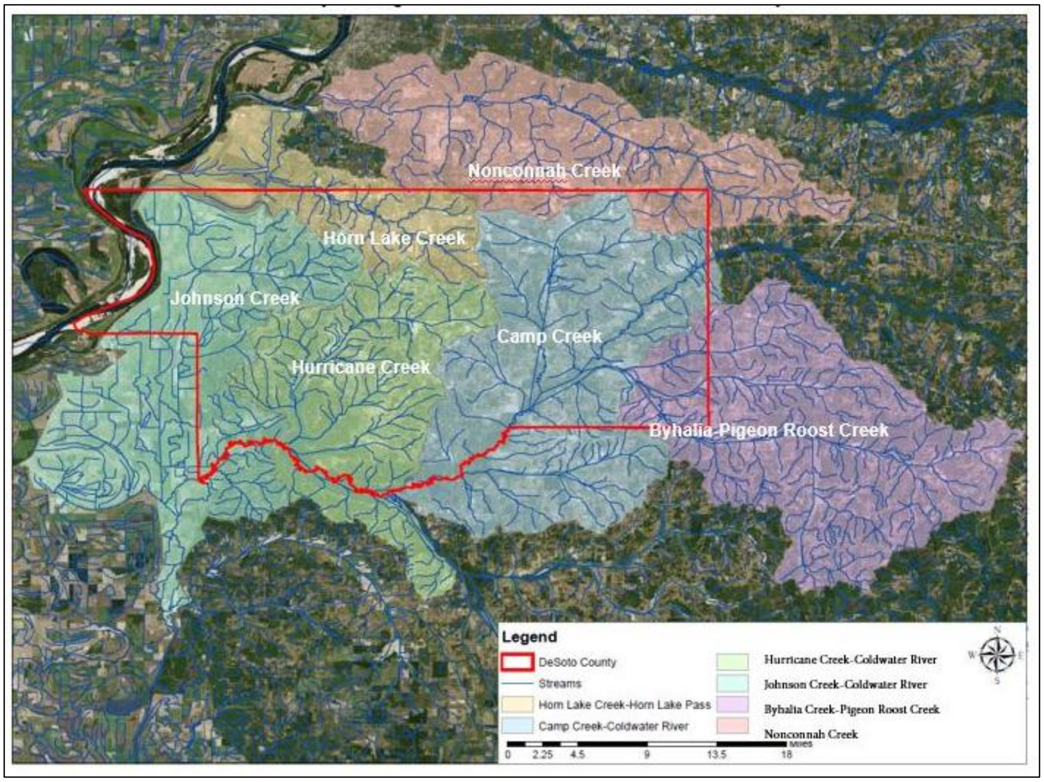
Mississippi Valley Division,
Regional Planning and Environment Division South

Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study, DeSoto County Mississippi



Appendix A – Environmental Section Appendix

September 2022

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BACKGROUND AND OBJECTIVES

The U.S. Army Corps of Engineers (USACE) has quantified potential benefits to existing aquatic and riparian habitats in Desoto County, Mississippi resulting from the proposed construction of alternatives discussed in the final Integrated Feasibility Report and Environmental Impact Statement (final IFR-EIS) for the Memphis Metropolitan Stormwater-North DeSoto, DeSoto County, Mississippi Feasibility Study. Data for variables associated with the stream condition index (SCI) model was collected by the Engineering Research and Design Center-Environmental Laboratory (ERDC-EL), Aquatic Ecology & Invasive Species Branch during field work conducted in 2020.

Land-use, or habitat, types within the study area primarily includes agricultural land, forest, and developed/residential areas, other land-use types include hay/pasture, shrub-scrub, herbaceous, and barren land. Agricultural lands and developed areas provide limited terrestrial habitat for a small number of species. Bottomland hardwoods (BLH) are the predominant terrestrial habitat within the Mississippi Alluvial Valley (MAV), and therefore was the habitat most appropriate for restoration. The two dominant BLH communities are riverfront BLH and mixed BLH. Dominant species of the riverfront BLH communities include cottonwood *(Populus deltoides),* sycamore *(Platanus occidentalis),* and black willow (*Salix nigra)*, while dominant mixed BLH species include pecan (Carya spp.), green ash *(Fraxinus pennsylvanica),* sugarberry *(Celtis laevigata),* hackberry *(Celtis occidentalis),* oaks *(Quercus* spp.), and elm *(Ulmus* spp.).

There are two components to the Memphis Metropolitan Stormwater-North DeSoto, DeSoto County, Mississippi Feasibility Study (hereafter referred to as, the Study): Flood Risk Management (FRM) and Aquatic Ecosystem Restoration (AER). Objectives for the Study include (1) Reduce flood damages to residential and commercial property in DeSoto County, (2) Reduce impacts to critical infrastructure, (3) Reduce risk to human life from flooding and rainfall events throughout Desoto County, (4) Restore aquatic habitat by reducing channel degradation such as incision and erosion, (5) Restore suitable habitat for native and special status species. USACE determined the pre-work baseline habitat suitability for target species using the SCI model to derive estimates of benefits to habitat for “with-project” actions. No significant adverse ecological impacts, due to the FRM component of the Study, are anticipated; therefore, no additional discussion of the FRM component is contained in this appendix.

OVERVIEW AND JUSTIFICATION FOR USING THE STREAM CONDITION INDEX MODEL

A full description of the SCI Model is given in the “Model Documentation, *Stream Condition Index Model,* DeSoto County, Mississippi” included in Section II of this Appendix. An ecological model was developed for DeSoto County, Mississippi. The primary problem identified in the study area is the risk of flood damages primarily in the Horn Lake Creek and Coldwater River Basins. A multidisciplinary team was convened to identify water resource problems, needs and opportunities and target stream reaches of immediate concern. Because of the high flood risk and flashy conditions, stream channels in the study area were highly eroded, and in many cases, exhibit steep banks with little to no protection. The Stream Condition Index (SCI) model provides a means to quantify overall habitat suitability under various management alternatives. SCI model input variables are derived from species-specific habitat requirements for specific species in a defined area. The SCI model rates the quality of available habitat using a scale of 0 (unsuitable) to 1.0 (optimal). Land cover types were mapped in a defined area within 100 meters of each stream that was evaluated in the study area (Table 1).

METHODS

Selection of Field Sites

USACE-MVM provided ERDC-EL with a list of 11 Streams as potential restoration sites that had been identified by local stakeholders and the public. A 100-meter buffer from the top bank of each stream was established for all potential restoration activities to help identify potential sample sites for each land-use type. Many streams within Desoto County, Mississippi are difficult to access due to lack of rights-of-entry and inaccessible stream reaches. In addition, the Study area encompasses all of Desoto County making field sampling for the feasibility phase of the study unrealistic; therefore, 65 sample sites were visited along 10 representative streams (not necessarily the same as the 11 streams identified for restoration potential), including Johnson Creek, Horn Lake Creek, Camp Creek, Nolehoe Creek, Hurricane Creek, and Lick Creek. SCI scores were tabulated, as described within the "Model Documentation, *Stream Condition Index Model,* DeSoto County, Mississippi" included in Section II of this Appendix. Sample locations and SCI variables are tabulated in Table 2, and SCI scores and stream disturbance regime are included in Table 3. The streams that were sampled allowed the team to derive the appropriate SCI for each stream reach in the study area. To help alleviate time constraints, extrapolation was used to indicate potential ecological lift for each stream. Extrapolation is based on surface protection and is described below. Relate disturbance regime was determined by grouping the SCI scores in four classes: Relatively Undisturbed (0.8-1.0), Minimally Disturbed (0.6-0.8), Minor Disturbance to Biotic and Abiotic Attributes (0.2-0.6), and Severely Disturbed (0.0-0.2), highlighted in dark green, light green, yellow, and light red, respectively (Table 3). Consequently, a gradient of restoration potential was determined from Severely Disturbed with high potential to Relatively Undisturbed exhibiting best attainable conditions (Stoddard et al. 2006) thus target analog, reference reach conditions.

Methods for Quantifying Habitat Characteristics/Baseline Habitat Conditions

NLCD land cover was used to map vegetation cover types in the riparian zone within 100-meters from the stream banks. Depending on scale and data quality objectives, the left and right banks can be included together or separate. In this Study, the banks are combined for an overall estimation of cover types within the watershed. SCI scores are estimated from surface protection (SUR) by calculating a weighted sum of the cover types. The SCI versus Surface Protection (SUR) correlation is recommended at the GIS Watershed Scale in the planning phase of the project (e.g., watershed prioritization and restoration plan selection).

The following stream segments were assessed using SCI remotely via satellite imagery: Cane, Mussacana, Nonconnah, Nolehoe, Short Fork, and Red Banks. The following steps were followed in calculating AAHU for each of the six stream corridors:

1. NLCD land cover was determined for several cover types: cultivated crops, barren land, hay/pasture, herbaceous, and shrub/scrub (Table 1).

2. Since the estimation was determined, remotely via satellite imagery, this equation was used to calculate the SCI scores (SCI = 0.950(Surface Protection)-0.081). Process for evaluation development is included in the "Model Documentation, Stream Condition Index Model, DeSoto County, Mississippi" included in Section II of this Appendix.

3. SCI scores were used to calculate net gain (average annual habitat units) between the future without project condition and the future with project condition, due to stream restoration from the proposed grade control structures for stream stabilization (Tables 11-50).

Calculating Average Annual Habitat Units

The overall effects of each restoration plan were estimated by calculating the net change in Average Annual Habitat Units (AAHUs) between the No-action Alternative (Future Without Project Conditions (FWOP)) and the proposed Alternatives (Future with Project Conditions (FWP)) evaluated in the Integrated Feasibility Report and Environmental Impact Statement, hereafter referred to as the Main Report. The FWOP condition was determined using the SCI method described above applied over varying acreages as described in the Main Report. As no streambank stabilization is expected to occur in the FWOP condition, the ERDC – Coastal Hydraulics Laboratory estimates a loss of approximately 191 riparian acres over a 50-year period of analysis. This loss of acreage is incorporated into the FWOP condition in Year 25 for each stream in order to calculate net benefits for the FWP condition.

RESULTS

This IFR-EIS addresses the No Action Alternative and Alternatives 1, 4, 5a and 5b as described in greater detail in Section 5 of the IFR-EIS. With the no action alternative, streams would continue to destabilize, widen, and banks would continue to erode causing continued impacts from sedimentation, excess nutrients, and low dissolved oxygen. In addition, the widening would cause continued impacts to infrastructure, such as bridges and roads as well as residential property. Without construction of the NER Plan, it is estimated that approximately 191 acres of land adjacent to the final array of streams may be lost due to erosion and bank failures. Section 5 of the IFR-DEIS describes the Ecosystem Restoration alternatives and plan formulation. Table 10 shows a summary comparison of the evaluated plans for the AER components of the plan. Highlighted cells in Table 10 identify the combination of plans that were selected based on the outcome of the Cost Effectiveness – Incremental Cost Analysis Model which is run by USACE Economists to help identify plans that occur along the efficient frontier, or are the most cost-effective ecosystem restoration plans. Tables 11-50 show the differences in estimated outputs from the potential AER plans. Plan selection is described below in the Discussion Section.

Table 1. National Land Classification Data, Land-use Acreages per stream in the Desoto County Study.

National Land Classification Data											
Streams	Cultivated Crops	Deciduous Forest	Developed	Emergent Herbaceous Wetlands	Hay/Pasture	Herbaceous	Mixed Forest	Open Water	Shrub/Scrub	Woody Wetlands	Barren
Camp Creek	279.6	71.2	14.7	10.2	83	3.1	4.2	4	29.6	308	
Horn Lake Creek	77.8	141.9	261.5	11.3	107.4	3.6		3.3	68.1	348.5	
Johnson Creek	332	107.6	43.1	21.8	107.4	0.9	19.1	10.9	48.3	188.6	
Cane Creek	133	14.9	1.8	44.3	112.1	1.1		48.7	17.6	32	
Hurricane Creek	484.6	69.2	61.6	71.2	85	4.9		87.4	62.5	232.6	1.3
Lick Creek	93.2	76.3	146.1		24		0.4		19.6	110.5	4.9
Mussacana Creek	79.6	40.5	44	54	116.5	9.6	9.6	39.8	17.8	90.7	
Nonconnah Creek	275.8	162.6	646.1	4.7	76.1	7.3	3.3	4.4	73.8	212.6	0.4
Nolehoe Creek	94.1	29.4	191		16.5				18.5	19.1	20.7
Short Fork	267.8	75.6	66.3	8	119	4.9	0.4	5.8	31.4	70.5	
Red Banks	92.7	5.1	0.9	4.4	74.3		0.4	1.3	24.5	165	

Table 2. Stream Condition Index (SCI) Field Sampling Results

	Stream	Station ID	Assessment Date	Coordinates Lat (N)	Coordinates Long (W)	Location	CEM	CEM Index	ALT	STB	HAB	FC	CAN	RIP	DEP	DEN	SUR	ANG	UPP	MID	LOW	VEG	BED	SCI (15 Var)	SCI (15 Var) Normalized	SCI (5 Var)	SCI (5 Var) Normalized	(-) SCI (5 Var) Normalized	SCI SUR only	SCI SUR only Normalized	Disturbance Regime Based on 5 Variable SCI Equation
1		JR1		34.91886	90.18215	US61	4	0.8	0.5	0.6	0.8	0.8	0.9	0.9	0.4	0.6	0.9	0.5	1	1	0.1	0.3	0.5	0.57	0.56	0.64	0.71	-0.71	0.77	1.00	Minimally Disturbed
2		JR1A		34.91435	90.13149	Baldwin Rd. at Johnson Creek Greenway	4	0.8	0.6	0.5	0.6	0.8	0.9	0.6	0.4	0.5	0.7	0.4	1	1	0.1	0.7	0.5	0.55	0.53	0.53	0.53	-0.53	0.58	0.75	Minor Disturbed
3		JR2		34.91456	90.13246	Baldwin Rd. at Johnson Creek Greenway	2	0.4	0.3	0.4	0.7	0.7	0.8	0.5	0.2	0.3	0.6	0.4	1	1	0.1	0.7	0.5	0.44	0.37	0.51	0.50	-0.50	0.49	0.63	Minor Disturbed
4		JR3		34.91465	90.11366	South of Austin Rd.	2	0.4	0.2	0.3	0.4	0.3	0.6	0.4	0.1	0.3	0.4	0.3	1	1	0.1	0.7	0.3	0.33	0.20	0.34	0.23	-0.23	0.30	0.38	Minor Disturbed
5/6		JR4		34.91869	90.10389	Austin Rd. west of SR301	4	0.8	0.3	0.6	0.6	0.6	0.8	0.6	0.3	0.4	0.6	0.3	1	1	0.1	0.7	0.5	0.49	0.43	0.50	0.49	-0.49	0.49	0.63	Minor Disturbed
7	Johnson Creek	JR5	11/3/2020	34.92908	90.09662	SR301 south of Church Rd.	2	0.4	0.4	0.3	0.7	0.6	0.8	0.8	0.6	0.4	0.7	0.4	1	1	0.1	0.5	0.5	0.49	0.44	0.49	0.48	-0.48	0.58	0.75	Minor Disturbed
8		JR6		34.91451	90.13257	Baldwin Rd. south of Austin Rd.	4	0.8	0.3	0.5	0.6	0.6	0.8	0.6	0.3	0.4	0.6	0.3	1	1	0.1	0.5	0.5	0.47	0.40	0.49	0.46	-0.46	0.49	0.63	Minor Disturbed
9		JR6B		34.91451	90.13257	Baldwin Rd. south of Austin Rd.	4	0.8	0.6	0.7	0.4	0.8	0.9	0.8	0.4	0.5	0.8	0.5	1	1	0.1	0.5	0.5	0.56	0.53	0.56	0.58	-0.58	0.68	0.88	Minor Disturbed
10		JR7		34.9189	90.16277	Johnson Creek Greenway	2	0.4	0.4	0.4	0.7	0.4	0.6	0.7	0.7	0.6	0.7	0.5	1	1	0.1	0.5	0.5	0.50	0.45	0.55	0.56	-0.56	0.58	0.75	Minor Disturbed
11		JR1C		34.91887	90.16628	Johnson Creek Greenway	2	0.4	0.4	0.4	0.7	0.4	0.6	0.7	0.7	0.6	0.7	0.5	1	1	0.1	0.5	0.5	0.50	0.45	0.55	0.56	-0.56	0.58	0.75	Minor Disturbed
12		JR1D		34.91887	90.16628	Johnson Creek Greenway	3	0.5	0.3	0.3	0.8	0.9	0.9	0.9	0.5	0.8	0.9	0.2	1	1	0.1	0.5	0.5	0.51	0.47	0.46	0.43	-0.43	0.77	1.00	Minor Disturbed
13		HLC5		34.98444	90.0664	Horn Lake Rd.	3	0.5	0.2	0.1	0.4	0.3	0.2	0.3	0.4	0.2	0.3	0.2	1	1	0.1	0.5	0.5	0.29	0.15	0.26	0.11	-0.11	0.20	0.25	Severely Disturbed
14/15	Horn Lake Creek	HLC11	11/4/2020	34.96513	90.0174	US51 north of SR302	3	0.5	0.3	0.4	0.7	0.4	0.3	0.2	0.4	0.3	0.3	0.4	1	0.1	0.1	0.2	0.5	0.30	0.16	0.44	0.40	-0.40	0.20	0.25	Minor Disturbed
16		HLC13.5		34.95403	90.00542	I Blvd. off Expy Dr. west of I-55	2	0.4	0.9	1	0.8	0.8	1	1	0.6	0.9	0.9	0.6	1	1	0.7	0.9	0.7	0.79	0.88	0.79	0.94	-0.94	0.77	1.00	Relatively Undisturbed

17		HLC13.7		34.95403	90.00394	I Blvd. off Expy Dr. west of I-55	4	0.8	0.8	0.9	0.8	0.8	1	1	0.6	0.7	0.9	0.5	1	1	0.7	0.9	0.7	0.80	0.88	0.74	0.87	-0.87	0.77	1.00	Relatively Undisturbed
18		HLC15		34.94983	89.99241	Nail Rd. east of I-55	3	0.5	0.4	0.6	0.7	0.8	0.6	0.9	0.4	0.7	0.9	0.3	1	1	0.7	0.9	0.8	0.65	0.67	0.62	0.67	-0.67	0.77	1.00	Minimally Disturbed
19		HLC16		34.94553	89.98149	Elmore Rd. South of Nail Rd.	3	0.5	0.8	0.8	0.7	0.7	0.9	0.9	0.5	0.8	0.9	0.4	1	1	0.7	0.9	0.8	0.73	0.79	0.69	0.79	-0.79	0.77	1.00	Minimally Disturbed
20		HLC16		34.94461	89.98064	Elmore Rd. South of Nail Rd.	4	0.8	0.2	0.9	0.7	0.7	0.9	0.9	0.4	0.8	0.9	0.4	1	0.1	0.1	0.6	0.9	0.51	0.46	0.73	0.84	-0.84	0.77	1.00	Relatively Undisturbed
21		HLC17		34.93721	89.97173	Swinnea Rd. north of Church Rd.	3	0.5	0.8	0.8	0.7	0.7	0.7	0.8	0.5	0.8	0.9	0.4	1	0.7	0.1	0.7	0.8	0.60	0.60	0.69	0.79	-0.79	0.77	1.00	Minimally Disturbed
22	Johnson Creek	JR1E		near JR1D		Johnson Creek Greenway	4	0.8	0.2	0.5	0.8	0.7	0.5	0.7	0.4	0.6	0.8	0.3	1	1	0.7	0.9	0.5	0.58	0.57	0.54	0.56	-0.56	0.68	0.88	Minor Disturbed
23	Camp Creek	CC1		34.9444	89.86681	West Sandidge Rd. off US78	3	0.5	0.3	0.2	0.4	0.6	0.2	0.2	0.2	0.4	0.1	0.2	0.1	0.7	0.1	0.2	0.6	0.24	0.07	0.25	0.09	-0.09	0.01	0.00	Severely Disturbed
24*		NC1B		34.929	89.87154	West Sandidge Rd. off US78 at Bridge Out	3	0.5	0.2	0.1	0.4	0.4	0.2	0.3	0.4	0.3	0.4	0.1	0.1	0.7	0.1	0.2	0.3	0.22	0.05	0.22	0.04	-0.04	0.30	0.38	Severely Disturbed
25		NC10		34.94792	89.9009	Pleasant Hill Rd. north of Nail Rd.	4	0.8	0.6	0.7	0.6	0.7	0.8	0.6	0.6	0.6	0.6	0.3	1	0.7	0.1	0.5	0.8	0.55	0.52	0.57	0.60	-0.60	0.49	0.63	Minor Disturbed
26		Gully	11/5/2020	34.95473	89.90436	Gully at Meadow Brook Dr. south of SR302	3	0.5	0.1	0.1	0.2	0.1	0.2	0.3	0.4	0.2	0.3	0.1	1	0.1	0.1	0.6	0.4	0.20	0.02	0.19	0.00	0.00	0.20	0.25	Severely Disturbed
27	Nolehoe Creek	NC4		34.9548	89.90421	Stream at Meadow Brook Dr. south of SR302	4	0.8	0.1	0.7	0.2	0.3	0.4	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0.2	0.19	0.00	0.28	0.14	-0.14	0.11	0.13	Severely Disturbed
28		NC5B		34.96058	89.91959	Malone Rd. at corner of SR302	4	0.8	0.6	0.7	0.6	0.7	0.8	0.6	0.6	0.6	0.6	0.3	1	0.7	0.1	0.7	0.7	0.56	0.54	0.56	0.57	-0.57	0.49	0.63	Minor Disturbed
29		NC7		34.96058	89.91959	Malone Rd. at corner of SR302	4	0.8	0.4	0.3	0.4	0.5	0.3	0.3	0.1	0.2	0.2	0.2	0.1	1	0.1	0.4	0.7	0.27	0.12	0.32	0.21	-0.21	0.11	0.13	Minor Disturbed
30		NC7B		34.96204	89.91666	SR302 east of Malone Rd.	4	0.8	0.4	0.3	0.4	0.5	0.3	0.3	0.1	0.2	0.5	0.3	0.7	0.7	0.1	0.4	0.7	0.34	0.21	0.42	0.36	-0.36	0.39	0.50	Minor Disturbed
31		NC9		34.96183	89.89206	SR302 east of Southbranch Pkwy.	4	0.8	0.4	0.3	0.1	0.4	0.2	0.2	0.1	0.2	0.4	0.6	0.1	0.1	0.1	0.3	0.8	0.22	0.05	0.36	0.26	-0.26	0.30	0.38	Minor Disturbed
32		HC01		34.8786	89.93678	Getwell Rd. south of Pleasant Hill Rd.	4	0.8	0.4	0.3	0.1	0.4	0.2	0.4	0.3	0.4	0.5	0.6	0.1	1	0.1	0.4	0.8	0.32	0.19	0.37	0.29	-0.29	0.39	0.50	Minor Disturbed
33		HC02		34.8715	89.96924	South of Hall Rd. and east of I-55	3	0.5	0.5	0.5	0.4	0.3	0.3	0.5	0.3	0.6	0.5	0.2	0.1	1	0.7	0.3	0.8	0.39	0.29	0.44	0.39	-0.39	0.39	0.50	Minor Disturbed
34		HC05		34.87094	89.97321	South of Hall Rd. and east of I-55	4	0.8	0.4	0.3	0.1	0.4	0.2	0.2	0.1	0.2	0.2	0.2	0.1	1	1	0.3	0.8	0.27	0.12	0.25	0.09	-0.09	0.11	0.13	Severely Disturbed
35		HC06		34.87226	89.99687	Downstream of SR51	4	0.8	0.4	0.3	0.1	0.4	0.2	0.2	0.1	0.2	0.2	0.2	0.1	1	0.1	0.2	0.7	0.22	0.05	0.24	0.08	-0.08	0.11	0.13	Severely Disturbed
36		HC07	11/7/2020	34.87185	89.99453	Upstream of SR51	4	0.8	0.6	0.3	0.1	0.4	0.2	0.2	0.1	0.2	0.2	0.5	0.1	1	0.1	0.2	0.7	0.24	0.08	0.29	0.16	-0.16	0.11	0.13	Severely Disturbed
37	Hurricane Creek	HC08		34.87491	90.0144	Upstream of Odom Rd.	4	0.8	0.4	0.2	0.1	0.3	0.2	0.2	0.1	0.2	0.2	0.3	0.1	1	0.1	0.2	0.7	0.22	0.05	0.24	0.08	-0.08	0.11	0.13	Severely Disturbed
38		HC09		34.87488	90.01744	Downstream of Odom Rd.	4	0.8	0.4	0.2	0.1	0.3	0.2	0.2	0.1	0.2	0.2	0.3	0.1	1	0.1	0.2	0.7	0.22	0.05	0.24	0.08	-0.08	0.11	0.13	Severely Disturbed
39		HC10		34.8724	90.0461	South of Dean Rd.	3	0.5	0.4	0.6	0.6	0.8	0.9	0.9	0.4	0.9	0.9	0.4	1	1	0.7	0.9	0.8	0.68	0.72	0.64	0.70	-0.70	0.77	1.00	Minimally Disturbed
40		HC11		34.86261	90.06013	South of Dean Rd.	5	1.0	0.9	1	0.8	0.8	1	1	0.6	0.9	0.9	0.5	1	1	0.7	0.9	0.8	0.84	0.95	0.78	0.92	-0.92	0.77	1.00	Relatively Undisturbed
41		HC12		34.86215	90.06083	South of Dean Rd.	3	0.5	0.4	0.6	0.6	0.8	0.9	0.9	0.4	0.9	0.9	0.4	1	1	0.7	0.9	0.8	0.68	0.72	0.64	0.70	-0.70	0.77	1.00	Minimally Disturbed
42		HC13		34.84076	90.07808	Upstream of Fogg Rd. north of SR304	3	0.5	0.4	0.6	0.6	0.8	0.9	0.7	0.4	0.8	0.8	0.4	1	1	0.7	0.9	0.8	0.66	0.69	0.62	0.68	-0.68	0.68	0.88	Minimally Disturbed
43		HC14		34.84076	90.07808	Downstream of Fogg Rd. north of SR304	3	0.5	0.4	0.6	0.6	0.8	0.9	0.7	0.4	0.8	0.8	0.4	1	1	0.7	0.9	0.8	0.66	0.69	0.62	0.68	-0.68	0.68	0.88	Minimally Disturbed
44		CPC01	11/8/2020	34.93345	90.03283	Low Density Residential; Upstream of Church Rd.	5	1.0	0.8	0.7	0.8	0.9	1	0.8	0.6	0.8	0.9	0.6	1	1	0.7	0.9	0.8	0.81	0.91	0.75	0.88	-0.88	0.77	1.00	Relatively Undisturbed
45	Cow Pen Creek	CPC01		34.93345	90.03283	Low Density Residential; Downstream of Church Rd.	5	1.0	0.8	0.7	0.8	0.9	1	0.8	0.6	0.8	0.9	0.6	1	1	0.7	0.9	0.8	0.81	0.91	0.75	0.88	-0.88	0.77	1.00	Relatively Undisturbed
46		CPC02		34.94797	90.03831	High Density Residential; Upstream of Nail Rd.	5	1.0	0.8	0.7	0.8	0.9	1	0.8	0.6	0.8	0.9	0.6	1	1	0.7	0.9	0.8	0.81	0.91	0.75	0.88	-0.88	0.77	1.00	Relatively Undisturbed

47		CPC02		34.94797	90.03831	High Density Residential; Downstream of Nail Rd.	3	0.5	0.3	0.1	0.6	0.4	0.1	0.1	0.1	0.3	0.2	0.4	1	1	0.7	0.9	0.8	0.32	0.20	0.33	0.22	-0.22	0.11	0.13	Minor Disturbed
48		CPC03		34.96251	90.03903	High Density Residential/Commercial; Upstream of SR302	3	0.5	0.3	0.1	0.6	0.4	0.1	0.1	0.1	0.3	0.2	0.4	1	1	0.7	0.9	0.8	0.32	0.20	0.33	0.22	-0.22	0.11	0.13	Minor Disturbed
49		CPC03		34.96251	90.03903	High Density Residential/Commercial; Downstream of SR302	5	1.0	0.3	0.1	0.6	0.4	0.1	0.1	0.1	0.3	0.2	0.4	0.7	0.7	0.7	0.7	0.8	0.32	0.19	0.33	0.22	-0.22	0.11	0.13	Minor Disturbed
50	Rocky Creek	RC01		34.97749	89.97849	Upstream of Greenbrook Pkwy. South of Rascon Rd.	5	1.0	0.8	0.9	0.7	0.8	0.9	0.9	0.4	0.8	0.9	0.3	1	1	0.7	0.9	0.8	0.76	0.83	0.67	0.75	-0.75	0.77	1.00	Minimally Disturbed
51		RC01		34.97749	89.97849	Downstream of Greenbrook Pkwy. South of Rascon Rd.	5	1.0	0.8	0.9	0.7	0.8	0.9	0.9	0.4	0.8	0.9	0.3	1	1	0.7	0.9	0.8	0.76	0.83	0.67	0.75	-0.75	0.77	1.00	Minimally Disturbed
52	Bean Patch Creek	BPC01		34.89663	89.90044	Upstream of Pleasant Hill Rd.	5	1.0	0.9	0.9	0.7	0.9	0.9	0.7	0.5	0.9	0.9	0.4	1	1	0.7	0.9	0.8	0.79	0.87	0.71	0.82	-0.82	0.77	1.00	Relatively Undisturbed
53		BPC02		34.89663	89.90044	Downstream of Pleasant Hill Rd.	5	1.0	0.9	0.9	0.7	0.9	0.9	0.7	0.5	0.9	0.9	0.4	1	1	0.7	0.9	0.8	0.79	0.87	0.71	0.82	-0.82	0.77	1.00	Relatively Undisturbed
54	Lick Creek	LC01		34.93501	89.83993	Downstream of SR305, adjacent to George M. Harrison Park	5	1.0	1	1	0.8	0.9	1	0.7	0.6	1	0.9	0.4	1	1	0.7	0.9	0.8	0.83	0.93	0.75	0.87	-0.87	0.77	1.00	Relatively Undisturbed
55	Coldwater River	CWR01	11/9/2020	34.9073	89.75405	USGS Gage Calibration, downstream of SR178	5	1.0	1	1	0.8	1	1	1	0.6	1	0.9	0.6	1	1	0.7	0.9	0.8	0.88	1.00	0.81	0.97	-0.97	0.77	1.00	Relatively Undisturbed
56	Lick Creek	LC02	11/10/2020	34.93473	89.84031	Downstream of SR305, adjacent to George M. Harrison Park	5	1.0	0.2	0.6	0.8	0.6	0.9	1	0.5	0.8	0.9	0.3	1	1	0.1	0.7	0.8	0.59	0.58	0.64	0.70	-0.70	0.77	1.00	Minimally Disturbed
57		LC02B		34.93476	89.84076	Downstream of LC02	5	1.0	0.2	0.6	0.8	0.6	0.9	1	0.5	0.8	0.9	0.3	1	1	0.1	0.7	0.8	0.59	0.58	0.64	0.70	-0.70	0.77	1.00	Minimally Disturbed
58		LC03		34.93468	89.84188	Downstream of SR305, adjacent to George M. Harrison Park	5	1.0	0.2	0.3	0.8	0.3	0.6	0.6	0.3	0.5	0.5	0.2	1	1	0.1	0.7	0.8	0.44	0.37	0.45	0.41	-0.41	0.39	0.50	Minor Disturbed
59		LC04		34.94553	89.80887	At SR178 north of Victor Dr.	5	1.0	0.9	0.9	0.7	0.9	0.9	0.8	0.6	0.9	0.9	0.4	1	1	0.7	0.9	0.8	0.80	0.90	0.71	0.82	-0.82	0.77	1.00	Relatively Undisturbed
60		LC05		34.94706	89.79382	Upstream of Hacks Cross Rd.	5	1.0	0.9	0.9	0.6	1	1	1	0.6	0.9	0.9	0.5	1	1	0.7	0.9	0.8	0.83	0.93	0.72	0.83	-0.83	0.77	1.00	Relatively Undisturbed
61		LC06		34.9369	89.80397	At Loftin Dr. off SR178	5	1.0	0.2	0.8	0.2	0.4	0.2	0.1	0.1	0.4	0.8	0.6	0.5	0.7	0.7	0.6	0.4	0.36	0.26	0.50	0.48	-0.48	0.68	0.88	Minor Disturbed
62	Coldwater River	CWR02		34.82787	89.80397	Downstream of SR305	5	1.0	0.9	1	0.9	1	0.5	1	0.6	0.9	0.9	0.6	1	1	0.7	0.9	0.8	0.83	0.93	0.83	1.00	-1.00	0.77	1.00	Relatively Undisturbed
64	Camp Creek Canal	CCC02		34.93414	89.86643	Between Church and Craft Roads	5	1.0	0.6	0.7	0.5	0.6	0.6	0.6	0.4	0.8	0.8	0.2	1	1	0.7	0.9	0.8	0.64	0.66	0.54	0.55	-0.55	0.68	0.88	Minor Disturbed
65		CCC03		34.91912	89.87116	Upstream of College Rd.	5	1.0	0.5	0.6	0.5	0.5	0.7	0.4	0.1	0.5	0.5	0.2	0.1	0.1	0.1	0.2	0.6	0.29	0.15	0.45	0.41	-0.41	0.39	0.50	Minor Disturbed
66		CCC04		34.86231	89.88038	Upstream of SR304	5	1.0	0.6	0.2	0.5	0.5	0.4	0.5	0.2	0.5	0.5	0.2	0.1	0.1	0.1	0.2	0.6	0.28	0.14	0.36	0.27	-0.27	0.39	0.50	Minor Disturbed
67	Bean Patch Creek	BPC03		34.91878	89.91263	Upstream of College Rd.	5	1.0	0.8	0.4	0.5	0.5	0.6	0.7	0.2	0.5	0.5	0.2	0.1	0.1	0.1	0.3	0.8	0.34	0.22	0.44	0.39	-0.39	0.39	0.50	Minor Disturbed
68		BPC04		34.87024	89.88583	At I-269 (Facing downstream)	3	0.5	0.7	0.6	0.5	0.8	0.5	0.5	0.2	0.5	0.5	0.2	0.1	0.1	0.1	0.3	0.8	0.33	0.20	0.47	0.45	-0.45	0.39	0.50	Minor Disturbed

Table 3. Stream Condition Index calculated per stream reach (from variable in Table 2).

Station Number	Station ID	SCI (15 Var)	SCI (15 Var) Normalized	SCI (5 Var)	SCI (5 Var) Normalized	SCI SUR only	SCI SUR only Normalized	Disturbance Regime Based on 5 Variable SCI Equation
1	JR1	0.57	0.56	0.64	0.71	0.77	1.00	Minimally Disturbed
2	JR1A	0.55	0.53	0.53	0.53	0.58	0.75	Minor Disturbed
3	JR2	0.44	0.37	0.51	0.50	0.49	0.63	Minor Disturbed
4	JR3	0.33	0.20	0.34	0.23	0.30	0.38	Minor Disturbed
5/6	JR4	0.49	0.43	0.50	0.49	0.49	0.63	Minor Disturbed
7	JR5	0.49	0.44	0.49	0.48	0.58	0.75	Minor Disturbed
8	JR6	0.47	0.40	0.49	0.46	0.49	0.63	Minor Disturbed
9	JR6B	0.56	0.53	0.56	0.58	0.68	0.88	Minor Disturbed
10	JR7	0.50	0.45	0.55	0.56	0.58	0.75	Minor Disturbed
11	JR1C	0.50	0.45	0.55	0.56	0.58	0.75	Minor Disturbed
12	JR1D	0.51	0.47	0.46	0.43	0.77	1.00	Minor Disturbed
13	HLC5	0.29	0.15	0.26	0.11	0.20	0.25	Severely Disturbed
14/15	HLC11	0.30	0.16	0.44	0.40	0.20	0.25	Minor Disturbed
16	HLC13.5	0.79	0.88	0.79	0.94	0.77	1.00	Relatively Undisturbed
17	HLC13.7	0.80	0.88	0.74	0.87	0.77	1.00	Relatively Undisturbed
18	HLC15	0.65	0.67	0.62	0.67	0.77	1.00	Minimally Disturbed
19	HLC16	0.73	0.79	0.69	0.79	0.77	1.00	Minimally Disturbed
20	HLC16	0.51	0.46	0.73	0.84	0.77	1.00	Relatively Undisturbed
21	HLC17	0.60	0.60	0.69	0.79	0.77	1.00	Minimally Disturbed
22	JR1E	0.58	0.57	0.54	0.56	0.68	0.88	Minor Disturbed
23	CC1	0.24	0.07	0.25	0.09	0.01	0.00	Severely Disturbed
24*	NC1B	0.22	0.05	0.22	0.04	0.30	0.38	Severely Disturbed
25	NC10	0.55	0.52	0.57	0.60	0.49	0.63	Minor Disturbed
26	Gully	0.20	0.02	0.19	0.00	0.20	0.25	Severely Disturbed
27	NC4	0.19	0.00	0.28	0.14	0.11	0.13	Severely Disturbed
28	NC5B	0.56	0.54	0.56	0.57	0.49	0.63	Minor Disturbed
29	NC7	0.27	0.12	0.32	0.21	0.11	0.13	Minor Disturbed
30	NC7B	0.34	0.21	0.42	0.36	0.39	0.50	Minor Disturbed
31	NC9	0.22	0.05	0.36	0.26	0.30	0.38	Minor Disturbed
32	HC01	0.32	0.19	0.37	0.29	0.39	0.50	Minor Disturbed
33	HC02	0.39	0.29	0.44	0.39	0.39	0.50	Minor Disturbed
34	HC05	0.27	0.12	0.25	0.09	0.11	0.13	Severely Disturbed
35	HC06	0.22	0.05	0.24	0.08	0.11	0.13	Severely Disturbed
36	HC07	0.24	0.08	0.29	0.16	0.11	0.13	Severely Disturbed
37	HC08	0.22	0.05	0.24	0.08	0.11	0.13	Severely Disturbed
38	HC09	0.22	0.05	0.24	0.08	0.11	0.13	Severely Disturbed
39	HC10	0.68	0.72	0.64	0.70	0.77	1.00	Minimally Disturbed
40	HC11	0.84	0.95	0.78	0.92	0.77	1.00	Relatively Undisturbed
41	HC12	0.68	0.72	0.64	0.70	0.77	1.00	Minimally Disturbed
42	HC13	0.66	0.69	0.62	0.68	0.68	0.88	Minimally Disturbed
43	HC14	0.66	0.69	0.62	0.68	0.68	0.88	Minimally Disturbed
44	CPC01	0.81	0.91	0.75	0.88	0.77	1.00	Relatively Undisturbed
45	CPC01	0.81	0.91	0.75	0.88	0.77	1.00	Relatively Undisturbed
46	CPC02	0.81	0.91	0.75	0.88	0.77	1.00	Relatively Undisturbed
47	CPC02	0.32	0.20	0.33	0.22	0.11	0.13	Minor Disturbed
48	CPC03	0.32	0.20	0.33	0.22	0.11	0.13	Minor Disturbed
49	CPC03	0.32	0.19	0.33	0.22	0.11	0.13	Minor Disturbed
50	RC01	0.76	0.83	0.67	0.75	0.77	1.00	Minimally Disturbed
51	RC01	0.76	0.83	0.67	0.75	0.77	1.00	Minimally Disturbed
52	BPC01	0.79	0.87	0.71	0.82	0.77	1.00	Relatively Undisturbed
53	BPC02	0.79	0.87	0.71	0.82	0.77	1.00	Relatively Undisturbed
54	LC01	0.83	0.93	0.75	0.87	0.77	1.00	Relatively Undisturbed
55	CWR01	0.88	1.00	0.81	0.97	0.77	1.00	Relatively Undisturbed
56	LC02	0.59	0.58	0.64	0.70	0.77	1.00	Minimally Disturbed
57	LC02B	0.59	0.58	0.64	0.70	0.77	1.00	Minimally Disturbed
58	LC03	0.44	0.37	0.45	0.41	0.39	0.50	Minor Disturbed
59	LC04	0.80	0.90	0.71	0.82	0.77	1.00	Relatively Undisturbed
60	LC05	0.83	0.93	0.72	0.83	0.77	1.00	Relatively Undisturbed
61	LC06	0.36	0.26	0.50	0.48	0.68	0.88	Minor Disturbed
62	CWR02	0.83	0.93	0.83	1.00	0.77	1.00	Relatively Undisturbed
64	CCC02	0.64	0.66	0.54	0.55	0.68	0.88	Minor Disturbed
65	CCC03	0.29	0.15	0.45	0.41	0.39	0.50	Minor Disturbed
66	CCC04	0.28	0.14	0.36	0.27	0.39	0.50	Minor Disturbed
67	BPC03	0.34	0.22	0.44	0.39	0.39	0.50	Minor Disturbed
68	BPC04	0.33	0.20	0.47	0.45	0.39	0.50	Minor Disturbed

Table 4. Cane Creek SCI determination.

Cane	Acres	Percent	SUR	SCI
Cultivated Crops	133.0	0.78	0.2	**0.19**
Hay/Pasture	112.1	0.12	0.5	
Shrub/Scrub	17.6	0.10	0.7	
	262.6	**1.0**	0.5	**Normal Average**
			0.3	**Weighted Sum**

Table 5. Mussacana Creek SCI determination.

Mussacana	Acres	Percent	SUR	SCI
Barren Land	2.9	0.01	0.1	**0.31**
Cultivated Crops	79.6	0.35	0.2	
Hay/Pasture	116.5	0.51	0.5	
Herbaceous	9.6	0.04	0.7	
Shrub/Scrub	17.8	0.08	0.7	
	226.4	**1.0**	0.44	**Normal Average**
			0.41	**Weighted Sum**

Table 6. Nonconnah Creek SCI determination.

Nonconnah	Acres	Percent	SUR	SCI
Barren Land	0.4	0.00	0.1	**0.25**
Cultivated Crops	275.8	0.64	0.2	
Hay/Pasture	76.1	0.18	0.5	
Herbaceous	7.3	0.02	0.7	
Shrub/Scrub	73.8	0.17	0.7	
	433.4	**1.0**	0.44	**Normal Average**
			0.35	**Weighted Sum**

Table 7. Nolehoe Creek SCI determination.

Nolehoe	Acres	Percent	SUR	SCI
Cultivated Crops	94.1	0.73	0.2	**0.21**
Hay/Pasture	16.5	0.13	0.5	
Shrub/Scrub	18.5	0.14	0.7	
	129.1	**1.0**	0.47	**Normal Average**
			0.31	**Weighted Sum**

Table 8. Short Fork Creek SCI determination.

Short Fork	Acres	Percent	SUR	SCI
Cultivated Crops	267.8	0.63	0.2	**0.23**
Hay/Pasture	119.0	0.28	0.5	
Herbaceous	4.9	0.01	0.7	
Shrub/Scrub	31.4	0.07	0.7	
	423.1	**1.0**	0.525	**Normal Average**
			0.33	**Weighted Sum**

Table 9. Red Banks Creek SCI determination.

Red Banks	Acres	Percent	SUR	SCI
Cultivated Crops	92.7	0.48	0.2	**0.13**
Hay/Pasture	74.3	0.18	0.5	
Shrub/Scrub	24.5	0.06	0.7	
	191.5	**0.7**	0.466667	**Normal Average**
			0.23	**Weighted Sum**

Table 10. Summary of Ecosystem Restoration Alternatives

Stream Segment	25% Riparian with Grade Control (AAHU)	25% Acreage	10% Riparian with Grade Control (AAHU) – 5b	10% Acreage – 5b	Riparian Associated with Grade Control (AAHU) - 4	GC Associated Acreage - 4	Grade Control Only (AAHU)	Grade Control Only Acreage
Camp Creek	84	98	48	39	53	47	22	29
Johnson Creek	92	122	52	49	48	43	18	27.8
Cane Creek	45	66	21	26	7	6	3	4
Hurricane Creek	133	160	53	64	52	62	14	9.5
Lick Creek	20	36	10	14	8	11	3.5	5
Mussacana Creek	33	57	16	23	9	9	3	4.5
Nonconnah Creek	13	20	12	20	5	5	2	1.8
Nolehoe Creek	47	32	35	13	38	18	26	37
Short Fork	70	106	34	42	14	12	5	7.7
Red Banks	40	48	21	19	25	24	9	11.5

Table 11. 25% Reforestation of restorable areas (Camp Creek)

Camp Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	98	0.17	16.66
	1	98	0.2	19.6
	10	98	0.6	58.8
	25	98	0.95	93.1
	50	98	0.95	93.1
Without Project	0	98	0.17	16.66
	1	98	0.17	16.66
	10	98	0.17	16.66
	25	79	0.17	13.43
	50	79	0.17	13.43

Camp Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	29	0.16	4.64
	1	29	0.6	17.4
	10	29	0.95	27.55
	25	29	0.95	27.55
	50	29	0.95	27.55
Without Project	0	29	0.16	4.64
	1	29	0.16	4.64
	10	29	0.16	4.64
	25	29	0.16	4.64
	50	29	0.16	4.64

Camp Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.093333333	1.546666667	4.64	4.64
9	3.093333333	1.546666667	4.64	41.76
15	3.093333333	1.546666667	4.64	69.6
25	3.093333333	1.546666667	4.64	116
Cumulative HUs				232
Average Annual Habitat Units				**4.64**

Camp Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	11.10666667	5.553333333	16.66	16.66
9	11.10666667	5.553333333	16.66	149.94
15	10.03	5.015	15.045	225.675
25	8.953333333	4.476666667	13.43	335.75
Cumulative HUs				728.025
Average Annual Habitat Units				**14.5605**

Camp Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.346666667	3.673333333	11.02	11.02
9	14.98333333	7.491666667	22.475	202.275
15	18.36666667	9.183333333	27.55	413.25
25	18.36666667	9.183333333	27.55	688.75
Cumulative HUs				1315.295
Average Annual Habitat Units				**26.3059**

Camp Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	12.08666667	6.043333333	18.13	18.13
9	26.13333333	13.06666667	39.2	352.8
15	50.63333333	25.31666667	75.95	1139.25
25	62.06666667	31.03333333	93.1	2327.5
Cumulative HUs				3837.68
Average Annual Habitat Units				**76.7536**

25% Reforestation	
GC Benefits	21.6659
Riparian Benefits	62.1931
Total ER Benefits	**83.859**

Table 12. 10% Reforestation of restorable areas (Camp Creek)

Camp Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	39	0.17	6.63
	1	39	0.2	7.8
	10	39	0.6	23.4
	25	39	0.95	37.05
	50	39	0.95	37.05
Without Project	0	39	0.17	6.63
	1	39	0.17	6.63
	10	39	0.17	6.63
	25	20	0.17	3.4
	50	20	0.17	3.4

Camp Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	29	0.16	4.64
	1	29	0.6	17.4
	10	29	0.95	27.55
	25	29	0.95	27.55
	50	29	0.95	27.55
Without Project	0	29	0.16	4.64
	1	29	0.16	4.64
	10	29	0.16	4.64
	25	29	0.16	4.64
	50	29	0.16	4.64

Camp Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.093333333	1.546666667	4.64	4.64
9	3.093333333	1.546666667	4.64	41.76
15	3.093333333	1.546666667	4.64	69.6
25	3.093333333	1.546666667	4.64	116
Cumulative HUs				232
Average Annual Habitat Units				**4.64**

Camp Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.42	2.21	6.63	6.63
9	4.42	2.21	6.63	59.67
15	3.343333333	1.671666667	5.015	75.225
25	2.266666667	1.133333333	3.4	85
Cumulative HUs				226.525
Average Annual Habitat Units				**4.5305**

Camp Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.346666667	3.673333333	11.02	11.02
9	14.98333333	7.491666667	22.475	202.275
15	18.36666667	9.183333333	27.55	413.25
25	18.36666667	9.183333333	27.55	688.75
Cumulative HUs				1315.295
Average Annual Habitat Units				**26.3059**

Camp Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.81	2.405	7.215	7.215
9	10.4	5.2	15.6	140.4
15	20.15	10.075	30.225	453.375
25	24.7	12.35	37.05	926.25
Cumulative HUs				1527.24
Average Annual Habitat Units				**30.5448**

10% Reforestation	
GC Benefits	21.6659
Riparian Benefits	26.0143
Total ER Benefits	**47.6802**

Table 13. Grade Control Adjacent Reforestation (Camp Creek)

Camp Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	47	0.17	7.99
	1	47	0.2	9.4
	10	47	0.6	28.2
	25	47	0.95	44.65
	50	47	0.95	44.65
Without Project	0	47	0.17	7.99
	1	47	0.17	7.99
	10	47	0.17	7.99
	25	28	0.17	4.76
	50	28	0.17	4.76

Camp Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	29	0.16	4.64
	1	29	0.6	17.4
	10	29	0.95	27.55
	25	29	0.95	27.55
	50	29	0.95	27.55
Without Project	0	29	0.16	4.64
	1	29	0.16	4.64
	10	29	0.16	4.64
	25	29	0.16	4.64
	50	29	0.16	4.64

Camp Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.093333333	1.546666667	4.64	4.64
9	3.093333333	1.546666667	4.64	41.76
15	3.093333333	1.546666667	4.64	69.6
25	3.093333333	1.546666667	4.64	116
Cumulative HUs				232
Average Annual Habitat Units				**4.64**

Camp Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.326666667	2.663333333	7.99	7.99
9	5.326666667	2.663333333	7.99	71.91
15	4.25	2.125	6.375	95.625
25	3.173333333	1.586666667	4.76	119
Cumulative HUs				294.525
Average Annual Habitat Units				**5.8905**

Camp Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.346666667	3.673333333	11.02	11.02
9	14.98333333	7.491666667	22.475	202.275
15	18.36666667	9.183333333	27.55	413.25
25	18.36666667	9.183333333	27.55	688.75
Cumulative HUs				1315.295
Average Annual Habitat Units				**26.3059**

Camp Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.796666667	2.898333333	8.695	8.695
9	12.53333333	6.266666667	18.8	169.2
15	24.28333333	12.14166667	36.425	546.375
25	29.76666667	14.88333333	44.65	1116.25
Cumulative HUs				1840.52
Average Annual Habitat Units				**36.8104**

Grade Control Adjacent Reforestation	
GC Benefits	21.6659
Riparian Benefits	30.9199
Total ER Benefits	**52.5858**

Table 14. Grade Control Only (Camp Creek)

Camp Creek Grade Control (FWP)

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	29	0.16	4.64
	1	29	0.6	17.4
	10	29	0.95	27.55
	25	29	0.95	27.55
	50	29	0.95	27.55
Without Project	0	29	0.16	4.64
	1	29	0.16	4.64
	10	29	0.16	4.64
	25	29	0.16	4.64
	50	29	0.16	4.64

Camp Creek Grade Control (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.093333333	1.546666667	4.64	4.64
9	3.093333333	1.546666667	4.64	41.76
15	3.093333333	1.546666667	4.64	69.6
25	3.093333333	1.546666667	4.64	116
Cumulative HUs				232
Average Annual Habitat Units				**4.64**

Camp Creek Grade Control (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.346666667	3.673333333	11.02	11.02
9	14.98333333	7.491666667	22.475	202.275
15	18.36666667	9.183333333	27.55	413.25
25	18.36666667	9.183333333	27.55	688.75
Cumulative HUs				1315.295
Average Annual Habitat Units				**26.3059**

Grade Control Only		
	GC Benefits	21.6659
Total ER Benefits		**21.6659**

Table 15. 25% Reforestation of restorable areas (Johnson Creek)

Johnson Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	122	0.26	31.72
	1	122	0.3	36.6
	10	122	0.6	73.2
	25	122	0.95	115.9
	50	122	0.95	115.9
Without Project	0	122	0.26	31.72
	1	122	0.26	31.72
	10	122	0.26	31.72
	25	72	0.26	18.72
	50	72	0.26	18.72

Johnson Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	27.8	0.26	7.228
	1	27.8	0.6	16.68
	10	27.8	0.95	26.41
	25	27.8	0.95	26.41
	50	27.8	0.95	26.41
Without Project	0	27.8	0.26	7.228
	1	27.8	0.26	7.228
	10	27.8	0.26	7.228
	25	27.8	0.26	7.228
	50	27.8	0.26	7.228

Johnson Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.818666667	2.409333333	7.228	7.228
9	4.818666667	2.409333333	7.228	65.052
15	4.818666667	2.409333333	7.228	108.42
25	4.818666667	2.409333333	7.228	180.7
Cumulative HUs				361.4
Average Annual Habitat Units				**7.228**

Johnson Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	21.146667	10.5733333	31.72	31.72
9	21.146667	10.5733333	31.72	285.48
15	16.813333	8.40666667	25.22	378.3
25	12.48	6.24	18.72	468
Cumulative HUs				1163.5
Average Annual Habitat Units				**23.27**

Johnson Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.969333333	3.984666667	11.954	11.954
9	14.36333333	7.181666667	21.545	193.905
15	17.60666667	8.803333333	26.41	396.15
25	17.60666667	8.803333333	26.41	660.25
Cumulative HUs				1262.259
Average Annual Habitat Units				**25.24518**

Johnson Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	22.773333	11.3866667	34.16	34.16
9	36.6	18.3	54.9	494.1
15	63.033333	31.5166667	94.55	1418.25
25	77.266667	38.6333333	115.9	2897.5
Cumulative HUs				4844.01
Average Annual Habitat Units				**96.8802**

10% Reforestation	
GC Benefits	18.01718
Riparian Benefits	73.6102
Total ER Benefits	**91.62738**

Table 16. 10% Reforestation of restorable areas (Johnson Creek)

Johnson Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	49	0.26	12.74
	1	49	0.3	14.7
	10	49	0.6	29.4
	25	49	0.95	46.55
	50	49	0.95	46.55
Without Project	0	49	0.26	12.74
	1	49	0.26	12.74
	10	49	0.26	12.74
	25	0	0.26	0
	50	0	0.26	0

Johnson Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	27.8	0.26	7.228
	1	27.8	0.6	16.68
	10	27.8	0.95	26.41
	25	27.8	0.95	26.41
	50	27.8	0.95	26.41
Without Project	0	27.8	0.26	7.228
	1	27.8	0.26	7.228
	10	27.8	0.26	7.228
	25	27.8	0.26	7.228
	50	27.8	0.26	7.228

Johnson Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.8186667	2.409333333	7.228	7.228
9	4.8186667	2.409333333	7.228	65.052
15	4.8186667	2.409333333	7.228	108.42
25	4.8186667	2.409333333	7.228	180.7
Cumulative HUs				361.4
Average Annual Habitat Units				**7.228**

Johnson Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	8.49333	4.246667	12.74	12.74
9	8.49333	4.246667	12.74	114.66
15	4.24667	2.123333	6.37	95.55
25	0	0	0	0
Cumulative HUs				222.95
Average Annual Habitat Units				**4.459**

Johnson Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.9693333	3.984666667	11.954	11.954
9	14.363333	7.181666667	21.545	193.905
15	17.606667	8.803333333	26.41	396.15
25	17.606667	8.803333333	26.41	660.25
Cumulative HUs				1262.259
Average Annual Habitat Units				**25.24518**

Johnson Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.14667	4.573333	13.72	13.72
9	14.7	7.35	22.05	198.45
15	25.3167	12.65833	37.975	569.625
25	31.0333	15.51667	46.55	1163.75
Cumulative HUs				1945.545
Average Annual Habitat Units				**38.9109**

10% Reforestation	
GC Benefits	18.01718
Riparian Benefits	34.4519
Total ER Benefits	**52.46908**

Table 17. Grade Control Adjacent Reforestation (Johnson Creek)

Johnson Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	43	0.26	11.18
	1	43	0.3	12.9
	10	43	0.6	25.8
	25	43	0.95	40.85
	50	43	0.95	40.85
Without Project	0	43	0.26	11.18
	1	43	0.26	11.18
	10	43	0.26	11.18
	25	0	0.26	0
	50	0	0.26	0

Johnson Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	27.8	0.26	7.228
	1	27.8	0.6	16.68
	10	27.8	0.95	26.41
	25	27.8	0.95	26.41
	50	27.8	0.95	26.41
Without Project	0	27.8	0.26	7.228
	1	27.8	0.26	7.228
	10	27.8	0.26	7.228
	25	27.8	0.26	7.228
	50	27.8	0.26	7.228

Johnson Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.8186667	2.409333333	7.228	7.228
9	4.8186667	2.409333333	7.228	65.052
15	4.8186667	2.409333333	7.228	108.42
25	4.8186667	2.409333333	7.228	180.7
Cumulative HUs				361.4
Average Annual Habitat Units				**7.228**

Johnson Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.45333	3.7266666	11.18	11.18
9	7.45333	3.7266666	11.18	100.62
15	3.72667	1.8633333	5.59	83.85
25	0	0	0	0
Cumulative HUs				195.65
Average Annual Habitat Units				**3.913**

Johnson Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.9693333	3.984666667	11.954	11.954
9	14.363333	7.181666667	21.545	193.905
15	17.606667	8.803333333	26.41	396.15
25	17.606667	8.803333333	26.41	660.25
Cumulative HUs				1262.25 9
Average Annual Habitat Units				**25.245**

Johnson Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	8.02667	4.0133333	12.04	12.04
9	12.9	6.45	19.35	174.15
15	22.2167	11.108333	33.325	499.875
25	27.2333	13.616666	40.85	1021.25
Cumulative HUs				1707.315
Average Annual Habitat Units				**34.1463**

Grade Control Adjacent Reforestation	
GC Benefits	18.01718
Riparian Benefits	30.2333
Total ER Benefits	**48.2505**

Table 18. Grade Control Only (Johnson Creek)

	Johnson Creek Grade Control (FWP)			
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	27.8	0.26	7.228
	1	27.8	0.6	16.68
	10	27.8	0.95	26.41
	25	27.8	0.95	26.41
	50	27.8	0.95	26.41
Without Project	0	27.8	0.26	7.228
	1	27.8	0.26	7.228
	10	27.8	0.26	7.228
	25	27.8	0.26	7.228
	50	27.8	0.26	7.228

Johnson Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.818666667	2.409333333	7.228	7.228
9	4.818666667	2.409333333	7.228	65.052
15	4.818666667	2.409333333	7.228	108.42
25	4.818666667	2.409333333	7.228	180.7
Cumulative HUs				361.4
Average Annual Habitat Units				**7.228**

Johnson Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.969333333	3.984666667	11.954	11.954
9	14.36333333	7.181666667	21.545	193.905
15	17.60666667	8.803333333	26.41	396.15
25	17.60666667	8.803333333	26.41	660.25
Cumulative HUs				1262.259
Average Annual Habitat Units				**25.24518**

Grade Control Only		
	GC Benefits	18.01718
Total ER Benefits		**18.01718**

Table 19. 25% Reforestation of restorable areas (Cane Creek)

Cane Creek Riparian Restoration

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	66	0.19	12.54
	1	66	0.2	13.2
	10	66	0.6	39.6
	25	66	0.95	62.7
	50	66	0.95	62.7
Without Project	0	66	0.19	12.54
	1	66	0.19	12.54
	10	66	0.19	12.54
	25	43	0.19	8.17
	50	43	0.19	8.17

Cane Creek Grade Control

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.2	0.19	0.798
	1	4.2	0.6	2.52
	10	4.2	0.95	3.99
	25	4.2	0.95	3.99
	50	4.2	0.95	3.99
Without Project	0	4.2	0.19	0.798
	1	4.2	0.19	0.798
	10	4.2	0.19	0.798
	25	4.2	0.19	0.798
	50	4.2	0.19	0.798

Cane Creek Grade Control (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.532	0.266	0.798	0.798
9	0.532	0.266	0.798	7.182
15	0.532	0.266	0.798	11.97
25	0.532	0.266	0.798	19.95
Cumulative HUs				39.9
Average Annual Habitat Units				**0.798**

Cane Creek Riparian Restoration (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	8.36	4.18	12.54	12.54
9	8.36	4.18	12.54	112.86
15	6.903333333	3.451666667	10.355	155.325
25	5.446666667	2.723333333	8.17	204.25
Cumulative HUs				484.975
Average Annual Habitat Units				**9.6995**

Cane Creek Grade Control (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.106	0.553	1.659	1.659
9	2.17	1.085	3.255	29.295
15	2.66	1.33	3.99	59.85
25	2.66	1.33	3.99	99.75
Cumulative HUs				190.554
Average Annual Habitat Units				**3.81108**

Cane Creek Riparian Restoration (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	8.58	4.29	12.87	12.87
9	17.6	8.8	26.4	237.6
15	34.1	17.05	51.15	767.25
25	41.8	20.9	62.7	1567.5
Cumulative HUs				2585.22
Average Annual Habitat Units				**51.7044**

25% Reforestation	
GC Benefits	3.01308
Riparian Benefits	42.0049
Total ER Benefits	**45.018**

Table 20. 10% Reforestation of restorable areas (Cane Creek)

Cane Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	26	0.19	4.94
	1	26	0.2	5.2
	10	26	0.6	15.6
	25	26	0.95	24.7
	50	26	0.95	24.7
Without Project	0	26	0.19	4.94
	1	26	0.19	4.94
	10	26	0.19	4.94
	25	3	0.19	0.57
	50	3	0.19	0.57

Cane Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.2	0.19	0.798
	1	4.2	0.6	2.52
	10	4.2	0.95	3.99
	25	4.2	0.95	3.99
	50	4.2	0.95	3.99
Without Project	0	4.2	0.19	0.798
	1	4.2	0.19	0.798
	10	4.2	0.19	0.798
	25	4.2	0.19	0.798
	50	4.2	0.19	0.798

Cane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.532	0.266	0.798	0.798
9	0.532	0.266	0.798	7.182
15	0.532	0.266	0.798	11.97
25	0.532	0.266	0.798	19.95
Cumulative HUs				39.9
Average Annual Habitat Units				**0.798**

Cane Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.293333333	1.646666667	4.94	4.94
9	3.293333333	1.646666667	4.94	44.46
15	1.836666667	0.918333333	2.755	41.325
25	0.38	0.19	0.57	14.25
Cumulative HUs				104.975
Average Annual Habitat Units				**2.0995**

Cane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.106	0.553	1.659	1.659
9	2.17	1.085	3.255	29.295
15	2.66	1.33	3.99	59.85
25	2.66	1.33	3.99	99.75
Cumulative HUs				190.554
Average Annual Habitat Units				**3.81108**

Cane Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.38	1.69	5.07	5.07
9	6.933333333	3.466666667	10.4	93.6
15	13.43333333	6.716666667	20.15	302.25
25	16.46666667	8.233333333	24.7	617.5
Cumulative HUs				1018.42
Average Annual Habitat Units				**20.3684**

10% Reforestation	
GC Benefits	3.01308
Riparian Benefits	18.2689
Total ER Benefits	**21.28198**

Table 21. Grade Control Adjacent Reforestation (Cane Creek)

Cane Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	6	0.19	1.14
	1	6	0.2	1.2
	10	6	0.6	3.6
	25	6	0.95	5.7
	50	6	0.95	5.7
Without Project	0	6	0.19	1.14
	1	6	0.19	1.14
	10	6	0.19	1.14
	25	0	0.19	0
	50	0	0.19	0

Cane Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.2	0.19	0.798
	1	4.2	0.6	2.52
	10	4.2	0.95	3.99
	25	4.2	0.95	3.99
	50	4.2	0.95	3.99
Without Project	0	4.2	0.19	0.798
	1	4.2	0.19	0.798
	10	4.2	0.19	0.798
	25	4.2	0.19	0.798
	50	4.2	0.19	0.798

Cane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.532	0.266	0.798	0.798
9	0.532	0.266	0.798	7.182
15	0.532	0.266	0.798	11.97
25	0.532	0.266	0.798	19.95
Cumulative HUs				39.9
Average Annual Habitat Units				**0.798**

Cane Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.76	0.38	1.14	1.14
9	0.76	0.38	1.14	10.26
15	0.38	0.19	0.57	8.55
25	0	0	0	0
Cumulative HUs				19.95
Average Annual Habitat Units				**0.399**

Cane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.106	0.553	1.659	1.659
9	2.17	1.085	3.255	29.295
15	2.66	1.33	3.99	59.85
25	2.66	1.33	3.99	99.75
Cumulative HUs				190.554
Average Annual Habitat Units				**3.81108**

Cane Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.78	0.39	1.17	1.17
9	1.6	0.8	2.4	21.6
15	3.1	1.55	4.65	69.75
25	3.8	1.9	5.7	142.5
Cumulative HUs				235.02
Average Annual Habitat Units				**4.7004**

Grade Control Adjacent Reforestation	
GC Benefits	3.01308
Riparian Benefits	4.3014
Total ER Benefits	**7.31448**

Table 22. Grade Control Only (Cane Creek)

Cane Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.2	0.19	0.798
	1	4.2	0.6	2.52
	10	4.2	0.95	3.99
	25	4.2	0.95	3.99
	50	4.2	0.95	3.99
Without Project	0	4.2	0.19	0.798
	1	4.2	0.19	0.798
	10	4.2	0.19	0.798
	25	4.2	0.19	0.798
	50	4.2	0.19	0.798

Cane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.532	0.266	0.798	0.798
9	0.532	0.266	0.798	7.182
15	0.532	0.266	0.798	11.97
25	0.532	0.266	0.798	19.95
Cumulative HUs				39.9
Average Annual Habitat Units				**0.798**

Cane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.106	0.553	1.659	1.659
9	2.17	1.085	3.255	29.295
15	2.66	1.33	3.99	59.85
25	2.66	1.33	3.99	99.75
Cumulative HUs				190.554
Average Annual Habitat Units				**3.81108**

Grade Control Only		
	GC Benefits	3.01308
Total ER Benefits		**3.01308**

Table 23. 25% Reforestation of restorable areas (Hurricane Creek)

Hurricane Creek Riparian Restoration

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	160	0.03	4.8
	1	160	0.1	16
	10	160	0.6	96
	25	160	0.95	152
	50	160	0.95	152
Without Project	0	160	0.03	4.8
	1	160	0.03	4.8
	10	160	0.03	4.8
	25	123	0.03	3.69
	50	123	0.03	3.69

Hurricane Creek Grade Control

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	9.5	0.38	3.61
	1	9.5	0.6	5.7
	10	9.5	0.95	9.025
	25	9.5	0.95	9.025
	50	9.5	0.95	9.025
Without Project	0	9.5	0.38	3.61
	1	9.5	0.38	3.61
	10	9.5	0.38	3.61
	25	9.5	0.38	3.61
	50	9.5	0.38	3.61

Hurricane Creek Grade Control (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.406667	1.203333333	3.61	3.61
9	2.406667	1.203333333	3.61	32.49
15	2.406667	1.203333333	3.61	54.15
25	2.406667	1.203333333	3.61	90.25
Cumulative HUs				180.5
Average Annual Habitat Units				**3.61**

Hurricane Creek Riparian Restoration (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.2	1.6	4.8	4.8
9	3.2	1.6	4.8	43.2
15	2.83	1.415	4.245	63.675
25	2.46	1.23	3.69	92.25
Cumulative HUs				203.925
Average Annual Habitat Units				**4.0785**

Hurricane Creek Grade Control (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.103333	1.551666667	4.655	4.655
9	4.908333	2.454166667	7.3625	66.2625
15	6.016667	3.008333333	9.025	135.375
25	6.016667	3.008333333	9.025	225.625
Cumulative HUs				431.918
Average Annual Habitat Units				**8.6384**

Hurricane Creek Riparian Restoration (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	6.93333	3.46666667	10.4	10.4
9	37.3333	18.6666667	56	504
15	82.6667	41.3333333	124	1860
25	101.333	50.6666667	152	3800
Cumulative HUs				6174.4
Average Annual Habitat Units				**123.488**

25% Reforestation	
GC Benefits	5.02835
Riparian Benefits	119.4095
Total ER Benefits	**124.438**

Table 24. 10% Reforestation of restorable areas (Hurricane Creek)

Hurricane Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	64	0.03	1.92
	1	64	0.1	6.4
	10	64	0.6	38.4
	25	64	0.95	60.8
	50	64	0.95	60.8
Without Project	0	64	0.03	1.92
	1	64	0.03	1.92
	10	64	0.03	1.92
	25	27	0.03	0.81
	50	27	0.03	0.81

Hurricane Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	9.5	0.38	3.61
	1	9.5	0.6	5.7
	10	9.5	0.95	9.025
	25	9.5	0.95	9.025
	50	9.5	0.95	9.025
Without Project	0	9.5	0.38	3.61
	1	9.5	0.38	3.61
	10	9.5	0.38	3.61
	25	9.5	0.38	3.61
	50	9.5	0.38	3.61

Hurricane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.406667	1.203333333	3.61	3.61
9	2.406667	1.203333333	3.61	32.49
15	2.406667	1.203333333	3.61	54.15
25	2.406667	1.203333333	3.61	90.25
Cumulative HUs				180.5
Average Annual Habitat Units				**3.61**

Hurricane Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.28	0.64	1.92	1.92
9	1.28	0.64	1.92	17.28
15	0.91	0.455	1.365	20.475
25	0.54	0.27	0.81	20.25
Cumulative HUs				59.925
Average Annual Habitat Units				**1.1985**

Hurricane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.103333	1.551666667	4.655	4.655
9	4.908333	2.454166667	7.3625	66.2625
15	6.016667	3.008333333	9.025	135.375
25	6.016667	3.008333333	9.025	225.625
Cumulative HUs				431.9175
Average Annual Habitat Units				**8.63835**

Hurricane Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.7733	1.3867	4.16	4.16
9	14.933	7.4667	22.4	201.6
15	33.067	16.533	49.6	744
25	40.533	20.267	60.8	1520
Cumulative HUs				2469.76
Average Annual Habitat Units				**49.395**

10% Reforestation	
GC Benefits	5.02835
Riparian Benefits	48.1967
Total ER Benefits	**53.22505**

Table 25. Grade Control Adjacent Reforestation (Hurricane Creek)

Hurricane Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	62	0.03	1.86
	1	62	0.1	6.2
	10	62	0.6	37.2
	25	62	0.95	58.9
	50	62	0.95	58.9
Without Project	0	62	0.03	1.86
	1	62	0.03	1.86
	10	62	0.03	1.86
	25	0	0.03	0
	50	0	0.03	0

Hurricane Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	9.5	0.38	3.61
	1	9.5	0.6	5.7
	10	9.5	0.95	9.025
	25	9.5	0.95	9.025
	50	9.5	0.95	9.025
Without Project	0	9.5	0.38	3.61
	1	9.5	0.38	3.61
	10	9.5	0.38	3.61
	25	9.5	0.38	3.61
	50	9.5	0.38	3.61

Hurricane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.40667	1.203333333	3.61	3.61
9	2.40667	1.203333333	3.61	32.49
15	2.40667	1.203333333	3.61	54.15
25	2.40667	1.203333333	3.61	90.25
Cumulative HUs				180.5
Average Annual Habitat Units				**3.61**

Hurricane Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.24	0.62	1.86	1.86
9	1.24	0.62	1.86	16.74
15	0.62	0.31	0.93	13.95
25	0	0	0	0
Cumulative HUs				32.55
Average Annual Habitat Units				**0.651**

Hurricane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.10333	1.551666667	4.655	4.655
9	4.90833	2.454166667	7.3625	66.2625
15	6.01667	3.008333333	9.025	135.375
25	6.01667	3.008333333	9.025	225.625
Cumulative HUs				431.9175
Average Annual Habitat Units				**8.63835**

Hurricane Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.686667	1.3433	4.03	4.03
9	14.46667	7.2333	21.7	195.3
15	32.03333	16.016	48.05	720.75
25	39.26667	19.633	58.9	1472.5
Cumulative HUs				2392.58
Average Annual Habitat Units				**47.8516**

Grade Control Adjacent Reforestation	
GC Benefits	5.02835
Riparian Benefits	47.2006
Total ER Benefits	**52.22895**

Table 26. Grade Control Only (Hurricane Creek)

Hurricane Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	9.5	0.38	3.61
	1	9.5	0.6	5.7
	10	9.5	0.95	9.025
	25	9.5	0.95	9.025
	50	9.5	0.95	9.025
Without Project	0	9.5	0.38	3.61
	1	9.5	0.38	3.61
	10	9.5	0.38	3.61
	25	9.5	0.38	3.61
	50	9.5	0.38	3.61

Hurricane Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.406666667	1.203333333	3.61	3.61
9	2.406666667	1.203333333	3.61	32.49
15	2.406666667	1.203333333	3.61	54.15
25	2.406666667	1.203333333	3.61	90.25
Cumulative HUs				180.5
Average Annual Habitat Units				**3.61**

Hurricane Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.103333333	1.551666667	4.655	4.655
9	4.908333333	2.454166667	7.3625	66.2625
15	6.016666667	3.008333333	9.025	135.375
25	6.016666667	3.008333333	9.025	225.625
Cumulative HUs				431.9175
Average Annual Habitat Units				**8.63835**

Grade Control Only		
	GC Benefits	5.02835
Total ER Benefits		**5.02835**

Table 27. 25% Reforestation of restorable areas (Lick Creek)

Lick Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	36	0.39	14.04
	1	36	0.5	18
	10	36	0.6	21.6
	25	36	0.95	34.2
	50	36	0.95	34.2
Without Project	0	36	0.39	14.04
	1	36	0.39	14.04
	10	36	0.39	14.04
	25	32	0.39	12.48
	50	32	0.39	12.48

Lick Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	5	0.36	1.8
	1	5	0.6	3
	10	5	0.95	4.75
	25	5	0.95	4.75
	50	5	0.95	4.75
Without Project	0	5	0.36	1.8
	1	5	0.36	1.8
	10	5	0.36	1.8
	25	5	0.36	1.8
	50	5	0.36	1.8

Lick Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.2	0.6	1.8	1.8
9	1.2	0.6	1.8	16.2
15	1.2	0.6	1.8	27
25	1.2	0.6	1.8	45
Cumulative HUs				90
Average Annual Habitat Units				**1.8**

Lick Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.36	4.68	14.04	14.04
9	9.36	4.68	14.04	126.36
15	8.84	4.42	13.26	198.9
25	8.32	4.16	12.48	312
Cumulative HUs				651.3
Average Annual Habitat Units				**13.026**

Lick Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.6	0.8	2.4	2.4
9	2.583333	1.291667	3.875	34.875
15	3.166667	1.583333	4.75	71.25
25	3.166667	1.583333	4.75	118.75
Cumulative HUs				227.275
Average Annual Habitat Units				**4.5455**

Lick Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	10.68	5.34	16.02	16.02
9	13.2	6.6	19.8	178.2
15	18.6	9.3	27.9	418.5
25	22.8	11.4	34.2	855
Cumulative HUs				1467.72
Average Annual Habitat Units				**29.3544**

25% Reforestation	
GC Benefits	2.7455
Riparian Benefits	16.3284
Total ER Benefits	**19.074**

Table 28. 10% Reforestation of restorable areas (Lick Creek)

Lick Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	14	0.39	5.46
	1	14	0.5	7
	10	14	0.6	8.4
	25	14	0.95	13.3
	50	14	0.95	13.3
Without Project	0	14	0.39	5.46
	1	14	0.39	5.46
	10	14	0.39	5.46
	25	10	0.39	3.9
	50	10	0.39	3.9

Lick Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	5	0.36	1.8
	1	5	0.6	3
	10	5	0.95	4.75
	25	5	0.95	4.75
	50	5	0.95	4.75
Without Project	0	5	0.36	1.8
	1	5	0.36	1.8
	10	5	0.36	1.8
	25	5	0.36	1.8
	50	5	0.36	1.8

Lick Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.2	0.6	1.8	1.8
9	1.2	0.6	1.8	16.2
15	1.2	0.6	1.8	27
25	1.2	0.6	1.8	45
Cumulative HUs				90
Average Annual Habitat Units				**1.8**

Lick Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.64	1.82	5.46	5.46
9	3.64	1.82	5.46	49.14
15	3.12	1.56	4.68	70.2
25	2.6	1.3	3.9	97.5
Cumulative HUs				222.3
Average Annual Habitat Units				**4.446**

Lick Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.6	0.8	2.4	2.4
9	2.5833333	1.2916667	3.875	34.875
15	3.1666667	1.5833333	4.75	71.25
25	3.1666667	1.5833333	4.75	118.75
Cumulative HUs				227.275
Average Annual Habitat Units				**4.5455**

Lick Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.1533333	2.0766667	6.23	6.23
9	5.1333333	2.5666667	7.7	69.3
15	7.2333333	3.6166667	10.85	162.75
25	8.8666667	4.4333333	13.3	332.5
Cumulative HUs				570.78
Average Annual Habitat Units				**11.4156**

10% Reforestation	
GC Benefits	2.7455
Riparian Benefits	6.9696
Total ER Benefits	**9.7151**

Table 29. Grade Control Adjacent Reforestation (Lick Creek)

Lick Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	11	0.39	4.29
	1	11	0.5	5.5
	10	11	0.6	6.6
	25	11	0.95	10.45
	50	11	0.95	10.45
Without Project	0	11	0.39	4.29
	1	11	0.39	4.29
	10	11	0.39	4.29
	25	7	0.39	2.73
	50	7	0.39	2.73

Lick Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	5	0.36	1.8
	1	5	0.6	3
	10	5	0.95	4.75
	25	5	0.95	4.75
	50	5	0.95	4.75
Without Project	0	5	0.36	1.8
	1	5	0.36	1.8
	10	5	0.36	1.8
	25	5	0.36	1.8
	50	5	0.36	1.8

Lick Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.2	0.6	1.8	1.8
9	1.2	0.6	1.8	16.2
15	1.2	0.6	1.8	27
25	1.2	0.6	1.8	45
Cumulative HUs				90
Average Annual Habitat Units				**1.8**

Lick Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.86	1.43	4.29	4.29
9	2.86	1.43	4.29	38.61
15	2.34	1.17	3.51	52.65
25	1.82	0.91	2.73	68.25
Cumulative HUs				163.8
Average Annual Habitat Units				**3.276**

Lick Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.6	0.8	2.4	2.4
9	2.5833333	1.2916667	3.875	34.875
15	3.1666667	1.5833333	4.75	71.25
25	3.1666667	1.5833333	4.75	118.75
Cumulative HUs				227.275
Average Annual Habitat Units				**4.5455**

Lick Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.2633333	1.6316667	4.895	4.895
9	4.0333333	2.0166667	6.05	54.45
15	5.6833333	2.8416667	8.525	127.875
25	6.9666667	3.4833333	10.45	261.25
Cumulative HUs				448.47
Average Annual Habitat Units				**8.9694**

Grade Control Adjacent Reforestation	
GC Benefits	2.7455
Riparian Benefits	5.6934
Total ER Benefits	**8.4389**

Table 30. Grade Control Only (Lick Creek)

Lick Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	5	0.36	1.8
	1	5	0.6	3
	10	5	0.95	4.75
	25	5	0.95	4.75
	50	5	0.95	4.75
Without Project	0	5	0.36	1.8
	1	5	0.36	1.8
	10	5	0.36	1.8
	25	5	0.36	1.8
	50	5	0.36	1.8

Lick Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.2	0.6	1.8	1.8
9	1.2	0.6	1.8	16.2
15	1.2	0.6	1.8	27
25	1.2	0.6	1.8	45
Cumulative HUs				90
Average Annual Habitat Units				**1.8**

Lick Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.6	0.8	2.4	2.4
9	2.5833333	1.2916667	3.875	34.875
15	3.1666667	1.5833333	4.75	71.25
25	3.1666667	1.5833333	4.75	118.75
Cumulative HUs				227.275
Average Annual Habitat Units				**4.5455**

Grade Control Only		
	GC Benefits	2.7455
Total ER Benefits		**2.7455**

Table 31. 25% Reforestation of restorable areas (Mussacana Creek)

Mussacana Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	57	0.31	17.67
	1	57	0.5	28.5
	10	57	0.6	34.2
	25	57	0.95	54.15
	50	57	0.95	54.15
Without Project	0	57	0.31	17.67
	1	57	0.31	17.67
	10	57	0.31	17.67
	25	50	0.31	15.5
	50	50	0.31	15.5

Mussacana Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.5	0.31	1.395
	1	4.5	0.6	2.7
	10	4.5	0.95	4.275
	25	4.5	0.95	4.275
	50	4.5	0.95	4.275
Without Project	0	4.5	0.31	1.395
	1	4.5	0.31	1.395
	10	4.5	0.31	1.395
	25	4.5	0.31	1.395
	50	4.5	0.31	1.395

Mussacana Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.93	0.465	1.395	1.395
9	0.93	0.465	1.395	12.555
15	0.93	0.465	1.395	20.925
25	0.93	0.465	1.395	34.875
Cumulative HUs				69.75
Average Annual Habitat Units				**1.395**

Mussacana Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	11.78	5.89	17.67	17.67
9	11.78	5.89	17.67	159.03
15	11.0566667	5.52833333	16.585	248.775
25	10.3333333	5.16666667	15.5	387.5
Cumulative HUs				812.975
Average Annual Habitat Units				**16.2595**

Mussacana Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.365	0.6825	2.0475	2.0475
9	2.325	1.1625	3.4875	31.3875
15	2.85	1.425	4.275	64.125
25	2.85	1.425	4.275	106.875
Cumulative HUs				204.435
Average Annual Habitat Units				**4.0887**

Mussacana Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	15.39	7.695	23.085	23.085
9	20.9	10.45	31.35	282.15
15	29.45	14.725	44.175	662.625
25	36.1	18.05	54.15	1353.75
Cumulative HUs				2321.61
Average Annual Habitat Units				**46.4322**

25% Reforestation	
GC Benefits	2.6937
Riparian Benefits	30.1727
Total ER Benefits	**32.8664**

Table 32. 10% Reforestation of restorable areas (Mussacana Creek)

Mussacana Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	23	0.31	7.13
	1	23	0.5	11.5
	10	23	0.6	13.8
	25	23	0.95	21.85
	50	23	0.95	21.85
Without Project	0	23	0.31	7.13
	1	23	0.31	7.13
	10	23	0.31	7.13
	25	16	0.31	4.96
	50	16	0.31	4.96

Mussacana Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.5	0.31	1.395
	1	4.5	0.6	2.7
	10	4.5	0.95	4.275
	25	4.5	0.95	4.275
	50	4.5	0.95	4.275
Without Project	0	4.5	0.31	1.395
	1	4.5	0.31	1.395
	10	4.5	0.31	1.395
	25	4.5	0.31	1.395
	50	4.5	0.31	1.395

Mussacana Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.93	0.465	1.395	1.395
9	0.93	0.465	1.395	12.555
15	0.93	0.465	1.395	20.925
25	0.93	0.465	1.395	34.875
Cumulative HUs				69.75
Average Annual Habitat Units				**1.395**

Mussacana Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.75333333	2.37666667	7.13	7.13
9	4.75333333	2.37666667	7.13	64.17
15	4.03	2.015	6.045	90.675
25	3.30666667	1.65333333	4.96	124
Cumulative HUs				285.975
Average Annual Habitat Units				**5.7195**

Mussacana Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.365	0.6825	2.0475	2.0475
9	2.325	1.1625	3.4875	31.3875
15	2.85	1.425	4.275	64.125
25	2.85	1.425	4.275	106.875
Cumulative HUs				204.435
Average Annual Habitat Units				**4.0887**

Mussacana Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	6.21	3.105	9.315	9.315
9	8.43333333	4.21666667	12.65	113.85
15	11.8833333	5.94166667	17.825	267.375
25	14.5666667	7.28333333	21.85	546.25
Cumulative HUs				936.79
Average Annual Habitat Units				**18.7358**

10% Reforestation	
GC Benefits	2.6937
Riparian Benefits	13.0163
Total ER Benefits	**15.71**

Table 33. Grade Control Adjacent Reforestation (Mussacana Creek)

Mussacana Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	9	0.31	2.79
	1	9	0.5	4.5
	10	9	0.6	5.4
	25	9	0.95	8.55
	50	9	0.95	8.55
Without Project	0	9	0.31	2.79
	1	9	0.31	2.79
	10	9	0.31	2.79
	25	2	0.31	0.62
	50	2	0.31	0.62

Mussacana Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.5	0.31	1.395
	1	4.5	0.6	2.7
	10	4.5	0.95	4.275
	25	4.5	0.95	4.275
	50	4.5	0.95	4.275
Without Project	0	4.5	0.31	1.395
	1	4.5	0.31	1.395
	10	4.5	0.31	1.395
	25	4.5	0.31	1.395
	50	4.5	0.31	1.395

Mussacana Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.93	0.465	1.395	1.395
9	0.93	0.465	1.395	12.555
15	0.93	0.465	1.395	20.925
25	0.93	0.465	1.395	34.875
Cumulative HUs				69.75
Average Annual Habitat Units				**1.395**

Mussacana Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.86	0.93	2.79	2.79
9	1.86	0.93	2.79	25.11
15	1.13666667	0.56833333	1.705	25.575
25	0.41333333	0.20666667	0.62	15.5
Cumulative HUs				68.975
Average Annual Habitat Units				**1.3795**

Mussacana Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.365	0.6825	2.0475	2.0475
9	2.325	1.1625	3.4875	31.3875
15	2.85	1.425	4.275	64.125
25	2.85	1.425	4.275	106.875
Cumulative HUs				204.435
Average Annual Habitat Units				**4.0887**

Mussacana Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.43	1.215	3.645	3.645
9	3.3	1.65	4.95	44.55
15	4.65	2.325	6.975	104.625
25	5.7	2.85	8.55	213.75
Cumulative HUs				366.57
Average Annual Habitat Units				**7.3314**

Grade Control Adjacent Reforestation	
GC Benefits	2.6937
Riparian Benefits	5.9519
Total ER Benefits	**8.6456**

Table 34. Grade Control Only (Mussacana Creek)

Mussacana Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	4.5	0.31	1.395
	1	4.5	0.6	2.7
	10	4.5	0.95	4.275
	25	4.5	0.95	4.275
	50	4.5	0.95	4.275
Without Project	0	4.5	0.31	1.395
	1	4.5	0.31	1.395
	10	4.5	0.31	1.395
	25	4.5	0.31	1.395
	50	4.5	0.31	1.395

Mussacana Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.93	0.465	1.395	1.395
9	0.93	0.465	1.395	12.555
15	0.93	0.465	1.395	20.925
25	0.93	0.465	1.395	34.875
Cumulative HUs				69.75
Average Annual Habitat Units				**1.395**

Mussacana Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.365	0.6825	2.0475	2.0475
9	2.325	1.1625	3.4875	31.3875
15	2.85	1.425	4.275	64.125
25	2.85	1.425	4.275	106.875
Cumulative HUs				204.435
Average Annual Habitat Units				**4.0887**

Grade Control Only		
	GC Benefits	2.6937
Total ER Benefits		**2.6937**

Table 35. 25% Reforestation of restorable areas (Nonconnah Creek)

Nonconnah Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	20	0.25	5
	1	20	0.3	6
	10	20	0.6	12
	25	20	0.95	19
	50	20	0.95	19
Without Project	0	20	0.25	5
	1	20	0.25	5
	10	20	0.25	5
	25	20	0.25	5
	50	20	0.25	5

Nonconnah Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	2	0.35	0.7
	1	2	0.6	1.2
	10	2	0.95	1.9
	25	2	0.95	1.9
	50	2	0.95	1.9
Without Project	0	2	0.35	0.7
	1	2	0.35	0.7
	10	2	0.35	0.7
	25	2	0.35	0.7
	50	2	0.35	0.7

Nonconnah Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.466666667	0.233333333	0.7	0.7
9	0.466666667	0.233333333	0.7	6.3
15	0.466666667	0.233333333	0.7	10.5
25	0.466666667	0.233333333	0.7	17.5
Cumulative HUs				35
Average Annual Habitat Units				**0.7**

Nonconnah Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.333333333	1.666666667	5	5
9	3.333333333	1.666666667	5	45
15	3.333333333	1.666666667	5	75
25	3.333333333	1.666666667	5	125
Cumulative HUs				250
Average Annual Habitat Units				**5**

Nonconnah Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.633333333	0.316666667	0.95	0.95
9	1.033333333	0.516666667	1.55	13.95
15	1.266666667	0.633333333	1.9	28.5
25	1.266666667	0.633333333	1.9	47.5
Cumulative HUs				90.9
Average Annual Habitat Units				**1.818**

Nonconnah Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.666666667	1.833333333	5.5	5.5
9	6	3	9	81
15	10.33333333	5.166666667	15.5	232.5
25	12.66666667	6.333333333	19	475
Cumulative HUs				794
Average Annual Habitat Units				**15.88**

25% Reforestation	
GC Benefits	1.118
Riparian Benefits	10.88
Total ER Benefits	**11.998**

Table 36. 10% Reforestation of restorable areas (Nonconnah Creek)

Nonconnah Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	20	0.25	5
	1	20	0.3	6
	10	20	0.6	12
	25	20	0.95	19
	50	20	0.95	19
Without Project	0	20	0.25	5
	1	20	0.25	5
	10	20	0.25	5
	25	20	0.25	5
	50	20	0.25	5

Nonconnah Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	2	0.35	0.7
	1	2	0.6	1.2
	10	2	0.95	1.9
	25	2	0.95	1.9
	50	2	0.95	1.9
Without Project	0	2	0.35	0.7
	1	2	0.35	0.7
	10	2	0.35	0.7
	25	2	0.35	0.7
	50	2	0.35	0.7

Nonconnah Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.466666667	0.233333333	0.7	0.7
9	0.466666667	0.233333333	0.7	6.3
15	0.466666667	0.233333333	0.7	10.5
25	0.466666667	0.233333333	0.7	17.5
Cumulative HUs				35
Average Annual Habitat Units				**0.7**

Nonconnah Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.333333333	1.666666667	5	5
9	3.333333333	1.666666667	5	45
15	3.333333333	1.666666667	5	75
25	3.333333333	1.666666667	5	125
Cumulative HUs				250
Average Annual Habitat Units				**5**

Nonconnah Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.633333333	0.316666667	0.95	0.95
9	1.033333333	0.516666667	1.55	13.95
15	1.266666667	0.633333333	1.9	28.5
25	1.266666667	0.633333333	1.9	47.5
Cumulative HUs				90.9
Average Annual Habitat Units				**1.818**

Nonconnah Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.666666667	1.833333333	5.5	5.5
9	6	3	9	81
15	10.33333333	5.166666667	15.5	232.5
25	12.66666667	6.333333333	19	475
Cumulative HUs				794
Average Annual Habitat Units				**15.88**

10% Reforestation	
GC Benefits	1.118
Riparian Benefits	10.88
Total ER Benefits	**11.998**

Table 37. Grade Control Adjacent Reforestation (Nonconnah Creek)

Nonconnah Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	5	0.25	1.25
	1	5	0.3	1.5
	10	5	0.6	3
	25	5	0.95	4.75
	50	5	0.95	4.75
Without Project	0	5	0.25	1.25
	1	5	0.25	1.25
	10	5	0.25	1.25
	25	0	0.25	0
	50	0	0.25	0

Nonconnah Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	2	0.35	0.7
	1	2	0.6	1.2
	10	2	0.95	1.9
	25	2	0.95	1.9
	50	2	0.95	1.9
Without Project	0	2	0.35	0.7
	1	2	0.35	0.7
	10	2	0.35	0.7
	25	2	0.35	0.7
	50	2	0.35	0.7

Nonconnah Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.466666667	0.233333333	0.7	0.7
9	0.466666667	0.233333333	0.7	6.3
15	0.466666667	0.233333333	0.7	10.5
25	0.466666667	0.233333333	0.7	17.5
Cumulative HUs				35
Average Annual Habitat Units				**0.7**

Nonconnah Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.833333333	0.416666667	1.25	1.25
9	0.833333333	0.416666667	1.25	11.25
15	0.416666667	0.208333333	0.625	9.375
25	0	0	0	0
Cumulative HUs				21.875
Average Annual Habitat Units				**0.4375**

Nonconnah Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.633333333	0.316666667	0.95	0.95
9	1.033333333	0.516666667	1.55	13.95
15	1.266666667	0.633333333	1.9	28.5
25	1.266666667	0.633333333	1.9	47.5
Cumulative HUs				90.9
Average Annual Habitat Units				**1.818**

Nonconnah Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.916666667	0.458333333	1.375	1.375
9	1.5	0.75	2.25	20.25
15	2.583333333	1.291666667	3.875	58.125
25	3.166666667	1.583333333	4.75	118.75
Cumulative HUs				198.5
Average Annual Habitat Units				**3.97**

Grade Control Adjacent Reforestation	
GC Benefits	1.118
Riparian Benefits	3.5325
Total ER Benefits	**4.6505**

Table 38. Grade Control Only (Nonconnah Creek)

Nonconnah Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	2	0.35	0.7
	1	2	0.6	1.2
	10	2	0.95	1.9
	25	2	0.95	1.9
	50	2	0.95	1.9
Without Project	0	2	0.35	0.7
	1	2	0.35	0.7
	10	2	0.35	0.7
	25	2	0.35	0.7
	50	2	0.35	0.7

Nonconnah Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.466666667	0.233333333	0.7	0.7
9	0.466666667	0.233333333	0.7	6.3
15	0.466666667	0.233333333	0.7	10.5
25	0.466666667	0.233333333	0.7	17.5
Cumulative HUs				35
Average Annual Habitat Units				**0.7**

Nonconnah Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.633333333	0.316666667	0.95	0.95
9	1.033333333	0.516666667	1.55	13.95
15	1.266666667	0.633333333	1.9	28.5
25	1.266666667	0.633333333	1.9	47.5
Cumulative HUs				90.9
Average Annual Habitat Units				**1.818**

Grade Control Only		
	GC Benefits	1.118
Total ER Benefits		**1.118**

Table 39. 25% Reforestation of restorable areas (Nolehoe Creek)

Nolehoe Creek Riparian Restoration

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	32	0.21	6.72
	1	32	0.3	9.6
	10	32	0.6	19.2
	25	32	0.95	30.4
	50	32	0.95	30.4
Without Project	0	32	0.21	6.72
	1	32	0.21	6.72
	10	32	0.21	6.72
	25	17	0.21	3.57
	50	17	0.21	3.57

Nolehoe Creek Grade Control

	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	37	0.21	7.77
	1	37	0.6	22.2
	10	37	0.95	35.15
	25	37	0.95	35.15
	50	37	0.95	35.15
Without Project	0	37	0.21	7.77
	1	37	0.21	7.77
	10	37	0.21	7.77
	25	37	0.21	7.77
	50	37	0.21	7.77

Nolehoe Creek Grade Control (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.18	2.59	7.77	7.77
9	5.18	2.59	7.77	69.93
15	5.18	2.59	7.77	116.55
25	5.18	2.59	7.77	194.25
Cumulative HUs				388.5
Average Annual Habitat Units				**7.77**

Nolehoe Creek Riparian Restoration (FWOP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.48	2.24	6.72	6.72
9	4.48	2.24	6.72	60.48
15	3.43	1.715	5.145	77.175
25	2.38	1.19	3.57	89.25
Cumulative HUs				233.625
Average Annual Habitat Units				**4.6725**

Nolehoe Creek Grade Control (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.99	4.995	14.985	14.985
9	19.11666667	9.558333333	28.675	258.075
15	23.43333333	11.71666667	35.15	527.25
25	23.43333333	11.71666667	35.15	878.75
Cumulative HUs				1679.06
Average Annual Habitat Units				**33.5812**

Nolehoe Creek Riparian Restoration (FWP)

T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.44	2.72	8.16	8.16
9	9.6	4.8	14.4	129.6
15	16.53333333	8.266666667	24.8	372
25	20.26666667	10.13333333	30.4	760
Cumulative HUs				1269.76
Average Annual Habitat Units				**25.3952**

25% Reforestation	
GC Benefits	25.8112
Riparian Benefits	20.7227
Total ER Benefits	**46.5339**

Table 40. 10% Reforestation of restorable areas (Nolehoe Creek)

Nolehoe Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	13	0.21	2.73
	1	13	0.3	3.9
	10	13	0.6	7.8
	25	13	0.95	12.35
	50	13	0.95	12.35
Without Project	0	13	0.21	2.73
	1	13	0.21	2.73
	10	13	0.21	2.73
	25	0	0.21	0
	50	0	0.21	0

Nolehoe Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	37	0.21	7.77
	1	37	0.6	22.2
	10	37	0.95	35.15
	25	37	0.95	35.15
	50	37	0.95	35.15
Without Project	0	37	0.21	7.77
	1	37	0.21	7.77
	10	37	0.21	7.77
	25	37	0.21	7.77
	50	37	0.21	7.77

Nolehoe Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.18	2.59	7.77	7.77
9	5.18	2.59	7.77	69.93
15	5.18	2.59	7.77	116.55
25	5.18	2.59	7.77	194.25
Cumulative HUs				388.5
Average Annual Habitat Units				**7.77**

Nolehoe Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.82	0.91	2.73	2.73
9	1.82	0.91	2.73	24.57
15	0.91	0.455	1.365	20.475
25	0	0	0	0
Cumulative HUs				47.775
Average Annual Habitat Units				**0.9555**

Nolehoe Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.99	4.995	14.985	14.985
9	19.11666667	9.558333333	28.675	258.075
15	23.43333333	11.71666667	35.15	527.25
25	23.43333333	11.71666667	35.15	878.75
Cumulative HUs				1679.06
Average Annual Habitat Units				**33.5812**

Nolehoe Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.21	1.105	3.315	3.315
9	3.9	1.95	5.85	52.65
15	6.716666667	3.358333333	10.075	151.125
25	8.233333333	4.116666667	12.35	308.75
Cumulative HUs				515.84
Average Annual Habitat Units				**10.3168**

10% Reforestation	
GC Benefits	25.8112
Riparian Benefits	9.3613
Total ER Benefits	**35.1725**

Table 41. Grade Control Adjacent Reforestation (Nolehoe Creek)

Nolehoe Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	18	0.21	3.78
	1	18	0.3	5.4
	10	18	0.6	10.8
	25	18	0.95	17.1
	50	18	0.95	17.1
Without Project	0	18	0.21	3.78
	1	18	0.21	3.78
	10	18	0.21	3.78
	25	3	0.21	0.63
	50	3	0.21	0.63

Nolehoe Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	37	0.21	7.77
	1	37	0.6	22.2
	10	37	0.95	35.15
	25	37	0.95	35.15
	50	37	0.95	35.15
Without Project	0	37	0.21	7.77
	1	37	0.21	7.77
	10	37	0.21	7.77
	25	37	0.21	7.77
	50	37	0.21	7.77

Nolehoe Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.18	2.59	7.77	7.77
9	5.18	2.59	7.77	69.93
15	5.18	2.59	7.77	116.55
25	5.18	2.59	7.77	194.25
Cumulative HUs				388.5
Average Annual Habitat Units				**7.77**

Nolehoe Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.52	1.26	3.78	3.78
9	2.52	1.26	3.78	34.02
15	1.47	0.735	2.205	33.075
25	0.42	0.21	0.63	15.75
Cumulative HUs				86.625
Average Annual Habitat Units				**1.7325**

Nolehoe Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.99	4.995	14.985	14.985
9	19.11666667	9.558333333	28.675	258.075
15	23.43333333	11.71666667	35.15	527.25
25	23.43333333	11.71666667	35.15	878.75
Cumulative HUs				1679.06
Average Annual Habitat Units				**33.5812**

Nolehoe Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	3.06	1.53	4.59	4.59
9	5.4	2.7	8.1	72.9
15	9.3	4.65	13.95	209.25
25	11.4	5.7	17.1	427.5
Cumulative HUs				714.24
Average Annual Habitat Units				**14.2848**

Grade Control Adjacent Reforestation	
GC Benefits	25.8112
Riparian Benefits	12.5523
Total ER Benefits	**38.3635**

Table 42. Grade Control Only (Nolehoe Creek)

Nolehoe Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	37	0.21	7.77
	1	37	0.6	22.2
	10	37	0.95	35.15
	25	37	0.95	35.15
	50	37	0.95	35.15
Without Project	0	37	0.21	7.77
	1	37	0.21	7.77
	10	37	0.21	7.77
	25	37	0.21	7.77
	50	37	0.21	7.77

Nolehoe Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.18	2.59	7.77	7.77
9	5.18	2.59	7.77	69.93
15	5.18	2.59	7.77	116.55
25	5.18	2.59	7.77	194.25
Cumulative HUs				388.5
Average Annual Habitat Units				**7.77**

Nolehoe Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	9.99	4.995	14.985	14.985
9	19.11666667	9.558333333	28.675	258.075
15	23.43333333	11.71666667	35.15	527.25
25	23.43333333	11.71666667	35.15	878.75
Cumulative HUs				1679.06
Average Annual Habitat Units				**33.5812**

Grade Control Only		
	GC Benefits	25.8112
Total ER Benefits		**25.8112**

Table 43. 25% Reforestation of restorable areas (Short Fork Creek)

Short Fork Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	106	0.23	24.38
	1	106	0.3	31.8
	10	106	0.6	63.6
	25	106	0.95	100.7
	50	106	0.95	100.7
Without Project	0	106	0.23	24.38
	1	106	0.23	24.38
	10	106	0.23	24.38
	25	75	0.23	17.25
	50	75	0.23	17.25

Short Fork Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	7.7	0.23	1.771
	1	7.7	0.6	4.62
	10	7.7	0.95	7.315
	25	7.7	0.95	7.315
	50	7.7	0.95	7.315
Without Project	0	7.7	0.23	1.771
	1	7.7	0.23	1.771
	10	7.7	0.23	1.771
	25	7.7	0.23	1.771
	50	7.7	0.23	1.771

Short Fork Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.180666667	0.590333333	1.771	1.771
9	1.180666667	0.590333333	1.771	15.939
15	1.180666667	0.590333333	1.771	26.565
25	1.180666667	0.590333333	1.771	44.275
Cumulative HUs				88.55
Average Annual Habitat Units				**1.771**

Short Fork Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	16.25333333	8.126666667	24.38	24.38
9	16.25333333	8.126666667	24.38	219.42
15	13.87666667	6.938333333	20.815	312.225
25	11.5	5.75	17.25	431.25
Cumulative HUs				987.275
Average Annual Habitat Units				**19.7455**

Short Fork Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.130333333	1.065166667	3.1955	3.1955
9	3.978333333	1.989166667	5.9675	53.7075
15	4.876666667	2.438333333	7.315	109.725
25	4.876666667	2.438333333	7.315	182.875
Cumulative HUs				349.503
Average Annual Habitat Units				**6.99006**

Short Fork Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	18.72666667	9.363333333	28.09	28.09
9	31.8	15.9	47.7	429.3
15	54.76666667	27.38333333	82.15	1232.25
25	67.13333333	33.56666667	100.7	2517.5
Cumulative HUs				4207.14
Average Annual Habitat Units				**84.1428**

25% Reforestation	
GC Benefits	5.21906
Riparian Benefits	64.3973
Total ER Benefits	**69.61636**

Table 44. 10% Reforestation of restorable areas (Short Fork Creek)

Short Fork Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	42	0.23	9.66
	1	42	0.3	12.6
	10	42	0.6	25.2
	25	42	0.95	39.9
	50	42	0.95	39.9
Without Project	0	42	0.23	9.66
	1	42	0.23	9.66
	10	42	0.23	9.66
	25	9	0.23	2.07
	50	9	0.23	2.07

Short Fork Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	7.7	0.23	1.771
	1	7.7	0.6	4.62
	10	7.7	0.95	7.315
	25	7.7	0.95	7.315
	50	7.7	0.95	7.315
Without Project	0	7.7	0.23	1.771
	1	7.7	0.23	1.771
	10	7.7	0.23	1.771
	25	7.7	0.23	1.771
	50	7.7	0.23	1.771

Short Fork Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.180666667	0.590333333	1.771	1.771
9	1.180666667	0.590333333	1.771	15.939
15	1.180666667	0.590333333	1.771	26.565
25	1.180666667	0.590333333	1.771	44.275
Cumulative HUs				88.55
Average Annual Habitat Units				**1.771**

Short Fork Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	6.44	3.22	9.66	9.66
9	6.44	3.22	9.66	86.94
15	3.91	1.955	5.865	87.975
25	1.38	0.69	2.07	51.75
Cumulative HUs				236.325
Average Annual Habitat Units				**4.7265**

Short Fork Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.130333333	1.065166667	3.1955	3.1955
9	3.978333333	1.989166667	5.9675	53.7075
15	4.876666667	2.438333333	7.315	109.725
25	4.876666667	2.438333333	7.315	182.875
Cumulative HUs				349.503
Average Annual Habitat Units				**6.99006**

Short Fork Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	7.42	3.71	11.13	11.13
9	12.6	6.3	18.9	170.1
15	21.7	10.85	32.55	488.25
25	26.6	13.3	39.9	997.5
Cumulative HUs				1666.98
Average Annual Habitat Units				**33.3396**

10% Reforestation	
GC Benefits	5.21906
Riparian Benefits	28.6131
Total ER Benefits	**33.83216**

Table 45. Grade Control Adjacent Reforestation (Short Fork Creek)

Short Fork Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	12	0.23	2.76
	1	12	0.3	3.6
	10	12	0.6	7.2
	25	12	0.95	11.4
	50	12	0.95	11.4
Without Project	0	12	0.23	2.76
	1	12	0.23	2.76
	10	12	0.23	2.76
	25	0	0.23	0
	50	0	0.23	0

Short Fork Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	7.7	0.23	1.771
	1	7.7	0.6	4.62
	10	7.7	0.95	7.315
	25	7.7	0.95	7.315
	50	7.7	0.95	7.315
Without Project	0	7.7	0.23	1.771
	1	7.7	0.23	1.771
	10	7.7	0.23	1.771
	25	7.7	0.23	1.771
	50	7.7	0.23	1.771

Short Fork Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.180666667	0.590333333	1.771	1.771
9	1.180666667	0.590333333	1.771	15.939
15	1.180666667	0.590333333	1.771	26.565
25	1.180666667	0.590333333	1.771	44.275
Cumulative HUs				88.55
Average Annual Habitat Units				**1.771**

Short Fork Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.84	0.92	2.76	2.76
9	1.84	0.92	2.76	24.84
15	0.92	0.46	1.38	20.7
25	0	0	0	0
Cumulative HUs				48.3
Average Annual Habitat Units				**0.966**

Short Fork Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.130333333	1.065166667	3.1955	3.1955
9	3.978333333	1.989166667	5.9675	53.7075
15	4.876666667	2.438333333	7.315	109.725
25	4.876666667	2.438333333	7.315	182.875
Cumulative HUs				349.503
Average Annual Habitat Units				**6.99006**

Short Fork Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.12	1.06	3.18	3.18
9	3.6	1.8	5.4	48.6
15	6.2	3.1	9.3	139.5
25	7.6	3.8	11.4	285
Cumulative HUs				476.28
Average Annual Habitat Units				**9.5256**

Grade Control Adjacent Reforestation	
GC Benefits	5.21906
Riparian Benefits	8.5596
Total ER Benefits	**13.77866**

Table 46. Grade Control Only (Short Fork Creek)

Short Fork Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	7.7	0.23	1.771
	1	7.7	0.6	4.62
	10	7.7	0.95	7.315
	25	7.7	0.95	7.315
	50	7.7	0.95	7.315
Without Project	0	7.7	0.23	1.771
	1	7.7	0.23	1.771
	10	7.7	0.23	1.771
	25	7.7	0.23	1.771
	50	7.7	0.23	1.771

Short Fork Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.180666667	0.590333333	1.771	1.771
9	1.180666667	0.590333333	1.771	15.939
15	1.180666667	0.590333333	1.771	26.565
25	1.180666667	0.590333333	1.771	44.275
Cumulative HUs				88.55
Average Annual Habitat Units				**1.771**

Short Fork Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.130333333	1.065166667	3.1955	3.1955
9	3.978333333	1.989166667	5.9675	53.7075
15	4.876666667	2.438333333	7.315	109.725
25	4.876666667	2.438333333	7.315	182.875
Cumulative HUs				349.503
Average Annual Habitat Units				**6.99006**

Grade Control Only		
	GC Benefits	5.21906
Total ER Benefits		**5.21906**

Table 47. 25% Reforestation of restorable areas (Red Banks Creek)

Red Banks Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	48	0.13	6.24
	1	48	0.2	9.6
	10	48	0.6	28.8
	25	48	0.95	45.6
	50	48	0.95	45.6
Without Project	0	48	0.13	6.24
	1	48	0.13	6.24
	10	48	0.13	6.24
	25	48	0.13	6.24
	50	48	0.13	6.24

Red Banks Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	11.5	0.13	1.495
	1	11.5	0.6	6.9
	10	11.5	0.95	10.925
	25	11.5	0.95	10.925
	50	11.5	0.95	10.925
Without Project	0	11.5	0.13	1.495
	1	11.5	0.13	1.495
	10	11.5	0.13	1.495
	25	11.5	0.13	1.495
	50	11.5	0.13	1.495

Red Banks Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.996666667	0.498333333	1.495	1.495
9	0.996666667	0.498333333	1.495	13.455
15	0.996666667	0.498333333	1.495	22.425
25	0.996666667	0.498333333	1.495	37.375
Cumulative HUs				74.75
Average Annual Habitat Units				**1.495**

Red Banks Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	4.16	2.08	6.24	6.24
9	4.16	2.08	6.24	56.16
15	4.16	2.08	6.24	93.6
25	4.16	2.08	6.24	156
Cumulative HUs				312
Average Annual Habitat Units				**6.24**

Red Banks Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.798333333	1.399166667	4.1975	4.1975
9	5.941666667	2.970833333	8.9125	80.2125
15	7.283333333	3.641666667	10.925	163.875
25	7.283333333	3.641666667	10.925	273.125
Cumulative HUs				521.41
Average Annual Habitat Units				**10.4282**

Red Banks Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	5.28	2.64	7.92	7.92
9	12.8	6.4	19.2	172.8
15	24.8	12.4	37.2	558
25	30.4	15.2	45.6	1140
Cumulative HUs				1878.72
Average Annual Habitat Units				**37.5744**

25% Reforestation	
GC Benefits	8.9332
Riparian Benefits	31.3344
Total ER Benefits	**40.2676**

Table 48. 10% Reforestation of restorable areas (Red Banks Creek)

Red Banks Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	19	0.13	2.47
	1	19	0.2	3.8
	10	19	0.6	11.4
	25	19	0.95	18.05
	50	19	0.95	18.05
Without Project	0	19	0.13	2.47
	1	19	0.13	2.47
	10	19	0.13	2.47
	25	19	0.13	2.47
	50	19	0.13	2.47

Red Banks Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	11.5	0.13	1.495
	1	11.5	0.6	6.9
	10	11.5	0.95	10.925
	25	11.5	0.95	10.925
	50	11.5	0.95	10.925
Without Project	0	11.5	0.13	1.495
	1	11.5	0.13	1.495
	10	11.5	0.13	1.495
	25	11.5	0.13	1.495
	50	11.5	0.13	1.495

Red Banks Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.996666667	0.498333333	1.495	1.495
9	0.996666667	0.498333333	1.495	13.455
15	0.996666667	0.498333333	1.495	22.425
25	0.996666667	0.498333333	1.495	37.375
Cumulative HUs				74.75
Average Annual Habitat Units				**1.495**

Red Banks Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	1.646666667	0.823333333	2.47	2.47
9	1.646666667	0.823333333	2.47	22.23
15	1.646666667	0.823333333	2.47	37.05
25	1.646666667	0.823333333	2.47	61.75
Cumulative HUs				123.5
Average Annual Habitat Units				**2.47**

Red Banks Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.798333333	1.399166667	4.1975	4.1975
9	5.941666667	2.970833333	8.9125	80.2125
15	7.283333333	3.641666667	10.925	163.875
25	7.283333333	3.641666667	10.925	273.125
Cumulative HUs				521.41
Average Annual Habitat Units				**10.4282**

Red Banks Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.09	1.045	3.135	3.135
9	5.066666667	2.533333333	7.6	68.4
15	9.816666667	4.908333333	14.725	220.875
25	12.03333333	6.016666667	18.05	451.25
Cumulative HUs				743.66
Average Annual Habitat Units				**14.8732**

10% Reforestation	
GC Benefits	8.9332
Riparian Benefits	12.4032
Total ER Benefits	**21.3364**

Table 49. Grade Control Adjacent Reforestation (Red Banks Creek)

Red Banks Creek Riparian Restoration				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	24	0.13	3.12
	1	24	0.2	4.8
	10	24	0.6	14.4
	25	24	0.95	22.8
	50	24	0.95	22.8
Without Project	0	24	0.13	3.12
	1	24	0.13	3.12
	10	24	0.13	3.12
	25	24	0.13	3.12
	50	24	0.13	3.12

Red Banks Creek Grade Control				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	11.5	0.13	1.495
	1	11.5	0.6	6.9
	10	11.5	0.95	10.925
	25	11.5	0.95	10.925
	50	11.5	0.95	10.925
Without Project	0	11.5	0.13	1.495
	1	11.5	0.13	1.495
	10	11.5	0.13	1.495
	25	11.5	0.13	1.495
	50	11.5	0.13	1.495

Red Banks Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.996666667	0.498333333	1.495	1.495
9	0.996666667	0.498333333	1.495	13.455
15	0.996666667	0.498333333	1.495	22.425
25	0.996666667	0.498333333	1.495	37.375
Cumulative HUs				74.75
Average Annual Habitat Units				**1.495**

Red Banks Creek Riparian Restoration (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.08	1.04	3.12	3.12
9	2.08	1.04	3.12	28.08
15	2.08	1.04	3.12	46.8
25	2.08	1.04	3.12	78
Cumulative HUs				156
Average Annual Habitat Units				**3.12**

Red Banks Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.798333333	1.399166667	4.1975	4.1975
9	5.941666667	2.970833333	8.9125	80.2125
15	7.283333333	3.641666667	10.925	163.875
25	7.283333333	3.641666667	10.925	273.125
Cumulative HUs				521.41
Average Annual Habitat Units				**10.4282**

Red Banks Creek Riparian Restoration (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.64	1.32	3.96	3.96
9	6.4	3.2	9.6	86.4
15	12.4	6.2	18.6	279
25	15.2	7.6	22.8	570
Cumulative HUs				939.36
Average Annual Habitat Units				**18.7872**

Grade Control Adjacent Reforestation	
GC Benefits	8.9332
Riparian Benefits	15.6672
Total ER Benefits	**24.6004**

Table 50. Grade Control Only (Red Banks Creek)

Red Banks Creek Grade Control (FWP)				
	Target Year	Available Habitat Acres	H.S.I.	Total HU
With Project	0	11.5	0.13	1.495
	1	11.5	0.6	6.9
	10	11.5	0.95	10.925
	25	11.5	0.95	10.925
	50	11.5	0.95	10.925
Without Project	0	11.5	0.13	1.495
	1	11.5	0.13	1.495
	10	11.5	0.13	1.495
	25	11.5	0.13	1.495
	50	11.5	0.13	1.495

Red Banks Creek Grade Control (FWOP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	0.996666667	0.498333333	1.495	1.495
9	0.996666667	0.498333333	1.495	13.455
15	0.996666667	0.498333333	1.495	22.425
25	0.996666667	0.498333333	1.495	37.375
Cumulative HUs				74.75
Average Annual Habitat Units				**1.495**

Red Banks Creek Grade Control (FWP)				
T2-T1	*[(A1 x H1)+(A2 x H2)]/3*	*[(A2 x H1)+(A1 x H2)]/6*	*Sum of [(A1 x H1)+(A2 x H2)]/3 Answer and [(A2 x H1)+(A1 x H2)]/6 Answer*	*Answer Multiplied by T2-T1*
1	2.798333333	1.399166667	4.1975	4.1975
9	5.941666667	2.970833333	8.9125	80.2125
15	7.283333333	3.641666667	10.925	163.875
25	7.283333333	3.641666667	10.925	273.125
Cumulative HUs				521.41
Average Annual Habitat Units				**10.4282**

Grade Control Only		
	GC Benefits	8.9332
Total ER Benefits		**8.9332**

DISCUSSION

USACE attempted to directly sample stream reaches, when feasible. However, as discussed above, when stream reaches could not be directly sampled, USACE sampled a subset of sites and used the SUR to SCI correlation equation described in "Model Documentation, Stream Condition Index Model, DeSoto County, Mississippi" included in Section II of this Appendix to determine an SCI score for the stream reach. The inclusion of such correlation in the planning and feasibility phase of the Study influences the results by introducing potential error into the calculation of habitat units. However, this correlation ensures that the recommended plan includes habitat improvement over the largest, and most efficient, land-use in the Study area.

The most cost effective on each stream was determined to be either Alternative 4 or Alternative 5b depending on the stream. The recommended aquatic ecosystem restoration plan would benefit ecological resources, determined as significant through technical, public and institutional recognition. The proposed actions would improve ecological resources in ten degraded streams throughout Desoto County. Nonconnah Creek, flows into the Mississippi River Basin, while the other 9 streams flow into the Coldwater River Watershed and eventually into Arkabutla Lake/Reservoir (a USACE flood risk management project). Degradation in these streams leads to severe erosion resulting in excessive sedimentation in the Mississippi River and Arkabutla Lake. Implementing NER on these streams, restores and protects important habitat and reduces sediment loading in these waterbodies thereby reducing dredging costs, reducing flooding, and preventing ecosystem degradation associated with excess sedimentation. The proposed actions along Camp and Hurricane Creeks appear to be the most cost-effective as described in the main report and the Appendix L. Economics, providing the most habitat for the least cost. However, each stream restoration segment was determined to be cost-effective through the CE-ICA analysis described Appendix L.

Institutional recognition of a resource or effect means its importance is recognized and acknowledged in the laws, plans and policies of government and private groups. Institutional significance of the proposed NER Plan is demonstrated through the restoration of bottomland hardwood forest and arresting the on-going degradation of the streams through stabilization. Bottomland hardwood forest is documented as important migratory bird habitat (Migratory Bird Treaty Act of 1918, Migratory Bird Conservation Act of 1929, as amended) and potential reproductive and summer roosting habitat for the northern long-eared bat (Endangered Species Act of 1973, as amended).

Public recognition indicates that some segment of the general public recognizes the importance of an environmental resource. Public significance is indicated through the interest the public and non-federal sponsors have shown in the ecosystem restoration features and concerns with bank degradation and water quality. Technical recognition of a resource or an effect is based upon scientific or other technical criteria that establishes its significance. The NER Plan is significant based on the following resource characteristics: scarcity, representativeness, status and trends, connectivity, critical habitat, and biodiversity, each of which is further described below.

Scarcity is a measure of a resource's relative abundance within a specified geographic range. The proposed NER Plan would reforest approximately 324 acres of riparian buffers with native vegetation and stabilize and restore approximately 83 miles of in-stream habitat within the Mississippi Valley Loess Plain (MVLP) ecoregion.

Representativeness is a measure of a resource's ability to exemplify the natural habitat or ecosystems within a specified range. The proposed NER Plan would restore many of the streams in DeSoto County to a stable and representative condition of the MVLP.

Status and Trends is the occurrence and extent of the resource over time, how it has changed. The proposed NER Plan would arrest stream bed degradation and allow for the improvement of foraging, cover, and reproductive habitats for native fish, wildlife, and birds in the area. Connectivity is the potential for movement and dispersal of species throughout a given area of an ecosystem, considered in the context of a landscape or watershed. The proposed NER plan would reconnect approximately 83 stream miles in DeSoto County; provide riparian corridors that could connect streams to larger forested blocks and wetlands; reconnect isolated stands of habitat to allow movement and dispersal of species throughout the project area; and the design of the grade control structures would improve fish passage in the streams.

Limiting Habitat is essential for the conservation, survival, or recovery of one or more special status species and biodiversity is a measure of the variety of distinct species and the genetic variability within them. Implementation of the proposed NER plan would provide limiting habitat such as stable, connected stream reaches and improve biodiversity. Stream stabilization would promote re-colonization of hydrophytic and riparian vegetation contributing to healthy and diverse ecotones; grade control and bank stabilization structures along with riparian habitats would provide structure and restore function for/with macroinvertebrates; reforestation would provide foraging habitat and introduce important coarse woody debris and organic materials into the streams. The proposed NER plan would protect or provide habitat that would benefit endemic and/or species in need of conservation, including the Yazoo darter and Yazoo shiner, Southern red-bellied dace, and Piebald madtom (currently petitioned for listing under the ESA); the northern long-eared bat (NLEB) would benefit from reforestation (roosting), and grade control and bank stabilization techniques as aquatic insect habitat and pooling habitat would be restored; and reforestation of acreage within the Mississippi Flyway is beneficial to neo-tropical migratory birds and would promote forage and resting habitat.

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Model Documentation

Stream Condition Index Model

DeSoto County, Mississippi

(Bruce A. Pruitt, K. Jack Killgore, W. Todd Slack, and Andrea Carpenter-Crowther)

Appendix A. Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study

Abstract. An ecological model was developed for DeSoto County, Mississippi. The primary problem identified in the study area is the risk of flood damages primarily in the Horn Lake Creek and Coldwater River Basins. A multidisciplinary team was convened to identify water resource problems, needs and opportunities and target stream reaches of immediate concern. Because of the high flood risk and flashy conditions, stream channels in the study area were highly eroded, and in many cases, exhibit steep banks with little to no protection. The overarching goals of the DeSoto County study were to address flood problems and adverse impacts to stream corridors. Numerous objectives were identified to:

1) Reduce flood damages to businesses, residents and critical infrastructure.
2) Reduce risk to human life from flooding and rainfall events.
3) restore stream stability, sediment transport, aquatic diversity, and riparian condition.
4) Improve land use supportive of channel stabilization and ecosystem restoration.
5) Improve overall water quality supportive of aquatic resources.

In order to meet the above goals, an ecological model, Stream Condition Index (SCI), was formulated based on the degree of statistical correlation (dependency) between15 test variables. The initial variables were tested on 29 verification sites followed by 36 validation sites. Variables were scored on a scale from 0.0 (poor condition) to 1.0 (best attainable) either on-site or normalized to the same scale during post-processing. By using several iterations of statistical analysis, a set of three ecological models called the Stream Condition Index (SCI) were developed (*listed from the ground up*): (1) Surface Assessments, Stream Assessment Reach (SAR) or project footprint scale; (2) Low-Altitude Photogrammetry; and (3) GIS Satellite Scale. All three SCI equations can be used to assess projects at multiple scales using a watershed approach (EC 1105-2-411, Planning: Watershed Plans). Based on the results of the SCI modeling, eight stream reaches were considered relatively undisturbed and best attainable reference conditions in the DeSoto County study area. In contrast, eleven stream reaches scored below 0.2 and were considered severely disturbed. Based on cover types identified remotely via GIS and ground-truthed during the field excursion, a correlation was developed between SCI and surface protection (i.e., the riparian zone nearest to the channel banks). As evidenced by a Pearson's r^2 of 0.86, extrapolation power was strong, lending itself to estimate SCI scores in watersheds and stream reaches not field verified. The findings of this study can be utilized to prioritize watersheds for restoration, enhancement and conservation, plan and conduct intensive ecosystem studies, and assess ecosystem outcomes applicable to future with and without restoration actions including alternative, feasibility, and cost/benefit analyses.

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INTRODUCTION

Setting. Located in the northwest corner of Mississippi, the study area was within DeSoto County which is bordered to the north by Tennessee, to the west by Arkansas, and to the east and south by Marshall and Tate Counties, Mississippi, respectively. Desoto County lies mostly within the 8-digit USGS Hydrologic Unit Code (HUC8) 08030204 – Coldwater, while Horn Lake Creek and the headwaters of Nonconnah lie within the 08010211 – Horn Lake-Nonconnah HUC8. In addition, three Level IV Ecoregions are found within DeSoto County: Loess Plains, Bluff Hills, and Northern Holocene Meander Belts.

Statement of Problem. The primary problem identified in the study area was the risk of flood damages in Horn Lake Creek Basin and the Coldwater River Basin. Drainage from rainfall events originating from headwaters has caused flooding of residential and nonresidential structures downstream and erosion throughout the basins. The landscape has been heavily developed and has experienced altered hydrology. Critical Infrastructure, roads, schools and medical facilities are at risk of flooding and the inundation of roads during flood events is causing safety issues countywide. Major flood damage occurred in May 2010, May 2011, September 2014, and March 2016. Three documented deaths occurred in DeSoto County related to flooding. The 2014 flood inundated the county and stranded many people in their vehicles due to flash flooding. Approximately 130 people were rescued from cars, apartments and a childcare facility. Sixty-six businesses and several homes were impacted. The county is currently raising one of the problem roadways that was inundated during this flood.

In addition to flooding many streams in the study area are experiencing channel degradation and aggradation caused by residential and commercial development, head cutting, channelization, erosive soils, agricultural practices, and other channel alterations in the DeSoto county watersheds have caused a decline in the ability of streams and adjacent lands to support the requisite functions for fish and wildlife.

Background. This study was undertaken by the USACE Memphis District and the USACE Engineer Research and Development Center (ERDC) as an integral part of the Memphis Metropolitan Stormwater Project—North DeSoto Draft Integrated Feasibility Study with Environmental Impact Statement. The purpose of the assessment was to develop a stream condition assessment method that identified existing conditions within the watershed, detailed the major water resources problems and opportunities in the watershed, and recommended tools and a strategic course of action for achieving the desired conditions in the watershed. Paramount to assessment of the DeSoto County watersheds across various degrees of ecological impairment at different scales, a set of ecological models, the "Stream Condition Index" (SCI) were formulated, tested and refined to: 1) assess existing conditions; 2) identify the problems in the watershed; 3) prioritize stream segments for restoration; 4) recommend structural and non-structural restoration design; and 5) provide a numerical assessment of alternatives for planning purposes. The SCI is a visual, multi-metric assessment tool using metrics to characterize the hydrologic, geomorphic, water quality, plant habitat and animal habitat of a selected stream reach.

This effort represents a method of assessing ecosystems using multi-attributes across multi-scales, called the “Multi-Scale Watershed Approach” (MSWA) that was first developed and certified through the National Ecosystem Planning Center of Expertise (ECO-PCX) for the Duck River Watershed Plan, located in middle Tennessee (Pruitt et al. 2020). The concept behind the MSWA was to establish a means of utilizing readily available data and surface assessments (i.e., “boots-on-the-ground” observations) to create an overall knowledge base focusing on watershed problems and opportunities. The outcome of MSWA can become the principle component of the decision-making process such that water resource managers have the ability to make scientifically defensible decisions not only at project specific scales, but also beyond the footprint of the project to the entire watershed. From the watershed perspective, the cause and effect relationships between land use, water quality and quantity, in-channel and riparian conditions, and biotic responses culminate at a single outlet from the watershed and are representative of the ecological condition of the watershed. In addition, assessment at the watershed scale offers advance planning including design, construction, and operation, maintenance, repair, replacement and restoration of aquatic ecosystems. Ultimately, a multi-scale approach offers several advantages which are discussed in the conclusions below.

Multi-Disciplinary Team. In August 2020, the MVM requested ERDC to conduct a study on selected streams (“Targeted Streams”) in Desoto County, Mississippi (hereinafter, referred to as “DeSoto study”). Problems and opportunities, goals and objectives were discussed during a series of conference calls which were memorialized in minutes and distributed to the Project Delivery Team (PDT). The PDT membership included:

District Engineers and Scientists
Elizabeth Burks, Civil Engineer, Project Manager, MVM
Andrea Carpenter Crowther, Biologist, MVM
Cherie Price, Chief, Coastal Planning Section, MVN
Jennifer Roberts, Planner, MVN
Mike Thron, Biologist, MVM
Evan Stewart, Economist, MVN
Jon Korneliussen, Civil Engineer, MVM
Zack Tieman, GIS Specialist, MVM
Cori Holloway, GIS Specialist, MVM
Edward Lambert, Chief, Environmental Compliance Branch, MVM
Donald Davenport, Hydraulic Engineer, MVM
ERDC Engineers and Scientists
Chris Haring, Fluvial Geomorphologist, ERDC-CHL
David Biedenharn, Hydraulic Engineer, ERDC-CHL
Todd Slack, Fish Ecologist/Mussel Specialist, Project POC, ERDC-EL-EEA
Jack Killgore, Fish Ecologist, ERDC-EEA
Bruce Pruitt, Professional Hydrologist, Senior Wetland Scientist, ERDC-EL-EEA

The project sponsor was the DeSoto County Government. Stakeholders included municipalities, residents and businesses in DeSoto County to include, but not limited to, the cities of Olive Branch, Hernando, Southaven and DeSoto. Since August 2020, regularly scheduled semi-monthly conference calls were attended by the PDT including ERDC scientists. Consequently, the process of data acquisition, reduction, analysis, and interpretation was well vetted by the PDT leading to the formulation and testing of three SCI models which are the subject of this model certification request.

ECO-PCX Consultation. Nathan Richards of the National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) was consulted for advice on model formulation on several occasions: pre-project consultation, prior to field surface assessments, during data reduction and interpretation, and post model formulation and associated preparation of this model documentation for certification. In addition, guidance provided by ECO-PCX as published in "Assuring quality of planning models – model certification/approval process, standard operating procedures" was followed (USACE 2012).

Project Goals. The Flood Risk Management (FRM) goal was to develop alternatives to reduce the severity of flood risk to infrastructure and human life. The federal objective of water and related land resources project planning is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements. Planning objectives represent desired positive changes to future conditions (USACE 2000, PGN). All objectives focused on alternatives within the study area and within the 50-year period of analysis from 2025 to 2075.

The National Ecosystem Restoration (NER) goal is to stabilize channels and connect and improve riparian buffer strips, to minimize channel degradation and erosion, and to support aquatic ecosystem form and function along main stem channels and tributaries in Desoto County. Ecosystem restoration is a primary mission of the USACE, intended to increase the quantity and/or quality of desired ecosystem resources (USACE 2000, PGN).

The overarching goals of the DeSoto study were to evaluate the stream corridors to establish current (baseline) conditions, and identify water resource problems, needs and opportunities. The results will be utilized to prioritize stream segments and watersheds for restoration, enhancement and conservation; plan and conduct ecosystem studies; and assess ecosystem outcomes ("EcoLift") applicable to future with (FWP) and without project (FWOP) scenarios including alternative, feasibility, and cost/benefit analyses.

Project Objectives. The planning objectives for this study were:

Objective 1. Reduce flood damages to businesses, residents, and infrastructure in DeSoto County.
Metric 1: The PDT will evaluate structure damage.

Objective 2. Reduce risks to critical infrastructure.
Metric 2: The PDT will evaluate water surface elevation.

Objective 3. Reduce risk to human life from flooding and rainfall events throughout the county.
Metric 3: The PDT will evaluate water surface elevation.

Objective 4. Support aquatic habitat by reducing channel degradation such as instability and erosion.
Metric 4: The PDT will evaluate channel dimensions, sediment transport, channel bed diversity, pools, and fish cover/canopy density, riparian zones and canopy density, habitat units, and turbidity.

Objective 5. Restore suitable habitat for native and special status species.
Metric 5: The PDT will evaluate habitat diversity, fish cover, canopy cover, and riparian zones and surface protection.

Based on the above objectives, the following tasks were identified:

1. Conduct a surface assessments (i.e., field "boots on the ground") on targeted streams.
2. Test, verify and refine the SCI within and across the targeted streams.
3. Identify watersheds at the HUC 12 scale and stream segments that need additional intensive studies.
4. Provide recommendations on long-term monitoring and condition trajectories;
5. Identify the cause and source of pollution including accelerated erosion, sediment transport and deposition, and habitat loss or aquatic biological impairment;
6. Establish attainable reference conditions at both watershed and stream segment scales;
7. Calculate Average Annual Stream Condition Units (AASCU) based on SCI scores generated on targeted streams.

METHODS

Several steps were undertaken pursuant to formulate and document a mathematical model (algorithm) supportive of achieving the project objectives and to identify key variables used in the SCI algorithm including (Figure 1):

1. Stratify study area by Level IV Ecoregions and HUC12 watersheds.
2. Map watersheds and stream reaches identified by the Memphis District for evaluation.

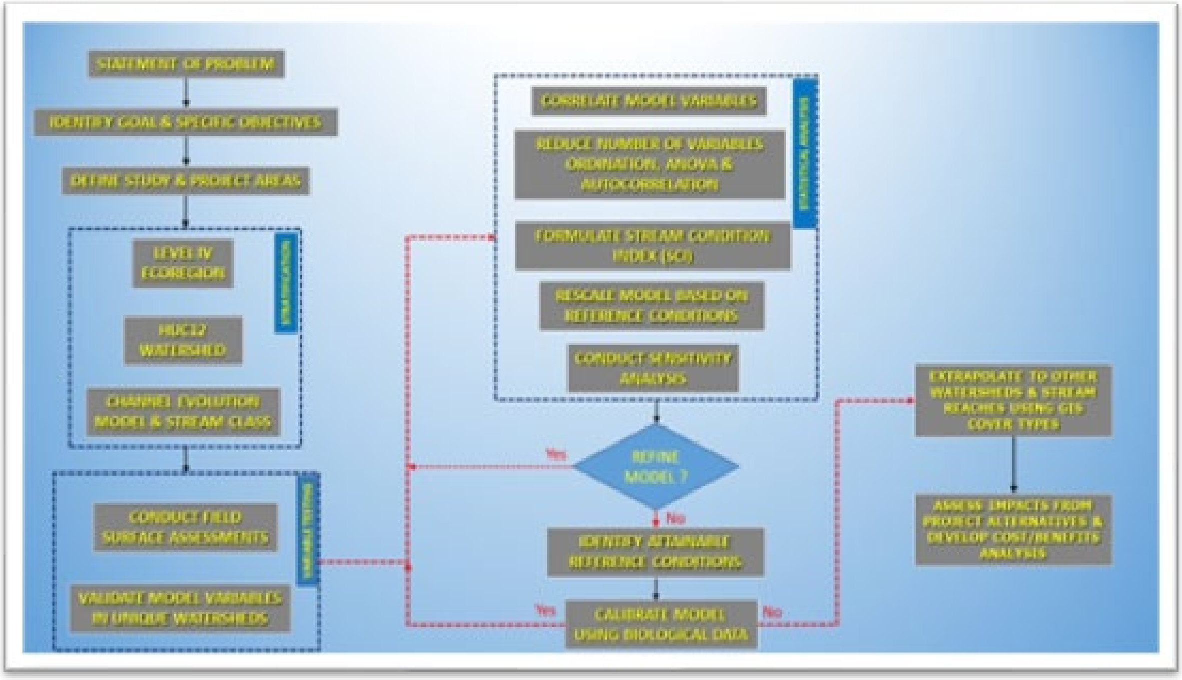

Figure 2. Model Documentation Process.

3. Classify targeted streams by the Channel Evolution Model (Schumm et al. 1984) and stream type using Rosgen's classification system (Rosgen 1994).
4. Field test variables used in the Duck River Watershed Certified Model.
5. Refine first set of test variables using statistical methods.
6. Determine logic of variable subset.
7. Conduct second level of statistical refinement using principal components analysis following by other parametric tests.
8. Review logic of second subset.
9. Formulate first SCI algorithm.
10. Verify correlations between and across SCI variables.
11. Perform sensitivity analysis on SCI.

Targeted Streams for Assessment. Major drainages within the County that were targeted in this study included (listed generally from east to west): Lick Creek, Coldwater River, Camp Creek, Bean Patch Creek, Rocky Creek, Cow Pen Creek, Nolehoe Creek, Hurricane Creek, Mussacana Creek, Nonconnah Creek, Horn Lake Creek, and Johnson Creek (hereinafter referred to as, "Targeted Streams").

Stratify by Ecoregions and Watersheds. The main purpose of stratification is to reduce natural variability (Figure 2). Stratification also facilitates statistical analysis by partitioning the dataset into subpopulations (sample sets). Consequently, subpopulations are generally more normally distributed as expressed in skewness and kurtosis.

Pursuant to identification of natural variability across physiographic regions and watersheds, the DeSoto Study area was stratified by three Level IV Ecoregion

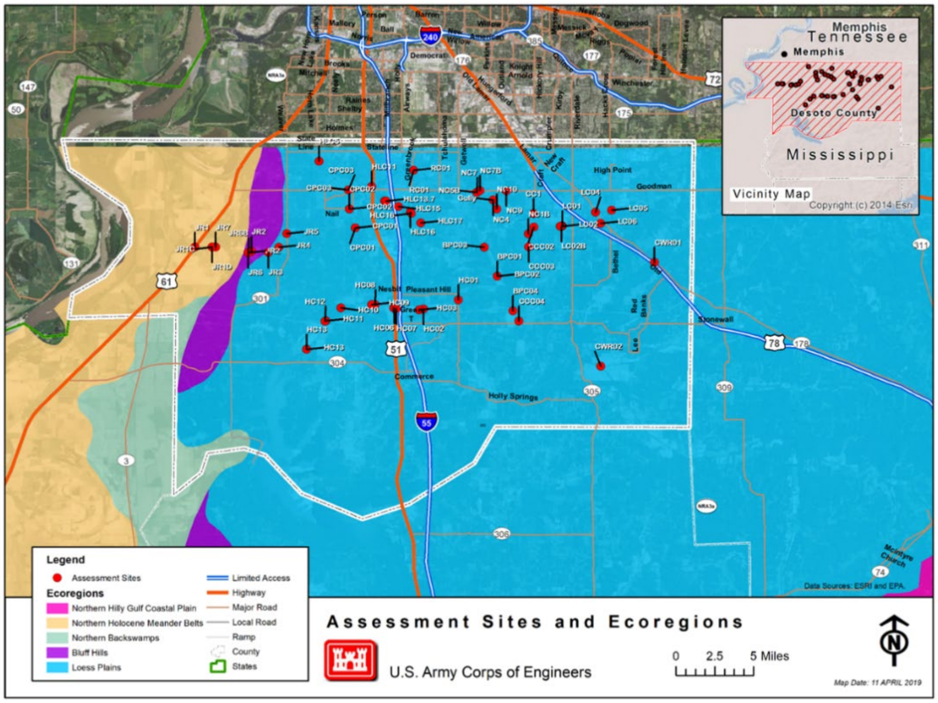

Figure 2. Mississippi Level IV Ecoregions depicting field surface assessment stations in red and DeSoto County boundary demarcated in white.

(from east to west): Loess Plains, Bluff Hills, and Northern Holocene Meander Belts (Figure 2) (Griffith et al., 1998 and Seaber et al., 1994). The second layer of stratification was by hydrologic unit code, HUC12 (Figure 3). Major watersheds included (listed from east to west): Coldwater River, Horn Lake Creek, Nesbit-Hurricane Creek, Frees Corners-Hurricane Creek, Johnson Creek and Upper Lake Cormorant Bayou. Finally, the Targeted Streams were stratified by channel evolution model – CEM (Schumm et al. 1984) and stream class (Rosgen 1994). A range of channel evolutionary stages were noted including incision (stage 2), widening (stage 3), somewhat stable with side bar formation (stage 4), and stable (stage 5). In general, the stream channels were trapezoidal in cross-section and considered a Rosgen “F” channel. However, in many cases, meandering stream channels (Rosgen “C”) were forming within the “F” channel. Consequently, many stream channels were evolved from Schumm stage 3 to stage 4.

Field Surface Assessments. Following a clear and concise statement of problem, identification of goals and objectives, and several PDT meetings (as stated above), field surface assessments were conducted November 3 through 10, 2020. Members of the field team included: Todd Slack, Jack Killgore, Bruce Pruitt, Chris Haring, David Biedenharn, Autumn Murray, and David May of ERDC. Rick Garay (Soil Technician, USDA-NRCS) joined the team and provided logistical support. In addition, Jon Korneliussen (MVM) accompanied the ERDC field team November 4 and 5. A subset of the targeted streams (29 stream reaches) was tested initially including: Johnson Creek, Horn Lake Creek, and Nolehoe Creek. Once site sampling methods were established November 3 – 5,

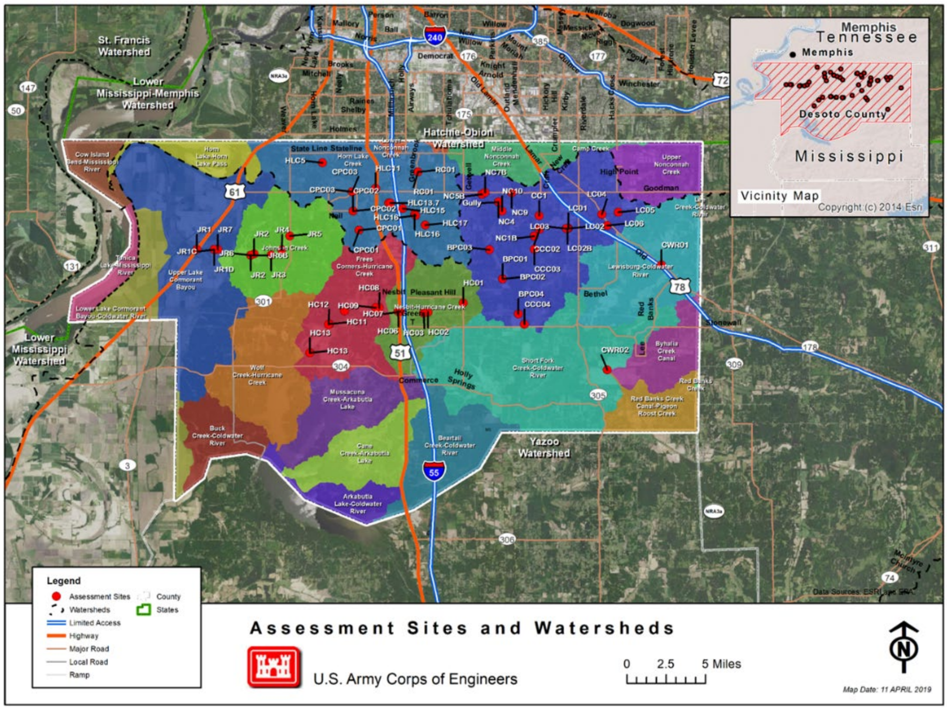

Figure 3. HUC12 watersheds depicting field surface assessment sites in red and DeSoto boundary demarcated in white.

the field team departed on November 6 with the exception of Bruce Pruitt who remained to validate model variables in unique watersheds not assessed initially. Dr. Pruitt validated model variables on an additional 36 stream reaches on Hurricane Creek, Cow Pen Creek, Rocky Creek Bean Patch Creek, Lick Creek, Coldwater River and Camp Creek Canal and departed on Nov. 10.

Variable Verification and Validation. The SCI was developed from interpretation of the surface assessments conducted at a total of 65 Targeted Stream reaches: 1) 29 sites were used to verify model variables for appropriateness in the region; and 2) 36 sites were used to validate the model variables by applying them in different watersheds. Initially, 15 physical and biological attributes were identified and tested that represented stream and riparian zone conditions, as follows (“initial test variables”) (Table 1):

1. CEM: Channel Evolution Model
2. ALT: Channel Alteration
3. STB: Bank Stability
4. HAB: Habitat Diversity
5. FIS: Fish Cover
6. CAN: Canopy Cover
7. RIP: Riparian Zone
8. DEP: Rooting Depth
9. DEN: Root Density
10. SUR: Surface Protection
11. ANG: Bank Angle

12. UPP: Upper Bank
13. MID: Middle Bank
14. LOW: Lower Bank
15. BED: Channel Bed Material and Stability

Table 1. Stream condition index (SCI) variable scoring and descriptions.

Category	Relatively Undisturbed	Minimal Disturbance	Minor Disturbance to Biotic and Abiotic Attributes	High Disturbance
Score →	1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1
Channel Evolution Model – Stage (CEM)	Stable channel: CEM stages 1 and 5	CEM stage 4	CEM stage 3	CEM stage 2
Channel Alteration (ALT)	Natural planform geometry; no structures, dikes. No evidence of down cutting or excessive lateral cutting	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levees are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/ or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Channel is actively down cutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.
Bank Stability (STB)	Banks are stable; 33% or more of eroding surface area of banks in outside bends is protected by roots or structural components that extend to the baseflow elevation.	Moderately stable; less than 33% of eroding surface area of banks in outside bends is protected by roots or structural components that extend to the baseflow elevation.	Moderately unstable; outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into steam annually, some slope failures apparent).	Unstable; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
Aquatic Habitat Diversity (HAB)	8 or more habitat types within the assessment reach	6-8 habitat types within the assessment reach	4-6 habitat types within the assessment reach	< 4 habitat types within the assessment reach
Fish Cover (FC)	>7 cover types available	4 to 7 cover types available	2 to 3 cover types available	Zero to 1 cover type available
Canopy (CAN)	> 90% shaded; full canopy; same shading condition throughout the reach.	25 to 90% of water surface shaded; mixture of conditions.	(intentionally blank)	< 25% water surface shaded in reach.
Riparian Zone (RIP)	Natural vegetation	Natural vegetation extends one active	Natural vegetation extends half of the	Natural vegetation extends a third of

	extends at least two active channel widths on each side.	channel width on each side. Or If less than one width, covers entire flood plain.	active channel width on each side.	the active channel width on each side. Or Filtering function moderately compromised.
Root Depth (DEP)	Root depth extends 80% to 100% of bank height	Root depth extends 60% to 79% of bank height	Root depth extends 30% to 59% of bank height	Root depth < 30 % of bank height
Root Density (DEN)	Root density coverage 80 to 100% of bank	Root density coverage 60 to 79% of bank	Root density coverage 30 to 59% of bank	Root density <30 % of bank
Surface Protection (SUR)	Top of bank surface protection 80 to 100% woody vegetation	Top of bank surface protection 60 to 790% woody vegetation	Top of bank surface protection 30 to 59% woody vegetation	Top of bank surface protection < 30% woody vegetation
Bank Angle (ANG)	Zero to 20% slope	21 to 60% slope	61 to 80% slope	>80% slope
Upper Bank Condition (UPP)	Structural or non-structural components protect >80% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Middle Bank Condition (MID)	Structural or non-structural components protect >80% surface area of middle 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Lower Bank Condition (LOW)	Structural or non-structural components protect >80% surface area of lower 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Bed Material and Stability (BED)	Bed material composed of cobble or larger particles or heavy clay pan; stable side and mid-channel bars present; accelerated aggregation or degradation not observed	Bed material composed of sand or cobble; moderately stable side and mid-channel bars present; accelerated aggregation or degradation not observed	Bed material composed of sand; moderately unstable side and mid-channel bars present; moderate accelerated aggregation or degradation observed	Bed material composed of unconsolidated substrate; highly unstable side and mid-channel bars present or not present at all; high accelerated aggregation or degradation observed

The above features were tested based on competency in regards to providing a rapid visual assessment, ability to discriminate between stream segments and watersheds, and capacity to determine departure from attainable reference conditions (discussed below). Because of the similarities observed in the field between CAN, RIP, UPP, MID, and LOW, they were lumped into one variable called vegetative cover (VEG). In combination with SUR, this facilitated extrapolation using GIS imagery. Consequently, candidate model variables were reduced to eleven variables:

1. CEM: Channel Evolution Model
2. ALT: Channel Alteration (Longitudinal Condition)
3. STB: Bank Stability
4. HAB: Habitat Diversity
5. FIS: Fish Cover
6. DEP: Rooting Depth
7. DEN: Root Density
8. SUR: Surface Protection
9. ANG: Bank Angle
10. VEG: Vegetative Cover
11. BED: Channel Bed Material and Stability

Major GIS Anderson land cover types used to extrapolate the 65 field verification and validation assessment sites included: cultivated crops, barren land, hay/pasture, herbaceous, forested and shrub/scrub. In addition, because of the strong correlation between VEG versus UPP, MID, LOW, CAN, and RIP, estimations of each variable can be calculated with a high degree of confidence.

Statistical Analysis. Each assessment variable was scored from 0.1 (severely disturbed) to 1.0 (relatively undisturbed) (Figure 4 and Table 1). Then, the set of 65 field sites were subjected to statistical analysis for model reduction and application at multiple scales. The objective of model reduction was two-fold: (1) construct a model that was more useful for environment management; and (2) formulate a model useable at multi-scales. The number of input parameters (variables) were reduced based on scale considerations using lumping and principal components analysis (PCA). First, the initial dataset was subjected to PCA (Primer, Version 6, Plymouth, UK). PCA is capable of transforming a large set of variables to a smaller set without compromising important environmental attributes. Consequently, simplicity is traded for a small reduction in accuracy such that the correspondence between variables can be visualized. Vectors represent the direction and magnitude of correlation between the environmental variables. Based on the results of PCA using 15 variables across 65 field sites, several sites responded similarly (highlighted in green circle) to variables as evidenced by the direction and magnitude of eigenvectors (highlighted with blue lines) (Figure 4). These sites are considered attainable reference conditions given they were located in areas with intact forested riparian zones and/or existing grade control structures.

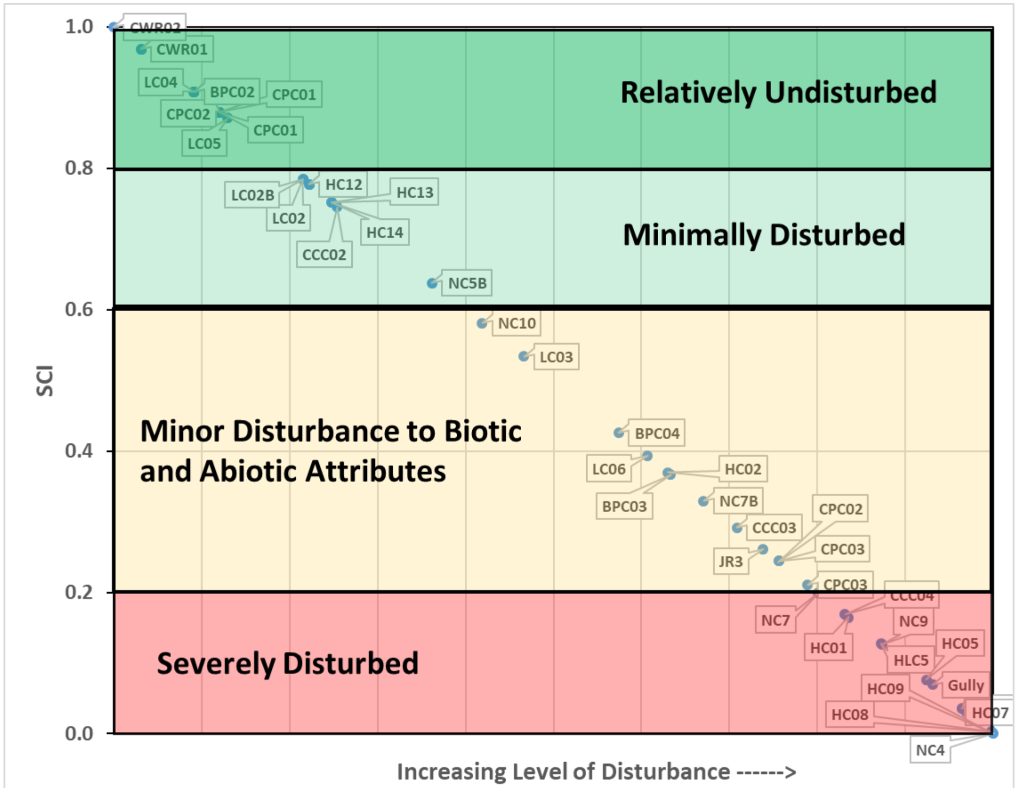

Figure 4. Ecological condition gradient highlighted in five categories based on SCI scores from 65 unique stream reaches (adapted from Pruitt et. al. 2012). Note similarity with gradient depicted in Figure 5.

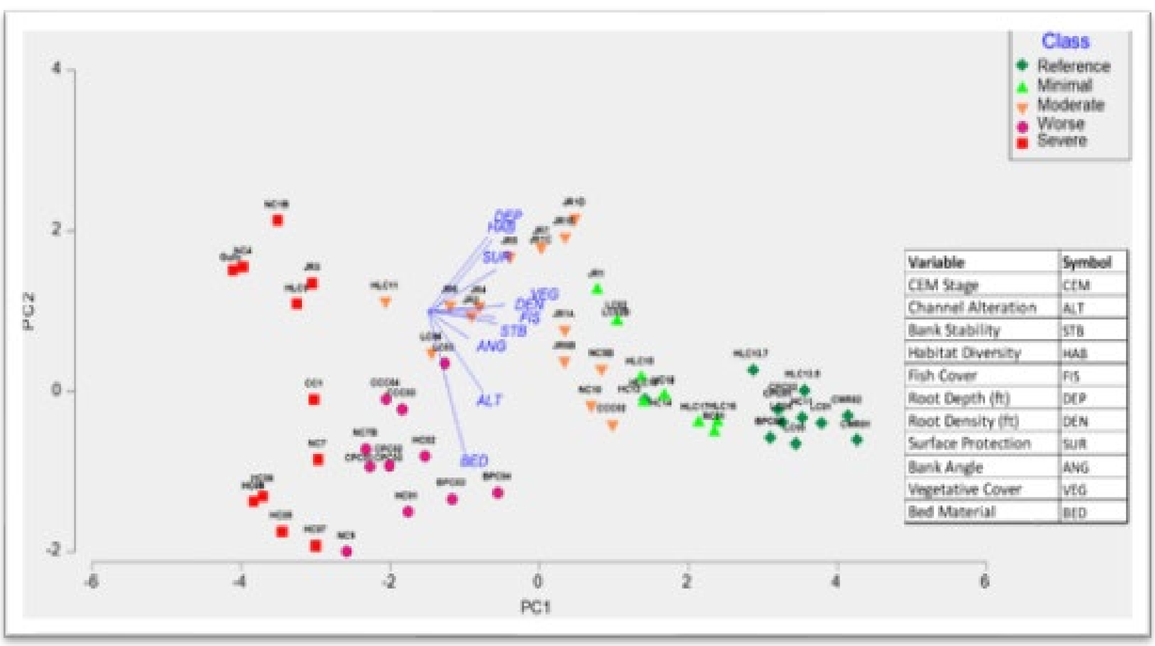

Figure 5. Dataset of 65 field surface assessment sites subjected to principle components analysis. Gradient of conditions based on variable scores oriented along PC1 axis. Eigenvectors, highlighted in blue, have both directional and magnitude components. Note grouping predominantly along watersheds.

Because of such a large dataset (n = 65), parametric statistical tests were justified based on the central limit theorem (CLT). CLT establishes that when additional variables are added, the frequency of the observation tends toward a normal distribution even if the original variables are not normally distributed. All multivariate analyses were performed using PRIMER ver. 7 (PRIMER-E Ltd™, Plymouth, UK); Anderson and Gorley 2007).

Spearman correlation coefficients were calculated between each of the variables to select those with highest correlation. Spearman correlation evaluates a monotonic relationship between two variables regardless of whether the relationship is linear or not. Consequently, in contrast to Pearson's correlation coefficient, Spearman is capable of correlating non-linear data (e.g., polynomial distribution). Spearman correlation coefficients were subjected to the t-test to determine significant correlations (2-tailed, α =0.05). With the exception of five cases (CEM vs. DEP, CEM vs. ANG, CEM vs. VEG, DEP vs. BED, and ANG vs. BED), the correlations were significant (Table 2). Some of the highest Spearman Coefficients were observed between SUR and the other ten variables (Table 3). Consequently, SUR can be estimated from GIS cover types in the riparian zone and extrapolated to other watersheds and stream reaches that did not receive surface assessments. See GIS Watershed Scale section below.

Selection of Appropriate Equation to Calculate SCI Score

Three SCI equations for use at different scales were verified and validated for model certification (*from the ground up*): 1) **Surface Assessments** ("boots-on-the-ground"); 2) **Low-Altitude Photogrammetry**; and 3) **GIS Watershed Scale**. All three equations can be used to assess projects at the same scale or at multiple scales using a watershed approach (EC 1105-2-411, Planning: Watershed Plans).

1) **Surface Assessments:** In general, surface assessments result in the highest data quality objectives (DQO) and the highest level of effort (LOE), thus require a relatively large number of unique field stations (minimum 20 stations recommended) unless the project study area is relatively small (e.g., less than one stream mile). Surface assessments offer several advantages including: 1) improved competency; 2) ability to assess and score each variable separately and identify problems and opportunities at the stream reach scale; and 3) facilitate restoration actions that target specific stream attributes (e.g., improve aquatic habitat (HAB) by stabilizing banks (STB) and restoring the riparian zone (RIP)).

General Project Objectives for Surface Assessments: Surface assessments should be conducted on proposed project sites that require intensive surveys necessary to identify stream features at a fine scale for restoration actions including: 1) Direct measures of channel capacity (e.g., cut and fill estimations); 2) Installation or placement of engineered structures (e.g., grade control structures, longitudinal toe stones); 3) Soil bioengineering plans and specifications; and 4) Compensatory mitigation credit calculations. Surface assessments can be combined with land cover types (GIS satellite imagery) to calculate SCI scores, loss of riparian zone vegetation, and balance debits (loss)

Table 2. Spearman correlation, T-Test for significance. Relations highlighted in red are not significant at α=0.05 level. Compare with Table 3.

T Test, one tail, p values (alpha = 0.05)											
Variables	CEM	ALT	STB	HAB	FIS	DEP	DEN	SUR	ANG	VEG	BED
CEM	1.0000	0.0001	0.0000	0.0255	0.0038	0.2365	0.0019	0.0046	0.1781	0.0518	0.0018
ALT		1.0000	0.0000	0.0078	0.0000	0.0000	0.0000	0.0000	0.0009	0.0014	0.0001
STB			1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0011
HAB				1.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000
FIS					1.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0005
DEP						1.0000	0.0000	0.0000	0.0004	0.0000	0.1414
DEN							1.0000	0.0000	0.0014	0.0000	0.0000
SUR								1.0000	0.0002	0.0000	0.0005
ANG									1.0000	0.0002	0.0722
VEG										1.0000	0.0001
BED											1.0000

Table 3. Spearman correlation coefficient, relations highlighted in red are not significant at α=0.05 level. Compare with Table 2.

Spearman Correlation Coefficent											
Variables	CEM	ALT	STB	HAB	FIS	DEP	DEN	SUR	ANG	VEG	BED
CEM	1.0000	0.4626	0.4965	0.2771	0.3538	0.1489	0.3783	0.3471	0.1691	0.2423	0.3790
ALT		1.0000	0.6539	0.3274	0.6753	0.4839	0.6061	0.5170	0.4028	0.3879	0.4630
STB			1.0000	0.5636	0.7423	0.6218	0.7995	0.8105	0.4590	0.5797	0.3972
HAB				1.0000	0.6492	0.7408	0.7319	0.7591	0.3745	0.6639	0.3061
FIS					1.0000	0.6362	0.8233	0.8185	0.4222	0.6658	0.4220
DEP						1.0000	0.7477	0.7523	0.4243	0.5257	0.1844
DEN							1.0000	0.9102	0.3883	0.7246	0.5433
SUR								1.0000	0.4509	0.7278	0.4186
ANG									1.0000	0.4493	0.2245
VEG										1.0000	0.4771
BED											1.0000

and credits (gain) generated from structural and non-structural construction activities. See Table 1 for variable descriptions for the following SCI equation:

$$SCI = \sqrt[15]{(CEM \times ALT \times STB \times HAB \times FC \times CAN \times RIP \times DEP \times DEN \times SUR \times ANG \times UPP \times MID \times LOW \times BED)} \quad (1)$$

2) **Low-Altitude Photogrammetry.** Low-altitude photogrammetry refers to high-resolution still photography (sometimes overlapped for stereoscoping) and/or video which is generally flown via fixed wing airplane, helicopter or unmanned aircraft systems (UAS) from an altitude less than 1000 feet. Low-altitude photogrammetry is considered moderate DQO and LOE. There are several technologies available to capture the terrain, channel geometry, and vegetation signatures including, but not limited to, black and white, true color, and infrared still photography, nano-hyperspectral imaging, thermal mapping, and light detection and ranging (LiDAR).

Assuming clear line of sight, low-altitude photogrammetry can detect a subset of five of the 15 variables used above in surface assessments including: channel stability (STB), aquatic habitat (HAB), surface protection (SUR), bank angle (ANG) from LiDAR cross-sectional geometry, and channel bed stability (BED) from LiDAR longitudinal profiles.

$$SCI = \sqrt[5]{(STB \times HAB \times SUR \times ANG \times BED)} \quad (2)$$

3) **GIS Watershed Scale.** SCI scores estimation from satellite imagery is considered relatively low DQO and LOE. Depending on the project objectives, the signature of vegetation cover types generated needs to be ground-truth. Consequently, if the project objective is to prioritize stream reaches at the watershed scale, ground-truth may not be necessary. However, a subset of stream reaches may need to be ground-truth. The SCI versus Surface Protection (SUR) correlation is recommended at the GIS Watershed Scale in the planning phase of the project (e.g., watershed prioritization):

$$SCI = 0.95\ (SUR) - 0.081 \quad (3)$$

This strong regression correlation ($r^2 = 0.86$, slope $p<0.0001$; y-intercept $p=0.0204$) is paramount in the extrapolation power using GIS Anderson cover types to estimate SCI in watersheds from SARs that received surface assessments to stream segments and reaches in unassessed watersheds. In addition, prioritization of stream reaches for restoration, enhancement and conservation using the SCI score based on SUR can be estimated rapidly using GIS cover types in the riparian zone. The observed relationship between surface protection on the stream levees and the SCI scores was considered rational and intuitive because once vegetative cover is removed from the stream channel, in-stream stability is compromised which is expressed in the overall SCI score including aquatic habitat loss (HAB) and associated biological impairment (FC).

Anderson et al. (1976) or an acceptable, updated version should be used to map vegetation cover types within seven meters (~23 feet) riparian zone on stream banks (Figure 4). Depending on scale and data quality objectives, the left and right banks can be included together or separate. In this example, the banks are combined for an overall estimation of cover types within the SAR or watershed scale. SCI scores are estimated from surface protection (SUR) by calculating a weighted sum of the cover types (Table 4).

Attainable Reference Conditions. Establishment of attainable reference conditions in the DeSoto Study area based on aquatic diversity and habitat is fundamental to develop a gradient of impacts from which departure from reference conditions can be assessed (Pruitt et al. 2012) (Figure 4). Types of reference conditions can be on-site or off-site analogs, historical, constructed or by creating a regional index (Stoddard et al., 2006). Reference sites provide a scale, against which, to compare the condition of other sites. In addition to establishing achievable performance standards, monitoring analog reference sites in conjunction with restoration sites is paramount to address variation with respect to normal seasonal fluctuations, drought, climate change and catastrophic events (*force majeure*) which may not accurately reflect the cause of success or failure due to restoration actions.

In order to determine departure from reference conditions, reference watersheds and associated stream segments were identified within each HUC 12 watershed, if present. If the natural variation associated with the attributes across reference watersheds were insignificant, the reference watersheds were aggregated for comparison against other watersheds that are considered impaired. Watersheds with similar types and degree of impairment were aggregated based on PCA results (Figure 4). However, by constructing a reference state composed of the reference conditions identified, a reference standard would consist of a stream with minimal bank failure, natural planform, high canopy shading and a relatively broad forested riparian zone.

Sensitivity Analysis. The SCI model was tested to ensure that it was capable of addressing a full range of model inputs (variables) by using a partial sensitivity analysis, the most commonly used approach. A partial sensitivity analysis uses alternative values for individual key model inputs (variables). The process involves various ways of changing input variables of the model to see the effect on the output value (SCI score). Several scenarios were tested by subjecting: (1) one variable to the range of possible input values, while keeping the other five variables constant; (2) two variables to the range of possible input values, while keeping the other three variables constant; and (3) multiple variables with positive correlations to the range of possible input values, while keeping the other variables constant. Based on each of the aforementioned treatments, a complete range (0 to 1.0) of SCI scores was observed.

Model Calibration. In order to confirm the model, a subset of the 65 Targeted Stream reaches will be sampled for biological composition including fish and macroinvertebrates and riparian zone botanical composition. Based on the results of biological sampling, the final SCI model will be calibrated by varying input variables predominantly for habitat diversity (HAB) and surface protection (SUR).

Table 4. Anderson land cover types adapted to common settings found in the southeast United States.

Level I	Level II	Score
Urban or Built-up Land	Residential (Built out) (Enter RB)	0.5
	Residential (Under Development) (Enter RU)	0.3
	Commercial	0.1
	Mixed Urban or Built-up Land (Enter MU)	0.3
	Golf Course	0.5
Agricultural Land	Pasture	0.5
	Confined Feeding Operations (Enter Cow Lots)	0.1
	Cropland/Cultivated (Enter Row Crop)	0.2
Rangeland	Scrub-Shrub (Enter Shrub)	0.7
	Herbaceous	0.7
	Grasses	0.5
	Mixed Shrub/Herbaceous (in fallow) (Enter Mixed SH)	0.7
	Invasive Species (Enter Invasive))	0.1
Forest Land	Deciduous Forest (Enter Forested)	1.0
	Evergreen Forest (Enter Forested)	1.0
	Mixed Forest (Enter Forested)	1.0
	Forested Wetland (Enter Forested)	1.0
	Non-Forested Wetland (Enter Herbaceous)	0.7
Barren Land	Bare	0.1
Bank Armoring	Rip-rap	0.1

CONCLUSIONS

A total of 65 field surface assessment sites within three Level IV Ecosystems and across five major watersheds in DeSoto County were evaluated initially using a suite of 15 test variables representing physical and biological attributes. Based on statistical analyses, ecological models such as the SCI help define the problem; lead to a better understanding of the correspondence between biotic and abiotic attributes of an aquatic ecosystem; provide analytical tools to enhance data interpretation; enable comparisons between and across ecosystem types and physiography; and facilitate communication in regards to ecological processes and functions across scientific disciplines and to the public. In addition, a process-based approach was applied to this effort that identified critical processes and pathways in regards to the cause and effect relationship between hydrology, geomorphology and aquatic habitat.

The SCI provided an excellent method of rating stream reaches across watersheds based on their land cover types, riparian zone condition, stream geomorphology, and stream bedforms and associated aquatic habitat diversity. The SCI was formulated using statistical methods, consequently, reducing bias and subjectivity. Based on the SCI scores calculated across 65 unique stream reaches (29 field verification sites and 36 validation sites), the following can be concluded:

1. Removal, alteration and/or invasion of non-native vegetation (e.g., kudzu) is widespread in the DeSoto Study area resulting in bank stability problems as expressed in variables STB and SUR.
2. Agricultural practices, residential and commercial development, and removal of native vegetation have contributed to bank failure and erosion leading to high sediment loadings as evidenced by the condition of the riparian zone and bank stability.
3. As evidenced by reduction in fish cover and pools, fish and aquatic benthic habitat were likely adversely affected by hydrogeomorphic alteration including accelerated head cutting and associated channel widening and bank erosion hazard. However, biological sampling of fish, macroinvertebrates and mussels needs to be conducted to support this conclusion and calibrate the model.

Based on the direct relationship between SCI and surface protection (SUR), the biotic condition of the stream can be estimated from the SCI score, which is noteworthy because of the difficulty and expense of establishing biotic response variables. Consequently, by conducting a visual assessment of stream condition using the SCI, conclusions can be made in regards to fish diversity and distribution based on aquatic habitat (HAB) within a stream segment or a watershed. Overall, the results observed in this watershed assessment can be utilized to:

1. Prioritize stream segments and watersheds for restoration, enhancement, preservation (conservation), and future risk of aquatic impacts.
2. Assess proposed project alternative analysis and cost/benefit analysis.
3. Develop performance standards and success criteria applicable to restoration actions.
4. Address impacts or improvements beyond the footprint of the project.
5. Establish monitoring plans including adaptive management.
6. Forecast future ecosystem outcomes.
7. Estimate the long-term effects of climate change on ecosystem processes and functions.
8. Assess stream conditions elsewhere and compare against reference conditions established during this watershed assessment.
9. Justify proposed projects (i.e., J-Sheets) at the national significant priority scale.

The statistical treatise used in model development for the DeSoto Study area can be utilized elsewhere in other physiographies and USACE Districts. The protocol used herein for establishing stream corridor conditions is applicable to the Ecoregions and stream classes within DeSoto County. However, the protocol can be transported to other river basins with additional beta testing and model validation.

MODEL SUPPORT LITERATURE

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Section 3

Multi-Scale Watershed Assessment

Appendix A. Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study

User Guide: DeSoto County, Mississippi

Memphis District

Engineer Research and Development Center

Acknowledgments

The application of the Multi-Scale Watershed Assessment (MSWA) using the Stream Condition Index (SCI) model was a multidisciplinary and multiagency effort which included numerous coordinated meetings and field work by the Project Delivery Team (PDT) listed below. Photographs on cover page by Bruce Pruitt.

Regular conference calls, which facilitated the development of this User Guide, were held from July 2020 through April 2021 to discuss, in part, data acquisition, reduction, analysis, and interpretation related to the formulation of the SCI model. The SCI is the focus of this User Guide including the companion spreadsheet calculator. Andrea Carpenter-Crowther (Biologist, Memphis District) assisted Drs. Bruce Pruitt, Todd Slack and Jack Killgore (Fish and Invertebrate Ecology Team (FIET)) of the Engineering Research and Development Center (ERDC) in model formulation, verification, and application.

Caveats

As used herein, ecological models (SCI) are algorithms which are empirical equations that express a relationship or correlation based solely on observation rather than theory. An empirical equation is simply a mathematical statement of one or more correlations in the form of an equation. In this case, the correlations were observed to be positive (direct). In turn, the variables were observed to be dependent or independent with respect to each other. The observed interaction between variables occurs when the simultaneous influence of two measures on a model score is not additive. “Interaction” is analogous to dependence where a variable has a statistically significant influence on other variables.

This User Guide was developed as part of the North DeSoto County watershed assessment under the 1996 Memphis Metro Authority. The watershed assessment was undertaken by the USACE Memphis District and the Engineer Research and Development Center (ERDC). The SCI described herein was field verified and validated. Verification is defined as the field testing and initial refinement of model variables. Validation is defined as checking or proving the refined variables are usable in different watersheds not part of the initial assessment. Consequently, validation confirms the application of the model variables within the study area.

Appropriate Citation

B.A. Pruitt, K.J. Killgore, W.T. Slack, and Andrea Carpenter-Crowther. 2021. Multi-Scale Watershed Assessment User Guide for North DeSoto County, Mississippi, Engineer Research and Development Center. *In support of* the North DeSoto County Environmental Impact Statement, U.S. Army Corps of Engineers, Memphis District.

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Background

This User Guide was developed by the USACE Engineer Research and Development Center (ERDC) as an integral part of the Draft Integrated Feasibility Report (IFR) and Environmental Impact Statement (DEIS) developed by the Mississippi River Valley Division, Regional Planning and Environmental Division South (RPEDS) for the North DeSoto Feasibility Study, DeSoto County, Mississippi. The study area included the Horn Lake Creek, Hurricane Creek, Johnson Creek, and Coldwater River watersheds including the cities of Horn Lake, Southaven, Olive Branch, Walls, and Hernando located in northern DeSoto County, Mississippi (hereinafter, referred to as “DeSoto study”). The primary problem identified in the study area is the risk of flood damages in numerous watersheds lying within the Horn Lake Creek and Coldwater River basins. Because of the high flood risk and flashy conditions, stream channels are highly eroded and, in many cases, exhibit steep banks with little to no protection. Consequently, aquatic habitat and biodiversity have been compromised.

This User Guide was developed to provide detailed variable descriptions for the practitioner to score and rank stream conditions at a range of scales from the stream segment scale to the watershed scale. The purpose of this User Guide is to provide detailed guidance on using a visual stream condition assessment called, the Stream Condition Index (SCI). Paramount to assessment of the DeSoto County watersheds across various degrees of ecological impairment at different scales, the SCI was formulated, verified, and validated at 65 unique stream reaches across 12 watersheds. The SCI was used to identify a gradient of stream conditions including attainable reference conditions at multiple scales, describe the major water resources problems and opportunities in the region, calculate Annual Average Habitat Units (AAHU), as part of the Habitat Evaluation Procedure (USFWS 1980), and recommend a strategic course of action for achieving the desired conditions in the study area.

The DeSoto study is a modification of the watershed assessment certified for use in the Duck River basin located south of Nashville, TN (Pruitt et al. 2020). The Duck River watershed assessment represented a new method of assessing ecosystems using multi-attributes across multi-scales, called the “Multi-Scale Watershed Approach (MSWA). The concept behind the MSWA was to establish a means of utilizing readily available data to create an overall knowledge base collected by multiple agencies and stakeholders. The outcome of MSWA can become the principle component of the decision-making process such that water resource managers have the ability to make scientifically defensible decisions not only at project specific scales, but also beyond the footprint of the project to the entire watershed. From the watershed perspective, the cause and effect relationships between land use, water quality and quantity, in-channel and riparian conditions, and biotic responses culminate at a single outlet from the watershed and are representative of the ecological condition of the watershed. In addition, assessment at the watershed scale offers advance planning including design, construction, operation, maintenance, repair, replacement and restoration of aquatic ecosystems. This User Guide has immediate utilization including: 1) watershed prioritization; 2) trend analysis; 3) identification of reference attainable conditions; 4) statistical extrapolation and comparison of reference conditions across watersheds; and 5) monitor ecosystem outcomes or ecological lift (i.e., restoration success) including ecological benefits of channel stabilization measures. The results of the SCI can be used in future watershed assessments and associated environmental planning in DeSoto County and throughout the ecoregion.

Multi-DisciplinaryTeam

In August 2020, MVM requested ERDC to conduct a study on selected streams ("Targeted Streams") in DeSoto County, Mississippi. Problems, opportunities, goals and objectives were discussed during a series of conference calls which were documented in minutes and distributed to the Project Delivery Team (PDT). The PDT membership included:

Scientist / Role	Discipline	Affiliation
Elizabeth Burks, Project Manager	Civil Engineer	MVM
Andrea Carpenter-Crowther, MVM POC	Biologist	MVM
Cherie Price, Supervisor	Civil Engineer	MVM
Mike Thorn, Review	Biologist	MVM
Evan Stewart, Review	Economist	MVM
Jon Korneliussen, Review	Civil Engineer	MVM
Zack Tieman, Land Cover Mapping	GIS Specialist	MVM
Cori Holloway, Land Cover Mapping	GIS Specialist	MVM
Edward Lambert, Chief	Biologist	MVM
Donald Davenport, Review	Hydraulic Engineer	MVM
Todd Slack, ERDC POC, Author	Fish Ecologist	ERDC-EEA
Bruce Pruitt, Senior Author, Tech. Rpt.	Watershed Hydrologist	ERDC-EEA
Jack Killgore, Author	Fish Ecologist	ERDC-EEA
Chris Haring	Geomorphologist	ERDC-CHL
David Biedenharn	Hydraulic Engineer	ERDC-CHL

The project sponsor is the DeSoto County Government. Stakeholders include municipalities, residents and businesses in DeSoto County to include but not limited to the cities of Olive Branch, Hernando, and Southaven. Since July 2020, regularly scheduled semi-monthly conference calls have been organized and attended by the PDT including ERDC scientists. Consequently, the process of data acquisition, reduction, analysis, and interpretation has been well vetted by the PDT leading to the formulation and testing of the SCI which is the subject of this User Guide.

Geographic Region and Scale

This User Guide was developed for the application of the MSWA protocol. It was designed to be applied consistently and rapidly, yet maintain precision and reproducibility across assessment areas and between practitioners possessing a fundamental understanding of hydrological, geomorphic, and ecological processes. The assessment protocol is based primarily on physical and biological attributes of stream corridors including aquatic habitat, riparian zone, and watershed/valley conditions. It is intended to be applied at multiple scales using satellite imagery (GIS), low altitude photogrammetry (if available), surface assessments (boots-on-the-ground) or in combination.

The MSWA User Guide provides a means of systematic assessment of relevant aspects of stream and riparian zone conditions with respect to geophysical and biological attributes, assuring that all important factors are consistent and reproducible among users. Because of its utility, ease-of-use and application across several scales, the MSWA using satellite imagery, LiDAR, and low altitude, high resolution photogrammetry (if available) provides the following advantages:

1. At watershed and stream segment scales, it provides a rapid and reproducible method of covering more area expeditiously.
2. Acquiring private property access is not usually required.
3. Planform geometry (meander wavelength, radius-of-curvature, and amplitude) is easily elucidated and measured using photogrammetry especially on large rivers.
4. Watershed-scale models (SCI) can be tested, refined and finalized by re-visiting the historic and current photogrammetry several times without the need for additional fieldwork.
5. Land use/cover and relative riparian zone condition is more obtainable.
6. Identification of sources of pollutants and sources of accelerated sediment is easily elucidated.
7. Identification of attainable reference conditions, by establishing the reference domain of all stream segments, is more easily achieved.
8. At the valley flat scale, photogrammetry assessments facilitate the potential of re-coupling adjacent wetlands to the frequent flood event.
9. The upstream and downstream effects of dams (fish barriers) can be visualized better.

10. Based on historic and contemporary satellite imagery, trend analysis can be conducted at watershed and stream segment scales including monitoring natural and anthropogenic changes, catastrophic events, and effects of climate change on stream hydrology and geomorphology.

Initially, the SCI was formulated and certified by ECO-PCX for the Duck Watershed, Tennessee (Pruitt et al. 2020). Consequently, that certified model and associated variables were tested and refined for use in the DeSoto study.

User Guide Purpose

The MSWA User Guide was developed as a companion to the Excel ™ spreadsheet used to calculate the SCI and subsequent Habitat Units. The MSWA is meant to be a rapid, uncomplicated method. In general, it represents a relatively coarse level in a hierarchy of ecological assessment protocols. However, based on model verification and validation from surface assessments, the SCI calculator and associated input variables can be applied at a range of scales from the stream segment scale to a coarser watershed scale.

The overall purpose of this User Guide is to provide the rationale and scoring descriptions of the input variables required in the SCI. Even though the SCI was formulated based on surface assessments, the protocol can be extrapolated using Geographic Information Systems (GIS). Thus, it can be used at multiple scales: 1) surface assessments; 2) low altitude flyovers (e.g., helicopters, unmanned aircraft systems); and 3) GIS satellite imagery. Consequently, MSWA can be used for remote surveys, reconnaissance including identification of attainable reference conditions, routine on-ground, field assessments at the stream segment scale, or identification of more intensive investigations. Generally, remote or reconnaissance assessments are conducted first, followed by identification of areas needing more intensive investigations. In addition, MSWA can be used for determining departure from attainable reference conditions and monitoring of restoration activities including developing success and performance criteria.

In general, this user guide provides three options to evaluate streams at different spatial scales: GIS satellite imagery, low-altitude photogrammetry, and surface assessments. The practitioner would use readily available data to score or rank model variables. This initial approach is limited to remote surveys using aerial imagery (preferably low altitude photogrammetry), web-based tools and data sources, and information already published in existing reports (e.g., ambient monitoring). At this level, practitioners would need to rely on indicators or surrogates of stream condition or impairment and land use stressors unless previous assessment data are available. However, as additional sites are scored via reconnaissance, an environmental gradient of stream conditions is realized, and sites can be prioritized for intensive studies or stratified into a sample population for statistical extrapolation to the parent population across watershed boundaries. Intensive assessments require effort beyond the scope of the MSWA and associated variables and site scoring. However, the SCI should be verified by conducting surface assessments using scientifically accepted sampling methods and protocols.

Surface Assessments (Model Verification and Validation)

Following a clear and concise statement of problem, identification of goals and objectives, and several PDT meetings (as stated above), field surface assessments were conducted November 3 through 10, 2020. Members of the field team included: David Biedenharn, Chris Haring, Jack Killgore, David May, Autumn Murray, Bruce Pruitt, and Todd Slack of ERDC. Rick Garay (Soil Technician, USDA-NRCS) joined the team and provided logistical support. In addition, Jon Korneliussen (Civil Engineer, MVM) accompanied the ERDC field team November 4 and 5. A subset of the Targeted Streams (29 stream reaches) was tested (i.e., model verification) initially which included: Johnson Creek, Horn Lake Creek, and Nolehoe Creek watersheds. Once sampling methods were established November 3 – 5, the field team departed on November 6 with the exception of Bruce Pruitt who remained to validate model variables in unique watersheds not assessed initially (i.e., model validation including an additional 36 stream reaches on Hurricane Creek, Cow Pen Creek, Rocky Creek Bean Patch Creek, Lick Creek, Coldwater River and Camp Creek Canal). Model validation for the project area was completed November 10.

Application of the SCI to Calculate AAHU

Average Annual Habitat Units (AAHU) have been used to estimate project cost/benefits and forecast Future without Project (FWOP) and Future with Project (FWP). Historically, AAHUs are calculated based on the Habitat Evaluation Procedure (HEP), which is the product of Habitat Suitability Indices (HSI) and area of the project (e.g., acres) to obtain Habitat Units (HU) annualized over the life of the project (AAHUs). Consequently, in the past, a Tentatively Selected Plan (TSP) has been justified by ecological restoration benefits based on AAHUs. AAHUs are used as input to the Cost Effectiveness Incremental Cost Analysis (CE/ICA) per ER 1105-2-100 to compare the alternative plans' average annual cost against the AAHU estimates. Several problems have arisen by limiting the TSP to AAHUs based predominantly on traditional measures of habitat suitability:

- Attempts to estimate AAHUs based on the HSI scores (habitat requirements) of individual evaluation species have often fallen short of accounting for structure, function, and processes especially at the ecosystem scale.
- A common pitfall in developing a TSP from AAHUs generated from HSI of evaluation species is a suite of functions and processes are not accounted for including stream and valley components (e.g., riparian zone condition).

- The effects of restoration measures including engineered channel stability structures cannot be adequately evaluated using traditional “Blue Book” HSI models.
- The results of on-site HSI models cannot be easily extrapolated to multiple scales from the stream reach to stream segment to watershed scales.

Ecological models, such as the SCI, help define the problem, lead to a better understanding of the correspondence between biotic and abiotic attributes of an aquatic ecosystem, provide analytical tools to enhance data interpretation, enable comparisons between and across ecosystem types and physiography, and facilitate communication in regards to ecological processes and functions across scientific disciplines and to the public. In addition, a process-based approach was applied to this effort that identified critical processes and pathways in regards to the cause and effect relationship between geospatial data and stream conditions.

The SCI provides an excellent method of rating watersheds based on their valley land use and cover, riparian zone condition, stream geomorphology, stream bedforms and habitat diversity, and water quality conditions. The SCI was formulated using statistical methods, consequently, reducing bias and subjectivity yet increasing model extrapolation power. This User Guide was developed to provide detailed variable descriptions for the practitioner to score and rank stream conditions at a range of scales from the stream segment scale to the watershed scale using the spreadsheet calculator. The spreadsheet calculator is designed to characterize and generate a SCI value for each station intended to be included within the analyses. Utilizing the spreadsheet calculator provides a means to better document station by station assessments but will also require a second stage approach in order to compile all of the SCI values for the project area to illustrate patterns/trends. The spreadsheet calculator is capable of scoring 15 variables (MSWA_SCI_Calculator.xlsx).

Documentation of each of the 15 variables will be facilitated within the SCI Calculator and self-populated on the SCI Score Card tab 21. The Calculator is composed of 24 worksheets (“tabs”) as follows (numbers below coincide with worksheet sequence in SCI Calculator):

1. Desktop
2. Available_Data_Web_Resources
3. Site_Properties
4. ID_Stressors

SCI Variables:

5. Channel Evolution Model (CEM)
6. Hydrologic Alteration (ALT)
7. Bank Stability (STB)
8. Aquatic Habitat Diversity (HAB)
9. Fish Cover (FC)

10. Canopy (CAN)
11. Riparian Zone (RIP)
12. Root Depth (DEP)
13. Root Density (DEN)
14. Surface Protection (SUR)
15. Bank Angle (ANG)
16. Upper Bank Condition (UPP)
17. Middle Bank Condition (MID)
18. Lower Bank Condition (LOW)
19. Bed Material and Stability (BED)
20. Advanced_User_All_Variables
21. SCI_SUR (Surface Protection)
22. SCI_5_Variables
23. SCI_Score_Card
24. SCI_Summary_Table

Tab 1: Desktop

In general, the Desktop tab (Tab 1) is populated with background information prior to remote assessments or surface assessments ("boots-on-the-ground"). It provides remote characterization and stream morphology. However, it should be updated as additional information is made available following remote or surface assessments. The project objectives should be clear and concise, provide the foundation for the project outcomes, and facilitate the decision-making process. The Desktop includes information at coarse or broad scales not limited to GIS imagery, all of which, improve the knowledge base and identification of stream conditions at physiographic and watershed scales.

The users should complete this worksheet based on GIS analysis and available data. However, in many cases, the existing stream morphology may not be known until a field surface assessment is conducted. In addition, protocols such as Bank Erosion Hazard (Rosgen 2001) and width-depth ratios require more effort than required to collect visual data needed for the SCI score. Even though more intensive, direct measures are not required to run the SCI model, direct measures can be used to validate and improve model confidence and reduce uncertainty. Consequently, it is at the discretion of the practitioner to determine the level of effort required to meet the project objectives and decision process.

Tab 2: Available Data and Web Resources

Tab 2 provides potential resources needed to populate Tab1. The importance of compiling existing studies and dataset into a knowledge base cannot be over emphasized. Existing studies and databases provide a means of improving and validating indirect measures and observations (i.e., surrogates). Sources of pertinent data can be obtained from local, state and federal agencies, non-governmental organizations, state and federal parks, and a plethora of on-line web sites. Obviously, since web resources are listed, the practitioner should update this worksheet frequently.

Tab 3: Site Properties

In general, descriptions of site properties are surface assessments (e.g., X, Y and Z). However, remote data visualized from satellite imagery or low-altitude photogrammetry can also be used to populate this worksheet. Even though the approximate location of the Stream Assessment Reach (SAR) was established on the Desktop Tab 1, more precise GPS coordinates should be obtained during the surface assessment.

Tab 4: Identification (ID) of Stressors

In the context of the MSWA and the User Guide, stress refers to any cause of stream physical or hydrologic alteration or aquatic life impairment from in-stream or land use sources of pollution or disturbance. Several causes of stress or disturbance at different scales can be attributed to the following stressors:

Watershed, Valley and Riparian Zone Scales

- Vegetative Clearing
- Soil exposure or compaction
- Land grading
- Hard surfacing and imperious surfaces
- Contaminant runoff
- Irrigation and drainage
- Overgrazing
- Cattle access
- Concentrated feed lots and operations
- Roads and railroads
- Utility crossings
- Trails

- Reduction in floodplain
- Exotic or non-native species

Stream Reach or Segment Scale

- Channelization or dredging
- Woody debris removal (de-snagging operations)
- Head cutting (channel degradation)
- Accelerated sedimentation/siltation (channel aggradation)
- Dams
- Artificial levees
- Water withdrawal
- Streambed disturbance
- Stream bank armoring
- Dredging for mineral extraction
- Bridges/culverts (especially undersized)
- Piped discharge

When scoring model variables, the above stressors and potential sources of stream impairment should be recorded on the ID Stressors worksheet. Establishing the cause and effect relationship is critical in the decision process and also leads to project justification and significant project ranking ("J-Sheets"). It also facilitates the process of project prioritization and alternative analysis and ultimately restoration objectives including the need to integrate natural channel design with engineering methods necessary to stabilize stream beds and stream banks characterized with high bank erosion hazard.

Tabs 5 through 19: SCI Scoring System

Each assessment variable is scored from 0.1 (severely disturbed) to 1.0 (relatively undisturbed) (Figure 1 and Table 1). Using the appropriate variable worksheet in the Excel™ Spreadsheet Calculator, record the score that best fits the observations you make based on the narrative descriptions provided for each variable. Unless otherwise directed, assign the lowest score that applies to be consistent and environmental conservative. For example, if a reach exhibits attributes of several narrative descriptions, assign a score based on the lowest scoring description that contains indicators present within the reach. You may record values intermediate to those listed. However, round off each score to the nearest tenth (e.g., 0.28 = 0.3). Some background information is provided for each assessment variable, as well as a description of what to look for. If the evaluation is conducted on-ground, the SAR should be bound at a minimum of two meander wavelengths. If the evaluation is conducted remotely using satellite imagery or low altitude photogrammetry, the SAR can be bound at the discretion of the practitioner at any stream length depending on the project objectives and stream condition consistency. However, the limitations and assumptions made with remote sensing techniques should be clearly articulated. In general, when satellite imagery is used, the SCI is best estimated from surface protection (SUR) on Tab 23 as described below. However, a subset (sample set) of remotely assessed SARs that represent the population of SARs within a given ecoregion and watershed should be ground-truth (surface assessment) and field verified to confirm the Level II Anderson land cover type(s) (Anderson et al. 1976).

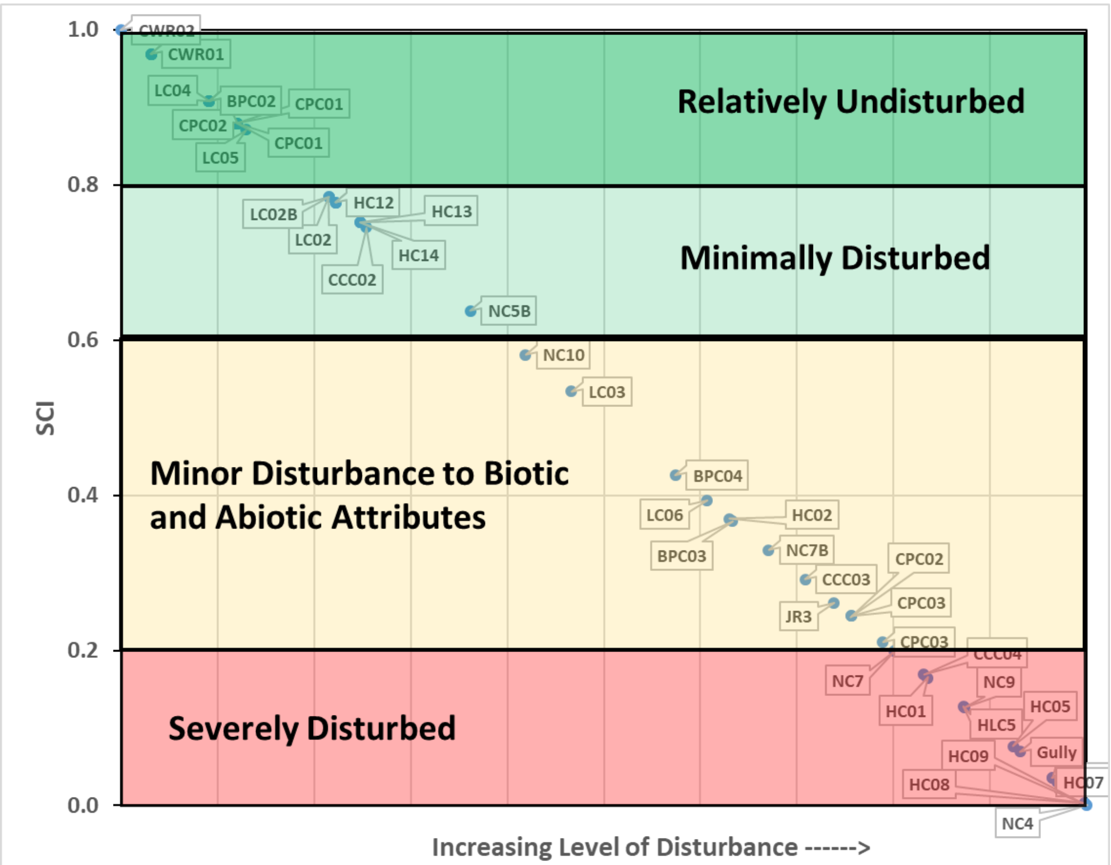

Figure 1. Level of disturbance based on SCI scores depicting DeSoto study field sites. See Tab 24 in Spreadsheet Calculator (adapted from Pruitt et al. 2020).

Table 1. Stream Condition Index (SCI) Variable Score Criteria.

Category	Relatively Undisturbed	Minimal Disturbance	Minor Disturbance to Biotic and Abiotic Attributes	High Disturbance
Score →	1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1
Channel Evolution Model – Stage (CEM)	Stable channel: CEM stages 1 and 5	CEM stage 4	CEM stage 3	CEM stage 2
Channel Alteration (ALT)	Natural planform geometry; no structures, dikes. No evidence of down cutting or excessive lateral cutting	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levees are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/ or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Channel is actively down cutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.
Bank Stability (STB)	Banks are stable; 33% or more of eroding surface area of banks in outside bends is protected by roots or structural components that extend to the baseflow elevation.	Moderately stable; less than 33% of eroding surface area of banks in outside bends is protected by roots or structural components that extend to the baseflow elevation.	Moderately unstable; outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into steam annually, some slope failures apparent).	Unstable; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
Aquatic Habitat Diversity (HAB)	8 or more habitat types within the assessment reach	6-8 habitat types within the assessment reach	4-6 habitat types within the assessment reach	< 4 habitat types within the assessment reach
Fish Cover (FC)	>7 cover types available	4 to 7 cover types available	2 to 3 cover types available	Zero to 1 cover type available
Canopy (CAN)	> 90% shaded; full canopy; same shading condition throughout the reach.	25 to 90% of water surface shaded; mixture of conditions.	(intentionally blank)	< 25% water surface shaded in reach.
Riparian Zone (RIP)	Natural vegetation	Natural vegetation	Natural vegetation extends half of the	Natural vegetation extends a third of

	extends at least two active channel widths on each side.	extends one active channel width on each side. Or If less than one width, covers entire flood plain.	active channel width on each side.	the active channel width on each side. Or Filtering function moderately compromised.
Root Depth (DEP)	Root depth extends 80% to 100% of bank height	Root depth extends 60% to 79% of bank height	Root depth extends 30% to 59% of bank height	Root depth < 30 % of bank height
Root Density (DEN)	Root density coverage 80 to 100% of bank	Root density coverage 60 to 79% of bank	Root density coverage 30 to 59% of bank	Root density <30 % of bank
Surface Protection (SUR)	Top of bank surface protection 80 to 100% woody vegetation	Top of bank surface protection 60 to 790% woody vegetation	Top of bank surface protection 30 to 59% woody vegetation	Top of bank surface protection < 30% woody vegetation
Bank Angle (ANG)	Zero to 20% slope	21 to 60% slope	61 to 80% slope	>80% slope
Upper Bank Condition (UPP)	Structural or non-structural components protect >80% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Middle Bank Condition (MID)	Structural or non-structural components protect >80% surface area of middle 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Lower Bank Condition (LOW)	Structural or non-structural components protect >80% surface area of lower 1/3 of channel bank	Structural or non-structural components protect 60 to 70% surface area of upper 1/3 of channel bank	Structural or non-structural components protect 30 to 50% surface area of upper 1/3 of channel bank	Structural or non-structural components protect <20% surface area of upper 1/3 of channel bank
Bed Material and Stability (BED)	Bed material composed of cobble or larger particles or heavy clay pan; stable side and mid-channel bars present; accelerated aggregation or degradation not	Bed material composed of sand or cobble; moderately stable side and mid-channel bars present; accelerated aggregation or degradation not observed	Bed material composed of sand; moderately unstable side and mid-channel bars present; moderate accelerated aggregation or degradation observed	Bed material composed of unconsolidated substrate; highly unstable side and mid-channel bars present or not present at all; high accelerated aggregation or degradation

	observed			observed

CEM stages 1 and 5 Stable Stream Channel			CEM stage 4 Bed Lowing or Incision		CEM stage 3 Widening Stage			CEM stage 2 Deeping (Incision) Stage	
1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

Maintaining a natural channel within a normal range of geomorphic dimensions is important for several reasons including sediment transport, depth variation, bedform and aquatic habitat maintenance, aquatic fauna access to multiple habitats. Generally, the width, depth and cross-sectional area of the stream channel are measured at bankfull dimension (Figure 2). Bankfull discharge maintains the channel's cross-sectional geometry within normal ranges with respect to the watershed size. Within incised stream channels, bankfull dimensions may be contained within the channel levees, (i.e., low entrenchment ratio or high incision).

Indicators of CEM Stage

Evidence of channel instability includes increase in channel width, as measured from levee to levee (channelfull width) or bankfull width, mid-channel bar formation, and bank failure. An increase in channel width can be determined by comparison with a reference reach of similar watershed size, a dramatic width change relative to upstream or downstream, regional hydraulic curves, or departure from reported ranges of channel width based on stream class. Ideally, determination of channel width should be measured at a riffle. If local regional curves are not available, bankfull channel dimensions versus drainage area can be used (Dunne and Leopold 1978).

Figure 2. Stream cross-section illustrating channelfull versus bankfull in an incised channel.

Theoretically, a stream channel evolves through several stages in response to disturbance: Stage 1, stage form; Stage 2, deepening or incision; Stage 3, widening; Stage 4, deposition on point or side bars; Stage 4: re-stabilization in process (Figure 3), and Stage 5: stable form usually a channel formed within the historic channel dimension. If bankfull is channelfull and incipient overbank flooding occurs on the frequent flood event (recurrence interval 1 to 2 years), the CEM is stage 1, the stable form. However, if bankfull is contained within the channel (channelfull), stages 2 through 5 are likely and overbank flooding on the frequent flood event is not evident. Evidence of stage 2 includes: vertical or near vertical channel banks, bank failure, head cutting of the channel bed, bank vegetation below bankfull precluded, side and point bars removed; Evidence of stage 3 includes: bank undercutting, roots exposed, bank failure, flanking and failure of woody vegetation; Evidence of stage 4 includes: sediment deposition and storage in side, mid and point bars; Evidence of stage 5 includes: revegetation of channel bars, return to a diverse bedform distribution, and cross-sectional geometry similar to attainable reference conditions.

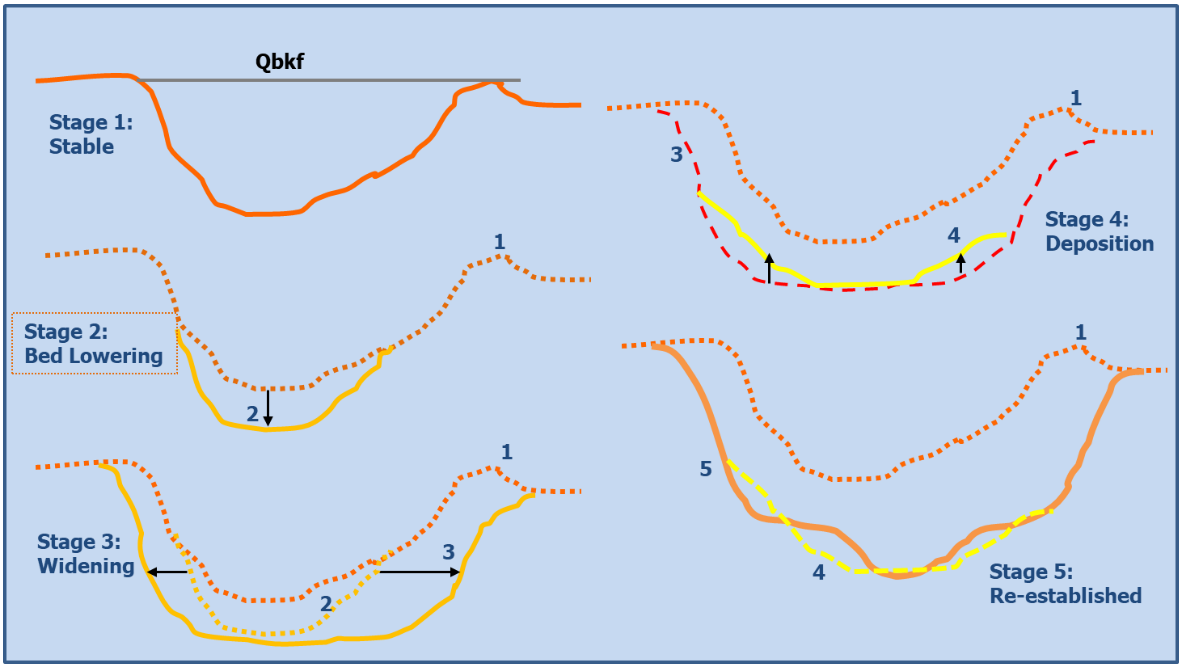

Figure 3. Channel Evolution Model (CEM), Qbkf = discharge at bankfull; solid lines represent the current CEM stage; dotted lines represent previous CEM stage (adapted from Schumm 1977).

ALT: Channel Alteration

Natural planform geometry; no structures, dikes. No evidence of down cutting or excessive lateral cutting	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levees are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/ or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Channel is actively downcutting or widening. >50% of the reach with riprap or channel-ization. Dikes or levees prevent access to the floodplain.
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

Indicators of Channel Alteration

Stream meandering generally increases as the gradient of the surrounding valley decreases. Often, development in the area results in changes to this meandering pattern and the flow of a stream. These changes in turn may affect the way a stream naturally functions, such as the transport of sediment and the development and maintenance of habitat for fish, aquatic insects, and aquatic plants. Some modifications to stream channels have more impact on stream health than others. For example, channelization and dams affect a stream more than the presence of pilings or other supports for road crossings.

Indicators of downcutting in the stream channel include nickpoints associated with headcuts in the stream bottom and exposure of cultural features, such as pipelines that were initially buried under the stream. Exposed footings in bridges and culvert out- lets that are higher than the water surface during low flows are other examples. A lack of sediment depositional features, such as regularly-spaced point bars, is normally an indicator of incision. A low vertical scarp at the toe of the streambank may indicate down cutting, especially if the scarp occurs on the inside of a meander. Another visual indicator of current or past down cutting is high streambanks with woody vegetation growing well below the top of the bank (as a channel incises the bankfull flow line moves down- ward within the former bankfull channel). Excessive bank erosion is indicated by unvegetated banks in areas of the stream where they are not normally found, such as straight sections between meanders or on the inside of curves.

Active down cutting and excessive lateral cutting are serious impairments to stream functions and processes. Both conditions are indicative of an unstable stream channel. Usually, this instability must be addressed before committing time and money toward improving other stream problems. For example, restoring the woody vegetation within the riparian zone becomes increasingly difficult when a channel is downcutting because banks continue to be undermined and the water table drops below the root zone of the plants during their growing season. In this situation or when a channel is fairly stable, but already incised from previous down- cutting or mechanical dredging, it is usually necessary to plant upland species, rather than hydrophytic, or to apply irrigation for several growing seasons, or both. Extensive bank-armoring of channels to stop lateral cutting usually leads to more problems (especially downstream). Often stability can be obtained by using a series of structures (barbs, groins, jetties, deflectors, weirs, vortex weirs) that reduce water velocity, deflect currents, or act as gradient controls. These structures are used in conjunction with large woody debris and woody vegetation plantings.

Bankfull flows, as well as flooding, are important to maintaining channel shape and function (e.g., sediment transport) and maintaining the physical habitat for animals and plants. High flows scour fine sediment to keep gravel areas clean for fish and other aquatic organisms. These flows also redistribute larger sediment, such as gravel, cobbles, and boulders, as well as large woody debris, to form pool and riffle habitat important to stream biota. The river channel and flood plain exist in dynamic equilibrium, having evolved in the present climatic regime and geomorphic setting. The relationship of water and sediment is the basis for the dynamic equilibrium that maintains the form and function of the river channel. The energy of the river (water velocity and depth) should be in balance with the bedload (volume and particle size of the sediment). Any change in the flow regime alters this balance (Lane 1955).

If a river is not incised and has access to its flood plain, decreases in the frequency of bankfull and out-of-bank flows decrease the river's ability to transport sediment. This can result in excess sediment deposition, channel widening and shallowing, and, ultimately, in *braiding* of the channel. Rosgen (1996) defines braiding as a stream with three or more smaller channels. These smaller channels are extremely unstable, rarely have woody vegetation along their banks, and provide poor habitat for stream biota. A *split channel,* however, has two or more smaller channels (called side channels) that are usually very stable, have woody vegetation along their banks, and provide excellent habitat. Conversely, an increase in flood flows or the confinement of the river away from its flood plain (from either incision or levees) increases the energy available to transport sediment and can result in bank and channel erosion.

The low flow or baseflow during the dry periods of summer or fall usually comes from groundwater entering the stream through the stream banks and bottom. A decrease in the low-flow rate will result in a smaller portion of the channel suitable for aquatic organisms. The withdrawal of water from streams for irrigation or industry and the placement of dams often change the normal low-flow pattern. Baseflow can also be affected by management and land use within the watershed — less infiltration of precipitation reduces baseflow and increases the frequency and severity of high flow events. For example, urbanization increases runoff and can increase the frequency of flooding to every year or more often and also reduce low flows. Overgrazing and clearcutting can have similar, although typically less severe, effects. The last description in the last box refers to the increased flood frequency that occurs with the above watershed changes.

Signs of channelization or straightening of the stream may include an unnaturally straight section of the stream, high banks, dikes or berms, lack of flow diversity (e.g., few point bars and deep pools), and uniform-sized bed materials (e.g., all cobbles where there should be mixes of gravel and cobble). In newly channelized reaches, vegetation may be missing or appear very different (different species, not as well developed) from the bank vegetation of areas that were not channelized. Older channelized reaches may also have little or no vegetation or have grasses instead of woody vegetation. Drop structures (such as check dams), irrigation diversions, culverts, bridge abutments, and riprap also indicate changes to the stream channel.

Ask the landowner about the frequency of flooding and about summer low-flow conditions. A flood plain should be inundated during flows that equal or exceed the 1.5- to 2.0-year flow event (2 out of 3 years or every other year). Be cautious because water in an adjacent field does not necessarily indicate natural flooding. The water may have flowed overland from a low spot in the bank outside the assessment reach.

Evidence of flooding includes high water marks (such as water lines), sediment deposits, or stream debris. Look for these on the banks, on the bank side trees or rocks, or on other structures (such as road pilings or culverts). Excess sediment deposits and wide, shallow channels could indicate a loss of sediment transport capacity. The loss of transport capacity can result in a stream with three or more channels (braiding).

STB: Bank Stability

Banks are stable; banks are low (at elevation of active flood plain); 33% or more of eroding surface area of banks in outside bends is protected by roots that extend to the baseflow elevation.	Moderately stable; banks are low (at elevation of active flood plain); less than 33% of eroding surface area of banks in outside bends is protected by roots that extend to the baseflow elevation.	Moderately unstable; banks may be low, but typically are high (flooding occurs 1 year out of 5 or less frequently); out- side bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into steam annually, some slope failures apparent).	Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

Indicators of Bank Instability

This element is the existence of or the potential for detachment of soil from the upper, middle and lower stream banks and its movement into the stream. Some bank erosion is normal in a healthy stream. Excessive bank erosion occurs where riparian zones are degraded or where the stream is unstable because of changes in hydrology, sediment load, or isolation from the flood plain. High and steep banks are more susceptible to erosion or collapse. All outside bends of streams erode, so even a stable stream may have 50 percent of its banks bare and eroding. A healthy riparian corridor with a vegetated flood plain contributes to bank stability. The roots of perennial grasses or woody vegetation typically extend to the baseflow elevation of water in streams that have bank heights of 6 feet or less. The root masses help hold the bank soils together and physically protect the bank from scour during bankfull and flooding events. Vegetation seldom becomes established below the elevation of the bankfull surface because of the frequency of inundation and the un- stable bottom conditions as the stream moves its bedload.

The type of vegetation is important. For example, trees, shrubs, sedges, and rushes have the type of root masses capable of withstanding high streamflow events, while Kentucky bluegrass does not. Soil type at the surface and below the surface also influences bank stability. For example, banks with a thin soil cover over gravel or sand are more prone to collapse than are banks with a deep soil layer.

Signs of erosion include unvegetated stretches, exposed tree roots, or scalloped edges. Evidence of construction, vehicular, or animal paths near banks or grazing areas leading directly to the water's edge suggest conditions that may lead to the collapse of banks. Estimate the size or area of the bank affected relative to the total bank area. This element may be difficult to score during high water.

HAB: Aquatic Habitat Diversity

8 or more habitat types within the SAR	6-8 habitat types within the SAR	4-6 habitat types within the SAR	< 4 habitat types within the SAR
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

Habitat Types

Runs — Bedform characterized by a disturbed surface, moderate to fast current, turbulent flow and vertical mixing of the water column. Runs often occur below or between pools and generally improve oxygen dynamics and convey nutrients and insect drift to downstream bedform forms of slower current. Increased water velocity in runs is preferred by rheophilic fish and insects and may be the only location where noticeable flow occurs in an otherwise pooled environment.

Pools—Bedform characterized by a smooth undisturbed surface, generally slow to no current, soft substrates of silt and mud, and deep enough to provide protective cover for fish (75 to 100% deeper than the prevailing stream depth).). Pools are utilized by lentic fishes, such as sunfishes.

Pools are important breeding, resting and feeding sites for fish. A healthy stream has a mix of shallow and deep pools. A *deep* pool is 1.6 to 2 times deeper than the prevailing depth, while a *shallow* pool is less than 1.5 times deeper than the prevailing depth. Pools are abundant if a deep pool is in each of the meander bends in the reach being assessed. To determine if pools are abundant, look at a longer sample length than one that is 12 active channel widths in length. Generally, only 1 or 2 pools would typically form within a reach as long as 12 active channel widths. In low order, high gradient streams, pools are abundant if there is more than one pool every 4 channel widths.

Bedform or physical habitat diversity and abundance are estimated based on walking the stream or probing from the streambank with a stick or length of rebar. You should find deep pools on the outside of meander bends. In shallow, clear streams a visual inspection may provide an accurate estimate. In deep streams or streams with low visibility, this assessment characteristic may be difficult to determine and should not be scored.

Riffles— Bedform characterized by broken water surface, rocky or firm substrate, moderate or swift current with noticeable turbulence, relatively shallow depth (usually less than 24 inches but can be deeper). This habitat is important to Litho-Psammophilic fishes, or those species that deposit eggs over sand or gravel (Balon 1984) including species of conservation importance such as madtoms, minnows and darters. Riffle-oriented aquatic insects, including ecologically important EPT taxa (Ephemeroptera, Plecoptera, Tricoptera), require riffles to complete one or more of their life cycles.

Glides— This bedform can be combined with riffles. Glides usually occur immediately downstream of pools, are characterized with laminar (even) flow, and approximately equal depth in cross-section. In gravel based streams, gravel will accumulate in glides making for excellent breeding/egg laying habitat for fish. In general, glides are the best place to gage stream velocity and discharge.

Leaf Packs— Leaves provide allochthonous input of particulate organic matter derived from the riparian zone of streams. In addition to the nutritional value of leaf packs, they also provide feeding, resting and attachment for aquatic macroinverbrates especially shredders and grazers. This feature also provides refugia for amphibians and speleophlic fishes such as madtoms.

Undercut Banks-- Undercut banks generally from in meandering streams that erode the outer bank with an over-hanging bench of soil often held together by the roots of plants and trees. The bank and roots provide feeding, resting and attachment for aquatic macroinverbrates especially nest builders, speleophlic fishes that deposit eggs in crevices, and overhead cover for cryptic fishes and amphibians. Undercut banks also serve as velocity refugia for nearby riffles, runs, and during flood events.

Coarse Woody Debris— Coarse woody debris (CWD) originates from limbs and twigs falling from surrounding trees enhancing habitat heterogeneity. CWD can increase retention of organic matter, alter velocity regimes, and provide stable substrates for the attachment of periphyton, in addition to providing important feeding areas for aquatic macroinverbrates (shredders, filters, and gatherers) and herbivorous and insectivorous fish.

Cobble or Larger Bed Material— Cobble and large bed material are over 60 mm in diameter and can be flat or irregular shaped rocks. They increase substrate roughness, expand boundary layers in swift water habitats, and increases overall stream bottom heterogeneity. As such, they provide "living space" for refugia and attachment for aquatic macroinvertebrates and create scour holes for fish.

Good Water Quality— Water quality requirements specific to the species and age classes of fish and aquatic macroinvertebrates. Usually within the ranges provided by Federal and State water quality standards. General guidelines are adequate dissolved oxygen greater than 5 mg/l, pH that ranges from 6 to 8, and turbidity less than 25 mg/l except after rainstorms.

Submerged Aquatic (SAV) and Emergent Vegetation— Provides habitat for feeding, breeding and refugia for aquatic macroinvertebrates and fish. Aquatic plants provide structurally complex habitats for young-of-year fishes increasing survival and recruitment, and substrates for macroinvertebrates increasing overall food resources.

Water Clarity. The condition of the water quality has a bearing on this variable. Water clarity is often an indicator of water quality in the form of turbidity, color, and other visual characteristics which can be compared with a healthy or reference stream. The depth to which an object can be clearly seen is a measure of turbidity. Turbidity is caused mostly by particles of soil and organic matter suspended in the water column. Water often shows some turbidity after a storm event because of soil and organic particles carried by runoff into the stream or suspended by turbulence. The water in some streams may be naturally tea-colored. This is particularly true in watersheds with extensive bog and wetland areas. Water that has slight nutrient enrichment may support communities of algae, which provide a greenish color to the water. Streams with heavy loads of nutrients have thick coatings of algae attached to the rocks and other submerged objects. In degraded streams, floating algal mats, surface scum, or pollutants, such as dyes and oil, may be visible.

Clarity of the water is an obvious and easy feature to assess. The deeper an object in the water can be seen, the lower the amount of turbidity. Use the depth that objects are visible only if the stream is deep enough to evaluate turbidity using this approach. For example, if the water is clear, but only 1 foot deep, do not rate it as if an object became obscured at a depth of 1 foot. This measure should be taken after a stream has had the opportunity to "settle" following a storm event. A pea-green color indicates nutrient enrichment beyond what the stream can naturally absorb.

Nutrient Enrichment. Nutrient enrichment is often reflected by the types and amounts of aquatic vegetation in the water. High levels of nutrients (especially phosphorus and nitrogen) promote an overabundance of algae and floating and rooted macrophytes. The presence of some aquatic vegetation is normal in streams. Algae and macrophytes provide habitat and food for all stream animals. However, an excessive amount of aquatic vegetation is not beneficial to most stream life. Plant respiration and decomposition of dead vegetation consume dissolved oxygen in the water. Lack of dissolved oxygen creates stress for all aquatic organisms and can cause fish kills. A landowner may have seen fish gulping for air at the water surface during warm weather, indicating a lack of dissolved oxygen.

Some aquatic vegetation (rooted macrophytes, floating plants, and algae attached to substrates) is normal and indicates a healthy stream. Excess nutrients cause excess growth of algae and macrophytes, which can create greenish color to the water. As nutrient loads increase the green becomes more intense and macrophytes become more lush and deep green. Intense algal blooms, thick mats of algae, or dense stands of macrophytes degrade water quality and habitat. Clear water and a diverse aquatic plant community without dense plant populations are optimal for this characteristic.

FC: Fish Cover

> 7 cover types within the SAR	4 to 7 cover types within the SAR	2 to 3 cover types within the SAR	Zero to 1 cover type within the SAR
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

Cover types: Logs/large woody debris, deep pools, overhanging vegetation, boulders/cobble, riffles, undercut banks, thick root mats, dense macrophyte beds, isolated/backwater pools, other:____.

This assessment element measures availability of physical habitat for fish to feed, find refugia from high water velocity, and utilize structure to balance predator-prey relationships. The potential for the maintenance of a healthy fish community and its ability to recover from disturbance is dependent on the variety and abundance of suitable habitat and cover available. Note, many indicators of FC overlap with HAB as described above.

Evidence of Good Fish Cover: Observe the number of different habitat and cover types *within a representative sub-section of the assessment* reach that is equivalent in length to *five times* the active channel width. Each cover type must be present in appreciable amounts to score. Cover types are described below.

Logs/large woody debris—Fallen trees or parts of trees that provide structure and attachment for aquatic macroinvertebrates and hiding places for fish.

Deep pools—Areas characterized by a smooth undisturbed surface, generally slow current, and deep enough to provide protective cover for fish (75 to 100% deeper than the prevailing stream depth).

Overhanging vegetation—Trees, shrubs, vines, or perennial herbaceous vegetation that hangs immediately over the stream surface, providing shade and cover.

Boulders/cobble—Boulders are rounded stones more than 10 inches in diameter or large slabs more than 10 inches in length; cobbles are stones between 2.5 and 10 inches in diameter.

Undercut banks—Eroded areas extending horizontally beneath the surface of the bank forming underwater pockets used by fish for hiding and protection.

Thick roots mats—Dense mats of roots and rootlets (generally from trees) at or beneath the water surface forming structure for invertebrate attachment and fish cover.

Dense macrophyte beds—Beds of emergent (e.g., water willow), floating leaf (e.g., water lily), or submerged (e.g., riverweed) aquatic vegetation thick enough to provide invertebrate attachment and fish cover.

Riffles—Area characterized by broken water surface, rocky or firm substrate, moderate or swift current, and relatively shallow depth (usually less than 18 inches).

Isolated/backwater pools—Areas disconnected from the main channel or connected as a "blind" side channel, characterized by a lack of flow except in periods of high water.

Water Quality, Clarity, and Nutrient Enrichment—See HAB above.

CAN: Canopy

> 90% shaded; full canopy; same shading condition throughout the reach.	25 to 90% of water surface shaded; mixture of conditions.	intentionally blank	< 25% water surface shaded in reach.
1.0 0.9 0.8	0.7 0.6	0.5 0.4	0.2 0.1

Shading of the stream is important because it keeps water cool and limits algal growth. Cool water has a greater oxygen holding capacity than does warm water. When streamside trees are removed, the stream is exposed to the warming effects of the sun causing the water temperature to increase for longer periods during the daylight hours and for more days during the year. This shift in light intensity and temperature causes a decline in the numbers of certain species of fish, insects, and other invertebrates and some aquatic plants. They may be replaced altogether by other species that are more tolerant of increased light intensity, low dissolved oxygen, and warmer water temperature. For example, many obligate riverine fish require cool, oxygen-rich water. Loss of streamside vegetation (and also channel widening) that cause increased water temperature and decreased oxygen levels are major contributing factors to the decrease in abundance of stream fishes. Increased light and the warmer water also promote excessive growth of submerged macrophytes and algae that compromises the biotic community of the stream. The temperature at the reach you are assessing will be affected by the amount of shading 2 to 3 miles upstream.

Estimating Canopy Cover: Try to estimate the portion of the water surface area for the whole reach that is shaded by estimating areas with no shade, poor shade, and shade. Time of the year, time of the day, and weather can affect your observation of shading. Therefore, the relative amount of shade is estimated by assuming that the sun is directly overhead and the vegetation is in full leaf-out. First evaluate the shading conditions for the reach; then determine (by talking with the land- owner) shading conditions 2 to 3 miles upstream. Alternatively, use aerial photographs taken during full leaf out. The following rough guidelines for percent shade may be used:

stream surface not visible ....>90
surface slightly visible or visible only in patches………………………………. 70 – 90
surface visible, but banks not visible…………………………………….……..40 – 70

surface visible and banks visible at times.…………………………..………….20 – 40
surface and banks visible ....………………………..……….……<20

RIP: Riparian Zone

Natural vegetation extends at least two active channel widths on each side.	Natural vegetation extends one active channel width on each side. ***or*** If less than one width, covers entire floodplain.	Natural vegetation extends half of the active channel width on each side.	Natural vegetation extends a third of the active channel width on each side. ***or*** Filtering function moderately compromised.
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

This element is the width of the natural vegetation zone from the edge of the active channel out onto the floodplain. For this element, the word natural means plant communities with (1) all appropriate structural components, and (2) species native to the site or introduced species that function similar to native species at reference sites.

A healthy riparian vegetation zone is one of the most important elements for a healthy stream ecosystem. The quality of the riparian zone increases with the width and the complexity of the woody vegetation within it. This zone:

- Reduces the amount of pollutants that reach the stream in surface runoff.
- Helps control erosion.
- Provides a microclimate that is cooler during the summer providing cooler water for aquatic organisms.
- Provides large woody debris from fallen trees and limbs that form instream cover, create pools, stabilize the streambed, and provide habitat for stream biota.
- Provides fish habitat in the form of undercut banks with the "ceiling" held together by roots of woody vegetation.
- Provides organic material for stream biota that, among other functions, is the base of the food chain in lower order streams.
- Provides habitat for terrestrial insects that drop in the stream and become food for fish, and habitat and travel corridors for terrestrial animals.
- Dissipates energy during flood events.

- Often provides the only refuge areas for fish during out-of-bank flows (behind trees, stumps, and logs).

The type, timing, intensity, and extent of activity in riparian zones are critical in determining the impact on these areas. Narrow riparian zones and/or riparian zones that have roads, agricultural activities, residential or commercial structures, or significant areas of bare soils have reduced functional value for the stream. The filtering function of riparian zones can be compromised by concentrated flows. No evidence of concentrated flows through the zone should occur or, if concentrated flows are evident, they should be from land areas appropriately buffered with vegetated strips.

Evidence of Riparian Zone Condition: Compare the width of the riparian zone to the active channel width. In steep, V-shaped valleys there may not be enough room for a flood plain riparian zone to extend as far as one or two active channel widths. In this case, observe how much of the flood plain is covered by riparian zone. The vegetation must be natural and consist of all of the structural components (aquatic plants, sedges or rushes, grasses, forbs, shrubs, understory trees, and overstory trees) appropriate for the area. A common problem is lack of shrubs and understory trees. Another common problem is lack of regeneration. The presence of only mature vegetation and few seedlings indicates lack of regeneration. Do not consider incomplete plant communities as natural. Healthy riparian zones on both sides of the stream are important for the health of the entire system. If one side is lacking the protective vegetative cover, the entire reach of the stream will be affected. In doing the assessment, examine both sides of the stream and note on the diagram which side of the stream has problems. There should be no evidence of concentrated flows through the riparian zone that are not adequately buffered before entering the riparian zone.

For the following four variables, use guidance provided by Rosgen (2001)

DEP: Root Depth

Root depth extends 80% to 100% of bank height	Root depth extends 60% to 79% of bank height	Root depth extends 30% to 59% of bank height	Root depth < 30 % of bank height
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

DEN: Root Density

Root density coverage 80 to 100% of bank			Root density coverage 60 to 79% of bank		Root density coverage 30 to 59% of bank			Root density <30 % of bank	
1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

SUR: Surface Protection

Top of bank surface protection 80 to 100% woody vegetation			Top of bank surface protection 60 to 79% woody vegetation		Top of bank surface protection 30 to 59% woody vegetation			Top of bank surface protection < 30% woody vegetation	
1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

ANG: Bank Angle

Zero to 20% slope			21 to 60% slope		61 to 80% slope			>80% slope	
1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

Upper (UPP), Middle (MID) and Lower (LOW) Channel Bank

Structural or non-structural components protect >80% surface area of 1/3 of channel bank			Structural or non-structural components protect 60 to 70% surface area of 1/3 of channel bank		Structural or non-structural components protect 30 to 50% surface area of 1/3 of channel bank			Structural or non-structural components protect <20% surface area of 1/3 of channel bank	
1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

Channel bank protection is assessed at three different areas on 1/3 vertical positions: upper (UPP), middle (MID) and lower (LOW). Consequently, the bank is scored three times at each bank position. If the channel is small and banks not tall (generally, first and second order streams), the same score can be used for all three positions.

Bed material composed of cobble, larger particles or heavy clay pan; stable side and mid-channel bars present; accelerated aggregation or degradation not observed. Channel bed is stable.	Bed material composed of sand or cobble; moderately stable side and mid-channel bars present; accelerated aggregation or degradation not observed.	Bed material composed of sand; moderately unstable side and mid-channel bars present; moderate accelerated aggregation or degradation observed.	Bed material composed of unconsolidated substrate; highly unstable side and mid-channel bars present or not present at all; high accelerated aggregation or degradation observed.
1.0 0.9 0.8	0.7 0.6	0.5 0.4 0.3	0.2 0.1

Tab 20: SCI Summary – All Variables

Users that have experience in identification of indicators of model variables (advanced user) can populate the SCI Summary directly (Tab 20). Direct use of this tab is meant for very rapid surface assessment which should take less than one hour depending on logistics. All 15 variables are assessed using this worksheet. In addition, stressors should be recorded by the stressor numbers listed on Tab 4.

The SCI model, which included 15 variables, was formulated using a modification of Duck River multi-scale watershed assessment (Pruitt et al. 2020). Since the SCI represents a multi-scale assessment method, it is recommended to collect data at several scales *(from the ground up)*: 1) **Surface Assessments**, Stream Assessment Reach (SAR) ("boots-on-the-ground") or project footprint scale; 2) **Low-Altitude Photogrammetry**; and 3) **GIS Satellite Scale**. In addition, the SCI scores can be calculated at all three scales or in any combination on the same study reach. The following data collection process is meant for guidance and is neither all inclusive nor recommended in the exact stepwise order as presented herein.

Desktop (Calculator Worksheets 1 and 2):

1. Statement of problem based on the decision that needs to be made.
2. Identify project goal and specific objectives.
3. Compile readily available and pertinent databases (see second worksheet in Excel™ Calculator).
4. Bound study area (watershed-scale) and project area (Stream Assessment Reach, SAR).
5. Stratify study area by Level IV Ecoregions and HUC12 watersheds.
6. Map stream segments for assessment in the context of their watersheds (GIS Anderson land cover types).

Field Excursion (Calculator Worksheet 3 and 4):

7. Establish the boundaries of the study and project areas. The study area may include the entire watershed, whereas, the project area represents the footprint of the assessment area or construction area within the watershed.
8. Classify SAR by the Channel Evolution Model (Schumm et al. 1984) and stream type using Rosgen's classification system (Rosgen 1994).
9. Identify stressors using surface assessments, low-altitude photogrammetry and/or satellite imagery (Calculator Tab 4).

Surface Assessment – All Variables (Calculator Worksheets 5 to 19):

10. Conduct surface assessments using 15 SCI variables (provide training, if necessary, for consistency and reproducibility among practitioners).

Advanced User (Calculator Worksheet 20):

11. Depending on the user's understanding and experience in using the SCI

model and spreadsheet, the Advanced User's worksheet can be used as a rapid assessment.

10. Run Excel™ Spreadsheet Calculator and generate SCI scores.

Remote Satellite or Low Altitude Photogrammetry (Calculator Worksheet 21):

11. *In lieu* of or in addition to Surface Assessments, estimate the SCI score (Figure 4). In general, riparian vegetation cover types are estimated based on Anderson cover types (Anderson et al. 1976) pertinent to the region (Table 2). It is recommended to ground-truth a statistical subset of riparian cover types that are determined remotely and extrapolate the signature of the verified cover types to other stream reaches or watersheds in the ecoregion.

Table 2. Anderson land cover types adapted to common settings found in the southeast United States.

Level I	Level II	Score
Urban or Built-up Land	Residential (Built out) (Enter RB)	0.5
	Residential (Under Development) (Enter RU)	0.3
	Commercial	0.1
	Mixed Urban or Built-up Land (Enter MU)	0.3
	Golf Course	0.5
Agricultural Land	Pasture	0.5
	Confined Feeding Operations (Enter Cow Lots)	0.1
	Cropland/Cultivated (Enter Row Crop)	0.2
Rangeland	Scrub-Shrub (Enter Shrub)	0.7
	Herbaceous	0.7
	Grasses	0.5
	Mixed Shrub/Herbaceous (in fallow) (Enter Mixed SH)	0.7
	Invasive Species (Enter Invasive))	0.1
Forest Land	Deciduous Forest (Enter Forested)	1.0
	Evergreen Forest (Enter Forested)	1.0
	Mixed Forest (Enter Forested)	1.0
	Forested Wetland (Enter Forested)	1.0
	Non-Forested Wetland (Enter Herbaceous)	0.7
Barren Land	Bare	0.1
Bank Armoring	Rip-rap	0.1

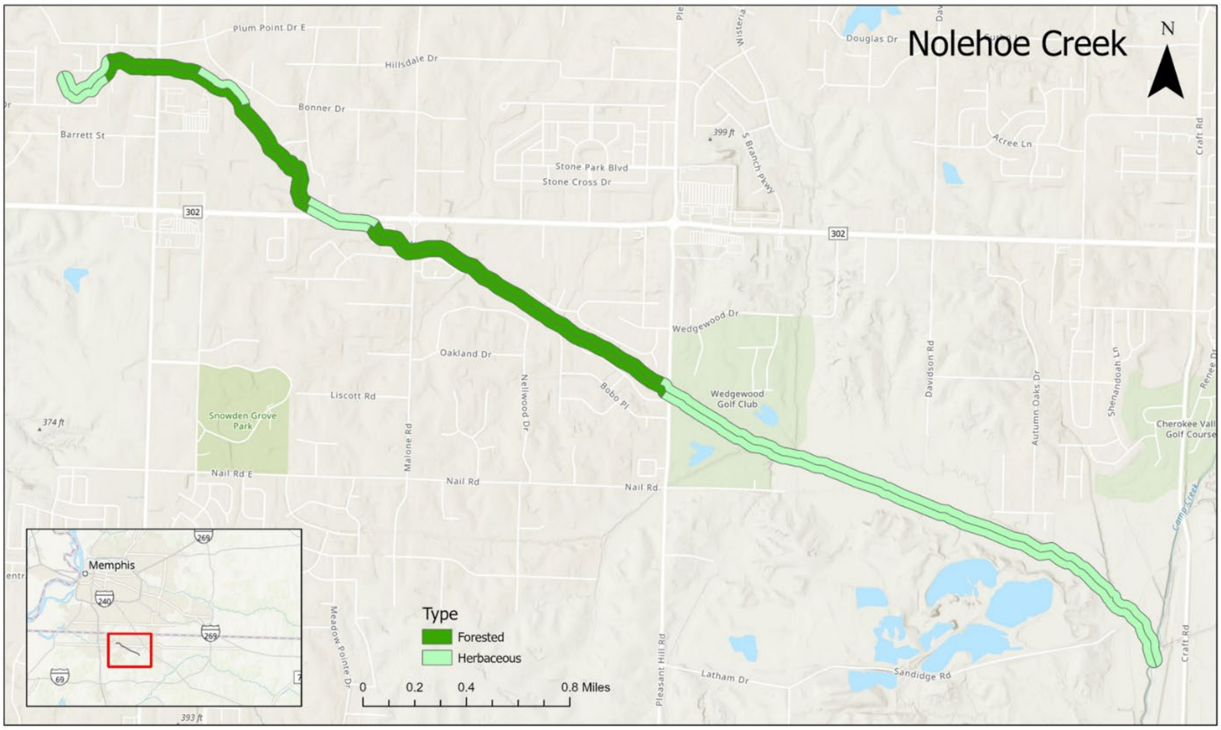

Figure 4. Distribution of Anderson cover types, forested and herbaceous, using Nolehoe Creek, DeSoto County, MS as an example (7 meter riparian width demarcated on each bank).

Application of Stream Condition Index in Resource Planning

By conducting a visual assessment of stream condition using the SCI, conclusions can be made in regards to physical and biological stream attributes at multiple scales (watershed, stream segment or reach). Overall, the results of SCI scores can be utilized to:

1. Prioritize stream segments and watersheds for restoration, enhancement, preservation (conservation), and future risk of aquatic impacts.
2. Evaluate project alternative analysis and cost/benefit analysis.
3. Develop performance standards and success criteria applicable to restoration actions.
4. Address impacts or improvements beyond the footprint of the project.
5. Establish monitoring plans including adaptive management.
6. Forecast future ecosystem lift or outcomes.
7. Estimate the long-term effects of climate change on ecosystem processes and functions.
8. Assess stream conditions elsewhere and compare against reference

conditions established during this watershed assessment.

9. Justify proposed projects at the national significant priority scale.

Selection of Appropriate Equation to Calculate SCI Score

Three SCI equations for use at different scales are used in the Excel™ Calculator as described in this User Guide (*from the ground up*): 1) Surface Assessments-SAR ("boots-on-the-ground") or project footprint scale; 2) Low-Altitude Photogrammetry; and 3) GIS Watershed Scale. All three equations can be used to assess projects at the same scale or at multiple scales using a watershed approach (EC 1105-2-411, Planning: Watershed Plans).

1) Surface Assessments: In general, surface assessments result in the highest data quality objectives (DQO) and the highest level of effort (LOE), thus require a relatively large number of unique field stations (minimum 20 stations recommended) unless the project study area is relatively small (e.g., less than one stream mile). Surface assessments offer several advantages including: 1) improved competence; 2) ability to assess and score each variable separately and identify problems and opportunities at the stream reach scale; and 3) facilitate restoration actions that target specific stream attributes (e.g., improve aquatic habitat (HAB) by stabilizing banks (STB) and restoring the riparian zone (RIP)).

General Project Objectives for Surface Assessments: Surface assessments should be conducted on proposed project sites that require intensive surveys necessary to identify stream features at a fine scale for restoration actions including: 1) Direct measures of channel capacity (e.g., cut and fill estimations); 2) Installation or placement of engineered structures (e.g., grade control structures, longitudinal toe stones); 3) Soil bioengineering plans and specifications; and 4) Compensatory mitigation credit calculations. Surface assessments can be combined with land cover types (GIS satellite imagery) to calculate SCI scores, loss of riparian zone vegetation, and balance debits (loss) and credits (gain) generated from structural and non-structural construction activities. See Table 1 for variable descriptions for the following SCI equation:

$$SCI = \sqrt[15]{(CEM \times ALT \times STB \times HAB \times FC \times CAN \times RIP \times DEP \times DEN \times SUR \times ANG \times UPP \times MID \times LOW \times BED)} \quad (1)$$

2) Low-Altitude Photogrammetry. Low-altitude photogrammetry refers to high-resolution still photography (sometimes overlapped for stereoscoping) and/or video which is generally flown via fixed wing airplane, helicopter or unmanned aircraft systems (UAS) from an altitude less than 1000 feet. Low-altitude photogrammetry is considered moderate DQO and LOE. There are several technologies available to capture the terrain, channel geometry, and vegetation signatures including, but not limited to, black and white, true color, and infrared still photography, nano-hyperspectral imaging, thermal mapping, and light detection and ranging (LiDAR).

Assuming clear line of site, low-altitude photogrammetry can detect a subset of five of the 15 variables used above in surface assessments including: channel stability (STB), aquatic habitat (HAB), surface protection (SUR), bank angle (ANG) from LiDAR cross-sectional geometry, and channel bed stability (BED) from LiDAR longitudinal profiles (Spreadsheet Calculator Tab 22).

$$\text{SCI} = \sqrt[5]{(\text{STB X HAB X SUR X ANG X BED})} \qquad (2)$$

3) GIS Watershed Scale. SCI scores estimation from satellite imagery is considered relatively low DQO and LOE. Depending on the project objectives, the signature of vegetation cover types generated needs to be ground-truth. Consequently, if the project objective is to prioritize stream reaches at the watershed scale, ground-truth may not be necessary. However, a subset of stream reaches may need to be ground-truth. The SCI versus Surface Protection (SUR) correlation is recommended at the GIS Watershed Scale in the planning phase of the project (e.g., watershed prioritization):

$$\text{SCI} = 0.95\ (\text{SUR}) - 0.081 \qquad (3)$$

This strong regression correlation ($r^2 = 0.86$) is paramount in the extrapolation power using GIS Anderson cover types to estimate SCI in watersheds from SARs that received surface assessments to stream segments and reaches in unassessed watersheds. In addition, prioritization of stream reaches for restoration, enhancement and conservation using the SCI score based on SUR can be estimated rapidly using GIS cover types in the riparian zone (Spreadsheet Calculator Tab 23).

Anderson et al. (1976) or an acceptable, updated version should be used to map vegetation cover types within seven meters (~23 feet) riparian zone on stream banks (Figure 4). Depending on scale and data quality objectives, the left and right banks can be included together or separate. In this example, the banks are combined for an overall estimation of cover types within the SAR or watershed scale. SCI scores are estimated from surface protection (SUR) by calculating a weighted sum of the cover types (Figure 4 and Tab 23 of the Spreadsheet Calculator).

This multiscale approach with application of three SCI equations is described below as scenarios using actual observational data collected in DeSoto County, Mississippi.

Scenario 1 (Surface plus GIS Satellite Assessment Scales): **Horn Lake Creek Channel Enlargement**

Project Description and Objectives (see Spreadsheet Calculator Tab 26): The Horn Lake Creek channel enlargement project located downstream of Goodman Road, Horn Lake, DeSoto County, Mississippi, is used here as an example. The Horn Lake Creek channel enlargement will increase the bottom width to 40 feet for approximately 2,900 linear feet from Mile 18.86 to Mile 19.41 (approximately 0.8 miles), downstream of Goodman Road (Figure 5). in Horn Lake, MS. The banks of the improved channel will be flattened to a 3H to 1V slope for stability (Figure 6). The enlargement and slope flattening will require 95,000 cubic yards of excavation, all of which will be disposed off site. Approximately 22,750 tons of riprap will be placed to prevent scour damage. The riprap will be placed in a three-foot deep layer on the bottom and 5 feet up both banks. The riprap will be placed over approximately 6,000 tons of filter material. The upper banks will be protected with 18,780 square yards of turf reinforcing mat. The channel improvements will be optimized during feasibility-level design. A new existing-conditions survey will provide the data necessary to finalize design elevations. Special consideration will be given to transitioning into and out of the enlargement area, utilities, and any heavily-scoured areas in the project footprint. Ten acres of tree clearing in the riparian zone will be required along the project stream reach.

During the field verification conducted on November 3-10, 2020, the ERDC field team conducted surface assessments on two SARs within the construction segment: HLC5 and HLC11. HLC05 was selected to assess ecological outcomes and calculate SCU since HLC05 was located near the middle of construction site and represented the predominant condition of the stream segment. The existing channel is characteristic of the region: deeply incised (low entrenchment ratio), trapezoidal shaped, steep, highly erodible banks, and instable channel bed dominated with sand, silt and clay. The riparian zone was assessed separately from the channel re-construction since improvements in the stream channel would be realized almost immediately. In contrast, the riparian zone restoration will require several years before a mature hardwood stand occurs. In addition, in order to capture the riparian zone condition over the entire project area, the surface protection (SUR) was estimated from GIS imagery. The following steps were followed to estimate Net EcoLift over a 50-year horizon (refer to Spreadsheet Calculator Tab 26):

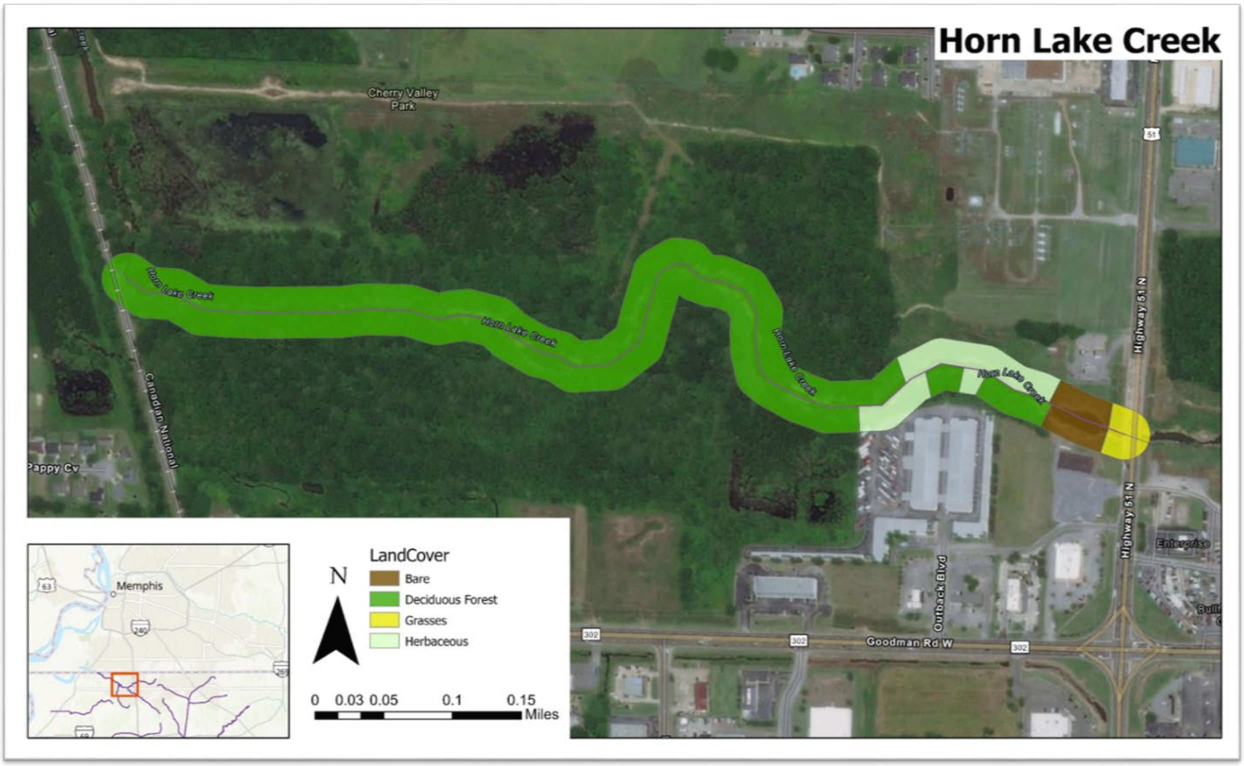

Figure 5. Distribution of Anderson cover types, forested and herbaceous, using Horn Lake Creek Channel Enlargement Project, DeSoto County, MS as an example (7 meter riparian width demarcated on each bank).

Step 1. Estimate area of riparian zone based on a 200-foot riparian width and project length of 0.8 miles.
Step 2. Calculate Future With (FWP) and Future Without Project (FWOP) from SCI equation.
Step 3. Estimate SCI and Stream Condition Units (SCU) from SUR.
Step 4. Calculate Net EcoLift from the sum of riparian forest loss and channel stability gain.

Scenario 2 (Low Altitude Photogrammetry or GIS Local Scale): **Stormwater Detention Pond Site Selection Suitability, Capacity, and Net Change in Average Annual Habitat Units (AAHU) using SCI**

Potential Project Objectives (see Spreadsheet Calculator Tab 27): The USACE Memphis District (MVM) proposed four stormwater detention ponds to reduce flood damages to businesses, residents, and infrastructure in DeSoto County, MS. The objectives were: 1) Estimate SCI scores under future with (FWP) and future without project (FWOP) scenarios; 2) Based on project area, convert the SCI scores to Stream Condition Units (SCU); 3) Estimate net change in Average Annual Habitat Units (AAHU) over a 50-year project horizon.

Four detention ponds were proposed (Lateral D, Cow Pen [Upper], Cow Pen [Ballfield], and Rocky Creeks). Since Cow Pen (Upper) and Cow Pen (Ballfield) were located adjacent to each other and share the same watershed, the contributing source area of Cow Pen (Upper) was used for watershed yield calculations (not included herein) and SCI scores.

Anderson cover types were used for the three proposed detention ponds to estimate the difference between future with (FWP) and future without project (FWOP), and ultimately average annual habitat units (AAHU). The Stream Condition Index (SCI) was calculated using the weighted sum of the cover types present in the riparian zone (Surface Protection – SUR) (see Equation 3 above).

Scenario 3 (GIS Watershed Scale): **Map stream corridors at the watershed scale using Anderson cover types.**
Potential Project Objectives. 1) Prioritize stream segments and watersheds for restoration, enhancement, preservation (conservation), and future risk of aquatic impacts; 2) Identify attainable reference conditions; 3) Establish watershed-scale, monitoring plans and forecast future conditions (trend analysis); 4) Extrapolate SCI scores from surface assessments across watersheds.

Anderson et al. (1976) or an acceptable, updated version should be used to map vegetation cover types within seven meters (~23 feet) riparian zone on stream banks (Figure 4). Depending on scale and data quality objectives, the left and right banks can be included together or separate. In this example, the banks are combined for an overall estimation of cover types within the SAR or watershed scale. SCI scores are estimated from surface protection (SUR) by calculating a weighted sum of the cover types (Figure 4 and Tab 23 of the Spreadsheet Calculator).

The SCI versus Surface Protection (SUR) correlation is recommended at the GIS Watershed Scale in the planning phase of the project (e.g., watershed prioritization):

$$SCI = 0.95\,(SUR) - 0.081 \qquad (3)$$

This strong regression correlation ($r^2 = 0.86$) is paramount in the extrapolation power using GIS Anderson cover types to estimate SCI in watersheds from SARs that received surface assessments to stream segments and reaches in unassessed watersheds. In addition, prioritization of stream reaches for restoration, enhancement and conservation using the SCI score based on SUR can be estimated rapidly using GIS cover types in the riparian zone (Spreadsheet Calculator Tab 23).

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Section 4

Monitoring and Adaptive Management Plan

This Monitoring and Adaptive Management (M&AM) Plan is designed to aid in the success of the recommended ecosystem restoration project in DeSoto County, Mississippi. Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007), as amended by Section 1161 of the WRDA 2016, requires the development of a plan to monitor for the ecological success of an ecosystem restoration project. The following information is required and included in this plan:

1. Types and number of restoration activities to be carried out;
2. Physical actions to be undertaken to achieve project objectives;
3. Functions and values that will result from the restoration plan;
4. Monitoring activities to be carried out;
5. Criteria for ecosystem restoration success;
6. The estimated cost and duration of the monitoring; and
7. A contingency plan for taking corrective actions in cases in which the monitoring demonstrates that the restoration measures are not achieving ecological success in accordance with the criteria described in the monitoring plan.

Within a period of ten years from completion of construction of an ecosystem restoration project, monitoring shall be a cost-shared project cost. Any additional monitoring required beyond ten years will be a non-Federal responsibility. In addition, the same guidance requires that an adaptive management plan is developed for all USACE ecosystem restoration projects. The need for adaptive management will be determined using information generated by implementation of the monitoring plan. This information would be used by the USACE, in conjunction with the non-federal sponsor and interagency team, to guide decisions on operational or structural changes (adaptive management) that may be needed to ensure that the ecosystem restoration project meets the success criteria.

MONITORING PLAN

1.1 ECOLOGICAL SUCCESS CRITERIA FOR BOTTOMLAND HARDWOOD FOREST (BLH) RESTORATION

A. Initial Success Criteria

1. Achieve a minimum survival of 75% of planted canopy species (planting density would be determined in coordination with the inter-agency team (IAT) once a site and specific vegetation suite has been selected). Minimum survival of planted canopy species is necessary to ensure that a suitable amount of canopy is replaced, in time, to promote species diversity, improve forage and nutrient cycling, enhance surface protection, and to restore habitat for migratory songbirds and other species.

2. The observed composition must approximate the planted species composition and percentages specified in the initial plantings component

of the final planting plan. A final planting plan would be created in coordination with the non-federal sponsor, IAT, and interested federally recognized tribes, per the Programmatic Agreement. It is critical to ensure that desirable native species, including mast-producers, are included in the reforestation rather than allowing fast-growing early successional species to colonize the area, prolonging the regeneration of a mature BLH forest.

3. These criteria would apply to the initial plantings, as well as any subsequent re-plantings necessary to achieve this initial success requirement. Greater flexibility for species composition or canopy coverage may be necessary if initial success criteria is not met within 3 years.

Monitoring for initial success criteria should occur annually. It should be noted that initial success criteria is expected to be met within one year of the initial planting. If initial success criteria are not met within one year of planting, see Adaptive Management Strategies identified in Section 1.8, below.

B. Intermediate Success Criteria

1. Maintain a minimum survival of 70% of planted living native canopy species per acre (density may include planted trees and/or naturally recruited native canopy species).

2. Achieve a minimum density of 50% of the living hard-mast producing species in the canopy stratum (planted trees and/or naturally recruited native canopy species). The remaining trees in the canopy stratum may be comprised of soft-mast producing native species.

3. Demonstrate that vegetation satisfies USACE hydrophytic vegetation criteria. Community must exhibit characteristics and diversity indicative of a viable native forested wetland community, i.e. vegetation community where more than 50% of all dominant species are facultative (FAC), FAC wet and/or obligate.

Intermediate success criteria should be met within 5 years of the initial success determination. Monitoring for intermediate success criteria should occur biannually, at a minimum. If intermediate success criteria are not met within 5 years of planting, see Adaptive Management Strategies identified in Section 1.8, below.

C. Long-Term Success Criteria (Within 4 growing seasons following attainment of Intermediate Success Criteria and maintained for the duration of the remaining 50-year project life).

1. Maintain survival of approximately 50% by planted and/or naturally recruited native canopy species. If the project doesn’t meet 50% canopy survival within approximately 6 years following attainment of Intermediate Success Criteria, the IAT would meet and discuss path forward.

2. Maintain a minimum density of 50% of the living hard-mast producing species in the canopy stratum (planted trees and/or naturally recruited native canopy species). The remaining trees in the canopy stratum may be comprised of soft-mast producing native species.

3. Maintain USACE hydrophytic vegetation criteria. The plant community must exhibit characteristics and diversity indicative of a viable native forested wetland community, i.e. vegetation community where more than 50% of all dominant species are FAC, FAC wet and/or obligate.

Long-term success criteria should be met within 4 years of the initial success determination. Monitoring for long-term success criteria should occur biannually, at a minimum. If intermediate success criteria are not met within 4 years of planting, see Adaptive Management Strategies identified in Section 1.8, below.

1.2 ECOLOGICAL SUCCESS CRITERIA FOR STREAM STABILIZATION

A. Initial Success Criteria (End of first growing season following construction of grade control structures)

1. Structures would be inspected to ensure structure integrity, satisfactory slopes, and stability. Stream stability is reliant upon structure stability. Loss of structure stability could lead to flanking and/or failure of grade control in streams causing a loss of stream stability up and downstream of the structure, jeopardizing the system.

2. Prior to construction of the grade control structures, streams would be evaluated using the channel evolution model (CEM) to establish baseline conditions. Note areas where bank height exceeds critical bank height. Establishing the baseline would allow for future monitoring to view changes in the channel and determine the need for further improvements or adaptive management.

3. The following stream characteristics would be evaluated at baseline condition using the Stream Condition Index Model: bank stability, bank angle, surface protection, habitat diversity, fish cover, canopy cover, riparian zones, rooting depth, and root density. These criteria would be used to evaluate the benefits of the work on channel geomorphology, water quality, and plant and animal habitat within the restoration area.

Initial success criteria should be met within 1 year of construction of the grade control structures and associated bank stabilization. Monitoring for initial success criteria should occur annually. If initial success criteria is not met within 1 year of construction, see Adaptive Management Strategies identified in Section 1.8, below.

B. Intermediate Success Criteria (End of second growing season following construction of grade control structures, or 1 growing season after initial success criteria are met)

1. Maintain structure integrity to ensure continued improvements in channel stability.

2. Streams would be evaluated using the channel evolution model to evaluate how the stabilized stream reaches progress to reach an equilibrium. Stabilized stream reaches should show reduction in bank failures, bank erosion, and improvement in habitat. Bank heights that were noted as exceeding critical bank height during the monitoring period for initial success begin to show improvement.

3. The following stream characteristics would show improvement, as compared with baseline conditions noted during the monitoring period for initial success: bank stability, bank angle, surface protection, habitat diversity, fish cover, canopy cover, riparian zones, rooting depth, and root density using the Stream Condition Index Model. This information would be evaluated to determine the actual benefits realized due to the stream stabilization.

Intermediate success criteria should be met within 5 years of the initial success determination. Monitoring for intermediate success criteria should occur biannually, at a minimum. If intermediate success criteria are not met within 5 years of the initial success determination, see Adaptive Management Strategies identified in Section 1.8, below.

C. Long-Term Success Criteria (Within 3 growing seasons following attainment of intermediate success criteria and maintained for the duration of the remaining 50-year project life).

1. A stable structure is in place, which has begun to function as a natural part of the stream environment providing substrate for macro-invertebrates, spawning habitat for (some) fish species, and other aquatic species to colonize along with the natural reestablishment of native vegetation. Pool and riffle sequences are reestablished, providing dissipation of stream flow energy.

2. Streams would be evaluated using the channel evolution model to evaluate how the stabilized stream reaches progress to reach an equilibrium. Stabilized stream reaches begin to form floodplain berms and benches to provide further stability to over-steepened streambanks. New channel margins for the recruitment of woody species riparian corridors provide stable terrestrial and aquatic habitat. Bank heights that were noted as exceeding critical bank height during the monitoring period for initial success are improved and mass wasting along banks is significantly reduced, or no longer occurs, within the restored stream reach.

3. The following stream characteristics would achieve the best attainable condition for the restored stream reach: bank stability, bank angle, surface protection, habitat diversity, fish cover, canopy cover, riparian zones,

rooting depth, and root density. This information would be evaluated to determine the actual benefits realized due to the stream stabilization.

Long-term success criteria should be met within 4 years of the intermediate success determination. Monitoring for long-term success criteria should occur biannually, at a minimum. If long-term success criteria are not met within 4 years of the intermediate success determination, see Adaptive Management Strategies identified in Section 1.8, below.

During an annual monitoring event, each constructed grade control structure and associated bank protection should be monitored for the success criteria noted above. This should occur in conjunction with the monitoring for reforestation to alleviate multiple trips into the field. It is estimated that, due to the difficulty in accessing some areas along streams, that these monitoring events would require approximately 160-200 person hours of labor for each stream, totaling approximately $16,000-$20,000 per stream for monitoring and report writing. This estimate would likely need to be adjusted for each stream, due to field conditions, number of structures, and accessibility. The cost of monitoring included in the total project cost and cost shared with the non-Federal sponsor shall not exceed one percent of the total first cost of ecosystem restoration features. The monitoring team should consist of (at least) a biologist and engineer who are familiar with the intent of the stream stabilization and success criteria.

Habitat Suitability: Populations of wildlife would increasingly utilize the restored stream reaches for food, shelter, and/or reproductive purposes as the habitat stabilizes and stream functions return and increase. A comparison of the future with and future without project conditions would be conducted to ensure the physical condition of the stream and/or adjacent areas are suitable for native wildlife populations.

Periodic surveys of aquatic invertebrates, fish, and wildlife in representative reaches would be documented. Any observations of fauna and non-living remains of fauna would be documented and photographed in each trip report. Any direct observations of wildlife usage would be noted and photographed. General observations of evidence of wildlife usage including scat, used food sources, remnants of hatched eggs, etc. would also be noted in each trip report. Observations of invasive or non-native species, or other detrimental factors would also be documented to aid in the development or execution of adaptive management solutions.

1.3 MONITORING REPORTS

Monitoring Reports would be drafted and coordinated after each annual assessment of the restoration sites.

1.3.1 Baseline Monitoring Report

Within 90 days of completion of the general construction of grade control structures with associated bank protection and/or restoration of riparian corridor/BLH, a baseline monitoring report shall be prepared. Information provided would include the following items:

- A detailed discussion of all restoration activities completed with as-built drawings of completed activities and specifications included.

- A description of habitats and notable features within the restoration site(s).

- Maps/aerial photography of restoration site(s) showing the approximate boundaries of constructed features including planted areas, grade control structures, stone toe (or other) bank protection, site access, areas that required (or may require further) eradication of invasive and nuisance plant species, surface water management features, proposed monitoring transects/plots, photo station locations, and if applicable, piezometer and staff gage locations.

- A detailed inventory of all canopy and midstory species planted, including the number of each species planted and the stock size planted. General locations of plantings should be included and indicated on maps/aerial photography, to the extent practicable.

- A detailed inventory of all grade control and/or associated bank protection. A discussion of the site per the channel evolution model, would be included. Discussion should include bank height and slopes and stream cross sectional data. In addition, the following stream characteristics would be evaluated at baseline condition using the Stream Condition Index Model: bank stability, bank angle, surface protection, habitat diversity, fish cover, canopy cover, riparian zones, rooting depth, and root density.

- Initial and final construction surveys for areas that required topographic alterations, including elevations of all constructed surface water drainage features, culverts, and/or water control structures. The initial and final construction surveys should include cross-sectional surveys of topographic alterations involving the removal of existing linear features such as berms/spoil banks, or the filling of existing linear ditches or canals. The number of cross-sections must be sufficient to represent elevations of these features. The initial and final construction surveys must include areas where existing berms, spoil banks, or dikes have been breached, if applicable.

- Qualitative observations would be made to document existing conditions and would include, but not be limited to, potential problem zones, general condition of native vegetation, and wildlife utilization as observed during monitoring.

- Photographs documenting conditions in the project area would be taken at the time of monitoring and at permanent photo stations within the mitigation site. At least two photos would be taken at each station with the view of each photo always oriented in the same general direction from one monitoring event to the next. The number of photo stations required, and the locations of these stations would vary depending on the restoration site(s). The USACE would make this determination in coordination with the IAT.

1.3.2 **Annual Monitoring Reports**

All monitoring reports generated after the Baseline Monitoring Report would be called Initial, Intermediate or Long-Term Success Criteria Monitoring Reports and shall be numbered sequentially based on the year in which the monitoring occurred (i.e. Initial Success Criteria Monitoring Report, 2019). All Monitoring Reports shall provide the following information unless otherwise noted:

- All items required for the Baseline Monitoring Report should be included in each annual monitoring report. The Annual Monitoring Reports should be comprehensive, beginning with the baseline monitoring event and progressing through each monitoring event so that a clear progression of habitat improvement and/or needs for adaptive management can be clearly shown and understood.
- A brief description of maintenance and/or adaptive management activities (if applicable) performed since the previous monitoring report should be described. In addition, a discussion of any other significant occurrences (i.e. severe storm events, encroachment, etc.) should be included.
- A detailed inventory of each grade control and/or associated bank protection structure should be made. A discussion of the site/stream reach, per the channel evolution model, would be included.
    - Bank height and slopes and stream cross sectional data, as compared to previous conditions;
    - description of structure integrity, slopes, and stability;
    - description of stabilized stream reach based on the channel evolution model;
    - a suitability index would be determined for each of the following characteristics using the Stream Condition Index Model: bank stability, bank angle, surface protection, habitat diversity, fish cover, canopy cover, riparian zones, rooting depth, and root density which would be compared with the baseline conditions noted in the Baseline Report.
- Quantitative data regarding planted species would be collected from circular plots having a radius of approximately 30 feet, *and* (2) permanent transects sampled using the point-centered quarter method with a

minimum of 20 sampling points established along the course of each transect, *or* (3) permanent belt transects approximately 50 feet wide and perpendicular to planted rows. The number of permanent monitoring plots and transects, as well as the length of each transect would vary depending on the restoration site. The USACE would make this determination prior to the first monitoring event in coordination with the IAT. This document may be supplemented, or monitoring plans specific to each stream restoration, may be required. Data recorded in each plot or transect would include:

  - Number of living planted canopy species (present within plots and along transects) and the species composition;
  - number of living planted midstory species (present within plots and along transects) and the species composition;
  - average density of living planted canopy species (i.e., the total number of each species present per acre, plot method) and the species composition (transect method);
  - average density of living planted canopy species (i.e., the total number of each species present per acre, plot method) and the species composition (transect method);
  - wetland indicator status of each species observed;
  - average percent cover accounted for by invasive or nuisance plant species (all vegetative strata combined).

- Quantitative data regarding plants in the understory stratum would be gathered from sampling quadrats. These sampling quadrats would be established either along the axis of the belt transects discussed above, or at sampling points established along point-centered quarter transects discussed above, depending on which sampling method is used. Each sampling quadrat would be approximately 1 meter X 1 meter in size. The total number of sampling quadrats needed along each sampling transect would be determined by the USACE in coordination with the IAT. Data recorded from the sampling quadrats would include:
  - List of understory species identified in each quadrat;
  - average percent cover by native understory species;
  - composition of native understory species;
  - wetland indicator status of each species observed;
  - average percent cover by invasive and nuisance plant species.

- A summary assessment of all data and observations along with recommendations for the likelihood of success and/or the need for adaptive management activities.
- A brief description of anticipated adaptive management work to be conducted during the period from the current monitoring report to the next monitoring report.

1.4 MONITORING SCHEDULE AND MAINTENANCE RESPONSIBILITIES

Monitoring would be dependent upon site conditions but should be conducted within the growing season to determine the survival of planted trees and for ease of identification of plant species. Monitoring reports would be submitted to the IAT and non-federal sponsor, as soon as possible but no later than December 31 of that year.

The USACE would be responsible for conducting the monitoring events and preparing the associated monitoring reports until the long-term success criteria are achieved, as described above. If, after 10 years the long-term success criteria have not been met, a determination would be made as to future monitoring requirements, roles and responsibilities. Coordination with the IAT and non-federal sponsor would occur annually to share monitoring results and reports and to determine the likelihood of success and/or need for adaptive management.

Section 2039(e) of WRDA 2007, as amended by Section 1161 of the WRDA 2016, directs that the responsibility of a non-federal interest for operations and maintenance (O&M) of the nonstructural and nonmechanical elements of a project (or component of a project) for ecosystem restoration shall cease 10 years after the date on which the Secretary makes a determination of success per Section 2039(b)(2). The Secretary is not responsible for the O&M of any components of a project with respect to which a nonfederal interest is released from obligations under Section 2039(e).

It is recommended that restoration features be constructed in phases. For example, the grade control and associated bank stabilization should be constructed prior to reforestation. This construction ordering would allow stabilization to occur prior to reforestation to prevent the loss of newly planted acreage, and to allow space for construction access. This scenario may require adjustment to the typical monitoring schedule, described above, in order to develop a reasonable and efficient monitoring schedule that covers all restoration features. Such adjustments, if necessary, would be made at the time final site-specific monitoring plans are generated. This schedule would be prepared by the USACE in coordination with the non-federal sponsor and the IAT.

Adaptive Management Plan

This section details the Adaptive Management planning for ecosystem restoration features for the North DeSoto County Feasibility Study. The importance of natural variability to ecological resilience and productivity in the DeSoto County area is being taken into consideration. By developing an AM plan, effective operational decisions and enhancement of socio-economic and ecological benefits can be made. In addition, based on the results and interim conclusions made during the prescribed monitoring process, adjustments can be made in the monitoring plan.

Flexibility would be retained in the management of the riparian restoration and grade control structure placement and design that would provide options to maximize benefits to all fish and wildlife resources. Adaptive management decisions would be based upon monitoring results with input from the IAT. Additionally, overall project construction may be adjusted if the ecosystem restoration project does not function, as intended. Examples of adaptive management actions may include, but are not limited to, replanting of riparian buffers and/or BLH forested areas if survival criteria are not met, planting different types of vegetation, thinning, or implementing modified methods to enhance and restore hydrology, if necessary.

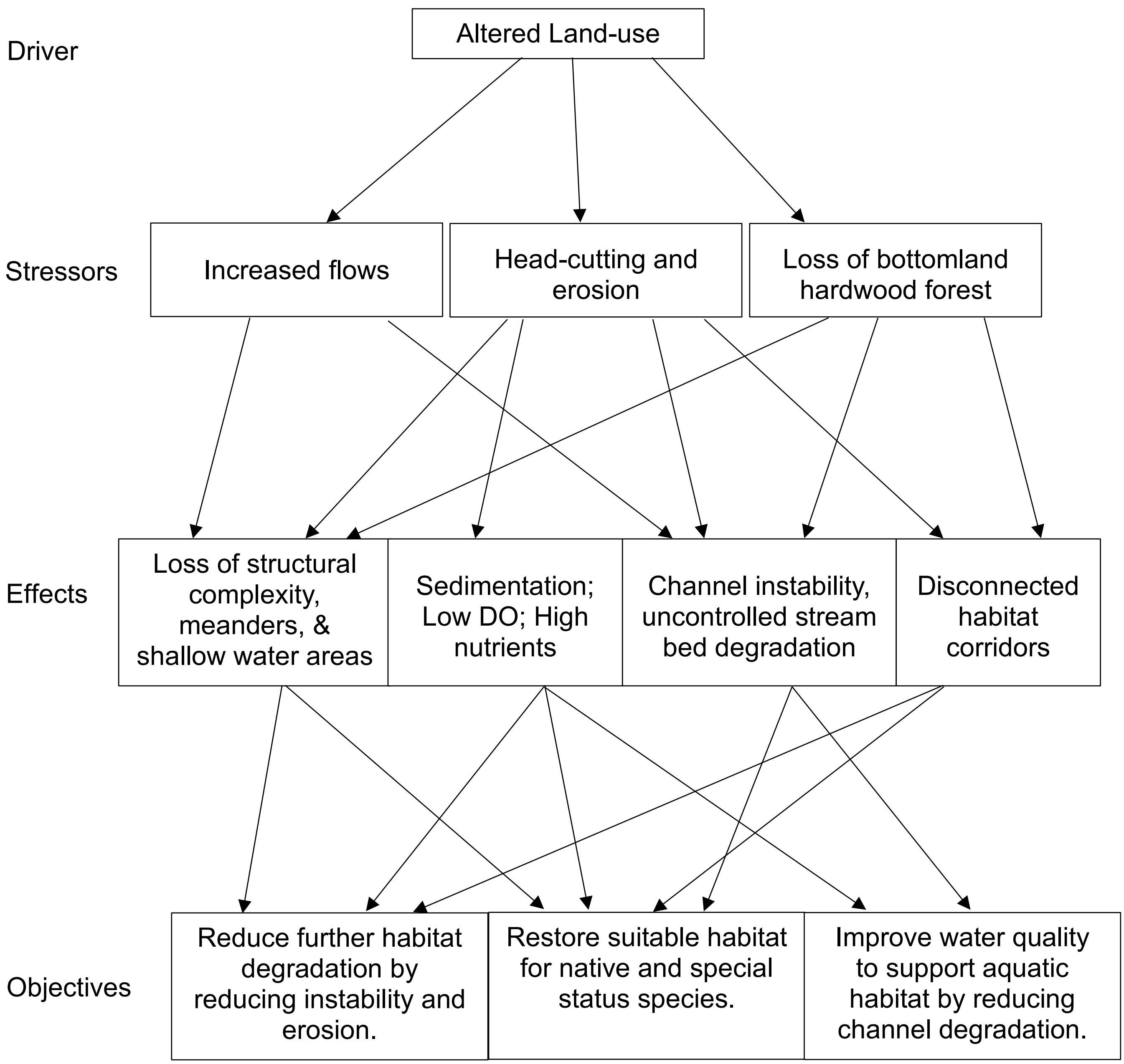
1.5 ADAPTIVE MANAGEMENT PLANNING

Adaptive management planning includes: 1) development of a Conceptual Ecological Model (CEM), 2) identification of key project uncertainties and associated risks, 3) evaluation of the ecosystem restoration projects for adaptive management needs and 4) the identification of potential adaptive management actions to ensure the constructed project meets identified success criteria. Costs for adaptive management actions may not exceed 3% of the total project cost. The adaptive management plan is a living document and would be refined as necessary as new project information becomes available.

1.6 CONCEPTUAL ECOLOGICAL MODEL (CEM)

A CEM identifies the major stressors and drivers affecting proposed ecosystem restoration project for the DeSoto County project (Table 2). The CEM does not attempt to explain all possible relationships of potential factors influencing the restoration sites; rather, the CEM presents only those relationships and factors deemed most relevant to obtaining the required acres/average annual habitat units (AAHUs). Furthermore, this CEM represents the current understanding of these factors and would be updated and modified, as necessary, as new information becomes available.

Conceptual Ecological Model for DeSoto County Ecosystem Restoration



1.7 SOURCES OF UNCERTAINTY AND ASSOCIATED RISKS

A fundamental tenet underlying adaptive management is decision making and achieving desired project outcomes in the face of uncertainties. There are uncertainties associated with restoration of ecosystems within highly developed systems. The project delivery team (PDT) identified the following uncertainties during the planning process.

1. Climate change could cause planted tree mortality or damage to grade control structures:
    a. Storm frequency
    b. Intensity
    c. Timing

2. Hydrologic trends at reforestation sites are currently unknown

3. Uncertainty relative to achieving ecological success in BLH restoration sites:
    a. Water, sediment, and nutrient requirements
    b. Magnitude and duration of wet/dry cycles
    c. Adverse effects of invasive species

4. Loss rate of vegetative plantings due to herbivory, human encroachment, or other undetermined factors.

5. Uncertainty relative to achieving ecological success with grade control structures:
    a. Actual acreage stabilized with structures
    b. Magnitude and duration of channel stability
    c. Changes in bed-slope and sediment loads up and downstream of stabilized reaches

6. Fluvial systems are dynamic in nature; therefore, existing conditions can change in a short period of time.

7. Existing LiDAR data used for the analysis is approximately 10 years old and may not accurately reflect existing conditions. The data was used to identity channel stability issues and locations within the watershed where those issues are occurring. Channel stability issues were qualitatively field-identified on only three (3) watersheds with no new channel survey data collected. The specific locations of these trends have likely changed since the LiDAR data was collected, and will continue to change until construction of stabilization measures are complete.

8. Grade control structure locations were selected based on channel slopes (determined from LiDAR, as noted above). Actual detailed design locations must be field verified, and adjusted prior to final designs.

9. Any future projects, federal or otherwise, constructed downstream of the proposed grade control structures or in the Coldwater River could cause changes in the stability of the tributaries that may undermine or destabilize the existing structures and habitat gains.

1.8 ADAPTIVE MANAGEMENT STRATEGY

If at any point during the monitoring phase, the success criteria identified in Sections 1.1 and 1.2 are not achieved, as scheduled, a determination on reason(s) for delayed success would be required. The determination would assist in selecting the appropriate adaptive management action(s). For example, a severe weather event (such as extreme cold or extended high-water) or poor seedling quality, may cause mortality that isn't indicative of a deficiency with the restoration plan or site, and a replant may be sufficient to achieve success. However, if a site is discovered to be too wet or dry to support the species list, a revision to the planting plan would be required. The USACE, non-federal sponsor and IAT would convene to decide between remedial actions. See Section 1.9 below for potential adaptive management actions.

Potential Adaptive Management Strategies:

1. Additional or modified vegetative plantings, as needed, to meet identified success criteria.

2. Microtopography work on acquired sites to obtain suitable elevations for BLH reforestation and habitat diversity.

3. Invasive species control (likely to include controlled burns or herbicidal spot treatments) to ensure survival of native species and meet required success criteria.

4. Acquisition of additional reforestation acreage.

5. Modification of design (height, riffle length, slopes) for grade control structures.

6. Modification of grade control structure locations.
   a. Structure locations should not be in meander bends but in cross-over locations
   b. Structure locations can be adjusted to address tributary channel stability
   c. Structure locations require adjustments based on floodplain and terrace locations
   d. Structure locations may be adjusted to protect infrastructure such as utility crossings, bridges and roadways.

7. Addition of grade control structures up or downstream of the currently identified degradational reaches.

8. Some meander bends may require additional hard-structural bank protection (riprap), longitudinal stone toe protection, or soft-structural bank protection (woody material with limited riprap).

1.9 ADAPTIVE MANAGEMENT EVALUATION

As part of the North DeSoto Ecosystem Restoration Project, the grade control and reforestation sites would be further evaluated to develop a project with minimal risk and uncertainty. The items listed below would be incorporated into the Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) plans to minimize project risks subject to the above limitations as set forth in Section 2039 of WRDA 2007, as amended by Section 1161 of the WRDA 2016.

- Success criteria (achieving target habitat improvements for grade control and reforestation)
- Detailed planting guidelines for BLH (species composition, spacing, sourcing, etc.)
- Detailed design guidelines for grade control structures to allow for fish passage and minimal disruption to in-stream habitats
- Invasive species control plans

As part of the adaptive management planning effort, the ecosystem restoration project features would be evaluated using the CEM and identified uncertainty and risk to determine the need for additional actions or costs. These efforts are undertaken to ensure that the project meets the required success criteria. The following potential adaptive management actions or may be required to ensure the expected environmental benefits are achieved. Additional actions may be proposed with the acquisition of new information or with the realization of previously unidentified risks.

Potential adaptive management actions with associated uncertainties addressed are shown in Table 1., below.

Uncertainties/Risks	Potential Adaptive Management Actions							
	Replanting	Microtopography	Invasive species control	Additional reforestation acreage	Modification of design for grade control structures	Location of grade control structures	Additional grade control structures	Bank protection
Climate change	x	x		x	x	x	x	x
Hydrologic trends at reforestation sites	x	x		x	x	x	x	x
Uncertainty relative to achieving ecological success in BLH restoration sites	x	x	x	x				
Achieving ecological success in BLH restoration sites	x	x	x	x				
Loss rate of vegetative plantings	x	x	x	x				
Uncertainty relative to achieving ecological success with grade control structures					x	x	x	x
Dynamic nature of fluvial systems					x	x	x	x
Dated LiDAR data					x	x	x	x
Potential future projects unrelated	x				x	x	x	x

If monitoring reveals the restoration project is not meeting the identified success criteria, one or a combination of appropriate activities identified above would be implemented. Specific measures to implement any Potential Action, if determined necessary to achieve project benefits, would be coordinated with the NFS and the IAT, to determine the appropriate course of action. The USACE would be responsible for performing any necessary corrective actions, but the overall cost would be shared with the NFS according to the project cost-share agreement.

The USACE would monitor the project until the success criteria are met. Construction and monitoring would be funded in accordance with all applicable cost-share agreements with the NFS. The USACE would monitor (on a cost-shared basis) the completed restoration to determine whether any adaptive management are necessary to achieve the identified success criteria. Once the USACE determines that the restoration is successful, maintenance would be performed by the NFS as part of its OMRR&R obligations. The USACE would retain the final decision on the success determination until all parties are in agreement. If structural changes are necessary to meet success criteria, the USACE would implement appropriate adaptive management measures, as described above, in accordance with cost-sharing requirements, and subject to availability of funding.

1.10 **MAINTENANCE PLAN**

Maintenance is an integral part of the Adaptive Management Plan. A description and schedule of maintenance requirements to ensure the continued viability of the resource once initial construction is completed would be prepared. Likely measures may include invasive species control, ensuring that any required channel work is stable, correcting deficiencies, and maintaining control over access to the area where restoration occurs. Maintenance of the project area, such that the total average vegetative cover accounted for by invasive species and the total average vegetative cover accounted for by nuisance species each constitute less than 5% of the total average plant cover throughout the 50-year project life. Inspections to determine the need for invasive/nuisance control would be conducted during monitoring events, as described, until the long-term success criteria for vegetation is achieved. Ten years after ecological success has been determined the responsibility of a non-federal sponsor to conduct O&M activities on nonstructural and nonmechanical elements of an ecosystem restoration project (or component of a project) will cease. Operation, maintenance, repair, replacement and rehabilitation of structural and mechanical elements of an ecosystem restoration project (or component of a project) will continue as outlined in the operations manual for the project as the OMRR&R is subject to the above limitations as set forth in Section 2039 of WRDA 2007, as amended by Section 1161 of the WRDA 2016. Cessation of O&M activities does not alter the non-federal sponsor's obligation to retain in public ownership the real property interests required for an ecosystem restoration project for so long as the project remains authorized.

Section 5

Proposed Planting Plan for Desoto County Streams.

There are 11 streams that would require planting to meet the purposes of the ecosystem restoration plan. The streams occur throughout Desoto County, Mississippi and encompass approximately 344 acres of farmland, shrub/scrub, fallow and pasturelands. Land use was largely determined through National Landuse Classification Data and proposed planting areas were proposed using GIS and Google Earth approximation. Figures 2-12 show the proposed locations of reforestation. Specific planting plans will be developed and coordinated in future phases of design to include the pre-construction, engineering and design phase (PED) and more detailed design phases as construction authorization and appropriation is received. Coordination of specific detailed planting plans would include the interagency team, federally recognized tribes, the non-federal sponsor, and other interested stakeholders.

The proposed riparian reforestation tracts includes various elevations; therefore, flood frequency and duration is not currently known for individual tracts. As tracts are identified and acquired, LiDar or more accurate elevational surveys would occur to identify the appropriate planting scheme for each acquired tract. Tracts are expected to be delineated into planting zones to reflect the historical vegetative communities. For example, lands that are prone to regular flooding, due to lower ground elevations and/or annual exceedance probabilities, would likely include species that such as a mix of bald cypress, water locust, water elm, and water tupelo; while less flood prone (higher elevation) lands would be planted with species such as swamp chestnut oak (*Quercus michauxii*), water oak (*Quercus nigra*), overcup oak (*Quercus lyrata*), red maple (*Acer rubrum*), and pecan (*Carya illinoinensis*). Native understory species would also be included in each specific planting plan that would be coordinated with the team noted above. At present, it is assumed that reforestation would occur in rows with 10-foot centers at a rate of approximately 436 trees per acre. Monitoring and adaptive management would occur as described in Appendix D of this document.

A general description of the restoration work includes the following:

- Remove and dispose of non-native vegetation, as necessary.
- Prepare land for planting: Removal of artificial berms/levees, ditches, or other man-made structures/features that could inhibit successful restoration of a naturally functioning riparian forest; Addition of microtopography/swales for topographic and habitat diversity; Removal and stockpiling of top soil from any excavation/earth work for use once earthwork is complete.
- Install appropriate species (1-2-year seedlings, or larger and hardier plantings, depending on site conditions) as determined through coordination with the interagency team, federally recognized tribes, the non-federal sponsor, and other interested stakeholders. Understory species would also be incorporated into the installation, as determined appropriate through coordination with the team noted above.
- Install appropriate signage to indicate an active restoration site to deter unintended impacts to the site the due to encroachment by the public/adjacent landowners.
- Follow Appendix D. Monitoring and Adaptive Management Plan to determine the success of the site(s).

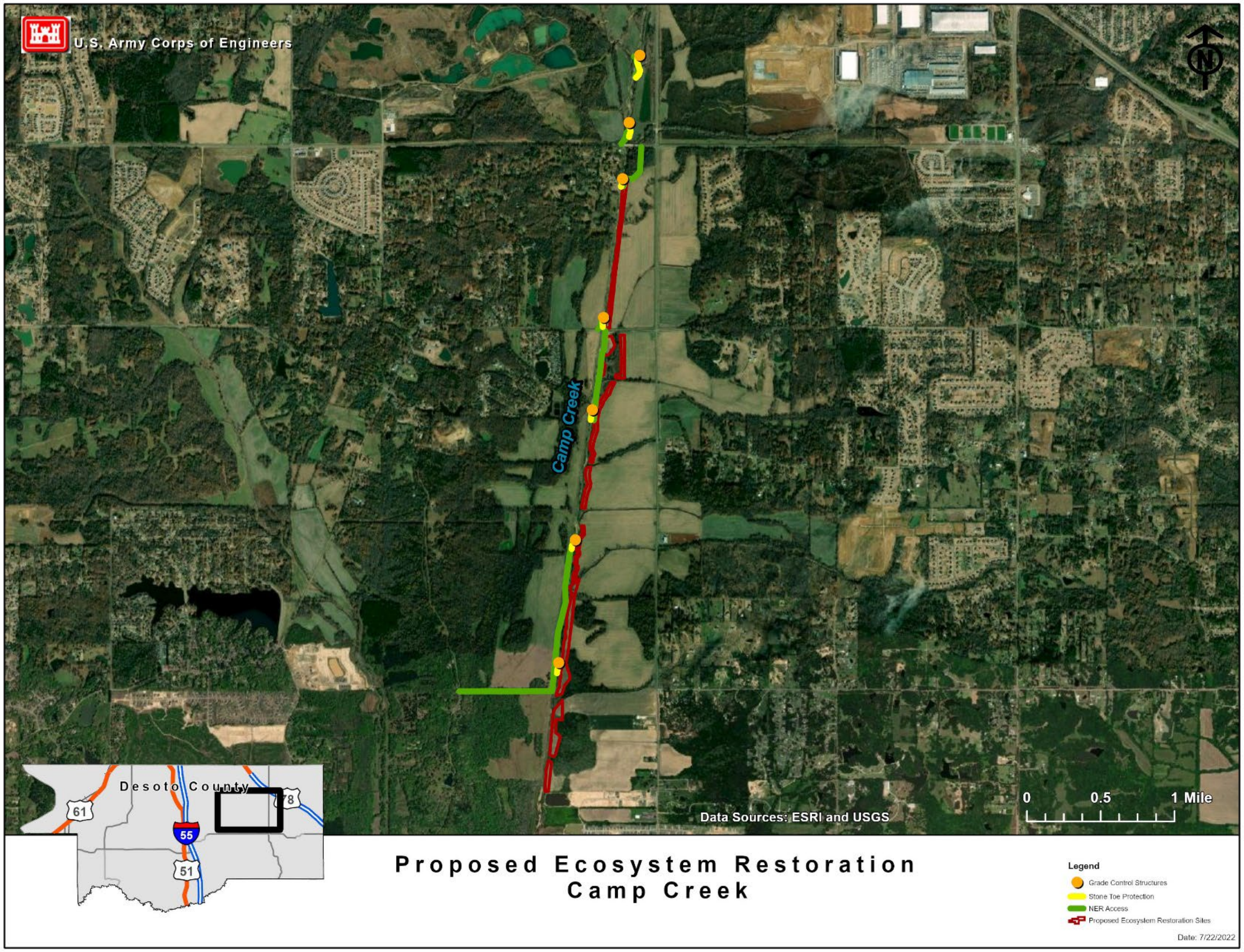


Figure 2. Camp Creek proposed reforestation locations.

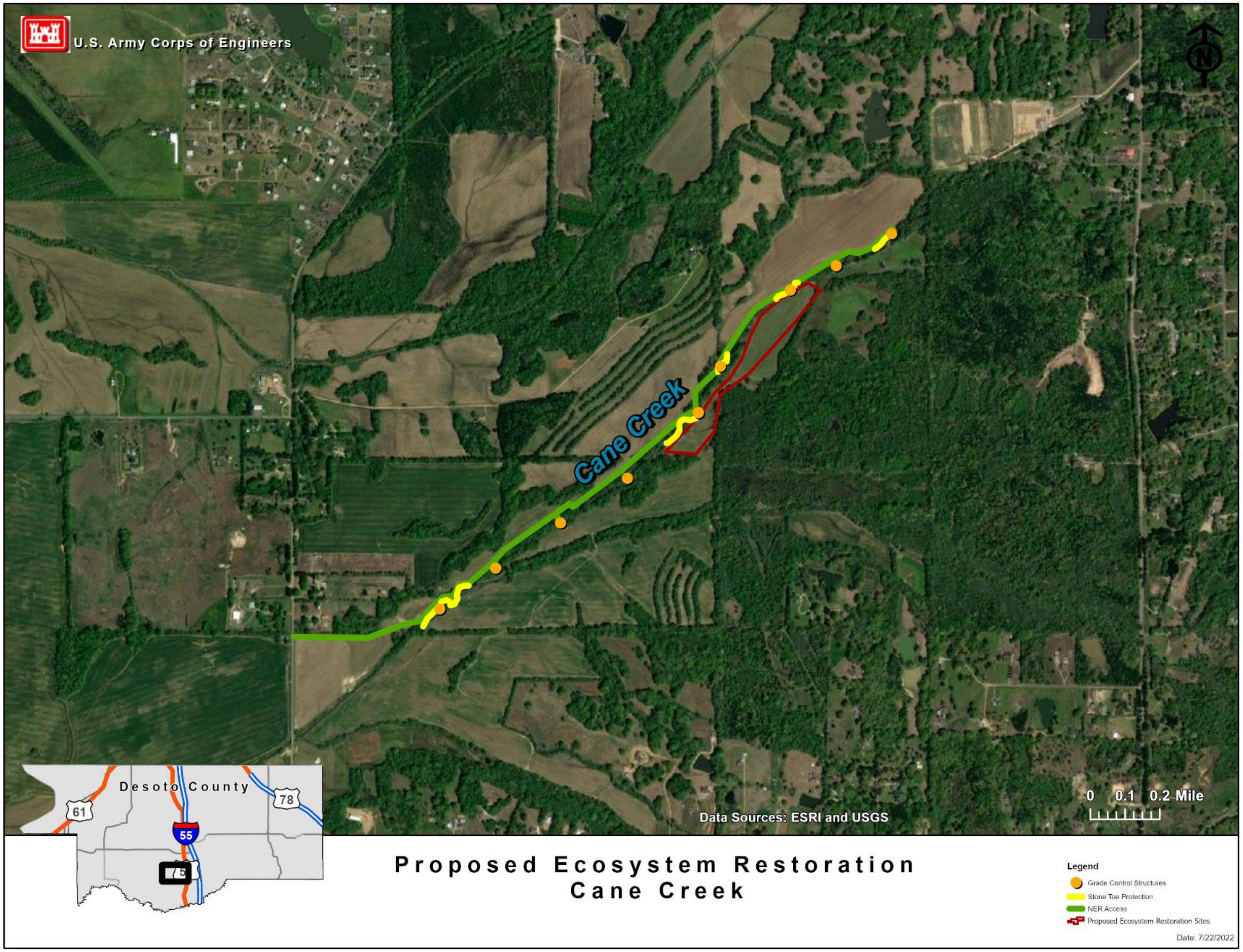


Figure 3. Cane Creek proposed reforestation locations.

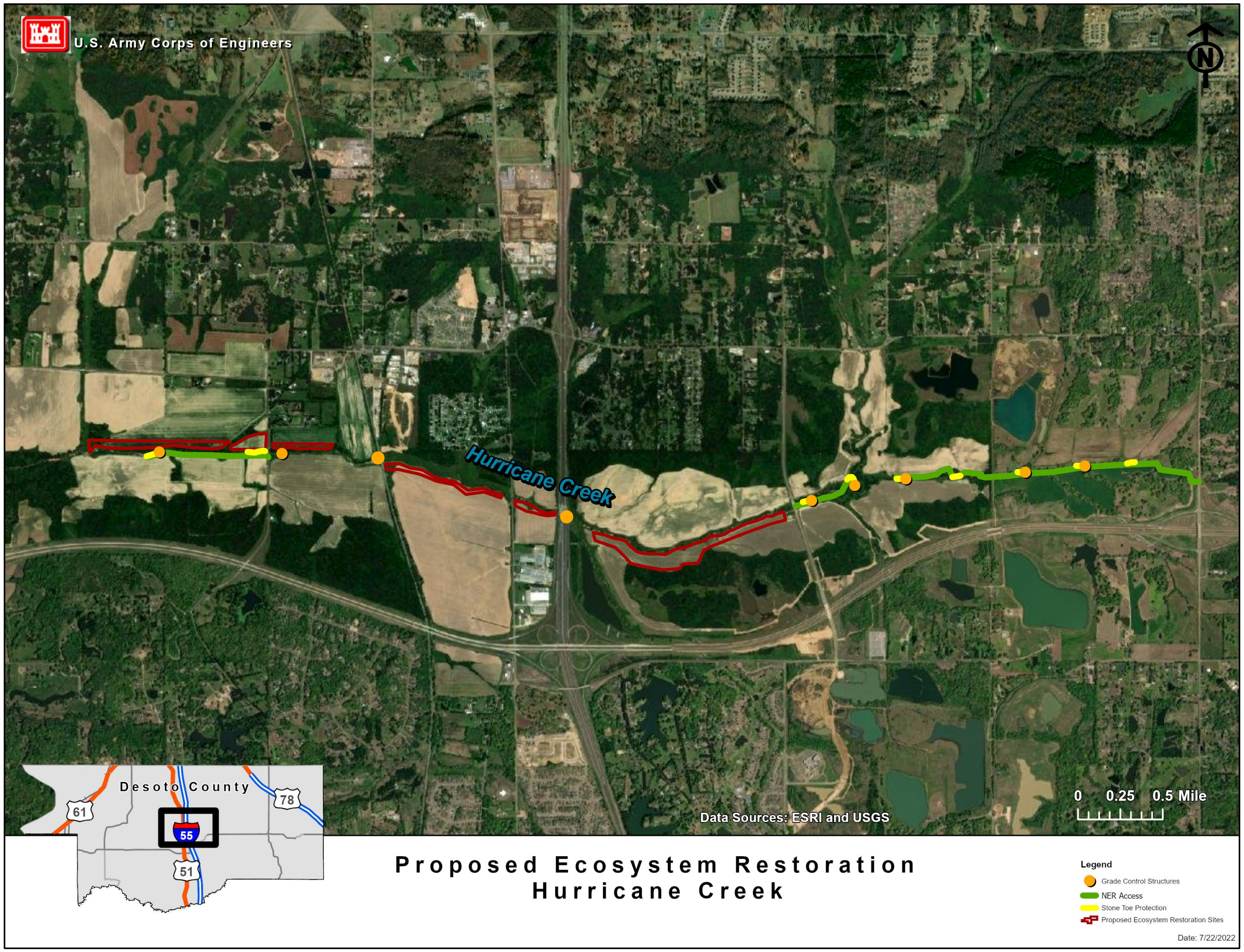


Figure 4. Hurricane Creek proposed reforestation locations.

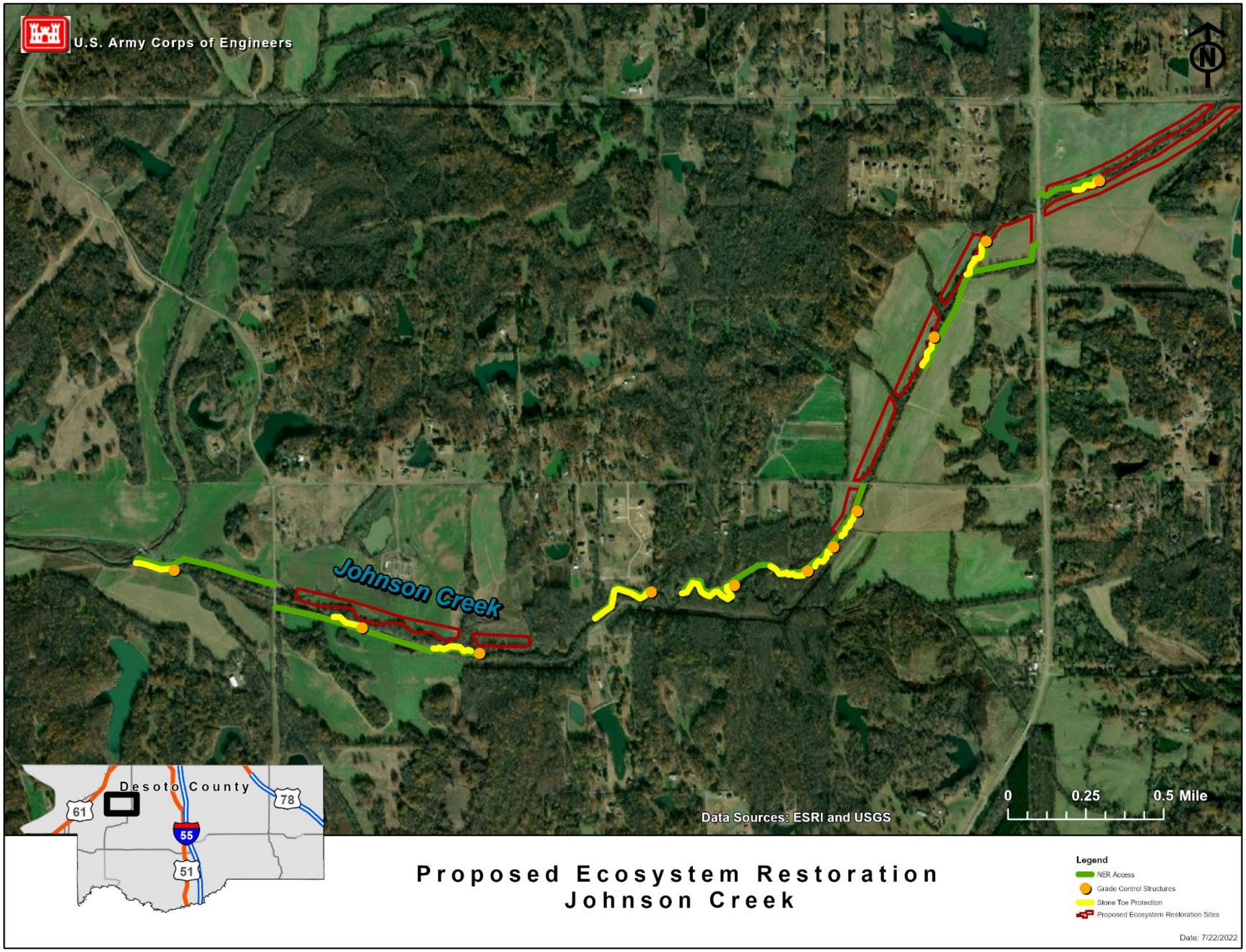


Figure 5. Johnson Creek proposed reforestation locations.

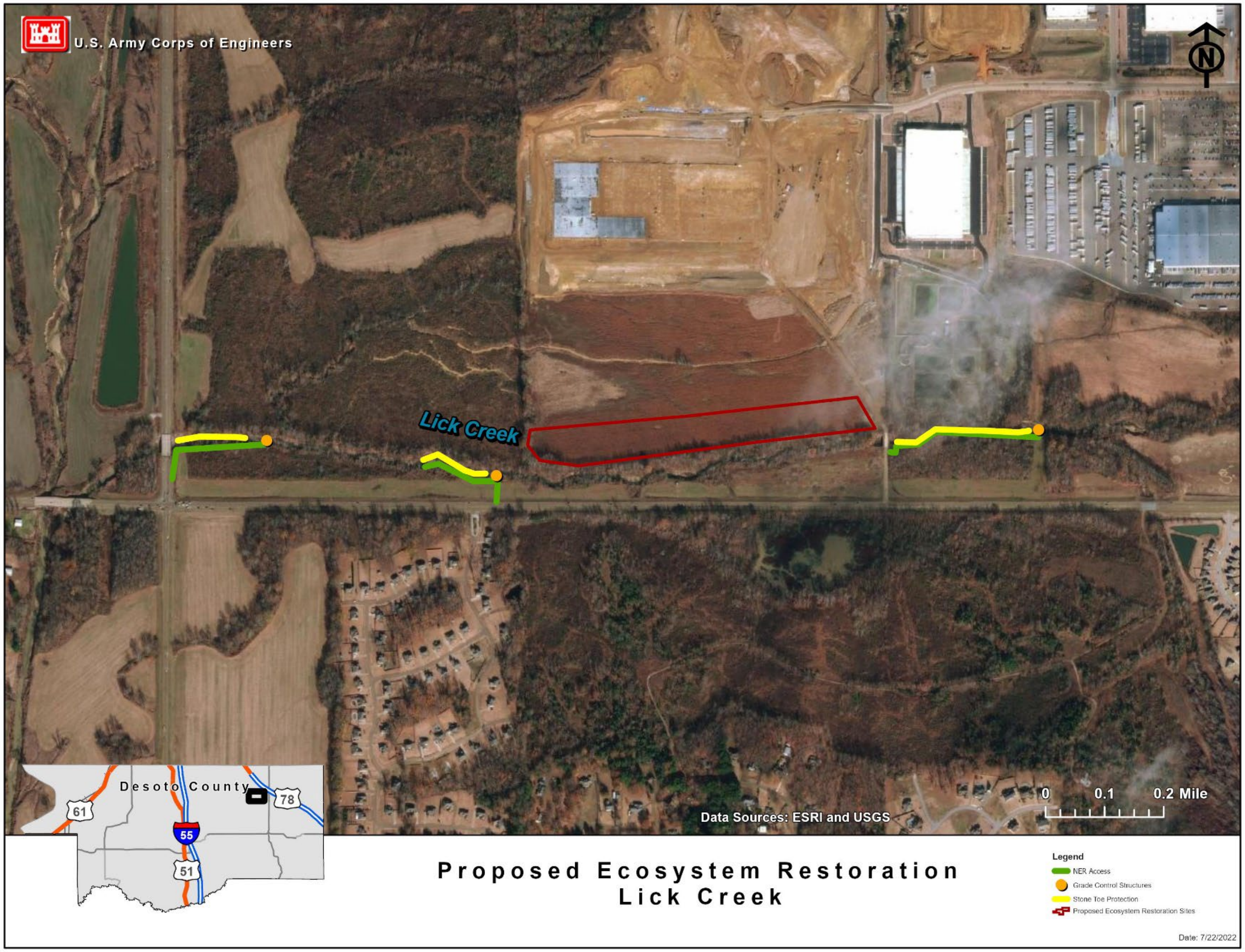


Figure 6. Lick Creek proposed reforestation locations.

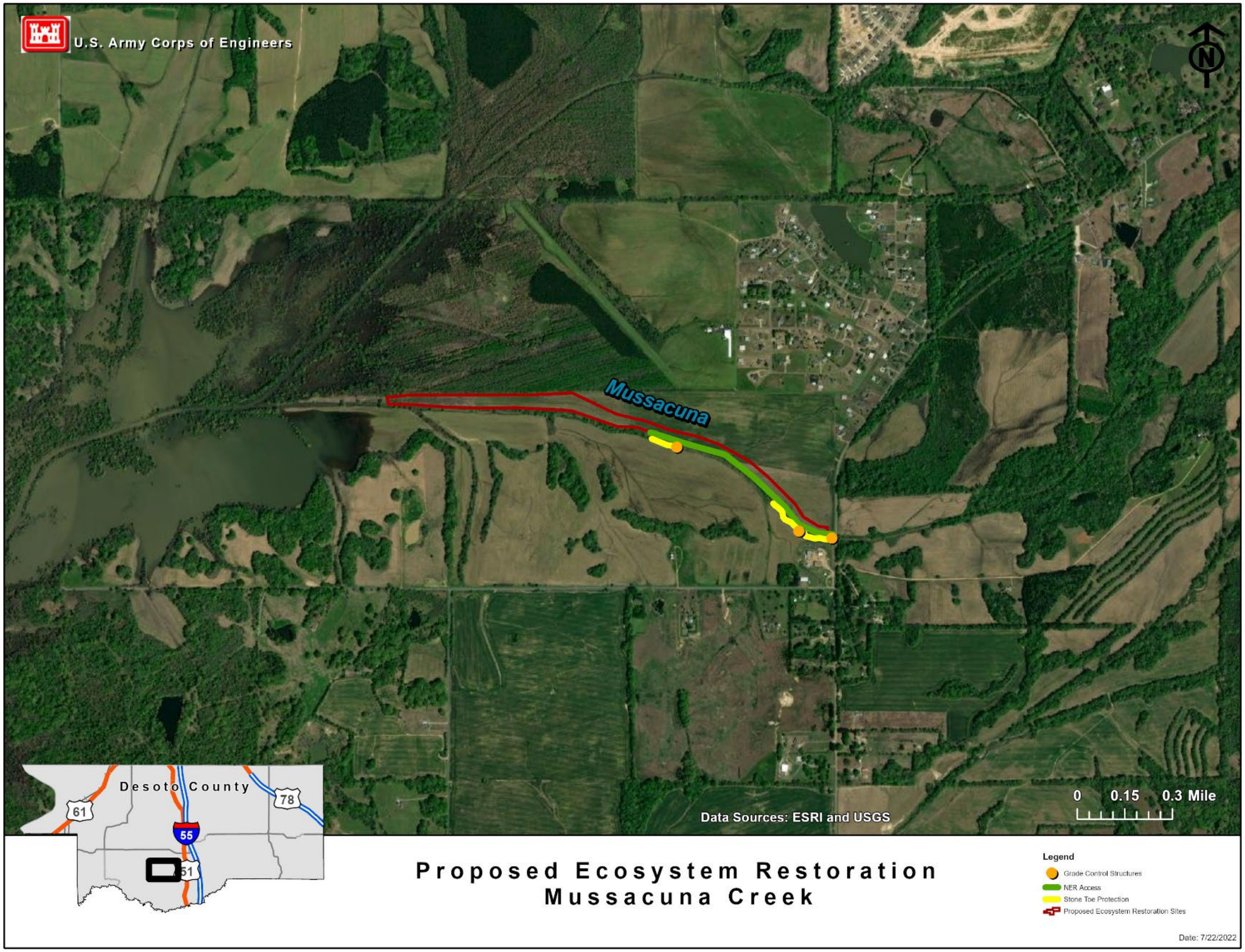


Figure 7. Mussacuna Creek proposed reforestation locations.

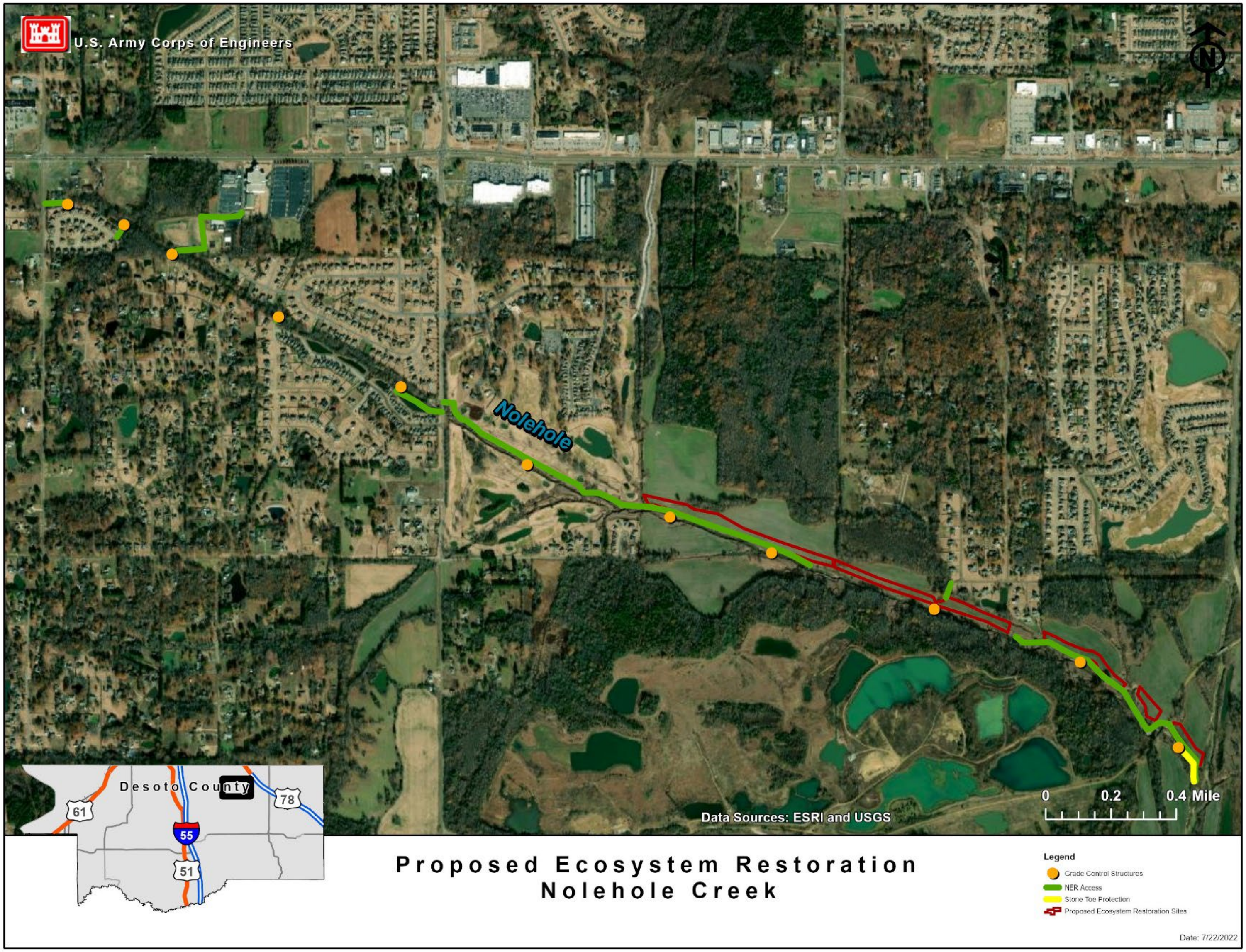


Figure 8. Nolehoe Creek proposed reforestation locations.

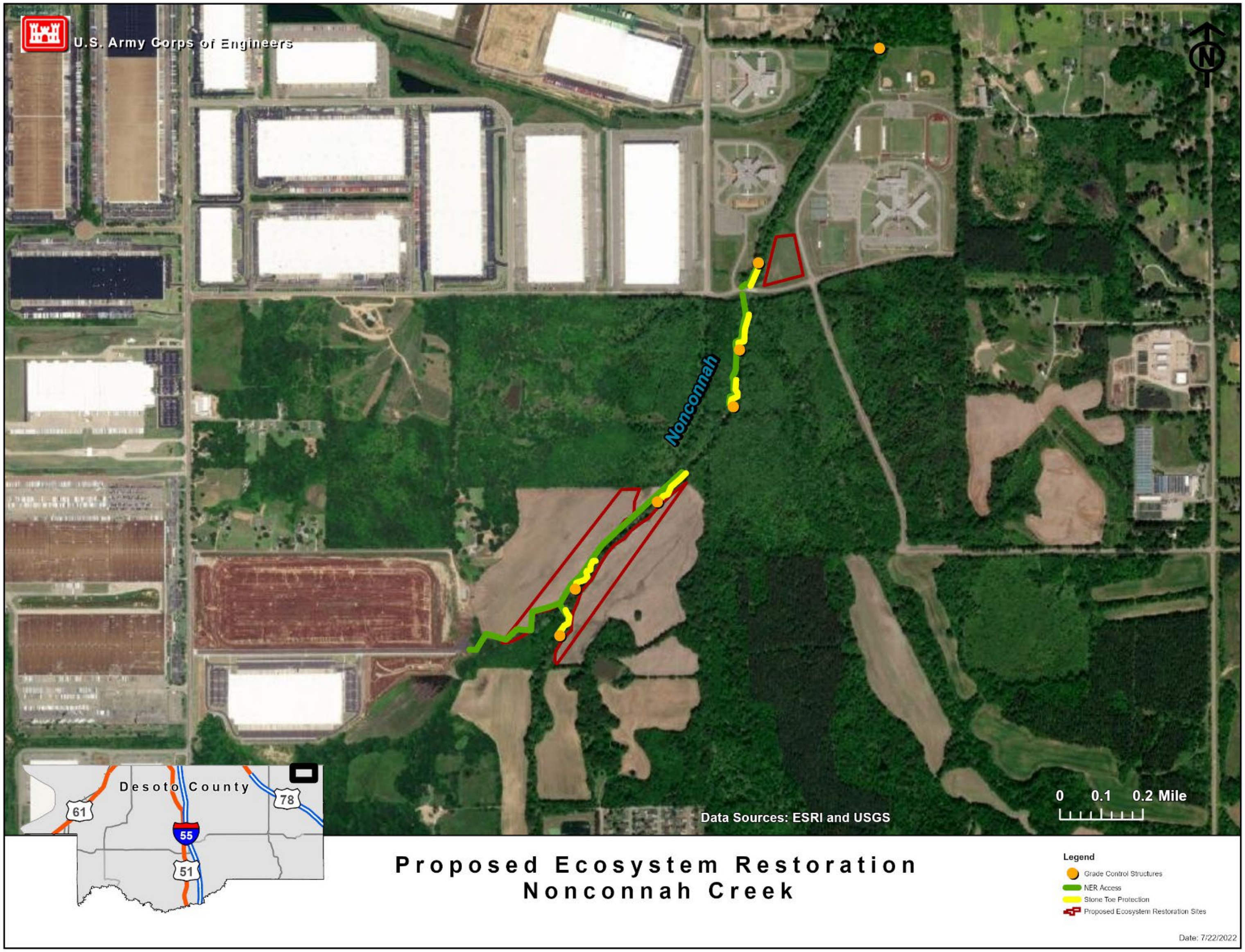


Figure 9. Nonconnah Creek proposed reforestation locations.

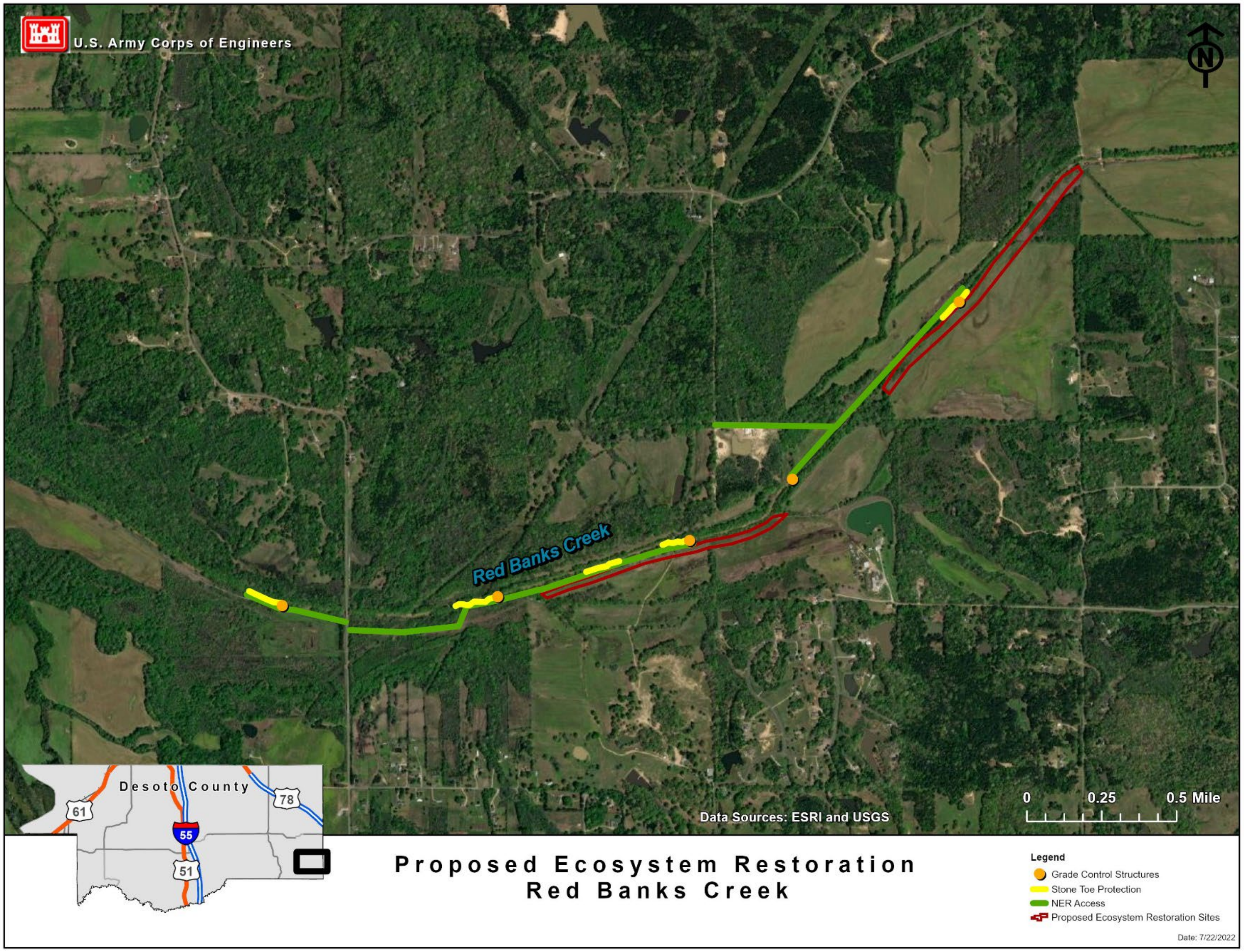


Figure 10. Red Banks Creek proposed reforestation locations.

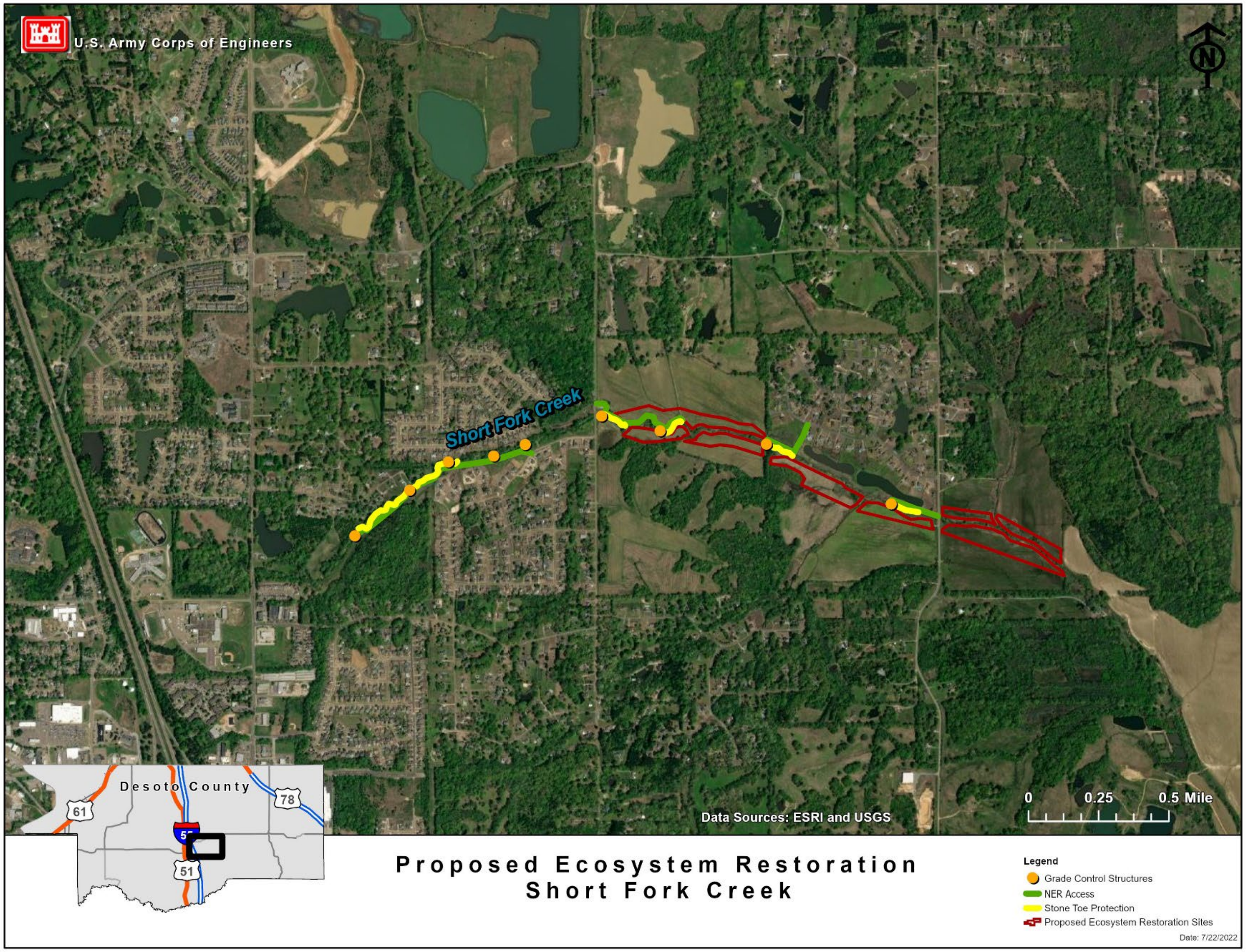
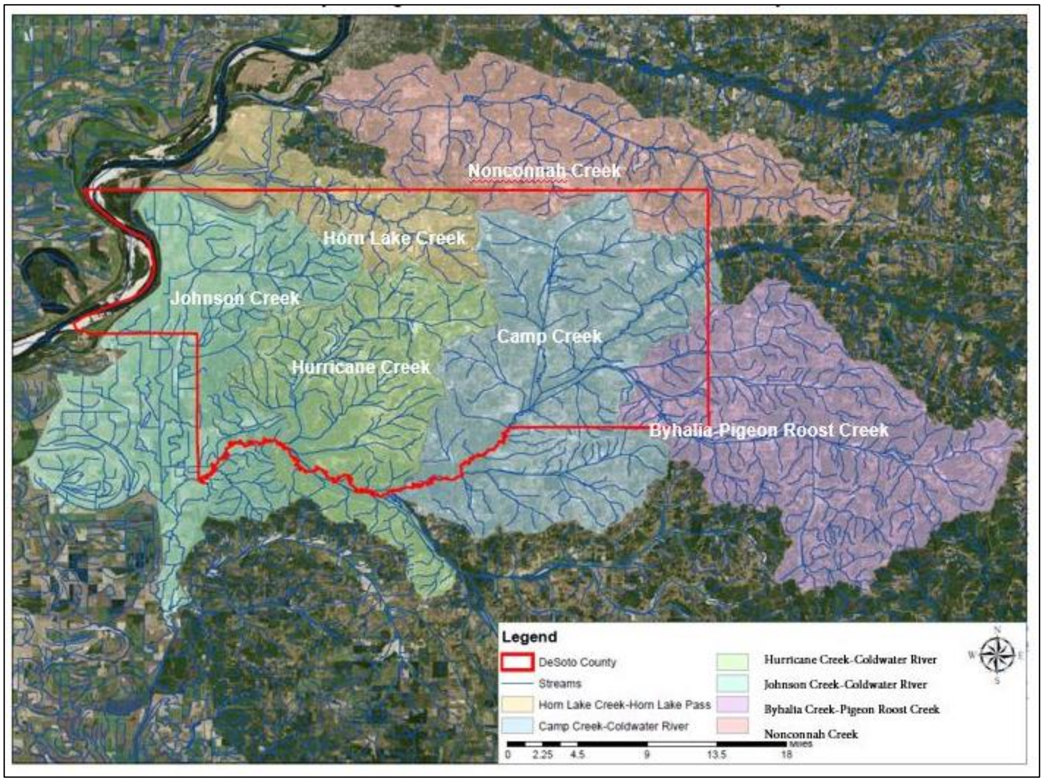


Figure 11. Short Fork Creek proposed reforestation locations.

Mississippi Valley Division,
Regional Planning and Environment Division South

Section 6

Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study, DeSoto County Mississippi



PRELIMINARY Draft 404(b)(1) Analysis

May 2022

LIST OF TABLES

Section 1
Introduction

The following short form 404(b)(1) evaluation follows the format designed by the Office of the Chief of Engineers, (OCE). As a measure to avoid unnecessary paperwork and to streamline regulation procedures while fulfilling the spirit and intent of environmental statutes, Memphis District is using this format for all proposed project elements requiring 404 evaluation but involving no significant adverse impacts to water quality.

1.1 PROJECT DESCRIPTION

There are two components of the Memphis Metropolitan Stormwater-North DeSoto, DeSoto County, Mississippi Feasibility Study, flood-risk management and ecosystem restoration. The proposed flood risk management (FRM) plan for the DeSoto County Feasibility Study was determined to include an approximatley 3,000 linear foot levee and floodwall system combined with a nonstructural aggregation to address residual flooding. The proposed ecosystem restoration (ER) plan consists of 11 streams with a system of grade control structures (GCS) and a riparian reforestation feature totaling approximately 344 acres.

The proposed levee would parallel Highway 51 and the floodwall would be constructed behind a shopping center, where levee construction is not feasible. The proposed levee and floodwall system would protect the Bullfrog Corner area of Horn Lake, Mississippi. Water quality and aquatic resources would be expected to improve as compared to the existing conditions and future without project. The proposed floodwall construction would occur along a highly impacted reach of Horn Lake Creek where commercial development and parking lot pavement extends to the top left descending bank of the stream immediately upstream of Goodman Road. A substantial amount of storm-water runoff from parking lots and litter from the overflow of garbage bins occurs in the proposed floodwall reach of the stream which adversely impacts water quality. Non-structural features would likely include dry-floodproofing of commercial structures. There are approximately 29 commercial structures east of the levee floodwall system that are expected to require non-structural measures.

The levee would run approximately 2,475 linear feet adjacent to US Highway 51 with an average height of 5 feet. An approximately 600 linear-foot ditch would drain a depression on the riverside of the levee which, if left in place could cause levee foundation saturation and stability issues. The majority of the proposed levee construction would occur along Highway 51 and is spaced at a distance greater than approximately 450 feet from the stream. Post-construction, this space would be available for native revegetation and reforestation. Detailed plans have not been developed, as the use of the area as a potential borrow site has not been fully determined. Where development makes a levee infeasible, protection would transition to a linear 525-foot floodwall. The location of the levee prevents further development and provides floodplain functions and reforestation acreage, integrating the flood risk management system with the surrounding natural and human environment while creating a pleasant environment for human use and potential recreation opportunities. Once a determination is made on the suitability of the area for borrow, a landscape design would incorporate appropriate nature-based features such as microtopography and native vegetation. The landscape/borrow source plan would be fully coordinated with the local sponsor, interagency team and consulting Tribes during planning and design to determine and incorporate needs and expectations.

The ER plan consists of 11 streams that would have a system of grade control structures (GCS) placed in each of the creeks. The plan also includes a riparian reforestation plan to reforest approximately 344 acres of riparian habitat (Table E:1-1. National Ecosystem Restoration Plan). The ecosystem restoration goal is to stabilize channels and connect/improve riparian habitat, which would minimize channel degradation and erosion and support aquatic ecosystem form and function along main stem channels and tributaries in the DeSoto County watersheds. Currently, the erosion, head-cutting and stream bed degradation leads to bank failures, sedimentation, and prevents stable habitat from forming. Channel degradation and aggradation caused by residential and commercial development, channelization, erosive soils, agricultural practices, and other channel alterations in the DeSoto County watersheds have caused a decline in the ability of streams and adjacent lands to support the requisite functions for fish and wildlife.

The streams in DeSoto County that have total maximum daily loads (TMDL) assigned are noted in (Table E:1-2. MDEQ Water Quality Designations). The most prevalent water quality concerns as noted from the MDEQ TMDL reports are excessive nutrients, organic enrichment/low dissolved oxygen, and sedimentation. In addition, Red Banks Creek is listed as biologically impaired due to toxicity.

The Coldwater River Basin is located within the larger Yazoo Drainage Basin and is impounded by a flood control dam that changed the hydrologic regime and created Arkabutla Lake. As such, the Coldwater River system is highly modified and fish passage has been blocked. Substrates consist of silty, clay and sand sediments. Streams that flow into the Coldwater River as well as the Horn Lake – Nonconnah Basin are generally sluggish. Sedimentation appears to have increased over time in the study area’s streams due to high stream flows causing erosion and bank failures during flood events along with incision, head-cutting, heavy agricultural practices, and commercial and residential development. In addition, low normal flows, and aggradation in some areas along with bare, unshaded banks, and excess nutrients cause low dissolved oxygen impairing streams for biological use. Riparian and potentially reforestable acreages were determined using National Land Cover Data mapping within 328 feet of each stream. Categories assumed to be reforestable include cultivated crops, barren land, hay/pasture, herbaceous, and shrub/scrub.

Grade control structures were identified as systems of structures paired with various stabilization techniques such as stone toes, channel training structures, and pool and riffle components.

Table E:1-1. National Ecosystem Restoration Plan

Stream	Alt #	Alternative Description	AAHUs	Cost of Construction[1]
Camp Creek	CP-4	8 GCS + 47 riparian acres	53	$3,166,536
Horn Lake Creek	HLC-4	14 GCS+ 17 riparian acres	53	$6,982,973
Johnson Creek	JC-5b	11 GCS+ 49 riparian acres	52	$4,033,823
Cane Creek	CN-5b	9 GCS+ 26 riparian acres	21	$2,461,923
Hurricane Creek	HC-5b	5 GCS + 64 riparian acres	62	$4,084,715
Lick Creek	LC-5b	2 GCS + 14 riparian acres	11	$1,014,851
Mussacuna Creek	MC-5b	2 GCS + 23 riparian acres	16	$1,516,149
Nonconnah Creek	NoN-5b	6 GCS + 20 riparian acres	13	$1,502,193
Nolehoe Creek	NL-4	11 GCS + 18 riparian acres	38	$3,251,283
Short Fork	SF-5b	9 GCS + 42 riparian acres	34	$2,773,875
Red Banks	RB-4	5 GCS + 24 riparian acres	25	$2,647,779
11 streams		**88 GCS+ 344 acres**	**378**	**$33,436,100**

Table E:1-2. MDEQ Water Quality Designations

Stream	Water quality status (MDEQ data)
Horn Lake Creek	303(d) Listed due to Pollutants: Nutrient Pollution Organic Enrichment Low Dissolved Oxygen (DO) Sedimentation Total Phosphorus TMDL Report Completed in 2005 for Sediment TMDL Report Completed in 2006 for Organic Enrichment/Low DO, and Nutrients
Camp Creek	TMDL Report Completed 2008 Biological Impairment(s) due to: Ammonia Toxicity Total Nitrogen/Phosphorus Organic Enrichment/Low DO and Nutrients Sedimentation
Johnson Creek	TMDL Reports Completed in 2008 Biological Impairment(s) due to: Organic Enrichment/Low DO Nutrients Sedimentation

Hurricane Creek	TMDL Report Completed in 2003 Biological Impairment(s) due to: Organic Enrichment/Low DO Nutrients
Cane Creek	Biological Impairment: Organic Enrichment/Low DO and Nutrients Sedimentation Pesticides
Mussacuna Creek	TMDL Reports Completed in 2008 and 2020 Biological Impairment(s) due to: Organic Enrichment/Low DO Nutrients Sedimentation
Red Banks Creek	Biologically Impaired, no pollutants identified; No TMDL
Short Fork Creek	TMDL Report Completed in 2020 Biological Impairment(s) due to: Sedimentation

Section 2
Review of Compliance

2.1 REVIEW OF COMPLIANCE

Table E:2-1. Review of Compliance (§230.10 (a)-(d))

A review of this project indicates that:	Preliminary[1]	Final[2]
a. The discharge represents the least environmentally damaging practicable alternative and if in a special aquatic site, the activity associated with the discharge must have direct access or proximity to, or be located in the aquatic ecosystem to fulfill its basic purpose (if no, see section 2 and information gathered for environmental assessment alternative);	YES	
b. The activity does not appear to: (1) violate applicable state water quality standards or effluent standards prohibited under Section 307 of the Clean Water Act; (2) jeopardize the existence of Federally listed endangered or threatened species or their habitat; and (3) violate requirements of any Federally designated marine sanctuary (if no, see section 2b and check responses from resource and water quality certifying agencies);	YES	
c. The activity will not cause or contribute to significant degradation of waters of the United States including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, esthetic, and economic values (if no, see section 2);	YES	
d. Appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem (if no, see section 5).	YES	

Section 3
Technical Evaluation Factors

3.1 TECHNICAL EVALUATION FACTORS

Table E:3-1. Technical Evaluation Factors (Subparts C-F)

	N/A	Not Significant	Significant *
Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C)			
(1) Substrate impacts.		Y	
(2) Suspended particulates/turbidity impacts.		Y	
(3) Water column impacts.		Y	
(4) Alteration of current patterns and water circulation.		Y	
(5) Alteration of normal water fluctuations/ hydroperiod.		Y	
(6) Alteration of salinity gradients.	Y		
Biological Characteristics of the Aquatic Ecosystem (Subpart D)			
(1) Effect on threatened/endangered species and their habitat.		Y	
(2) Effect on the aquatic food web.		Y	
(3) Effect on other wildlife (mammals, birds, reptiles, and amphibians).		Y	
Special Aquatic Sites (Subpart E)			
(1) Sanctuaries and refuges.	Y		
(2) Wetlands.		Y	
(3) Mud flats.	Y		
(4) Vegetated shallows.	Y		
(5) Coral reefs.	Y		
(6) Riffle and pool complexes.	Y		
Human Use Characteristics (Subpart F)			
(1) Effects on municipal and private water supplies.	Y		
(2) Recreational and commercial fisheries impacts.	Y		
(3) Effects on water-related recreation.	Y		
(4) Esthetic impacts.		Y	
(5) Effects on parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.	Y		

*No significant effects are anticipated

Section 4
Evaluation of Dredged or Fill Material

4.1 EVALUATION OF DREDGED OR FILL MATERIAL

Table E:4-1. Evaluation of Dredged or Fill Material (Subpart G)

a. The following information has been considered in evaluating the biological availability of possible contaminants in dredged or fill material.	
(1) Physical characteristics	Y
(2) Hydrography in relation to known or anticipated sources of contaminants	Y
(3) Results from previous testing of the material or similar material in the vicinity of the project *	Y
(4) Known, significant sources of persistent pesticides from land runoff or percolation	Y
(5) Spill records for petroleum products or designated (Section 311 of CWA) hazardous substances	Y
(6) Other public records of significant introduction of contaminants from industries, municipalities, or other sources	Y
(7) Known existence of substantial material deposits of substances which could be released in harmful quantities to the aquatic environment by man-induced discharge activities	Y
(8) Other sources (specify)	NA

* Riprap placement required for the grade control structures would consist of clean rock from a reputable source.

Section 5
Hazardous, Toxic, and Radioactive Waste

The USACE is obligated under Engineer Regulation (ER) 1165-2-132 to assume responsibility for the reasonable identification and evaluation of all Hazardous, Toxic, and Radioactive Waste (HTRW) contamination within the vicinity of proposed actions. ER 1165-2-132 identifies that HTRW policy is to avoid the use of project funds for HTRW removal and remediation activities. The NFS would be responsible for planning and accomplishing any HTRW response measures and would not receive credit for the costs incurred.

An abridged HTRW Phase 1 Environmental Site Assessment (ESA) was conducted for the draft Integrated Feasibility Report and Environmental Impact Statement (draft IFR-EIS). This ESA was conducted to facilitate early identification and consideration of HTRW issues. The study area was surveyed via aerial photography and environmental database searches.

Several potential Recognized Environmental Conditions (REC) were identified in the ESA. When the final IFR-EIS is completed, Record of Decision (ROD) is signed, and funding allocated, then a final full Phase I ESA would be executed on the project feature prior to construction. It is anticipated that any HTRW sites would be avoided through design changes, if necessary.

Section 6
Disposal Site Delineation

6.1 DISPOSAL SITE DELINEATION ((§230.11(F))

The disposal sites have not been fully identified at this stage of the study. All excavated material would be placed into an upland, no adverse effects to wetlands or other waters of the United States are anticipated. Table 6-1 lists the factors considered in the disposal site delineation.

Table E:6-1. Disposal Site Delineation

a. The following factors, as appropriate, have been considered in evaluating the disposal site.	
(1) Depth of water at disposal site	Yes
(2) Current velocity, direction, and variability at disposal site	Yes
(3) Degree of turbulence	Yes
(4) Water column stratification	NA
(5) Discharge vessel speed and direction	NA
(6) Rate of discharge	NA
(7) Dredged material characteristics (constituents, amount, and type of material, settling velocities)	NA
(8) Number of discharges per unit of time	NA
(9) Other factors affecting rates and patterns of mixing (specify)	NA
b. An evaluation of the appropriate factors in 4a above indicates that the disposal site and/or size of mixing zone are acceptable.	Yes

Section 7
Actions to Minimize Adverse Effects

7.1 ACTIONS TO MINIMIZE ADVERSE EFFECTS

Initial FRM plan proposed in 2021 (Eliminated from consideration):

- Channel enlargement and detention basins are no longer proposed as implementable alternatives.
    - Impacts were expected to require 50-60 acres of tree clearing and compensatory mitigation.
    - Full riprap channel to extend approximately 0.8 miles downstream of Highway 51 in Horn Lake Creek.
    - Channel enlargement would have widened the channel bottom width from 15-25 feet to an approximately 40-foot bottom width.

Proposed FRM plan:

- Levee and floodwall system combined with a nonstructural aggregation to address residual flooding.
    - Insignificant tree clearing, no compensatory mitigation is required.
    - Channelization is no longer required.
    - Best management practices to control erosion and reduce turbidity would be followed.
    - Appropriate technology/machinery would be used at each discharge site.
    - As locations are finalized/prior to the placement of material a survey of human use would be conducted to ensure minimization and avoidance of impacts to human use.

No adverse effects to wetlands or other waters of the United States have been identified.

Proposed ER plan:

- A system of grade control structures (GCS) and a riparian reforestation feature totaling approximately 344 acres.
    - Surveys for special status aquatic species would be conducted as locations for grade control are finalized prior to construction.

- Site-specific surveys to determine extent of tree-clearing for structure placement would be conducted as locations for grade control are finalized prior to construction.
- Best management practices to control erosion and reduce turbidity would be followed.
- Appropriate technology/machinery would be used at each discharge site.
- As locations are finalized/prior to the placement of material a survey of human use would be conducted to ensure minimization and avoidance of impacts to human use.

Other actions may be taken, as necessary once locations are finalized.

Table E: 7-1. Disposal Site Delineation

All appropriate and practicable steps have been taken, through application of the recommendations of §230.70-230.77 to ensure minimal adverse effects of the proposed discharge.	YES

Section 8
Factual Determination

8.1 FACTUAL DETERMINATION (§230.11)

Table E:8-1. Factual Determination

A review of appropriate information as identified in Sections 2-7 above indicates that there is minimal potential for short- or long-term environmental effects of the proposed discharge as related to:	Preliminary	Final
Physical substrate at the disposal site.	YES	
Water circulation, fluctuation and salinity.	YES	
Suspended particulates/turbidity.	YES	
Contaminant availability.	YES	
Aquatic ecosystem structure and function.	YES	
Disposal site.	YES	
Cumulative impact on the aquatic ecosystem.	YES	
Secondary impacts on the aquatic ecosystem.	YES	

A negative, significant, or unknown response indicates that the project may not be in compliance with the Section 404(b)(1) Guidelines.

[1]Negative responses to three or more of the compliance criteria at this stage indicates that the proposed projects may not be evaluated using this "short form procedure." Care should be used in assessing pertinent portions of the technical information of items 2a-d, before completing the final review of compliance.

[2]Negative responses to one of the compliance criteria at this stage indicates that the proposed project does not comply with the guidelines. If the economics of navigation and anchorage of Section 404(b)(2) are to be evaluated in the decision-making process, the "short form" evaluation process is inappropriate.

[3]If the dredged or fill material cannot be excluded from individual testing, the "short form" evaluation process is inappropriate.

Section 9

Evaluation Responsibility

a. Water Quality input provided by: Andrea Carpenter-Crowther

Position: Environmental Manager

Date: 5 April 2022

b. This evaluation was reviewed by: Edward P. Lambert

Position: Chief, Environmental Compliance Branch Regional Planning and Environmental Division South

Date: 5 April 2022

Section 10

Findings

Table E:10-1. Findings

Findings	Preliminary	Final
The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines	YES	
There is a less damaging practicable alternative	NO	
The proposed discharge will result in significant degradation of the aquatic ecosystem	NO	
The proposed discharge does not include all practicable and appropriate measures to minimize potential harm to the aquatic ecosystem	NO	

Date:________________ ______________________________

Zachary L. Miller
COLONEL, EN
Commanding