Southeast White Oak River
Shellfish Restoration Project

Final Report
March, 2009

Sponsors

N.C. Division of Water Quality, N.C. Department of Transportation, N.C. Coastal Federation, Town of Cedar Point, N.C.

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- Frank Tursi, project coordinator, N.C. Coastal Federation

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Laura Kelm, then a student at Duke University who was working on her master's degree in environmental policy, spent a summer as an intern at the N.C. Coastal Federation. She worked almost exclusively on this project doing much of the necessary background work, such as monitoring stream flows and surveying landowners. She ended up writing her thesis on shellfish TMDLs in the Southeast.

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List of Abbreviations

BMP	Best Management Practice
CAFO	Confined Animal Feeding Operations
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
DEH	Division of Environmental Health
DEM	Digital Elevation Model
DENR	N.C. Department of Environment and Natural Resources
DOT	N.C. Department of Transportation
GIS	Geographic Information System
HSPF	Hydrological Simulation Program FORTRAN
HUC	Hydrologic Unit Code
LA	Load Allocation
LID	Low-impact development
LSPC	Loading Simulation Program in C^{++}
MF	MF is an abbreviation for the membrane filter procedure for bacteriological analysis.
ml	Milliliter(s)
MLW	Mean Low Water
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Cover
NOAA	National Ocean and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NCAC	N.C. Administration Code
NSSP	National Shellfish Sanitation Program
SA	Class SA water body: suitable for commercial shellfishing and all other tidal
SSO	Sanitary Sewer Overflows
T^{-1}	Per Tidal Cycle
TMDL	Total Maximum Daily Load
TP	Tidal Prism model
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

Executive Summary

The 42-mile-long White Oak River is one of the last relatively unblemished watery jewels of the N.C. coast. The predominantly black water river meanders through Jones, Carteret and Onslow counties along the central N.C. coast, gradually widening as it flows past Swansboro and into the Atlantic Ocean. It drains almost 12,000 acres of estuaries -- saltwater marshes lined with cordgrass, narrow and impenetrable hardwood swamps and rare stands of red cedar that are flooded with wind tides. The lower portion of the river was so renowned for fat oysters and clams that in times past competing watermen came to blows over its bounty at places that now bear names like Battleground Rock. The lower river is also a designated primary nursery area for such commercially important species as shrimp, spot, Atlantic croaker, blue crabs, weakfish and southern flounder.

A River in Trouble

Figure 1: Closure sign on the White Oak.

But the river has been discovered. The permanent population along the lower White Oak increased by almost a third since 1990, and the amount of developed land increased 82 percent during the same period. With the growth have come bacteria. Since the late 1990s, much of the lower White Oak has been added to North Carolina's list of impaired waters because of bacterial pollution. Forty-two percent of the rivers' oyster and clam beds are permanently closed to shellfishing because of high bacteria levels. Fully two-thirds of the river's shellfish beds are now permanently off limits or close temporarily after a moderate rain. State monitoring indicates that increased runoff from urbanization is the probable cause of the bacterial pollution.

Section 303(d) of the federal Clean Water Act (CWA) and the implementing regulations by U.S. Environmental Protection Agency (EPA) require states to identify and list waters in which current required controls of a specified substance are inadequate to achieve water quality standards. For waters listed on what is commonly called the 303(d) list, the CWA requires states to either devise a Total Maximum Daily Load (TMDL) of the specified substance that the water body can receive without violating water quality standards or demonstrate that water quality standards are being met. Section 319 of the CWA also makes grants available to states, local governments and non-profit agencies to undertake TMDL studies

Seeking a Remedy

The N.C. Coastal Federation, a non-profit conservation group headquartered in Carteret County about 10 miles from the White Oak River, partnered with two state agencies – the N.C. Division of Water Quality (DWQ) and the N.C. Department of Transportation (DOT) – and Cedar Point, a small town in westernmost Carteret County on banks of the river. The partners received a Section 319 Nonpoint Pollution Control grant in 2006 to study four small watersheds along the southeast White Oak in Cedar Point – Dubling and Boathouse creeks, Hills Bay and the area north of the N.C. 24 bridge to Swansboro. All had been closed to shellfishing in last five years and appear on North Carolina's 2005 303(d) list. Figure 2 is a map of the project area.

The project's broad goal was to build the foundation for the restoration of shellfish waters in the White Oak. It attempted to do that by:

- Determining where the bacteria were coming from and how they were getting into the water
- Educating the public about stormwater and its effects on water quality
- Developing TMDLs for three of the watersheds
- Crafting Watershed Implementation Plans to meet the TMDLs
- Identifying sites to install best-management practices (BMPs)

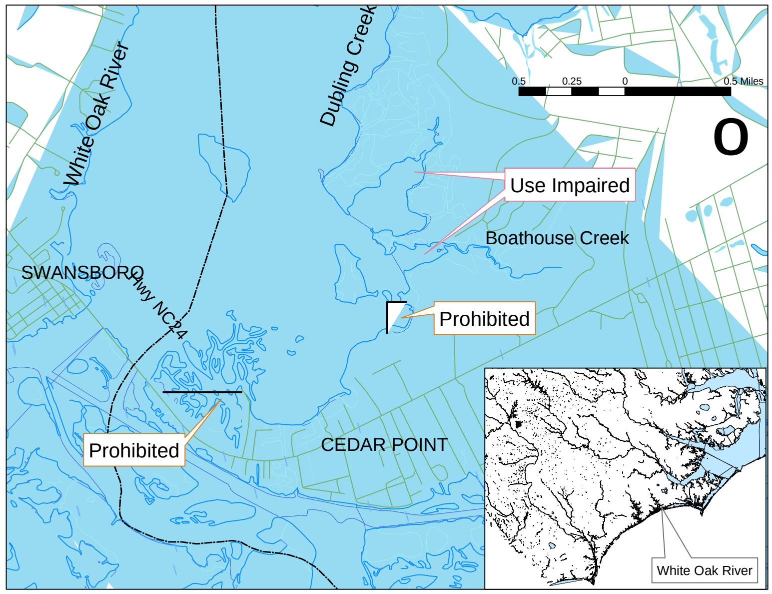

Figure 2: Project Map

Ultimately, the partners hoped that the study would begin to reverse the trend of shellfish closures in the White Oak.

Testing the Water

Much of the first two years of the study were spent taking water samples to test for fecal coliform bacteria. Found only in the digestive tract of warm-blooded mammals, that species of bacteria isn't generally harmful. If it's in the water, however, there's a good chance that dangerous bacteria are there as well. Fecal coliforms are the indicator species used by the state to determine shellfish closures.

In the most comprehensive bacteria sampling ever done on the White Oak, 25 trained volunteers, following a quality-assurance plan approved by DWQ and EPA, took 220 samples from 70 sites in the four watersheds. The intensive sampling was needed to supplement the state's more limited testing in order to better inform the computer models that would devise the TMDLs.

To try to pinpoint pollution "hotspots" in order to determine the best locations for BMPs, the volunteers went far upstream from the state's routine sampling stations, which are generally at the mouths of the creeks. They sampled bays, creeks, storm drains, roadside ditches, boat ramps and mosquito canals. All the samples were analyzed at a state-certified laboratory in Jacksonville, N.C.

Eighty-nine percent of the samples exceeded the bacteria standard for shellfish waters. Of the 113 samples taken from the largest watershed, Boathouse Creek, all but three exceeded the standard. At many of the sites, the bacteria levels were hundreds of times higher than the standard. Bacteria levels in some of the samples from ditches that drain N.C. 24, the main road through the watersheds, were tens of thousands of times higher. The levels generally increased at all sample sites after a rain.

Sources vs. Flow

The samplers didn't find many obvious pollution sources. There are no sewer plants dumping into the watersheds and no industrial discharges. They didn't find illicit pipes, dog pens at the water's edge or failing septic tanks. If fact, as part of the study, the partners examined county health department records and found no unusually high rates of septic-tank failures in the project area.

Instead, the samplers found a severely altered landscape – forests that have been cut down and replaced with parking lots, roads that have been widened, farm fields that have been replaced with rooftops and driveways. A maze of ditches, pipes, culverts and swales crisscrosses the land. They are designed to do one thing – quickly move runoff to the nearby creeks. On a natural coastal landscape, very little of that runoff would make it to surface waters. It would be absorbed by the sandy soils, taken up by plants and trees or evaporated.

The University of North Carolina's Institute of Marine Sciences in Morehead City confirmed the partner's suspicions. It volunteered to do limited genetic testing on 15 samples with the highest bacteria levels. Those tests confirmed that the bacteria came from animals, not humans.

The study's partners concluded that trying to reduce the sources -- deer, raccoons or pets -- was unreasonable. They, instead, turned their attention to the land. Fixing the land by attempting to mimic natural drainage patterns would reduce the flow of runoff into the creeks. It was a more practical alternative and offered a reasonable chance of meeting the study's goals. Restoring natural drainage patterns to reduce the flow of runoff became the focus of the watershed plans that were devised to meet the TMDLs.

It's interesting to note that a study on stormwater commissioned by EPA that was released in October 2008, towards the end of the project, reached the same conclusions. The National Research Council in *Urban Stormwater Management in the United States* noted that "… the regulation of stormwater is hampered by its association with a statute that focuses primarily on specific pollutants and ignores the volume of discharges." Among its recommendations, the council urged EPA to consider flow and impervious surface coverage as proxies for stormwater pollutant loading.

TMDL Development

TMDLs of fecal coliform were computed for Boathouse Creek, Dubling Creek and Hills Bay. A TMDL wasn't developed for the area north of the N.C. 24 bridge because the hydrodynamics weren't conducive to using the modeling approach used for the other TMDLs. That area, however, is included in the watershed plans.

A variety of data at the watershed scale were used to identify potential fecal coliform contributions. The potential fecal coliform contributions were estimated using project monitoring data, landowner surveys and Geographic Information Systems (GIS) data coverage including land use, property and soils. DOT is the lone National Pollution Discharge Elimination System (NPDES) permitted stormwater point source in the shellfish areas addressed in this report. Highway 24 is the largest road in the area and has a closed stormwater conveyance system. Other DOT roads in the area primary rely on open channels for stormwater drainage.

The linked watershed and Tidal Prism modeling approach was used to estimate current fecal coliform load from watersheds and to simulate fecal coliform concentrations in the watersheds. This approach has been used for TMDLs in Maryland, Virginia and at Jarrett Bay in North Carolina. The long-term model results were used to establish allowable loads for each restricted shellfish harvesting area. Since the real-time model simulation is used to establish TMDLs, it accounts for the seasonal variability and critical conditions, which thereby represents the hydrology, hydrodynamics and water quality condition of each selected restricted shellfish harvesting area. The load is then allocated to sources (land use) by determining the proportional contribution of each source based on animal/source density per land use acre times the fecal coliform production.

One of the critical tasks for these TMDLs is to determine current loads from all potential sources in the watershed. The procedure needs to account for temporal variability caused by the seasonal variation and the wet-dry hydrological conditions. Long-term model simulation was conducted to simulate fecal coliform concentration in the water bodies. The long-term daily mean load is estimated for each watershed based on the watershed model results. These results were then used to estimate the current load condition. The allowable loads for each restricted shellfish harvesting area were then computed using both the median water-quality standard for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 90th percentile standard of 43 MPN/100ml. An explicit Margin of Safety (MOS) of 12 percent was incorporated into the analysis to account for uncertainty by lowering the 90th percentile target from 43 to 38.

The goal of load allocation is to determine the estimated loads for each drainage area while ensuring that the water quality standard can be attained. For restricted shellfish harvesting areas, the 90th percentile criterion requires the greatest reduction. Therefore, the load reduction scenario is developed based on the 90th percentile water quality standard. The TMDLs are shown in Table 1.

Table 1: TMDLs

Water body	Pollutant	Existing	WLA	LA	MOS[1]	Reduction Required[2]	TMDL
Boathouse Creek	Fecal coliform (counts/day)	**6.17×10^{11}**	**9.91×10^{9}**	**1.75×10^{11}**	**2.41×10^{10}**	66%	**2.09×10^{11}**
Dubling Creek	Fecal coliform (counts/day)	**1.77×10^{11}**	0.00	**1.53×10^{11}**	**5.00×10^{9}**	11%	**1.58×10^{11}**
White Oak River	Fecal coliform (counts/day)	**2.88×10^{10}**	**6.60×10^{8}**	**1.24×10^{10}**	**1.44×10^{9}**	50%	**1.45×10^{10}**

Notes: WLA = waste load allocation, LA = load allocation, MOS = margin of safety

[1] Margin of safety (MOS) equivalent 11.6 percent of the target concentration in all embayments. Used a target of 38 instead of 43. MOS load in table represents the difference between total loading using those targets.
[2] The reduction required in this table includes the margin of safety. The actual reduction required should not count the margin of safety so the overall reductions required would be 70%, 14%, and 55%, respectively.

Watershed Plans

The project's partners devised watershed plans, which usually aren't included with TMDLs. Following EPA's Nine Key Elements, the plans outline a long-term, broad strategy that attempts to overcome the traditional failure of individual stormwater controls by employing varied integrated measures throughout the four watersheds. The plans are focused mainly on reducing the flow of runoff into the impaired waters by infiltrating or reusing runoff and not solely on source reduction. Among the more than 30 specific BMPs included in the plans are infiltration areas aimed at reducing flow at known bacterial "hotspots," public education on source reduction, individual homeowner BMPs using low-impact development (LID) and other green infrastructure techniques and local regulations or ordinances designed to more effectively control stormwater runoff.

Other Deliverables

Aside from the three TMDLs for 303(d)-listed waters and the accompanying watershed plans, the study also resulted in:

- **Increased Education and Public Awareness**. A stakeholders group of local people helped direct the project. Frank Tursi, the project coordinator, gave more than 30 presentations on the project to civic groups and local governments. It was the subject of more than dozen TV, radio and newspaper stories. The study results and recommendations were summarized in newspaper tabloid format and inserted in a local newspaper. A public meeting was held at the end of the project to discuss the findings and recommendations.
- **DOTs Participation**. DOT has committed to installing retrofit stormwater BMPs to reduce the amount of runoff from N.C.24 that flows into the project's creeks. These BMPs would be used by DOT as credit for compliance with their NPDES stormwater permit and directly support the goals of this project.

What We Learned

It's all about flow. In impaired shellfish waters not affected by point sources, reducing the amount of stormwater entering the water is the most critical factor in restoring the designated use. Reducing animal sources isn't practical. Fixing the land to restore natural drainage patterns offers a more realistic alternative. Yet, state and federal laws are grounded in bacteria reductions and ignore the volume of the discharge. The computer models used to devise TMDLs and the engineers who employ them focus on reducing sources. EPA and DWQ need to devise alternative strategies that emphasize flow reduction.

Finally, no one reading this report will be alive to see the restoration of impaired shellfish waters in North Carolina if a study like this one must be repeated for each impaired water body. There is not enough money or time. We suspect that, in most cases, the results will be the same. EPA and DWQ should craft "general" TMDLs that could be applied to similar water bodies that meet a similar set of circumstances and criteria.

Introduction/Background

Watershed Description
Boathouse Creek, Dubling Creek, Hills Bay and the area north of the N.C. 24 bridge are four small watersheds in the White Oak River Basin (N.C. Subbasin 30501 – HUC 03020106020030) in Carteret County, east of Swansboro, along the central N.C. coast.

Below are thumbnail descriptions of the three watersheds for which TMDLs were devised. A TMDL wasn't done for the area around the bridge because the hydrodynamics weren't conducive to using the modeling approach used for the other TMDLs. That area, however, is included in the watershed plans.

- **Dubling Creek**: About 650 meters long and about 130 meters wide near its head and 280 meters near the mouth. The drainage area is about 246 acres (1.0 km^2) and is contained entirely within the Croatan National Forest. The land use is primarily wetland in the low-lying areas surrounding the creek and longleaf pine forest in the uplands.

- **Boathouse Creek:** About 650 meters long and about 90 meters wide near the head and 180 meters near the mouth. The drainage area is about 546 acres (2.2 km^2), making it the largest of the project watersheds. The land around the embayment and riparian areas is wetland, while the upland portion of the watershed is a mixture of commercial, residential, athletic park and forest.

- **Hills Bay**: About 190 meters long and about 60 meters wide near the head and 300 meters near the mouth. The mean depth of the embayment is about 0.6 m (mean low water). The drainage area is about 152 acres (0.6 km^2). Wetlands surround the embayment, while the upland is a mix of herbaceous grassland, forest, residences and commercial use around N.C. 24.

The dominant tide in this region is the lunar semi-diurnal (M_2) tide with an assumed mean tidal range of 1.6 ft (based on the NOAA station at Bogue Inlet) with a tidal period of 12.42 hours (NOAA, 2004).

Land Use/Land Cover
Cedar Point, a small town with a population of less than 1,000, is the only municipality in the project area, which is dominated by light commercial development along N.C. 24, which is the main road through the watersheds, and residential development elsewhere.

The permanent population in the project area increased by almost a third since 1990, according to the 2000 Census, and the amount of developed land increased 82 percent during the same period.

A land-use file unique to this project was created based on 2004 aerial orthophotography. For the TMDL model, the land use data were grouped into five categories: wetland, pasture/herbaceous, forest, urban and DOT. No livestock are present on the pasture land and there is no cropland in the project area. Land-use statistics are listed in Tables 2 through 4. In Dubling Creek, wetland and forest are the dominant land uses in the watershed. Boathouse Creek is more evenly distributed between urban, forest, wetland and pasture/herbaceous cover. The Hills Bay embayment watershed has more pasture and forest but also has residential areas and commercial land cover along N.C. 24.

Table 2: Land-use distributions for Boathouse Creek Watershed

Land use	Area (acres)	Percent
Wetland	61.74	11.3
Pasture/Herbaceous	55.18	10.1
Forest	206.53	37.7
Urban	196.72	35.9
NCDOT	27.90	5.1
Total	548.07	100

Table 3: Land use distributions for Dubling Creek Watershed

Land use	Area (acres)	Percent
Wetland	119.44	48.5
Pasture/Herbaceous	16.49	6.7
Forest	101.25	41.2
Urban	8.74	3.6
NCDOT	0.1	0.04
Total	246.02	100

Table 4: Land use distributions for Hills Bay Embayment

Land use	Area (acres)	Percent
Wetland	11.54	7.6
Pasture/Herbaceous	67.82	44.8
Forest	37.76	25.0
Urban	26.55	17.6
NCDOT	7.55	5.0
Total	151.22	100

Water Quality Characterization

North Carolina classifies all the waters in the project area as Class SA, which are suitable for commercial shellfishing and all other tidal saltwater use (NCAD 2003). Here are the applicable water-quality standards for Shellfish Harvesting Waters (15A NCAC 02B.0221 -- Tidal Salt Water Quality Standards for Class SA Waters):

> *"Organisms of coliform group: fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions."*

The Shellfish Sanitation and Recreational Water Quality Section of the Division of Environmental Health (DEH) is responsible for monitoring shellfish harvesting waters to ensure oysters and clams are safe for human consumption. DEH adheres to the requirements of the National Shellfish Sanitation Program, with oversight by the U.S. Food and Drug Administration. DEH conducts shoreline surveys and collects routine bacteria water-quality samples in the shellfish-growing areas of North Carolina. The data are used to determine if the water-quality criteria are being met. If the criteria are exceeded, the shellfish areas are closed to harvest, at least temporarily, and consequently the designated use is not being achieved. The waters are then considered impaired under Section 303(d) of the CWA.

For SA waters, fecal coliform bacteria are the pollutants that might impair this use. That species of bacteria are found in the intestinal tract of humans and other warm-blooded animals. Few fecal coliform bacteria are pathogenic; however, elevated levels of fecal coliform in shellfish waters indicates recent sources of pollution and the possible presence of dangerous bacteria. Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted water include viral and bacterial gastroenteritis and hepatitis A. Fecal coliform in surface waters may come from point sources (i.e., NPDES stormwater conveyances) and nonpoint sources.

All the waters in the project area are within DEH's D-3 the shellfish-growing area. DEH monitors the project's embayments using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. In addition to the routine bacteriological monitoring of the areas, conditional area samples are collected after rainfall for some stations. DEH's eight fecal coliform stations in and around the project area (Figure 3) are mostly located in the embayments, and most data were collected at least six times a year from 1991 (except Boathouse Creek where sampling began in 2004) until the present. Based on field measurements, the fecal coliform concentrations exceed the water quality standards at three stations: 19, 19A, and 56. Violations indicate that observed concentrations exceed the 90^{th} percentile water quality standard of 43 MPN per 100 ml. Though the last 30 samples taken at station 56 are below the 90^{th} percentile standard, the 90^{th} percentile remained above 50 MPN/100ml from October 2004 through October 2007. Similarly, the 90^{th} percentile exceeded the standard at station 20 as recently as September 2003. A summary of the data appears in Table 5.

Based on that sampling, Boathouse Creek, Dubling Creek, and Hills Bay are currently rated as Prohibited and are closed permanently to shellfishing, according to DEH. The area southeast of the N.C. 24 bridge contains DEHSS station 20. According to the 2006 Sanitary Survey, this is one of the few areas that showed improvement in the D-3 growing area. However, the area just south of station 20 is (remains) classified as Prohibited (Closed) for shellfish harvesting.

Table 5: A Summary of Statistics of Observation Data (as of March 2008)

Station	Area	**Last 30 sample geometric mean** (MPN /100ml)	**Last 30 sample Median** (MPN /100ml)	**Last 30 sample 90%** (MPN/100ml)
56	Dubling Creek	7.1	7.8	36
56B	Outside Dubling	4.6	3.3	18
20	NC24 Bridge Area	6.9	5.6	27
20A	Outside NC24 Bridge Area	5.4	5.7	16
19A	Boathouse Creek	18.8	22	130
19C	Outside Boathouse	6.0	6.8	33
19	Hills Bay Embayment	17.7	19.5	91
19D	Outside Embayment	5.4	5.3	18.5

All of the waters in the project area became impaired since 2000. The state determined that polluted runoff from developed land uses was the likely cause.

The creeks became part of the grim arithmetic of the White Oak. Currently, 42 percent of the river's shellfish beds are closed permanently to harvest because of high bacteria levels. Add those areas that close temporarily after a 1.5-inch rainfall or open only during times of drought and almost two-thirds of the river's 11,239 acres of SA waters are now impaired. Figure 4 shows the permanently closed shellfishing areas in the lower White Oak.

Project Partners

The N.C. Coastal Federation, a 501(c)3 environmental advocacy group with headquarters about 10 miles from the White Oak, in 2006 teamed with DWQ, DOT and Cedar Point to receive a Section 319 Nonpoint Pollution Control grant to conduct the TMDL study required by the CWA. The partners also proposed to devise watershed plan to implement strategies intended to meet the TMDL targets

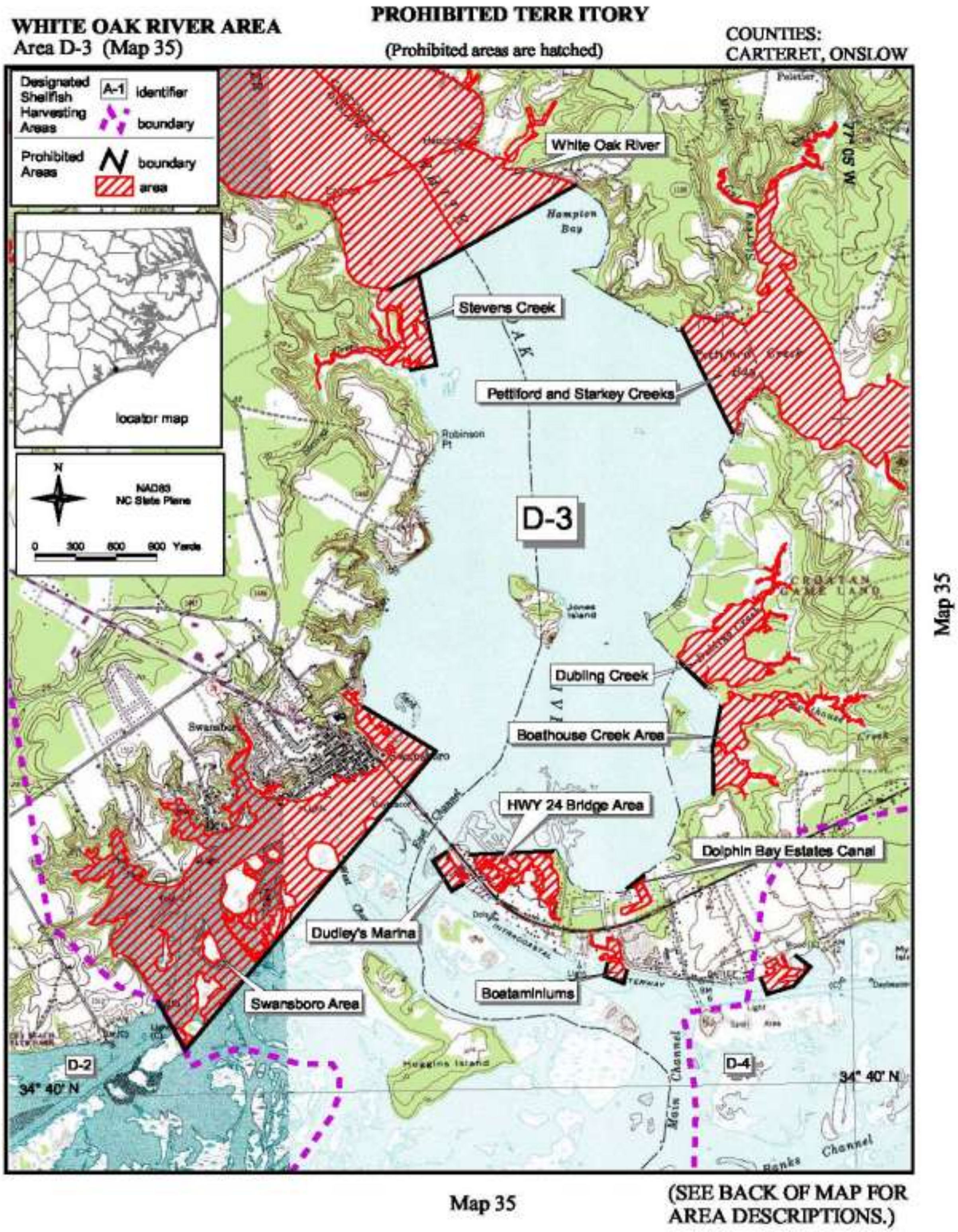

Figure 4: Prohibited shellfish areas in the lower White Oak River

Purposes and Goals

The broad purpose of the study was to begin the eventual restoration of shellfish waters in the White Oak. The specific goals as detailed in the grant proposal were:

- To assess the sources of bacteria in four impaired coastal watersheds.
- To devise the necessary the TMDLs for those watersheds. As already noted the area around the N.C. 24 bridge was later removed from the TMDL list because its hydrodynamic wasn't conducive to TMDLs modeling.
- To prepare Watershed Plans, following EPA's nine key elements, for all four water bodies in order to implement the strategies needed to meet the TMDL targets.
- To educate people along the lower White Oak about the effects of polluted runoff on shellfishing waters.
- To engage DOT in a strategy to reduce the flow of highway runoff into the watersheds.

The partners are pleased to report that all the goals were met with no significant changes.

Deliverables

1. <u>Fecal coliform source assessment.</u>
    - DEH Shellfish Sanitation will conduct a shoreline survey in the area in 2005. DEH will construct a GIS database of this survey.

      DEH conducted the shoreline survey using improved mapping techniques that identified stormwater discharges. The survey methodology uses both GIS and GPS mapping technology to identify and spatially map potential sources of pollution, including stormwater outfalls, slip docks, agriculture and new subdivisions. The survey was used as a starting point for the source assessment.

    - Collect 240 fecal coliform samples. These samples will be analyzed by a DWQ-certified laboratory, Beacham Labs in Jacksonville, N.C. A wet weather and dry weather sampling strategy will be devised to enable categorization and prioritization of sources. Additionally, the samples will generally proceed from a downstream to upstream fashion throughout the watershed in order to identify 'hot spot' areas. Once these have been identified additional sampling will be conducted to target sources as appropriate. Field observations, land use/land cover data, and other relevant information will also be used to supplement monitoring data and identify likely significant sources.

      Twenty-five volunteers were trained to take the bacteria samples. They followed a strict protocol that was outlined in an EPA- and DWQ-approved Quality Assurance Project Plan (see Appendix E). Fifty-two sampling sites were originally chosen. Some were dropped after initial testing revealed low bacteria levels. Others were added in an attempt to pinpoint source "hotspots." In all, samples were drawn from 70 different sites (Figure 5). The drought in 2007 greatly hampered the sampling effort. It just didn't rain often enough or hard enough to take samples. A "wet" sample was *defined as a minimum of 0.50 inches of rain in 24 hours. The drought forced us to extend the project for six months to allow for more sampling. Ultimately, 220 samples were collected and analyzed. Bacteria levels that far exceed the shellfish standard were found at almost all sample sites. See Appendix C for all sample results.*

Dr. Rachel Noble of the University of North Carolina's Institute of Marine Sciences analyzed the DNA of 15 of the highest bacteria samples. All were "natural," meaning they didn't originate with humans.

- Conduct watershed surveys to better estimate populations of humans, pets, livestock, and wildlife. Also, the number of septic systems will be identified. DEH's shoreline survey includes visual inspection of septic systems. There is no centralized sanitary sewer in the study area. There are package treatment plants that will be located and examined to determine if they contribute to fecal coliform loading. The most up-to-date information will be used to support the TMDL assessment.

  We attempted to contact every landowner in the project area by letter and telephone to inquire about pet ownership, the type of wildlife they see around their homes and whether they are fulltime residents. About 20 percent of the landowners responded.

  We also examined the records at the Carteret County Health Department to determine the rates of failure and repair of septic tanks in the project area. We found no unusually high rates, but officials at the health department noted that many of the septic systems were installed in marginal soils years ago under more lenient regulations than are in place today. They doubted that many of the conventional septic systems now in the ground could be permitted under current regulations. This seemed especially apt at Ocean Spray, an older subdivision near the headwaters of Boathouse Creek. Samples taken from drainage ditches in the subdivision and in the creek bordering Ocean Spray revealed unusually high levels of bacteria. Many Ocean Spray residents are seasonal, according to our surveys, and use their septic system for a few months each year. Though the systems aren't showing classic signs of failure, their age, their infrequent and inefficient use, the marginal soils and the ditching may be the reasons for the high bacteria levels. The Watershed Plan recommends intensive groundwater monitoring to determine whether the septic systems are the source of the problem along that portion of Boathouse Creek.

  No package plants were indentified in the project area.

- Define watershed boundaries, including stormwater conveyance systems.

  Topographic maps combined with walking the watershed were used to determine the boundaries. DOT provided maps of its stormwater conveyance system for N.C 24.

Figure 5: Project Monitoring Stations

2. Stakeholder meetings, which will:
    - Satisfy information/education component of EPA 9 Key Elements.
    - Shape modeling decision and assumptions.
    - Identify BMP sites for Watershed Implementation Plans.
    - Inform TMDL allocation decision (i.e., where to seek reductions).
    - Resolve conflict (i.e., reduce finger pointing and increase action).

The public involvement and educational components ended up being much more extensive than proposed. The stakeholders met four times to discuss the project. But comments from the larger community were invited at two community meetings attended by more than 100 people. Frank Tursi, the project coordinator, gave more than 30 presentations on the project to local governments and church and civic groups. It was featured in more than 20 media stories.

3. TMDLs for 303(d)-listed waters in Dubling Creek, Boathouse Creek and embayment south of Boathouse Creek (15 acres). These are 'High Priority' listings on North Carolina's 2002 list.
    - Buck Engineering Will use an EPA- and DWQ-approved watershed model, HSPF, LSPC or SWAT.
    - For the response model, Buck Engineering will use the Tidal Prism Model, which is being used for TMDLs in Va. and N.C. (Jarrett Bay). The Tidal Prism Model is DWQ- and EPA-approved.

The linked watershed and Tidal Prism modeling approach was used to estimate current fecal coliform load from watersheds and to simulate fecal coliform concentrations in the embayments. This approach has been used for TMDLs in Maryland, Virginia, and Jarrett Bay in North Carolina. The long-term model results were used to establish allowable loads for each restricted shellfish harvesting area. Since the real-time model simulation is used to establish TMDLs, it accounts for the seasonal variability and critical conditions, which thereby represents the hydrology, hydrodynamics, and water quality condition of each selected restricted shellfish harvesting area. The load is then allocated to sources (land use) by determining the proportional contribution of each source based on animal/source density per land use acre times the fecal coliform production. See the Appendix A, the TMDL document, for a fuller technical description of how the TMDL was devised.

Baker Engineering bought Buck Engineering soon after the project began.

4. Watershed Implementation Plans will be prepared by Buck Engineering for TMDL waters above and for recent DEHSS listing near Hwy. N.C .24 bridge (44 acres). These will adhere to EPA's 9 Key Elements for Watershed Implementation Plans. In addition, they will:
    - Address two general pathogen categories: 1) at the source (e.g., failing septic systems); and 2) treat water after contamination (e.g. stormwater).
    - Address dry and wet weather sources.
    - Identify at least 24 BMP sites (6 per impaired water body) and prescribe specific treatments to reduce fecal coliform loading.

- Include schedules for obtaining funding to implement BMPs and schedules to implement BMPs once funding has been secured.

Implementation plans (Appendix B) were developed for all four watersheds in an effort to meet the specified TMDLs. These plans may be amended over time as part of an adaptive management approach as more information becomes available. The plans offer a broad suite of 33 integrated, site-specific stormwater BMPs, both structural and non-structural and their effects were quantified with the aid of the TMDL models. This process of developing the plans followed EPA's Nine Key Elements for implementing watershed plans using incremental Section 319 funds.

Mechanisms for reducing fecal coliform include implementation of appropriate structural BMPs, education on source reduction, individual homeowner BMPs using LID and other green infrastructure techniques and local regulations or ordinances designed to more effectively control stormwater runoff. See Table 6 for a complete description of the recommended BMPs. Cost estimates and timetables are included in the plans.

This is a long-term, broad strategy that attempts to overcome the traditional failure of individual stormwater controls by employing varied integrated measures throughout the watershed. The structural steps outlined in the plans are focused mainly on reducing the flow of runoff into the impaired waters by infiltrating or reusing runoff and not solely on source reduction. The National Research Council, in its report Urban Stormwater Management in the United States, *recently identified the reliance on individual stormwater controls that attempt to reduce the sources of stormwater pollution as a general failure of stormwater TMDLs.*

5. <u>Tabloid inserts</u> in local newspapers to raise awareness of project and actions needed to restore shellfish waters.

A four-page publication (Appendix C) summarizing the study results and watershed plan recommendations was prepared and inserted into the Tideland News *of Swansboro and distributed to its 3,600 subscribers on Feb. 25. Four hundred additional copies were are also printed for general distribution.*

6. <u>Final project report</u> prepared by NCCF to report and explain results and fulfill funding requirement.

This is the final report.

Table 6: Potential BMP database

Dubling Creek Watershed

Potential BMP location	Severity of Bacteria Loading	Comments
Walking trail	High	Pet waste disposal stations and signs explaining the problem
Wetland ditches	High	Eliminate future maintenance of mosquito ditches so they are allowed to naturally fill in and re-vegetate
Mine pond	Moderate	Engineer outlet structure to retain high flows and gradually release runoff. Open tree canopy to allow greater exposure to sunlight.
Forest	Moderate	Allow reforestation to occur following hurricanes. Also, tree plantings in select locations.
Mine site	Moderate	Re-vegetate this area.
Roads	Moderate	Look for areas where runoff from roads accumulates and becomes channelized. Correct these problems.
Pasture	Moderate	Add a field edge buffer and possibly level spreader

Boathouse Creek Watershed

Potential BMP location	Severity of Bacteria Loading	Comments
Western Park near entrance	High	Wetland feature currently present. Could install an outlet structure and expand basin to detain flow and enhance the wetland.
Western Park near tennis courts	High	An infiltration basin/trench could be constructed along the wood line.
Western Park swale at southwestern corner	Moderate	The bacteria levels at this location are not very high but it could be a good future site if conditions change.
Western Park pet waste	High	Pet waste disposal stations and signs explaining the problem.
Ocean Spray septic systems	Moderate	Further monitor this potential source with piezometers/wells. Set up a septage authority and seek grant funds to update systems in need of replacement.
Ocean Spray ditch near BC21	High	Could do a level spreader and filter strip or a terraced wetland here. Would need to purchase undeveloped lot.
Ocean Spray ditch near BC22	Moderate	Swale running through backyard of numerous properties. Difficult access, might access below from Western Park.
Ocean Spray ditch near BC23	High	Existing wetland feature could be enhanced. Difficult access and minimal space. Might consider site below that could be accessed through Western Park but would need to cross Boathouse Creek.
Cedar Point Town Hall	Low	Room for a small infiltration basin or bioretention area. Install cisterns at town hall and at planned maintenance building.
NCDOT pipe outlet at BC11	High	Existing J-shaped open channel could be re-engineered to detain/infiltrate runoff discharged from pipe outlet. Pipe outlet and part of channel located on private property. May need to purchase additional land.
NCDOT outfall at BC26	Moderate	This receiving channel is considered to be jurisdictional. Survey and engineering evaluation necessary to determine feasibility of a conventional stormwater BMP which would be located on private property due to very limited public ROW. Alternatively, source control measures and/or filter-type treatment within the closed conveyance system may be implemented.
Boat ramp at mouth of Boathouse Creek	Moderate	Good site to install a small BMP with educational signage.

Table 6: continued		
USFS campground	Moderate-High	Check the septic system here. Add pet waste disposal stations and educational signs.
Marsh Harbour		Recommend LID in third phase. Incorporate voluntary LID and homeowner education in existing phases. Purchase large waterfront buffer from existing undeveloped lots.
Stormwater ordinance		Town of Cedar Point plans to make Low Impact Development an option for developers.
Hills Bay Embayment Watershed		
Potential BMP location	**Severity of Bacteria Loading**	**Comments**
NCDOT pipe outlet off Bluff Rd	High	Pipe outlet located on private property (church). Depth to seasonal high water table may influence BMP selection. Survey and engineering evaluation necessary in order to identify candidate BMPs due to site constraints. Little elevation difference between pipe and receiving channel inverts. Significant amounts of excavation may be required depending on BMP selection. Flow splitter will be required due to high runoff volumes. Alternatively, source control measures and/or filter-type treatment within the closed conveyance system may be implemented
Swale draining Octagon House property	Moderate-High	Work with Masons to ensure they develop property with water protection as a primary goal, use LID techniques. Or install a level spreader and filter strip if site is not developed.
Swale draining land adjacent to Octagon	Moderate-High	Install a level spreader and filter strip above the drainage to the tidal creek.
Swale draining Jones property	Moderate-High	Install a level spreader and filter strip above the drainage to the tidal creek.
Church off of Bluff Rd.	Moderate	Install level spreader and filter strip.
Bluff Rd across from church	Moderate	Install at bioretention area where this runoff concentrates.
NC 24 border in sws 201	High	Install a level spreader and filter strip above existing pond.
Septic systems	Moderate	Might seek to upgrade these systems.
Bridges Watershed		
Potential BMP location	**Severity of Bacteria Loading**	**Comments**
Septic systems		Limited available space, soils, and proximity to the shellfish waters suggest that optimum systems are needed here.
Backyard rain gardens		Teach homeowners how to construct rain gardens to treat runoff from their property. Install neighborhood rain gardens as demonstration project.
Education		Educational campaign to inform limited number of residences bordering shellfish waters about pet waste, septic systems, and rain gardens.

Methodology/Execution

Organization
A project team met at least quarterly to guide the execution of the study. The team consisted of representatives of the project partners and the project engineer. The members of the project team were:

- Andy McDaniel of the N.C. Department of Transportation's Hydraulics Unit
- Chris Seaberg, town administrator, Cedar Point
- Adugna Kebede, environmental modeler at the N.C. Division of Water Quality's TMDL Unit
- Todd Miller, executive director of the N.C. Coastal Federation
- Frank Tursi, Cape Lookout Coastkeeper, N.C. Coastal Federation
- Chris Roessler of Baker Engineering

Frank Tursi was the project coordinator and was responsible communicating with other members of the project team, devising the sampling protocol, recruiting and training the volunteer samplers, overseeing the sampling, acting as a liaison with the Cedar Point Town Council and Planning Board and with DWQ, writing press releases and handling media inquiries.

One of the first things that the project team did was approve a work plan (Appendix D) that organized the project's deliverables by quarter. Though the steps had to be modified as developing circumstances dictated, the plan was a general blueprint for the project.

Getting the Lay of the Land
Several members of the project team were unfamiliar with geography of the project area. The first several meetings of the team were spent in the field, walking the ground or in the N.C. Coastal Federation boat. On those trips, team members determined the watershed boundaries, did extensive bathymetric surveys of each of the watershed and scouted for the initial sampling sites.

Sampling the Water
Collecting bacteria samples from the watersheds occupied the first two years of the project. After the Quality Assurance Project Plan (Appendix E) was approved by DWQ and EPA, the N.C. Coastal Federation set about recruiting volunteers. It issued a press release (Appendix F) that explained the project and asked for volunteers to help collect samples. The release received widespread media coverage.

Thirty-three people from communities on or near the White Oak responded to the release and attended a Saturday training class. At the class, Frank Tursi explained the project in depth and described the sampling methodology that was outlined in the quality assurance plan. He also explained how to fill in the data sheets and chain-of-custody forms that were to accompany each sample and demonstrated how to properly collect the samples without contaminating them.

Twenty five people ultimately volunteered to take the samples. Most were paired in teams of two and assigned no more than three contiguous sampling sites. Frank accompanied the teams in the field on their first sampling assignments to ensure that the proper protocols were being followed.

Figure 6: Samplers Jack Cleaves, front, and Smoke Betts on Boathouse Creek

Safety was a prime consideration. Most of the samples would be taken during or just after a rain, and we wanted to avoid sending the volunteers out on the water in boats or kayaks during inclement weather. We tried to choose sampling sites that could be accessed from public land, roads or docks. Some, though, were on private property. We sent letters (Appendix G) to the landowners asking for their permission. Most granted it, and a few volunteered to take the samples themselves. Frank took most of the open-water samples with Coastal Federation boats. Three shallow-water sampling sites were assigned to two of the most-experienced kayakers.

The samplers fell into a comfortable routine. We placed the “official” rain gage at the Cedar Point Town Hall, which was in the geographic center of the watershed. Don Relearn, maintenance supervisor for the town, kept a daily log of rainfall at the gage. The sampling protocol defined “wet” samples as those taken within 24 hours of rainfall of at least 0.50 inches. When the required amount was measured at the gage, Don called Frank, who then notified the samplers by phone or email. After collecting the samples, the volunteers place them, the data sheets and the chain-of-custody forms in a cooler of ice outside town hall. Frank or a volunteer then took the samples to the laboratory in Jacksonville, making sure they got there within four hours of collection.

A drought in 2007 played havoc with the sampling schedule. Not enough rain fell to allow for ample sampling. We had to request a six-month extension of the project to allow more time to collect the required samples.

TMDLs and Watershed Plans
Chris Roessler devised the three TMDLs. He also crafted the watershed plans with help from Frank and the other project team members. See the Appendix A (TMDL study) and Appendix B (Watershed Implementation Plans) for detailed descriptions of the methodologies used for each.

Outputs and Results

TMDL Load Reductions
The goal of load allocation in the TMDLs is to determine the estimated loads for each drainage area while ensuring that the water quality standard can be attained. For restricted shellfish harvesting areas, the 90th percentile criterion requires the greatest reduction. Therefore, the load reduction scenario was developed based on the 90th percentile water-quality standard. The load reductions needed in the watershed of each restricted shellfish harvesting area to meet the shellfish criteria and the load allocations required to meet the TMDLs with a margin of safety are:

- Dubling Creek -- 14 percent
- Boathouse Creek – 70 percent
- Hills Bay – 55 percent

These are the loading reductions required from all sources taken collectively.

Implementation BMPs
Implementation plans accompany the TMDL. The project watersheds were explored in detail to identify potential stormwater BMP sites. Non-structural BMPs, such as education and implementing a stormwater ordinance by Cedar Point, were also included. This effort produced 33 potential bacteria load reducing measures.

Will they work? We conducted a literature review to determine the amount of bacteria reduction that might be expected from structural stormwater BMPs (Schueler and Holland, 2000; NCDWQ, 2007; Boyer, 2007; Coyne et al., 1995). These sources were combined using best professional judgment to produce one reduction percentage per BMP type. The results are shown in Table 7, and the Watershed Plans (Appendix B, pp.30-37) fully explain the methods we used to calibrate the model simulations that predicted the reduction of bacteria loading if the BMPs are implemented. It should be noted that these modeled reductions don't include education or the stormwater ordinance. Education would help existing loading by reducing sources but the ordinance would presumably focus on future sources. Septic reductions were factored in the modeling.

The results are positive for Dubling Creek. It appears that the shellfish waters will be able to meet the designated use if the identified measures are implemented. The results are not encouraging for Boathouse Creek and Hills Bay, however. The maximum 90th percentile dips slightly in both cases: from 120 to 110 in Boathouse Creek and from 90 to 70 in the embayment. The impairments in those watersheds, especially in Boathouse Creek, are more intractable. The reductions required by the TMDLs will need to be implemented on essentially every developed parcel in the watershed. This is very difficult task because of constraints caused by a lack of available space for retrofits and existing infrastructure. Where these constraints can be

Table 7: Expected Fecal Coliform Bacteria Removal by BMP Type

BMP Type	NC BMP Manual	Center for Watershed Protection	Delaware Dept of Nat Res and Env Control	Removal based on BPJ
Bioretention	High		>99%	90%
Sw wetland	Med		78-90%	70%
Wet detention	Med	65% (n=10)	44-99%	65%
Sand filter	High	58% (n=9)	35-83%	70%
Filter strip	Med	57% (Coyne et al., 1995)		55%
Grassed swale	Low	-58% (n=5)		0%
Restored buffer	Med		43-57%	50%
Infiltration device	High			90%
Dry ext. detention	Med			70%
Permeable pavement	Low			30%
Green roof	Low			30%

overcome, BMP sites have been recommended. However, the reductions may be closer to reaching standards than the\ models predict because there is not a linear relationship between loading and bacteria concentrations in the embayment. This was observed in the modeling to determine the TMDLs.

It's also difficult to precisely predict the result of management measures over time. A good start is to implement the most important sites and continue down the list. If monitoring is continued during this process, it should be possible to see the effects of the initial measures. This may allow modifications to the modeling and the implementation plans. This process is known as adaptive management.

Over time, more BMP sites may be identified. In the meantime, there is plenty of work to implement the identified measures. A key component that hasn't been factored into the modeling is education. If this is instituted successfully, bacteria source reduction may be substantial. Source reduction is the most effective means of addressing bacteria from both a cost and quantity perspective

Source reduction would be critical in areas such as Ocean Spray and around the N.C. 24 bridge. Rain gardens are also practical solutions in these areas because suitable retrofit BMP sites are, for the most part, not present.

Source reduction will not be effective at reducing bacteria from wildlife. However, hydrologic improvements may lower this by decreasing overland flow.

In conclusion, the shellfish impairments are difficult to manage because much of the bacteria come from wildlife. It may be easier to do on developed land (e.g., a stormwater conveyance pipe) but the treatment options are reduced on forest and wetland. Where possible, the implementation plans recommend alternative treatment measures, such as allowing mosquito ditches to naturally fill and promoting forest re-growth. Even with loading from developed land, retrofit BMPs are often not feasible. And when they are feasible, they are expensive. Nevertheless, this is the scenario for impaired shellfish waters along the North Carolina coast. This project may serve as a pilot for how to cost effectively manage the problem.

Outcomes and Conclusions

This project has already helped clean up the White Oak River, and not a shovel of dirt has yet been turned on any of its recommended BMPs. Just as this project began, Wal-mart announced plans to build a store in Cedar Point, in the headwaters of Boathouse Creek. The company needed the land rezoned and its site plan approved. At the packed public hearing of the Town Council, the mayor of Cedar Point and a member of the project's stakeholders group asked Frank Tursi, the project's leader, what the proposed 16 acres of parking lot and rooftop would do to water quality in the creek. Frank said it certainly wouldn't help it.

The town board refused to rezone the land until Wal-mart agreed to better control stormwater from the site. After several months of discussion, the company agreed to design a stormwater system that would treat 10 times as much runoff than state rules at the time required. It also agreed to use pervious pavement in its parking lot, and the town waived a landscaping requirement to allow the company to build large bioretention cells in the parking lot to treat runoff.

A year later, as the bacteria sample results were coming in, the project played a prominent role in the N.C. Coastal Federation's efforts to strengthen North Carolina's coastal stormwater regulations. Frank used the project's sampling results to illustrate the issues. He held two community meetings about the project and took reporters out on the river. The White Oak River became the face of a failed policy. In the face of stiff opposition, the N.C. General Assembly withstood passed tougher stormwater regulations.

DOT, a project partner, has committed to tackling the two storm drains that convey runoff from N.C. 24 into Boathouse Creek. Project sampling showed that discharge from the two the drains routinely dump bacteria that is tens of thousands of times higher than the state standard.

Even before the project was completed, Cedar Point was making plans to follow up on its recommendation. It applied for a 319 grant to do some of the BMPs recommended in the watershed plans. It and neighboring Cape Carteret hope to develop a stormwater ordinance that would encourage LID and other green infrastructure in future commercial and residential construction. It intends to use LID techniques to control stormwater at its town hall and hopes to partner with a state agency to employ such techniques in people's yards and businesses. DWQ recently notified the town that its proposal is being considered for funding.

DOT has added the BMPs recommended for Western Park in its package of stimulus projects that it submitted to the federal Department of Transportation.

While it has already led to water-quality benefits, the project, we think, also illustrates some serious flaws in the strategies state and federal officials use to control stormwater, now the largest source of water pollution along the N.C. coast. Those strategies focus almost entirely on reducing the sources of pollution. That's what the modeling software attempts to do. That's what the engineers who employ those models were trained to do. As this project shows, it's an impossible task when the sources are mostly natural or otherwise not easily traced. Where the bacteria are coming from isn't as important as how they're getting into the water. Reduce the flow and you reduce the problem. Zero has a powerful multiplying effect.

Finally, we suspect that many of the tens of thousands of acres of impaired shellfish waters along the N.C. coast are pretty much like the ones we studied here – moderately developed watersheds with no major industry, sewer plant or other point source. Like Boathouse Creek or Hills Bay, the land around them has been ditched and piped, its forests replaced with parking lots, rooftops and driveways. Deer, raccoon and Fido and Fifi are main sources of bacteria. Do we have to spend another three years and $200,000 to figure that out? If so, meeting the CWA's mandate to restore these impaired waters is a goal few people reading this will be alive to see. We think there must be a better way. Many state agencies offer general permits for activities that meeting a broad set of criteria and circumstances because they know that what the outcome. We suggest that EPA and DWQ devise a general TMDL that could be applied to similar watersheds that are affected by similar problems.

Budget

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