CHAPTER 10 – BACTERIA AND WATER QUALITY IMPACTS

Recreational waters, particularly coastal areas, are valued worldwide for their economic, ecological and cultural significance. Like many states, the livelihood of North Carolina communities that cater to water related activities can be severely impacted if bacteria levels are above the water quality standards because the high levels often result in closed swimming areas and/or restricted and even prohibited shellfish harvesting. This chapter reviews how bacteria is used as a water quality indicator. It includes how bacteria can impact water quality, provides an overview of water quality standards for freshwater and saltwater and reviews best management practices (BMPs) and management strategies that can reduce bacteria numbers in waterbodies throughout the state.

10.1 IDENTIFYING BACTERIA AND ITS SOURCE

Microbes are defined as any microscopic organism and include protozoa (single-celled organisms), viruses and bacteria. Most microbes are beneficial or harmless to human health, but some are pathogenic and can cause a variety of human illnesses (NCNERR, no date). In North Carolina, fecal coliform and enterococci serve as bacterial indicators of water quality. Increased levels in aquatic environments provide a warning of sewage treatment failure, a break in the integrity of a water distribution system or possible contamination with other disease causing pathogens.

Sources of Bacteria in Surface Waters

- Urban stormwater
- Animals including wildlife, livestock and domesticated pets
- Improperly designed or managed animal waste facilities
- Livestock with direct, easy access to streams
- Improperly treated discharges of domestic wastewater including leaking or failing septic systems and straight pipes
- Marinas

No matter what the bacteria or microorganism type (i.e., virus, protozoan parasites), point and nonpoint source pollution contribute to the bacterial numbers in waterbodies. Point source pollution includes municipal wastewater treatment plants, sewage spills and permitted discharges. Nonpoint source pollution includes agricultural runoff, animal waste, human waste, leaky sewer lines, on-site septic systems, straight pipes, stormwater runoff from developed land including roads, buildings and residential yards and surface or land application of human and/or animal waste. Identifying possible sources of microbes is the first step in developing strategies to reduce their numbers in recreational waters.

10.1.1 FECAL COLIFORM BACTERIA

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. The bacteria can be found in the digestive tract of warm-blooded animals and aid in the digestion of food. In themselves, fecal coliform bacteria do not pose a danger to people or animals; however, where fecal coliform are present, disease-causing bacteria may also be present. Fecal coliform contamination often indicates that water is polluted with human or animal waste, which can harbor other pathogens that may threaten human health. Under favorable conditions (i.e., warm, dark, moist, organic-rich environment), fecal coliform bacteria can survive in bottom sediments for an extended period of time (Howell et *al*., 1996; Sherer et *al*., 1992; Schillinger and Gannon, 1985; Center for Watershed Protection, 1999).

Consequently, the concentration of bacteria measured in a water column can reflect both recent inputs as well as the re-suspension of older inputs. In North Carolina, fecal coliform bacteria are used to assess the water quality of fresh surface water (Class B and C) and saltwaters used for shellfish harvesting (Class SA).

Reducing fecal coliform bacteria in wastewater requires a disinfection process, which typically involves the use of chlorine and other disinfectants. Although these materials may kill the fecal coliform bacteria and other disease-causing microbes, the disinfectants also kill other microbes that are essential to the aquatic environment. This often endangers the survival of species dependent on these other microbes.

10.1.2 Enterococci Bacteria

Like fecal coliform bacteria, enterococci are passed through the fecal excrement of humans, livestock and wildlife. The bacteria can be found in the digestive tract of warm-blooded animals and aid in the digestion of food. EPA approves the use of enterococci as an indicator of water quality in recreation bathing waters. In North Carolina, enterococci bacteria are used to assess surface saltwaters used for recreational purposes (Class SA, SB and SC).

10.1.3 Human Sources of Bacteria

Not all sanitary sewer systems offer high levels of pollution reduction. Potential pathways for human sewage to enter surface water include combined sewer overflows, sanitary sewer overflows, illegal sanitary connections to storm drains, transient or inadvertent dumping and failing septic systems (Center for Watershed Protection, 1999).

In the United States, there are nearly 800 cities with combined sewer systems (EPA, July 2006b). Combined sewer systems can be found in many older cities and are designed to collect human sewage, industrial wastewater and stormwater in the same pipe. Most of the time, all three can be transported to a wastewater treatment plant where it is treated and discharged to surface water; however, overflows can occur during heavy rain events. The overflow from the combined sewer system (CSO) contains stormwater and untreated human and industrial waste, toxic materials and debris. No combined sewer systems are located in North Carolina (EPA, July 2006b).

Even when stormwater and wastewater are separated, sanitary sewer overflows (SSO) can also occur. SSOs are discharges of raw sewage from municipal sanitary sewer systems. They are often caused by blockages and/or breaks in sewer lines, power failures at pumping stations and/or when infiltration and inflow exceed the capacity of the wastewater treatment plant (Center for Watershed Protection, 1999). By leaving sewer lines, entering basements and pooling on city streets, SSOs can create a serious human health hazard (EPA, July 2006c). Many SSOs occur during storm events because stormwater enters leaking, or broken, sewer pipes (Center for Watershed Protection, 1999). Often referred to as urban wet weather flows (WWFs), CSO, SSO and stormwater can discharge treated and untreated waste directly to surface water. These discharges consist of point and diffuse nonpoint source pollution and often include high levels of bacteria. More information on CSOs and SSOs can be found on the EPA's NPDES Web site (http://cfpub.epa.gov/npdes/).

Because it is difficult to identify sewer versus stormwater pipes during construction activities, hundreds of improper connections to stormwater pipes can introduce human sewage to surface water. Commonly referred to as illicit connections, they can have a significant impact on bacterial counts in surface water (Center for Watershed Protection, 1999).

Illegal dumping of sewage from septage vacuum trucks, garbage trucks, recreational vehicles and portable toilets along with livestock carriers can also contribute to bacterial loads; however, it is difficult to quantify how much each of these may be contributing to surface waters. Failing septic systems and straight pipes are also considered illegal because of their potential impact to water quality. Septic systems must be properly located, installed and maintained if they are to effectively remove bacteria from human waste (Center for Watershed Protection, 1999). More information about on-site waste management can be found in Section 10.3.3 and 10.4.3

10.1.4 NON-HUMAN SOURCES OF BACTERIA

Most of the bacteria present in stormwater runoff is generally assumed to be from non-human sources. Dogs, cats, raccoons, rats, beaver, gulls, geese, pigeons and even insects influence bacterial numbers in many urban and rural watersheds. Given their population density, daily defecation rate and pathogen infection rate, dogs and cats appear to be a major source of fecal coliform bacteria in urban watersheds. The excrement of dogs and cats also contains other microbes including *Giardia* and *Salmonella*, both of which can cause serious stomach ailments in humans (Center for Watershed Protection, 1999).

In highly urban areas, rats and pigeons can be a major source of bacteria, and in many suburban watersheds, raccoons live underground in stormwater pipes and use ledges in the storm drain inlets for shelter. Thus allowing easy transport of excrement and bacteria to the closest waterbody. Many researchers also believe that geese, gulls and ducks may be a major bacterial source in urban areas. More research needs to be conducted to confirm bacterial impacts from geese, gulls and ducks, but it is generally speculated that bacteria numbers will be highest in small impoundments and concrete storage reservoirs used for stormwater storage and/or treatment (Center for Watershed Protection, 1999).

Table 10-1 Numbers of Viable Bacteria Found Per Gram of Feces of Adult Animals (Median values from 10 animals) (NCNERR, Fall 2003)

Animal	E. coli	Enterococci
Cow	20,000	200,000
Horse	13,000	6,300,000
Pig	3,200,000	2,500,000
Sheep	3,200,000	1,300,000
Chicken	4,000,000	32,000,000
Dog	32,000,000	40,000,000
Cat	40,000,000	200,000,000
Human	5,000,000	160,000

If feedlots and pastures are not managed properly, livestock (i.e., cattle, horses, sheep, pigs, chickens, turkeys) can also have a significant impact on bacterial numbers (Table 10-1). Improperly designed or managed animal feedlots and/or animal waste operations not only increase bacterial numbers but also introduce sediment, nutrients and oxygen-consuming organics to the stream (EPA, March 2005). Livestock in streams and stormwater runoff from pasturelands are also potential sources for fecal coliform bacteria. Limiting direct, easy access to streams can dramatically reduce impacts from bacteria, and several rules and regulations are in place to properly deal with animal waste issues (Chapter 6).

10.2 IMPACTS ON WATER QUALITY AND HUMAN HEALTH

10.2.1 ENVIRONMENTAL IMPACTS

From a human perspective, bacteria often impacts the recreational use of a waterbody making an area undesirable for swimming, wading and even fishing. From a biological perspective, the mode of bacterial transport – sediment, organic material (i.e., excrement) and stormwater runoff – can impact aquatic habitat, erode streambanks and impact watershed function. Aerobic decomposition of the organic material can reduce dissolved oxygen levels. If the dissolved oxygen level is too low, it can kill aquatic organisms.

Variables that Influence Movement and Transport of Indicator Bacteria

- Water discharge rates (or instream flow)
- Storm events
- Land disturbances
- Proximity to surface water
- Land use – urban, forest, agriculture, septic tanks
- Runoff volume and rate – impervious surface cover, type of vegetation, BMPs

Wastewater treatment methods can indirectly impact an aquatic ecosystem as well. Reduction of fecal coliform bacteria in wastewater may require the use of chlorine or other disinfectant chemicals. Such material may kill the disease-causing bacteria, but these same bacteria may be essential to maintaining the aquatic ecosystem, endangering species that may be dependent on the bacteria for its survival.

10.2.2 HUMAN HEALTH HAZARDS

Large quantities of fecal coliform bacteria in water may indicate a higher risk of pathogens being present. Some of the waterborne pathogenic diseases include ear infections, typhoid fever, viral and bacterial gastroenteritis, cholera and hepatitis A. Like many other bacteria, fecal coliform can usually be killed by boiling water or by treating the water with chlorine. Thoroughly washing with soap after contact with contaminated water will also help prevent infections. Throughout the United States, municipalities that maintain public water supplies are required to monitor and kill harmful microorganisms before water is distributed for public consumption.

10.3 WATER QUALITY STANDARDS AND COASTAL STORMWATER REGULATIONS

Microbial or bacterial contamination is addressed through the Safe Drinking Water Act (SDWA) and the Clean Water Act. The SDWA enables regulation of contamination of finished drinking water and protection of source waters while the Clean Water Act enables protection of surface water for drinking, recreation and as an aquatic food source. Programs under the two Acts have historically followed separate paths using differing indicators of contamination and different approaches; however, concerns about future increases in microbial contamination and potential for emergence of new threats, such as endocrine disrupting chemicals, create a need to consider a strategy for the future that unites the influence of the two programs. Objectives of the strategy are to address all-important sources of contamination, anticipate emerging problems and use program and research activities efficiently to protect public health (EPA, July 2006a).

Throughout the nation, water quality standards for bacteria are based on human health for recreation and shellfish harvesting and consumption (15A NCAC 2B .0200). North Carolina evaluates waters for the support of primary recreation activities such as swimming, water-skiing, skin diving and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis. Waters of the state designated for these uses are classified as Class B, SB and SA.

North Carolina also evaluates waters used for secondary recreation activities such as wading, boating and other uses not involving human body contact with water where such activities take place on an infrequent, unorganized or incidental basis. These waters are classified as Class C, SC and WS. Table 10-2 identifies the major responsibilities of various DENR agencies in regulating recreational and shellfish waters.

Table 10-2 Microbial Related Activities and Responsible DENR Agency (adapted from NCNEER, Technical Paper – Addressing Microbial Pollution in Coastal Waters)

Microbial/Monitoring Activity	Responsible Agency
Microbial water quality monitoring for fresh and estuarine waters	DWQ Environmental Sciences Section (ESS)
Microbial water quality monitoring of estuarine and ocean waters for recreational beaches	DEH Shellfish Sanitation & Recreational Water Quality Section
Shoreline Surveys of shellfish growing areas	DEH Shellfish Sanitation & Recreational Water Quality Section
Regulating shellfish harvesting	Division of Marine Fisheries (DMF)
Recommending and tracking shellfish growing area closures	DEH Shellfish Sanitation & Recreational Water Quality Section
Assessing lose of use of swimming waters and shellfish harvesting	DWQ Planning Section
Developing total maximum daily loads (TMDLs)	DWQ Planning Section
Posting swimming advisories	DEH Shellfish Sanitation & Recreational Water Quality Section

10.3.1 Recreational Water Quality Standards

DWQ conducts monthly ambient water quality monitoring that includes fecal coliform bacteria testing. In addition to DWQ ambient monitoring, the DEH tests coastal recreational waters (i.e., beaches, sounds, bays) for bacteria levels to assess the relative safety of these waters for swimming. If an area has elevated bacteria levels, health officials will advise people not swim in the area by posting a swimming advisory and by notifying the local media and county health department.

The fecal coliform standard for freshwater is 200 colonies per 100 milliliters (ml) of water based on at least five consecutive samples taken during a 30-day period, not to exceed 400 colonies per 100ml in more than 20 percent of the samples during the same period (15A NCAC 2B .0219). The 200 colonies per 100ml standard is intended to ensure that waters are safe enough for water contact through recreation. Class B waters are impaired in the recreation category if the water quality standard for fecal coliform bacteria is exceeded. Fecal coliform bacteria are identified as the stressor to these waters. Class C and WS waters are not rated if the geometric mean exceeds 400 colonies per 100 ml.

Coastal recreational waters are monitored through the DEH Recreational Water Quality Monitoring Program (http://www.deh.enr.state.nc.us/shellfish/Water_Monitoring/RWQweb/home.htm). Water quality objectives and criteria have been established with the main goal of protecting public health. By evaluating and monitoring the quality of North Carolina's coastal recreational waters, DEH can notify the public when bacteriological standards for safe bodily contact are exceeded. Specific objectives of DEH are to:

- Identify swimming areas/beaches and classify them based on human recreational usage.
- Identify monitoring stations that exceed the enterococci geometric mean and single-sample maximum criteria using the Enterolert Most Probable Number (MPN) method for enumeration.
- Evaluate the public health significance of approximately twenty (20) ocean stormwater outfalls/drains.
- Document trends in coastal bacteriological water quality.

DEH has established Tier I, II and III swimming areas/beaches based on their recreational usage. Swimming advisory signs are posted and press releases issued for Tier I swimming areas or beaches (swimming areas used daily) when a minimum of five samples, equally spaced over 30 days, exceed a geometric mean of 35 enterococci per 100 ml or when a single sample exceeds 500 enterococci per 100 ml. The public is notified only by press release, without an advisory sign, when a single sample exceeds 104 enterococci per 100 ml and is less than 500 enterococci per 100 ml. If a second sample exceeds 104 enterococci per 100 ml, an advisory is posted and the public will be notified by press release. An advisory will also be issued when at least two of three samples from a monitoring site exceed 104 enterococci per 100 ml. For an advisory to be rescinded, the station must have two consecutive samples below 35 enterococci per 100 ml.

In cases where a station under advisory is subject to triplicate sampling, two of the three samples must be under the single-sample maximum of 104 enterococci per 100 ml. If two of the three samples are above the single-sample maximum of 104 enterococci per 100 ml, an advisory will be put into place. The advisory will be rescinded when two of the three re-samples are under the single-sample level, as long as the running geometric mean of 35 enterococci per 100 ml has not been exceeded.

Beaches that violate the single-sample maximum criteria are re-sampled at the time of the public notification and/or sign posting, depending on the level of the exceedence. If the re-sample is satisfactory, the advisory may be lifted as early as 24 hours from the time of the initial advisory notification or posting. If the re-sample is unsatisfactory, but the geometric mean is not exceeded, the sign remains posted. If the re-sampling causes the exceedence of the geometric mean, then the geometric mean criteria apply.

The timeframe for posting swimming advisory signs at Tier I beaches, based on the enterococci geometric mean, runs from the beginning of May through the end of September. Weekly sampling of Tier I beaches is from April to October. During April and October, advisories at all Tier I monitoring sites are based on the single-sample maximum for Tier II beaches/swimming areas (276 enterococci per 100 ml.).

Tier II and Tier III beaches/swimming areas are sampled twice monthly from April to October, with the advisories based entirely on the single sample maximum criteria. For Tier II sites (areas are used infrequently and usually by watercraft), public notification and a swimming advisory sign are posted when a single sample exceeds 500 enterococci per 100 ml. A public notification without the advisory sign occurs when a single sample exceeds 276 enterococci per 100 ml but is less than 500 enterococci per 100 ml. If a second sample exceeds 276 enterococci per 100 ml, an advisory is posted and the public is notified. Weekly sampling of the site continues until the enterococci counts are less than 276 enterococci per 100 ml.

Because of infrequent use, Tier III swimming areas/beaches do not receive public notification or advisory signs until the second sample exceeds 500 enterococci per 100 ml. If the second sample exceeds 500 enterococci per 100 ml, an advisory sign and public notification are issued. Weekly sampling of the site will continue until the enterococci counts are less than 500 enterococci per 100 ml.

Other swimming advisories will be posted as precautionary measures when the following activities occur:

- Pumping of floodwaters between the primary dune and the ocean beaches.
- Stormwater outfalls/drains discharge onto ocean beaches. Storm drains that have flow that may be able to reach ocean recreational waters are posted with advisory signs.
- Disposal of dredge material from closed shellfishing waters on ocean beaches.

These swimming advisories are rescinded 24 hours after visible discharge into the ocean ceases. Swimming advisories are not posted from November through March; however, all sampling stations are sampled once per month during the non-swimming season.

DWQ does not directly use enterococci data from the DEH Recreational Water Quality Monitoring Program to assign use support ratings. The use support ratings applied to the recreation category are currently based on the state's fecal coliform bacteria water quality standard where ambient monitoring data are available or on the duration of local or state health agencies posted swimming advisories. The advisories are based on the state's enterococcus bacteria standards. Waters are impaired for recreation when swimming advisories are posted for more than 61 days during a five-year assessment period. Enterococci bacteria are identified as the stressor in these waters.

10.3.2 Shellfish Harvesting Water Quality Standards

The Shellfish Sanitation Section of DEH is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting for human consumption and the inspection and certification of shellfish and crustacean processing plants. Classifications of coastal waters for shellfish harvesting are done by means of a Sanitary Survey, which includes: a shoreline survey, a hydrographic survey and a bacteriological survey of growing waters. The shoreline survey identifies potential pollution sources. The hydrographic survey evaluates meteorological and hydrographic features of the area that may affect the distribution of pollutants. The bacteriological survey assesses water quality using bacteria as water quality indicators. Sanitary Surveys are conducted of all potential shellfish growing areas in coastal North Carolina and recommendations are made to the DMF of which areas should be closed for shellfish harvesting. Based on the results of the survey, waters are classified into one of five categories (Table 10-3).

DEH follows guidelines set by the Interstate Shellfish Sanitation Conference (ISSC) (http://www.issc.org/) contained in the *National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish Model Ordinance*. The U.S. Food and Drug Administration (FDA) administer the NSSP.

DWQ assesses use support for the shellfish-harvesting category based on the DEH growing area classification. By definition, conditionally approved-open (CAO) growing areas are areas that DEH has determined do not meet water quality standards; however, the pollutant event is known and predictable and can by managed by a plan. DWQ identifies these waters as impaired for shellfish harvesting. Conditionally approved-closed (CAC), restricted (RES) and prohibited (PRO) growing areas are also considered impaired for shellfish harvesting. Fecal coliform bacteria are identified as the stressor.

DWQ, DEH, Division of Coastal Management (DMC) (http://dcm2.enr.state.nc.us/) and DMF are engaged in developing a database with georeferenced (GIS) shellfish harvesting areas. The new database and GIS tools will be valuable for the several DENR agencies and local health departments to continue to work together to better serve the public. Using the new database with georeferenced areas and monitoring sites, DEH will be able to report the number of days each area is closed excluding closures related to large or named storms events.

10.3.3 On-site Wastewater Treatment

The On-Site Wastewater Section (OSWS) (http://www.deh.enr.state.nc.us/osww_new//index.htm) of DEH writes, oversees and enforces the rules and laws regulating the design, installation, repair, operation and maintenance of on-site wastewater treatment systems for the protection of human and environmental health from microbial contamination. OSWS provides statewide regulatory and consultative services to local health departments and numerous other clients, including builders, developers, land- and homeowners, system installers, system operators, engineers, soil scientists, geologists and environmental health consultants. However, an authorized environmental health specialist in each county health department conducts the actual implementation of the regulations (i.e., site evaluation, permitting of new systems).

Table 10-3 Shellfish Growing Area Classifications and Criteria

DEH Classification	Definitions and Water Quality Criteria
Approved (APP)	DEFINITION: These areas are always open to shellfish harvesting and close only after rare, heavy rainfall events such as hurricanes. CRITERIA: The median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of the water shall not exceed 14 per 100 milliliters (ml), and the estimated 90th percentile shall not exceed an MPN of 43 MPN per 100 ml for a 5-tube decimal dilution test. Under sampling for adverse pollution conditions, the median fecal coliform or geometric mean MPN of the water shall not exceed 14 per 100 ml, and not more than 10 percent of the samples shall exceed 43 MPN per 100 ml for a 5-tube decimal dilution test.
Conditionally Approved-Open (CAO)	DEFINITION: CAO areas permit shellfish harvesting when environmental conditions result in fecal coliform bacteria levels lower than the state standard in areas that otherwise might be closed for harvesting. These areas are open to harvesting much of the year but are closed immediately after certain rainfall events. There are concerns that these areas may be closed more often and stay closed for longer periods as development proceeds in coastal areas adjacent to Class SA waters. CRITERIA: 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 by a plan. These areas tend to be open more frequently than closed.
Conditionally Approved-Closed (CAC)	DEFINITION: CAC areas permit shellfish harvesting when environmental conditions result in fecal coliform bacteria levels lower than state standards in areas that are typically closed to shellfish harvesting. These areas are monitored regularly to determine if temporary openings are possible. These waters are rarely open to shellfish harvesting. CRITERIA: 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 by a plan. These areas tend to be closed more frequently than open.
Restricted (RES)	DEFINITION: Most of the RES and PRO areas receive runoff that consistently results in fecal coliform bacteria levels above the state standard. In many areas, contamination (fecal coliform bacteria) may be from several different sources at different times of year. CRITERIA: Sanitary Survey indicates limited degree of pollution, and the area is not contaminated to the extent that consumption of shellfish could be hazardous after controlled depuration or relaying.
Prohibited (PRO)	CRITERIA: Sanitary Survey is not routinely conducted; area is closed due to regulations related to the presence of point source discharges or marinas; or previous sampling data did not meet criteria for APP, CAO, CAC or RES classification.

All of the rules and regulations including horizontal setbacks, depth to groundwater, soils requirements, loading rates, etc., are specific to North Carolina and are based on scientific studies of microbial fate and transport. These rules are constructed to protect groundwater and surface water from microbial contamination as well as other contaminants. The onsite treatment regulations are devised to minimize migration of microbes and pathogens to groundwater and surface water. More information related to on-site waste management can be found on the DEH OSWS Web site (http://www.deh.enr.state.nc.us/osww_new//index.htm).

10.3.4 COASTAL STORMWATER REGULATIONS

North Carolina's current stormwater regulatory programs for coastal areas were adopted in the late 1980's as three primary coastal programs:

- Coastal (State) Stormwater Program.
- Shellfishing (Class SA) Waters Program.
- Outstanding Resource Waters (ORW) Program.

Each of these programs requires engineered stormwater control structures for high-density projects; however, no engineered stormwater controls are required for low-density projects. High density is defined as more than 24 percent built-upon area or more than two dwelling units per acre. Recent reviews of scientific literature, however, show that varying degrees of stream degradation and impairment occurs when there are no structural stormwater controls and 10 to 15 percent impervious surface cover is established (Mallin et *al*., 2000).

Since 1990, over 1,157 acres of Class SA, ORW waters have been closed to commercial shellfish harvesting in North Carolina due to elevated levels of bacteria. The Shellfish Sanitation Program through DEH notes that stormwater runoff is the primary cause of bacterial contamination in more than 90 percent of the shellfish areas sampled (Street et *al*., 2005).

In light of the increased acreage of areas closed to shellfish harvesting, DWQ embarked on a study of the current conditions and impacts to the state's shellfish waters. DWQ found that between 1988 and 2005, 73 percent of new impervious surfaces in coastal areas were constructed under low-density provisions (<24 percent impervious surfaces), which do not require engineered stormwater controls. Instead these low-density projects rely on practices such as grass swales to protect water quality. The use of swales for low-density areas indicates only a 25 percent effectiveness rate in reducing bacterial contaminants. Instead of protecting water quality, grass swales may actually contribute to bacterial loading by providing a conduit to increase runoff volumes and rates. In contrast, engineered stormwater controls for high-density areas include wet ponds and wetlands with 70 and 78 percent bacteriological removal rates, respectively, if they are installed and maintained properly.

DWQ assessed recent data and information on acres of shellfish closures in six tidal creeks in New Hanover County in the Neuse River basin (Mallin, 2006). The research focused on a county whose population grew 25 percent between 1990 and 2000 and is expected to increase an additional 31 percent by 2020. The research found a strong correlation between bacteria levels and impervious surfaces in the watershed – the greater the amount of impervious surfaces, the greater the bacteria levels. This correlation has also been documented by other research in South Carolina's coastal tidal creeks (Holland, 2004). In addition, there is a strong association between turbidity and fecal coliform bacteria levels in these estuarine waters.

DWQ's assessment of research results show that the acreages of shellfish waters closed to shellfish harvesting has increased significantly between 1988 and 2005, and there have been new closures after the implementation of the current stormwater programs. North Carolina waters permanently closed to shellfishing have increased by approximately 19 percent since 1984. The reliance on no engineered stormwater controls for low-density projects is the major identifiable shortfall in the current programs. Without changes to these programs, there will be continued degradation of shellfishing waters. More information on stormwater regulations and BMPs can be found in Chapter 5.

10.4 Reducing Water Quality Impacts from Bacteria

Even though state and federal agencies test water quality and regulate microbial pollution across the nation, it is actions taken by local governments and organizations that have the greatest potential to protect waterbodies from bacterial threats. The ideas and/or management strategies in this section are best implemented on the local level. Education, watershed planning, good site design, stormwater control and maintenance are practices that can be used to reduce total runoff volume and bacterial loading to improve water quality and habitat conditions.

> ***General Management Strategies to Address Bacteria in Surface and Groundwater***
>
> - ❑ Proper maintenance and pumping of septic tanks every three to five years.
> - ❑ Maintenance and repair of sanitary sewer lines.
> - ❑ Elimination of straight pipes.
> - ❑ Proper management of livestock to keep wastes from reaching surface water.
> - ❑ Encourage local health department to routinely monitor those areas known for organized swimming.

10.4.1 Reducing and Treating Stormwater Runoff

For the most part, bacteria enter recreational waterbodies through stormwater runoff. There are many aspects of development that can influence bacteria export from urban areas. Some of the most common are the size of the disturbed area, size of vegetated buffer, amount of impervious surface cover and the design and use of sediment or stormwater control devices. Table 10-4 identifies structural and nonstructural BMPs for urban stormwater control. Structural BMPs are typically designed to reduce sediment and the pollutants associated with it (i.e., nutrients, microbes, metals). In addition to reducing sediment and bacterial loads, structural BMPs can also stabilize streambanks and protect the riparian zone. Nonstructural BMPs such as a design manual or a public outreach and education program encourage comprehensive and effective implementation of structural BMPs. BMP characteristics, pollutant-specific effectiveness, reliability, feasibility, costs and design considerations can be found in the DWQ Manual of Stormwater Best Management Practices. The 1999 manual is being updated and the draft 2005 version is available on the DWQ Web site (http://h2o.enr.state.nc.us/su/Manuals_Factsheets.htm#StormwaterManuals). Information can also be found on the NC State University Department of Biological and Agricultural Engineering – Stormwater Engineering Group Web site (www.bae.ncsu.edu/stormwater/).

Table 10-4 Structural and Nonstructural BMPs for Urban Stormwater Control

Structural BMPs	Nonstructural BMPs	
❑ Wet Detention Basin ❑ Constructed Wetlands ❑ Wet Retention Basin ❑ Dry Detention Basin ❑ Infiltration Basin ❑ Vegetative Practices (i.e., filter strips, grass swales with check dams) ❑ Sand Filter ❑ Oil and Grease Separator ❑ Rollover Curbing	❑ Preventive Measures (i.e., limit impervious surface cover) ❑ Pollutant Minimization ❑ Exposure Reduction (i.e., schedule/rotate land disturbance) ❑ Landscaping and Lawn Maintenance Controls ❑ Animal Waste Collection ❑ Curb Elimination ❑ Parking Lot and Street Cleaning	❑ Catch Basin Cleaning ❑ Riparian Area Protection ❑ Public Education ❑ Identification and Enforcement of Illegal Discharges ❑ Land Use Control (i.e., low impact development, comprehensive site planning, riparian zone protection, conservation easement)

10.4.2 Land Use Planning to Reduce Impacts of Future Development

A variety of land use planning techniques and policy options are available for a community to consider in addressing nonpoint source pollution management and general water quality problems. Zoning restrictions, development and design standards and BMPs can be incorporated into many existing town and county ordinances, but each locality must decide how best to allocate limited resources to protect water quality and prevent nonpoint source pollution while still supporting economic growth. The only mandate for local land use plans in North Carolina is the Coastal Area Management Act (CAMA), which requires land use plans for all twenty coastal counties. The land use plan examines the relationship between land uses and other areas of interest such as transportation, recreation, infrastructure and protection of natural resources. Through a planning process, a community gathers data and public input in an attempt to guide a community's future development (WECO, 2003).

Residents and visitors to North Carolina are beginning to speak out and demand more protection of the natural resources people enjoy. Several examples can be found throughout the State where citizen complaints and participation in local planning decisions have resulted in better and more protective measures being installed in new residential and commercial developments. This is particularly true in the twenty coastal counties.

Many communities are looking at the challenges and opportunities that development offers to their communities seriously. For example, much of the Bogue Sound in the White Oak River basin is closed to shellfish harvesting. Bogue Watch, which drains into Bogue Sound, is a new development in Carteret County that is designed to control stormwater runoff and protect the natural environment surrounding the sound. Site plans indicate that the development contains 287 lots with facilities (i.e., fishing piers, parks) on the water. The subdivision, which has nearly 25 percent of its land surface planned for impervious surfaces, will have six common areas with five waterfront parks and piers. There will also be five holding ponds for stormwater runoff, vegetated areas to filter runoff, 38 acres of open space and several large ponds for treated wastewater. Four lots are not being developed to allow for stormwater controls. Based on the local community, the developer determined that it was important to design Bogue Watch in such a way that it would balance the community's quality and way of life with environmental protection.

Outside of Carteret County in the White Oak River basin, the Town of Bath (Beaufort County) approved a 6-month moratorium on new subdivisions. The moratorium allowed the town board time to assess how the town wanted to develop its remaining waterfront lots and where the town needed to protect its resources. In addition, Pamlico County approved an ordinance to limit density and height of developments along the water.

Proactive planning efforts at the local level are needed to assure that development is done in a manner that maintains water quality. Used effectively, land use planning can find a balance between water quality protection, natural resource management and economic growth. Growth management requires planning for the needs of future population increases, as well as developing and enforcing environmental protection measures. These actions are critical to water quality management and the quality of life for the residents of North Carolina. County and regional land use plans should incorporate proactive measures to meet future growth demands to prevent water quality deterioration and consider cumulative impacts to water quality. They should incorporate strategies such as land conservation, open space and riparian area protection to reduce the amount of stormwater runoff, and consequently, bacteria entering a surface waterbody

Planning Recommendations for New Development

- ❑ Minimize number and width of residential streets.
- ❑ Minimize size of parking areas (angled parking & narrower slots).
- ❑ Place sidewalks on only one side of residential streets.
- ❑ Minimize culvert pipe and hardened stormwater conveyances.
- ❑ Vegetate road right-of-ways, parking lot islands and highway dividers to increase infiltration.
- ❑ Plant and protect natural buffer zones along streams and tributaries.

To prevent further impairment in urban watersheds, local governments should:

- ❑ Identify and protect waters that are threatened by development.
- ❑ Protect existing riparian habitat along streams and restore it where possible.
- ❑ Implement stormwater BMPs during and after development.
- ❑ Develop land use and site development plans that minimize disturbance in sensitive areas.
- ❑ Minimize impervious surfaces including roads and parking lots.
- ❑ Develop public outreach programs to educate citizens about stormwater runoff.

Action needs be taken at the local level to plan for new development in urban and rural areas. For more detailed information regarding recommendations for new development, refer to EPA's Watershed Academy Web site (www.epa.gov/owow/watershed/wacademy/acad2000/protection). Information can also be found on the Center for Watershed Protection Web site (www.cwp.org) and the Web site for the Low Impact Development Center (www.lowimpactdevelopment.org). Land use planning and management techniques can also be found in the Nonpoint Source Pollution Prevention and Control through Land Use Planning and Management Document available on the DWQ Web site (http://h2o.enr.state.nc.us/nps/CNPSCP/documents/FinalNPSManual.pdf). For an example of local community planning effort to reduce stormwater runoff, visit www.charmeck.org/Home.htm.

10.4.3 On-site Wastewater Management

Throughout the state, the increase in development has resulted in an increase in demand for individual wastewater treatment systems. Many require higher flows on small tracks of land. Wastewater from many households is not treated at wastewater treatment plants associated with NPDES discharge permits. Instead, it is treated on-site through the use of permitted septic systems. Poorly planned and/or maintained systems can fail and contribute to nonpoint source pollution. Wastewater from some of these homes illegally discharges directly to streams through what is known as a "straight pipe". In other cases, wastewater from failing septic systems makes its way to streams or contaminates groundwater. Straight piping and failing septic systems are illegal discharges of wastewater into waters of the state.

With on-site septic systems, the septic tank unit treats some wastes, and the drainfield associated with the septic tank provides further treatment and filtration of the pollutants and pathogens found in wastewater. A septic system that is operating properly does not discharge untreated wastewater to streams and lakes or to the ground's surface where it can run into nearby surface waters. Septic systems are a safe and effective long-term method for treating wastewater if they are sited, sized and maintained properly. If the tank or drainfield are improperly located or constructed, or the systems are not maintained, nearby wells and surface waters may become contaminated, causing potential risks to human health. Septic tanks must be properly installed and maintained to ensure they function properly over the life of the system. Information about the proper installation and maintenance of septic tanks can be obtained by calling the environmental health sections of the local county health departments.

Several studies have evaluated septic systems and the impact they can have on bacterial numbers within a waterbody. For example, research in areas of South Florida found that septic tanks in porous soils can readily pass through the soil and enter coastal waters near the shore within hours. In some areas, fecal bacteria counts were higher upon outgoing tides and in wetter years due to subsurface movement through saturated soils and increased runoff due to rain. Ditching and draining appear to facilitate the flow of septic waste to surface waters (Paul et *al*. 2000). The conclusion – sandy soils and high water tables appear to be unsuitable for septic systems, yet these systems are relied on heavily in many coastal areas (including eastern North Carolina) for waste management.

Research (Tschetter and Maiolo, 1984) has also shown a correlation between coastal population growth in North Carolina and the closure of waters to shellfishing. Unfortunately, this work is too general to be useful for land management purposes. A specific study of coastal watersheds in New Hanover County (Duda and Cromartie, 1982), however, found that closings generally occurred in areas that had more than one septic system drainfield per every seven acres of watershed. It is unclear how subsurface drainage networks may have contributed to the closings, or how widely the results of this investigation can be applied. The results, however, indicate that there is an empirical relationship between land development and shellfish water closures that should not be ignored if shellfish waters are to be adequately protected or restored.

Local governments around the country are finding innovative ways to address improperly installed and/or failing septic systems. For example, in order to protect water quality in the Chesapeake Bay, Arlington County, Virginia has adopted an ordinance requiring all septic tanks be pumped at least once every five years (USEPA, 1993). Stinson Beach, California developed a management program for on-site systems after discovering that malfunctioning systems were threatening public health (Herring, 1996). Homeowners here pay a monthly fee to cover the cost of inspections and testing, in addition to any construction and repair costs (USEPA, 1993). In the Puget Sound area, where a significant shellfish resource has been threatened by fecal coliform contamination from a number of sources, most counties have established revolving loan funds to facilitate the repair of failing systems (Center for Watershed Protection, 1995).

Experience has shown that widespread community support is generally necessary to mount an effective campaign that addresses septic system contamination issues, and that this support is unlikely to be forthcoming in the absence of any significant perceived benefits (Herring, 1996). In North Carolina, the Wastewater Discharge Elimination (WaDE) Program (http://www.deh.enr.state.nc.us/osww_new//WaDE.htm) through the OSWS in DEH was established pursuant to Senate Law 1996-18es2, Section 27.26 (http://www.ncleg.net/gascripts/BillLookUp/BillLookUp.pl?Session=1995e2&BillID=H53), to identify and eliminate discharges from straight pipes and failing septic systems to land surfaces and streams. Funds appropriated by the NC General Assembly support a two-member team to address the straight pipe and failing septic system issues in North Carolina. Additional financial support has been secured through grants from the NC CMTF and the EPA 319 Non-Point Source Program (http://www.epa.gov/owow/nps/cwact.html).

Strong collaboration with local and federal agencies as well as the public, the media and environmental groups is the hallmark of the WaDE program and the key to its successes thus far.

10.4.4 Monitoring Sanitary Sewers

Sewer connections can leak or rupture, allowing sewage to flow into surface waterbodies. Common causes of sewer failures and overflows are tree roots growing into sewer lines, excessive rainfall and age. Grease, a by-product of cooking, can also enter sanitary sewers through household and/or restaurant drains. Grease sticks to the inside of sewer pipes, building up over time. If the entire sewer pipe becomes blocked, sewage can overflow into yards, streets and surface water.

To help prevent bacterial contamination from human and industrial waste, communities should evaluate where sewer lines are in relation to a stream corridor, replace fractured or damaged sewer lines and monitor lines regularly. When evaluating the need for sewer line extensions, communities should keep in mind that extensions to existing water and sewer lines encourage more development, which often results in more impervious surface cover and nonpoint source pollution from cumulative and secondary impacts.

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