2021

Little River Watershed In-Stream Wetland Phase II

Project Final Report

Albemarle Resource Conservation & Development Council

6/28/2021

NC-DEQ Grant Contract No. 7360
February 1, 2018 to June 30, 2021
Federal Grant Amount: $116,736
Non-Federal Match: $79,600
Author: Mark Powell, Program & Project Management Consultant

Acknowledgements

The Albemarle Resource Conservation and Development Council (ARC&D) gratefully acknowledges the **EPA Section 319 Grant** for the Little River Watershed In-Stream Wetland Project Phase II. The grant was a catalyst for strengthening our partnership to restore and protect water quality in the watershed.

The ARC&D gratefully acknowledges the support of the project's partners:

Nina Needham, Participating Farmer, EPA 319 Little River Watershed In-Stream Wetland Phase II
Wade Boyce, Participating Farmer, EPA 319 Little River Watershed In-Stream Wetland Phase I
Steve Harris, Participating Farmer, CWMTF/USFWS In-stream Wetland Project
Dwane Hinson, Pasquotank SWCD Technician
Jacob Peele, Perquimans SWCD Technician
Pasquotank Soil and Water Conservation District
Perquimans Soil and Water Conservation District
Sparty Hammett, Pasquotank County Manager
Frank Heath, Perquimans County Manger
Rodney Saunders, Saunders and Sons Excavating
Rodney Johnson, Albemarle RC&D Council Member and Resident of the Little River Watershed
Green Saves Green
Perquimans County Waterway Watch
Albemarle Commission

Table of Contents

Attachments

1. In-Stream Wetland Construction Designs and Specifications
2. Conservation Agreement between Nina Needham and Pasquotank SWCD
3. Voluntary Conservation Agreement for Creek and River Buffers
4. Waterfront Parcel Value Sensitivity Associated with Poor Water Quality and Algal Blooms
5. Summary of Water Quality Monitoring Data for the Little River Watershed
6. Resolution for Strengthening Critical Drainage and Water Management Infrastructure

Executive Summary

The Albemarle Resource Conservation and Development Council, Albemarle Commission, Perquimans and Pasquotank Counties, Soil and Water Conservation Districts (SWCD), universities, local community groups, and state and federal agencies are working together to restore the Little River watershed, which includes eight miles of impaired river in Perquimans and Pasquotank Counties. The 86,000 acre Little River watershed was once rich in biodiversity with key anadromous fish and shellfish areas, and swamp forests critical to support native fish and wildlife, mitigate flooding, and protect water quality.

Agricultural operations have opened drainage canals that directly carry sediments and nutrients to the river, and residential and commercial developments have increased pollution from stormwater runoff. Swamp forest buffers have been eliminated or degraded in some locations along the river.

Most of the canals that flow into the Little River are on private lands, and constructing in-stream wetlands along these privately owned canals is critical for effectively managing stormwater in the watershed. The 2,000 ft. in-stream wetland on the Nina Needham farm filters nutrients and sediment from a 3,000-acre watershed with a direct outlet to the Little River. The in-stream wetland also has helped stabilize the watershed drainage system and make it more resilient to major storm events.

Purpose, goals, and objectives

The purpose of the project was to help restore the health and integrity of the Little River watershed.

The goals of the project were:

- Develop and demonstrate on privately-owned canals a practical and effective stormwater system for improving water quality at a watershed scale.
- Develop practical and useful communication tools for public outreach and education.
- Create a practical framework for restoring similar watersheds in eastern North Carolina.

The objectives of the project were:

- Construct eight acres of in-stream wetland and buffers on a main drainage canal on privately owned agricultural lands
- Communicate the impacts and broad application of the project through field days, publications, project partners, and web sites.

The project's lessons learned include:

- Substantial planning and staff time are required from project conceptualization to construction

- In-stream wetland projects are a component of improving whole-farm water management
- Water quality improvement should be implemented at a watershed scale
- In-stream wetland projects are effective for educating the public about the importance of managing stormwater to protect water quality.

The Needham in-stream wetland, and two other in-stream wetlands in the upper watershed are creating a critical mass of Best Management Practices (BMPs), which are needed to effectively manage stormwater above and along the impaired section of the Little River. The projects also demonstrate how the same stormwater system may be used on privately-owned canals throughout the watershed that flow into the Little River. The impact of agriculture on water quality of the Little River watershed is typical to watersheds in eastern NC, and the in-stream wetland system could be replicated throughout the region.

Project Background

The Albemarle Resource Conservation and Development Council (ARCD), Albemarle Commission, Perquimans and Pasquotank Counties, Soil and Water Conservation Districts (SWCD), universities, local community groups, and state and federal agencies are working together to restore the Little River watershed (Pasquotank River Basin, HU-10), which includes eight miles of impaired river (2012, 2014, 2016, 303d list) in Perquimans and Pasquotank Counties. The 86,000 acre Little River watershed was once rich in biodiversity with key anadromous fish and shellfish areas, and swamp forests critical to support native fish and wildlife, mitigate flooding, and protect water quality. Unique characteristics of the watershed as defined by the *NC Biodiversity Wildlife Habitat Assessment* and other sources include:

- Approximately 5,300 acres of Strategic Habitat Area
- Approximately 2,500 acres and 17,000 acres of Exceptional and Substantial wetlands, respectively
- Approximately 7.5 square miles of Critical anadromous fish spawning areas
- Submerged Aquatic Vegetation along the Albemarle Sound (433 acres Patchy and 107 acres Dense)
- Nine animal, plant and natural communities identified by the NC Natural Heritage Program
- Shortnose and Atlantic Sturgeon on the Endangered Species list, Grassleaf Arrowhead on the Federal Species of Concern list, and Bald Eagles under the Bald and Golden Eagle Protection Act.

The unique characteristics of the watershed are mapped in **Figure 1**.

Agricultural operations and residential and commercial development have significantly impacted water quality and fisheries in the Little River watershed. Agricultural operations have opened drainage canals that directly carry sediments and nutrients to the river, and residential and commercial development have increased pollution from stormwater runoff. Swamp forest buffers have been eliminated or severely degraded in some locations along the river. As a result, the upper and lower sections of the Little River have been included at different times on the 303(d) list of impaired waters, beginning in 1998 with the upper section of the river from its source to Halls Creek (12 mi.) for low Dissolved Oxygen (DO). In 2012 and 2014, a section of the Little River from SR 1225 to Halls Creek (approx. 8 miles), was listed as impaired in the aquatic life category. Over the course of a five-year assessment period, nearly 11 percent of samples were above the water quality standard for Chlorophyll *a* indicating nutrient enrichment in this segment of the river. The same 8-mile section of river is on the 2016 list of impaired waters.

Many drainage canals that flow into the Little River are on private lands, and constructing in-stream wetlands along these canals is critical for effectively managing stormwater in the watershed. In 2016, the ARCD, Pasquotank County, and Pasquotank SWCD used grants from the Clean Water Management Trust Fund (CWMTF) and US Fish and Wildlife Service (USFWS) to construct 4,800 ft. of instream wetland on a privately-owned canal in the upper part of the watershed. At the same time, the ARCD, Perquimans County, and Perquimans SWCD used an EPA 319 grant to construct 2,000 ft. of in-stream wetland on the Wade Boyce farm, which is just above the impaired section of the Little River. This EPA 319-funded project in-stream wetland was constructed in 2018 along 2,000 ft. of privately-owned canal that drains approximately 3,000 acres of agricultural land and solar farms on the Pasquotank County side of the watershed.

The 2,000 ft. in-stream wetland on the Needham farm filters nutrients and sediment from a 3,000-acre watershed with a direct outlet to the Little River (**Figure 2**). Design and construction included the following components:

- Reconfiguration and improvement of the ditch channel
- Stabilization of the side banks
- Fine grading adjacent cropland
- Installation of rock drop structures to funnel stormwater from adjacent cropland
- Establishment of a 50 ft. grass buffer.

The construction designs and specifications are included as an attachment to this report.

These in-stream wetland projects are creating a critical mass of BMPs, which are needed to effectively manage stormwater above and along the impaired section of the Little River (**Figure 3**). The projects also demonstrate how the same stormwater system may be used on privately-owned canals throughout the watershed that flow into the Little River (**Figure 4**). The impact of agriculture on water quality of the Little River watershed is typical to watersheds in eastern NC, and the in-stream wetland system could be replicated throughout the region.

Photos of EPA 319 Needham pre-and post-in-stream wetland project are provided in **Figures 5-8**. Photos of the CWMTF-USFWS in-stream wetland project on the Steve Harris tract are provided in **Figure 9.** Pre-and post-construction photos of the EPA 319 Phase I in-stream wetland on the Wade Boyce tract are provided in **Figures 10-11**.

The in-stream wetlands are a component of a broader effort to restore the Little River watershed following state and local recommendations, and public participation. With a grant from Clean Water Act 205j program, the Albemarle Commission and ARC&D collaborated in 2014 and 2015 with Perquimans and Pasquotank Counties, universities, local community groups, and state and federal agencies to develop a long-range watershed restoration plan. Key activities identified in the plan include the construction of in-stream wetlands, establishment of riparian buffers, access improvements, and public education and awareness.

Purpose, goals, and objectives

The purpose of the EPA 319 – funded in-stream wetland project on the Needham farm was to help restore the health and integrity of the Little River watershed.
The goals of the project were:

- Develop and demonstrate on privately-owned canals a practical and effective stormwater system for improving water quality at a watershed scale
- Develop practical and useful communication tools for public outreach and education
- Create a practical framework for restoring similar watersheds in eastern North Carolina.

The objectives of the project were:

- Construct eight acres of in-stream wetland and buffers on a main drainage canal on privately owned agricultural lands
- Communicate the impacts and broad application of the project through field days, publications, project partners, and web sites.

Project Successes

In-stream wetlands are one component of improving farm water management.
The project developed a model for working with private landowners to construct in-stream wetlands on main agricultural drainage canals in the Little River watershed. The landowner on this project, Nina Needham, was concerned about how much land she was going to have to set aside for the project including the in-stream wetland and buffer. The project design included improvements to drainage and water management on land adjacent to the in-stream wetland, which helped convince her that the project would be to her overall benefit. The instream wetland became an integral component of her overall effort to improve drainage and water management on her land. The in-stream wetland designs are attached to this report.

Straightforward conservation agreement. The project helped develop a model conservation agreement that is legally binding, but does not overburden landowners with technical and legal language. The agreement between Nina Needham and the Pasquotank SWCD includes a 10-year conservation period for the wetland and buffer. The SWCD manages the conservation agreement and the project is included it in its Spot Check program. The same conservation agreement was used on two other in-stream wetland projects in the Little River watershed. *The signed conservation agreement between Pasquotank SWCD and Nina Needham is attached to this final report.*

Increased public awareness for conservation practices to protect water quality. The ARC&D worked with volunteers in the Green Saves Green group to organize the first Green Saves Green Expo at the Museum of the Albemarle in Elizabeth City in March, 2018. Approximately 1,600 people attended the event with 60 sponsors and vendors. Mark Powell had a table with information about the EPA 319 in-stream wetland projects, and the partnership to protect and improve water quality in the Little River watershed. The poster display is attached to this report. Three van tours carried 80 people to see the Amazon Wind Farm, and the in-stream wetland projects in the watershed. Mark Powell gave each tour group a summary of how the in-stream wetlands are helping protect and improve water quality in the watershed. Participants had many questions about how poor water quality is related to the harmful algal blooms (HABs) that have returned to Albemarle waters after an absence of 30-35 years. The extensive and persistent HABs in the Little River and Dance's Bay in 2017 were the first blooms that long-time residents had ever experienced.

Increased public awareness of water quality issues in the Little River watershed, including the link to HABs, helped motivate a group of local residents to begin a citizen science initiative to monitor water quality. Each summer since 2018, the citizen scientists have collected monthly water samples from seven to ten locations on the Little River from the top of the watershed to Symonds Creek in the lower part of the watershed. The group sends the samples to the NCDA lab for analysis of Organic N and Total P, which per DEQ data collected at its river monitoring station on old US17, have been increasing over the past 20 and 35 years, respectively. The objective of this work is to help identify where these nutrients are coming into the river, and then work back to help identify and address the sources. The CWMTF/USFWS in-stream wetland project supported the first two years of monitoring, and Pasquotank SWCD has supported the monitoring program since then.

The HABs that have occurred in Albemarle waters each summer since 2015 have caused widespread public concern about water quality. The HABs are a threat to the regional economy, much of which depends on good and safe water quality. A recent study of the economic value of natural resources in the Albemarle-Pamlico watershed sponsored by the Albemarle-Pamlico National Estuary Program (APNEP) found that the combination of commercial fishing, outdoor recreation, property value enhancement due to its natural beauty, support of endangered species, and carbon sequestration have been valued at more than $4 billion dollars annually (Van Houtven et al., 2016).

The greatest direct impact to local economies from poor water quality and HABs may be a decrease in waterfront property values. A 2015 assessment of the economic value of clean water in Lake Champlain found that HABs resulted in a $4,900 and $53,000 price decrease per average single family dwelling and seasonal residence, respectively (Voight et al., 2016). A 2017 study on the effects of HABs on property values in six Ohio counties showed capitalization losses associated with near lake homes between 11% and 17% rising to above 22% for lake adjacent homes. For properties on Grand Lake Saint Mary's, the same study showed one-time capitalization losses exceeding $51 million for near lake homes (Wolf et al., 2017).

A recent study of the potential impact of HABs on waterfront property values in Chowan, Perquimans and Pasquotank counties found that a 10% reduction in property values would reduce annual tax revenues by $226,292, $229,996, and $390,122, respectively (Powell, 2020). For waterfront properties in the Little River watershed the same study estimated a 10% reduction in property values would reduce annual tax revenues by approximately $94,000. *The study is included as an attachment to this report*

Increased knowledge of the nutrients driving the HABs.
As mentioned previously, the EPA phase II in-stream wetland project helped create public awareness of water quality issues, and the specific actions that residents may take to improve water quality. Water quality monitoring conducted each summer by local residents is a good example. The water quality data collected in the Little River watershed since 2018 also has increased our knowledge about the specific nutrients driving the blooms. This knowledge has been used to develop a new regional research initiative to identify the causes of, and solutions to, the HABs. *A summary of water quality data from 2018 to June 2021 is included as an attachment.*

With a 2017-2020 planning grant from the Clean Water Management Trust Fund (now the NC Land and Water Fund), a partnership of the Albemarle Commission (AC), ARC&D, Chowan-Edenton Environmental Group (CEEG), Green Saves Green (GSG), Perquimans County Waterway Watch (PCWW), Soil and Water Conservation Districts (SWCD), state agencies, local governments, and UNC Institute of Marine Sciences (UNCIMS) conducted research which included a regional water quality sampling strategy to assess the importance of many different sources of nutrients (large rivers, atmospheric deposition, clear cutting of swamp forest, microbial N_2 fixation, and nitrogen and phosphorus loading from small coastal plain streams) that are stimulating the blooms. Citizen scientists collected monthly (May-September) water samples from 41 key locations on the Chowan River, Potecasi Creek, Edenton Bay, Little River, Perquimans River and tributary creeks, and tributaries to the Pasquotank River. The samples were sent to the NC Department of Agriculture (NCDA) lab in Raleigh to screen for nutrient hotspots, and duplicate samples from key locations were sent to the UNCIMS lab in Morehead City to provide a more accurate quantification of the nutrient concentrations. The water quality data from all sample locations may be viewed on ArcGIS Online: https://arcg.is/11GfuC0

The ARC&D website has information about HABs and the partnership's collaborative research to determine the causes of and solutions to the blooms in the CR-AS: https://www.albemarlercd.org/fighting-algal-blooms.html

Key findings from the 2017-2020 regional algal bloom planning project include:

Chowan River Basin

- Chlorophyll-*a* is increasing—nutrient loading from VA is low, but is high in the main stem of the Chowan River in NC
- A general increase in organic N, reduction in nitrates, and ammonium is low and stable

Pasquotank River Basin

- Total phosphorus and organic N are increasing in the Little River.
- Many tributary creeks in the region are showing relatively high Total P.

Region Wide

- Small, unassessed coastal streams could contribute up to 40% of the nutrients to the CR-AS.
- Cyanobacterial N_2 fixation may be a significant source of internal N loading and hence should be considered in parallel with N loading from tributaries.

The new regional research initiative is focusing on key research topics identified in the 2017-2020 regional algal bloom planning project (Hall and Paerl, 2020). The initiative also will implement strategies to inform the public about HABs, and the collective and individual actions that stakeholders may take to reduce the nutrients that are stimulating the HABs.

1. With assistance from citizen science groups, determine nutrient loads from coastal plain tributaries. Nutrient concentrations of coastal plain streams are largely unknown, but the few that have been measured indicate that they have 2-3 times the concentrations of piedmont rivers and could contribute up to 40% of the nutrient load to the Chowan River and Albemarle Sound.
    a. Measure concentrations of nutrients (N and P) in coastal streams representative of different land uses and soil types.
2. Quantify cyanobacterial N_2 fixation as a source of nitrogen to the Albemarle Sound system. The biomass of potentially N_2-fixing cyanobacterial species has increased 100 fold in the past 20 years. At current levels of cyanobacteria biomass, cyanobacterial N fixation could be similar in magnitude to N loading from tributaries combined.
    a. Directly measure cyanobacterial N_2 fixation at representative sites throughout the Chowan River and Albemarle Sound.
3. Discover sources of dissolved organic nitrogen (DON), which is an emerging source of nutrient pollution contributing to the over-enrichment of nitrogen in the CR-AS, but also the Neuse, Tar-Pamlico, New River, Cape Fear, and White Oak basins. Results from the proposed work in the CR-AS will guide stakeholders towards strategies that can reduce DON inputs, as well as create an assessment

tool to evaluate BMPs for management of this nitrogen form. Knowledge gained from CR-AS will transfer to other NC river basins.
4. Identify and implement effective strategies to inform the public about algal blooms, and the collective and individual actions that may be taken by stakeholders to reduce the nutrients that are driving the blooms.

Developed strong local partnerships and support for watershed protection.
The project developed strong partnerships with Pasquotank and Perquimans county managers and commissioners, and SWCD supervisors. Dwane Hinson and Mark Powell provided regular updates on the in-stream wetland project in particular, and water quality issues in the Little River watershed, in general. As a result, the counties have increased money each year for water quality activities in the watershed including monitoring.

The project also helped strengthen the regional ARC&D, SWCD, and local government partnership that has collaborated for many years on stormwater wetland projects in Northeast N.C., including the Town of Edenton's EPA-funded wetland on Filbert's Creek, and the stormwater wetlands at Edenton airport and Chowan Golf Club. A map of stormwater wetlands in northeast NC funded by EPA grants, and other grants, is included in **Figure 12**.

On August 25, 2018 Mark Powell gave a presentation to sixty people in Edenton on the regional partnership to protect and improve water quality including the effort to identify the causes of the algal blooms that have returned to Albemarle waters after an absence of 30-35 years. The presentation also included a description of regional stormwater management projects including the EPA-funded in-stream wetland projects in the Little River watershed.

The EPA-funded in-stream wetland project helped increase awareness of HABs and water quality issues with local governments, state legislators, and the public. At the request of the ARC&D, eight county Boards of Commissioners in northeast NC signed formal resolutions to work in partnership with local groups and state legislators to bring additional resources to the region to study the causes of and solutions to the algal blooms. The resolution also was adopted by SWCDs, local Chambers of Commerce, businesses, towns, churches, and over 200 residents. *A copy of the resolution is included as an attachment to this report.*

Project Failures

The project Scope of Work included field days for farmers, conservation professionals, and local government representatives. However, the project was not able to organize field days after the in-stream wetland was well-established with vegetation due to COVID restrictions.

The project proposed to establish eight acres of in-stream wetland and 50 ft. buffers along both sides. However, the project established 4.3 acres of in-stream wetland and buffer along one side of the wetland due to ownership issues with the land adjacent to the solar farm. The original design of the in-stream wetland included the canal extending to the north to the railroad tract. The project was not able to include this section of canal also due to ownership issues.

Project Lessons Learned

Substantial planning is required from project conceptualization to construction. In-stream wetland projects on private lands require substantial planning and meetings with landowners. The **first step** is to identify a drainage canal with potential to construct an in-stream wetland. The **second step** is to talk with the landowner about developing such a project. If the landowner is receptive, then the **third step** is to conduct field work to determine the scale and cost of the project. This includes determining the project's construction footprint, activities, and buffer areas. This information is then presented to the landowner for review and comments. Changes may be made to the design based on feedback from the landowner. If the landowner wishes to proceed with the project, the **fourth step** is to look for grant opportunities and matching funds. Substantial ARC&D and SWCD staff time is required to move a project from the concept phase to design and construction.

In-stream wetland projects are a component of whole-farm water management. Landowners are naturally concerned about how much farmland they will have to give up to construct in-stream wetlands. This was the case with Nina Needham. Dwane Hinson designed the in-stream wetland with the goal of improving water quality, and at the same time, improving drainage and water management on the adjacent farmland. Needham was more receptive to the project, and less concerned about giving up some farmland, when she learned that she would be able to improve drainage, and decrease soil erosion. Wade Boyce and Steve Harris had similar concerns on their EPA and CWMTF funded in-stream wetland project, respectively.

Water quality improvement should be implemented at a watershed scale.
Most of the canals that flow into the Little River are on private lands, and constructing in-stream wetlands along these privately owned canals is critical for effectively managing stormwater in the watershed. The Wade Boyce, Steve Harris and Nina Needham in-stream wetlands are creating a critical mass of BMPs, which are needed to effectively manage stormwater above and along the impaired section of the Little River. The projects also demonstrate how the same stormwater system may be used on privately-owned canals that flow into the Little River throughout the watershed. The impact of agriculture on water quality of the Little River watershed is typical to watersheds in eastern NC, and the in-stream wetland system could be replicated throughout the region.

The nine-element restoration plan for the Little River watershed also identified the conservation of swamp forest buffers as a key activity for improving and protecting water quality. Swamp forests in the watershed are critical for storing and filtering stormwater, and providing key habitat for fish and wildlife. These forests are slow growing and there is a lack of information on how recent, large clearcuts of swamp forests with little or no buffers are impacting water temperature and nutrient release into the Little River. In 2016, the ARC&D, Perquimans and Pasquotank SWCD, and Perquimans and Pasquotank county managers and commissioners worked together to develop a program whereby landowners may enroll a minimum 300 ft. buffer of swamp forest in a voluntary conservation agreement. In exchange, landowners receive a grant incentive based on the tax value of the enrolled acreage. Wade Boyce enrolled 20 acres of swamp forest in the conservation program. Nina Needham did not have any swamp forest for the conservation program. *A copy of the voluntary conservation agreement is included as an attachment to this report.*

The in-stream wetland project helped increase public participation to protect water quality.
The EPA Phase I and II instream wetland projects helped increase public awareness of the importance of these BMPs for protecting water quality in the Little River watershed. The HABs that occurred in the Little River in 2018 and 2020 created significant public concern about water quality, and the in-stream wetland projects helped demonstrate how the BMPs can protect and improve water quality. As a result, Perquimans and Pasquotank counties have allocated additional funds each year to support water quality protection projects. Local citizens began water quality monitoring programs in the Little River watershed and tributaries to the Pasquotank River with financial support from the counties and SWCD. The EPA-funded in-stream wetland projects helped people understand how the BMPs are important components of a watershed scale program to protect and improve water quality.

Load reduction data

The EPA phase II in-stream wetland project did not include a water quality monitoring component. However, in northeast N.C, the Natural Resources Conservation Service estimates reduced sediment loading, phosphorus, and nitrogen by approximately 6 tons/yr, 32 lbs/yr, and 16 lbs/yr, respectively in the 3,200-acre drainage area.

The Little River watershed has many locations with Total P above .40 ppm, impairment for Chlorophyll *a,* and high values for TKN and Organic N. Symonds Creek, a tributary to the Little River in the lower section of the watershed, has been for many years a hot spot for sediment loading. Water quality monitoring in the tributary in the summer and fall of 2019 showed high levels of P, which may be legacy P from years of potato and cabbage cultivation. The levels of P in Symonds Creek also are within the upper range of P levels measured by NCDEQ at its permanent monitoring station on the Little River at Woodville. Phosphorus and Organic N have been increasing for the past 35 and 20 years, respectively, at the Woodville station, which is in the middle of the eight-mile impaired section of river.

The EPA phase I in-stream wetland project was monitored by a graduate student in the NC State University Department of Biological and Agricultural Engineering. The study's conclusions are summarized below. It is important to note the difference in designs of the phase I and phase II instream wetlands. The phase I instream wetland included rock weirs to hold water at different stages. The phase II in-stream wetland did not include rock weirs due to tail water concerns. The bottom of the canal was widened but not deepened due to its elevation in relation to the Little River.

N.C. State Study Conclusions.
To remediate the impairment of the Little River, the ARC&D developed a watershed plan to implement multiple linear in-stream wetlands within low order streams and agricultural ditches. A 13-week pilot study was then conducted on the EPA Phase I in-stream wetland project. The study was conducted in three phases, a concentration analysis pre-vegetation establishment, a concentration analysis post-vegetation establishment, and a load analysis with established vegetation.

From these results, it was observed that TN was exported, while TP and TSS were removed from the water column by the in-stream wetland (ISW), albeit at lower percent reductions (-3%, 15%, 47%, respectively) than those observed in the concentration analysis. The magnitude of TN export by the ISW was 1.7-kg or 0.02-kg/day of TN. When broken down by nitrogen species, NO_3-N was removed through the system (1.8-kg or 32%), but this removal was offset by discharges of ON and NH_4-N. It should be noted that the N concentrations and the loads delivered to the ISW were lower than is often observed in the Middle coastal Plain. The magnitude of TP removal was 3.4-kg or 0.04-kg/day of TP and the magnitude of TSS removal was 2750-kg or 30-kg/day during the 13-week load analysis. Removal estimates of nutrient and sediment pollution from the ISW was based primarily on the load reductions during relatively short period (13-weeks during Fall 2017) after only 2 growing seasons post-construction. Additionally, the load analysis possibly underestimated the treatment ability due to a small amount of additional water inputs that were unaccounted for; however, the use of base flow conditions in the load analysis likely also overestimated the actual treatment ability of the ISW when using total flow conditions. Therefore, the estimated treatment ability presented was a fair representation of the overall treatment ability of the ISW at its current age.

Analysis of the data indicated some nutrient and sediment retention, but the treatment abilities of the relatively young linear wetland were limited. Vegetation establishment was likely slowed due to Hurricane Matthew in October of 2016 that required some replanting by ARC&D. In addition to age, several design factors including a high wetland to watershed ratio, low hydraulic retention time, low upstream N concentrations, and additional surface & subsurface drainage water entering the wetland reach reduced its treatment efficiency. Ideally, a linear wetland of the same size built to maximize nutrient removal would have a smaller contributing watershed, nearly complete wetland vegetative coverage, and limited lateral contributions of nutrients along the reach. The ISW should also ideally contain some additional water level control along the length of the ISW and at the outlet to hold retain water at a deeper depth for longer periods, while slowly releasing it downstream following rainfall events.

Monitoring of this linear wetland has provided enough data to indicate that the ISW can provide some level of nutrient and sediment removal, but the magnitude of the removal is still somewhat unclear. The inability of the ISW to remove pollutants to treatment goals proposed by the ARC&D in their nine-element restoration plan (2015) does not mean that linear wetlands should not be used as part of an overall watershed management plan. ISWs integrated into that plan have both pros and cons that should be considered.

Potential benefits of linear wetlands include:

- Simple to design and construct
- Relatively small footprint constructed mainly in existing ditch infrastructure.
- Increased drainage capacity (wider cross section area of drainage canals)
- Improved bank stability
- Reduced ditch maintenance, saving farmers time and money
- Removal of N, P, and TSS (however, the removal efficiency will be variable as a function of incoming load, hydraulic retention time (HRT) and watershed location)
- Since the main channel is mostly left undisturbed during construction, the practice maintains existing and enhances ecological function in the ditch or canal.

Potential disadvantages of linear wetlands include:

- Loss of farmable land (1-3 acres/mi of ditch)
- Increased initial costs associated with earthmoving ($5-20 per ft), but less than stream restoration) and subsurface and surface drainage retrofits in adjacent fields
- Depending on local soil properties, banks may still slump
- If water control is included in the design, farmers may not accept or maintain structures
- Because so few have been built and monitored, they remain unproven. Actual nutrient and sediment retention in these practices are still unclear.

Many questions about ISWs remain, including the range of expected load reductions and what load reductions are needed to justify more widespread use of this practice to improve water quality in the Little River. To answer these questions continued study at this site as it ages, and at other future sites is recommended. If a future project is funded, it should be located and designed with monitoring in mind and include the following elements:

- A control section (i.e., unimproved canal) and a linear wetland section to measure and document head-to head treatment improvements
- Few drainage discharges along canal length, with no discharges being ideal
- Designed with permanent stable cross sections for more accurate flow monitoring, and adjustable weirs to control flow and depth
- Monitoring of lateral and subsurface contributions of water and pollutants.
- Enough funding to monitor the site as it develops (not just year 1).

Further studies will be needed to answer these questions, but based on this study linear wetlands have potential to be an additional tool to improve water quality, particularly in eastern NC.

Final Budget

The final Section 319 project expenses were $108,818.99. The final non-federal match was $68,961.60. The final percent of total budget for Section 319 and non-federal match was 61% and 39%, respectively.

Budget Categories (itemize all categories)	Section 319			Non-Federal Match *	Total
	Year 1	Year 2	Year 3	Total	
Personnel/Salary	$ 1,461.50	$ 3,136.40	$ -	$ 7,458.00	$ 12,055.90
Fringe Benefits	$ 487.50	$ 1,045.39	$ -	$ -	$ 1,532.89
Supplies	$ -	$ -	$ -	$ -	$ -
Equipment				$ -	$ -
Travel	$ -	$ -		$ -	$ -
Contractual	$40,538.28	$13,731.00	$38,526.28	$30,969.60	$ 123,765.16
Other	$ -	$ -	$ -	$30,534.00	$ 30,534.00
Total Direct	$42,487.28	$17,912.79	$38,526.28	$68,961.60	$ 167,887.95
Indirect (max. 10% of direct costs, per 40 CFR 35.268)	$ 4,248.73	$ 1,791.28	$ 3,852.63	$ -	$ 9,893
Annual Totals	$46,736.01	$19,704.07	$42,378.91	$68,961.60	$ 177,780.59
Grand Total	$ 108,818.99			$68,961.60	$ 177,780.59
% of Total Budget	61%			39%	100%

References

Hall, N. and H. Paerl. 2020. *Quantitative Evaluation of Changing Nutrient Sources to the Albemarle Sound System*. Report prepared for the Albemarle Commission under Clean Water Management Trust Fund Planning Grant 2017-801. 34 p.

Powell, M. H. 2020. *Waterfront Parcel Value Sensitivity Associated with Poor Water Quality and Algal Bloo*ms. Report prepared for the Albemarle Commission under Clean Water Management Trust Fund Planning Grant 2017-801. 10 p.

Wolf, D.H. and A. Klaiber. 2016. *Bloom and bust: Toxic algae's impact on nearby property values*. Ecological Economics, 2017; 135: 209 DOI: 10.1016/j.ecolecon.2016.12.007

Van Houtven, G., C. Van Winkle, M. O'Neil, K. Matthews, and P. Sinha. 2016. *Economic Valuation of the Albemarle-Pamlico Watershed's Natural Resources.* RTI International. Report prepared for the Albemarle-Pamlico National Estuary Partnership.

Voigt, B., J. Lees, and J. Erikson. 2015. *An Assessment of the Economic Value of Clean Water in Lake Champlain*. Technical Report 81. Prepared for The Lake Champlain Basin Program and New England Interstate Water Pollution Control Commission, p. 31

Figure 1. Unique Features of the Little River Watershed.

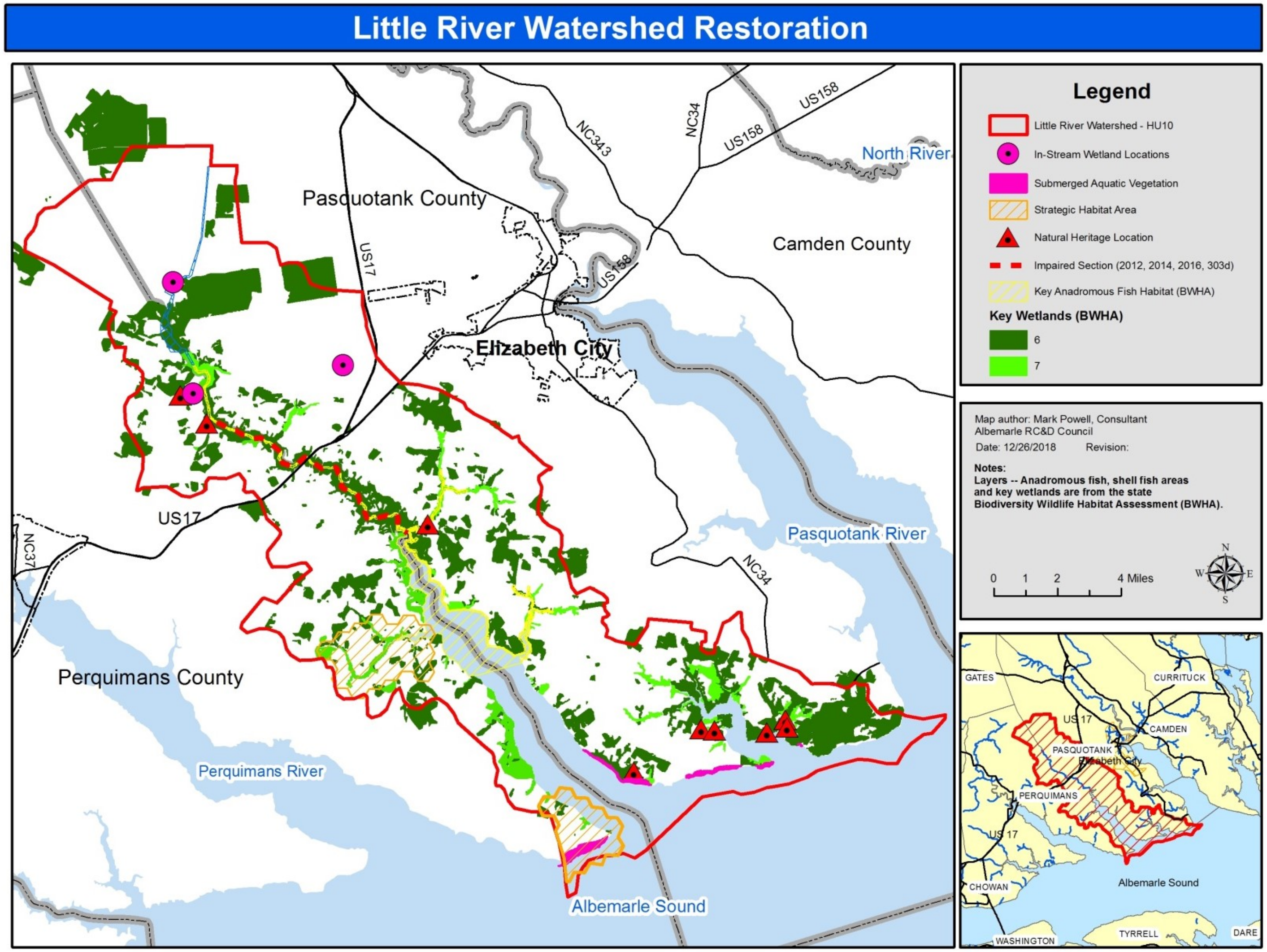
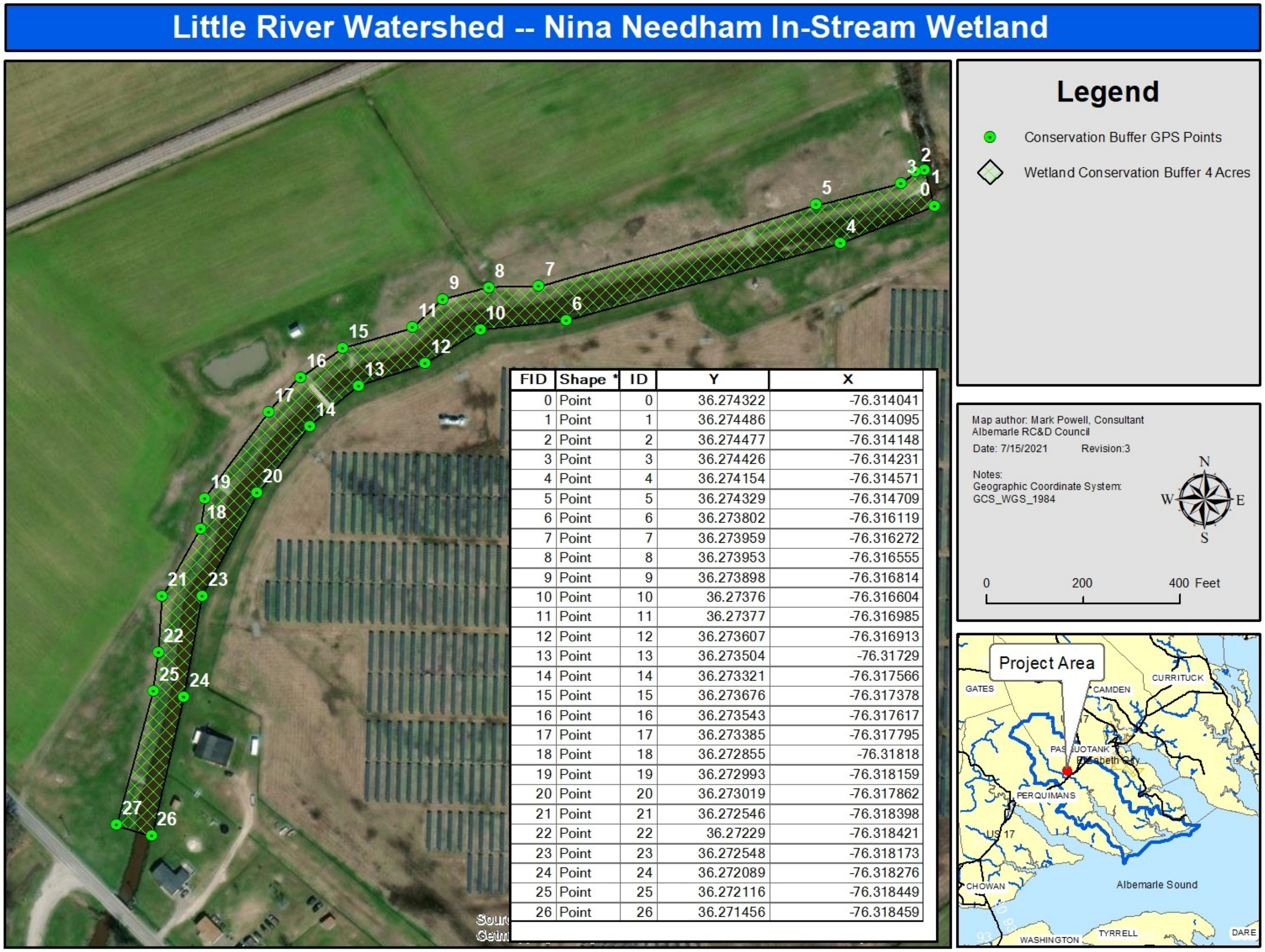


Figure 2. 2,000 ft. In-Stream Wetland on the Nina Needham Farm.



FID	Shape *	ID	Y	X
0	Point	0	36.274322	-76.314041
1	Point	1	36.274486	-76.314095
2	Point	2	36.274477	-76.314148
3	Point	3	36.274426	-76.314231
4	Point	4	36.274154	-76.314571
5	Point	5	36.274329	-76.314709
6	Point	6	36.273802	-76.316119
7	Point	7	36.273959	-76.316272
8	Point	8	36.273953	-76.316555
9	Point	9	36.273898	-76.316814
10	Point	10	36.27376	-76.316604
11	Point	11	36.27377	-76.316985
12	Point	12	36.273607	-76.316913
13	Point	13	36.273504	-76.31729
14	Point	14	36.273321	-76.317566
15	Point	15	36.273676	-76.317378
16	Point	16	36.273543	-76.317617
17	Point	17	36.273385	-76.317795
18	Point	18	36.272855	-76.31818
19	Point	19	36.272993	-76.318159
20	Point	20	36.273019	-76.317862
21	Point	21	36.272546	-76.318398
22	Point	22	36.27229	-76.318421
23	Point	23	36.272548	-76.318173
24	Point	24	36.272089	-76.318276
25	Point	25	36.272116	-76.318449
26	Point	26	36.271456	-76.318459

Figure 3. Existing and Proposed In-Stream Wetland Projects in the Upper Little River Watershed.

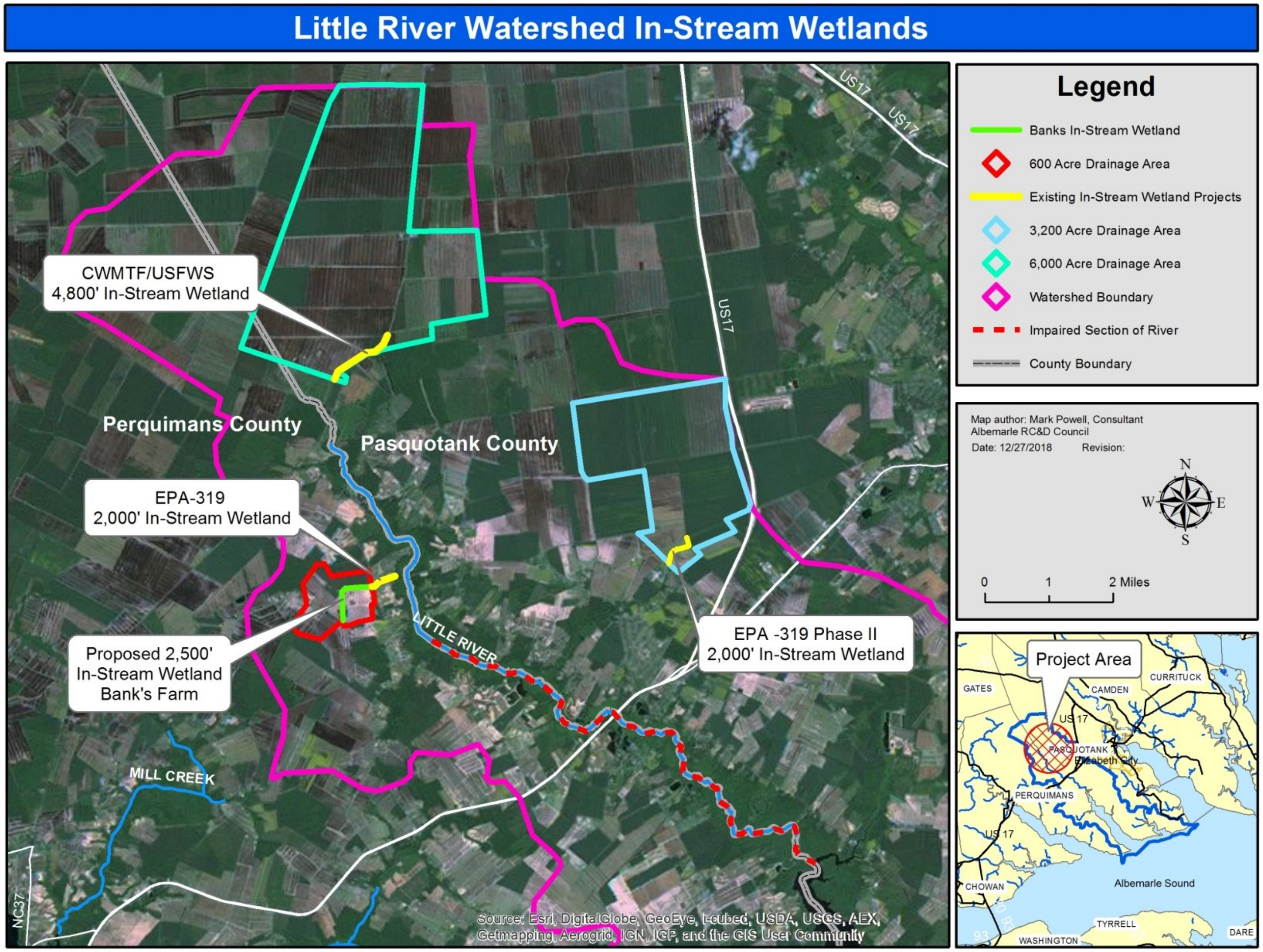


Figure 4. Privately-Owned Canals in the Little River Watershed.

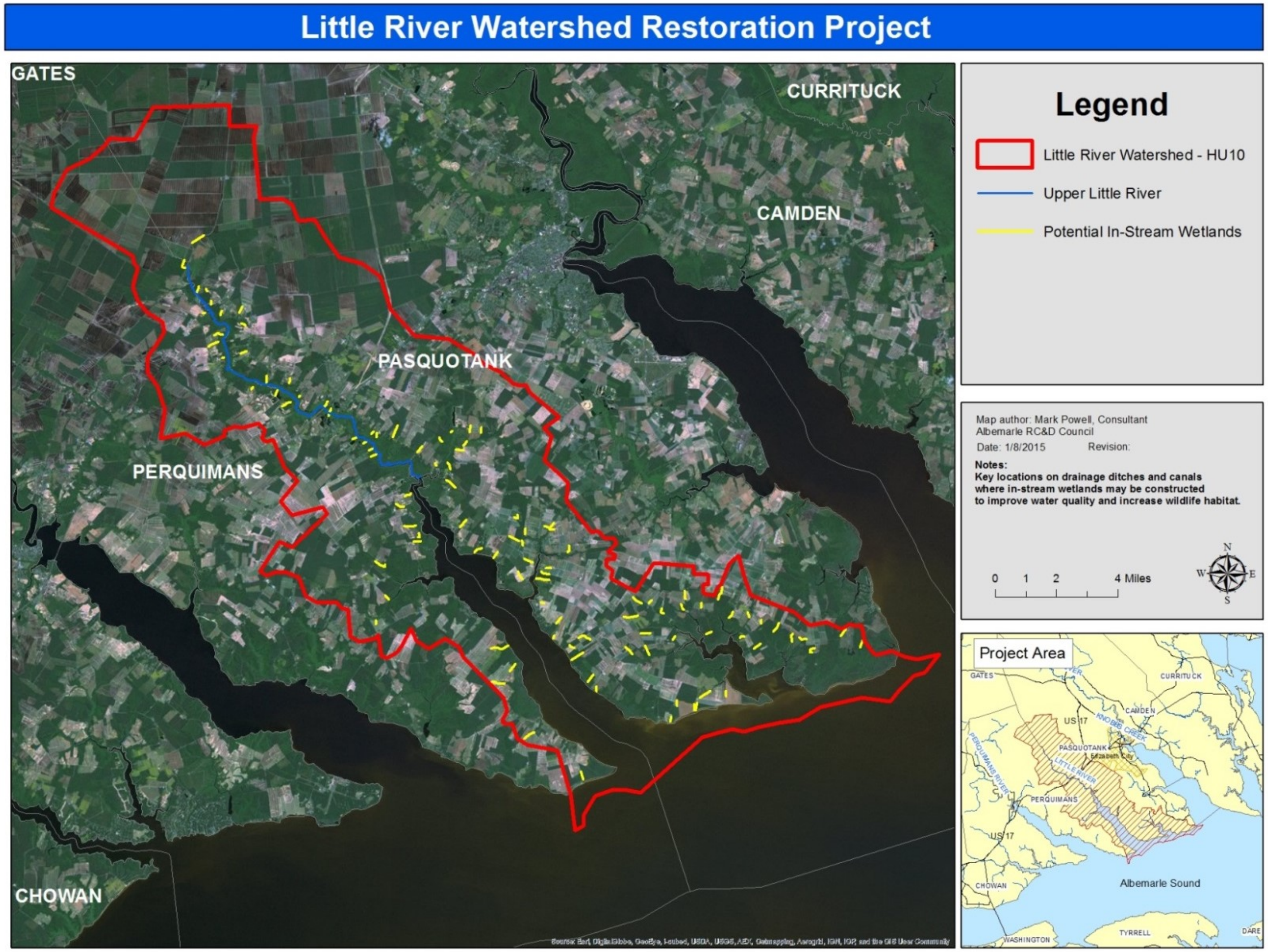


Figure 5. Needham Tract Drainage Canal Prior to Construction of In-stream Wetland in 2018 with EPA 319 Grant.

The head of the canal was highly eroded where stormwater enters from cropland.

Drainage canal carries stormwater to the Little River from approximately 3,000 acres of cropland and solar farm.

V-ditches from adjacent farmland carry stormwater directly to the drainage canal.

Stormwater from the adjacent solar flows to the drainage canal.

Figure 6. Needham Tract In-stream Wetland Construction

Pre-Project Canal

Pre-Project Canal

Site prep, removing stumps and grading site. Landowner provided in-kind work.

Site prep, removing stumps and grading site.

Widening canal and sloping banks.

Widening canal and sloping banks.

.

Figure 7. Needham Tract Drainage Canal after Construction of 2,000 ft. In-stream Wetland in 2018 with EPA 319 Grant.

Side banks were stabilized. The in-stream wetland bottom elevation is the same as the Little River.

Adjacent land was graded to rock drop structures along the in-stream wetland to prevent side bank erosion.

Canal side banks were stabilized.

The in-stream wetland helps filter sediment from cropland above the wetland.

Rock structures help filter stormwater from adjacent cropland.

Side banks were sloped and stabilized.

Figure 8. Needham Completed 2,000 ft. In-stream Wetland in with EPA 319 Grant.

The farmer above the in-stream wetland recently cleared all vegetation from his canal. The resulting soil erosion was filtered through the wetland.

The upper part of the in-stream wetland is well established with plants and is helping filter stormwater from adjacent cropland.

The in-stream wetland is well established with plants and is helping filter stormwater from adjacent cropland.

The in-stream wetland is well established with plants and is helping filter stormwater from adjacent cropland.

Spadderdock and pickerel weed are becoming better established.

Enrichment planting was done in May of 2019, 2020 and 2021.

Figure 9. Wade Boyce Tract Drainage Canal Before Project.

The drainage canal before the project had very little buffer and stormwater from cropland drained directly to the canal.

Drainage canal was a major source of sediment and nutrients entering the Little River above the impaired section.

Figure 10. Boyce Farm In-stream Wetland 2016-2017.

Rock weirs were installed along wetland to stage water for native wetland plants.

Stormwater flows from cropland to rock drop structures, and rock weirs stage water for wetland plants.

Wetland plants were planted May 2016, and replanted in May 2017 due to damage from Hurricane Matthew.

Tile lines and water control boxes help the farmer better manage subsurface water on adjacent farmland.

Informational signage at the head of the in-stream wetland

J-hooks were installed at curves of in-stream wetland to prevent erosion of the side banks.

Figure 11. Boyce Farm In-stream Wetland 2017-2021.

Upper in-stream wetland and
50 ft. grass buffers. Wetland plants are
well established (2021)

Upper in-stream wetland and
50 ft. grass buffers.

Repaired bank at head of in-stream
wetland, damaged by Hurricane Matthew.

Wetland plants were well established by
late 2017.

Lower in-stream wetland with NCSU
monitoring station.

Lower in-stream wetland and
50 ft. grass buffers.

Figure 12. Photos of 4,800 ft. In-stream Wetland on the Steve Harris Farm in the Upper Watershed in Pasquotank County funded by CWMTF and USFWS.

Wetland pockets where drainage ditches run from field into the wetland.

Wetland along 4,800’ of main drainage canal with seeded bank and wetland plants along shelf. View looking northeast.

In-stream wetland, view looking northeast.

Informational signage at the head of the in-stream wetland.

Figure 13. Constructed Wetlands in Northeast N.C.