Chapter 13
Water Quality Stressors

13.1 Stressor and Sources Identification

13.1.1 Introduction - Stressors

Water quality stressors are identified when impacts have been noted to biological (fish and benthic) communities or water quality standards have been violated. Stressors apply to one or more use support categories and may be identified for Impaired, as well as Supporting but impacted/noted waters. In many cases, identifying stressors is challenging because direct measurements of the stressor may be difficult or prohibitively expensive. DWQ staff use field observations from sample sites, special studies and data from ambient monitoring stations as well as information from other agencies and the public to identify potential water quality stressors. It is important to identify stressors and potential sources of stressors so that the limited resources of water quality programs can be targeted to address the water quality problems. Specific aquatic life stressors are defined in Section 13.2 and 13.3.

Most stressors to the biological community are composed of a complex grouping of many different stressors that individually may not degrade water quality or aquatic habitat, but together can severely degrade aquatic life. Sources of stressors are most often associated with land use in a watershed, as well as the quality and quantity of any treated wastewater that may be entering a stream. During naturally severe conditions such as droughts or floods, any individual stressor or group of stressors may have more severe impacts to aquatic life than during normal climatic conditions. The most common source of stressors is from altered watershed hydrology.

Stressors to recreation use include pathogenic indicators such as fecal coliform bacteria, *escheria coli* (*E. coli*) and *enterococci*. In the fish consumption category, mercury is typically the noted stressor. However, other substance may also result in the issuance of a fish consumption advisory or advice by the NC Division of Health and Human Services (NCDHHS) such as dioxin and selenium.

13.1.2 Introduction - Stressor Sources

As discussed above, sources of stressors most often come from a watershed where the hydrology is altered enough to allow the stressor to be easily delivered to a stream during a rain event along with unnaturally large amounts of water. DWQ identifies the source of a stressor as specifically as possible depending on the amount of information available in a watershed. Most often the source is based on the predominant land use in a watershed. Stressors sources identified in the Roanoke River basin during this assessment period include urban or impervious surface areas, residential and commercial development, road building, agriculture, and forestry/timber harvesting. Point source discharges are also considered a water quality stressor source.

13.1.3 Overview of Stressors Identified in the Roanoke River Basin

The stressors noted below are summarized from all waters and for all use support categories. Figure 18 identifies stressors noted for Impaired waters in the Roanoke River basin during the most recent assessment period. The stressors noted in these figures may not be the sole reason for an Impaired use support rating. Stressors that are listed due to standards violations may require TMDL development for waters where these stressors are identified (dissolved oxygen, turbidity, and fecal coliform bacteria). All waters in the basin are Impaired on an evaluated basis in the fish consumption category where mercury is the stressor of concern (not depicted in the graphs; 2,204 freshwater stream miles, 37,543 freshwater acres, and 1,467 saltwater acres). Figures 19 and 20 identify stressors noted for Impacted waters in the Roanoke River basin during the most recent assessment period (1999 to 2004). The stressors noted in these figures did not necessarily result in an Impaired use support rating. However, these could lead to future Impairment if corrective action is not taken. For specific discussions of stressors to Impaired or Impacted waters refer to the subbasin chapters 1 through 10. Stressor definitions and impacts are discussed in the remainder of this chapter.

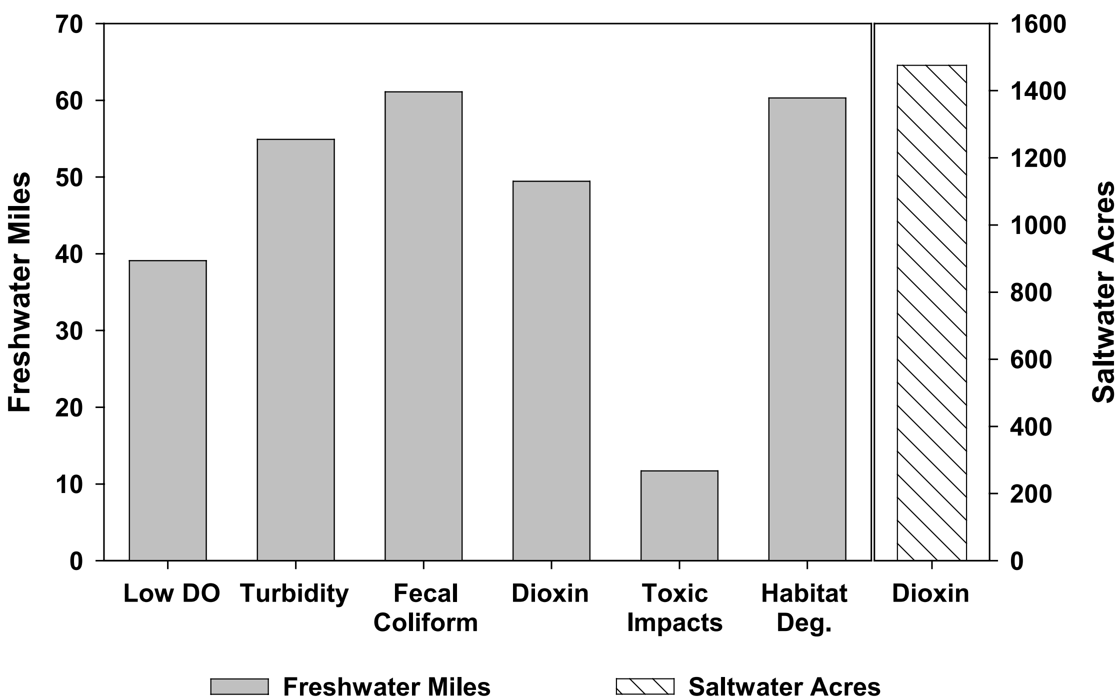

Figure 18 - Noted Stressors to Impaired Freshwater Streams Miles and Saltwater Acres in the Roanoke River Basin.

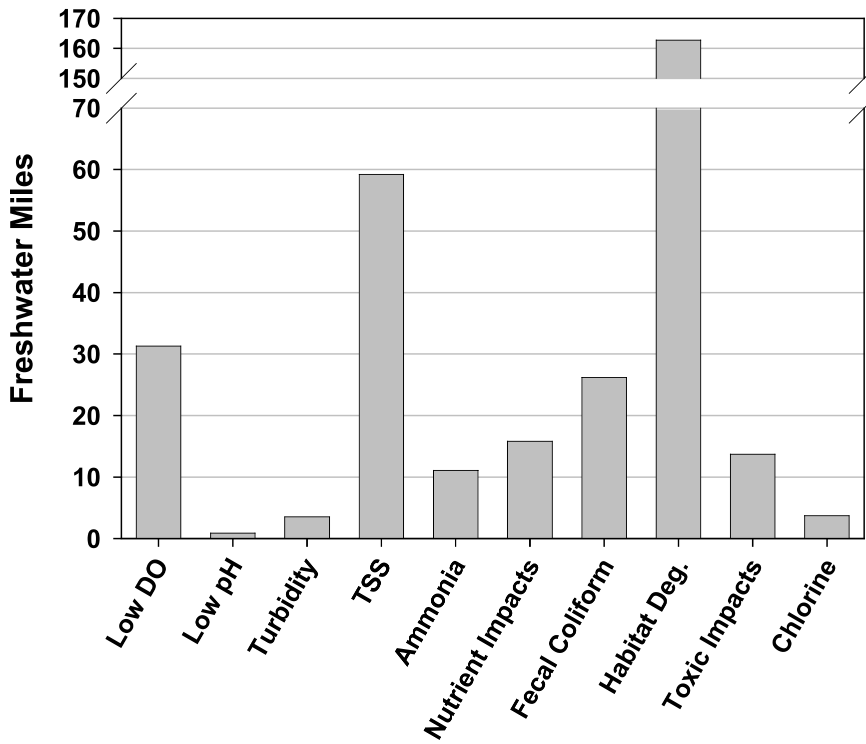

Figure 19 - Noted Stressors to Impacted Freshwater Streams/Rivers in the Roanoke River Basin

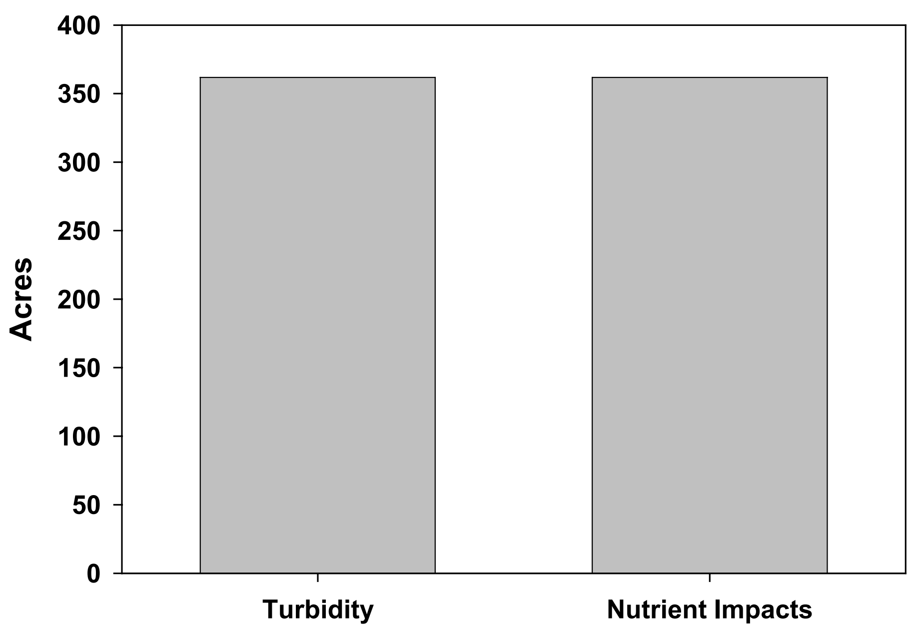

Figure 20 - Noted Stressors to Impacted Freshwater Acres in the Roanoke River Basin

13.1.4 Overview of Stressors Sources Identified in the Roanoke River Basin

The sources noted below are summarized for all waters and for all use support categories. Figure 21 and 22 identify sources of stressors noted for waters in the Roanoke River Basin during the most recent assessment period. Refer to the subbasin chapters (Chapters 1 – 10) for a complete listing and discussion of sources by stream.

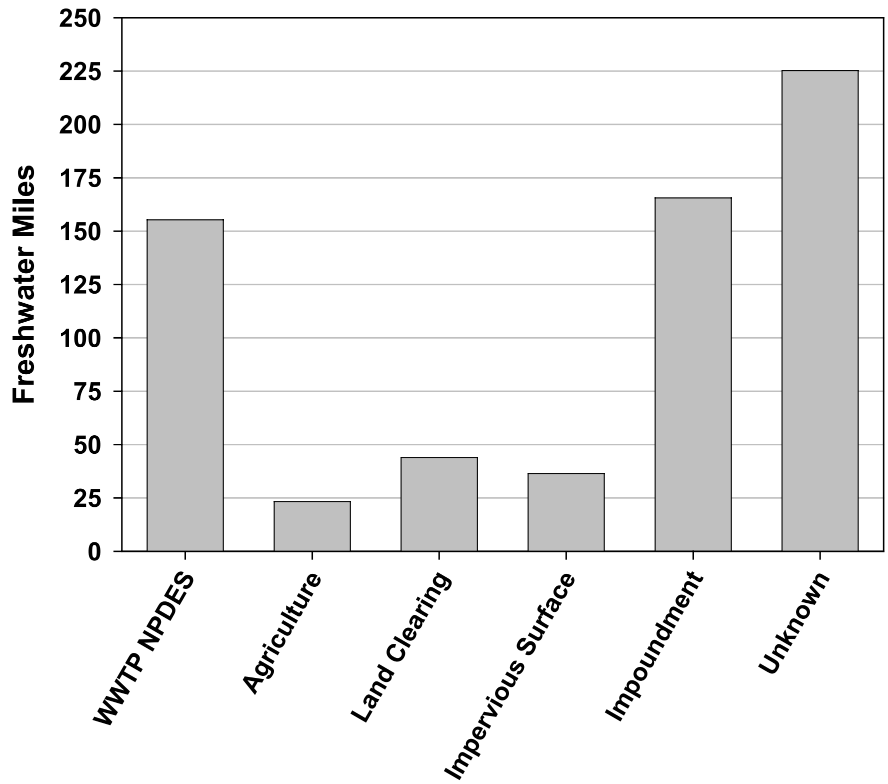

Figure 21 - Sources of Stressors Identified in the Roanoke River Basin (Freshwater Stream Miles)

Wastewater treatment plants (WWTPs) were noted as a potential source to many of the freshwater stream miles (155) and saltwater acres (1,476) in the Roanoke River basin. WWTPs are just one of many sources that can contribute excess nutrients that may increase the potential for algal blooms and cause exceedances of the chlorophyll *a* standard. This can include all discharges upstream of the area of Impairment or noted impacts. Most of these impacts were localized and based on permit violations. Better treatment technology and permit compliance has greatly decreased the number of stream miles locally impacted by WWTPs.

Agriculture was noted as a potential source of water quality stressors when field observations and watershed studies noted agriculture as the predominant land cover. In the Roanoke River basin, the majority of agricultural land is cultivated crop. Impacts to streams from agricultural activities can include excessive nutrient loading, pesticide and herbicide contamination, bacterial contamination, and sedimentation. Agriculture was noted as a source of stressors in 23 stream miles. Agriculture impacts and programs are discussed in more detail in Chapter 16.

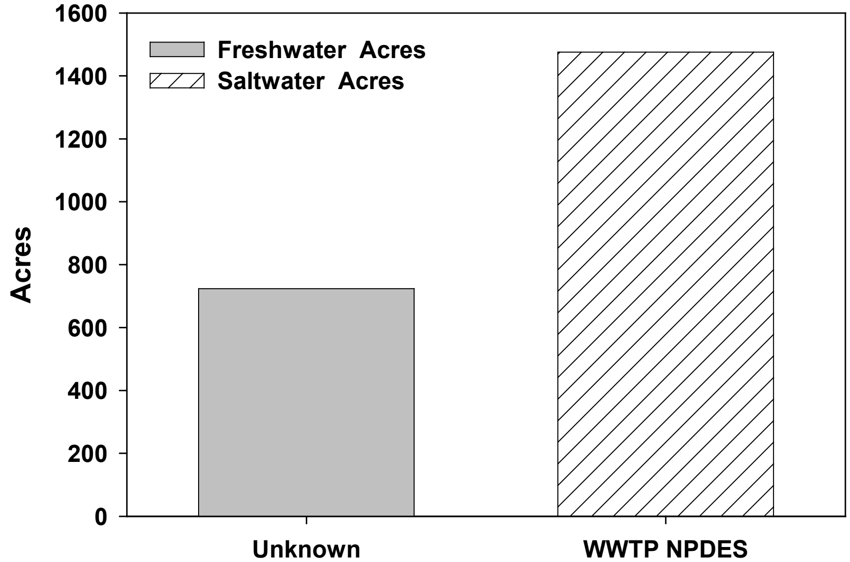

Figure 22 - Sources of Stressors Identified in the Roanoke River Basin (Fresh and Saltwater Acres)

Land clearing activities for residential and commercial development, for road/highway construction as well as for timber harvest/clear cutting were noted as potential sources of water quality stressors to 44 stream miles. Streams where land clearing is a noted source are likely to be more heavily impacted in the future by increased development and impervious surfaces. Impervious surface accounted for an additional 37 stream miles with noted impacts in the Roanoke River basin. Refer to Chapter 12 for more information related to population growth and land cover changes and its potential impacts on water quality.

In the Roanoke River basin there are 11 major impoundments. These are used as water supply reservoirs as well as for flood control and hydropower production. Impacts to water quality can also be magnified by the presence of a reservoir. Dams significantly slow the flow of water and create conditions not present in riverine systems. These conditions increase nutrient availability and give algae more time to grow. In theory, a reservoir may suffer the symptoms of excessive nutrient and sediment inputs, while a river receiving the same level of pollutants may not. The way in which these reservoirs/lakes are managed influence the quality of the water in the basin. For example, the amount of water released into the lower Roanoke River influences the extensive floodplain. As water is released from the floodplain back into the Roanoke River mainstem it carries low dissolved oxygen water as well as a high BOD material. This can result in dissolved oxygen sags, which impacts the water quality and aquatic health (i.e., fish kills) in the river.

Stressor sources could not be identified for 225 stream miles in the Roanoke River basin. These stream segments may be in areas where sources could not be identified during field observations, but the streams had noted impacts (e.g., habitat degradation). DWQ and the local agencies will work to identify potential sources for these stream segments during the next basinwide cycle.

13.2 Aquatic Life Stressors - Habitat Degradation

13.2.1 Introduction and Overview

Instream habitat degradation is identified as a notable reduction in habitat diversity or a negative change in habitat. This term may include sedimentation, lack of organic (woody and leaf) habitats and channelization. These stressors to aquatic insect and fish communities can be caused by many different land use activities and less often by discharges of treated wastewater. In the Roanoke River basin, 60 stream miles are Impaired where at least one form of habitat degradation has been identified as the stressor. There is an additional 163 stream miles where habitat degradation is a noted impact to water quality. Many of the stressors discussed below are either directly caused by or are a symptom of altered watershed hydrology. The altered hydrology increases both sources of stressors and delivery of stressors to receiving waters. Refer to the subbasin chapters (Chapters 1-10) for more information on the types of habitat degradation noted at sample locations and in watershed studies.

Some Best Management Practices

Agriculture

- No till or conservation tillage practices
- Strip cropping and contour farming
- Leaving natural buffer areas around small streams and rivers

Construction

- Using phased grading/seeding plans
- Limiting time of exposure
- Planting temporary ground cover
- Using sediment basins and traps

Forestry

- Controlling runoff from logging roads
- Replanting vegetation on disturbed areas
- Leaving natural buffer areas around small streams and rivers
- Avoid stream crossings during forest operations

Good instream habitat is necessary for aquatic life to survive and reproduce. Streams that typically show signs of habitat degradation are in watersheds that have a large amount of land-disturbing activities (construction, mining, timber harvest and agricultural activities) or a large percentage of impervious surface area. A watershed in which most of the riparian vegetation has been removed from streams or channelization has occurred also exhibits instream habitat degradation. Streams that receive a discharge quantity that is much greater than the natural flow in the stream often have degraded habitat as well. All of these activities result in altered watershed hydrology.

Quantifying amounts of habitat degradation is difficult in most cases. To assess instream habitat degradation in most streams would require extensive technical and monetary resources and even more resources to restore the stream. Although DWQ and other agencies are starting to address this issue, local efforts are needed to prevent further instream habitat degradation and to restore streams that have been Impaired by activities that cause habitat degradation. As point sources become less of a source of water quality impairment, nonpoint sources that pollute water and cause habitat degradation need to be addressed to further improve water quality in North Carolina's streams and rivers.

13.2.2 Sedimentation

Sedimentation is a natural process that is important to the maintenance of diverse aquatic habitats. Overloading of sediment in the form of sand, silt and clay particles fills pools and covers or embeds riffles that are vital aquatic insect and fish habitats. A diversity of these habitats is important for maintenance of biological integrity. Suspended sediment can decrease primary productivity (i.e., photosynthesis) by shading sunlight from aquatic plants, affecting the overall productivity of a stream system. Suspended sediment also has several effects on various fish species including avoidance and redistribution, reduced feeding efficiency, and therefore, reduced growth by some species, respiratory problems, reduced tolerance to diseases and toxicants, and increased physiological stress (Roell, 1999). Sediment filling rivers, streams and reservoirs also decreases their storage volume and increases the frequency of floods (NCDENR-DLR, 1998). Suspended sediment also increases the cost of treating municipal drinking water. Sediment overloading to many streams has reduced biological diversity to the point of the stream being Impaired for aquatic life.

Sediment is the earthen material that is dislodged and transported from its original location by the erosive forces of wind, water or ice. The redeposition of the sediment is sedimentation. The grading and tilling of surfaces for construction of roads and buildings, crop production, livestock grazing and timber harvesting contribute to accelerated erosion rates by loosening the soils thereby allowing more soil than usual to become detached and transported by wind or water.

Streambank erosion, caused by very high stormwater flows after rain events, is another source of sediment overloading. Watersheds with large amounts of impervious surfaces transport water to streams very rapidly and at higher volumes than occurs in watersheds with little impervious surfaces. In many urban areas, stormwater is delivered directly by storm sewers. This high volume and velocity of water after rain events undercuts streambanks causing bank failure and large amounts of sediment to be deposited directly into the stream. Many urban streams are adversely impacted by sediment overloading from the watershed as well as from the streambanks.

Sedimentation can be controlled during most land-disturbing activities by using appropriate BMPs. Substantial amounts of erosion can be prevented by planning to minimize the amount and time that land is exposed during land-disturbing activities and by minimizing impervious surface area and direct stormwater outlets to streams. Refer to chapter 14 for more information on programs designed to reduce sedimentation.

Land Clearing Activities
Erosion and sedimentation can be controlled during most land-disturbing activities by using appropriate BMPs. In fact, substantial amounts of erosion can be prevented by planning to minimize the (1) amount and (2) time the land is exposed. DWQ's role in sediment control is to work cooperatively with those agencies that administer sediment control programs in order to maximize the effectiveness of the programs and to protect water quality. Where programs are not effective, as evidenced by a violation of instream water quality standards, and where DWQ can identify a source, then appropriate enforcement action can be taken. Generally, this entails requiring the landowner or responsible party to install acceptable BMPs.

As a result of new stormwater rules enacted by EPA in 1999, construction or land development activities that disturb one acre or more are required to obtain a NPDES stormwater permit. An erosion and sediment control plan must also be developed and approved for these sites under the state's Sedimentation Pollution Control Act (SPCA) administered by the NC Division of Land Resources. Site disturbances of less than one acre are required to use BMPs, but an approved plan is not required.

Forestry operations in North Carolina are subject to regulation under the Sedimentation Pollution Control Act of 1973 (G.S. Chapter 113A, Article 4 referred to as "SPCA"). However, forestry operations may be exempted from the permit requirements in the SPCA, if the operations meet compliance standards outlined in the *Forest Practices Guidelines Related to Water Quality* (15A NCAC 1I .0101-.0209, referred to as "FPGs") and General Statutes regarding stream obstruction (G.S. 77-13 and G.S. 77-14). More information on forestry in the Roanoke River basin is available in Chapter 17 and on the Water Quality Section of the Division of Forest Resources (DFR) website at http://www.dfr.state.nc.us.

For agricultural activities that are not subject to the SPCA, sediment controls are carried out on a voluntary basis through programs administered by several different agencies (see Appendix VIII for further information).

Stronger Rules for Sediment Control

The Division of Land Resources (DLR) has the primary responsibility for assuring that erosion is minimized and sedimentation is reduced during construction activities. In November 2005, the NC Sedimentation Control Commission adopted significant changes for strengthening the Erosion and Sedimentation Control Program (NCDENR-DLR, November 2005) as follows:

- allows state and local erosion and sediment control programs to require a pre-construction conference when one is deemed necessary;
- surfaces must be non-erosive and stable within 15 working days or 90 calendar days after completion of the activity;
- graded slopes must be vegetated or otherwise stabilized within 21 calendar days of completion of a phase of grading;
- provides that no person may initiate a land-disturbing activity until notifying the agency that issued the plan approval of the date the activity will begin; and
- allows assessment penalties for significant violations upon initial issuance of a Notice of Violation (NOV).

Additionally, during its 1999 session, the NC General Assembly passed House Bill 1098 to strengthen the Sediment Pollution Control Act of 1973 (SPCA). The bill made the following changes to the Act (NCDENR-DLR, July-September 1999):

- increases the maximum civil penalty for violating the SPCA from $500 to $5000 per day;
- provides that a person may be assessed a civil penalty from the date a violation is detected if the deadline stated in the Notice of Violation is not met;
- provides that approval of an erosion control plan is conditioned on compliance with federal and state water quality laws, regulations and rules;

- provides that any erosion control plan that involves using ditches for the purpose of dewatering or lowering the water table must be forwarded to the Director of DWQ;
- amends the General Statutes governing licensing of general contractors to provide that the State Licensing Board for General Contractors shall test applicants' knowledge of requirements of the SPCA and rules adopted pursuant to the Act; and
- removes a cap on the percentage of administrative costs that may be recovered through plan review fees.

For information on North Carolina's Erosion and Sedimentation Control Program or to report erosion and sedimentation problems, visit the new website at http://www.dlr.enr.state.nc.us/ or you may call the NC Division of Land Resources, Land Quality Section at (919) 733-4574.

Recent Review of Sediment Control Research

Two of the most commonly used sediment control devices are silt fences and sediment basins. In 2005, DLR revised the requirements for these and other BMP's to make them more efficient at trapping and containing sediment on site. These revisions are based upon research done by NC State University, NC Department of Transportation, and other professional engineers.

Currently, sediment basins are designed to have a minimum volume of 1,800 cubic feet per acre of drainage area and a surface area of 325 square feet per cfs of Q_{10} peak flow. Sediment basins are designed to temporarily pool runoff water to allow sediment to settle before the water is discharged. Unfortunately, they are usually not very efficient due to high turbulence, which takes the runoff quickly to the outlet with little interaction with most of the basin. Per the 2005 revisions, three baffles are now required for a basin of this size. Baffles improve the rate of sediment retention by distributing the flow and reducing turbulence, allowing the baffles to capture soil particles 50 percent smaller than those captured without the use of baffles. Baffles also lower the chances of short-circuiting. To further improve sediment retention, the use of a skimmer attached at the bottom of a riser pipe is suggested. Skimmers are a dewatering mechanism that pulls water from the top of the water column. After the runoff has passed through the baffles, the sediment has had time to drop to the bottom of the water column. Therefore, the overflow water at the top will have the least amount of sediment particles.

Sediment fences are also used very frequently and are inefficient at capturing sediment before it leaves the site. This BMP is overused and, in most cases, is installed improperly. For these reasons DLR has revised the requirements to make it more efficient. For better support, the use of steel posts in the place of wooden posts is now required. The fence should be anchored by placing 12 inches of washed stone on the toe of the fence that should be facing uphill. Another method to anchor the fence is to slice the fabric into the ground. This method uses specially designed equipment to insert the fabric into a cut sliced in the ground with a disc. By slicing the fabric into the ground, excavating a trench can be avoided. Sediment fences require that installation is done properly and regular maintenance is scheduled.

Other new technologies such as applications of flocculants, rolled erosion control products, hardware cloth and gravel inlet protection, rock pipe inlet protection, and rock doughnut inlet protection are specified in the *North Carolina Erosion and Sediment Control Planning and Design Manual*, which can be found at http://dlr.enr.state.nc.us/pages/manualsandvideos.html. These technologies can significantly increase efficiency of trapping sediment on land disturbing sites. Research funded by the Sedimentation Control Commission (SCC) and the NC Department of Transportation (NCDOT) at NCSU demonstrated that turbidity levels could approach the current turbidity standard of 50 NTU (for waters not classified Tr) in runoff if these devices are used. However, the most important factor in reducing sedimentation is timely cover of cleared land with mulch matting or netting that are adequately tacked. It has been conclusively proven that use of ground cover (temporary or permanent) dramatically reduces erosion rates.

13.2.3 Loss of Riparian Vegetation and Organic Aquatic Microhabitats

During the 2004 basinwide sampling, DWQ biologists reported degradation of aquatic communities at numerous sites throughout the Roanoke River basin in association with narrow or nonexistent zones of native riparian vegetation. Riparian vegetation loss was common in rural and residential areas as well as in urban areas. The loss of riparian vegetation and subsequent reduction of organic aquatic habitats is caused by removal of riparian areas most commonly by land clearing for development, field agriculture, and pastureland as well as forestry and by grazing animals. Instream organic habitat removal has also been caused by de-snagging activities.

Removing trees, shrubs and other vegetation to plant grass or place rock (also known as riprap) along the bank of a river or stream degrades water quality. Removing riparian vegetation eliminates habitat for aquatic macroinvertebrates that are food for trout and other fish. Rocks or concrete lining a bank absorb the sun’s heat and warm the water. Some fish require cooler water temperatures as well as the higher levels of dissolved oxygen cooler water provides. Trees, shrubs and other native vegetation cool the water by shading it. Straightening a stream, clearing streambank vegetation, and lining the banks with grass or rock severely impact the habitat that aquatic insects and fish need to survive.

Establishing, conserving and managing streamside vegetation (riparian buffer) is one of the most economical and efficient BMPs. Forested buffers in particular provide a variety of benefits including filtering runoff and taking up nutrients, moderating water temperature, preventing erosion and loss of land, providing flood control and helping to moderate streamflow, and providing food and habitat for both aquatic and terrestrial wildlife. To obtain a free copy of DWQ’s *Buffers for Clean Water* brochure, call (919) 733-5083, ext. 558.

Organic microhabitat (leafpacks, sticks and large wood) and edge habitat (root banks and undercut banks) play very important roles in a stream ecosystem. Organic matter in the form of leaves, sticks and other materials serve as the base of the food web for small streams. Additionally, these microhabitats serve as special niches for different species of benthic macroinvertebrates, providing food and/or habitat. For example, many stoneflies are found almost exclusively in leafpacks and on small sticks. Some beetle species prefer edge habitat, such as undercut banks. If these microhabitat types are not present, there is no place for these specialized macroinvertebrates to live and feed. The absence of these microhabitats in some streams in the Roanoke River basin is directly related to the absence of riparian vegetation. Organic microhabitats are critical to headwater streams, the health of which is linked to the health of the entire downstream watershed.

13.2.4 Channelization

Channelization refers to the physical alteration of naturally occurring stream and riverbeds. Channelization is caused by mechanical straightening of channels or by hydraulic overloading during rain events. Often streams in urban areas become channelized as part of the development process in essence using the stream channels as stormwater conveyances. Although increased flooding, bank erosion and channel instability often occur in downstream areas after channelization has occurred, flood control, reduced erosion, increased usable land area, greater navigability and more efficient drainage are frequently cited as the objectives of channelization projects (McGarvey, 1996).

> ***Typical Channel Modifications***
>
> - Removal of any obstructions, natural or artificial, that inhibit a stream's capacity to convey water (clearing and snagging).
> - Widening, deepening or straightening of the channel to maximize conveyance of water.
> - Lining the bed or banks with rock or other resistant materials.

Channelization reduces the sinuosity of streams greatly increasing the velocity of water flowing down these streams. Direct or immediate biological effects of channelization include injury and mortality of benthic macroinvertebrates, fish, shellfish/mussels and other wildlife populations, as well as habitat loss. Indirect biological effects include changes in benthic macroinvertebrate, fish and wildlife community structures, favoring species that are more tolerant of or better adapted to the altered habitat (McGarvey, 1996).

Restoration or recovery of channelized streams may occur through processes, both naturally and artificially induced. In general, streams that have not been excessively stressed by the channelization process can be expected to return to their original forms. However, streams that have been extensively altered may establish a new, artificial equilibrium (especially when the channelized streambed has been hardened). In such cases, the stream may enter a vicious cycle of erosion and continuous entrenchment. Once the benefits of a channelization project become outweighed by the costs, both in money and environmental integrity, channel restoration efforts are likely to be taken (McGarvey, 1996).

Channelization of streams within the continental United States is extensive and promises to become even more so as urban development continues. Overall estimates of lost or altered riparian habitats within US streams are as high as 70 percent. Unfortunately, the dynamic nature of stream ecosystems makes it difficult (if not impossible) to quantitatively predict the effects of channelization (McGarvey, 1996). Channelization has occurred historically in parts of the Roanoke River basin and continues to occur in some watersheds, especially in small headwater streams.

13.2.5 Recommendations for Reducing Habitat Degradation

In March 2002, the Environmental Management Commission (EMC) sent a letter to the Sedimentation Control Commission (SCC) outlining seven recommendations for improving erosion and sedimentation control, based on a comprehensive performance review of the turbidity standard conducted in 2001 by DWQ staff. Specifically, the recommendations are that the EMC and SCC:

1. evaluate, in consultation with the Attorney General's Office, whether statutory authority is adequate to mandate temporary ground cover over a percentage of the uncovered area at a construction site within a specific time after the initial disturbance of the area. If it is found that statutory authority does not exist, then the EMC and SCC should prepare resolutions for the General Assembly supporting new legislation to this effect;

2. prepare resolutions supporting new legislation to increase the maximum penalty allowed in the Sedimentation Pollution Control Act from $5,000 to $25,000 for the initial response to a noncompliant site;

3. jointly support a review of the existing Erosion and Sediment Control Planning and Design Manual by DLR. This review should include, but not be limited to, a redesign of the minimum specifications for sedimentation basins;

4. evaluate, in consultation with the Attorney General's Office, whether the statutory authority is adequate for effective use of the "Stop Work Order" tool and, if found not to be adequate, to prepare resolutions for the General Assembly supporting new legislation that will enable staff to more effectively use the "Stop Work Order" tool;

5. support increased research into and experimentation with the use of polyacrylamides (PAMs) and other innovative soil stabilization and turbidity reduction techniques;

6. jointly support and encourage the awarding of significant monetary penalties for all activities found to be in violation of their Stormwater Construction General Permit, their Erosion and Sediment Control Plan, or the turbidity standard; and

7. hold those individuals who cause serious degradation of the environment through excessive turbidity and sedimentation ultimately responsible for restoration of the area.

DWQ will continue to work cooperatively with DLR and local programs that administer sediment control in order to maximize the effectiveness of the programs and to take appropriate enforcement action when necessary to protect or restore water quality. However, more voluntary implementation of BMPs is needed for activities that are not subject to these rules in order to substantially reduce the amount of widespread sedimentation present in the Roanoke River basin. Additionally, more public education is needed basinwide to educate landowners about the value of riparian vegetation along small tributaries and the impacts of sedimentation to aquatic life.

Funding is available through numerous federal and state programs for landowners to restore and/or protect riparian buffer zones along fields or pastures, develop alternative watering sources for livestock, and fence animals out of streams (refer to Chapters 11 and 16). EPA's *Catalog of Federal Funding Sources for Watershed Protection* (Document 841-B-99-003) outlines some of these and other programs aimed at protecting water quality. A copy may be obtained by calling the National Center for Environmental Publications and Information at (800) 490-9198 or by visiting the website at http://www.epa.gov/OWOW/watershed/wacademy/fund.html. Local contacts for various state and local agencies are listed in Appendix VIII.

13.3 Aquatic Life Stressors – Water Quality Standard Violations

13.3.1 Introduction and Overview

In addition to the habitat stressors discussed in the previous section, the stressors discussed below are identified by water quality standards. These are usually direct measures of water quality parameters from ambient water quality monitoring stations. The water quality standards are designed to protect aquatic life. As with habitat degradation, altered watershed hydrology greatly increases the sources of these stressors as well as delivery of the stressors to the receiving waters. The following are water quality standards that were identified for waters with noted impacts. Refer to the subbasin chapters (Chapter 1 – 10) for more information on the affected waters.

13.3.2 Low Dissolved Oxygen

Maintaining an adequate amount of dissolved oxygen (DO) is critical to the survival of aquatic life and to the general health of surface waters. A number of factors influence DO concentrations including water temperature, depth and turbulence. Additionally, in the Roanoke River basin, a large floodplain drainage system and flow management from upstream impoundments also influences DO. Oxygen-consuming wastes such as decomposing organic matter and some chemicals can reduce DO levels in surface water through biological activity and chemical reactions. NPDES permits for wastewater discharges set limits on certain parameters in order to control the effects that oxygen depletion can have in receiving waters.

Waters are Impaired for aquatic life when greater than 10 percent of samples collected exceed the state DO standard and at least 10 samples were collected. The DO water quality standard for Class C waters is not less than a daily average of 5 mg/l with a minimum instantaneous value of not less than 4 mg/l. Swamp waters (supplemental Class Sw) may have lower values if caused by natural conditions. In the Roanoke River basin during this assessment period, there were 39 stream miles that are Impaired where low DO is a stressor. There were also over 30 freshwater stream miles where low DO is a stressor for waters with noted impacts, although many of these streams are in swampy areas where low DO levels are likely from natural sources.

13.3.3 Turbidity

The major sources of elevated turbidity are from agriculture and land clearing activities as well as from urban stormwater. These sources also add other pollutants beside suspended particulates. Waters are Impaired for aquatic life when greater than 10 percent of samples collected exceed the state turbidity standard and at least 10 samples were collected. The turbidity water quality standard for Class C waters are not to exceed 50 Nephelometric Turbidity Units (NTU). However, trout waters (Tr) are not to exceed 10 NTUs. In the Roanoke River basin during this assessment period, there were 55 stream miles Impaired where turbidity is a stressor; of these 11.6 were trout stream miles. There were also 4 freshwater stream miles and 362 freshwater acres that are impacted where turbidity is a stressor.

13.3.4 Toxic Impacts

Toxic impacts are noted as a stressor during biological monitoring or when identified from NPDES compliance reports. Waters are not impaired due to toxic impacts, but toxic impacts can be noted as a potential stressor on the system, which can ultimately result in impairment. During the most recent assessment period, toxic impacts were noted on 25.5 stream miles. Of these, 9.2 miles of the Dan River and 4.5 miles of Marlowe Creek are noted as having toxic impacts due to WWTP whole effluent toxicity (WET) test failures in the last two years of the assessment period (Chapter 1 and 5). Toxic impacts were also noted as a stressor for 11.8 miles of the Little Island Creek due to the watershed being encompassed by a defunct Tungsten mine (Chapter 6).

13.3.5 Other Aquatic Life Stressors

Several noted stressors to aquatic life are identified from WWTP NPDES compliance reports. Waters are not Impaired due to permit violations, however these violation can be noted as a potential stressor on the system. In the Roanoke River basin during this assessment period, there were 59, 11, 4, and 1 stream mile impacted where Total Suspended Solids (TSS), ammonia, chlorine and pH respectively were the noted stressors.

13.4 Recreation Stressor

13.4.1 Fecal Coliform Bacteria

Water quality standards for fecal coliform bacteria are intended to ensure safe use of waters for recreation (refer to Administrative Code Section 15A NCAC 2B .0200). The North Carolina fecal coliform standard for freshwater is 200 colonies/100ml based on the geometric mean of at least five consecutive samples taken during a 30-day period and not to exceed 400 colonies/100ml in more than 20 percent of the samples during the same period. In the Roanoke River basin, there were 43.3 stream miles where this standard was exceeded. These waters are Impaired for recreation. An additional 8 stream miles exceeded the fecal coliform bacteria screening criteria. These waters were not intensively sampled to assess the standard as described above, but had either a geometric mean above 200 colonies/100ml and/or 20 percent of samples exceeded 400 colonies/100ml over the five-year assessment period. These waters are discussed in the subbasin chapters. A total of 230.6 stream miles were monitored for recreation, of these only 111 stream miles are class B waters.

As stated above, there were 43 stream miles Impaired due to fecal coliform bacteria standard violations. There were an additional 18 Impaired stream miles that were noted as having fecal coliform bacteria as a noted stressor and another 26 stream miles for waters with noted impacts. These come from ambient data as well as from WWTP NPDES compliance reports.

A number of factors beyond the control of any state regulatory agency contribute to elevated levels of disease-causing bacteria. Therefore, the state does not encourage swimming in surface waters. To assure that waters are safe for swimming indicates a need to test waters for pathogenic bacteria. Although fecal coliform standards have been used to indicate the microbiological quality of surface waters for swimming for more than 50 years, the value of this indicator is often questioned. Evidence collected during the past several decades suggests that the coliform group may not adequately indicate the presence of pathogenic viruses or parasites in water.

Fecal coliform bacteria live in the digestive tract of warm-blooded animals (humans as well as other mammals) and are excreted in their waste. Fecal coliform bacteria generally do not pose a danger to most people or animals. However, where fecal coliform are present, disease-causing bacteria may also be present and water that is polluted by human or animal waste can harbor other pathogens that may threaten human health.

Sources of Fecal Coliform in Surface Waters

- Urban stormwater
- Wild animals and domestic pets
- Improperly designed or managed animal waste facilities
- Livestock with direct access to streams
- Improperly treated discharges of domestic wastewater, including leaking or failing septic systems and straight pipes

The presence of disease-causing bacteria tends to affect humans more than aquatic creatures. High levels of fecal coliform bacteria can indicate high levels of sewage or animal wastes that could make water unsafe for human contact (swimming). Fecal coliform bacteria and other potential pathogens associated with waste from warm-blooded animals are not harmful to fish and aquatic insects. However, high levels of fecal coliform bacteria may indicate contamination that increases the risk of contact with harmful pathogens in surface waters. Pathogens associated with fecal coliform bacteria can cause diarrhea, dysentery, cholera and typhoid fever in humans. Some pathogens can also cause infection in open wounds.

Under favorable conditions, fecal coliform bacteria can survive in bottom sediments for an extended period (Howell et al., 1996; Sherer et al., 1992; Schillinger and Gannon, 1985). Therefore, concentrations of bacteria measured in the water column can reflect both recent inputs as well as the resuspension of older inputs.

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 pathogenic disease-causing bacteria, they also kill bacteria essential to the proper balance of the aquatic environment, and thereby, endanger the survival of species dependent on those bacteria.

The detection and identification of specific pathogenic bacteria, viruses and parasites such as *Giardia*, *Cryptosporidium* and *Shigella* are expensive, and results are generally difficult to reproduce quantitatively. Also, to ensure the water is safe for swimming would require a whole suite of tests for many organisms, as the presence/absence of one organism would not document the presence/absence of another. This type of testing program is not possible due to resource constraints.

13.5 Fish Consumption Stressors

The presence and accumulation of mercury in North Carolina's aquatic environment are similar to contamination observed throughout the country. Mercury has a complex life in the environment, moving from the atmosphere to soil, to surface water, and eventually, to biological organisms. Mercury circulates in the environment as a result of natural and human (anthropogenic) activities. A dominant pathway for mercury in the environment is through the atmosphere. Mercury emitted from industrial and municipal stacks into the ambient air can circulate around the globe. At any point, mercury may then be deposited onto land and water. Once in the water, mercury can accumulate in fish tissue and humans. Mercury is also commonly found in wastewater; however, mercury in wastewater is typically not at levels that could be solely responsible for elevated fish levels

Fish is part of a healthy diet and an excellent source of protein and other essential nutrients. However, nearly all fish and shellfish contain trace levels of mercury. The risks from mercury in fish depend on the amount of fish eaten and the levels of mercury in the fish. In March 2003, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) issued a joint consumer advisory for mercury in fish and shellfish. The advice is for women who might become pregnant, women who are pregnant, nursing mothers, and young children. Aside from being issued jointly by two federal agencies, this advisory is important because it emphasizes positive benefits of eating fish and gives examples of commonly eaten fish that are low in mercury. In the past, the FDA issued an advisory on consumption of commercially caught fish, while the EPA issued advice on recreationally caught fish.

By following these three recommendations for selecting and eating fish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury. These recommendations are:

- **Do not eat shark, swordfish, king mackerel, or tilefish**. They contain high levels of mercury.

- Eat up to 12 ounces (two average meals) a week of a variety of fish and shellfish that are lower in mercury. Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish. Another commonly eaten fish, albacore ("white") tuna, has more mercury than canned light tuna. So, when choosing your two meals of fish, you may eat up to 6 ounces (one average meal) of albacore per week.

- Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters. Don't consume any other fish during that week.

For more detailed information, visit EPA's website at http://www.epa.gov/waterscience/fish/ or visit the FDA at http://www.cfsan.fda.gov/seafood1.html. The FDA's food information toll-free phone number is 1-888-SAFEFOOD.

The NC Department of Health and Human Services (NCDHHS) also issues fish consumption advisories and advice for those fish species and areas at risk for contaminants. NCDHHS notifies people to either limit consumption or avoid eating certain kinds of fish. While most freshwater fish in North Carolina contain very low levels of mercury and are safe to eat, several species have been found to have higher levels. More information regarding use support assessment methodology related to fish consumption advisories and advice can be found in Appendix X.

Due to high levels of mercury in seventeen saltwater and five freshwater fish species, the NCDHHS offers the following health advice (updated March 31, 2006).

Women of childbearing age (15 to 44 years), pregnant women, nursing women, and children under 15:

- **Do not eat** the following ocean fish: almaco jack, banded rudderfish, canned white tuna (albacore tuna), cobia, crevalle jack, greater amberjack, south Atlantic grouper (gag, scamp, red, and snowy), king mackerel, ladyfish, little tunny, marlin, orange roughy, shark, Spanish mackerel, swordfish, tilefish, or tuna (fresh or frozen).
- **Do not eat** the following freshwater fish: bowfin (blackfish), catfish (caught wild), chain pickerel (jack fish), or warmouth caught in North Carolina waters south and east of Interstate 85.
- **Do not eat** largemouth bass caught in North Carolina waters (statewide).
- Eat up to two meals per week of other fish. A meal is 6 ounces of cooked fish for adults or 2 ounces of cooked fish for children under 15.

All other people:

- Eat no more than one meal (6 ounces) per week of ocean and/or freshwater fish listed above. These fish are often high in mercury.
- Eat up to four meals per week of other fish. A meal is 6 ounces of cooked fish for adults or 2 ounces of cooked fish for children under 15.

For more information and detailed listing of site-specific advisories, visit the NCDHHS website at http://www.schs.state.nc.us/epi/fish/current.html or call (919) 733-3816.