

Coastal Texas Protection and
Restoration Feasibility Study
Final Feasibility Report

Appendix E-3:

Cost Effectiveness - Incremental Cost Analysis

August 2021

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INTRODUCTION

Comparing benefits and costs for ecosystem restoration provides a challenge to planners and decision makers because benefits and costs are not measured in the same units. Environmental restoration benefits can be measured in habitat units or some other physical unit, while costs are measured in dollars. Therefore, benefits and costs cannot be directly compared. Two analyses are conducted to help planners and decision makers identify plans for implementation, though the analyses themselves do not identify a single ideal plan. These two techniques are cost effectiveness and incremental cost analysis. Use of these techniques are described in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies* (U.S. Water Resources Council 1983).

Cost effectiveness compares the annual costs and benefits of plans under consideration to identify the least cost plan alternative for each possible level of environmental output, and for any level of investment, the maximum level of output is identified.

Incremental cost analysis of the cost-effective plans is conducted to reveal changes in costs as output levels are increased. Results from both analyses are presented graphically to help planners and decision makers select plans. For each of the best buy plans identified through incremental cost analysis, an “is it worth it?” analysis is then conducted for each incremental measure or plan to justify the incremental cost per unit of output to arrive at a recommended plan.

For this study, the environmental output is the average annual habitat unit (AAHU). The development of the AAHU is discussed in detail in the environmental technical appendix.

MEASURES AND ALTERNATIVES

Nine management measures were identified through screening process to serve as the building blocks for the fully-formed alternatives to be evaluated with CE/ICA analysis. Four of the management measures were developed with two scales, effectively creating 13 management measures for creating alternatives. Scale 1 assumes there are no out-year nourishment actions beyond the initial construction. Scale 2 assumes one or more out-year nourishment after initial construction and within the 50-year period of analysis, varying by measure. A list of the measures along with nourishment cycles is present in Table 1. More detailed information can be found in the Environmental technical appendix. Each measure acts independently in creating environmental benefits (output), there being no synergistic or redundant effects on benefits when measures are combined to form alternatives. Given this independence, environmental benefits and project first costs were developed separately for each measure and are fully additive when measures are combined to form alternatives.

Table 1. List of Management Measures, Scales and Out-Year Nourishments

Measure	Description	Out-Year Nourishment		
		Frequency	Timing (year)	Duration (Years)
G-5	Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration	1	10	15
G-28-1	Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Scale 1)			
G-28-2	Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Scale 2)	1	30	10
B-2	Follets Island Gulf Beach and Dune Restoration	1	10	10
B-12-1	Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection (Scale 1)			
B-12-2	Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection (Scale 2)	1	30	21
CA-5-1	Keller Bay Restoration (Scale 1)			
CA-5-2	Keller Bay Restoration (Scale 2)	1	30	5
CA-6	Powderhorn Shoreline Protection and Wetland Restoration			
M-8-1	East Matagorda Bay Shoreline Protection (Scale 1)			
M-8-2	East Matagorda Bay Shoreline Protection (Scale 2)	1	30	5
SP-1	Redfish Bay Protection and Enhancement			
W-3	Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	Every 3 Years		1

During the plan formulation process, a series of planning strategies based on planning objectives were defined. These strategies serve as the basis of organizing the management measures into fully-formed alternatives to meet that strategy. There are six alternatives (aligning with six strategies), each with two scales consistent with measure scales. Scale 1 alternatives assume no out-year nourishment for measures G-28, B-12, CA-5, and M-8. Scale 2 alternatives assume there is out-year nourishment for those measures, if they are included in the alternative. Measures G-5, B-2 and W-3 will have out-year nourishment in any alternative where they are included. Table 2 provides a list of the six alternatives and their scales and identification of the strategy for that alternative. Table 3 provides a crosswalk of management measures to alternatives.

Table 2. List of Fully Formed Alternatives

Alternative/Scale	Strategy/Description
Alternative 1-1	Coast-wide All-Inclusive Restoration Alternative (Scale 1)
Alternative 1-2	Coast-wide All-Inclusive Restoration Alternative (Scale 2)
Alternative 2-1	Coast-wide Restoration of Critical Geomorphic or Landscape Features (Scale 1)
Alternative 2-2	Coast-wide Restoration of Critical Geomorphic or Landscape Features (Scale 2)
Alternative 3-1	Coast-wide Barrier System Restoration (Scale 1)
Alternative 3-2	Coast-wide Barrier System Restoration (Scale 2)
Alternative 4-1	Coast-wide Bay System Restoration (Scale 1)
Alternative 4-2	Coast-wide Bay System Restoration (Scale 2)
Alternative 5-1	Coast-wide Ecosystem Restoration Contributing to Infrastructure Risk Reduction (Scale 1)
Alternative 5-2	Coast-wide Ecosystem Restoration Contributing to Infrastructure Risk Reduction (Scale 2)
Alternative 6-1	Top Performers (Scale 1)
Alternative 6-2	Top Performers (Scale 2)

Table 3. Crosswalk of Measures by Alternative

Alt.	Measures												
	G5	G28-1	G28-2	B2	B12-1	B12-2	CA5-1	CA5-2	CA6	M8-1	M8-2	SP1	W3
1-1	•	•		•	•		•		•	•		•	•
1-2	•		•	•		•		•	•		•	•	•
2-1	•			•	•				•				•
2-2	•			•		•			•				•
3-1	•	•		•									•
3-2	•		•	•									•
4-1		•			•		•		•	•		•	
4-2			•			•		•	•		•	•	
5-1	•	•		•	•								
5-2	•		•	•		•							
6-1	•	•		•	•				•				
6-2	•		•	•		•			•				

ENVIRONMENTAL RESTORATION BENEFITS

To determine benefits of an environmental restoration plan, future with-project and future without-project environmental outputs are developed using appropriate models. These models generate indices which are multiplied by the affected acres to calculate habitat units (HUs). The models used for this study are the Habitat Evaluation and Assessment Tool (HEAT) and the Wetland Value Assessment (WVA). The habitat units are then averaged over the planning period to get average annual habitat units (AAHUs). Future without-project AAHUs are subtracted from the future with-project AAHUs to derive the measure or alternative's output, or benefit. A summary the AAHUs for each of the measures and scales is presented in Table 4. A more detailed discussion of the development of the AAHUs is found in the Environmental technical appendix.

Table 4. Average Annual Habitat Units by Measure and Scale

Measure	Without Project	With Project	Net AAHUs
G-5	804	2,624	1,820
G-28-1	20,327	21,414	1,087
G-28-2	20,327	29,537	9,210
B-2	222	613	391
B-12-1	30,357	31,618	1,261
B-12-2	30,357	47,591	17,234
CA-5-1	559	781	222
CA-5-2	559	890	331
CA-6	901	919	18
M-8-1	10,769	10,992	223
M-8-2	10,769	17,072	6,303
SP-1	20	3,521	3,501
W-3	8,279	38,815	30,536

RISK AND UNCERTAINTY

Risk based economic models estimate benefits for FRM and CSRMs projects by sampling variable inputs from a distribution of possible values. The economic analysis of ecosystem restoration measures is not risk based. The benefit stream is a function of the AAHUs calculated considering critical physical habitat conditions in the study area over the period of analysis. Risk and uncertainty is captured in the assumptions applied in the model application to assess habitat suitability. Where uncertainty exists, the assumptions reflected worst case conditions to avoid overestimating project success. A Monitoring and Adaptive Management Plan (MAMP) establishes a procedure to assess success and address risks to the project before benefits streams are permanently impacted from physical conditions in the study area that are unanticipated.

PROJECT FIRST COSTS

Planning level construction costs were developed for each measure, inclusive of real estate values for lands to be acquired and the economic use of lands currently owned by the sponsor or Federal agency (but not required to be purchased). To estimate project first costs, monitoring and adaptive management costs and cultural resource costs were also developed for each measure. This section provides an overview of those costs the steps used to annualize those cost for comparison to AAHUs.

CONSTRUCTION COSTS

Construction first cost estimates include dredging excavation, material placement, breakwaters, plantings, and real estate requirements for each of the management measures for both initial construction and continued construction (out-year nourishments). For each measure, a low and high cost was estimated, with an average of the two used for alternative evaluation. A summary

of these costs is presented in Table 5. Additional information about the development of these costs can be found in the cost engineering appendix.

Table 5. Low, High and Average Cost Estimates for Initial Construction and Continuing Construction (\$1,000, October 2017 Prices)

Measure	Initial Construction - Low Estimate	Initial Construction - High Estimate	Initial Construction - Average Estimate	Continuing Construction - Low Estimate	Continuing Construction - High Estimate	Continuing Construction - Average Estimate	Total of Average Initial and Continuing Construction Estimates
G-5	\$2,974,454	\$3,711,107	\$3,342,781	\$946,809	\$1,325,533	\$1,136,171	\$4,478,952
G-28-1	757,074	989,345	873,210	0	0	0	873,210
G-28-2	757,074	989,345	873,210	474,513	664,318	569,416	1,442,626
B-2	433,386	600,155	516,771	517,313	724,238	620,776	1,137,547
B-12-1	517,262	717,713	617,488	0	0	0	617,488
B-12-2	517,262	717,713	617,488	2,925,131	4,095,183	3,510,157	4,127,645
CA-5-1	46,692	65,369	56,031	0	0	0	56,031
CA-5-2	46,692	65,369	56,031	15,685	21,959	18,822	74,853
CA-6	64,078	88,280	76,179	0	0	0	76,179
M-8-1	149,971	209,720	179,846	0	0	0	179,846
M-8-2	149,971	209,720	179,846	298,825	418,355	358,590	538,436
SP-1	274,405	384,164	329,285	0	0	0	329,285
W-3	36,098	50,039	43,069	433,173	606,442	519,808	562,877

MONITORING AND ADAPTIVE MANAGEMENT AND CULTURAL RESOURCES COSTS

In addition to construction costs, the first cost used for comparison to benefits must also include cost estimates for monitoring and potential adaptive management actions and cultural resources. Monitoring and adaptive management cost estimates are based on a percentage the initial construction cost for each of the measures, as shown in Table 6. Cultural Resources cost estimates for each measure are shown in Table 7. Additional information for these estimates can be found in the respective technical appendices.

Table 6. Monitoring and Adaptive Management Costs (\$1,000)

Measure	Percentage of Initial Construction	Monitoring and Adaptive Management Costs
G-5	1.0%	\$33,428
G-28-1	3.0%	26,196
G-28-2	3.0%	26,196
B-2	1.0%	6,145
B-12-1	3.0%	18,525
B-12-2	3.0%	18,525
CA-5-1	2.0%	1,121
CA-5-2	2.0%	1,121
CA-6	2.0%	1,524
M-8-1	3.0%	5,395
M-8-2	3.0%	5,395
SP-1	3.0%	9,879
W-3	2.0%	861

Table 7. Cultural Resources Costs (\$1,000)

Measure	Cultural Resources Survey, National Register of Historical Places Testing and Mitigation Costs
G-5	\$671,790
G-28-1	1,887,925
G-28-2	1,887,925
B-2	182,752
B-12-1	3,036,277
B-12-2	3,036,277
CA-5-1	203,580
CA-5-2	203,580
CA-6	200,753
M-8-1	761,021
M-8-2	761,021
SP-1	125,255
W-3	3,731,748

AVERAGE ANNUAL COSTS

Project costs were annualized using annualizer module of the *IWR Planning Suite*, v. 2.0.6 software package, which is the USACE certified tool for developing annual costs. Initial construction first costs were annualized from the beginning of construction to the base year, which for these measures is the year of completion of construction when benefits begin to accrue.

Tables 9 through 12 display the development of the average annual costs for the outyear nourishments.

Table 8. Derivation of Average Annual Costs for Initial Construction (\$1,000, October 2017 Prices, 2.75% Interest Rate, 50 Year Period of Analysis)

Measure	Initial Construction Cost	Monitoring and Adaptive Management	Cultural Resources Costs	Initial Construction First Cost	Initial Construction Duration (Years)	Interest During Construction	Investment Costs	Interest	Amortization	Average Annual Initial Construction First Cost
G-5	\$3,342,781	\$33,428	672	\$3,376,881	15	\$790,838	\$4,167,719	\$114,612	\$39,764	\$154,376
G-28-1	873,210	26,196	1,888	901,294	7	91,323	992,617	27,297	9,470	36,767
G-28-2	873,210	26,196	1,888	901,294	7	91,323	992,617	27,297	9,470	36,767
B-2	516,771	5,168	183	522,122	10	77,722	599,844	16,496	5,723	22,219
B-12-1	617,488	18,525	3,036	639,049	7	64,752	703,801	19,355	6,715	26,070
B-12-2	617,488	18,525	3,036	639,049	7	64,752	703,801	19,355	6,715	26,070
CA-5-1	56,031	1,121	204	57,356	5	4,075	61,431	1,689	586	2,275
CA-5-2	56,031	1,121	204	57,356	5	4,075	61,431	1,689	586	2,275
CA-6	76,179	1,524	201	77,904	5	5,536	83,440	2,295	796	3,091
M-8-1	179,846	5,395	761	186,002	5	13,217	199,219	5,479	1,901	7,380
M-8-2	179,846	5,395	761	186,002	5	13,217	199,219	5,479	1,901	7,380
SP-1	329,285	9,879	125	339,289	5	24,110	363,399	9,993	3,467	13,460
W-3	43,069	861	3,732	47,662	2	1,319	48,981	1,347	467	1,814

Table 9. Development of Average Annual Continuing Construction Cost for Measures G-5 and G-28-2 (October 2017 Prices 2.75% Discount Rate, 50 Year Period of Analysis)

Period	G-5				G-28-2			
	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction
1			0	0.00			0	0.00
2			0	0.00			0	0.00
3			0	0.00			0	0.00
4			0	0.00			0	0.00
5			0	0.00			0	0.00
6			0	0.00			0	0.00
7			0	0.00			0	0.00
8			0	0.00			0	0.00
9			0	0.00			0	0.00
10		75,744,733	75,744,733	57,747,625.79			0	0.00
11		75,744,733	75,744,733	56,202,068.90			0	0.00
12		75,744,733	75,744,733	54,697,877.27			0	0.00
13		75,744,733	75,744,733	53,233,943.82			0	0.00
14		75,744,733	75,744,733	51,809,191.06			0	0.00
15		75,744,733	75,744,733	50,422,570.38			0	0.00
16		75,744,733	75,744,733	49,073,061.20			0	0.00
17		75,744,733	75,744,733	47,759,670.26			0	0.00
18		75,744,733	75,744,733	46,481,430.91			0	0.00
19		75,744,733	75,744,733	45,237,402.35			0	0.00
20		75,744,733	75,744,733	44,026,668.95			0	0.00
21		75,744,733	75,744,733	42,848,339.61			0	0.00
22		75,744,733	75,744,733	41,701,547.07			0	0.00
23		75,744,733	75,744,733	40,585,447.27			0	0.00
24		75,744,733	75,744,733	39,499,218.75			0	0.00
25			0	0.00			0	0.00
26			0	0.00			0	0.00
27			0	0.00			0	0.00
28			0	0.00			0	0.00
29			0	0.00			0	0.00
30			0	0.00		56,941,600	56,941,600	25,233,340.60
31			0	0.00		56,941,600	56,941,600	24,557,995.71
32			0	0.00		56,941,600	56,941,600	23,900,725.75
33			0	0.00		56,941,600	56,941,600	23,261,046.96
34			0	0.00		56,941,600	56,941,600	22,638,488.53
35			0	0.00		56,941,600	56,941,600	22,032,592.24
36			0	0.00		56,941,600	56,941,600	21,442,912.16
37			0	0.00		56,941,600	56,941,600	20,869,014.27
38			0	0.00		56,941,600	56,941,600	20,310,476.17
39			0	0.00		56,941,600	56,941,600	19,766,886.78
40			0	0.00			0	0.00
41			0	0.00			0	0.00
42			0	0.00			0	0.00
43			0	0.00			0	0.00
44			0	0.00			0	0.00
45			0	0.00			0	0.00
46			0	0.00			0	0.00
47			0	0.00			0	0.00
48			0	0.00			0	0.00
49			0	0.00			0	0.00
50			0	0.00			0	0.00
Present Value				721,326,064				224,013,479
Average Annual Cost				26,718,581				8,297,665
Present Value (\$1,000)				721,326				224,013
Average Annual Cost (\$1,000)				26,719				8,298

Table 10. Development of Average Annual Continuing Construction Cost for Measures B-2 and B-12-2 (2.75% Discount Rate, 50 Year Period of Analysis)

Period	B-2				B-12-2			
	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction
1			0	0.00			0	0.00
2			0	0.00			0	0.00
3			0	0.00			0	0.00
4			0	0.00			0	0.00
5			0	0.00			0	0.00
6			0	0.00			0	0.00
7			0	0.00			0	0.00
8			0	0.00			0	0.00
9			0	0.00			0	0.00
10		62,077,600	62,077,600	47,327,832.22			0	0.00
11		62,077,600	62,077,600	46,061,150.58			0	0.00
12		62,077,600	62,077,600	44,828,370.39			0	0.00
13		62,077,600	62,077,600	43,628,584.32			0	0.00
14		62,077,600	62,077,600	42,460,909.32			0	0.00
15		62,077,600	62,077,600	41,324,485.95			0	0.00
16		62,077,600	62,077,600	40,218,477.81			0	0.00
17		62,077,600	62,077,600	39,142,070.86			0	0.00
18		62,077,600	62,077,600	38,094,472.86			0	0.00
19		62,077,600	62,077,600	37,074,912.76			0	0.00
20			0	0.00			0	0.00
21			0	0.00			0	0.00
22			0	0.00			0	0.00
23			0	0.00			0	0.00
24			0	0.00			0	0.00
25			0	0.00			0	0.00
26			0	0.00			0	0.00
27			0	0.00			0	0.00
28			0	0.00			0	0.00
29			0	0.00			0	0.00
30			0	0.00		167,150,333	167,150,333	74,071,702.99
31			0	0.00		167,150,333	167,150,333	72,089,248.66
32			0	0.00		167,150,333	167,150,333	70,159,852.71
33			0	0.00		167,150,333	167,150,333	68,282,095.09
34			0	0.00		167,150,333	167,150,333	66,454,593.76
35			0	0.00		167,150,333	167,150,333	64,676,003.66
36			0	0.00		167,150,333	167,150,333	62,945,015.73
37			0	0.00		167,150,333	167,150,333	61,260,355.94
38			0	0.00		167,150,333	167,150,333	59,620,784.37
39			0	0.00		167,150,333	167,150,333	58,025,094.28
40			0	0.00		167,150,333	167,150,333	56,472,111.22
41			0	0.00		167,150,333	167,150,333	54,960,692.18
42			0	0.00		167,150,333	167,150,333	53,489,724.75
43			0	0.00		167,150,333	167,150,333	52,058,126.28
44			0	0.00		167,150,333	167,150,333	50,664,843.10
45			0	0.00		167,150,333	167,150,333	49,308,849.73
46			0	0.00		167,150,333	167,150,333	47,989,148.15
47			0	0.00		167,150,333	167,150,333	46,704,767.06
48			0	0.00		167,150,333	167,150,333	45,454,761.13
49			0	0.00		167,150,333	167,150,333	44,238,210.34
50			0	0.00		167,150,333	167,150,333	43,054,219.31
Present Value				420,161,267				1,201,980,200
Average Annual Cost				15,563,160				44,522,451
Present Value (\$1,000)				420,161				1,201,980
Average Annual Cost (\$1,000)				15,563				44,522

Table 11. Development of Average Annual Continuing Construction Cost for Measures CA-5-2 and M-8-2 (2.75% Discount Rate, 50 Year Period of Analysis)

Period	CA-5-2				M-8-2			
	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction	O&M	Continuing Construction	Subtotal	Present Value Continuing Construction
1			0	0.00			0	0.00
2			0	0.00			0	0.00
3			0	0.00			0	0.00
4			0	0.00			0	0.00
5			0	0.00			0	0.00
6			0	0.00			0	0.00
7			0	0.00			0	0.00
8			0	0.00			0	0.00
9			0	0.00			0	0.00
10			0	0.00			0	0.00
11			0	0.00			0	0.00
12			0	0.00			0	0.00
13			0	0.00			0	0.00
14			0	0.00			0	0.00
15			0	0.00			0	0.00
16			0	0.00			0	0.00
17			0	0.00			0	0.00
18			0	0.00			0	0.00
19			0	0.00			0	0.00
20			0	0.00			0	0.00
21			0	0.00			0	0.00
22			0	0.00			0	0.00
23			0	0.00			0	0.00
24			0	0.00			0	0.00
25			0	0.00			0	0.00
26			0	0.00			0	0.00
27			0	0.00			0	0.00
28			0	0.00			0	0.00
29			0	0.00			0	0.00
30		3,764,400	3,764,400	1,668,172.08		71,718,000	71,718,000	31,781,416.76
31		3,764,400	3,764,400	1,623,525.14		71,718,000	71,718,000	30,930,819.23
32		3,764,400	3,764,400	1,580,073.13		71,718,000	71,718,000	30,102,987.09
33		3,764,400	3,764,400	1,537,784.07		71,718,000	71,718,000	29,297,311.04
34		3,764,400	3,764,400	1,496,626.83		71,718,000	71,718,000	28,513,198.09
35			0	0.00			0	0.00
36			0	0.00			0	0.00
37			0	0.00			0	0.00
38			0	0.00			0	0.00
39			0	0.00			0	0.00
40			0	0.00			0	0.00
41			0	0.00			0	0.00
42			0	0.00			0	0.00
43			0	0.00			0	0.00
44			0	0.00			0	0.00
45			0	0.00			0	0.00
46			0	0.00			0	0.00
47			0	0.00			0	0.00
48			0	0.00			0	0.00
49			0	0.00			0	0.00
50			0	0.00			0	0.00
Present Value				\$7,906,181				\$150,625,732
Average Annual Cost				\$292,852				\$5,579,315
Present Value (\$1,000)				\$7,906				\$150,626
Average Annual Cost (\$1,000)				\$293				\$5,579

Table 12. Development of Average Annual Continuing Construction Cost for Measures W-3 (2.75% Discount Rate, 50 Year Period of Analysis)

Period	W-3			Present Value Continuing Construction
	O&M	Continuing Construction	Subtotal	
1			0	0.00
2			0	0.00
3		32,488,000	32,488,000	29,948,666.17
4			0	0.00
5			0	0.00
6		32,488,000	32,488,000	27,607,812.27
7			0	0.00
8			0	0.00
9		32,488,000	32,488,000	25,449,924.69
10			0	0.00
11			0	0.00
12		32,488,000	32,488,000	23,460,702.37
13			0	0.00
14			0	0.00
15		32,488,000	32,488,000	21,626,962.05
16			0	0.00
17			0	0.00
18		32,488,000	32,488,000	19,936,550.93
19			0	0.00
20			0	0.00
21		32,488,000	32,488,000	18,378,266.08
22			0	0.00
23			0	0.00
24		32,488,000	32,488,000	16,941,780.21
25			0	0.00
26			0	0.00
27		32,488,000	32,488,000	15,617,573.25
28			0	0.00
29			0	0.00
30		32,488,000	32,488,000	14,396,869.24
31			0	0.00
32			0	0.00
33		32,488,000	32,488,000	13,271,578.14
34			0	0.00
35			0	0.00
36		32,488,000	32,488,000	12,234,242.28
37			0	0.00
38			0	0.00
39		32,488,000	32,488,000	11,277,986.88
40			0	0.00
41			0	0.00
42		32,488,000	32,488,000	10,396,474.52
43			0	0.00
44			0	0.00
45		32,488,000	32,488,000	9,583,863.11
46			0	0.00
47			0	0.00
48		32,488,000	32,488,000	8,834,767.20
49			0	0.00
50			0	0.00
Present Value				278,964,019.40
Average Annual Cost				10,333,083.79
Present Value (\$1,000)				278,964
Average Annual Cost (\$1,000)				10,333

Table 13 provides a summary of the average annual initial construction, average annual continuing construction and the sum of the two, average annual project first cost.

Table 13. Average Annual Project First Costs

Measure	Average Annual Construction Cost	Average Annual Continuing Construction Cost	Average Annual Project First Cost
G-5	\$154,376	\$26,719	\$181,095
G-28-1	36,767	0	36,767
G-28-2	36,767	8,298	45,065
B-2	22,219	15,563	37,782
B-12-1	26,070	0	26,070
B-12-2	26,070	44,522	70,592
CA-5-1	2,275	0	2,275
CA-5-2	2,275	293	2,568
CA-6	3,091	0	3,091
M-8-1	7,380	0	7,380
M-8-2	7,380	5,579	12,959
SP-1	13,460	0	13,460
W-3	1,814	10,333	12,147

As previously described, the cost and output (AAHUs) for each measure are added together to create the fully formed plans. A summary of costs and benefits by fully formed alternative is displayed in Table 14.

Table 14. Summary of Project First Costs (\$1,000, October 2017 Prices, 2.75% Interest Rate, 50 Year Period of Analysis) and Net AAHU's by Alternative

Alternative	Initial Construction Cost	Monitoring and Adaptive Management Costs	Cultural Cost	Continuing Construction Cost	Total First Cost	Average Annual Project Cost	Net AAHUs
Alternative 1-1	\$6,034,660	\$102,097	\$10,802	\$2,276,755	\$8,424,314	\$320,067	39,059
Alternative 1-2	6,034,660	102,097	10,802	6,733,740	12,881,299	378,759	69,344
Alternative 2-1	4,596,288	59,506	7,824	2,276,755	6,940,373	260,185	34,026
Alternative 2-2	4,596,288	59,506	7,824	5,786,912	10,450,530	304,707	49,999
Alternative 3-1	4,775,831	65,653	6,475	2,276,755	7,124,714	267,791	33,834
Alternative 3-2	4,775,831	65,653	6,475	2,846,171	7,694,130	276,089	41,957
Alternative 4-1	2,132,039	62,640	6,215	0	2,200,894	89,043	6,312
Alternative 4-2	2,132,039	62,640	6,215	4,456,985	6,657,879	147,735	36,597
Alternative 5-1	5,350,250	83,317	5,779	1,756,947	7,196,293	281,714	4,559
Alternative 5-2	5,350,250	83,317	5,779	5,836,520	11,275,866	334,534	28,655
Alternative 6-1	5,426,429	84,841	5,980	1,756,947	7,274,197	284,805	4,577
Alternative 6-2	5,426,429	84,841	5,980	5,836,520	11,353,770	337,625	28,673

COST EFFECTIVENESS AND INCREMENTAL COST ANALYSIS

To conduct the CE/ICA analysis, environmental restoration benefits (increase in with-project AAHUs) and annual costs (expressed in thousands of dollars) were entered into IWR Planning Suite. The analysis is in two parts. Cost effective analysis identifies all of the cost-effective plans. The cost-effective plans are incrementally evaluated on incremental cost per incremental output to identify the best buy plans.

COST EFFECTIVENESS

The 12 fully formed plans were entered into IWR Planning Suite. The cost-effective analysis identified five plans as cost effective, including the no action plan. They are No Action, Alternative 1-2, Alternative 3-2, Alternative 4-1 and Alternative 4-2. This analysis is depicted graphically in Figure 1 .

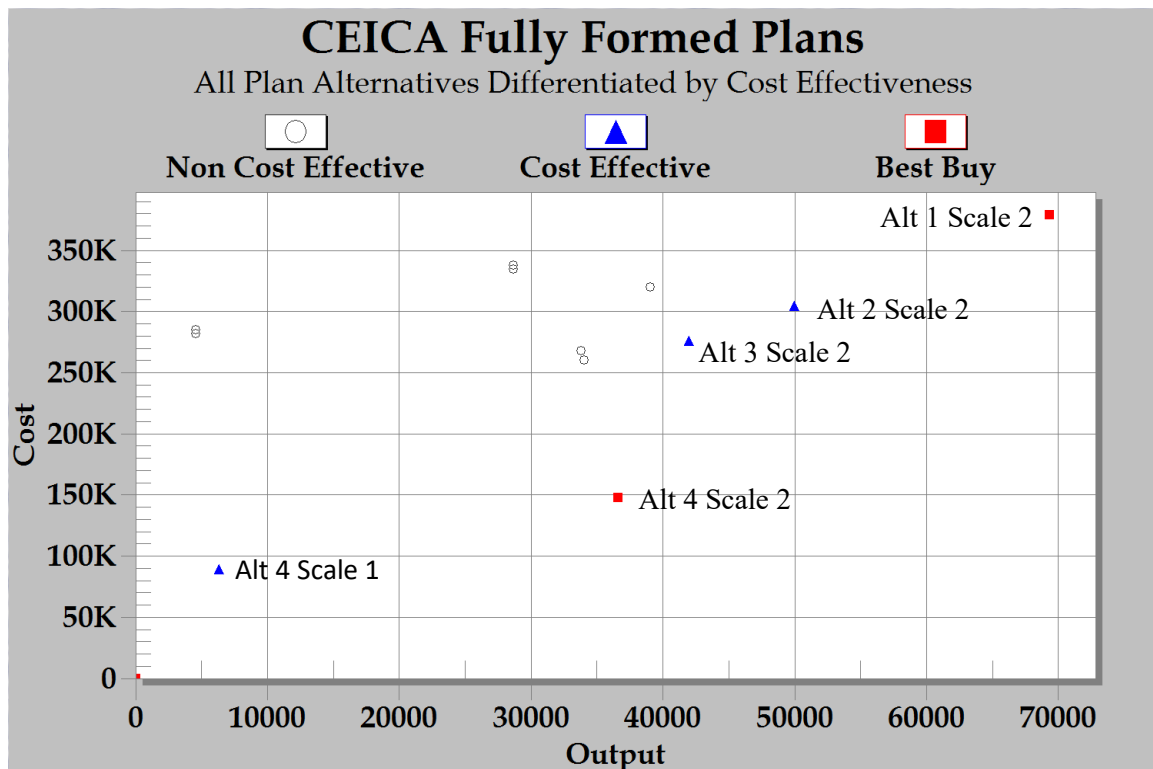


Figure 1. CE/ICA Results

INCREMENTAL COST ANALYSIS AND BEST BUY PLANS

The next step in the CE/ICA analysis is to perform an incremental cost analysis (ICA) on the cost-effective plans. ICA compares the incremental cost per incremental benefit (output or lift in environmental output) among the plans to identify plans that maximize the last dollar spent. Starting with the no action plan, the incremental cost per incremental benefit is calculated from

the no action for each cost-effective plan. The plan with the least incremental cost per incremental output is identified as the first of the “with-project” best buy plans. Then starting with that plan, the incremental cost per incremental benefit is calculated between that plan and each remaining cost-effective plan, and the one with the least incremental cost per incremental benefit is identified as the next plan in the array of best buy plans. This iteration continues until there are no remaining plans. The last plan in the best buy array, is typically the “kitchen sink” plan, or the plan that contains all of the management measures being analyzed.

From the cost-effective alternatives, three (including the no action plan) were identified as “Best Buy” plans. The results of the analysis are shown graphically in Figure 2. The numerical output of the incremental analysis is displayed in Table 15. Alternative 4 Scale 2 provides an incremental output of 36,597 AAHUs over the no action plan, with an incremental cost per incremental output of \$4 thousand. It has a total cost, including initial construction and outyear nourishment of \$6.7 billion.

Alternative 1 Scale 2 provides a total of 69,344 AAHUs, and incremental increase over Alternative 4 Scale 2 of 32,747 AAHUs. The incremental cost per incremental output for Alternative 1 Scale 2 is \$7 thousand over the prior alternative. It has a total cost of \$12.9 billion.

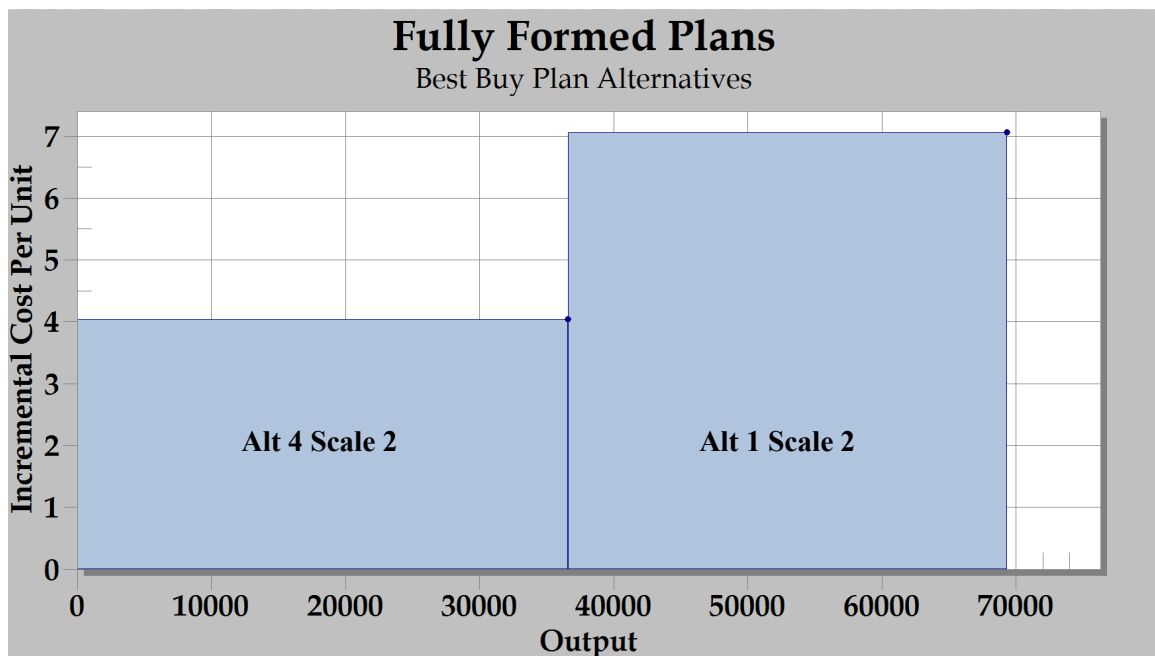


Figure 2. Incremental Comparison of Best Buy Alternatives

Table 15. Summary of Best Buy Plans

Alternative	Output (AAHU)	Cost (Average Annual, (\$1,000))	Average Cost (\$1,000/AAHU)	Incremental Cost (\$1,000)	Incremental Output	Incremental Cost per Output (\$1,000)	Total Cost (\$1,000)
No Action	0	0					
Alt 4 Scale 2	36,597	\$147,735	\$4.04	\$147,735	36,597	4.04	\$6,657,879
Alt 1 Scale 2	69,344	\$378,759	\$5.46	\$231,024	32,747	\$7.05	\$12,881,299

ADDITIONAL CEICA ANALYSES

ANALYSIS ALLOWING PLANNING SUITE TO ASSEMBLE PLANS

During the plan formulation workshops, it was suggested the evaluation of alternatives have should not assume the fully formed plans would provide the best overall solution. There is the possibility that some other assemblage of measures could provide a better solution in terms of environmental output and cost effectiveness. As a consideration for this possibility, an additional CEICA was conducted where each individual measure was input into Planning Suite, allowing the software to assemble plans. This generate numerous additional cost-effective plans, as sown in Figure 3.

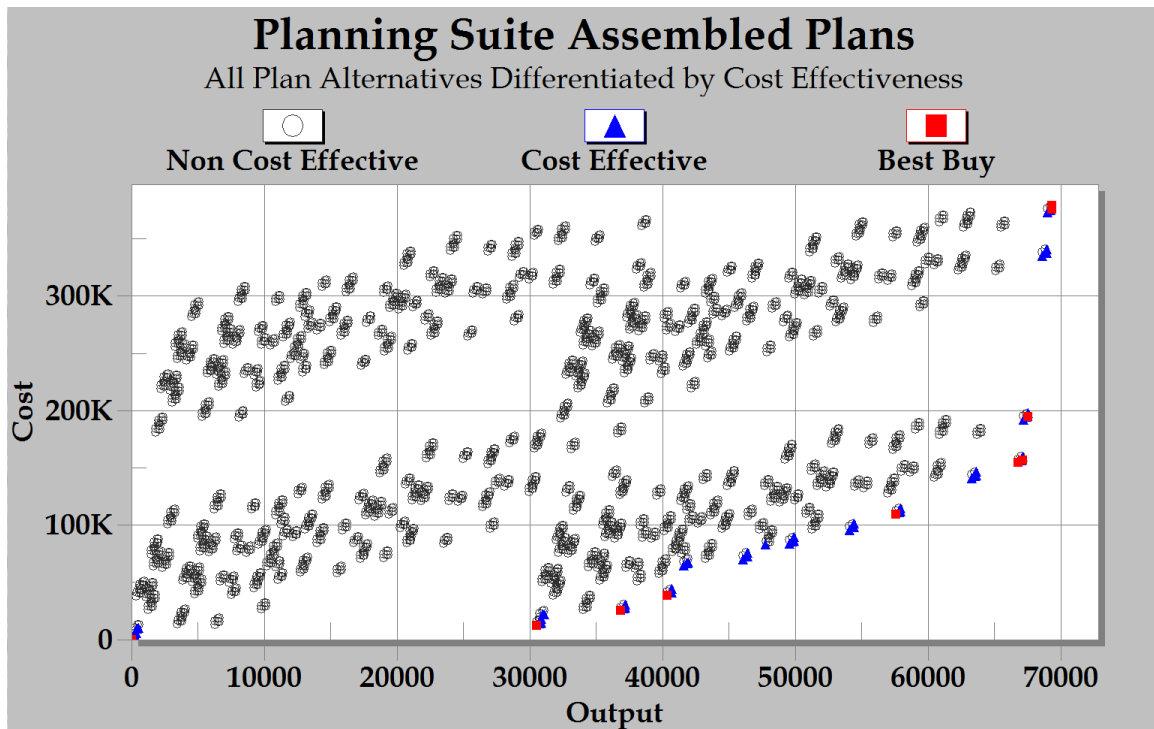


Figure 3. Cost Effective Analysis of Software Generated Plans

The cost-effective plans were incrementally analyzed, which resulted in ten best buy plans (including the No Action Plan). The output is displayed in Figure 4 and Table 16. A visual inspection shows a significant breakpoint or increase in incremental costs between the 6th and 7th plans, identified as Alternative 7 in Figure 4. This alternative is highlighted in bold-face text in Table 16.

Comparing this alternative to those that were fully formed prior to analysis (Table 17) show that Alternative Z was very similar in cost and composition to Alternative 4 Scale 2 form the full formed plans. Assuming the largest plan (Alternative 1-2) provides 100% of the potential output of 69,344 AAHUs, we can see that Alternative 4-2 only provides 53% while Alternative Z provides 97% of the measured output but has a comparable project cost to Alternative 4-2. Upon looking at the measures composing these two alternatives, the significant difference is W-3. It alone accounts for 44% of the measured benefit but is not part of Alternative 4-2.

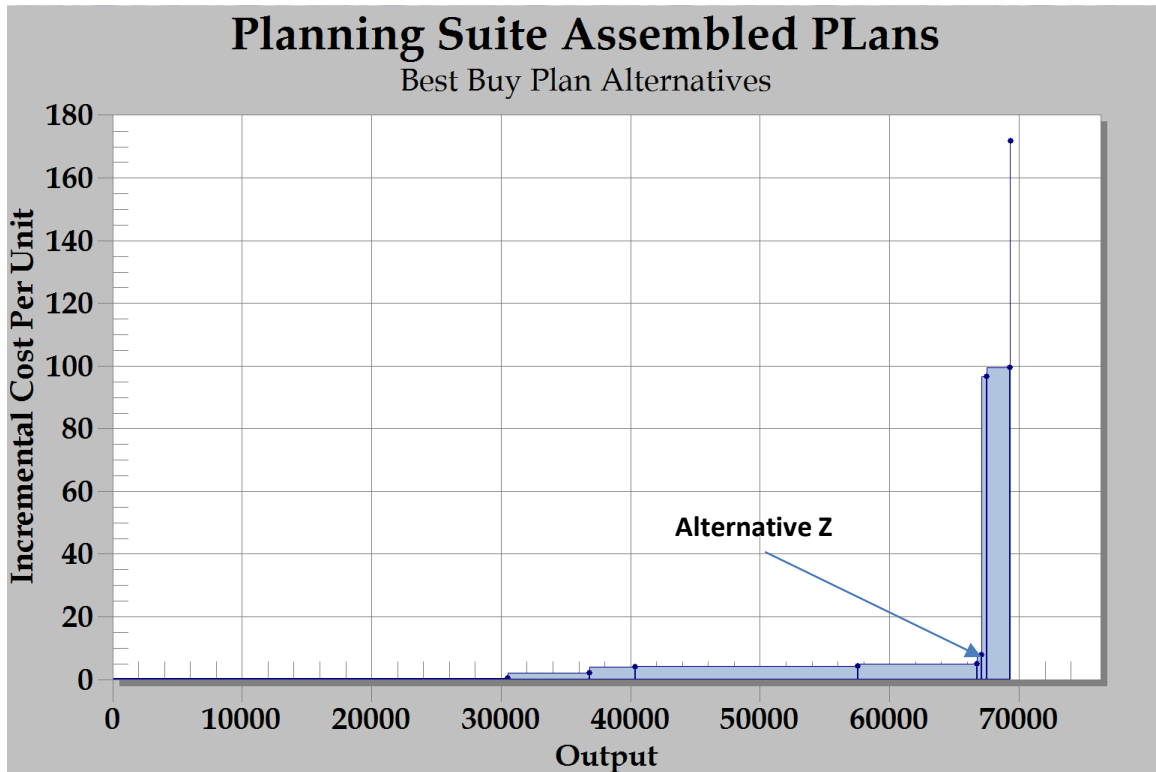


Figure 4. Best Buy Array of Software Assembled Plans

Table 16. Best Buy Summary of Software Assembled Plans

Alternative (Measure Composition)	Output (AAHU)	Cost (\$1,000)	Average Cost (\$1,000/AAHU)	Incremental Cost	Incremental Output	Incremental Cost per Output
No Action	0	0				
W3	30,536	12,147	\$0.40	\$12,147	30,536	\$0.40
W3, M8-2	36,839	25,106	\$0.68	\$12,959	6,303	\$2.06
W3, M8-2, SP1	40,340	38,566	\$0.96	\$13,460	3,501	\$3.84
W3, M8-2, SP1, B12-2	57,574	109,158	\$1.90	\$70,592	17,234	\$4.10
W3, M8-2, SP1, B12-2, G28-2	66,784	154,223	\$2.31	\$45,065	9,210	\$4.89
W3, M8-2, SP1, B12-2, G28-2, CA5-2	67,115	156,791	\$2.34	\$2,568	331	\$7.76
W3, M8-2, SP1, B12-2, G28-2, CA5-2, B2	67,506	194,573	\$2.88	\$37,782	391	\$96.63
W3, M8-2, SP1, B12-2, G28-2, CA5-2, B2, G5	69,326	375,668	\$5.42	\$181,095	1,820	\$99.50
W3, M8-2, SP1, B12-2, G28-2, CA5-2, B2, G5, CA6	69,344	378,759	\$5.46	\$3,091	18	\$171.72

Table 17. Comparison of Fully Formed Alternatives to Alternative Z

Alternative	Output	Percent of Potential Measured Output	Total Cost
Alternative 1-2	69,344	100%	12,881,299
Alternative 4-2	36,597	53%	6,657,879
Alternative Z	67,115	97%	7,147,445
Measure W3	30,536	44%	567,470

Given the similarities to Alternative 4-2, the PDT revisited the original formulation to identify why it was not included and discovered that in earlier formulations of the respective strategy, the measure had been included, but was simply screened out by the preliminary screening process. The PDT feels that adding Measure W3 to Alternative 4 (Scales 1 and 2) is consistent with the planning strategies related to Alternative 4. This led to revising Alternative 4 (Scale 1 and 2) to include W3, and a one additional CEICA runs to be confident in the results.

REVISION OF ALTERNATIVE 4

In this last CEICA run, the annual costs and benefits associated with measure W3 were added to the existing numbers for Alternative 4 (Scales 1 and 2). The resulting cost-effective analysis is shown in Figure 4. The analysis resulted in four cost effective plans: No Action, Alternative 4 Scale 1(revised), Alternative 4 Scale 2 (revised), and Alternative 1 Scale 2.

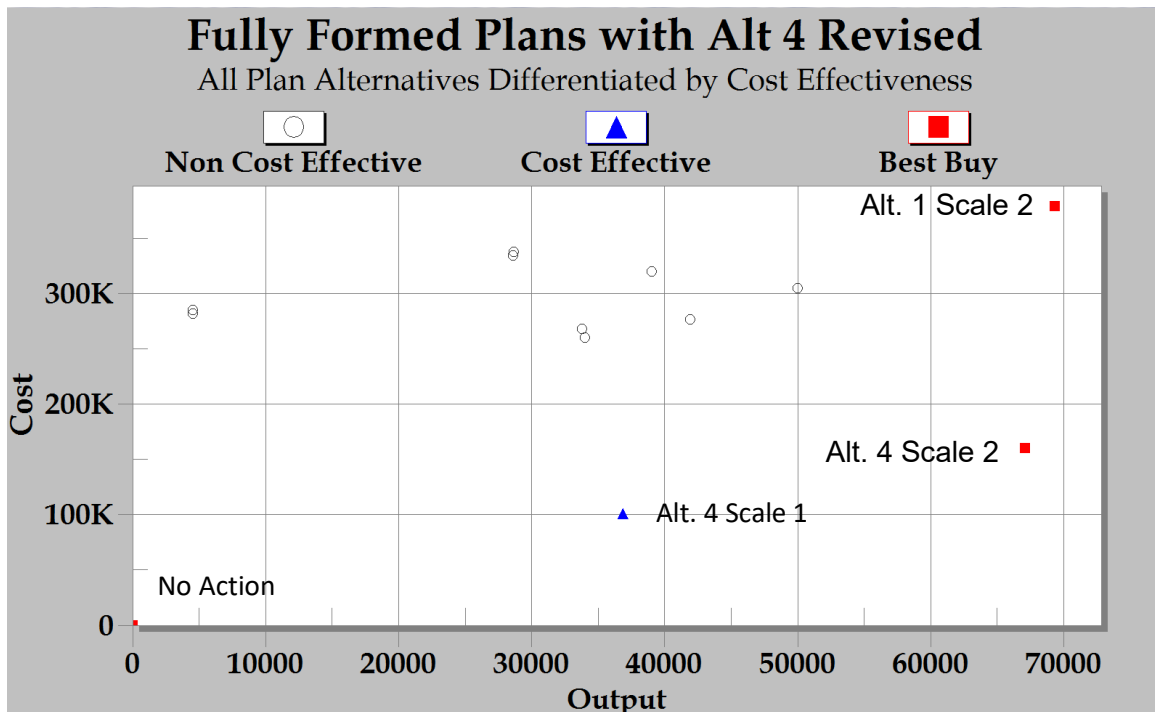


Figure 5. Cost Effective Analysis with Revised Alternative 4

The incremental cost analysis is presented in Figure 6 Table 18. Of the cost-effective plans, only three are best buys: No Action, Alternative 4 Scale 2 (revised) and Alternative 1 Scale 2. The revised Alternative 4 Scale 2 provides a gain of 67,133 AAHUs over the No Action alternative. The incremental cost per incremental output is \$2.4 thousand. The project cost (including initial construction and outyear nourishment) is \$7.2 billion.

Alternative 1 Scale 2 provides a total output of 69,244 AAHUs, which 32,747 additional AAHUs over Alternative 4 Scale 2 (revised). The incremental cost per incremental output is \$99 thousand and the project cost is \$12.9 billion.

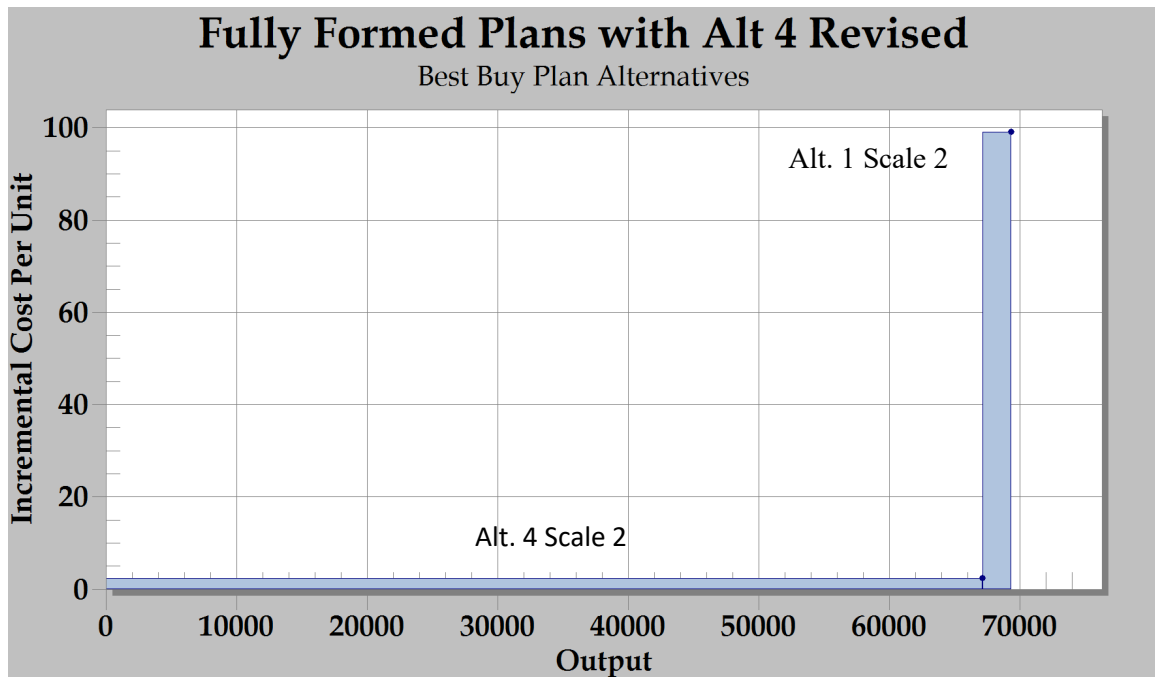


Figure 6. Best Buy Array with Alternative 4 Revised

Table 18. Summary of Incremental Cost Analysis with Alternative 4 revised

Alternative	Output (AAHU)	Cost (\$1,000)	Average Cost (\$1,000/AAHU)	Incremental Cost (\$1,000)	Incremental Output	Incremental Cost per Output (\$1,000)	Total Cost (\$1,000)
No Action	0	0					
Alt 4* Sale 2	67,133	\$159,882	\$2.38	\$159,882	67,133	\$2.38	\$7,225,239
Alt 1 Scale 2	69,344	\$378,759	\$5.46	\$231,024	32,747	\$98.99	\$12,881,299

In comparing the three CEICA runs, the PDT feels the final run identifies the best alternatives for evaluation for the ER and tentatively selected plan. Because of the significant incremental output created by Measure W3 at a comparatively low added cost, and that the measure is consistent with the planning strategy for Alternative 4, it is felt the revision to Alternative 4 is sound. When comparing the two best buy plans, there is a distinct increase in incremental costs per incremental out going from Alternative 4 Scale 2 to Alternative 1 Scale 2, as well as a significant increase in project costs. However, not all of the benefits are measures by the environmental models used, leaving a significant portion underrepresented in the CEICA analysis.

POST REVIEW CEICA RUN

Following two public, agency technical and policy reviews, several changes were made to the formulation, modeling and calculation of habitat units and project first costs. Details of these changes can be found in the plan formulation and environmental technical appendices. One significant change was a policy decision that the out year nourishments could not be considered as part of the plans, and therefore all scale 2 and other out year nourishments were removed from the ecosystem restoration measures. Additionally, it was determined that measure G5 would be removed from the ecosystem plans and considered as part of the coastal storm risk management (CSRМ) measures. As previously discussed, measure W3 was added to Alternative 4, and remains so in this final analysis.

Table 19 shows the six fully-formed alternatives based on planning strategy that will be evaluated. The measures making up each alternative is shown in Table 20, and the project first cost of each measure is shown in Table 21 and the revised AAHUs are presented in Table 22.

Table 19. Fully-Formed Alternatives

Alternative/Scale	Strategy/Description
Alternative 1	Coast-wide All-Inclusive Restoration Alternative
Alternative 2	Coast-wide Restoration of Critical Geomorphic or Landscape Features
Alternative 3	Coast-wide Barrier System Restoration
Alternative 4	Coast-wide Bay System Restoration
Alternative 5	Coast-wide Ecosystem Restoration Contributing to Infrastructure Risk Reduction
Alternative 6	Top Performers

Table 20. Matrix of Measure by Alternative

Alternative	G28	B2	B12	CA5	CA6	M8	SP1	W3
1	•	•	•	•	•	•	•	•
2		•	•		•			•
3	•	•						•
4	•		•	•	•	•	•	•
5	•	•	•					
6	•	•	•		•			

Table 21. Project First Cost by Measure (\$1,000, October 2020 Prices)

Measure	First Cost
G-28	\$935,313
B-2	59,058
B-12	802,638
CA-5	76,808
CA-6	107,313
M-8	281,647
SP-1	344,045
W-3	65,911

Table 22. Average Annual Habitat Units by Measure

Measure	Without Project	With Project	Net AAHUs	Acres
G-28	265	1,561	1,296	1,653
B-2	6	247	241	691
B-12	199	1,496	1,297	1,121
CA-5	2	242	240	300
CA-6	900	919	19	2,416
M-8	186	668	482	766
SP-1	20	3,521	3,501	3,453
W-3	26,092	40,029	13,937	56,858

A summary of the project first costs, interest during construction and CEICA inputs is shown in Table 22. Project first costs range from \$1.03 billion for Alternative 2 to \$2.7 billion for Alternative 1. The net AAHUs range from 2,853 for Alternative 6 to 15,494 to 21,013 for Alternative 4. Average annual project first costs were computed for each alternative in the manner previously described in this appendix, with updated costs expressed in October 2020 prices, a 2.5% discount rate and a 50 year period of analysis.

Table 23. Summary of CEICA Inputs (\$1,000, October 2020 Prices, 2.5% Discount Rate, 50 Year Period of Analysis)

Alternative	First Cost	Interest During Construction	Average Annual Project Cost	Net AAHUs	Acres	Total Project First Cost Per Acre
Alternative 1	\$2,672,733	\$221,088	\$102,032	21,013	67,258	\$40
Alternative 2	1,034,920	\$90,091	\$39,666	15,494	61,086	\$17
Alternative 3	1,060,282	\$95,343	\$40,745	15,474	59,202	\$18
Alternative 4	2,613,675	\$213,154	\$99,670	20,772	66,567	\$39
Alternative 5	1,797,009	\$167,272	\$69,257	2,834	3,465	\$519
Alternative 6	1,657,069	\$174,184	\$73,285	2,853	5,881	\$324

The cost effective analysis identified four cost effective plans:

- No Action
- Alternative 1
- Alternative 2
- Alternative 4

Three of the plans, No Action, Alternative 1 and Alternative 2 were identified as best buy plans. Alternatives 3,5 and 6 were not cost effective plans. A graphical summary of the cost effective analysis is shown in Figure 7.

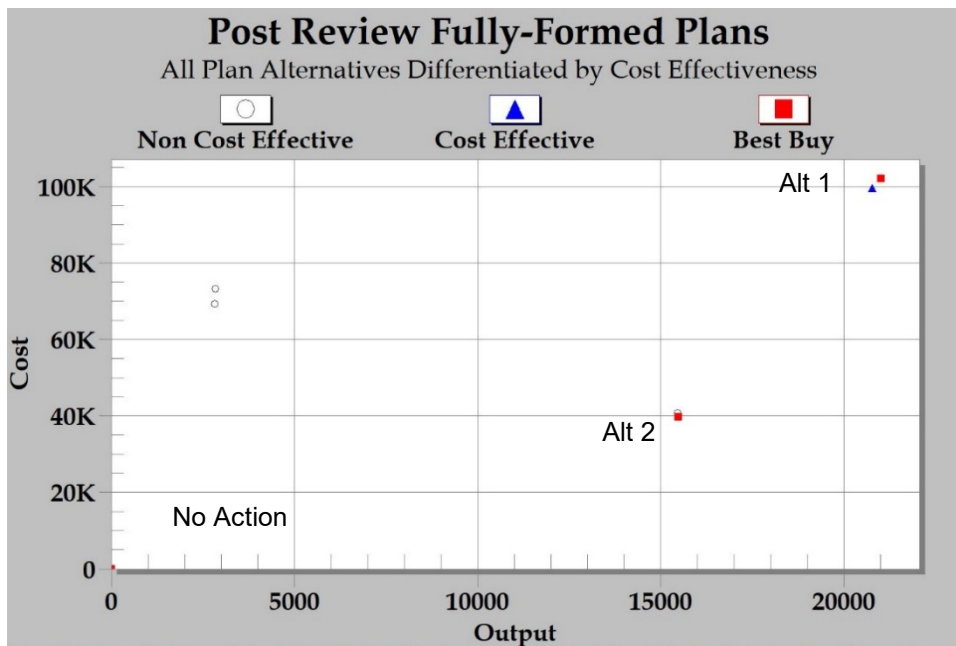


Figure 7. Post Review Cost Effective Plans

The incremental analysis of the best buy array is presented in Table 23 and Figure 8.

Table 24. Incremental Cost Summary for Post Review Alternatives

Alternative	Output (AAHU)	Cost (\$1,000)	Average Cost (\$1,000/AAHU)	Incremental Cost (\$1,000)	Incremental Output	Incremental Cost per Output (\$1,000)	First Cost (\$1,000)
No Action	0	0					
2	15,494	\$39,666	\$2.56	\$39,666	15,494	\$2.56	\$1,034,920
1	21,013	\$102,032	\$4.86	\$62,366	5,519	\$11.30	\$2,672,733

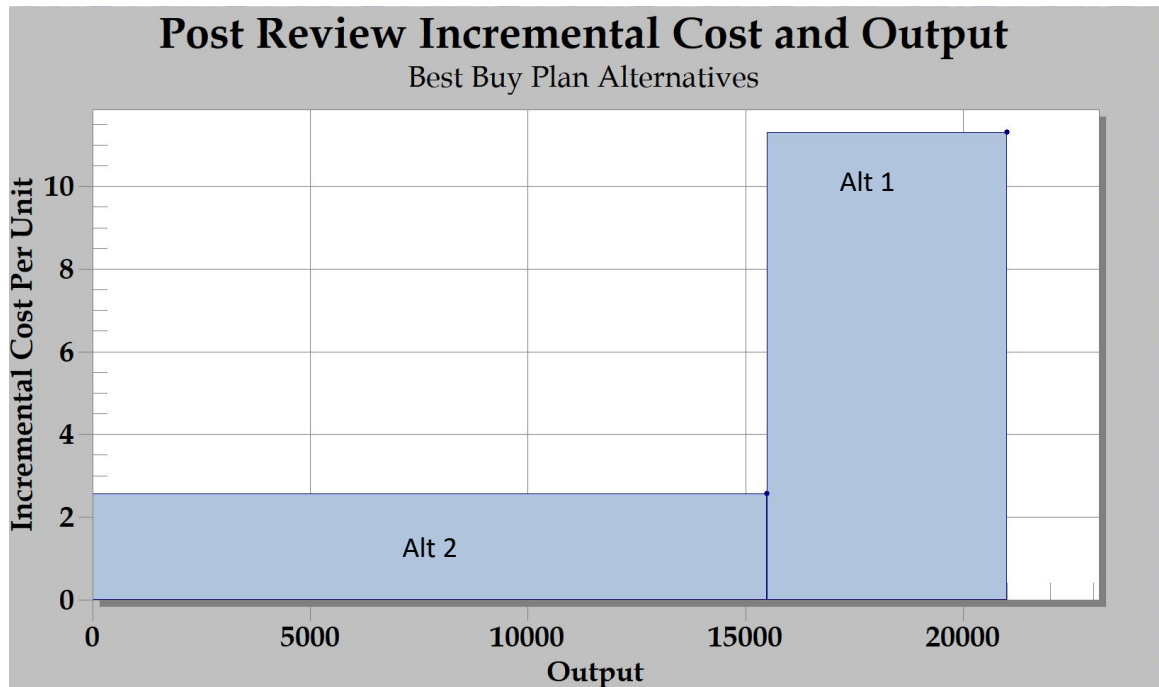


Figure 8. Incremental Cost of Post Review Best Buy Plans

Alternative 2 provides the least incremental cost per incremental output over the no action plan with an increase of 15,499 AAHUs. The incremental cost per incremental AAHU is \$2,560 and a total project cost of \$1.03 billion.

Alternative 1 provides 21,023 AAHUs, an incremental increase of 5,519 AAHUs over Alternative 2. The incremental cost per additional unit of output is \$11,300. The project first cost is \$2.7 billion.

In order to arrive at the recommended NER plan, an “Is It Worth It” analysis is carried out on the incremental plans as presented, making the case why that plan is worth the higher incremental cost per incremental output. That analysis can be found in the main report and plan formulation and environmental appendices.