

CHAPTER 11 – NUTRIENTS AND IMPACTS TO WATER QUALITY

Nutrients are chemical elements and compounds found in the environment that plants and animals need to grow and survive. For water-quality investigations, the various forms of nitrogen and phosphorus are the nutrients of interest. The forms include nitrate, nitrite, ammonia, organic nitrogen (in the form of plant material or other organic compounds) and phosphates (orthophosphate and others). Nitrate is the most common form of nitrogen and phosphates are the most common forms of phosphorus found in natural waters. High concentrations of nutrients in waterbodies can potentially cause eutrophication and hypoxia (USGS, December 2006).

Nitrogen and phosphorus are common components of fertilizers, animal and human wastes, vegetation, aquaculture and some industrial processes. Nutrients in surface waters come from both point and nonpoint sources including agricultural and urban runoff, wastewater treatment plants, forestry activities and atmospheric deposition. Nutrients in nonpoint source runoff come mostly from fertilizer and animal wastes. Nutrients in point source discharges typically come from human waste, food residues, cleaning agents and industrial processes.

This chapter provides an overview of nutrients (phosphorus and nitrogen) and how they can impact water quality, defines nutrient sensitive waters (NSW) and management strategies that have been adopted by the state to protect those waters, and reviews lake and estuary nutrient monitoring protocols and strategies.

11.1 IMPACTS TO WATER QUALITY

The primary limiting nutrients in freshwaters are phosphorus (P) and nitrogen (N). A limiting nutrient is a chemical necessary for plant growth. Once the limiting nutrient is exhausted, plant growth ceases. Phosphorus and nitrogen have different chemical properties and are involved in different chemical processes; however, both are transported to receiving waterbodies by rain, stormwater runoff, groundwater and industrial and residential waste effluents. Phosphorus is a mineral nutrient introduced into biological processes through the breakdown of rock and soil minerals. It is primarily found in two forms – organic and inorganic. Phosphorus readily adsorbs to clay particles in the water column, which reduces its availability for uptake by algae, bacteria and macrophytes (aquatic plants).

Nitrogen (N_2), however, is primarily found in the air. Nitrogen gas is not readily available for plant uptake; however, a number of bacteria and cyanobacteria (blue-green algae) are able to convert nitrogen gas to a useable form. Most plants and animals utilize ammonium (NH_4^+) and nitrate (NO_3^-) ions – the mineral forms of nitrogen – in everyday biological functions (EPA, July 2000). Both are important factors to consider when evaluating watershed function and health.

11.1.1 ECOLOGICAL IMPACTS

While nutrients are beneficial to aquatic life in small amounts, excessive nutrient concentrations can stimulate algal blooms and plant growth in streams, ponds, lakes, reservoirs and estuaries and along shoreline. Through respiration and decomposition, algal blooms can deplete the water column of dissolved oxygen and contribute to serious water quality problems. Algal blooms can

also be aesthetically undesirable, alter the native composition and species diversity of aquatic communities, impair recreational uses of surface waters, impede commercial fishing and pose problems for water treatment systems. In many waterbodies, light, temperature, algal buoyancy, organic and inorganic nutrients and predation by larger organisms (i.e., zooplankton, crustaceans, rotifers, etc.) will influence algal growth (Wetzel, 2001).

Algal growth and the depletion of dissolved oxygen caused by nutrient enrichment fluctuate seasonally, sometimes over the course of a single day (diurnal fluctuations). In the presence of sunlight, for example, algae and other plants produce oxygen through the process of photosynthesis. At night, however, photosynthesis and dissolved oxygen production slow down causing oxygen to be consumed by algae through respiration. During the summer months, the daily cycle of daytime oxygen production and nighttime depletion can result in supersaturation - a condition that occurs when dissolved oxygen levels are greater than the saturation value for a given temperature and atmospheric pressure. High dissolved gas levels can be lethal to fish populations by inhibiting respiratory processes.

Algae may also settle to the bottom of a waterbody and contribute to sediment oxygen demand (SOD) as it decomposes through bacterial action. This type of decomposition lowers dissolved oxygen concentrations in the bottom waters of lakes, rivers and estuaries. Hypoxia – waters that contain less than 2 parts per million (ppm, or 2 milligrams per liter) dissolved oxygen – can cause severe stress and even kill bottom dwelling organisms. This loss of biological activity and fish kills can lead to significant cultural and economic impacts on local communities dependent on recreational and commercial fisheries (EPA, July 2000).

Many aquatic plants positively affect water quality by removing and storing nutrients from the aquatic system. They also provide food and shelter for many aquatic organisms. Excess N and P inputs, however, can lead to excessive growth. Some examples of aquatic plants include milfoil, alligator weed and *Hydrilla*. Diurnal changes in pH and dissolved oxygen, which occur during photosynthesis and respiration, impact the release and/or uptake of heavy metals or other toxic substances in the water column. If water clarity is decreased (turbidity increases and sunlight cannot penetrate the water column), macrophytes can die, but algae may thrive and create a dense algal mat. Increased algal biomass and loss of macrophytes can reduce habitat availability, change water chemistry and alter aquatic species diversity and abundance (EPA, July 2000).

Chlorophyll *a*, a constituent of most algae, is a widely used indicator of algal biomass. North Carolina has a chlorophyll *a* standard of 40 $\mu\text{g/l}$ (micrograms per liter) for lakes, reservoirs and slow-moving waters not designated as trout waters and a 15 $\mu\text{g/l}$ standard for trout waters.

11.1.2 HUMAN HEALTH AND RECREATIONAL IMPACTS

Light, temperature, substrate, existing water chemistry and biological communities play a role in the nuisance level of algae and macrophytes within a waterbody. Algal blooms and macrophytes often interfere with aesthetic and recreational uses, cause taste and odor problems in drinking water supplies and can even become toxic depending upon the type of algal growth.

Human health problems associated with nutrient enrichment include the formation of trihalomethanes (THMs). THMs are produced when certain organic compounds (i.e., humic

substances, algal metabolites and decomposition products) are chlorinated or brominated during the disinfection process for drinking water purposes. THMs are carcinogenic. Their production is highly dependent upon the density of algae and the level of eutrophication in the raw water supply (EPA, July 2000).

Nutrient enrichment can also cause methemoglobinemia (“blue-baby syndrome) in infants less than 6 months of age. Methoemoglobinemia or “blue-baby” syndrome is a potentially fatal blood disorder for infants less than six months old. The disorder reduces the oxygen-carrying capacity of blood. It is associated with nitrates in drinking water above the Maximum Contaminant Level (MCL) of nitrate as nitrogen (NO₃-N) at 10 ppm as set by the US Environmental Protection Agency (EPA) (Benton Franklin Health District, 2002; EPA, July 2000).

One of the most expensive impacts of nutrient enrichment is the increase in time and money required to treat drinking water. Algae and macrophytes can clog filters, corrode intake pipes and require greater volumes of water treatment chemicals (EPA, July 2000).

11.1.3 RESERVOIR AND LAKE EUTROPHICATION

Eutrophication is a process where waterbodies, such as lakes, estuaries or slow-moving streams, receive excess nutrient that stimulate excessive plant growth (algae, periphyton attached to algae and nuisance plant weeds). When a surface waterbody becomes nutrient rich, is biologically productive and able to support high levels of algal or macrophytic growth, it is classified as eutrophic. As a group, reservoirs tend to have higher inflows. Thus, nutrient loads are higher in reservoirs than natural lakes and are more likely to be eutrophic. In North Carolina, this is especially true of piedmont reservoirs.

The classical lake succession sequence is usually depicted as a unidirectional progression corresponding to a gradual increase in lake productivity from oligotrophy to hypereutrophy. In watersheds that remain relatively undisturbed, lakes can retain the same trophic status for thousands of years. On the other hand, rapid changes in lake nutrient status and productivity are often the result of cultural eutrophication - human disturbances in the watershed - rather than gradual enrichment and filling of the lake through natural processes.

Eutrophic conditions can, but do not always, interfere with the designated use of a waterbody. Eutrophication in North Carolina reservoirs is often associated with a shift in the phytoplankton community towards a system dominated by blue-green algae. Blue-green algae are notorious for taste and odor problems that often require additional (and more expensive) treatment to make the finished drinking water palatable. Blue-green algae are also a very poor food source for herbaceous fish and large zooplankton. This can lead to a change in the composition of lake fish

LAKE TROPHIC LEVELS

Oligotrophic

Nutrient-poor and low biological productivity. Typical of cold-water lakes.

Mesotrophic

Intermediate nutrient availability and biological productivity.

Eutrophic

Nutrient-rich and highly productive.

Hypereutrophic

Extreme productivity characterized by algal blooms or dense macrophytes populations or both frequently having a high level of sedimentation.

and/or a need for more frequent stocking of prey fish (i.e., threadfin shad) to support the game fish population.

11.1.4 COASTAL ECOSYSTEMS

Eutrophication of coastal rivers, estuaries and bays can change the structure of entire ecological communities and impact the economic viability of local fisheries. Indirectly, eutrophication can deplete oxygen from the water column creating hypoxic and anoxic conditions, which reduces habitat suitability for many species and changes interactions between predators and their prey.

For example, periods of low oxygen tend to shift the seafloor community away from large, long-lived clams to much smaller, opportunistic, short-lived species that can colonize and complete their life cycle between periods of hypoxia. Zooplankton, which would normally migrate toward the bottom waters during the day to avoid predation, are forced to remain near the surface where they are readily seen by fish that prey on them. Directly, increased nutrients alter community structure by impacting algal species. Some species are well adapted to low-nutrient conditions, while others prefer high N and P levels. These differences allow for diverse algal species in coastal communities; however, eutrophication can alter their diversity and abundance (Howarth *et al.*, 2000).

Changes in algal species can also impact the viability of local fisheries. Moderate nutrient enrichment can lead to an increase of economically viable fish. More algae means more zooplankton, a food source for many fish species. Severe nutrient enrichment, however, can limit the amount of viable fish and alter the biological diversity and abundance of some species. Coral reefs and seagrass beds can also be impacted by nutrient enrichment due to changes in both algal and fish species (Howarth *et al.*, 2000).

11.2 NUTRIENT SENSITIVE WATERS AND NUTRIENT MANAGEMENT STRATEGIES TO PROTECT WATER QUALITY

Reductions in nutrient loads are needed to limit the potential for algal growth and fish kills and to assure the protection of instream chlorophyll *a* standards in the state's waterways. Point source controls typically include permit limitations for total phosphorus (TP) and/or total nitrogen (TN) levels through the National Pollutant Discharge Elimination System (NPDES) permitting process. Nonpoint source controls of nutrients generally include best management practices (BMPs) that control nutrient loading from agricultural land, urban areas and other nonpoint sources. Several structural and nonstructural BMPs are discussed throughout this document, but there are also several state mandated nutrient strategies in place to limit nutrient enrichment throughout several North Carolina watersheds.

11.2.1 NUTRIENT SENSITIVE WATERS

Nutrient sensitive waters (NSW) is a supplemental water classification applied to waters that are experiencing, or are subject to, excessive growths of microscopic or macroscopic vegetation. The NC Environmental Management Commission (EMC) defines excessive vegetative growth as that

WATERS CLASSIFIED AS NSW

- Neuse River basin
- Tar-Pamlico River basin
- Chowan River basin
- New River watershed in the White Oak River basin
- Jordan Lake (Reservoir) watershed in the Cape Fear River Basin

growth which can substantially impair the use of a waterbody for its best usage as determined by the classification applied to that waterbody (Rule 15A NCAC 02B.0223).

NSW may include any or all waters within a river basin that the EMC deems is necessary to effectively control excessive growths of aquatic vegetation. For the purposes of this classification, "nutrients" refers to phosphorus and nitrogen, although other nutrients or chemicals may be specified if it is determined that they are essential to the growth of aquatic vegetation.

No increase in nutrients over background levels is allowed within NSW waters unless it can be shown that:

- ❑ The increase is the result of natural variations;
- ❑ The increase will not endanger human health, safety or welfare; and
- ❑ Preventing the increase would cause a serious economic hardship without equal or greater public benefits.

In addition to being classified as NSW, waters in the Neuse and Tar-Pamlico River basins are protected by a set of permanent rules. The rules are part of a management strategy to reduce nutrient inputs throughout the entire river basin. Both sets of rules are the result of problems associated with excess nutrient enrichment in and near the estuaries – low dissolved oxygen levels, harmful algal blooms, fish kills and other symptoms of stress and diseases to the aquatic community.

11.2.2 NORTH CAROLINA'S NUTRIENT CRITERIA IMPLEMENTATION PLAN

North Carolina firmly believes that a proactive management strategy based on adaptive management techniques is the most viable method to control excessive nutrients from point and nonpoint sources. North Carolina has established itself as a leader in the field of site-specific, flexible nutrient control strategies through the implementation of a comprehensive nutrient management program for surface waters. This existing program has included nutrient response criteria, ambient monitoring programs, use support methodologies, nutrient TMDLs, nitrogen and phosphorous permit limits and the supplemental classification NSW for certain waters of the State.

North Carolina recognizes that additional proactive nutrient control measures are warranted based upon the latest advances in nutrient management practices and the continued eutrophication of waters. Accordingly, DWQ has developed a plan for nutrient control in surface waters across the state. The plan is designed to build upon and refine the nutrient control achievements that have already been attained in the State. It is the goal of the Nutrient Criteria Implementation Plan to reduce and protect surface waters from eutrophication by developing regionally-specific nutrient response criteria that will be augmented by site-specific nitrogen and phosphorous control mechanisms. Additional information that provides a defensible linkage of cause to response to effect will be a prerequisite to completely understand the causal variable data. The full details of the Nutrient Criteria Implementation Plan and North Carolina's agreement with Region 4 Environmental Protection Agency (EPA) can be found on the

Classifications and Standards Unit Web site
(http://h2o.enr.state.nc.us/csu/swstdsfaq.html#NC_Nutrient_Plan).

11.2.3 NUTRIENT MANAGEMENT STRATEGIES – TAR-PAMLICO RIVER BASIN

The Tar-Pamlico River Basin is the fourth largest river basin in North Carolina and a major tributary to the Pamlico Sound. Together, the Pamlico Sound and neighboring Albemarle Sound constitute one of the most productive estuarine systems in the country and are part of the EPA's National Estuary Program.

The Tar-Pamlico River basin begins in the Piedmont of North Carolina and extends approximately 180 miles through the Coastal Plain to the Pamlico Sound. The Tar River collects water from approximately 2,300 miles of freshwater streams before entering the estuarine Pamlico River at Washington. The 5,400 square mile basin encompasses portions of 17 counties, including the cities of Rocky Mount, Tarboro and Greenville, as well as many agricultural and forested areas. The basin also provides a habitat for nine state or federally listed threatened or endangered freshwater mussel species and includes two national wildlife refuges (Lake Mattamuskeet and Swan Quarter).

Throughout the mid-1970s and 1980s, algal blooms and fish kills in the upper Pamlico estuary were linked to excessive nutrient levels in the river. Following a record-setting year of reported fish kills in 1989, the EMC supplementally classified the Tar-Pamlico River Basin as NSW. On December 14, 1989, the EMC approved the first phase of a nutrient management strategy (Phase I) that targeted point sources of pollution (i.e., wastewater, industrial and commercial effluent). Several of the discharges formed the Tar-Pamlico Basin Association (the Association). Working with the state and several environmental groups, the Association presented an innovative nutrient-trading program between point and nonpoint sources of pollution. The Association agreed to either reduce their nutrient loading to the estuary or, if they exceeded an annual collective loading cap, to fund agricultural BMPs through the state's existing Agricultural Cost Share Program (ACSP). This agreement allowed discharges in the Association to find more cost-effective ways to collectively meet the nutrient-loading cap. The Agreement also provided a more cost-effective nutrient reduction alternative if the Association couldn't meet its cap – payments for agricultural BMPs that are documented to be more cost effective than retrofits or treatment modifications during expansion. Phase I ran from 1990 to 1994.

Phase II (1995 to 2004) of the program was adopted by the EMC in December 1994 and used an estuarine model to establish an interim goal of a 30 percent reduction in total nitrogen loads to the estuary from the 1991 conditions and no increase in the phosphorus loads. The EMC noted that these rules could be adjusted in the future to reflect progress (or lack thereof) in achieving the goal. The goal would also be adjusted to reflect changes in technology and BMPs. Phase II also includes a separate nonpoint source strategy that initially began as a voluntary program in 1996. The voluntary plan relied on the existing program to achieve the goals through better targeting, coordination and increased efforts to obtain resource agency staff and cost share resources. It also included action plans for nine different nonpoint source categories: agriculture, forestry, urban stormwater, construction, on-site wastewater, solid waste disposal, wetlands, groundwater and atmospheric deposition.

In July 1998, the EMC determined that voluntary reduction of nonpoint source pollution was inadequate and called for rule development to achieve the nonpoint source reduction goals. Seven professionally facilitated stakeholder teams were formed to evaluate all aspects of the rule making process. Between December 1999 and September 2001, the EMC adopted a set of rules covering four subject areas for the Tar-Pamlico River basin – riparian buffers, nutrient management, urban stormwater and agriculture (Table 11-1). Since it was estimated that agricultural practices (i.e., crops, animal operations, etc.) were responsible for most of the nonpoint source nutrient loading in the estuary, the agricultural community was tasked with achieving most of the nonpoint source reductions. Annual reports are presented to the EMC to provide updates on the effectiveness of the nutrient management strategies implemented by the agricultural community.

Phase III of the nutrient management strategies was adopted by the EMC in April 2005 and continues the structure established in Phase II. The Phase III agreement updated the point source association membership and related nutrient caps. It proposed actions within the first two years of its adoption to improve the nutrient offset rate, resolve related offset credit issues and revisit alternative offset options. It also established a ten-year estuary performance objective. More information on the Tar-Pamlico River Nutrient Management Strategies can be found on the

Table 11-1 Rules Adopted by the EMC for Nutrient Management in the Tar-Pamlico River Basin

Rule Subject	Rule Number	Effective Date	Purpose
Riparian Buffers	15A NCAC 2B .0259	August 2000	Protects and preserves existing riparian buffers and maintain nutrient removal functions.
- Protection	15A NCAC 2B .0260	August 2000	Sets forth mitigation requirements that apply to the riparian buffer protection program.
- Mitigation	15A NCAC 2B .0261	August 2000	Defines the requirements for delegating implementation and enforcement of the buffer protection program.
Nutrient Management	15A NCAC 2B .0257	April 2001	Establishes the five-year goal of reducing nitrogen loading in the Pamlico estuary by 30 percent (based on 1991 levels) and capping phosphorus loading.
Stormwater Requirements (Basinwide) ¹	15A NCAC 2B .0258	April 2001	Achieve and maintain the goals for N and P reduction in the estuary; provide control for peak stormwater flows from new development to ensure existing riparian buffers and streams are not compromised by channel erosion; and minimize N and P loading from existing developed areas.
Agriculture – Nutrient Loading Goals	15A NCAC 2B .0255	April 2001	Specifies that agricultural operations (i.e., crops, horticulture, livestock, poultry) collectively meet the N and P reduction goals.
Agriculture – Nutrient Control Strategies	15A NCAC 2B .0256	September 2001	Defines processes by which agricultural operations will collectively limit N and P loading to the estuary.
<p>¹ In September 2004, DWQ updated the stormwater nutrient removal efficiencies for stormwater BMPs under the Rule .0258. The memo can be found on the DWQ website (http://h2o.enr.state.nc.us/nps/documents/BMPNutrientRemovalEfficiencies_001.pdf). The DWQ Stormwater Manual can alls be found on the DWQ Web site (http://h2o.enr.state.nc.us/su/Manuals_Factsheets.htm).</p>			

DWQ Planning Section Web site

(<http://h2o.enr.state.nc.us/nps/tarpam.htm#Buffer%20Protection%20Rules>). Specific rule language can be found in the document *Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands (15A NCAC 2B .0200)* (<http://h2o.enr.state.nc.us/admin/rules/documents/rb080104.pdf>).

11.2.4 NUTRIENT MANAGEMENT STRATEGIES – NEUSE RIVER BASIN

The Neuse River originates in north central North Carolina, flows southeast until it broadens and changes from a free-flowing freshwater river to a tidal estuary that eventually flows into the Pamlico Sound. The Neuse River basin is the third largest river basin in North Carolina and one of only four major river basins whose boundaries are located entirely within the state.

The Neuse River collects water from approximately 3,500 miles of freshwater streams, 16,000 acres of freshwater reservoirs and lakes and 37,000 acres of estuarine waters. The 6,200 square mile basin encompasses portions of 18 counties, including the cities of Raleigh, Durham, Goldsboro, Kinston, New Bern and Wilson, as well as many agricultural and forested areas.

Throughout the late 1970s and early 1980s, eutrophication in the lower Neuse River basin was evident with nuisance algal blooms prevalent in the upper part of the estuary. In 1988, following several years of nuisance algal blooms, the EMC supplementally classified all waters in the Neuse River basin as NSW. Years following the NSW classification still showed that excess nutrients were still a problem in the estuary. In 1996, given the long history of problems associated with excess nutrients in the Neuse River basin, the EMC held four public hearings concerning the adoption of rules to control nitrogen and phosphorus loading throughout the entire river basin. In December 1997, the EMC adopted permanent rules to support implementation of Neuse River Nutrient Sensitive Waters Management Strategies. The goal was to reduce the average annual load of nitrogen delivered to the Neuse River estuary from point and nonpoint sources by a minimum of 30 percent from the average annual load calculated from the period of 1991 to 1995 (Table 11-2). The regulated community had to comply with these rules within five years of the effective date of August 1, 1998. Annual reports are presented to the EMC to provide updates on the effectiveness of the nutrient management strategies implemented by the agricultural community. More information on the Neuse River Nutrient Management Strategies can be found on the DWQ Planning Section Web site (http://h2o.enr.state.nc.us/nps/Neuse_NSW_Rules.htm). Specific rule language can be found in the document *Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands (15A NCAC 2B .0200)* (<http://h2o.enr.state.nc.us/admin/rules/documents/rb080104.pdf>).

11.2.5 NUTRIENT MANAGEMENT FOR LANDOWNERS

People often think of agriculture, industries and big business when it comes to water pollution, but individuals contribute to water pollution as well. Eroded soil, automotive fluids, fertilizer, pet waste, trash and other contaminants are often a part of every day activities. While each

individual's contribution may seem very small, the cumulative effect over time can have a significant impact on North Carolina's waterways.

Individuals can reduce their water pollution contribution by reducing the volume of stormwater leaving their property and by reducing the amount of pollutants used for household cleaning and/or landscaping yards. Landowners often apply commercial fertilizers and pesticides before evaluating the soil's chemistry for nutrient concentrations. This often leads to over application of nutrients. The nutrients (i.e., nitrogen and phosphorus) that are not utilized by plants will become mobile during a rain event and enter the nearest waterbody as part of the stormwater runoff. Landowners should remember to use only the amount necessary and be careful to avoid paved or hardened surfaces that act as expressways for pollutants into the state's waterways. More stormwater management strategies for homeowners can be found in the brochure *Improving Water Quality in Your Own Backyard* available on the DWQ Web site (<http://h2o.enr.state.nc.us/Wateryouknow.htm>).

Table 11-2 Rules Adopted by the EMC for Nutrient Management in the Neuse River Basin

Rule Subject	Rule Number	Effective Date	Purpose
Basin Nutrient Reduction Goal	15A NCAC 2B .0232	August 1998	Establishes the five-year goal of reducing N loading in the Neuse River estuary by 30 percent (based on average annual loads from 1991 to 1995).
Riparian Buffer Protection	15A NCAC 2B .0233	August 2000	Protects and preserves existing riparian buffers in the basin to maintain nutrient removal functions.
Wastewater Discharge Requirements	15A NCAC 2B .0234	January 1998 (Temporary) August 1998 April 2003 (Amended)	Establishes minimum nutrient control requirements for point source discharges to maintain or restore the water quality in the estuary and protect designated uses.
Stormwater Requirements (Basinwide) ¹	15A NCAC 2B .0235	August 1998	Identifies local governments that must implement stormwater controls to control nutrient loading in the estuary.
Agriculture Nitrogen Loading Reduction	15A NCAC 2B .0236	August 1998	Specifies that all persons engaging in agricultural operations must collectively achieve and maintain the 30 percent N reduction goal.
BMP Cost-Effectiveness Rate (BMPc)	15A NCAC 2B .0237	April 1997	Establishes the BMPc, which is the cost to achieve reduction of one kilogram of total N through the use of BMPs.
Agriculture Nitrogen Reduction Strategy	15A NCAC 2B .0238	September 2001	Explains the requirements that apply to all persons who engage in agricultural activities; establishes the formation of a Basin Oversight Committee (BOC) and local advisory committees.
Nutrient Management	15A NCAC 2B .0239	August 1998	Identifies persons responsible for obtaining training certificates for nutrient management (i.e., persons who apply fertilizers, develop nutrient management plans, etc.).
Nutrient Offset Payments	15A NCAC 2B .0240	August 1998	Establishes that an offset payment can be made if nutrient management controls are not meeting the N reduction goal.
Riparian Buffer Mitigation	15A NCAC 2B .0241	August 2000	Defines the requirements for delegating implementation and enforcement of the buffer protection program (.0233).
Mitigation Program	15A NCAC 2B .0242	August 2000	Defines the mitigation requirements that apply to the existing riparian buffer protection program (.0233).
<p>¹ In September 2004, DWQ updated the stormwater nutrient removal efficiencies for stormwater BMPs under the Rule .0258. The memo can be found on the DWQ website (http://h2o.enr.state.nc.us/nps/documents/BMPNutrientRemovalEfficiencies_001.pdf). The DWQ Stormwater Manual can alls be found on the DWQ Web site (http://h2o.enr.state.nc.us/su/Manuals_Factsheets.htm).</p>			

11.3 MONITORING NUTRIENTS

11.3.1 EVALUATING ALGAE AND AQUATIC PLANTS

The Algal and Aquatic Plan (A&AP) Assessment Program in the Environmental Sciences Section (ESS) of DWQ provides support to the Ambient Monitoring Program, Lakes Assessment Program and regional office staff in the analysis of algal and aquatic plant assemblages. The major focus is phytoplankton. Phytoplankton are defined as the suspended microscopic plants found in the water column capable of performing photosynthesis. The A&AP Assessment Program:

- ❑ Documents problematic algal growths.
- ❑ Identifies problematic taxa and their distribution.
- ❑ Investigates possible causes of fish kills.
- ❑ Investigates taste and odor problems in drinking water supplies.
- ❑ Provide habitat characterization for bioassessment evaluations.

The program performs two types of evaluations – episodic and routine. Episodic evaluations make up the majority of the analysis performed. Samples are collected in response to specific events such as fish kills, algal blooms and nuisance aquatic plant and algal growths. Routine evaluations are targeted studies of specific watersheds through the Ambient Monitoring Program or the Intensive Survey Unit. Routine evaluations assess changes in algal assemblages over time and often focus on estuarine systems where frequent algal blooms and fish kills have occurred due to nutrient enrichment. More information on the A&AP Assessment Program can be found on the DWQ ESS Web site (<http://h2o.enr.state.nc.us/esb/algal.html>).

The NC State University through the College of Agriculture and Life Sciences has an Aquatic Plant Management Web site (www.weedscience.ncsu.edu/aquaticweeds/factsheets.html). Several “fact sheets” related to aquatic plants and aquatic weed management can be found here. In addition, the DENR Division of Water Resources (DWR) also has an Aquatic Weed Control Program. Information about this program can be found on the DWR Web site (www.ncwater.org/Education_and_Technical_Assistance/Aquatic_Weed_Control/).

11.3.2 MONITORING LAKES AND RESERVOIRS

Lakes and reservoirs are valued for the multiple benefits they provide to the public, including recreational boating, fishing, drinking water and aesthetic enjoyment. The Lake Assessment Program (<http://h2o.enr.state.nc.us/esb/isu.html>) seeks to protect these waters through monitoring, pollution prevention and control, restoration and public education activities. Assessments have been made at many publicly accessible lakes, lakes that supply domestic drinking water and lakes (public or private) where water quality problems have been observed. Data are used to determine the trophic state of each lake (a relative measure of nutrient enrichment and productivity) and whether the designated uses of the lake have been threatened or impacted by pollution.

Lakes are classified for a variety of uses. All lakes monitored as part of North Carolina's Ambient Lakes Monitoring Program carry the Class C (aquatic life) classification, and most are classified for swimming (Class B) and/or water supply (Class WS-I, WS-II, WS-III, WS-IV or WS-V). The surface water quality numeric standard specifically associated with recreation is fecal coliform bacteria (Chapter 10). For water supplies, however, there are numeric and narrative standards. There are 29 numeric standards (i.e., pH, dissolved oxygen, metals, nitrite, etc.) based on human consumption of water and fish. Narrative standards include aesthetics such as odor and untreated wastes. There are other numeric standards that also apply to lakes for the protection of aquatic life and human health. These standards also apply to all other waters of the state and are listed under the Class C rules.

One of the major problems associated with lakes and reservoirs is increasing eutrophication related to nutrient inputs. Several water quality parameters help to describe the level of eutrophication. Since nutrient impacts are not always reflected in the parameters sampled through the Ambient Lakes Monitoring Program, a more holistic, or weight of evidence approach, is necessary. For instance, some lakes have taste and odor problems associated with particular algal species, yet these lakes do not have chlorophyll *a* concentrations above the 40 µg/l numeric standard often enough to impair the lake based on the chlorophyll *a* standard. In addition, each reservoir possesses unique traits (i.e., watershed area, volume, depth, retention time, etc.) that dramatically influence its water quality, but that cannot be evaluated through water quality standard comparisons. In such waterbodies, aquatic life may be impaired even though a particular indicator is below the water quality standard. Where exceedances of surface water quality standards are not sufficient to evaluate a lake or reservoir, the weight of evidence approach can take into consideration indicators and parameters not identified in the water quality standards to allow a more sound and robust determination of water quality.

The weight of evidence approach uses the following sources of information to determine the eutrophication (nutrient enrichment) level as a means of assessing lake use support in the aquatic life category:

- ❑ Quantitative water quality parameters including physical and chemical parameters (i.e., dissolved oxygen, chlorophyll *a*, pH, etc.)
- ❑ Reported algal blooms and/or fish kills
- ❑ Watershed characteristics including lake size, volume, retention time, volume loss, etc.
- ❑ Third party reports related to taste and odor complaints, hydrocarbon sheens, colors or other aesthetic and safety considerations reported by citizens, water treatment plant operators, state agencies, etc.

More information on the Lakes Assessment Program can be found on the DWQ Environmental Sciences Section Web site (<http://h2o.enr.state.nc.us/esb/isu.html>).

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