Appendix E – Cost Effective/ Incremental Cost Analysis

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US Army Corps of Engineers ®

Horry County STORM WATER MANAGEMENT

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List of Acronyms

AAHU	Average Annual Habitat Unit
CE/ICA	Cost Effectiveness / Incremental Cost Analysis
EGM	Economic Guidance Memorandum
ICA	Incremental Cost Analysis
IDC	Interest During Construction
NER	National Ecosystem Restoration
OMRR&R	Operations, Maintenance, Repair, Replacement, and Rehabilitation

1 Introduction

Comparing benefits and costs for aquatic ecosystem restoration provides a challenge to planners and decision makers because benefits and costs are not measured in the same units. Aquatic ecosystem 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 proposed plan.

For this study, the environmental output is the average annual habitat unit (AAHU), which is derived from the product of a Habitat Suitability Index and an alternatives acreage. The development of the AAHU is discussed in detail in the Appendix B – Environmental.

2 Measures and Alternatives

2.1 Measures

A measure is defined as a means to an end; an act, step, or procedure designed for the accomplishment of an objective. In other words, a measure is a feature (structure), or an activity, that can be implemented at a specific geographic site to address one or more planning objectives. Measures are the building blocks of alternatives and are categorized as structural and non-structural. Equal consideration was given to measures during the planning process while conducting this feasibility study. A detailed description of each of these can be read in the Main Report Chapter 3.9.

- Floodplain Benching
- Log Drop Structures
- Root Wads
- Rock Riffle Structure with Bank Stabilization
- 701 Breaching

2.2 Alternatives

The array of management measures was combined into alternatives that would address aquatic ecosystem restoration of the riverine habitats, as well as restore structure and function of the study area. Each of the alternatives listed below could be a standalone plan or be combined with other alternatives to form a suite of plans.

3 Average Annual Habitat Units and Costs

In order to determine benefits of an aquatic ecosystem restoration plan, future with-project environmental outputs are compared to future without-project outputs. The difference between the two represents the benefits from project implementation. The Average Annual Habitat Units (AAHUs) were calculated using the Annualizer Tool in the Institute for Water Resources Planning Suite II. Appendix B – Environmental provides further documentation on how AAHUs were calculated for each Future-Without Project (FWOP) and Future-With Project (FWP) condition benefits.

3.1 Existing and Future-Without Project Average Annual Habitat Units

For this study, FWOP baseline conditions are assumed to be the same as existing conditions, given the existing habitat quality. Future-Without Project conditions were estimated by a team of biologists, including representatives from USACE, Horry County SC, as well as representatives for the resource agencies of the state of South Carolina.

3.2 Future-With Project Average Annual Habitat Units

Aquatic ecosystem restoration benefits are calculated by subtracting the FWOP AAHU from the FWP AAHU. For the comparison of measures, both environmental outputs and costs were annualized over a 50-year life of the project using the FY 2020 Federal Discount Rate of 2.75% (per EGM 20-01 dated 31 October 2019). The 50-year planning horizon is used primarily for analytical purposes pertaining to the benefit-cost calculations; actual benefits may well indeed be realized longer than 50 years and any discussion of such longer-term benefitting would be found in Appendix B.

The resulting benefits are then used, along with annual costs, to identify cost effective plans and perform incremental cost analysis. The calculation of benefits (outputs/AAHUs) are shown in Table 1.

3.3 Costs

Total project economic costs were annualized using the Annualizer Tool in Institute for Water Resources (IWR) Planning Suite II. A period of analysis of 50 years was used, along with a Federal Discount rate of 2.75% (per EGM 20-01 dated 31 October 2019). Prices are expressed in October 2019 dollars.

Table 2 provides a summary of total and annual costs, including an initial estimate of annualized Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) for each alternative. Project first cost includes construction costs; planning, engineering, and design (PED); construction management; and contingency estimates. Real estate cost was estimated on a per-acre basis for each alternative and includes a contingency factor. Construction durations were estimated to be 12 months or fewer for all alternatives, thus negating the need for calculating interest during construction (IDC). Construction first costs and real estate cost are summed in order to calculate the annual investment costs. The annual with-project OMRR&R is added to the annual investment cost to obtain the total annual costs.

Table 1. The calculation of benefits (outputs/AAHUs).

Reach	Alternatives	FWOP AAHU	FWP AAHU	AAHU Benefits	Acres
1. Daniel Rd to El Bethel	Floodplain Bench with Plantings	3.6	16.7	13.1	36.2
	Log Drop Structures	3.6	6.3	2.7	36.2
	Bench and Logs	3.6	17.1	13.5	36.2
2. El Bethel to Mill Pond Rd	Floodplain Bench with Plantings	2.7	14.7	12.0	27.3
	Log Drop Structures	2.7	8.1	5.3	27.3
	Root Wads	2.7	8.1	5.3	27.3
	Rock Riffle Structure w/ Bank Stabilization	2.7	9.7	7.0	27.3
	FP Bench with Plantings and Log Drop Structures	2.7	15.8	13.1	27.3
	FP Bench with plantings and Root Wads	2.7	15.7	13.0	27.3
	FP Bench with plantings and Rock Riffle Structure w/ Bank Stabilization	2.7	16.7	14.0	27.3
	Log Drop Structure and Root Wads	2.7	9.6	6.9	27.3
	Log Drop Structure and Rock Riffle Structure w/ Bank Stabilization	2.7	9.7	7.0	27.3
	Root Wads and Rock Riffle w/ Bank Stabilization	2.7	9.7	7.0	27.3
	FP Bench with plantings, Root Wads, and Log Drop Structure	2.7	15.5	12.8	27.3
	FP Bench with plantings, Log Drops, and Rock Riffle Structure w/ Bank Stabilization	2.7	16.7	14.0	27.3
	FP Bench with plantings, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	2.7	16.7	14.0	27.3
	Log Drops, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	2.7	10.4	7.7	27.3
	FP Bench with plantings, Log Drops, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	2.7	17.8	15.1	27.3
3. Reach 701	Breaching	1.6	5.7	4.1	16

Table 2. Total and Annual Costs, Including Initial Estimate of Annualized OMRR&R for Each Alternative

Reach	Project First Cost	Real Estate	IDC	Economic Cost	Annual Investment Cost	Annual M&AM	Annual OMRRR	Total Annual Cost
1. Daniel Rd to El Bethel								
Floodplain Bench with Plantings	$248,600	$155,000	N/A	$403,600	$15,000	$4,000	$1,200	$20,200
Log Drop Structures	$13,400	$40,000	N/A	$53,400	$2,000	$1,600	$800	$4,400
Bench and Logs	$262,000	$275,000	N/A	$537,000	$19,900	$5,700	$2,000	$27,600
2. El Bethel to Mill Pond Rd								
Floodplain Bench with plantings	$327,500	$200,000	N/A	$527,500	$19,500	$2,400	$700	$22,600
Log Drop Structures	$26,700	$12,500	N/A	$39,200	$1,500	$3,300	$1,600	$6,300
Root Wads	$27,700	$27,500	N/A	$55,200	$2,000	$3,400	$1,700	$7,100
Rock Riffle Structure w/ Bank Stabilization	$129,000	$41,500	N/A	$170,500	$6,300	$3,000	$1,300	$10,600
FP Bench with plantings and Log Drop Structures	$354,200	$200,000	N/A	$554,200	$20,500	$5,700	$2,300	$28,500
FP Bench with plantings and Root Wads	$355,100	$200,000	N/A	$555,100	$20,600	$5,800	$2,300	$28,700
FP Bench with plantings and Rock Riffle Structure w/ Bank Stabilization	$456,500	$200,000	N/A	$656,500	$24,300	$5,400	$2,000	$31,700
Log Drop Structure and Root Wads	$54,400	$115,000	N/A	$169,400	$6,300	$6,600	$3,300	$16,200
Log Drop Structure and Rock Riffle Structure w/ Bank Stabilization	$155,800	$115,000	N/A	$270,800	$10,000	$6,300	$3,000	$19,200
Root Wads and Rock Riffle w/ Bank Stabilization	$156,700	$115,000	N/A	$271,700	$10,100	$6,400	$3,000	$19,500
FP Bench with plantings, Root Wads, and Log Drop Structure	$381,900	$200,000	N/A	$581,900	$21,600	$9,000	$4,000	$34,600
FP Bench with plantings, Log Drops, and Rock Riffle Structure w/ Bank Stabilization	$483,200	$200,000	N/A	$683,200	$25,300	$8,700	$3,600	$37,600
FP Bench with plantings, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	$484,100	$200,000	N/A	$684,100	$25,300	$8,800	$3,700	$37,800
Log Drops, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	$183,400	$105,000	N/A	$288,400	$10,700	$9,600	$4,600	$24,900
FP Bench with plantings, Log Drops, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	$510,900	$200,000	N/A	$710,900	$26,300	$12,000	$5,300	$43,700
3. Reach 701								
01 Breaching	$103,100	$67,500	N/A	$170,600	$6,300	$12,700	$6,300	$25,300

3.4 Cost Effectiveness and Incremental Cost Analysis

To conduct the CE/ICA analysis, aquatic ecosystem restoration benefits (increase in with-project AAHUs) and annual costs were entered into IWR Planning Suite II. All three reaches' alternatives are combinable, but combinations within each reach are mutually exclusive. No other combinability or dependency relationships were entered into IWR Planning Suite. Using the management measures, the plan generator in the software was used to create all possible combinations of the measures. This resulted in 10 cost effective plans for each reach, shown in Table 3.

Cost effective plans are defined as the least expensive plan for a given set of benefits, or environmental output. In other words, no other plan would provide the same or more benefits for a lower cost.

Table 3. Annual Benefits and Annual Cost for Cost Effective Alternatives by Reach

Reach	Alternatives	AAHU	Annual Cost ($1s) October 2019 Prices
1. Daniel Rd to El Bethel	Floodplain Bench with Plantings	13.1	$20,200
	Log Drop Structures	2.7	$4,400
	Bench and Logs	13.5	$27,600
2. El Bethel to Mill Pond Rd	Floodplain Bench with Plantings	12.0	$22,600
	Log Drop Structures	5.3	$6,300
	Rock Riffles with Bank Stabilization	7.0	$10,600
	FP Bench with Plantings and Log Drop Structures	13.1	$28,500
	FP Bench with plantings and Rock Riffle Structure w/ Bank Stabilization	14.0	$31,700
	FP Bench with plantings, Log Drops, Root Wads, and Rock Riffle Structure w/ Bank Stabilization	15.1	$43,700
3. Reach 701	Breaching	4.1	$25,300

3.4.1 Cost Effective Plans

Subsequently, a second model run of the software was conducted in order to identify Cost Effective alternatives for the entire study area. Thirteen inter-reach combinations resulted in being identified as Cost Effective, including the No Action Plan by definition. The results are shown in Figure 1 and Tables 4 and 5.

Note that cost effective plans (red triangles) include those identified as “Best Buy” plans (green squares), which will be discussed in the next section.

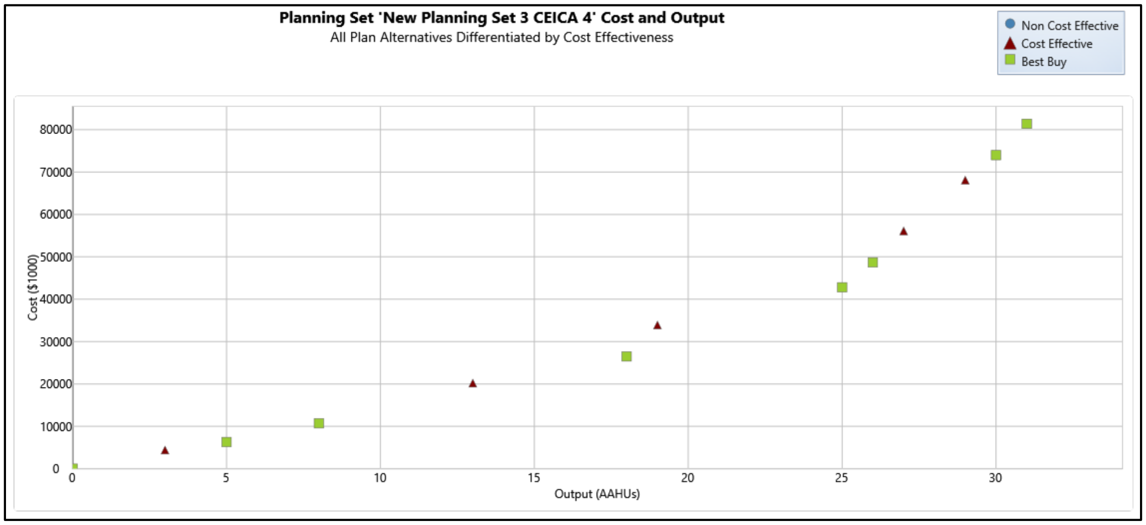

Figure 1. Cost Effective Results

Table 4. Cost Effective Plans

Solution	Code
R1 Bench	ROB
R1 Logs	EOL
R1 Bench & Logs Combo	EOC
R2 Bench	RTB
R2 Logs	RTL
R2 Bench & Logs Combo	RTC
R3 Bench	REE

Table 5. Cost Effective Plans, Habitat Outputs and Cost

Cost Effective Plans	Plan Description	AAHUs	Annualized Cost ($1s)	Annualized Cost/AAHUs ($1)
No Action Plan	No Action Plan	0	$0	0
ROB0ROL1ROC0RTB0RTL0RTC0REE0	Reach 1 Logs	3	$4,400	$1,470
ROB0ROL0ROC0RTB0RTL1RTC0REE0	R2 Logs	5	$6,300	$1,260
ROB0ROL1ROC0RTB0RTL1RTC0REE0	R1 Logs + R2 Logs	8	$10,700	$1,340
ROB1ROL0ROC0RTB0RTL0RTC0REE0	R1 Bench	13	$20,200	$1,550
ROB1ROL0ROC0RTB0RTL1RTC0REE0	R1 Bench + R2 Logs	18	$26,500	$1,470
ROB0ROL0ROC1RTB0RTL1RTC0REE0	R1 (B & L) + R2 Logs	19	$33,900	$1,780
ROB1ROL0ROC0RTB1RTL0RTC0REE0	R1 Bench + R2 Bench	25	$42,800	$1,710
ROB1ROL0ROC0RTB0RTL0RTC1REE0	R1 Bench + R2 (B & L)	26	$48,700	$1,870
ROB0ROL0ROC1RTB0RTL0RTC1REE0	R1 (B & L) + R2 (B & L)	27	$56,100	$2,080
ROB1ROL0ROC0RTB1RTL0RTC0REE1	R1 Bench + R2 Bench + R3 Breach	29	$68,100	$2,350
ROB1ROL0ROC0RTB0RTL0RTC1REE1	R1 Bench + R2 (B & L) + R3 Breach	30	$74,000	$2,470
ROB0ROL0ROC1RTB0RTL0RTC1REE1	R1 (B & L) + R2 (B & L) + R3 Breach	31	$81,400	$2,630

3.4.2 Incremental 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 process continues until there are 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, seven were identified as "Best Buy" plans (including the No Action plan). The results of the analysis is shown graphically in Figure 2 and Table 6.

The alternative Best Buy plans are:

Plan 1: No Action

Plan 2: Reach 2 Logs

Plan 3: Reach 1 Logs + Reach 2 Logs

Plan 4: Reach 1 Bench + Reach 2 Logs

Plan 5: Reach 1 Bench + Reach 2 Bench

Plan 6: Reach 1 Bench + Reach 2 (Bench & Logs)

Plan 7: Reach 1 Bench + Reach 2 (Bench & Logs) + Reach 3 Breach

Plan 8: Reach 1 (Bench & Logs) + Reach 2 (Bench & Logs) + Reach 3 Breach

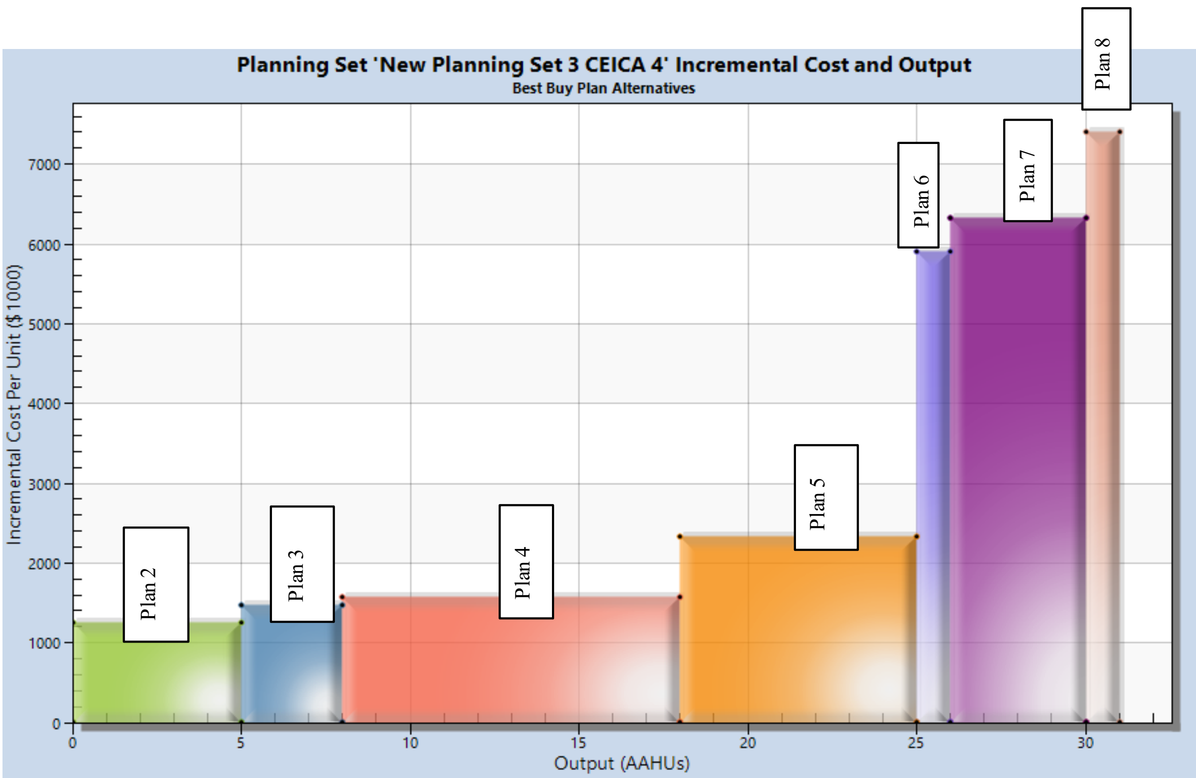

Figure 2. Incremental Cost Analysis Result

Table 6. Best Buy Plans

Plan	Increased AAHUs	Total Annualized Cost ($1s)	Total Annualized Cost/AAHUs ($1s)	Incremental Cost ($1s)	Incremental AAHUs	Incremental Cost per AAHU	Plan First + Real Estate Costs
Plan 1: No Action	0	$0	0	0	0	0	$0
Plan 2: Reach 2 Logs	5	$6,300	$1,260	$6,300	5	$1,260	$39,200
Plan 3: Reach 1 Logs + Reach 2 Logs	8	$10,700	$1,340	$4,400	3	$1,470	$92,600
Plan 4: Reach 1 Bench + Reach 2 Logs	18	$26,500	$1,470	$15,800	10	$1,580	$442,800
Plan 5: Reach 1 Bench + Reach 2 Bench	25	$42,800	$1,710	$16,300	7	$2,330	$931,100
Plan 6: Reach 1 Bench + Reach 2 Bench & Logs	26	$48,700	$1,870	$5,900	1	$5,900	$957,800
Plan 7: Reach 1 Bench + Reach 2 Bench & Logs + Reach 3 Breach	30	$74,000	$2470	$25,300	4	$6,330	$1,128,400
Plan 8: Reach 1 Bench & Logs + Reach 2 Bench & Logs + Reach 3 Breach	31	$81,400	$2,630	$7,400	1	$7,400	$1,261,800

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