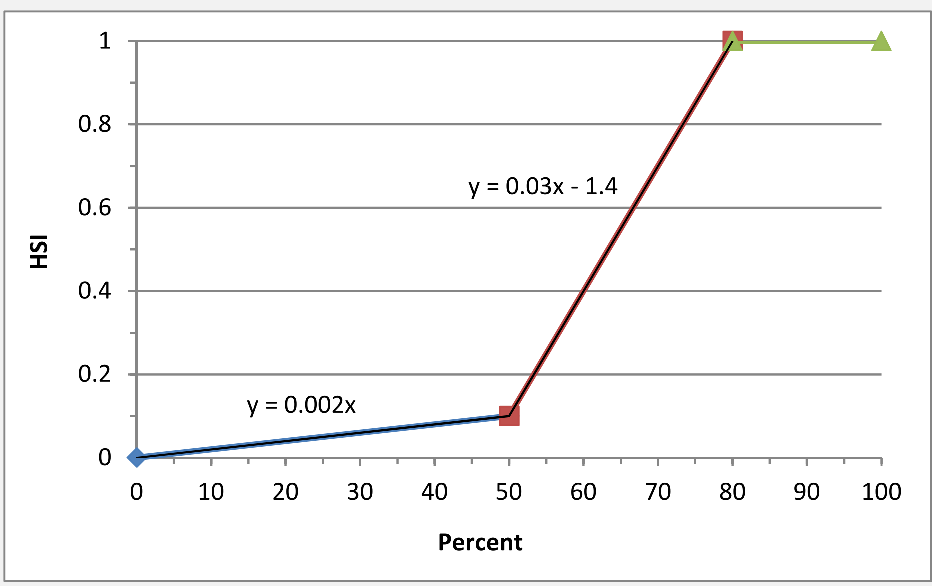
2. bluejoint reedgrass, reed canarygrass, sedges

3. buttonbush, mangrove

4. Other growth forms not listed

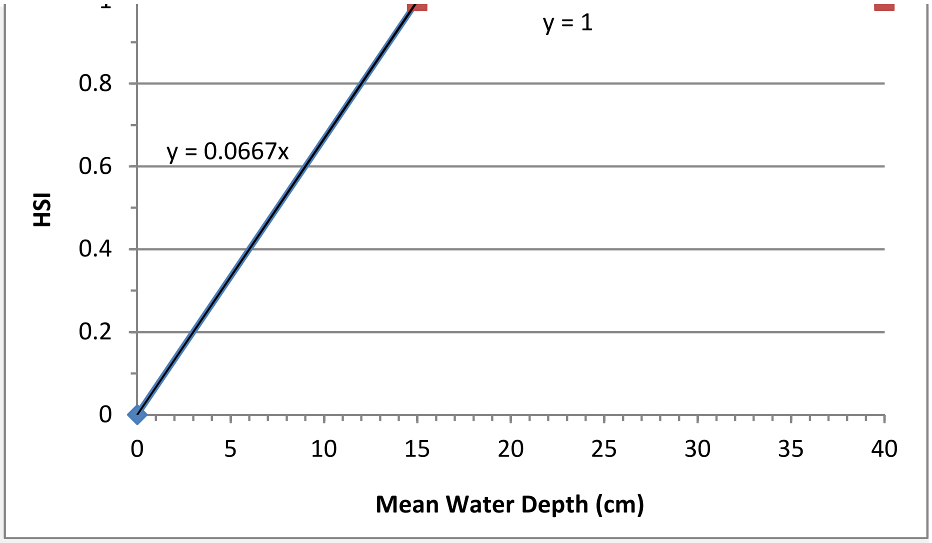
V2 - Percent canopy cover of emergent herbaceous vegetation

X	Y
0	0
50	0.1
80	1
100	1



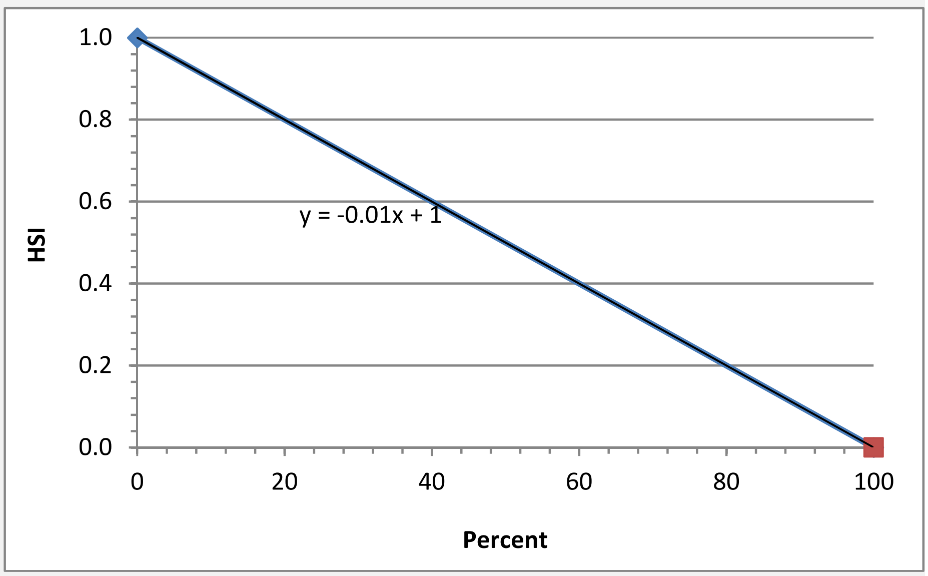
V3 - Mean Water Depth

X	Y
0	0
15	1
40	1



V4 - Percent canopy cover of woody vegetation

X	Y
0	1
100	0



MARSH WREN (*Cistothorus palustris*) HABITAT SUITABILITY INDEX (HSI) WORKSHEET Enter Data Values below which are highlighted green *Consult model documentation for applicability and limitations before using this spreadsheet*	Worksheet Description (*optional*)	Page

Enter Condition:	Recommended Plan	Enter Year:	TY 0	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	4) Other...	0.00	Existing Condition is unvegetated open water
V2	Percent canopy cover of emergent herbaceous vegetation	0%	0.00	
V3	Mean water depth (**cm**)	103.6	1.00	Mean Tide Level (MTL) is 3-4 feet existing (3.4)
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.00	

Enter Condition:	Recommended Plan	Enter Year:	TY 1	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	Some cattails should establish within 1 year
V2	Percent canopy cover of emergent herbaceous vegetation	4%	0.01	
V3	Mean water depth (**cm**)	99.1	1.00	MTL is 3.25 after 1 year of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.20	

Enter Condition:	Recommended Plan	Enter Year:	TY 2	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	5%	0.01	
V3	Mean water depth (**cm**)	94.5	1.00	MTL is 3.1 after 2 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.22	

Enter Condition:	Resommended Plan	Enter Year:	TY 3	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	9%	0.02	
V3	Mean water depth (**cm**)	89.9	1.00	MTL is 2.95 after 3 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.26	

Enter Condition:	Recommended Plan	Enter Year:	TY 4	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	12%	0.02	
V3	Mean water depth (**cm**)	85.3	1.00	MTL is 2.8 after 4 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.29	

Enter Condition:	Recommended Plan	Enter Year:	TY 5	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	16%	0.03	
V3	Mean water depth (**cm**)	80.8	1.00	MTL is 2.65 after 5 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.32	

Enter Condition:	Recommended Plan	Enter Year:	TY 6	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	18%	0.04	
V3	Mean water depth (**cm**)	76.2	1.00	MTL is 2.5 after 6 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.33	

Enter Condition:	Recommended Plan	Enter Year:	TY 7	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	20%	0.04	MTL is 2.3 after 7 years of construction
V3	Mean water depth (**cm**)	70.1	1.00	
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.34	

MARSH WREN (*Cistothorus palustris*) HABITAT SUITABILITY INDEX (HSI) WORKSHEET Enter Data Values below which are highlighted green *Consult model documentation for applicability and limitations before using this spreadsheet.*	Worksheet Description (*optional*)	Page

Enter Condition:	Recommended Plan	Enter Year:	TY 8	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	21%	0.04	
V3	Mean water depth (**cm**)	64.0	1.00	MTL is 2.1 after 8 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.35	

Enter Condition:	Recommended Plan	Enter Year:	TY 9	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	22%	0.04	
V3	Mean water depth (**cm**)	57.9	1.00	MTL is 1.9 after 9 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.35	

Enter Condition:	Recommended Plan	Enter Year:	TY 10	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	22%	0.04	26% is the maximum plantable acreage
V3	Mean water depth (**cm**)	51.8	1.00	MTL is 1.7 after 10 years of construction
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.35	

Enter Condition:	Final Year of Planting	Enter Year:	TY 11	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	24%	0.05	
V3	Mean water depth (**cm**)	51.8	1.00	
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.36	

Enter Condition:	End of Monitoring Period	Enter Year:	TY 13	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	25%	0.05	
V3	Mean water depth (**cm**)	51.8	1.00	
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.37	

Enter Condition:	Period of Analysis	Enter Year:	TY 50	
Variable	Description	Data	HSI	Comments
V1	Growth form of emergent hydrophytes	1) Cattails...	1.00	
V2	Percent canopy cover of emergent herbaceous vegetation	26%	0.05	
V3	Mean water depth (**cm**)	51.8	1.00	
V4	Percent canopy cover of woody vegetation	0%	1.00	
	Final HSI		0.37	

Habitat Evaluation Procedures
Delta Islands and Levees Feasibility Study
February 2014

Introduction:

This application of Habitat Evaluation Procedures (HEP) is intended to quantify the anticipated benefits to fish and wildlife resources that would occur with the creation of intertidal marsh ecosystem restoration proposed in the Delta Islands and Levees Feasibility Study (Delta Study).

Project Description:

Corps of Engineers-Sacramento District (Corps) and the Central Valley Flood Protection Board (CVFPB) are considering restoration of intertidal marsh habitat using dredged material at Big Break and Little Frank's Tract. The ecosystem restoration measures that were retained through all screenings include: restore intertidal habitat with subsidence reversal at Big Break, Frank's Tract, and Little Frank's Tract. Detailed descriptions and final increments of these measures follow.

Prior to levee construction in the 1800's, Big Break, Frank's Tract, and Little Frank's Tract were comprised of intertidal marsh. Levees were constructed to drain the lands for agricultural use, resulting in subsidence of the land surface. Levee failure occurred in the early to mid 1900's and these areas were not reclaimed; however, enough subsidence had already occurred that these open water expanses now function ecologically as lakes, providing no value to native species.

The primary action required to restore habitat value to native species at Big Break, Frank's Tract, and Little Frank's Tract is subsidence reversal. Similar restoration actions were undertaken by USACE in the 1990's at nearby Venice Cut and Donlon Island. This restoration has demonstrated that subsidence reversal to restore land surface to intertidal elevations, along with minimal plantings, can result in successful restoration of intertidal marsh with 80% vegetation coverage within 2 years. Measures considered at Big Break, Frank's Tract, and Little Frank's Tract are based on the success of these reference sites.

Subsidence Reversal

While target elevations are consistent between the sites, current elevations vary from site to site, resulting in differing requirements for volume of material per acre. Intertidal marsh restoration at Big Break (1,064 acres of marsh with an additional 15% of open water) would require 12.7 million cubic yards of material, or 9,400 cubic yards of material per acre. Intertidal marsh restoration at Frank's Tracts (2,470 acres of marsh with an additional 15% of open water) would require 42.6 million cubic yards of material, or 17,200 cubic yards of material per acre. Intertidal marsh restoration at Little Frank's Tracts (273 acres of marsh with an additional 15% of open water) would require 4.6 million cubic yards of material, or 16,800 cubic yards of material per acre.

Increments were developed for each site based on availability and proximity of fill material, as this is the primary driver in restoring ecological function and the primary driver of cost. Based on monitoring results from the Donlon Island and Venice Cut reference sites, it is expected that placement of fill material to the appropriate elevations, followed by plantings of bulrush will be the only required actions to restore intertidal marsh. As elevations are relatively constant within each site, calculations were made to determine the volume of fill needed per acre at each site. Volumes of available material were matched to the most efficient potential site. Potential sources of material include:

- *Direct placement from Operations and Maintenance dredging of the Stockton Deep Water Ship Channel* – assumes normal hydraulic dredging operations with suspended material directly placed into the restoration area(s) via pipeline and contained in an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways;
- *Pumping previously dredged material from nearby stockpiles* – utilize previously dredged material in nearby stockpiles by creating a slurry that can be pumped into the restoration area(s) via pipeline and contained in an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways; and
- *Trucking and/or barging material from borrow sites within a 30 mile radius* – truck and/or barge material from borrow sites within a 30 mile radius and place material into the restoration area(s) either directly from trucks (where possible) or via excavators on barges into an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways.

Vegetation

Dredged material will be transported to the site as described above and placed to bring the substrate to a target elevation of 4.5 feet mean sea level. This area will be conducive to aquatic vegetation and anchored to the adjacent existing levee. The planting design includes planting bulrush (Typha sp.) over the area and will be suitable to develop intertidal marsh habitat. Plantings will be installed at 3 feet o.c. over 10% of the intertidal marsh area. The plant material may be nursery grown, or collected from nearby sources and directly planted at the site.

Increments

Increments of restoration at each site were developed based on an acre grid system. Available fill material calculations were used to determine the size of increments, i.e., how many grid cells each increment included. Locations of increments are general within each site and are based on proximity to fill material, proximity to remnant levees for improved constructability, and connectivity to existing habitat. Measures considered at Big Break, Frank's Tract, and Little Frank's Tract are based on the success of these reference sites.

HEP Overview:

The HEP is a methodology developed by the Fish and Wildlife Service (Service) and other State and Federal resource agencies which can be used to document the quality and quantity of available habitat for selected fish and wildlife species. The HEP provides information for two general types of habitat comparisons: (1) the relative value of different areas at the same point in time; and (2) the relative value of the same areas at future points in time. By combining the two types of comparisons, the impacts of the proposed or anticipated land-use and or water-use changes on habitat can be quantified. In a similar manner, any compensation needs (in terms of acreage) for the project can also be quantified, provided a mitigation plan has been developed for specific mitigation sites.

A HEP application is based on the assumption that the value of a habitat for a selected species or the value of a community can be described in a model which produces a Habitat Suitability Index (HSI). This HSI value (from 0.0 to 1.0) is multiplied by the area of available habitat to obtain Habitat Units (HUs). The HU and Average Annual Habitat Units (AAHUs) over the life of the project are then used in the comparison described above. The reliability of a HEP application and the significance of HUs are directly dependent on the ability of the user to assign a well-defined and accurate HSI to the selected evaluation elements or communities. In addition, a user must be able to measure the areas of each distinct habitat being utilized by fish and wildlife species within the project area. Both the HSIs and the habitat acreages must also be reasonably estimable at various future points in time. The HEP Team, comprised of Corps, DWR, and Service, staff, determined that the HEP criteria could be met, or at least reasonably approximated, for the Delta Study. Thus HEP was considered an appropriate analytical tool to assess the proposed restoration project.

General HEP Assumptions:

Some general assumptions are necessary to use HEP and HSI Models in the impact assessment.

Use of HEP:

- The HEP is the preferred method to evaluate the impacts of the proposed project on fish and/or wildlife resources.
- The HEP is a suitable methodology for quantifying project-induced impacts on fish and wildlife habitats.
- Quality and quantity of fish and wildlife habitat can generally be numerically described using the indices derived from the HSI models and associated habitat units.
- The HEP assessment is applicable to the habitat types being evaluated.

Use of HSI Models

- The HSI models are hypotheses based on available data.
- The HSI models are conceptual models and may not measure all ecological factors that affect the quality of a given cover-type for the evaluation species (e.g. vulnerability to predation). In some cases, assumptions may need to be made by the HEP Team and incorporated into the analysis to account for loss of those factors not reflected by the model.

Methodology:

This HEP application will be used to quantify the value of the ecosystem restoration of intertidal marsh habitat proposed in the Delta Study.

A site visit to Big Break, Little Frank's Tract, Frank's Tract, and Donlon Island was attended by Department of Water Resources (Ted Frink), Service (Brian Hansen), NMFS (Mike Hendrick and Julie Wolford), and Corps (Brad Johnson and Brian Luke) on November 13, 2013. The HEP team considered the proposed design, Donlon Island restoration site, a previous HEP for the Bethel Island Levee Improvement Project, and Corps approved models in selecting the appropriate HSI for the proposed intertidal marsh restoration.

The marsh wren HSI model was selected for use in projects with intertidal marsh habitats. Marsh wrens require dense stands of emergent herbaceous vegetation, typically cattails and bulrushes *(Typha* spp.) for nesting and cover. They prefer emergent vegetation in relatively deeper water, > 15 centimeters deep is considered optimum.

Model assumptions were developed as the basis for the assessment. The assumption regarding existing and future without-project conditions is that little to no intertidal marsh habitat is or will be present at the sites; therefore, AAHUs without-project are projected at 0.

The future with-project assumption is that elevations are restored to support a robust intertidal marsh habitat shown in Table 1. Given these assumptions, long-term losses and gains in HUs can be estimated for each future scenario over the life of the project, and then expressed as AAHU gains (Table 2). A HSI value was calculated for each variable at year 1, 2, 25, and 50. A higher numerical rating is indicative of a higher suitability for the evaluated element. The HSI, when multiplied by the area of the habitat, yields HUs, a measure of the quality and quantity of the habitat. Four habitat variables are used in this model to characterize the suitability of a wetland for supplying cover and reproductive needs of marsh wrens.

- Variable 1 – Growth form of emergent hydrophytes – Vegetation will be cattails and bulrushes;
- Variable 2 – Canopy cover of emergent herbaceous vegetation – Based on data collected from restoration efforts at Donlon and Venice Cut Islands, canopy cover of emergent herbaceous vegetation would quickly increase to 80% within 2 years from construction;
- Variable 3 – Mean water depth – Mean water depth would exceed 15 centimeters; and
- Variable 4 – Canopy cover of woody vegetation – The target design elevations would be too low to support woody riparian vegetation.

Table 1.

HEP - FUTURE WITH-PROJECT									
Time	**Variables**				**Suitability Index**				**Output**
	V1	**V2**	**V3**	**V4**	**SI-V1**	**SI-V2**	**SI-V3**	**SI-V4**	**HSI**
TY1	Cat 1	11.1%	> 15 cm	0%	1.00	0.01	1.00	1.00	0.22
TY2	Cat 1	80%	> 15 cm	0%	1.00	1.00	1.00	1.00	1.00
TY25	Cat 1	80%	> 15 cm	0%	1.00	1.00	1.00	1.00	1.00
TY50	Cat 1	80%	> 15 cm	0%	1.00	1.00	1.00	1.00	1.00
HSI = (V1*V2*V3)^1/3*V4						Time-weighted Average			0.98

*Based on: Gutzwiller, K.J. and S.H. Anderson. 1987. Habitat Suitability Index Models: Marsh Wren. Fish and Wildlife Service Biological Report 82(10.139).

Results and Discussion:

Table 2 shows the net change in AAHU's for intertidal marsh habitat that could be created resulting from the Delta Study. The three restoration areas are divided into increments based on amount of available fill material. The large value in AAHU's for acres created can be explained by the quick establishment of intertidal marsh habitat (80% in 2 years) demonstrated in the restoration completed at Donlon Island and Venice Cut.

Table 2.

DELTA ISLANDS AND LEVEES FEASIBILITY STUDY ECOSYSTEM RESTORATION OUTPUTS				
Big Break				
Increment	***Habitat Restored***			
	Intertidal marsh Restored (acres)	***AAHU's Without Project***	***AAHU's With Project***	***Net Change in AAHU's***
1	41.94	0	41.3	41.3
2	10.4	0	10.2	10.2
3	17.61	0	17.3	17.3
4	0.94	0	0.9	0.9
5	10.44	0	10.3	10.3
6	4.15	0	4.1	4.1
7	978.51	0	963.2	963.2
Grand Total:	**1063.99**		**1047.4**	**1047.4**

Little Frank's Tract				
Increment	***Habitat Restored***			
	Intertidal marsh Restored (acres)	***AAHU's Without Project***	***AAHU's With Project***	***Net Change in AAHU's***
LFT1	9.15	0	9.0	9.0
LFT2	263.85	0	259.7	259.7
Grand Total:	**273**	**0**	**268.7**	**268.7**

Frank's Tract				
Increment	***Habitat Restored***			
	Intertidal marsh Restored (acres)	***AAHU's Without Project***	***AAHU's With Project***	***Net Change in AAHU's***
FT1	19.7	0	19.4	19.4
FT2	119.27	0	117.4	117.4
FT3	2331.03	0	2294.7	2294.7
Grand Total:	**2470**	**0**	**2431.5**	**2431.5**

Cost Effectiveness and Incremental Cost Analysis
Delta Islands and Levees Feasibility Study
February 2014

Introduction

Ecosystem restoration is one of the primary missions of the Corps of Engineers Civil Works program. The Corps objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to NER are increases in the net quantity and/or quality of desired ecosystem resources. Measurement of NER is based on changes in ecological resource quality and 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. Thus, single purpose ecosystem restoration plans shall be formulated and evaluated in terms of their net contributions to increases in ecosystem value (NER outputs) expressed in non-monetary units (habitat units).

For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be a cost effective plan for achieving the desired level of output and economically justified (determined to be worth its investment cost). This plan shall be identified as the NER Plan. This formulation, evaluation, and selection process is described below.

A Cost Effectiveness and Incremental Cost Analysis (CE/ICA) analysis was conducted using benefit and cost inputs using the certified IWR-Planning Suite software version 2.0.6.0 (IWR-PLAN).

Restoration Measures

The plan formulation process is described in detail in Section 3 of the Integrated Report. That section describes the evaluation and screening of ecosystem measures and ultimately included or excluded from the array of plans being considered. The ecosystem restoration measures that were retained through all screenings include: restore intertidal habitat with subsidence reversal at Big Break, Frank's Tract, and Little Frank's Tract.

The primary action required to restore habitat value to native species at Big Break, Frank's Tract, and Little Frank's Tract is subsidence reversal. Similar restoration actions were undertaken by USACE in the 1990's at nearby Venice Cut and Donlon Island. This restoration has demonstrated that subsidence reversal to restore land surface to intertidal elevations, along with minimal plantings, can result in successful restoration of intertidal marsh with 80% vegetation coverage within 2 years. Measures considered at Big Break, Frank's Tract, and Little Frank's Tract are based on the success of these reference sites.

Subsidence Reversal

Studies conducted on reference sites at Donlon and Venice Cut Islands indicate that optimum marsh wren habitat (i.e., where vegetative cover is greater than 75%) is found at elevations ranging from approximately 2.8 to 4.8 feet. Therefore, using a conservative approach for estimating quantity of fill, a target elevation of 4.5 feet was used to estimate fill quantities.

While target elevations are consistent between the sites, current elevations vary from site to site, resulting in differing requirements for volume of material per acre. Intertidal marsh restoration at Big Break (1,064 acres of marsh with an additional 15% of open water) would require 12.7 million cubic yards of material, or 9,400 cubic yards of material per acre. Intertidal marsh restoration at Frank's Tracts (2,470 acres of marsh with an additional 15% of open water) would require 42.6 million cubic yards of material, or 17,200 cubic yards of material per acre. Intertidal marsh restoration at Little Frank's Tracts (273 acres of marsh with an additional 15% of open water) would require 4.6 million cubic yards of material, or 16,800 cubic yards of material per acre.

Increments were developed for each site based on availability and proximity of fill material, as this is the primary driver in restoring ecological function and the primary driver of cost. Based on monitoring results from the Donlon Island and Venice Cut reference sites, it is expected that placement of fill material to the appropriate elevations, followed by minimal plantings of rushes will be the only required actions to restore intertidal marsh. As elevations are relatively constant within each site, calculations were made to determine the volume of fill needed per acre at each site. Volumes of available material were matched to the most efficient potential site. Potential sources of material include:

- *Direct placement from Operations and Maintenance dredging of the Stockton Deep Water Ship Channel* – assumes normal hydraulic dredging operations with suspended material directly placed into the restoration area(s) via pipeline and contained in an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways;
- *Pumping previously dredged material from nearby stockpiles* – utilize previously dredged material in nearby stockpiles by creating a slurry that can be pumped into the restoration area(s) via pipeline and contained in an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways; and
- *Trucking and/or barging material from borrow sites within a 30 mile radius* – truck and/or barge material from borrow sites within a 30 mile radius and place material into the restoration area(s) either directly from trucks (where possible) or via excavators on barges into an enclosed area surrounded by either existing high ground (remnant levees) or sacrificial hay bales and silt curtains to allow suspended material to settle and water to filter through the silt curtains prior to exiting the site back into the waterways.

Vegetation

Dredged material will be transported to the site as described above and placed to bring the substrate to a target elevation of 4.5 feet mean sea level. This area will be conducive to aquatic vegetation and anchored to the adjacent existing levee. The planting design includes planting bulrush (Typha sp.) over the area and will be suitable to develop intertidal marsh habitat. Plantings will be installed at 3 feet on center over 10% of the intertidal marsh area. The plant material may be nursery grown, or collected from nearby sources and directly planted at the site. It is anticipated that cattails will self-propagate on site. Additionally, 25 acres of the adjacent existing levee will be treated to remove invasive non-native species, such as Himalayan blackberry, pampas grass, pepper weed, etc. Records and reports will be required to document what was done and how the site and plants progressed.

The restoration measures analyzed for the CE/ICA would restore intertidal habitat with subsidence reversal at Big Break, Little Frank's Tract, and Frank's Tract.

Cost Effectiveness and Incremental Cost Analysis

A CE/ICA analysis was conducted using benefit and cost inputs with the IWR-PLAN. The various separable element features were evaluated and compared, and recombined by the software as discussed within this section.

The CE/ICA is an evaluation tool which considers and identifies the relationship between changes in cost and changes in quantified, but not monetized, habitat benefits. The evaluation is used to identify the most cost-effective alternative plans to reach various levels of restoration output and to provide information about whether increasing levels of restoration are worth the successively added costs. The CE/ICA is a planning tool to help identify cost-effective plans which provide the highest habitat output relative to cost.

Functionally, the CE/ICA provides a framework for combining individual measures into alternative plans. The software expedites this effort of testing each combination of measures and tabulating the resulting costs and environmental benefits.

Cost Effectiveness Analysis

When there is no monetary measure of benefits but project outcomes can be described and quantified in some dimension, cost effectiveness analysis can be used to assist on the decision making process. Cost effectiveness analysis seeks to answer the question: given an adequately described objective, what is the least-costly way of attaining the objective? A plan is considered cost effective if it provides a given level of output for the least cost. Cost effectiveness analysis was used to identify the least cost solution for each level of environmental output being considered.

The cost effectiveness analysis is the first step in the CE/ICA, and compares the Average Annual Habitat Units (AAHUs) potentially achieved by each alternative to the cost of each alternative to generate a "cost per AAHU." This cost provides a means to compare the cost-effectiveness of each plan. The three criteria used for identifying non-cost effective plans or combinations include (1) the same level of output could be produced by another plan at less cost; (2) a larger output level could be produced at the same cost; or (3) a larger output level could be produced at less cost. Cost-effectiveness is one of the criteria by which all plans are judged and plays a role in the selection of the National Ecosystem Restoration (NER) Plan. Non-cost effective combinations of plans are dropped from further consideration.

Incremental Cost Analysis

Incremental cost analysis compares the additional costs to the additional outputs of an alternative. It is a tool that can assist in the plan formulation and evaluation process. The analysis consists of examining increments of plans or project features to determine their incremental costs and incremental benefits. Increments of plans continue to be added and evaluated as long as the incremental benefits exceed the incremental costs. When the incremental costs exceed the incremental benefits, no further increments are added. Incremental analysis helps to identify and display variations in costs among different increments of restoration measures and alternative plans. Incremental analysis helps decision makers determine the most desirable level of output relative to costs and other decision criteria.

The incremental cost analysis portion of the CE/ICA compares the incremental costs for each additional unit of output from one cost effective plan to the next to identify “best buy” plans. The first step in developing “best buy” plans is to determine the incremental cost per unit. The plan with the lowest incremental cost per unit over the No Action Alternative is the first incremental best buy plan. Plans that have a higher incremental cost per unit for a lower level of output are eliminated. The next step is to recalculate the incremental cost per unit for the remaining plans. This process is reiterated until the lowest incremental cost per unit for the next level of output is determined. The intent of the incremental analysis is to identify successively larger plans with the smallest incremental cost per unit of incremental output.

Selection Considerations

For ecosystem restoration, the recommended plan should be the justified alternative and scale having the maximum excess of monetary and non-monetary beneficial effects over monetary and nonmonetary costs. This plan occurs where the incremental beneficial effects just equal the incremental costs, or alternatively stated, where the extra environmental value is just worth the extra costs. A plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, is identified as the National Ecosystem Restoration (NER) Plan. The selected plan should be cost effective and justified in achieving the desired level of output. Thus, the NER plan is selected from the suite of cost effective plans identified in the CE/ICA. While the NER Plan is not required to be a best buy plan, this is often the case. The results of the CE/ICA do not provide a discrete decision, but rather they offer tools to help inform a decision.

Costs

The construction methodologies used to generate the cost estimate follow standard industry practices for standard wet and dry earthwork conditions. Earthwork crews were developed in MCACES MII with production quantities pulled from the Cost Engineering Section ProdQuant.xls spreadsheet. The dry earthwork techniques rely primarily on heavy earthmoving equipment including: Dozers, scrapers and hydraulic excavators while the wet earthwork techniques rely on barge mounted cranes with a low draft. Pumping costs were generated from an MCACES MII model refined with bid information from multiple contractor proposals for similar work in the immediate area. Pumping techniques require pipes to be laid over land and secured to the river channel bottom as needed to maintain the most direct, cost efficient and low environmental and local impact. The material source sites placing at Big Break are assumed to be dependent on the McCormick dredge material storage site pumping operation in order to create cost savings by utilizing McCormick's infrastructure following completion of its pumping operation. The outflow of the pipe is considered mobile and would be repositioned regularly in order to spread materials throughout the site. Some leveling of deposited material may be required. Normal O&M dredging costs were excluded from this analysis, only the additional pumping needed for restoration was considered. A summary of construction costs are included in Table 1.

Table 1: Costs of Increments/Measures (Sept 2013 Price Level)

BIG BREAK

INCREMENT	ACRE	VOLUME (CY)	DEPTH (FT)	SOURCE	METHOD	DEPENDENT ON:	INC TRANS DISTANCE (mi)	SLURRY AND PUMPING UNIT COST ($/CY)	INC TURBIDITY RADIUS(ft)	HAY BALE/SILT SCREEN (1,000s)	ALLOCATED ANCHORED DIST(ft)	PIPE ANCHORING (1,000s)	PLANTINGS (1,000s)	RIGHT OF WAY (1,000s)	SUB TOTAL (1,000s)	MOB / DEMOB (1,000s)	15%PED/ 8.5%CM/ CONT%* (1,000s)	TOTAL COST (1,000s)	TOTAL COST PER ACRE (1,000s)	TOTAL COST Annualized Costs ($) (1,000s)
1	41.9	500,000	6.9	O&M	DIRECT PLACEMENT	NONE	NO COST	$4.92	2,855.86	$242.25	0	$0	$220	$72	$2,995	$299	$1,149	$4,443	$106	$198.05
2	10.4	124,023	6.9	McCORMICK	PUMPING	NONE	1.70	$12.70	1,422.34	$120.67	4,900	$497	$55	$72	$2,320	$232	$884	$3,435	$330	$153.12
3	17.6	209,992	6.9	SCOUR	PUMPING	McCORMICK	2.60	$19.41	1,850.77	$160.51	0	$0	$92	$204	$4,533	$227	$1,702	$6,461	$367	$288.01
FOR COMPARISON	12.8	153,115	6.9	BRADFORD	PUMPING	NONE	3.25	$19.36	1,580.38	$138.52	500	$73	$67	$259	$3,502	$350	$1,573	$5,425	$422	$241.83
4	0.9	11,263	6.9	AUG. PIT	PUMPING	McCORMICK	2.80	$19.51	428.63	$40.57	0	$0	$5	$208	$473	$24	$104	$601	$636	$26.79
5	10.4	124,500	6.9	DECKER	PUMPING	McCORMICK	2.85	$19.53	1,425.07	$120.89	550	$76	$55	$136	$2,819	$141	$1,055	$4,015	$384	$178.96
6	4.2	49,500	6.9	RIO VISTA	PUMPING	McCORMICK	5.55	$26.23	898.57	$78.07	3,800	$391	$22	$72	$1,861	$93	$704	$2,658	$640	$118.48
SUM (1-6)	85.5	1,019,278																		
7	978.5	11,666,297	6.9	VARIOUS	TRUCKING	NONE	VARIES	$103.50	13,794.89	$1,126.84	0	$0	$5,127	$0	$1,213,716	$500	$588,652	$1,214,305	$1,241	$54,126.68
TOTAL SUM (1-7)	1,064.0	12,685,575																		

FRANKS TRACT

INCREMENT	ACRE	VOLUME (CY)	DEPTH (FT)	SOURCE	METHOD	DEPENDENT ON:	INC TRANS DISTANCE (mi)	SLURRY AND PUMPING UNIT COST ($/CY)	INC TURBIDITY RADIUS(ft)	HAY BALE/SILT SCREEN (1,000s)	ALLOCATED ANCHORED DIST(ft)	PIPE ANCHORING (1,000s)	PLANTINGS (1,000s)	RIGHT OF WAY (1,000s)	SUB TOTAL (1,000s)	MOB / DEMOB (1,000s)	15%PED/ 8.5%CM/ CONT%* (1,000s)	TOTAL COST (1,000s)	TOTAL COST PER ACRE (1,000s)	TOTAL COST Annualized Costs ($) (1,000s)
1	19.7	339,020	10.3	ROBERTS 2	PUMPING	NONE	10.5	$34.66	2,351.60	$196	1,600	$1,985	$88	$848	$14,868	$500	$6,800	$22,168	$1,126	$988
2	119.3	2,053,084	10.3	ROBERTS 1	PUMPING	ROBERTS 2	1.7	$35.96	5,787.02	$476	0	$0	$533	$144	$74,983	$250	$36,297	$111,530	$935	$4,971
SUM (1-2)	139.0	2,392,104																		
3	2331.0	40,255,878	10.3	VARIOUS	TRUCKING/BARGING	NONE	VARIES	$88.50	25,625.14	$2,089	0	$0	$10,408	$0	$3,575,142	$500	$1,733,944	$5,309,586	$2,278	$236,671
TOTAL SUM (1-3)	2470.0	42,647,982																		

LITTLE FRANKS TRACT

INCREMENT	ACRE	VOLUME (CY)	DEPTH (FT)	SOURCE	METHOD	DEPENDENT ON:	INC TRANS DISTANCE (mi)	SLURRY AND PUMPING UNIT COST ($/CY)	INC TURBIDITY RADIUS(ft)	HAY BALE/SILT SCREEN (1,000s)	ALLOCATED ANCHORED DIST(ft)	PIPE ANCHORING (1,000s)	PLANTINGS (1,000s)	RIGHT OF WAY (1,000s)	SUB TOTAL (1,000s)	MOB / DEMOB (1,000s)	15%PED/ 8.5%CM/ CONT%* (1,000s)	TOTAL COST (1,000s)	TOTAL COST PER ACRE (1,000s)	TOTAL COST Annualized Costs ($) (1,000s)
1	9.2	153,115	9.9	BRADFORD	PUMPING	NONE	1	$11.62	1,580.38	$228	500	$73	$55	$119	$2,254	$428	$886	$3,568	$390	$159
2	263.8	4,414,248	9.9	VARIOUS	TRUCKING/BARGING	NONE	VARIES	$84.10	8,485.55	$695	0	$0	$1,575	$0	$373,508	$500	$181,152	$555,160	$2,104	$24,746
TOTAL SUM (1-2)	273.0	4,567,363																		

Increments

The inputs into the IWR-PLAN included seven increments, or solutions as identified in the model, for Big Break, three increments for Frank’s Tract, and two increments for Little Frank’s Tract (Table 2). Increments of restoration at each site were developed based on an acre grid system. Available fill material calculations were used to determine the size of increments, i.e., how many grid cells each increment included. It should be noted that the first increments at each site are relatively small, with a large increment for the remainder of the site. This sizing is a product of available fill material. The smaller increments were developed based on available material that could be transported to the site without major modifications (i.e., construction of a bridge, multiple transfers between trucks and barges, etc.). The larger increment includes the remainder of each site for which a more efficient source of available material could not be identified. Locations of increments are general within each site and are based on proximity to fill material, proximity to remnant levees for improved constructability, and connectivity to existing habitat.

Table 2: Final Increments/Measures

BIG BREAK					
INCREMENT	**ACREAGE**	**VOLUME (CY)**	**DEPTH (FT)**	**SOURCE**	**METHOD**
1	41.9	500,000	6.9	O&M	DIRECT PLACEMENT
2	10.4	124,023	6.9	McCORMICK	PUMPING
3	17.6	209,992	6.9	SCOUR	PUMPING
4	0.9	11,263	6.9	AUG. PIT	PUMPING
5	10.4	124,500	6.9	DECKER	PUMPING
6	4.2	49,500	6.9	RIO VISTA	PUMPING
7	978.5	11,666,297	6.9	VARIOUS	TRUCKING/BARGING
TOTAL SUM (1-7)	1,064.0	12,685,575			

FRANK’S TRACT					
INCREMENT	**ACREAGE**	**VOLUME (CY)**	**DEPTH (FT)**	**SOURCE**	**METHOD**
1	19.7	339,020	10.3	ROBERTS 2	PUMPING
2	119.3	2,053,084	10.3	ROBERTS 1	PUMPING
3	2,331.0	40,255,878	10.3	VARIOUS	TRUCKING/BARGING
TOTAL SUM (1-3)	2,470.0	42,647,982			

LITTLE FRANK’S TRACT					
INCREMENT	**ACREAGE**	**VOLUME (CY)**	**DEPTH (FT)**	**SOURCE**	**METHOD**
1	9.2	153,115	9.9	BRADFORD	PUMPING
2	263.9	4,414,248	9.9	VARIOUS	TRUCKING/BARGING
TOTAL SUM (1-2)	273.0	4,567,363			

CE/ICA Model Implementation

The restoration increments that were developed based on source material, material distribution method, and location were entered in the IWR model as solutions. The model inputs include two relationship dependencies. Big Break increments 3, 4, 5, and 6 all depend on increment 2, pumping from McCormick Pit. Source material for the dependent increments will first be pumped to McCormick Pit and then pumped from McCormick Pit to the restoration site. The second relationship dependency is Frank’s Tract increment 2, which is dependent on increment 1, pumping from Roberts Island 2. Source material from increment 2 (Roberts Island 1) will first be pumped to Roberts Island 2 and then pumped from Roberts Island 2 to the restoration site.

Results

This comparison between increments was made using IWR-PLAN to conduct cost effectiveness and incremental cost analysis based on costs (dollars) and outputs (marsh wren AAHU). Incremental costs per unit of output were used to identify major breakpoints in cost efficiency among the alternatives. These outputs are shown in Tables 3 and 4, and Figures 1 and 2:

The model run resulted in a total of 536 cost effective plans. Of these cost effective plans, 12 plans were identified as best buy plans including the no action plan. Table 3 presents the cost, benefits, and incremental cost for each of the 12 best buy plans.

Outputs increase as alternatives progress (1-12); however, these outputs are achieved at increasingly higher incremental costs. Breaks in incremental cost are found at Alternatives 2, 6, 8, and 12; therefore, these alternatives were identified as the most logical candidates for plan selection. The incremental cost per AAHU for Alternative 2 is about $4,800 which is associated with maintenance dredging and is the least expensive means of obtaining material. The increase in cost per AAHU of Alternative 3-6 ranges from about $15,000 to $17,700. The increase reflects the use of stockpiles dredged material. Alternatives 7 and 8 are in the next increment break of about $30,000 per AAHU. This increase is due to the having to pump a longer distance and pumping across the Sacramento River from the Rio Vista Pit for Alternative 7, and for pumping a relatively small amount of material from Augusto Pit for Alternative 8. The incremental break at Alternative 9 of about $43,500 is due to the increase in distance to pump from Roberts Island 1 and 2 to the Frank's Tract site. The three final alternatives have the largest cost per AAHU. Even though the AAHU output is substantially higher, the cost of having to truck or barge the needed material ranges from about $56,000 to $103,000 per AAHU.

Table 3: Incremental Cost and Outputs of Alternatives

ALT	Marsh Wren Habitat Output (AAHU)	Total Annual Cost ($1,000)	Average Cost per AAHU ($1)	Incremental Cost ($1,000)	Incremental Output	Incremental Cost Per Output ($1)
1	0.0	$0	$0	$0	0	$0
2	41.3	$198	$4,794	$198	41.3	$4,794
3	51.5	$351	$6,816	$153	10.2	$15,000
4	68.8	$639	$9,288	$288	17.3	$16,647
5	79.1	$818	$10,341	$179	10.3	$17,379

6	**88.1**	**$977**	**$11,090**	**$159**	**9**	**$17,667**
7	**92.2**	**$1,095**	**$11,876**	**$118**	**4.1**	**$28,780**
8	**93.1**	**$1,122**	**$12,052**	**$27**	**0.9**	**$30,000**
9	**229.9**	**$7,081**	**$30,800**	**$5,959**	**136.8**	**$43,560**
10	**1,193.1**	**$61,208**	**$51,302**	**$54,127**	**963.2**	**$56,195**
11	**1,452.8**	**$85,954**	**$59,164**	**$24,746**	**259.7**	**$95,287**
12	**3,747.5**	**$322,625**	**$86,091**	**$236,671**	**2294.7**	**$103,138**

Figure 1: Incremental Cost and Outputs of Alternatives 1-12

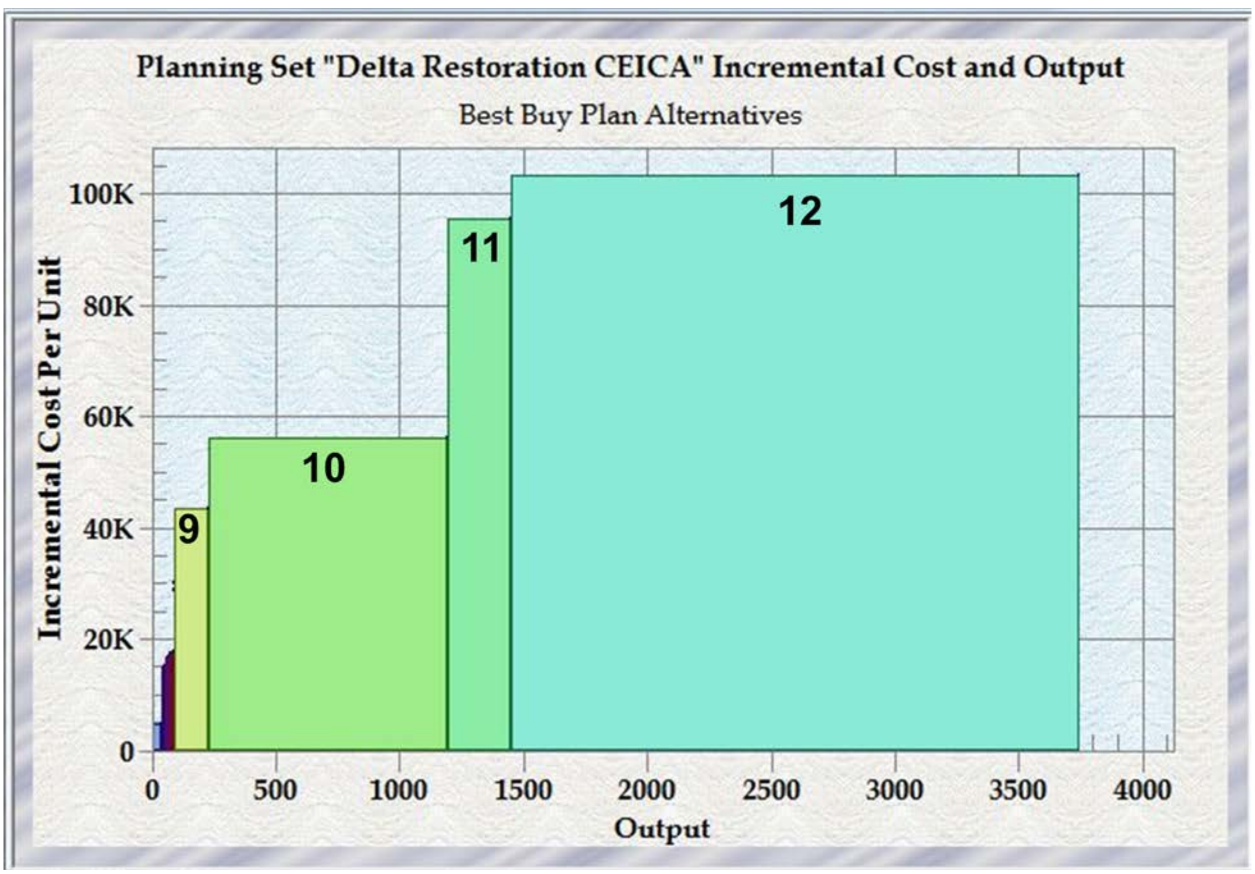
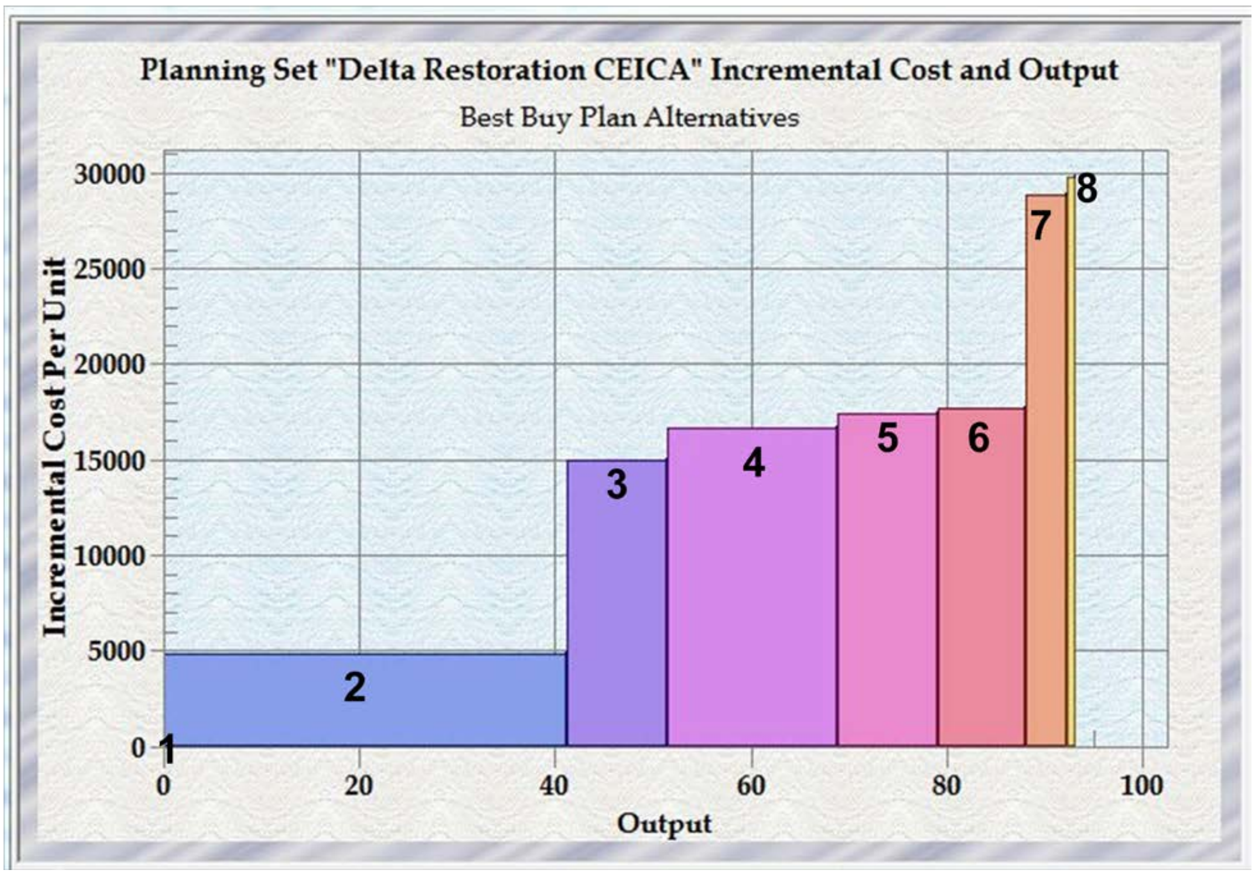


Table 4: Bar Graph Outputs and Increments

Bar Graph	**Plan Alternative**	**AAHU (Marsh**	**Location – Increment**

		Wren)	
	1	0	No Action
1- BB_1	2	41.3	Big Break – 1
2- BB_2	3	51.5	Big Break – 1,2
3- BB_3	4	68.8	Big Break – 1,2, 3
4- BB_5	5	79.1	Big Break – 1,2,3,5
5- LFT_1	6	88.1	Big Break – 1,2,3,5 & Little Frank's Tract 1
6- BB_6	7	92.2	Big Break – 1,2,3,5,6 & Little Frank's Tract 1
7- BB_4	8	93.1	Big Break – 1,2,3,4,5,6 & Little Frank's Tract 1
8- FT_1&2	9	229.9	Big Break – 1,2,3,4,5,6 & Little Frank's Tract 1 & Frank's Tract 1,2
9- BB_7	10	1,193.1	Big Break – 1,2,3,4,5,6,7 & Little Frank's Tract 1 & Frank's Tract 1,2
10- LFT_2	11	1,452.8	Big Break – 1,2,3,4,5,6,7 & Little Frank's Tract 1,2 & Frank's Tract 1,2
11- FT_3	12	3,747.5	Big Break – 1,2,3,4,5,6,7 & Little Frank's Tract 1,2 & Frank's Tract 1,2,3

Figure 2: Incremental Cost and Outputs of Alternatives 1-8



Final Array of Alternatives

The CE/ICA analysis resulted in 12 restoration alternatives including the "no action" alternative.

Alternative 1 is the no action plan and assumes no action is taken as the result of this study.

Alternative 2 includes only increment 1 at Big Break, which would result in 42 acres of restored intertidal marsh habitat, requiring 500k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years. The total cost of this alternative is $5.4 million.

Alternative 3 includes increments 1 and 2 at Big Break, which would result in 52 acres of restored intertidal marsh habitat, requiring 624k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick placement site. The total cost of this alternative is $8.8 million.

Alternative 4 includes increments 1, 2, and 3 at Big Break, which would result in 70 acres of restored intertidal marsh habitat, requiring 834k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick and Scour placement sites. The total cost of this alternative is $14.7 million.

Alternative 5 includes increments 1, 2, 3, and 5 at Big Break, which would result in 80 acres of restored intertidal marsh habitat, requiring 959k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick, Scour, and Decker placement sites. The total cost of this alternative is $18.5 million.

Alternative 6 includes increments 1, 2, 3, and 5 at Big Break and increment 1 at Little Frank’s Tract, which would result in 89.5 acres of restored intertidal marsh habitat, requiring 1,112k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick, Scour, Decker, and Bradford placement sites. The total cost of this alternative is $21.9 million.

Alternative 7 includes increments 1, 2, 3, 4, and 5 at Big Break and increment 1 at Little Frank’s Tract, which would result in 90.5 acres of restored intertidal marsh habitat, requiring 1,123k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, and Augusta Pit placement sites. The total cost of this alternative is $22.4 million.

Alternative 8 includes increments 1, 2, 3, 4, 5, and 6 at Big Break and increment 1 at Little Frank’s Tract, which would result in 95 acres of restored intertidal marsh habitat, requiring 1,173k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, Augusta Pit, and Rio Vista placement sites. The total cost of this alternative is $25.2 million.

Alternative 9 includes increments 1, 2, 3, 4, 5, and 6 at Big Break; increment 1 at Little Frank's Tract; and increments 1 and 2 at Frank's Tract, which would result in 234 acres of restored intertidal marsh habitat, requiring 3,564k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years and via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, Augusta Pit, Rio Vista, Roberts 1, and Roberts 2 placement sites. The total cost of this alternative is $149.9 million.

Alternative 10 includes increments 1, 2, 3, 4, 5, 6, and 7 at Big Break; increment 1 at Little Frank's Tract; and increments 1 and 2 at Frank's Tract, which would result in 1,212 acres of restored intertidal marsh habitat, requiring 15,231k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years; via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, Augusta Pit, Rio Vista, Roberts 1, and Roberts 2 placement sites; and via trucking and barging from borrow sites within a 30 mile radius. The total cost of this alternative is $2,039.9 million.

Alternative 11 includes increments 1, 2, 3, 4, 5, 6, and 7 at Big Break; increments 1 and 2 at Little Frank's Tract; and increments 1 and 2 at Frank's Tract, which would result in 1,476 acres of restored intertidal marsh habitat, requiring 19,645k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years; via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, Augusta Pit, Rio Vista, Roberts 1, and Roberts 2 placement sites; and via trucking and barging from borrow sites within a 30 mile radius. The total cost of this alternative is $2,695.4 million.

Alternative 12 includes increments 1, 2, 3, 4, 5, 6, and 7 at Big Break; increments 1 and 2 at Little Frank's Tract; and increments 1, 2, and 3 at Frank's Tract, which would result in 3,807 acres of restored intertidal marsh habitat, requiring 59,901k cubic yards of fill material which would be placed via direct placement of dredged material from yearly Operations and Maintenance dredging from the Stockton Deep Water Ship Channel for a period of five years; via pumping of previously dredged material from the McCormick, Scour, Decker, Bradford, Augusta Pit, Rio Vista, Roberts 1, and Roberts 2 placement sites; and via trucking and barging from borrow sites within a 30 mile radius. The total cost of this alternative is $8,673.4 million.