UPPER MISSISSIPPI RIVER RESTORATION
FEASIBILITY REPORT
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

BEAVER ISLAND
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX D

HABITAT EVALUATION AND QUANTIFICATION

UPPER MISSISSIPPI RIVER RESTORATION
FEASIBILITY REPORT
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BEAVER ISLAND
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POOL 14, UPPER MISSISSIPPI RIVER MILES 513.0-517.0
CLINTON COUNTY, IOWA

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APPENDIX D

HABITAT EVALUATION AND QUANTIFICATION

I. INTRODUCTION

This appendix presents an ecological habitat assessment of the Project area and quantification, to the extent possible, of the aquatic and floodplain ecological benefits resulting from the proposed alternatives for the *Beaver Island Habitat Rehabilitation and Enhancement Project* (Project). This assessment includes a summary of the existing biological conditions used in the evaluation, as well as a forecast for future conditions under the No Action Alternative and each potential Project measure. The evaluation was conducted by a multi-agency team of biologists from the U.S. Fish & Wildlife Service (USFWS); the Iowa Department of Natural Resources (IADNR); and the U.S. Army Corps of Engineers (Corps), Rock Island District.

II. EXISTING AND FUTURE WITHOUT PROJECT BIOLOGICAL CONDITIONS

A. Aquatic Habitat. Tables D-1 through D-3 provide summaries of conditions in the Project area. Existing food data was obtained from IADNR electrofishing data from the Project; water quality data was collected by the Corps (2005-present); land cover data was obtained through field surveys; substrate information was gathered from geotechnical borings and mussel survey data; and velocities were generated from H&H modeling and field collections. Future With and Without Project data was estimated using best professional judgment of the evaluation team and H&H modeling, when applicable. Inherent in best professional judgment are the underlying assumptions, which are described in Section III, C. 2 of this Appendix. Section II of the Main Report, *Affected Environment*, includes a description of how these parameters influence fish life history and habitat quality.

B. Floodplain Habitat. Following construction of Lock and Dam 14, the physical conditions at Beaver Island were altered significantly. Water levels increased by about 8 feet, which significantly altered the hydrology and forest conditions of the Project area. Where 14 species including several hard mast species were once prominent on the island, now only silver maple and 5 other species inhabit the area. This is due primarily to increased inundation during flood events (greater than 90 percent of the Project area is inundated during a 2-year event) and the inability for trees to regenerate. Forest stands are mature, even-aged, and experiencing a high rate of mortality without recruitment. Consequently, percent open canopy is increasing with reed canary grass (invasive species) thriving in those areas. Information contained in Table D-4 was obtained through pre-dam topography maps; 1982 & 2011 forest surveys; LIDAR survey data; GIS analyses; H&H modeling; and consensus of the resource managers.

Table D-1: Aquatic Evaluation Areas with Associated Field Data for Food, Water Quality, Cover, Reproduction, and Water Velocity Parameters under Existing Conditions (Year 0)

	Food	Water Quality			Cover					Reproduction	Other
Evaluation Area	**Forage**	**Temp (min/max)**	**Minimum D.O.**	**Avg Turbidity**	**% Cover (vegetation)**	**% Cover (logs, brush)**	**% Pool/ Backwater**	**Avg Depth**	**% Area > 4ft depth**	**Substrate**	**Velocity (spawn, rear, overwinter)**
Lacustrine Habitat	115 g/m^3	0.3 / 29.8	3.0- 5.0 mg/L	64 ppm	14.3	10.9	53.4	0.7 m	0.9	sand/silt/ floodplain	5.6, 5.6, 1.4 cm/s
Riverine Habitat	75 g/m^3	0.1 / 28.0	>5 mg/L	105 ppm	11.7		0	3.0 m	85	littoral zone sand/structure	30 cm/s

Table D-2: Aquatic Evaluation Areas with Associated Estimates for Food, Water Quality, Cover, Reproduction, and Water Velocity Parameters Under the No Action Alternative (Target Year 25)

	Food	Water Quality			Cover					Reproduction	Other
Evaluation Area	**Forage**	**Temp (min/max)**	**Minimum D.O.**	**Avg Turbidity**	**% Cover (vegetation)**	**% Cover (logs, brush)**	**% Pool/ Backwater**	**Avg Depth**	**% Area > 4ft depth**	**Substrate**	**Velocity (spawn, rear, overwinter)**
Lacustrine Habitat	120 g/m^3	0.4 / 29.8	2.0- 4.0 mg/L	64 ppm	15.0	10.9	46.9	0.6	0.5	sand/silt/ floodplain	5.6, 5.6, 1.4 cm/s
Riverine Habitat	50 g/m^3	0.1 / 28.0	>5 mg/L	105 ppm	7.4		0	3.0 m	85	littoral zone sand/structure	30 cm/s

Table D-3: Aquatic Evaluation Areas with Associated Estimates for Food, Water Quality, Cover, Reproduction, and Water Velocity Parameters Under the No Action Alternative (Target Year 50)

	Food	Water Quality			Cover					Reproduction	Other
Evaluation Area	**Forage**	**Temp (min/max)**	**Minimum D.O.**	**Avg Turbidity**	**% Cover (vegetation)**	**% Cover (logs, brush)**	**% Pool/ Backwater**	**Avg Depth**	**% Area > 4ft depth**	**Substrate**	**Velocity (spawn, rear, overwinter)**
Lacustrine Habitat	125 g/m^3	0.4 / 29.8	1.5- 4.0 mg/L	64 ppm	17.0	10.9	45.8	0.5	0.1	sand/silt/ floodplain	5.6, 5.6, 1.4 cm/s
Riverine Habitat	21.5 g/m^3	0.1 / 28.0	>5 mg/L	105 ppm	5.1		0	3.0 m	85	littoral zone sand/structure	30 cm/s

Table D-4: Floodplain Habitat Evaluation Area with Measurements for Various Floodplain Habitat Parameters by Pre-Dam Conditions, Existing Conditions, and Future Without Project Conditions (Target Years 25 and 50)

Evaluation Period	% Forested	% Open Canopy	Surface Acres > 2-yr Flood El.	Dominant Species and PrecentTotal[1]				Forest Stand Average Age	Reed Canary Grass %
Pre-Dam	95%	5%	89.0 acres	8 Spp - 50%	ACSA2 - 30%	ULAM - 12%	Other 8%	-	-
Existing	85%	15%	19.0 acres	ACSA2 - 75%	ULAM - 10%	PODE - 3%	4 Spp. 12%	85	4%
FWOP TY 25	70%	30%	13.0 acres	ACSA2 - 80%	ULAM - 5%	PODE - 5%	3 Spp. 10%	110	11%
FWOP TY 50	65%	35%	11.0 acres	ACSA2 - 85%	ULAM 5%	PODE - 2%	3 Spp. 8%	135	15%

[1] ACSA2 = silver maple
ULAM = American elm
PODE3 = eastern cottonwood
other *spp.* = pin oak, bur oak, swamp white oak, river birch, pecan, black walnut, black willow, Kentucky coffeetree, etc.

III. HABITAT BENEFIT EVALUATION METHODS

The purpose of the habitat benefit evaluation is to evaluate and quantify, to the extent possible, environmental benefits of alternative plans for aquatic and floodplain habitat improvements. The evaluation was conducted by a multi-agency team which included representatives from the USFWS, the IADNR, and the Corps. Aquatic benefits were quantified through the use of Engineering Circular 1105-2-412, *Assuring Quality of Planning Models* and the Upper Mississippi River System Overwintering Bluegill and Walleye Habitat Suitability Index Models (HEP; USFWS 1980). Floodplain benefits were quantified through the use of the Corps-certified Hydrologic Engineering Center-Ecosystem Functions Model (HEC-EFM).

A. Quantity Component. Traditionally, the Corps has used the quantity and quality of habitat jointly, in the form of habitat units, to measure benefits provided by ecosystem restoration projects. The quantity portion is often measured as area (acres of habitat, landform, etc.) or number of species; in some systems, it is measured as length (miles of stream bank). The evaluation conducted for the Project uses acres, delineated by polygons, to represent the quantity. The area associated with each management measure must have a clear definition for use as guidance in estimating the area component of the ecosystem output model, and must be applied consistently to all actions evaluated.

For this Project, three different scales of area were considered to determine which would be the most suitable area metric to use in the analysis; for each scale, the capabilities and limitations were considered.

1. Action Footprint. The action footprint is a measurement of the physical footprint of the management measures. For example, the surface area covered by excavated material placement or the area excavated in a backwater. When multiple management measures are included in an action, the footprint equals the total of the management-measure footprints with no double counting of overlap areas addressed by two or more management measures. Acreage differs for future without project and with project alternatives due to the trade-off between unlimiting habitat (ex: wetland) for limiting habitat (ex: aquatic).

- **Capability.** Can be accurately quantified with a high degree of certainty
- **Limitation.** Grossly underestimates the areal extent of ecological benefits from each management measure because process restoration covers a broader area

2. Area of Restored Process. This is a measurement of the area directly affected by the restoration of processes. The measurement would include the footprint as well as the effect of processes (biotic and abiotic) which result in a detectable difference in composition, structure, or function, as compared to the existing condition.

- **Capability.** Can be accurately quantified with high level of certainty for some management measures (for example, those that restore wetland habitat gradation in which deep water transitions to aquatic bed to emergent wetland to seasonally inundated scrub/shrub habitat and finally to temporarily inundated forested wetland), and more fully captures the area that would experience ecological benefits from restoration of a process

- **Limitation.** Difficult to quantify with certainty for some management measures (for example, those management measures that restore sediment transport and delivery); does not identify whether an action is too small to have a significant benefit to the ecosystem

3. **Potential Area of Influence.** This is a measurement of the area that could benefit from the process restoration provided by the action. In some cases, this may be the same as the area of restored process. In other cases, it could extend beyond the area of restored process to the greater ecosystem area that a stressor affects or indirect effects can extend well beyond the immediate area of stressor removal. While potential area of influence is an estimated area that is more consistent with the guidance calling for a systems approach (ER 1165-2-501), it was not feasible to devise consistent rules for defining this area. For instance, an increase in primary productivity has an effect across a much larger spatial area than just the area where new aquatic vegetation is placed; however, the affected area would be difficult to quantify systematically.

- **Capability.** Fully captures the area of ecological benefits of a given management measure
- **Limitation.** Not feasible to estimate with any degree of certainty and consistency

For this Project it was determined, of the three scales considered, using area of restored process is the optimal approach to estimating ecological benefits beyond the specific action footprint with the least amount of uncertainty. The action footprint was considered to provide too significant an underestimate and did not fully measure the benefits of the Project. Estimating the potential area of influence scale was considered too uncertain and speculative.

To define the area of restored process for each measure at the proposed action locations, the target processes were identified (Table D-5) and the area of restored process determined (Table D-6).

Table D-5: Management Measures which Restore Process and Area of Restored Process

Management Measure	Process Restored	Area of Restored Process
Backwater Excavation and Substrate/Cover	Habitat connectivity, lacustrine and littoral habitat structure and function	Excavated area plus area of direct influence resulting from the interconnection of habitat. This area includes the restored photic zone, littoral zone, and interconnected spawning, rearing, and overwintering fish habitat.
Closure Structure	Sedimentation reduction and hydrology – reduced flow and velocity	Reduced sedimentation and area of low flow created by structure during overwintering conditions.
Island Protection and Stabilization	Hydrology - flow, velocity, sediment transport; Littoral processes, habitat connectivity, habitat structure	Area of flow, sediment transport, and habitat structure and function restored, (compared to existing hydrology) by the feature.
Increased Floodplain Elevation through Excavated Material Placement	Hydrology - water inundation and duration	Footprint plus area in which the measure has an influence on forest canopy cover, species or composition; or reproduction, rearing, and foraging habitat. This edge influence has been shown to be more than 100m for some primary and secondary processes (Harper et al. 2005).
Mast Tree Planting	Habitat connectivity, forest structure and function	

Table D-6: Aquatic and Floodplain Areas under Consideration for this Assessment, Including Area Used for Evaluation

Habitat Type	Evaluation Area	Area Evaluated
Aquatic	Backwater Overwintering	216 acres
	Albany Slough - Riprap	32 acres
	Albany Slough – Chevron	42 acres
Floodplain	Bottomland Forest Restoration	157 acres

B. Quality of Aquatic Benefits. The methodology utilized for evaluating benefits to aquatic habitat incorporates the HEP format, which was developed by the USFWS. HEP is a habitat-based evaluation methodology used in project planning. The procedure documents the quality and quantity of available habitat for selected fish and wildlife species. HEP is based on the assumption that habitat for selected fish and wildlife species can be described by a Habitat Suitability Index (HSI). This index value (on a scale from 0.0 to 1.0) is multiplied by the area of applicable habitat to obtain Habitat Units (HUs), which are used in comparisons of the relative value of fish and wildlife habitat at points in time.

Changes in HUs will occur as a habitat matures naturally or is influenced by development. These changes influence the cumulative HUs derived over the life of the Project (50 years). Habitat Units are calculated for select target years (existing, 1, 5, 20, 35, 50) and annualized (using IWR Planning Suite NER Annualizer) over the life of the Project to derive Average Annual Habitat Units (AAHUs). AAHUs are used as the output measurement to compare the features and alternatives for the proposed Project.

1. Backwater Habitat. The bluegill (Stuber et al. 1982a; Palesh and Anderson 1990) Corps-approved (per EC 1105-2-412) HSI model was used to assess the backwater habitat benefits resulting from excavation of Lower Cut, Stewart Lake, Blue Bell Lake, Sand Burr Lake, Upper Lake, Small Lake, Upper Cut, and the installation of a closure structure at the head of Upper Cut to reduce sedimentation and flow impacts to the lower lakes. These species were selected because they require backwater habitat for all or most of their life cycle and are often limited in the availability of high quality overwintering habitat.

The following assumptions in applying the *bluegill HSI model* were made:

Baseline Condition. Detailed water quality data was collected from 2011 to present at monitoring stations in the backwater area. Due to the length of the data collection and location, it was assumed the data collected at each station was representative of the entire backwater. For the purposes of model input, the spawning season was May to June, growing season June to September, and overwintering December to February. It was assumed the water quality entering Beaver Island via Upper Cut was similar to Beaver Slough and the main channel.

Future Without Project Conditions. Future conditions of all backwater lakes were based on an average sedimentation rate of 1 cm/year over the next 50 years. This rate was determined based on H&H modeling output and sedimentation information obtained from IADNR sedimentation studies. It is not likely aquatic habitat loss would be linear as most sedimentation occurs during flooding events. Nonetheless, over time aquatic habitat will be reduced significantly. Remaining lentic habitat will consist of isolated interior shallow pools with fish access only during high water events or small (<0.5 acre) limited overwintering areas. It is probable Beaver Island will continue to provide spawning habitat based off of future floodplain conditions. Rearing and foraging habitat currently provided by the interior backwaters will be substantially reduced as remaining pool habitat will have impaired water quality or restricted access during average flows. Consequently, summer habitat will either shift to another backwater complex or other flowing channels, if available, in Pool 14. Finally, overwintering habitat will continue to be limited to near zero within the interior backwaters of the Project.

Future With Project Conditions. The proposed final depth of each backwater lake is 8 feet. With approximately 1.6 feet of sediment accumulating over 50 years, adequate depths would still be present for overwintering habitat. Therefore, it was assumed percent backwater would increase to near 75%, minimum D.O. of >4 mg/l after excavation, average temperature would be 2.6°C , and average velocity would be 0.3 cm/s (with berm placement site). Percent of the backwater greater than 4 feet in depth would increase to 27.5% percent with a slight decrease over time due to sedimentation on the slopes of the excavation site.

2. **Riverine Habitat.** The Corps-approved (EC 1105-2-412) walleye (McMahon et al. 1984) HSI model was used to assess the riverine habitat benefits resulting from Albany Island protection via riprap bank stabilization or chevron construction, and mussel substrate habitat installation. Walleye was selected because it is rheophilic or oriented to flow, and captures the benefits from an increase in forage, water clarity, and spawning habitat afforded by the measures. Additionally, walleye is a popular host fish species for numerous freshwater mussels which inhabit the Project area. So, in addition to quantifying the direct impacts to the fish community, the walleye also allows the evaluation of potential benefits to the freshwater mussel community by increasing the abundance of

suitable fish hosts. This provides a more robust analysis of the year-round fish and mussel habitat afforded by these measures.

The following assumptions in applying the *walleye HSI models* were made:

Baseline Condition. Water quality data from the main channel was assumed to be similar to Albany Slough. Although the volume of water flowing through Albany Slough is less, the velocities should be similar. For the purposes of model input, the spawning season for walleye was March to May and growing season June to October.

Future Without Project Conditions. It was assumed Albany Island would continue to experience erosion at a rate of 2 percent loss in acreage per year. This essentially reduces the island evaluation area about 24 acres by year 50. Consequently, available habitat structure and cover, food production, and potential spawning habitat for walleye would be reduced.

Future With Project Conditions. Protection of the island would reduce erosion and potentially initiate island growth through reduced year-round velocities and aggradation of sediments. Rock would increase habitat structure for fish cover. Due to the increase in habitat availability and complexity, cover and forage fish abundance is expected to increase. Most importantly perhaps is the continued structure and function of the island and side channel complex. This continues to provide the functional attributes necessary for the freshwater mussel community to continue to exist, reproduce, and recruit to the population.

C. Quality of Floodplain Benefits. The Corps-certified (per EC 1105-2-412) (HEC-EFM) was used to quantify the habitat benefits associated with increases in topographic diversity and bottomland forest restoration.

1. Purpose of Model. The model estimates the potential forest community benefit from changing the relative surface area of the Project site within specific flood zones. The area in each flood zone is compared among several reference conditions to assess physical changes affecting plant communities. In this case the historic condition is represented by pre-dam hydrology (<1935) and the present hydrology has been in place since the 1970s. Alternative restoration states include the area and height of topographic diversity. Topographic diversity is important because different plant communities occur within specific flood zones, and lack of physical diversity can lead to low plant community diversity as has been seen in large rivers nation-wide.

The theory behind this analysis is firmly entrenched in plant community ecology; plants are adapted to specific moisture tolerance. Many plant species drown when inundated for too long. Forest species are grouped into one of three different groups based upon their tolerance (maximum, moderate, and minimum) to sustained inundation. Each tolerance category is assigned a number of days which refers to the maximum duration the group can withstand inundation, beyond which mortality sets in. A forest benefit metric is calculated by integrating the acres subject to flooding with the number of trees likely to occur within specific flood zones relevant to the survival and distribution of trees (DeJager et al. 2012; Figure D-1).

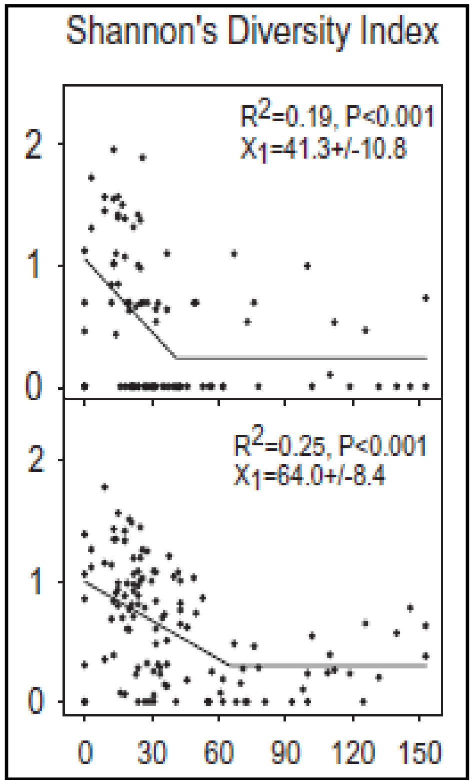

Figure D-1: Flood Frequency (x-axis), Understory (Top Graph) Diversity (y-axis); Overstory (Bottom Graph) Relationships in Upper Mississippi River Floodplain Forests (DeJager et al., 2012)

The underlying premise of the quality score is that as the site tracks in the direction of the pre-dam conditions habitat quality increases for numerous floodplain animals and Neotropical migrant bird species. Timber stands improve to be enhanced in diversity, evenness, age, and growth, providing a more balanced forest structure. The pre-dam hydrologic condition was established as the reference condition against which the existing condition and Project alternatives are compared. The index value (on a scale from 0.0 to 1.0) is multiplied by the area of applicable habitat to obtain HU s, which are used in comparisons of the relative value of the forest community habitat at points in time.

Changes occur over time as a habitat matures naturally or is influenced by development. These changes influence the cumulative HUs derived over the life of the Project (50-years). HUs are calculated for the Pre-dam, Existing, Future with, and Future Without-Project conditions. HUs were calculated for each target year (pre-dam, existing, 25, 50) and annualized (using IWR Planning Suite NER Annualizer) over the life of the Project (50-years) to derive AAHUs. AAHUs are used as the output measurement to compare the features and alternatives for the proposed Project.

2. Assumptions. The biggest assumption of the analysis and use of HEC-EFM is as the distribution of flood zones track towards the distribution of the pre-dam condition overall floodplain habitat quality improves for all floodplain species. This is primarily due to a diverse array of tree species, ages, growth patterns, and distributions of elevation resulting in more habitat availability, connectivity, and function. The analysis assumes tree species distribution is correlated with flood frequency as reported in the scientific literature. The Future Without-Project (FWOP) conditions assume tree mortality and tree recruitment will continue at a rate similar to the last 30 years. Open canopy areas will result in reed canary grass residence. The FWOP conditions assume sedimentation and increasing water inundation and duration will continue resulting in a continued loss of topographic diversity.

IV. HABITAT EVALUATION RESULTS

Section V of the main report, *Development and Evaluation of Alternatives*, describes each potential Project measure in detail. After a lengthy process involving preliminary analysis, identification of compatibility, dependencies, and input from our resource agencies, the Project planning team identified a list of measures to be formulated into alternatives before this habitat quantification exercise (Table D-7). Tables D-8, D-9, and D-10 provide summaries of the results of the habitat benefit evaluation.

A. Aquatic Benefits. Tables D-8 and D-9 provide the final suitability index (SI), acres for each alternative, habitat units, gross AAHUs, and net AAHUs (lift) for each target year under consideration.

B. Floodplain Benefits. Table D-10 provides the final suitability index (SI), acres for each alternative, habitat units, gross AAHUs, and net AAHUs (lift) for each target year under consideration.

Table D-7: Combined Aquatic Diversity Measures (A2-K2)

A2	All Lakes w/closure
C2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr Lakes w/closure
D2	Lower Cut, Stewart, Small Lakes w/closure
E2	Lower Cut, Blue Bell, Sand Burr Lakes w/closure
F2	Lower Cut, Stewart, Blue Bell, Sand Burr Lakes w/closure
G2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr, Lower Lakes w/closure
H2	Lower Cut, Blue Bell, Sand Burr, Lower Lakes w/closure
I2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lakes w/closure
J2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Cuts and Upper Lake w/closure
K2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Cuts and Upper Lake w/closure
L1	Albany Island Chevron Protection
L2	Albany Island Chevron Protection w/ mussel substrate
L3	Albany Island Riprap Head-end
L4	Albany Island Riprap Head-end Protection w/ mussel substrate

Table D-8: Benefit Evaluation Results for the Albany Island Protection Measure – Walleye

Measure	Number	Description	Condition	Year	Output: WAE SI	Acres	HUs	AAHUs	Net AAHUs
Albany Slough Island Protection and Mussel Substrate	0	No Action	Existing	2020	0.3	32	9.6	4.10	**0.0**
			FWOP	2025	0.25	29	7.3		
				2040	0.2	20.3	4.1		
				2070	0.15	8.12	1.2		
	L1	Chevron Riprap Protection	With Project	2020	0.6	42	25.2	20.20	**16.1**
				2025	0.55	42	23.1		
				2040	0.5	42	21.0		
				2055	0.45	42	18.9		
				2070	0.4	42	16.8		
	L2	Chevron Riprap Protection w/Substrate	With Project	2020	0.65	42	27.3	27.30	**23.2**
				2025	0.65	42	27.3		
				2040	0.65	42	27.3		
				2055	0.65	42	27.3		
				2070	0.65	42	27.3		
	L3	Riprap Protection	With Project	2020	0.31	32	9.9	10.55	**6.5**
				2025	0.33	32	10.6		
				2040	0.33	32	10.6		
				2055	0.33	32	10.6		
				2070	0.33	32	10.6		
	L4	Riprap Protection w/Substrate	With Project	2020	0.36	32	11.5	11.48	**7.4**
				2025	0.36	32	11.5		
				2040	0.36	32	11.5		
				2055	0.36	32	11.5		
				2070	0.36	32	11.5		

Table D-9: Benefit Evaluation Results for the Backwater Excavation Measures – Bluegill

Measure	Number	Description	Condition	Year	Output: BLG	Acres	HUs	AAHUs	Net AAHUs
Overwintering Fish Habitat	0	No Action	Existing	0	0.39	178	70.0	43.0	**0.0**
			FWOP	5	0.30	177	54.0		
				20	0.30	172	52.0		
				50	0.10	165	17.0		
	A2	All Lake Features w/ Closure Structure	With Project	1	0.75	216	163.0	173.00	**130.0**
				5	0.80	216	173.0		
				20	0.81	216	176.0		
				35	0.81	216	175.0		
				50	0.81	216	175.0		
	C2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr	With Project	1	0.79	216	171.0	169.00	**126.0**
				5	0.79	216	171.0		
				20	0.79	216	170.0		
				35	0.78	216	170.0		
				50	0.78	216	169.0		
	D2	Lower Cut, Stewart, Small	With Project	1	0.69	216	150.0	148.00	**105.0**
				5	0.69	216	150.0		
				20	0.69	216	150.0		
				35	0.68	216	147.0		
				50	0.67	216	145.0		
	E2	Lower Cut, Blue Bell, Sand Burr	With Project	1	0.76	216	165.0	164.00	**121.0**
				5	0.76	216	165.0		
				20	0.76	216	165.0		
				35	0.76	216	165.0		
				50	0.75	216	162.0		
	F2	Lower Cut, Stewart, Blue Bell, Sand Burr	With Project	1	0.74	216	160.0	158.00	**115.0**
				5	0.74	216	160.0		
				20	0.73	216	158.0		
				35	0.73	216	158.0		
				50	0.73	216	158.0		

Table D-9: Benefit Evaluation Results for the Backwater Excavation Measures – Bluegill

Measure	Number	Description	Condition	Year	Output				
					BLG	**Acres**	**HUs**	**AAHUs**	**Net AAHUs**
Overwintering Fish Habitat	G2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.80	216	173.0	174.00	**131.0**
				5	0.81	216	175.0		
				20	0.81	216	175.0		
				35	0.81	216	175.0		
				50	0.80	216	173.0		
	H2	Lower Cut, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.79	216	171.0	169.00	**126.0**
				5	0.79	216	171.0		
				20	0.79	216	171.0		
				35	0.78	216	169.0		
				50	0.78	216	169.0		
	I2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.80	216	173.0	172.00	**129.0**
				5	0.80	216	173.0		
				20	0.80	216	173.0		
				35	0.80	216	173.0		
				50	0.79	216	171.0		
	J2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Cuts w/Closure	With Project	1	0.80	216	173.0	178.00	**135.0**
				5	0.83	216	180.0		
				20	0.83	216	180.0		
				35	0.82	216	178.0		
				50	0.82	216	178.0		
	K2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Cuts w/Closure	With Project	1	0.80	216	173.0	180.00	**137.0**
				5	0.83	216	180.0		
				20	0.84	216	182.0		
				35	0.84	216	182.0		
				50	0.83	216	180.0		

Table D-10: Floodplain Benefit Evaluation Results for Each Alternative Considered

					Output				
Measure	**Number**	**Description**	**Condition**	**Year**	**HEC-EFM**	**Acres**	**HUs**	**AAHUs**	**Net AAHUs**
Floodplain Forest	0	No Action	Existing	0	0.22	157	34.5	23.00	**0.0**
			FWOP	5	0.22	157	34.5		
				20	0.13	157	20.4		
				50	0.11	157	17.3		
	A2	All Features w/ Closure Structure	With Project	1	0.22	157	34.5	131.00	**108.0**
				5	0.91	157	142.9		
				20	0.87	157	136.6		
				50	0.83	157	130.3		
	C2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr	With Project	1	0.22	157	34.5	93.00	**70.0**
				5	0.64	157	100.5		
				20	0.62	157	97.3		
				50	0.59	157	92.6		
	D2	Lower Cut, Stewart, Small	With Project	1	0.22	157	34.5	74.00	**51.0**
				5	0.51	157	80.1		
				20	0.49	157	76.9		
				50	0.47	157	73.8		
	E2	Lower Cut, Blue Bell, Sand Burr	With Project	1	0.22	157	34.5	82.00	**59.0**
				5	0.56	157	87.9		
				20	0.54	157	84.8		
				50	0.52	157	81.6		
	F2	Lower Cut, Stewart, Blue Bell, Sand Burr	With Project	1	0.22	157	34.5	95.00	**72.0**
				5	0.65	157	102.1		
				20	0.63	157	98.9		
				50	0.60	157	94.2		
	G2	Lower Cut, Stewart, Small, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.22	157	34.5	109.00	**86.0**
				5	0.75	157	117.8		
				20	0.72	157	113.0		
				50	0.70	157	109.9		

Table D-10: Floodplain Benefit Evaluation Results for Each Alternative Considered

Measure	Number	Description	Condition	Year	Output: HEC-EFM	Acres	HUs	AAHUs	Net AAHUs
Floodplain Forest	H2	Lower Cut, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.22	157	34.5	98.00	**75.0**
				5	0.68	157	106.8		
				20	0.65	157	102.1		
				50	0.62	157	97.3		
	I2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake	With Project	1	0.22	157	34.5	112.00	**89.0**
				5	0.77	157	120.9		
				20	0.74	157	116.2		
				50	0.71	157	111.5		
	J2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Cuts w/Closure	With Project	1	0.22	157	34.5	124.00	**101.0**
				5	0.86	157	135.0		
				20	0.82	157	128.7		
				50	0.79	157	124.0		
	K2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Cuts w/Closure	With Project	1	0.22	157	34.5	132.00	**109.0**
				5	0.92	157	144.4		
				20	0.88	157	138.2		
				50	0.84	157	131.9		

V. COST EFFECTIVENESS AND INCREMENTAL ANALYSIS OF ALTERNATIVES

Comparison of alternative feature designs and combinations of features is accomplished through cost-effectiveness evaluation and incremental cost analysis. Cost-effectiveness evaluation is used to identify the least costly solution to achieve a range of Project benefits. Incremental cost analysis is a tool that can assist in making decisions on the scale or size of the Project or of individual features by determining changes in costs associated with increasing levels of benefits.

A. Enhancement Features. The proposed Project involves two primary enhancement features, Aquatic Diversity and Topographic Diversity.

Aquatic Diversity. Excavation using a mechanical dredge has been proposed as a potential feature to provide suitable year-round habitat for fish, which includes critical overwintering habitat for centrarchid fish species. Excavation will also provide material to increase topographic diversity within the floodplain forest. Mechanical excavation or dredging would be required for these aquatic diversity sites. A list of design constraints or considerations is listed in Appendix M, *Engineering Design*, although following is a list of some of these considerations.

- Minimum width: 60 foot bottom when allowed by existing topography. Maximize dredge cut widths to create a full width lake excavation where possible
- Channel slopes 4H:1V
- Allowable overwintering flow: as close to 0 as possible
- Connect cuts to deep water
- Place cuts in areas fish use
- Make cuts deep enough that they do not freeze (habitat benefits for water > 4 feet)
- Make cuts deep enough that they do not fill in during the 50-year Project life (expect 1.6 feet of sedimentation in 50 years)
    - Overwintering depth 6 feet plus 2 additional feet for sedimentation
    - Connection depth 4 feet plus 2 additional feet for sedimentation
    - Deep hole depth 8 feet plus 2 additional feet for sedimentation

Mechanical dredging would necessitate adjacent placement. A floating excavator, barge mounted crane or barge mounted excavator could be used. For areas with a larger bottom width for the excavation area or a further reach for placement of dredged material, a barge mounted crane with a bucket of sufficient size would likely be used. All areas proposed for dredging or excavation are surrounded by trees which overhang the pool, so tree clearing would be required prior to side casting the material. The location of the channel provides immediate access to adjacent spawning and rearing habitat, and ingress and egress of fish. Refer to Appendix M, *Engineering Design*, for photographs of various dredges which may be used.

Topographic Diversity. Topographic diversity sites were originally laid out as sites adjacent to the aquatic diversity sites. During development of the TSP, additional design considerations such as bat habitat, diverse and non-diverse forest locations, heron rookeries, and existing contours were incorporated into the TSP design.

The following design considerations are outlined in Appendix M, *Engineering Design*:

- Avoid existing diverse forest locations, and in some cases, avoid specific trees
- Place excavated material in areas with lower quality forest and lower elevations
- Maximize placement heights for planting survivability
- Do not impact flood heights
- Minimize footprint of proposed features
- Consider flat slopes for erosion control
- Provide sufficient placement capacity for excavated material
- Ensure sites can be constructed using typical construction equipment

Optimum elevations for tree survival were developed using forestry and hydraulics information. A result of this analysis is provided in Appendix H, *Hydrology and Hydraulics*, and is outlined in Table D-11. A climate change analysis is also provided in Appendix H. Water surface elevations near RM 514 are outlined in Table D-12.

All topographic diversity sites will require the existing trees (if present) to be cleared and removed off site, then material will be placed to construct the site to an optimum elevation for tree survival. Material will come from excavated channels within Beaver Island. The sites will either be sloped to drain, or will have +/- 1 foot elevation changes to create swales across the wider sites.

Once shaping is complete, temporary seeding may be employed if permanent seeding cannot be planted immediately. Each topographic diversity location will be divided into ½ acre plots that will be planted with different tree sizes. Forested wetland shrubs will be interplanted with the tree plantings. An understory seed mixture will be planted underneath the shrubs and trees. A buffer mix to include seeds and stakes will be planted on the slopes approaching the planting areas.

Topographic diversity sites are shown on Plate 7, C-102 in Appendix O, *Plates*. Additional information on the plantings are shown on Plates 24 through 30, L-102-L-603. Timber Stand Improvement activities will be implemented on approximately 350 acres of Beaver Island. Timber Stand Improvement may include the following activities:

- Crop Tree Release
- Girdling
- Tree Plantings
- Selective Harvest

Table D-11: Topographic Diversity Berm Elevations

	Design Criteria	Elev. w/o Climate Change (NAVD88)	Elev. w/ Climate Change (NAVD88)
UPPER (Design Elev.) Berm Elevation for Tree-Plantings (@RM 514)	EFM 25% Exceedance Probability for **Minimally** Tolerant Species (**25** days inundation duration during growing season 4/15 to 10/15)	577.9 (578.7 MSL1912)	579.8 (580.6 MSL1912)
LOWER (Planting Elev.) Berm Elevation for Tree-Plantings (@RM 514)	EFM 25% Exceedance Probability for **Moderately** Tolerant Species (**35** days inundation duration during growing season 4/15 to 10/15)	576.7 (577.6 MSL1912)	578.3 (579.2 MSL1912)

Table D-12: Water Surface Elevations at River Mile 514

Item	Elevation (NAVD88)
Flat Pool	571.2
Aquatic Habitat Benefits	<572.2
Floodplain Habitat Benefits	>572.2
50% Chance Exceedance of Flood (2 yr)	578.66
20 % Chance Exceedance of Flood (5 yr)	581.36
10% Chance Exceedance of Flood (10 yr)	583.3 NAVD88

B. Cost Estimates for Habitat Improvements. Tables D-13 and D-14 show the estimated outputs (in AAHUs) and annualized costs for each alternative. The annualized costs include estimates for construction, adaptive management, monitoring, and OMRR&R.

C. Incremental Analysis of Project Alternatives. Potential management measures were combined into alternatives using the IWR Planning Suite II tool. The IWR Planning Suite II tool was developed to aide environmental and ecosystem restoration planning studies perform Cost-Effectiveness and Incremental Cost Analyses (CE/ICA) on alternatives. Cost-Effectiveness output determines which alternatives are the least costly for a given level of environmental output. Incremental Cost Analyses evaluates the efficiency of the cost-effective alternatives, to determine which provide the greatest increase in output for the least increase in cost. The primary assumption used to conduct the Beaver Island CE/ICA was that AAHUs for all analyzed habitats were assumed to have equal value when comparing alternative plans.

Of the 105 Project alternatives that were developed from all possible combinations, 19 were cost effective (Table D-14 and Figure D-2). From the 19 cost effective plans, 4 best buy plans (including the No Action Alternative) were determined (Table D-15 and Figure D-3).

Table D-13: Environmental Output and Costs of Focused Array of Alternative
(May 2016 Price Level – 50 year period of analysis using 3.125% discount rate)

Symbol	Measures	Over-wintering (Net AAHUs)	Floodplain Forest (Net AAHUs)	Island Prot./Mussel Substrate (Net AAHUs)	Total Gross AAHUs	Net AAHUs	Construction Costs w/ Contingency ($)	Annualized Costs ($)	Annualized Operation Costs ($)	Annualized Maintenance Costs ($)	Annualized Adaptive Mgmt Costs ($)	Interest During Construction ($)	Total Annualized Costs ($)
0	No Action Plan	0	0	0	70.1	0	0	0	0	0	0	0	0
D2L3	Lower Cut, Stewart, Small, Riprap, Closure	105	51	6.5	232.6	162.5	10,741,000	447,655	1,084	11,537	20,448	15,802	496,526
D2L4	Lower Cut, Stewart, Small, Riprap w/substrate, Closure	105	51	7.4	233.5	163.4	10,821,000	450,990	1,084	11,537	20,448	15,201	499,260
D2L1	Lower Cut, Stewart, Small, Chevron, Closure	105	51	16.1	242.2	172.1	11,154,000	464,868	1,084	11,537	20,448	15,678	513,615
D2L2	Lower Cut, Stewart, Small, Chevron w/substrate, Closure	105	51	23.2	249.3	179.2	11,234,000	468,202	1,084	11,537	20,448	17,191	518,462
E2L1	Lower Cut, Blue Bell, Sand Burr, Chevron, Closure	121	59	16.1	266.2	196.1	15,513,000	646,539	1,084	12,600	20,448	41,027	721,698
F2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Closure, Chevron	115	72	16.1	273.2	203.1	17,414,000	725,768	1,245	15,259	14,475	48,149	804,896
E2L2	Lower Cut, Blue Bell, Sand Burr, Chevron w/substrate, Closure	121	59	23.2	273.3	203.2	15,593,000	649,873	1,084	12,600	14,475	41,226	719,258
F2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Closure, Chevron w/substrate	115	72	23.2	280.3	210.2	17,495,000	729,144	1,245	15,259	15,745	48,348	809,741
H2L1	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron	126	75	16.1	287.2	217.1	17,952,000	748,190	1,245	16,588	15,745	49,622	831,390
H2L2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron w/substrate	126	75	23.2	294.3	224.2	18,033,000	751,566	1,245	16,588	17,228	49,861	836,488
I2L3	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Riprap	129	89	6.5	294.6	224.5	19,659,000	819,333	1,406	19,246	19,064	68,683	927,732
H2L3	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Riprap w/substrate	126	75	6.5	277.6	207.5	19,741,000	822.751	1,406	19,246	19,064	70,553	933,020
G2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron	131	86	16.1	303.2	233.1	20,080,000	836,879	1,406	19,246	17,228	70,155	944,914
G2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron w/substrate	131	86	23.2	310.3	240.2	20,162,000	840,297	1,406	19,246	19,064	70,434	950,447
J2L1	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron	135	101	16.1	322.2	252.1	23,724,000	988,751	1,568	20,044	19,615	87,306	1,117,284
J2L2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron w/substrate	135	101	23.2	329.3	259.2	23,806,000	992,169	1,568	20,044	19,064	87,584	1,120,429
K2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron	137	109	16.1	332.2	262.1	25,494,000	1,062,520	1,729	22,702	21,451	93,792	1,202,194
K2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron w/substrate	137	109	23.2	339.3	269.2	25,576,000	1,065,938	1,729	22,702	19,615	94,110	1,204,094

Table D-14: Focused Array of Alternatives Differentiated by Cost Effectiveness

Alt. Number	Alternative	Annualized Cost ($)	Output (AAHU)	Average Cost ($)	Cost Effective
0	No Action Plan	0	0	0	Best Buy
D2L3	Lower Cut, Stewart, Small, Riprap, Closure	496,526	162.5	3,056	Yes
D2L4	Lower Cut, Stewart, Small, Riprap w/substrate, Closure	499,260	163.4	3,055	Yes
D2L1	Lower Cut, Stewart, Small, Chevron, Closure	513,615	172.1	2,984	Yes
D2L2	Lower Cut, Stewart, Small, Chevron w/substrate, Closure	518,462	179.2	2,893	Best Buy
E2L1	Lower Cut, Blue Bell, Sand Burr, Chevron, Closure	721,698	196.1	3,680	No
F2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Closure, Chevron	804,896	203.1	3,963	No
E2L2	Lower Cut, Blue Bell, Sand Burr, Chevron w/substrate, Closure	719,258	203.2	3,540	Yes
F2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Closure, Chevron w/substrate	809,741	210.2	3,852	Yes
H2L1	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron	831,390	217.1	3,830	Yes
H2L2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron w/substrate	836,488	224.2	3,731	Yes
I2L3	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Riprap	927,732	224.5	4,132	Yes
H2L3	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Riprap w/substrate	933,020	207.5	4,496	Yes
G2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron	944,914	233.1	4,054	Yes
G2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron w/substrate	950,447	240.2	3,957	Best Buy
J2L1	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron	1,117,284	252.1	4,432	Yes
J2L2	Lower Cut, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron w/substrate	1,120,429	259.2	4,323	Yes
K2L1	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron	1,202,194	262.1	4,587	Yes
K2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron w/substrate	1,204,094	269.2	4,473	Best Buy

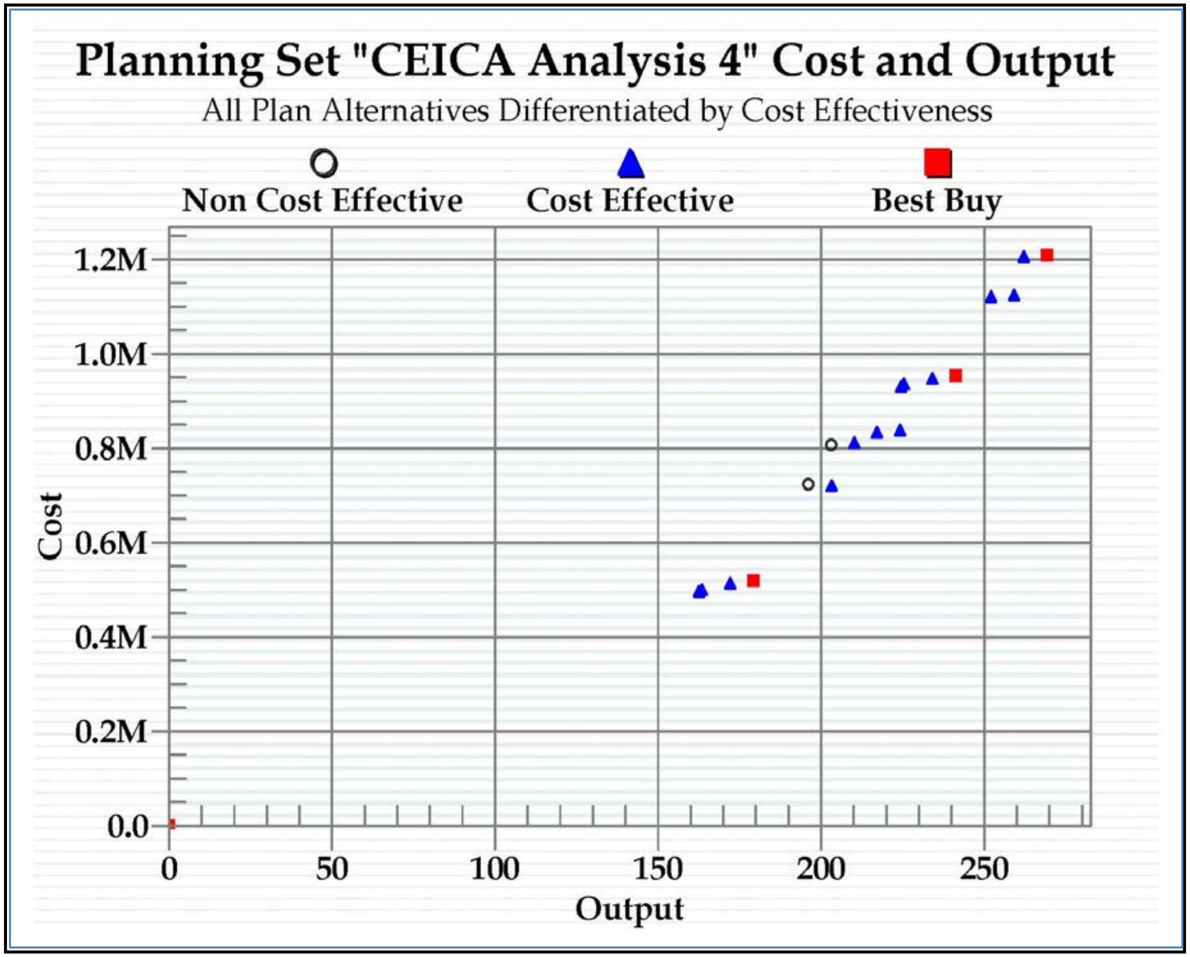

Figure D-2. All Plan Alternatives Differentiated by Cost Effectiveness

Table D-15: "Best Buy" Combinations

Symbol	Alternative	Outputs (HU)	Annualized Cost ($)	Average Cost ($)	Incremental Cost ($)	Incremental Output (HU)	Incremental Cost/Output ($/HU)
0	No Action Plan	0	0	0	0	0	0
D2L2	Lower Cut, Stewart, Small, Chevron w/substrate, Closure	179.2	518,462	2,893	518,462	179.2	2,893
G2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Closure, Chevron w/substrate	240.2	950,447	3,957	431,985	61.0	7,082
K2L2	Lower Cut, Stewart, Blue Bell, Sand Burr, Lower Lake, Upper Lake, Upper Cut, Closure, Chevron w/substrate	269.2	1,204,094	4,473	253,647	29.0	8,746

Costs were prepared using May 2016 price levels and are based on a 50-year project life, 3.125 percent interest rate

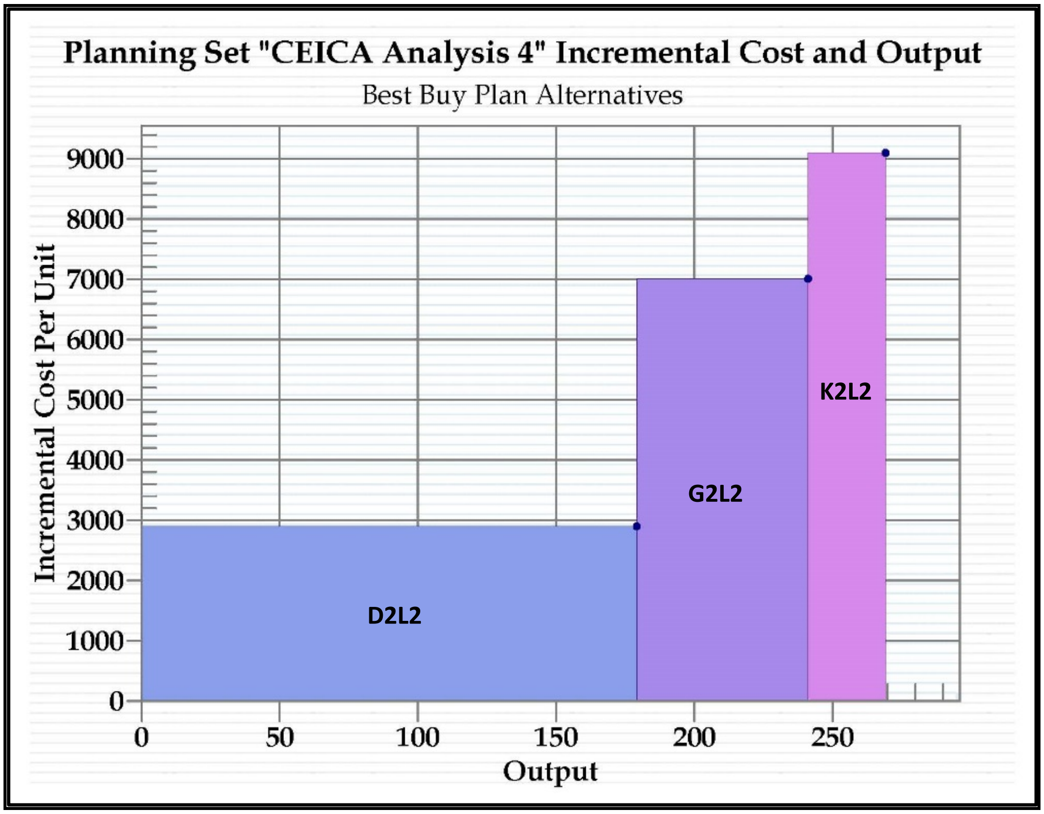

Figure D-3: **"**Best Buy" Plans

VI. RECOMMENDED PLAN DISCUSSION

The results of the habitat analysis support the premise that the functions and values of the Project can be restored by implementing one of the described cost effective alternatives or best buy plans. The HEP analysis indicates substantial improvements in both aquatic and floodplain habitats of the Project. Overwintering habitat would be significantly improved through excavation and island protection, which greatly enhances habitat diversity through habitat complexity, protection, and growth. Floodplain habitat can certainly be improved through Topographic Diversity, which creates the opportunity for hardwood species to survive and grow. This in turn provides a significant improvement in food, cover, breeding, and overwintering habitat for nearly every species of wildlife residing in and/or migrating to the floodplain. Due to the acreage of the Project floodplain, it is difficult for a single Project to re-create conditions which were present prior to the 9-foot channel implementation. However, this Project would make great strides in restoring the structure and function those conditions provided.

VII. LITERATURE CITED

DeJager, N. R., M. Thomsen, and Y. Yin. 2012. Threshold effects of flood duration on the vegetation and soils of the Upper Mississippi River floodplain, USA. Forest Ecology and Management 270:135-146

Harper, K. A., S. E. MacDonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, D. Roberts, M. S. Jaiteh, and P. Esseen. 2005. Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology 19:768-782

Institute for Water Resources Planning. 2008. Planning Suite Incremental Cost Analysis (CE-ICA) Software (Version 2.0.6.0) website: http://www.pmcl.com/iwrplan/GenInfoOverview.asp

McMahon, T. E., J. W. Terrell, and P. C. Nelson. 1982. Habitat suitability index models: channel catfish. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10.2. 29pp

1984. Habitat suitability index models: walleye. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10.56. 33pp

Palesh, G. and D. Anderson. 1990. Modification of the habitat suitability index model for the bluegill (*Lepomis macrochirus*) for winter conditions for upper Mississippi River backwater habitats. St. Paul District, Corps of Engineers. January 1990

Stuber, R. J., G. Gebhart and O. E. Maughan. 1982a. Habitat suitability index models: bluegill. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10.8. 26pp

1982b. Habitat suitability index models: largemouth bass. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10.16. 33pp

Theiling, C.H. & Nestler, J.M. 2010. River stage response to alteration of Upper Mississippi River channels, floodplains, and watersheds. *Hydrobiologia* 640:17-47

USFWS. 1980. Habitat Evaluation Procedures, Ecological Services Manual. Washington, DC. 102pp