BRADLEY AND HEWLETTS CREEKS WATERSHED RESTORATION PLAN

The City of Wilmington

With Contributing Partners:
North Carolina Coastal Federation
Withers & Ravenel Engineers
Town of Wrightsville Beach
UNCW Center for Marine Science

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ACRONYMS, ABBREVIATIONS, and GLOSSARY

APPROVED AREA - An area determined suitable for the harvest of shellfish for direct market purposes.

BIORETENTION AREAS - Also known as rain gardens, these provide onsite retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff.

BMP - Best Management Practice. Any action or on-the-ground practice that reduces the amount of stormwater and pollution flowing into waterways. For example, rain gardens, buffers, minimizing use of chemical fertilizers and pesticides, and picking up after pets are all stormwater BMPs.

CFPUA – Cape Fear Public Utility Authority.

CFU - Colony Forming Unit used to measure fecal coliform concentrations.

CISTERNS - Storage tanks for rainfall that has been collected from a roof or some other catchment area.

CONDITIONALLY APPROVED CLOSED - An area subject to predictable intermittent pollution that may be used for harvesting shellfish for direct market purposes when management plan criteria are met, generally during drought conditions.

CONDITIONALLY APPROVED OPEN - An area subject to predictable intermittent pollution that may be used for harvesting shellfish for direct market purposes when management plan criteria are met, generally during low rainfall conditions.

CWA - Clean Water Act

DEGRADED WATERS - General description of surface waters that have elevated pollution levels, could include high bacteria levels, pathogens, sediment, low dissolved oxygen, and/or high nutrient levels. This is not a legal description of impairment (see impaired waters definition below).

EPA - US Environmental Protection Agency

FECAL COLIFORM - Bacteria present in the intestines and feces of warm-blooded animals. High levels of fecal coliform bacteria in a waterway can indicate the presence of other disease-causing organisms. Bacteria of the coliform group which will produce gas from lactose in a multiple tube procedure liquid medium (EC or A-1) within 24 plus or minus two hours at 44.5 degrees C plus or minus 2 degrees C in a water bath.

FLOW - The volume of water, often measured in cubic feet per second (cfs), flowing in a stream or through a stormwater conveyance system.

GROWING WATERS - Waters that support or could support shellfish life.

HYDROLOGIC CYCLE - The cycle by which water evaporates from oceans and other bodies of water, accumulates as water vapor in clouds, and returns to oceans and other bodies of water as precipitation or groundwater. Also known as the water cycle.

HYDROGRAPH - A graph showing changes in the discharge of a surface water river, stream or creek over a period of time.

HYDROLOGY - The science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, flow to the seas, etc.

IMPAIRED WATERS - For the purposes of this Plan, any saltwater classified for shellfish harvest (SA) that is not managed as an "Approved Area" by the Division of Environmental Health, or any saltwater classified for swimming (SB) where swimming advisories are being issued. These waters have been listed as impaired on the state's 303(d) list for EPA.
IMPERVIOUS COVER - A hard surface area, such as a parking lot or rooftop, that prevents or retards water from entering the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.
LID - Low Impact Development is integration of site ecological and environmental goals and requirements into all phases of urban planning and design from the individual residential lot level to the entire watershed.
MAXIMUM EXTENT PRACTICABLE - According to EPA, available and capable of being done after taking into consideration cost, existing technology and logistics in light of overall project purpose.
MS4s – "Municipal Separate Storm Sewer" that conveys stormwater via pipes, ditches, roads, and other man-made conveyances in urbanized areas that serve populations of less than 100,000 (40 CFR 122.26(b)(8)).
NCCF –North Carolina Coastal Federation
NCDOT - NC Department of Transportation
NCDWQ - NC Division of Water Quality
NC EMC - NC Environmental Management Commission
NGO – Non-Governmental Organization
NHSWCD – New Hanover Soil & Water Conservation District
NPDES - National Pollutant Discharge Elimination System
NSSP - National Shellfish Sanitation Program
PROHIBITED AREA - An area unsuitable for the harvesting of shellfish for direct market purposes.
RAIN BARRELS - Barrels designed to collect and store rooftop runoff.
RAIN GARDENS - See bioretention area. Synonymous with bioretention area, this term is typically used for general audience discussions.
RETROFITTING - Structural stormwater management measures for urban watersheds designed to help reduce the effect of impervious areas, minimize channel erosion, reduce pollutant loads, promote conditions for improved aquatic habitat, and correct past efforts that no longer represent the best science or technology. Examples include bioretention area, rain gardens, re-routing downspouts.
SA - Saltwater classified by the EMC for shellfish harvesting. These are waters that should support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes.
SB - Saltwater classified by the EMC for swimming.
SC - Saltwater classified by the EMC for fish propagation and incidental swimming. The waters are safe for swimming but have a higher risk of pollution and human illness than SB waters.
SS - Shellfish Sanitation Section, NC Division of Marine Fisheries, NC DENR. In 2011 the NC General Assembly transferred the shellfish and recreational water quality functions of this agency from the NC Division of Environmental Health to the NC Division of Marine Fisheries.

TOTAL MAXIMUM DAILY LOAD - Section 303(d) of the Clean Water Act establishes the Total Maximum Daily Load (TMDL) program, a water quality-based approach to regulating waters that fail to meet water quality standards despite the use of pollution control requirements. A TMDL is a calculation of the maximum quantity of a given pollutant that may be added to a waterbody from all sources without exceeding the applicable water quality standard for that pollutant. States must establish TMDLs for all pollutants that prevent waters from attaining water quality goals. The TMDL helps regulators devise the limitation necessary to meet water quality standards by identifying and quantifying the individual sources contributing to a particular water quality problem.
STORMWATER - Water from rain that flows over the land surface, picking up pollutants that are on the ground.
303(d) LIST - Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. Category 5 impaired waters require the development of a TMDL.
TIDAL CREEK - A shallow estuary that is affected by the ebb and flow of ocean tides.
UNC-CH – University of North Carolina at Chapel Hill
UNCW – University of North Carolina at Wilmington
WATERSHED – An area of land, governed by the topography**,** that drains to a specific body of water such as a creek, lake or river.
WB – Town of Wrightsville Beach

Figure 1. Shellfish closure boundary showing impaired waters of Hewletts Creek.

EXECUTIVE SUMMARY

Bradley and Hewletts Creeks are polluted with unacceptably high levels of fecal bacteria that have resulted in a prohibition on the harvest of shellfish for human consumption. In addition, swimming advisories are issued within the Bradley Creek watershed at Wrightsville Beach due to unacceptable levels of enterococci bacteria.

Shellfish closures and swimming advisories are indicators of poor water quality and result in some of these waters being listed as "impaired" by the US Environmental Protection Agency (EPA). With support from the NC Division of Water Quality (DWQ), the City of Wilmington working with the Town of Wrightsville Beach and its partner the North Carolina Coastal Federation (NCCF) has chosen to develop this comprehensive voluntary watershed restoration plan (Plan) in an effort to reduce pollution in these waterways. This Plan covers these two watersheds for the purposes of qualifying to use EPA Section 319 funding to restore impaired water quality.

Stormwater runoff is the primary cause of water quality impairment in the Bradley and Hewletts Creek watersheds. Intense urbanization in the watersheds of the creeks has hardened the natural landscape, limiting their capacity to infiltrate and store rainfall as they did prior to development. Instead of soaking into the ground and being taken up by vegetation, a much larger proportion of rain now quickly runs over the surface of the urban landscape and into the creeks. This stormwater runoff picks up bacteria and transports them to the creek much like a bus picks up and discharges its passengers.

The City and its partners have developed this Plan that focuses on reducing the amount of surface runoff that transports bacteria into the creeks. Restoring water quality in these creeks will be a long-term, multi-decade effort. Polluted shellfish growing waters are the byproduct of previous development practices that have occurred over the last 50 years that reduced the functional capacity of these two watersheds to infiltrate rainfall. Gradual improvements in water quality will occur as hydrologic restoration efforts are carried out within existing and new land uses.

The City wants to reduce pollutant-laden stormwater runoff so that shellfish growing waters that are classified for shellfish harvest (SA) may eventually reopen to harvest. Within portions of the Bradley Creek watershed, the Town of Wrightsville Beach is also interested in preventing swimming advisories that are posted in waters designated for swimming (SB). Interim goals of this Plan include improving water quality over time so that the existing NC Shellfish Sanitation (SS) shellfish growing water harvest classifications are revised from "Prohibited Area" to "Approved Areas" that can be opened to harvest more and more frequently. Once growing waters are managed as "Approved Areas" they will no longer be listed as "impaired" by EPA. The Plan will also work to reduce the need for swimming advisories within the Bradley Creek watershed, specifically along the shoreline in Banks Channel in WB, with a goal of removing these waters from being listed as "impaired."

When surface waters no longer comply with assigned water quality classifications and standards, the federal Clean Water Act mandates that steps be taken to remove the water quality impairment and restore water quality to acceptable levels. This normally involves conducting a study called a Total Maximum Daily Load (TMDL) that determines how much pollution loads should be reduced to restore water quality. Once the TMDL is completed, then a watershed restoration plan is devised to accomplish the desired reductions in pollution loads.

TMDL studies typically cost many thousands of dollars and can take several years to complete. For tidal watersheds like Bradley and Hewletts Creeks where most pollution is caused by stormwater runoff and not discharges of industrial or domestic wastewater, the science behind estimating acceptable waste load allocations through the TMDL process is not precise. However, there has been extensive scientific study in North Carolina over the past several decades as to the causes of shellfish closures in tidal creeks such as Bradley and Hewletts Creeks, and the City and its partners believe this existing information provides a sufficient basis to develop this Plan without spending more time and resources going through the TMDL process. DWQ supported the City's strategy to prepare this Plan without first conducting a TMDL study and provided financial support to develop the Plan through a Section 319 Grant.

Two recent TMDLs and watershed restoration plans approved by DWQ and EPA for the Lockwoods Folly River and White Oak River provided guidance for the City to follow in developing this Plan. These plans documented that restoration of water quality in tidal waters similar to Bradley and Hewletts Creeks depends upon reducing the volume of stormwater shed from existing land uses, as well as controlling the volume of runoff generated by new land uses. The reasons for this are the following:

(1) Sources of fecal bacteria are widespread and will continue to persist. Bacteria come from wildlife, pets, and other warm-blooded animals. While this is a human health problem and such sources should be removed, it is difficult to reduce all of these sources to a level necessary to significantly improve water quality for shellfishing.
(2) Cleaning up shellfish and swimming waters by treating runoff to levels that comply with water quality standards for bacteria is not practical. The tidal waters need almost pristine water quality to allow for the harvest of shellfish and for swimming. While technology is available to properly clean runoff, retrofitting an already developed urban area with such systems can be prohibitively expensive to achieve sufficiently high removal rates necessary to meet shellfishing and swimming standards.
(3) Recontamination of treated runoff is extremely problematic. Even if it were cost effective to comply with water quality standards for shellfishing and swimming by treating runoff to remove bacteria, any "clean" runoff discharged back onto the landscape would then become a vehicle to transport downstream bacteria, lessening the overall benefits of treatment.

Instead of attempting to eliminate all sources of bacteria, this Plan seeks to reduce the transport of bacteria by reducing the volume of surface runoff. The Plan has adopted a goal to reduce the volume of runoff from the one-year, 24-hour design storm in both watersheds by the amount that was generated by land uses in 1981, with interim goals based upon stormwater volumes generated from land uses that existed in 2010, 2006, 2002, and 1998.

These dates roughly correspond with significant shellfish harvest closures that have occurred in the Hewletts Creek watershed.

These volume reduction goals were selected for both watersheds even though water quality impairments have existed in the Bradley Creek watershed since 1947. Shellfish harvest in Hewletts Creek has become increasingly impaired because of stormwater runoff since 1973, and there is sufficient data to calculate runoff volumes associated with land uses since 1981. The causes of impaired waters in the Bradley Creek watershed are much more complicated. Until the early 1980s, there were discharges of poorly treated sewage into these waters as well as increasing amounts of stormwater runoff. These waters have three classifications (SA, SB, and SC). While water quality in Bradley Creek is more degraded than in Hewletts Creek, there are much fewer legally "impaired" waters because of the extensive areas covered by the SC and SB classifications. The waters classified as "impaired" are only along the shoreline of the Town of Wrightsville Beach in Banks Channel. Thus, it was decided that using the same baseline years for both watersheds for setting stormwater reduction goals should be adequate to address these impairments within the Bradley Creek watershed. The Plan includes on-going evaluations to determine if this decision was correct, and reduction goals can be adjusted in the future if they are found to be too low or too high.

The long-term goal is to approach the pre-closure surface water hydrology for these two watersheds to the maximum extent feasible. In surface water hydrology, a hydrograph is a time record of the discharge of a creek. Rainfall is typically the main input to a watershed and the stream flow is the output of the watershed. A hydrograph is a representation of how a creek within watershed responds to rainfall over a period of time.

How creeks within a watershed respond to rainfall depends on a variety of factors that affect the shape of a hydrograph. Many of these factors, such as geology, seasons, and weather, cannot be directly influenced by human activities. However, several key factors including land-use, vegetation, and soil compaction can be significantly modified by land uses. By working to restore the functional capacity of soils and vegetation in the watersheds to absorb and use rain, the hydrograph can be altered to begin to approach what it was in earlier years.

The Plan focuses on the use of decentralized stormwater reduction measures that aim to reduce stormwater runoff by infiltrating it back into the landscape where rain falls, especially in those locations where low-cost retrofits offer highly effective opportunities. Where feasible, other fecal bacteria reduction practices, such as constructed wetlands that promote increased evapotranspiration, are advocated. Additional benefits of this Plan include reducing suspended solids, nutrients, and other pollutants in the creeks as well as reducing stream channel degradation by erosive forces.

To restore the creeks, the Plan relies on watershed-wide collaborations that integrate the activities, efforts, and resources of various individuals, organizations, and government entities. It recommends six management objectives and 35 specific actions to accomplish the goal of the Plan. While some of these management objectives and actions are currently being used and can be done with existing resources, others will require significant new resources to carry out. Needed resources in the form of staff, funds, partnerships, and time are outlined for each of the management actions contained in the Plan.

This plan incorporates all nine elements of a watershed management plan as required by EPA as necessary to qualify for 319 funding that is used to restore impaired waters. This plan will be used by the City of Wilmington and its partners as their restoration strategy for addressing the bacterial pollution that has caused “impaired” water quality in Bradley and Hewletts Creeks watersheds. The Plan is based on the following assumptions regarding changes in the watersheds:

(1) New development designed to minimum State and City stormwater requirements are assumed to have net-zero impact on the hydrograph of the one year, 24-hour design storm.
(2) New development that goes beyond minimum regulations has a positive effect that can be tracked.
(3) Increases in impervious surfaces without any additional treatment have negative impact that can be measured.
(4) Stormwater quality improvement projects that result in volume reductions have a positive impact that can be measured.
(5) Drainage or flood improvement projects have a neutral impact.
(6) Retrofits for existing developed areas have a positive impact.
(7) Volume assumptions are based upon the one-year, 24-hour rain event equaling 3.95 inches of rainfall.

In summary, the goal of this plan is to restore shellfish and swimming water quality impaired by unacceptable levels of bacteria in the surface waters within the Bradley Creek and Hewletts Creek watersheds. This will be accomplished by the following management objectives:

(1) Continue existing programs that address water quality impairments in both watersheds.
(2) Determine appropriate water quality classifications and designated uses where water quality impairment exists.
(3) Reduce the transport of bacteria from land to water by reducing the volume of stormwater runoff.
(4) Promote/focus stormwater reduction efforts in locations where they yield the greatest and most cost effective stormwater volume reductions.
(5) Form and maintain partnerships to carry out the plan.
(6) Evaluate plan success and modify strategies and programs as needed.

INTRODUCTION

This watershed restoration plan provides a long-term management framework to address water quality impairments caused by high bacteria levels in Bradley and Hewletts Creeks' watersheds. Some of the waters classified for shellfish harvest and swimming within these two watersheds are not meeting their designated uses. In the years and decades to come, the positive effects of this Plan will result in the gradual improvement of water quality. This positive trend in water quality will be demonstrated by reducing the frequency of swimming advisories within the Bradley Creek watershed along Banks Channel as well as an expansion of shellfish growing areas that are classified SA and open to harvest. Within the Hewletts Creek watershed, improvements in water quality will result in SA classified waters being upgraded from "Prohibited" to allow temporary openings for shellfish harvest and ultimately to a permanently "Approved" harvest status.

The Plan identifies six objectives and 37 actions to restore and protect water quality in compliance with water quality laws and regulations pursuant to the federal Clean Water Act of 1972. All these strategies and actions are focused on reducing the transport of bacteria into the creeks by significantly reducing the volume of stormwater runoff from existing and new development. The goal of the plan is to approach the natural runoff volumes that existed before intense development occurred at a time when shellfish harvest and swimming was still not restricted. This was before these watersheds were hardened by urban development that caused more surface runoff.

Water quality restoration will be accomplished by using stormwater best management practices (BMPs) designed to accomplish stormwater volume reduction and by other stormwater management strategies (such as stream restoration projects) that have beneficial effects on reducing the peak and overall runoff volumes. By focusing on infiltration and other techniques to slow and absorb stormwater to reduce runoff, the goal is to mimic the natural hydrology that existed prior to intense urban influence through the cumulative effect of BMP retrofits, impervious disconnection efforts, and other techniques. Additionally, by incorporating LID design techniques into site plans for new development and redevelopment, stormwater volumes, peak stormwater flow rates, and bacteria pollutant loads will be reduced. Proposed strategies also include the development of management tools such as a GIS Atlas and accounting system that tracks new and retrofit projects and measures results.

This plan was developed in lieu of preparing a TMDL for these two watersheds. TMDLs are normally required for "impaired" waters to determine what new limitations are necessary to meet water quality standards by identifying and quantifying the individual sources contributing to a particular water quality problem. This Plan did not require preparation of a TMDL, because decades of accumulated water quality monitoring and scientific research by government agencies and the University of North Carolina at Wilmington (UNCW) have provided ample documentation of the relationships among intensity of land uses, greater hydrologic modifications within these two tidal creek watersheds, and increasing bacteria levels. The City and project partners hope to demonstrate an efficient and effective method for local governments to solve water quality impairments in tidal creeks and sounds throughout North Carolina without first exhausting valuable time and resources in preparing TMDL's.

WATER QUALITY STANDARDS AND CLASSIFICATIONS

Congress enacted the federal Clean Water Act in 1972 to establish uniform national standards to restore and maintain the chemical, physical, and biological integrity of our nation's waters. It contains provisions that address the pollution of shell fishing waters as well as other water quality issues.

Protecting existing uses of public waters is one of the most powerful provisions of the Clean Water Act. Congress recognized that we must stop polluting our water if we are to prevent degradation of its uses. Even the loss of potential economic profits from development does not outweigh the public's right to use the water.

To limit pollution, the Clean Water Act requires that "existing uses" of the waters be maintained. In other words, waters may not be polluted to the point that they no longer support their uses such as swimming, shellfishing, and fish propagation. A use is "existing" if it has been available since November 28, 1975 when the regulation was adopted by the EPA. Pollution disposal is not a protected use for waters.

The state water quality classification of a water body specifies which uses are to be protected. Saltwater classifications for North Carolina's coastal areas are SA, SB, and SC. For example, the SA classification is for shellfishing waters while SB classifications are for organized or frequently used swimming waters. Each classification also specifies the maximum concentrations of various pollutants that will be allowed. Every creek, river, stream, estuary, section of the ocean, or other segment of water in the state has been assigned a water quality classification and corresponding standards. Unnamed and unclassified freshwater tributaries to SA, SB, or SC waters have the same classification as their receiving waters. (See Appendix A for a complete listing of classifications.)

A basic use of all waters is the propagation and maintenance of aquatic life, including plants and animals. The anti-degradation regulation requires that existing uses be protected even if the uses or threatening pollutants are not specifically mentioned in the classification and standards. For example, if shellfish harvest is taking place in waters classified SB for swimming, any pollution that would close those waters to shellfish harvest violates the anti-degradation requirement because it eliminates the water's use. For this reason, SB waters used for shellfish harvest should be reclassified as SA waters to be consistent with the federal Clean Water Act.

A water quality classification cannot be changed to eliminate an "existing use" that has existed at any time since November 28, 1975. For areas that have not had an "existing use" since 1975, a use attainability study must still show that pollution is irreversible, or the area is not suitable for the classified use, before an assigned water classification can be changed to eliminate a designated use.

Waters classified SA are protected for market purpose shellfishing and have stringent bacteriological standards. Disease causing bacteria and viruses are concentrated in clams and oysters as they filter food from the water. Since shellfish can be eaten raw, the water must be free of disease-carrying pollutants. Therefore, in order to protect public health, sewage discharges into SA waters are prohibited.

The Shellfish Sanitation Branch of the Division of Marine Fisheries (DMF) is responsible for monitoring shellfishing waters. Waters that exceed the fecal coliform standard, or are adjacent to a known threat of pollution, are closed to shellfishing by the state. To protect existing shellfishing waters, sources of pollution that cause closure of waters must not be allowed. Shellfish growing areas classifications are explained in Table 1.

NC Shellfish Sanitation Growing Area Classifications	
Approved	These areas are always open to shellfish harvesting and close only after rare heavy rainfall events such as hurricanes. The medium fecal coliform Most Probably Number (MPN) or geometric mean MPN of water shall not exceed 14 per 100 milliliters, and the estimated 90th percentile shall not exceed an MPN of 43 per 100 milliliters for a five-tube decimal dilution test.
Conditionally Approved-Open Shellfish Areas	Sanitary Survey indicates an area can meet approved area criteria for a reasonable period of time, and the pollutant event is known and predictable and can be managed with a plan. These areas are open to harvest much of the year, but are immediately closed after certain sized rainfall events (refer to SS Shellfish Sanitation growing area management plans for specific closure strategies).
Conditionally Approved-Close Shellfish Areas	Sanitary Survey indicates an area can meet approved area criteria during dry periods of time, and the pollutant event is known and predictable and can be managed with a plan. This growing area classification allows harvest when fecal coliform bacteria levels are lower than the state standard in areas that otherwise might be closed to harvesting. These areas are regularly monitored to determine if temporary openings are possible.
Prohibited Shellfish Harvest Areas	Sanitary Survey is not routinely conducted because previous sampling data did not meet criteria for Approval or Conditionally Approved. Area may also be closed as a matter of regulation due to the presence of point source discharges or high concentrations of boats with heads.

Table 1. NC DMF Growing Area Classifications.

The saltwater classification SB designates waters used for organized or frequent swimming, skiing, and fish propagation. A SB classification requires that waste treatment plants have backup equipment to ensure that no untreated sewage flows into the waters. The backup provisions must include standby power and two parallel treatment units. SS monitors a type of bacteria called enterococci in waters frequently used for swimming. Like fecal coliform, enterococci are also found in the intestines of warm-blooded animals such as birds, dogs, raccoons and people. Enterococci will not make you sick; however, it is often associated with other bacteria and viruses that can cause water-borne illness. To comply with the swimming water quality levels set by the EPA and the state, water test results have to fall below a set average as well as a single-sample level. The average is the geometric mean of five weekly samples taken within a 30-day period. The geometric mean cannot exceed 35 enterococci per 100 milliliters of water.

The saltwater classification SC designates waters used for fish propagation and incidental swimming. The waters are safe for swimming but have a higher risk of pollution and human illness than do SB waters. Treated sewage may be discharged into SC waters if it will not impair the uses of the SC waters or any downstream SA or SB waters.

The NC Environmental Management Commission (EMC) determines water quality classifications and standards pursuant to the federal Clean Water Act. The classifications and standards are regulations and must have a public hearing to be changed. The state system for adopting and maintaining classifications and standards must comply with federal regulations, and EPA must approve every proposed change.

In addition, the EMC has authority to fine anyone who violates water quality standards even if the activity causing the pollution does not require a permit. However, this authority is seldom used when a permit is not involved. The staff of the Division of Water Quality (DWQ), issues permits, sets fines, and provides enforcement.

REASONS FOR COASTAL WATER QUALITY IMPAIRMENT

Dating back to the early 1980s, scientists and regulators in North Carolina have been drawing links between the intensity of land use and increases in fecal coliform bacteria concentrations within coastal watersheds. A report titled Coastal Development and Shellfish Waters prepared by state water quality regulators in 1985 linked coastal development to high bacteria levels stating, "High density development with large areas of impervious surface cover will produce larger runoff volumes with associated pollutant levels."[1] That report provided the basis for the EMC to adopt its first comprehensive coastal stormwater rules in 1986. While these rules have changed over the years, the Commission's coastal stormwater rules are authorized based upon the Commission's legal authority to require "non-discharge" pollution control systems to protect water quality. That is because the Commission concluded that it could not devise any workable rules that would assure that frequent discharges of even "treated" stormwater into classified shellfish waters would comply with the fecal coliform water quality standard. The EMC's newly developed NPDES stormwater program mandated by EPA does not allow for any new or enlarged stormwater discharges to SA or SB waters.

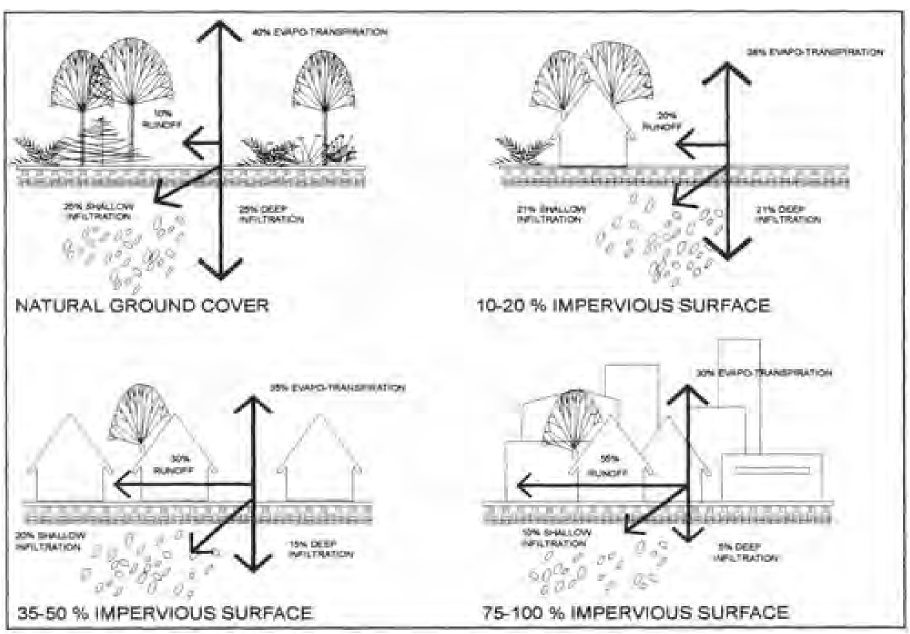


Figure 2. Image courtesy of Encyclopedia of Earth.

[1] Coastal Development and Shellfish Waters, now NC DENR, 1985.

In a natural landscape, waste from animals does not threaten the water quality of tidal creeks because most of it stays on the landscape and is not carried into adjacent creeks and streams. However, as stormwater runoff increases with the intensity of land uses, it washes bacteria off the landscape into the creeks.

Water quality in coastal waters is negatively impacted when the natural landscape is changed by drainage, hardened surfaces, and vegetation removal. Altering the land cover in an area by adding roofs, driveways, parking lots, yards, ditching, cutting down trees and underbrush all drastically change the hydrology of a watershed. During the natural hydrologic cycle, approximately 30 percent of rainwater is used by vegetation while the remaining water infiltrates into the ground where bacteria and other pollutants are removed by filtration as the water moves through the soil and into the groundwater. During most normal weather conditions, very little surface runoff is produced. However, as watersheds become more developed, there is less vegetation to take up rainwater and less water infiltrates into the soil. In this case, the amount of surface runoff increases as it passes over the landscape picking up bacteria and other pollutants and washing them directly into the tidal creeks.

Past efforts to manage runoff throughout the coast have failed to prevent increased bacterial contamination of shellfish waters. Some of the reasons that this increase has occurred include:

(1) Most coastal communities have no comprehensive program to reduce the volume of stormwater generated by existing development; and
(2) Regulations for new development have not prevented increased discharges of polluted runoff.

In 2008, DWQ revised its coastal stormwater rules for new development to address the need to control larger volumes of stormwater. These new rules should prevent increased pollution from new development, however, they have no impact on pollution caused by existing development.

As a study published by Mallin *et al.* (2000) points out, it is quality, rather than quantity, of land development that is the most important influence on urban and suburban nonpoint source fecal coliform pollution.[2] Conventional development techniques have squandered the functional capacity of the landscape to naturally absorb stormwater. Often, stormwater problems are compounded by the conventional drainage systems that move stormwater rapidly off the land instead of slowing it down to infiltrate into the ground.

In more recent years, DWQ and the City of Wilmington have recognized that previously adopted coastal stormwater rules were not adequately protecting water quality. In 2008, these rules were updated and revised however, much of the development in these watersheds had already occurred. The City encourages the use of Low Impact Development (LID) techniques as a way to meet the revised coastal stormwater rules to better control runoff. These efforts focus on new development and redevelopment to prevent water

[2] Mallin, Mike, Kathleen Williams, E. Cariter Esham, and R. Patrick Lowe. "Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds." *Ecological Applications*. 10.4 (2000): 1053. Print.

quality degradation from becoming worse, but in order for water quality to be restored, stormwater runoff from existing development must be managed.

The tidal creek water quality studies by Mallin and others funded by Wilmington have demonstrated that there is a very strong correlation between impervious surface coverage and fecal coliform abundance. Overall, most chronic bacterial pollution in these creeks results from stormwater runoff. It has been estimated that water quality is impacted when impervious surface coverage reaches a threshold of as little as 10 percent.[3] Hardened surfaces reduce infiltration capacity and are directly connected to the creeks by the way drainage systems have been designed.

PHYSICAL DESCRIPTIONS OF THE WATERSHEDS & MAPS

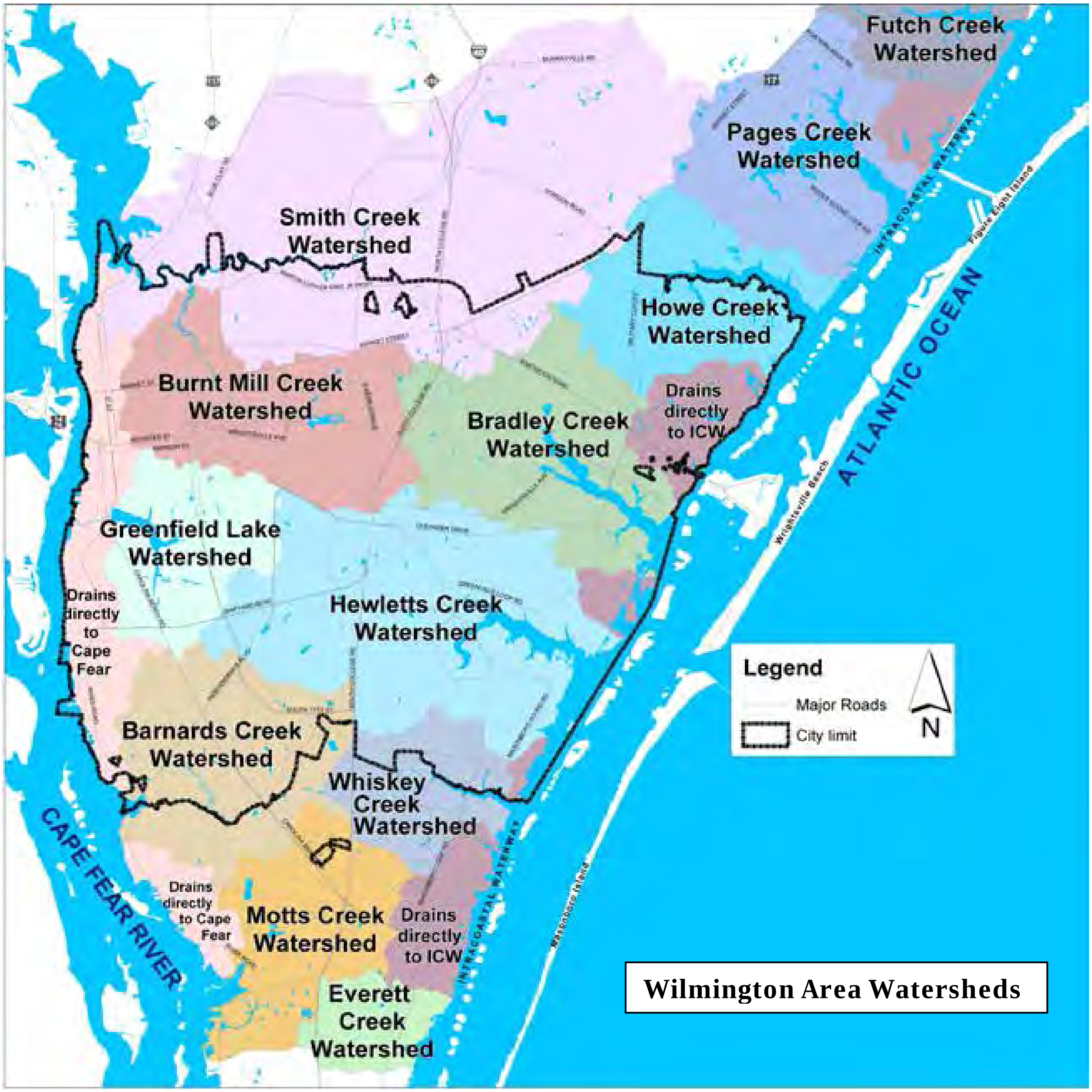
Bradley and Hewletts Creeks are located within Wilmington and are adjacent to each other. Both creeks drain directly into the Intracoastal Waterway. Currents in both watersheds are influenced by tides that rise and fall through the Masonboro Inlet twice a day. These creeks are not only the largest and most developed tidal creeks in Wilmington but are also some of the most polluted.

Both creeks are designated as Primary Nursery Areas by the NC Division of Marine Fisheries, and are considered very productive nursery grounds for a wide variety of finfish that are caught commercially and recreationally throughout North Carolina. Table 2 provides an estimate of land uses within both watersheds. Both Bradley and Hewletts Creek watersheds are heavily developed with impervious surface coverage of 23% and 19%, respectively.

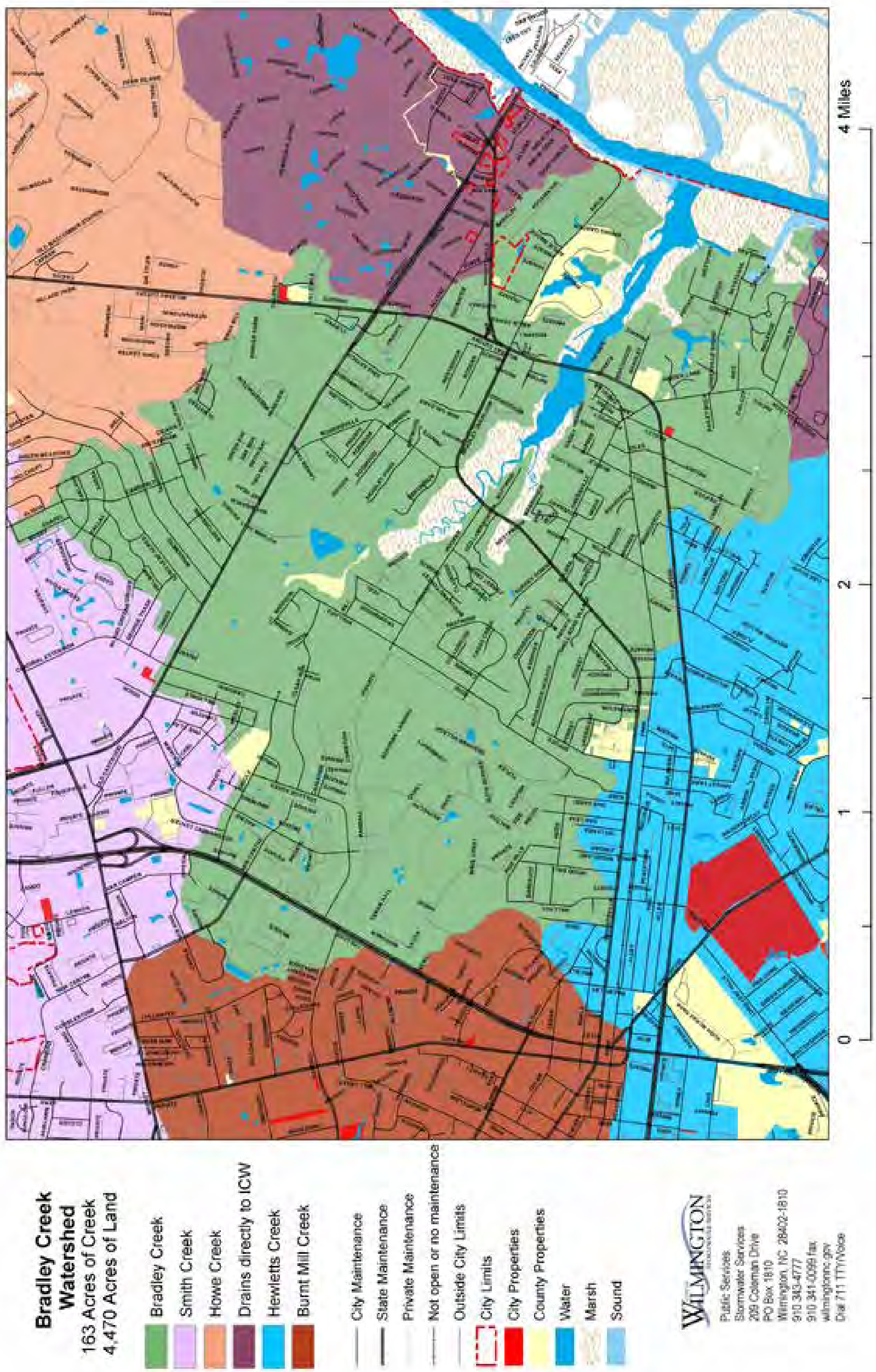
Bradley Creek drains an area of 7.2 square miles, including most of the UNC Wilmington campus, directly into the Intracoastal Waterway. Almost 85 percent of the watershed is developed with an estimated population of 14,780 people. Residential is the most prevalent land use in the watershed, with office & institutional constituting the second most prevalent land use. About 46% of the land area in the Bradley Creek watershed within 1000 feet of the creek is residential.

Hewletts Creek drains an area of 11.6 square miles into the Intracoastal Waterway. Almost 85 percent of the watershed is developed with an estimated population of 24,746 people. Residential is the most prevalent land use in the watershed, with vacant land and commercial uses constituting the next most prevalent land uses. About 44% of the land area in the Bradley Creek watershed within 1000 feet of the creek is residential.

[3] Id.


Futch Creek Watershed
Pages Creek Watershed
Smith Creek Watershed
Howe Creek Watershed
Burnt Mill Creek Watershed
Drains directly to ICW
Bradley Creek Watershed
Greenfield Lake Watershed
Drains directly to Cape Fear
Hewletts Creek Watershed
Barnards Creek Watershed
Whiskey Creek Watershed
Drains directly to Cape Fear
Motts Creek Watershed
Drains directly to ICW
Everett Creek Watershed
ATLANTIC OCEAN
CAPE FEAR RIVER
INTRACOASTAL WATERWAY
Legend
Major Roads
City limit
N
Wilmington Area Watersheds


Tidal Creek Watersheds
Futch Creek
Pages Creek
Howe Creek
Bradley Creek
Hewletts Creek
Whiskey Creek
Atlantic Ocean
0 5,000 10,000 20,000
Feet
N


Bradley Creek Watershed
163 Acres of Creek
4,470 Acres of Land
Bradley Creek
Smith Creek
Howe Creek
Drains directly to ICW
Hewletts Creek
Burnt Mill Creek
City Maintenance
State Maintenance
Private Maintenance
Not open or no maintenance
Outside City Limits
City Limits
City Properties
County Properties
Water
Marsh
Sound
WILMINGTON
Public Services
Stormwater Services
209 Coleman Drive
PO Box 1810
Wilmington, NC 28402-1810
910 343-4777
910 341-0099 fax
wilmingtonnc.gov
Dial 711 TTY/Voice
0
1
2
4 Miles

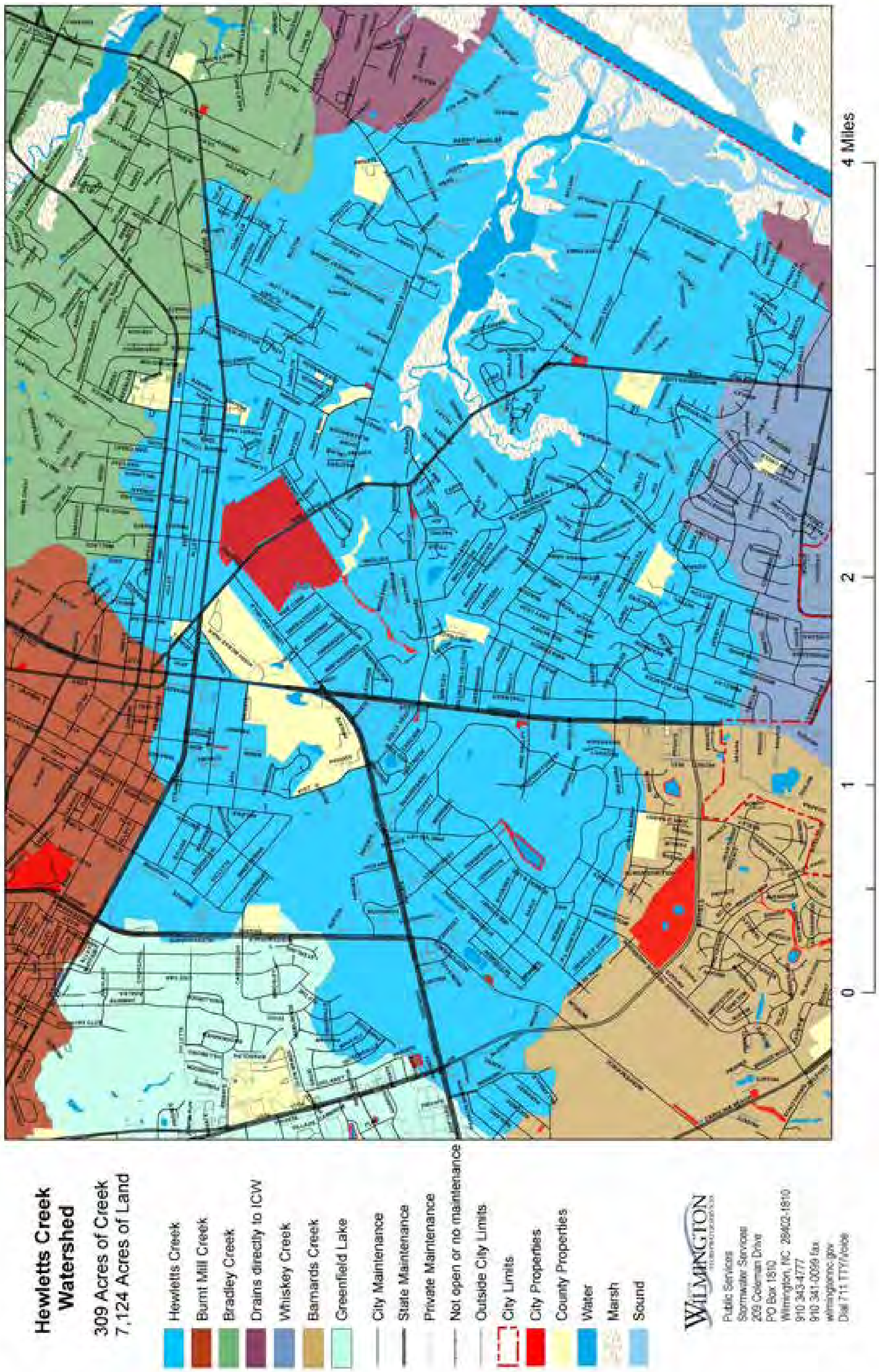


Figure 3. Wilmington Watersheds Maps.

WATER QUALITY IMPAIRMENTS WITHIN THE WATERSHEDS

For many years it was assumed that most bacterial pollution in coastal waters resulted from inadequate treatment or spills of human sewage. Past attempts to reopen shellfish waters in these two creeks focused on removing human sources of bacteria such as septic tanks.

	Bradley Creek		**Hewletts Creek**	
Land Use	Acreage	% of Total	Acreage	% of Total
Agricultural	12.09	0.31	28.50	0.46
Commercial	260.13	6.60	470.56	7.59
Industrial	—	—	—	—
Mobile Home	96.24	2.44	26.98	0.44
Multi-Family	236.55	6.01	231.84	3.74
Office & Institutional	803.01	20.38	433.41	6.99
Recreation	59.64	1.51	404.05	6.52
Residential	1833.85	46.55	3678.56	59.31
Utilities	7.46	0.19	36.96	0.60
Cemetery	30.58	0.78	4.48	0.07
Vacant / Undeveloped	599.74	15.22	886.53	14.29
Totals	3,939.27	100%	6,201.87	100%

Table 2. Land Use Categories for Bradley and Hewletts Creeks watersheds, City of Wilmington.

Discharges of poorly treated sewage in the Bradley Creek watershed undoubtedly contributed to degraded water quality. These discharges were eliminated after there were millions of dollars of investments in expanding a centralized sewer system in the early 1980s to provide wastewater treatment for nearly all residents and businesses throughout these two watersheds. According to the State's most recent shoreline surveys for bacterial pollution sources conducted by the N.C. Division of Environmental Health, there are no permitted sewage discharges or malfunctioning septic systems affecting Hewletts or Bradley Creeks. The Cape Fear Public Utility Authority (CFPUA) provides centralized wastewater collection and treatment for both watersheds.

Accidental discharges of human sewage have occurred as a result of leaks and spills from the centralized wastewater collection system. The February 2011 Sanitary Survey prepared by SS for Bradley Creek, reports that on July 11, 2007 there was a 13,000 gallon sewer spill into Bradley Creek from one of the lift stations. The last Sanitary Survey for Hewletts Creek reports five major sewage spills resulting in several temporary and expanded shellfish closures and swimming advisories. The volume of these spills ranged up to 3 million gallons. Sewage spills and leaks also pollute creek sediments. Figure 4 shows locations of wastewater lift stations in the watershed. Appendix E lists stations by name.

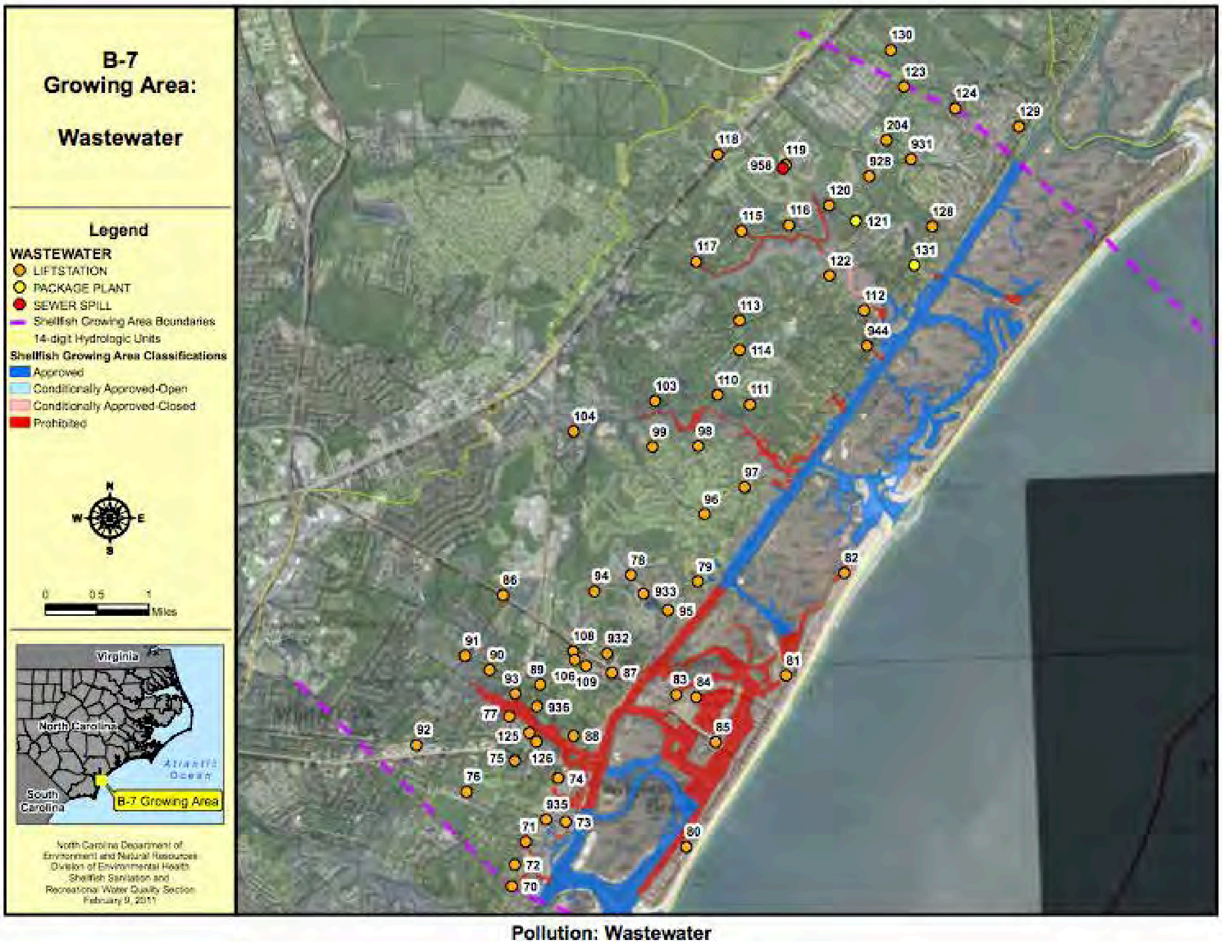


Figure 4. Wastewater lift stations within the Bradley Creek watershed.

Contaminated sediment can serve as fecal bacteria reservoirs for months after a spill. These bacteria are re-suspended when pulses of stormwater impact the sediments. While leaking and malfunctioning sewer collection systems have caused high levels of bacterial contamination in the creeks, these sources and events are episodic in nature, and cannot be blamed for the chronically high bacteria levels that have persisted over the years and consistently spike after rainfall. Ongoing water quality sampling conducted by state agencies and Dr. Mike Mallin at UNCW's Center for Marine Science has continually shown Bradley and Hewletts Creeks to be violating water quality standards for fecal bacteria. In most cases, the classified SA waters in these watersheds are only marginally over the bacteria limits for SA waters giving hope that restoring water quality can be achieved with the right management strategies.

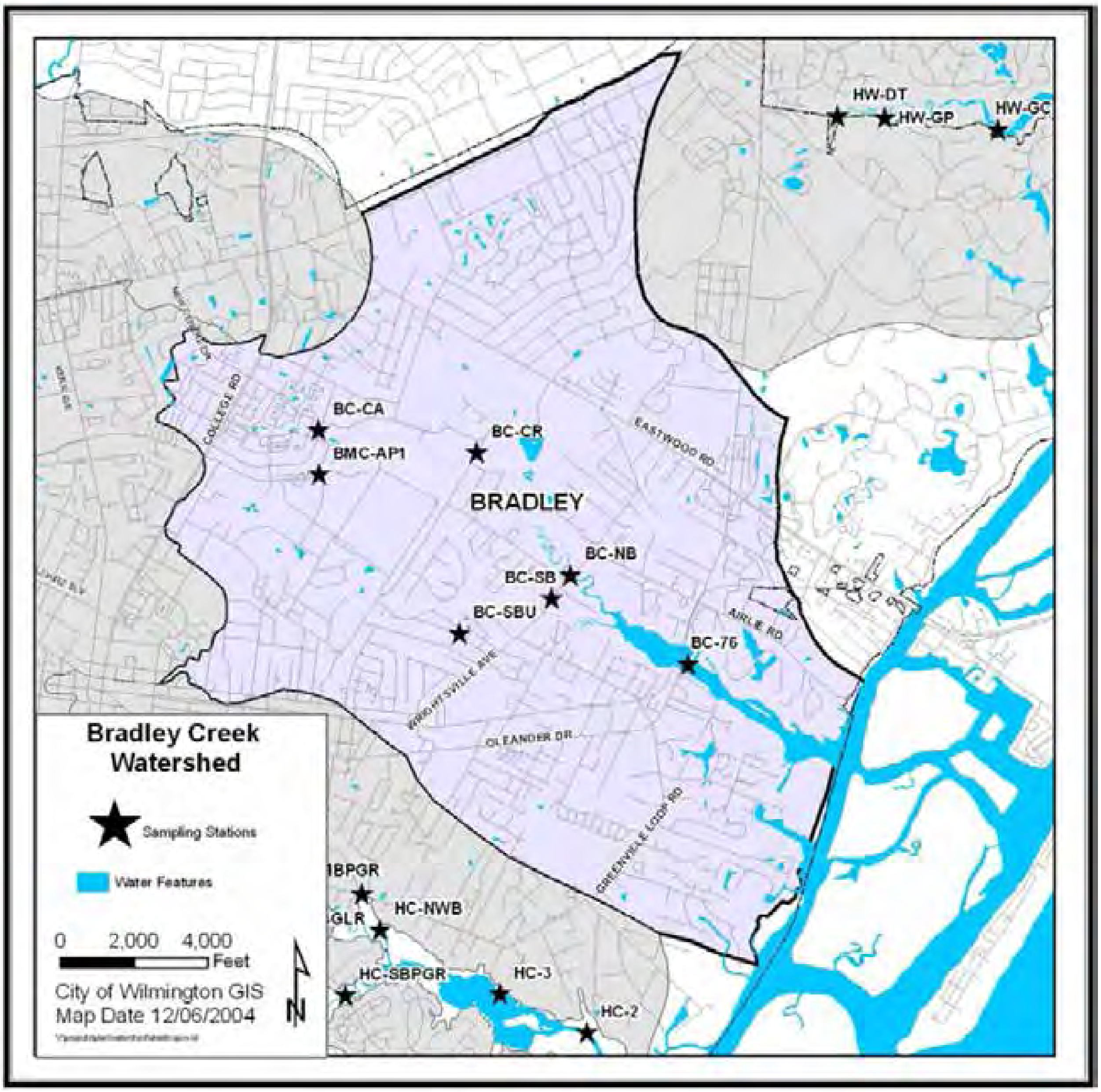


Figure 5. Water Quality Sampling Stations in Bradley Creek, City of Wilmington.

North Carolina automatically closes waters around marinas for shellfishing, and sets the closure boundary based on a formula that includes the marina type and the number of boat slips. There are no automatic closures due to marinas in Hewletts Creek watershed. There is a small closure of SA waters within the SA waters along Banks Channel in the Bradley Creek watershed. Thus, automatic closures because of marinas are not a major impediment to re-opening closed SA classified shellfish waters.

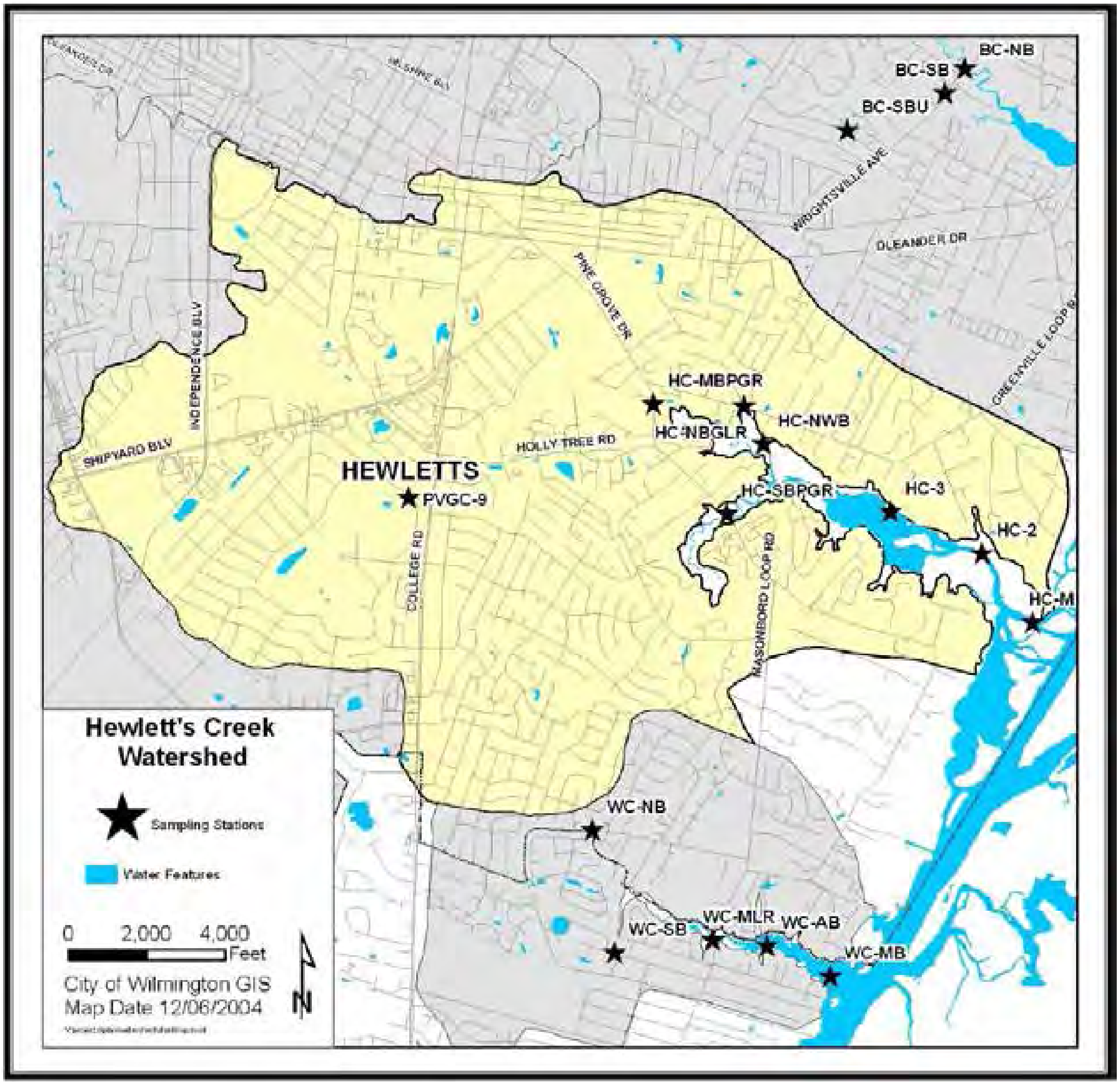


Figure 6. Water Quality Sampling Stations in Hewletts Creek, City of Wilmington.

Water quality monitoring in these two creeks indicates that the primary chronic source of fecal coliform bacteria is feces from non-human sources such as wildlife and domestic pets, with periodic human sources. This has been documented in nearby coastal waters as well. Two recently completed TMDL allocations for fecal coliform approved by DWQ and EPA for the lower White Oak River in Carteret County and the Lockwoods Folly River in Brunswick County found that non-human sources were the overwhelming cause of water quality impairments. Fecal coliform originates in the intestines of warm-blooded animals such as deer, raccoons, birds, dogs, cats, and waterfowl. Since the overwhelming source of fecal coliform bacteria is non-human and impractical to regulate, instead of removing the source, this Plan focuses on reducing the volume of stormwater carrying these pollutants to the estuary.

BRADLEY CREEK WATERSHED

SS concludes that: "Runoff from impervious surfaces, subdivisions, and other cleared land is a contributing factor to fecal coliform levels in the B-7 area." It states that Bradley Creek receives "large amounts of residential and urban runoff." Sources of pollution and SS sampling stations are shown in Figure 7. The report finds that both residential and commercial development have created significant changes in the landscape that have resulted in large areas of impervious surface. "Areas once wooded and largely undeveloped have been replaced by restaurants, businesses, and parking areas", the report states. Shellfish waters in Bradley Creek and in adjacent areas of Masonboro Sound were first closed to harvest in 1947 to protect public health because of high bacteria levels (See Appendix C for history of shellfish closures).

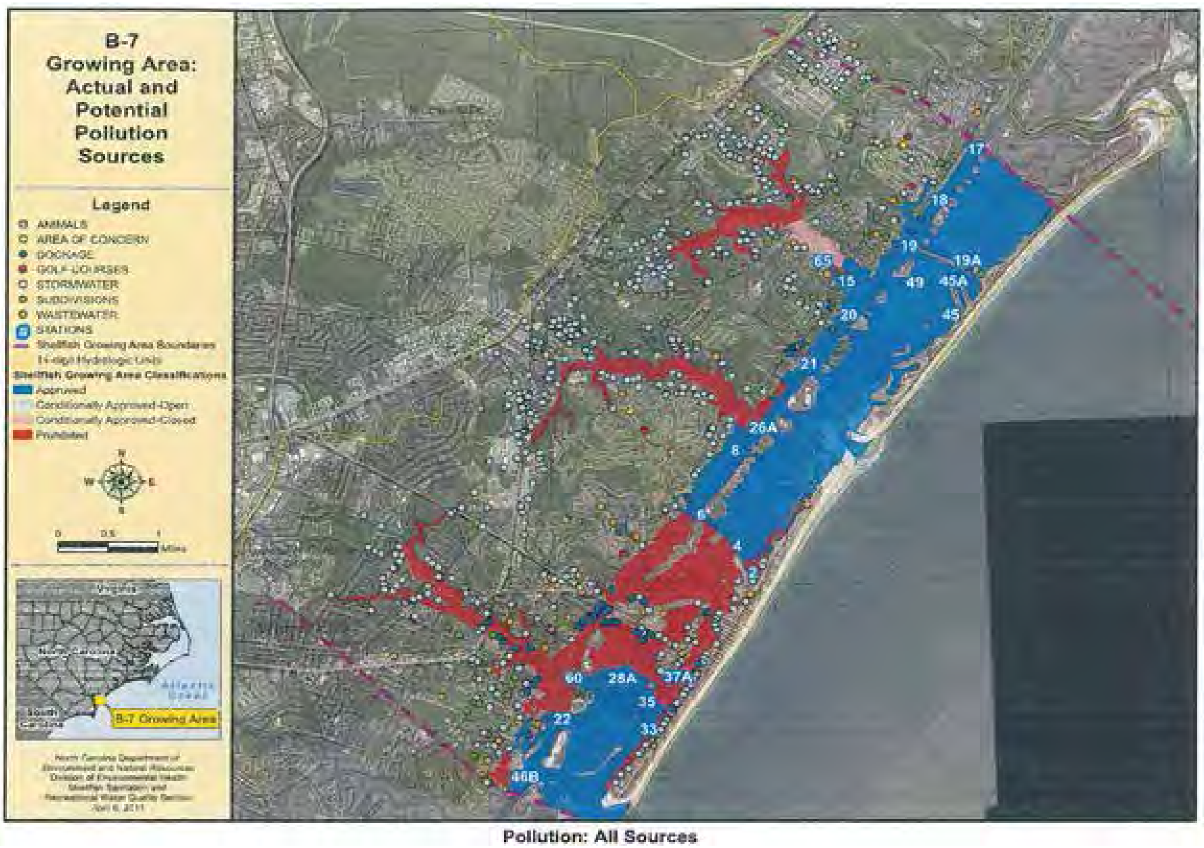


Figure 7. Bradley Creek SS Growing Area Survey and Sampling Stations.

Originally, sanitary survey reports prepared by SS indicate that most of these closures were the result of wastewater treatment discharges associated with sewage treatment plants and large marinas. There were nine treatment plants in the Wrightsville Beach area and five discharged into waters of the ICW. For example, there was an indication of failure of the Bradley Creek Marina sewage system in the 1977 report, after which the State warned the Marina that their system was not adequate. The 1977 survey report also cited 53 sewage violations. The Wrightsville Beach treatment plant was cited as a major source of pollution throughout survey reports. In 1983 the Wrightsville Treatment Plant closed and the town connected to the county sewer system.

From the late 80s to the early 90s, SS concluded in its surveys that the major cause of fecal coliform had become stormwater runoff. Appendix D provides fecal coliform sampling data collected by SS in the Bradley Creek watershed. Figure 8 shows the locations of stormwater outfalls into the watershed.

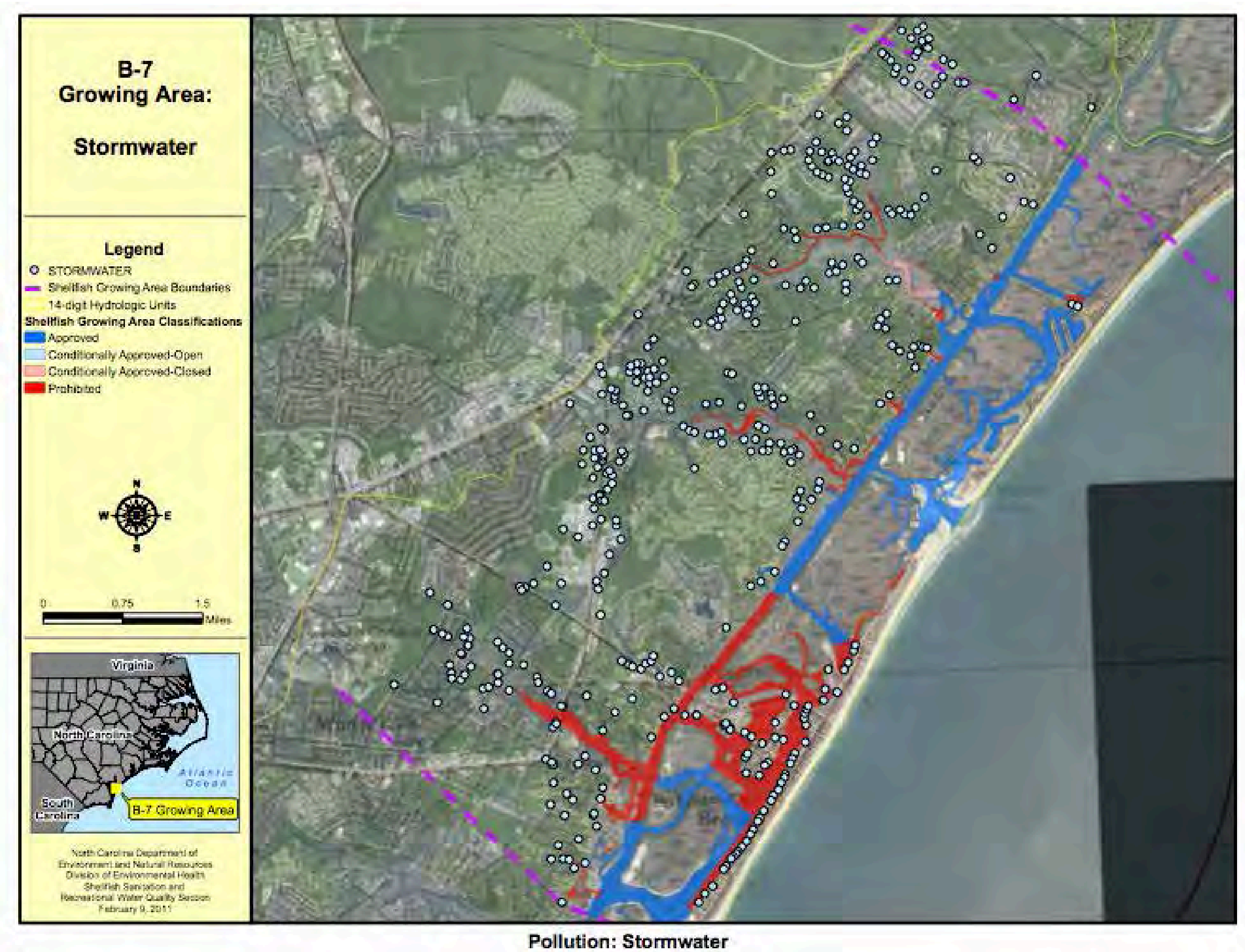


Figure 8. Stormwater Outfalls into Bradley Creek watershed (SS).

Bradley Creek was originally classified as SA waters (for shellfish harvest) but in 1987 the EMC reclassified the waters from SA to SC.[4] DWQ conducted a Use Attainability Study that concluded the waters could not be cleaned up for shellfish harvest due to the presence of marinas and stormwater pollution inputs. North Carolina has an automatic closure of waters for shellfish harvest due to the potential for discharge of untreated human sewage from boats. Today, Bradley Creek is classified as a SC water, which designates it for fish propagation and secondary recreation. The creek is in compliance with the stream classification standards assigned by the State for SC. Figure 9 shows the location of marinas and dockage facilities within the watershed. Appendix F provides a list of these

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[4] Report of Proceedings for Proposed Reclassification of Waters in the Wrightsville Beach Area and the Bald Head Island Marina Basin in the Cape Fear River Basin, November 17, 1986.

marinas and the number of slips they contain. This list was compiled by SS when it did its sanitary survey in 2010.

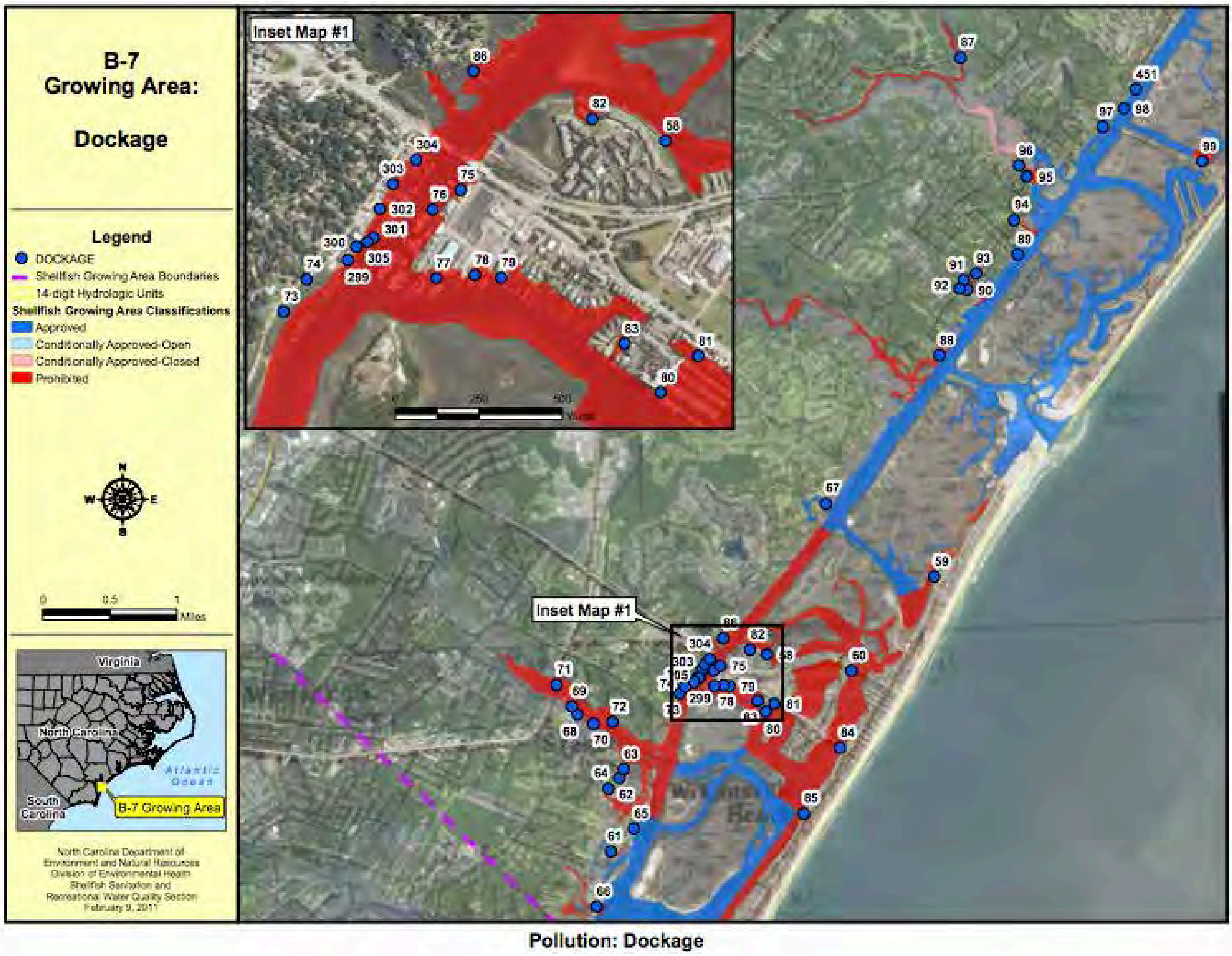


Figure 9. Location of marinas and dockage facilities within the Bradley Creek watershed (SS).

As illustrated in Figure 10, all the waters colored red have high fecal coliform levels that result in a prohibition on shellfish harvest. The hatched areas on the map are automatically closed to shellfish harvest by application of SS's marina policy. This automatic closure means that even if water quality improves within the hatched areas, the use of these waters for shellfish harvest cannot be restored. Figure 11 overlays the shellfish growing area classifications as designated by SS with the water quality classifications that are assigned by the EMC. All SA waters that are closed to harvest within this area are closed as a result of the SS marina automatic closure policy. The map also illustrates that there are "approved" waters for shellfish harvest that are currently classified as SB waters (the blue areas that are north of the line that runs from the northern shoreline at the mouth of Bradley Creek straight across to Wrightsville Beach).

This SB area also contains some "prohibited" shellfish growing waters that are closed due to unacceptable fecal coliform levels, and not because they are within the automatic closure zone of marinas situated near Wrightsville Beach.

Figure 10. Shellfish closures in Bradley Creek watershed. Hatched areas are automatically closed by application of SS's marina closure regulations. Map provided by SS.

To comply with the swimming water quality levels set by the EPA and the state, water test results for enterococci have to fall below a set average as well as a single-sample level. The average is the geometric mean of five weekly samples taken within a 30-day period. The geometric mean cannot exceed 35 enterococci per 100 milliliters of water. Since 1997, swimming advisories have been posted within the watershed in Banks Channel behind Wrightsville Beach when samples exceed the level set for it based on swimming usage. Advisories based on single sample results are retested at the time of the posting. Because of these advisories, these waters are also listed as impaired in the 2010 NC Water Quality Assessment and Impaired Waters 303(d) List under Category 5. (See schematic of 303(d) categories in Appendix B.)

Figure 11. Shellfish harvest classifications by SS overlaid with water quality surface water classifications assigned by the EMC. Map provided by SS.

In conclusion, water quality management issues facing the Bradley Creek watershed include:

(1) Even though scientific studies indicate that water quality within the creek is degraded, there are no federal or state legal requirements to restore water quality within the SC classified waters of Bradley Creek.
(2) The SA classified waters along the Banks Channel shoreline of Wrightsville Beach within the Bradley Creek watershed are "legally impaired." No harvest of shellfish has occurred in these waters since 1947. They are permanently closed to shellfishing as a result of high fecal coliform levels as well as the SS automatic closure policy for marinas. This means that even if water quality improves in this area, it will be impossible to restore the designated use of these waters for shellfish harvest.
(3) Some of the SB classified waters within Masonboro Sound within the Bradley Creek watershed have been re-opened in recent years for shellfish harvest as a result of improving water quality. Shellfishing is now an "existing use" of these waters.
(4) Swimming advisories are issued for the SB classified waters along the Banks Channel shoreline of Wrightsville Beach within the Bradley Creek watershed. These advisories mean that these waters are legally "impaired" for their designated use pursuant to the federal Clean Water Act.
(5) There are SB classified waters within Masonboro Sound within the Bradley Creek watershed that are currently closed to shellfish harvest, but which could potentially be restored for shellfish harvest.

HEWLETTS CREEK WATERSHED

The history of shellfish closures in the Hewletts Creek watershed are much more recent than the one of Bradley Creek. Figure 12 illustrates how the closure line has moved downstream in the creek since 1974. The lower portion of the estuary was closed to harvest in March 2002, and since then the closures have extended outside the creek into the sound (See Figure 13). The complete history of closures is provided in Appendix G.

The last comprehensive shoreline survey for Hewletts Creek was completed by SS on November 19, 2006, and then updated in 2008. The report found that most of the subdivisions along Hewletts Creek consist of upscale homes on one or two acre lots that are very well maintained, but: "…they do not have adequate Riparian Buffer Zones with native vegetation to control storm water runoff." According to the report, most of the residential lots within the watershed range in size from ¼ to ¾ acre. The report observes that stormwater runoff from subdivisions within the watershed flows into drainage ditches, and discharges from those ditches, is a major source of fecal coliform in the creek.

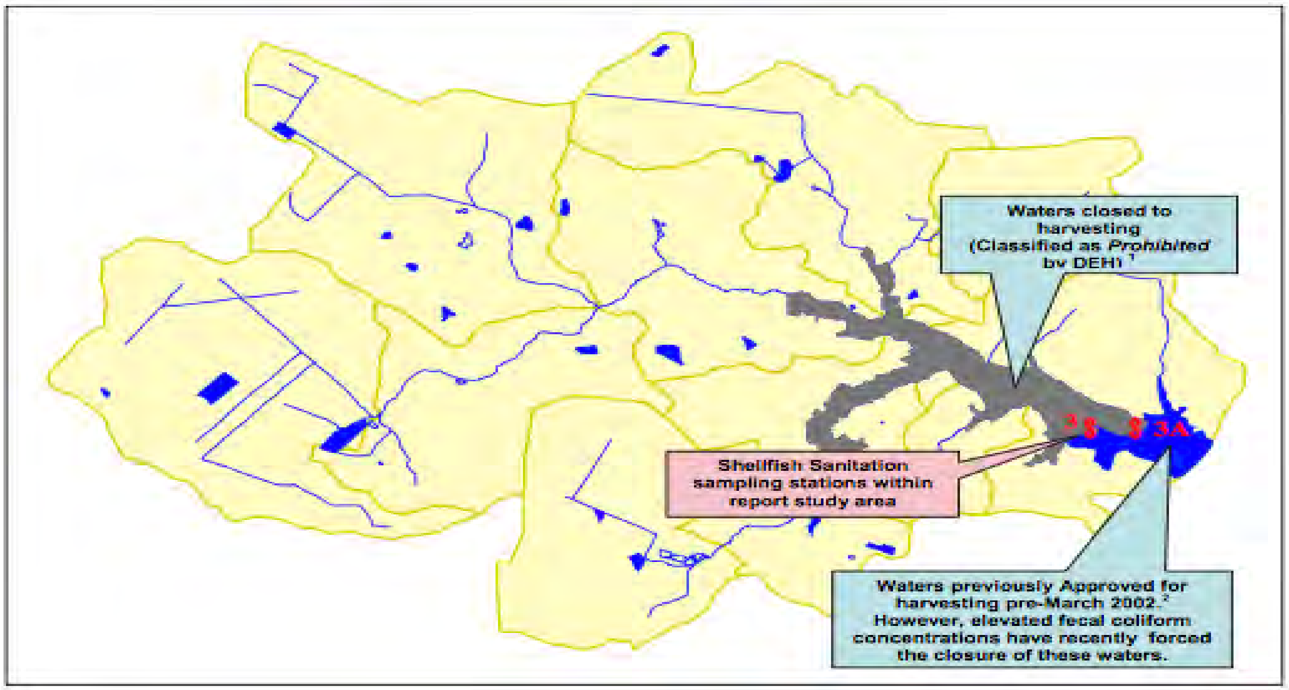


Figure 12. Shellfish closure history in Hewletts Creek, Dewberry and Associates.

Figure 13. Hewletts Creek Growing Area Survey and Sampling Stations, SS.

The creek is classified as SA waters which means it should support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes. Hewletts Creek was first closed to shellfishing in 1973 based upon unacceptable levels of bacteria. Then in 1978, approximately 83 acres of the creek were reopened for harvest, leaving only the upper portions of the creek polluted. Then in 2002, the closure area was again enlarged to extend to the mouth of the creek, and then again in 2006 and 2009 additional closures occurred outside the creek's mouth in Masonboro Sound (See Appendix G). Hewletts has been listed in the 2010 N.C. Water Quality Assessment and Impaired Waters 303(d) List under Category 5.

The most recently collected fecal coliform samples collected by SS in Hewletts Creek watershed were at Station 4, 5, 7 and 9 shown in Figure 14. The data collected from these stations are provided in Appendix H.

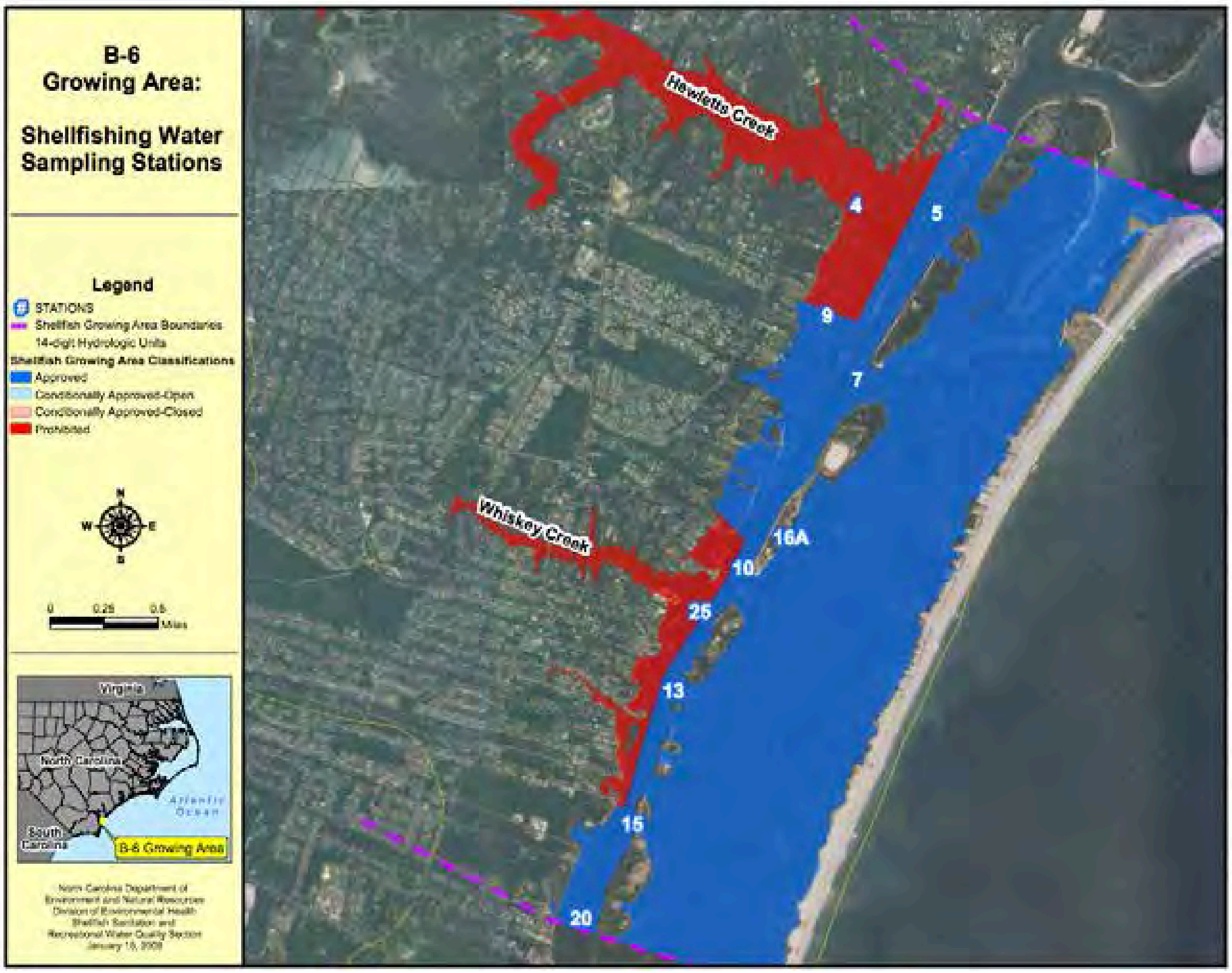


Figure 14. SS sampling stations 4, 5, 7 and 9 in Hewletts Creek watershed.

In conclusion, water quality management issues facing the Hewletts Creek watershed include:

(1) The upper portion of the creek closed to shellfish harvest in 1973. It does not have an "existing use" for shellfish harvest as designated by the federal Clean Water Act. This portion of the creek contains abundant populations of oysters and clams, and the waters are not closed automatically because of nearby marinas. An improvement in water quality could restore shellfish harvest in this area of the creek.
(2) The lower portion of the creek and the waters outside the creek in Masonboro Sound were closed to shellfish harvest after November 28, 1975, and therefore, shellfish harvest is considered to be an "existing use" pursuant to the Clean Water Act.
(3) All the waters of Hewletts Creek and Masonboro Sound that are currently closed to shellfish harvest are classified as SA, and are "impaired." As long as this "impairment" exists, there is an obligation to restore shellfish harvest to these waters.

EXISTING MANAGEMENT STRATEGIES

Regulatory changes, existing management efforts, and extensive water quality monitoring undertaken by the City represent its commitment to protect and restore water quality. These programs focus primarily on new development, on existing drainage problems, and on reducing overall pollution levels from an array of known sources such as pets, illicit discharges, construction sites, and deteriorating sewer lines. While certain elements of the City's program specifically focus on fecal coliform (pet waste ordinance, post-construction ordinance requirements to maximize fecal coliform reduction), it is very difficult to measure what effect these programs have on preventing and reducing fecal coliform pollution within the tidal creeks. This is because these programs are designed to prevent increased pollution from new development, or to prevent further degradation by controlling known sources of bacteria. Also, public participation in pet waste programs can be measured and these initiatives prevent further water quality degradation, however beneficial gains in water quality are sometimes impacted by sources beyond our control (i.e. wildlife).

Wilmington became a Phase II community on March 1, 2007 when the NPDES Phase II permit issued by DWQ to the City became effective.

In 2007 and 2008, new coastal stormwater standards and Phase II NPDES rules were adopted by the State of North Carolina that reflect a much better understanding of what it will take to prevent bacteria pollution of coastal waters.

These new Coastal Stormwater Rules and NPDES permits require designing non-discharging stormwater systems that will infiltrate a one-year 24-hour storm, or approximately 3.95 inches of rainfall. The City realized the critical importance of controlling the volume of stormwater runoff as well, and has adopted its own design criteria including standards that promote new development to incorporate LID that mimic the natural hydrology. These regulatory changes clearly recognize the critical role that altered hydrology plays in causing water quality impairments in these tidal creeks. The existing regulatory framework for managing stormwater is outlined in Table 3.

Clean Water Act	· 1987 amendments included Section 319, which addresses the need for greater federal leadership to help focus state and local nonpoint source efforts. Under Section 319, Wilmington received grant money that supports a wide variety of activities – including funding for this plan. · Standards for SA waters – 14CFU/100ml · Require impaired waters to develop a TMDL and/or Watershed Restoration Plan http://www.epa.gov/regulations/laws/cwa.html
NPDES Phase II Program	· Promulgated by the EPA in December 1999 · Expands the NPDES stormwater program · Extends coverage to operators of small MS4s · Six minimum measures: · Public Education and Outreach · Public Participation and Involvement · Illicit Discharge Detection and Elimination · Construction Site Runoff Control · Post-Construction Runoff Control · Pollution Prevention and Good Housekeeping for Municipal Operations http://cfpub.epa.gov/npdes/home.cfm?program_id=6
City of Wilmington NPDES Stormwater Permit	· Issued (amended) March 1, 2007 · Requires public education and involvement programs · Requires use of BMPs to control fecal coliform to the maximum extent practical · Prohibits new discharges and increases in discharge volumes to SA waters · Water Quality Recovery Program is required for degraded waters subject to TMDL http://www.wilmingtonnc.gov/public_services/stormwater/npdes_permit.aspx
Wilmington Stormwater Ordinance	· Adopted more stringent stormwater rules for areas within a half mile of shellfishing waters · Require a stormwater permit be obtained: o Commercial – 10,000 sq. ft. of disturbance o Residential – 1 acre of disturbance · Change impervious surface trigger to 12% (from 25%) · Change building setback from mean high water to 50 feet (from 30 feet) · Require capture of 3.95 inches of rain from 1-yr., 24-hour storm event (from 1.5 inches) · Exclude wetlands from calculations http://library1.municode.com/default-test/DocView/14101/1/132/146
City of Wilmington Tree Preservation Ordinance	· Retention standards for existing trees for new development and redevelopment; mitigation of removal of regulated trees · Landscaping requirements for parking lots, street yards, street plaza trees, buffers, and disturbed areas http://library1.municode.com/default-test/DocView/14101/1/132/140
City of Wilmington Exceptional Design Standards	· Requires LID practices for development to exceed 25% impervious surface area in environmentally-sensitive areas · Bonus points for pervious pavement, wetland restoration, other measures http://library1.municode.com/default-test/DocView/14101/1/132/142

City of Wilmington Conservation Resource Regulations	· Require protection of most wetlands with variable setback depending on wetland type · Requires 35 foot vegetative buffer for high value wetlands (coastal and non-coastal marsh) http://library1.municode.com/default-test/DocView/14101/1/132/138
Wilmington – New Hanover County Joint CAMA Plan 2006 Update	· Adopted by the City of Wilmington and New Hanover County in 2006 · Certified by the Coastal Resources Commission in 2006 · Promote improved water quality and watershed-based water quality standards. (3.1) · Supports continued and expanded water quality monitoring (3.1) · Support restoring shell fishing to SA waters and restoring water quality of all non-supporting surface waters (3.1) · Support employment of stormwater BMP retrofits to mitigate water quality impacts from existing development (1.6) http://www.wilmingtonnc.gov/CAMA Plan 2006.pdf
City of Wilmington Future Land Use Plan	· Adopted by City Council in 2004 · Promote improved water quality and watershed-based water quality standards. · Support provisions in NPDES Permit · Support use of LID in new and redevelopment · Encourage education of homeowners and HOA to use best management practices · Supports development of water quality indicators to monitor effectiveness of programs http://www.wilmingtonnc.gov/development_services/plans_documents/future_land_use_plan.aspx
Joint City of Wilmington – New Hanover County LID Manual	· Adopted by the City of Wilmington December 2008 · Provides technical guidance on the application of LID principles, planning, and practices as an acceptable and voluntary approach to meeting stormwater management objectives · Developed a spreadsheet tool, LID-EZ: · Aids engineers, planners, and developers with design and permitting of LID projects · Quantifies the effect of the structural and non-structural BMPs on the overall hydrology of residential and commercial developments http://www.wilmingtonnc.gov/LID manual.pdf

Table 3. Legal, planning and regulatory framework for managing stormwater by the City of Wilmington.

GOALS, OBJECTIVES, AND MANAGEMENT ACTIONS

The goal of this Plan is to remove the legal water quality "impairments" within these two watersheds. This will be accomplished by reducing the bacteria in the "impaired waters" of Bradley Creek and Hewletts Creek watersheds that are classified for shellfish harvest and swimming, and by properly classifying some of the waters to reflect their "existing uses" and water quality conditions.

The "impaired waters" that are the focus of this goal are waters classified as SA and SB. The impaired waters include:

(1) Masonboro Sound along the shoreline of Banks Channel next to Wrightsville Beach. All of these waters along the shoreline of Wrightsville Beach are impaired for their use for swimming and the SA portion of these waters is also impaired for shellfish harvest; and

(2) All of Hewletts Creek and waters outside the creek in Masonboro Sound that are closed to shellfish harvest.

This goal will be accomplished over the next several decades by achieving six objectives and six types of management actions identified below. The City believes that over time, reductions in the volume of stormwater runoff that are achieved as a result of this Plan will result in measurable water quality improvements that will be realized by gradual increases in opportunities to harvest shellfish and swim in these waters. Stormwater runoff that transports ubiquitous sources of bacteria is the primary and chronic cause of the water quality impairment in these two watersheds. The six objectives and 35 management actions of this Plan include:

Objective One: CONTINUE EXISTING PROGRAMS THAT ADDRESS WATER QUALITY IMPAIRMENTS IN BOTH WATERSHEDS

This Plan reaffirms the need for existing programs that are helping to address water quality impairments in these two watersheds. These include programs that are designed to prevent further degradation of water quality and engage residents in water quality protection and restoration efforts. These programs can be continued with existing program budgets. The need is for these existing programs to prevent additional increases in stormwater runoff volume that result from the one-year, 24-hour storm event.

Action 1-1: Implement and enforce existing stormwater management requirements for new development and redevelopment projects. Incorporate LID design and specifications into the City's Technical Standards Manual and Handbook.

Action 1-2: Continue to promote LID designs in all new private residential, commercial, and industrial developments through site design reviews and educational programming.

Action 1-3: Continue to cooperate with the NC Community Conservation Assistance Program (CCAP) via NHSWCD to encourage the installation of stormwater reduction measures for existing development.

Action 1-4: Maintain existing educational programs that help City residents better understand how stormwater degrades water quality and what they can do to help reduce fecal coliform pollution within these two watersheds.

Action 1-5: Reflect watershed restoration strategy in the city plans, NPDES stormwater permit, and capital improvement program.

Action 1-6: Continue education and code enforcement programs aimed at reducing and eliminating sources of bacteria and pathogens related to human and pet waste.

Discussion of Approaches to Achieving Management Actions

Achieving these actions will depend on existing programs that are currently funded and implemented throughout the two watersheds and city wide. The promotion of LID in new development and for redevelopment depends upon continued and expanded application of the LID Guidance Manual and LID-EZ permitting tool coupled with providing alternative LID technical standards.

In November 2009, the city enacted a new pet waste ordinance directed at reducing fecal coliform pollution. Since these are relatively new requirements, the plan is to fully implement these provisions through education and enforcement. The provisions of this ordinance require pet owners to:

(1) Fully and immediately clean up after pets on any public property. (Public property consists of streets, sidewalks, right of ways, parks, plazas, stream banks, public accesses, pathways, drainage ways, storm drains, creeks, officially accepted easements, etc.);

(2) Carry a cleanup device (i.e., bag, scooper) at all times;

(2) Show the cleanup device to a Code Enforcement Official, if requested;

(4) Bag and dispose of pet waste in a closed trash receptacle or refuse container;

(5) Do not flush pet waste down the toilet (Cape Fear Public Utility Authority ordinance); and

(6) Fines for non-compliance with the City's pet waste ordinance are $250 for each occurrence.

A stormwater code enforcement officer regularly enforces these provisions. Other ongoing pet waste/fecal coliform education efforts include:

(1) Printed posters and flyers;

(2) Thirty-second Public Service Announcements aired in paid campaigns on mass media TV and radio stations;

(2) Information airing on city's cable television channel;

(4) Public stormwater presentations to community groups; and
(4) Attendance and displays at pet-related local events such as Paw Jam and the Pet Expo.

The city is also implementing the "Canines for Clean Water Program." This program is a voluntary program for dog owners that encourages them to sign a public pledge promising to clean up after their pet and dispose of the waste properly. Once a pledge is signed, pet owners receive a free dog bandana, educational and other program materials. Dog owners are then encouraged to submit a photo of their pooch to the online Canines for Clean Water photo gallery: www.wilmingtonnc.gov/canines

In addition to pet waste reduction efforts, the City has an Illicit Discharge Detection and Elimination Program. This program tracks down and eliminates illicit sources of fecal contamination such as sewer spills, septic failures, and residential discharges. This is accomplished via citizen reports to the stormwater hotline, field observations, and water quality monitoring by UNCW.

The city operates an aggressive Street Sweeping Program in these watersheds to minimize the amount of dirt and pollutants flowing from roadways into waterways.

Objective Two: DETERMINE APPROPRIATE WATER QUALITY CLASSIFICATIONS AND DESIGNATED USES WHERE WATER QUALITY IMPAIRMENT EXISTS

Monitoring of water quality in the areas that have been closed to shellfish harvest is limited, and not adequate to determine their current status and trends in water quality. Monitoring needs to be undertaken and analyzed to better determine current water quality conditions, and to evaluate the appropriateness of existing water quality classifications and designated uses.

Action 2-1: Work with SS, UNCW and NCCF to conduct preliminary evaluations of water quality to determine where further intensive (SS) water quality investigations are needed.

Action 2-2: Work with SS to establish new monitoring stations for fecal coliform in the waters influenced by the Bradley Creek watershed along the edge of the automatic closure boundary shown in Figure 7. These new sampling stations should be paired with stations 22, 60, 28A, and 35.

Action 2-3: Work with SS to establish monitoring stations for fecal coliform within the impaired SA waters in Hewletts Creek and within the closed shellfish waters in Masonboro Sound outside the creek. Stations are shown in Figure 15.

Action 2-4: Evaluate the results of on-going bacteria source monitoring in Banks Channel paid for by the Town of Wrightsville Beach and conducted by the UNC Institute of Marine Sciences.

Action 2-5: Request a Use Attainability Study for the remaining SA waters within the Bradley Creek watershed (along Banks Channel next to Wrightsville Beach) that are currently closed to shellfish harvest because of the SS automatic marina closure rule. These waters have not had shellfish harvest since 1947. If the study concludes that shellfish harvest is not an existing use, and harvest cannot be restored, then request that the EMC reclassify these waters as SB.

Action 2-6: Request a Use Attainability Study for all "Approved" waters for shellfish harvest by SS that are currently classified as SB waters by the EMC within waters influenced by the Bradley Creek Watershed. If the study finds that shellfish harvest is an existing use then request that the EMC reclassify these waters as SA.

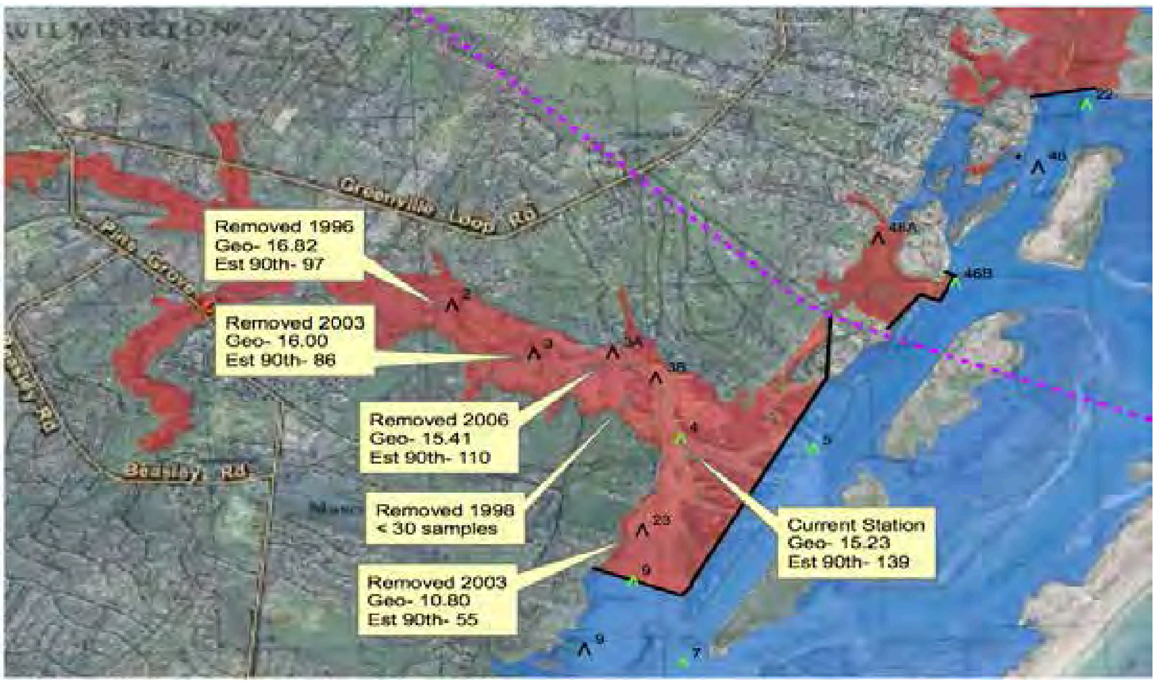


Figure 15. SS monitoring stations for fecal coliform that need to be reinstated to gauge success of this plan.

Action 2-7: Evaluate if cleanup efforts will allow for any waters classified as SB within waters influenced by the Bradley Creek watershed to be opened for shellfish harvest if the trend to continued improvements in water quality continues. If shellfish harvest is allowed in these waters, request a Use Attainability Study to determine if these waters should be reclassified as SA.

Action 2-8: Evaluate the status and trend in bacterial contamination within the entire Hewletts Creek watershed based upon more intensive data collection as part of plan implementation. Evaluate the success of cleanup efforts, and make sure that positive trends in water quality are reflected in how shellfish harvest is managed by assuring that adequate data exists upon which to make prudent management decisions that are protective of public health.

Discussion of Approaches to Achieving Management Actions

There is a need to more closely monitor fecal coliform and enterococci levels within the impaired waters to determine baseline conditions, if cleanup efforts are succeeding, and when these waters can be reopened for shellfish harvest and there is no longer a need for swimming advisories. SS generally does not sample "Prohibited" growing areas because they are no longer managed for shellfish harvest. However, because the City and its partners are attempting to re-establish shellfish harvest and prevent swimming advisories in these impaired waters, SS has indicated a willingness to expand the existing number of water quality sampling stations to determine whether it can reclassify these waters to allow harvest in the future. In addition, the City will modify its own water quality monitoring to determine if new sampling stations can be established to help it evaluate the success of this Plan.

Existing water quality classifications within the two watersheds need to be evaluated to make sure they are appropriate. The plan recognizes the need to enhance water quality restoration efforts, and no changes in classifications should occur that will result in weaker water quality protection standards. There are two areas of classifications that need to be examined: (1) the portions of the SB waters within the Bradley Creek watershed that are currently open to shellfish harvest, and which should be reclassified as SA; and (2) the SA waters in Banks Channel that are automatically closed to shellfish harvest, and which have been continuously closed to harvest since 1947. The plan seeks to restore shellfish harvest in the upper half of Hewletts Creek since the SA standard is required there to maintain these existing water quality safeguards and to support water quality restoration efforts in the lower half of Hewletts Creek and in the areas where it flows into Masonboro Sound.

Objective Three: TRACK THE REDUCTION OF TRANSPORT OF BACTERIA FROM LAND TO WATER

The volume of stormwater runoff from the land into the water needs to be reduced to restore water quality. The objective of the Plan is to reduce the volume of stormwater generated and conveyed from the land uses to levels that occurred in 1981.

Action 3-1: Secure and budget funds to install retrofits in the Bradley Creek watershed to reduce the volume of runoff, establish how much volume can be reduced based upon available funds, and track reductions using measurement tools provided by this plan.

Action 3-2: Secure and budget funds to install retrofits in the Hewletts Creek watershed to reduce the volume of runoff, establish how much volume can be reduced based upon available funds, and track reductions using measurement tools provided by this plan.

Discussion of Approaches to Achieving Management Actions

Reducing the volume of stormwater runoff generated and conveyed from land uses within these two watersheds should significantly reduce prohibitions on shellfish harvesting and recreational uses that result in "impaired" waters. This Plan establishes interim objectives to work towards incrementally improving watershed health.

The Plan is based in the belief that the increased urbanity of the land within the watersheds has been a primary driver for watershed impairments. Land use is being used as the primary indicator of watershed change over the years. To determine the goals of the plan we first attempted to quantify the change in land use within each watershed. This Plan assimilates watershed health to runoff volume. To determine the runoff volume from a watershed, some information about the composition of the watershed and the rainfall distribution must be determined.

Beginning with aerial photos from 1981, Withers & Ravenel (W&R) completed a parcel based land use analysis in which areas of generally homogenous land use were measured and cataloged. Within each delineated land use zone, W&R estimated an average percent impervious cover present within that area. For landscaped or wooded areas, the capability of the land to absorb rainwater has a direct influence on how much water will run off from the land. Therefore in addition to the impervious areas, W&R also determined the soil types within each watershed. This impervious area and soil data was then sorted by type of land use - residential, commercial, or public right-of-way. The totals from each delineated zone were then tabulated in Microsoft Excel and input into watershed modeling software. The software was used to generate hydrographs for each watershed.

The Soil Conservation Service (SCS) Method was used to develop runoff hydrographs for the Type III, 24-hour duration storm event for the Wilmington area. The NC Environmental Management Commission and DWQ established a design storm in 2008 for coastal stormwater regulations based upon what they believe is necessary to protect SA waters. New development near SA waters must be designed to infiltrate the 1-year, 24-hour rainfall event, or approximately 3.95 inches of rainfall in a 24-hour period. This design storm provides the basis for calculating the amount of stormwater volume that needs to be reduced to eliminate the shellfish harvest closures in these creeks.

The SCS Method requires three basic parameters: a curve number (CN), time of concentration (t_c), and drainage area. Curve numbers were based on soil type and land use as determined from the GIS and aerial photo analysis described above. Soil types were delineated from the USDA Web Soil Survey and data from New Hanover County GIS soil data files. The time of concentration (the time is takes water to flow from the upstream portions of the watershed to the actual creek) was set at 30-minutes because of proximity of most of the urbanized area to the creek's themselves. Drainage areas were determined using watershed boundary data provided by the City and were verified by W&R during the land use analysis.

The scope of work included the following analyses:

(1) Estimation of the 1-year 24 hour runoff volumes;
(2) Simulation of the 1-year rainfall event for the Wilmington area; and
(3) Formulation of the 1-year flood hydrographs for each land use scenario in each watershed.

The results of the hydrology calculations are used in the hydraulic analyses. The rainfall/runoff hydrographs have been compiled to create a computer simulation model using Bentley PondPack v10.0 software. The results of the PondPack model were then used to assess the change in peak discharges and total runoff volume from each watershed for the design rainfall event. The PondPack modeling results are provided as appendices to this report.

The runoff hydrographs depict the anticipated rate of runoff, or flow rate, at any given time during a typical storm event. Most rain events begin slowly, and then reach a peak intensity before fading away as the storm passes. The response from the watershed is similar at first. Most rainfall is absorbed into the landscape until a critical depth of rain has fallen – generally a tenth of an inch or so. At that point, runoff begins to flow through the conveyance systems (channels, ditches, creeks, pipes etc). That runoff takes time to reach the outfall – in this case the mouth of the creek, but eventually the peak rate of runoff is reached – represented by the high point on the hydrograph curve.

Watersheds – both developed and undeveloped – have a measurable capacity to detain and hold water for short periods of time during and after storms. Because of this, after the peak of the hydrograph is reached, there is a slower transition back to base flow conditions. Looking at the hydrograph, there is a steep ascent to the peak runoff rate, but then as the watershed empties and runoff flows into the Intracoastal Waterway, conditions slowly return back to normal levels.

Stormwater runoff volume is a factor of land use conditions and rainfall depth. Changes to the land use within any given watershed can have a direct impact on the volume of surface runoff anticipated in response to a given rainfall. As pervious areas (undeveloped wooded area) are converted into developed area, the addition of impervious surfaces and the reduction in wooded areas means that less rainfall will infiltrate into the soil or be intercepted by tree canopies. The resulting impacts are numerous – an increased volume of water entering surface waters, runoff reaches surface waters faster, runoff temperatures increase just to name a few. The increased rate of runoff can also increase the probability that pollutants, previously sequestered within the landscape, are now transported directly to surface waters.

Ultimately, the goal is to improve water quality so as to restore shellfishing wherever feasible in these two watersheds, and to eliminate the need for swimming advisories in the SB waters that are influenced by the Bradley Creek watershed.

For Bradley Creek, there is not sufficient land use data to be able to accurately estimate the pre-shellfish closure hydrograph that existed in 1947. As noted earlier, these closures were probably a result of discharges of poorly treated sewage from numerous wastewater treatment plants and boats, as well as runoff from development. In recent years, a positive trend in water quality has been documented by SS in Masonboro Sound near Banks Channel. While the storm hydrograph based upon these land use data for Bradley Creek does not represent a pre-shellfish or swimming closure condition for these SA and SB waters, this plan uses the 1981 hydrograph as a baseline condition for establishing its stormwater volume reduction goal for this watershed.

For the Bradley Creek watershed, the 1-year, 24-hour storm (3.95" of rainfall) currently generates approximately 105 million gallons of stormwater runoff. In 1981, that same rainfall amount generated approximately 44 million gallons of runoff. Thus, the changes in land-use that have occurred since 1981 have increased the volume of runoff by approximately 61 million gallons. This hydrograph is shown in Figure 16.

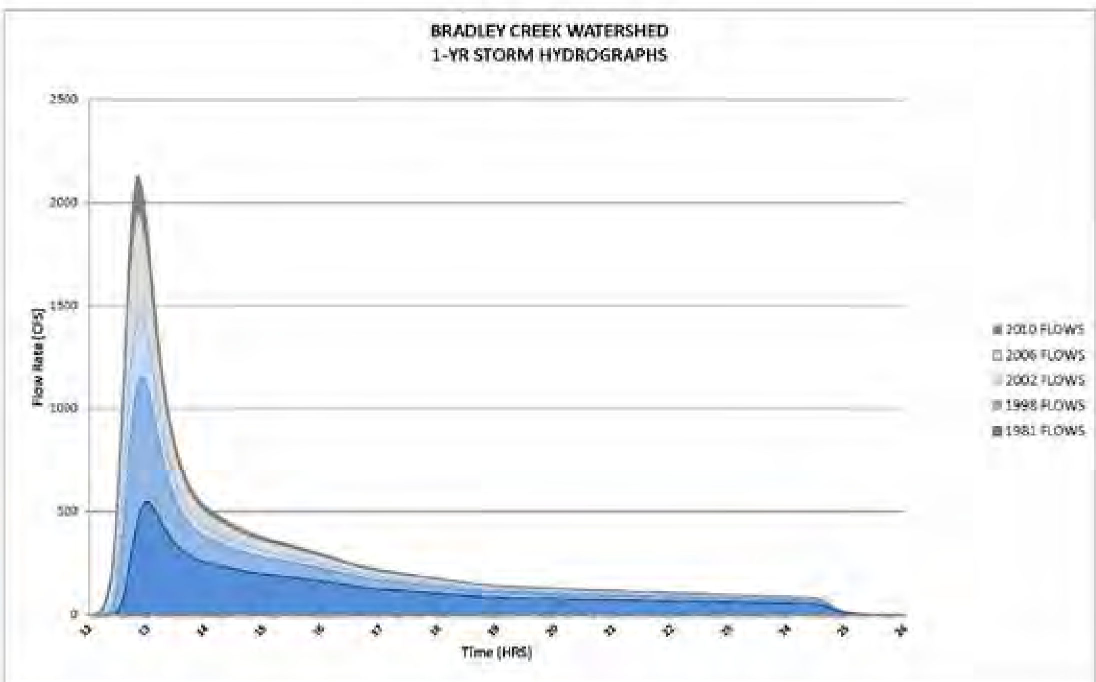


Figure 16. Bradley Creek Watershed Hydrograph.

The City and Wrightsville Beach believe this provides sufficient volume reduction targets because the area of impairment is not within the SC waters of the creek, but along the shoreline of Wrightsville Beach where swimming advisories have been issued in SB waters, and there are closed SA waters. The City and Wrightsville Beach plan to re-evaluate this goal as it reduces stormwater volumes to determine if it is adequate to obtain the necessary improvements to water quality. If bacteria levels do not drop sufficiently within the SA and SB waters, the stormwater volume reduction goal will be increased so that bacteria reductions are achieved based upon water quality monitoring. The Town of

Wrightsville Beach and NC DOT will further evaluate if there are practical ways to reduce the volume of discharges from the existing storm drains into Banks Channel.

For Hewletts Creek, the closure for shellfish harvest first occurred in 1973 in the upper portions of the creek. The lower portions of the creek were permanently closed in 2002. Land use data from 2010, 2006, 2002, 1998, and 1981 serve as excellent baseline years for establishing incremental targets for reducing stormwater volume.

In Hewletts Creek, the amount of watershed development that occurred between 1981 and 2010 has resulted in an additional 80 million gallons of stormwater runoff being generated. In 1981, a one-year, 24-hour storm generated approximately 79 million gallons of runoff. In 2010, that same sized storm generated approximately 159 million gallons of runoff. This hydrograph is shown in Figure 17.

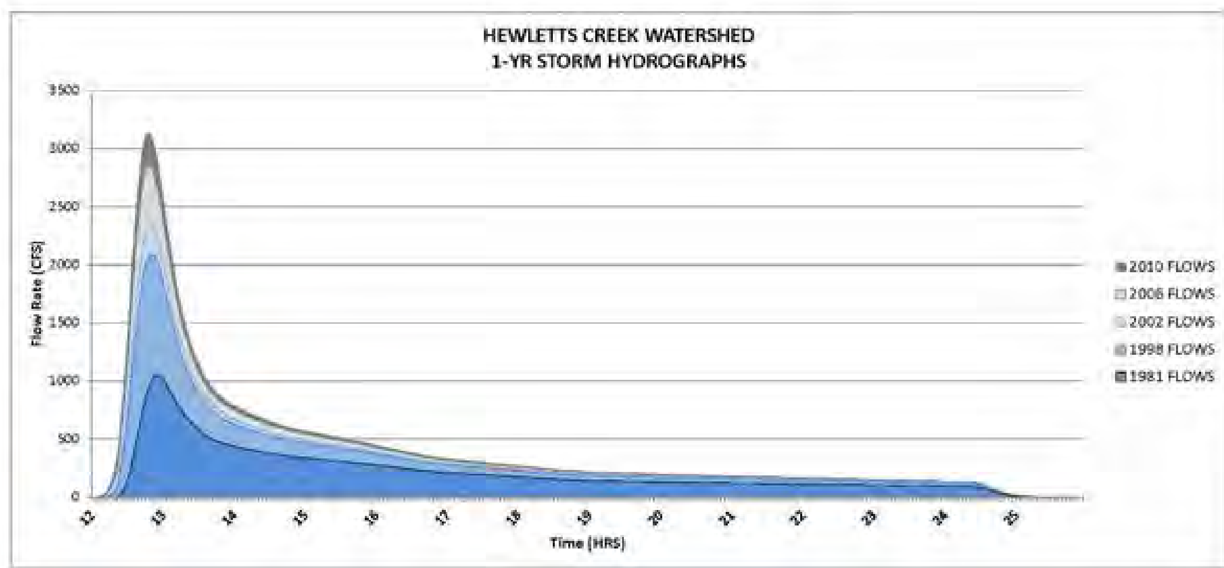


Figure 17: Hewletts Creek Watershed Hydrograph.

Tables 4 and 5 lists the results of the hydrograph analysis, showing the increase in runoff volume from the 1-yr 24-hour storm as development increased. The 2010 data reflects the current condition, and the results from the other years listed are being used as the incremental target conditions. As volume reduction strategies are implemented across each watershed, the net reduction in runoff volume will be subtracted from the 2010 runoff volume, and compared to the target years to determine the percent of progress made towards each of the goals.

1-yr Runoff Volume			
	ac-ft	cf	gal
2010	323.62	14,096,887	105,444,716
2006	303.92	13,238,755	99,025,889
2002	248.01	10,803,316	80,808,801
1998	213.44	9,297,446	69,544,899
1981	136.49	5,945,504	44,472,373

Table 4. Bradley Creek hydrograph analysis.

1-yr Runoff Volume			
	ac-ft	cf	gal
2010	487.63	21,241,163	158,883,898
2006	456.87	19,901,257	148,861,404
2002	397.92	17,333,395	129,653,796
1998	369.72	16,105,003	120,465,424
1981	241.90	10,537,164	78,817,987

Table 5. Hewletts Creek hydrograph analysis.

Table 6 is a breakdown of tables 4 and 5, showing the percent reductions in total runoff volume required to reach each incremental target from the 2010 baseline scenario.

	1981	1998	2002	2006
2010 Bradley Creek	58%	34%	23%	6%
2010 Hewletts Creek	50%	24%	18%	6%

Table 6. Volume reduction targets (2010 land use compared to milestones).

Impervious area was categorized by commercial, residential, or public right of way. All public right of way areas were estimated to be 80% impervious based on an analysis of existing City transportation corridors and standard NCDOT roadway standards. Commercial impervious areas were assumed to be directly connected to piped drainage networks. This means that the runoff from these areas has little or no chance to infiltrate into the ground before it reaches the creek. Residential impervious areas were considered to be only 50% connected impervious area. This adjust reduces the overall runoff volume from the impervious area by accounting for the impact of roofs without gutters, driveways which promote sheet flow, and disconnected downspouts. Runoff from these areas likely has a chance to infiltrate into the surrounding landscaped or wooded areas prior to being conveyed to the creek.

No adjustments were made for existing BMPs or retrofits within the drainage basin. Additionally, the hydrograph models do not reflect the impact that currently undersized conveyances may have on the actual peak flow or runoff volumes that impact the watershed hydrology. Ongoing flood management strategies being used by the City to protect the citizens and property often result in larger conveyances (pipes, channels, diversions etc) to move water through the watershed more efficiently. The hydrograph analysis assumes that the conveyance systems are maximized for efficiency. Therefore as flood mitigation projects are completed, there is no negative impact to progress made towards the watershed goals.

Additionally, due to current stormwater regulations being enforced by the City, new development projects will be required to install stormwater control measures. In regards to this plan, because the BMPs required for new development all require management of the water quality volume, they should be built to control a volume of water which corresponds to the same principles of this plan. Therefore, future development will have no net impact on the 2010 hydrograph, and therefore the starting condition will remain constant as the City continues to develop new areas. Redevelopment of existing impervious area, when completed by a private developer, may include new BMPs and volume reduction measures not currently in place. In this event, the BMP should be added to the atlas, and the benefit should be accounted for when working towards watershed goals.

It should be noted that as impervious area and urban development increases, this does not necessarily mean that watersheds will degrade. This plan aims to address water quality impairments by proactively improving the way in which the City manages runoff from impervious areas. Removing the impervious area is only one of many techniques available to the administrators of this plan, and in some cases it may prove to be a highly beneficial and cost effective practice. However, in the long term, strategies deeply rooted in impervious area reduction alone seldom prove to be sustainable when examining the environmental, social, and economic impact of watershed restoration efforts. For this reason, a multitude of volume reduction strategies are included in the plan, and as this plan evolves over time additional innovative strategies and practices should be encouraged when they are both feasible and practical.

Objective Four: FOCUS STORMWATER REDUCTION EFFORTS IN LOCATIONS WHERE THEY WILL YIELD THE GREATEST AND MOST COST EFFECTIVE VOLUME REDUCTIONS

It will only be possible to obtain significant reductions in the volume of stormwater runoff if strategic decisions are made about how to achieve the most benefit for the staff and resources used.

Action 4-1: Promote use of the GIS web based retrofit atlas (developed for this Plan) to aid homeowners, engineers, planners, and developers in identifying cost-effective retrofit opportunities, designing retrofit projects, and quantifying the impact on decreasing runoff volume.

Action 4-2: Investigate cost-effective methods of working with landowners to disconnect impervious surfaces.

Action 4-3: Promote LID retrofits of existing private development; with emphasis on promoting the appropriate use of cost-effective stormwater reduction measures that are most cost effective.

Action 4-4: Promote tree planting within watersheds on private and public properties.

Action 4-5: Promote installation of stormwater reduction measures on City streets based on the design and specifications manual (Appendix J) in future capital improvement projects that involve city-owned streets, rights-of-way and other public property.

Action 4-6: Pursue strategy with NCDOT that any new road upgrade or maintenance plans include plans for reducing the hydrograph along that section of road.

Action 4-7: Promote LID retrofit designs in all future publicly funded maintenance or redevelopment projects involving City owned buildings, parks, municipal parking lots and drainage systems.

Action 4-8: Promote and assist with LID retrofits for county schools within these watersheds.

Action 4-9: Encourage UNCW to develop a campus-wide master plan that promotes LID retrofits for existing development.

Action 4-10: Evaluate properties for retrofit or restoration potential. (See Figure 18.)

Action 4-11: Evaluate existing stormwater ponds on private and public properties for potential volume reduction enhancements, and if feasible, retrofit them to achieve volume reduction.

Figure 18. Retrofit installed at Bradley Creek School.

Discussion of Approach to Achieving Objective

Four criteria have been selected to prioritize where investments in stormwater reduction retrofit projects should be made. These include: (1) runoff volume reduction potential; (2) fecal coliform pollutant removal potential; (3) cost effectiveness; and (4) proximity to SA surface waters. Figure 19 shows soil limitations for infiltration to help guide the selection of stormwater reduction retrofit measures.

Figure 19. Soil suitability in Bradley and Hewletts Creek Watershed.

Table 7 provides the total number of acres and parcels that are within the areas of the watershed that have slight, moderate, and severe limitations on infiltrating stormwater based upon septic tank suitability.

Watershed	Good Soils (acres/parcels)	Fair Soils (acres/parcels)	Poor Soils (acres/parcels)
Bradley	588/1739	906/2149	2301/5962
Hewletts	832/1959	2935/1034	4234/4234

Table 7. Soil suitability for infiltrating stormwater by acres and number of parcels in each watershed.

Table 8 lists recommended stormwater reduction measures that can be used in various soil and water table conditions, as well as the relative amount of stormwater volume that can be reduced by the measure based upon soil conditions. Exact performance of measures will depend upon site conditions, proper installation and maintenance.

Type of Stormwater Infiltration Practice	Potential for Beneficial Hydrograph Modification		
	Good Soils	Fair Soils	Poor Soils
Rooftop Disconnection	High	High	Medium
Disconnected Impervious Surfaces	High	High	Medium
Restore Natural Areas	High	High	Medium
Stormwater Wetland	High	High	Medium
Linear LID for Streets, Roads	High	Medium	Medium
Landscape (Large) LID Retrofits	High	Medium	Medium
Wet Detention Basin	High	Medium	Low
Raingarden	High	Medium	Do Not Use
Bioretention	High	Medium	Do Not Use
Infiltration Swale, Basin	High	Medium	Do Not Use
Permeable Pavement	High	Medium	Do Not Use
Riparian Buffer Restoration	Medium	Low	Low
Plant Trees	Low	Low	Low
Rainwater Harvesting	Low	Low	Low
Green Roofs	Low	Low	Low

Table 8. Appropriate stormwater reduction practices based upon potential for beneficial hydrograph modification.

Table 9 gives an average amount of stormwater volume that is currently created by existing land uses within the two watersheds on each parcel and acre, as well as the average volume reduction that will be necessary to meet the goals of the plan. These average figures illustrate that stormwater volume will need to be reduced by nearly half on each parcel. While the average size of each parcel ranges from .38 to 0.9 acres, each watershed contains very large and very small parcels and the opportunities to use various stormwater volume reduction measures will vary depending on the size of parcels and landownership patterns.

Watershed	Average Parcel Size	Existing Volume (Based on Hydrographs)		Reduction of Volume Required (Based on Hydrographs)	
		Gallons/Parcel	Gallons /Acre	Gallons/Parcel	Gallons/Acre
Bradley	.38 acres	10,051	26,087	5,982	15,528
Hewletts	.90 acres	20,892	18,852	10,718	9,671

Table 9. Stormwater Volume reduction goals by parcel and acre for each watershed based upon overall volume reduction needed as calculated by hydrographs.

Objective Five: FORM AND MAINTAIN PARTNERSHIPS

Accomplishing the actions called for in this Plan require partnerships with state and local government agencies, not-for-profit organizations, universities, landowners and residents.

Action 5-1: Work with partners to educate watershed stakeholders (residents, homeowners, and local government elected officials) about the need and cost-effective strategies to reduce stormwater volume to remove impairments to SA waters. This could include targeted educational campaigns and establishing new partnerships to carry out retrofit programs.

Action 5-2: Work with governmental agencies and NGOs to secure grants to reach large numbers of landowners to enable them to install low-cost retrofits that disconnect impervious surfaces and enhance the infiltration of stormwater.

Action 5-3: Provide strategies and policies for City departments to carry out plan by incorporating runoff reduction strategies into the Capital Improvement Plan process.

Action 5-4: Promote use of GIS Atlas among key departments in their routine business.

Action 5-5: Promote existing technical training opportunities for planners, engineers, developers, landscapers and local government staff on techniques to reduce volume of stormwater in Bradley and Hewletts Creek watersheds.

Action 5-6: Work with UNC-W to identify and pursue retrofit projects that reduce stormwater volume.

Discussion of Approach to Achieving Objective

These partnerships are vital for several reasons including to: (1) Leverage existing resources since increases in revenues to carry out this Plan will be difficult to secure in on-going lean budget times; (2) Secure available grant funds from federal, state and private sources that can be used to implement individual actions; and (3) Accomplish individual actions through voluntary efforts by partners that can be done through existing budgets and operations. The City already works with many key partners and it will continue to seek to strengthen these relationships using the goal and objectives of this Plan.

Objective Six: MEASURE SUCCESS AND ADAPT PLAN BASED UPON RESULTS

Progress made in achieving water quality improvements will be measured. This Plan will be adapted as necessary based upon this monitoring.

Action 6-1: Use on-line GIS BMP Atlas to track progress toward watershed goals.

Action 6-2: Work with SS, WB, and UNCW to closely monitor water quality in the impaired waters to determine if plan is having its intended water quality benefits.

Action 6-3: Conduct an annual and five year assessment on the success of the Plan, taking into account the amount of stormwater volume reduction achieved, the cost of measures installed, and any trends in water quality impairments observed.

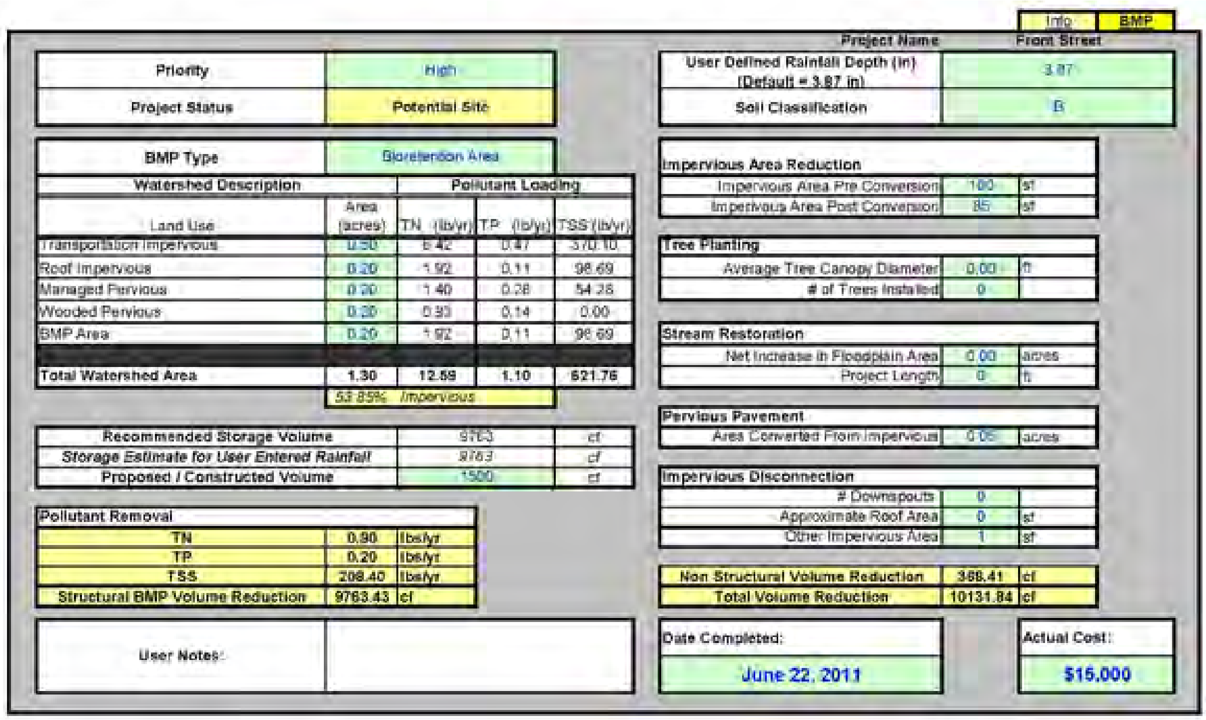
Discussion of Approach to Achieving Objective

This plan will continue to be a work in progress for years to come. It will need to be refined and adapted as the City gains more experience in how to achieve its stormwater reduction goals. The water quality impairments being addressed by the Plan took decades to develop, and it will require decades to improve. The key interim indicators of plan success include: (1) no increase in the acreage of shellfish harvest closures in target watersheds; (2) more frequent opportunities to temporarily open waters for shellfish harvest as a result of improving water quality; and (3) less need for swimming advisories. This will be measured through the shellfish sanitation and recreational swimming management efforts conducted by SS as well as continued water quality monitoring conducted by the City.

Withers & Ravenel has developed a suite of watershed management tools to track the plan's progress towards meeting the incremental indicators of success outlined by the plan. The online GIS BMP atlas is rooted in a geospatially referenced catalog of individual BMP locations. This online atlas allows the city to document water quality characteristics of individual retrofits within each watershed and then compare the cumulative impact of those BMPs against the incremental volume reduction objectives established by the land use and hydrograph analysis.

Users can also track costs, perform cost benefit analyses, and perform custom searches based on BMP characteristics or location. Once entered into the system, each retrofit site is stored as a point on the map, allowing the City to quickly view BMPs, completed or proposed, in any area of the City. The tool also provides opportunities to stress through existing outreach efforts the critical importance of reducing the amount of stormwater being generated by existing land uses, and how citizens can assist in accomplishing such reductions on just about any property they manage.

The process begins with the City entering data on individual BMP retrofit sites within the target watersheds. Complete BMP design data is sorted and basic pollutant removal data is completed using the equations established during development of the Tar Pamlico nutrient management strategy. This produces an estimated reduction in Nitrogen, Phosphorous, and TSS for each BMP site. For structural BMPs, the volume reductions are calculated by the user. For common structural BMPs (infiltration basins, wetlands, wet ponds, rain gardens, cisterns, etc) any water quality volume stored and infiltrated or detained for at least 2 days is credited as runoff volume removed from the hydrograph (Figure 20).



Info BMP

Project Name: Front Street

Priority	High
Project Status	Potential Site
BMP Type	Bioretention Area

Watershed Description		Pollutant Loading		
Land Use	Area (acres)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Transportation Impervious	0.50	6.42	0.47	370.10
Roof Impervious	0.20	1.92	0.11	98.69
Managed Pervious	0.20	1.40	0.28	54.28
Wooded Pervious	0.20	0.93	0.14	0.00
BMP Area	0.20	1.92	0.11	98.69
Total Watershed Area	1.30	12.59	1.10	621.76
	53.85% Impervious			

Recommended Storage Volume	9763	cf
Storage Estimate for User Entered Rainfall	*9763*	cf
Proposed / Constructed Volume	1500	cf

Pollutant Removal		
TN	0.90	lbs/yr
TP	0.20	lbs/yr
TSS	208.40	lbs/yr
Structural BMP Volume Reduction	9763.43	cf

User Notes:

User Defined Rainfall Depth (in) (Default = 3.87 in)	3.87
Soil Classification	B

Impervious Area Reduction		
Impervious Area Pre Conversion	100	sf
Impervious Area Post Conversion	85	sf
Tree Planting		
Average Tree Canopy Diameter	0.00	ft
# of Trees Installed	0	
Stream Restoration		
Net Increase in Floodplain Area	0.00	acres
Project Length	0	ft
Pervious Pavement		
Area Converted From Impervious	0.05	acres
Impervious Disconnection		
# Downspouts	0	
Approximate Roof Area	0	sf
Other Impervious Area	1	sf
Non Structural Volume Reduction	368.41	cf
Total Volume Reduction	10131.84	cf

Date Completed: June 22, 2011

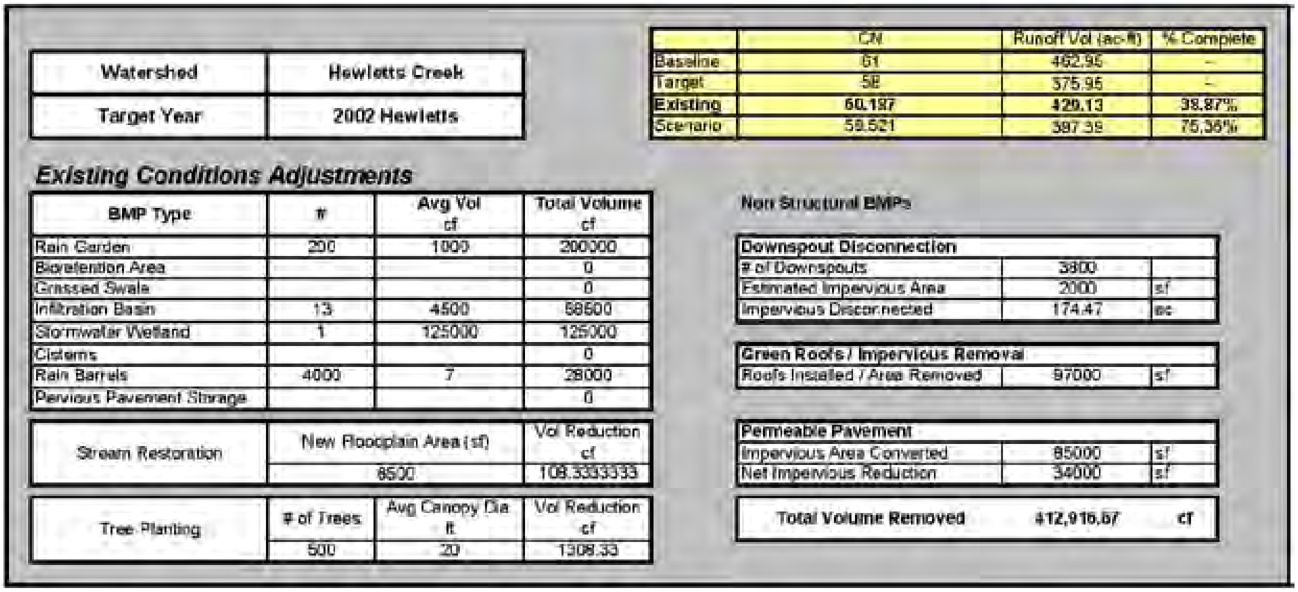
Actual Cost: $15,000

Figure 20. Data sheet in on-line GIS BMP Atlas.

For vegetation based BMPs such as stream restoration, or tree planting, the volume reduction is quantified based on a combination of estimated canopy interception and vegetation uptake potential of the total planted area. For each of these BMPs tree canopies were estimated to intercept and capture 0.1" of rainfall. Stream restoration doubles that credit to 0.2" of rainfall interception due to the additional storage and infiltration available within the newly created floodplain areas. The impact of pervious pavement is analyzed based on a change in curve number, and the process is very similar to the methods described in the current BMP manual. If additional storage volume is included in the subsurface gravel base, then it should be input in the structural BMP fields as well. For disconnected impervious surfaces, the volume reduction is not computed until the next step in the analysis process – analysis of the cumulative effect of all the BMPs within the watershed.

In most cases, the data for multiple BMPs in one project can be input as one BMP on the map. The calculators are programmed to analyze the cumulative impact of a few BMPs per site, however if multiple structural BMPs are used, multiple sites will need to be entered to correctly compute the net pollutant removal benefits provided.

With numerous individual volume reduction projects cataloged into the BMP atlas, the next step is to quantify the cumulative impact of multiple BMPs on the entire watershed. Using a pre-defined script within the software, the plan administrators can quickly define a selection set of BMPs to include in the analysis. Typically this will include determining the watershed for which the report is needed, and also deciding whether to include only the BMPs which have been completed, or to also include the BMPs which are in the planning stages. Once the selection set is determined, the script will pull data from each individual BMP and quantify the total column reduction. Data is sorted by BMP type. This is called the "Existing Conditions" report (Figure 21).



Watershed	Hewletts Creek
Target Year	2002 Hewletts

	CN	Runoff Vol (ac-ft)	% Complete
Baseline	61	462.95	-
Target	58	375.95	-
Existing	60.197	429.13	38.87%
Scenario	59.521	397.39	75.36%

Existing Conditions Adjustments

BMP Type	#	Avg Vol cf	Total Volume cf
Rain Garden	200	1000	200000
Bioretention Area			0
Grassed Swale			0
Infiltration Basin	13	4500	58500
Stormwater Wetland	1	125000	125000
Cisterns			0
Rain Barrels	4000	7	28000
Pervious Pavement Storage			0

Stream Restoration	New Floodplain Area (sf)	Vol Reduction cf
	6500	108.3333333

Tree Planting	# of Trees	Avg Canopy Dia ft	Vol Reduction cf
	500	20	1308.33

Non Structural BMPs

Downspout Disconnection		
# of Downspouts	3800	
Estimated Impervious Area	2000	sf
Impervious Disconnected	174.47	ac

Green Roofs / Impervious Removal		
Roofs Installed / Area Removed	97000	sf

Permeable Pavement		
Impervious Area Converted	85000	sf
Net Impervious Reduction	34000	sf

Total Volume Removed	412,916.67	cf

Figure 21. Data sheet in on-line GIS BMP Atlas to quantify the cumulative impact of multiple BMPs on volume reduction.

Analysis of the data is completed by the program using calculation methods described in "Urban Hydrology for Small Watersheds" (TR-55). In summary, the program calculates the cumulative volume reduction achieved by the individual BMPs then adds that to the volume adjustment attributable to any additional disconnected impervious area. This tab is intended to quantify the impact of completed projects on the results from the 2010 land use study. The sum total is then removed from the 2010 runoff volume previously computed. The net volume is then compared to any one of the pre-determined hydrograph goals. The results are reported in the top right corner of the screen. Data from the baseline (2010 data) and the target condition are listed, and the impact of the selected BMPs is shown on the line labeled "Existing."

The line labeled "Scenario" operates in the same way as the Existing Condition report, except that the user can enter data not shown on the map. The intent of this is to quickly quantify the impact of proposed long-range plans. These plans may not be at the stage where individual projects have been identified or added to the map yet. Instead, they are more general in nature and may reflect outreach initiatives with unknown results. The data from the scenario tab is added to the net impact of the "Existing Conditions" results to report a cumulative impact of completed projects in addition to the long term watershed restoration plans.

Factors such as population growth, changes in regulations and ordinances, and the success or failure of management actions can influence the relevance and effectiveness of this plan. It is important to evaluate and adapt management objectives and actions based upon

observed results. The on-line GIS BMP Atlas provides a measuring tool to keep track of how much stormwater volume is reduced for each watershed. It will require continual updating to be a useful tool. On-going water quality monitoring of the impaired waters is also essential to determine if shellfish harvest and swimming can be restored.
Retrofit measures installed will be tracked using the Excel based tracking and planning tool that is part of the GIS Atlas. City administrators will be able to evaluate anticipated watershed management efforts and immediately view their potential impact on each watershed. Additionally, as improvements are completed and management plans are acted on, City administrators can enter that data into a watershed plan database and chart progress towards the target conditions.

In general, the evaluation tool is based on current LID calculation methods as used in LID-EZ. Using simple calculations, the infiltration volume or detention volume for standard BMPs can be entered into the spreadsheet. That volume will then be subtracted from the 2010 runoff volume, and a net reduction in runoff volume can be calculated. Non-traditional BMPs such as disconnection of impervious area and tree planting programs will also be easily quantified. The City can enter the amount of impervious area that has been disconnected from the drainage system (allowing for a portion of the runoff volume to infiltrate into the surrounding soils) and a new Curve Number can be calculated using standard SCS methods as described in TR-20 and TR-55.

Five recently installed stormwater reduction measures at Alderman and Bradley Creek Elementary Schools (both of which are in the Hewletts Creek Watershed) provide examples of the data that will be tallied in the on-line GIS BMP Atlas. The total amount of stormwater reduction can be calculated for each retrofit measure installed. Here is an example of data that will be entered into the GIS Atlas for these five measures. The total reduction in stormwater volume from a one-year, 24-hour storm was calculated to be 63,959 gallons. See Table 10 for details.

Device Installed	Drainage Area Treated (sf)	Impervious Area Treated (sf)	Size of Device (sf)	Storage Volume for 1-Year, 24-Hour Storm (gallons)
Bioretention #1	15,850	9,850	2,500	9,351
Bioretention #2	8,700	6,400	1,600	8,977
Bioretention #3	2,175	261	1,800	10,099
Wetland #1	88,305	74,820	1,940	17,766
Wetland #2	26,535	10,440	1,940	17,766
Total Storage Volume:				63,959

Table 10. Alderman and Bradley Creek schools installed water quality stormwater reduction measures.

For tree cover, data will be gathered to quantify the amount of rainfall that can be captured by average size tree canopies taking into account the average loss of trees each year due to storms, disease, and etc. As trees are planted in the watershed and mature, the Atlas will allow for stormwater volume to be removed from the hydrograph, and a net runoff volume will be calculated.

In short, all techniques and practices employed by the City as part of this plan will be quantified, and at any point in time, the City can report progress towards the target conditions. The tool will also prove to be an effective reference guide for evaluating long term plans and establishing goals for annual watershed improvement plans.

As new techniques and designs are identified, they will be added to the stormwater reduction measures toolbox. Continued water quality monitoring of bacteria levels by UNCW and the State will provide evidence of how successful the plan has been in restoring water quality.

By working with SS and UNCW, the City and its partners will encourage increased water quality monitoring within the impaired SA and SB waters to determine if water quality improvements are being observed, and ultimately if shellfish harvest can be allowed and if the need for swimming advisories is reduced. These areas of impairment within the SA waters have not been intensively monitored, and without such analysis it will be impossible to determine if the plan has made progress or succeeded in cleaning up these waters, or if it needs to be changed because it is not yielding expected benefits.

This plan should be evaluated periodically (at least every five years) and adapted to reflect experiences gained in carrying out management actions, new technology and techniques, and the results of water quality monitoring.

SUMMARY OF OBJECTIVES AND ACTIONS

Objective	Action #	Specific Action	Timeline	Partners
1. Continue Existing Programs that Address Water Quality Impairments in Both Watersheds	Action 1-1	Implement and enforce existing stormwater requirements for new development and redevelopment	On-going	City of Wilmington – Stormwater Services, Engineering, Development Services; NC DWQ, WB
	Action 1-2	Continue to promote LID designs	On-going	City of Wilmington – Stormwater Services, Engineering, Development Services; NC DWQ, WB
	Action 1-3	Continue to cooperate with CCAP	On-going	City of Wilmington – Engineering, Development Services; NCCF, WB, New Hanover Soil & Water
	Action 1-4	Maintain existing educational programs	On-going	City of Wilmington - Stormwater Services; NCCF, New Hanover Soil & Water, WB
	Action 1-5	Reflect plan in other City plans and NPDES annual permit report	As plans are updated	City of Wilmington – Stormwater Services, Engineering, Development Services: WB, NCCF
	Action 1-6	Continue education and code enforcement programs that reduce and eliminate sources of bacteria and pathogens related to human and pet waste	On-going	City of Wilmington – Stormwater Services; WB

Objective	Action #	Specific Action	Timeline	Partners
2. Determine Appropriate Water Quality Classifications and Designated Uses Where Water Quality Impairment Exists	Action 2-1	Work with SS, UNCW, WB and NCCF to conduct preliminary evaluations of water quality to determine where more intensive state (SS) water quality investigations are needed	Year 1, establish preliminary monitoring	City of Wilmington – Stormwater Services; UNCW, SS, WB, NCCF
	Action 2-2	Work with SS to establish new monitoring stations within impaired waters influenced by the Bradley Creek watershed	Year 2 based upon preliminary monitoring	City of Wilmington – Stormwater Services; UNCW, SS, WB, NCCF
	Action 2-3	Work with SS to establish new monitoring stations within impaired waters influenced by the Hewletts Creek Watershed	Year 2 based upon preliminary monitoring	City of Wilmington – Stormwater Services; UNCW, SS, WB, NCCF
	Action 2-4	Evaluate the results of bacterial source monitoring in Banks Channel that is being conducted by UNC-CH	Study underway, evaluate results in Year 1	WB, UNC-CH, UNCW, NCCF
	Action 2-5	Request Use Attainability Study on SA waters along Wrightsville Beach shoreline in Banks Channel. These waters are automatically closed to Shellfish Harvest due to marinas, and have been polluted since 1947.	Year 2	WB, NCCF, NC DWQ
	Action 2-6	Request Use Attainability Study on SB waters now "Approved" for	Year 2	City of Wilmington, WB, NCCF, NC DWQ

		shellfish harvest in waters influenced by the Bradley Creek Watershed		
	Action 2-7	Determine if there is potential to restore shellfish harvest in any additional waters classified as SB that are influenced by the Bradley Creek Watershed	Years 4-5	City of Wilmington – Stormwater Services; UNCW, SS, WB, NCCF
	Action 2-8	Evaluate the status and trends in bacterial contamination within the entire Hewletts Creek watershed based upon more intensive data collected as part of plan implementation	Year 5	City of Wilmington – Stormwater Services; UNCW, SS, NC DWQ, NCCF

Objective	Action #	Specific Action	Timeline	Partners
3. Track the reduction of the transport of bacteria from land to water	Action 3-1	Secure and budget funds for retrofits in the Bradley Creek watershed, deter-mine volume that can be reduced with funds, and track actual reductions using measurement tools	Secure funds years 1 & 2, design retrofits year 3, install and track reductions years 4 & 5	City of Wilmington – Stormwater Services; UNCW, SS, NC DWQ, NCCF
	Action 3-2	Secure and budget funds for retrofits in the Hewletts Creek watershed, deter-mine volume that can be reduced with funds, and track actual reductions using measurement tools	Secure funds years 1 & 2, design retrofits year 3, install and track reductions years 4 & 5	City of Wilmington – Stormwater Services; UNCW, SS, NC DWQ, NCCF

Objective	Action #	Specific Action	Timeline	Partners
4. Promote/ Focus Stormwater Reduction Efforts	Action 4-1	Promote use of GIS web based retrofit Atlas	Each year	City of Wilmington – Stormwater Services, Engineering, Development Services; WB, NCCF
	Action 4-2	Investigate cost effective methods of working with landowners to disconnect impervious surfaces	Year 1 & 2	NCCF, City of Wilmington, WB
	Action 4-3	Promote LID retrofits within private development	Each year	City of Wilmington – Stormwater Services, Engineering, Development Services; WB, NCCF. Use existing educational programs to promote retrofits for volume reduction
	Action 4-4	Promote tree planting and retention	Each year	Wilmington Tree Commission; City of Wilmington - Development Services, Stormwater Services; Keep New Hanover Beautiful, NCCF, Cooperative Extension, WB
	Action 4-5	Promote stormwater reduction measures on City streets in future capital improvement projects	Dependent on Capital Improveme nt schedule	City of Wilmington - Stormwater Services, Engineering, Streets Divisions, Development Services; WB, NCCF
	Action 4-6	Pursue strategy with NCDOT to incorporate retrofits into highway upgrades	Years 1 – 5	City of Wilmington - Development Services, Stormwater Services; NCDOT, NCCF, WB
	Action 4-7	Promote LID retrofits in future publicly funded maintenance or redevelopment of City owned buildings, parks, parking lots, and drainage systems	Based upon project schedules	City of Wilmington – Engineering, Stormwater Services, Community Services, Development Services; WB, NCCF
	Action 4-8	Promote and assist with LID retrofits at	Ongoing based upon	NCCF, New Hanover County School System,

		county schools	efforts at schools	CCAP
	Action 4-9	Encourage UNC-W to develop campus wide master plan to retrofit to reduce stormwater volume	Year 3	City of Wilmington - Stormwater Services, Development Services; UNCW, NCCF
	Action 4-10	Evaluate properties for retrofit or restoration potential.	Year 2	City of Wilmington - Stormwater Services, Development Services; WB
	Action 4-11	Evaluate existing stormwater ponds on public and private properties for potential volume reductions enhancements, and if feasible, retrofit them to achieve volume reductions	Years 3 - 5	Evaluation potential retrofits, funds to retrofit will come through annual budgeting or from outside grant sources. City of Wilmington - Stormwater Services; WB, NCCF

Objective	Action #	Specific Action	Timeline	Partners
5. Form and Maintain Partnerships	Action 5-1	Work with partners to educate stakeholders	Years 1 – 5	City of Wilmington - Stormwater Services, Development Services; NCCF, New Hanover Soil & Water, WB
	Action 5-2	Work with government agencies and NGOs to secure grants for retrofits and other programs	Years 1 – 5	City of Wilmington – Stormwater Services; Development Services; NCCF, WB, Cape Fear Public Utilities
	Action 5-3	Provide strategies and policies for city departments to carry out plan by incorporating runoff reduction strategies into the CIP process.	Years 1 – 5	City of Wilmington - Stormwater Services; Development Services, and Finance Depts.; NCCF
	Action 5-4	Promote use of atlas among key City departments in their routine business	Years 1 – 5	City of Wilmington - Stormwater Services, Development Services; NCCF, WB

	Action 5-5	Promote existing technical training opportunities to advance plan	Years 1 – 5	Special training arranged by partners using their own funds and grants, City of Wilmington - Stormwater Services, Development Services; WB, NCCF
	Action 5-6	Work with UNCW on retrofit projects	Years 1 – 5	grants, capital improvements City of Wilmington - Stormwater Services; UNCW, NCCF

Objective	Action #	Specific Action	Timeline	Partners
6. Evaluate Success and Modify Plan Based Upon Results	Action 6-1	Use atlas accounting system to track progress toward watershed goals.	Years 1 – 5	City of Wilmington - Stormwater Services, Development Services; NCCF, WB
	Action 6-2	Work with SS, WB, and UNCW to monitor water quality status and trends	Years 1 – 5	City of Wilmington - Stormwater Services, Development Services; NCCF, WB, UNCW
	Action 6-3	Conduct annual and five year assessment of plan's success and modify plan as needed	Yearly	City of Wilmington - Stormwater Services, Development Services; NCCF, WB, UNCW

Table 11. Summary of objectives and actions.

USE OF PLAN

This plan will serve as the City's watershed restoration blueprint for Bradley and Hewletts Creeks. As written, this plan intends to accomplish the following:

1. Document and explain the causes of water quality impairments in these two watersheds, and why reducing the volume of stormwater is key to removing those impairments.
2. Identify which management measures are successful in reducing the amount of stormwater transported to surface waters base upon physical factors, institutional constraints, cost effectiveness, and other factors that influence their feasibility and efficacy.
3. Establish quantifiable benchmarks for how much stormwater volume must be reduced based upon hydrographs that have been developed using historic and current land use data.
4. Provide incremental mileposts for measuring the success of the plan, with periodic opportunities to adjust the implementation strategies based upon measured results.
5. Establish a mechanism of using historic and future water quality monitoring to determine compliance with water quality standards, and
6. Provide a GIS Atlas as an implementation tracking tool to quantify the effect on stormwater volume of each action that is implemented as a result of the plan and scenario analysis tool to assist with prioritizing projects and resource allocation.

The plan includes the nine key elements recommended by EPA as being integral to a watershed restoration plan (Table 12).

EPA's 9-Key Elements
1. An information/education component to enhance public understanding of the project.
2. A monitoring component to evaluate the effectiveness of the implementation efforts over time measured against the criteria (used to determine whether loading reductions are achieved).
3. An identification of the causes (stressors) and sources or groups that need to be controlled to achieve pollutant load reductions estimated in the watershed.
4. An estimate of the pollutant load reductions expected for the management measures.
5. A description of the Nonpoint Source pollution (NPS) management measures that will need to be implemented to achieve load reductions as well as to achieve other watershed goals identified in the watershed based plan.
6. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards.
7. An estimate of the amount of technical and financial assistance needed, associated costs and/or sources, and authorities that will be relied upon, to implement the plan.
8. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.
9. A description of interim, measureable milestones for determining whether NPS management measures or other control actions are being implemented.

Table 12. EPA's 9-key elements of a watershed restoration plan.

In addition, this plan addresses the six required elements that EPA requires to be included in a watershed restoration plan for it to serve in lieu of a TMDL. The City does not intend to have the plan used in this manner at this time since it will implement the plan voluntarily using its existing management framework and partners. If it should be required to prepare a TMDL sometime in the future for these watersheds, the belief is that EPA rules will allow this plan to be used as an alternative management measure to obviate the need for a TMDL. Specifically, surface waters do not have to be included on the Section 303(d) list if other pollution control requirements (e.g., best management practices) required by local, State, or Federal authority" are stringent enough to result in achieving applicable water quality standards within a reasonable period of time. A complete watershed restoration plan can provide the alternative management measures that exceed TMDL requirements (Table 13).

Six Elements for TMDL Exemption 1. Identification of segment and statement of problems causing the impairment. 2. Description of pollution controls and how they will achieve water quality standards. 3. An estimate or projection of the time when water quality standards will be met. 4. Schedule for implementing pollution controls. 5. Monitoring plan to track effectiveness of pollution controls. 6. Commitment to revise pollution controls, as necessary.

Table 13. Six required elements of a watershed restoration plan to serve in lieu of a TMDL.

APPENDIX A: DWQ WATER QUALITY CLASSIFICATIONS

Division of Water Quality Tidal Saltwater Classification System Primary Classifications[i]	
Class	**Best Uses**
SC	Saltwater Class C. Aquatic life propagation and maintenance of biological integrity (including fishing, fish, and functioning primary nursery areas (PNA's)), wildlife, secondary recreation (including recreational fishing, boating, and water related activities involving minimal skin contact), and any other usage except primary recreation or shellfishing for market purposes.
SB	Saltwater Class B. Primary recreation (including swimming on a frequent or organized basis) and any other usage specified for SC waters.
SA	Saltwater Class A. Shellfishing for market purposes and any other usage specified for SB or SC waters. All SA waters are also High Quality Waters (HQW).

Division of Water Quality Surface Freshwater Classification System Primary Classifications[ii]	
Class	**Best Uses**
C	Waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. There are no restrictions on watershed development of types of use.
B	Waters used for primary recreation and other uses suitable for Class C. There are no restrictions on development of types of discharges
WS-I	Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection for their water supplies. WS-I waters are within natural and undeveloped watersheds in public ownership with no point source discharges. All WS-I waters are HQW by definition.
WS-II	Waters used as sources of potable water supply where a WS-I classification is not feasible. WS-II waters are generally predominantly in undeveloped watersheds, and only general permits for discharges are allowed. All WS-II waters are also HQW.
WS-III	Waters used as sources of potable water supply where more protective WS-I and WS-II classifications are not feasible. WS-III waters are typically in low to moderately developed watershed; general discharge permits only are allowed near the water supply intake whereas domestic and non-process industrial discharges are allowed in the rest of the water supply watershed.
WS-IV	Water used as sources of potable water supply where a WS-I, WS-II, or WS-III classification is not feasible. WS-IV waters are generally in moderately to highly developed watersheds or Protected Areas, and involve no categorical restrictions on discharge.
WS-V	Water protected as water supplies which are generally upstream and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used for water supply. Unlike other WS classifications, WS-V has no categorical restrictions on watershed development or wastewater discharges, and local governments are not required to adopt watershed protection ordinances.

Division of Water Quality Supplemental Classifications[iii]	
Class	**Best Uses**
HQW	High Quality Waters. Waters which are rated excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, native and special native trout waters (and tributaries) designated by the Wildlife Resources Commission, primary nursery areas (PNA's) designated by the Marine Fisheries Commission, and other functional nursery areas designed by the Marine Fisheries Commission.
NSW	Nutrient Sensitive Waters. Waters that experience or are subject to excessive growths of microscopic or macroscopic vegetation. Excessive growths are growths which the Commission determines impair the use of the water for its best usage as determined by the classification applied to such waters.
ORW	Outstanding Resource Waters. Unique and special surface waters of the state that are of exceptional state or national recreational or ecological significance that require special protection to maintain existing uses.
Sw	Swamp Waters. Water which are topographically located so as to generally have very low velocities and other characteristics different from adjacent streams draining to steeper topography.
Tr	Trout Waters. Waters which have conditions that shall sustain and allow for trout propagation and survival of stocked trout on a year-round basis.

Classifications of other Divisions[iv]	
Class	**Best Uses**
Division of Coastal Management (DCM)	
AEC	Estuarine Areas of Environmental Concern. Coastal water and land areas of significant economic and biological values to the state.
Division of Marine Fisheries (DMF)	
PNA	Primary Nursery Areas. Growing areas where populations of juvenile finfish and shellfish of economic importance occur. PNA's are also HQW.
Division of Environmental Health (SS)	
Approved	Suitable growing area for harvesting shellfish for direct marketing to the public.
Conditionally approved	Growing areas subject to predictable intermittent pollution but suitable for harvesting shellfish for marketing when Management Plan conditions are met.
Restricted	Growing area suitable for shellfish harvesting by permit only. Shellfish must be purified by approved process.
Prohibited	Area unsuitable for harvesting shellfish for direct marketing due to presence of high fecal coliform, point source discharge, or marine, or no current sanitary survey.

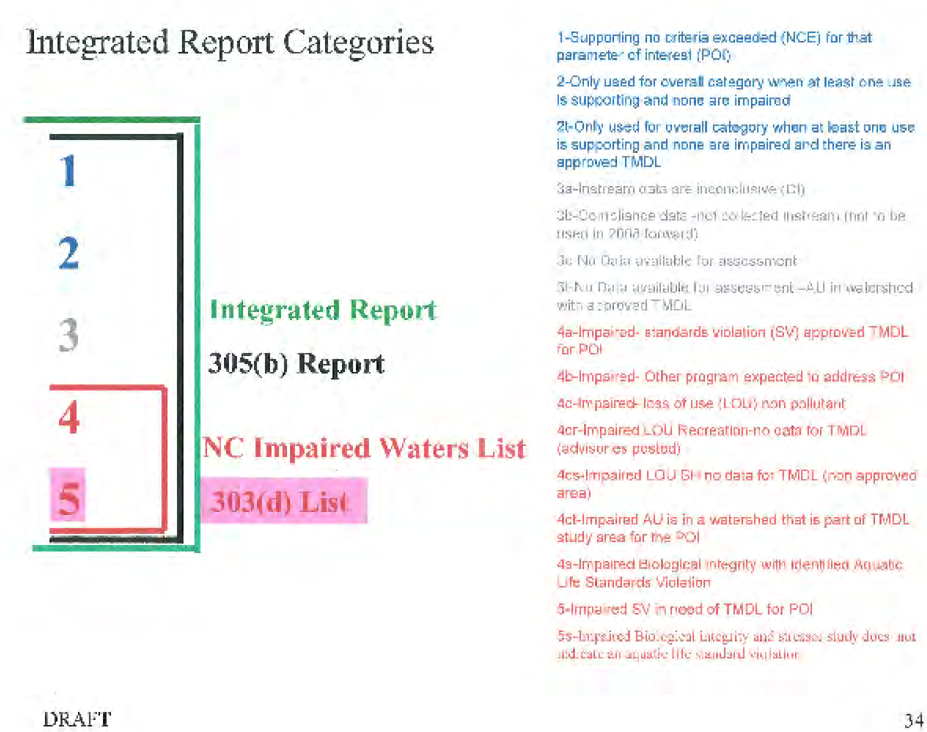
[i] North Carolina Department of Environment and Natural Resources, Division of Water Quality Water Quality Section-Planning Branch, *North Carolina Water Quality Assessment and Impaired Waters List February 2003 (02IRMT04Ff),* (Raleigh, NC, 2003) 10.

[ii] North Carolina Department of Environment and Natural Resources, Division of Water Quality, *A Guide to Surface Freshwater Classifications in North Carolina,* Water Quality Planning Branch, (Raleigh, NC, 2001).

[iii] North Carolina Department of Environment and Natural Resources, Division of Water Quality Water Quality Section-Planning Branch, *North Carolina Water Quality Assessment and Impaired Waters List February 2003 (02IRMT04Ff),* (Raleigh, NC, 2003) 10.

[iv] North Carolina Department of Environment and Natural Resources, Division of Water Quality, *A Guide to North Carolina's Tidal Saltwater Classifications,* (Raleigh, NC, 2001).

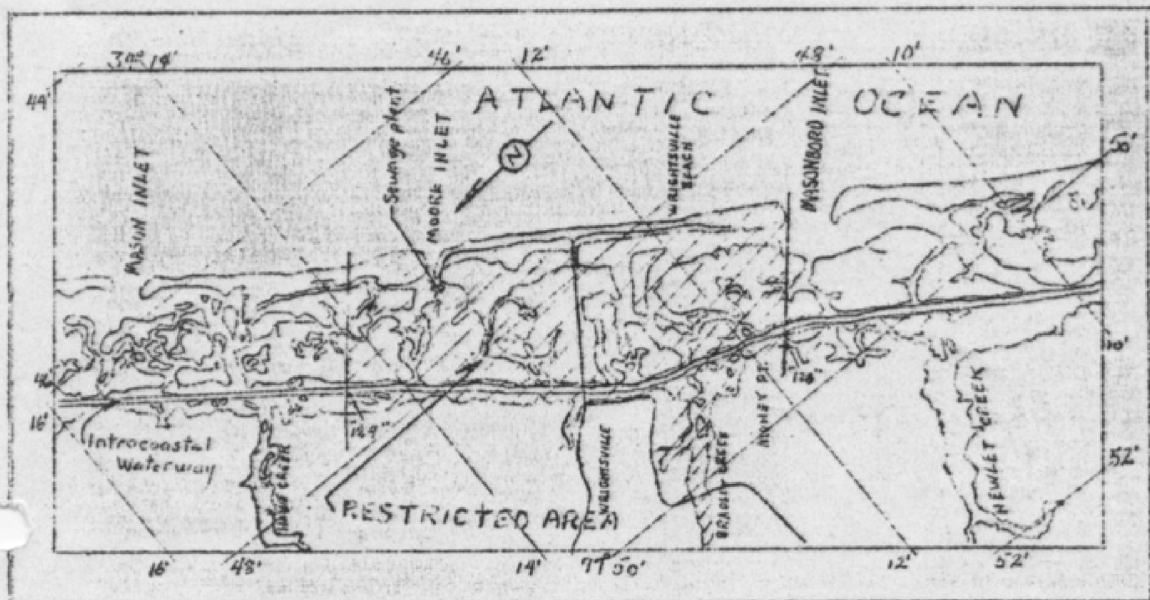
APPENDIX B: 303(d) LIST INTEGRATED REPORT CATEGORIES



APPENDIX C: HISTORY OF CLOSURES FOR BRADLEY CREEK

RESTRICTED SHELLFISH AREA

WRIGHTSVILLE AREA--- NEW HANOVER COUNTY



SHELLFISH RULE 107 :

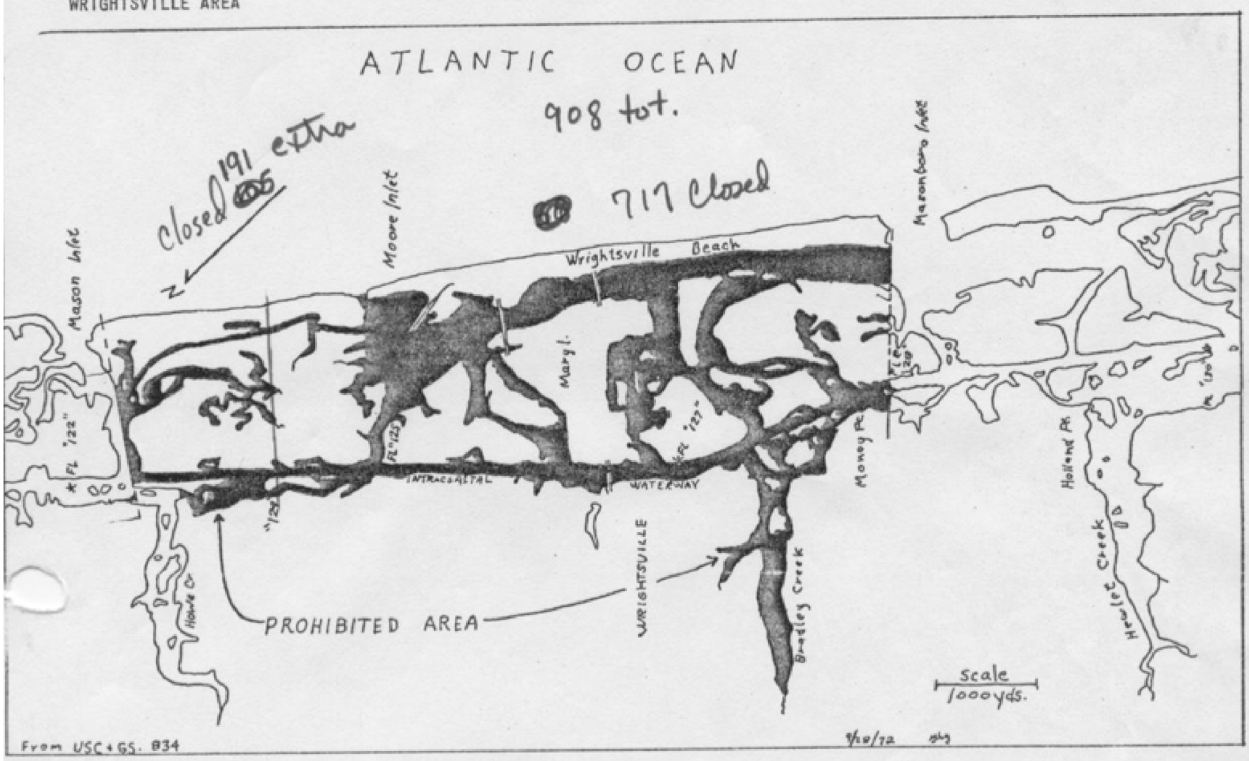
It shall be unlawful for any person, firm or corporation to take, catch, bed, lay out, or float any clams or oysters, or for any person, firm or corporation to sell, offer for sale, or to have in his or their possession any clams or oysters taken, caught, bedded, laid out or floated within the following territory: In any of the waters within a line beginning at the point of beach on the northeast shore of Masonboro Inlet extending in a northeasterly direction along the shore of the Atlantic Ocean to a point on the shore 1100 yards beyond the northeast shore of Moore Inlet; thence due northwest through Channel Marker #124 of the Intracoastal Waterway to a point on the mainland; thence in a southwesterly direction along the mainland to a point on Money Point; thence due southeast through the Intracoastal waterway Channel Marker #128 to the point of the beginning to include a slough known as Moore Creek, Stokeley Cut, Bowden Cut, Banks Channel, Wrightsville Cut, Shin Creek, Bradley Creek to its beginning, that portion of the Intracoastal waterway between Channel Markers #124 and #128, and all tidal creeks on the northwest side of the Intracoastal waterway between these markers.

(Passed at the meeting of the Board of Conservation and Development, Division of Commercial Fisheries at Atlantic Beach, North Carolina, August 28-29-30, 1947)

PROHIBITED AREA MAP

WRIGHTSVILLE AREA

NEW HANOVER COUNTY



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

I. Wrightsville Beach Area:

All of the waters, including the creeks, bays, and tributaries of the sound, including Bradley Creek, lying between an area bounded on the southwest by a line drawn from the southernmost point of the North Shore of Masonboro Inlet through Intracoastal Waterway Channel Marker FLR "128" to the mainland; and bounded on the northeast by a line beginning at a point by Mason Inlet, 34° 14' 43" N - 77° 46' 35" W, thence, to a point 34° 14' 56" N - 77° 47' 02" W, on the northwest side of Intracoastal Waterway and thence, to a point 34° 14' 51" N - 77° 47' 15" W, on the Southwest Shore of Howe Creek.

9/29/72

APPENDIX D: SS WATER QUALITY SAMPLING RESULTS FOR BRADLEY CREEK WATERSHED

	DATE	STATION	TIDE	SALINITY	FC	Log FC
1	1/25/2006	28A	3/4 EBB	32	110.0	2.041
2	3/28/2006	28A	2/3 EBB	35	2.0	0.301
3	4/24/2006	28A	2/3 EBB	35	7.8	0.892
4	5/23/2006	28A	2/3 EBB	35	1.7	0.230
5	7/20/2006	28A	Late EBB	36	7.8	0.892
6	8/2/2006	28A	3/4 EBB	35	7.8	0.892
7	4/23/2007	28A	1/3 FLD	36	1.7	0.230
8	5/21/2007	28A	1/2 FLD	36	4.5	0.653
9	7/5/2007	28A	1/2 FLD	38	1.7	0.230
10	8/27/2007	28A	1/4 EBB	37	4.5	0.653
11	10/17/2007	28A	1/2 FLD	38	2.0	0.301
12	2/5/2008	28A	3/4 ebb	35	2.0	0.301
13	3/27/2008	28A	1/4 flood	36	1.7	0.230
14	5/8/2008	28A	3/4 flood	36	2.0	0.301
15	07/14/2008	28A	1/4 ebb	36	6.8	0.833
16	09/03/2008	28A	hi slack	36	1.7	0.230
17	10/16/2008	28A	hi slack	35	2.0	0.301
18	02/02/2009	28A	1/2 flood	37	13.0	1.114
19	03/23/2009	28A	1/2 ebb	34	2.0	0.301
20	04/28/2009	28A	1/2 fld	37	1.7	0.230
21	07/20/2009	28A	1/2 ebb	36	13.0	1.114
22	08/11/2009	28A	3/4 FLD	36	2.0	0.301
23	09/16/2009	28A	1/12 EBB	36	2.0	0.301
24	02/22/2010	28A	1/4 fld	35	1.7	0.230
25	03/23/2010	28A	early fld	33	2.0	0.301
26	05/10/2010	28A	1/2 flood	35	1.8	0.255
27	06/08/2010	28A	Late EBB	33	4.5	0.653
28	07/20/2010	28A	low slack	35	6.8	0.833
29	08/31/2010	28A	1/4 flood	36	2.0	0.301
30	01/04/2011	28A	1/2 Ebb	36	1.7	0.230

Log Avg:	0.52264608
Log SD:	0.411228793
# > 43:	1
# > 260:	0
Median:	2
Geomean:	3.331548039
Est 90th:	11

	DATE	STATION	TIDE	SALINITY	FC	Log FC
1	1/25/2006	33	3/4 EBB	30	**23.0**	1.362
2	3/28/2006	33	2/3 EBB	35	1.7	0.230
3	4/24/2006	33	2/3 EBB	35	**33.0**	1.519
4	5/23/2006	33	2/3 EBB	35	1.7	0.230
5	7/20/2006	33	Late EBB	35	13.0	1.114
6	8/2/2006	33	3/4 EBB	35	1.7	0.230
7	4/23/2007	33	1/3 FLD	36	2.0	0.301
8	5/21/2007	33	1/2 FLD	36	1.7	0.230
9	7/5/2007	33	1/2 FLD	36	1.7	0.230
10	8/27/2007	33	1/4 EBB	36	4.0	0.602
11	10/17/2007	33	1/2 FLD	38	2.0	0.301
12	2/5/2008	33	3/4 ebb	34	7.8	0.892
13	3/27/2008	33	1/4 flood	35	1.7	0.230
14	5/8/2008	33	3/4 flood	36	1.7	0.230
15	07/14/2008	33	1/4 ebb	36	4.5	0.653
16	09/03/2008	33	hi slack	36	1.7	0.230
17	10/16/2008	33	hi slack	37	2.0	0.301
18	02/02/2009	33	1/2 flood	36	1.7	0.230
19	03/23/2009	33	1/2 ebb	35	1.7	0.230
20	04/28/2009	33	1/2 fld	36	2.0	0.301
21	07/20/2009	33	1/2 ebb	35	7.8	0.892
22	08/11/2009	33	3/4 FLD	37	2.0	0.301
23	09/16/2009	33	1/12 EBB	35	2.0	0.301
24	02/22/2010	33	1/4 fld	31	1.8	0.255
25	03/23/2010	33	early fld	31	2.0	0.301
26	05/10/2010	33	1/2 flood	35	2.0	0.301
27	06/08/2010	33	Late EBB	33	7.8	0.892
28	07/20/2010	33	low slack	35	4.5	0.653
29	08/31/2010	33	1/4 flood	36	**130.0**	2.114
30	01/04/2011	33	1/2 Ebb	36	2.0	0.301

Log Avg:	0.5320643
Log SD:	0.469489502
# > 43:	1
# > 260:	0
Median:	2
Geomean:	3.404585927
Est 90th:	13

	DATE	STATION	TIDE	SALINITY	FC	Log FC
1	1/25/2006	35	3/4 EBB	30	14.0	1.146
2	3/28/2006	35	2/3 EBB	36	1.7	0.230
3	4/24/2006	35	2/3 EBB	35	4.5	0.653
4	5/23/2006	35	2/3 EBB	35	4.0	0.602
5	7/20/2006	35	Late EBB	35	4.5	0.653
6	8/2/2006	35	3/4 EBB	35	1.7	0.230
7	4/23/2007	35	1/3 FLD	36	1.8	0.255
8	5/21/2007	35	1/2 FLD	36	2.0	0.301
9	7/5/2007	35	1/2 FLD	38	1.7	0.230
10	8/27/2007	35	1/4 EBB	37	2.0	0.301
11	10/17/2007	35	1/2 FLD	38	1.7	0.230
12	2/5/2008	35	3/4 ebb	35	1.8	0.255
13	3/27/2008	35	1/4 flood	35	4.5	0.653
14	5/8/2008	35	3/4 flood	36	1.8	0.255
15	07/14/2008	35	1/4 ebb	36	1.7	0.230
16	09/03/2008	35	hi slack	37	2.0	0.301
17	10/16/2008	35	hi slack	38	2.0	0.301
18	02/02/2009	35	1/2 flood	36	4.5	0.653
19	03/23/2009	35	1/2 ebb	35	1.7	0.230
20	04/28/2009	35	1/2 fld	36	2.0	0.301
21	07/20/2009	35	1/2 ebb	36	7.8	0.892
22	08/11/2009	35	3/4 FLD	36	1.7	0.230
23	09/16/2009	35	1/12 EBB	35	4.5	0.653
24	02/22/2010	35	1/4 fld	34	2.0	0.301
25	03/23/2010	35	early fld	32	7.8	0.892
26	05/10/2010	35	1/2 flood	35	7.8	0.892
27	06/08/2010	35	Late EBB	34	2.0	0.301
28	07/20/2010	35	low slack	34	2.0	0.301
29	08/31/2010	35	1/4 flood	36	4.5	0.653
30	01/04/2011	35	1/2 Ebb	37	4.5	0.653

Log Avg:	0.459471979
Log SD:	0.263212694
# > 43:	0
# > 260:	0
Median:	2
Geomean:	2.880527188
Est 90th:	6

	DATE	STATION	TIDE	SALINITY	FC	Log FC
1	3/28/2006	46A	2/3 EBB	35	4.5	0.653
2	4/24/2006	46A	2/3 EBB	35	**22.0**	1.342
3	5/23/2006	46A	2/3 EBB	35	**110.0**	2.041
4	7/20/2006	46A	Late EBB	35	13.0	1.114
5	8/2/2006	46A	3/4 EBB	35	11.0	1.041
6	4/23/2007	46A	1/3 FLD	36	4.0	0.602
7	5/21/2007	46A	1/2 FLD	36	11.0	1.041
8	7/5/2007	46A	1/2 FLD	38	11.0	1.041
9	8/27/2007	46A	1/4 EBB	36	**110.0**	2.041
10	10/17/2007	46A	1/2 FLD	38	4.0	0.602
11	2/5/2008	46A	3/4 ebb	34	**49.0**	1.690
12	3/27/2008	46A	1/4 flood	32	4.0	0.602
13	5/8/2008	46A	3/4 flood	35	**17.0**	1.230
14	07/14/2008	46A	1/4 ebb	35	**23.0**	1.362
15	09/03/2008	46A	hi slack	36	1.7	0.230
16	10/16/2008	46A	hi slack	36	7.8	0.892
17	02/02/2009	46A	1/2 flood	32	11.0	1.041
18	03/23/2009	46A	1/2 ebb	34	**79.0**	1.898
19	04/28/2009	46A	1/2 fld	35	7.8	0.892
20	07/20/2009	46A	1/2 ebb	36	**49.0**	1.690
21	08/11/2009	46A	3/4 FLD	35	7.8	0.892
22	09/16/2009	46A	1/12 EBB	36	2.0	0.301
23	02/22/2010	46A	1/4 fld	31	13.0	1.114
24	03/23/2010	46A	early fld	29	4.5	0.653
25	05/10/2010	46A	1/2 flood	35	**23.0**	1.362
26	06/08/2010	46A	Late EBB	32	**49.0**	1.690
27	07/20/2010	46A	low slack	32	4.0	0.602
28	08/31/2010	46A	1/4 flood	35	6.8	0.833
29	01/04/2011	46A	1/2 Ebb	36	2.0	0.301
30						

Log Avg:	-
Log SD:	-
# > 43:	6
# > 260:	0
Median:	11
Geomean:	11.53338972
Est 90th:	-

	DATE	STATION	TIDE	SALINITY	FC	Log FC
1	1/25/2006	60	3/4 EBB	31	13.0	1.114
2	3/28/2006	60	2/3 EBB	35	1.7	0.230
3	4/24/2006	60	2/3 EBB	35	7.8	0.892
4	5/23/2006	60	2/3 EBB	36	**23.0**	1.362
5	7/20/2006	60	Late EBB	35	2.0	0.301
6	8/2/2006	60	3/4 EBB	35	**17.0**	1.230
7	4/23/2007	60	1/3 FLD	36	2.0	0.301
8	5/21/2007	60	1/2 FLD	36	1.8	0.255
9	7/5/2007	60	1/2 FLD	40	4.0	0.602
10	8/27/2007	60	1/4 EBB	36	1.7	0.230
11	10/17/2007	60	1/2 FLD	38	6.8	0.833
12	2/5/2008	60	3/4 ebb	34	4.5	0.653
13	3/27/2008	60	1/4 flood	34	1.7	0.230
14	5/8/2008	60	3/4 flood	35	7.8	0.892
15	07/14/2008	60	1/4 ebb	36	6.8	0.833
16	09/03/2008	60	hi slack	38	1.7	0.230
17	10/16/2008	60	hi slack	36	1.7	0.230
18	02/02/2009	60	1/2 flood	35	2.0	0.301
19	03/23/2009	60	1/2 ebb	34	1.7	0.230
20	04/28/2009	60	1/2 fld	35	2.0	0.301
21	07/20/2009	60	1/2 ebb	36	**21.0**	1.322
22	08/11/2009	60	3/4 FLD	36	2.0	0.301
23	09/16/2009	60	1/12 EBB	35	11.0	1.041
24	02/22/2010	60	1/4 fld	26	2.0	0.301
25	03/23/2010	60	early fld	32	12.0	1.079
26	05/10/2010	60	1/2 flood	35	13.0	1.114
27	06/08/2010	60	Late EBB	32	**49.0**	1.690
28	07/20/2010	60	low slack	36	7.8	0.892
29	08/31/2010	60	1/4 flood	36	2.0	0.301
30	01/04/2011	60	1/2 Ebb	36	2.0	0.301

Log Avg:	0.65319443
Log SD:	0.438487823
# > 43:	1
# > 260:	0
Median:	3
Geomean:	4.499812628
Est 90th:	16

APPENDIX E: SS LIST OF WASTEWATER LIFT STATIONS IN BRADLEY CREEK WATERSHED

SGA Index	Marina Name	Total Slips	Comments
58	Channel Walk	42	-
59	Cordgrass Bay	29	-
60	Lookout Harbour	36	-
61	Turtle Harbor	43	-
62	Oak Landing	16	-
63	West Port	16	-
64	Shandy Point Boat Basin	60	-
65	Greenville Sound Gardens	23	Meets Exemption Criteria
66	Shinn Point	64	Ramp
67	Landfall Marina	10	No Closure
68	Creekside Yacht Club	23	Includes 387 Dry Slips, Pumpout, and Fuel Service
69	Bradley Creek Marina	213	Includes Drystack and Pumpout
70	Bradley Oaks Condominiums Dockage	16	-
71	Airlie West	11	-
72	Spring Creek Community Dockage	10	-
73	Edgewater Marina	36	-
74	Gray Gables Yacht Club	21	-
75	Overbecks Marina	19	-
76	Wrightsville Yacht Club	106	Includes Transient Dockage, Pumpout, and Fuel Service
77	Marine Max	52	Includes Drystack, Pumpout, Haulout, and Repair Service
78	Motts Channel Seafood	28	-
79	Atlantic Marine	30	Includes Drystack and Fuel Service
80	Sea Path Marina	207	1470 Feet Linear Dockage; Transient, Pumpout, and Fuel Service
81	The Moorings	20	-
82	Lees Cut Marina	52	-
83	Sunset Harbor	12	-
84	Wynn Plaza Municipal Dockage	6	Includes Transient Dockage
85	Carolina Yacht Club	26	Ramp
86	Summerrest Marina	18	-
87	Oyster Point Dockage	46	1140 Feet Linear Dockage
88	Masons Bluff Marina	10	No Closure
89	Register Place Dockage	26	Meets Exemption Criteria
90	Anchors Bend Marina	46	-
91	Middle Sound Marina	33	Includes Pumpout
92	Davis Marina	13	-
93	Oak Winds Private Dockage	24	-
94	Mason Landing Yacht Club	40	Includes Pumpout and Ramp
95	Canadys Marina	86	Includes Fuel Service
96	Masons Marina	43	Ramp
97	Figure Eight Harbor	25	Ramp
98	Avenel Marina	28	Meets Exemption Criteria
99	Figure Eight Island Yacht Club	95	-
299	Dockside Marina	30	Includes Fuel Service
300	Sea Gate Office Park	7	-
301	Crockers Landing	31	-
302	Airlie Marina and Yacht Club	55	Includes Pumpout
303	Airlie Seafood Company	22	-
304	Bridge Tender Marina	65	Includes Transient Dockage, Pumpout, and Fuel Service
305	Alpha Mortgage Marina	11	-
451	Eagle Point Marina	10	No Closure

APPENDIX F: SS LIST OF MARINAS IN BRADLEY CREEK WATERSHED

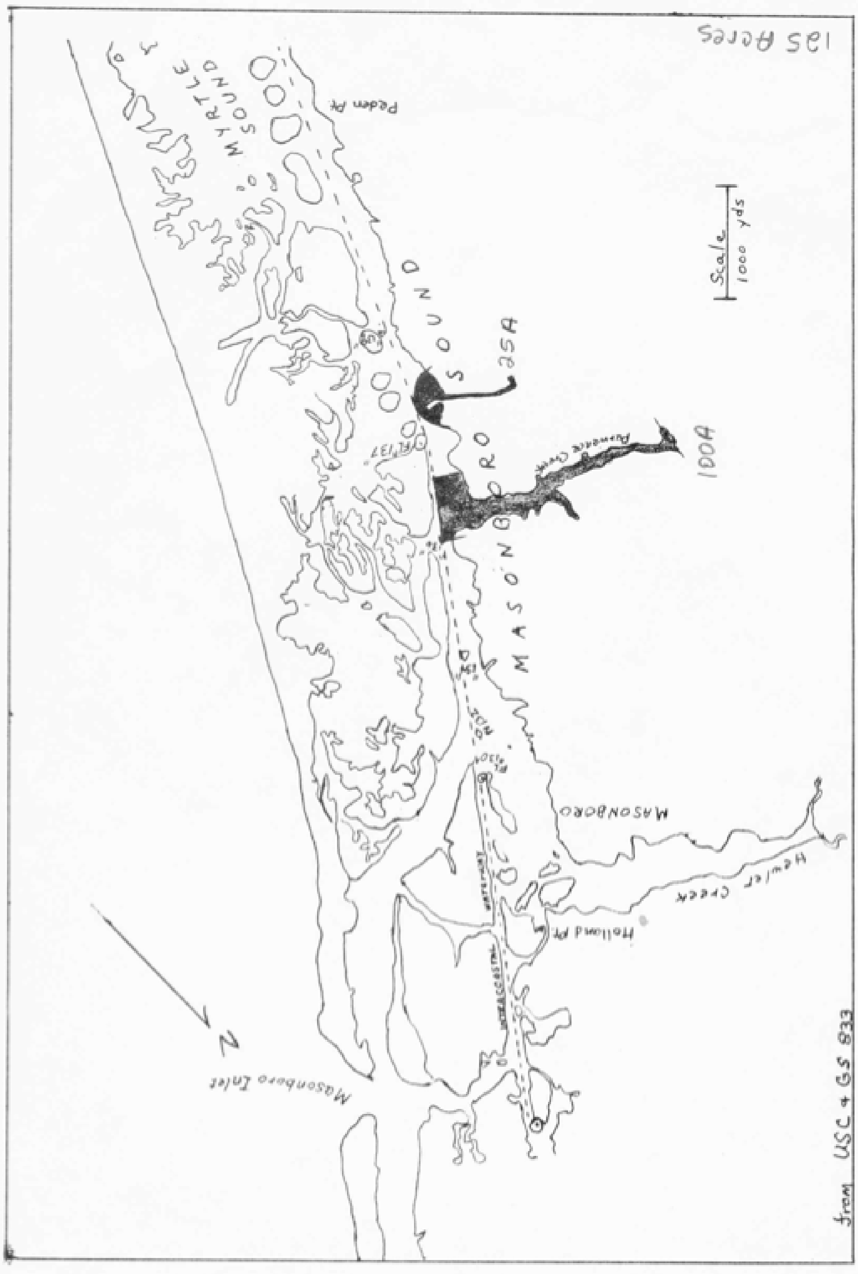
SGA Index	Marina Name	Total Slips	Comments
58	Channel Walk	42	-
59	Cordgrass Bay	29	-
60	Lookout Harbour	36	-
61	Turtle Harbor	43	-
62	Oak Landing	16	-
63	West Port	16	-
64	Shandy Point Boat Basin	60	-
65	Greenville Sound Gardens	23	Meets Exemption Criteria
66	Shinn Point	64	Ramp
67	Landfall Marina	10	No Closure
68	Creekside Yacht Club	23	Includes 387 Dry Slips, Pumpout, and Fuel Service
69	Bradley Creek Marina	213	Includes Drystack and Pumpout
70	Bradley Oaks Condominiums Dockage	16	-
71	Airlie West	11	-
72	Spring Creek Community Dockage	10	-
73	Edgewater Marina	36	-
74	Gray Gables Yacht Club	21	-
75	Overbecks Marina	19	-
76	Wrightsville Yacht Club	106	Includes Transient Dockage, Pumpout, and Fuel Service
77	Marine Max	52	Includes Drystack, Pumpout, Haulout, and Repair Service
78	Motts Channel Seafood	28	-
79	Atlantic Marine	30	Includes Drystack and Fuel Service
80	Sea Path Marina	207	1470 Feet Linear Dockage; Transient, Pumpout, and Fuel Service
81	The Moorings	20	-
82	Lees Cut Marina	52	-
83	Sunset Harbor	12	-
84	Wynn Plaza Municipal Dockage	6	Includes Transient Dockage
85	Carolina Yacht Club	26	Ramp
86	Summercrest Marina	18	-
87	Oyster Point Dockage	46	1140 Feet Linear Dockage
88	Masons Bluff Marina	10	No Closure
89	Register Place Dockage	26	Meets Exemption Criteria
90	Anchors Bend Marina	46	-
91	Middle Sound Marina	33	Includes Pumpout
92	Davis Marina	13	-
93	Oak Winds Private Dockage	24	-
94	Mason Landing Yacht Club	40	Includes Pumpout and Ramp
95	Canadys Marina	86	Includes Fuel Service
96	Masons Marina	43	Ramp
97	Figure Eight Harbor	25	Ramp
98	Avenel Marina	28	Meets Exemption Criteria
99	Figure Eight Island Yacht Club	95	-
299	Dockside Marina	30	Includes Fuel Service
300	Sea Gate Office Park	7	-
301	Crockers Landing	31	-
302	Airlie Marina and Yacht Club	55	Includes Pumpout
303	Airlie Seafood Company	22	-
304	Bridge Tender Marina	65	Includes Transient Dockage, Pumpout, and Fuel Service
305	Alpha Mortgage Marina	11	-
451	Eagle Point Marina	10	No Closure

APPENDIX G: HISTORY OF CLOSURES FOR HEWLETTS CREEK

PROHIBITED SHELLFISH TERRITORY

MASONBORO SOUND AREA

NEW HANOVER COUNTY



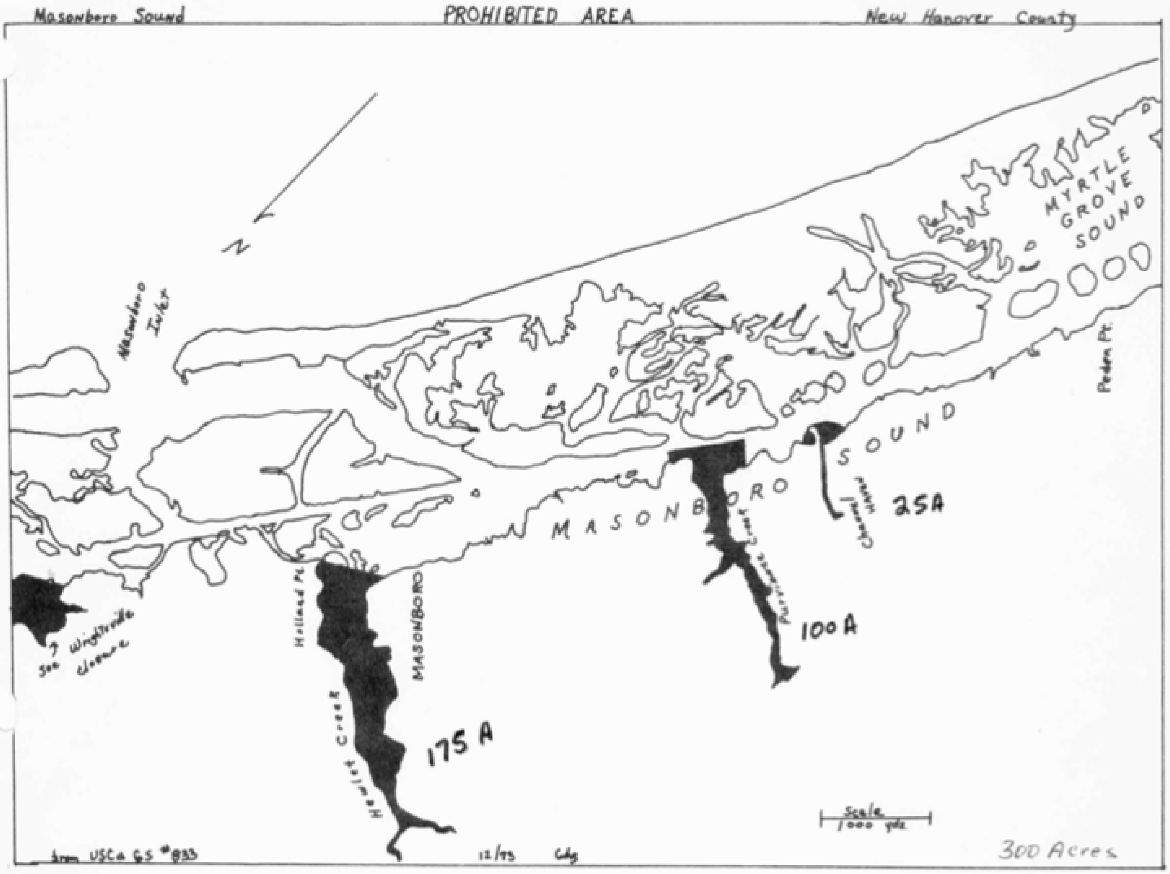
Masonboro Sound Area -- No person shall take or attempt to take, any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following polluted areas:

Beginning at a point on the shore (34° 9' 32" N - 77° 51' 10" W); thence 124° M 75 yards to Day Beacon #136 (34° 9' 30" N - 77° 51' 7" W); thence 214° M 650 yards to a point (34° 9' 14" N - 77° 51' 20" W); thence 300° M 240 yards to a point on the shore (34° 9' 17" N - 77° 51' 28" W); to include all of Purviance Creek and its tributaries.

Within two hundred (200) yards of Channel Haven Boat Marina.

10/27/71

B-6



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

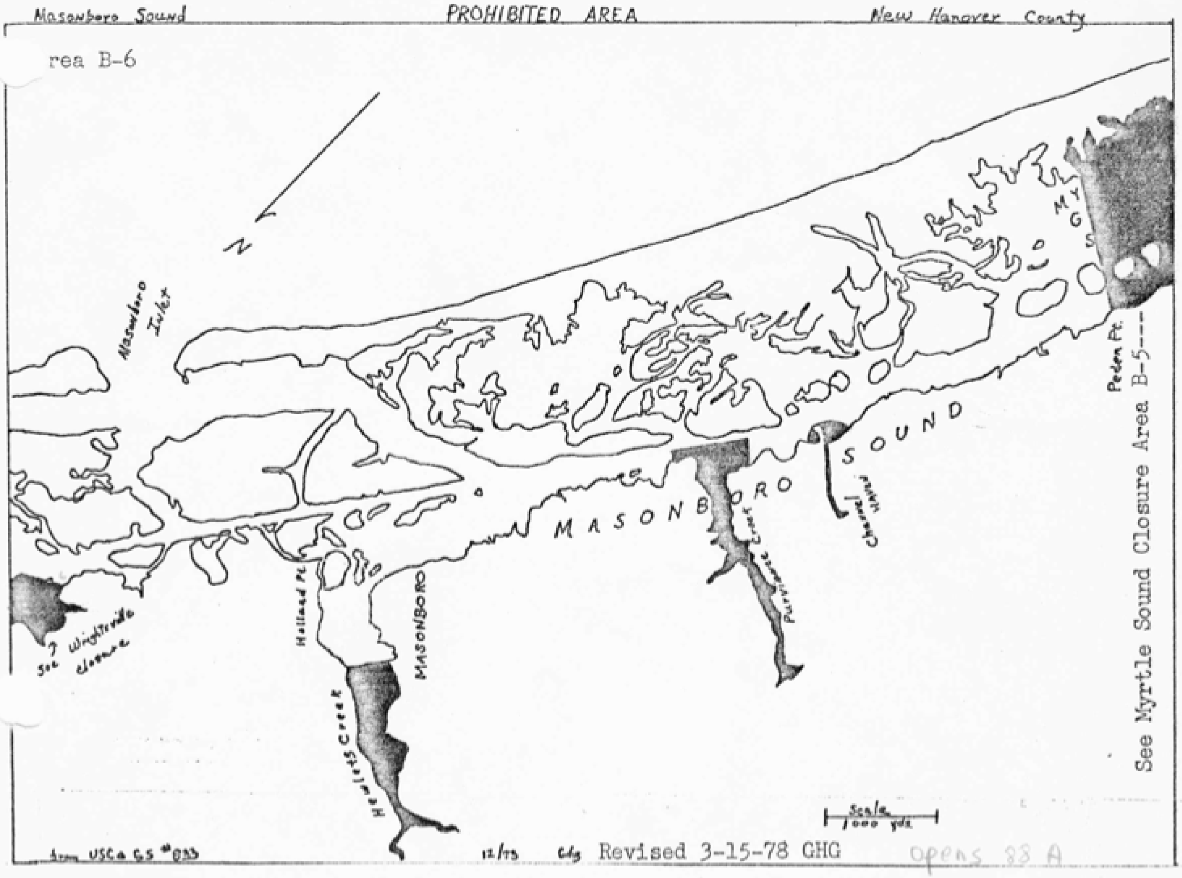
Hewlett Creek Area:

Upstream of a line beginning at a point on the west shore of Hewlett Creek at 34° 10' 52" N. - 77° 50' 35" W.; thence 61° M, to a point on Holland Point at 34° 11' 02" N. - 77° 50' 18" W.

Purviance Creek:

Beginning at a point on the shore 34° 09' 32" N. - 77° 51' 10" W.; thence 124° M, 75 yards to Day Beacon #136 34° 09' 30" N. - 77° 51' 07" W.; thence 214° M, 650 yards to a point 34° 09' 14" N. - 77° 51' 20" W.; thence 300° M, 240 yards to a point on the shore 34° 09' 17" N. - 77° 51' 28" W.; to include all of Purviance Creek and its tributaries.

Within two hundred (200) yards of Channel Haven Boat Marina.



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

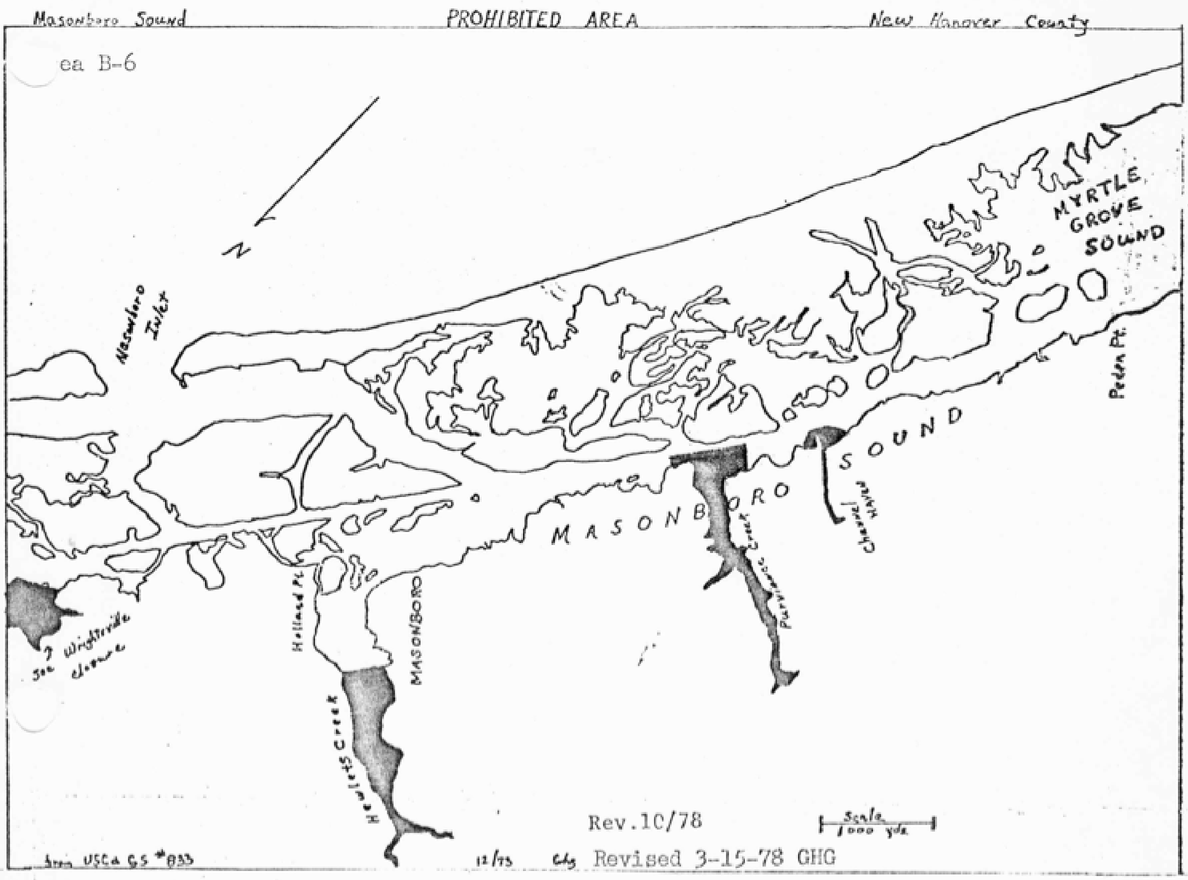
Hewletts Creek Area:

All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N - 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N - 77° 50' 56" W.

Purviance Creek:

Beginning at a point on the shore 34° 09' 32" N - 77° 51' 10" W; thence 124° M, 75 yards to Day Beacon #136 34° 09' 30" N - 77° 51' 07" W; thence 214° M, 650 yards to a point 34° 09' 14" N - 77° 51' 20" W; thence 300° M, 240 yards to a point on the shore 34° 09' 17" N - 77° 51' 28" W; to include all of Purviance Creek and its tributaries.

Within two hundred (200) yards of Channel Haven Boat Marina.



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

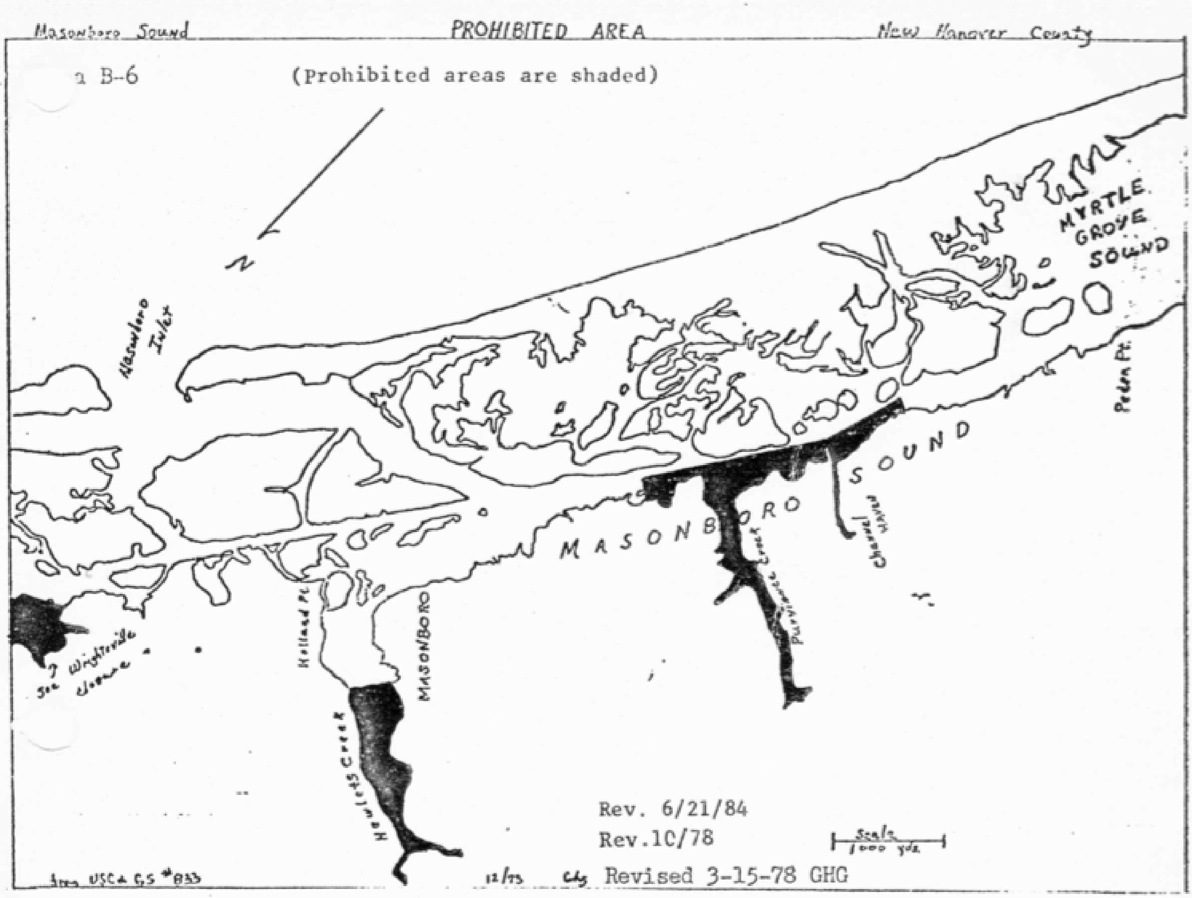
Hewletts Creek Area:

All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N - 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N - 77° 50' 56" W.

Purviance Creek:

Beginning at a point on the shore 34° 09' 32" N - 77° 51' 10" W; thence 124° M, 75 yards to Day Beacon #136 34° 09' 30" N - 77° 51' 07" W; thence 214° M, 650 yards to a point 34° 09' 14" N - 77° 51' 20" W; thence 300° M, 240 yards to a point on the ›re 34° 09' 17" N - 77° 51' 28" W; to include all of Purviance Creek and its ›ributaries.

Within two hundred (200) yards of Channel Haven Boat Marina.



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

Hewletts Creek Area:

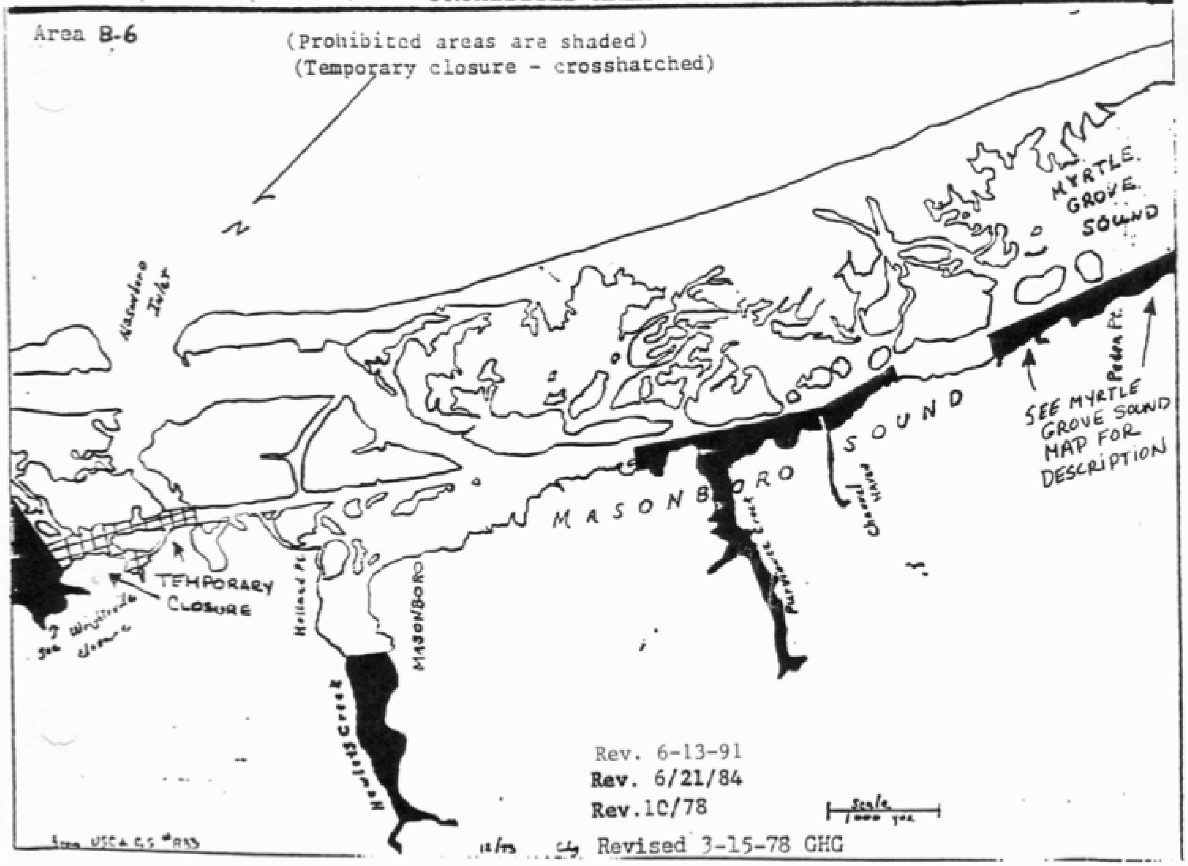
All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N - 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N - 77° 50' 56" W.

Purviance Creek: (Whiskey Creek)

Beginning at a point on the mainland at 34° 08' 36" N - 77° 51' 41" W, near ICWW Marker #139; thence in a straight line to ICWW Marker #139 at 34° 08' 35" N - 77° 51' 37" W; thence in a northeasterly direction following ...utheast side of ICWW Channel to a point approximately 350 yards northeast ... ICWW Marker #136 at 34° 09' 37" N - 77° 50' 59" W; thence in a straight line to mainland at 34° 09' 42" N - 77° 51' 05" W; thence southerly along mainland shoreline back to the point of beginning. This is to include Purviance (Whiskey) Creek, Channel Haven, and all other tributaries within said boundary.

MASONBORO SOUND **NEW HANOVER COUNTY**

(MAP 45) PROHIBITED AREA



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

Hewletts Creek Area:

All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N - 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N - 77° 50' 56" W.

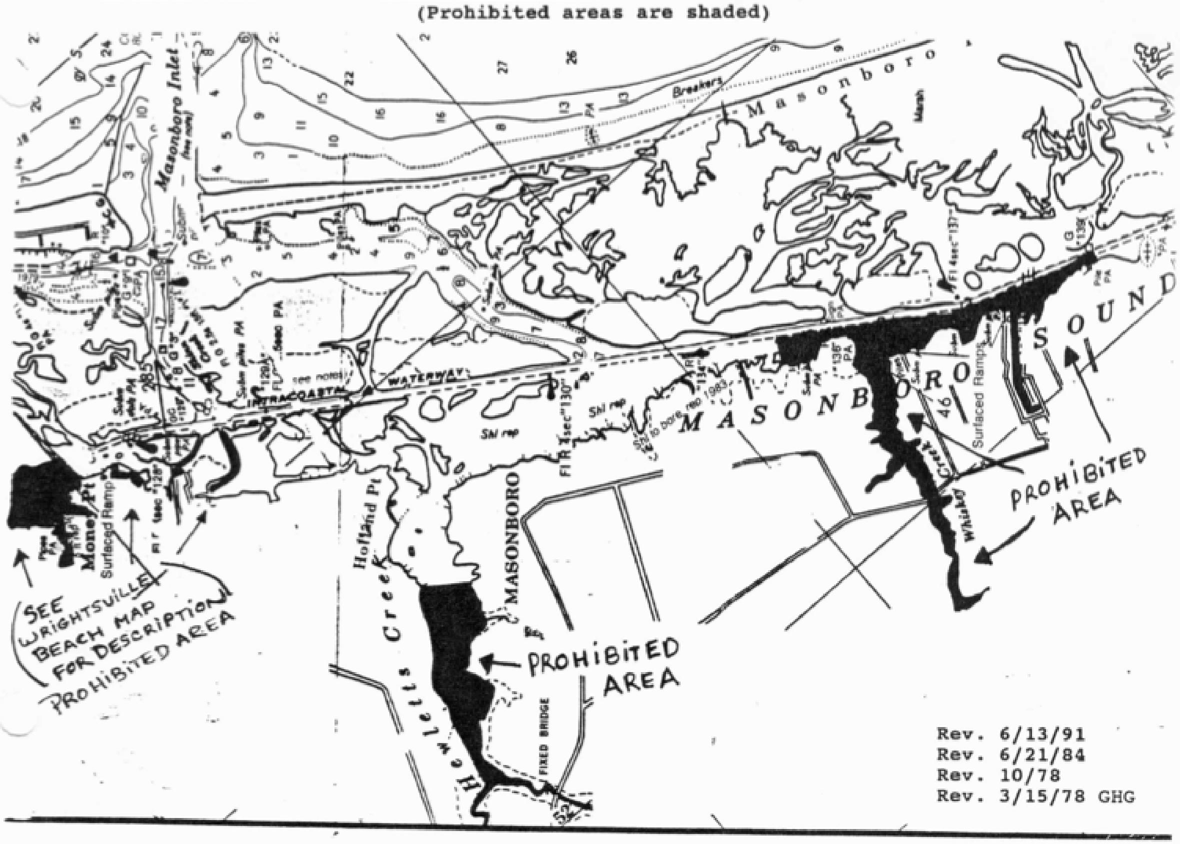
Purviance Creek: (Whiskey Creek)

Beginning at a point on the mainland at 34° 08' 36" N - 77° 51' 41" W, near ICWW Marker #139; thence in a straight line to ICWW Marker #139 at 34° 08' 35" N - 77° 51' 37" W; thence in a northeasterly direction following southeast side of ICWW Channel to a point approximately 350 yards northeast of ICWW Marker #136 at 34° 09' 37" N - 77° 50' 59" W; thence in a straight : to mainland at 34° 09' 42" N - 77° 51' 05" W; thence southerly along mainland shoreline back to the point of beginning. This is to include Purviance (Whiskey) Creek, Channel Haven, and all other tributaries within said boundary.

MASONBORO SOUND **NEW HANOVER COUNTY**

Area B-6 (Map 45) PROHIBITED AREA

(Prohibited areas are shaded)



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

Hewletts Creek Area:

All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N – 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N – 77° 50' 56" W.

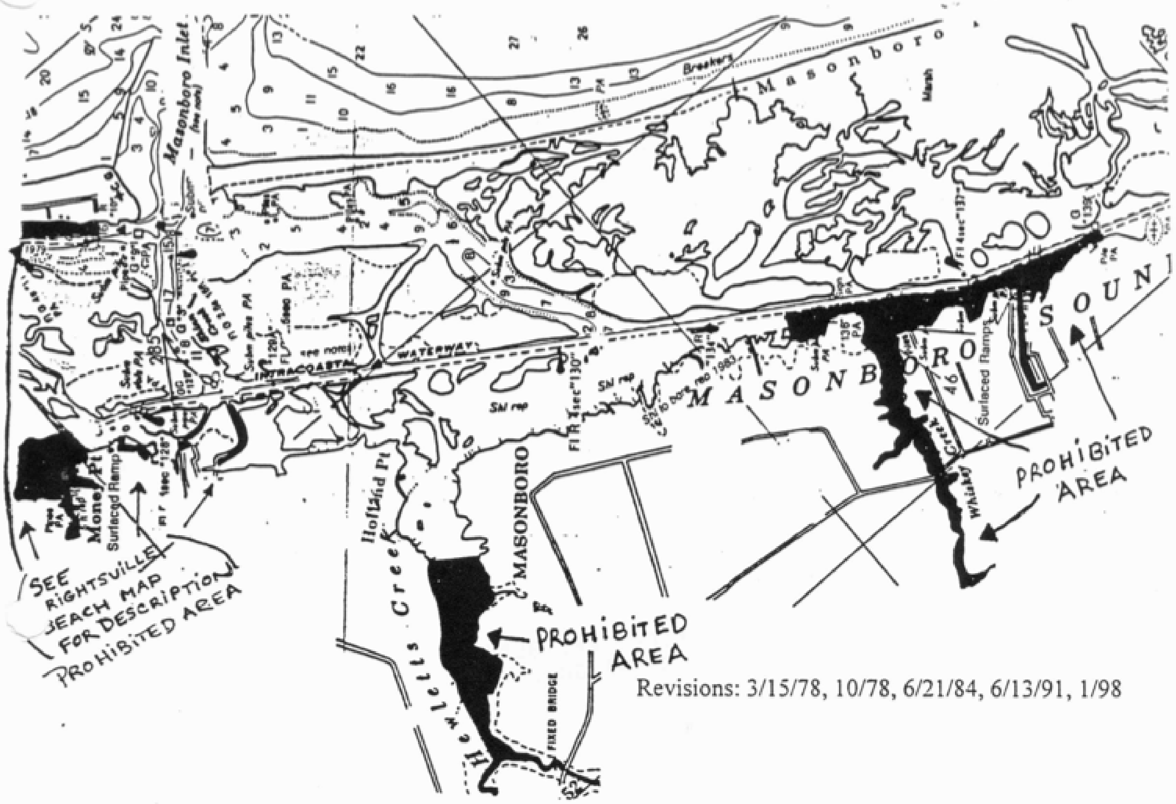
Purviance Creek (Whiskey Creek):

Beginning at a point on the mainland at 34° 08' 36" N – 77° 51' 41" W, near ICWW Marker #139; thence in a straight line to ICWW Marker #139 at 34° 08' 35" N – 77° 51' 37" W; thence in a northeasterly direction following southeast side of ICWW Channel to a point approximately 350 yards northeast of ICWW Marker #136 at 34° 09' 37" N – 77° 50' 59" W; thence in a straight line to mainland at 34° 09' 42" N – 77° 51' 05" W; thence southerly along mainland shoreline back to the point of beginning. This is to include Purviance (Whiskey) Creek, Channel Haven, and all other tributaries within said boundary.

PROHIBITED TERRITORY

MASONBORO & SOUND CREEKS — NEW HANOVER COUNTY

Area B-6 (Map 45) — (Prohibited areas are shaded)



Revisions: 3/15/78, 10/78, 6/21/84, 6/13/91, 1/98

No person shall take or attempt to take, any oysters, clams or mussels or possess, sell, or offer for sale any oysters, clams or mussels taken from the following areas, at any time:

(45) **MASONBORO SOUND**

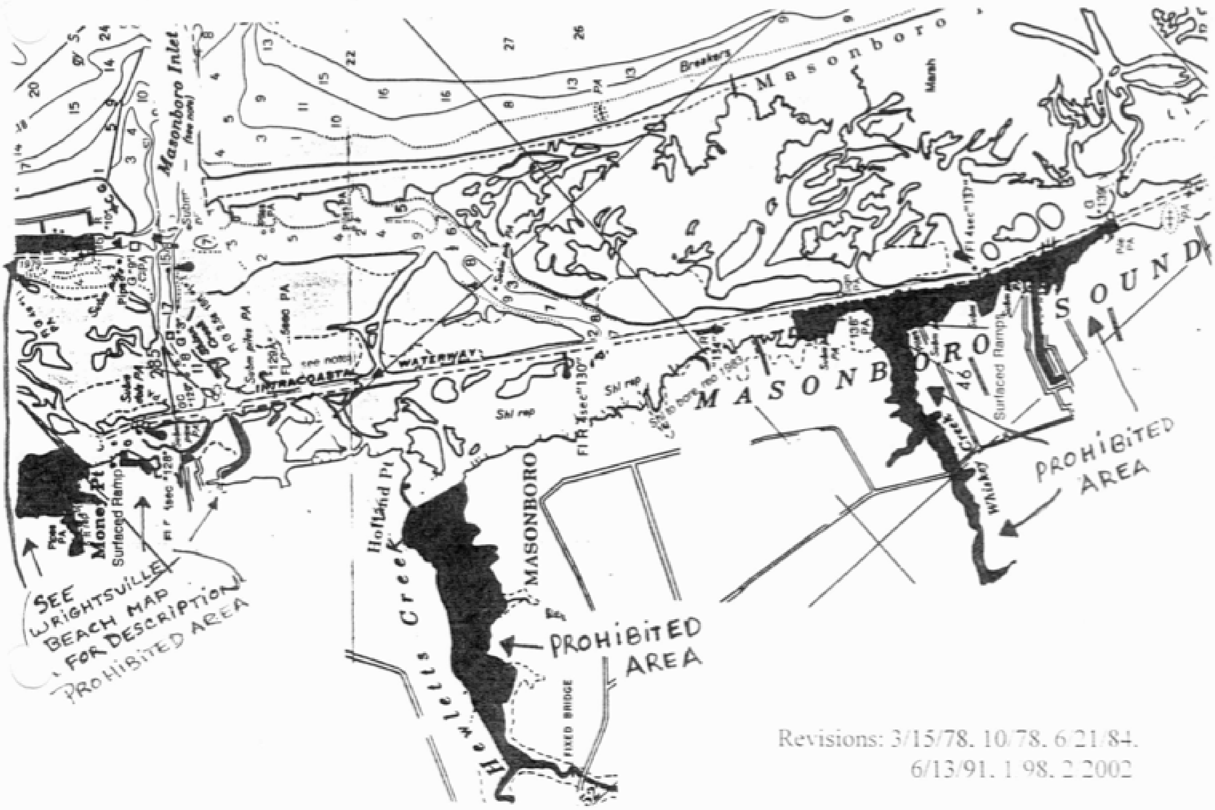
(a) **Hewletts Creek Area** - All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 18" N - 77° 50' 50" W; thence in a straight line to a point on the southwest shore at 34° 11' 07" N - 77° 50' 56" W.

(b) **Purviance Creek (Whiskey Creek)** - Beginning at a point on the mainland at 34° 08' 36" N - 77° 51' 41" W, near ICWW Marker #139; thence in a straight line to ICWW Marker #139 at 34° 08' 35" N - 77° 51' 37" W; thence in a northeasterly direction following southeast side of ICWW Channel to a point approximately 350 yards northeast of ICWW Marker #136 at 34° 09' 37" N - 77° 50' 59" W; thence in a straight line to mainland at 34° 09' 42" N - 77° 51' 05" W; thence southerly along mainland shoreline back to the point of beginning. This is to include Purviance (Whiskey) Creek, Channel Haven, and all other tributaries within said boundary.

PROHIBITED TERRITORY

MASONBORO & SOUND CREEKS NEW HANOVER COUNTY

Area B-6 (Map 45) (Prohibited areas are shaded)



Revisions: 3/15/78. 10/78. 6/21/84. 6/13/91. 1/98. 2/2002

No person shall take or attempt to take, any oysters, clams or mussels or possess, sell, or offer for sale any oysters, clams or mussels taken from the following areas, at any time:

(45) MASONBORO SOUND

(a) **Hewletts Creek Area** - All the waters upstream of a line beginning at a point on the northeast shore of Hewletts Creek at 34° 11' 12" N - 77° 50' 31" W; thence in a straight line to a point on the southwest shore at 34° 11' 00" N - 77° 50' 33" W.

(b) **Purviance Creek (Whiskey Creek)** - Beginning at a point on the mainland at 34° 08' 36" N - 77° 51' 41" W, near ICWW Marker #139; thence in a straight line to ICWW Marker #139 at 34° 08' 35" N - 77° 51' 37" W; thence in a northeasterly direction following southeast side of ICWW Channel to a point approximately 350 yards northeast of ICWW Marker #136 at 34° 09' 37" N - 77° 50' 59" W; thence in a straight line to mainland at 34° 09' 42" N - 77° 51' 05" W; thence southerly along mainland shoreline back to the point of beginning. This is to include Purviance (Whiskey) Creek, Channel Haven, and all other tributaries within said boundary.

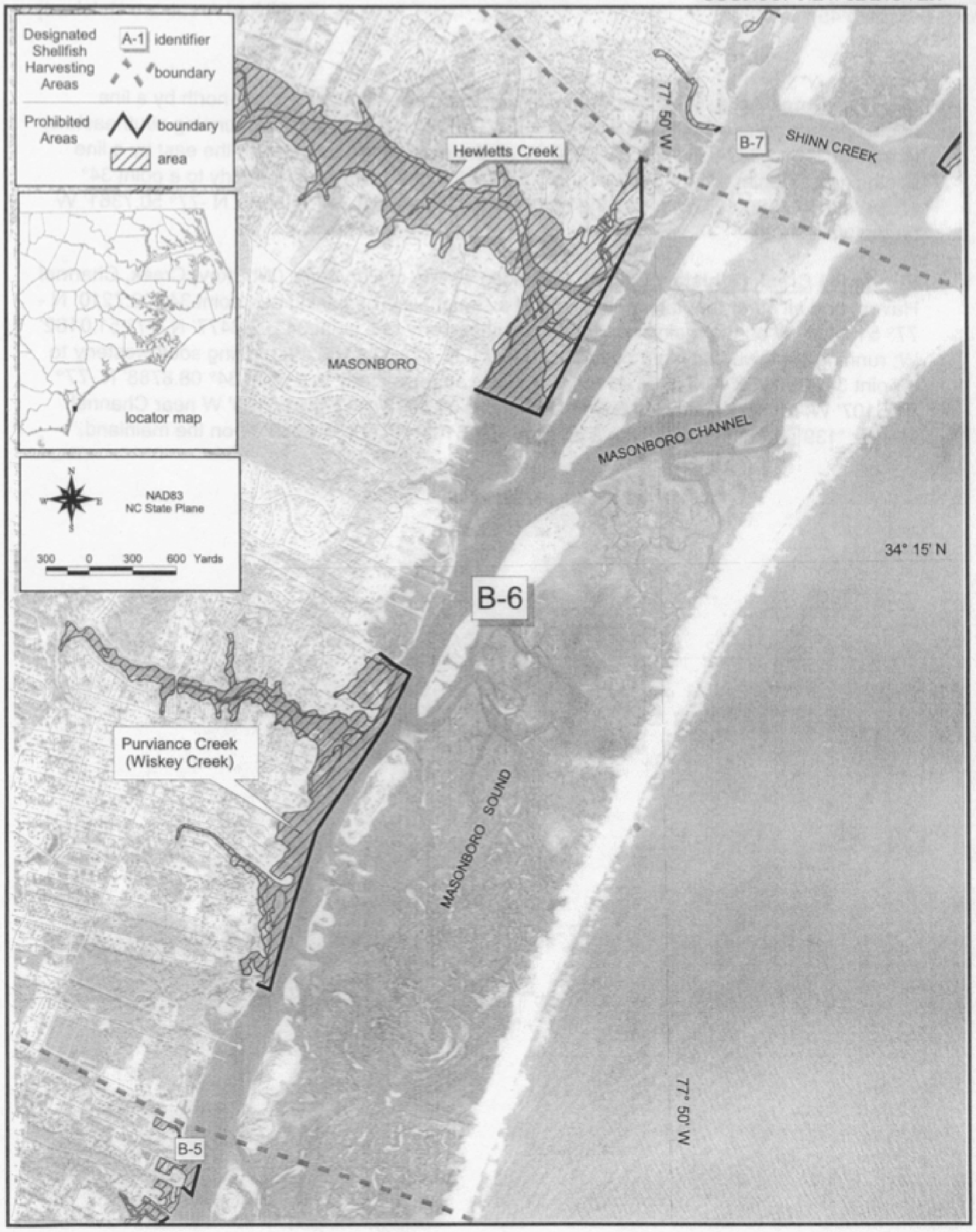
MASONBORO SOUND & CREEKS

Area B-6 (Map 45)

PROHIBITED TERRITORY

(Prohibited areas are hatched)

COUNTY: NEW HANOVER



Map 45

Rev. 12/06

Map 45

(SEE BACK OF MAP FOR AREA DESCRIPTIONS.)

MASONBORO SOUND & CREEKS

Area B-6 (Map 45)

PROHIBITED TERRITORY

(Prohibited areas are hatched)

COUNTY: NEW HANOVER

Map 45

Map 45

(SEE BACK OF MAP FOR AREA DESCRIPTIONS.)

Rev 12/06, 1/09

APPENDIX H: SS WATER QUALITY SAMPLING RESULTS FOR HEWLETTS CREEK WATERSHED

DATE	STAT.	NO.	TIDE	SALINITY	F/C	LOG F/C
1/28/2004	4		1/2 FLD	34	**49.0**	1.6902
2/16/2004	4		2/3 EBB	26	**110.0**	2.0414
3/31/2004	4		2/3 EBB	30	**79.0**	1.8976
6/24/2004	4		1/4 FLD	31	**70.0**	1.8451
10/18/2004	4		2/3 FLD	32	1.7	0.2304
11/10/2004	4		2/3 EBB	33	**79.0**	1.8976
1/4/2005	4		1/3 FLD	26	14.0	1.1461
2/8/2005	4		1/3 EBB	36	13.0	1.1139
3/7/2005	4		1/3 FLD	26	4.5	0.6532
4/19/2005	4		2/3 EBB	26	**49.0**	1.6902
6/7/2005	4		2/3 FLD	32	6.8	0.8325
8/8/2005	4		2/3 FLD	35	3.7	0.5682
1/5/2006	4		Late FLD	35	1.7	0.2304
4/3/2006	4		1/2 FLD	38	1.8	0.2553
4/26/2006	4		Early FLD	34	**240.0**	2.3802
5/30/2006	4		1/4 EBB	36	1.7	0.2304
7/12/2006	4		1/2 FLD	35	**23.0**	1.3617
8/9/2006	4		1/3 EBB	36	11.0	1.0414
1/24/2007	4		3/4 FLD	35	1.7	0.2304
3/5/2007	4		Early EBB	36	4.0	0.6021
4/2/2007	4		1/3 EBB	36	6.8	0.8325
7/18/2007	4		1/2 FLD	36	1.7	0.2304
8/20/2007	4		1/4 FLD	35	4.0	0.6021
9/17/2007	4		1/2 FLD	36	9.2	0.9638
1/23/2008	4		1/4 EBB	38	**27.0**	1.4314
2/14/2008	4		low slack	24	**220.0**	2.3424
4/29/2008	4		3/4 EBB	30	**110.0**	2.0414
06/26/2008	4		1/4 FLD	35	13.0	1.1139
08/14/2008	4		1/4 EBB	32	**79.0**	1.8976
10/2/2008	4		3/4 FLD	38	4.5	0.6532

Number	30
Log Avg:	1.134909
Log SD:	0.697209
# > 43:	10
# > 260:	0
Median:	12
Geomean:	13.64307
Est 90th:	106

DATE	STAT.	NO.	TIDE	SALINITY	F/C	LOG F/C
1/28/2004	5		1/2 FLD	34	**49.0**	1.6902
2/16/2004	5		2/3 EBB	32	11.0	1.0414
3/31/2004	5		2/3 EBB	32	**17.0**	1.2304
6/24/2004	5		1/4 FLD	32	2.0	0.3010
10/18/2004	5		2/3 FLD	32	1.7	0.2304
11/10/2004	5		2/3 EBB	34	1.8	0.2553
1/4/2005	5		1/3 FLD	28	1.7	0.2304
2/8/2005	5		1/3 EBB	36	**23.0**	1.3617
3/7/2005	5		1/3 FLD	29	1.7	0.2304
4/19/2005	5		2/3 EBB	29	**23.0**	1.3617
6/7/2005	5		2/3 FLD	32	1.7	0.2304
8/8/2005	5		2/3 FLD	35	1.7	0.2304
1/5/2006	5		Late FLD	35	4.5	0.6532
4/3/2006	5		1/2 FLD	37	2.0	0.3010
4/26/2006	5		Early FLD	35	2.0	0.3010
5/30/2006	5		1/4 EBB	36	1.7	0.2304
7/12/2006	5		1/2 FLD	35	4.5	0.6532
8/9/2006	5		1/3 EBB	36	7.8	0.8921
1/24/2007	5		3/4 FLD	35	6.8	0.8325
3/5/2007	5		Early EBB	36	1.7	0.2304
4/2/2007	5		1/3 EBB	36	4.5	0.6532
7/18/2007	5		1/2 FLD	38	1.7	0.2304
8/20/2007	5		1/4 FLD	35	4.0	0.6021
9/17/2007	5		1/2 FLD	36	7.8	0.8921
1/23/2008	5		1/4 EBB	38	1.7	0.2304
2/14/2008	5		low slack	32	**49.0**	1.6902
4/29/2008	5		3/4 EBB	30	13.0	1.1139
06/26/2008	5		1/4 FLD	35	1.7	0.2304
08/14/2008	5		1/4 EBB	34	**49.0**	1.6902
10/2/2008	5		3/4 FLD	38	1.7	0.2304

Number	30
Log Avg:	0.668381
Log SD:	0.510734
# > 43:	3
# > 260:	0
Median:	3
Geomean:	4.659981
Est 90th:	20

DATE	STAT.	NO.	TIDE	SALINITY	F/C	LOG F/C
1/28/2004	7		1/2 FLD	34	**17.0**	1.2304
2/16/2004	7		2/3 EBB	28	**17.0**	1.2304
3/31/2004	7		2/3 EBB	32	**540.0**	2.7324
6/24/2004	7		1/4 FLD	31	2.0	0.3010
10/18/2004	7		2/3 FLD	32	1.7	0.2304
11/10/2004	7		2/3 EBB	35	4.5	0.6532
1/4/2005	7		1/3 FLD	26	1.7	0.2304
2/8/2005	7		1/3 EBB	36	**23.0**	1.3617
3/7/2005	7		1/3 FLD	26	4.5	0.6532
4/19/2005	7		2/3 EBB	28	13.0	1.1139
6/7/2005	7		2/3 FLD	32	2.0	0.3010
8/8/2005	7		2/3 FLD	34	1.7	0.2304
1/5/2006	7		Late FLD	35	2.0	0.3010
4/3/2006	7		1/2 FLD	37	2.0	0.3010
4/26/2006	7		Early FLD	35	7.8	0.8921
5/30/2006	7		1/4 EBB	35	1.7	0.2304
7/12/2006	7		1/2 FLD	34	2.0	0.3010
8/9/2006	7		1/3 EBB	35	4.5	0.6532
1/24/2007	7		3/4 FLD	35	4.0	0.6021
3/5/2007	7		Early EBB	36	2.0	0.3010
4/2/2007	7		1/3 EBB	35	2.0	0.3010
7/18/2007	7		1/2 FLD	36	4.0	0.6021
8/20/2007	7		1/4 FLD	35	2.0	0.3010
9/17/2007	7		1/2 FLD	36	2.0	0.3010
1/23/2008	7		1/4 EBB	38	4.0	0.6021
2/14/2008	7		low slack	32	11.0	1.0414
4/29/2008	7		3/4 EBB	32	4.5	0.6532
06/26/2008	7		1/4 FLD	35	2.0	0.3010
08/14/2008	7		1/4 EBB	34	**17.0**	1.2304
10/2/2008	7		3/4 FLD	38	4.0	0.6021

Number	30
Log Avg:	0.65953
Log SD:	0.532046
# > 43:	1
# > 260:	1
Median:	4
Geomean:	4.566003
Est 90th:	21

Table 12. SS sampling results for station 7 in Hewletts Creek Watershed

DATE	STAT.	NO.	TIDE	SALINITY	F/C	LOG F/C
10/3/2001	9		1/4 EBB	37	1.7	0.2304
1/2/2002	9		3/4 FLD	37	1.7	0.2304
2/21/2002	9		Early FLD	36	**49.0**	1.6902
4/11/2002	9		Early EBB	36	2.0	0.3010
5/2/2002	9		1/2 FLD	37	4.5	0.6532
9/12/2002	9		1/2 FLD	39	6.8	0.8325
11/21/2002	9		Early EBB	34	6.8	0.8325
1/15/2003	9		1/3 EBB	35	13.0	1.1139
4/2/2003	9		3/4 FLD	26	4.5	0.6532
5/6/2003	9		1/2 FLD	30	4.5	0.6532
6/18/2003	9		1/2 FLD	36	1.7	0.2304
7/28/2003	9		1/2 EBB	30	**350.0**	2.5441
10/21/2003	9		2/3 EBB	30	7.8	0.8921
4/3/2006	9		1/2 FLD	35	7.8	0.8921
4/26/2006	9		Early FLD	35	4.5	0.6532
5/30/2006	9		1/4 EBB	35	1.7	0.2304
7/12/2006	9		1/2 FLD	33	13.0	1.1139
8/9/2006	9		1/3 EBB	35	**17.0**	1.2304
1/24/2007	9		3/4 FLD	34	2.0	0.3010
3/5/2007	9		Early EBB	35	1.7	0.2304
4/2/2007	9		1/3 EBB	34	1.7	0.2304
7/18/2007	9		1/2 FLD	36	1.7	0.2304
8/20/2007	9		1/4 FLD	34	1.8	0.2553
9/17/2007	9		1/2 FLD	36	4.0	0.6021
1/23/2008	9		1/4 EBB	38	1.8	0.2553
2/14/2008	9		low slack	32	6.8	0.8325
4/29/2008	9		3/4 EBB	33	**33.0**	1.5185
06/26/2008	9		1/4 FLD	35	2.0	0.3010
08/14/2008	9		1/4 EBB	34	**22.0**	1.3424
10/2/2008	9		3/4 FLD	36	**22.0**	1.3424

Number	30
Log Avg:	0.747304
Log SD:	0.556929
# > 43:	2
# > 260:	1
Median:	4.5
Geomean:	5.588717
Est 90th:	28

APPENDIX I: CITY OF WILMINGTON LID STREET DESIGN MANUAL

CITY OF WILMINGTON
"GREEN STREET"
STORMWATER MANAGEMENT
DEVICES

DESIGN MANUAL

REVISION DATE: AUGUST 2011
NOT APPROVED FOR DISTRIBUTION

PREPARED BY
WITHERS & RAVENEL
111 Mackenan Drive
Cary, NC 27511

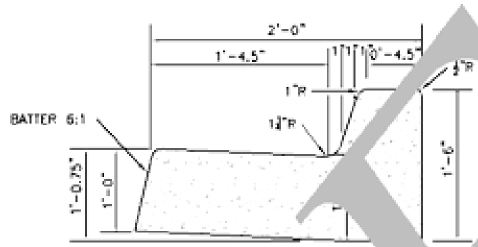
The purpose of this manual is to provide example designs of typical stormwater runoff reduction practices which can be used within the public right of way. The measures shown are examples of the techniques and processes encouraged with the watershed management plan.

These details are intended to serve as the starting point for stormwater retrofits alongside active roadways. These details outline the major design elements of curbside stormwater management facilities. Roadside safety, pedestrian safety, maintenance, gutter spread and other factors must still be evaluated prior to implementation. Additionally, existing utilities or environmental conditions may make it necessary to modify or revise the standard designs to fit each individual BMP location. Curbside stormwater management may not be feasible in all locations.

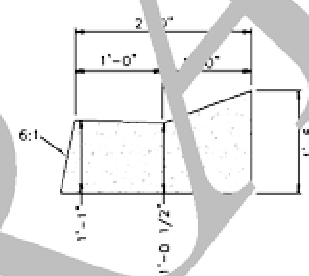
These runoff reduction measures are intended to capture, store, treat and/or infiltrate stormwater runoff from public streets and potentially adjacent residences or businesses. The objective of these measures is consistent with the strategies outlined in the watershed restoration plan for Bradley and Hewletts Creek. These designs, however, can be implemented throughout the City and can aid in reducing nuisance flooding while also adding water quality benefits to systems which have direct discharges into any of the surface waters within the City.

In many cases, the installation of these devices can provide a positive cost benefit compared trying to achieve the same water quality benefit using conventional stormwater solutions.

For additional information, contact Dave Mayes, Stormwater Services Division, or Phil Prete, Environmental Planning.



MODIFIED TYPE "A" CURB AND GU



MODIFIED CURB AND GUTTER

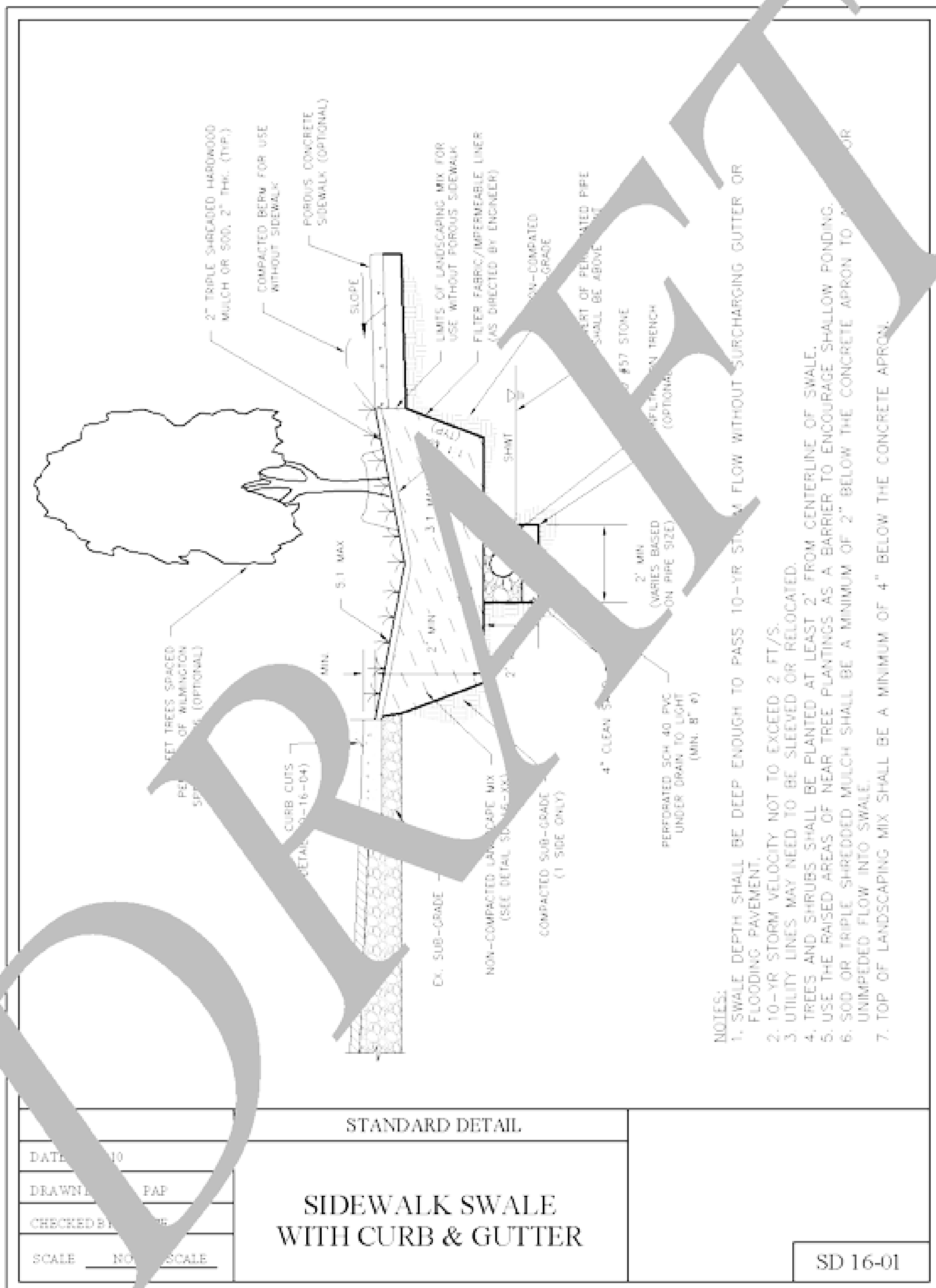
NOTES:
1. MODIFIED CURB A UTTER TO BE USED WHEN ADJACENT TO SURFACE STORMWATER FACILITIES.
2. CURB EXPOSURE I . VARY ONLY AS SHOWN ON PLANS OR AS APPROVED.

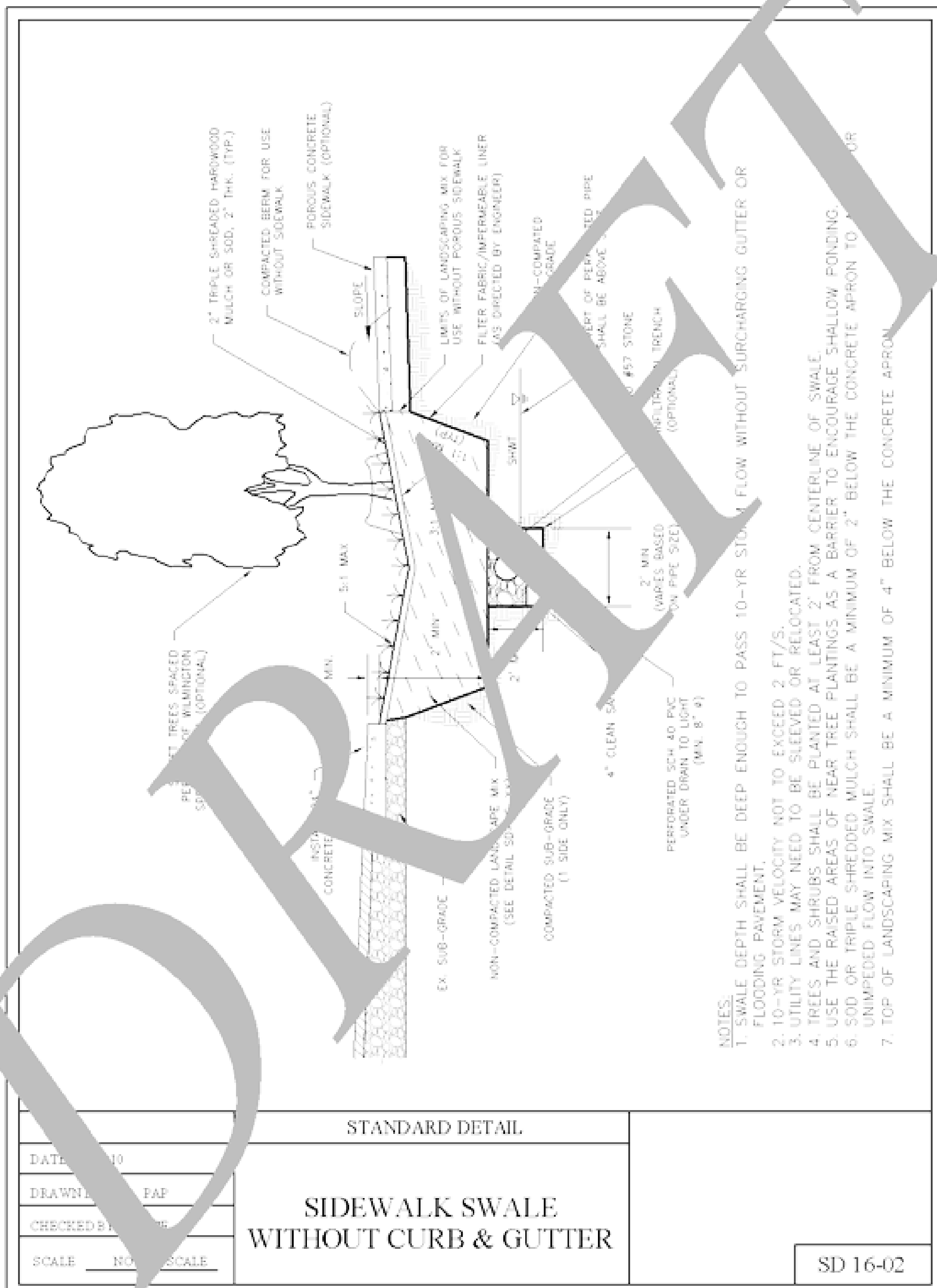
STANDARD DETAIL

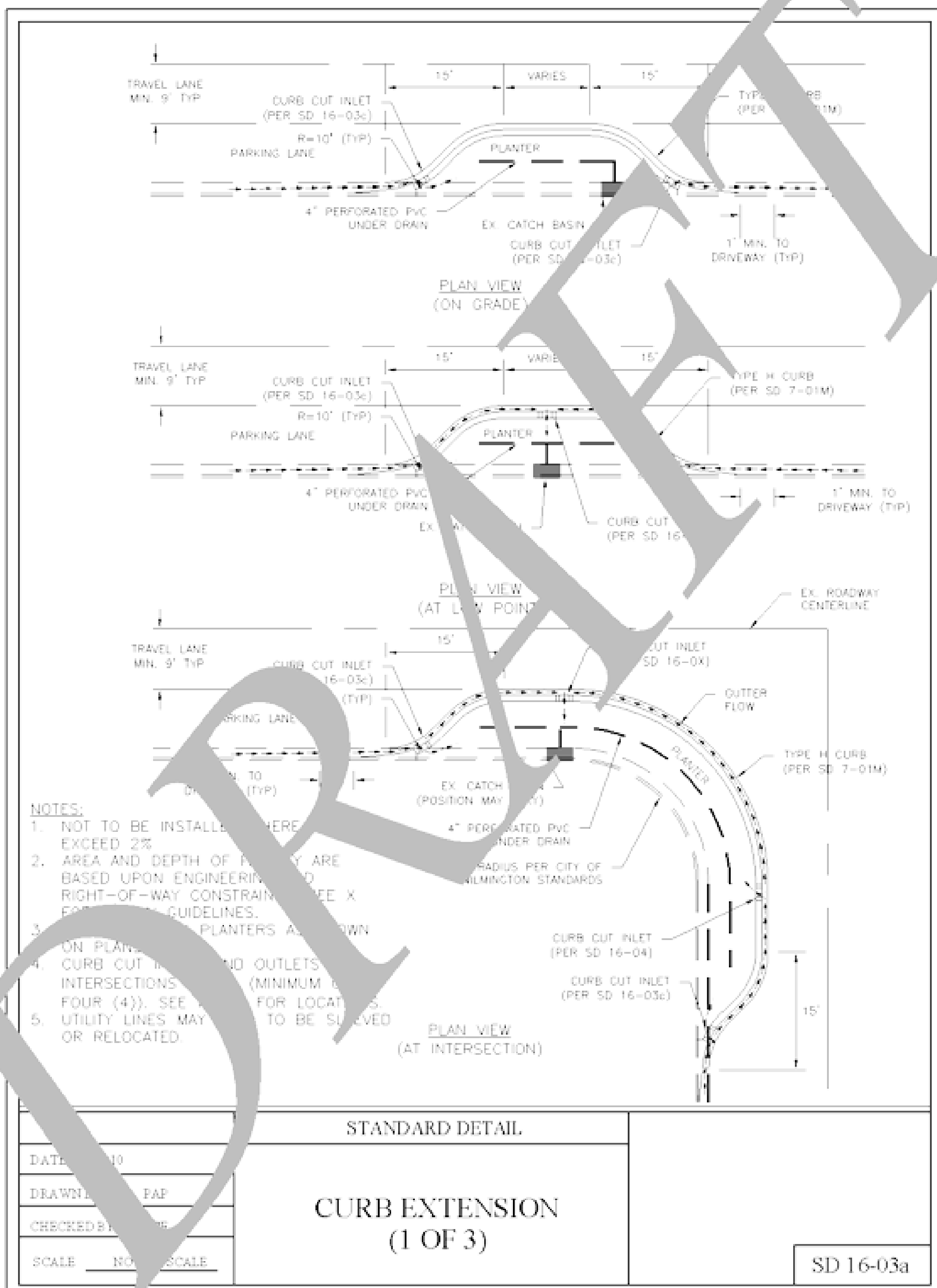
DATE 10
DRAWN PAP
CHECKED B
SCALE NO SCALE

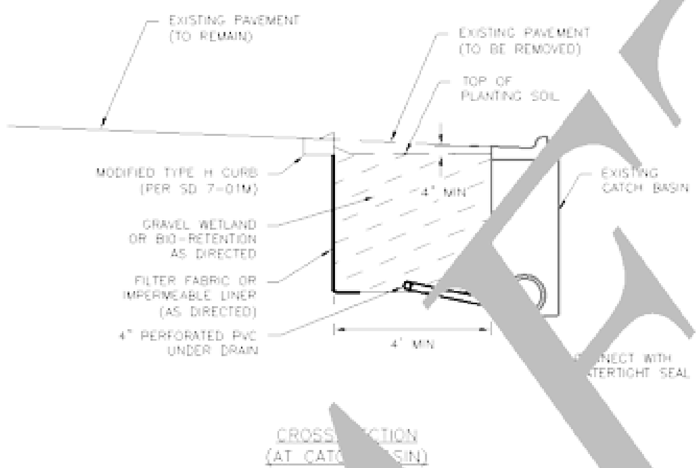
MODIFIED
CURB AND GUTTER
TYPES "A" AND "H"

SD 7-01M


NOTES:
2. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
3. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
4. TREES AND SHRUBS SHALL BE PLANTED AT LEAST 2' FROM CENTERLINE OF SWALE.
7. TOP OF LANDSCAPING MIX SHALL BE A MINIMUM OF 4" BELOW THE CONCRETE APRON.
STANDARD DETAIL
SIDEWALK SWALE
WITH CURB & GUTTER
SD 16-01


2" TRIPLE SHREDDED HARDWOOD MULCH OR SOD, 2" THK. (TYP.)
COMPACTED BERM FOR USE WITHOUT SIDEWALK
POROUS CONCRETE SIDEWALK (OPTIONAL)
SLOPE
LIMITS OF LANDSCAPING MIX FOR USE WITHOUT POROUS SIDEWALK
FILTER FABRIC/IMPERMEABLE LINER (AS DIRECTED BY ENGINEER)
SHWT
#57 STONE
5:1 MAX
2' MIN
(VARIES BASED ON PIPE SIZE)
PERFORATED SCH 40 PVC UNDER DRAIN TO LIGHT (MIN. 8" ø)
EX. SUB-GRADE
COMPACTED SUB-GRADE (1 SIDE ONLY)
NOTES:
1. SWALE DEPTH SHALL BE DEEP ENOUGH TO PASS 10-YR STO FLOW WITHOUT SURCHARGING GUTTER OR FLOODING PAVEMENT.
2. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
3. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
4. TREES AND SHRUBS SHALL BE PLANTED AT LEAST 2' FROM CENTERLINE OF SWALE.
5. USE THE RAISED AREAS OF NEAR TREE PLANTINGS AS A BARRIER TO ENCOURAGE SHALLOW PONDING.
6. SOD OR TRIPLE SHREDDED MULCH SHALL BE A MINIMUM OF 2" BELOW THE CONCRETE APRON TO UNIMPEDED FLOW INTO SWALE.
7. TOP OF LANDSCAPING MIX SHALL BE A MINIMUM OF 4" BELOW THE CONCRETE APRON.
STANDARD DETAIL
DATE
DRAWN PAP
CHECKED B
SCALE
SIDEWALK SWALE
WITHOUT CURB & GUTTER
SD 16-02


TRAVEL LANE
MIN. 9' TYP
CURB CUT INLET
(PER SD 16-03c)
R=10' (TYP)
PARKING LANE
PLANTER
15'
VARIES
4" PERFORATED PVC
UNDER DRAIN
EX. CATCH BASIN
1' MIN. TO
DRIVEWAY (TYP)
PLAN VIEW
(ON GRADE)
TYPE H CURB
(PER SD 7-01M)
EX. ROADWAY
CENTERLINE
GUTTER
FLOW
NOTES:
STANDARD DETAIL
CURB EXTENSION
(1 OF 3)
SD 16-03a



STANDARD DETAIL

DATE

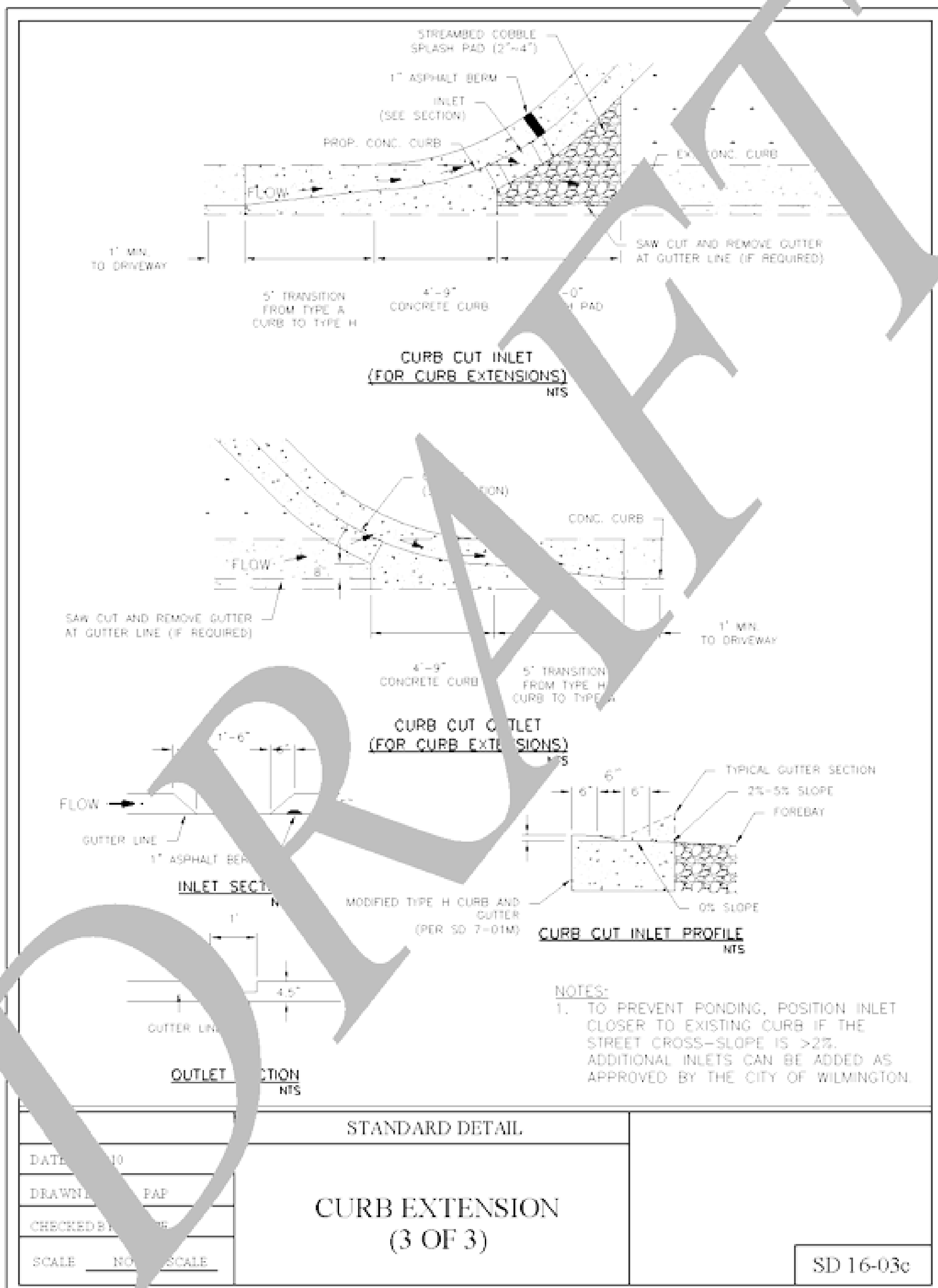
DRAWN PAP

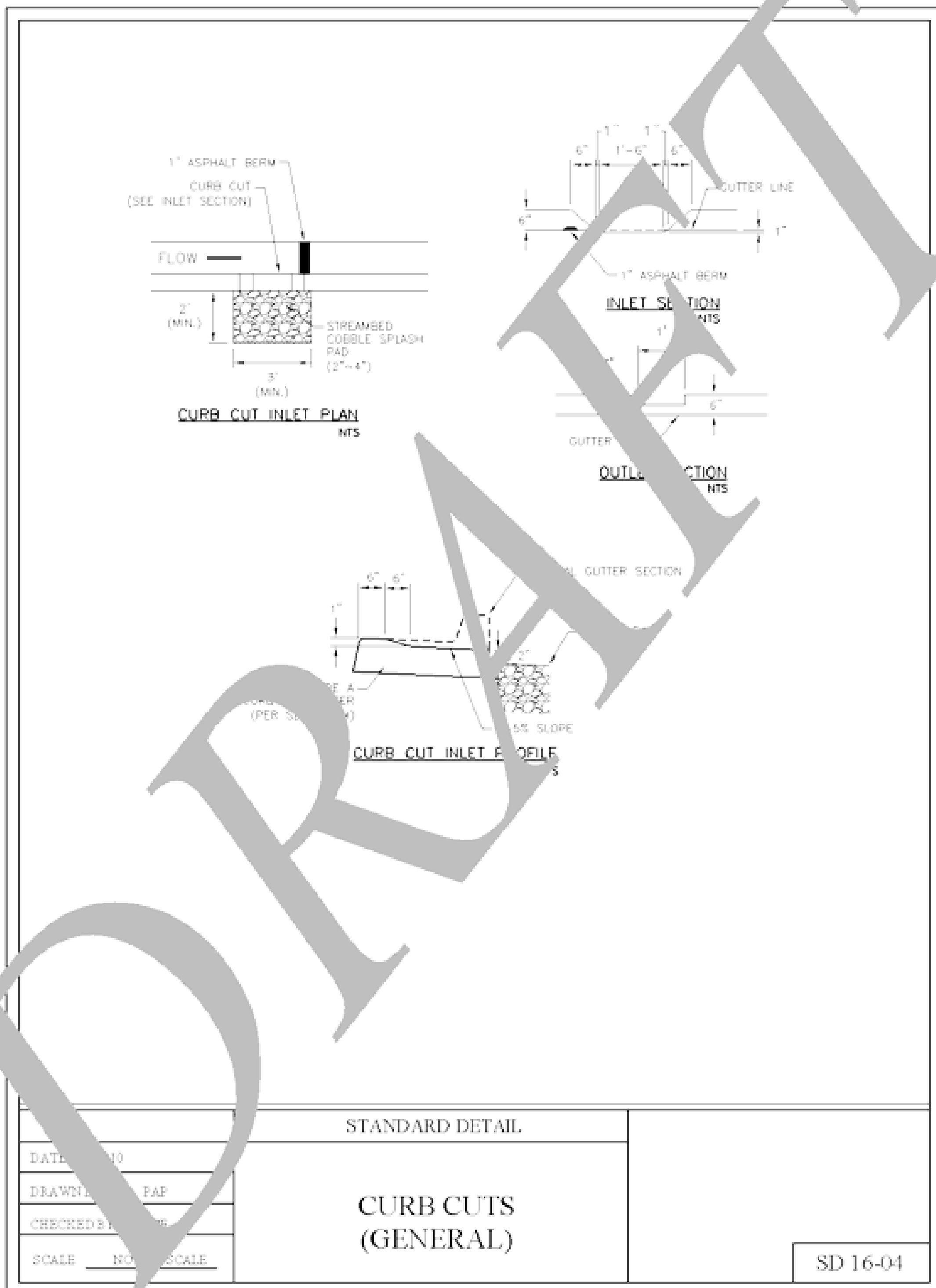
CHECKED B

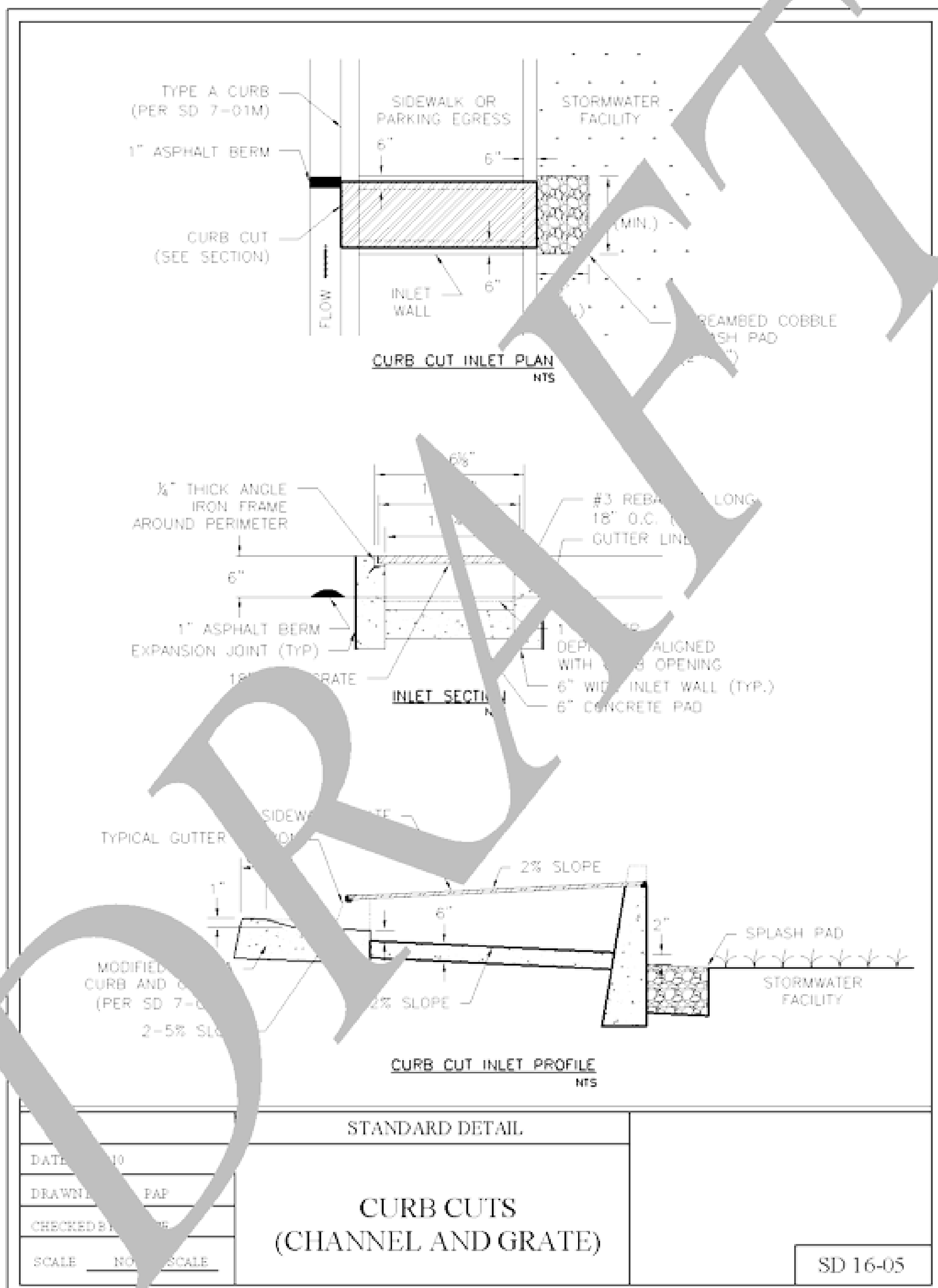
SCALE

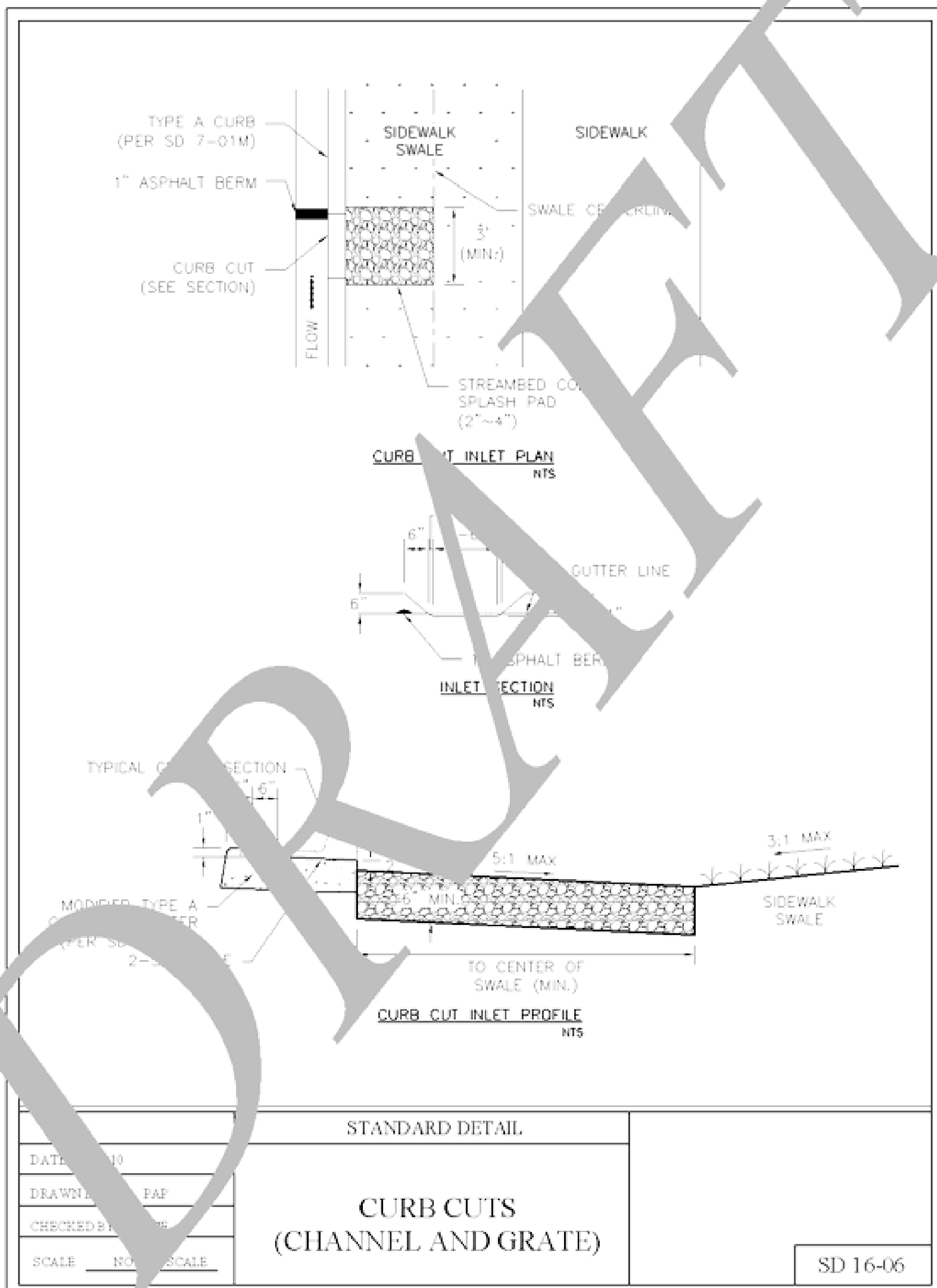
CURB EXTENSION
(2 OF 3)

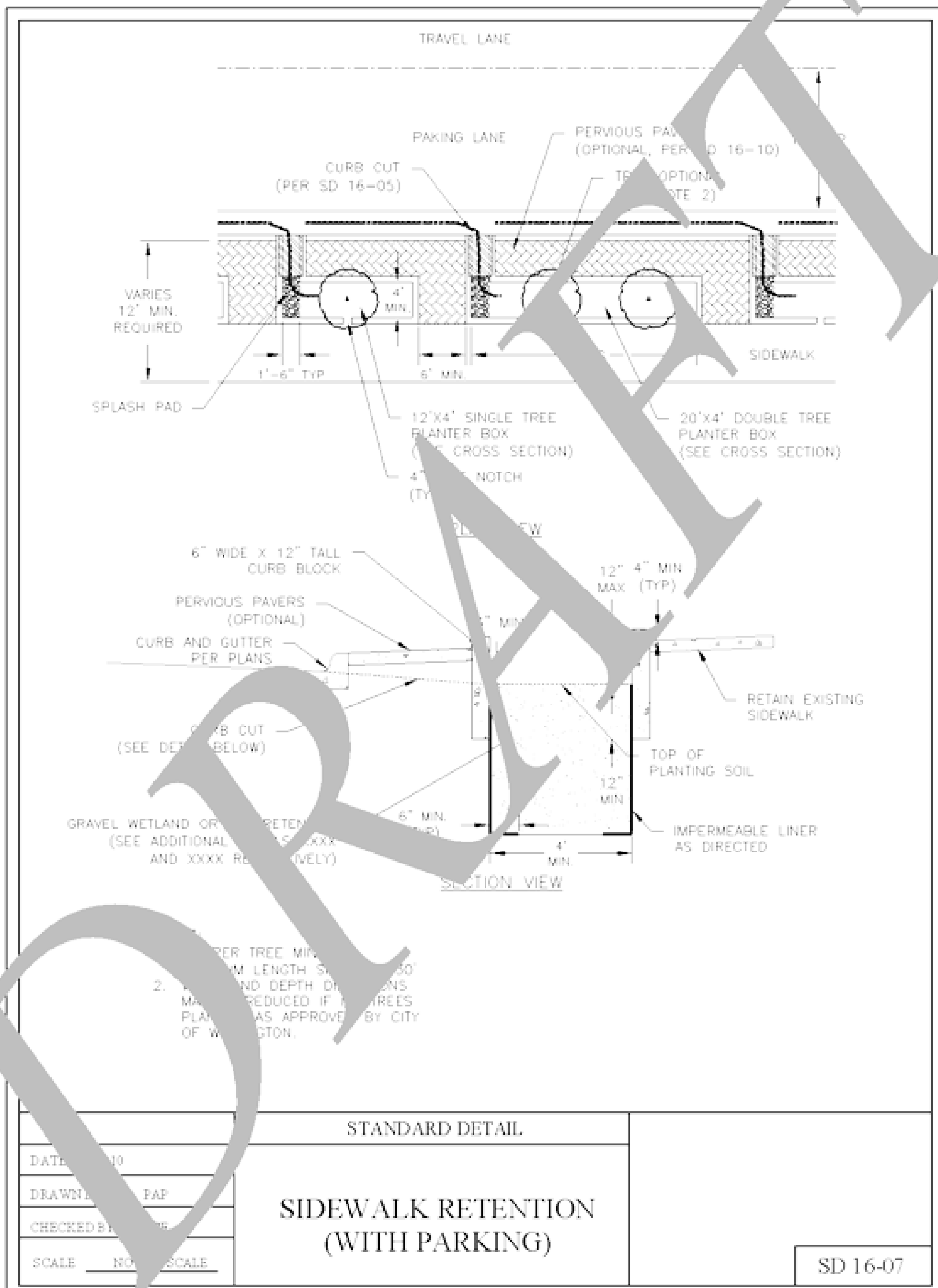
SD 16-03b

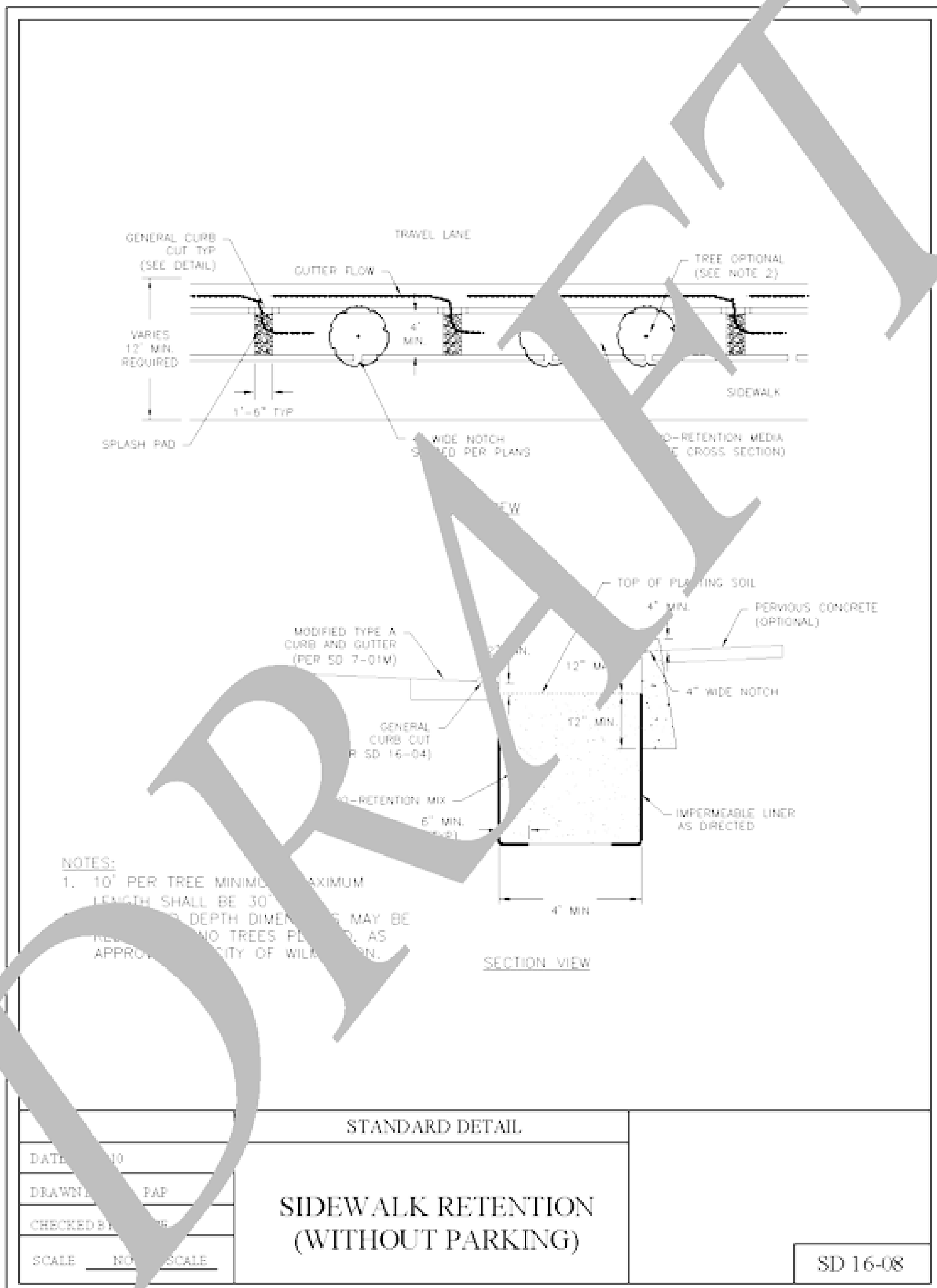

STREAMBED COBBLE SPLASH PAD (2"-4")
1" ASPHALT BERM
INLET (SEE SECTION)
PROP. CONC. CURB
FLOW
SAW CUT AND REMOVE GUTTER AT GUTTER LINE (IF REQUIRED)
1' MIN. TO DRIVEWAY
5' TRANSITION FROM TYPE A CURB TO TYPE H
4'-9" CONCRETE CURB
CURB CUT INLET (FOR CURB EXTENSIONS)
NTS
CONC. CURB
FLOW
SAW CUT AND REMOVE GUTTER AT GUTTER LINE (IF REQUIRED)
1' MIN. TO DRIVEWAY
4'-9" CONCRETE CURB
CURB CUT OUTLET (FOR CURB EXTENSIONS)
FLOW
GUTTER LINE
TYPICAL GUTTER SECTION
2%-5% SLOPE
FOREBAY
MODIFIED TYPE H CURB AND GUTTER (PER SD 7-01M)
0% SLOPE
CURB CUT INLET PROFILE
NTS
4.5"
NOTES:
1. TO PREVENT PONDING, POSITION INLET CLOSER TO EXISTING CURB IF THE STREET CROSS-SLOPE IS >2%. ADDITIONAL INLETS CAN BE ADDED AS APPROVED BY THE CITY OF WILMINGTON.
NTS
STANDARD DETAIL
CURB EXTENSION (3 OF 3)
SD 16-03c

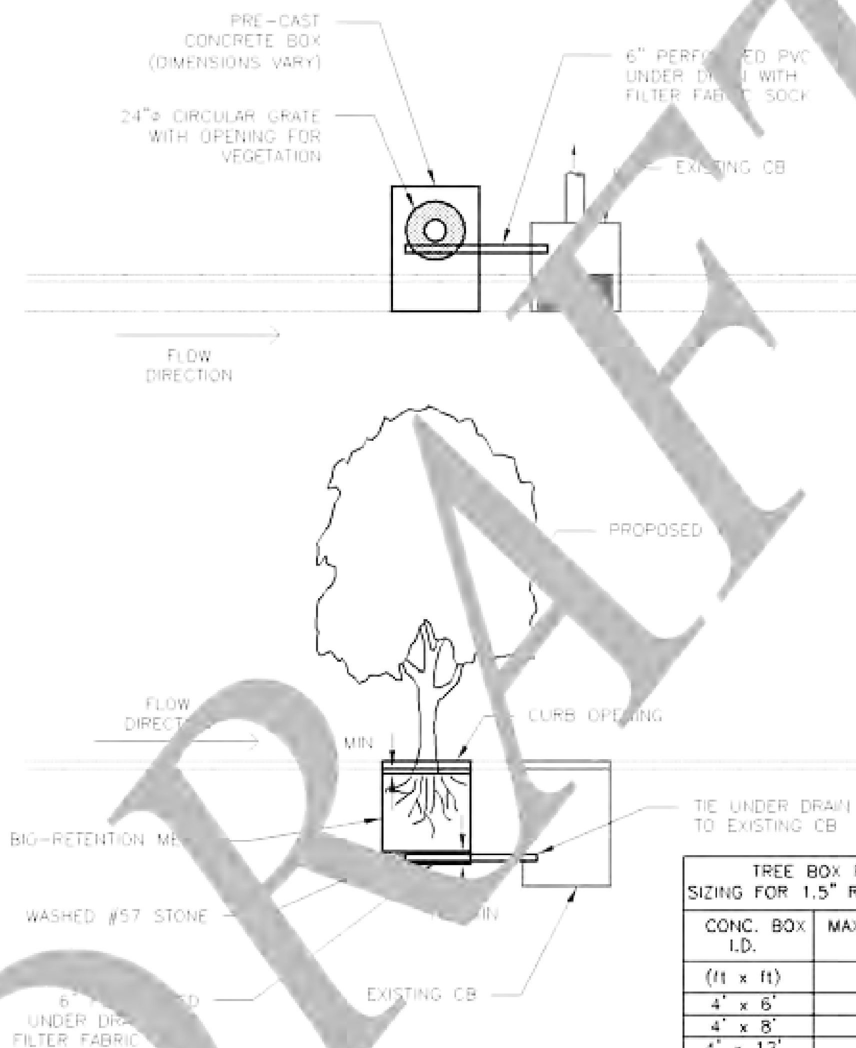

1" ASPHALT BERM
CURB CUT
(SEE INLET SECTION)
FLOW
2'
(MIN.)
STREAMBED
COBBLE SPLASH
PAD
(2"-4")
3'
(MIN.)
CURB CUT INLET PLAN
NTS
GUTTER LINE
1" ASPHALT BERM
GUTTER
GUTTER SECTION
5% SLOPE
STANDARD DETAIL
PAP
CURB CUTS
(GENERAL)
SD 16-04


TYPE A CURB
(PER SD 7-01M)
SIDEWALK OR
PARKING EGRESS
STORMWATER
FACILITY
1" ASPHALT BERM
6"
6"
CURB CUT
(SEE SECTION)
(MIN.)
FLOW
INLET
WALL
6"
CURB CUT INLET PLAN
NTS
¼" THICK ANGLE
IRON FRAME
AROUND PERIMETER
6"
1" ASPHALT BERM
EXPANSION JOINT (TYP)
GUTTER LINE
6" WIDE INLET WALL (TYP.)
6" CONCRETE PAD
INLET SECTION
TYPICAL GUTTER
2% SLOPE
1"
6"
2"
SPLASH PAD
STORMWATER
FACILITY
2% SLOPE
CURB CUT INLET PROFILE
NTS
STANDARD DETAIL
PAP
SCALE
CURB CUTS
(CHANNEL AND GRATE)
SD 16-05


TYPE A CURB
(PER SD 7-01M)
1" ASPHALT BERM
CURB CUT
(SEE SECTION)
FLOW
SIDEWALK
SWALE
SIDEWALK
3'
(MIN.)
SPLASH PAD
(2"~4")
GUTTER LINE
5:1 MAX
3:1 MAX
SIDEWALK
SWALE
TO CENTER OF
SWALE (MIN.)
CURB CUT INLET PROFILE
NTS
STANDARD DETAIL
CURB CUTS
(CHANNEL AND GRATE)
SD 16-06


TRAVEL LANE
PAKING LANE
CURB CUT
(PER SD 16-05)
VARIES
12' MIN.
REQUIRED
4'
MIN.
SIDEWALK
1'-6" TYP
6' MIN
SPLASH PAD
12'X4' SINGLE TREE
PLANTER BOX
20'X4' DOUBLE TREE
PLANTER BOX
(SEE CROSS SECTION)
6" WIDE X 12" TALL
CURB BLOCK
PERVIOUS PAVERS
(OPTIONAL)
CURB AND GUTTER
PER PLANS
12"
MAX
4" MIN
(TYP)
RETAIN EXISTING
SIDEWALK
TOP OF
PLANTING SOIL
12"
MIN
IMPERMEABLE LINER
AS DIRECTED
4'
MIN
SECTION VIEW
STANDARD DETAIL
SIDEWALK RETENTION
(WITH PARKING)
SD 16-07


GENERAL CURB CUT TYP (SEE DETAIL)
TRAVEL LANE
GUTTER FLOW
TREE OPTIONAL (SEE NOTE 2)
VARIES 12" MIN. REQUIRED
4" MIN.
SIDEWALK
1'-6" TYP
SPLASH PAD
TOP OF PLANTING SOIL
4" MIN.
PERVIOUS CONCRETE (OPTIONAL)
MODIFIED TYPE A CURB AND GUTTER (PER SD 7-01M)
4" WIDE NOTCH
12" MIN.
GENERAL CURB CUT
IMPERMEABLE LINER AS DIRECTED
6" MIN.
4' MIN
NOTES:
SECTION VIEW
STANDARD DETAIL
SIDEWALK RETENTION
(WITHOUT PARKING)
SD 16-08



TREE BOX FILTER SIZING FOR 1.5" RAINFALL	
CONC. BOX I.D.	MAX IMPERVIOUS AREA
(ft x ft)	(ac.)
4' x 6'	0.14
4' x 8'	0.19
4' x 12'	0.28
6' x 6'	0.21
6' x 8'	0.28
6' x 10'	0.35
6' x 12'	0.42
7' x 13'	0.54

STANDARD DETAIL

DATE 10

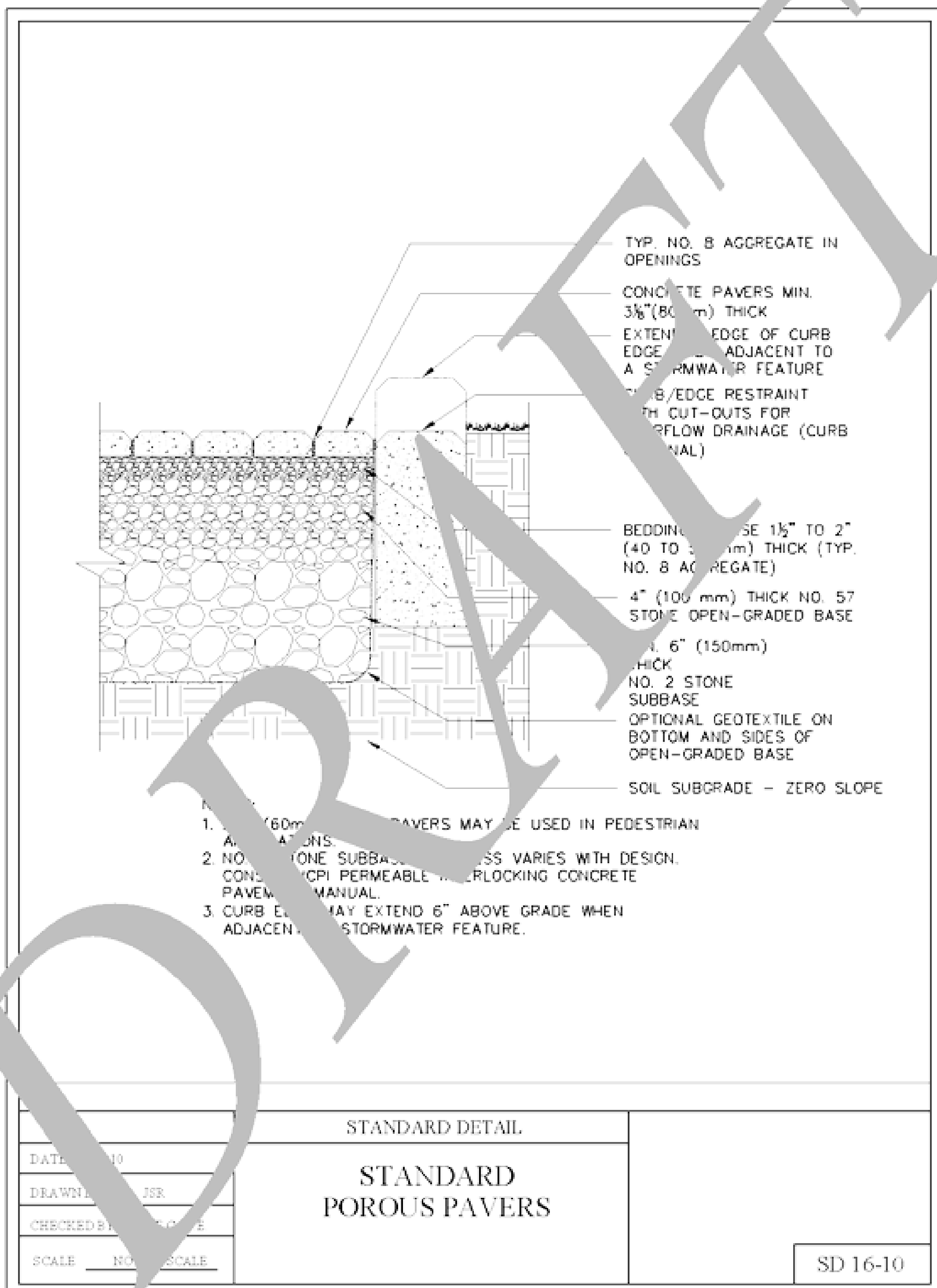
DRAWN BY PAP

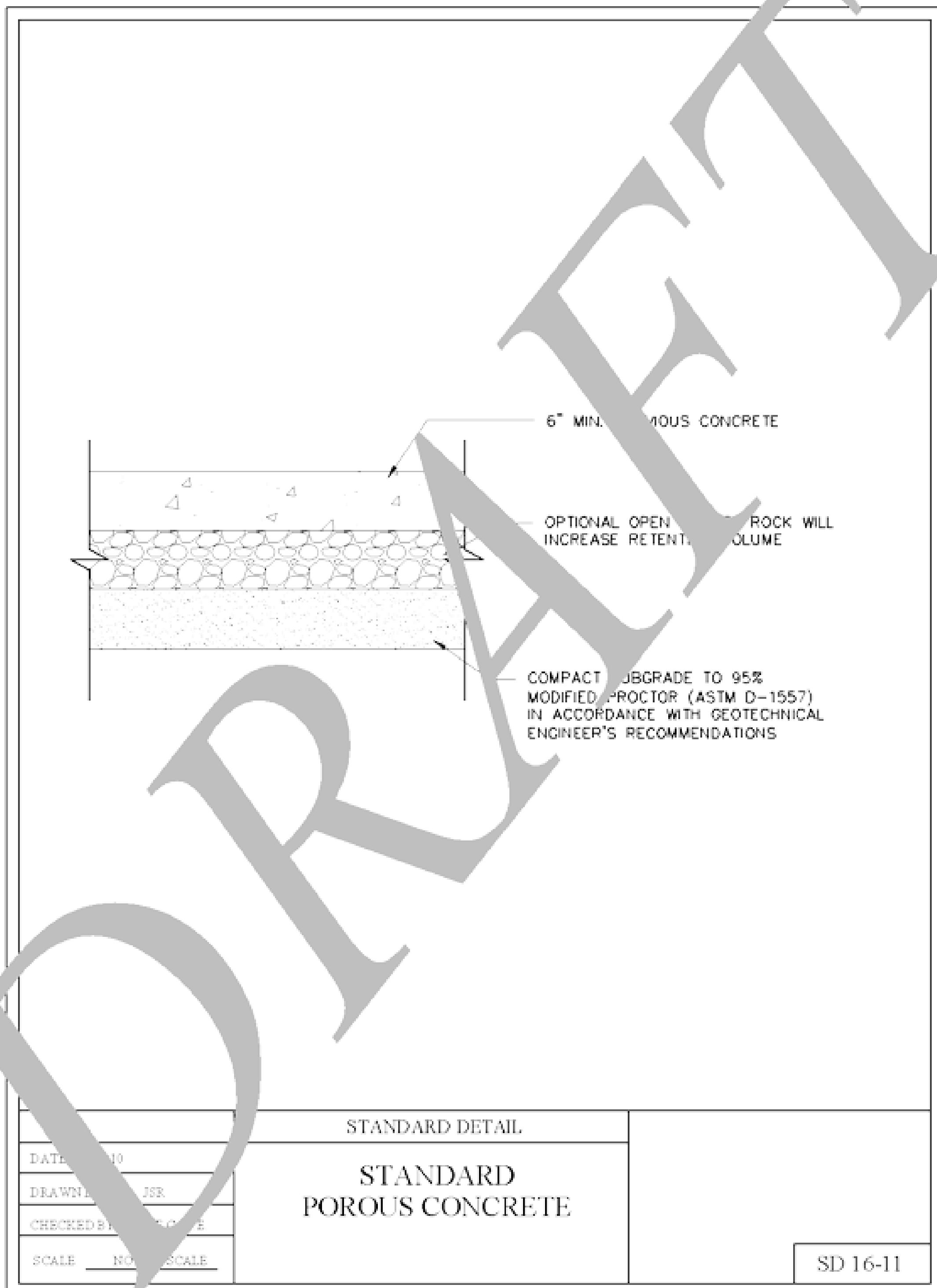
CHECKED BY

SCALE NO SCALE

STANDARD URBAN TREE PLANTER BOX

SD 16-09


TYP. NO. 8 AGGREGATE IN OPENINGS
CONCRETE PAVERS MIN.
EXTEN EDGE OF CURB
EDGE ADJACENT TO
A STORMWATER FEATURE
WITH CUT-OUTS FOR
RFLOW DRAINAGE (CURB
(40 TO mm) THICK (TYP.
NO. 8 AGGREGATE)
4" (100 mm) THICK NO. 57
STONE OPEN-GRADED BASE
6" (150mm)
NO. 2 STONE
SUBBASE
OPTIONAL GEOTEXTILE ON
BOTTOM AND SIDES OF
OPEN-GRADED BASE
SOIL SUBGRADE - ZERO SLOPE
PAVERS MAY BE USED IN PEDESTRIAN
STONE SUBBASE THICKNESS VARIES WITH DESIGN.
3. CURB EDGE MAY EXTEND 6" ABOVE GRADE WHEN
STORMWATER FEATURE.
STANDARD DETAIL
STANDARD
POROUS PAVERS
DATE
DRAWN
JSR
CHECKED
SCALE
SCALE
SD 16-10



MODIFIED PROCTOR (ASTM D-1557)
IN ACCORDANCE WITH GEOTECHNICAL
ENGINEER'S RECOMMENDATIONS
STANDARD DETAIL
STANDARD
POROUS CONCRETE
SD 16-11

APPENDIX J: POND PACK SUMMARY RESULTS

Type.... Master Network Summary Page 1.01
Name.... Watershed
File.... K:\07\07-0650\070655.08-Gray to Blue\H-H\Hydrographs 111110.ppw

MASTER DESIGN STORM SUMMARY

Network Storm Collection: Wilmington

Return Event	Total Depth in	Rainfall Type	RNF ID
10	6.7200	Synthetic Curve	TypeIII 24hr
1	3.9500	Synthetic Curve	TypeIII 24hr

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Qpeak cfs	Max WSEL ft	Max Pond Storage ac-ft
1981 BRADLEY	AREA	10	616.960		12.4000	4245.39		
1981 BRADLEY	AREA	1	136.494		12.6000	551.03		
1981 HEWLETTS	AREA	10	1043.262		12.4000	7304.61		
1981 HEWLETTS	AREA	1	241.897		12.5500	1047.76		
1998 BRADLEY	AREA	10	787.034		12.4000	5791.91		
1998 BRADLEY	AREA	1	213.437		12.5000	1157.66		
1998 HEWLETTS	AREA	10	1318.887		12.4000	9791.55		
1998 HEWLETTS	AREA	1	369.723		12.5000	2089.44		
2002 BRADLEY	AREA	10	857.501		12.4000	6415.32		
2002 BRADLEY	AREA	1	248.014		12.4500	1453.19		
2002 HEWLETTS	AREA	10	1375.781		12.4000	10292.80		
2002 HEWLETTS	AREA	1	397.915		12.4500	2331.51		
2006 BRADLEY	AREA	10	965.862		12.4000	7355.19		
2006 BRADLEY	AREA	1	303.921		12.4500	1957.54		

S/N: Bentley Systems, Inc.
Bentley PondPack (10.00.027.00) 4:35 PM 8/6/2012

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Qpeak cfs	Max WSEL ft	Max Pond Storage ac-ft
2006 HEWLETTS	AREA	10	1491.198		12.4000	11297.77		
2006 HEWLETTS	AREA	1	456.874		12.4500	2864.47		
2010 BRADLEY	AREA	10	1002.633		12.4000	7669.15		
2010 BRADLEY	AREA	1	323.621		12.4500	2133.41		
2010 HEWLETTS	AREA	10	1549.693		12.4000	11801.16		
2010 HEWLETTS	AREA	1	487.632		12.4500	3140.81		
*OUT 1981	JCT	10	1660.222		12.4000	11550.00		
*OUT 1981	JCT	1	378.391		12.6000	1598.49		
*OUT 1998	JCT	10	2105.920		12.4000	15583.46		
*OUT 1998	JCT	1	583.160		12.5000	3247.09		
*OUT 2002	JCT	10	2233.282		12.4000	16708.12		
*OUT 2002	JCT	1	645.930		12.4500	3784.70		
*OUT 2006	JCT	10	2457.062		12.4000	18652.96		
*OUT 2006	JCT	1	760.795		12.4500	4822.01		
*OUT 2010	JCT	10	2552.327		12.4000	19470.31		
*OUT 2010	JCT	1	811.252		12.4500	5274.22		