

# Crabtree Swamp Aquatic Ecosystem Restoration Project



Draft Report  
September 2020



US Army Corps  
of Engineers ®



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## 1 Introduction

Study was initiated in August 2015 for a Continuing Authorities 206 project for Aquatic Ecosystem Restoration in Crabtree Swamp. A Feasibility Cost Share Agreement (FCSA) was signed between USACE and Horry County on April 19, 2019. This integrated feasibility document details the planning process undertaken for the CAP Section 206 Crabtree Swamp Ecosystem Restoration Feasibility Study and documents the environmental assessment to satisfy the National Environmental Policy Act.

### 1.1 Study Purpose and Need for Action

#### 1.1.1 Resource of Regional Significance

Guidance for USACE ecosystem restoration projects requires the identification of significant resources and attributes that are likely to be affected by the project. Resource significance is determined by the importance and non-monetary value of the resource based on institutional, public, and technical recognition in the study area.



*Toxolasma pullus*  
(Savannah lilliput mussel)



*Anguilla rostrata*  
(American eel)

**Figure 1. Significant Resources in the Project Area.**

The significant resources we have identified that will be positively impacted by this project are *Toxolasma pullus* (Savannah lilliput mussel) and *Anguilla rostrata* (American eel), (Fig. 1).

Institutionally, *T pullus* is significant as it is considered an at-risk species by USFWS. It is a priority for propagation according to Appendix B of the draft South Carolina (SC) Mussel Recovery Strategy proposed by the Charleston Ecological Field Office of the US Fish and Wildlife Service (USFWS). South Carolina Department of Natural Resources (SCDNR) considers *T. pullus* to be a Highest Priority Species of Conservation Concern and is partnering with USFWS on propagation efforts (M. Wolf, personal communication, 6 Apr 2020).

*Anguilla rostrata* is significant in that it is under survival pressure and has been reviewed for listing by the USFWS (USFWS, 2015). The Atlantic States Marine Fisheries Commission (ASMFC) manages the American eel fisheries in territorial seas and inland waters along the Atlantic coast. They have developed a Fishery Management Plan (FMP) for the American Eel American eel because the stock was considered depleted in a 2017 assessment (ASMFC, 2019). The International Union for Conservation of Nature (IUNC), a non-regulatory agency that provides information and analyses on biological species to help preserve biodiversity, has listed the American eel as endangered (Jacoby, Casselman, DeLucia, & Gollock, 2017; USFWS, 2015).

Publicly, the Crabtree Swamp watershed as a whole is significant. There is collaboration by local entities to naturalize Crabtree Swamp. It's known as the Crabtree Swamp Restoration Initiative where the mission is to "restore Crabtree Swamp to a more natural state that adheres to or exceeds state and Federal water quality standards, minimizes flood damage to people and their property, and provides suitable wildlife habitat." The aquatic ecosystem restoration initiative began after Horry County Stormwater Management and the City of Conway Water Quality and Drainage Commission identified the aquatic ecosystem restoration of Crabtree Swamp as a high priority. They were joined by Coastal Carolina University, Crabtree Swamp Watershed Conservation District, and Horry Soil and Water Conservation District in finalizing a memorandum of understanding (MOU) in January 2008 to proceed with discrete aquatic ecosystem restoration activities within the impaired swamp system. (Fuss, Garigen, Libes & Dignam, 2010). The intent of the MOU is to:

- Support and encourage a spirit of cooperation throughout the watershed among and between the jurisdictions and their representatives, while recognizing and affirming the rights and responsibilities of each
- Utilize common and innovative aquatic ecosystem restoration techniques to achieve water quality and quantity objectives, including: a) off-channel flood storage and attenuation, b) in-channel stream improvements, c) stream buffers to protect banks and filter pollutants, d) water-quality focused ditch maintenance and bank stabilization procedures
- Engage in community education, outreach, and involvement
- Monitor water quality to evaluate success of aquatic ecosystem restoration efforts and to direct project amendments to address any shortcomings
- Promote and support opportunities to transform Crabtree Swamp into an attractive public amenity by integrating and coordinating with plans and activities designed to preserve and manage open space and greenways for conservation, traditional uses, and low-impact recreation

These same measures are included in the Natural Resources Elements of the Horry County Comprehensive Plan adopted by the Horry County Planning and Zoning Department 3 Mar 2015.

Technically, the species we have identified as significant resources are imperiled throughout their range and at risk of extirpation from Crabtree Swamp. *T. pullus* was identified in Crabtree Swamp in 2007 where this was the last known occurrence of a live specimen of this species in the Waccamaw River drainage. A formal petition for listing *T. pullus* as threatened or endangered was filed in 2010. In 2011, a 90-day finding determined that listing may be warranted (USFWS, 2019). *T. pullus* are found in shallow waters along the shoreline of streams and are thought to be found in backwaters. They are important as filter feeders that help clean the water, and they are an important food source for fish, birds, and terrestrial animals. *T. pullus* suspend along the shoreline where they are susceptible to erosion, pollution, and desiccation. Because mussels are filter feeders, they may become stressed when their gills become clogged with large amounts of sediments that cannot be digested, such as sand or silt suspended in the water column (Bogan, Alderman & Price, 2008). Very little is known about the lifecycle of *T. pullus*. Hanlon and Levin in their 2004 investigation of *T. pullus* in North Carolina found gravid females in water temperatures ranging from 23°C to 28°C and 100% of the females sampled between the months of June and August were gravid. Gravid females release glochidia when a suitable host is near. The glochidia attach to the gills of the host then drop off at maturity (Bogan, Alderman & Price, 2008). Sunfish species are known hosts for *T. pullus* glochidia and the primary dispersal mechanism for the species. In tanks at a national hatchery *Lepomis auritus* (redbreast sunfish) were successfully inoculated with *T. pullus* glochidia. Three weeks later at water temperatures between 21°C and 23°C over 100 mussels matured and dropped from the *L. auritus*. Work is being done to replicate this in the wild (M Wolf, personal communication 6Apr2020). Removing barriers to dispersal of the glochidia is an important component to the recovery of *T. pullus* (NatureServe, 2019). *Anguilla rostrata* is a ubiquitous fish species but has been reviewed for listing under the Endangered Species Act. Its historical freshwater range is the North

Atlantic coast from Greenland to Central America and the Caribbean and inland into the upper Midwest and the Great Plains. It is an important commercial fishery and prey species for fish, aquatic mammals, and birds. *A. rostrata* spawn at sea then makes its way to near shore or freshwater habitats to live to sexual maturity. Freshwater overwintering habitat is not well documented, but yellow eels, a juvenile stage, have been observed to overwinter in mud bottoms. There is a slow rate of maturation requiring eight to over 24 years to attain sexual maturity. At that point they return to sea to reproduce. All spawning occurs in the Sargasso Sea (Jacoby, Casselman, DeLucia & Gollock, 2017; USFWS, 2015)

*A. rostrata* are able to negotiate many barriers to varying degrees, yet they are under survival pressure as a result of barriers within streams. Other extreme pressures they are facing are sediments and toxins in the water column and over-fishing. (USFWS, 2015). Abundance of *A. rostrata* throughout its range is not well understood, but it is believed to be 30% less than historical highs, 40% greater than historical lows, and stable since 2007 (USFWS, 2015). Life stage of harvested eel are not reported, but the harvest of yellow eel is a cumulative stress, over multiple years on a juvenile life stage where mortality occurs prior to spawning (ASMFC, 2019; USFWS, 2015).

Federal interest in the Crabtree Swamp Aquatic Ecosystem Restoration Study was verified June 2016 approving USACE Charleston District (the District) to enter into a comprehensive study of alternatives to address the degraded aquatic ecosystem in Crabtree Swamp, Horry County, SC (USACE, 2016). This feasibility study will make recommendations for implementation of measures to improve the quality of the aquatic ecosystem.

### **1.1.2 Study Purpose**

The purpose of this study is to naturalize the aquatic ecosystem processes in Crabtree Swamp to improve survivability of resources of regional significance that have been identified.

### **1.1.3 Need for Action**

The North American freshwater ecosystems are some of the most threatened ecosystems in the world. Forty-four percent of North American river miles are considered impaired due to hydrologic modifications and agricultural runoff. During the 20th century more than 120 North American freshwater species went extinct (Center for Biodiversity, 2010). The southeast US freshwater ecosystem is imperiled. In one peer-reviewed study, the investigators modeled future extinction rates. They predict that freshwater animals in the southeast US will go extinct at a rate of 4% per decade. This is similar to the extinction rate projected for tropical rainforests and it is 5 times the rate of extinction predicted for terrestrial animals in the southeast US. The major factors in these extinction predictions include direct alterations to waterways, deforestation, and poor agricultural practices (Center for Biodiversity, 2010). Thirty-seven percent of the wetlands in South Carolina have been lost. Deforestation in South Carolina is largely due to agriculture where most of the virgin forests were cut by the early 20th century and it is estimated that close to 500,000 acres of forested land has been lost entirely (Wear & Greis, 2002). In watersheds where large percentages of deforestation has occurred, runoff from great distances carries sediments and toxins from many sources into the streams or rivers degrading water quality (Bogan, Alderman & Price, 2008). This degradation of the overall ecosystem in the southeast US is resulting in more than 70% of mussel species, 48% of freshwater crustaceans, and 28% of fish species considered endangered, threatened, or at risk (Center for Biodiversity, 2010).

## **1.2 Scope**

The scope of this project is to take a functional approach to naturalizing Crabtree Swamp. The project area runs from the bridge at Daniel Road downstream to the bridge at Long Avenue (Fig. 2). Measures will be proposed that are consistent with the standards of USACE that will restore processes in the stream using materials that are most consistent with the local environment. This functional approach will focus on reconnecting habitat; restoring hydrologic, geologic, and riparian processes, and improving instream habitat wherever possible.

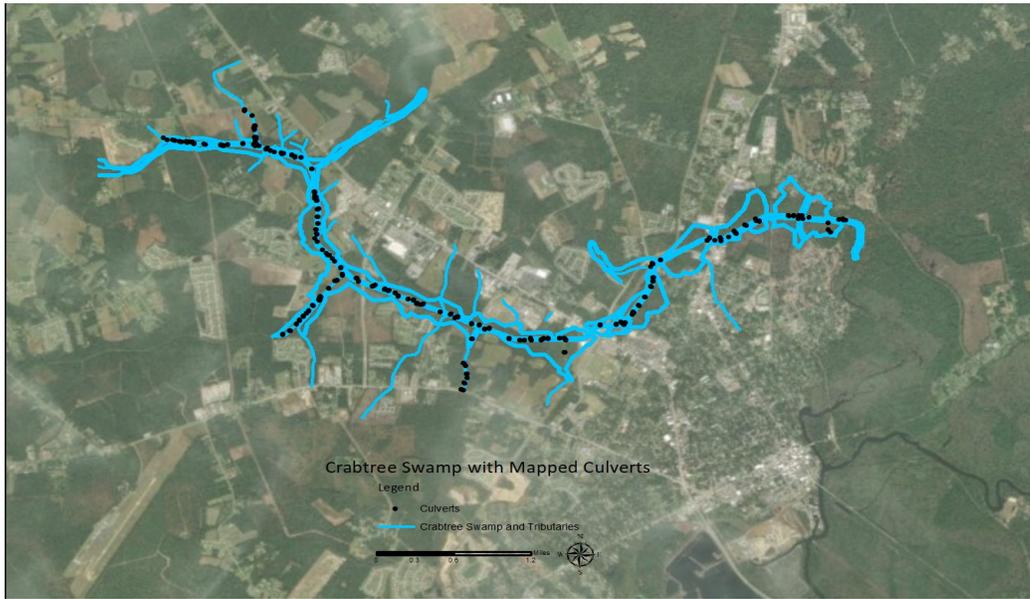


**Table 1. Prior Studies and Reports Pertaining to Crabtree Swamp, Horry County, South Carolina.**

<b>Date</b>	<b>Activity</b>
1964	Formation of Crabtree Swamp Watershed District (Horry County, personal correspondence)
1964	Clearing, snagging, and dredging the channel under Section 208 of the Flood Control Act for purposes of minimizing agricultural damages by 3-year flood events (USACE, 1982)
1973	A Flood Plain Information Report was written under the authority of Section 206 of the Flood Control Act by USACE, Charleston District for the City of Conway (USACE, 1982)
1980s	USDA improved drainage of agricultural lands (Fuss, Garigen, Libes & Dignam, 2010 and R Harper, personal communication, 24Sep2019.)
1982	Section 205 Reconnaissance Report (USACE, 1982)
1996	Crabtree Swamp identified as 303(d) impaired water body by EPA under Clean Water Act (CWA) for high fecal coliform and low DO (Burge & Libes, 2019)
1999-2001	CWA Section 319 grant awarded to S Libes, PhD (CCU) to investigate water quality in Crabtree Swamp and Kingston Lake (USACE, 2015)
Ongoing	USGS continuous water quality monitoring gage funded by local agencies (USACE, 2015)
2006	Conway Water Quality and Drainage Commission and Horry County Stormwater identifies aquatic ecosystem restoration of Crabtree Swamp as high priority (Fuss, Garigen, Libes & Dignam, 2010)
2006-2009	Development of watershed management plan for Kingston Lake Watershed, including focus on Crabtree Swamp, with US EPA Wetland Program Development Grant via CCU (Dr. Libes), (Fuss, Garigen, Libes & Dignam, 2010)
May 2007	SC DNR Stream Assessment station in Crabtree Swamp yields two rare freshwater mussel species (USACE, 2016).
2008	Crabtree Swamp Watershed Restoration Initiative, a multi-agency collaboration begins as a memorandum of understanding was signed (Fuss, Garigen, Libes & Dignam, 2010)
January-July 2008	Water quality monitoring at 17 sites (CCU) funded by Horry County; hydrodynamic model developed (Clemson) funded by SC Water Resources Center (USACE, 2015)
March 2008	SC DHEC macro-invertebrate assessment in Crabtree Swamp and Kingston Lake Watersheds (USACE, 2015)
Spring 2009	Construction of Crabtree Swamp aquatic ecosystem restoration demonstration project/flood plain benching (Fuss, Garigen, Libes & Dignam, 2010)
May 2009	Native tree and shrub planting at stream/floodplain site. planted with over 500 trees and shrubs of species native to coastal floodplain habitats (Fuss, Garigen, Libes & Dignam, 2010).
June 2009-present	Hydrologic, geomorphic, rainfall and vegetative monitoring of stream/floodplain site (USACE, 2015)
Spring 2010	Topographic survey of Crabtree Swamp channel (NRCS, 2010)

July 2010	Less intensive channel maintenance measures instituted to accommodate natural channel morphology (USACE, 2015)
2011	Planning and permitting for Phase 2 stream/floodplain benching project (USACE, 2015)
2012	Start and completion of Phase 2 floodplain benching project (USACE, 2015)
2013	Low-head rock weir installations by Horry County Stormwater Management (CCU EQL, 2019)
June 2015	USFWS Crabtree Swamp mussel survey (USFWS, unpublished report)
August 2015	SC-DNR Electrofishing sampling (SC-DNR, unpublished report)
2019	Drainage Repairs funded by NRCS including 2 low-head weirs and installing a pipe in a now open drainage ditch that flows into Crabtree Swamp just upstream of the US 501 bridge (NRCS, 2019).

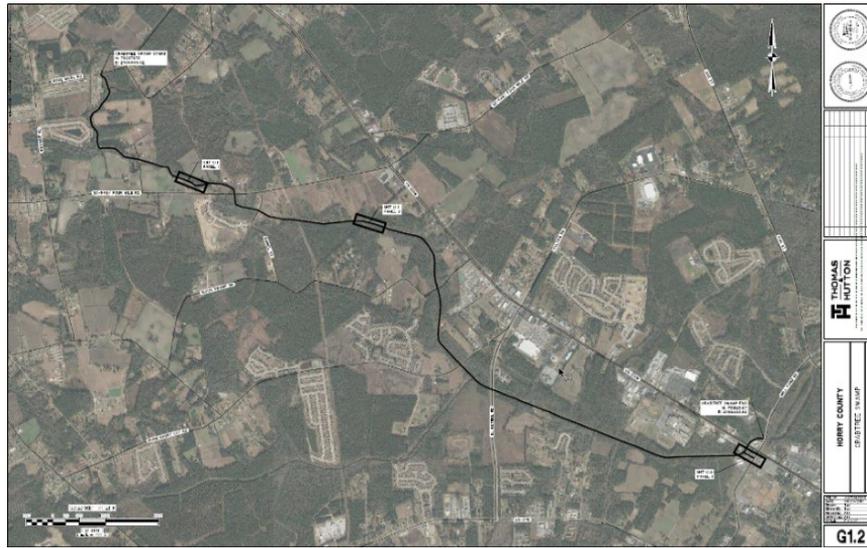
Natural Resources Conservation Service (NRCS) has had many projects in the Crabtree Swamp watershed. Their earlier projects provide drainage to lands in support of agriculture (Fig. 3).



**Figure 3. Drainage Culverts Mapped by NRCS**

More recently they have provided property owners financial assistance to repair failing septic systems or connect to sewer lines. This money was awarded to them through the Clean Water Act (CWA) Section 319 grants to address poor water quality associated with high *Escherichia coli* counts. They have also provided funds and expertise in bank stabilization through their Emergency Watershed Protection

(EWP) program which allows them to quickly address serious and long-lasting damages to infrastructure and land resulting from natural disasters (Fig. 4)



**Figure 4. 2019 NRCS Drainage Repair Project.**

The most significant effort toward aquatic ecosystem restoration has been the 2-phase, contiguous installation of 4,400 lf of flood plain benching with 2,300 lf installed in 2009 and 2,100 lf of benching installed in 2012 (Fig. 5).



**Figure 5. 2012 Planting of Floodplain Bench (Thepaut, Libes, Young, Fuss & Jayakaran, 2012).**

The project reshaped relic dredge spoil deposits into a new floodplain. Design was based on updated HEC-RAS that Clemson University conducted for the County where the bench elevation was designed to be inundated during a 2-year storm event (Fuss, Garigen, Libes & Dignam, 2010). This is consistent with the design of the USACE Section 208 project. A 2-stage design was used to reconnect the channel with the remnant bottomland hardwood floodplain via a gently sloping riparian bench. Using USFWS funding, the County planted the newly created floodplain bench with a mix of native shrubs and trees in a way that could test which species were best suited to the stressors associated with both, aquatic and upland zones as the bench is inundated during moderate and high rainfall events (Thepaut, Libes, Young, Fuss, & Jayakaran, 2012). The plantings were assessed at least once a year between 2009 and 2012. There was a 66% vegetation survival rate at the demonstration site. Seven species had a high mortality rate and six species had a very successful survival rate. The successful species were *Cephalanthus occidentalis* (button bush), *Taxodium distichum* (bald cypress), *Ilex cassine* (dahoon holly), *Faxinus pennsylvanica* (green ash), *Diospyros virginiana* (persimmon), *Betula nigra* (river birch). Guided by these survivability rates an additional section of floodplain just upstream of the demonstration site was planted in 2012.

Two low-head rock weirs were installed by Horry County in 2013 and 2014 and 2 more were installed by NRCS in 2019 (Fig. 6).



**Figure 6. Low-head Rock Weirs Designed by NRCS.**

Each of the structures was installed in the incised, upper reaches of Crabtree Swamp. The structures were designed by NRCS with the objectives of halting channel incision, reducing channel velocities, and allowing for sediment accumulation upstream of these features. The structures have withstood historic flooding events and have provided channel stability and aquatic life habitat.

### **1.5.1 Previously Constructed Projects**

Documented manipulation of Crabtree Swamp began in the 1960s with a USACE project authorized under Section 208 of the Flood Control Act of 1954 (Table 1). The Crabtree Swamp Section 208 project allowed for snagging and clearing in a reach of Crabtree Swamp downstream of the current

project area. Though not in the description of a Section 208 project, dredging was allowed in 7 miles of Crabtree Swamp upstream of Long Avenue under the Section 208 authority. The project was designed for flood control and major drainage that would minimize agricultural damages caused by a 3-year flood frequency. There was an anticipated 20-year project life after its completion in Fiscal Year 1966. Officially, the project was never de-authorized (USACE, 1982; J Jellema, personal communication, 4Sep2019). The footprint of the dredging portion of the Section 208 project is also the footprint of this current CAP 206 study.

## **2 Existing Conditions and Future Without-project Conditions**

This section provides a summary description of the existing conditions and future without-project conditions and establishes a baseline for each of the following resources:

- air quality;
- biological resources;
- climate;
- cultural resources;
- geology and soils;
- groundwater;
- hazardous and toxic waste;
- hydrology and floodplains;
- land use;
- noise;
- recreation and aesthetics;
- socioeconomics and environmental justice;
- threatened and endangered species;
- transportation, and utilities;
- water quality; and
- wetlands.

This section also includes discussion on the affected environment as it relates to the National Environmental Policy Act (NEPA). The affected environment includes the natural and physical environment, and the relationship of people with the environment.

The planning horizon for projecting the future without-project condition is 50 years. This is in accordance with Engineering Regulation 1105-2-100 for water resources projects and represents as far into the future that we can reasonably predict the most likely existing condition. The feasibility phase occurs from 2019-2020. Once the project receives Congressional approval and appropriations are allocated, the project enters the engineering and design phase before beginning construction. The project is authorized for 50 years once appropriations have been allocated and agreements between USACE and NFS have been signed.

### **2.1 Future Without-project Conditions**

Under future without-project conditions (FWOP), Crabtree Swamp within the study area would remain channelized and disconnected from its floodplain, offering degraded and fragmented aquatic habitat with low biological diversity. No restoration or enhancement measures would be implemented within the study area. The maintained channel and stream banks would continue to offer no substrate or cover suitable for colonization by aquatic species, and high-water velocities associated with storm events would further erode stream banks and channel substrate. As channel depths increase, viable fish populations would eventually be unable to migrate upstream due to permanent barriers such as perched culverts that are too high to allow fish passage.

### **2.2 Air Quality**

Air quality in a given location is described by the concentration of various pollutants in the atmosphere. A region's air quality is influenced by many factors including the type and amount of pollutants emitted into the atmosphere, the size and topography of the air basin, and the prevailing meteorological conditions. The significance of the pollutant concentration is determined by comparing it to the Federal and state ambient air quality standards. The Clean Air Act (CAA) and its subsequent amendments (CAAA) established the National Ambient Air Quality Standards (NAAQS) for six principal

air pollutants, also known as “criteria air pollutants.” The pollutants include carbon monoxide (CO), Lead (Pb), nitrogen dioxide (NO<sub>2</sub>), particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), ozone (O<sub>3</sub>) and sulfur dioxide (SO<sub>2</sub>).

A locality’s air quality status and the stringency of air pollution standards and regulations depend on whether monitored pollutant concentrations attain the levels defined in the NAAQS. To ensure the NAAQS are achieved and/or maintained, the CAAA requires each state to develop a State Implementation Plan (SIP). The South Carolina Department of Health and Environmental Control (SCDHEC) – Bureau of Air Quality oversees the state’s air agendas, including the SIP. The state and national ambient air quality standards are presented in Table 2 below. They represent the maximum allowable atmospheric concentrations that may occur while ensuring protection of public health and welfare, with a reasonable margin of safety. Short-term standards (1, 8, and 24-hour periods) are established for pollutants contributing to acute health effects, while long-term standards (quarterly and annual averages) are established for pollutants contributing to chronic health effects.

**Table 2. South Carolina Ambient Air Quality Standards.**

Pollutant	Reference	Measuring Interval	Standard Level			
			mg/m <sup>3</sup>	µg/m <sup>3</sup>	ppm	ppb
Sulfur Dioxide	40 CFR 50.4	3 hour (secondary)	-	1300	0.5	-
	40 CFR 50.5					
	40 CFR 50.17	1-hour (primary)	-	-	-	75
PM <sub>10</sub>	40 CFR 50.6	24 hour	-	150	-	-
PM <sub>2.5</sub>	40 CFR 50.18	24 hour (primary)	-	35	-	-
	40 CFR 50.18	Annual (primary)	-	12	-	-
	40 CFR 50.13	24 hour (secondary)	-	35	-	-
	40 CFR 50.13	Annual (secondary)	-	15	-	-
Carbon Monoxide	40 CFR 50.8	1 hour (no secondary)	40	-	35	-
		8 hour (no secondary)	10	-	9	-
Ozone	40 CFR 50.15	8 hour (2008)	-	-	0.075	-
	40 CFR 50.19	8 hour (2015)	-	-	0.070	-
Nitrogen Dioxide	40 CFR 50.11	Annual	-	100	0.053	53
		1-hour				100
Lead	40 CFR 50.16	Rolling 3-month average	-	0.15	-	-

South Carolina Department of Health and Environmental Control Air Pollution Control Regulations and Standards, Regulation 61-62.5 Air Pollution Control Standards, Standard No. 2, Ambient Air Quality Standards.

If the concentration of one or more criteria pollutants in a geographic area is found to exceed the regulated threshold level for one or more of the NAAQS, the area may be classified as a non-attainment area. Areas with concentrations of criteria pollutants that are below the levels established by the NAAQS are considered either in attainment or unclassifiable areas. All pollutants are currently classified as “attainment” for Horry County, South Carolina (USEPA, 2020). Additional sources of air pollution are likely as growth in the area increases. However, expanding clean energy use and fuel-efficient vehicles should mitigate the increased growth.

**2.3 Biological Resources**

Several areas in and adjacent to the study area include forests and swamps as well as a few isolated open fields. In these areas, a variety of wildlife species are expected to occur. Species present may include deer and small mammals (e.g., squirrels, mice, opossum, raccoon, rabbit, fox, skunk, bats, and beavers), birds (e.g., various songbirds and waterfowl, hawks, and owls), reptiles/amphibians (e.g.,

frogs, toads, lizards, snakes, turtles) and aquatic species (e.g., fish, macroinvertebrates, and mollusks). In addition, waterfowl such as herons have been seen foraging in the drainage canals feeding to Crabtree Swamp and beaver activity was observed in the area just below El Bethel Road. Fish sampling of Crabtree Swamp conducted in August 2015 by the South Carolina Department of Natural Resources (SCDNR) captured 167 fish identified as sunfish species, mosquito fish, bullhead species, hogchoker, largemouth bass, tessellated darter, pumpkinseed, coastal shiner, and American eel (SCDNR, unpublished report). A 2007 mussel survey revealed the presence of mussel species in a single pool upstream of a recently installed structure above El Bethel Road. However, this species has not been documented in Crabtree Swamp since 2007 and the continued maintenance of the channel combined with the impaired water quality and flow conditions, reduces the likelihood of suitable habitat to support the species today or in the future. As growth in the area continues, an increase in impervious surface is expected to occur, leading to an increase in storm flows and further degradation of the stream bed and banks. This will result in a decrease in suitable habitat for aquatic species and viable fish populations will be less able to migrate upstream due to perched culverts. This will reduce foraging habitat for many species including small mammals and birds.

## 2.4 Climate

According to the Köppen climate classification, South Carolina is classified as a humid subtropical climate. In Conway, the summers can be hot and muggy, and the winters can be cold, cloudy, and windy. Conway typically experiences its coldest month in January with an average high of 57 °F and warmest month in July with an average high of 91 °F. The average annual temperature is approximately 75 °F. The average annual precipitation is approximately 52 inches per year with the highest rainfall totals occurring during July, August, and September. During these months, the city of Conway receives between 5.5 and 7.4 inches of rain per month.

### 2.4.1 Climate Change and Greenhouse Gases

According to the Intergovernmental Panel on Climate Change (IPCC), global warming and climate change have been observed since the mid-20<sup>th</sup> century and are expected to continue into the future which would contribute to a continued or possibly accelerated sea level rise. Executive Order (EO) 13693 Planning for Federal Sustainability in the Next Decade was issued on March 19, 2015, with a goal of maintaining Federal leadership and sustainability in greenhouse gas emission reductions. On August 2, 2016, the Council on Environmental Quality (CEQ) released *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas (GHG) Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews*. This guidance applied to all Federal actions subject to NEPA and recommended an assessment of GHG emissions as well as the effects of climate change on a proposed action and its environmental effects. However, in 2017, President Trump issued EO 13783, Promoting Energy Independence and Economic Growth. EO 13783 rescinded EO 13693 and directed the CEQ to rescind the 2016 guidance. On June 21, 2019, the CEQ published *Draft NEPA Guidance on Consideration of Greenhouse Gas Emissions* in the Federal Register. The new guidance focuses on evaluating greenhouse gas emissions for proposed major Federal actions in order to facilitate more timely environmental reviews. Greenhouse gases include carbon dioxide, methane, nitrous oxide, fluorinated gases, and ground-level ozone. In 2015, the Environmental Protection Agency (USEPA) strengthened the NAAQS for ground-level ozone from 0.75ppm to 1.07 ppm. As discussed under air quality in Section 2.2, Horry County is designated as “attainment” for 8-hour ground-level ozone.

In general, the state of South Carolina has warmed by one-half to one degree (F) over the last century. This increase is less than that of most of the nation. It is expected that in the coming decades, changing climate in South Carolina will lead to an increase in the number of unpleasantly hot days, an increase in heat-related illness, an increase in inland flooding, a decrease in crop yields, and harm to livestock (USEPA 2020). A climate assessment to evaluate sea level change was performed for this EA. Details regarding this assessment may be found in Appendix A (Engineering).

## **2.5 Cultural Resources**

The National Historic Preservation Act (NHPA) defines cultural resources as prehistoric and historic sites, structures, districts, or any other physical evidence of human activity considered important to a culture, a subculture, or a community for scientific, traditional, religious, or any other reason. Several Federal laws and regulations protect these resources, including the NHPA of 1966, the Archaeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act of 1978, the Archaeological Resources Protection Act of 1979, and the Native American Graves Protection and Repatriation Act of 1990. Section 106 of the NHPA and its implementing regulations, 36 CFR Part 800, requires Federal agencies to evaluate the effects of their activities on historic properties.

A review of the South Carolina Department of Archives and History (SCDAH) database revealed there are no previously identified historic structures or historic areas located in or near the study area.

## **2.6 Geology and Soils**

Conway is located in the Atlantic Coastal Plain physiographic province in South Carolina. The topography of the outer coastal plain area is flat with low elevations. Elevations along Crabtree Swamp range from a minimum 23 North American Vertical Datum (NAVD) 88 to a maximum 60 NAVD 88. The Conway formation, located between the Horry Barrier and the Conway Barrier, is the primary geologic formation found in Conway and the study area. The formation consists of back-barrier sediments mainly comprised of muds, fluvial sands, and barrier beach sands less than 3 million years that were deposited from the late Pleistocene era (Cooke, 1936).

The soils within the study area are mapped as Meggett loam (NRCS, 2020). These soils are characterized as poorly drained soils with a dark greyish-brown, loamy surface layer and a mottled-grey, loamy or clay sub-surface layer. Meggett soils are typically found in drainage ways and floodplains, have a shallow water table, and are prone to flooding and ponding. Other minor soils that may be found in this mapping unit include Wahee, Ogeechee, Johnston, Rutledge, Pocomoke, and Hobcaw. Future development is likely to result in a loss of soils in the streambed and streambanks and an increase in downstream sediments.

## **2.7 Groundwater**

The City of Conway is located within the Waccamaw Capacity Use Area (WCUA), an area encompassing all of Georgetown and Horry County where groundwater use is regulated under a groundwater management plan. In the WCUA, water withdrawals of 3 million gallons or more per day require a Groundwater Withdrawal Permit from DHEC. The WCUA is one of four state-designated Capacity Use Areas in South Carolina.

In the outer Coastal Plain, aquifers and confining layers typically are comprised of crystalline carbonate rocks, sands, silts, clays, and gravels. While groundwater recharge flows can be slow-moving, the hydraulic conductivities are generally suitable enough to produce large volumes of groundwater (Campbell 2010). The S.C. Department of Natural Resources (DNR) maintains seven groundwater monitoring wells in the aquifers serving the WCUA; one well in the surficial aquifer in Georgetown County, five wells in the Crouch Branch aquifer in Horry County, and one well in the McQueen Branch aquifer in Georgetown County. Data from these wells indicate the Crouch Branch water levels have been steadily declining over the past 50 years while the McQueen Branch water levels have increased approximately 10 feet since 1999. The surficial aquifer is recharged through precipitation, so water levels fluctuate based on storm events and seasonal evapotranspiration.

Currently, there are 224 Capacity Area unit wells permitted in the WCUA. Approximately 174 of these wells are in Horry County and utilized for golf courses (78), industrial (3), agricultural irrigation (13), water supply (63) and other (16). The highest demand is for water supply at 2,236 million gallons (MG), or 78% of the total water use in Horry County for 2017 (SCDHEC, 2019). Water supply needs are

likely to increase with additional development. However, these needs would be managed under the WCUA.

## **2.8 Hazardous and Toxic Waste**

In accordance with Resource Conservation and Recovery Act (RCRA), facilities that generate, transport, treat, store, or dispose of hazardous waste must provide information about their activities to state environmental agencies. U.S. EPA identified two RCRA facilities in the vicinity of the study area. Speedway #4583 (service station) is located at 2301 Main Street and the S.C. Department of Agriculture, is located at 2200 Main Street. Both facilities are in compliance and neither facility is within the study area boundaries. In the future, it is unlikely that hazardous waste facilities would be located within the study area due to zoning restrictions and easements.

### **2.8.1 Toxic Waste**

The Toxic Substances Control Act of 1976 (TSCA) regulates chemical toxins and gives EPA the authority to require reporting, record-keeping, testing requirements, and restrictions for these substances. Specific chemicals that may be included under TSCA include polychlorinated biphenyls (PCBs), asbestos, radon and lead-based paint. American Marble Company located at 2420 Main Street in Conway, is the only facility monitored under TSCA. The last reported release for this facility under the Toxic Release Inventory (TRI) was in 2007 for the chemical styrene. Styrene is a derivative of benzene used to make latex, synthetic rubber, and resins. Since the US National Toxicology Program (NTP) listed styrene in its 2011 report on carcinogens, resin manufacturers have worked to replace styrene with alternatives (Composite World 2020). This facility is located outside the study area. In the future, it is unlikely that toxic waste facilities would be located within the study area due to zoning restrictions and easements.

## **2.9 Hydrology and Floodplains**

The study area falls entirely within the boundaries of the Kingston Lake watershed (Hydrologic Unit Code 03040206-08). The Kingston Lake watershed includes approximately 184 stream miles and drains approximately 130 square miles. The Crabtree Swamp watershed encompasses approximately 18 square miles and receives drainage from Ned Creek, Thompson Swamp, Oakey Swamp, Beaver Hole Swamp, Altman Branch, as well as discharge from over 100 agriculture pipes/tiles that empty directly into the channel.

The headwaters of Crabtree Swamp originate just east of the intersection of Ned Swamp Road and Wayside Road, and flow east/southeast and parallel to Highway 501 before crossing under the highway and flowing through North Conway and into Kinston Lake. Kinston Lake discharges into the Waccamaw River, which flows into the Great Pee Dee River and the Atlantic Ocean. Crabtree Swamp was once a low-gradient coastal plain tributary until the 1960s when the US Army Corps of Engineers (USACE) dredged an eight-mile canal through the swamp to prevent and control flooding. The dredging of the channel and the placement of the dredge materials along the stream banks isolated the stream from its floodplain, contributing to instability and bank failures. Today, the channel is deeply incised, and the riparian buffer is maintained by the city to remove woody vegetation, resulting in a trapezoidal canal with no sinuosity to reduce stream velocities and little habitat to support aquatic life. The FWOP would result in continued maintenance of the channel and streambanks and further degradation of the ecosystem from increased storm flow velocities.

### **2.9.1 Floodplains**

Floodplains are areas bordering rivers and streams, which typically experience flooding during period of high discharge. The 100-year floodplain includes land that has a 1% probability of flooding in any given year. The 500-year floodplain has a 1 in 500 (0.2%) probability of flooding. According to the Federal Emergency Management Area (FEMA) Flood Insurance Rate Maps (FIRMs), the study area

located above Dunn Shortcut Road is designated as “A” (high flood risk areas). Below Dunn Shortcut Road and extending to Long Avenue, the study area is designated as “AE” (high flood risk areas) or “X” (moderate to low flood risk areas) (FEMA 2020). Development activities in regulatory floodplain areas are limited in accordance with Executive Order (EO) 11988, Floodplain Management. The majority of Crabtree Swamp is currently disconnected from its floodplain due to adjacent berms constructed as a result of channel dredging. In future years, continued maintenance of the canal will result in additional placement of berm materials, leaving the stream permanently disconnected from its adjacent floodplain.

## **2.10 Land Use**

Land use typically refers to human alteration of the natural environment for the purpose of development, agriculture, or recreational enjoyment and is typically regulated by local ordinances, management plans and government regulations. Natural land use classifications include wildlife areas, forests, and other open or undeveloped areas. Human-modified land use classifications include residential, commercial, industrial, utilities, agricultural, recreational, and other developed uses. Land use within the Conway city limits includes 59.26% residential, 7.0% commercial, 2.59% industrial, 6.75% agriculture, 8.5% undeveloped, and 15.9% other. Lands adjacent to the study area are generally a mix of residential, forests and woodlands, utilities and roads, and institutional and commercial facilities. Within the study area, the county currently maintains a 150-foot maintenance easement surrounding Crabtree Swamp that does not allow for development. The study area will also require a permanent easement and no land use changes will be permitted. While residential and commercial land use surrounding the study area is expected to increase in the future, development within the study area is unlikely since the city will continue to maintain the existing easements.

### **2.10.1 Prime Farmland and Farmland of Statewide Importance**

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and which is available for these uses. Prime farmland can be cropland, pastureland, range land, forest land, or other open vegetated lands, but cannot be urban land or water. Farmland of statewide importance includes tracts of land that have been designated for agriculture by State law for the production of food, fiber, forage, feed, and oilseed crops. Approximately 60% of the total land area in Horry County is classified as prime farmland or farmland of statewide importance, but only 12.8% is currently in use (Horry County 2020). The U.S. Department of Agriculture (USDA) has not classified any prime or unique farmland within the study area boundaries and this is not expected to change in the future.

## **2.11 Noise**

Noise is often defined as any sound that is undesirable because it interferes with communication, is intense enough to damage hearing, diminishes the quality of the environment, or is otherwise annoying. The Noise Pollution Act of 1972, as amended, is a national statute intended to protect the public from noise that could adversely affect their health and welfare. The restoration areas are located primarily within the Conway city limits. Two major highways, 501 and 701, intersect with Crabtree Swamp at the midpoint and lower sections of the study area. The upper section of the study area, beginning at Daniel Road and extending to El Bethel Road, is identified as Reach 1. Reach 1 is mostly rural with areas of agriculture mixed with single family homes. The middle section of the study area, identified as Reach 2, extends from El Bethel Road to Highway 701. Reach 2 is a mixture of urban and suburban areas with housing developments, cemeteries, schools, and commercial facilities. The lower reach, Reach 3, begins at Highway 701 and extends to Long Avenue. Long Avenue is the terminus of the study area. Reach 3 is buffered by forests and large areas of wetlands. New development is currently increasing upstream of El Bethel Road and is expected to continue into the future. This will likely require new road construction as well as expansion of existing roadways including Highway 501. The primary source of noise in the study area is traffic and secondary noise would be associated with agriculture, schools, and construction (new

development). Noise associated with construction and traffic is expected to increase in the study area as growth continues. Noise associated with agriculture is expected to decrease as development increases.

## **2.12 Recreation and Aesthetics**

Outdoor recreation can involve land and water activities such as hiking, swimming, boating, cycling, or fishing. There are limited recreational opportunities within and immediately adjacent to the study area. A walking trail runs along the north bank of the creek, extending from Highway 701 to Long Avenue. There are no boat ramps or beach areas within the study area and fishing and swimming opportunities are restricted due to the high levels of bacteria found in Crabtree Swamp (Burge and Libes, 2019). The City of Conway and Horry County value conservation lands and the benefits they provide. Therefore, it is expected that

### **2.12.1 Aesthetics**

Visual aesthetics refers to the beauty or pleasing appearance of elements of the environment. Crabtree Swamp was a low gradient coastal plain swamp prior to its channelization in the 1960s. The headwaters originate northwest of the city of Conway and flow through Conway before terminating in Kinston Lake. In the upper reaches, the channel is narrow and flanked by steep banks. With each intersecting drainage, the channel widens but maintains a homogeneous pattern and profile. Stream banks remain steep and are maintained by the city from the headwaters to Highway 701 and there is little visual appeal. From 701 to Longs Avenue, the channel widens out and the banks are forested and shady with a walking trail which supports the aesthetic value of this reach. In the future, aesthetics are unlikely to improve along Crabtree Swamp as the county intends to continue maintenance in the channel and along the streambanks.

## **2.13 Socioeconomics and Environmental Justice**

Socioeconomics comprises the basic attributes and resources associated with the human environment, particularly population and economic activity. In 2015, the population for Horry County was estimated at 309,199. This includes a total population of 76,118 for eight municipalities (Atlantic Beach, Aynor, Briarcliffe Acres, Conway, Loris, Myrtle Beach, North Myrtle Beach, and Surfside) as well a population of 233,081 for the unincorporated areas of the County. The population of Conway was estimated at 21,053; 28% of the municipal population for Horry County and 6.8% of the total population for Horry County. In 2015, the median household income for Horry County was \$43,299 compared to the state average of \$45,483. The number of Horry County residents living below the poverty level in 2015 was 51,988 or 18.1% of the overall population. The percentage of the population below the poverty level in the United States in 2015 was 15.5% and 17.9% in South Carolina. Between 2000 and 2010, Conway had a population growth of 45.1%, nearly 10% higher than Horry County. The population is anticipated to increase by as much as 55% by the year 2040. However, the number of families in Conway that fall below the poverty level appears to be increasing.

### **2.13.1 Environmental Justice**

According to Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, each Federal agency must ensure that its programs, policies, and activities do not have the effect of excluding participation in, denying the benefits of, or subjecting persons to discrimination based on their race, color, national origin, or income level. Agencies must assess whether disproportionately high and adverse effects would be imposed on minority or low-income areas by Federal actions. Key demographic measures for a 0.5-mile radius surrounding the study area are provided in Table 3 and compared to South Carolina and United States percentiles. Based on a summary from US Census Bureau's American Community Survey (ACS) for 2013-2017, the population of this area is 4,584. The minority population is 1,878 or 41%. The per capita income is \$23,238. Approximately 2,120 residents (age 16+) in this area are employed and the analyzed area has a 4% unemployment rate.

**Table 3. Demographic Data for 0.5-mile Surrounding Crabtree Swamp Study Area.**

Demographic Indicator	0.5-mile Study Area	Percentile in State	Percentile in U.S.
Demographic Index	43%	66	67
Minority Population	41%	64	60
Low Income Population	45%	65	73
Linguistic Isolated Population	2%	74	54
Population with less than high school Education	15%	62	67
Population under 5 years of age	8%	77	74
Population over 64 years of age	18%	68	71

All data is taken from the USEPA’s environmental justice mapping and screening EJSCREEN. Definitions of table metrics are available online at: <https://www.epa.gov/ejscreen/overview-demographic-indicators-ejscreen>

**2.14 Threatened and Endangered Species**

Table 4 contains a list of Federal and state endangered, threatened, and at risk species that have been identified by the U.S. Fish and Wildlife Service (FWS) and the South Carolina Department of Natural Resources (SCDNR) as possibly occurring in Horry County, SC (list last updated September 9, 2019) (USFWS, 2020) (SCDNR, 2020). The Federally listed endangered and threatened species that have the potential to occur in the study area include the Northern long-eared bat, the Red-cockaded woodpecker, and the American wood stork. These species are likely to use the study area for foraging habitat which would be reduced as the ecosystem suffers further degradation in the future. USACE has determined that the No critical habitat for any species has been identified within the study area.

**2.14.1 Northern Long-eared Bat**

USFWS lists the northern long-eared bat as threatened wherever it may be found. It was Federally listed as threatened on April 2, 2015 due to a decline in populations from the spread of white nose syndrome. The brown colored bat is approximately 3 to 3.7 inches in length with a wingspan of 9 to 10 inches. The species winter hibernacula include caves, or mines that maintain a constant temperature, have high humidity, and no air currents. Foraging and roosting typically occurs in upland forests during the spring and summer months. Northern long-eared bats may roost individually or in colonies underneath the bark and within cavities and crevices of live and dead trees. They forage along forested hillsides and ridges and feed on various insect species found on vegetation and water surfaces (USFWS, 2020).

**2.14.2 Red-cockaded Woodpecker**

USFWS and the state of South Carolina both list the red-cockaded woodpecker as an endangered species. The black and white bird is approximately 7 inches in length with a wingspan of 15 inches. The RCW is a non-migratory bird that is endemic to the pine forests of the southeastern United States and can be found in mature pine forests, preferably longleaf pine. The RCW species live in clusters, and on average, require about 200 acres of managed pine habitat for foraging and nesting. A major threat to their existence is habitat loss.

**2.14.3 American Wood Stork**

USFWS lists the American wood stork as threatened in Horry County, and South Carolina lists the species as state endangered. Wood storks can reach up to 45 inches in height and typically have a wingspan of 60 to 65 inches. They nest in large rookeries, in freshwater and brackish wetlands. In South

Carolina, the species lays eggs from March to late May with hatching occurring in late summer. The species forages in freshwater marshes, tidal creeks, and ponded depressions where fish may concentrate. The decline in populations is primarily attributed to a reduction in food habitat. This includes the loss of wetlands as well as alterations in water regimes due to construction of levees, canals, and floodgates. Optimal water regimes for this species involve periods of flooding alternating with dryer periods, allowing fish to concentrate in large numbers as waters recede (USFWS 2020).

**Table 4. Federal and State Threatened, Endangered, and At-Risk Species for Horry County.**

CATEGORY	COMMON NAME	SCIENTIFIC NAME	CRITICAL HABITAT	FEDERAL STATUS	STATE STATUS
Birds	American wood stork	<i>Mycteria americana</i>	N	Threatened	Endangered
	Piping Plover	<i>Charadrius melodus</i>	Y	Threatened	Endangered
	Red knot	<i>Calidris canutus rufa</i>	N	Threatened	N/A
	Red -cockaded woodpecker	<i>Picoides borealis</i>	N	Endangered	Endangered
	Saltmarsh sparrow	<i>Ammospiza caudacuta</i>	N/A	At Risk	N/A
	Black-capped petrel	<i>Pterodroma hasitata</i>	N/A	At Risk	N/A
	Least Tern	<i>Sterna antillarum</i>	N/A	N/A	Threatened
	Bald Eagle	<i>Haliaeetus leucocephalus</i>	N/A	Bald and Golden Eagle Protection Act	Threatened
Fishes	Atlantic sturgeon	<i>Acipenser oxyrinchus</i>	N	Endangered	N/A
	Shortnose sturgeon	<i>Acipenser brevirosturm</i>	N	Endangered	Endangered
	Carolina pygmy sunfish	<i>Elassoma boehlkei</i>	N/A	N/A	Threatened
	Robust redbhorse	<i>Moxostoma robustum</i>	N/A	At Risk	N/A
Mammals	Northern long-eared bat	<i>Myotis septentrionalis</i>	N	Threatened	N/A
	Finback whale	<i>Balaenoptera physalus</i>	N	Endangered	Endangered
	Humpback whale	<i>Megaptera novaengliae</i>	N	Endangered	Endangered
	Right whale	<i>Balaena glacialis</i>	N	Endangered	
	Sei whale	<i>Balaenoptera borealis</i>	N	Endangered	N/A
	Sperm whale	<i>Physeter macrocephalus</i>	N	Endangered	N/A
	West Indian manatee	<i>Trichechus manatus</i>	N	Threatened	Endangered
	Rafinesque's Big-eared Bat	<i>Corynorhinus rafinesquii</i>	N/A	N/A	Endangered
	Tri-colored bat	<i>Perimyotis subflavus</i>	N/A	At Risk	N/A
Plants	American chaffseed	<i>Schwalbea americana</i>	N	Endangered	N/A
	Seabeach amaranth	<i>Amaranthus pumilus</i>	N	Threatened	N/A
	Harper's fimbriatilis	<i>Fimbristylis perpusilla</i>	N/A	At Risk	N/A
	Ciliate-leaf tickseed	<i>Coreopsis integrifolia</i>	N/A	At Risk	N/A
	Godfrey's stitchwort	<i>Minuartia godfreyi</i>	N/A	At Risk	N/A
	Seabeach amaranth	<i>Amaranthus pumilus</i>	N/A	At Risk	N/A
	Venus flytrap	<i>Dionaea muscipula</i>	N/A	At Risk	N/A
	Carolina-birds-in-a-nest	<i>Macbridea caroliniana</i>	N/A	At Risk	N/A
	Wire-leaved dropseed	<i>Sporobolus teretifolius</i>	N/A	At Risk	N/A
Reptiles	Green sea turtle	<i>Chelonia mydas</i>	N	Threatened	Threatened
	Kemp's ridley sea turtle	<i>Lepidochelys kempii</i>	N	Endangered	Endangered
	Leatherback sea turtle	<i>Dermochelys coriacea</i>	N	Endangered	Endangered
	Loggerhead sea turtle	<i>Caretta caretta</i>	Y	Threatened	Threatened
	Southern hognose snake	<i>Heterodon simus</i>	N/A	At Risk	Threatened
	American alligator	<i>Alligator mississippiensis</i>	N/A	N/A	Threatened
	Spotted turtle	<i>Clemmys guttata</i>	N/A	At Risk	Threatened

**2.15 Transportation and Utilities**

The study area begins at Daniel Road and ends at Longs Avenue. Within the study area, there are 9 road crossings, one railroad crossing, and one utility easement. The road crossings include Sioux Swamp Road, Dunn Shortcut Road, and El Bethel Road in the upper reach; Church Street (Highway 501),

Oak Street, and Mill Pond Road (two crossings) in the mid-section; and Highway 701 and Sherwood Drive in the lower reach. A railroad bridge crosses the study area between Highway 701 and Sherwood Drive and a utility easement intersects the creek just below Daniel Road. Additional infrastructure will be required to support future growth including roadways and utilities.

## **2.16 Water Quality**

SCDHEC's water quality standards were established to protect and improve water quality for the citizens of South Carolina in accordance with Section 303 of the Clean Water Act. SCDHEC Water Classifications and Standards (R61-68) provides the rules and standards applicable to all surface waters, including class descriptions and designations. Within the study area, Crabtree Swamp is classified as FW for freshwaters. Freshwaters are considered suitable for primary and secondary contact recreation, as a source for drinking water supply after conventional treatment in accordance with DHEC requirements, suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora, and suitable for industrial and agricultural uses.

Water quality standards for freshwaters place limits on the levels of dissolved oxygen, turbidity, and bacteria allowed in these waters based on the designated uses. A water body that fails to meet state water quality standards is considered "impaired" and added to the state 303(d) list of impaired waters. Within the study area, the 2018 South Carolina 303(d) List of Impaired Waters identifies Crabtree Creek as impaired for aquatic life and recreation caused by low dissolved oxygen levels and high levels of E. coli bacteria. Water quality monitoring at the 501 bridge and the Long Avenue bridge has documented high levels of E-coli bacteria and low dissolved oxygen levels since at least 2010. The primary pollutant of concern within the watershed is E.coli bacteria and studies are ongoing to determine the source. A private watershed plan for Crabtree Swamp, sponsored by the Crabtree Watershed Board, was updated in March 2019 and outlines initiatives for improving the water quality. As growth in the area increases, water quality will likely remain impaired or further degrade unless the source of the bacteria can be identified, and measures implemented.

## **2.17 Wetlands**

The term, "wetlands," refers to areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (33 CFR 328.3(c)(4)). These areas are known to support both aquatic and terrestrial species. Executive Order 11990, Protection of Wetlands, directs Federal agencies to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. According to the National Wetlands Inventory (NWI) maps, areas within the 100-year floodplain of Crabtree Swamp are mapped as wetlands. The majority of NWI mapped wetlands in the study area are designated as PFO1 (Palustrine Forested or Shrub, freshwater). A jurisdictional delineation to confirm wetland boundaries has not been conducted for the study area.

### **3 Plan Formulation**

The PDT went through the SMART planning process to develop alternative plans and ultimately chose a plan that meets USACE standards, is embraced by Horry County, accepted by the local community, and naturalizes Crabtree Swamp using natural and nature-based features. Details are provided in subsequent sections.

A Federal Cost-share Agreement was signed between USACE and Horry County in April 2019. Between April 2019 and March 2020, the scope of the project was determined. Existing data was collected. Problems, opportunities, objectives, and risks were identified. Measures to address the problems were investigated. Effective measures were combined in various ways to create alternative plans. The alternative plans were evaluated environmentally, hydrologically, hydraulically, and economically to determine which plans were cost effective while optimizing benefits to the ecosystem. A plan was selected that if implemented rectifies many of the problems that were identified in the study. The plan meets the objectives of the study and provides desirable opportunities not specifically targeted in the naturalization of Crabtree Swamp.

An internal progress review in March 2020 achieved the goal of a Tentatively Selected Plan Milestone Meeting. This allowed the study to move into the District Quality Control (DQC) review phase. The PDT addressed the DQC comments and refined the report. The study went through Agency Technical Review in August 2020 and will be available for public review and comments in September 2020.

#### **3.1 Problems and Opportunities**

Anthropogenic hydrologic alterations have changed the ecology of the Crabtree Swamp watershed. Elimination and disconnection of floodplains from the stream channel have greatly reduced energy dissipation availability within the system. This has caused changes in the channel form as high energy is sustained during peak velocities. This means Crabtree Swamp is in disequilibrium as it has very little available resistance to balance erosive forces (Hawley 2018). The channel is mostly straight and incised with homologous morphology. This channelization has led to habitat fragmentation, scouring, bank destabilization, and a decline in suitability of the system for aquatic life.

Crabtree Swamp has been grossly modified over time. Numerous culverts have been installed throughout the project area accelerating drainage of adjacent lands into the stream in support of agricultural operations. Woody debris has been removed and the stream has been deepened and widened in what was once accepted practices to reduce flooding for short flood frequency intervals (USACE, 1964).

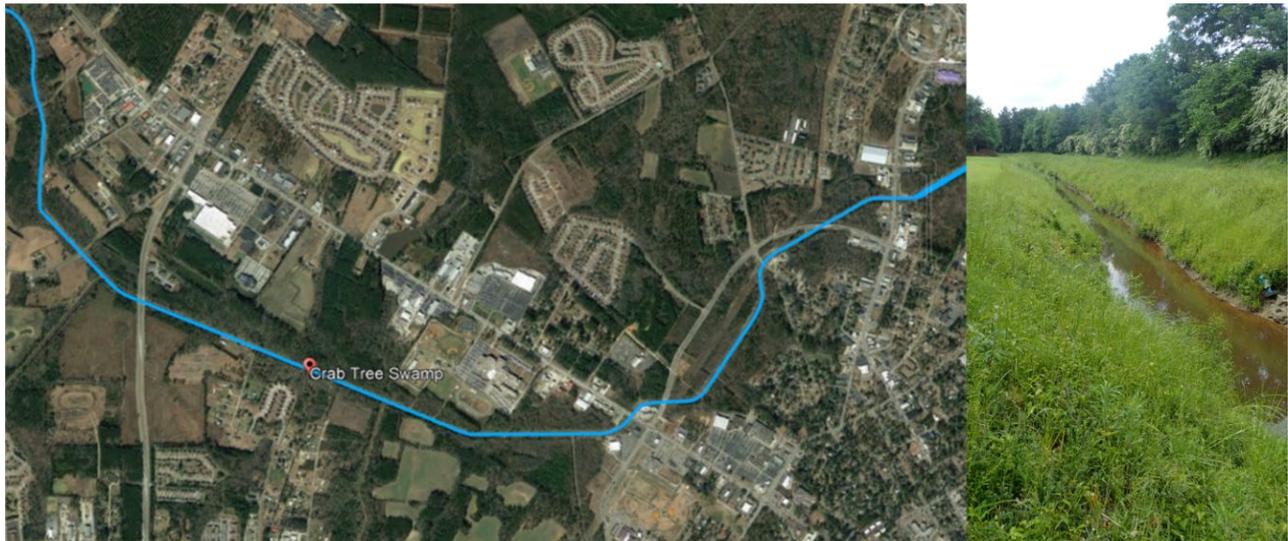
##### **Problem Statements**

- Disconnection of floodplains from Crabtree Swamp has reduced habitat for aquatic organisms and species of concern (Fig. 8).
- Floodplain disconnection has greatly reduced energy dissipation in the Crabtree Swamp system facilitating channelization.
- Stream banks along Crabtree Swamp are destabilized due to channelization.
- Discharge rates in the Crabtree Swamp system have been modified due to channelization.
- Morphological homogeneity of Crabtree Swamp has been facilitated by channelization (Fig.9).
- Channelization of Crabtree Swamp has induced scouring.

- Scours have fragmented habitat within the channel by creating a barrier to passage, upstream, of aquatic organisms and species of concern (Fig. 10).



**Figure 9. Habitat Fragmentation and Bank Destabilization.**



**Figure 8. Channelization and Homologous Stream Morphology.**

### **Opportunities**

Though this is not a water quality project, the planning development team (PDT) feel as though much of what we want to accomplish will also improve water quality through the 50-year life of the project. Improved water quality will enhance the probability aquatic organisms will repopulate Crabtree Swamp. The PDT also believe that once stream processes are naturalized the system will become more appealing to the public and will likely increase use along the shoreline through the 50-year life of the

project. These opportunities are consistent with the goals of the Crabtree Swamp Restoration Initiative and the Horry County Comprehensive Plan.

- bird watching
- fishing
- positive alterations to current flood patterns by slowing velocities and spreading out the water during large rain events
- improved water quality for aquatic organisms
- expand walking trail
- educational opportunities

### **3.2 Planning Goals and Objectives**

The goal of this project is to naturalize Crabtree Swamp by reinstating functionality throughout the system for the 50-year life of the project. This will be accomplished by reconnecting the stream habitat to the floodplain habitat and by reducing water velocities during storm events. This helps prevent further channelization and reintroduces heterogeneity to stream morphology. This will be accomplished by meeting the following objectives over the 50-year life of the project.

- Eliminate barriers that prevent the passage of aquatic animals/species of concern
- Improve habitat for aquatic organisms/species of concern by increasing connectivity to the floodplain.
- Improve stream morphology so that bank failures and scouring resulting in sedimentation is greatly reduced.
- Create conditions within the stream and flood plains that will optimize survivability for species of concern.
- The objective of aquatic ecosystem restoration is to naturalize degraded, significant ecosystem structure, function, and/or dynamic processes. Naturalized ecosystems should mimic, as closely as possible, conditions which would occur in the system in the absence of anthropogenic change. Success includes increased species diversity and the self-sustainability of functional improvements to the system.

#### **3.2.1 Selection Criteria for the Preferred Plan**

For this study, each alternative plan has been formulated to be acceptable to Horry County, the public, and State and Federal resource agencies. The alternative plans are complete in that the plans have included technical input from State and Federal resource agencies, real estate has been considered, and monitoring, maintenance, and adaptive management framed. The alternative plans are cost effective. They will make a significant contribution to naturalizing an impaired ecosystem and enhancing habitat for declining populations of imperiled aquatic resources.

Prior to running the CE/ICA the PDT determined that implementing the Newberry rock-riffle structure was not worth the cost. It will not effectively reconnect habitat as it will only increase the in-stream water elevation to the needed 6” through the culvert at the most 45 time each year. To achieve these additional 45 passage possibilities a high-water event is still required to achieve the increased water elevation. This is the greatest incremental cost for an additional AAHU while the effectiveness and efficacy of aquatic life passage are questionable.

The National Ecosystem Restoration (NER) plan is the plan that maximizes benefits over costs. It is the plan where the extra environmental benefits achieved is just worth the extra cost of implementing that plan. In this study, the environmental benefits are measured in AAHUs and annualized costs are measured in dollars. The AAHUs and annualized costs were examined for cost effectiveness and the costs were analyzed, incrementally, for each AAHU benefit yielded. Together these analyses are known as CE/ICA and are used to identify an alternative plan for implementation.

The cost effectiveness analysis identifies the plans that costs the least while yielding the greatest environmental benefits and are referred to as best buy plans. These best buy plans are used in incremental cost analysis to compare the added cost for each additional environmental benefit yielded in each alternative plan. The plan with the lowest incremental cost per unit of incremental benefit is then identified. Because all of the plans in the final array of alternative plans represent some level of naturalization benefiting the environment, additional criteria is need to be considered before selecting the NER plan. An “is it worth it” analysis is used to help differentiate each alternative plan from the others.

### **3.3 Planning Constraints**

There was a Section 208 project authorized in 1964 and construction completed in 1966. The project was designed for flood control to prevent agricultural damages caused by flooding equal to a 3-yr flood event. No structure employed will interfere with this for the 50-year life of the project.

- Section 208 project for Crabtree Swamp that was designed to reduce the effects of a 3-year flood event throughout the current project area.
- Easements held by Horry County.
- Infrastructure (i.e. Bridges and transformer).
- Negative alterations to current flood patterns.

### **3.4 Initial Screening of Measures**

The PDT researched, presented, and discussed all management measures appropriate in addressing the problems, goals, and objectives identified in this study. Table 5 is the matrix used to evaluate the stand-alone measures. Each measure was discussed and assigned a numerical value between 0 and 2, according to the impact that measure is projected to have on each identified problem and constraint. A score of zero indicates that the measure does not meet the objective, 1 partially meets the objective, and 2 fully meets the objective. A total score of 20 would indicate that a measure fully meets each objective and is not impacted by any constraints. A score of 10 would indicate that a measure partially meets objectives and is partially impacted by constraints. A score of less than 10 indicates that a measure does not meet objectives and is impacted by constraints. The measures that scored 10 or higher moved forward for further consideration in the planning process.

Table 5. Stand Alone Array of Measures.

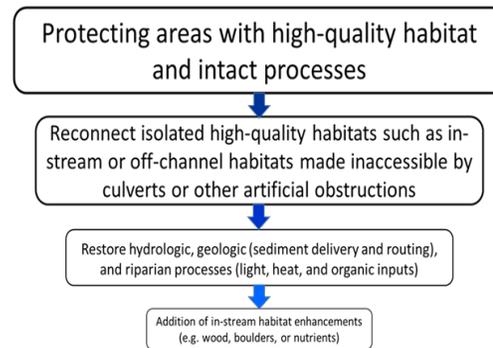
MANAGEMENT MEASURE	ELIMINATE BARRIERS THAT PREVENT AQUATIC LIFE PASSAGE	INCREASING CONNECTION TO THE FLOODPLAIN	MINIMIZING BANK FAILURES THAT RESULT IN SEDIMENTATION	STRUCTURAL HETEROGENEITY	DECREASE IMPACTS FROM PEAK VELOCITY	REAL ESTATE AVAILABILITY	UTILITIES LOCATED ON ONE SIDE OF CANAL	MEASURES IMPLEMENTED MUST BE ABLE TO WITHSTAND HIGH FLOW	WORK NEAR BRIDGES MUST BE APPROVED BY DOT	CANNOT RAISE BASE FLOOD ELEVATION	Environmental Quality (EQ)	Score, Measure Carried Forward (needs 10 points)
Floodplain Benches	Does not eliminate barriers	Creates habitat, allows movement of nutrients and organic material	slow flow to reduce erosion - only during high flows		Spreads water out and slows it down	May be a challenge in certain portions of the project area	May be a challenge in certain portions of the project area	Floodplain connections will actually help during periods of high flow	Work not intended to be near bridges	Floodplain connections will have a positive impact on the BFE		
	0	2	1	2	2	1	1	2	2	2		15
Raise/Step up elevation within existing scour pool				Will add variation to the channel	Will slow water where the step up is within the scour pool itself, but will not slow water to the left and right of the culvert	Will be within stream channel, so adjacent real estate required. Real estate required for access						
	2	0	1	2	1	2	2	1	1	1		13
Series of Step Pools/Riffle Pools	2	0	1	2	1	2	2	1	1	1		13
Planting				shade for aquatic life - cool temperatures								
	0	0	2	2	1	1	1	1	2	1		11
Weirs (mini-dam to raise water upstream)	2	0	0	2	2	2	2	1	1	1		13
Weirs/ Grade control structures	0	0	1	2	1	2	2	1	1	1		11
Pipe Siphon	1	0	0	0	0	2	2	1	1	2		9
Bringing stream back to level of culvert - Fill dirt/boulders or other high velocity material												
	2	0	0	1	0	2	2	1	1	1		10
Bypass channel	2	0	0	0	0	0	0	1	0	2		5
Replace Culvert with open-bottom bridge	2	0	0	0	2	2	1	2	0	2		11
Fish Ladder - must be through culvert	2	0	0	0	0	2	2	2	1	2		11
Berm breeches	place of refuge during peak velocity; will allow invertebrates to pass; not eels/bluegill											
	2	2	0	1	2	2	1	1	2	2		15

### 3.4.1 Final Array of Management Measures

The basis for choosing the final array of management measures was heavily influenced by peer-reviewed literature, ERDC - WOTS consultations, past projects, and hydrologic models. We took a functional system approach to mitigating or eliminating problems within the stream that will improve habitat to a levels that will make it likely that the regionally significant species and the proxy species will establish healthy populations in Crabtree Swamp (Fig. 11).

(ERDC TN-EMRRP SR-42, Roni et al., 2002)

#### Hierarchical Approach to Prioritization of Restoration Actions



**Figure 10. Approach to Naturalizing Crabtree Swamp.**

After an initial screening of measures and further defining the problems by reach, the PDT consulted with ERDC-WOTS. The PDT sought corroboration of the completeness and effectiveness of the array of measures that were being considered. We wanted to investigate if there were other technologies or materials in pursuit of stream naturalization to consider. Several measures that met the criteria to move forward for consideration during initial screening were eliminated after our consultations with ERDC-WOTS and new measures were added.

#### Measures Eliminated after Consultations with ERDC-WOTS

- Raising water elevation to level of culvert using dirt or boulders or other high velocity material to fill existing scour pool was eliminated because raising water elevation can be achieved by more effective methods
- Series of step-pool/riffle pools was eliminated due to likelihood of failure during repeated high velocity events.
- Low-head rock weir was eliminated because large rocks are not found in the coastal plains.
- A fish ladder through US 501 bridge culvert was eliminated because aquatic life passage can be achieved using less conspicuous and complicated methods yielding similar results.

#### Additional Measures Added for Consideration after Consultations with ERDC-WOTS

- Use of log-drop structure rather than low-head rock weir
- Bank stabilization using rip-rap below the water line and soil lifts above to support a Newberry rock riffle structure for grade control downstream of the US 501 bridge rather than a rock weir or series of weirs
- Root wads along the stream banks to improve morphological heterogeneity

### 3.4.2 Description of Each Measure Carried Forward

The measures carried forward are:

- floodplain benching
- log-drop structures
- root wads
- Newberry rock riffle structure with bank stabilization
- berm breaching

Topsoil from each excavation site will be retained and replace for use in revegetation. Top soil is characterized as natural, friable soil representative of productive, well-drained soils in the area, free of sub-soil, stumps, and rocks larger than one inch diameter, brush, weeds, toxic substances, and other material detrimental to plant growth. The top soil will be stripped and kept separate from other excavated materials, brush, litter, objectionable weeds, roots, or stones larger than 1 inch in diameter. The top soil will then be placed and spread on the excavated areas after they have been graded and prepared for revegetation. If necessary, the top soil should be amended to achieve a pH ranging between 5.5 and 7 prior to planting. Plant species and ratios for revegetation will be drawn from “Plant Survival in the Floodplain Restoration of Crabtree Swamp, Horry County, SC” as described by Thepaut, Libes, Young, Fuss & Jayakaran in 2012.

#### Floodplain Benching

Figure 15 is a schematic similar to the floodplain bench that Horry County installed in 2 phases and is a template for this project. All floodplain benching will be of similar design, a 12-ft wide flat riparian bench followed by a 30-ft wide bench at 1.0% slope with a 1V:1H slope to tie into the natural grade Placement and elevation will differ and are proposed to be placed in Reach 1 and Reach 2. All floodplain benching will be accompanied by revegetation of the excavated area.

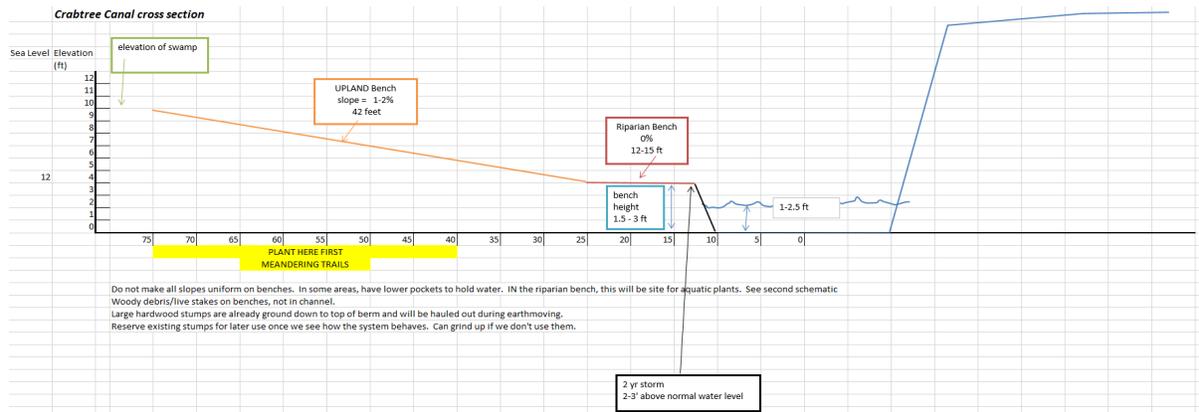
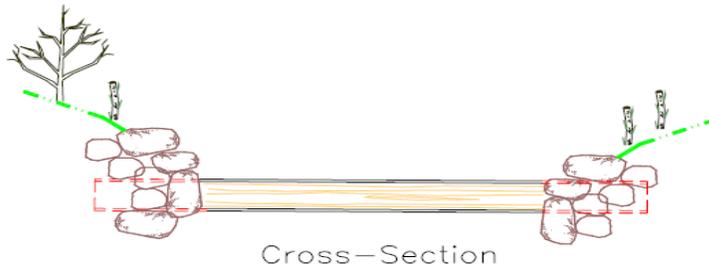


Figure 11. Schematic of Floodplain Bench.

### Log-drop Structure

The log drop structure will be 24-inches in diameter, placed across the channel at an elevation that is largely submerged. It will penetrate 10-ft into the bank on each side and anchored by approximately 2 cubic yards (CY). It will be designed to withstand the 25-year storm velocities and the rip-rap will be covered with top soil and revegetated (Fig. 16).



**Figure 12. Drawing of Log-drop Structure.**

### Root Wads

Root wads will be installed along the stream bank where the trunk of the tree will be embedded into the bank where 2/3 of the root wad would be above the average water level and 1/3 of the root wad would be below the average water level (Fig 17). Each root wad will be 10 LF along the length of the channel, and they will be installed on opposite banks. Some coir material will be used (see Berm Breaching) to reinforce the bank then covered with top soil and revegetated.

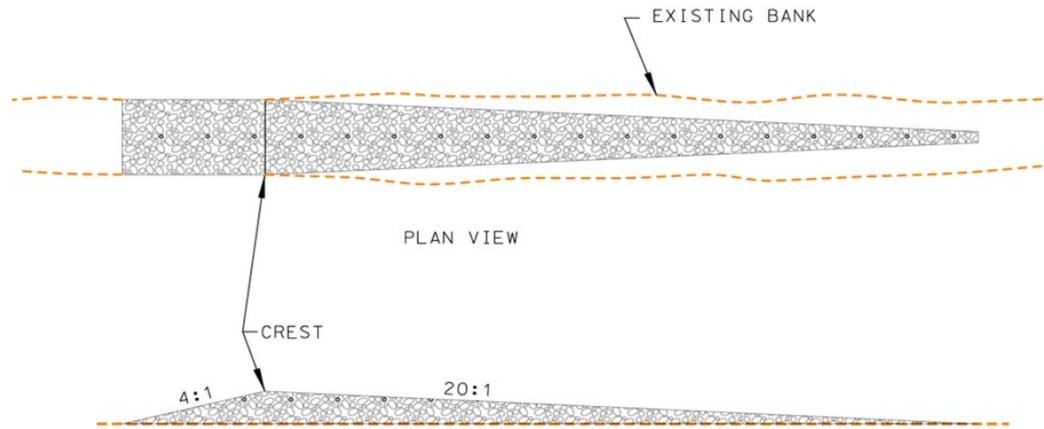


**Figure 13. An example of Root Wads Placed along a Stream Bank to Improve Newberry Rock Riffle Morphologic Heterogeneity.**

### Newberry Rock-riffle Structure

This provides grade control with a V-notch structure at the crest and an apron of rock downstream in the channel (Fig 18). The intent is to raise the base flow stage to elevation 6.5-ft NAVD88, to enable fish passage through the Highway 501 culvert invert of 6.0-ft NAVD88 while reducing bank scour. The

depth through the culvert will provide fish passage through the culvert to the upstream reaches of the project area and will not become a barrier to aquatic life when water levels are low.

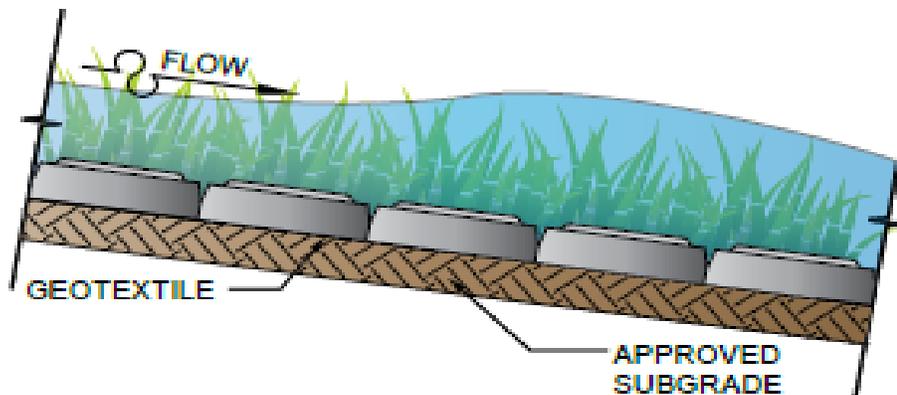


**Figure 14. Drawing of Newberry Rock-riffle Structure.**

The rock should be keyed into both the channel bed and the bank, and should be lined beneath with a geotextile fabric to prevent loss of fine material. The Newbury structure will be approximately three feet high at its crest, 72 feet in length to achieve the design slopes, and constructed of well graded stone of various sizes ranging from boulders to fine material. The design includes application of a sealant to be applied during construction, to ensure the structure is water-tight. The bank stabilization at the scoured area will include grading the bank to a slope of 2H: 1V, install rip-rap to the top of bank then covered with top-soil and revegetate. For this measure to be effective in improving fish passage upstream it must provide near continuous water flow 6" above the base of the culvert from June through August each year for the 50-year life of the project.

### Berm Breaching

Six cuts in existing berms along the banks on both sides of the channel in Reach 3. The number of cuts and their locations coincide with low sites where erosion is already occurring, The design includes each cut to be made down to elevation 6.0-ft NAVD88 and will range between 150 linear feet (LF) to 370 LF. The side slopes will be 3H:1V on each side up to grade and will be armored with articulated concrete



**Figure 15. Drawing of Articulated Concrete Block Mats.**

block mat (ACBM) to prevent erosion (Fig. 19). Topsoil will be replaced at the top of the berm cuts and revegetated. The rest of the berm cuts will be revegetation with volunteer plants.

### 3.5 Reaches

The project area was divided into 3 “reaches” for ease of discussion and because different sections of the stream needed to be addressed in different ways. The goal is naturalizing Crabtree Swamp through the cumulative effects of the measures taken in all 3 reaches (Fig. 12).

The most upstream section of the stream we called Reach 1. Reach 1 is between Daniel Road and El Bethel Road. It is more rural and is likely to have more vegetation along the stream banks. It is furthest upstream so the cumulative effect of the numerous culverts draining into the stream bringing nutrients, inducing sedimentation, and channelization should be somewhat less than the reaches downstream. This reach of the stream is channelized and confined, with steeply sloped banks. Two low-head rock weirs were installed in this reach by NRCS in the fall of 2019 and 2 were installed by Horry County in 2013. USFWS did a mussel survey in Crabtree Swamp in 2015. The Service assessed three sections of Crabtree (Two of which are defined in this project as reaches 1 and 2, respectively.) The section that was assess for mussels in Reach 1 includes the 250 meter stretch upstream/downstream from one of the low-rock weir structures and Sioux Swamp Drive.

The channel below the grade control shows no meanders or sinuosity. The substrate is mainly clay and lacks any coarse sediment. Conversely, above the low-grade rock weir grade is a pool that slows velocity and dissipates energy and is noticeably deeper. The substrate consists of coarse sand and gravel.

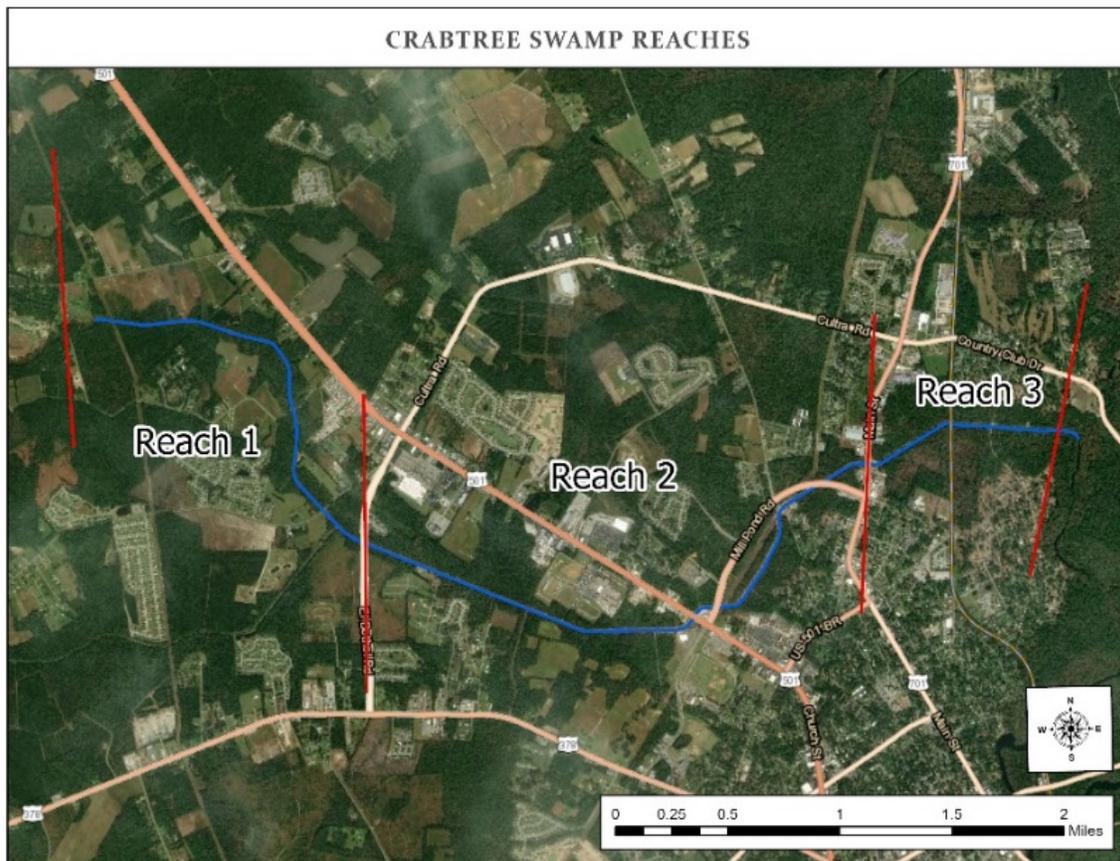


Figure 16. Delineation of the Three Reaches Used for Planning Purposes.

Canopy cover was sparse but present. No woody debris was observed. Batiscope and excavation revealed the presence of live mussels, consisting of *Elliptio complanata* and *Elliptio icternia*. All of these mussels were found between the grade control and Sioux Swamp Bridge. The survey also found a moderate population of *Corbicula* clams. Relict and live shell fragments were also observed (USFWS, unpublished report),”

Reach 2 is immediately downstream of Reach 1 and is between El Bethel Road and US 701. This reach of the stream runs through the City of Conway, behind Conway High School, under US 501, and around a heavily armored BP gas station. There is a barrier to aquatic life passage at the US 501 bridge. It was documented by USFWS in their 2015 mussel survey that “scouring has caused the stream elevation to drop many inches below the road culvert that is insurmountable by most aquatic life during much of the year. A mile-long floodplain bench has been installed in this reach. This reach is highly channelized throughout; confined within a narrow trapezoidal cross-section approximately 3-6 meters wide at the streambed and with very steeply sloped banks approximately 3-6 meters high. The wetted width was approximately 2-4 meters. The banks were vegetated with grasses, sedges, and several other herbaceous plants. Although confined to the narrow channel, the waterway meandered very slightly around vegetated in-channel bars composed of coarse sand and some pea-sized gravel. We observed willows at the water’s edge that appeared to be facilitating the formation of in-channel meanders. However, these willows appeared to have been sprayed with herbicide as leaves were still attached, browned and dead. Submerged aquatic vegetation was abundant throughout the reach. The lack of in-stream features likely makes Crabtree Swamp very hydraulically efficient at this site, transporting water and entrained sediment very quickly. Concurrently, we estimate that seasonally high flows likely create shearing velocities that may displace habitats and less motile benthic animals. We observed a lack of stable depositional areas. We observed virtually no canopy cover at this reach. Very little, if any, woody debris was entrained in the channel. The coarse sand-dominated streambed appeared to be structured only by herbaceous plants with relatively small root systems. The reach lacked any diversity of mesohabitat; the entire surveyed reach was essentially one run. No riffle habitat was apparent in this reach, and only one pool (approximately 1 meter deep) was observed near a culvert at the lower end of the reach (left descending bank) that drains a densely vegetated pine forest. At the time of survey, Crabtree Swamp was somewhat turbid, shallow, and hot. There was less than 20% cloud cover at the time of survey. We estimate that the water temperature was approximately 27-29°C. The water temperature at the only pool was significantly cooler (by approximately 5-6°C).” They used various methods to survey mussels in this reach where they found “live and dead invasive *Corbicula* clams were throughout the reach. *Campeloma decisum* snails were also abundant, and their densities were higher in micro-depositional areas where live and dead organic vegetation was entrained or submerged. No live or fresh-dead mussels were observed. We observed relict shell and shell fragments of what appeared to be species of the genus *Elliptio*. It is likely that this shell material was transported from upstream habitats. Except for Eastern Mosquitofish, no fish species were observed. We observed a low diversity of aquatic insect fauna. However, live and dead dragonfly larvae and their exuviae were abundant throughout the reach (USFWS, unpublished report).”

Reach 3 runs from US 701 downstream to Long Avenue demarking the terminus of the project. It is in a wetland under a dense canopy of cypress with very little connectivity between the channel and the floodplain. A nature trail maintained by the City of Conway is located along the entire length of the reach on the north bank. There is a gated, service road off of Long Avenue that is used to access a utility substation. It is approximately 0.15 miles long. It runs parallel and adjacent to the project area.

### 3.6 Reference Stream

There was a short segment of stream in Reach 2 that served as our reference stream. It is an example of early stream succession where there is natural log-drop structures and early development of sinuosity. It was noted in the 2015 mussel survey as a portion of the stream that was achieving some level of morphological diversity but that it appeared to have been treated with herbicide. Figure 13 is what we

believe the stream should look like very early in the naturalization process post construction of this project.



**Figure 17. Reference Stream in Reach 2 Immediately Downstream of the El Bethel Bridge.**

### 3.7 Proxy for Functionality

The PDT identified the redbreast sunfish (*Lepomis auritus*) as an appropriate proxy for aquatic ecosystem restoration of a functioning system in Crabtree Swamp. *Lepomis auritus* was found in all parts of the stream in a SC-DNR electrofishing sampling event in 2015. Like *T. pullus* and *A. rostrata* (regionally significant resources), *L. auritus* populations are in decline as a result of dwindling habitat and poor water quality. All aquatic ecosystem restoration decisions were made based on efficacy of improving habitat for *L. auritus* in support of the life cycles of *T. pullus* and *A. rostrata* while averting significant changes to 100-year flood elevations.

*Lepomis auritus* needs the settling out of dissolved chemicals and sediments from the water column as high levels of sedimentation or toxins can overwhelm their physical systems. They need shade and detritus to reduce water temperature and provide appropriate nutrients. *L. auritus* prefer structural complexity for foraging and they need the acidic, carbon rich, dissolved organic matter that is associated with course woody debris (CWD). These are the same needs as *T. pullus* and *A. rostrata*.

South Carolina Department of Natural Resources sampled three sites for fish density and diversity in early August of 2015 using electro-fishing techniques. All sampling occurred in a single day where the 3 events took place from 9:00 am to noon. Each event lasted 20 minutes. The individual sites SC-DNR sampled align with the 3 reaches we delineated for our planning purposes. Of 167 fish caught and identified by SC-DNR at the three sites, 98, or 58.7%, of them were *L. auritus* (Fig. 13). So, we know that *L. auritus* are found in the project area at a higher abundance than any other fish species and that its overall populations are in decline due to the same factors as *T. pullus* and *A. rostrata*.

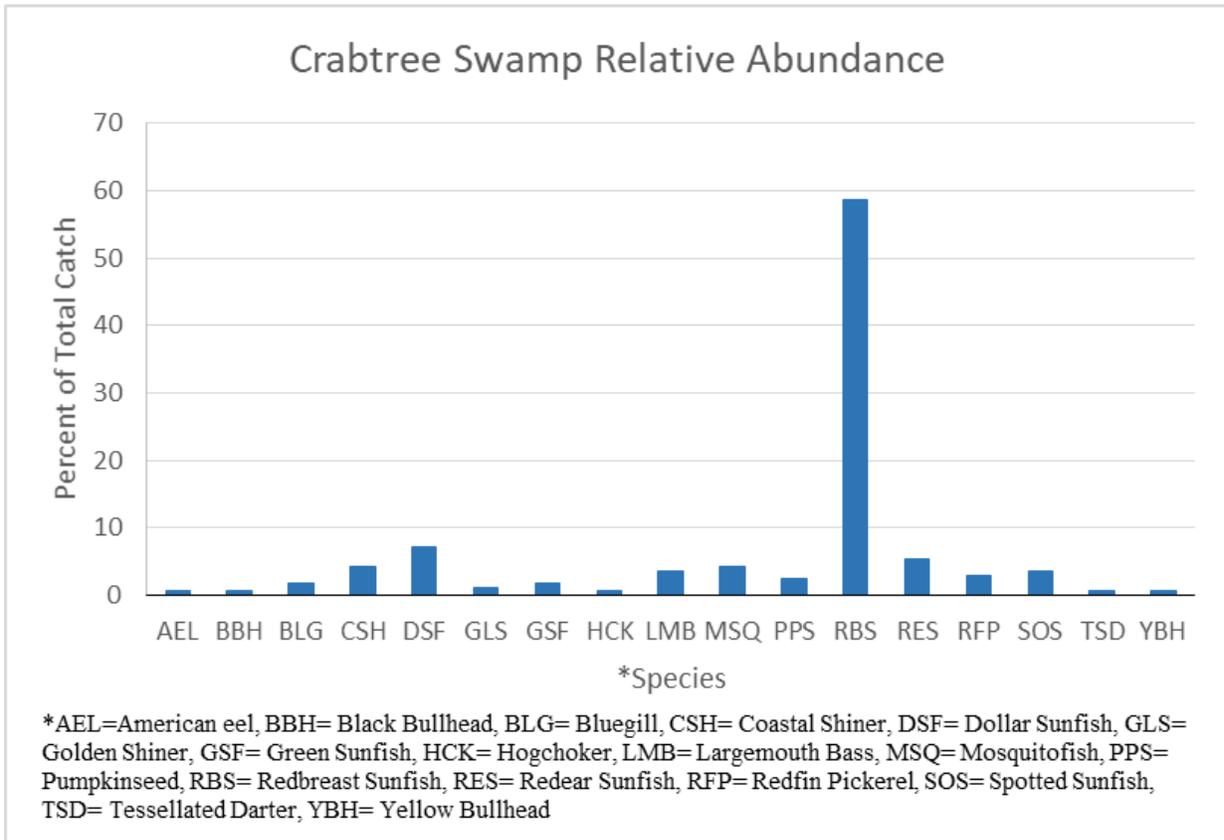


Figure 18. Results of SC-DNR's 2015 Electrofishing Sampling in Crabtree Swamp.

For the purposes of aquatic ecosystem restoration in Crabtree Swamp, the PDT believes there needs to be an intersection between the required environment for gravid females of *T. pullus* and the required environment to support *L. auritus* between the months of June and August, at a minimum, over the 50-year life of the project. This will increase the probability that gravid female *T. pullus* will deposit their glochidia on the gills of *L. auritus* enabling dispersal of *T. pullus* upstream as *L. auritus* move through the system. During SC-DNR’s fish sampling events, they also recorded some data relating to water quality parameters (Table 6).

Reach 1 has better overall water quality than Reach 2 and Reach 3 with lower water temperature, higher levels of dissolved oxygen (DO) and lower conductivity. Water temperature was at its highest in Reach 2. This is expected as there is very little shade to deflect solar radiation from the water in this section of the channel. Conversely, it was surprising that the water temperature in Reach 3 was almost as high as Reach 2 as it is shaded from direct solar radiation by a cypress canopy along the entirety of the reach. Gravid female *T. pullus* have been documented to release glochidia to *L. auritus* with the glochidia transforming and dropping off of *L. auritus* as mature *T. pullus* in water temperatures ranging between 16°C and 21°C (USFWS, unpublished report). It is likely that the current water temperatures throughout the project area cannot support the regionally significant species or the proxy species.

Reaches 2 and 3 have DO levels below the limits required to support our regionally significant resources and our proxy species. Low DO is related to high water temperatures and is an indicator of high levels of pollution. These are DO levels nearing anoxic conditions and likely relate to the high levels of fecal contamination that resulted in Crabtree Swamp being listed as an impaired waterbody by the EPA in 1996. High levels of bacteria, untreated, or partially treated sewage use dissolve oxygen. It is likely that the water throughout the project area and certainly in Reaches 2 and 3 are anoxic at during parts of the year. The current levels of DO in Reaches 2 and 3 cannot support the regionally significant species or the proxy species

Conductivity is a measure of ionized particles in the water column. The higher the nutrient and sediments loads in a system the higher the conductivity. High levels of nutrients in the water column can cause physiological toxic overloads in aquatic organisms resulting in death. High levels of sediments in the water column can cause death in aquatic organisms as they are unable to rid their gills of the sediments fast enough causing asphyxiation. Reach 2 has a 29.7% higher concentration of ions in the water column than Reach 1. Reach 3 has a 54.5% higher concentration of ions in the water column than Reach 1. Reach 3 has a 35.4% higher concentration of ions in the water column than Reach 2. This illustrates how nutrient loading may be accumulating as water passes from Reach 1 to Reach 2 to Reach 3. The increase in conductivity of the water as it moves downstream in Crabtree Swamp may diminish the possibility of survivability of the regionally significant species or the proxy species as they move downstream. Conditions need to be suitable in all reaches of the system to ensure dispersal and survivability of aquatic organisms throughout the system.

**Table 6. Water Quality Reading from SC-DNR's 2015 Electrofishing Sampling in Crabtree Swamp**

Project Reach	Water Temp (° C)	DO (mg/L)	Conductivity (µS)
Reach 1	25.3	7.55	135
Reach 2	27.7	4.73	192
Reach 3	27.4	3.78	297

**3.8 Benefits Calculated**

A habitat suitability index model (HSI) developed for *Lepomis auritus* (redbreast sunfish) was used to determine benefits expressed as average annual habitat units (AAHUs) for alternatives that were carried forward from the first screening. Average annual habitat units were determined for future without project (FWOP) and for future with project (FWP) meaning implementation of each of the alternative plans. The difference between the two are the benefits realized from implementation of the project. This HSI was designed for *L. auritus* in the Savannah River in South Carolina and is most effective when used in the southeastern coastal plain where streams have a low gradient and few riffle-pool sequences. The HSI for *L. auritus* was used to calculate average annual habitat units (AAHUs) where it considers food, cover, conditions for reproduction, and water quality. The model provides an index of the ability of an area to support a self-perpetuating population of *L. auritus* (Aho, Anderson, and Terrell, 1986). The details of the HIS analysis can be found in Appendix B.

Annualized costs associated with each measure in each reach was estimated and then aligned with the costs for FWP (Table 7, for more information on costs see Appendix C). The AAHUs and annualized costs were then used to calculate cost effectiveness and incremental cost analyses for this aquatic ecosystem restoration project.

**Table 7. Net Benefits and Annualized Costs used in Cost Effectiveness and Incremental Cost Analyses.**

Measure	Acres	Reach	FWOP <sup>1</sup> AAHUs	FWP <sup>2</sup> AAHUs	NET BENEFITS	Ann <sup>3</sup> . Cost (Oct 2019 Price Level;50- yrs @ 2.75%
FPB <sup>4</sup>	36.2	Reach 1	3.62	16.69	13.07	\$20,200
LDS <sup>5</sup>	36.2	Reach 1	3.62	6.34	2.72	\$4,400
FPB and LDS	36.2	Reach 1	3.62	17.14	13.52	\$27,600
FPB	27.3	Reach 2	2.73	14.7	11.97	\$22,600
LDS	27.3	Reach 2	2.73	8.05	5.32	\$6,600
RW <sup>6</sup>	27.3	Reach 2	2.73	8.05	5.32	\$7,100
RRS <sup>7</sup>	27.3	Reach 2	2.73	9.69	6.96	\$10,600
FPB and LDS	27.3	Reach 2	2.73	15.81	13.08	\$28,500
FPB and RW	27.3	Reach 2	2.73	15.74	13.01	\$28,700
FPB and RRS	27.3	Reach 2	2.73	16.68	13.95	\$31,700
LDS and RW	27.3	Reach 2	2.73	9.58	6.85	\$16,200
LDS and RRS	27.3	Reach 2	2.73	9.69	6.96	\$19,200
RW and RRS	27.3	Reach 2	2.73	9.69	6.96	\$19,500
FPB, RW, and LDS	27.3	Reach 2	2.73	15.52	12.79	\$34,600

FPB, LDS, and RRS	27.3	Reach 2	2.73	16.68	13.95	\$37,600
FPB, RW, and RRS	27.3	Reach 2	2.73	16.68	13.95	\$37,800
LDS, RW, and RRS	27.3	Reach 2	2.73	10.43	7.7	\$24,900
FPB, LD, RW, and RRS	27.3	Reach 2	2.73	17.84	15.11	\$43,700
BB <sup>8</sup>	16	Reach 3	1.6	5.68	4.08	\$25,300

<sup>1</sup>FWOP = Future without Project

<sup>2</sup>FWP = Future with Project

<sup>3</sup>Ann. = Annualized

<sup>4</sup>FPB = Floodplain Bench

<sup>5</sup>LDS = Log Drop Structures

<sup>6</sup>RW = Root Wads

<sup>7</sup>RRS = Newberry Rock Riffle Structure with Bank Stabilization

<sup>8</sup>BB = Berm Breach

### 3.9 Key Uncertainties

The PDT is confident that the work we are proposing can be constructed within the confines of the easements the County already has in place. The PDT has spoken with SC Department of Transportation (SC DOT) about the aquatic life passage issues at the US 501 bridge. The scope of the project and potential measures to be employed in the vicinity of the US 501 bridge were discussed. The SC-DOT implied that no special permission was warranted but a general permit was likely to be required.

The greatest uncertainty we have through the 50-year life of the project is with regard to bank stabilization just downstream of the US 501 bridge. In 1964, with the section 208 project, many adjacent property owners signed maintenance easements with the county for the flood control project. The property owner where the bank stabilization is occurring did not sign an easement agreement with the county nor have subsequent owners of this property. It is our understanding that the property owner does not want a perpetual easement on his property but is interested in bank stabilization. No agreement or understanding has been reached with this property owner. If no agreement can be made bank stabilization at that site will be removed from the project.

There is uncertainty around development and if best management practices around construction are being followed. Future impacts to habitat in the form of water quality degradation is a possibility if setbacks, buffers, and construction best management practices are not put in place or adhered to.

### 3.10 Selecting an Alternative Plan to Recommend for Implementation

When naturalizing an aquatic ecosystem, habitats and processes are prioritized according to their importance in improving system functionality (Fig. 10). This means that all AAHUs are not equal. Below are rankings of habitats and processes according to their importance in improving system functionality. There are four rankings with the first one listed having the highest priority in improving system functionality.

1. Protecting high quality habitat.
2. Reconnecting in-stream or off-channel habitats.
3. Naturalizing processes such as sediment delivery, light, heat, and organic inputs.
4. Adding structures to improve habitat by diversifying channel morphology.

Table 8 presents the environmental benefits and the annualized costs used in CE/ICA for each of the measures in each of the reaches. It also shows the ranking by importance to system improvement for each individual measure. These rankings help us analyze the environmental benefits derived from each

combination of measures used in the alternative plans to determine which plan is most worth the cost of implementation.

Table 8. Prioritization of Naturalized Habitat Alternatives.

Measures	Acres	Reach	FWOP <sup>1</sup> AAHUs	FWP <sup>2</sup> AAHUs	NET BENEFITS (AAHUs)	Ann <sup>3</sup> . Cost (Oct 2019 Price Lev; 50-yrs @ 2.75%	Rankings by Importance to System Improvement
FPB <sup>4</sup>	36.2	Reach 1	3.62	16.69	13.07	\$20,200	3
LDS <sup>5</sup>	36.2	Reach 1	3.62	6.34	2.72	\$4,400	4
FPB	27.3	Reach 2	2.73	14.7	11.97	\$22,600	3
LDS	27.3	Reach 2	2.73	8.05	5.32	\$6,600	4
RW <sup>6</sup>	27.3	Reach 2	2.73	8.05	5.32	\$7,100	4
RRS <sup>7</sup>	27.3	Reach 2	2.73	9.69	6.96	\$10,600	2
BB <sup>8</sup>	16	Reach 3	1.6	5.68	4.08	\$25,300	2

<sup>1</sup>FWOP = Future without Project

<sup>2</sup>FWP = Future with Project

<sup>3</sup>Ann. = Annualized

<sup>4</sup>FPB = Floodplain Bench

<sup>5</sup>LDS = Log Drop Structures

<sup>6</sup>RW = Root Wads

<sup>7</sup>RRS = Newberry Rock Riffle Structure with Bank Stabilization

<sup>8</sup>BB = Berm Breach

Berm breaching in Reach 3 is an example of how quality of naturalized habitat and its ranking in importance to system improvement might influence the decision of recommending a plan that includes this measure. The environmental benefits derived by breaching the berm to reconnect to off-channel habitat might be considered small for a moderate amount of costs when compared to the environmental benefits derived by implementing other measures at a similar cost (e.g. floodplain benching in Reach 2). Reconnecting the main channel to off-channel habitat was ranked second in improving system functionality. Berm breaching has a higher priority than floodplain benching, yet, floodplain benching produces almost 3 times the environmental benefits compared to berm breaching at a similar cost. Prioritization in improving system functionality may then outweigh the benefits that come with floodplain benching because it is less important in improving system processes. This project did not identify high quality habitat for protection therefore, berm breaching is a measure with the highest ranking in improving system functionality in this project.

The PDT believed that there was a very high likelihood that an alternative plan that included all of the features described above would be identified as cost effective and would provide the greatest benefits to the ecosystem and naturalization of Crabtree Swamp. A very important aspect of naturalizing Crabtree Swamp is reconnecting in-stream habitat by solving the obstacle to fish passage at the US-501 bridge. It was determined that near-continuous flow of water over the perched bridge culvert could not be achieved with the Newberry rock-riffle structure without raising the base-flow elevation of the stream. The number of times conditions might be favorable for passage might increase as many as 45 times a year with a Newberry rock-riffle structure without increasing base-flow elevations. These 45 additional passage events would require rainfall. Location for placement of the Newberry rock-riffle structure is in the most conspicuous part of the project area and would only be functional a few times each year. It is the most expensive feature identified in the study and it is not natural or nature-based in design. Because of these reasons the Newberry rock riffle structure was no longer seen as a viable option. Other fish passage measure dropped out early in the process as being impractical or an ineffective option. Not being able to

solve the fish passage problem, the PDT relied on the Red-breast Habitat Suitability Model and CE/ICA to tentatively select an alternative plan.

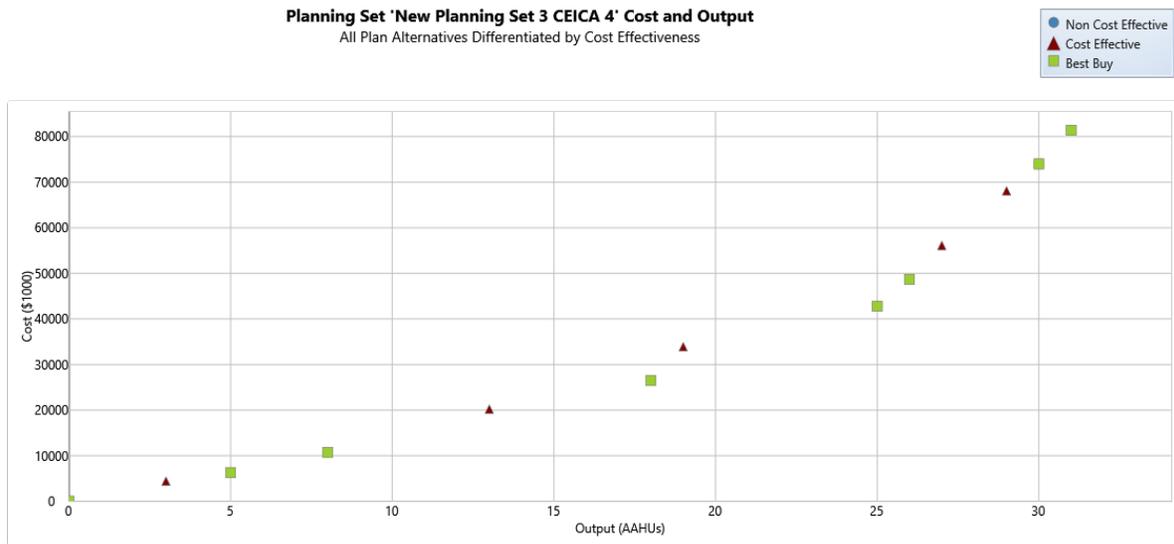
**3.10.1 Is It worth It Analysis on Final Array of Alternatives**

The “is it worth it” analysis for the final array of alternative plans includes quantitative and qualitative selection criteria to help in deciding which plan most effectively, efficiently, and completely naturalizes an aquatic ecosystem while being acceptable to the public and government agencies.

Selection criteria include:

- Incremental benefit
- Incremental cost
- Quality of naturalized habitat
- Number of targeted habitat types to be naturalized

Management measures and their associated environmental benefits (AAHUs) and annual costs (FY 2020 dollars) were utilized in the Institute for Water Resources (IWR) Planning Suite II (planning suite) to conduct Cost Effectiveness and Incremental Cost Analyses (CE/ICA, for more information see Appendix E). The plan generator in the planning suite software used each of the management measures to create all possible combinations of measures. Each of these combinations is referred to as an alternative plan, or simply, alternative. The plan generator created 13 cost effective alternatives. A cost-effective alternative is a plan that is the least expensive plan for a given set of benefits (Fig. 19).



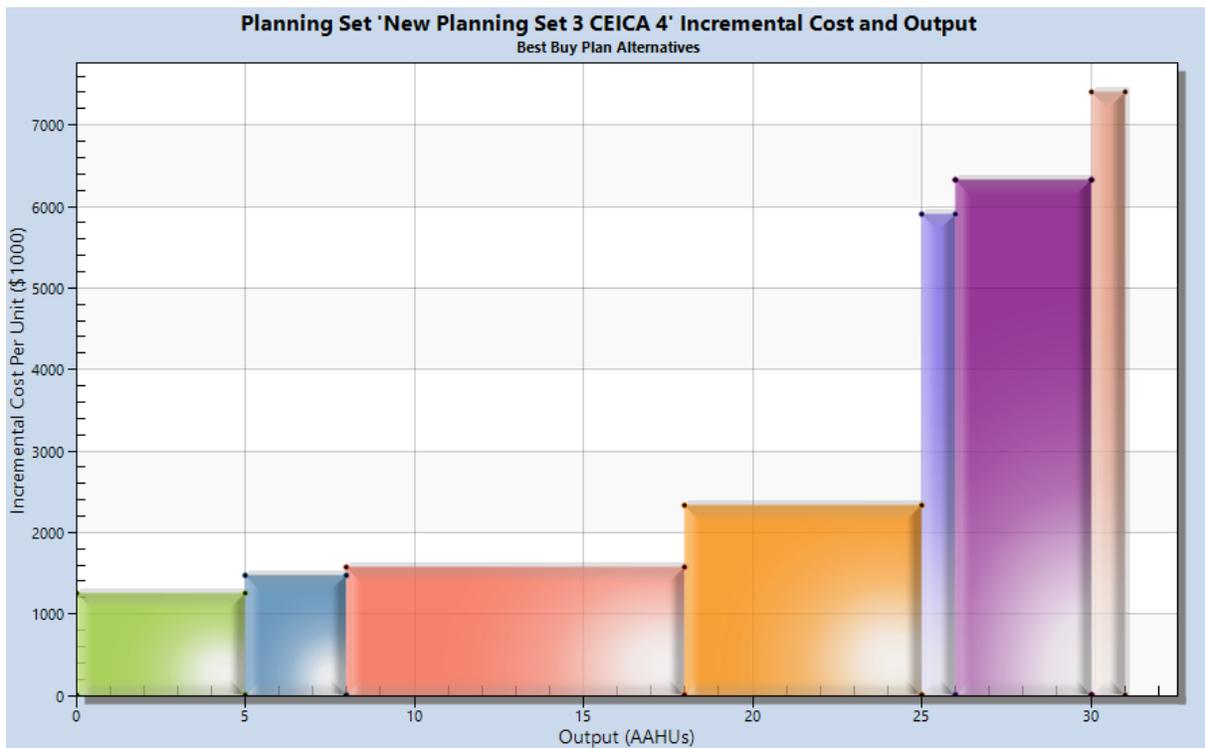
**Figure 19. Cost Effective Plans Generated by IWR Planning Suite II.**

The next step was to perform incremental cost analyses on the cost-effective plans. The ICA identifies plans that maximize the last dollar spent on the last benefit produced. Starting with the no action plan, the incremental cost per incremental benefit is calculated from the no action for each cost-effective plan. The plan with the least incremental cost per incremental output is identified as the first of the “with-project” best buy plans. Then starting with that plan, the incremental cost per incremental benefit is calculated between that plan and each remaining cost-effective plan. The one with the least incremental cost per incremental benefit is identified as the next plan in the array of best buy plans. This process continues until there are no remaining plans. The last plan in the best buy plan is the plan that typically includes all of the measures being considered.

From the cost-effective alternatives, eight were identified as “Best Buy” plans. The results of the incremental cost analyses are shown in Figure 20. **Error! Reference source not found.**

The best buy plans represented in Figure 20 are described below. The horizontal axis (x-axis) represents environmental benefits gained by implementing that plan. The vertical axis (y-axis) represents costs in US dollars.

- Plan 1 (not pictured): No Action
- Plan 2 (green bar): Log-drop structure (Reach 2)
- Plan 3 (blue bar): Log-drop structure (Reach1) + Log-drop structure (Reach 2)
- Plan 4 (red bar): Floodplain bench (Reach1) + Log-drop structure (Reach 2)
- Plan 5 (yellow bar): Floodplain bench (Reach1) + Floodplain bench (Reach 2)
- Plan 6 (light purple bar): Bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2)
- Plan 7 (dark purple bar): Floodplain bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2) + Berm breach (Reach 3)
- Plan 8 (beige bar): Log-drop structure & Floodplain bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2) + Berm breach (Reach 3)



**Figure 20. Incremental Cost Analyses of the “With-project” Best Buy Plans.**

Root wads were not included in any best buy or cost effective plans. Because of this, root wads are no longer being considered as a habitat improvement feature for implementation.

Table 9 presents incremental environmental benefits (AAHUs), incremental cost for each incremental environmental benefit (\$1), and each plan’s first cost or the cost of the project if the project were to be built at current price levels.

**Table 9. Incremental Costs of Best Buy Plans.**

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

**Plan 1 – No Action Plan**

Plan 1 would leave Crabtree Swamp with existing conditions; system processes and functionality would likely continue to deteriorate over time. This would not help to naturalize this scarce ecosystem nor would it help survivability of our regional significant resources. Plan 1 would not reconnect off-channel and in-channel habitat. It would not naturalize processes such as sediment delivery, light, heat, and organic inputs. It would not improve in-stream habitat by diversifying channel morphology.

**Plan 2 - Log-drop structure (Reach 2)**

This plan calls for construction of a log-drop structure in Reach 2. Implementing this plan improves in-stream habitat by diversifying channel morphology. Log-drop structures create pooling where aquatic organisms can seek shelter and find food as lower trophic organisms require these same conditions for lifecycle phases. The water moving over the structure creates aeration improving water quality locally. This reach of the project area is highly channelized, currently, providing very little habitat for aquatic organisms. Five habitat units are realized if this plan is implemented and the cost of that 5<sup>th</sup> habitat unit is \$1,260 (Table 9). This plan realizes 16% of the possible benefits identified in this study at a first cost of \$39,200.

**Plan 3 - Log-drop structure (Reach1) + Log-drop structure (Reach 2)**

This plan calls for construction of a log-drop structure in Reach 1 and a log-drop structure in Reach 2. Implementing these measures will improve in-stream habitat by diversifying channel morphology. The benefit of implementing this plan is that improvements will be made to two reaches within the project area by improving habitat and water quality in support of aquatic organisms. The major drawback of this plan is that no improvements to the system are made from the most downstream reach of

the project area until this upper most reach. Therefore, there is a great segment of channel with impaired conditions what aquatic organisms must navigate before reaching this area of improved conditions. A total of eight habitat units are realized if this plan is implemented; that is three more AAHUs than in Plan 2. The cost of that 3<sup>rd</sup> additional habitat unit gained in this plan is \$1,470 (Table 9). This plan realizes 26% of the possible benefits identified in this study at a first cost of \$92,600. That is a 38% increase in environmental benefits over Plan 2.

**Plan 4 - Floodplain bench (Reach 1) + Log-drop structure (Reach2)**

This plan calls for construction of floodplain benches in Reach 1 and a log-drop structure in Reach 2. Implementing these measures will improves in-stream habitat by diversifying channel morphology. It will also naturalize processes such as sediment delivery, light, heat, and organic inputs by allowing water velocities to slow during high rain events enabling sediments and nutrients to settle out of the water column before re-entering the main channel. A total of 18 habitat units are realized if this plan is implemented; that is 10 more AAHUs than in Plan 3. The cost of that 10<sup>th</sup> additional habitat unit gained in this plan is \$1,580.00 (Table 9). This plan realizes 58% of the possible benefits identified in this study at a first cost of \$442,800; that is a 56% increase in environmental benefits over Plan 3.

**Plan 5 - Floodplain bench (Reach1) + Floodplain bench (Reach 2)**

This plan calls for construction of floodplain benches in Reach 1 and floodplain benches in Reach 2. Implementing these measures will naturalize processes such as sediment delivery, light, heat, and organic inputs by allowing water velocities to slow during high rain events enabling sediments and nutrients to settle out of the water column before re-entering the main channel. A total of 25 habitat units are realized if this plan is implemented. That is 7 more AAHUs than in Plan 4. The cost of that 7<sup>th</sup> additional habitat unit gained in this plan is \$2,330 (Table 9). This plan realizes 81% of the possible benefits identified in this study at a first cost of \$931,100. That is a 28% increase in environmental benefits over Plan 4.

**Plan 6 - Floodplain bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2)**

This plan calls for construction of floodplain benches in Reach 1 and a log-drop structure and floodplain benches in Reach 2. Implementing these measures will improves in-stream habitat by diversifying channel morphology. It will naturalize processes such as sediment delivery, light, heat, and organic inputs by allowing water velocities to slow during high rain events enabling sediments and nutrients to settle out of the water column before re-entering the main channel. A total of 26 habitat units are realized if this plan is implemented. Adding the log-drop structure to Reach 2 yields 1 additional AAHU than Plan 5 and the cost of that one additional habitat unit is \$5,900.00 (Table 9). This plan realizes 84% of the possible benefits identified in this study at a first cost of \$957,800. That is a 4% increase in environmental benefits over Plan 5.

The framework and associated environmental relationships for the Redbreast Sunfish Model were developed using information detailing the distribution, survivorship, growth rate abundance, and reproductive capabilities of the redbreast sunfish and similar species, as described in the literature, to develop the suitability index curves based on how the identified variables could limit population response. The model identifies potential pathways through food, water quality, reproduction, and cover components. However, the model gives *equal weight to all variables* so classifying a variable under a specific component is not required. The model outcome is an HSI with a value from 0 to 1 (1 representing optimal habitat) that is based on the minimum suitability index value (see Table 10).

**Table 10. Redbreast Sunfish Habitat Suitability Index Model.**

Species	Life Requisites	HIS Formula
Redbreast Sunfish	Food, Cover, Reproduction, Water, Quality, Other	HSI = Minimum SI of [V1, V2, V4, V5, V6, V7, V8, V9, V10, V13]
	Habitat Variables	
	V1	Hard Structural Cover
	V2	Vegetative Cover
	V4	Temperature During Spawning Season
	V5	Current Velocity
	V6	Substrate Composition
	V7	pH
	V8	Dissolved Oxygen
	V9	Turbidity
	V10	Temperature During Growing Season
	V13	Stream Width

The AAHUs for each alternative are based on the habitat suitability index value (HSI) which is based on the minimum variable score and the benefits accumulated over a 50 year period based on the lowest SI score at various intervals (1 year, 5 year, 10 year, 25 year, and 50 year). The acreage of the area evaluated also factors into the scores.

For Plan 5, Floodplain bench (Reach 1) + Floodplain bench (Reach 2), achieving 25 AAHUs with annualized costs of \$42,800.

For Plan 6, Floodplain bench (Reach 1) + Log-drop structure & Floodplain bench (Reach 2), the AAHUs increase to 26 and the annualized cost increases to \$48,700. Based on the increase of 1 AAHU, it appears there is little benefit to adding the log structures. However, since the AAHUs are based on the lowest SI score, this does not show all of the benefits provided by the log structures. Adding the log structures increased benefits for variables V1, V2, V3, and V10. However, these benefits did not show up in the final AAHUs because the AAHU score is based on the variable with the lowest value. Because of the environmental benefits gained by placing the log-drop structure in reach 2 warrant the costs, the PDT believes this plan should move forward in consideration for implementation.

**Plan 7 - Floodplain bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2) + Berm breach (Reach 3)**

This plan calls for construction of floodplain benches in Reach 1, log-drop structures and floodplain benches in Reach 2, and a series of 6 berm breaches in Reach 3. Implementing log-drop structures will improve in-stream habitat by diversifying channel morphology. Floodplain benching will naturalize processes such as sediment delivery, light, heat, and organic inputs by allowing water velocities to slow during high rain events enabling sediments and nutrients to settle out of the water column before re-entering the main channel. Berm breaching will reconnect the main channel with off-channel habitat.

Reconnection of habitat is the highest priority in restoring functionality to system processes (Table 8). A total of 30 habitat units are realized if this plan is implemented. That is 4 more AAHUs than in Plan 6. The cost of that last additional habitat unit gained in this plan is \$6,325.00 (Table 9). This plan realizes 97% of the possible benefits identified in this study at a first cost of \$1,128,400. That is a 13% increase in environmental benefits over Plan 6.

**Plan 8 (beige bar): Log-drop structure & Floodplain bench (Reach1) + Log-drop structure & Floodplain bench (Reach 2) + Berm breach (Reach 3)**

Plan 8 is worth the Federal and local investment. It will realize 31 habitat units. That is 1 additional AAHU than Plan 7 and will enhance aquatic habitat throughout the system in multiple ways. Like Plan 7, the AAHUs do not reflect all of the benefits provided by adding a log drop structure to Reach 1 because the AAHUs are based on the lowest SI value. Including a single log drop structure in Reach 1 would provide benefits in four other habitat variables that are not reflected in the AAHU score. Plan 8 realizes 100% of the possible benefits identified in this study and is a 3% increase in environmental benefits over Plan 7. The first cost of Plan 8 is \$1,261,800. The cost of the additional habitat unit is \$7,400.00 (Table 9).

The PDT believes that Plan 8 is worth the additional costs to bring habitat improvement in more one way throughout the study area. This plan effectively improves the functionality of the system by naturalizing processes for the lowest incremental cost per unit of incremental benefit. This plan naturalizes processes such as sediment delivery and improves water quality by improving light, heat, and organic inputs which are limiting factors for survivability of the significant resources and proxy species we have identified in this study. By implementing structures within the system that mimic what naturally occurs in the region, little to no maintenance over the 50-year life of the project will be necessary. Naturalizing sediment delivery, light, heat, and organic inputs will increase the likelihood that species diversity and abundance will improve as these functional improvements will be self-sustaining over the 50-year life of the project. Plan 8 has been formulated to be acceptable to Horry County, the public, and State and Federal resource agencies. It is complete in that it has included technical input from State and Federal resource agencies, real estate has been considered, and monitoring, maintenance, and adaptive management framed. It is cost effective best buy plan and will make a significant contribution to naturalizing an impaired aquatic ecosystem and enhancing habitat for declining populations of imperiled aquatic resources.

## **4 Preferred Plan**

The Preferred Plan is Plan 8 and is the NER plan. This plan naturalizes Crabtree Swamp by placing log-drop structures and floodplain benches in reaches 1 and 2. This will greatly improve stream processes leading to enhanced functionality of the system. Morphological heterogeneity will be reintroduced to the channel providing greatly needed habitat for significant and proxy species. Revegetation of the shoreline will provide shade and detritus, carrying the right types of nutrients to the system, helping improve water chemistry in support of the significant and proxy species in this study. Berm breaching in reach 3 will reconnect off-channel habitat with the main channel. High velocity flows of water will be allowed to spread out and slow, depositing sediments and nutrients before reentering the main channel.

### **4.1 Description of the Preferred Plan/NER Plan**

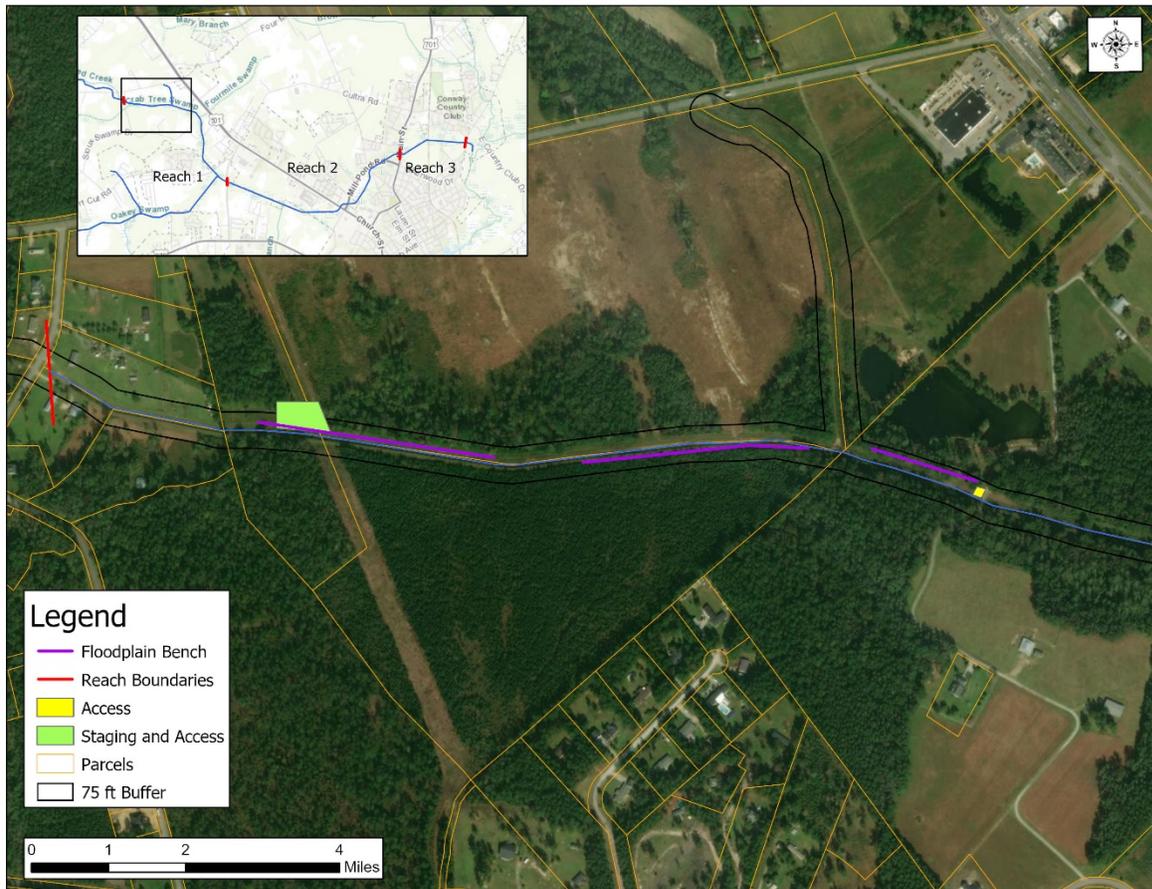
The preferred plan has features that positively affect the entire project area. Though the PDT was able to propose measures that achieve off-channel to main-channel reconnection of habitat, it was unable to recommend measures to reconnect in-channel habitat at the perched culvert under the US-501 bridge. Currently, water elevation is 6” above the bottom of the culvert during certain storm events. This is the water elevation that was identified as the minimum water elevation needed for *L. auritus* to pass through the culvert at the US 501 bridge. The PDT was unable to formulate a recommendation to achieve this goal without raising the base elevation of water in the channel. Frequency of passage could have been achieved. The rock-riffle structure could have increased the number of times there was a 6” water elevation in the culvert by as many as 45. With the rock-riffle structure being the most expensive and conspicuous feature associated with the project, anything less than a near continuous water elevation of 6” moving through the culvert year-round was deemed inadequate. Bank stabilization at the US 501 bridge was only considered in association with the rock-riffle structure. There was a need to stabilize the bank in order to construct the rock-riffle structure. With the inability to provide continuous flow of water through the culvert at a 6” elevation the rock-riffle structure and bank stabilization measures were deemed inefficient, ineffective, and were dropped from further consideration.

#### **Aquatic ecosystem restoration Features**

- Floodplain Benching
- Log-drop Structures
- Berm Breaching

### Reach 1 – Daniel Road to El Bethel Road

Reach 1 runs from Daniel Road at the upstream end of the project area to the bridge at El Bethel Road. The management measures proposed for Reach 1 included four floodplain benches (alternating banks) and a log drop structure. The component locations are shown in Figures 21 and 22.



**Figure 21. Placement of 3 of the 4 Floodplain benches proposed in Reach 1.**

The floodplain bench design is the same as that already constructed. A profile sketch of the design is shown in Appendix A, Figure 2-2. It consists of a 12-ft wide flat riparian bench at the 50% Annual Exceedance Probability (AEP), or 2-year, 24-hour flood elevation, a 30-ft wide bench at 1.0% slope (moving up the bank perpendicular to the channel), and a 1V:1H slope to tie into natural grade. Any areas within the floodplain bench footprint that are at a lower elevation than the bench design will not be filled in. The floodplain benches will be planted with native wetland vegetation. The lengths and bench elevations are as follows (moving from upstream to downstream):

- Reach 1 bench #1: 987 LF of floodplain bench at elevation 25.75-ft NAVD88 on the left bank (looking downstream).

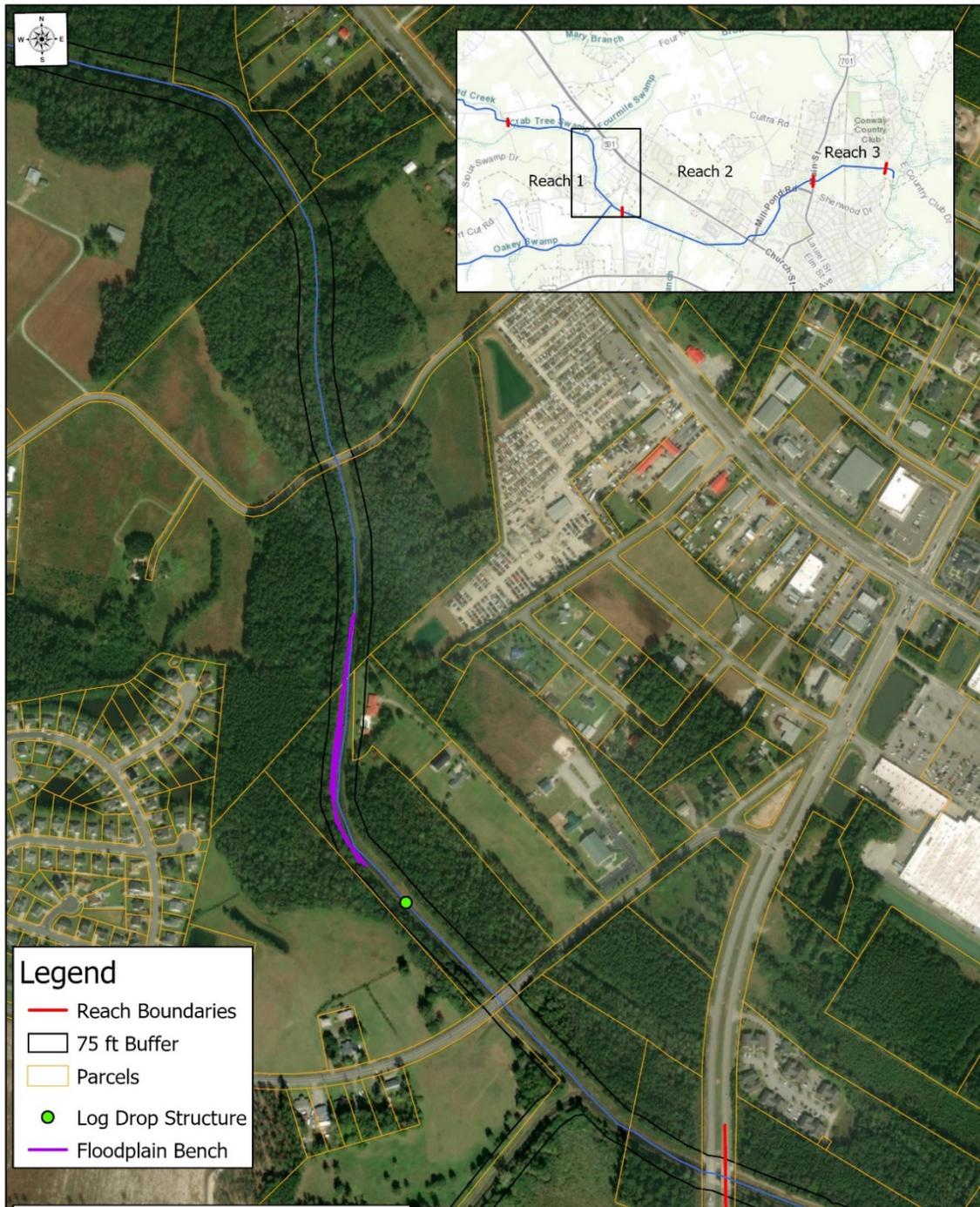


Figure 22 . Placement of 4th Floodplain Bench and Log-drop Structure Proposed in Reach 1.

- Reach 1 bench #2: 900 LF of floodplain bench at elevation 23.30-ft NAVD88 on the right bank (looking downstream).
- Reach 1 bench #3: 455 LF of floodplain bench at elevation 22.75-ft NAVD88 on the left bank (looking downstream).

- Reach 1 bench #4: 1119 LF of floodplain bench at elevations ranging from 17.15 down to 15.79-ft NAVD88 on the right bank (looking downstream).

Drop structures are low-head structures constructed across the entire width of a channel, and are designed to stabilize channel grades, improve fish passage, create habitat, and reduce erosion and incising (Saldi-Caromile et.al, 2004). The log drop structure is designed to have a 24-inch log across the channel, placed at an elevation that is largely submerged, with a 10-ft penetration into the bank on each side. Approximately 2 cubic yards (CY) of riprap will be placed on each bank to anchor the log. The largest D50 will be determined during the Design and Implementation Phase (DI) to withstand the 4% AEP storm velocities. The riprap will be covered with soil and plantings. The sketch in Appendix A, Figure 2-3 shows the concept, as described by Saldi-Caromile et al (2004).

## Reach 2 – El Bethel Road to US Highway 701

Reach 2 runs from El Bethel Road to US Highway 701. The management measures proposed for Reach 2 includes three floodplain benches (all on the south bank), removal of culverts, and replacing the two existing, naturally-occurring drop structures just downstream of El Bethel Road assuming they are no longer in place when design begins (Fig. 23).

All floodplain benches in this reach are located on the south bank, due to the presence of utility pipes on the north bank. The floodplain benches will be planted with native vegetation. The bench dimensions are as follows:

- Reach 2 Bench #1: 486 LF of floodplain bench at elevation 12.80-ft NAVD88 on the right bank (looking downstream).
- Reach 2 Bench #2: 888 LF of floodplain bench at elevation 12.40-ft NAVD88 on the right bank.
- Reach 2 Bench #3: 1878 LF of floodplain bench at elevation 5.0-ft NAVD88 on the right bank.

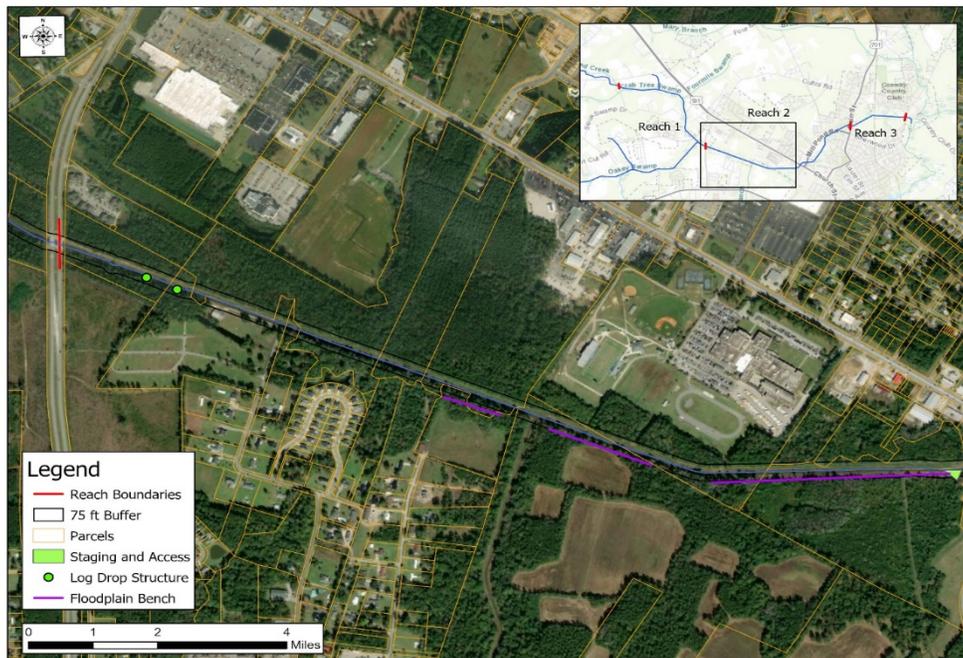


Figure 23. Placement of Features Proposed in Reach 2.

### Reach 3 – Highway 701 Bridge to Long Avenue

Reach 3 runs between Highway 701 to Long Avenue, at the downstream end of the project area. The management measures proposed for Reach 3 included six berm cuts in existing berms along the banks on both sides of the channel. The locations of these berm cuts, shown in Figure 24, were chosen as they are in areas along the berms that are low in elevation as a result of naturally occurring erosion. The design includes each cut to be made down to elevation 6.0-ft NAVD88, with side slopes of 3H:1V on each side up to grade, and armoring with articulated concrete block mat (ACBM) to prevent erosion. The cut measurements are as follows, moving from upstream to downstream:

- 1 - south bank looking downstream, approximately 280 LF
- 2 - north bank looking downstream, approximately 200 LF
- 3 - south bank looking downstream, approximately 300 LF
- 4 - north bank looking downstream, approximately 150 LF
- 5 - north bank looking downstream, approximately 350 LF
- 6 - south bank looking downstream, approximately 370 LF

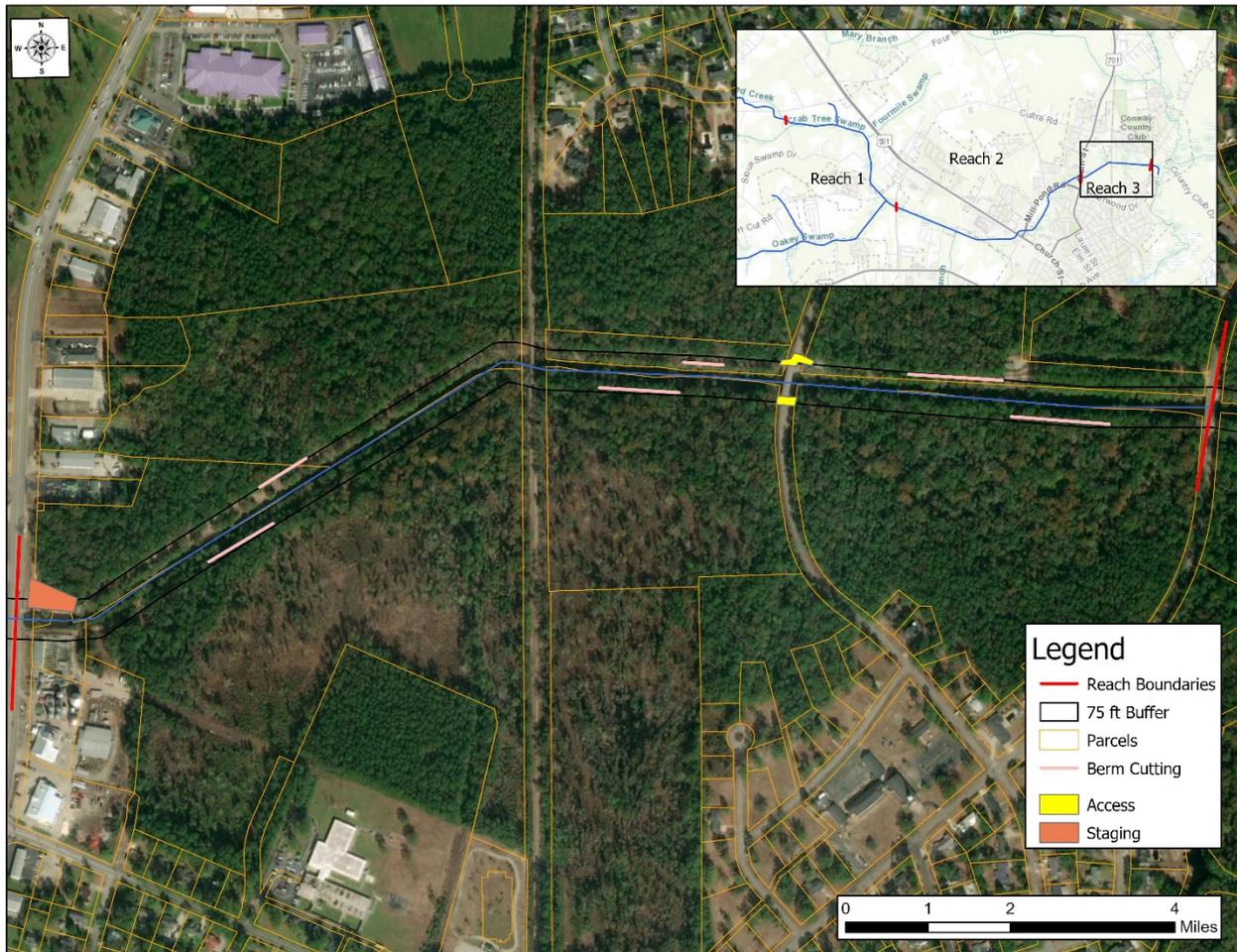


Figure 24. Placement of Berm Breaches Proposed in Reach 3.

## 4.2 Benefits Gained for Regionally Significant Resource

Naturalizing Crabtree Swamp will provide the greatest opportunity of saving *T. pullus* from extirpation from in the Waccamaw River watershed. By improving dissolved oxygen levels and reducing sedimentation *T. pullus* has a better chance at survival in Crabtree Swamp. It will also relieve some of the pressures on the survivability of *A. rostrata* in the region. The anthropogenic blockage of stream systems is greatly reducing the amount of habitat available to *A. rostrata*. By improving water chemistry in Crabtree Swamp this will give *A. rostrata* an opportunity to increase population density in the system as they prefer 4 mg/L of dissolved oxygen or more to thrive.. *Lepomis auritus* is the proxy for health of the system for our significant resource species. This family of fish are important on their own. They are game species and an important food source for iconic species such as the wood stork. The implementation of this plan will allow *L. auritus* to thrive and with it comes increased diversity.

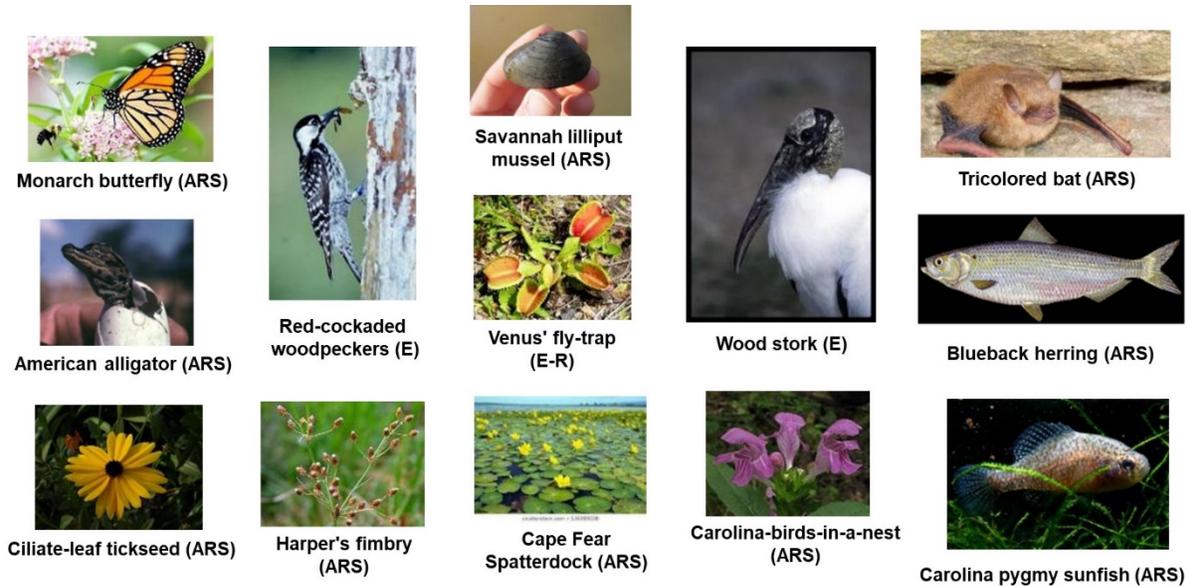
### 4.2.1 Scarcity

Over half of the wetlands in the 48 conterminous United States have been lost since Europeans began settling North America in the early 1600s. They were considered impediments to travel and food production as well as breeding grounds for disease (Dahl & Allord, 1994). Drainage of swamps in South Carolina was first recorded in 1754. The first of the Swamp Land Acts was passed in 1849 with follow-on legislation in 1850 and 1860. This legislation allowed the federal government to grant wetlands to the states for the purpose of drainage and reclamation making it clear that the Federal Government promoted these practices in support of settlement and development. This set the stage for significant loss of wetlands in South Carolina between 1800 and 1860 (Dahl & Allord, 1994). Between 1900 and 1950 there were further notable wetland losses in South Carolina. It was during this period that the Federal government provided free engineering service to farmers to drain wetlands. The Federal government entered into cost-share drainage projects and it helped stand-up drainage districts to coordinate effort to remove surface water from wetlands. Over 80% of wetland losses are attributed to agriculture where tile and open-ditch drainage were responsible for the loss of 550,000 acres per year on average from the mid-1950s to the mid-1970s (Dahl & Allord, 1994).

### 4.2.2 Representativeness

The coastal plains of South Carolina are part of a larger palustrine wetland system that is a known biodiversity hotspot, historically dominated by trees, shrubs, persistent emergent vegetation, mosses and lichens (Center for Biodiversity, 2010; USACE, 1982; USFWS, 1979). Over millions of years, this ecosystem has become a unique assemblage of plants and animals found nowhere else on earth. The integrated ecosystem of aquatic and riparian habitats provides greater environmental outputs than would be possible as separate habitats. For example, 62% of fish species found in the US are found in the southeast. Ninety-one percent of the freshwater mussel species found in the US are found in the southeast. Forty-eight percent of the damselfly species found in the US are found in the southeast. There are more amphibian species found in the southeast than any other region in the US.

Horry County and Crabtree Swamp represents the robustness of these systems to persevere and the great need to reverse the anthropogenic pressures currently being applied to these systems. There are 35 at-risk (ARS), candidate, threatened, or endangered (E, E-R (under review)) species recognized by the US Fish and Wildlife Service with known occurrences in Horry County (USFWS, 2020). Thirteen of these species either live in the freshwater environment or are dependent upon it for survival (Fig 25)



**Figure 25. Subset of Listed Species Known to Occur in Horry County.**

#### 4.2.3 Status and Trends

Rivers and streams throughout the nation are highly modified and disconnected, especially pertaining to aquatic life passage, sedimentation, and nutrient loading within stream systems. Without the implementation of the NER plan, the functionality of Crabtree Swamp would continue to degrade. This degradation contributes to the shrinking in acreage of the unique and biodiverse wetland ecosystem in the southeast United States. This includes the continued pressures leading to localized extinction of many species including the species of regional significance. The pressures on this system can be alleviated. The segment of Reach 2 that was used as a reference stream is a testament to how nature rectifies anthropogenic intervention if human manipulation ceases. Implementation of these measures will accelerate naturalization and the negative impacts to system processes. This plan will improve habitat connectivity, slow high-water velocities, allow sediments and nutrients to settle out of flood waters before re-entering the main channel, and by improving instream habitat by increasing morphological diversity.

#### 4.2.4 Connectivity

Connectivity is critical for improving survivability of the significant resources identified in this study. The dispersal of *T. pullus* and *A. rostrata* are limiting factors in their localized survivability. This plan will improve connectivity to habitat that will help these species reestablish and thrive in the system by providing off-channel access for rearing and for respite during high velocity events.

#### 4.2.5 Limiting Habitat

Fragmented habitat is causing localized extinction of *A. rostrata*. Poor water quality is causing the demise of *T. pullus*. Increased sedimentation is interfering with oxygen exchange in both of these significant resources. These are all limiting habitat factors that are being addressed by the NER plan. Implementing this plan will greatly improve habitat limiting survivability of the significant resources.

#### 4.2.6 Biodiversity

The central concept driving the Crabtree Swamp aquatic ecosystem restoration study is improving system processes to improve diversity of habitats within the study area. Diversity of habitats will provide resources for a diverse community of lower trophic level organisms which in turn supports a more diverse upper level trophic community. The proposed measures improve the likelihood of survivability of the

resources of regional significance, and provides the basis to improve biodiversity within the entire Crabtree Swamp watershed.

#### **4.3 Benefits of the Preferred plan to Other Federal Goals and Objectives**

Improving habitat for the significant resources identified in this plan will help to improve over all biodiversity. If habitat improves for *L. auritus* then habitat improves for the other sunfish species identified in the system. Sunfish species are an important food source for the remaining breeding pairs of wood storks that depend on the dwindling wetlands of South Carolina. Wood storks are an endangered species according to USFWS and *T. pullus* are a species at risk. Both are protected by SC-DNR. If habitat improves for filter feeder such as *T. pullus* then the improved water quality they help provide will be beneficial for all aquatic organisms in the system.

## **5 Environmental Consequences**

### **5.1 Environmental Consequences of No-Action and Preferred Plan Alternatives**

This chapter analyzes the potential environmental consequences of implementing the no-action alternative and the preferred plan alternative. The “no-action” alternative serves as a baseline against which the preferred plan alternative can be evaluated. This section describes the impacts of the two alternatives for each of the following resources:

- air quality
- biological resources
- climate change, greenhouse gases, and sea level rise
- cultural resources
- geology and soils
- groundwater
- hydrology and floodplains
- noise
- recreation and aesthetics
- socioeconomics and environmental justice
- threatened and endangered species
- transportation, and utilities
- water quality
- wetlands

Potential environmental consequences associated with hazardous and toxic waste, and land use were evaluated through a preliminary screening process and were determined to have no effect. Therefore, those resources will not be analyzed in this section.

### **5.2 Air Quality**

#### **5.2.1 No-action Plan**

Under the no-action plan, there would be no construction activities or soil disturbance and therefore, no impacts to existing air quality.

#### **5.2.2 Preferred Plan**

Adverse effects to air quality may occur during construction of the preferred plan. However, the effects are expected to be temporary and minor. There would be localized reduction in the air quality during construction as a result of exhaust emissions from construction equipment and fugitive dust from ground disturbing activities. These impacts would be temporary and minor in nature and should cease once construction activities are completed. Horry County is currently in attainment and there would be no long-term change in ambient air quality as a result of the preferred plan.

### **5.3 Biological Resources**

#### **5.3.1 No-action Plan**

Under the no-action plan, restoration activities would not occur, and the area would continue to be maintained by the city. Under the current maintenance plan and along the upper reaches of the study area extending from Daniel Road to Highway 501, vegetation is removed along the stream banks on a routine basis, leaving denuded areas that do not provide wildlife shelter or habitat. Without woody vegetation, there is little if any leaf litter to support macroinvertebrate populations in the stream and the lack of shading leads to increased water temperatures, discouraging fish spawning during the summer months. During storm events, increased velocities would continue to erode stream bed and banks, creating

restrictions to fish passage at road crossings. Under this plan, there would be long-term negative impacts to biological resources.

### **5.3.2 Preferred Plan**

Under the preferred plan, construction of the floodplain areas with plantings would provide shelter and habitat for small mammals, birds, reptiles, and amphibians that would typically occupy riparian areas; and provide leaf litter and shading of the stream habitat, thereby attracting macroinvertebrates and fish species. The installation of log drop structures would create pools, contributing to bed diversity and reducing stream velocities during storm events. Pools also provide refuge for fish species during spawning season and periods of low flow. Breaching of the berms along Crabtree Swamp from Highway 701 to Long Avenue would allow a more natural and unimpeded access to the adjacent floodplain wetlands during storm events, reducing stream velocities and increasing habitat for aquatic species. Species that currently inhabit the study area would most likely relocate during construction but return once construction activities have ceased. This would result in temporary and minor impacts to biological resources that would be offset by the proposed habitat improvements. Overall, implementation of this alternative would provide long-term beneficial effects to biological resources.

## **5.4 Climate Change, Greenhouse Gases, and Sea Level Rise**

### **5.4.1 No-action Plan**

Under the no-action plan, there would be no increase in greenhouse gases since no construction activities would take place. Based on the climate assessment (Appendix A, Engineering), over the 50-year life of the project we should see a small upward trend in precipitation as well as increased precipitation variability. The climate assessment indicates a slight temperature decrease trend for the project area.

### **5.4.2 Preferred Plan**

Under the preferred plan, there would be temporary, minor increases in greenhouse gas emissions due to exhaust emissions from construction equipment. However, as discussed under Section 5.2.2, these impacts will be short-term and minimal.

An evaluation of the vulnerability of the project features due to Sea Level Rise was performed using a web based USACE model (Appendix A, Engineering). The results indicate that for the 50-year project, sea level rise will reach 0.66, 1.26, and 3.22 feet NAVD88 for the low, intermediate, and high curves. Based on the intermediate curve, sea level rise will not affect the upper reaches of the study area. Wetlands adjacent to Crabtree Swamp and below Highway 701 are considered low elevation areas that could experience increased flooding and increased salinity levels within the project timeframe. The proposed measures are intended to improve stream habitat by restoring floodplain connectivity and improving bed diversity which will result in reducing flow velocities during storm events and providing refuge for aquatic species during periods of low flow. These benefits should improve resiliency of the stream system to withstand potential impacts due to future sea level rise and climate change.

## **5.5 Cultural Resources**

### **5.5.1 No-action Plan**

Under the no-action plan, there would be no adverse effects to cultural resources since there would be no construction activity or ground disturbance.

### **5.5.2 Preferred Plan**

Implementation of the preferred plan would involve soil excavation within the riparian corridor to create floodplain benching along the upper reaches between Daniel Road and Highway 501. The stream

banks will be excavated to a maximum elevation of approximately 5 feet NAVD 88. While review of the SCDAAH database did not reveal any known historic sites along Crabtree Swamp, there is the potential for unidentified archeological sites to exist since early settlements were commonly located near water sources. The study area has not been surveyed for cultural resources therefore, excavation to this depth could potentially uncover unidentified cultural sites or artifacts. However, the risk is minimal based on past disturbance of the floodplain due to dredging and maintenance activities. Consultation with the State Historic Preservation Office (SHPO) will be initiated during the public review.

## **5.6 5.6 Geology and Soils**

### **5.6.1 5.6.1 No-action Plan**

Under the no-action plan, no ground disturbing activities would occur and there would be no changes to the topography or geology of the study area. However, soil loss would continue to occur from erosion of the stream bed and banks during high flows.

### **5.6.2 5.6.2 Preferred Plan**

Under the preferred plan, construction of floodplain benches would permanently remove approximately 41,954 cubic yards of soil from the study area and the soil would be transported to an offsite placement area to be determined by the non-federal sponsor. However, the top layer of soil (approximately 6-12 inches) would be stockpiled during excavation and replaced prior to planting to encourage vegetation growth and survival. The downstream breaches would remove soil from a berm comprised of soils left from dredging of the stream channel. Best Management Practices (BMPs) would be implemented during construction to minimize sedimentation and erosion from soil disturbance. The excavation should not exceed 5 feet NAVD 88. This plan would cause permanent impacts to topography and soils. However, the study area has experienced soil disturbance from past anthropogenic activities including maintenance and dredging of the channel, streambanks, and terrace. The excavated floodplains would be re-vegetated with native trees and shrubs that will stabilize and enrich the soils. Therefore, impacts to soils in the study area would be minimal overall.

No faults have been identified within the study area and Conway is located in a region classified as a low seismic risk area (SCDNR 2020). Based on data collected from 1698 to present, no earthquakes have occurred in Horry County (SCEMD 2020). There would be no impacts to geologic faults due to implementation of this plan.

## **5.7 5.7 Groundwater**

### **5.7.1 5.7.1 No-action Plan**

Under the no-action plan, there would be no changes in the existing groundwater conditions in the study area and therefore, no impacts to groundwater resources.

### **5.7.2 5.7.2 Preferred Plan**

Under the no-action plan, there would be beneficial effects to groundwater. Construction of a vegetated floodplain bench will allow for floodwaters to spread out and infiltrate slowly, replenishing groundwater resources and maintaining baseflow in the channel. Widening the downstream breaches between Highway 701 and Long Avenue will increase floodplain connectivity between the stream and the adjacent wetlands, which should raise groundwater levels in the wetland areas.

## **5.8 5.8 Hydrology and Floodplains**

### **5.8.1 5.8.1 No-action Plan**

Under the no-action plan, there would be no changes to the flow regime of Crabtree Swamp and no construction would occur within the floodplain. Typical of urban areas, high velocity stream flows during rain events would continue to erode streambanks and bed substrate. Eroded sediments would be

transported downstream, disrupting aquatic species and burying their habitat. As a result of this alternative, there would be no changes to hydrology or the floodplain, however the channel would remain disconnected. As a result, the channel would continue to degrade due to high velocity flows during storm events.

### **5.8.2 Preferred Plan**

The preferred plan will involve direct impacts to the Crabtree Creek floodplain associated with construction activities related to floodplain benching and widening of berm breaches. However, these impacts would be temporary, and excavation of the floodplain is intended to restore floodplain connectivity and will result in a reduction of stream flow velocities during storm events by providing additional storage capacities. The log drop structures are intended to increase bed diversity by encouraging the development of pools, which may also aid in reducing flow velocities. Each measure under this alternative was evaluated to determine its potential to increase flood risk (Appendix A, Engineering). Results from HEC-HMS modeling indicate that this alternative would not cause an increase in base flood elevations or contribute to downstream flooding. Therefore, implementation of this plan would comply with E.O. 11988 and would not cause permanent impacts to floodplains.

## **5.9 Noise**

### **5.9.1 No-action Plan**

Under the no-action plan, construction activities related to ecosystem restoration would not occur. Therefore, there would be no increase in noise levels within the study area.

### **5.9.2 Preferred Plan**

Under the preferred plan, increased noise levels would be expected during the construction period due to the operation of heavy equipment. In the upper reaches of the study area, Crabtree Swamp is bordered primarily by forested areas that separate the stream from low and high density residential, agriculture fields, and a cemetery and a school. In the lower reach, the stream is surrounded by a wide forested buffer and the adjacent walking trail. Noise associated with construction activities would occur during daytime hours and would be of limited duration. In addition, the forested areas would provide a buffer to the sounds of heavy equipment. Therefore, noise impacts associated with this plan would be short-term and minor.

## **5.10 Recreation and Aesthetics**

### **5.10.1 No-action Plan**

Under the no-action plan, the proposed restoration measures would not occur. Regular flooding of the recreational trail adjacent to Crabtree between Highway 701 and Long Avenue would continue to occur during rain events, reducing access to the walking trail. The upper reaches of Crabtree Swamp would remain a homogenous trapezoidal channel with steep maintained banks and lack of woody vegetation that provide little if any visual attraction. The recreational trail adjacent to the lower reach of Crabtree Swamp would continue to flood during storm events due to the existing berm separating the stream from its floodplain.

### **5.10.2 Preferred Plan**

Crabtree Swamp was a low gradient coastal plain swamp prior to its channelization in the 1960s. While the proposed measures under the preferred plan will not return Crabtree Swamp to its historic condition, they will increase ecosystem functions while improving aesthetics through construction of a forested riparian floodplain corridor. Installation of structures to promote bed diversity and bank stabilization would reduce storm flows and improve aquatic habitat, attracting increased numbers of migratory bird species and waterfowl for nature enthusiasts and bird watchers. Widening of the downstream breaches will allow unimpeded flows to the adjacent wetlands, reducing flooding of the

recreational trail during high flows. While the public would be unable to utilize the recreation trail during construction activities on the adjacent berm, the impacts would be temporary and minor. Overall, implementation of this alternative would result in beneficial effects to recreation and aesthetics.

## **5.11 Socioeconomics and Environmental Justice**

### **5.11.1 No-action Plan**

Under the no-action plan, there would be no change in existing conditions and no impacts to the human environment would occur. Similarly, this alternative would not result in adverse impacts to any populations; low income, minority or otherwise.

### **5.11.2 Preferred Plan**

Under the preferred plan, there would be no increase in adverse flood risk to adjacent properties since this was established as a primary constraint for the study. The proposed restoration measures would convert Crabtree Swamp from a trapezoidal channel to a more natural and aesthetically pleasing forested environment that provides value to the community. Also, the proximity to the school could provide opportunities for enhanced outdoor educational experiences. Breaching of the floodplain berm along the lower reach would allow water in the channel to spread out onto the floodplain during high water events, reducing the potential for flooding of the existing adjacent recreational trail and providing additional benefits to the local community. Therefore, the preferred plan is expected to have beneficial effects to the population and would not result in adverse effects to low income or minority populations.

## **5.12 Threatened and Endangered Species**

### **5.12.1 No-action Plan**

Under the no-action plan, the channel would remain a homogenous trapezoidal channel with little habit for macroinvertebrates or fish. High velocity flows would continue to erode streambanks and increase sediment loading downstream, burying aquatic species. The berms along the stream channel from Highway 701 to Long Avenue would continue to restrict flows to the adjacent wetland habitats, reducing foraging habitat for bird species. This alternative would not prevent the Northern long-eared bat or the Red cockaded woodpecker from utilizing the study area for foraging.

### **5.12.2 Preferred Plan**

There are no known occurrences of state or Federal threatened or endangered species within the project area (SCDNR 2020). One state at-risk species, the American eel, was identified in 2007 in Crabtree Swamp, between El Bethel Road and Highway 501. There are no known Northern long-eared bat hibernacula in the study area and no tree removal is anticipated for the proposed measures. Managed pine forests are located in the near vicinity; however, there are no identified red cockaded woodpecker nests in these locations. The study area does not contain suitable habitat to support a colony of the American wood stork and it would be very unlikely to find manatee in Crabtree Swamp. However, the study area could be used for foraging by the wood stork as well as other bird species, and the Northern long-eared bat. The proposed measures would provide beneficial effects to these species. The floodplain benching along the upper reaches would contribute to maintaining stream baseflows in the summer months when fish species are spawning. The planted vegetation would add leaf litter and woody debris to the channel, providing food and habitat for aquatic insects, and maintaining ecosystem structure by supporting the food chain. The aquatic insects would attract fish species which provide a food source for reptiles, small mammals and bird populations. Breaching of the berm along the lower reach will allow more natural and unimpeded hydrology to the adjacent floodplain wetlands, improving foraging habitat for the endangered American wood stork. The construction activities could result in temporary impacts to foraging species; however, any disruptions would be of limited duration and species would be expected to return to the area once construction activities cease. USACE has determined that the project may affect,

but is not likely to adversely affect the Northern long-eared bat, and the American wood stork, and would have no effect to any other threatened or endangered species listed for Horry County.

### **5.13 Transportation and Utilities**

#### **5.13.1 No-action Plan**

Under the no-action plan, there would be no impacts to transportation or utilities.

#### **5.13.2 Preferred Plan**

Under the preferred plan, there would be short-term, minor impacts to traffic during construction activities. Traffic congestion could occur during periods where construction vehicles are transporting equipment and/or materials to and from construction sites, particularly along Highway 501. However, any delays associated with this alternative would be less than significant and would cease once construction is complete. No construction would occur within the utility easement in Reach 1.

### **5.14 Water Quality**

#### **5.14.1 No-action Plan**

Under the no-action plan, no measures would be implemented, and the stream channel would continue to degrade from fluctuations in flow regime and stream temperatures due to disconnection from its floodplain, and the absence of riparian vegetation. Dissolved oxygen levels would remain low, and turbidity levels would remain elevated, adversely affecting aquatic species survival.

#### **5.14.2 Preferred Plan**

The preferred plan would lead to short term increases in turbidity levels during construction. However, Best Management Practices (BMPs) would be implemented as appropriate to minimize the migration of sediments downstream. While the study is not intended to improve water quality impairments caused by other entities, this alternative would result in beneficial effects to water quality associated with reduced stream velocities during storm events and maintenance of baseflows during periods of low flows. Crabtree Swamp has been included on the state 303(d) list for low dissolved oxygen levels since 2006. Construction of floodplain benching with planting of vegetation will allow storm flows to spread out and slowly filter through the soil. In addition to reducing stream velocities that cause bank erosion and increase turbidity, the soil filtration process will remove pollutants from stormwater runoff and facilitate more stable downstream flows, supporting DO improvements. Overall, this plan could result in positive effects to water quality.

### **5.15 Wetlands**

#### **5.15.1 No-action Plan**

Under the no-action plan, no construction would occur, and no wetlands would be affected.

#### **5.15.2 Preferred Plan**

The preferred plan includes excavation of the stream banks to create a floodplain bench, installation of structures within the stream channel and banks, and widening of berms combined with installation of a low water crossing. While the NWI maps depict the entire floodplain area as wetlands, channel incision that occurred as a result of past dredging has lowered groundwater levels in many areas adjacent to the stream, leaving most of these terraced areas lacking sufficient hydrology to support wetlands. Continued channel maintenance has prevented natural channel evolution which would have provided an opportunity for floodplain wetland development. Small areas of wetlands that may exist within the study area could be temporarily impacted by installation of the log structures and berm widening in the lower reaches. However, over the long-term, the restoration measures are expected to result in an overall increase in wetland acreage. A wetland delineation of construction areas should be

completed prior to beginning construction activities. No net loss of wetlands would occur with the preferred plan and the overall effects would be beneficial.

### **5.16 Cumulative Effects**

This integrated report also considers the effects of cumulative impacts as required in 40 CFR 1508.7. A cumulative impact, as defined by the CEQ, is the "...impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of which agency (Federal or non-federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

The impacts of the preferred plan when considered along with past, present and future actions, are cumulatively insignificant. The overall lack of adverse effects associated with this alternative, as documented here, demonstrates both the benign nature and limited impacts of this project. No long-term negative impacts would occur from implementation of the preferred plan; however, this alternative would provide long-term beneficial effects to the natural environment, water resources, recreation and aesthetics. Any impacts associated with the preferred plan, when added to other past, present and reasonably foreseeable future actions are collectively insignificant.

The past, present, and reasonably foreseeable future actions in or near the study area are summarized below and evaluated for cumulative effects with the selected plan. The key resource areas assessed for cumulative effects include wetlands, water quality, and biological resources.

#### **5.16.1 Past, Present, and Reasonably Foreseeable Future Actions**

##### **Crabtree Swamp 208 Project**

The USACE project was authorized under Section 208 of the Flood Control Act of 1954 and constructed in the mid-1960s. The project was designed as flood control and major drainage project to prevent agricultural damages caused by floods equal to the 3-year frequency. Crabtree Swamp was dredged and widened, and the dredge materials were deposited on the adjacent banks, creating a levee system that disconnected the floodplain, increased water velocities, and eliminated aquatic habitat and fish spawning grounds. The stream channel has continued to degrade as development in the area has increased, resulting in erosive channel velocities that contribute to incising and scouring of the stream bed and bank, bank failures, high densities of invasive plant species, and loss of aquatic habitat.

##### **2009 and 2012 Floodplain Restoration**

The restoration project sponsored by Horry County and the City of Conway, with assistance from Federal agencies and two universities, was intended to stabilize a section of Crabtree Swamp located between Oak Street and Millpond Road. The project involved the restoration of the natural floodplain along approximately one mile of Crabtree Swamp to slow flow velocities, increase water storage, and reduce erosion.

##### **2015 NRCS Rock Weir Installation**

Horry County and NRCS installed two rock grade control structures in the headwaters of Crabtree Swamp, above Daniel Road, to reduce storm flow and increase aquatic habitat.

##### **NRCS Drainage Improvements**

The 2019 project involves bank stabilization and bank repairs along three sections of Crabtree Creek.

##### **RJC Railroad Bridge Replacement**

The purpose of the proposed project is to replace a dated bridge which has exceeded its design life and needs replacement for safe and reliable railroad transportation. The trestle crosses Crabtree Swamp between Highway 701 and Long Avenue. The project limits and access area encompass

approximately 4.2 acres. The project will result in 0.007 acre of permanent impacts and 0.08 acre of temporary impacts to freshwater wetlands. Following construction, all temporary impact areas will be returned to their pre-construction elevations and re-vegetated. The project will have no effects to endangered species or cultural resources. The project should be completed within the next 2 years.

### **Ned Creek Residential Development**

In December 2019, a request for rezoning a tract of land for residential development was reviewed and approved by the county. The proposed development is adjacent to Ned Creek and Highway 548 and includes 141 residential lots. Timeline is unknown but construction would likely begin in the next 2 years.

### **TNC Flood Reduction Project**

The Nature Conservancy, in partnership with Horry County, has proposed a nature-based solution to address flooding in the community located near Freeman and Godfrey Avenues in Conway. The project is intended to mimic natural hydrology utilizing a bio-retention system to reduce flash flood loading into Crabtree Swamp. The 8-acre project area, located adjacent to Crabtree Swamp between Highway 701 and Long Avenue, includes lots that were transferred to the city through the FEMA buyout system. The design will incorporate forested wetlands, constructed wetlands, open water systems and recreational features.

## **5.16.2 Resource Areas Evaluated for Cumulative Effects**

### **Biological Resources**

The selected plan, when considered with past, present, and reasonably foreseeable future actions within the study area, will result in temporary and minor cumulative effects and long-term beneficial effects to biological resources. Upland and aquatic species typically leave the area during construction to seek shelter and food, returning once construction activities cease. The primary action affecting biological species occurred in 1966 with the USACE 208 project through dredging of the stream channel and the associated levee system. However, many of the past and future actions were designed to repair Crabtree Swamp and provide benefits to biological resources by increasing and improving habitat areas. The site that will be utilized for the residential development currently includes agricultural lands used for crop production and as such, has limited habitat for species and the wetland acreage that will be filled for the railroad bridge replacement has been reduced to a very small area of degraded wetlands (304 ft<sup>2</sup>). However, the 2009 and 2012 floodplain restorations, the 2015 rock weir installation, the NRCS drainage improvements, have contributed to increasing and improving aquatic habitat and the proposed TNC flood reduction project is expected to increase wetland acreage in the watershed. The preferred plan is expected to increase habitat for aquatic species by decreasing the velocity of storm flows, promoting development of sinuosity, and riffle/pool habitat, and adding woody debris to the channel. This will also provide beneficial effects to wildlife and waterfowl, including migratory species, that utilize the area for foraging. When considered with past, present and reasonably foreseeable future projects in the watershed, the cumulative effects associated with implementation of the preferred plan would be beneficial.

### **Wetlands**

The selected plan, when considered with past, present, and reasonably foreseeable future projects, will not result in significant wetland impacts. The USACE 208 project, while intended to provide flood relief to adjacent agricultural lands, ultimately resulted in separating the stream from its adjacent floodplain, reducing wetland acreage in the Crabtree Creek study area. The selected plan is designed to restore floodplain connectivity and improve stream and wetland functions. The 2009 and 2012 floodplain restorations, NRCS rock weir installations, and drainage improvements, were designed to restore ecological functions and may increase the quantity and quality of wetland resources. The floodplain restorations in 2009 and 2012 have provided additional storage for storm flows, reducing erosive velocities, restoring aquatic habitat, and increasing wetland acreage as demonstrated by the planted species that have thrived in these locations. The 2015 and 2019 NRCS projects have improved stream

functions by restoring aquatic habitat and increasing bed diversity, and have stabilized areas experiencing erosion and bank failure. The TNC Flood Reduction Project proposes forested wetlands, constructed wetlands, open water, and other nature-based features designed to reduce stormflow velocities and create additional flood storage. The TNC project will increase wetland acreage while improving the existing wetlands in areas adjacent to Crabtree Creek. The two projects most likely to cause adverse wetland impacts are the railroad bridge replacement and the proposed residential development. The bridge replacement will result in direct temporary and permanent wetland impacts related to construction activities. However, all temporary impact areas will be returned to grade and replanted following construction, and the permanent wetland loss is limited to 0.007 acre of low-quality wetlands. The wetland impacts associated with the proposed development are unknown at this time. However, the project would be required to meet Federal and state regulatory permitting and mitigation requirements, limiting their contribution to cumulative effects. The preferred plan is expected to restore floodplain connectivity to the channel in the upper reaches and allow greater access to the floodplains in the lower reach, resulting in hydrologic improvements to existing wetlands. When considered with past, present and reasonably foreseeable future projects in the watershed, the cumulative effects associated with implementation of the preferred plan are expected to be beneficial.

### **Water Quality**

The identified past, present and future reasonably foreseeable actions, when combined with the effects of the selected plan, could incrementally increase water turbidity and suspended sediments during construction activities within and adjacent to Crabtree Swamp. These effects would be greater if the proposed future actions were conducted simultaneously. However, all present and future actions are required to adhere to local, state, and Federal regulations and best management practices, which are designed to limit negative impacts to water quality. Compliance of present and future projects with these regulations, combined with implementation of best management practices for the selected plan, would minimize any adverse cumulative impacts. Presently, Crabtree Swamp is included on the state 303(d) list for impaired waters due to low dissolved oxygen and increased levels of bacteria. Low dissolved oxygen levels can be related to excessive algae growth from elevated levels of nitrogen and phosphorus, typically found in fertilizers used for agriculture. A recent study conducted by Coastal Carolina University determined the elevated bacteria levels in Crabtree Swamp could be human-source bacteria (Burge and Libes 2019). Construction of the vegetated floodplains, included as a measure in the selected plan, would provide a benefit to water quality in Crabtree Swamp by allowing storm flows to filter slowly through the floodplain soils, reducing the amount of nutrients and bacteria reaching the stream. Considering the potential benefits of the preferred plan and the regulatory requirements for future and existing projects, no cumulative adverse effects to water quality would occur. Overall, implementation of the preferred plan is anticipated to result in water quality improvements.

## **6 Project Implementation and Public Involvement**

### **6.1 Project Implementation**

Project implementation for CAP 206 Aquatic Ecosystem Restoration occurs in three phases: 1) Pre-construction engineering and design (PED), 2) Construction, and 3) Monitoring and Adaptive Management. These three phases are covered under a single authorization from Congress.

#### **6.1.1 Pre-Construction Engineering and Design**

The PED phase for CAP 206 Aquatic Ecosystem Restoration projects is cost-shared with the Non-federal sponsor at a 65% Federal, 35% Non-federal. The cost breakdown is shown in Table 13.

Prior to initiating the PED phase, the design team will develop a project management plan (PMP) that is developed by and agreed upon by all parties involved in the PED phase. The PMP defines the scope, work breakdown structure, schedule, and budget required. Additionally, the PMP will cover value management and engineering, quality control, communication, change management, and acquisition strategy.

Activities that occur during PED include the completion of a Design Documentation Report (DDR), plans and specifications (P&S), execution of the Project Partnership Agreement (PPA), and contract award activities. Continued coordination with Federal and state agencies will ensure that the final design achieves aquatic ecosystem restoration goals while avoiding adverse impacts.

The development of DDR includes completing the final design of project features. As part of the DDR, the team would complete and ground surveys, utility surveys, and testing for subsurface (geotechnical) conditions as necessary to complete then final design.

Plans and specifications include the development of project construction drawings and specifications, estimation of final quantities, and the completion of the government cost estimate. Drawings and specifications are made available to contractors interested in bidding on the construction of the proposed project.

The PPA is a binding agreement between the Federal government and the non-Federal sponsor which must be approved and executed prior to the start of construction. The PPA sets forth the obligations of each party.

#### **6.1.2 Real Estate Acquisition**

The Horry County is responsible for the lands, easements, rights-of-way, relocations, and disposal areas (LERRDs) required for project construction, and operation and maintenance of the project. Anticipated requirements for the project area described in Appendix D, Real Estate, and costs are summarized in Table 13. Following the execution of the PPA, the non-Federal sponsor would be provided a right of way map delineating the real estate necessary for construction, operation, and maintenance of the proposed project. Real estate activities will be coordinated between Horry County and real estate office in the USACE Savannah District. Horry County Stormwater Management manages easements that originated with the Crabtree Swamp Watershed District. All of the work proposed for this project will be implemented on or accessed from these easements. The District Chief of Real Estate is required to certify in writing that sufficient real property interest is available to support construction of the project.

#### **6.1.3 Contract Advertisement and Award**

Once the PPA is executed, the plans and specifications completed, and the real estate acquisition is certified, a construction contract would be solicited and advertised. Prior to awarding the contract, the non-Federal sponsor must provide any applicable cash contribution. The contract would be awarded to the lowest responsive bidder and notice to proceed can be expected within 30-45 days from bid opening.

#### **6.1.4 Project Construction**

After award of the construction contract, USACE will manage project construction. Construction of berm breaching, floodplain benches, and log-drop structures is expected to take approximately 6 months (Table 14). Planting will begin when floodplain bench grading is complete, and when it is seasonally appropriate.

#### **6.1.5 Monitoring and Adaptive Management**

In an effort to ensure the success of the preferred plan, the restoration measures implemented will be periodically surveyed to provide feedback on the response of the ecosystem and its resources to the management measures taken. By connecting the ecosystem response to the aquatic ecosystem restoration as well as the management measures, potential beneficial adaptations and adjustments to the project or management plan can be identified to ensure continued success of the project. This is especially true of the plantings that will be periodically monitored from their initial planting until reasonable plant maturity is achieved.

Cost shared monitoring will occur during construction. Observations will be recorded and pictures taken to be used to chronicle construction. This information will be included in a year-end report prepared by Horry County due to USACE-PM by December 31<sup>st</sup> of the year(s) construction is performed. Post-construction monitoring will occur for 5 years after completion of construction. The cost of monitoring has been included in the total project cost and will be cost shared between USACE and Horry County. These costs will not exceed one percent of the total first cost of aquatic ecosystem restoration features. If during the post-implementation monitoring phase, negative unintended outcomes are discovered this will trigger adaptive management (Table 11). If there is a need for adaptive management the cost of these actions will be limited to 3 percent of the total project cost excluding monitoring costs (ER 1105-2-100, 3-25). Information gathered throughout each year will be included in a year-end report prepared by Horry County due to USACE-PM by December 31<sup>st</sup> of each of these 5 years.

**Table 11. Crabtree Swamp Monitoring and Adaptive Management Plan. Project-years 1-5.**

Monitoring	Method	Criteria	Adaptive Management
Woody Stem Count, Density, Growth	10' x10' plots representing 2% of planted area. Species should be tagged and labeled and location identified. Monitoring should be conducted on an annual basis and includes species ID, species count, and measurement of height, root collar diameter, and lateral growth.	Maintain 85% survival rate through year 3 monitoring and 70% at year 5. Planted stems should demonstrate an annual increase in height, root collar diameter and lateral growth.	If survival rate drops below 85% within the first 2 years, recommend removal of dead woody stems and re-planting. If survival rate drops below 60% within the first 2 years, area should be evaluated to determine if soil enhancements or modification species is warranted.
Non-native Vegetation	Planted areas should be monitored once every 6 months for evidence of invasive species.	<1% non-native species through year 3 and 5% at year 5	The first five years should be closely monitored and any evidence of invasive species requires immediate chemical treatment and/or mechanical removal to limit spread.
Species Dominance	Planted areas should be monitored once every 6 months for evidence of single species dominance.	No more than 25% of any one species	If monitoring indicates a pattern of species dominance based on the criteria, thinning of the dominant species should be implemented to ensure species diversity.
Log Drop Structures	All structures should be monitored once every six months and after large storm events, to ensure the structure is stable and functioning.	Structure is functional with no evidence of piping or erosion.	If structure failure is observed, structure should be repaired or replaced as necessary. If piping of structure or bank erosion is noted, structure should be evaluated to determine the cause (installation errors related to elevation or tie in, etc.). If necessary, structure should be re-installed and anchored properly. Any bed or bank erosion should be repaired and the area stabilized as soon as possible.
Encroachment	Signs indicating boundaries of aquatic ecosystem restoration area should be placed at 100 foot intervals to prevent encroachment. Areas should be monitored for encroachment every 6 months for years 1-5 OMMMR and on an annual basis for years 6-10 OMMMR.	No encroachment of planted areas (mowing) or vandalism	If encroachment involves mowing of aquatic ecosystem restoration areas, the Sponsor should be notified to assist in educating parties involved. All mowed areas should be re-planted with container size trees of the appropriate species. For vandalism, notify and work with sponsor to remedy. May require installation of cameras or more frequent checks on area.

**6.1.6 Operation, Maintenance, Repair, Replacement, Rehabilitation (OMRR&R)**

The Non-federal sponsor is responsible for the OMRR&R of the completed project. USACE, Charleston District will provide an updated OMRR&R plan upon successful completion of project

construction prior to turning over the project to the Non-federal sponsor. The OMRRR of the proposed aquatic ecosystem restoration project will include the structural integrity of log-drop structures, floodplain benching, berm breaches, and survivability of revegetated areas (Table 12, see Appendix G). Ten years after ecological success has been determined, the responsibility of Horry County to conduct O&M activities on non-mechanical and non-structural elements of an ecosystem aquatic ecosystem restoration project is no longer necessary (WRDA 2016, Section 1161). A measure of success will be to compare the evolution of the entire project area with the reference reach of the Crabtree Swamp system detailed in this report. The goal is for the entirety of the project area to develop complexity within the channel as can be seen in the reference reach.

**Table 12. Crabtree Swamp Operations, Maintenance, Repair, Rehabilitation, and Replacement Plan. Project-years 6-50.**

Monitoring	Method	Criteria	Adaptive Management
Woody Stem Count, Growth, Cover, Diversity	10' x10' plots representing 2% of planted area. For years 1-10 OMMMR, monitoring should be conducted on an annual basis. Data to be collected includes species ID, species count, species height, measurement of diameter at base height (DBH) and percent leaf cover.	Maintain 60% survival rate year 1-5 of OMMMR and 50% for years 6-10 of OMMMR. No additional plant count, growth, cover or diversity monitoring is required thereafter.	If native vegetation is present that provides adequate replacement for planted stems, no additional planting is required. Areas not meeting criteria should be assessed to determine appropriate solution (plant additional stems or add additional monitoring).
Non-native Vegetation	Planted areas should be monitored once every 6 months for evidence of invasive species for years 1-10 of OMMMR and discontinued thereafter.	<5% non-native species through year 5 of OMMMR, <10% years 6-10.	Evidence of invasive species should require immediate chemical treatment and/or mechanical removal to limit spread.
Species Dominance	Planted areas should be monitored once every 6 months for evidence of species dominance for first 5 years of OMMMR, on an annual basis for years 6-10, and discontinued thereafter.	No more than 25% of any one species for years 1-10 OMRRR.	If monitoring indicates a pattern of species dominance based on the criteria, thinning of the dominant species should be implemented to ensure species diversity.
Log Drop Structures	For years 1-5 of OMMMR, all structures should be monitored once every six months and after large storm events to ensure the structure is stable and functioning, on an annual basis for years 6-15, and every 5 years thereafter OR until it is determined that maximum benefit has been achieved (by evidence of planform and bedform channel development).	Structure is functional with no evidence of piping or erosion.	If structure failure is observed, structure should be repaired or replaced as necessary. Bank erosion should be repaired, and the area stabilized as soon as possible.
Encroachment	Signs indicating boundaries of aquatic ecosystem restoration area should be placed at 100-foot intervals to prevent encroachment. Years 1-5 OMMMR, areas should be monitored every six months for encroachment, on an	No encroachment of planted areas (mowing) or vandalism (signs, planted stems, structures)	If encroachment involves mowing of aquatic ecosystem restoration areas, the Sponsor should provide education to parties involved. All mowed areas should be re-planted with container size trees of the appropriate species. For

	annual basis for years 6-10 OMMMR.		vandalism, notify and work with sponsor to remedy. May require installation of cameras or more frequent checks on area.
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**6.2 Total Project Cost and Cost Sharing**

Total project costs are represented in Table 14. CAP 206 Aquatic Ecosystem Restoration projects are cost shared 65% Federal, 35% Non-federal sponsor. The Non-federal sponsor’s costs include the acquisition of real estate required for the project. Horry County holds maintenance easements along both sides of the Crabtree Swamp channel, however easements specifying aquatic ecosystem restoration activities will be required. Real estate costs are included in Table 15, Cost Apportionment. The balance of the Non-federal sponsor’s cost share will be contributed in cash or in-kind work.

**Table 13. Cost Summary (Total Project Cost, Fully Funded FY20 price level)**

Item	Cost (in thousands of dollars)
Bank Stabilization	\$2,321
Fish & Wildlife Facilities	\$39
Lands and Damages	\$874
Planning, Engineering & Design	\$781
Construction Management	\$320
<b>Project Cost Totals</b>	<b>\$4,334</b>

**Table 14. Cost Apportionment for implementation of preferred plan.**

Item	Federal	Non-federal	Total
Bank Stabilization	\$2,321		\$2,321
Fish & Wildlife Facilities	\$39		\$39
Lands and Damages		\$874	\$874
Planning, Engineering & Design	\$781		\$781
Construction Management	\$320		\$320
<b>Total Implementation Costs</b>	<b>\$3,460</b>	<b>\$874</b>	<b>\$4,334</b>
Adjustments to achieve 65%-35% cost share	(\$643)	\$643	
<b>Total Cost per entity</b>	<b>\$2,817</b>	<b>\$1,517</b>	<b>\$4,334</b>

**6.3 Project Implementation Schedule**

Table 16 is a proposed project implementation schedule for the Preferred plan. The schedule will be refined after the cost risk analysis is completed. The final schedule will be coordinated and approved by the Non-federal sponsor and included in the PED PMP.

**Table 15. Proposed Project Implementation Schedule.**

Task Name	Duration	Start	Finish
Implementation and Design Phase Initiated	60 days	Friday 11/13/20	Thursday 2/4/21

Project Partnership Agreement Executed	60 days	Friday 2/5/21	Thursday 4/29/21
Project Approved	60 days	Friday 4/30/21	Thursday 7/22/21
Plans and Specifications	9 months	Friday 4/30/21	Thursday 1/6/22
Real Estate Certification	18 months	Friday 4/30/21	Thursday 9/15/22
Initiate Advertising	60 days	Friday 9/16/22	Thursday 12/8/22
Contract Bid Opening	30 days	Friday 12/9/22	Thursday 1/19/23
Construction Contract Award	30 days	Friday 1/20/23	Thursday 3/2/23
Notice to Proceed	30 days	Friday 3/3/23	Thursday 4/13/23
Construction begins	1 day	Friday 4/14/23	Friday 4/14/23
Construction Complete	6 months	Monday 4/17/23	Friday 9/29/23
Operations and Maintenance	72 months	Monday 10/2/23	Friday 4/6/29
Project Fiscally Complete	6 months	Monday 4/9/29	Friday 9/21/29

### 6.3.1 View of the Non-federal Sponsor

The Preferred Plan aligns with several objectives of the Crabtree Swamp Watershed Restoration Initiative as outlined in a Memorandum of Understanding between Horry County, the City of Conway, SC, Crabtree Swamp Watershed Conservation District, and Horry Soil and Water Conservation District. The Preferred plan restores Crabtree Swamp to a more natural state. It provides suitable habitat for wildlife. It encourages a spirit of cooperation throughout the watershed among and between the jurisdictions. It utilizes innovative aquatic ecosystem restoration techniques to achieve off-channel flood storage, in-channel stream improvements, and stream buffers to protect banks and filter pollutants. If recommendations for this study are followed (Section 6.8) this project will help engage the community and promote their involvement through outreach and education. The required monitoring can partially be accomplished through partnership with Conway High School students and staff. The Crabtree Swamp Nature Trail could be extended, up-stream, to further transform Crabtree Swamp into an attractive public amenity.

The preferred plan aligns with several objectives of the Horry County Environmental Comprehensive Plan. The preferred plan will improve a lower order stream in the Waccamaw River Basin. All features of the plan use natural and nature-based feature technology. Mature and naturalized shoreline vegetation in conjunction with floodplain bench installations will help slow and absorb floodwaters. (Horry County, 2019).

Horry County is identified as the Non-federal sponsor. Horry County supports the preferred plan and intends to participate in its implementation. A letter of support stating this intention is forthcoming and will be included before this report is submitted for final review.

### 6.3.2 Views of Resource Agencies

The USFWS has served as an advisor to the project in relation to improvements required for *T. pullus* population survivability in Crabtree Swamp. Suggestions were made that if conditions in Crabtree Swamp improve to a satisfactory level that Crabtree Swamp may be a site for reintroduction of *T. pullus*. They also provided technical advice on best ways to achieve aquatic life passage through the US-501 bridge perched culverts.

The NRCS has provided historical and technical knowledge on agricultural and 303(d) impaired water body activities in the watershed. They have been awarded funds from EPA to identify failing septic systems and help with repairs or hook-up to public sewage disposal systems. They provided GIS data for

land drainage, information on grants to improve fecal coliform inputs into the system, and schematics of low-head rock weirs and floodplain benching that have been installed in Crabtree Swamp in the past.

### **6.3.3 Environmental Operating Procedures**

The Crabtree Swamp Aquatic Ecosystem Restoration Project restores more natural stream flow creating a naturally functioning system capable of sustaining aquatic habitats and balanced sediment flows. The project balances aquatic ecosystem restoration with flood risk by restoring habitat to support resources of regional significance without increasing base flow elevations. The plan is consistent with all applicable laws and policies. Horry County and USACE continued to meet responsibility and accountability for the project in accordance with these laws and policies. The PDT used appropriate ways and means to assess cumulative impacts to the environment through the National Environmental Policy Act and the use of engineering models, environmental surveys and coordination with natural resource agencies. As a result of employing a risk management and systems approach throughout the life cycle of the project, the project design evolved to address as many concerns as possible with no mitigation required to address adverse impacts.

## **6.4 Environmental Compliance**

This section demonstrates how the preferred plan would comply with applicable environmental laws and regulations.

### **6.4.1 Advisory Circular 150/5200-33A – Hazardous Wildlife Attractants on/near Airports**

The advisory circular provides guidance on certain land uses that have the potential to attract hazardous wildlife on or near public-use airports. In response to the Advisory Circular, the United States Army as well as other Federal agencies, signed a Memorandum of Agreement (MOA) with the Federal Aviation Administration (FAA) to address aircraft-wildlife strikes. The MOA establishes procedures necessary to coordinate their missions to more effectively address existing and future environmental conditions contributing to aircraft-wildlife strikes throughout the United States. The nearest airports to the study area the Conway-Horry County Airport and the Myrtle Beach International Airport. The Conway-Horry County airport is located approximately four miles from the study area and the Myrtle Beach International Airport is located approximately 13 miles from the airport. The selected plan will not create any open bodies of water; however the downstream berm breaches could result in increased water levels in the adjacent wetlands during and immediately after storm events. While the study area does not appear to fall within the boundaries of the flight path for the Conway-Horry County airport, and falls outside the ten-mile radius of the Myrtle Beach International airport flight path, USACE intends to coordinate the selected plan with both airports to ensure there will be no increased risk of bird strikes.

### **6.4.2 National Wild and Scenic Rivers**

The National Wild and Scenic Rivers system was created by Congress in 1968 under Public Law 98-42 pursuant to 16 USC 1271 et seq., for the purpose of preserving rivers systems determined to have outstanding natural, cultural, or recreational values for the enjoyment of present and future generations. The selected plan would not affect any portion of a stream that is currently included in the National Wild and Scenic Rivers system.

### **6.4.3 Section 176(C) Clean Air Act**

Pursuant to this Act, Federal agencies are required to review all air emissions resulting from Federally funded actions to ensure conformity with the State Implementation Plans for non-attainment areas. Horry County is currently in attainment for all air emissions and the selected plan would not cause or contribute to non-attainment. Therefore, the selected plan would be in compliance with this Act.

#### **6.4.4 Sections 404 of the Clean Water Act**

USACE is responsible for regulating the discharge of dredged and fill material into waters of the United States, including wetlands. Although USACE does not issue itself permits for construction activities in these waters, USACE must meet all legal requirements of the Act. Department of the Army (DA) Nationwide Permit (NWP) No. 27 authorizes activities associated with the restoration, enhancement and establishment of tidal and non-tidal wetlands and riparian areas, provided the activities will result in a net increase in aquatic resource functions. The preferred plan is intended to enhance and restore freshwater stream and wetland functions and will result in a net benefit to these resources. The SCDHEC issued a Section 401 Water Quality Certification and Coastal Zone Consistency Certification for Nationwide Permits on March 7, 2017. CWA Section 404 and implementing USACE regulations at 33 C.F.R. 336(c) (4) and 33 C.F.R. 320.4(b) require USACE to avoid, minimize, and mitigate impacts to waters of the U.S., including wetlands. Because the selected plan would result in a net increase in resource functions and services, it would meet the terms and conditions of NWP 27 and no mitigation would be required. The preferred plan is consistent with the 404(b)(1) analysis conducted for this study (see Appendix F).

#### **6.4.5 Coastal Zone Management Act of 1972**

Horry County is one of eight coastal counties in South Carolina that are subject to the State's Coastal Zone Management Program (CZMP). Because South Carolina's CZMP is Federally approved, all Federal activities require Federal consistency review and approval by the SCDHEC Office of Coastal Resource Management (OCRM). The proposed measures are expected to provide a benefit to coastal aquatic resources and meet the terms and conditions for Coastal Zone Consistency Certification. . A Coastal Zone Consistency request will be submitted to OCRM during the public review process.

#### **6.4.6 Section 106 of the National Historic Preservation Act**

Section 106 of the National Historic Preservation Act requires that Federal agencies consider the effects of their undertakings on historic properties. USACE reviewed the SCDAH database and requested input on the study from thirteen Federally recognized Native American tribes. No historic areas or properties eligible for listing in the National Register were identified in the database and no information was provided by any Native American tribes. The selected plan will be coordinated with SHPO during the public review process to ensure compliance with Section 106.

#### **6.4.7 Fish and Wildlife Coordination Act**

The Fish and Wildlife Coordination Act (FWCA) requires that Federal agencies, when impounding, diverting, channelizing, controlling or modifying streams or other water bodies, to consult with the USFWS and appropriate state fish and wildlife agencies, to ensure that wildlife conservation is considered in the development of such plans. The USFWS was invited to participate in the planning of this project and has been consulted during development of this study. Coordination will continue through the public review process to meet the requirements of this ACT.

#### **6.4.8 1541(b) of the Farmland and Protection Policy Act**

This act requires Federal agencies to take into account adverse effects of their programs on the preservation of farmland, to consider alternatives that could lessen these effects, and to ensure their programs are compatible with other state and local programs that protect farmland, as practicable. For the purposes of this Act, farmland includes prime farmland, unique farmland, and farmland of state or local importance. The study area falls within the boundaries of existing maintenance easements held by the city of Conway. The selected plan would not result in any unnecessary or irreversible conversion of farmlands.

#### **6.4.9 Environmental Justice in Minority Populations and Low-income Populations**

Executive Order 12898 directs that Federal agencies ensure that their programs, policies, and activities do not result in adverse effects to low-income or minority populations. Demographic data reviewed for a 0.5-mile radius surrounding the study area indicate that low income and minority populations represent less than half of the local population and are lower than state and Federal averages. The selected plan would not have disproportionately high or adverse effects to these populations and no environmental justice concerns are anticipated. Therefore, the selected plan would be consistent with EO 12898.

#### **6.4.10 Executive Order 11988, Floodplain Management**

The intent of EO 11988 is to avoid, to the extent practicable, the short-term and long-term adverse impacts associated with occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development where a practicable alternative exists. The purpose of this study is to restore and enhance aquatic habitat. Therefore, no practical alternatives to siting the proposed measures within the base floodplain exists. The proposed measures will not reduce existing floodplain capacity or increase flood risk and real estate protection mechanisms will prevent development within the study area.

#### **6.4.11 Executive Order 13751, Protecting the Nation from the Impacts of Invasive Species**

This order amended EO 13112, Invasive Species, and directs Federal agencies to refrain from authorizing, funding, or implementing actions that are likely to cause or promote the introduction, establishment, or spread of invasive species in the United States. Channelization of Crabtree Swamp and ongoing maintenance along the riparian floodplain has allowed non-native plant species to thrive. The measures included in the selected plan would provide for removal of existing non-native species and the establishment of native vegetation on the proposed floodplain benches. Monitoring and adaptive measurement measures are designed to maintain non-native populations to a maximum of 1% of planted species. Operations and maintenance of the study area during long term management by the non-Federal sponsor would ensure a minimal presence of any invasive species. In compliance with EO 13751, the selected plan would not cause or contribute to the establishment or spread of exotic or non-native species and would restore native populations of plant species to the study area.

#### **6.4.12 Executive Order 11990, Protection of Wetlands**

This EO directs Federal agencies to take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. They should consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. The selected plan is intended to restore and enhance aquatic habitats, including wetlands. If impacts to wetlands occur during construction activities, they are expected to be temporary and minor. Overall, the proposed measures should result in a net increase in wetland functions.

### **6.5 Mitigation**

No Clean Water Act mitigation is required for the Preferred plan. However, during construction and maintenance of the restorative measures, best management practices would be followed to further minimize impacts to the environment. All practicable means to avoid or minimize environmental impacts due to construction of the Preferred plan will be considered. The Preferred plan will be designed with the smallest practicable footprint to still meet the requirements of the proposed project.

### **6.6 Public Involvement**

Letters have been sent to adjacent landowners, and Federal, state, and local agencies requesting input on the project.

### **6.6.1 Agency Coordination**

A technical stakeholder meeting was held on September 24, 2019. The purpose of the meeting was to introduce the project by presenting problems and objectives with goals and some solution measures. The goal of the meeting was to gather input from these different perspectives on similar projects they may have been involved with, what materials and measures they may have implemented, and if their agencies or groups might object or have concerns with the proposed plan. Attendees were:

- USACE (5 representatives)
- Coastal Carolina University (CCU, 3 representatives)
- Waccamaw Riverkeeper
- Winyah Rivers Alliance
- National Resources Conservation Service (4 representatives)
- Horry County Stormwater Management (Non-federal Sponsor, 3 representatives)
- US Fish and Wildlife Service (2 representatives)
- SC Department of Natural Resources
- Horry County Soil/Water District
- US Geological Survey
- City of Conway
- SC Department of Transportation (3 representatives)

Coordination letters were sent to the parties below soliciting input on the Crabtree Swamp study.

- South Carolina Department of Transportation
- Natural Resource Conservation Service
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency
- National Marine Fisheries Service
- South Carolina Department of Archives and History
- South Carolina Department of Health and Environmental Control
- Horry County Government
- City of Conway
- South Carolina Department of Natural Resources
- U.S. Army Corps of Engineers, Regulatory Division
- Coastal Carolina University
- Winyah Rivers Alliance
- The Nature Conservancy
- Eastern Shawnee Tribe of Oklahoma
- Chickasaw Nation
- Kialegee Tribal Town
- Absentee-Shawnee Tribe of Indians of Oklahoma
- Catawba Indian Nation
- Thlopthlocco Tribal Town
- Delaware Tribe of Indians
- Alabama-Quassarte Tribal Town
- Poarch Band of Creek Indians
- Shawnee Tribe
- Eastern Band of the Cherokee Indians

### **6.6.2 Public Information and Review**

A letter was sent to all adjacent landowners requesting their input. A public meeting will be held during the 30-day review of the draft report that will also be posted on USACE, Charleston District

website. The plan will likely be presented to the Horry County Council at their regular meeting on July 14, 2020 and to the Horry County Stormwater Advisory Board at their regular meeting on July 15, 2020. A meeting to present the plan to the general public will be held immediately following the July 15, 2020 Horry County Stormwater Advisory Board meeting.

The Nature Conservancy (TNC) in partnership with the City of Conway has designed a stormwater retention system adjacent to part of the project area in Reach 3. Two representatives from USACE, Charleston attended a kick-off meeting for their project in the City of Conway on January 23, 2020. That led to USACE hosting an informational meeting with TNC at Charleston District Headquarters Building on February 7, 2020. Both TNC and USACE believe the projects are complimentary to each other (see Appendix H).

## **6.7 Conclusions**

The Preferred plan and the No-action alternative have been evaluated in this Feasibility Study and integrated EA. No significant impacts to the human environment are identified from the implementation of the Preferred plan. The Preferred plan consists of a log-drop structure and floodplain benching in Reach 1, floodplain benching, log-drop structure, and root wads in Reach 2, and berm breaching in Reach 3.

The Preferred plan will cause no long-term adverse environmental impacts within the study area. There are no negative impacts to habitat for threatened or endangered species. All impacts to wetlands and waters of the U.S. have been evaluated in the 404(b)(1) analysis and will only enhance habitat. Adverse impacts to cultural resources, either buried or in the cultural landscape will be identified and appropriate mitigation will be completed prior to project construction.

As an aquatic ecosystem restoration project, the Preferred Plan is intended to benefit functional processes in Crabtree Swamp. Based on the findings in this report, USACE determined that an Environmental Impact Statement (EIS) was not require and has prepared a Finding of No Significant Impact (FONSI) under NEPA.

It is imperative that post implementation monitoring, and adaptive management recommendations be followed to allow vegetation along the shoreline to naturalize. The success of the project largely depends upon a functioning shoreline vegetation community that contributes detritus to the system and provides shade to the stream channel to help regulate water temperature. It is highly recommended that Horry County develop a robust outreach and education program geared toward public understanding of the science and benefits of stream naturalization. It is recommended that the City of Conway and Horry County explore extending the Crabtree Swamp Nature Trail upstream and engage with Conway High School and encourage stream science and watershed health be incorporated into curriculum.

## **7 District Engineer's Recommendation**

I propose that the recommended plan described in the Crabtree Swamp Aquatic Ecosystem Restoration Project, Integrated Feasibility Report and Environmental Assessment be authorized for implementation under the authority of Section 206 of the WRDA of 1996, Public Law 104-303, as a federal project, with such modifications as in the discretion of the Chief of Engineers may be advisable. The total cost of this project is currently estimated at \$ \_\_\_\_\_.

Prior to construction, and during the design and implementation phase, the non-Federal sponsor would: (1) provide all lands, easements, and rights of way necessary for project construction and operation and maintenance; (2) hold and save harmless the United States from damages due to the construction or operation and maintenance of the project; and (3) agree to meet the requirements for non-Federal responsibilities as outlined in this report and future legal documents. The non-Federal sponsor would also operate and maintain the project after construction for the life of the project (so long as the project remains authorized). Horry County has demonstrated that it has the authority and the financial capability to provide all Local Sponsor requirements for the implementation, operation, and maintenance of the project.

The recommendations contained herein reflect the information available at this time and current Department of the Army policies governing formulation of individual projects. They do not reflect the program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch.

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DATE

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Lieutenant Colonel, U.S. Army  
Commander and District Engineer

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