BASINWIDE ASSESSMENT REPORT

ROANOKE RIVER BASIN

NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Division of Water Quality
Water Quality Section
Environmental Sciences Branch

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EXECUTIVE SUMMARY

This document presents a water quality assessment of the Roanoke River basin. Information reported by outside researchers and other agencies is also presented. Division monitoring programs covered within this report include benthic macroinvertebrates, fish tissue, lake assessments, ambient water quality, and aquatic toxicity for the period 1995 - 1999. Studies conducted prior to 1995 were previously summarized in NCDEHNR (1996).

The document is structured with physical, geographical, and water quality discussions given at the beginning of each subbasin section. General water quality conditions are presented in an upstream to downstream format. Subbasins within the basin are described by a six digit code (030201 - 030210), but are often referred to by their last two digits (e.g. Subbasin 01).

The Roanoke River originates in the Blue Ridge mountains of Virginia and flows east-southeast through the piedmont and coastal plain to the Albemarle Sound in North Carolina (Figure 1). The watershed is approximately 9,666 mi^2, with about 3,600 mi^2 in North Carolina. Land use based on 1992 National Resources Inventory data indicated 61% of the basin was forested and 25% was agriculture. Flow of the Roanoke River in North Carolina is intensively regulated.

Upper Roanoke River Basin (Subbasins 1 - 6)
The upper Roanoke River drainage contains the Dan River in North Carolina, its tributaries, and some tributaries that drain into Kerr Reservoir. Headwater reaches of the Dan River are in Virginia. Major tributaries of the Dan River in the upper section include Town Fork Creek, Snow Creek, and Double Creek. Erosion problems are widespread, and streams are sandy with deeply entrenched channels.

The upper Dan River area shows characteristics of both the mountain and piedmont ecoregions. The fairly steep to moderate topography of headwater reaches of most tributaries have allowed them to remain forested, while many downstream sections are intensively farmed. The uppermost reach of the river in North Carolina is a relatively high gradient montane river. Downstream reaches are more typical of piedmont river systems.

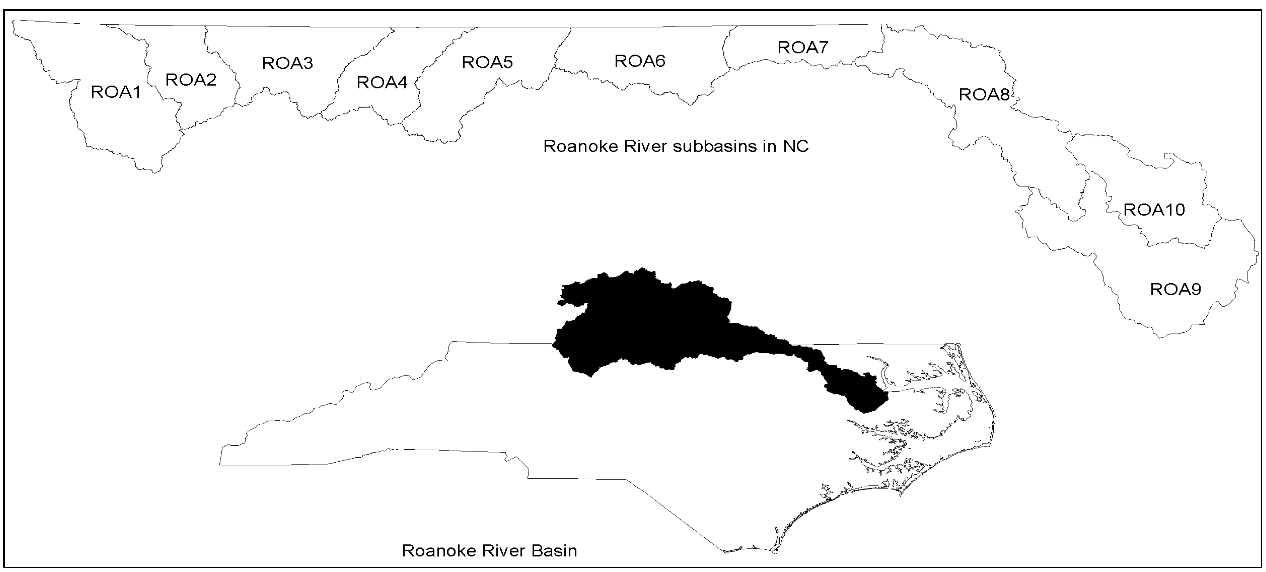

Figure 1. Geographical relationships of the Roanoke River basin.

Ambient water quality information is collected from the Dan River near Francisco. This location is near the Virginia/North Carolina state line and monitors water quality conditions of the river as it flows into North Carolina. These data have indicated good water quality, with few violations in water quality standards. However, the river is very turbid after rainfall events. Benthos data from this site have indicated a Good bioclassification since 1984, except in 1990, when an Excellent rating was given.

A second benthos site on the Dan River below Snow Creek improved from Good-Fair in 1994 to Good in 1999. The very high flows in 1994 may have scoured the benthic community, causing the lower rating.

North Double Creek and Snow Creek are located in agricultural areas. Their benthos ratings have fluctuated between Fair and Good-Fair. Improvements at North Double Creek may be due to implementation of conservation practices. In a special study conducted in 1995, two sites in the middle portion of Town Fork Creek were rated as Good-Fair. The upstream portion, however, was given a Poor rating. This upper part of Town Creek had habitat and organic enrichment problems.

Investigations have been conducted on three lakes within this subbasin: Hanging Rock Lake, Kernersville Reservoir, and Belews Lake. Hanging Rock Lake was classified as oligotrophic with no water quality problems. Kernersville Lake changed from a mesotrophic classification in 1994 to a eutrophic classification in 1999. This lake has elevated nitrogen and phosphorus concentrations, and in 1999 chlorophyll *a* concentrations were greater than the state standard.

Belews Lake was also classified as oligotrophic, but a fish consumption advisory remains in effect for a few species due to elevated concentrations of selenium in the tissue. The source of selenium was the historic discharge from the ash pond basin of Duke Power Company's Belews Creek Steam Station. This discharge was rerouted to the Dan River in 1985, and selenium body burdens in fish have been gradually declining.

Another major tributary of the Dan River is the Mayo River, which has most of its watershed in Virginia. Land use is primarily agriculture or forest. There are only two municipal areas in the watershed: Madison and Mayodan. Other large tributaries in this subbasin include Hogans Creek and Beaver Island Creek. The Mayodan WWTP (design flow = 1.25 MGD) discharges to the Mayo River near the confluence with the Dan River.

Ambient water quality was monitored at the Mayo River near Price. This location is near the Virginia/North Carolina state line. These data suggested good water quality, with very few violations of water quality standards.

Benthic macroinvertebrate samples have been collected at two sites on the Mayo River. These sites were sampled under extremely low flow conditions during 1999. Such conditions might be expected to reduce the effects of nonpoint source runoff, but would likely magnify the effects of point source dischargers. In 1999, the Mayo River near the North Carolina/Virginia state line was rated as Good. However, a decline in biological integrity prior to the confluence with the Dan River resulted in a Good-Fair rating. Problems in the lower Mayo River were most evident at low flow, and these problems may be related to point source dischargers from the Town of Mayodan. The site near Mayodan had been Good in 1994, a high flow year.

Below the confluence with the Mayo River, the Dan River flows for 25-30 miles in North Carolina, then flows back into Virginia. The Smith River is a major tributary to this portion of the Dan River. Most of the Smith River catchment is in Virginia, and flow into North Carolina is regulated by Philpott Reservoir. Other smaller tributaries include Jacobs Creek, Buffalo Creek, and Wolf Island Creek. Eden and Reidsville are the only two major municipal areas in this section.

Fish tissue samples were collected from the Dan River near Eden and all metal concentrations were less than US EPA, FDA, and State of North Carolina criteria.

Ambient monitoring data were collected from three locations in this subbasin: the Dan River near Wentworth, the Smith River at Eden, and the Dan River near Mayfield. The ambient monitoring site on the Smith River is located near the Virginia/North Carolina boundary. Data from this location has shown very few violations of North Carolina water quality standards. Flow is regulated by the discharge from the upstream Philpott Reservoir and water quality problems had been noted downstream of the Town of Martinsville's WWTP.

This facility is approximately 12 river miles above the Smith River monitoring location, but below the Philpott Reservoir. Historically, this facility had been responsible for elevated concentrations of chloride and total dissolved solids in the Smith River, but neither parameter had indicated problems in the last five years. The Smith River, however, continued to have high conductivity values (median = 183 μmhos/cm).

Extremes in flows in the summer of 1999 resulting from extreme drought conditions, followed by a succession of hurricanes limited benthos sampling to only the Smith River. A Fair bioclassification for the Smith River near Eden was found in 1994 and 1999.

The two ambient sites on the Dan River monitored conditions in the Smith River and the influence of dischargers near the Town of Eden. There were few violations of water quality standards at either site. Median conductivity at the Mayfield site was more than twice the median value at the Wentworth site (57 *vs*. 125 μmhos/cm).

Before the Dan River flows back into North Carolina from Virginia, it receives effluent from the Danville Northside WWTP. There is a short stretch of river in North Carolina and then it flows once again back into Virginia. Three tributaries in this area are Moon Creek, Rattlesnake Creek, and Country Line Creek. In Virginia, the Dan River forms the headwaters of the John H. Kerr Reservoir, which straddles the North Carolina/Virginia state line.

Ambient monitoring data were collected from the Dan River at Milton. Good water quality conditions have been recorded at this location, with very few violations of state water quality standards.

During the dry summer of 1999, many streams in this subbasin had little or no visible flow. No benthic invertebrate samples were collected from Country Line Creek. However, the low-flow conditions did make it possible to collect samples for the first time from the Dan River near Milton. These produced a Good bioclassification.

The next downstream area includes the watersheds of Hyco Reservoir and the Hyco River (which flows into Virginia), Mayo Reservoir and Mayo Creek. These systems join the Dan River and eventually flow into an arm of John H. Kerr Reservoir in Virginia. Tributary streams are low gradient, sandy systems.

Ambient monitoring data were collected from five streams in this area: Hyco Creek near Leasburg, Hyco River near McGhees Mill, Marlowe Creek near Woodsdale, Hyco River near Denniston, Virginia, and Mayo Creek near Bethel Hill. The Marlowe Creek site is downstream from the Roxboro WWTP (5.0 MGD) which resulted in elevated nitrate+nitrite nitrogen, total phosphorus, and copper concentrations. The benthos bioclassification for Marlowe Creek improved from Poor in 1994 to Fair in 1999. This change coincided with a reduction in the facility's effluent toxicity.

Historically, Hyco Creek received a Good-Fair rating under low and normal flow conditions, but declined to a Fair classification under high flow conditions. No sample was collected in 1999 because no flowing water was observed in the creek during the sampling period. Observations during the very dry summer of

1999 indicated that many other streams in this subbasin also stopped flowing. This seasonally intermittent low flow may limit the diversity of the fish and macroinvertebrate communities.

Four lakes in this subbasin are monitored as part of the Lakes Assessment Program: Hyco Lake, Lake Roxboro, Roxboro Lake, and Mayo Reservoir. Hyco Lake and Mayo Reservoir were classified as oligotrophic, while Lake Roxboro and Roxboro Lake were eutrophic. No algal blooms have been reported in any of these lakes.

A four-unit coal-fired power plant is located on Hyco Lake, and discharge from its ash ponds had resulted in elevated levels of selenium in the water, biota, and sediments of the reservoir. The ash pond wet discharge was eliminated in 1990. Since then, the fishery has shown signs of recovery and the fish consumption advisory was revised in May 1995 to include only common carp, white catfish and green sunfish.

Mayo Reservoir, which also receives effluent from a power plant's ash pond, had elevated selenium levels, but there were no violations of water quality standards. Hydrilla and Brazilian elodea, both nuisance aquatic macrophytes, have colonized large areas of the littoral zone in Mayo Reservoir.

Other small to medium-sized headwater tributaries of John H. Kerr Reservoir include Aarons Creek, Grassy Creek, Island Creek, and Nutbush Creek. These are in the piedmont ecoregion which is characterized by low, rolling hills and streams of moderate gradient. Henderson is the only urban area, with the Henderson - Nutbush Creek WWTP (4.14 MGD) the only large discharger. Benthos sampling of Nutbush Creek gave Fair bioclassifications in 1994 and 1999.

Ambient monitoring data were collected from Nutbush Creek near Henderson, downstream of the WWTP. During this monitoring cycle, most conventional water quality parameters did not show any violations of water quality standards. The Henderson WWTP has been under Special Order by Consent for failure to meet its toxicity limits. This SOC expired in September 1999 and is currently under review.

Although the effluent is still toxic, the town has made substantial progress in identifying which industries may be the sources of these problems. Long term monitoring at this site has shown an increase in dissolved oxygen and declines in fecal coliform, turbidity, nitrogen, and phosphorus measurements. These changes were the result of substantial improvements at the treatment plant beginning in 1988.

The Nutbush Creek Arm of Kerr Reservoir has been monitored by the Division since 1982. Historically, this portion of the reservoir has been rated either mesotrophic or eutrophic. In 1999, it was rated as mesotrophic. Fish tissue samples were collected in 1999 from Kerr Reservoir at the mouth of Nutbush Creek and analyzed for metals and PCBs. Two of the 19 striped bass samples had PCB concentrations greater than the US EPA screening value. One largemouth bass sample had a mercury concentration greater than the US EPA criteria screening value. Except for the statewide consumption advisory for bowfin, there are no specific advisories in place for fish in Kerr Reservoir.

Lower Roanoke River basin (Subbasins 7 - 10)

The lower Roanoke River basin begins with Lake Gaston, which is located directly below John H. Kerr Reservoir, and its many small tributaries, including Sixpound Creek and Smith Creek. The Roanoke River begins below Lake Gaston.

Macroinvertebrate surveys produced a Fair rating for Smith Creek and a Good-Fair rating for Sixpound Creek. Both sites indicated improved water quality during the low flow and drought like conditions in the summer of 1999 in contrast to the high flows experienced in 1994. Although Smith Creek had a large reduction in intolerant taxa in 1994, it retained a Fair rating, as has been found since 1984.

The reduction in taxa during high flows is characteristic of the effects of scour, particularly in streams that become very turbid after rain.

Ambient water chemistry data were also collected from Smith Creek at the site near Paschall. Dissolved oxygen concentrations were lower here (6.6 mg/l median) than at any other tributary sites. Approximately, 26% of the observations were less than 5.0 mg/l.

Lake Gaston was classified as oligotrophic or mesotrophic in 1999. The nuisance aquatic macrophyte, *Hydrilla*, continued to expand its coverage in the reservoir. In the spring of 1999, 5,000 grass carp were stocked in an effort to control this and other exotic plants. Twenty fish from Lake Gaston were analyzed for mercury contamination. None of the samples were found to have concentrations greater than US EPA or FDA criteria.

Roanoke Rapids Lake is located below Lake Gaston, and has extensive growths of nuisance aquatic macrophytes. More than 30% of the entire lake's surface area is covered with *Hydrilla*. *Myriophyllum spicatum* and *Egeria* were also present in the lake. The lake was mesotrophic for 2 of the 3 sampling periods during 1999.

The 60 mile stretch of the Roanoke River below this lake is within the transition zone from piedmont to coastal plain ecoregions. Roanoke Rapids/Weldon is the only urban area, and most of the land use is forest or agriculture.

Ambient monitoring data were collected from three sites in this section of the river: at Roanoke Rapids, near Scotland Neck, and near Lewiston. Although there were no substantial water quality problems, median total suspended solids and nitrate + nitrite nitrogen concentrations increased in a downstream manner from Roanoke Rapids to Lewiston, then declined from Lewiston to San Souci.

Roanoke River at Scotland Neck maintained its Good benthos rating in 1999, as was found in 1994. A second site on the Roanoke River, near Halifax, was also rated Good and Quankey Creek below the Halifax WWTP maintained the Fair rating it received in 1992.

Fish tissue samples were collected from two sites on the Roanoke River in 1995 and 1999. Six bowfin samples from the river at Weldon had mercury concentrations greater than the EPA screening value of 0.6 µg/g. At Scotland Neck, of the 23 fish tested for mercury contamination, one largemouth bass had a concentration greater than the US EPA screening value and one bowfin had a concentration greater than the FDA criteria of 1.0 µg/g.

Deep Creek, Oconeechee Creek, Quankey Creek (above the Town of Halifax's WWTP), Kehukee Swamp, and Conoconnara Swamp were not rated using macroinvertebrate data because of their swampy character. These streams exhibited few signs of anthropogenic stress.

Further downstream, near Williamston and Plymouth, the watersheds are entirely in the coastal plain. The Roanoke River in this area is bordered by extensive floodplain forests. The Nature Conservancy has identified these high quality alluvial bottomland hardwood forests as the largest intact and least disturbed ecosystem of this type in the mid-Atlantic region.

Ambient water chemistry data have been collected from sites on the Roanoke River near Williamston, Plymouth, and Sans Souci. These data have shown no major water quality problems from these areas with the exception of elevated ammonia nitrogen (NH_3) concentrations at San Souci (median = 0.75 mg/l). The largest discharges in this area are Weyerhaeuser (82.5 MGD), Williamston's WWTP (2.0 MGD), Alamac Knit Fabrics (1.5 MGD), and Plymouth's WWTP (0.8 MGD), all of which discharge to the Roanoke River.

Dissolved oxygen concentrations in the mainstem of the lower Roanoke River were one of the most important water quality issues addressed during this basinwide assessment period. The significance of this issue was the result of a fish kill during summer 1995 after an abrupt decrease (from 18,000 cfs to less than 3,000 cfs) in the discharge from the upstream impoundments. This drop occurred within one day and allowed water with low dissolved oxygen concentrations to drain from riparian wetlands along the lower Roanoke River into the mainstem portion of the river. This large volume of anoxic water mixed with the water in the mainstem portion of the river and caused a dramatic reduction in dissolved oxygen, resulting in a large fish kill and mortality of other aquatic life.

Following this event, a plan was developed to minimize the negative impacts of swamp water with low dissolved oxygen during the transition from flood control by the upstream reservoirs. The plan, known as the "Betterment Plan" extends the period in which flow is decreased from the Roanoke Rapids Dam. This results in a decrease in the rate in which water drains from the riparian wetlands downstream back into the Roanoke River.

The Roanoke River from Williamston to the mouth remains under a fish consumption advisory for all species except herring and shad, due to dioxin contamination. Yearly monitoring by Weyerhaeuser indicates that dioxin levels in fish are gradually decreasing since Weyerhaeuser Corporation instituted dioxin reduction and management programs. Dioxin toxicity equivalents have been less than the NC criteria of 3.0 pg/g in samples collected near Williamston since 1994.

Based on macroinvertebrate data, the Roanoke River has been assigned Good-Fair bioclassifications from near Hamilton to below Williamston. The lower section of the river, near the Plymouth and Sans Souci area, has experienced a mild temporary estuarine influence in some years, but is still regarded as a lower coastal plain freshwater river. Macroinvertebrate data from the Roanoke River at San Souci has suggested good water quality. Tributaries to the Roanoke River, such as Conoho Creek and Conaby Creek are swampy and may experience periods of very little or no flow.

The Cashie River is the largest downstream tributary of the Roanoke River and the Town of Windsor is the largest municipality in this watershed. The Cashie River and its tributaries often stop flowing in the summer, making water quality assessments more difficult. Land use in the area is primarily forest with a mix of agricultural activities.

Ambient monitoring data were collected from the Cashie River near Lewiston. Low dissolved oxygen concentrations occurred frequently; the median concentration was approximately 3 mg/l over the past five years. Fecal coliform bacteria were also greater at this site than at any other site in the coastal plain. Total Kjeldahl nitrogen and total phosphorus were also elevated compared to other coastal plain stations.

Benthos sampling of the lower Cashie River and Hoggard Mill Creek suggested natural communities, with a number of rare invertebrate species. The upper Cashie River, Roquist Swamp, and Wading Place Creek showed some evidence of stress.

Flow Regulation in the Roanoke River Basin

Flow in the Roanoke River basin is controlled or regulated by six reservoirs. Smith Mountain Lake, Philpott Reservoir and Leesville Lake occur entirely within Virginia and are located in or near the mountains. The remaining reservoirs, John H. Kerr Reservoir, Lake Gaston and Roanoke Rapids Lake, lie along the Virginia /North Carolina border and are near one another. These reservoirs are managed by Virginia Power/North Carolina Power and the U.S. Army Corps of Engineers for hydroelectric production and flood control.

Understanding the reservoirs' physical attributes (Table 1) and how river flow is managed provides insight on the water quality concerns of the three North Carolina reservoirs and the Roanoke River downstream of Roanoke Rapids Lake:

Kerr Reservoir

Kerr Reservoir was constructed in 1950 and is located at river mile 179. The reservoir is managed by the USCOE primarily for flood control and secondarily for hydroelectricity. As a result, this reservoir has a larger flood storage capacity than Lake Gaston or Roanoke Rapids. This capacity is located between the 300 and 320 ft. contour elevations. Because flood control is the primary function of the reservoir, there is minimal water level fluctuations.

Lake Gaston

Lake Gaston was created between 1960 and 1962 by Virginia/North Carolina Power. The reservoir, located at river mile 146, functions in hydroelectric production. The water level fluctuation is generally ± 1 ft when the reservoir is being operated for energy production. Lake Gaston has an additional three feet of storage (between the 200 and 203 ft. contour elevations) for flood control and represents an additional 63,000 Ac-ft.

Roanoke Rapids Lake

Roanoke Rapids Lake, located at river mile 138, was constructed by Virginia/North Carolina Power between 1953 and 1955. The production of hydroelectricity is its sole function. The reservoir has no flood storage capacity. It is linked directly with Lake Gaston. Because of the differences in hydraulic and storage capacities between the two reservoirs, drawdown may range between 3-5 ft/day during operations at Roanoke Rapids Lake.

Three factors influence how water is discharged among the reservoirs and the portion of the river below Roanoke Rapids Lake. These include reservoir operations during flood periods, energy demand, and reservoir operations during striped bass spawning season. Generally, if flood flows at Kerr and Gaston exceed their respective maximum turbine capacities, excess flows may be passed through their spillways. Specifics as to how water is allocated among reservoirs for flood control may be found in North Carolina Power (1995).

Water allocation among the reservoirs for energy production varies depending on the quantity of water available and the demand for energy. During normal river flow, at least one generating unit is always operated at Roanoke Rapids to maintain a minimum flow of 2,000 cfs. However during the weekends, the facility at Lake Gaston is not usually operated. Thus, a drawdown of 2.5 ft. will occur in Roanoke Rapids Lake to maintain a minimum flow of 2,000 cfs below the reservoir.

The lower Roanoke River (below Roanoke Rapids) supports an important recreational and commercial fishery. Anadromous fish using the river include Atlantic sturgeon, blueback herring, alewife, hickory shad, American shad, white perch, and striped bass. The portion of the river between river miles 78 and 137 are important spawning areas for striped bass. Spawning begins in April and ends by mid-June. In the 1980's, a decline in the number of spawning striped bass was noted. This was followed by a decline in the commercial harvest of this species.

Table 1. Physical attributes of Kerr Reservoir, Lake Gaston, and Roanoke Rapids Lake.

Reservoir	Elevation (ft.)	Area (Ac)	Volume (Ac-ft.)	Drawdown (ft.)	Flood Storage (Ac-ft.)	Retention Time (days)[1]
Kerr	300	48,900	1,472,000	see text	1,278,000	93
Gaston	200	203,000	450,000	1	63,000	29
Roanoke Rapids	132	46,000	77,140	3-5	0	5

[1] Based on a mean annual flow of 7,951 cfs as measured at Roanoke Rapids Lake, NC.

These declines have been attributed to overfishing, altered flows, and deterioration in water quality by various researchers. One management strategy being used to recover the striped bass fishery has been to alter river flows during the spawning season (Table 2). Moderately high flows are maintained during the spring to attract adult fish to the spawning grounds. In addition, stable target average daily flows are now required to ensure proper and successful delivery of healthy larval fish to the Albemarle Sound.

Table 2. Flow regime below Roanoke Rapids Lake during the striped bass spawning season.

Dates	Target Average Daily Flow (cfs)	Lower Limit (cfs)	Upper Limit (cfs)
April 1-15	8,500	6,600	13,700
April 16-30	7,800	5,800	11,000
May 1-15	6,500	4,700	9,500
May 16-31	5,900	4,400	9,500
June 1-15	5,300	4,000	9,500

Executive Summaries By Program Area

BENTHIC MACROINVERTEBRATES

Bioclassifications and Water Quality Changes

One hundred fifty-five benthic macroinvertebrate samples have been collected from 79 sites in the Roanoke River basin since 1983. Only 51 of these sites have been assigned a bioclassification with existing Division criteria (Figure 2). Most of the rated streams were in the mountains or piedmont ecoregion of the basin.

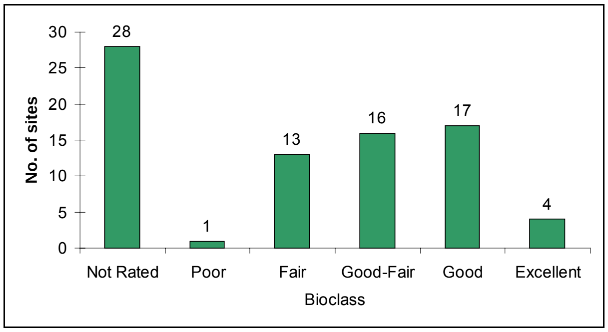

Figure 2. Bioclassifications of 79 sites collected in the Roanoke River basin, 1983 - 1999.

Many of the streams evaluated as "Not Rated" were in the coastal plain and were not assigned a rating because bioclassification criteria for swamp type streams are still in development. Information from monitoring swamp type streams was used in a narrative sense to highlight areas of best and worst water quality. Until criteria exist, narrative descriptions will be used to monitor future changes in water quality.

In 1999, sampling was hampered by extremes in stream flows. Many streams ceased flowing during the summer drought, while other sites could not be sampled because of flooding events. Samples were obtained from 35 sites (Figure 3). Most of the streams classified as "Not Rated" were coastal plain swamp type streams in Subbasins 08 - 10. Many of these sites were also sampled for the first time.

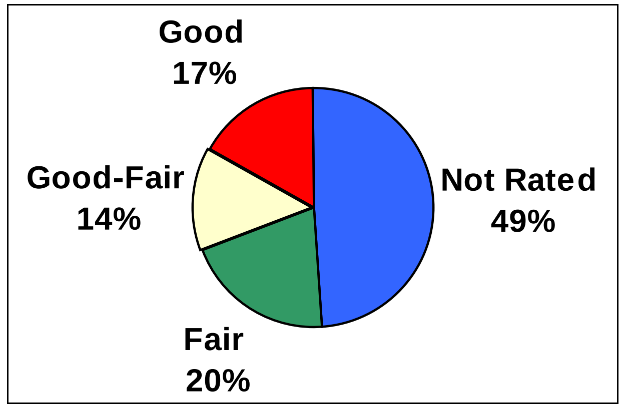

Figure 3. Bioclassification of 35 basinwide sites in the Roanoke River basin, 1999. Note: no sites were rated as Excellent or Poor.

The distribution of the 1999 ratings was similar to the distribution of water quality ratings for all sites sampled since 1983, although the latter data set included some Excellent and Poor sites (Figure 3 and Table 3).

Table 3. Bioclassifications of 79 sites by subbasin in the Roanoke River basin, 1983 - 1999.[1]

Drainage	E	G	G-F	F	P	NR
Upper Dan River	3	7	7	2	1	0
Mayo River	-	2	3	-	-	0
Middle Dan River	1	4	-	2	-	3
Lower Dan River	-	1	1	-	-	0
Hyco River	-	-	-	2	-	0
Kerr Reservoir tributaries	-	-	2	3	-	2
Lake Gaston tributaries	-	-	1	1	-	0
Upper Roanoke River		3	-	3	-	5
Lower Roanoke River	-	-	2	-	-	10
Cashie River	-	-	-	-	-	8
Total (n)	4	17	16	13	1	28
Total (%)	5	22	20	18	3	33

[1]E = excellent, G = Good, G-F = Good-Fair, F = Fair, P = Poor, and NR = not rated.

There was little indication of widespread changes in water quality in the Roanoke River basin, but individual sites sometimes showed distinct long-term or short-term changes in water quality.

The supplemental classification of ORW has been assigned to Indian Creek and Cascade Creek in Hanging Rock State Park. These are the only ORW streams in the basin; there are no streams supplementally classified as HQW. Good water quality ratings were assigned to the upper Mayo

River and to many sites on the Dan River and upper Roanoke River (in Subbasin 08).

Nonpoint source runoff from agricultural areas produced Fair or Good-Fair ratings in some streams. Point source problems also cause problems in a few streams, including the Smith River, Marlowe Creek, and Nutbush Creek. The 1999 data also suggested point source problems in the lower Mayo River.

Overall, the water quality in the basin has not changed since the last monitoring cycle (Figure 4). Between cycle changes were evaluated at 15 sites which were rated in 1994 and 1999. The majority of these sites had no changes in water quality other than flow-related changes in ratings.

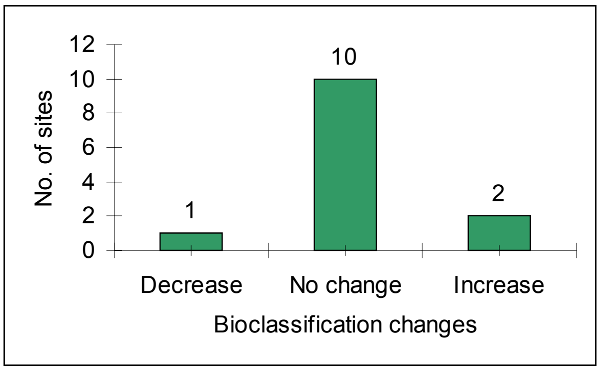

Figure 4. Short-term changes in bioclassifications at 13 sites in the Roanoke River basin, 1994 and 1999.

Changes in water quality or bioclassifications were observed:

- Marlowe Creek and Nutbush Creek had Poor ratings in earlier surveys due to the effects of wastewater treatment plants. Better operation of these facilities improved both stream's rating to Fair.
- Improvements at North Double Creek (from Fair to Good-Fair) may be related to the installation of conservation practices in this watershed, although between-year changes in flow might also have affected the bioclassification change.
- The lower Mayo River changed from Good in 1994 to Good-Fair in 1999. This decline under low-flow conditions suggested point source impacts.
- Most Roanoke River sites were stable, with slight changes associated with sampling period differences in flow.
- The higher bioclassification seen in 1994 and 1999 for the Roanoke River near Scotland Neck reflected a change in collection techniques, rather than any true improvement in water quality.

Long-term (> 5 year's of data) changes in bioclassification were evaluated at six sites (Figure 5). These data indicated that water quality did not decline at any of these long-term monitoring sites.

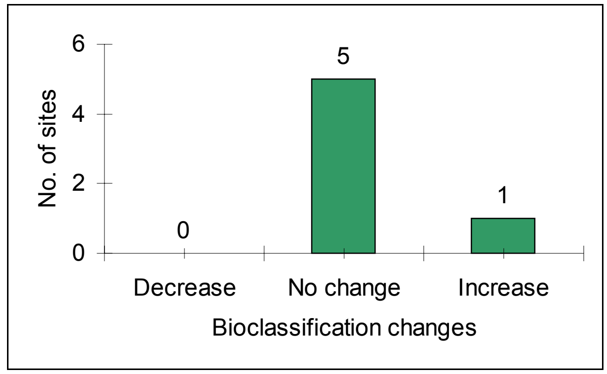

Figure 5. Long-term changes in bioclassifications at six sites in the Roanoke River basin, 1983 - 1999.

New Species and Distributional Records for the Benthic Invertebrate Fauna

Several rare or unusual invertebrate species were collected in the basin during 1999 basinwide monitoring. These taxa tended to be found in either the headwater areas of the Dan River or in the lower Roanoke River and its tributaries. Rare species found in the upper Dan River included *Ephoron leukon*, *Mayatrichia ayama*, and *Neotrichia*. A midge (*Rheopelopia* cf. *paramaculipennis*), that was found in the Dan River at Milton, represented a new state record.

The Roanoke River is thought to harbor a variety of rare mussel species, although current information is limited. Recent collections in the Roanoke River near Weldon as part of the relicensing efforts of the Roanoke Rapids and Lake Gaston hydroelectric projects yielded eight species:

- *Alasmidonta undulata, Elliptio lanceolata*, and *Elliptio roanokensis* (all classified as threatened in North Carolina),
- *Lampsilis radiata* and *Leptodea ochracea* (both classified as special concern in North Carolina); and
- *Lasmigona subviridis* (classified as endangered at the state and federal level).

Elliptio lanceolata was also found by Division biologists in Kehukee Swamp during 1999.

The lower Roanoke River from Scotland Neck to Sans Souci is also important habitat for the rare crayfish, *Orconectes virginiensis*.

Monitoring of the Roanoke River discovered:

- populations of two rare mayflies -- *Ephemerella argo* and *Pseudocentroptiloides usa;*
- two rare species of *Ceraclea,* and
- several rare midge taxa which were found in midstream sand habitats -- *Chernovskia orbicus*, *Demicryptochironomus*, and *Paratendipes basidens*.

Little information existed on the invertebrate fauna of swamp streams in the lower basin. Winter monitoring in 1999 documented:

- *Leptophlebia bradleyi* in Roquist Swamp and Conoconnara Swamp;
- *Prostoia* (*hallasi*?) in Oconeechee Creek and the Roanoke River at Williamston;
- *Ceraclea* cf. *cama* in the lower Conoho Creek and Hoggards Mill Creek;
- *Platycentropus* cf. *amicus* was abundant at lower Conoho Creek, Kehukee Swamp and Roquist Swamp;
- *Nehalennia irene* in Hoggards Mill Creek;
- *Epiaeschna heros* in Wading Place Creek and Cashie River; and
- *Planorbula armiger* in Conoconnara Swamp and lower Conoho Creek.

FISHERIES

Fish Community Structure

Approximately 102 species have been collected from the Roanoke River basin in North Carolina (Menhinick 1991; Rohde, *et al*. 1998). Special status has been granted to seven of these species by the United States Department of the Interior, the North Carolina Wildlife Resources Commission, or the North Carolina Natural Heritage Program under the North Carolina State Endangered Species Act (G.S. 113-311 to 113-337 (LeGrand and Hall 1999; Menhinick and Braswell 1997) (Table 4). Additional information on these seven species may be found in Menhinick and Braswell (1997) and Rohde, *et al*. (1998).

Fish Kills

The Division has systematically monitored and reported on fish kill events across the state since 1996. From 1994 to 1999, field investigators reported five kill events in the Roanoke River basin. Fish kills occurred on the Roanoke River proper from Roanoke Rapids to Jamesville and along the Cashie River near Windsor and Sans Souci. Mortality estimates ranged from 30 to more than 10,000 fish per event.

The reduction of water over the dam at Roanoke Rapids Lake caused several large kill events during 1995. During July 1995, approximately 8,000 striped bass with a replacement value of more than $230,000 were killed in the Roanoke River when flows were reduced from 20,000 to 2,000 cfs within a short period of time (Freeman 1995). The magnitude of this event led to an agreement between upstream dam operators and state resource agencies regarding future flow reductions in the river (refer to the Ambient Monitoring System section).

Kill events were also reported following Hurricane Fran and Hurricane Bonnie in 1996 and 1998, respectively.

Table 4. Species of fish listed as endangered, rare, threatened, or of special concern in the Roanoke River basin in North Carolina.

Species	Common Name	State or Federal Status	State Rank[1]
Acipenser oxyrhynchus	Atlantic sturgeon	State - Special Concern	S3
Exoglossum maxillingua	Cutlips minnow	State - Endangered	S1
Scartomyzon ariommum	Bigeye jumprock	State - Special Concern	S2
Thoburnia hamiltoni	Rustyside sucker	State - Endangered	S1
Noturus gilberti	Orangefin madtom	State - Endangered	S1
Etheostoma collis	Carolina darter	State - Special Concern	S2
Etheostoma podostemone	Riverweed darter	State - Special Concern	S2

[1]S1 = critically imperiled in North Carolina because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from North Carolina; S2 = imperiled in North Carolina because of rarity or because of some factor(s) making it very vulnerable to extirpation from North Carolina; S3 = rare or uncommon in North Carolina (LeGrand and Hall 1999).

Fish Tissue

The Division conducted fish tissue surveys at eight stations within the basin from 1994 to 1999. These surveys were conducted as part of the mercury contaminant in fish assessments in the eastern part of the state and during routine basinwide assessments.

Most tissue samples collected during the period contained metal and organic contaminants at undetectable levels or at levels less than the US EPA, US FDA, and State of North Carolina criteria (Figure 6).

Elevated mercury concentrations were, however, measured in fish samples from 6 of the 8 stations. Such levels were most often detected in largemouth bass and bowfin, two species at the top of the food chain and most often associated with mercury bioaccumulation in North Carolina. More than 50% of the samples collected from the Roanoke River at Williamston and from the Cashie River at Windsor contained mercury concentrations exceeding the state criteria. Presently, there are no consumption advisories for mercury contaminated fish in the Roanoke River basin. However, a statewide advisory for the consumption of bowfin was issued in 1997.

All other detected metal analytes (arsenic, cadmium, chromium, copper, lead, nickel, selenium, and zinc) were present in tissue samples at concentrations less than US EPA, US FDA, and State of North Carolina fish consumption criteria.

Fish consumption advisories have been issued for several waterbodies within the basin. Belews Lake in Stokes and Rockingham counties remains under a consumption advisory first issued in 1988 due to elevated selenium concentrations from the Duke Power Company Belews Creek Steam Station's ash basin discharge. The discharge was rerouted from the lake to the Dan River in 1985. The advisory was revised in July 1995 to include only common carp, redear sunfish, black crappie, and white crappie. Selenium concentrations in fish from Belews Lake have exhibited a decreasing trend in recent years but still remain at levels which warrant an advisory.

The consumption of fish from Hyco Reservoir in Person and Caswell counties also remains under an advisory due to elevated selenium levels from the Carolina Power & Light Company Roxboro Steam Electric Plant's ash pond discharge. First issued in 1988, the advisory was revised in 1995. The advisory remains in effect for common carp, white catfish, and green sunfish.

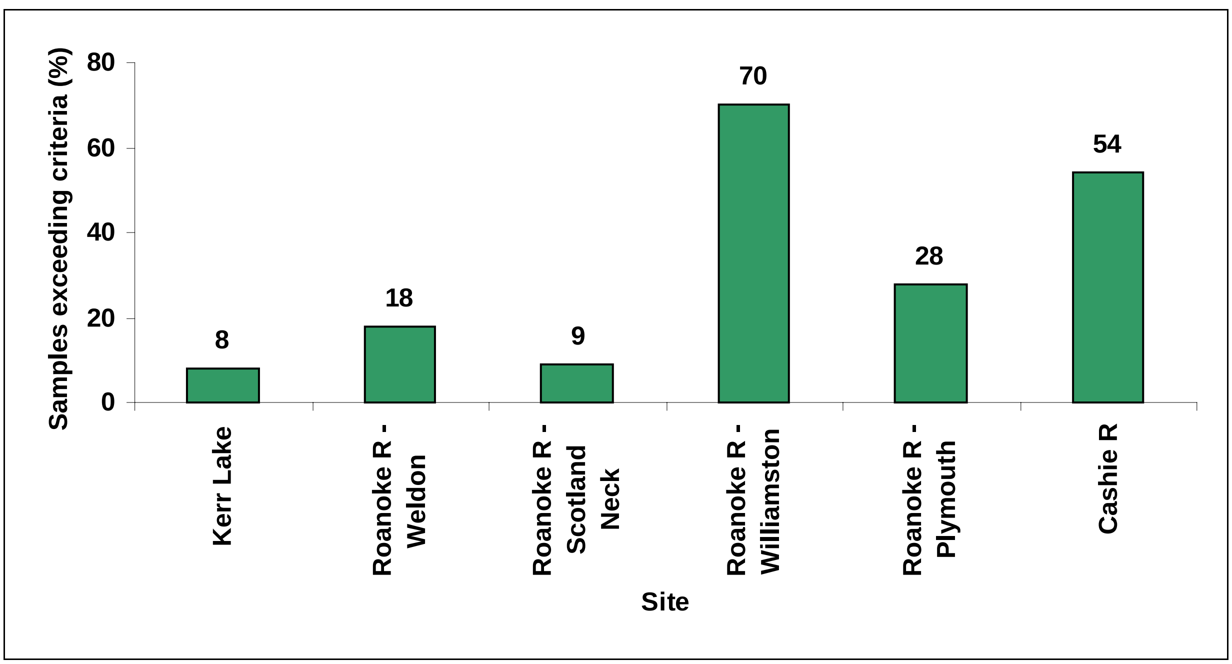

Figure 6 **Fish tissue monitoring in the Roanoke River basin, 1994 - 1999. Note: no samples from the Dan River at Eden or from Lake Gaston near Henrico exceeded any criteria.**

Annual monitoring by the mill has indicated that dioxin concentrations in fish tissue are gradually decreasing since the mill initiated dioxin reduction and management programs in early 1990s. Results from 1994 through 1998 indicated dioxin toxicity equivalents (TEQ, the sum of 2,3,7,8 TCDD and 2,3,7,8 TCDF congeners concentrations) in samples collected near Williamston were less than the North Carolina consumption advisory criterion of 3.0 pg/g. However, dioxin TEQ concentrations continued to be near or above the criterion in bottom feeding species collected near the river's mouth and below the mill discharge.

LAKE ASSESSMENT

Eleven lakes in the Roanoke River basin were sampled as part of the Lake Assessment program (Table 5). Five lakes (Hanging Rock Lake, Belews Lake, Hyco Lake, Mayo Reservoir, and Lake Gaston) exhibited low biological productivity (NCTSI < -2.0). Two lakes, (John H. Kerr Reservoir (the Nutbush Creek arm) and Roanoke Rapids Reservoir), demonstrated moderate biological productivity (-2.0 < NCTSI < 0.0); and four lakes (Kernersville Reservoir, Farmer Lake, Lake Roxboro, and Roxboro Lake) were found to be very biologically productive (0.0 < NCTSI < 5.0) (Figure 7).

Hydrilla, an invasive macrophyte, was found in Belews Lake, Mayo Reservoir, Lake Gaston, Roanoke Rapids Lake, and John. H. Kerr Reservoir.

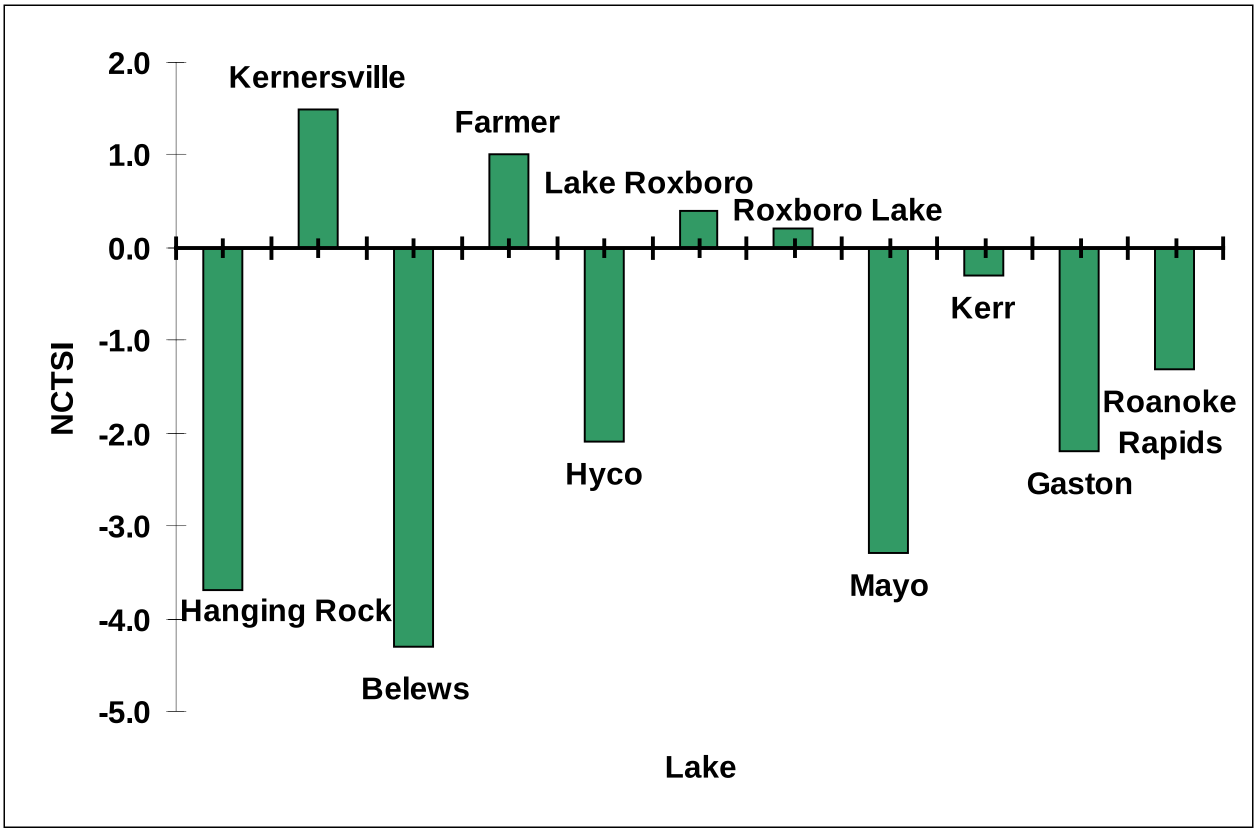

Figure 7. North Carolina Trophic Index scores for lakes and reservoirs within the Roanoke River basin, August 1999.

Table 5. Lakes and reservoirs monitored in the Roanoke River basin in 1999.

Subbasin/Lake	County	Classification	Surface Area (Ac)	Mean Depth (ft)	Volume (X 10^6 m^3)	Watershed (mi^2)
01						
Hanging Rock Lake	Stokes	B	12	2	0.003	1.1
Kernersville Res.	Forsyth	WS-IV, CA	45	16	0.4	5.3
Belews Lake	Forsyth/Stokes/ Rockingham/Guilford	WS-IV, B, C	4030	49	228	46
04						
Farmer Lake	Caswell	WS-II, CA	368	20	6.5	48
05						
Hyco Lake	Person/Caswell	WS-V, B	3750	20	99	188
Lake Roxboro	Person	WS-II, B	195	20	10.8	24
Roxboro Lake	Person	WS-II, CA	212	12	0.3	196
Mayo Res.	Person	WS-V, B	2800	30	105	51
06						
John H. Kerr Res.	Warren/Vance/Granville	B, C	48999	35	448	761
07						
Lake Gaston	Warren/Halifax/ Northampton	WS-V, WS-IV, B, CA	20299	20	512	8239
08						
Roanoke Rapids Res.	Northampton/Halifax	WS-IV, B, CA	4893	16	96	8294

AMBIENT MONITORING SYSTEM

There are 21 ambient water quality monitoring stations located in the Roanoke River basin. These stations are sampled monthly for 27 parameters. Important findings during the recent (09/01/1994 to 08/31/1999) monitoring cycle included:

Temporal Patterns

Overall, measurements of water quality parameters showed few temporal patterns. An exception to this is the site located on Nutbush Creek. Here, water quality improved greatly during the mid 1980's as improvements to the Town of Henderson's WWTP were implemented.

At other sites, distinct spatial differences occurred and depended whether or not the sites were located upstream or downstream of waste-water dischargers.

Fecal Coliform Bacteria

Fecal coliform bacteria concentrations, represented by geometric means, showed few temporal patterns. The only site with a geometric mean greater than 200 colonies/100 ml for this assessment period (09/01/1994 to 08/31/1999) was located on Marlowe Creek (Station N4400000). Most stations (14 out of 21) had geometric means less than 100 colonies/100ml.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were low in the Smith River (at Penshall, Station N6400000). Approximately 25% of the measurements were less than 5.0 mg/l. This site is located in a slow and sluggish area of the river and these conditions might have influenced these measurements.

The Cashie River also exhibited low DO concentrations, but the monitoring site is located in swamp waters, and the low DO conditions are due to natural conditions.

Dissolved oxygen problems in the lower Roanoke River resulting from sudden changes in flow from the hydroelectric facilities upstream have been addressed by regulatory agencies. During the transition from flood control to base flow, the discharges through the Roanoke Rapids powerhouse are now gradually rather than abruptly decreased.

Turbidity

More turbidity measurements greater than 50 NTU occurred in the Dan River subbasins, than in the Roanoke River subbasins. The standard for trout waters (10 NTU) was exceeded 35% of the time (N = 54). However few observations were greater than 50 NTU.

Nutrients

No temporal patterns were noted for nutrients, except for Nutbush Creek. As with other parameters, differences among stations reflected whether or not a wastewater discharge was located upstream.

Metals

Copper and iron were the only two metals that often exceed their actions levels. Iron is a common element in clay soils, therefore elevated concentrations may reflect the geochemistry of the watershed.

In general, elevated concentrations of copper were found at sites located downstream of wastewater discharges.

Relicensing of the Lake Gaston and Roanoke Rapids Hydroelectric Plants
North Carolina Power Company's federal license (Federal Energy Regulatory Commission, FERC) to operate the Lake Gaston and Roanoke Rapids hydroelectric facilities will expire in January, 2001. As a result, North Carolina Power Company initiated a variety of studies in 1994 to support a new FERC license. Many of these studies addressed water quality issues in the reservoirs and downstream of Roanoke Rapids. Results of these studies are available as reports. The most prominent water quality issue associated with the operation of the hydroelectric facilities and Kerr Reservoir (operated by the US Corps of Engineers) is how the changes in discharge from Kerr Reservoir affect water draining from riparian wetlands along the lower Roanoke River.

Sustained periods of high discharges from the reservoirs will result in flooding of the extensive riparian wetlands downstream. If the high discharges are suddenly and dramatically decreased, then water from the riparian wetlands will drain into the mainstem portion of the lower Roanoke. If this situation occurs during the summer, the water draining from the wetlands may carry a high biochemical oxygen demand (BOD) and have dissolved oxygen concentrations low enough to adversely affect dissolved oxygen concentrations in the Roanoke River. A large fish kill occurred when this situation occurred in 1995.

This problem resulted in an agreement (Roanoke River Betterment Plan) that large discharges of water will be followed by a gradual and sequential series of discharges, thus allowing water from the riparian wetlands to gradually mix with water in the mainstem of the Roanoke River and prevent sudden decreases in dissolved oxygen concentrations. This procedure has been followed since the 1995 fish kill, and no fill kills have been associated with decreases in discharges from the reservoirs.

The Nature Conservancy's "Last Great Places"
The lower Roanoke River floodplain is one of the outstanding ecosystems targeted by The Nature Conservancy's (TNC) "Last Great Places" initiative (Jessop 1997). TNC has identified the extent of high quality alluvial bottomland hardwood (wetland) forests along the lower Roanoke River as the largest intact and least disturbed ecosystem of this type along the mid-Atlantic region. As a result, TNC initiated a variety of studies in these wetland habitats. Although these studies do not address traditional water quality issues associated with ambient monitoring, the studies provide insights into the relationships between hydrology and wetland ecosystems.

AQUATIC TOXICITY MONITORING

Twenty-nine facility permits in the Roanoke River basin currently require whole effluent toxicity (WET) monitoring. Twenty-seven facility permits have a WET limit; the other two facilities have episodic discharges and their permits specify monitoring with no limit. Since 1993, the compliance rate of these 27 facilities has stabilized at approximately 90 - 95%.

Facilities which have had problems meeting the toxicity limits were:

- The Cogentrix Corporation's Roxboro plant (Subbasin 05). This facility, which discharges to an unnamed tributary of Mitchell Creek, experienced problems meeting its whole effluent toxicity limit in 1997 and in the latter half of 1999. The 1997 failures were traced to a change in a water treatment chemical applied to the facility's cooling towers. The late 1999 toxicity problems were also associated with the facility's cooling tower blowdown discharge. Areas of investigation as of January 2000 included cooling tower chemicals and the Roxboro water supply.

- The City of Henderson WWTP (Subbasin 06). This facility, which discharges to Nutbush Creek, has a long history of experiencing problems with its whole effluent toxicity. The facility's Special Order by Consent (SOC) expired on September 30, 1999 and an application for an extension of the SOC was submitted by the City. Toxicity reduction activities performed included refractory toxicity testing that targeted at least two industrial contributors as sources of toxicity.

INTRODUCTION TO PROGRAM METHODS

The Division uses a basinwide approach to water quality management. Activities within the Division, including permitting, monitoring, modeling, nonpoint source assessments, and planning are coordinated and integrated for each of the 17 major river basins within the state. All basins are reassessed every five years, and the Roanoke River basin was sampled by the Environmental Sciences Branch in 1994 and 1999.

The Environmental Sciences Branch collects a variety of biological, chemical, and physical data that can be used in a myriad of ways within the basinwide planning program. In some areas there may be adequate data from several program areas to allow a fairly comprehensive analysis of ecological integrity or water quality. In other areas, data may be limited to one program area, such as only benthic macroinvertebrate data or only fisheries data, with no other information available. Such data may or may not be adequate to provide a definitive assessment of water quality, but can provide general indications of water quality. The primary program areas from which data were drawn for this assessment of the Roanoke River basin include benthic macroinvertebrates, fish tissue, lake assessment, ambient monitoring, and aquatic toxicity monitoring.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates, or benthos, are organisms that live in and on the bottom substrates of rivers and streams. These organisms are primarily aquatic insect larvae. The use of benthos data has proven to be a reliable monitoring tool, as benthic macroinvertebrates are sensitive to subtle changes in water quality. Since many taxa in a community have life cycles of six months to one year, the effects of short term pollution (such as a spill) will generally not be overcome until the following generation appears. The benthic community also integrates the effects of a wide array of potential pollutant mixtures.

Sampling methods and criteria have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample from flowing waters based on the number of taxa present in the intolerant groups Ephemeroptera, Plecoptera and Trichoptera (EPT S) (Appendix B1). Likewise, ratings can be assigned with a North Carolina Biotic Index (NCBI). This index summarizes tolerance data for all taxa in each collection. These bioclassifications primarily reflect the influence of chemical pollutants. The major physical pollutant, sediment, is not assessed as well by a taxa richness analysis. Different criteria have been developed for different ecoregions (mountains, piedmont, and coastal) within North Carolina for freshwater flowing waterbodies.

Bioclassifications listed in this report (Appendix B2) may differ from older reports because evaluation criteria have changed since 1983. Originally, total taxa richness and EPT taxa richness criteria were used, then just EPT taxa richness, and now BI as well as EPT taxa richness criteria are used for flowing freshwater sites. Refinements of the criteria continue to occur as more data are gathered.

FISHERIES

Fish Tissue

Because fish spend their entire lives in the aquatic environment, they incorporate chemicals from this environment into their body tissues. Contamination of aquatic resources have been documented for heavy metals, pesticides, and other complex organic compounds. Once these contaminants reach surface waters, they may be available for bioaccumulation, either directly or through aquatic food webs, and may accumulate in fish and shellfish tissues. Results from fish tissue monitoring can serve as an important indicator of further contamination of sediments and surface water.

All fish samples were collected according to the DWQ's Standard Operating Procedures (NCDEHNR 1997). Analysis results are used as indicators for human health concerns, fish and wildlife health concerns, and the presence and concentrations of various chemicals in the ecosystem (Appendix FT1).

Fish Kills

Fish kills investigation protocols were established in 1996 by the Division to investigate, report, and track fish kill events throughout the state. Fish kill and fish health data collected by trained Division and other resource agency personnel are recorded on a standardized form and forwarded to the Environmental Sciences Branch where the data are reviewed.

Fish kill investigation forms and supple-mental information are compiled in a database where the data can be managed and retrieved for use in reporting to concerned parties. Information on fish kills in other basins may be found on the Division's website (refer to the Glossary).

LAKE ASSESSMENT

Lakes are valued for the multiple benefits they provide to the public, including recreational boating, fishing, drinking water, and aesthetic enjoyment. Assessments have been made at publicly accessible lakes, at lakes which supply domestic drinking water, and lakes (public or private) where water quality problems have been observed.

Physical field measurements (dissolved oxygen, pH, water temperature, and conductivity) are made with a calibrated Hydrolab™. Readings are taken at the surface of the lake (0.15 meters) and at 1 m increments to the bottom of the lake. Secchi depths are measured at each sampling station with a weighted Secchi disk attached to a rope marked off in centimeters. Surface water samples are collected for chloride, hardness, fecal coliform bacteria, and metals. A Labline™ sampler is used to composite water samples within the photic zone (a depth equal to twice the Secchi depth). Nutrients, chlorophyll *a*, solids, turbidity and phytoplankton are collected at this depth. Nutrients and chlorophyll *a* from the photic zone are used to calculate the North Carolina Trophic State Index score. The Labline™ sampler is also used to collect a grab water samples near the bottom of the lake for nutrients. Water samples are collected and preserved in accordance with protocols specified in (NCDEHNR 1996b).

Data are used to determine the trophic state of each lake, a relative measure of nutrient enrichment and productivity. These determinations are based on information from the most recent summertime sampling (Appendices L1 - L3).

AMBIENT MONITORING SYSTEM

Assessments of water quality can be obtained from information about the biological communities present in a body of water or from field and laboratory measurements of particular water quality parameters. This section summarizes the field and laboratory measures of water quality, typically referred to as ambient water quality measures.

The Ambient Monitoring System is a network of stream, lake, and estuarine stations strategically located for the collection of physical and chemical water quality data. Parametric coverage is tiered by freshwater or saltwater waterbody classification and corresponding water quality standards. Under this arrangement, core parameters are based on Class C waters with additional parameters appended when justified (Table 6).

Table 6. Freshwater parametric coverage for the ambient monitoring system.[1]

Parameter	All freshwater	Water Supply
Field		
Dissolved oxygen	x	x
pH	x	x
Conductivity	✔	✔
Temperature	✔	✔
Nutrients		
Total phosphorus	✔	✔
Ammonia as N	✔	✔
Total Kjeldahl as N	✔	✔
Nitrate + nitrite as N	✔	x
Other		
Total suspended solids	✔	.
Total dissolved solids	.	x
Turbidity	x	x
Hardness	✔	x
Chloride	x	x
Bacteria		
Fecal coliform bacteria	x	x
Total coliform bacteria	.	x
Metals		
Aluminum	✔	✔
Arsenic	x	x
Cadmium	x	x
Chromium	x	x
Copper	x	x
Iron	x	x
Lead	x	x
Mercury	x	x
Nickel	x	x
Silver	x	x
Zinc	x	x
Manganese	.	x
Biological		
Chlorophyll *a*[2]	x	x

[1]A check (✔) indicates the parameter is collected; an 'x' indicates the parameter is collected and has a standard or action level.
[2]Chlorophyll *a* is collected in Nutrient Sensitive Waters (NSW).

Summaries of water quality parameters measured during the five year period (September 1, 1994 – August 31, 1999) are provided (refer to Tables 35 - 55). These tables present the number of samples collected and the number (and proportion) of samples greater than or less than a water quality reference value.

In addition, a description of how the data are distributed is provided using percentiles. Percentiles describe the proportion of observations less than a specific value or concentration. For example, the 50th percentile (also called the median) provides the value (or concentration) of the parameter in which one half (50%) of the observations lie.

The water quality reference value may be a narrative or numeric standard, or an action level as specified in the North Carolina Administrative Code 15A NCAC 2B .0200. Zinc is not included in the summaries for metals because recent (since April 1995) sampling or analyses may have been contaminated with zinc and the data may be unreliable.

In this report, conductivity is synonymous with conductivity. It is given in micromhos per centimeter (µmhos/cm) at 25 ^{o}C.

AQUATIC TOXICITY MONITORING

Acute and/or chronic toxicity tests are used to determine toxicity of discharges to sensitive aquatic species (usually fathead minnows or the water flea, *Ceriodaphnia dubia*). Results of these tests have been shown by several researchers to be predictive of discharge effects on receiving stream populations.

Many facilities are required to monitor whole effluent toxicity by their NPDES permit or by administrative letter. Facilities without monitoring requirements may have their effluents evaluated for toxicity by the Division's Aquatic Toxicology Laboratory. If toxicity is detected, the Division may include aquatic toxicity testing upon permit renewal.

The Aquatic Toxicology Unit maintains a compliance summary for all facilities required to perform tests and provides a monthly update of this information to regional offices and Division administration. Ambient toxicity tests can be used to evaluate stream water quality relative to other stream sites and/or a point source discharge.

ROANOKE RIVER SUBBASIN 01

Description

This subbasin contains the uppermost reaches of the Dan River in North Carolina (Figure 8), although the headwater reaches of the river are in Virginia. Major tributaries within the North Carolina section in this subbasin include Town Fork Creek, Snow Creek, and Double Creek.

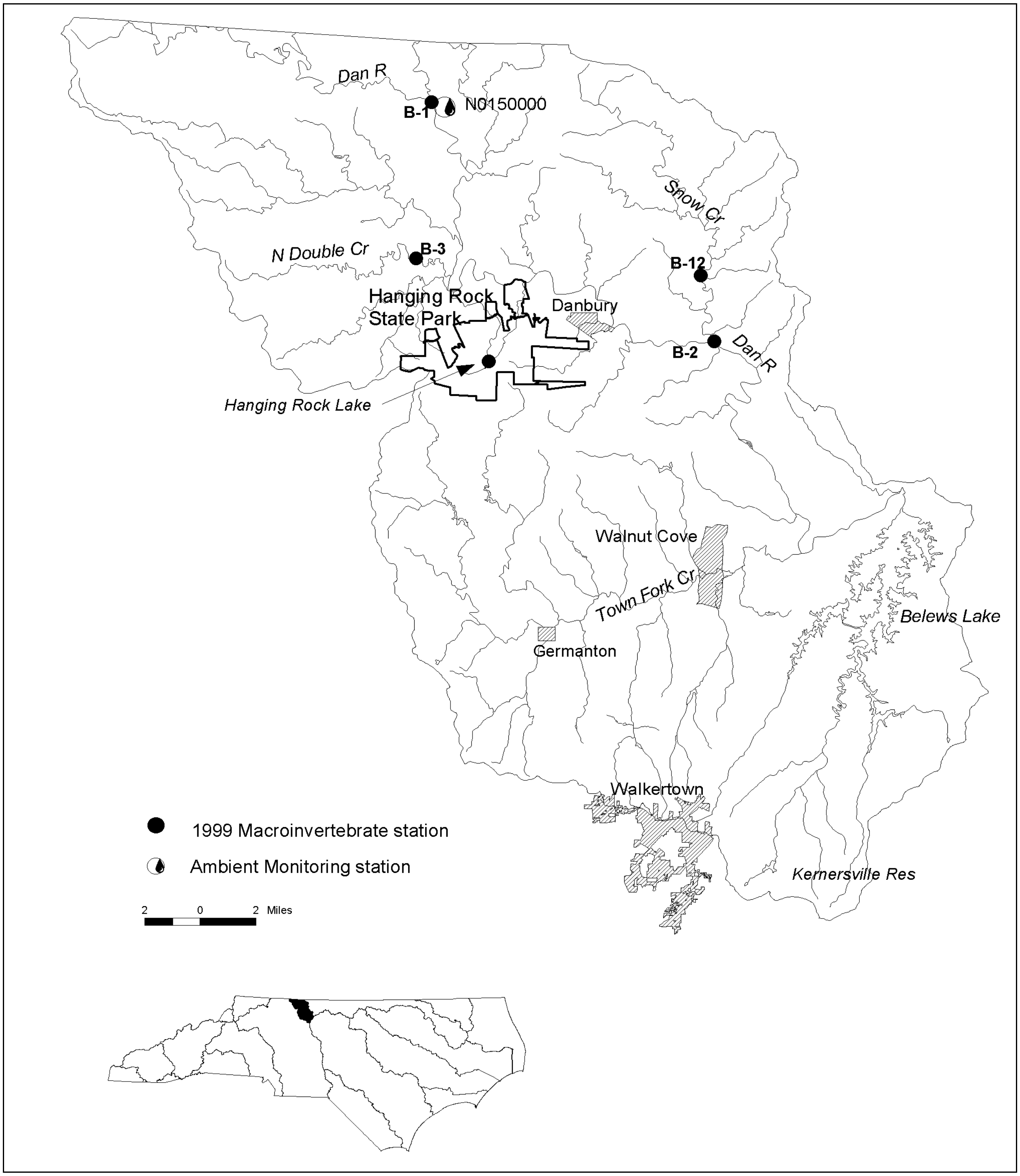

Figure 8. **Sampling sites in Subbasin 01 in the Roanoke River basin.**

These tributaries and major sections of the Dan River are deeply entrenched, suggesting the effects of long-term erosion. Soil erosion rates as great as 21 tons/acre/year have been documented for cultivated cropland in the Upper Dan River (USDA 1992). This compared to 7.3 tons/acre/year from cultivated cropland for the nearby Upper Tar River basin.

Characteristics of this subbasin are borderline between mountain and piedmont ecoregions. As a result of fairly steep to moderate topography, headwater reaches of most tributaries are forested, while many downstream sections are intensively farmed.

This subbasin contains 63 NPDES permitted dischargers. The largest discharger is the Town of Walnut Cove's WWTP which discharges 0.5 MGD to Town Creek. Duke Power Company's Belews Creek Steam Station discharges cooling water to Belews Lake and ash pond basin effluent to the Dan River. Five dischargers are required to monitor their effluent's toxicity: Kobe Copper Products, two Stokes County high schools, Rayco Utilities, and Duke Power's Belews Creek Steam Station.

Overview of water quality

Ambient water quality information is collected from the Dan River near Francisco. This location is near the Virginia/North Carolina state line and monitors water quality conditions of the river as it flows into North Carolina. These data have indicated good water quality, with few violations in water quality standards. However, the river is very turbid after rainfall events.

Benthic macroinvertebrate samples have been collected from 20 locations in this subbasin since 1983 (Table 7 and Appendix B2). Good bioclassifications have been recorded from the two Dan River locations, but more variable results have been observed at tributary sites. Excellent bioclassifications have been recorded only from small headwater tributaries in Hanging Rock State Park.

Nonpoint source pollution seemed to be the major problem within this subbasin. The sites with the lowest ratings (Fair) are in areas of agricultural land use. Many of the tributary streams are very sandy. North Double Creek and Snow Creek are located in agricultural areas. Their ratings have fluctuated between Fair and Good-Fair. In a Special Study conducted in 1995, two sites in the middle portion of Town Fork Creek were rated as Good-Fair. The upstream portion, however, was given a Poor rating. This part of Town Creek had habitat and organic enrichment problems.

The majority of the between sample period changes in water quality were either very small or most likely caused by differences in flow. Improvements at North Double Creek, however, may be due to implementation of conservation practices.

Five dischargers are required to monitor their effluent's toxicity. There were no indications of toxicity problems in 1999. There have been substantial improvements in effluent toxicity relative to earlier self-monitoring data.

Table 7. Waterbodies monitored in Subbasin 01 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-1[2]	Dan R	Stokes	NC 704	Good	Good
B-2	North Double Cr	Stokes	SR 1504	Fair	Good-Fair
B-11	Dan R	Stokes	SR 1695	Good-Fair	Good
B-12	Snow Cr	Stokes	SR 1673	Good-Fair	Fair
	Hanging Rock Lake	Stokes		Oligotrophic	Oligotrophic
	Kernersville Res.	Rockingham		Mesotrophic	Eutrophic
	Belews Lake	Stokes		Oligotrophic	Oligotrophic

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

Investigations have been conducted on three lakes within this subbasin: Hanging Rock Lake, Kernersville Reservoir, and Belews Lake. Hanging Rock Lake is classified as oligotrophic, with no water quality problems. Kernersville Lake changed from a mesotrophic classification in 1994 to a eutrophic classification in 1999. This lake has high nitrogen and phosphorus concentrations, and in 1999 chlorophyll *a* concentrations were greater than the state standard. No algal blooms, however, have been reported for Kernersville Lake.

Belews Lake is also classified as oligotrophic, but a fish consumption advisory remains in effect for a few species to due to elevated concentrations of selenium in the tissue. The source of selenium was the historic discharge from the ash pond basin of Duke Power Company's Belews Creek Steam Station. This discharge was rerouted to the Dan River in 1985, and selenium body burdens in fish have been gradually declining.

River and Stream Assessment

Benthic macroinvertebrates in this subbasin were sampled under extreme low flow conditions in 1999. For larger streams affected by nonpoint source pollution, a sharp decline in flow would be expected to cause an increase in macroinvertebrate taxa richness. An increase in EPT taxa richness values may result in a higher bioclassification, but this trend might not persist under more normal flow conditions. Smaller streams, however, would be adversely affected by extremely low flow. No sample was collected at Town Fork Creek in 1999 due to inaccessibility to this part of the stream.

Dan River, NC 704

This portion of the Dan River near Francisco is about 20 m wide, with good boulder-rubble habitat. There were few habitat problems, although the substrate was embedded (20-40%) and pools were infrequent. Benthic macroinvertebrate samples have been collected from this site during six different years, producing either a Good (five collections) or an Excellent bioclassification (one collection (Appendix B2 and Table 7). Taxa richness and abundance values were much lower in 1994 during a period of extreme high flow than in 1999 during a period of low flow.

Many mountain species are present in this portion of the Dan River, including two of the dominant taxa: *Drunella allegheniensis* and *Symphito-psyche morosa*. Individual taxa often had large between-year changes in abundance that may reflect between-year changes in temperature and/or flow regime.

Unusual taxa at this site included:

- *Ephoron leukon* (common-abundant),
- *Paragnetina ichusa* (rare),
- *Mayatrichia ayama* (a single individual in 1984),
- *Neotrichia* (rare),
- *Gomphus spiniceps* (rare), and
- Crayfish collected from this site in 1999 hosted an unusually diverse community of cambarinicolid worms, including at least three species (based on gross morphological differences).

North Double Creek, SR 1504

North Double Creek is a small tributary (six meters wide) of the Dan River. The stream flows through a highly agricultural catchment and was selected by the Natural Resource Conservation Service to receive Public Law 566 funding to install conservation practices to improve water quality (EHNR-DOA 1990). The substrate at this site was dominated by sand and gravel (90%) and there were infrequent riffles. Sand-dominated streams are particularly susceptible to the effects of scour during high flow due to the unstable nature of the substrate.

EPT taxa richness showed the expected increase under low-flow conditions, but also observed was a change in EPT biotic index values (Figure 9) and a very large increase in EPT abundance from 50 in 1994 to 104 in 1999.

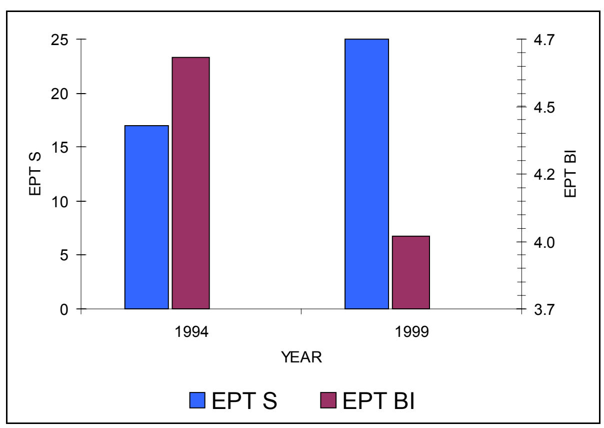

Figure 9. EPT (EPT S) taxa richness and biotic index (EPT BI) for North Double Creek, SR 1504, Stokes County.

Two intolerant taxa, *Leucrocuta* and *Chimara,* were absent or rare in 1994, but abundant in 1999. Further collections will be required to determine if the change in bioclassification is entirely due to low flow in 1999 (Table 8), or if installation of conservation practices also contributed to the observed improvement. Comparisons with Snow Creek suggested that both factors may be important.

Table 8. Flow and bioclassifications for North Double Creek, SR 1504, Stokes County.

Year	Flow	Rating
1994	High	Fair
1999	Low	Good-Fair

Dan River, SR 1695
Relative to the site at Francisco, this portion of the Dan River is wider (45 m) and has a lower gradient than the upstream site at NC 704. The habitat is similar to that found at Francisco, but a reduction in the abundance of mountain species suggests warmer water temperatures.

Samples were collected only in 1994 and 1999, and there was a large increase in taxa richness in 1999 (Figure 10).

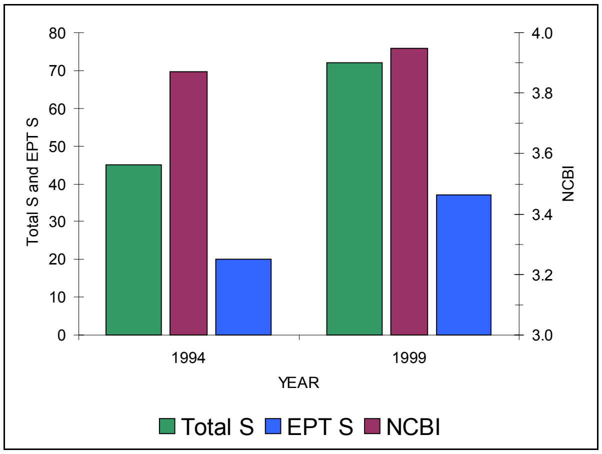

Figure 10. Total (Total S) and EPT (EPT S) taxa richness, and biotic index (NCBI) for the Dan River, SR 1695, Stokes County.

No corresponding large change in biotic index values was observed, suggesting the change in bioclassification might have been flow-related (Table 9), and did not reflect a long-term change in water quality. The ratings at this site are expected to fluctuate between Good and Good-Fair, depending on flow conditions.

Table 9. Flow and bioclassifications for the Dan River, SR 1695, Stokes County.

Year	Flow	Rating
1994	High	Good-Fair
1999	Low	Good

Snow Creek, SR 1673
Snow Creek is a relatively large stream (8-12 m wide) that is typical of tributary streams in this subbasin. Some evidence of enrichment was observed in both 1994 and 1999. Abundant periphyton growth was noted in 1994 and floating algal mats were observed under low-flow conditions in August 1999. The substrate was very sandy (50-60% sand and gravel) and heavily embedded. Riffle areas were infrequent and there were many breaks in the riparian zone.

This site was borderline between a Good-Fair and Fair bioclassification using mountain ecoregion criteria (Table 10).

Table 10. Flow and bioclassifications for Snow Creek, SR 1673, Stokes County.

Year	Flow	Rating
1994	High	Good-Fair
1999	Low	Fair

The between-year shift in bioclassification reflected only a small shift in EPT taxa richness (Figure 11). Both collections recorded low EPT abundance (61 and 62), with values most typical of a Fair rating (45-91).

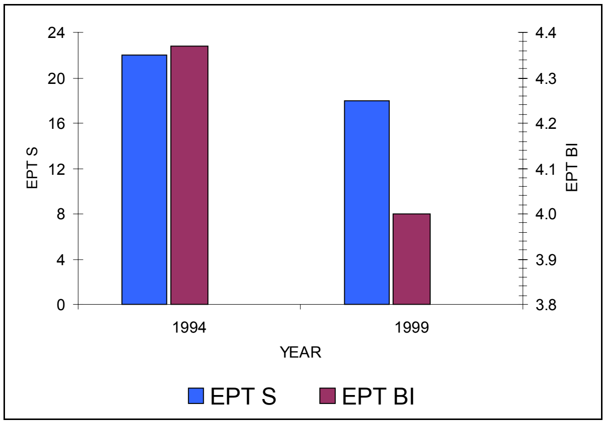

Figure 11. EPT (EPT S) taxa richness and biotic index (EPT BI) for Snow Creek, SR 1673, Stokes County.

SPECIAL STUDIES

Town Fork Creek and Neatman Creek

Town Fork Creek and Neatman Creek were sampled at four locations in September 1995 (Biological Assessment Unit Memorandum B-950919) (Appendix B2). These collections were made to supplement fish community sampling conducted by the North Carolina Wildlife Resources Commission. The upper section of Town Creek received a Poor rating, the middle section a Good-Fair rating, and Neatman Creek a Good rating

The segment of Town Creek above SR 1970 had poor instream habitat (a sandy substrate) and also appeared organically enriched with midges and worms dominant. Stoneflies (the most intolerant group) were absent or rare at all Town Fork sites. There is one permitted discharger (Briarwood Subdivision) that dischargers to a tributary upstream of this section of Town Fork Creek. The facility has had chronic problems with its solids concentrations in the effluent.

The most downstream site (Town Creek at Germantown) was about five miles upstream of the basinwide site at Walnut Cove. Good-Fair ratings have been recorded at both locations, suggesting no between-year changes in water quality.

Hanging Rock State Park

Cascade Creek and Indian Creek are two small streams in Hanging Rock State Park. These streams were sampled for benthic macroinvertebrates to evaluate the stream's suitability for supplemental reclassification as ORW or HQW (Biological Assessment Unit Memorandum B-950914). Two segments were found to qualify for ORW designation: UT Cascade Lake (above Hanging Rock Lake) and Indian Creek to Window Falls. Both streams were reclassified as ORW in 1998. One rare caddisfly (*Diplectrona metaqui*) was collected in Cascade Creek, although this collection did not occur within the ORW area.

Lake Assessment

Hanging Rock Lake

Hanging Rock Lake is a 12 acre impoundment located within Hanging Rock State Park (Figure 12). The reservoir, created in 1938, drains a 445-acre watershed which is primarily forested.

Hanging Rock Lake was most recently sampled during the summer of 1999 (Table 11 and Appendices L2 and L3). Based on the calculated NCTSI scores, the lake was determined to be mesotrophic-oligotrophic in June and oligotrophic in July and August. With one exception, the lake has been rated oligotrophic since 1981.

There have been no anecdotal reports of algal blooms or changes in water clarity of the lake. The aquatic plant, bladderwort (*Utricularia*), has recently been found in deep areas near the dam during the summer months. The plant has not become a nuisance (Tommy Wagoner, Hanging Rock State Park Superintendent, pers. com.).

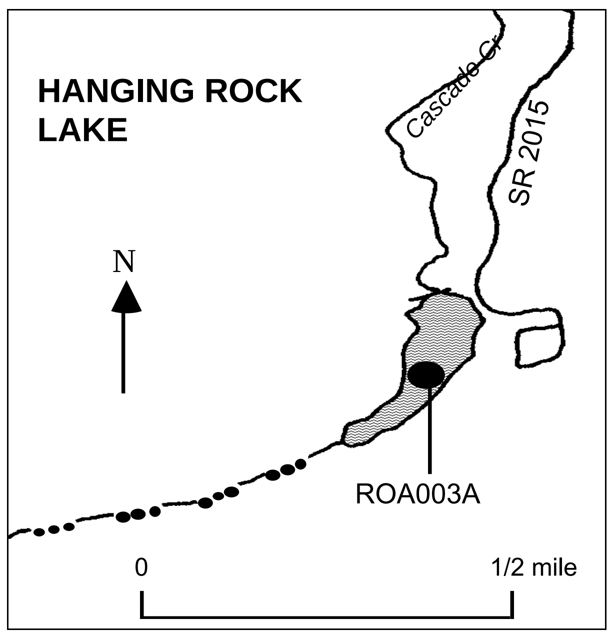

Figure 12. Monitoring site at Hanging Rock Lake, Stokes County.

Table 11. Biological monitoring and water chemistry data from Hanging Rock Lake, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/31/1999	-3.7	Oligotrophic	0.01	0.10	16	3.1
07/20/1999	-2.6	Oligotrophic	0.02	0.13	18	3.8
06/23/1999	-2.0	Mesotrophic	0.02	0.20	17	3.8
08/30/1994	-2.3	Oligotrophic	0.02	0.21	10	3.8

Kernersville Reservoir

Kernersville Reservoir, built in 1952, is a back-up water supply for the Town of Kernersville (Figure 13). Since 1984, Kernersville has been buying their potable water from the City of Winston-Salem. The reservoir now serves as an emergency water supply.

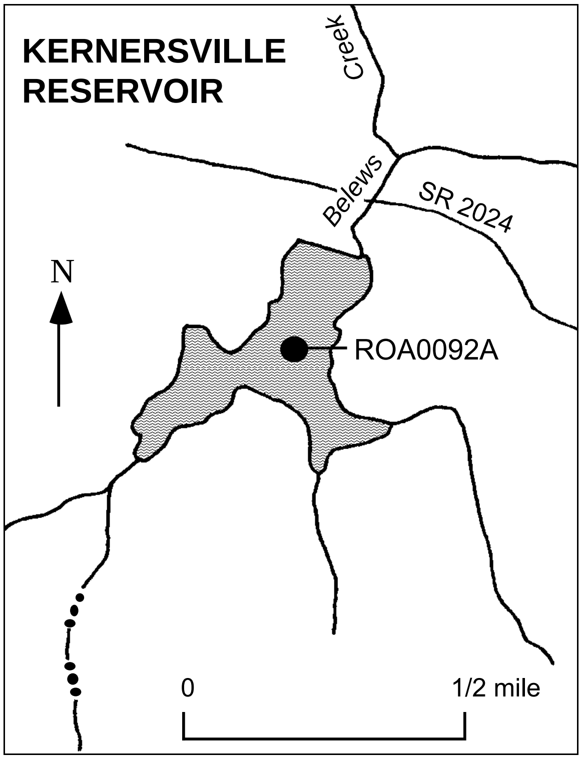

Figure 13. Monitoring site at Kernersville Reservoir, Forsyth County.

The lake is primarily spring-fed although there is one tributary -- Belews Creek. Upstream land use in the lake's 3.3 mi^2 watershed area is changing towards more industrial uses. But, the land immediately adjacent to the lake is protected from disturbance.

Kernersville Reservoir was most recently sampled during the summer of 1999 (Table 12 and Appendices L2 and L3). The chlorophyll *a* concentration in June (82 µg/l) was greater than the state water quality standard (40 µg/l) and Secchi depth was less than 1 m. The chlorophyll a concentrations observed in 1999 were greater than those observed in 1994 and 1988. All metals (except for copper) were within applicable state water quality standards. One copper concentration in July (7.7 µg/l) was slightly greater than the state water quality action level of 7.0 µg/l.

Based on the calculated NCTSI scores, Kernersville Reservoir was eutrophic in June and August. [The score was not calculated for July due to a sample collection error.]

There have been no anecdotal reports of nuisance aquatic plants, algal blooms, or changes in water clarity of the lake (Mike Anderson, Forsyth County Parks and Recreation Department, pers. com.).

Table 12. Biological monitoring and water chemistry data from Kernersville Reservoir, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/04/1999	1.5	Eutrophic	0.03	0.40	35	1.1
07/20/1999	---	---	0.03	0.12	---	1.5
06/21/1999	2.5	Eutrophic	0.03	0.39	82	0.8
08/30/1994	-0.2	Mesotrophic	0.04	.32	4	1.0

Belews Lake

Belews Lake is located on Belews Creek, a tributary of the Dan River (Figure 14). The lake was built by Duke Power Company in 1973 to provide a source of condenser cooling water for the Belews Creek Steam Station. The maximum depth of the lake is approximately 44 m. The hilly watershed is mostly forested and agricultural with some urban areas. The reservoir's retention time is approximately 1,500 days.

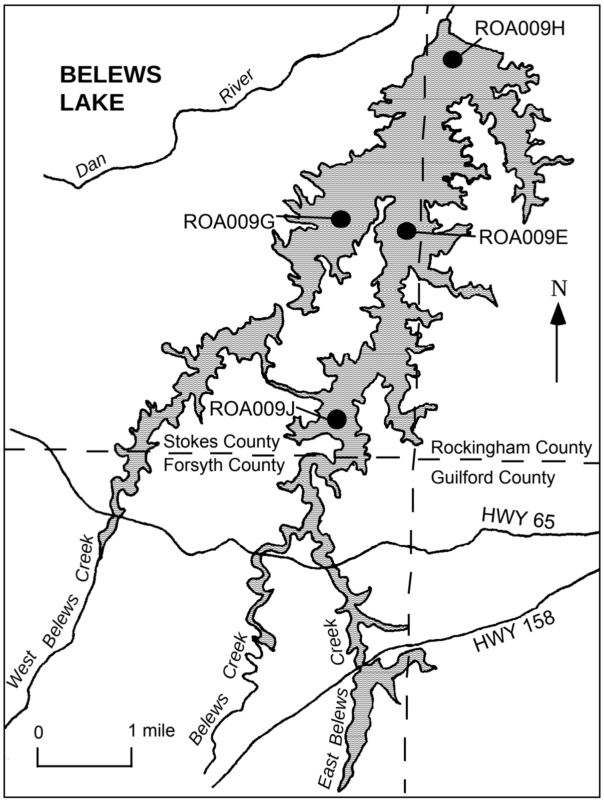

Figure 14. Monitoring sites at Belews Lake.

Belews Lake was most recently sampled during the summer of 1999 (Table 13 and Appendices L2 and L3). Surface dissolved oxygen concentrations were lowest in August and ranged from 5.5 to 6.9 mg/l. Nutrient and chlorophyll *a* concentrations were consistent with those observed from previous monitoring efforts. Surface water selenium concentrations were less than the laboratory detection limit (< 5.0 µg/l). Based on the calculated NCTSI scores, the lake was found to be oligotrophic on all sample dates.

Data collected from 1981 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 15). Median Secchi depths, total phosphorus, and chlorophyll *a* concentrations were similar among the four sites. Median total organic nitrogen was greatest at the site located at the lower end of the East Belews Creek arm (Station ROA009E).

A fish consumption advisory for selenium contamination in common carp, redear sunfish, and crappie remains in effect for Belews Lake (State Health Director, June 1999).

There have been no anecdotal reports of algal blooms in the lake. Generally, water clarity in the main body of the lake has not deteriorated. In recent years, however, the upper end of the reservoir lake has become turbid following rainfall events (Ron Lewis, Duke Energy, pers. com). *Hydrilla* was found in the lake in 1999. Herbicides were applied with staff assistance from the North Carolina Division of Water Resources (Ken Manuel, Duke Energy, pers. com).

Belews Lake and the Dan River are routinely monitored by Duke Power to assess the effects of rerouting the power plant's ash basin discharge from the lake to the Dan River. The discharge was diverted beginning in 1985.

No noticeable changes in the water or sediment chemistries have been observed in the Dan River. Arsenic and selenium concentrations in the lake water column have been less than water quality standards since 1987. Arsenic and selenium concentrations in the lake sediments have shown no decreasing or increasing inter-annual trends. There was, however, a definite spatial difference with higher concentrations of sediment arsenic and selenium occurring in deep lake as compared with shallow lake locations.

Table 13. Biological monitoring and water chemistry data from Belews Lake, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/25/1999	-4.3	Oligotrophic	0.01	0.17	6	3.9
07/08/1999	-3.7	Oligotrophic	0.01	0.19	9	3.1
06/09/1999	-4.5	Oligotrophic	0.01	0.18	4	3.2
08/16/1994	-5.3	Oligotrophic	0.02	0.15	1	2.7

Selenium concentrations in benthic macroinvertebrates have declined, but are still at levels higher than those observed in benthic macroinvertebrates found in uncontaminated waters (DPC 1996).

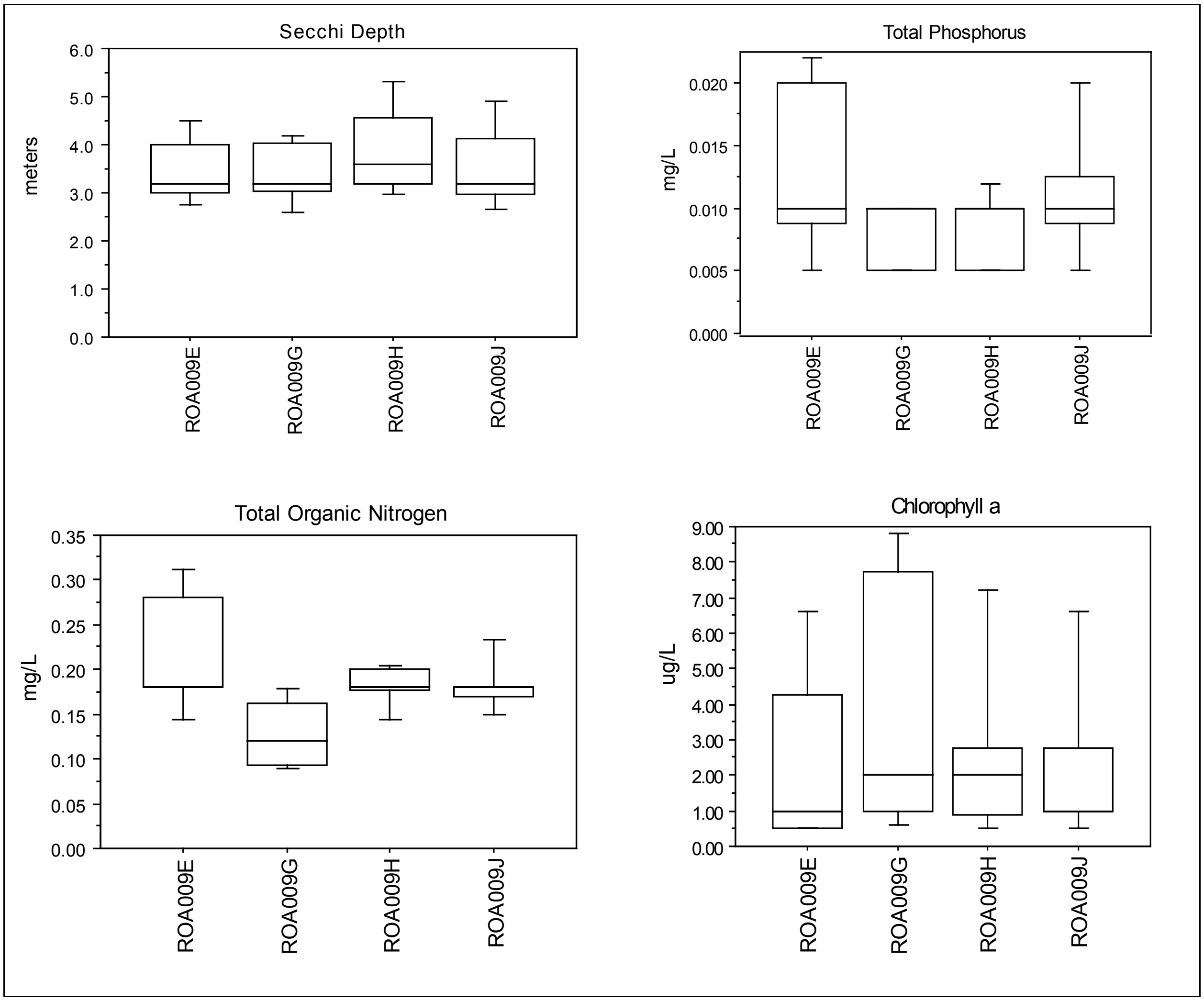

Figure 15. Spatial relationships among biological and water chemistry data from Belews Lake, 1981 – 1999 (n = 13).

ROANOKE RIVER SUBBASIN 02

Description

This subbasin contains a very short reach (approximately 10 mi.) of the Dan River and the entire North Carolina section of the Mayo River (Figure 16). However, most of the Mayo River's catchment is in Virginia.

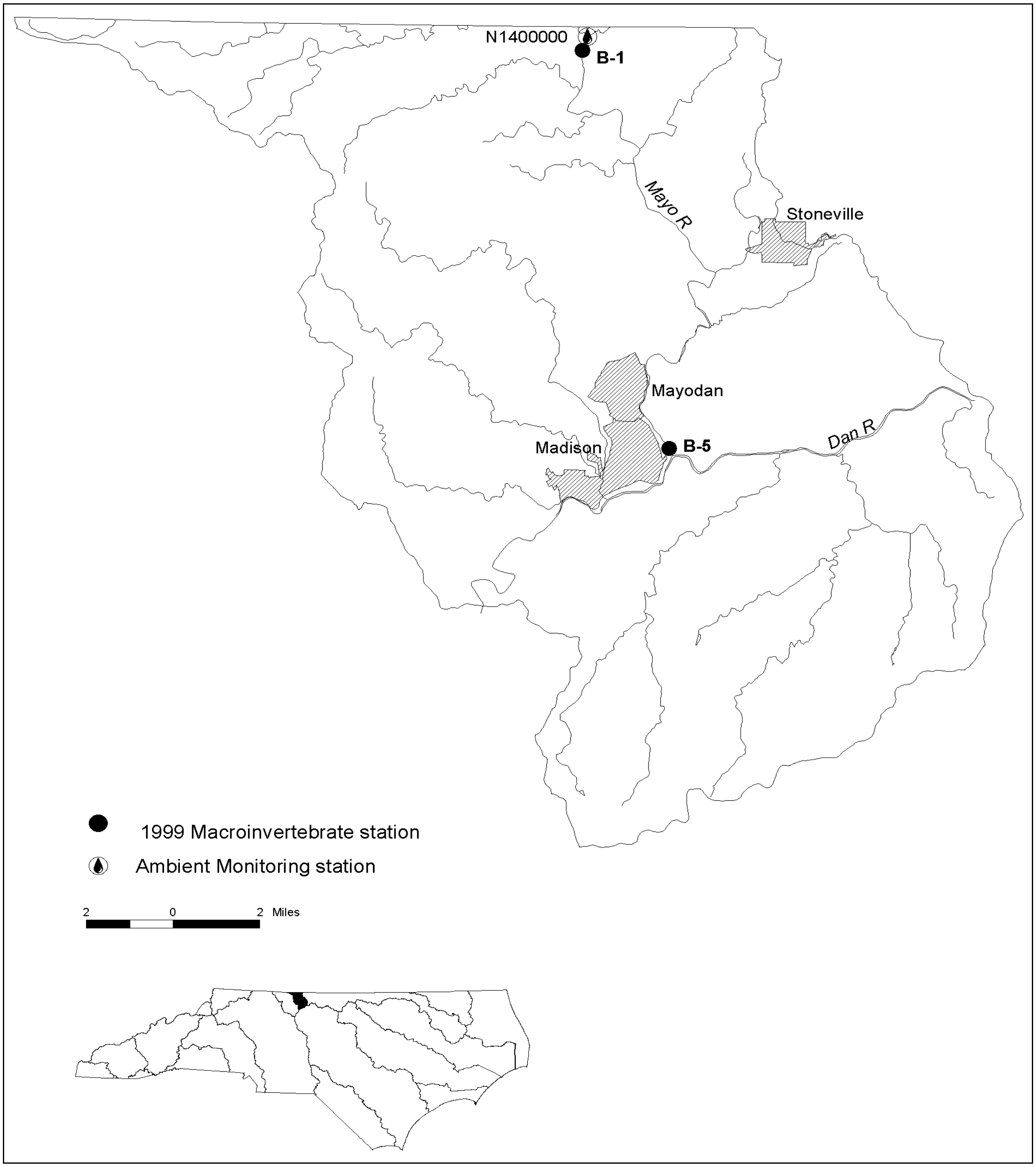

Figure 16. Sampling sites in Subbasin 02 in the Roanoke River basin.

Other large tributaries in this subbasin include Hogans Creek and Beaver Island Creek. The only two municipal areas in the catchment are the towns of Madison and Mayodan. Most of the land use within the catchment is agricultural or forest.

This subbasin contains eight NPDES permitted dischargers. The largest ones are the Town of Madison's WWTP (0.8 MGD to the Dan River) and the Town of Mayodan's WWTP (3 MGD to the Mayo River). Three facilities are required to monitor their effluent's toxicity: the Town of Mayodan's WWTP, the Town of Stoneville's WWTP, and Britthaven of Madison.

Overview of water quality

Ambient water quality is monitored at the Mayo River near Price. This location is near the Virginia/North Carolina state line and monitors water quality conditions of the river as it flows into North Carolina. These data suggested good water quality, with very few violations of water quality standards.

In this subbasin, benthic macroinvertebrate samples have been collected only from two sites on the Mayo River (Table 14). These two sites were sampled under extremely low flow conditions during 1999. Such conditions might be expected to reduce the effects of nonpoint source runoff, but would magnify the effects of point source dischargers. In 1999, the Mayo River near the North Carolina/Virginia state line was rated as Good. However, a decline in biological integrity prior to the confluence with the Dan River resulted in a Good-Fair rating. Problems in the lower Mayo River are most evident at low flow, and these problems were probably related to point source dischargers from the Town of Mayodan. The site near Mayodan showed a decline in water quality between 1994 (high flow) and 1999 (low flow).

The three wastewater treatment facilities which monitor their effluent's toxicity had no indications of problems in 1999. There has been some reduction in effluent toxicity relative to earlier self-monitoring data.

Table 14. Waterbodies monitored in Subbasin 02 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-1[2]	Mayo R	Rockingham	SR 1358	Good	Good
B-5	Mayo R	Rockingham	SR 2177	Good	Good-Fair

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Mayo River, SR 1358, near Price
This site near Price is also near the North Carolina/Virginia state line. Monitoring is conducted at this site to assess potential water quality problems entering from Virginia such as agricultural activities and the effluent from the Town of Stuart's WWTP.

Conductivity at this site increased slightly during low flow, supporting the possibility of point source effects. In August 1999, conductivity was 60 µmhos/cm during low flow conditions. The long-term mean at this site is 42 µmhos/cm. Regression of conductivity against flow at this site also indicated a significant inverse relationship between the two variables, although the regression was based upon a relatively narrow range of observations (30-60µmhos/cm). Values in this range are usually not associated with water quality problems.

This part of the Mayo River is about 50 m wide with large amounts of boulder and bedrock. This location is somewhat atypical for the Mayo River, due to the large bedrock ledges that provide stable habitat for benthic macroinvertebrates.

Benthic macroinvertebrate data from this portion of the river have produced a consistent Good bioclassification over five collection periods from 1986 to 1999 (Table 15)

Table 15. Flow and bioclassifications for the Mayo River, SR 1358, Rockingham County.

Year	Flow	Rating
1986	Low	Good
1987	Normal	Good
1989	High	Good
1994	High	Good
1999	Low	Good

High flow reduced EPT abundance (in 1994), but EPT taxa richness did not increase at low flow (Figure 17).

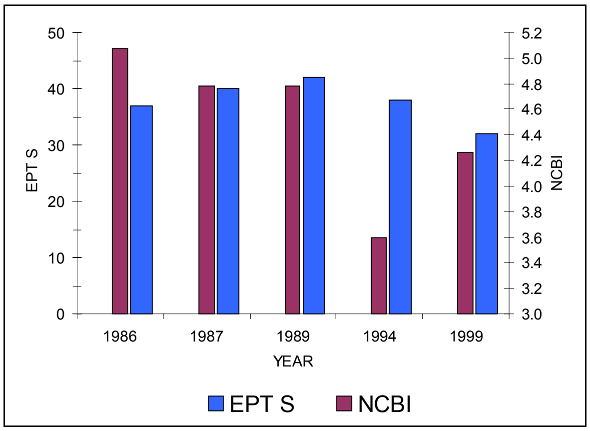

Figure 17. EPT (EPT S) taxa richness and biotic index (NCBI) for the Mayo River, SR 1358, Rockingham County.

Organic indicator species, such as *Chironomus*, *Procladius*, and *Dicrotendipes,* were abundant only during low flow in 1986, suggesting a reduction in organic loading to this portion of the Mayo River. This pattern accounted for a decline in biotic index values from 1986 to 1999.

Several unusual caddisflies, suggesting good water quality, have been collected at this site: *Ceraclea mentiea*, *Neotrichia,* and *Protoptila*. The Asiatic Clam (*Corbicula fluminea*) invaded this site between 1994 and 1999.

Mayo River, SR 2177

The Mayo River at SR 2177 is a wide (30 meters) and sandy river. A Good bioclassification was assigned to this location in 1994 at high flow, but it showed a sharp decline to Good-Fair under low-flow conditions in 1999 (Table 16 and Figure 18). A decline in water quality at low flow suggested point source impacts, although the Mayodan WWTP was passing self-monitoring toxicity tests.

Table 16. Flow and bioclassifications for the Mayo River, SR 2177, Rockingham County.

Year	Flow	Rating
1994	High	Good
1999	Low	Good-Fair

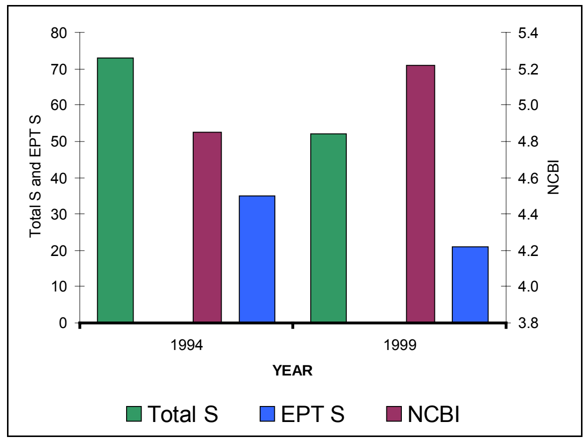

Figure 18. Total (Total S) and EPT (EPT S) taxa richness and biotic index (NCBI) for the Mayo River, SR 2177, Rockingham County.

The benthic fauna is generally dominated by facultative taxa, although several intolerant taxa were found in both years. The most abundant midges in 1999 suggested toxic problems: *Cricotopus bicinctus*, *C. varipes* gr., and *Cardiocladius*.

ROANOKE RIVER SUBBASIN 03

Description

This subbasin contains approximately 25 river miles of the Dan River, prior to its flowing back into Virginia (Figure 19). The Smith River is a major tributary of the Dan in this subbasin. Most of the Smith River catchment is in Virginia, and flow in North Carolina is regulated by the upstream Philpott Reservoir. Other smaller tributaries include Jacobs Creek, Buffalo Creek, and Wolf Island Creek.

The towns of Eden and Reidsville are the only two major municipal areas in the subbasin. Land use in this subbasin is typical of the piedmont ecoregion with the rolling topography dominated by agricultural activities and forest.

There are 19 NPDES permitted dischargers within the North Carolina portion of the subbasin. The Smith River may also be affected by other dischargers, especially the Town of Martinsville's WWTP in Virginia. The largest facilities discharge to the Dan River. They include two Eden wastewater treatment plants (0.5 and 13.5 MGD), Fieldcrest/Cannon (0.5 MGD), and Miller Brewing Company (5.2 MGD). Four facilities are required to monitor their effluent's toxicity: Duke Power's Dan River Station, Miller Brewing Company, and the two Town of Eden WWTP discharges.

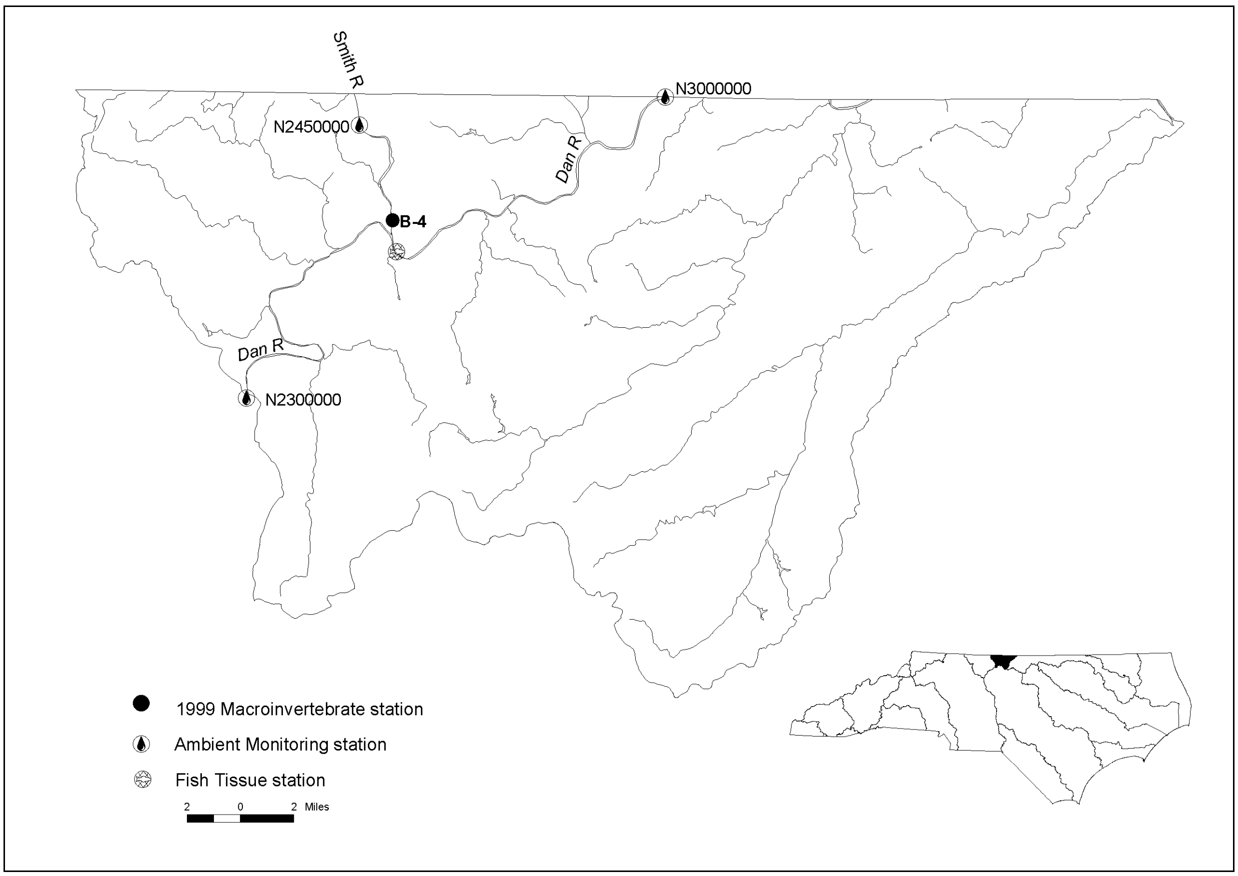

Figure 19. Sampling sites in Subbasin 03 in the Roanoke River basin.

Overview of water quality

Benthic macroinvertebrate samples have been collected from seven streams in this subbasin since 1983, but extremes in flow conditions during 1999 made it difficult to collect samples at most sites in this subbasin. High flows towards the end of August in 1994 and 1999 caused the cancellation of sampling at most river sites, while some tributary sites had stopped flowing during drought conditions by mid-August.

Current data are available only from the Smith River (Table 17). A Fair bioclassification for the Smith River near Eden was the result of flow regulation and possible impacts from the Town of Martinsville's WWTP (in Virginia).

Fish tissue samples were collected from the Dan River near Eden, where all metal concentrations were less than state and federal criteria.

Ambient monitoring data were collected from three locations in this subbasin: two sites on the Dan River (near Wentworth and near Mayfield) and from the Smith River at Eden.

The monitoring site on the Smith River is located near the Virginia/North Carolina boundary. Data from this location has shown very few violations of North Carolina water quality standards. Flow is regulated by the discharge from the upstream Philpott Reservoir and water quality problems had been noted downstream of the Town of Martinsville's WWTP. Historically, this facility had been responsible for elevated concentrations of chloride and total dissolved solids in the Smith River, but neither parameter had indicated problems in the last five years. The Smith River, however, continued to have elevated conductivity (median = 183 µmhos/cm) relative to other sites in the subbasin.

The two sites on the Dan River monitored the influences of the Smith River and dischargers near the Town of Eden. There were few violations of water quality standards at either site. Median conductivity at the Mayfield site was more than twice the median value at the Wentworth site (57 *vs*. 125 µmhos/cm).

Four NPDES permitted facilities in this subbasin are required to monitor their effluent's toxicity. All facilities discharge to the Dan River and none of these dischargers failed self-monitoring tests in 1999.

Table 17. Waterbodies monitored in Subbasin 03 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-4[2]	Smith R	Rockingham	NC 14	Fair	Fair

[1]B = benthic macroinvertebrate.
[2]Data are available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Smith River, NC 14
Benthic macroinvertebrates samples have been collected at this site five times since 1984. Ratings have fluctuated between Fair and Good-Fair (Appendix B2).

Ambient water quality monitoring at this site has documented a mean conductivity of 170 µmhos/cm. During the time of the benthic invertebrate sample collection the conductivity was 248 µmhos/cm. The structure of the benthic macroinvertebrate community did not suggest being affected by either low dissolved oxygen concentrations or high organic loading.

SPECIAL STUDY
Hogans Creek Stream Restoration Project
Macroinvertebrate samples were collected from three sites on an unnamed tributary to Hogans Creek in November 1996 and in June 1998 (Biological Assessment Unit Memorandum B-970127). This small stream is located in Pittsylvannia County (Virginia) and in northern Caswell County. These samples were intended to document conditions prior to stream restoration. The existing stream channel had been channelized (straightened) and is severely entrenched. A new natural stream channel will be constructed with normal riffle-pool sequences.

Additional Data

Dan River, SR 1761

Although not sampled in 1999 due to high flow conditions, the benthic invertebrate community has been rated from Excellent to Good-Fair (Appendix B2). Duke Power Company personnel also annually monitor this site and have produced similar ratings (for example refer to DPC 1999).

Fish Tissue

Dan River near Eden

Nineteen tissue samples were taken from largemouth bass, sunfishes, and suckers during August 1999 and analyzed for metal contaminants (Appendix FT1). All concentrations were less than US EPA, FDA, and the State of North Carolina criteria.

Duke Power Company also monitors fish tissue contaminants in the Dan River near Eden near the Belews Creek Steam Station's ash basin discharge. The most recent data collected in 1998 showed selenium concentrations ranging from 0.10 to 1.03 µg/g (DPC 1999). These concentrations were much less than the state's advisory criterion of 5µg/g. for selenium.

ROANOKE RIVER SUBBASIN 04

Description

This subbasin contains a very short reach of the Dan River (approximately 8 river miles) and three larger tributaries: Moon Creek, Rattlesnake Creek, and Country Line Creek (Figure 20). The Dan River in this subbasin flows into North Carolina from Virginia, after receiving effluent from the Town of Danville's Northside WWTP and urban runoff, and then flows once again back into Virginia. The Dan River forms the headwaters of the John H. Kerr Reservoir, which straddles the North Carolina/Virginia state line. Tributary streams within this subbasin are low gradient and sediment-dominated systems, typical of the piedmont ecoregion. Land use is primarily agricultural with row crops and pasture.

Yanceyville is the only town within the subbasin. This subbasin contains nine permitted dischargers. The largest facility is Yanceyville's WWTP which is permitted to discharge 0.45 MGD to Country Line Creek. This is also the only facility required to monitor its effluent's toxicity.

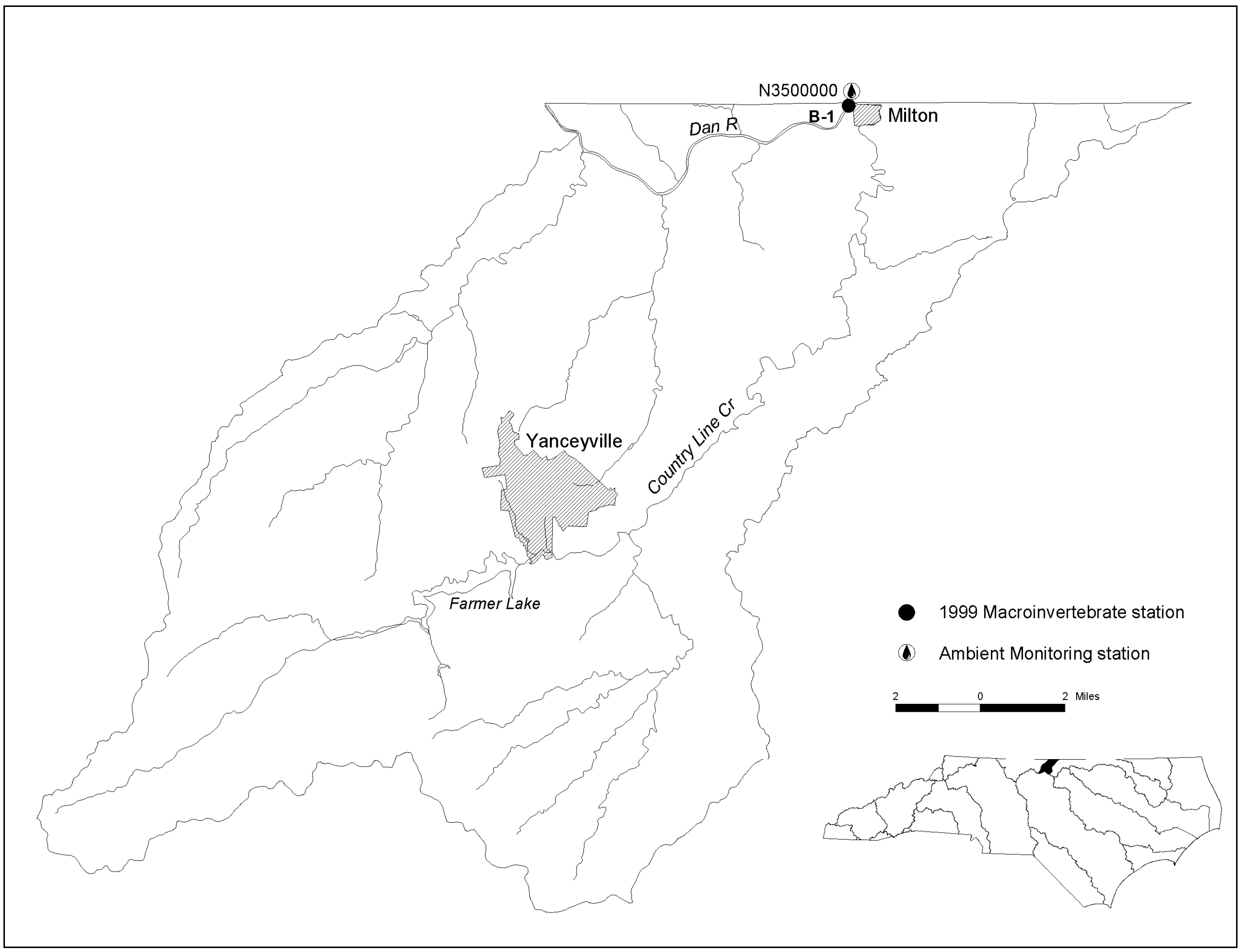

Figure 20. Sampling sites in Subbasin 04 in the Roanoke River basin.

Overview of water quality

During the dry summer of 1999, many streams in this subbasin had little or no visible flow. No benthic macroinvertebrate samples were collected from Country Line Creek. However, the low-flow conditions did make it possible to collect samples for the first time from the Dan River near Milton.

Historical benthic macroinvertebrate data from Country Line Creek resulted in either Good or Good-Fair bioclassifications. This site is downstream of the Town of Yanceyville's WWTP and the catchment is dominated by agricultural land uses. The lowest bioclassifications were recorded after high-flow events, suggesting this catchment is more affected by nonpoint source runoff than point source dischargers.

Benthic macroinvertebrate collections in 1999 from the Dan River produced a Good bioclassification (Table 18). A new species record was also documented for this site.

Farmer Lake is the only reservoir monitored in this subbasin as part of the Lake Assessment Program. Classified as slightly eutrophic, no algal blooms have been reported from this reservoir.

Ambient monitoring data were collected from the Dan River at Milton. Good water quality conditions have been recorded at this site with very few violations of water quality standards.

Table 18. Waterbodies monitored in Subbasin 04 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-1	Dan R	Caswell	NC 57	---	Good
	Farmer Lake	Caswell		Eutrophic	Eutrophic

[1]B = benthic macroinvertebrate monitoring sites.

River and Stream Assessment

Dan River, NC 57

The Dan River at Milton is about 70 m wide with a sand and boulder substrate. Under normal flow conditions, this site is too deep to sample for benthos. But in 1999, under extreme low flow conditions, it was shallow enough to sample.

This site received a Good rating, with few differences between the community observed here compared to collections from the upstream site at Mayfield (Subbasin 03). The only significant difference between sites was a reduction in the abundance of stoneflies, especially *Acroneuria abnormis*. The abundance of *Physella* suggested some microhabitats with low dissolved oxygen concentrations. *Rheopelopia* cf. *Paramacullpennis,* a chironomid collected from this site, represented a new state record.

Lake Assessment

Farmer Lake

Farmer Lake is a 368 acre water supply reservoir built in 1983 by the Town of Yanceyville (Figure 21). The reservoir is located on an unnamed tributary of Country Line Creek in Caswell County. The lake is secondarily used for recreation. The watershed includes agricultural and forested lands.

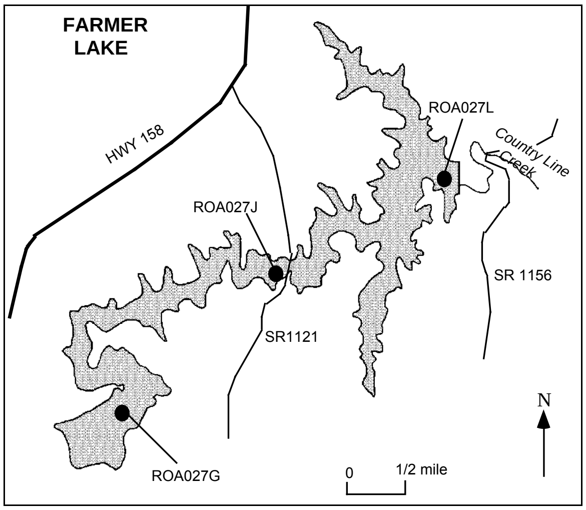

Figure 21. Monitoring sites at Farmer Lake, Caswell County.

Farmer Lake was most recently sampled during the summer of 1999 (Table 19 and Appendices L2 and L3). Mean chlorophyll *a* concentrations increased from 8 µg/L in June to 44 µg/L in August. In July and August, the chlorophyll *a* concentrations for the upstream site (Station ROA027G) were greater than the water quality standard of 40 µg/L. Mean values for turbidity, nitrite plus nitrate, and total inorganic nitrogen also increased from June to August. Metals were within applicable water quality standards.

Calculated NCTSI scores indicated that this lake was mesotrophic in June and eutrophic in July and August.

Data collected from 1981 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 22). Median Secchi depths increased from the upstream site to the site near the dam. Median concentrations of total phosphorus, total organic nitrogen, and chlorophyll a showed the opposite spatial pattern.

There have been no reports of algae blooms in the lake. There have also been no public complaints regarding taste or odor problems in water taken from this lake. The watershed has been relatively stable with no new development (Bill Carter, Director of Public Utilities, Town of Yanceyville, pers com.).

Table 19. Biological monitoring and water chemistry data from Farmer Lake, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/03/1999	1.0	Eutrophic	0.03	0.33	44	1.6
07/07/1999	0.1	Eutrophic	0.01	0.36	30	1.4
06/10/1999	-0.3	Mesotrophic	0.03	0.29	8	1.2
08/23/1994	0.7	Eutrophic	0.04	0.40	7	0.8

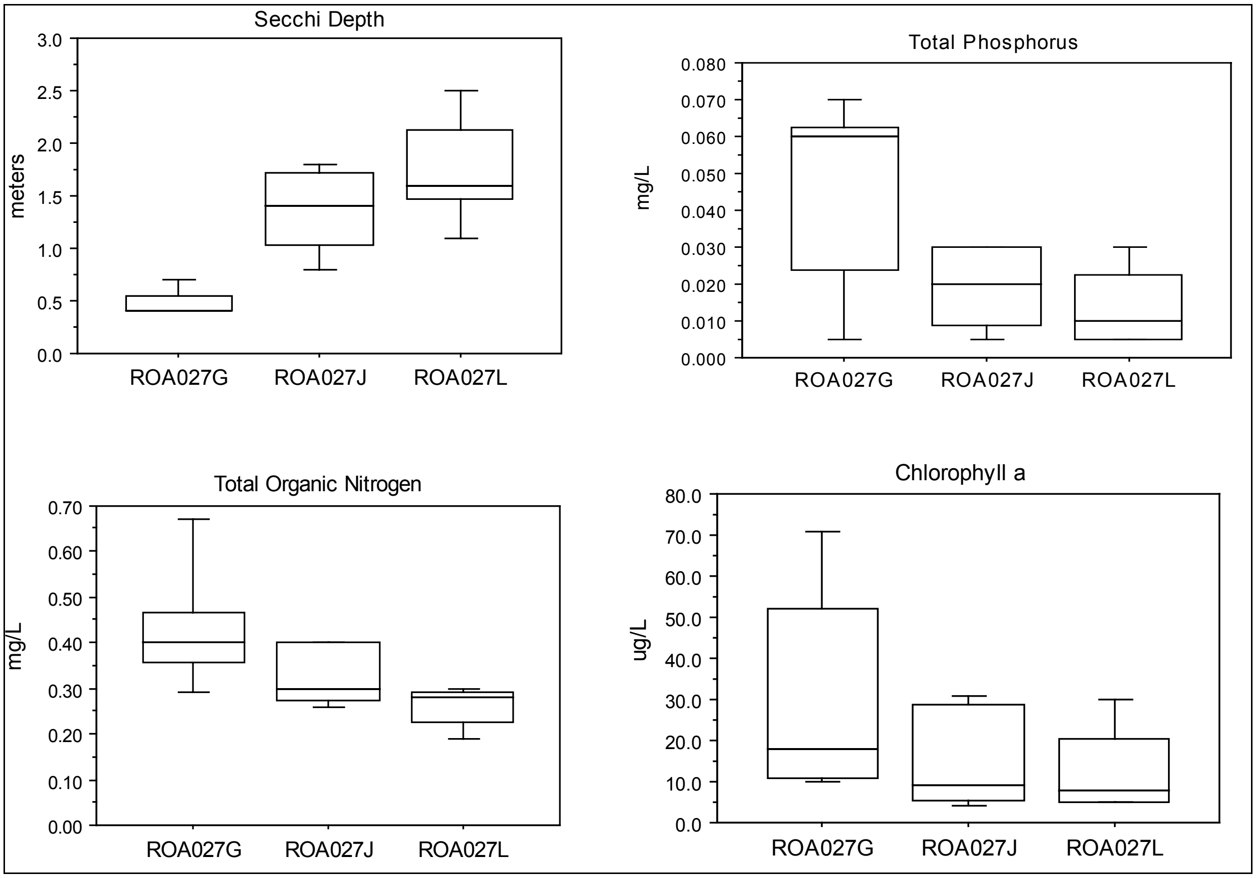

Figure 22. Spatial relationships among biological and water chemistry data from Farmer Lake, 1991 – 1999 (n = 5).

ROANOKE RIVER SUBBASIN 05

Description

This subbasin contains the watershed of Hyco Reservoir and the Hyco River before it flows into Virginia (Figure 23). This subbasin also contains Mayo Creek and Mayo Reservoir. Tributary streams within this subbasin are low gradient, sandy streams typical of the piedmont ecoregion. Land use is primarily agricultural with row crops and pasture.

This subbasin contains 23 permitted dischargers. The Town of Roxboro is the largest dischargers with a 5.0 MGD facility (instream waste concentration at 7Q10 = 99.9 %) that discharges to Marlowe Creek.

Additionally, Carolina Power and Light Company's (CP&L) Roxboro and Mayo Steam Generating plants discharge, by design and permit, tens of millions of gallons per day of cooling water to Hyco Lake and Mayo Reservoir. The Town of Roxboro's WWTP, two discharges from the Roxboro Plant, the Mayo Plant, and Cogentrix are required to monitor their effluent's toxicity.

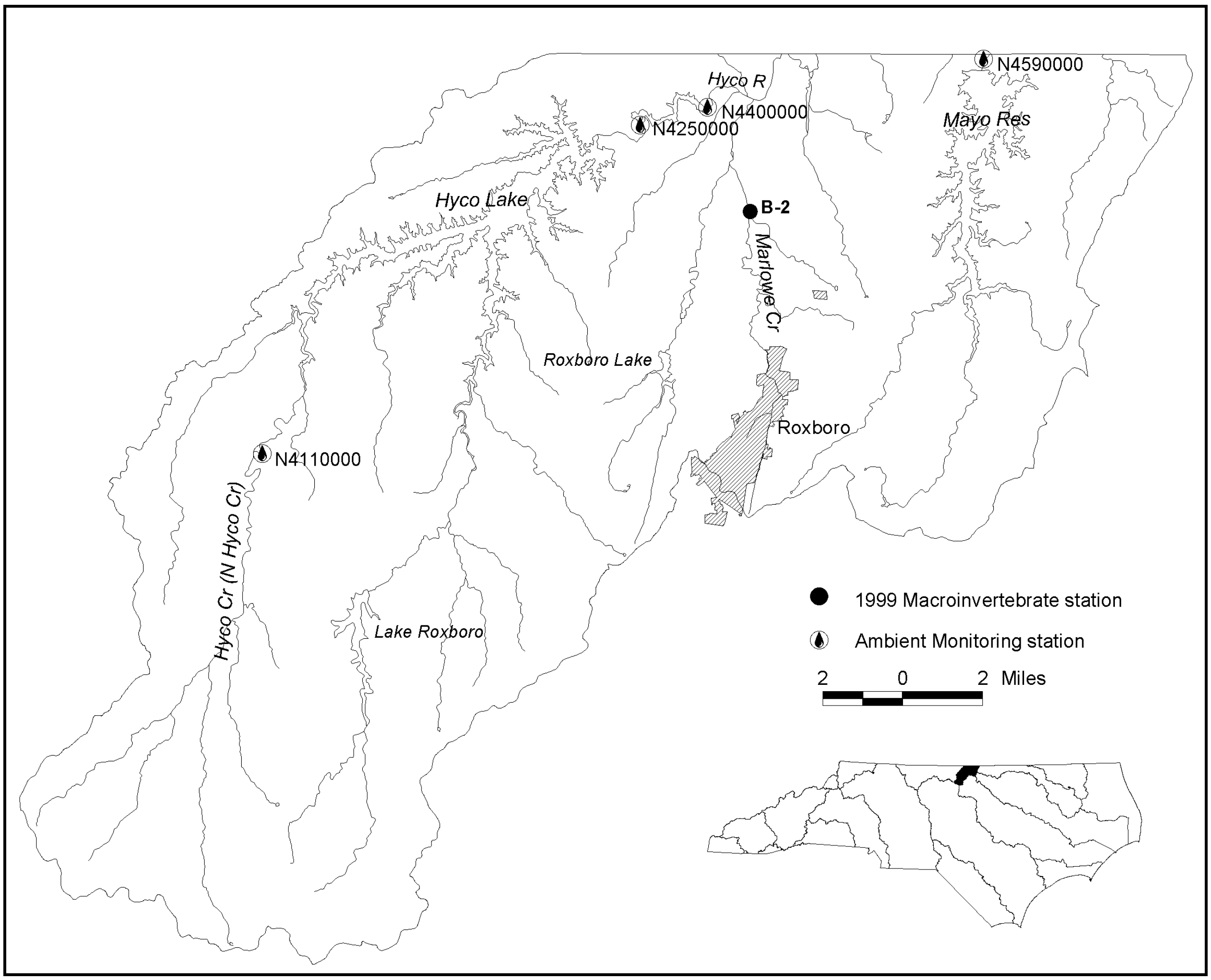

Figure 23. Sampling sites in Subbasin 05 in the Roanoke River basin.

Overview of water quality

Benthic macroinvertebrates have been collected from only two sites in this subbasin: Hyco Creek and Marlowe Creek (Appendix B2). Historically, Hyco Creek received a Good-Fair rating under low flow and normal flow conditions, but declined to a Fair classification under high flow conditions. This pattern suggested nonpoint source impact to this stream. No sample was collected in 1999 because no flowing water was observed in the creek during the sampling period.

Observations during the very dry summer of 1999 indicated that many other streams in this subbasin also stopped flowing. This seasonally intermittent low flow may limit the diversity of the fish and macroinvertebrate communities.

Marlowe Creek is affected by the discharge from the Town of Roxboro's WWTP, but the bioclassification improved from Poor in 1994 to Fair in 1999 (Table 20). This change coincided with a reduction in the facility's effluent toxicity.

Four lakes in this subbasin are monitored as part of the Lake Assessment Program: Hyco Lake, Lake Roxboro, Roxboro Lake, and Mayo Reservoir. Hyco Lake and Mayo Reservoir are classified as oligotrophic, while Lake Roxboro and Roxboro Lake are eutrophic. No algal blooms have been reported in any of these lakes.

A four-unit coal-fired power plant is located on Hyco Lake, and discharge from its ash ponds had resulted in elevated levels of selenium in the water, biota, and sediments of the reservoir. The ash pond wet discharge was eliminated in 1990. Since then, the fishery has shown signs of recovery and the fish consumption advisory remains in effect for only a few species.

Mayo Reservoir, which also receives effluent from another power plant's ash pond also had elevated selenium levels, but there were no violations of water quality standards. Hydrilla and Brazilian elodea, both nuisance aquatic macrophytes, have colonized large areas of the littoral zone in Mayo Reservoir.

Ambient monitoring data were collected from five streams in this subbasin: Hyco Creek near Leasburg, Hyco River near Mcghees Mill, Marlowe Creek near Woodsdale, Hyco River near Denniston, Virginia, and Mayo Creek near Bethel Hill. The Marlowe Creek site is downstream from the Roxboro WWTP which resulted in elevated nitrate+nitrite nitrogen, total phosphorus, and copper concentrations.

Four other dischargers besides the Town of Roxboro's WWTP also monitor their effluent's toxicity. Only the Cogentrix facility which discharges to an unnamed tributary of Mitchell Creek had toxicity problems in 1999.

Table 20. Waterbodies monitored in Subbasin 05 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-2	Marlowe Cr	Person	SR 1322	Poor	Fair
	Hyco Lake	Person/Caswell		Mesotrophic	Oligotrophic
	Lake Roxboro	Person		Eutrophic	Eutrophic
	Roxboro Lake	Person		Eutrophic	Eutrophic
	Mayo Reservoir	Person		Oligotrophic	Oligotrophic

[1]B = benthic macroinvertebrate monitoring sites.

River and Stream Assessment

Marlowe Creek, SR 1322
Marlowe Creek at this location is 7 m wide with a sand-gravel substrate. This site is located downstream of the Roxboro WWTP, which has a design flow of 5.0 MGD and makes up almost all of the stream flow (99%) under 7Q10 low flow conditions. Prior to 1996, the treatment plant reported sporadic chronic toxicity violations. But since then, it has been in compliance with its toxicity limits.

Coinciding with this decrease in effluent toxicity, the bioclassification improved from Poor in 1994 to Fair in 1999 (Table 21 and Figure 24). Under low flow conditions experienced in 1999, minimal effluent dilution would be expected. Thus, the improved bioclassification clearly indicated an improvement in water quality.

Table 21. Flow and bioclassifications for Marlowe Creek, SR 1322, Person County.

Year	Flow	Rating
1994	Normal	Poor
1999	Low	Fair

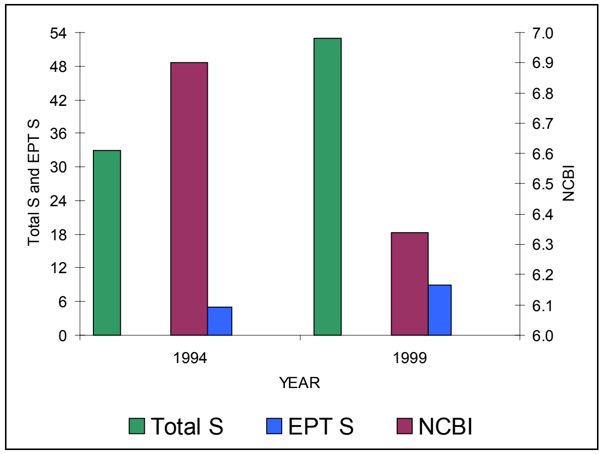

Figure 24. Total (Total S) and EPT (EPT S) taxonomic richness and biotic index (NCBI) for Marlowe Creek, SR 1322, Person County.

Lake Assessment

Hyco Lake
Hyco Lake is located on the Hyco River, approximately three miles south of the Virginia State line in Person and Caswell counties. The lake has a maximum depth of 15 meters and a mean hydraulic retention time of 180 days. The watershed is characterized by rolling hills; land use along the 256 km shoreline is primarily residential, forested, or industrial.

Hyco Lake was most recently sampled during the summer of 1999 (Table 22 and Appendices L2 and L3). All selenium concentrations were less than the laboratory detection level (< 5.0 µg/l) except for Station ROA030F in June (6.4 µg/l). Fecal coliform bacteria concentra-tions were within applicable water quality standards. Calculated NCTSI scores indicated that the lake was oligotrophic during the summer.

Data collected from 1983 through 1999 for the four constituents of the NCTSI suggested little observable differences between the four monitoring stations.

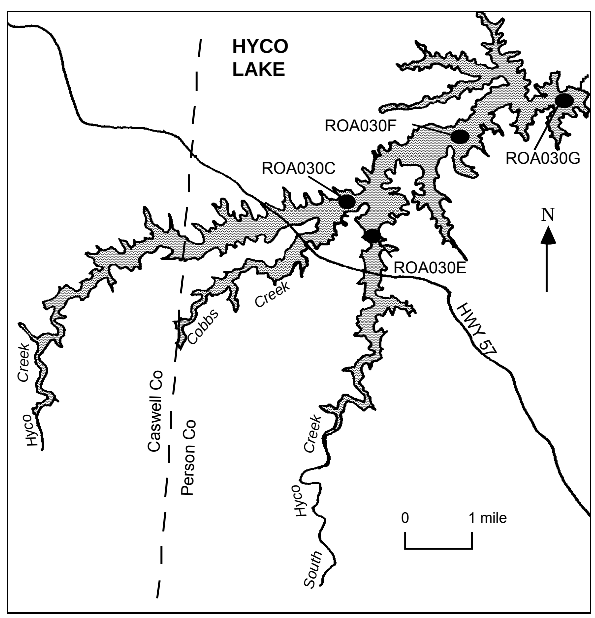

Figure 25. Monitoring sites at Hyco Lake, Person and Caswell counties.

Table 22. **Biological monitoring and water chemistry data from Hyco Lake, 1994 - 1999.**

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/17/1999	-2.1	Oligotrophic	< 0.01	0.39	10	1.7
07/20/1999	-2.4	Oligotrophic	0.01	0.15	19	2.4
06/01/1999	-4.0	Oligotrophic	< 0.01	0.17	4	1.6
08/18/1994	-1.9	Mesotrophic	0.03	0.26	2	1.4

There have been no anecdotal reports of algal blooms in the lake. There are no aquatic macrophytes, native or exotic, in the lake due to the introduction in the 1980s of the exotic, blue tilapia and redbelly tilapia. Although the headwaters of the lake become turbid rainfall events, the main body of the lake has not experienced any significant changes in water clarity. New residential development has occurred along the shoreline in recent years (Ronald Hobbs, Carolina Power and Light Company, pers. com).

Recent monitoring by Carolina Power & Light Company documented selenium in the surface waters at concentrations less than 5 µg/l in 1997 and 1998. A shift in the fish community from undesirable, selenium-tolerant species such as satinfin shiner and green sunfish to a bluegill-dominated community was first observed in 1994. Electrofishing catch rates in 1997 and 1998 for largemouth bass and bluegill met expectations for a piedmont reservoir and indicated successful reproduction of these sport species was occurring in the lake (CP&L 1998; CP&L 1999a).

The consumption of fish from the lake remains under an advisory due to elevated selenium levels from the plant's ash pond discharge. First issued in 1988, the advisory was revised in 1995. Since the fall of 1996, mean selenium concentrations in green sunfish and white catfish have been less than consumption criteria of 5µg/g. Selenium concentrations in common carp also declined below this threshold during 1998. However, the advisory remains in effect for common carp, white catfish, and green sunfish.

Lake Roxboro

Lake Roxboro is a 195 acre reservoir located in Caswell and Person counties near the Town of Roxboro. The lake was filled in 1978 and is owned by the Town of Roxboro. The main tributary to the lake is South Hyco Creek. Land uses in the watershed includes agriculture, forest, and residential areas.

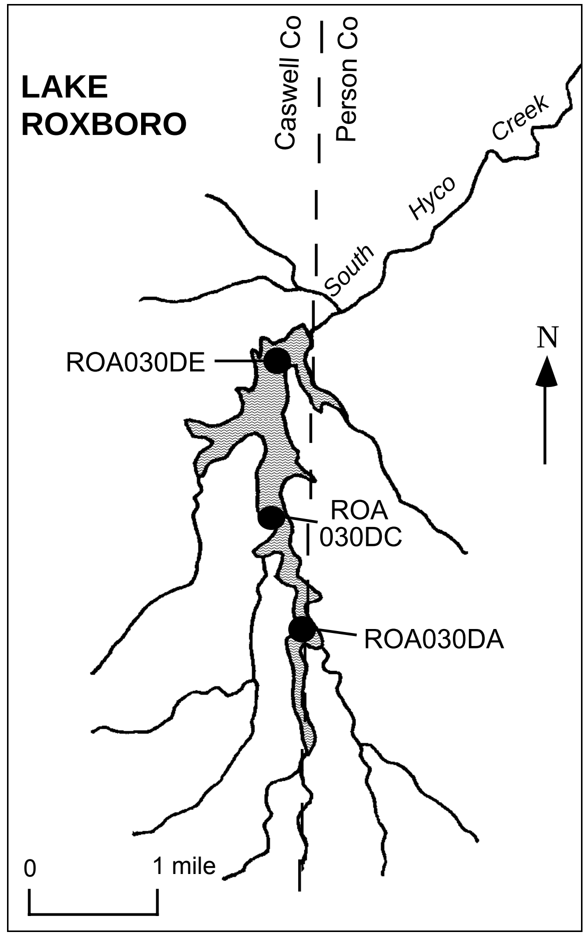

Figure 26. **Monitoring sites at Lake Roxboro, Person County.**

The reservoir was most recently sampled during the summer of 1999 (Table23 and Appendices L2 and L3). The greatest mean chlorophyll *a* (33 µg/l) and ammonia concentrations (0.05 mg/l) were observed in August. The chlorophyll a concentrations in the upper end of the lake (Station ROA030DA) were greater than the water quality standard (40 µg/l) in July and August (51 and 55 µg/l, respectively). Concentra-tions of metals were within the applicable water quality standards. The reservoir was determined to be mesotrophic in June and eutrophic in July and August based on calculated NCTSI scores.

Data collected from 1983 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 27). The median Secchi depth at the upper end of the lake (Station ROA030DA) was less than the medians measured at the mid- and lower lake sites. Median total phosphorus and chlorophyll *a* concentrations were greatest at the upstream site; median concentrations of total organic nitrogen were not spatially different.

There have been no anecdotal reports of algal blooms or nuisance aquatic macrophytes in the lake. A moratorium existed on new developments near the lake and the lake continued to serve as a back-up water supply for the Town of Roxboro (Rhonda Rogers, Water Resources, Town of Roxboro, pers. com).

Table 23. Biological monitoring and water chemistry data Lake Roxboro, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/03/1999	0.4	Eutrophic	0.01	0.38	33	1.2
07/07/1999	0.3	Eutrophic	0.01	0.46	26	1.3
06/10/1999	-0.3	Mesotrophic	0.02	0.33	14	1.8
08/04/1994	0.5	Eutrophic	0.03	0.36	10	1.0

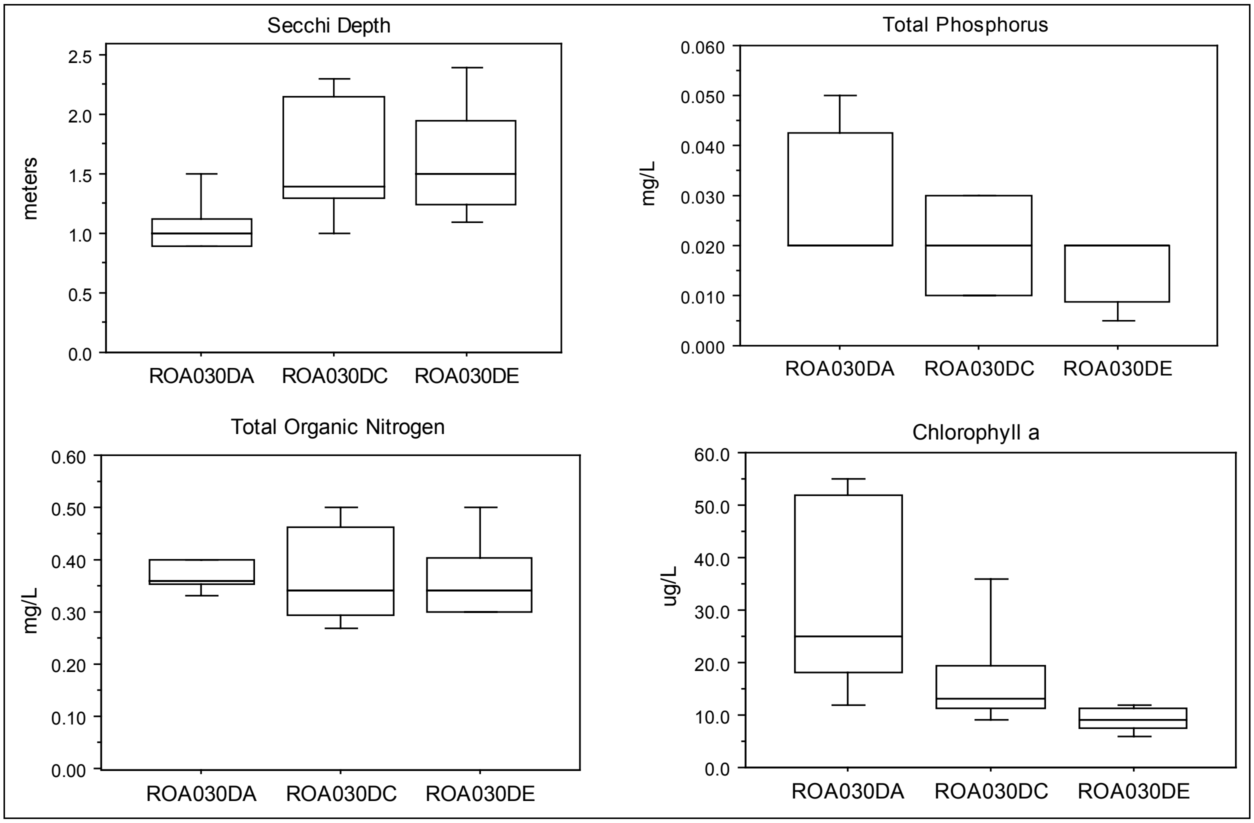

Figure 27. Spatial relationships among biological and water chemistry data from Lake Roxboro, 1988 – 1999 (n = 5).

Roxboro Lake

Roxboro Lake (also called Lake Isaac Walton) is located in Person County near the Town of Roxboro (Figure 28). Built in the 1930s, the lake is the primary water supply for the town. Satterfield Creek and Storys Creek are the main tributaries. Maximum depth is about seven meters and retention time is approximately 30 days. The watershed is comprised of agricultural lands and residential areas.

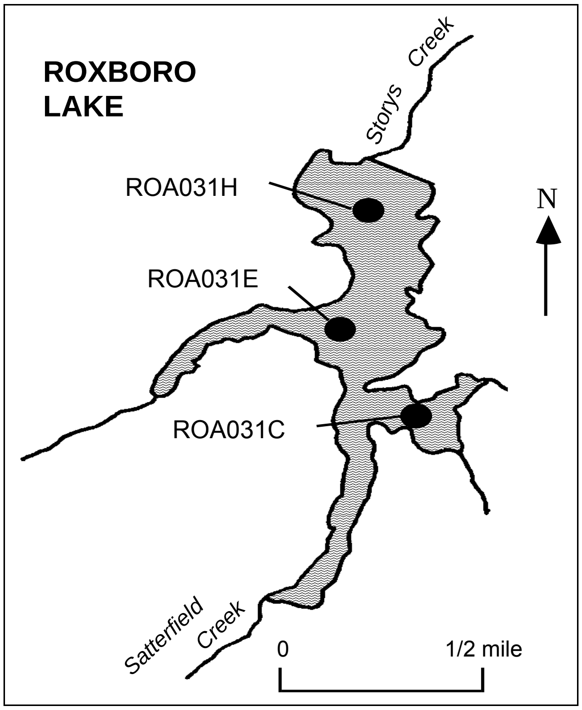

Figure 28. Monitoring sites at Roxboro Lake, Person County.

The reservoir was most recently sampled during the summer of 1999 (Table 24 and Appendices L2 and L3). All chlorophyll a concentrations in July and August were greater than the state water quality standard of 40 µg/l. Concentrations of metals were within the applicable water quality standards. Calculated NCTSI scores indicated that the lake was mesotrophic in June and eutrophic in July and August.

Data collected from 1983 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 29). Median Secchi depth was lowest at the upper site (Station ROA031C) as compared with the mid- and lower lake sites. Median total phosphorus was also greatest at this site; median total organic nitrogen and chlorophyll a concentrations were not different spatially.

There have been no reports of algae blooms, fish kills, or problems with excessive growth of aquatic plants in Roxboro Lake, nor has there been very much new development within the lake's watershed. A couple of times a year, high manganese levels occur along with increased turbidity in the lake which is attributed with turnover events (Rhonda Rogers, Water Resources, Town of Roxboro, pers. com).

Table 24. Biological monitoring and water chemistry data from Roxboro Lake, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/17/1999	0.2	Eutrophic	<0.01	0.37	53	0.7
07/20/1999	1.7	Eutrophic	0.02	0.31	64	0.8
06/08/1999	-1.0	Mesotrophic	0.02	0.29	6	1.4
08/04/1994	0.3	Eutrophic	0.02	0.44	10	1.1

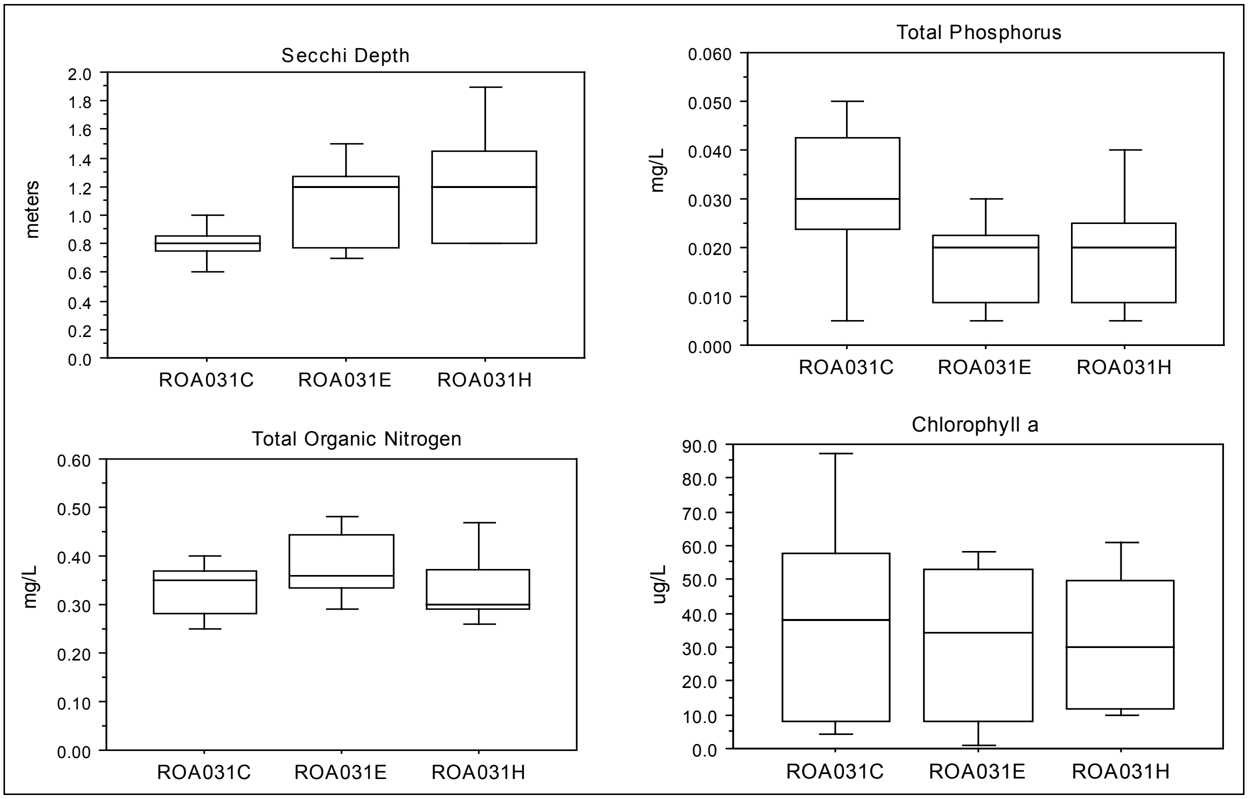

Figure 29. Spatial relationships among biological and water chemistry data from Roxboro Lake, 1988 – 1999 (n = 5).

Mayo Reservoir

Mayo Reservoir is an impoundment of Mayo Creek in Person County just south of the Virginia border (Figure 30). The watershed is characterized by rolling hills with forests, agriculture, and some residential development. The reservoir covers 2,800 acres and has average retention time of 36 months (CP&L, 1994b). Owned by CP&L, the reservoir was constructed in 1983 to provide cooling water for the Mayo Steam Electric Plant.

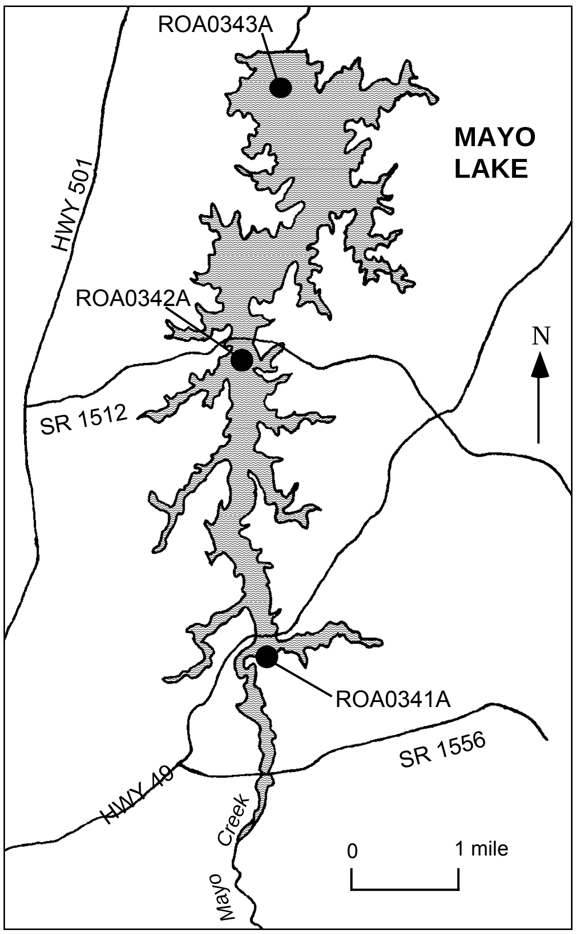

Figure 30. Monitoring sites at Mayo Reservoir, Person County.

The reservoir was most recently sampled during the summer of 1999 (Table 25 and Appendices L2 and L3). Total phosphorus concentrations were either at or below the laboratory detection level of 0.01 mg/l. Selenium concentrations in the surface waters were also consistently less than the laboratory detection level. Based on the calculated NCTSI scores, Mayo Reservoir was oligotrophic during the summer.

Data collected from 1983 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 31). Typical lentic spatial patterns were observed:

- median Secchi depths increased towards the dam; and
- median total phosphorus, total organic nitrogen, and chlorophyll *a* concentrations decreased towards the dam.

There have been no anecdotal reports of algal blooms in the lake. Like many piedmont reservoirs, the headwaters become turbid following rainfall events while water clarity in the main body of the lake has remained relatively unchanged.

Introduced plant and animal species found in the reservoir include:

- Brazilian elodea (*Egeria densa*),
- Hydrilla *(Hydrilla verticillata)*,
- Asiatic clam (*Corbicula fluminea*), and
- Alewife (*Alosa pseudoharengus*)

There has been minimal new development within the reservoir's watershed with the exception of some land clearing for new residential developments outside of the lake's protected shoreline (Ronald Hobbs, CP&L, pers. com.).

Trace metal contaminants in fish tissue are periodically monitored by CP&L. Concentrations were variable from 1994 to 1998 at all stations sampled. Contaminants were generally higher in liver tissue than in muscle samples (CP&L 1998).

Table 25. Biological monitoring and water chemistry data from Mayo Reservoir, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/17/1999	-3.3	Oligotrophic	< 0.01	0.28	8	2.9
07/20/1999	-3.2	Oligotrophic	0.01	0.18	8	2.8
06/01/1999	-5.9	Oligotrophic	< 0.01	0.10	3	2.7
08/18/1994	-5.7	Oligotrophic	0.01	0.07	2	2.9

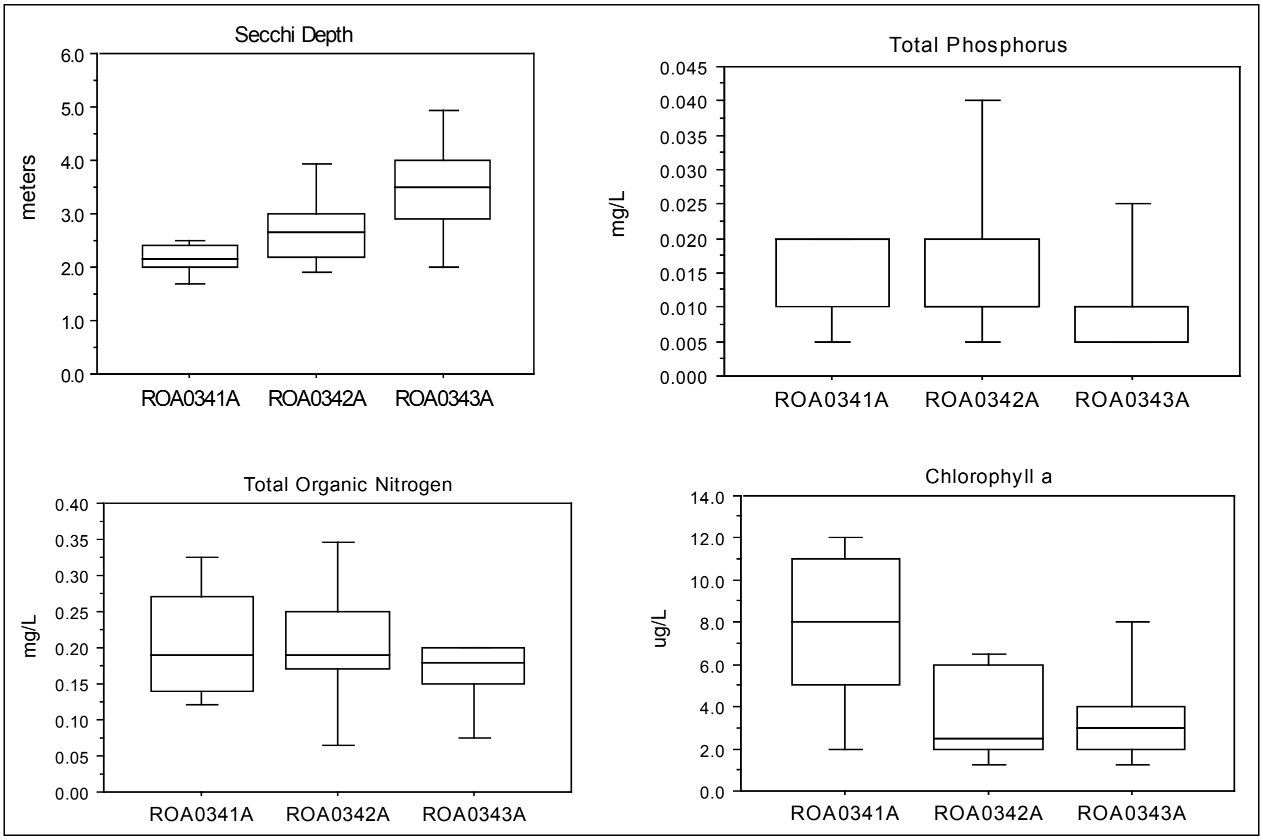

Figure 31. Spatial relationships among biological and water chemistry data from Mayo Reservoir, 1983 – 1999 (n = 10).

ROANOKE RIVER SUBBASIN 06

Description

This subbasin contains many small to medium-sized headwater tributaries of John H. Kerr Reservoir (Figure 32). These tributaries include Aarons Creek, Grassy Creek, Island Creek, and Nutbush Creek. This is a piedmont ecoregion characterized by low, rolling hills and streams of moderate gradient. Headwater reaches of many tributaries were forested, while downstream reaches were farmed. Row crops and pasture were the most prevalent agricultural land uses.

Most stream systems appeared to carry heavy sediment bedloads and were very turbid after heavy rain events. Observations during the very dry summer of 1999 indicated that many streams in this subbasin stopped flowing during the severe drought conditions. This seasonal intermittent flow may limit the diversity of fish and macroinvertebrate communities.

The Town of Henderson is the only metropolitan area in the subbasin. There are four dischargers in this subbasin. Henderson's WWTP discharges 4 MGD to Nutbush Creek. This facility is also required to monitor its effluent's toxicity.

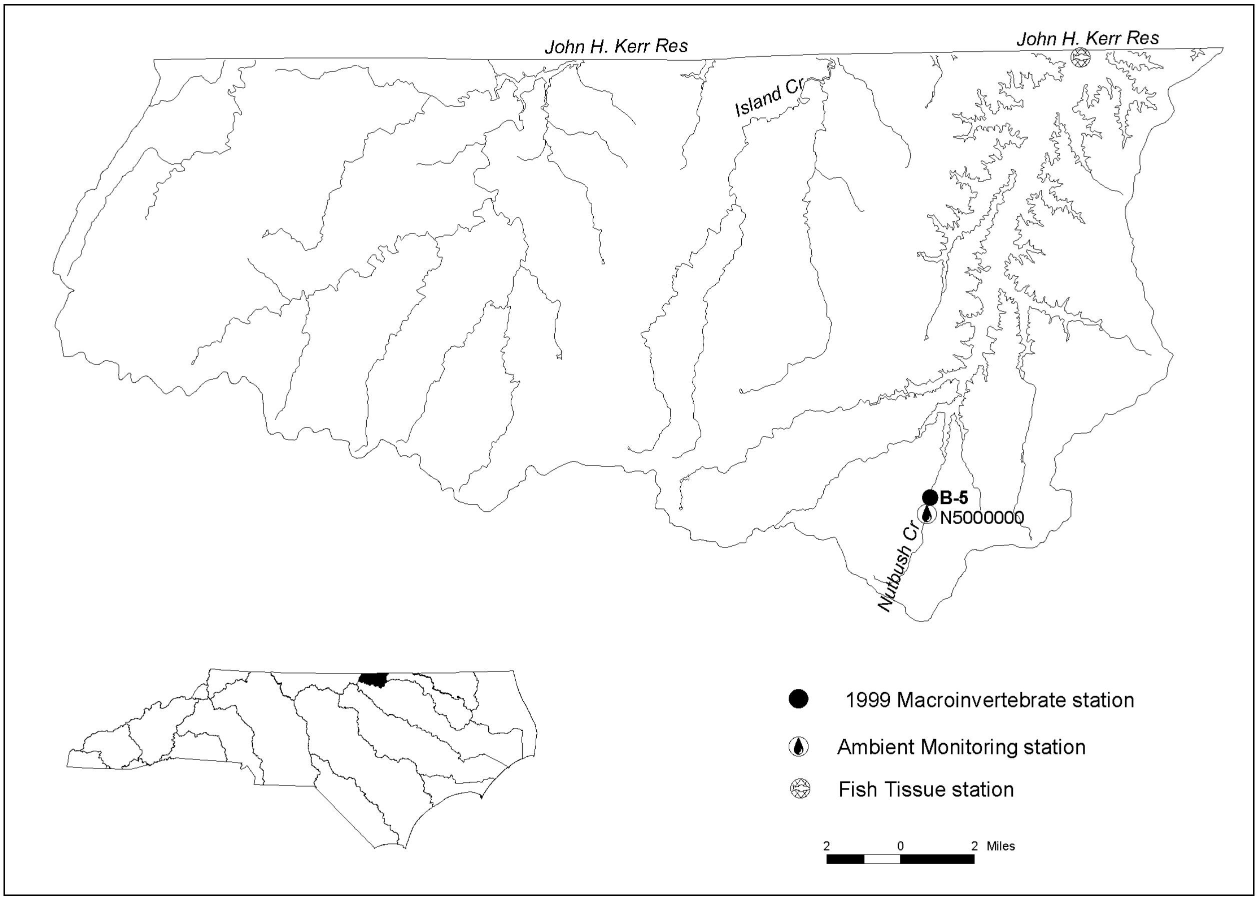

Figure 32. Sampling sites in Subbasin 06 in the Roanoke River basin.

Overview of water quality

Benthic macroinvertebrate samples have been collected from seven locations in this subbasin since 1983, with Fair bioclassifications at the majority of these locations (Appendix B2). The best water quality (Good-Fair bioclassification) was found at Island Creek and Little Island Creek. Island Creek, however, had no flowing water in August 1999 and could not be sampled. The only stream sampled in this subbasin in 1999 for benthic macroinvertebrates was Nutbush Creek (Table 26). Nutbush Creek improved from Poor in 1983 to Fair in 1994, and has remained Fair since then even during the extreme low flows of 1999 when the WWTP influences would be expected to be greater.

Fish tissue samples were collected in 1999 from Kerr Reservoir at the mouth of Nutbush Creek and analyzed for metals and PCBs. Two of the 19 striped bass samples had PCB concentrations greater than the US EPA screening value. One largemouth bass sample had a mercury concentration greater than the US EPA criteria screening value.

Ambient monitoring data were collected from Nutbush Creek near Henderson, downstream of the Town of Henderson's WWTP. During this monitoring cycle, most conventional water quality parameters did not show any violations of water quality standards. The Henderson WWTP has been under Special Order by Consent for failure to meet its toxicity limits. This SOC expired in September 1999 and is currently under review. Although the effluent is still toxic, the town has made substantial progress in identifying which industries may be the sources of these problems.

Furthermore, long term monitoring at this site has shown an increase in dissolved oxygen and declines in fecal coliform, turbidity, nitrogen, and phosphorus measurements. These changes were the result of improvements at the treatment plant beginning in 1988.

The Nutbush Creek Arm of Kerr Reservoir has been monitored by the Division since 1982. Historically, this portion of the reservoir has been rated either mesotrophic or eutrophic. In 1999, it was rated as mesotrophic.

Table 26. Waterbodies monitored in Subbasin 06 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-5[2]	Nutbush Cr	Vance	SR 1317	Fair	Fair
	J. H. Kerr Reservoir	Vance		Mesotrophic	Mesotrophic

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

Nutbush Creek, SR 1317

This site is located downstream of the Town of Henderson's WWTP and this discharge may constitute a large proportion of the instream flow during low flow conditions. Benthic macroinvertebrate samples have been collected four times from this location:

- during an intensive investigation of the WWTP in 1988;
- during basinwide sampling in 1994 and 1999; and
- as part of a statewide toxicity testing study in October of 1994.

This site improved from Poor in 1983 to Fair in 1994 and has remained Fair since then (Table 27).

Table 27. Flow and bioclassifications for Nutbush Creek, SR 1317, Vance County.

Year	Flow	Rating
1988	Normal	Poor
1994	Normal	Fair
1994	Normal	Fair
1999	Low	Fair

The WWTP made some upgrades to their processes in 1994 which resulted in some improvement in water quality. Organic indicator species (as measured by the NCBI) declined in abundance after 1988 (Figure 33) which indicated a reduction in organic loading to Nutbush Creek.

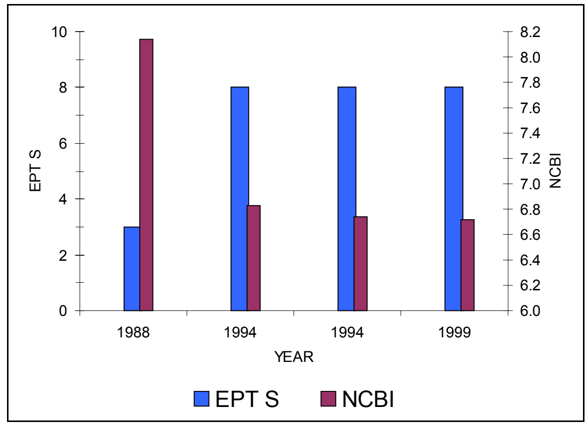

Figure 33. Total (Total S) and EPT (EPT S) taxa richness and biotic index (NCBI) for Nutbush Creek, SR 1317, Vance County.

Fish Tissue

Kerr Lake at mouth of Nutbush Creek

Thirty-six tissue samples were collected during January and May 1999 and analyzed for PCBs (striped bass, n = 19) and metal contaminants (largemouth bass, sunfishes, and catfish, n = 17) (Appendix FT2 and FT4). The PCB analyses were performed at the request of the North Carolina Wildlife Resources Commission. The Commission was concerned with possible PCB concentrations in striped bass in the North Carolina portion of the reservoir after detectable concentrations had been measured in the species in the Virginia portion of the reservoir.

Only two striped bass samples contained total PCB's at concentrations greater than the US EPA screening value of 0.01 µg/g. The other 17 samples had PCB concentrations less than the federal screening criteria.

Only one largemouth bass sample had mercury concentrations exceeding the US EPA screening value of 0.6 µg/g. All other contaminants in the 17 samples were less than the federal or state screening criteria (Appendix FT1).

Lake Assessment

John H. Kerr Reservoir

The John H. Kerr Reservoir (also called Kerr Lake) is a multipurpose impoundment of the Roanoke River. Constructed and operated by the US Army Corps of Engineers, the reservoir provides flood control, hydroelectric power, and recreational opportunities. The reservoir crosses the North Carolina-Virginia state line with the majority of the lake located in Virginia (Figure 34).

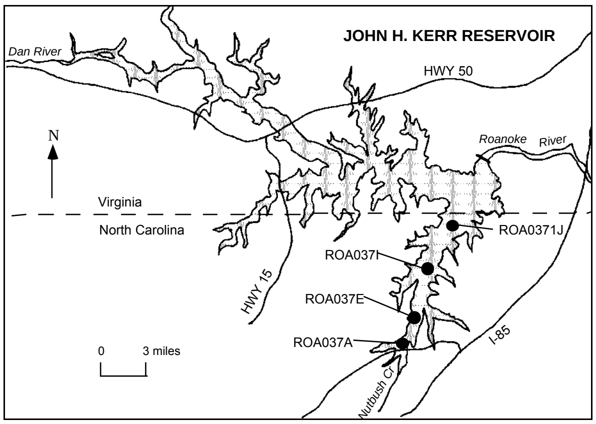

Figure 34. Monitoring sites at Kerr Reservoir, Vance County.

It is the first of three impoundments on the Roanoke River in North Carolina. The reservoir has a mean hydraulic retention time of 124 days. Major tributaries include the Roanoke River, Hyco River, Nutbush Creek, and the Dan River.

Sampling of the lake is confined to the Nutbush Creek Arm because it is the only portion of the lake that lies within North Carolina. The major land uses of this watershed are forest and agriculture.

The reservoir was most recently sampled during the summer of 1999 (Table 28 and Appendices L2 and L3). Fecal coliform bacteria concentrations were at or below 10 colonies per 100 ml.

Data collected from 1983 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 35). Median Secchi depth increased from the upstream site to the site near the lower end of the arm Median total phosphorus, total organic nitrogen, and chlorophyll *a* concentrations were also greater at the upper site than at the lower site

There have also been no anecdotal reports of algal blooms in this embayment. *Hydrilla*, an invasive aquatic macrophyte, has been observed in the Grassy Creek Arm of the reservoir since 1982 or 1983. It has not yet colonized the Nutbush Creek Arm. The Grassy Creek Arm is located to the west of the Nutbush Creek arm and flows from North Carolina into Virginia where it then joins the mainstem of the reservoir.

Significant residential development is occurring within the immediate area of the reservoir (Gordon Westenhaver, US COE, pers. com.).

Table 28. Biological monitoring and water chemistry data from John H. Kerr Reservoir, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/05/1999	-0.3	Mesotrophic	0.02	0.33	22	1.6
07/22/1999	-1.2	Mesotrophic	0.01	0.31	22	2.0
06/02/1999	-1.9	Mesotrophic	0.02	0.15	11	1.5
08/09/1994	-1.9	Mesotrophic	0.03	0.25	3	1.9

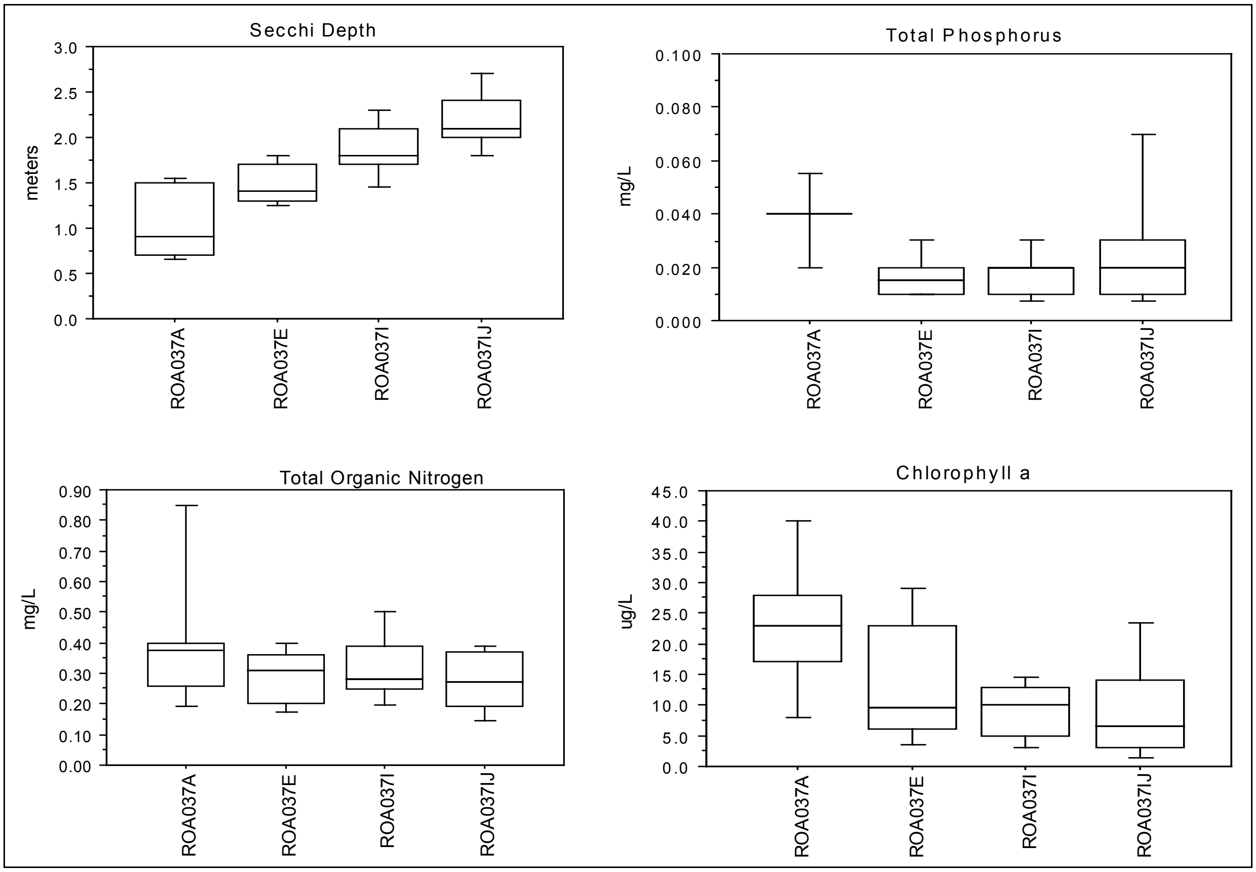

Figure 35. Spatial relationships among biological and water chemistry data from Kerr Reservoir, 1981 - 1999 (n = 10).

ROANOKE RIVER SUBBASIN 07

Description

This subbasin is located within the piedmont ecoregion and consists mainly of Lake Gaston and many small tributaries to the lake (Figure 36).

Land use is a combination of agriculture and forestry. There are no NPDES permitted dischargers in this subbasin.

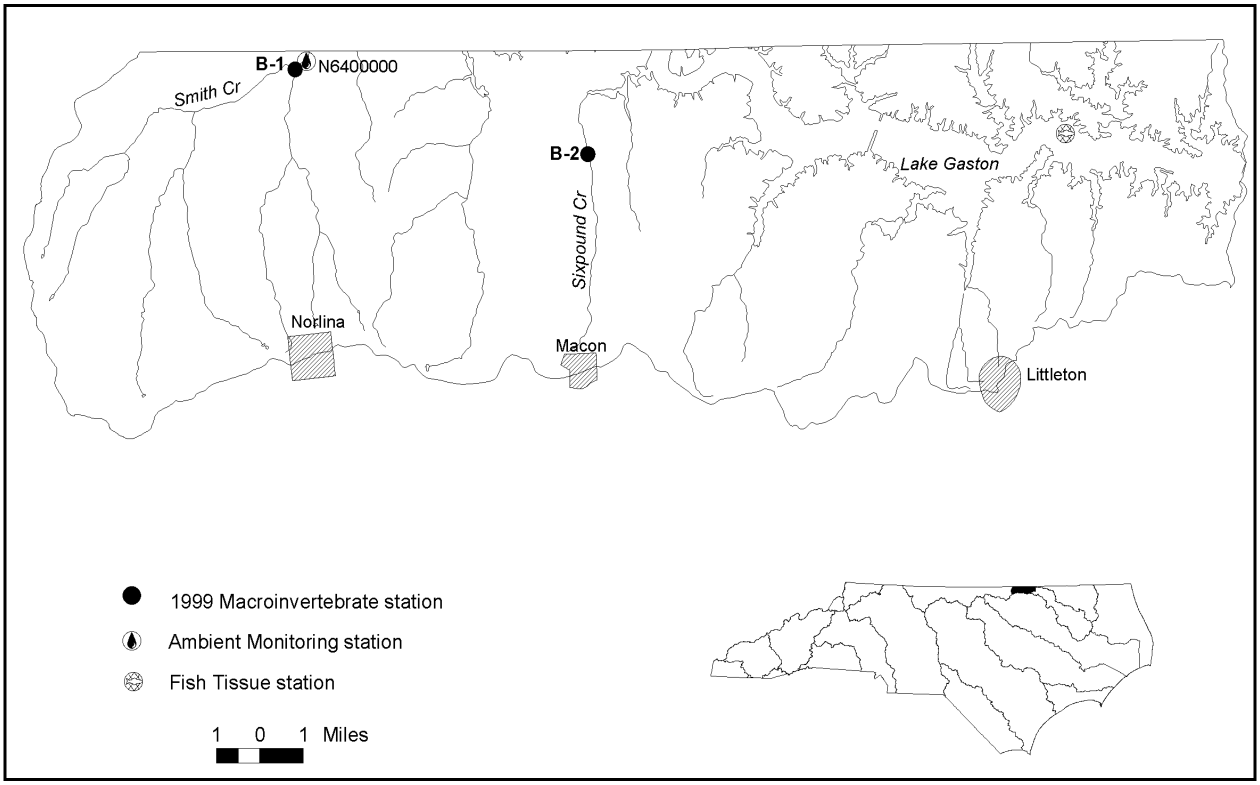

Figure 36. Sampling sites in Subbasin 07 in the Roanoke River basin.

Overview of water quality

Macroinvertebrate surveys conducted on Smith Creek produced a Fair rating while Sixpound Creek was rated Good-Fair (Table 29). Both sites indicated improved water quality during the low flow and drought like conditions in the summer of 1999 in contrast to the high flows experienced in 1994. The decline in water quality during high flows is characteristic of scour effects, particularly in streams that become very turbid after rain.

Ambient monitoring data were collected from Smith Creek near Paschall. Median dissolved oxygen concentrations were lower here (6.6 mg/l) than at any other tributary sites in the Roanoke River basin. Approximately 25% of the observations were less than 5.0 mg/l. Conductivity showed a steady increase between 1984 and 1995.

Table 29. Waterbodies monitored in Subbasin 07 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-1[2]	Smith Cr	Warren	US 1	Fair	Fair
B-2	Sixpound Cr	Warren	SR 1306	Fair	Good-Fair
	Lake Gaston	Warren, Halifax, & Northampton		Oligotrophic	Oligotrophic

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data available prior to 1994, refer to Appendix B2.

Lake Gaston has been classified as either oligotrophic or mesotrophic since 1985. The nuisance aquatic macrophyte, *Hydrilla* continued to expand its coverage in the reservoir.

Twenty fish from Lake Gaston were analyzed for mercury contamination. None of the samples were found to have concentrations greater than US EPA or FDA criteria.

River and Stream Assessment

Smith Creek, US 1
The substrate in this 10 m wide stream was almost entirely sand. The best habitats for macroinvertebrates were sticks, logs, and root mats. Water levels were elevated (0.5 m deep) and turbid following a week of rain.

Water quality at this site seemed to be a steady Fair rating since 1984. EPT S decreased by 50% in 1994 compared to 1989 (EPT S = 6 and 12, respectively). This decline was probably due to scour from the increased bedload transported by the stream during high flows. In 1999, EPT S was back to 1989 levels, indicating that 1994 was an anomalous year, rather than a declining trend.

Conductivity has been significantly ($p < 0.01$) increasing at this site over the last 15 years (Figure 37).

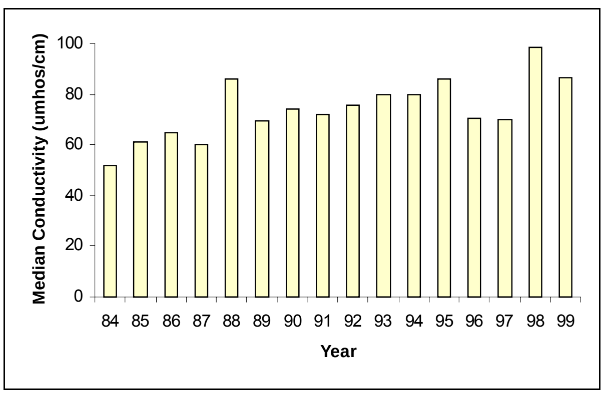

Figure 37. Median annual conductivity at Smith Creek at US 1, Warren County.

Sixpound Creek, SR 1306
The habitat available for macroinvertebrate colonization in this small (4 m wide) stream was very similar to that in Smith Creek, but with the addition of a single riffle at the bridge. Even though the streams appeared to be similar physically, there were definite differences in water chemistry between the two sites. On the day both sites were sampled, at Sixpound Creek the conductivity was 54 µmhos/cm lower, and the dissolved oxygen was 2.1 mg/l greater than at Smith Creek.

Even though a less intensive sampling method was used at this stream than at Smith Creek, more EPT taxa (14) and nearly twice as many intolerant organisms were collected from Sixpound Creek than at Smith Creek. As a result, Sixpound Creek was given a higher bioclassification (Good-Fair) than Smith Creek (Fair). This was also true when both sites were sampled in 1994. Sixpound Creek scored one bioclass lower in 1994 than in 1999 due to scour from high flows that year. Based on the bioclassification trends at Smith Creek, the 1999 rating of Good-Fair at Sixpound Creek seemed to be a more appropriate rating for this stream than the rating of Fair in 1994.

Fish Tissue

Lake Gaston
During July 1999, 20 tissue samples were collected from bluegill, largemouth bass, channel catfish, and yellow perch from Lake Gaston at SR 1214 near Henrico (North Hampton County).

All metal contaminant concentrations were less than federal and state criteria (Appendix FT1).

Lake Assessment

Lake Gaston

Lake Gaston is located on the North Carolina-Virginia border downstream from the Kerr Reservoir Dam on the Roanoke River (Figure 38).

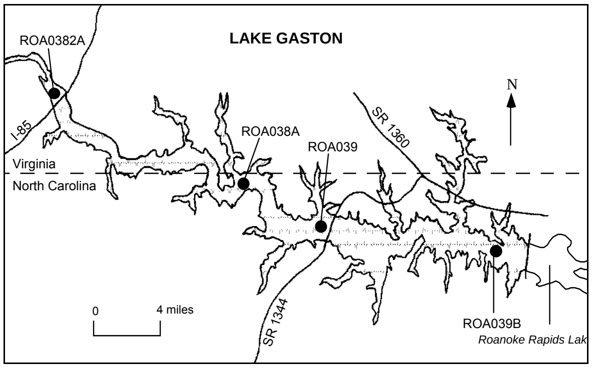

Figure 38. Monitoring sites at Lake Gaston, Warren and Halifax counties.

The lake was built in 1962 by the Virginia Electric and Power Company for the generation of hydroelectric power. The lake is also used extensively for recreation. Residential developments, campgrounds, golf courses, marinas, and swimming beaches are located along the shoreline.

Lake Gaston was most recently sampled during the summer of 1999 (Table 30 and Appendices L2 and L3). Chlorophyll *a* concentrations ranged from low to moderate with the greatest concentration (22 µg/l) observed at Station ROA038A in July. Concentrations of all metals, except for manganese, were within applicable water quality standards.

At the upstream site (Station ROA0382A), concentrations in July (220 µg/l) and August (300 µg/l) were greater than the water quality standard of 200 µg/l for a water supply waterbody. These elevated concentrations may have been the result of the hypolimnetic release from the J. H. Kerr Reservoir. Manganese concentrations at the remaining three sites were significantly lower and well within the water quality standard. Fecal coliform bacteria concentrations were consistently less than 10 colonies/100 ml.

Data collected from 1991 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 39). Mean Secchi depths increased from the upstream site downstream to the site near the dam. Mean total phosphorus and total organic nitrogen concentrations indicated a small spatial variation between the upstream and downstream sites. The mean chlorophyll *a* concentration was greatest at the site near the SR 1344 bridge (Station ROA039).

In 1999, there were several small fish kills (< 25 fish/event) in the lake (Wayne Jones, North carolina Wildlife Resources Commission, pers. com).

Growths of *Hydrilla* sp. and water lilies have increased in recent years in the lake. Areal coverage by *Hydrilla* was estimated at 3,400 acres, or approximately 62% of the surface area of the lake. Also present are Eurasian watermilfoil (*Myriophyllum spicatum*) and Brazilian elodea (*Egeria densa*). In the spring of 1999, 5,000 grass carp were stocked in an effort to control these exotic plants (David Demont, North Carolina Division of Water Resources, pers. com.).

Table 30. Biological monitoring and water chemistry data from Lake Gaston, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/05/1999	-2.2	Oligotrophic	0.01	0.24	12	1.9
07/22/1999	-1.8	Mesotrophic	0.01	0.22	15	2.0
06/02/1999	-3.6	Oligotrophic	0.01	0.13	5	1.6
08/09/1994	-2.5	Oligotrophic	0.02	0.20	2	1.6

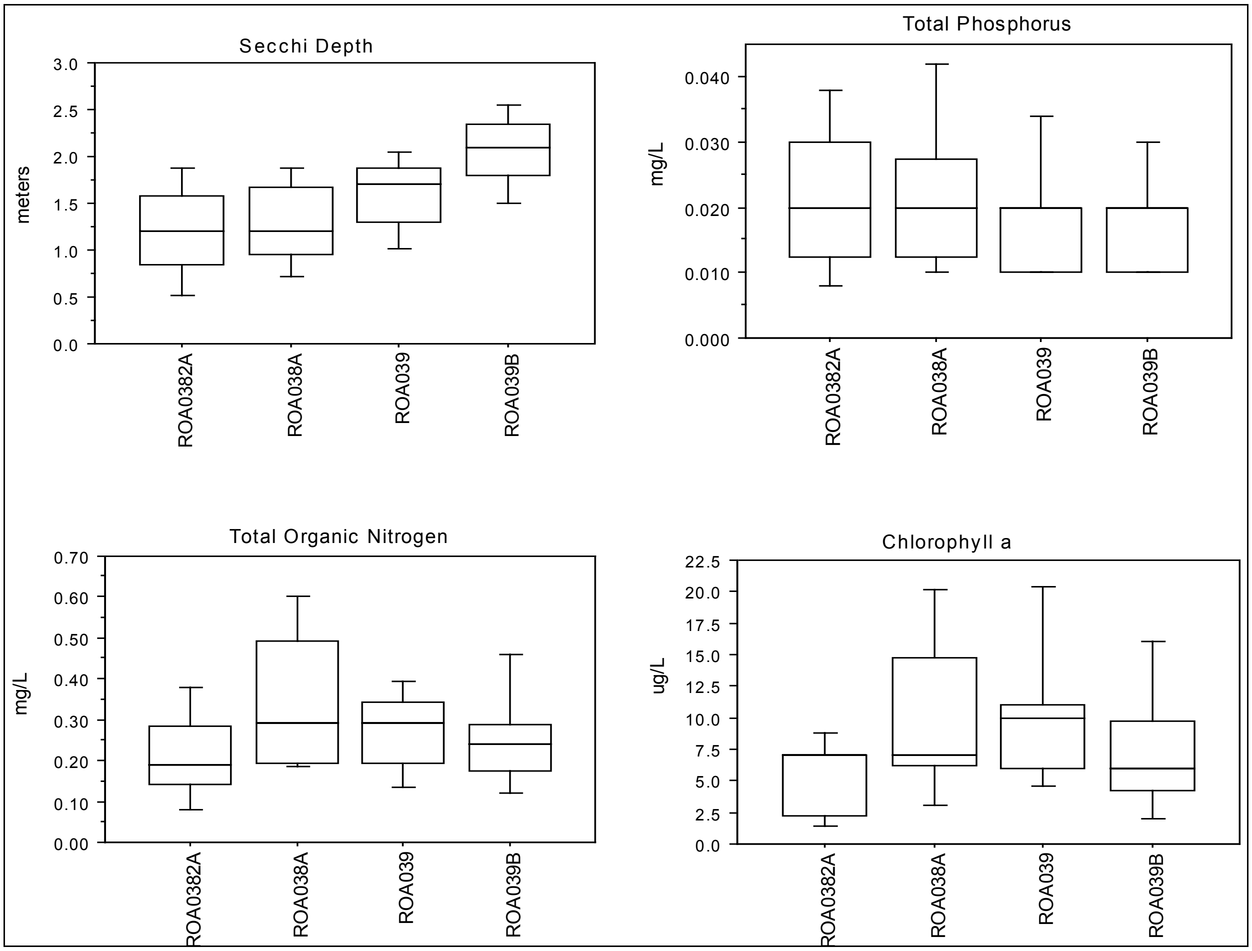

Figure 39. Spatial relationships among biological and water chemistry data from Lake Gaston, 1981 - 1999 (n = 11).

Dissolved oxygen conditions in Lake Gaston are influenced by the deep water release from the upstream Kerr Reservoir. During the summer, the surface dissolved oxygen concentrations in portions of Lake Gaston are often less than 5.0 mg/l (North Carolina Power, 1997a).

Surface dissolved oxygen concentrations and water temperatures at the upstream site (Station ROA0382A) were consistently lower than those of the other sampling sites during the summer months (Figures 40-42).

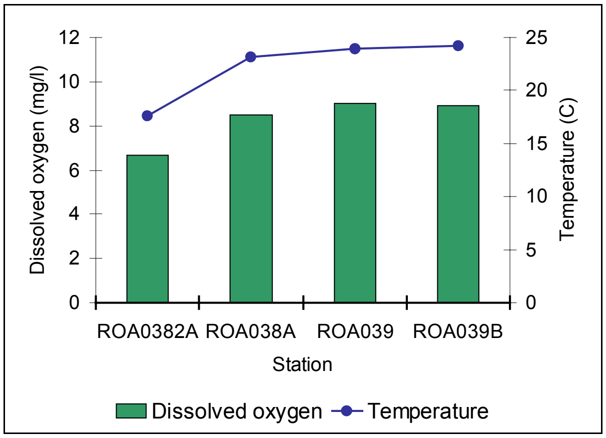

Figure 40. Dissolved oxygen concentrations and temperatures in the surface waters of Lake Gaston, June 10, 1999.

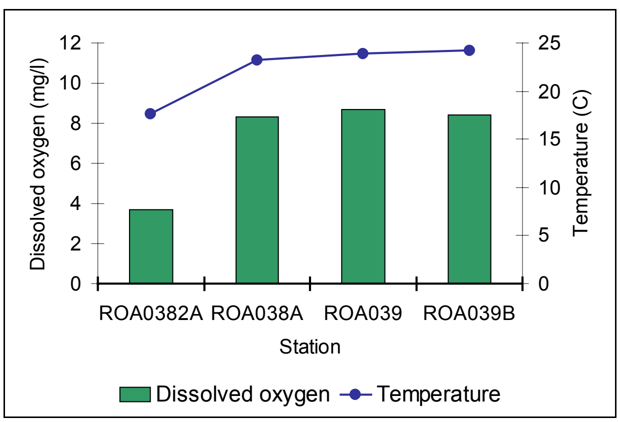

Figure 41. Dissolved oxygen concentrations and temperatures in the surface waters of Lake Gaston, July 22, 1999.

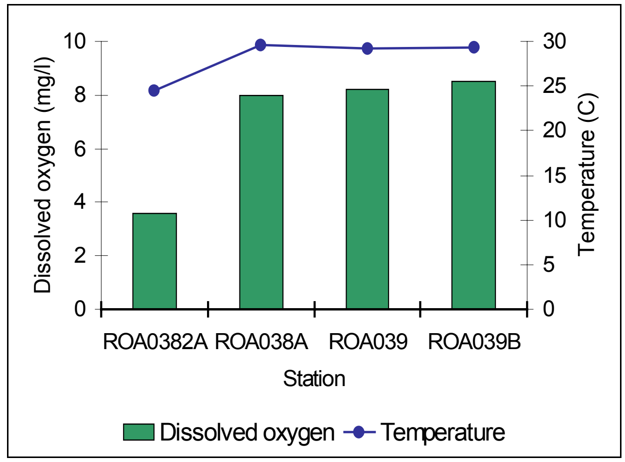

Figure 42. Dissolved oxygen concentrations and temperatures in the surface waters of Lake Gaston, August 5, 1999.

The dissolved oxygen concentrations at this station progressively declined throughout the summer (Figures 43-45).

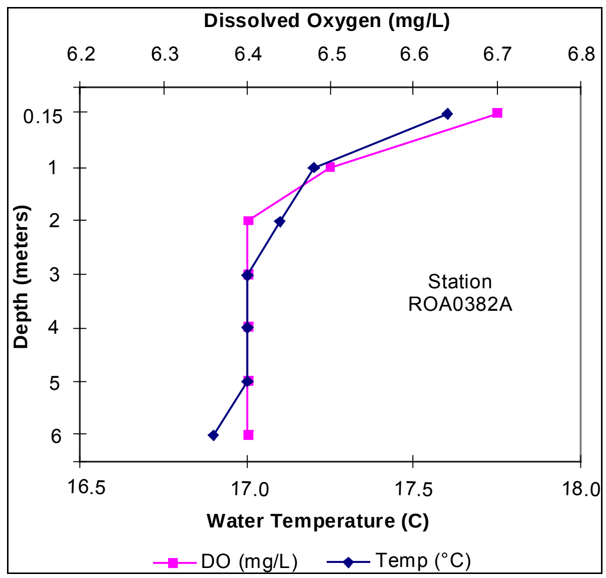

Figure 43. Dissolved oxygen concentration and temperature profiles at Station ROA0382A on Lake Gaston, June 10, 1999.

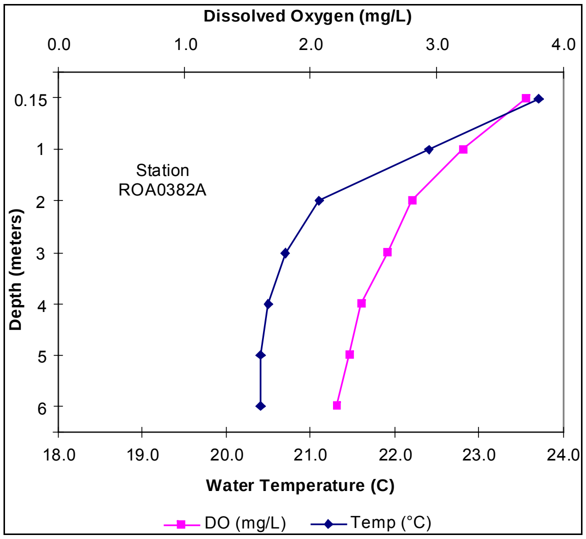

Figure 44. **Dissolved oxygen concentration and temperature profiles at Station ROA0382A on Lake Gaston, July 22, 1999.**

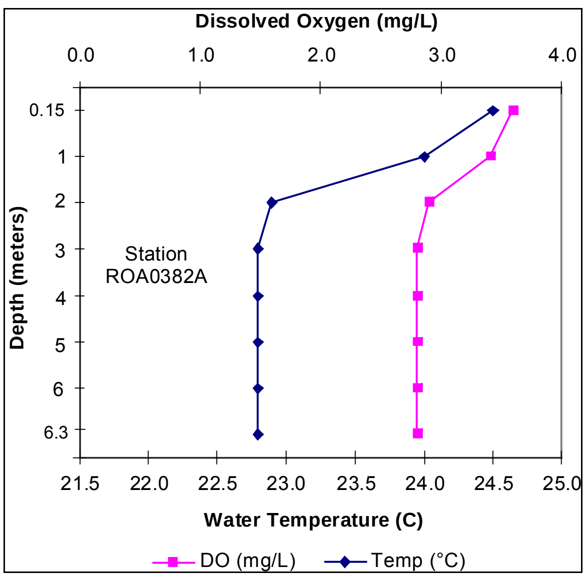

Figure 45. **Dissolved oxygen concentration and temperature profiles at Station ROA0382A on Lake Gaston, August 5, 1999.**

To improve the concentrations of dissolved oxygen in the upper end of Lake Gaston, the first of seven turbines at the upstream Kerr Dam was modified to inject air into the turbine discharge during the summer of 1999. Completion of this turbine aeration project is expected in the spring of 2000 (Bernie Scerbo, Kerr Reservoir Power-house, pers. com.).

Fish surveys were conducted in May, August, and October, 1996 in Lake Gaston as part of the Federal Energy Regulatory Commission relicensing process. Thirty-eight species were collected. Littoral zone species were dominated by sunfishes and largemouth bass. Pelagic zone species included white perch, gizzard shad, and alewife. The tributary arms of the lake were found to be more productive than the main lake based on the abundance of fish caught. Striped bass and walleye are stocked in the lake, however, few of these fish were captured during the survey.

Surface dissolved oxygen measured during fish sampling indicated that, with one exception, concentrations were greater than 5.0 mg/l (North Carolina Power, 1997b).

ROANOKE RIVER SUBBASIN 08

Description

The upper areas of this subbasin are within the piedmont ecoregion, while the lower portions are within the coastal plain (Figure 46). The main water bodies are Roanoke Rapids Lake and approximately 60 miles of the Roanoke River. With the exception of the Roanoke Rapids/Weldon urban area, most of the land use in the subbasin is forested or agricultural.

There are11 NPDES permitted dischargers in this subbasin. The largest facilities are Champion International (28 MGD), Roanoke Rapids WWTP (8.3 MGD), Perdue Farms (3.0 MGD), the Town of Weldon's WWTP (1.2 MGD), and the Department of Correction's Caledonia WWTP (0.8 MGD). All these discharges flow into the Roanoke River.

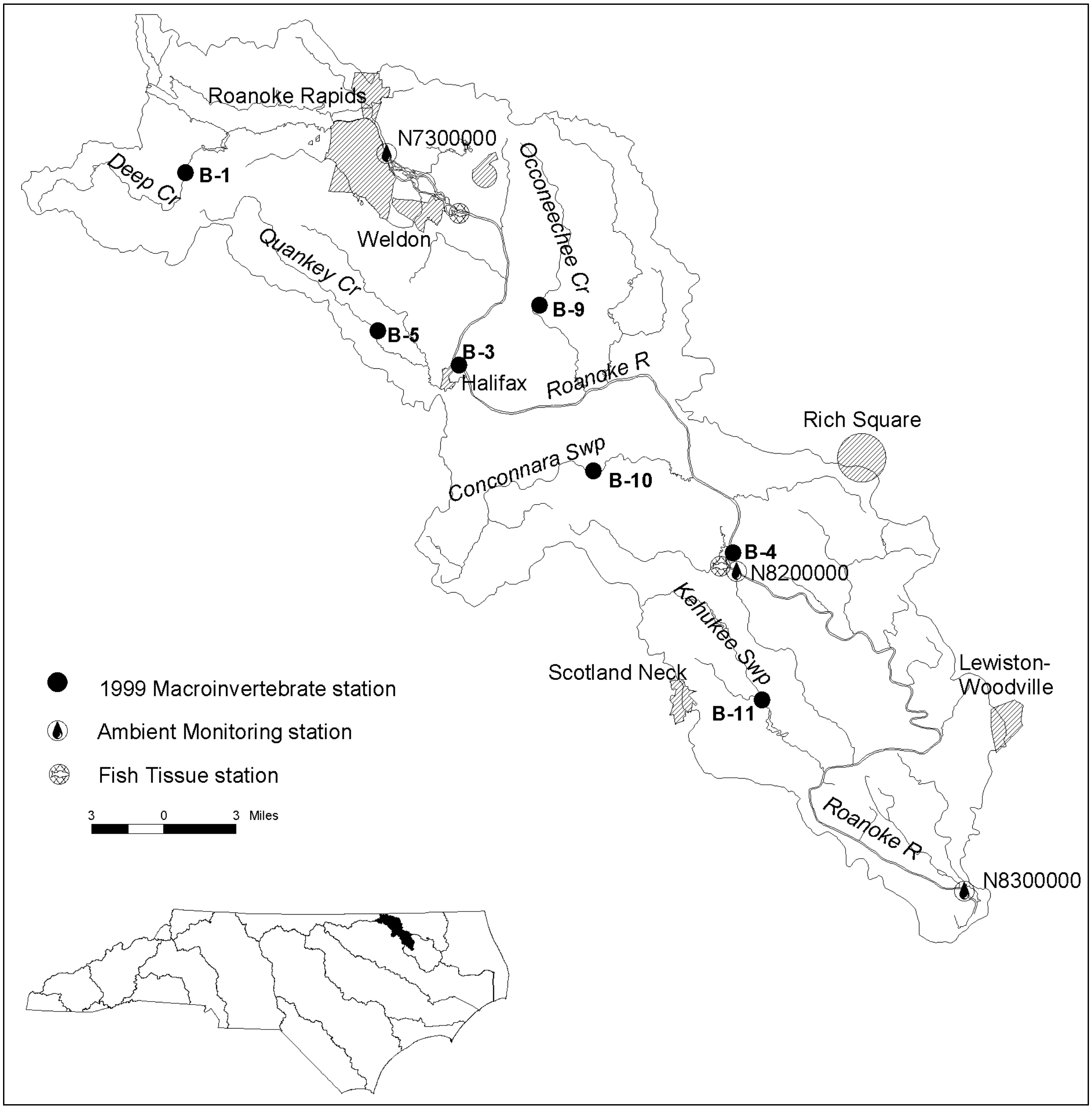

Figure 46. Sampling sites in Subbasin 08 in the Roanoke River basin.

Overview of water quality

Roanoke River at Scotland Neck maintained its Good rating (Table 31). A second site on the Roanoke River, at Halifax, was also rated Good while Quankey Creek below the Halifax WWTP maintained the Fair rating it received in 1992.

Deep Creek, Oconeechee Creek, Quankey Creek (above the Town of Halifax's WWTP), Conoconnara Swamp, and Kehukee Swamp were not rated using macroinvertebrate data because of their swampy character.

A mussel survey was conducted in 1996 by Virginia Electric & Power Company as part of its relicensing efforts for the Lake Gaston and Roanoke Rapids Lake hydroelectric projects. Eight of the 15 species that had been historically documented or believed to be present in the entire river were collected from a single 10 mile stretch of river (Pennington & Associates 1996).

Fish tissue samples were collected from two sites on the Roanoke River in 1995 and 1999. Six bowfin samples from the river at Weldon had mercury concentrations greater than the EPA screening value of 0.6 µg/g. At Scotland Neck, of the 23 fish tested for mercury contamination, one largemouth bass had a concentration greater than the US EPA screening value and one bowfin had a concentration greater than the FDA criteria of 1.0 µg/g.

Roanoke Rapids Lake was the only lake monitored in this subbasin. The lake has extensive growths of nuisance aquatic macrophytes. More than 30% of the entire lake's surface area is covered with *Hydrilla*. *Myriophyllum spicatum* and *Egeria* were also present in the lake. The lake is usually rated mesotrophic.

Ambient monitoring data were collected from three sites on the Roanoke River: at Roanoke Rapids, near Scotland Neck, and near Lewiston. Although there were no substantial water quality problems, median total suspended solids and nitrate + nitrite nitrogen concentrations increased in a downstream manner from Roanoke Rapids to Lewiston, then declined from Lewiston to San Souci (in the next subbasin).

Seven NPDES permitted facilities in this subbasin are required to perform toxicity tests on their effluent. The Panda-Rosemary facility, which failed the only toxicity test it performed in 1999, had the most inconsistent historic record, failing 39% of their toxicity tests before 1999. The Halifax WWTP was the only other facility that did not pass all of their tests in 1999.

Table 31. Waterbodies monitored in Subbasin 08 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Waterbody	County	Location	1994	1999
B-1	Deep Cr	Halifax	US 158	Fair	Not Rated
B-3	Roanoke R	Halifax	At Halifax	---	Good
B-4[2]	Roanoke R	Halifax	US 258, Scotland Neck	Good	Good
B-5	Quankey Cr	Halifax	NC 903	---	Not Rated
B-6	Quankey Cr	Halifax	NC 561	---	Fair
B-9	Oconeechee Cr	Northampton	SR 1126	---	Not Rated
B-10	Conoconnara Swp	Halifax	NC 561	---	Not Rated
B-11	Kehukee Swp	Halifax	SR 1804	---	Not Rated
	Roanoke Rapids Lake	Halifax		Oligotrophic	Mesotrophic

[1]B = benthic macroinvertebrate monitoring sites.
[2]Data are available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Flow in this portion of the Roanoke River is controlled by releases from the Roanoke Rapids Lake dam. Winter sampling of sites on the river were timed to coincide with a period of low release from the dam. Thus, allowing better access to the varied aquatic habitats present in the river.

Deep Creek, US 158
This 5 m wide stream possessed occasional gravel riffles, which suggested that this stream lies within the Piedmont ecoregion. There were several characteristics observed at the site that suggested that this stream should not be rated due to a previous lack of flow. The substrate and even the crayfish were stained black, consistent with surface alterations due to the presence of hydrogen sulfide.

Members of the filter feeding caddisfly family Hydropsychidae, ubiquitous in flowing streams, were absent. Another common mayfly, *Stenonema modestum*, was only represented by early instar larvae, which suggested that flow had resumed within the last month or two.

Roanoke River, Halifax
This portion of the river is deeply incised with steep banks. The river is confined to the channel under most flow conditions. This site was the only site on the Roanoke River shallow enough to be sampled without a boat. The Roanoke River at this site was approximately 50 m wide during the artificially low waters experienced during sampling. Rocky areas in good flow near the shoreline allowed the use of a kicknet to collect some samples. The river was rated Good.

Interesting taxa collected at this site included *Ephemerella argo*, a possible undescribed species of *Stenonema*, and two species of *Ceraclea*.

Roanoke River, US 258
This 50 m wide site at Scotland Neck has been sampled since 1985 and was sampled twice in 1999, once in March and again in July. Bioclassifications have changed from Good-Fair in the 1980s to Good in the 1990s. But these changes were likely the result of improved sampling techniques.

Interesting taxa collected at this site included the mayflies *Ephemerella argo* and *Pseudocentroptiloides usa* and two species of *Ceraclea*. As with most large river sites, snags in the current were the most productive habitat.

Quankey Creek, NC 903
This swamp stream had the best gravel riffles and highest habitat quality score (96) of any tributary sampled in the coastal plain of the basin. A high total number of taxa (40), EPT N (44) and EPT S (9) were found here which indicated a lack of major water quality problems in the stream. This upstream site had no visible flow during the summer months.

Quankey Creek, NC 561
This small, three meter wide stream probably flows in the summer only because of the additional volume of water provided by the discharge from the Town of Halifax's WWTP. The relatively high conductivity, 117 μmhos (compared to 70 μmhos at the upstream site at NC 903), reflected the influence of the plant.

The stream was very shallow (0.2 m) with discernable flow only in the narrowest portions of the channel. The channel was highly incised and the substrate was nearly all sand. A Fair bioclassification was assigned to this site, unchanged from a sample collected slightly upstream of this site in 1992.

Oconeechee Creek, SR 1126
This small, braided stream (three meters wide in winter) was 1 of 3 streams sampled in the Roanoke River basin's coastal plain that had a pH less than 6 (5.5 s.u.). The conductivity (51 μmhos/cm) measured at this site was the lowest measurement during the winter survey of Roanoke River basin swamp streams. The biotic index was also low (NCBI = 6.48). There was some depression of taxa richness values that might have indicated a slight unknown stress.

An unusual stonefly, *Prostoia* sp. was collected at the site. This may be the species *P. hallasi*, which is known only from the Great Dismal Swamp (VA).

Conoconnara Swamp, NC 561
Conoconnara Swamp was a large (25 m wide) stream with a braided channel. Most of the fauna collected during the winter from this stream came from macrophytes, rather than from the fine brown organic matter that comprised most of the substrate. Low EPT S (5) and EPT N (18) at this site might have been a sign of stress, an artifact of the braided channel, or a reflection of limited habitat diversity.

Two unusual taxa were collected from this site: the mayfly *Leptophlebia bradleyi* and the snail *Planorbula armiger*.

Kehukee Swamp, SR 1804
This five meter wide stream drains a watershed mixed with forestry and row crops (soybeans, sweet potatoes, and corn). A beaver dam was located just upstream of the sampling site and might have produced summer flow in only a short segment of the stream below the dam. The site was evaluated as a swamp stream, therefore it was not assigned a bioclassification.

The site was sampled in February and again in September 1999. The February sample showed a community more tolerant (NCBI = 7.11) than the other creeks sampled in this subbasin but this site also had high Total S (59) and EPT N (59).

Interesting taxa collected at this site were the state threatened mussel *Elliptio lanceolata* and the caddisfly *Playtcentropus amicus*.

Fish Tissue

Roanoke River, NC 158
Twenty seven samples were collected from the Roanoke River near Weldon in 1995 (n = 6) and 1999 (n = 21). The six bowfin samples collected during 1995 contained mercury concentrations greater than the US EPA screening value of 0.6 µg/g. In 1999, all samples had metal concentrations less than federal and state screening criteria. However, no bowfin samples were collected during 1999.

Roanoke River, NC 258
Twenty-three samples were collected during May 1999 from the Roanoke River near Scotland Neck for metals contaminants analysis. The mercury concentration for one largemouth bass sample exceeded the US EPA screening value of 0.6 µg/g and one bowfin sample contained mercury at a concentration greater than the US EPA criteria (0.06 µg/g) as well as the FDA and the North Carolina criteria of 1.0 µg/g. All other concentrations were less than federal and state criteria (Appendix FT2).

Lake Assessment

Roanoke Rapids Lake
Roanoke Rapids Lake is located on the Roanoke River immediately downstream from Lake Gaston (Figure 47). Built by the Virginia Electric & Power Company (VEPCO) to generate hydroelectricity, it is secondarily used for recreation and water supply.

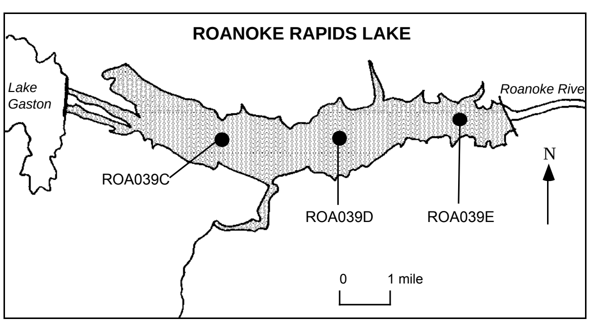

Figure 47. Monitoring sites on Roanoke Rapids Lake, Halifax County.

The reservoir was most recently sampled during the summer of 1999 (Table 32 and Appendices L2 and L3). Nutrient and chlorophyll *a* concentrations were similar to those previously measured . All metals were within the applicable water quality standards and fecal coliform bacteria concentrations were consistently less than 10 colonies/100 ml. Since 1982, the reservoir ratings, based on the NCTSI, have been either oligotrophic or mesotrophic.

Data collected from 1983 through 1999 for the four constituents of the NCTSI were summarized using box and whisker plots (Figure 48). Mean Secchi depths and total phosphorus concentrations were generally similar among the three sites.

In recent years, there has been an increase in *Hydrilla*, watermilfoil (*Myriophyllum*) and Brazilian elodea (*Egeria densa*) in the reservoir. Areal coverage by *Hydrilla* was estimated at 1,800 acres or approximately 30% of the surface area of the lake (David Demont, NCDWR, pers. com).

This reservoir is being monitored by VEPCO as part of its efforts to relicense the hydroelectric project. In 1994 and 1995, the lowest surface dissolved oxygen concentrations in the lake occurred near the upstream discharge from Lake

Gaston. Concentrations typically increased as water moved downstream towards the dam.

Surface concentrations in the upper end of the lake were greater in the summer of 1994 as compared with concentrations observed in the summer of 1995. During the middle of the summer of 1995, the mid- to upper end of the reservoir exhibited concentrations less than 5 mg/l. The lowest inflow dissolved oxygen concentrations based on measurements from the Lake Gaston tailrace ranged from 5 to 6 mg/l from early August through early September, 1994. From mid-July through early September, 1995, the lowest concentrations ranged from 2 to 4 mg/l (North Carolina Power 1997a).

Fish surveys during May, August, and October 1996 were also been conducted by VEPCO. Twenty-five species were collected with bluegill as the dominant littoral zone fish. Gizzard shad and channel catfish were co-dominant in the offshore areas. Bluegill was the most abundant species based on the use of electrofishing methods. However, the individual fish were relatively small and few were of desirable sport size. Striped bass, walleye, and black crappie, which are stocked by the North Carolina Wildlife Resources Commission, were not abundant (North Carolina Power 1997b).

Table 32. Biological monitoring and water chemistry data from Roanoke Rapids Lake, 1994 - 1999.

Date	NCTSI	Rating	TP (mg/l)	TON (mg/l)	CHL *a* (µg/l)	Secchi (m)
08/05/1999	-1.3	Mesotrophic	0.01	0.30	16	1.6
07/22/1999	-2.6	Oligotrophic	0.01	0.19	10	2.2
06/02/1999	-2.0	Mesotrophic	0.02	0.22	7	1.7
08/09/1994	-3.3	Oligotrophic	0.02	0.18	2	1.8

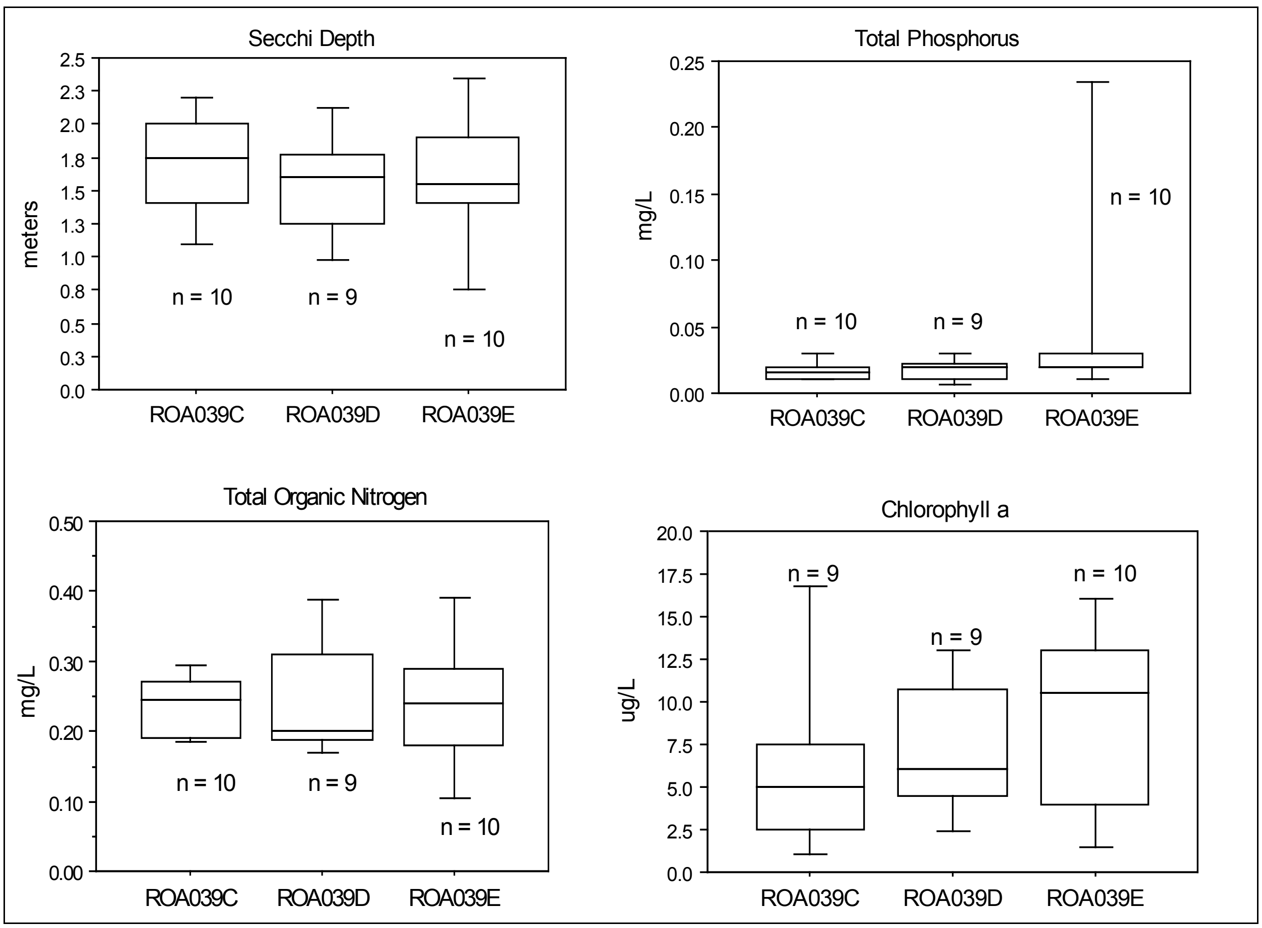

Figure 48. Spatial relationships among biological and water chemistry data from Lake Gaston, 1981 - 1999 (n = 11).

ROANOKE RIVER SUBBASIN 030209

Description

This subbasin is located within the coastal plain ecoregion (Figure 49). The two largest towns in the subbasin are Williamston and Plymouth. Primary land uses are agriculture and forest. There are nine NPDES permitted dischargers in the subbasin. The largest ones are Weyerhaeuser (82.5 MGD), Williamston's WWTP (2.0 MGD), Alamac Knit Fabrics (1.5 MGD), and Plymouth's WWTP (0.8 MGD), all of which discharge to the Roanoke River.

The Roanoke River in this subbasin is bordered by extensive floodplain forests. The areas are inundated during high flows when the river is bankful. Water returns to the river through only a few connections, locally called "guts".

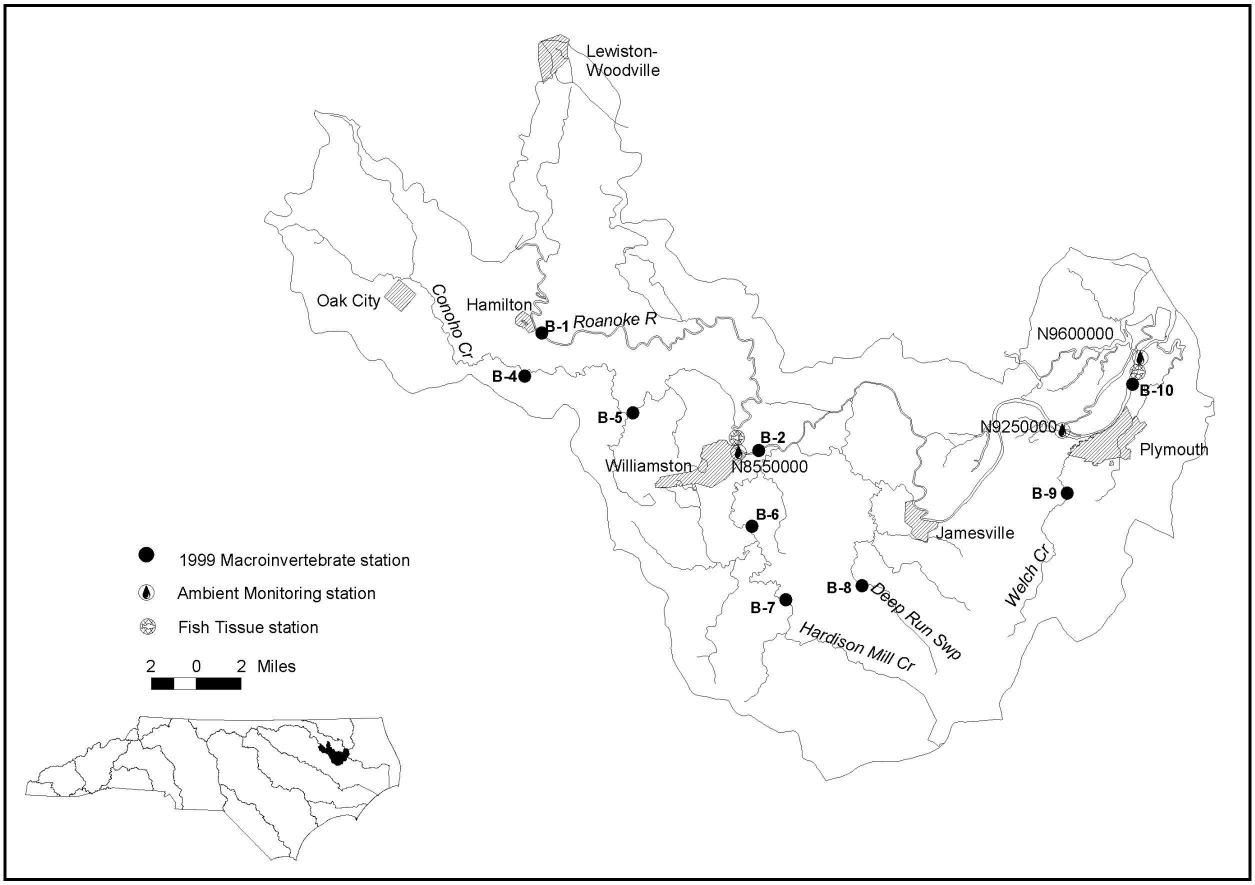

Figure 49. Sampling sites in Subbasin 09 in the Roanoke River basin.

Overview of water quality

Based on macroinvertebrate data, the Roanoke River has been assigned Good-Fair bioclassifications from the upper end of this subbasin to below Williamston (Table 33). The lower section of the river, near the Plymouth and Sans Souci areas, has experienced a mild temporary estuarine influence in some years, but is still regarded as a lower coastal plain freshwater river. Macroinvertebrate data from the Sans Souci area has suggested good water quality in this section of the river.

Tributaries to the Roanoke River in this subbasin are swampy and may experience periods of very little or no flow. The lower portion of Conoho Creek was found to represent nearly natural conditions, while the other swamps in this subbasin, the upper portion of Conoho Creek, the upper and lower portions of Hardison Mill Creek, and Welch Creek, suggested water quality or habitat problems. The most severe problems were observed in Deep Run Swamp, an area of intensive agricultural land use.

Fish tissue sample were collected from two sites on the Roanoke River in 1995 and 1999. Eight bowfin from the river near Williamston had mercury concentrations greater than FDA consumption criteria (1.0 µg/g) in 1995,. In 1999, 15 of 24 samples of bowfin, largemouth bass, and white catfish had mercury concentrations greater than US EPA and FDA criteria (0.6 µg/g and 1.0 µg/g, respectively).

Mercury concentrations were somewhat lower near Plymouth: 4 of 7 bowfin collected in 1995 had mercury concentrations in excess of FDA criteria. In 1999, 4 samples (three largemouth bass and one chain pickerel) out of 22 samples had concentrations which exceeded the US EPA criteria.

The Roanoke River from Williamston to the mouth remains under a fish consumption advisory due to dioxin contamination. Dioxin concentrations, however, have been declining since 1994.

Alamac Fabrics, Liberty Fabrics, Weyerhaeuser, and Williamston's WWTP are required to perform toxicity test on their effluent. In the past, Liberty Fabrics has had the most problems, failing 42% of its tests. In 1999, none of these facilities failed a test.

Ambient water chemistry data have been collected from sites on the Roanoke River near Williamston, Plymouth, and Sans Souci. These data have shown no major water quality problems from these areas with the exception of elevated ammonia nitrogen (NH_3) concentrations at San Souci (median = 0.75 mg/l).

In 1996 and 1997, personnel from the Roanoke River National Wildlife Refuge monitored the Roanoke River and its tributaries from Indian Creek to Coniott Creek for dissolved oxygen and pH. DO concentrations less than 2.0 mg/l were documented in Coniott Creek as early as April and persisted until November 1996. Depressed dissolved oxygen was less of a problem in 1997, when low readings were recorded only in July. Black Gut Creek showed depressed readings from August to October 1996. At other locations there were sporadic low DO events, but none were longer than two weeks duration (Richter, 1998).

Table 33. Waterbodies monitored in Subbasin 09 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Stream	County	Location	1994	1999
B-1	Roanoke R	Martin	near NC 125 and NC 903	Good	Good-Fair
B-2	Roanoke R	Martin	US 17, below Williamston	Good-Fair	Good-Fair
B-4	Conoho Cr	Martin	NC 125/903	Not Rated	Not Rated
B-5	Conoho Cr	Martin	SR 1417	---	Not Rated
B-6	Hardison Mill Cr	Martin	NC 171	---	Not Rated
B-7	Hardison Mill Cr	Martin	SR 1528	---	Not Rated
B-8	Deep Run Swp	Martin	NC 171	---	Not Rated
B-9	Welch Cr	Martin	SR 1522	---	Not Rated
B-10[2]	Roanoke R	Bertie	NC 45	Not Rated	Not Rated

[1]B = benthic macroinvertebrate assessment monitoring sites.
[2]Data available prior to 1994, refer to Appendix B2.

River and Stream Assessment

Roanoke River, NC 125 and NC 903
The Roanoke River was sampled by boat downstream of the Town of Hamilton to assess the possible effects of the Alamac Knit Fabrics discharge (1.5 MGD) on the river. Flow velocity in the river at this location is less than that observed further upstream in subbasin 08. Based upon an EPT S of 19 and an NCBI of 5.20, a Good-Fair bioclassification was assigned to this location in 1999. In 1994, however, the site was rated Good. This change may be related to the low flows in 1999.

Roanoke River, US 17
The Roanoke River below Williamston had similar physical characteristics as the site below Hamilton, but slightly less flow velocity. The Williamston site was below a RCRA pesticide cleanup site, United Organics Corporation (variable amount of cooling water and boiler blow-down and permitted stormwater discharge), and the Town of Williamston's WWTP.

Samples collected in the spring and summer of 1999 were rated as Good-Fair with similar EPT S and NCBI scores in 1994 and 1999.

Conoho Creek, NC 125/903
Conoho Creek was a braided stream below the NC 125/903 bridge, approximately 35 m wide, and impounded by a beaver dam above the bridge. In 1999, habitat at this site was very good (draft score = 92). However, the EPT N (14) and EPT S (3) were low and the NCBI was slightly elevated (7.29). Summer sampling in 1994 also documented low taxa richness.

Conoho Creek, SR 1417
This site was approximately 12 miles downstream from the NC 125/903 site. Here, Conoho Creek was much larger, over 100 m wide at the bridge, but quickly braided into several channels, each up to 25 m wide. Macroinvertebrate diversity (39 Total S and 5 EPT S) was higher here than anywhere else in this subbasin. EPT abundance (50) was more than double any other tributary stream in this subbasin.

This site exhibited a benthic community characteristic of a naturally functioning swamp.

Several uncommon taxa were collected at this site:
- The caddisfly *Polycentropus*, which was abundant here, appears to be a new species;
- Two other caddisflies which were abundant, *Ceraclea* c.f. *cama* and *Platycentropus amicus*, appear to be range extensions; and
- Two relatively uncommon snails, *Planorbula armiger* and *Planorbella trivolvis*, were also collected here and at only one other site in the basin.

Hardison Mill Creek, NC 171
This site was 15 m wide, had a confined channel, and was more than 1 m deep in most locations. The water was clear, rather than tannin-stained, even though the pH (4.8) was the lowest recorded in the subbasin. The relatively open canopy (50% shaded) provided enough light to allow prolific growths of macrophytes and filamentous algae.

Total S (24), EPT S (2) and EPT N (11) were all lower here than at any other site in this subbasin, except at Deep Run. The NCBI at this site (7.70) was the highest of any Roanoke River swamp tributaries sampled. This also indicated a very stressed community.

Hardison Mill Creek, SR 1528
This site was approximately six miles downstream from site at NC 171 and the overall health of the stream seemed to have recovered slightly. The habitat was better here than upstream (draft scores = 94 and 79, respectively) and included a short reach with good flow during winter. The pH also was greater (5.5 s.u.) than at the upstream site.

Compared to the upstream site, the NCBI had declined 0.4 units, to 7.29. EPT S and EPT N were still low relative to other swamp streams in the lower Roanoke River basin.

Deep Run Swamp, NC 171
The catchment of this five meter wide stream was mostly devoted to agriculture. The stream had had been channelized in this area and a layer of silt smothered most of the potential habitat. Possibly because of the ditching, Deep Run flowed all summer. The stream was not sampled in the late summer because of the impacts from Hurricane Dennis.

Even without a summer sample, it was evident that Deep Run was a heavily impacted stream. There were fewer Total S (21) and EPT S (1) collected at this site than any other coastal plain stream sampled during winter. In addition, only one EPT N was collected. The NCBI was high which also suggested stress. Mayflies and stoneflies were not found in either Deep Run Swamp or Hardison Mill Creek – the only streams sampled where the two groups were not collected.

Welch Creek, SR 1522
This six meter wide stream had a confined channel and seemed, like upper Conoho Creek, to be suffering a moderate amount of stress. Welch Creek and upper Conoho Creek had similar draft habitat scores (87 and 92, respectively) and conductivities (84 and 97 µmhos/cm, respectively).

These streams also had comparable macroinvertebrate communities. There was less than 10% difference in corrected Total S, EPT S, corrected EPT N and NCBI between Welch Creek and Conoho Creek.

Roanoke River, NC 45
The Roanoke River at NC 45 near San Souci is a large and very slow moving river. On occasion, it has experienced temporary, oligohaline conditions. Not withstanding these oligohaline intrusions, this location still functions primarily as a freshwater system.

A between sampling period comparison of the macroinvertebrate data showed that the Total S and EPT S values have fluctuated somewhat, but still showed an increase since 1983 (Figure 50).

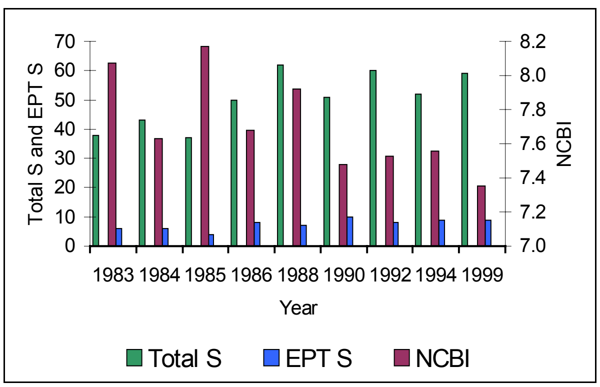

Figure 50. Total (Total S) and EPT (EPT S) taxa richness and biotic index (NCBI) for the Roanoke River, NC 45, Martin County.

The NCBI values have shown a general decrease since 1990. These metric values were comparable to other minimally impacted sites in the outer coastal plain. The greatest conductivity measurements were recorded in 1999. This suggested that a temporary oligohaline intrusion may have stressed the macroinvertebrate community.

A very rare crayfish species, *Orconectes* (*C.*) *virginiensis*, has been collected on five occasions at this site. This species appears to be confined to the lower Roanoke River basin and a few locations to the north of the site.

SPECIAL STUDIES
Swamp Biocriteria Validation
Benthic macroinvertebrates were collected at Indian Creek (SR 1105, Bertie County) in 1997 to validate biocriteria for swamps. It was determined that pH and stream channel type play a major factor in determining the benthic community. This stream had symptoms of severe organic enrichment.

Fish Tissue

Roanoke River, NC 17
Thirty-two samples were collected from the Roanoke River near Williamston in 1995 (n = 8) and 1999 (n = 24). The eight bowfin samples collected during 1995 contained mercury concentrations greater than the federal and state screening values. In 1999, mercury concentrations greater than the federal and state screening criteria were detected in 15 of the 24 samples composed of largemouth bass, bowfin, and white catfish. All other metals concentrations in 1995 and 1999 were less than the screening criteria (Appendix FT2).

Roanoke River, NC 45
Twenty-nine samples were collected from the Roanoke River at Plymouth during 1995 and 1999. Four of the seven bowfin samples collected during 1995 contained mercury concentrations greater than the federal and state screening criteria.

During July 1999, 22 samples (of multiple species) were collected. Three largemouth bass and one chain pickerel had mercury concentrations exceeding the US EPA screening value of 0.6 µg/g. All other analyses were less than federal and state screening criteria (Appendix FT2).

Dioxin Monitoring
From Williamston to its mouth at the Albemarle Sound, the Roanoke River remained under a fish consumption advisory for all species except herring and shad (blueback herring, American shad, hickory shad, and gizzard shad) due to dioxin contamination. Annual monitoring by Weyerhaeuser personnel indicated that dioxin concentrations in fish tissue were gradually decreasing since the mill initiated dioxin reduction and management programs in the early 1990s (Weyerhaeuser 1999.)

Dioxin toxicity equivalents (TEQ – the sum of 2,3,7,8 TCDD and 2,3,7,8 TCDF congeners) have been less than the North Carolina criteria of 3.0 pg/g in samples collected near Williamston since 1994 (Figure 57).

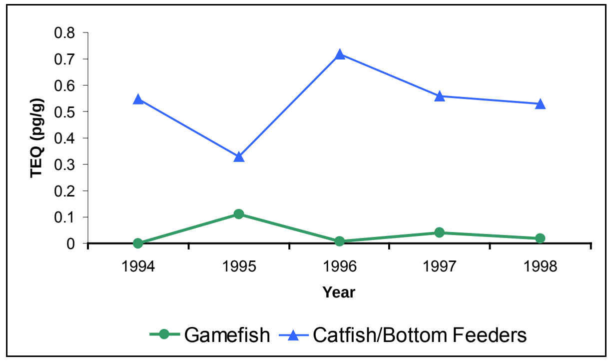

Figure 51. **Average toxicity equivalents (TEQ, pg/g) from the Roanoke River at Williamston, 1994 - 1998.**

Dioxin TEQ levels near or above the North Carolina criteria continued to be detected in catfish and bottom feeding species from the river at Marker 15 (near the mouth and below the mill discharge) (Figure 52).

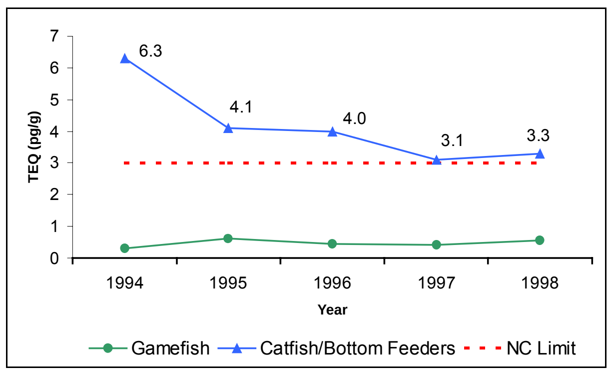

Figure 52. **Average toxicity equivalents (TEQ, pg/g) from the Roanoke River at Marker 15, 1994 - 1998.**

ROANOKE RIVER SUBBASIN 10

Description

This subbasin is located entirely within the coastal plain ecoregion and consists of the Cashie River and its tributaries (Figure 53). Most of these streams stop flowing in the summer, making water quality assessments more difficult. Land use in the area is primarily forest with a mix of agricultural activities. Windsor is the largest town in this subbasin. Of the four dischargers in the subbasin, only the Town of Windsor's WWTP (1.15 MGD), which discharges into a UT to Cashie River, is considered a major discharger.

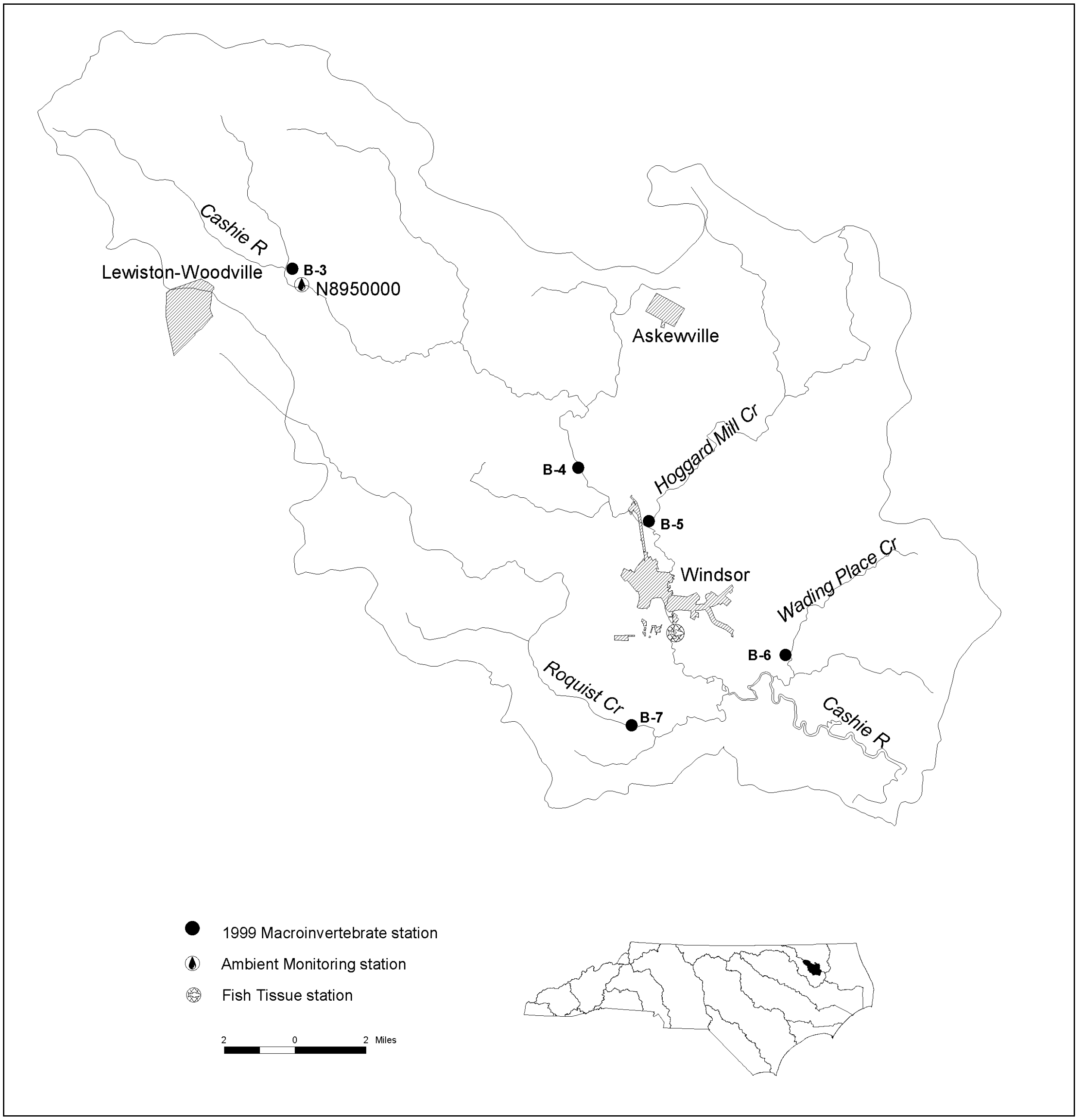

Figure 53. Sampling sites in Subbasin 10 in the Roanoke River basin.

Overview of water quality

No sites in this subbasin were sampled for benthic macroinvertebrates during both the 1994 and 1999 basin assessment periods. The assignment of bioclassifications based on macroinvertebrate data to streams in this subbasin is difficult due to the swampy characteristics of the streams and stagnant water conditions common in this area. Swamp sampling methods for benthos were used but these streams were not given a bioclassification (Table 34). These streams can not be compared to other streams in the lower Roanoke River basin.

These evaluations showed the lower Cashie River and Hoggard Mill Creek sites with few deviations from natural conditions. The upper Cashie River, Roquist Swamp, and Wading Place Creek sites showed some evidence of stress. These streams also supported several rare species of invertebrates.

Thirteen of 24 fish tissue samples, mostly from largemouth bass and bowfin, collected in 1999, contained mercury concentrations greater than the US EPA or FDA criteria (0.6 and 1.0 µg/g, respectively).

Ambient monitoring data was collected from the Cashie River near Lewiston. Low dissolved oxygen concentrations occurred frequently; the median concentration was approximately 3 mg/l over the past five years. Fecal coliform bacteria were also greater at this site than at any other site in the coastal plain. Nearly 25% of all observations were greater than the water quality standard of 200 colonies/100ml. Total Kjeldahl nitrogen and total phosphorus were also elevated compared to other coastal plain stations.

The Town of Windsor's WWTP is the only facility in this subbasin to perform toxicity tests. Through the year 2000, this facility has failed its toxicity tests 36% of the time (19 of 53 tests).

Table 34. Waterbodies monitored in Subbasin 10 in the Roanoke River basin for basinwide assessment, 1994 - 1999.

Map #[1]	Stream	County	Location	1994	1999
B-3	Cashie R	Bertie	SR 1219	----	Not Rated
B-4	Cashie R	Bertie	SR 1257	----	Not Rated
B-5	Hoggard Mill Cr	Bertie	SR 1301	----	Not Rated
B-6	Wading Place Cr	Bertie	NC 308	----	Not Rated
B-7	Roquist Swp	Bertie	US 13/17	----	Not Rated

[1]B = benthic macroinvertebrate assessment monitoring sites.

River and Stream Assessment

Cashie River, SR 1219
This upper portion of the Cashie River had a braided channel and was 20 m wide. The substrate was largely muddy sand. While the Total S was relatively high (41), EPT N (10) and the NCBI (7.48) , however, indicated some water quality problems.

Although this site was below the Lewiston/Woodville WWTP, taxa indicative of organic loading were not abundant. This suggested that the WWTP was not degrading the stream.

Cashie River, SR 1257
The river here is narrower (15 m) and deeper (one meter) than the upstream site at SR 1219. The NCBI was slightly lower (6.79) and the abundance of intolerant taxa was greater than at the upstream site. This was the only site in the subbasin where two stoneflies, *Taeniopteryx* and *Isoperla transmarina* group, were abundant. This suggested generally good water quality. Even though these two intolerant taxa were abundant, the dissolved oxygen concentrations were consistently depressed at this site. The median concentration over the last five years was 3.1 mg/l.

Hoggard Mill Creek, SR 1301
This 35 m wide stream had some of the best water quality in the subbasin despite siltation from the catchment filling in the stream's pools. The NCBI was low (6.75) and in addition, more Total S (46), EPT S (7), and unusual taxa (7) were collected at this site than anywhere else in this subbasin.

Unusual taxa collected here included the stonefly *Amphinemura*, the caddisfly *Ceraclea* c.f. *cama*, and the damselfly *Nehalennia irene*.

Wading Place Creek, NC 308
This small (6 m wide), silty stream was at least 1 m deep in most locations when it was sampled in March. EPT S (3) and EPT N (7) were low and NCBI (7.36) was elevated compared to other sites in this subbasin. It was not clear what could be the source of stress, considering that a large amount of the watershed was forested.

Roquist Swamp, US 13/17
This site was 50 m wide and 1 m deep below the bridge when it was sampled in March. Upstream, however, Roquist Swamp consisted of small, braided channels. The benthic community also presented conflicting biological and physical characteristics:

- Total S (31) and EPT S (4) were low compared to other sites in the subbasin;
- EPT N (31) and NCBI (6.98) were intermediate; and
- pH was high (6.2) considering that this stream primarily drains the Roquist Pocosin.

Two unusual species, the mayfly *Leptophlebia bradleyi*, and the caddisfly *Platycentropus* were abundant at this site.

Fish Tissue

Cashie River
In 1999. 24 samples, representing largemouth bass, bowfin, black crappie, sunfishes, and catfishes, were collected from the Cashie River at Windsor and analyzed for metals contaminants. Thirteen samples (of mainly largemouth bass and bowfin) contained mercury concentrations exceeding the US EPA or FDA and State of North Carolina screening values of 0.6 µg/g and 1.0 µg/g, respectively. All other metal contaminant concentrations were less than the federal or state criteria (Appendix FT2).

AMBIENT MONITORING SYSTEM

The Division collects ambient water quality information from approximately 421 active monitoring stations statewide. In the Roanoke River basin there are 21 stations (Figure 54 and Table 35).

The Roanoke River drains an area of approximately 9,666 mi^2 in Virginia and North Carolina. Traditionally, this basin is divided into two sections. The upper section is located above Roanoke Rapids Reservoir and includes Lake Gaston, Kerr Reservoir and the Dan River drainage (Subbasins 01-07). The lower basin (Subbasins 08-10) constitutes the remaining free flowing segment between the Roanoke Rapids Reservoir and the Albemarle Sound.

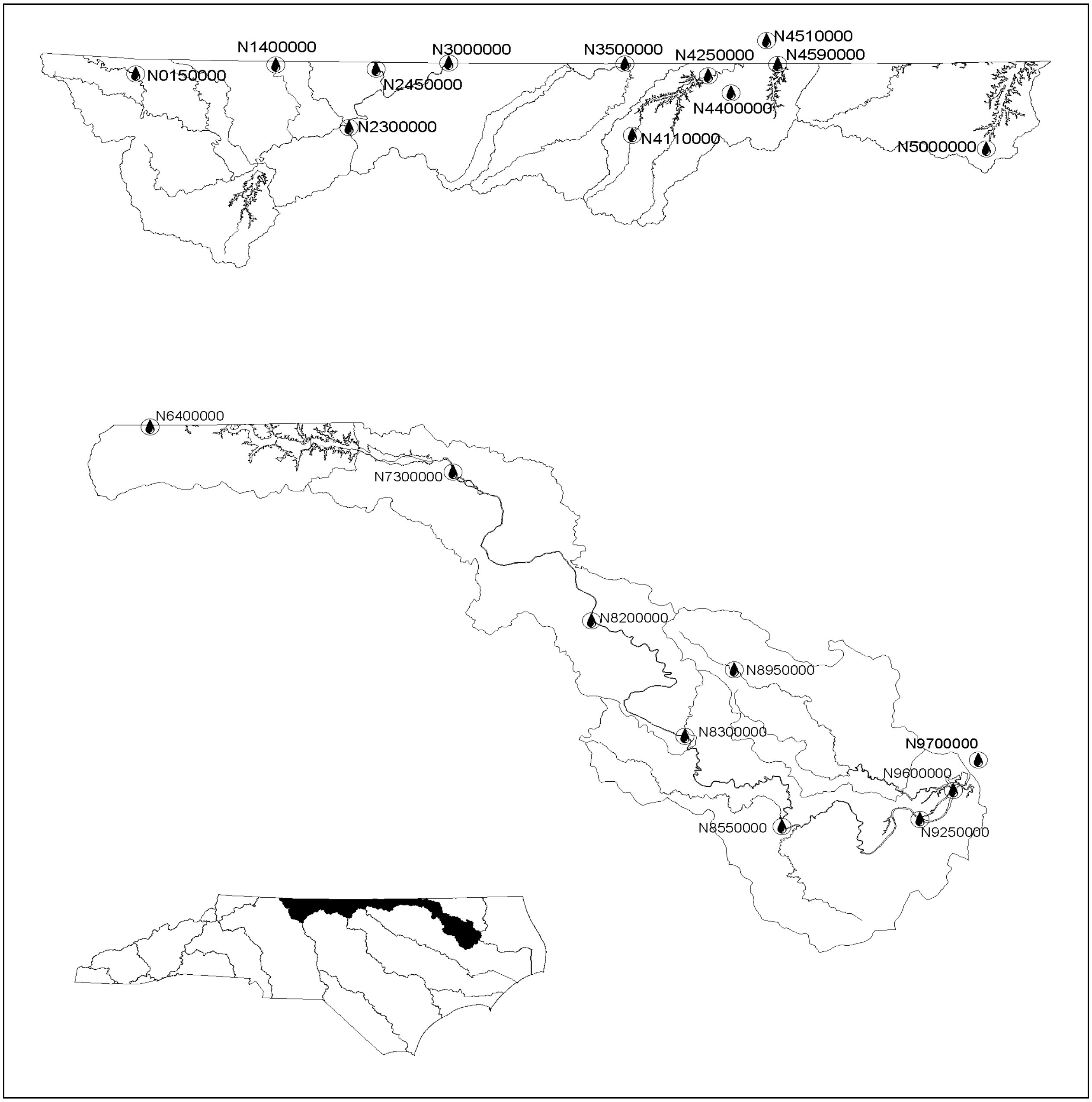

Figure 54. Ambient monitoring stations in the Roanoke River basin.

Table 35. Ambient monitoring system stations within the Roanoke River basin.

Subbasin/ Station code	Station	County	Class
01			
N0150000	Dan R at NC Hwy 704, near Francisco	Stokes	C Tr
02			
N1400000	Mayo R at SR 1358, near Price	Rockingham	WS-IV
03			
N2300000	Dan R at SR 2150, near Wentworth	Rockingham	WS-IV
N2450000	Smith R at NC Hwy 14, at Eden	Rockingham	WS-IV
N3000000	Dan R at SR 1716, near Mayfield	Rockingham	C
04			
N3500000	Dan R at NC Hwy 62 at NC-VA state line at Milton	Caswell	C
05			
N4110000	Hyco Cr at US Hwy 158, near Leasburg	Caswell	C
N4250000	Hyco R below afterbay dam, near Mcghees Mill	Person	C
N4400000	Marlowe Cr at SR 1322, near Woodsdale	Person	C
N4510000	Hyco R at US Hwy 501, near Denniston, VA	Halifax	III NT[1]
N4590000	Mayo Cr at SR 1501, near Bethel Hill	Person	C
06			
N5000000	Nutbush Cr at SR 1317, near Henderson	Vance	C
07			
N6400000	Smith Cr at US 1, near Paschall	Warren	C
08			
N7300000	Roanoke R at Roanoke Rapids	Halifax	C
N8200000	Roanoke R near Scotland Neck	Halifax	C
N8300000	Roanoke R at NC Hwy 11 Near Lewiston	Martin	C
09			
N8550000	Roanoke R at US Hwys 13 & 17 at Williamston	Martin	C
N9250000	Roanoke R 1.3 mi. upstream of Welch Cr near Plymouth	Martin	C Sw
N9600000	Roanoke R at Sans Souci	Bertie	C Sw
N9700000	Albemarle Sound (Batchelor Bay) near Black Walnut	Bertie	B Sw
10			
N8950000	Cashie R at SR 1219, near Lewiston	Bertie	C Sw

[1]Station N4510000 is located in Virginia

Box and whisker plots were used to depict differences in the concentrations of values for various parameters among stations (Figures 55-65). Overall, no temporal patterns were noted except for Nutbush Creek.

Fecal Coliform Bacteria

A summary of fecal coliform bacteria is provided (Table 36). This table provides the number of samples collected, the number and proportion of samples greater than 200 and 400 colonies/100ml and the geometric means for each station and for three time periods. These periods represent:

- the current basin assessment period (09/01/1994 to 08/31/1999);
- the five year period (09/01/1989 to 08/31/1994), and
- all data collected prior to 09/01/1989.

The only station that had a geometric mean greater than 200 colonies/100ml for the current basin assessment cycle was located at Marlowe Creek downstream of the Roxboro WWTP. High concentrations have been observed at the Dan River monitoring site at Wentworth, downstream of Madison and Mayodan and concentrations at Wentworth have been high for all three time periods.

Many stations show no appreciable temporal change among the three time periods. Concentrations have increased at stations located at Hyco Creek. and Marlowe Creek. Substantial decreases were observed at Nutbush Creek, Smith Creek, and the Roanoke R. at Scotland Neck.

Table 36. Summary of fecal coliform bacteria collections from the Roanoke River, 1968 - 1999[1].

Station	Sample dates			Number greater than		Percent greater than		Geometric
	First	Last	N	200	400	200	400	Mean
Dan R. - Francisco	03/31/1981	08/08/1989	68	22	11	32.4	16.2	129.3
	09/19/1989	08/17/1994	11	4	4	36.4	36.4	175.0
	09/21/1994	**08/25/1999**	**53**	**12**	**6**	**22.6**	**11.3**	**64.7**
Mayo R.	06/18/1968	08/08/1989	22	6	1	27.3	4.5	92.9
	09/19/1989	08/17/1994	11	4	3	36.4	27.3	119.4
	09/21/1994	**08/25/1999**	**55**	**18**	**8**	**32.7**	**14.5**	**106.5**
Dan R. - Wentworth	06/18/1968	08/08/1989	75	41	29	54.7	38.7	215.1
	09/19/1989	08/17/1994	10	4	4	40.0	40.0	238.5
	09/21/1994	**08/25/1999**	**55**	**24**	**16**	**43.6**	**29.1**	**187.7**
Smith R.	02/11/1981	08/09/1989	67	14	9	20.9	13.4	66.3
	09/20/1989	08/29/1994	11	2	2	18.2	18.2	76.6
	09/29/1994	**08/30/1999**	**52**	**12**	**6**	**23.1**	**11.5**	**84.4**
Dan R. - Mayfield	11/20/1968	08/09/1989	138	76	51	55.1	37.0	263.2
	09/20/1989	08/29/1994	11	4	2	36.4	18.2	84.9
	09/27/1994	**08/30/1999**	**54**	**18**	**12**	**33.3**	**22.2**	**92.4**
Dan R. - Milton	11/18/1968	08/9/1989	122	46	36	37.7	29.5	156.0
	09/20/1989	08/29/1994	10	2	2	20.0	20.0	82.4
	09/27/1994	**08/30/1999**	**51**	**18**	**12**	**35.3**	**23.5**	**117.5**
Hyco Cr.	01/02/1985	07/20/1989	21	2	2	9.5	9.5	34.3
	10/17/1989	08/29/1994	11	1	1	9.1	9.1	69.0
	09/27/1994	**08/30/1999**	**52**	**18**	**11**	**34.6**	**21.2**	**112.7**
Hyco R. – McGhees Mill	01/08/1981	08/10/1989	63	0	0	0.0	0.0	11.8
	09/19/1989	08/22/1994	11	0	0	0.0	0.0	10.0
	09/26/1994	**08/23/1999**	**45**	**1**	**1**	**2.2**	**2.2**	**19.5**
Marlowe Cr.	11/18/1968	08/10/1989	139	51	30	36.7	21.6	113.1
	11/16/1989	08/22/1994	10	4	3	40.0	30.0	145.4
	09/26/1994	**08/23/1999**	**58**	**34**	**17**	**58.6**	**29.3**	**206.8**
Hyco R. - Denniston	01/30/1985	08/10/1989	17	6	2	35.3	11.8	101.3
	09/19/1989	08/22/1994	11	2	1	18.2	9.1	81.7
	09/26/1994	**08/23/1999**	**58**	**15**	**11**	**25.9**	**19.0**	**110.1**
Mayo Cr.	01/30/1985	08/10/1989	17	0	0	0.0	0.0	13.9
	11/16/1989	08/22/1994	11	0	0	0.0	0.0	11.8
	09/26/1994	**08/23/1999**	**59**	**1**	**0**	**1.7**	**0.0**	**14.0**
Nutbush Cr.	11/25/1968	08/09/1989	165	88	81	53.3	49.1	437.3
	09/25/1989	08/29/1994	11	4	1	36.4	9.1	81.3
	09/29/1994	**08/10/1999**	**58**	**15**	**8**	**25.9**	**13.8**	**108.5**
Smith Cr.	01/02/1973	08/09/1989	142	59	37	41.5	26.1	146.5
	11/21/1989	08/29/1994	11	0	0	0.0	0.0	19.3
	09/29/1994	**08/10/1999**	**57**	**6**	**5**	**10.5**	**8.8**	**54.2**
Roanoke R. - R. Rapids	11/25/1968	08/30/1989	117	31	24	26.5	20.5	62.5
	09/27/1989	08/24/1994	10	0	0	0.0	0.0	12.0
	09/21/1994	**08/30/1999**	**58**	**0**	**0**	**0.0**	**0.0**	**21.4**
Roanoke R. - Scotland N.	11/26/1968	08/30/1989	172	84	51	48.8	29.7	203.3
	09/27/1989	08/24/1994	10	1	1	10.0	10.0	62.8
	09/21/1994	**08/30/1999**	**59**	**7**	**2**	**11.9**	**3.4**	**38.7**
Roanoke R. - Lewiston	12/04/1973	08/16/1989	147	36	18	24.5	12.2	87.4
	09/05/1989	08/29/1994	54	6	3	11.1	5.6	30.8
	09/21/1994	**08/24/1999**	**21**	**3**	**2**	**14.3**	**9.5**	**30.7**

Table 36 (continued).

Station	Sample dates First	Last	N	Number greater than 200	400	Percent greater than 200	400	Geometric Mean
Roanoke R. - US 13/17	06/15/1982	08/16/1989	49	3	2	6.1	4.1	42.5
	09/05/1989	08/29/1994	11	0	0	0.0	0.0	18.6
	09/21/1994	**08/24/1999**	**25**	**2**	**1**	**8.0**	**4.0**	**29.9**
Cashie R.	01/29/1985	08/16/1989	33	10	7	30.3	21.2	83.6
	09/5/1989	08/29/1994	26	2	1	7.7	3.8	36.7
	09/21/1994	**08/24/1999**	**23**	**5**	**2**	**21.7**	**8.7**	**78.8**
Roanoke R. - Plymouth	04/20/1982	08/29/1989	42	1	1	2.4	2.4	24.5
	09/27/1989	08/18/1994	9	0	0	0.0	0.0	13.2
	09/27/1994	**08/10/1999**	**23**	**1**	**1**	**4.3**	**4.3**	**21.1**
Roanoke R. - Sans Souci	11/27/1968	08/29/1989	114	11	4	9.6	3.5	32.9
	09/27/1989	08/18/1994	11	0	0	0.0	0.0	16.9
	09/27/1994	**08/10/1999**	**23**	**0**	**0**	**0.0**	**0.0**	**19.0**
Albemarle Sound	01/31/1974	08/29/1989	106	0	0	0.0	0.0	13.4
	09/29/1989	08/18/1994	39	0	0	0.0	0.0	11.2
	09/27/1994	**08/10/1999**	**24**	**0**	**0**	**0.0**	**0.0**	**12.3**

[1]Row in bold face represents the summary for the current basin assessment period (09/01/1994 to 08/31/1999).
N = number of samples.

The Dan River Subbasins

Data were collected from four mainstem stations along the Dan River and nine tributary stations (Tables 37 - 49 and Figures 54 and 56 - 65). Overall, few differences occurred among most parameters and stations. However, a few noteworthy deviations existed:

- Elevated conductivity could be seen at Marlowe Creek and Nutbush Creek (Figure 56) which might have reflected the input from upstream treatment plants.

- Dissolved oxygen was low at Smith Creek near Paschall with over 25% of 58 measurements being less than 5.0 mg/l (Figure 57 and Table 42). Most of depressed concentrations occurred during the summer when the water temperature was greater than 20^{o} C. The monitoring site is located near a sluggish portion of the stream which might have influenced these concentrations.

- Many mainstem and tributary stations had elevated total suspended solid concentrations and some turbidity samples exceeded the water quality standards (10 NTU for trout waters and 50 NTU for other lotic stations) (Tables 37 - 49 and Figures 60 and 61).

  Maximum values ranged between 90 and 210 NTU for the mainstem stations and between 19 and 1000 NTU for the tributaries. High turbidity was often associated with high flows resulting from rain. Turbidity exceeded the standard in more than 10% of samples collected from the mainstem sites at Wentworth and at Milton (Tables 39 and 42). Turbidity exceeded the standard most often (35% of the samples) at the Dan River site near Francisco. The river at this station is classified as trout waters and has a turbidity standard of 10 NTU.

- No temporal patterns were noted for nutrients except for Nutbush Creek (cf. Nutbush Creek Water Quality). The median concentration for ammonia nitrogen at Milton was slightly greater than the other stations on the Dan River and also has the greatest variation (Figure 62). The monitoring station at Milton is located downstream of Danville, VA and concentrations might have reflected upstream WWTP discharges from Virginia.

  The highest median nitrite + nitrate concentrations were found at Marlowe Creek and Nutbush Creek (2.4 and 9.8 mg/l respectively) (Figure 64; Tables 45 and 47). Elsewhere, median concentrations were less than 0.25 mg/l. In addition, these two stations had the highest concentrations of total phosphorus (Figure 65; Tables 45 and 47). These patterns may be attributed to upstream WWTP discharges.

- Copper and iron concentrations often exceeded their action levels. Iron is a common element in clay soils. Therefore, elevated iron concentra-tions may reflect the geochemistry of the watershed.

  Copper exceeded its action level of 7 µg/l in more that 10% of the samples from all stations in the Dan River watershed, except Smith Creek. Although the maximum concentrations ranged from 10 to 52 µg/l, concentrations less than 7 µg/l typically occurred in about 75% of the samples (Tables 37 - 49).

  An exception to this pattern was found at Marlowe Creek which is downstream of the Town of Roxboro's WWTP. Here, copper exceeded 7 µg/l in more than 75% of the samples (N = 57). The maximum detected concentration was 52 µg/l (Table 45).

  The ecological affects of high concentrations of metals cannot be discerned unless appropriate toxicity tests are performed or other translators are considered (e.g. dissolved organic carbon).

Nutbush Creek Water Quality
Water quality at Nutbush Creek has improved considerably since the early 1980's (Figures 66 - 68). Before 1983, many dissolved oxygen concentrations were less than 5.0 mg/l. Since 1983, there have been no recorded concentrations less than 5.0 mg/l (Figure 66).

Additional decreases can be observed for fecal coliform bacteria, turbidity, ammonia nitrogen, total Kjeldahl nitrogen, and total phosphorus (Figures 67 and 68). Nitrite+nitrate nitrogen has increased as a result of nitrifying ammonia and TKN (Figure 68). These improvements in water quality can be attributed to the elimination of a discharge in 1983 and to improvements at the Henderson WWTP beginning in 1988.

The Roanoke River Subbasins
There are six monitoring stations on the Roanoke River mainstem and one station at mouth of the Roanoke in Bachelor Bay (Figure 54). There is also one monitoring station on the Cashie River. The three most downstream mainstem stations (near Plymouth, at Sans Souci, and in the Albemarle Sound) and the site on the Cashie River are all classified as swamp waters. Dissolved oxygen concentrations and pH can be less than 5.0 mg/l and 6.0 s.u., respectively, if the values are due to natural conditions. Higher conductivity at the monitoring station near Sans Souci results from the salt water influence in Albemarle Sound.

- Dissolved Oxygen: Low dissolved oxygen (DO) concentrations were observed primarily in the Cashie River with 63% of 33 samples less than 5.0 mg/l (Table 57 and Figure 55). [Note: the instantaneous standard for dissolved oxygen (5.0 mg/l) does not apply when concentrations are due to natural conditions.]

- A similar pattern existed for pH with 42% of 33 samples less than 6.0 s.u. There were no measurements less than 4.3. s.u. The lowest value was 5.2 s.u.

- Nutrients: The Cashie River site had the highest median concentrations for total Kjeldahl nitrogen (0.5 mg/l) and total phosphorus (0.18 mg/l) and the lowest nitrite + nitrate nitrogen concentration (0.02 mg/) among the lower Roanoke River stations (Figures 62-65). Riparian areas along the Cashie River are swampy and thus, may affect nutrient concentrations. Low nitrite+nitrate concentrations may be the result of denitrification, a process common in wetland ecosystems. However, a special study would be needed to confirm this hypothesis.

- Like the Dan River watershed, iron and copper concentrations in the lower basin often exceed their action levels. Iron is a common element in soils, thus elevated concentrations of iron may only reflect the geochemistry of the basin. Copper exceeded the action level (7 µg/l) in more than 10% of the samples from the Roanoke River at Roanoke Rapids (10.2%), at Lewiston (12.1%), and near Plymouth (14.7%). Cadmium and nickel exceeded their standards for 2.9% of 34 samples collected near Plymouth. No other metals exceeded their reference levels.

Dissolved Oxygen Concentrations in the Lower Roanoke River
Dissolved oxygen concentrations in the mainstem of the lower Roanoke River were one of the most important water quality issues addressed during this basinwide assessment period. The significance of this issue was the result of a fish kill during summer 1995 after an abrupt decrease (from 18,000 cfs to less than 3,000 cfs) in the discharge from the upstream impoundments. This drop occurred within one day and allowed water

with low dissolved oxygen concentrations to drain from riparian wetlands along the lower Roanoke River into the mainstem portion of the river. This large volume of anoxic water mixed with the water in the mainstem portion of the river and caused a dramatic reduction in dissolved oxygen, resulting in a large fish kill and mortality of other aquatic life.

Following this event, a plan was developed to minimize the negative impacts of swamp water with low dissolved oxygen during the transition from flood control by the upstream reservoirs. The plan, known as the "Betterment Plan" extends the period in which flow is decreased from the Roanoke Rapids Dam. This results in a decrease in the rate in which water drains from the riparian wetlands downstream back into the Roanoke River.

A study conducted by Weyerhaeuser characterized dissolved oxygen and bio-chemical oxygen demand concentrations along the Roanoke River at different release rates from the Roanoke Rapids Dam during the transition from flood control to power generation after Hurricane Fran in September and October 1996 (Fromm and Lebo 1997).

The authors concluded: "*The modified flow schedule implemented prevented hypoxic DO concentrations along the lower Roanoke River during the transition from flood to low flow conditions*." The authors also noted that their study was not conducted during worse case (summer) conditions, and suggested modifications in the step down discharge procedure.

Table 37. Summary of water quality parameters collected from the Dan River, near Francisco (Station N0150000; Class C Tr) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	50	.	.	.	.	4	24	8	9	13	20	23
Conductivity	50	.	.	.	.	4	62	36	40	46	50	52
Dissolved Oxygen	50	.	6	0	.	8.2	12.8	8.8	9.4	10.5	11.8	12.3
pH (s.u.)	48	.	<6;>9	2	4.2	5.5	7.6	6.1	6.5	6.9	7.1	7.4
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	54	5	.	.	.	1	170	1	3	8	16	23
Hardness	54	0	.	0	.	10	64	14	16	19	26	38
Chloride	0	0	230	0	.	.	.	.	.	.	.	.
Turbidity (NTU)	54	0	10	19	35.2	1.4	90.0	1.9	2.8	6.9	13.0	23.1
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	53	12	200	12	22.6	10	2800	10	16	59	155	558
Nutrients												
NH_3 as N	53	15	.	.	.	0.01	0.22	0.01	0.01	0.03	0.05	0.09
TKN as N	53	2	.	.	.	0.1	0.5	0.1	0.1	0.1	0.2	0.3
NO_2+NO_3 as N	53	0	.	.	.	0.09	0.62	0.18	0.31	0.39	0.46	0.51
Total Phosphorus	53	7	.	.	.	0.01	0.24	0.01	0.01	0.03	0.04	0.06
Metals (total)												
Arsenic	53	53	50	0	.	10	10	10	10	10	10	10
Cadmium	53	53	0.4	N/A	.	2	2	2	2	2	2	2
Chromium	53	53	50	0	.	25	25	25	25	25	25	25
Copper	53	19	7	9	17.0	2	33	2.0	2.0	2.7	5.0	11.0
Iron	53	0	1000	13	24.5	88	8900	168	280	540	995	1720
Lead	53	53	25	0	.	10	10	10	10	10	10	10
Manganese	2	2	.	.		10	10	.	10	10	10	.
Nickel	53	53	88	.	.	10	10	10	10	10	10	10
Aluminum	53	1	.	.		50	8000	72	160	330	863	1300
Mercury	53	52	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 38. Summary of water quality parameters collected from the Mayo River, near Price (Station N1400000; Class WS-IV) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	53	.	.	.		1	26	7	10	13	21	24
Conductivity	53	.	.	.	.	31	59	34	41	49	51	56
Dissolved Oxygen	52	.	5	0	.	8.4	13.3	8.9	9.3	10.4	11.6	12.0
pH (s.u.)	50	.	<6;>9	1	2.0	5.9	8.0	6.7	7.0	7.3	7.5	7.7
Other												
Total Residue	54	0	500	1	1.9	37	860	46	53	65	87	131
Total Sus. Solids	56	3	.	.	.	1	640	2	4	8	19	68
Hardness	56	0	100	0	.	14	58	17	20	22	28	42
Chloride	53	0	230	0	.	1	4	2	2	2	3	4
Turbidity (NTU)	55	0	50	6	10.9	2.2	240.0	3.1	4.9	8.9	15.0	60.0
Bacteria												
Total coliform	55	0	50	53	96.4	27	35000	130	253	530	2000	9200
Fecal coliform	55	5	200	18	32.7	10	5800	10	30	91	293	2100
Nutrients												
NH_3 as N	55	15	.	.	.	0.01	0.15	0.01	0.01	0.03	0.05	0.08
TKN as N	55	1	.	.	.	0.1	0.4	0.1	0.1	0.2	0.2	0.2
NO_2+NO_3 as N	55	0	10	0	.	0.01	0.40	0.05	0.14	0.19	0.24	0.28
Total Phosphorus	55	6	.	.	.	0.01	0.55	0.01	0.02	0.03	0.05	0.12
Metals (total)												
Arsenic	54	54	50	0	.	10	10	10	10	10	10	10
Cadmium	54	53	2	0	.	2	2	2	2	2	2	2
Chromium	54	53	50	0	.	25	29	25	25	25	25	25
Copper	54	11	7	11	20.4	2	26	2.0	3.0	4.0	6.0	11.0
Iron	54	1	1000	19	35.2	10	14000	309	410	725	1400	3430
Lead	54	53	25	0	.	10	14	10	10	10	10	10
Manganese	53	1	200	2	3.8	10	300	12	17	28	44	85
Nickel	54	53	25	0	.	10	16	10	10	10	10	10
Aluminum	54	1	.	.		50	9800	88	170	440	810	3040
Mercury	54	54	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 39. Summary of water quality parameters collected from the Dan River, near Wentworth (Station N230000; Class WS-IV) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	53	.	.	.	.	2	29	8	10	14	22	26
Conductivity	53	.	.	.	.	37	119	47	51	57	62	65
Dissolved Oxygen	52	.	5	0	.	6.9	13.6	7.7	8.4	9.8	11.3	11.9
pH (s.u.)	50	.	<6;>9	0	.	6.3	8.0	6.8	7.0	7.1	7.3	7.6
Other												
Total Residue	52	0	500	0	.	43	290	56	65	78	120	193
Total Sus. Solids	55	3	.	.	.	1	180	2	6	13	39	80
Hardness	55	0	100	0	.	12	72	18	20	24	28	40
Chloride	53	0	230	0	.	2	6	2	3	3	4	4
Turbidity (NTU)	55	0	50	10	18.2	2.6	200.0	4.5	5.8	12.0	26.8	100.0
Bacteria												
Total coliform	55	0	50	54	98.2	10	53000	300	450	710	4775	11000
Fecal coliform	55	3	200	24	43.6	10	7500	27	80	160	500	2000
Nutrients												
NH_3 as N	55	11	.	.	.	0.01	0.23	0.01	0.02	0.04	0.06	0.10
TKN as N	55	1	.	.	.	0.1	6.1	0.1	0.2	0.2	0.3	0.4
NO_2+NO_3 as N	55	1	10	0	.	0.01	0.37	0.04	0.14	0.25	0.28	0.31
Total Phosphorus	55	7	.	.	.	0.01	0.30	0.01	0.02	0.04	0.07	0.18
Metals (total)												
Arsenic	53	53	50	0	.	10	10	10	10	10	10	10
Cadmium	54	54	2	0	.	0.2	2	2	2	2	2	2
Chromium	54	54	50	0	.	25	25	25	25	25	25	25
Copper	54	12	7	8	14.8	2	17	2.0	2.1	4.0	6.3	7.9
Iron	53	0	1000	24	45.3	280	14000	396	590	940	1950	3720
Lead	54	54	25	0	.	10	10	10	10	10	10	10
Manganese	53	0	.	.		14	160	21	28	40	66	110
Nickel	54	54	25	0	.	10	10	10	10	10	10	10
Aluminum	54	0	.	.		50	21000	149	270	675	1700	4410
Mercury	53	52	0.012	0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 40. Summary of water quality parameters collected from the Smith River at Eden (Station N2450000; Class WS-IV) during the period 09/01/1994 to 08/31/1999.

								Percentiles				
Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	10	25	50	75	90
Field												
Temperature (^oC)	50	.	.	.	.	4	27	7	8	15	22	24
Conductivity	50	.	.	.	.	49	427	96	126	183	248	295
Dissolved Oxygen	50	.	5	0	.	6.8	13.6	8.0	9.1	10.4	11.5	12.2
pH (s.u.)	47	.	<6;>9	0	.	6.1	8.0	6.5	6.9	7.1	7.3	7.5
Other												
Total Residue	52	0	500	1	1.9	78	770	93	110	140	180	223
Total Sus. Solids	53	4	.	.	.	1	630	1	2	6	20	32
Hardness	40	0	100	0	.	1	56	23	24	30	32	39
Chloride	53	0	230	0	.	6	98	10	13	28	48	64
Turbidity (NTU)	53	0	50	2	3.8	1.8	250.0	2.9	3.5	5.5	12.0	17.2
Bacteria												
Total coliform	52	0	50	50	96.2	32	36000	96	225	480	1850	4790
Fecal coliform	52	5	200	12	23.1	9	4000	10	39	82	200	473
Nutrients												
NH_3 as N	53	17	.	.	.	0.01	0.24	0.01	0.01	0.03	0.06	0.08
TKN as N	53	0	.	.	.	0.1	0.6	0.1	0.1	0.2	0.3	0.4
NO_2+NO_3 as N	53	0	10	0	.	0.06	0.48	0.14	0.18	0.22	0.30	0.36
Total Phosphorus	53	1	.	.	.	0.01	0.86	0.05	0.07	0.10	0.13	0.21
Metals (total)												
Arsenic	52	52	50	0	.	10	40	10	10	10	10	10
Cadmium	52	52	2	0	.	2	8	2	2	2	2	2
Chromium	52	51	50	0	.	25	100	25	25	25	25	25
Copper	52	6	7	10	19.2	2	27	2.0	2.6	4.0	6.5	9.2
Iron	43	0	1000	9	20.9	180	17000	286	350	540	1000	1920
Lead	52	51	25	0	.	10	40	10	10	10	10	10
Manganese	52	1	200	2		10	720	22	29	37	66	103
Nickel	52	51	25	0	.	10	40	10	10	10	10	10
Aluminum	43	1	.	.		50	9200	72	133	230	628	1100
Mercury	52	52	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = μmhos/cm; bacteria = no. colonies/100 ml; metals = μg/l; all others = mg/l.

Table 41. **Summary of water quality parameters collected from the Dan River, near Mayfield (Station N3000000; Class C) during the period 09/01/1994 to 08/31/1999.**

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^oC)	52	.	.	.	.	2	29	6	8	15	23	28
Conductivity	52	.	.	.	.	10	276	79	99	125	156	204
Dissolved Oxygen	52	.	5	0	.	6.1	13.4	7.7	8.4	10.1	11.6	12.4
pH (s.u.)	48	.	<6;>9	0	.	6.1	7.9	6.6	7.0	7.2	7.4	7.7
Other												
Total Residue	1	0	.	.	.	130	130	.	.	130	.	.
Total Sus. Solids	40	2	.	.	.	1	150	2	9	14	27	62
Hardness	54	0	.	.	.	19	55	22	24	28	36	42
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	55	0	50	5	9.1	2.0	190.0	4.5	6.2	10.0	21.8	50.0
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	54	10	200	18	33.3	6	4100	10	18	91	290	802
Nutrients												
NH_3 as N	55	16	.	.	.	0.01	0.12	0.01	0.01	0.03	0.05	0.07
TKN as N	55	0	.	.	.	0.1	0.5	0.1	0.2	0.2	0.3	0.4
NO_2+NO_3 as N	55	0	.	.	.	0.06	0.45	0.12	0.20	0.24	0.30	0.34
Total Phosphorus	55	1	.	.	.	0.01	0.29	0.04	0.06	0.08	0.12	0.16
Metals (total)												
Arsenic	54	54	50	0	.	10	40	10	10	10	10	10
Cadmium	54	53	2	1	1.9	2	8	2	2	2	2	2
Chromium	54	54	50	0	.	25	100	25	25	25	25	25
Copper	54	6	7	8	14.8	2	18	2.0	3.0	4.0	6.2	9.9
Iron	54	0	1000	26	48.1	250	14000	310	600	925	1600	4110
Lead	54	54	25	0	.	10	40	10	10	10	10	10
Manganese	2	0	.	.		31	44	.	31	38	44	.
Nickel	54	54	88	0	.	10	40	10	10	10	10	10
Aluminum	53	1	.	.		50	8500	92	255	620	1400	2840
Mercury	54	54	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 42. Summary of water quality parameters collected from the Dan River at Milton (Station N3500000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^oC)	49	.	.	.	.	5	30	7	9	17	25	29
Conductivity	49	.	.	.	.	42	269	85	102	137	173	233
Dissolved Oxygen	49	.	5	0	.	6.0	13.4	7.1	8.0	9.6	11.3	12.3
pH (s.u.)	47	.	<6;>9	0	.	6.6	8.2	6.7	7.0	7.1	7.3	7.4
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	52	0	.	.	.	2	400	5	8	18	33	116
Hardness	52	0	.	.	.	16	63	21	24	30	32	37
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	51	0	50	9	17.6	3.2	210.0	5.6	6.8	11.0	22.5	78.0
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	51	3	200	18	35.3	10	3900	19	36	91	363	1160
Nutrients												
NH_3 as N	52	5	.	.	.	0.01	0.39	0.01	0.03	0.05	0.11	0.19
TKN as N	52	0	.	.	.	0.1	0.6	0.1	0.2	0.3	0.4	0.4
NO_2+NO_3 as N	52	0	.	.	.	0.08	0.60	0.15	0.24	0.32	0.38	0.42
Total Phosphorus	52	0	.	.	.	0.01	0.44	0.04	0.06	0.09	0.12	0.17
Metals (total)												
Arsenic	51	51	50	0	.	10	40	10	10	10	10	10
Cadmium	51	51	2	0	.	2	20	2	2	2	2	2
Chromium	51	51	50	0	.	25	100	25	25	25	25	25
Copper	51	5	7	9	17.6	2	18	2.0	3.0	4.7	6.7	9.0
Iron	50	0	1000	24	48.0	320	14000	535	680	1000	2100	6100
Lead	51	50	25	0	.	10	40	10	10	10	10	10
Manganese	1	0	.	.		33	33	.	.	33	.	.
Nickel	51	51	88	0	.	10	40	10	10	10	10	10
Aluminum	50	1	.	.		50	14000	165	250	610	1400	5850
Mercury	51	51	0.012	N/A	.	0.2	2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = μmhos/cm; bacteria = no. colonies/100 ml; metals = μg/l; all others = mg/l.

Table 43. Summary of water quality parameters collected from Hyco Creek, near Leasburg (Station N4110000; Class C) during the period 09/01/1994 to 8/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	49	.	.	.	.	4	29	6	8	15	22	26
Conductivity	49	.	.	.	.	35	160	67	89	105	120	133
Dissolved Oxygen	49	.	5	0	.	5.8	13.0	7.0	7.4	10.0	11.2	12.2
pH (s.u.)	46	.	<6;>9	0	.	6.4	8.1	6.7	7.0	7.1	7.4	7.5
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	53	3	.	.	.	1	600	1	3	6	19	39
Hardness	53	0	.	.	.	20	86	34	37	42	52	56
Chloride	0	0	230	0	.	.	.	.	.	.	.	.
Turbidity (NTU)	52	0	50	5	9.6	3.5	1000	4.7	6.7	14.5	24.0	43.8
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	52	4	200	18	34.6	9	15000	18	36	91	300	821
Nutrients												
NH_3 as N	55	16	.	.	.	0.01	0.16	0.01	0.01	0.03	0.06	0.09
TKN as N	55	0	.	.	.	0.1	0.9	0.2	0.2	0.3	0.3	0.4
NO_2+NO_3 as N	55	6	.	.	.	0.01	1.20	0.01	0.03	0.08	0.12	0.17
Total Phosphorus	55	3	.	.	.	0.01	0.76	0.01	0.02	0.04	0.06	0.09
Metals (total)												
Arsenic	54	54	50	0	.	10	40	10	10	10	10	10
Cadmium	54	53	2	1	1.9	2	8	2	2	2	2	2
Chromium	54	53	50	0	.	25	100	25	25	25	25	25
Copper	54	13	7	15	27.8	2	43	2.0	2.0	3.5	8.0	13.1
Iron	54	0	1000	34	63.0	640	76000	689	910	1400	2000	3550
Lead	54	53	25	0	.	10	40	10	10	10	10	10
Manganese	1	0	.	.		130	130	.	.	130	.	.
Nickel	54	53	88	0	.	10	40	10	10	10	10	10
Aluminum	54	0	.	.		62	13000 0	92	140	530	1400	3600
Mercury	54	54	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 44. Summary of water quality parameters collected from the Hyco River, near McGhees Mill (Station N4250000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	44	.	.	.	.	4	26	7	12	17	22	25
Conductivity	43	.	.	.	.	52	910	63	73	92	104	118
Dissolved Oxygen	44	.	5	0	.	5.5	17.6	6.6	7.8	9.2	11.4	13.0
pH (s.u.)	40	.	<6;>9	0	.	6.2	7.8	6.6	7.1	7.2	7.4	7.5
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	44	3	.	.	.	1	60	1	4	6	10	16
Hardness	45	0	.	.	.	22	64	26	30	37	40	46
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	45	0	50	0	.	2.2	27.0	5.1	6.2	9.7	16.5	22.0
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	45	20	200	1	.	5	22000	10	10	10	36	64
Nutrients												
NH_3 as N	45	9	.	.	.	0.01	0.32	0.01	0.01	0.04	0.07	0.11
TKN as N	45	0	.	.	.	0.1	0.8	0.2	0.2	0.3	0.4	0.5
NO_2+NO_3 as N	45	5	.	.	.	0.01	2.00	0.01	0.02	0.08	0.16	0.23
Total Phosphorus	45	3	.	.	.	0.01	0.34	0.01	0.01	0.03	0.03	0.04
Metals (total)												
Arsenic	44	44	50	0	.	10	10	10	10	10	10	10
Cadmium	44	44	2	0	.	2	2	2	2	2	2	2
Chromium	44	44	50	0	.	25	25	25	25	25	25	25
Copper	44	4	7	6	13.6	2	27	2.0	3.0	4.1	6.0	8.0
Iron	44	0	1000	17	38.6	93	3100	268	485	875	1200	1800
Lead	44	44	25	0	.	10	10	10	10	10	10	10
Manganese	3	0	.	.		31	49	.	34	41	47	.
Nickel	44	44	88	0	.	10	10	10	10	10	10	10
Aluminum	44	1	.	.		50	3100	199	330	635	1100	2210
Mercury	44	44	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 45. Summary of water quality parameters collected from Marlowe Creek (Station N4400000; Class C) during the period 09/01/1994 to 08/31/1999.

								Percentiles				
Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	10	25	50	75	90
Field												
Temperature (^{o}C)	57	.	.	.	.	3	26	6	8	15	21	24
Conductivity	57	.	.	.	.	69	851	103	130	252	338	599
Dissolved Oxygen	56	.	5	0	.	6.4	16.3	7.3	8.1	9.8	11.6	12.5
pH (s.u.)	55	.	<6;>9	1	1.8	5.7	8.2	6.8	7.1	7.3	7.5	7.7
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	57	2	.	.	.	1	130	3	4	7	14	29
Hardness	58	0	.	.	.	29	60	31	34	36	40	45
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	58	0	50	3	5.2	2.0	100.0	2.9	4.0	6.4	15.0	30.1
Bacteria												
Total coliform	3	1	.	.		10	7400	.	25	70	5568	.
Fecal coliform	58	3	200	34	58.6	10	3900	21	82	255	610	1152
Nutrients												
NH_3 as N	57	7	.	.	.	0.01	0.31	0.01	0.02	0.04	0.08	0.12
TKN as N	57	0	.	.	.	0.1	1.4	0.3	0.4	0.5	0.6	0.8
NO_2+NO_3 as N	57	0	.	.	.	0.02	9.60	0.98	1.68	2.40	4.10	6.16
Total Phosphorus	57	0	.	.	.	0.03	5.30	0.29	0.37	0.75	1.45	2.68
Metals (total)												
Arsenic	57	57	50	0	.	10	10	10	10	10	10	10
Cadmium	57	57	2	0	.	2	2	2	2	2	2	2
Chromium	57	57	50	0	.	25	25	25	25	25	25	25
Copper	57	0	7	43	75.4	3.2	52	5.8	7.2	12.0	18.3	32.2
Iron	57	0	1000	13	22.8	200	3100	326	418	560	985	2220
Lead	57	56	25	0	.	10	19	10	10	10	10	10
Manganese	3	0	.	.		54	59	.	55	58	59	.
Nickel	57	55	88	0	.	10	27	10	10	10	10	10
Aluminum	57	0	.	.		62	3400	150	210	300	705	1600
Mercury	57	57	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = μmhos/cm; bacteria = no. colonies/100 ml; metals = μg/l; all others = mg/l.

Table 46. Summary of water quality parameters collected from the Hyco River (Station N4510000; Class C) during the period 9/1/1994 to 8/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	57	.	.	.	.	3	27	6	10	15	21	25
Conductivity	57	.	.	.	.	60	424	70	82	118	160	282
Dissolved Oxygen	57	.	5	0	.	5.4	17.1	6.2	7.5	8.8	10.9	12.5
pH (s.u.)	56	.	<6;>9	0	.	6.3	7.8	6.7	7.0	7.2	7.3	7.5
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	57	3	.	.	.	1	54	1	3	9	14	30
Hardness	59	0	.	.	.	22	63	30	32	38	42	52
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	59	0	50	2	3.4	1.7	300.0	3.9	5.9	11.0	21.3	32.4
Bacteria												
Total coliform	1	0	.	.		850	850	.	.	850	.	.
Fecal coliform	58	3	200	15	25.9	10	4300	19	36	115	210	814
Nutrients												
NH_3 as N	58	13	.	.	.	0.01	0.26	0.01	0.01	0.04	0.06	0.10
TKN as N	59	0	.	.	.	0.0	0.6	0.2	0.2	0.3	0.4	0.5
NO_2+NO_3 as N	59	0	.	.	.	0.17	3.90	0.23	0.30	0.38	0.64	1.04
Total Phosphorus	59	0	.	.	.	0.01	3.30	0.05	0.07	0.13	0.22	0.36
Metals (total)												
Arsenic	57	57	50	0	.	10	10	10	10	10	10	10
Cadmium	57	57	2	0	.	2	2	2	2	2	2	2
Chromium	57	57	50	0	.	25	25	25	25	25	25	25
Copper	57	3	7	17	29.8	2	75	2.8	4.0	5.0	7.5	10.0
Iron	57	0	1000	27	47.4	210	4900	440	598	890	1625	2300
Lead	57	57	25	0	.	10	10	10	10	10	10	10
Manganese	2	0	.	.		110	160	.	110	135	160	.
Nickel	57	57	88	0	.	10	10	10	10	10	10	10
Aluminum	57	0	.	.		55	8100	102	278	460	1425	1960
Mercury	57	57	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 47. Summary of water quality parameters collected from Mayo Creek (Station N4590000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^oC)	57	.	.	.	.	5	30	7	10	13	16	22
Conductivity	57	.	.	.	.	52	147.1	61	69	80	96	104
Dissolved Oxygen	57	.	5	0	.	5.4	17.4	7.6	8.6	9.3	10.9	12.4
pH (s.u.)	55	.	<6;>9	0	.	6.6	8.0	6.7	6.9	7.1	7.4	7.5
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	58	15	.	.	.	1	13	1	1	2	4	6
Hardness	58	0	.	.	.	3	62	24	28	32	38	43
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	59	6	50	0	.	1.0	19.0	1.0	1.2	1.4	2.0	3.5
Bacteria												
Total coliform	1	0	.	.		100	100	.	.	100	.	.
Fecal coliform	59	41	200	1	1.7	9	220	10	10	10	10	48
Nutrients												
NH_3 as N	58	12	.	.	.	0.01	0.18	0.01	0.01	0.04	0.06	0.10
TKN as N	58	1	.	.	.	0.1	0.7	0.1	0.2	0.2	0.3	0.4
NO_2+NO_3 as N	58	4	.	.	.	0.01	0.22	0.01	0.02	0.07	0.11	0.18
Total Phosphorus	58	18	.	.	.	0.01	0.09	0.01	0.01	0.01	0.02	0.02
Metals (total)												
Arsenic	58	57	50	0	.	10	25	10	10	10	10	10
Cadmium	58	58	2	0	.	2	2	2	2	2	2	2
Chromium	58	58	50	0	.	25	25	25	25	25	25	25
Copper	58	22	7	6	10.3	2	25	2.0	2.0	2.5	4.0	7.4
Iron	58	7	1000	1	1.7	50	4800	50	71	100	140	284
Lead	58	58	25	0	.	10	10	10	10	10	10	10
Manganese	4	1	.	.		10	55	.	18	32	47	.
Nickel	58	58	88	0	.	10	10	10	10	10	10	10
Aluminum	58	17	.	.		50	490	50	50	67	90	127
Mercury	58	57	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 48. Summary of water quality parameters collected from Nutbush Creek (Station N5000000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	58	.	.	.	.	5	28	9	11	18	23	25
Conductivity	58	.	.	.	.	20	898	219	325	408	525	697
Dissolved Oxygen	58	.	5	0	.	6.7	18.4	7.3	8.1	10.0	11.4	14.1
pH (s.u.)	56	.	<6;>9	0	.	6.8	8.7	7.2	7.3	7.6	7.7	7.9
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	58	11	.	.	.	1	38	1	1	2	5	9
Hardness	58	0	.	.	.	56	210	74	92	110	120	147
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	58	3	50	0	.	1.0	25.0	1.0	1.4	2.4	5.0	14.4
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	58	3	200	15	25.9	9	4900	18	45	105	210	1010
Nutrients												
NH_3 as N	60	10	.	.	.	0.01	0.16	0.01	0.01	0.04	0.07	0.10
TKN as N	60	0	.	.	.	0.3	1.4	0.5	0.5	0.6	0.8	0.9
NO_2+NO_3 as N	60	0	.	.	.	2.00	18.00	4.65	7.25	9.80	12.00	14.50
Total Phosphorus	60	0	.	.	.	0.06	1.50	0.13	0.18	0.35	0.50	0.81
Metals (total)												
Arsenic	57	57	50	0	.	10	10	10	10	10	10	10
Cadmium	57	57	2	0	.	2	2	2	2	2	2	2
Chromium	57	57	50	0	.	25	25	25	25	25	25	25
Copper	57	6	7	8	14.0	2	18	2.0	3.0	5.0	6.0	8.0
Iron	57	0	1000	1	1.8	57	1500	122	150	230	355	814
Lead	57	57	25	0	.	10	10	10	10	10	10	10
Manganese	1	0	.	.		38	38	.	.	38	.	.
Nickel	57	56	88	0	.	10	15	10	10	10	10	10
Aluminum	57	3	.	.		50	2000	58	78	130	250	732
Mercury	57	57	0.012	N/A	.	0.2	2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 49. Summary of water quality parameters collected from Smith Creek, near Paschall (Station N6400000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	58	.	.	.	.	3	27	6	10	17	22	25
Conductivity	58	.	.	.	.	10	161	49	67	78	97	112
Dissolved Oxygen	58	.	5	15	25.9	1.1	16.7	3.6	4.6	6.6	9.3	11.4
pH (s.u.)	57	.	<6; >9	0	.	6.0	7.6	6.3	6.7	6.8	7.0	7.3
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	56	9	.	.	.	1	38	1	1	2	5	11
Hardness	57	0	.	.	.	12	62	18	24	31	36	41
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	57	0	50	1	1.8	1.1	70.0	3.4	4.4	8.6	14.5	19.6
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	57	2	200	6	10.5	9	3900	12	25	54	93	262
Nutrients												
NH_3 as N	57	7	.	.	.	0.01	0.24	0.01	0.02	0.04	0.07	0.11
TKN as N	57	0	.	.	.	0.1	0.7	0.2	0.2	0.3	0.4	0.5
NO_2+NO_3 as N	57	16	.	.	.	0.01	0.31	0.01	0.01	0.04	0.07	0.15
Total Phosphorus	57	0	.	.	.	0.01	0.21	0.03	0.04	0.05	0.07	0.10
Metals (total)												
Arsenic	56	56	50	0	.	10	10	10	10	10	10	10
Cadmium	56	56	2	0	.	2	2	2	2	2	2	2
Chromium	56	56	50	0	.	25	25	25	25	25	25	25
Copper	56	26	7	2	3.6	2	10	2.0	2.0	2.3	4.0	6.0
Iron	56	0	1000	48	85.7	590	10000	962	1300	2050	2850	3990
Lead	56	56	25	0	.	10	10	10	10	10	10	10
Manganese	1	0	.	.		280	280	.	.	280	.	.
Nickel	56	56	88	0	.	10	10	10	10	10	10	10
Aluminum	56	6	.	.		50	2600	50	68	97	155	698
Mercury	56	56	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = μmhos/cm; bacteria = no. colonies/100 ml; metals = μg/l; all others = mg/l.

Table 50. Summary of water quality parameters collected from the Roanoke River at Roanoke Rapids (Station N7300000; Class WS-IV) during the period 09/01/1994 to 08/31/1999.

								Percentiles				
Parameter	**N**	**N < RL**	**Ref.**	**N > Ref.**	**% > Ref .**	**Min.**	**Max**	**10**	**25**	**50**	**75**	**90**
Field												
Temperature (^{o}C)	58	.	.	.	.	4	29	7	10	18	25	27
Conductivity	57	.	.	.	.	61	134	70	80	99	113	122
Dissolved Oxygen	58	.	5	0	0.0	5.0	17.0	5.9	6.8	8.8	11.0	12.3
pH (s.u.)	57	.	<6;>9	1	1.8	6.3	9.3	6.7	7.0	7.2	7.5	7.6
Other												
Total Residue	41	0	.	.	.	56	160	61	69	80	91	97
Total Sus. Solids	58	8	.	.	.	1	38	1	1	4	6	11
Hardness	59	0	.	.	.	20	98	26	28	32	38	43
Chloride	43	0	230	.	.	4	12	5	6	6	9	11
Turbidity (NTU)	59	1	50	0	0.0	1.0	29.0	1.3	1.6	3.2	6.4	12.6
Bacteria												
Total coliform	43	7	.	.		10	8000	10	20	82	248	508
Fecal coliform	58	26	200	0	0.0	10	170	10	10	10	50	100
Nutrients												
NH_3 as N	59	10	.	.	.	0.01	0.22	0.01	0.02	0.03	0.05	0.08
TKN as N	59	0	.	.	.	0.1	0.4	0.1	0.2	0.2	0.3	0.3
NO_2+NO_3 as N	59	3	10	0	.	0.01	0.29	0.03	0.09	0.13	0.20	0.23
Total Phosphorus	59	10	.	.	.	0.01	0.09	0.01	0.01	0.02	0.03	0.04
Metals (total)												
Arsenic	59	59	50	0	.	10	10	10	10	10	10	10
Cadmium	59	59	2	0	.	2	2	2	2	2	2	2
Chromium	59	59	50	0	.	25	25	25	25	25	25	25
Copper	59	22	7	6	10.2	2	38	2.0	2.0	2.5	4.0	7.7
Iron	59	1	1000	4	6.8	50	1700	82	150	220	438	716
Lead	59	59	25	0	.	10	10	10	10	10	10	10
Manganese	42	1	.	.		10	160	27	37	50	81	113
Nickel	59	59	88	0	.	10	10	10	10	10	10	10
Aluminum	59	7	.	.		50	1600	51	98	130	218	552
Mercury	59	59	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 51. Summary of water quality parameters collected from the Roanoke River, near Scotland Neck (Station N8200000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref .	Min.	Max	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	60	.	.	.	.	3	29	7	9	18	25	28
Conductivity	59	.	.	.	.	55	169	71	81	111	125	139
Dissolved Oxygen	60	.	5	2	3.3	4.0	15.0	6.5	7.0	8.6	10.7	11.5
pH (s.u.)	58	.	<6; >9	1	1.7	6.3	10.0	6.6	7.0	7.3	7.4	7.4
Other												
Total Residue	15	0	.	.	.	87	120	88	91	100	118	120
Total Sus. Solids	43	1	.	.	.	1	25	3	7	10	13	17
Hardness	61	0	.	.	.	18	94	28	30	32	36	44
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	61	0	50	0	.	2.1	31.0	3.0	4.5	6.8	11.3	21.2
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	59	9	200	7	11.9	9	820	10	10	36	69	270
Nutrients												
NH_3 as N	61	16	.	.	.	0.01	0.20	0.01	0.01	0.04	0.05	0.08
TKN as N	61	0	.	.	.	0.1	0.6	0.2	0.2	0.2	0.3	0.3
NO_2+NO_3 as N	61	0	.	.	.	0.06	0.34	0.13	0.16	0.19	0.22	0.28
Total Phosphorus	61	3	.	.	.	0.01	0.08	0.01	0.02	0.03	0.04	0.05
Metals (total)												
Arsenic	61	61	50	0	.	10	10	10	10	10	10	10
Cadmium	61	61	2	0	.	2	2	2	2	2	2	2
Chromium	61	61	50	0	.	25	25	25	25	25	25	25
Copper	61	23	7	6	9.8	2	23	2.0	2.0	3.0	4.2	7.8
Iron	61	0	1000	13	21.3	130	1900	234	413	640	880	1340
Lead	61	60	25	0	.	10	11	10	10	10	10	10
Manganese	0	0	.	.		.	.	.	.	.	.	.
Nickel	61	61	88	0	.	10	10	10	10	10	10	10
Aluminum	60	0	.	.		58	2300	140	270	435	760	1350
Mercury	61	60	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 52. Summary of water quality parameters collected from the Roanoke River, near Lewiston (Station N8300000; Class C) during the period 09/01/1994 to 08/31/1999.

								Percentiles				
Parameter	N	N < RL	Ref.	N > Ref.	% > Ref.	Min.	Max.	10	25	50	75	90
Field												
Temperature (^oC)	32	.	.	.	.	5	28	8	11	17	24	28
Conductivity	32	.	.	.	.	89	168	94	101	121	125	134
Dissolved Oxygen	32	.	5	1	3.1	2.6	12.2	6.5	7.1	8.4	9.4	10.9
pH (s.u.)	32	.	<6;>9	1	3.1	5.9	7.6	6.3	6.8	7.0	7.4	7.5
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	21	0	.	.	.	5	63	6	10	11	19	42
Hardness	20	0	.	.	.	26	98	27	28	30	38	53
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	21	0	50	0	,	3.8	31.0	4.9	5.9	8.1	10.3	24.0
Bacteria												
Total coliform	0	0	.	.		.	.	.	.	.	.	.
Fecal coliform	21	9	200	3	14.3	10	1195	10	10	18	52	418
Nutrients												
NH_3 as N	34	14	.	.	.	0.01	0.19	0.01	0.01	0.01	0.06	0.10
TKN as N	34	0	.	.	.	0.1	0.4	0.1	0.2	0.2	0.3	0.3
NO_2+NO_3 as N	34	0	.	.	.	0.08	0.31	0.15	0.17	0.21	0.23	0.28
Total Phosphorus	34	0	.	.	.	0.01	0.42	0.02	0.04	0.05	0.06	0.08
Metals (total)												
Arsenic	33	33	50	0	.	10	10	10	10	10	10	10
Cadmium	33	33	2	0	.	2	2	2	2	2	2	2
Chromium	33	33	50	0	.	25	25	25	25	25	25	25
Copper	33	11	7	4	12.1	2	44	2.0	2.0	2.6	4.2	7.5
Iron	34	0	1000	11	32.4	100	7400	327	470	735	1200	1730
Lead	33	33	25	0	.	10	10	10	10	10	10	10
Manganese	1	0	.	.	.	17	17	.	.	17	.	.
Nickel	33	33	88	0	.	10	10	10	10	10	10	10
Aluminum	34	1	.	.	.	50	2000	176	310	525	810	1340
Mercury	33	33	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement
As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 53. Summary of water quality parameters collected from the Roanoke River at Williamston (Station N8550000; Class C) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref.	Min.	Max.	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	32	.	.	.	.	6	29	8	10	16	25	28
Conductivity	32	.	.	.	.	9	151	95	101	120	135	142
Dissolved Oxygen	32	.	5	2	6.3	2.4	12.1	5.8	6.9	8.3	9.7	10.4
pH (s.u.)	32	.	<6;>9	0	.	6.2	7.8	6.6	6.7	7.0	7.3	7.4
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	24	0	.	.	.	4	51	7	8	10	12	21
Hardness	23	0	.	.	.	24	70	26	30	34	42	47
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	23	0	50	0	.	4.4	35.0	4.7	5.4	9.6	12.0	19.2
Bacteria												
Total coliform	1	0	.	.		7600	7600	.	.	7600	.	.
Fecal coliform	25	7	200	2	8.0	9	7600	10	10	20	46	120
Nutrients												
NH_3 as N	37	13	.	.	.	0.01	0.20	0.01	0.01	0.02	0.07	0.13
TKN as N	37	1	.	.	.	0.1	0.8	0.1	0.2	0.2	0.2	0.3
NO_2+NO_3 as N	37	1	.	.	.	0.01	0.29	0.14	0.17	0.20	0.22	0.26
Total Phosphorus	37	0	.	.	.	0.01	0.17	0.03	0.03	0.05	0.06	0.09
Metals (total)												
Arsenic	35	35	50	0	.	10	10	10	10	10	10	10
Cadmium	34	34	2	0	.	2	2	2	2	2	2	2
Chromium	34	34	50	0	.	25	25	25	25	25	25	25
Copper	34	13	7	1	2.9	2	8	2.0	2.0	2.7	3.8	6.1
Iron	35	0	1000	7	20.0	88	2600	350	503	700	950	1200
Lead	34	34	25	0	.	10	10	10	10	10	10	10
Manganese	1	0	.	.		24	24	.	.	24	.	.
Nickel	34	34	88	0	.	10	10	10	10	10	10	10
Aluminum	35	0	.	.		52	2400	250	353	550	750	970
Mercury	35	35	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 54. Summary of water quality parameters collected from the Roanoke River, near Plymouth (Station N9250000; Class C SW) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref.	Min.	Max.	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	34	.	.	.	.	7	30	9	11	18	26	29
Conductivity	34	.	.	.	.	85.7	518	92	99	117	125	138
Dissolved Oxygen	34	.	5	1	2.9	2.2	10.4	5.9	6.5	7.7	8.7	9.6
pH (s.u.)	34	.	<6;>9	2	5.9	5.9	8.8	6.4	6.7	6.9	7.3	7.4
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	24	2	.	.	.	1	15	1	3	4	10	14
Hardness	24	0	.	.	.	18	55	26	28	30	35	50
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	24	0	50	0	.	2.3	27.0	3.6	4.7	5.8	9.1	11.9
Bacteria												
Total coliform	0	0	.	.	.	.	.	.	.	.	.	.
Fecal coliform	23	9	200	1	4.3	9	485	10	10	10	43	112
Nutrients												
NH_3 as N	33	4	.	.	.	0.01	0.18	0.01	0.03	0.04	0.06	0.09
TKN as N	33	0	.	.	.	0.1	0.5	0.1	0.2	0.2	0.3	0.4
NO_2+NO_3 as N	33	0	.	.	.	0.05	0.27	0.09	0.12	0.17	0.20	0.23
Total Phosphorus	33	0	.	.	.	0.01	0.29	0.02	0.03	0.03	0.05	0.07
Metals (total)												
Arsenic	34	34	50	0	.	10	10	10	10	10	10	10
Cadmium	34	34	2	1	2.9	2	10	2	2	2	2	2
Chromium	34	34	50	0	.	25	25	25	25	25	25	25
Copper	34	8	7	5	14.7	2	110	2.0	2.0	3.2	4.2	11.7
Iron	34	0	1000	4	11.8	210	3900	280	310	470	850	1100
Lead	34	34	25	0	.	10	10	10	10	10	10	10
Manganese	0	0	.	.	.	.	.	.	.	.	.	.
Nickel	34	33	88	1	2.9	10	320	10	10	10	10	10
Aluminum	34	0	.	.	.	120	5800	120	160	290	400	552
Mercury	34	34	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 55. Summary of water quality parameters collected from the Roanoke River at Sans Souci (Station N9600000; Class C Sw) during the period 09/01/1994 to 08/31/1999.

								Percentiles				
Parameter	**N**	**N < RL**	**Ref.**	**N > Ref.**	**% > Ref.**	**Min.**	**Max.**	**10**	**25**	**50**	**75**	**90**
Field												
Temperature (^{o}C)	34	.	.	.	.	7	29	9	11	18	27	29
Conductivity	34	.	.	.	.	90.1	3047	101	113	143	174	259
Dissolved Oxygen	34	.	5	1	2.9	1.4	10.0	5.2	5.6	7.3	8.8	9.6
pH (s.u.)	34	.	<6;>9	0	.	6.2	7.5	6.6	6.9	7.0	7.1	7.4
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	24	1	.	.	.	1	18	1	1	2	5	10
Hardness	24	0	.	.	.	28	82	30	33	34	38	46
Chloride	12	0	230	.	.	6	30	6	8	12	15	21
Turbidity (NTU)	24	0	50	0	0.0	3.1	25.0	3.4	4.6	5.5	8.6	10.6
Bacteria												
Total coliform	0	0	.	.	.	.	.	.	.	.	.	.
Fecal coliform	23	12	200	0	.	10	180	10	10	10	37	84
Nutrients												
NH_3 as N	34	0	.	.	.	0.02	0.22	0.03	0.06	0.08	0.11	0.17
TKN as N	34	0	.	.	.	0.1	0.6	0.2	0.2	0.3	0.4	0.5
NO_2+NO_3 as N	34	0	.	.	.	0.02	0.27	0.09	0.11	0.16	0.18	0.22
Total Phosphorus	34	0	.	.	.	0.01	0.18	0.03	0.03	0.05	0.06	0.08
Metals (total)												
Arsenic	34	34	50	0	.	10	10	10	10	10	10	10
Cadmium	34	34	2	0	.	2	2	2	2	2	2	2
Chromium	34	34	50	0	.	25	25	25	25	25	25	25
Copper	34	9	7	3	8.8	2	19	2.0	2.0	2.8	3.6	6.5
Iron	34	0	1000	3	8.8	180	1500	220	280	415	730	1001
Lead	34	34	25	0	.	10	10	10	10	10	10	10
Manganese	0	0	.	.	.	.	.	.	.	.	.	.
Nickel	34	34	88	0	.	10	10	10	10	10	10	10
Aluminum	34	0	.	.	.	110	1600	120	140	270	450	721
Mercury	34	34	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 56. Summary of water quality parameters collected from the Albemarle Sound, near Black Walnut (Station N9700000; Class B Sw) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N< RL	Ref.	N > Ref.	% > Ref.	Min.	Max.	Percentiles 10	25	50	75	90
Field												
Temperature (^oC)	33	.	.	.	.	8	30	9	11	17	26	29
Conductivity	33	.	.	.	.	90.8	7960	103	117	198	1643	3152
Dissolved Oxygen	33	.	5	2	6.1	4.9	10.8	6.2	7.1	8.4	9.4	9.8
pH (s.u.)	33	.	<6;>9	0	.	6.5	7.8	6.5	7.0	7.1	7.4	7.6
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	22	2	.	.	.	1	81	1	2	3	5	11
Hardness	25	0	.	.	.	30	330	32	34	42	63	190
Chloride	25	0	230	.	.	7	970	7	10	21	76	600
Turbidity (NTU)	25	0	50	0	.	1.5	25.0	2.4	2.8	3.7	6.1	12.0
Bacteria												
Total coliform	0	0	.	.	.	.	.	.	.	.	.	.
Fecal coliform	24	19	200	0	.	9	65	10	10	10	10	32
Nutrients												
NH_3 as N	33	4	.	.	.	0.01	0.15	0.01	0.02	0.05	0.08	0.10
TKN as N	33	0	.	.	.	0.1	0.4	0.2	0.2	0.2	0.3	0.4
NO_2+NO_3 as N	33	1	.	.	.	0.01	0.23	0.03	0.06	0.11	0.18	0.19
Total Phosphorus	33	2	.	.	.	0.01	0.07	0.01	0.02	0.03	0.04	0.06
Metals (total)												
Arsenic	32	32	50	0	.	10	50	10	10	10	10	10
Cadmium	31	31	2	0	.	2	2	2	2	2	2	2
Chromium	32	32	50	0	.	25	25	25	25	25	25	25
Copper	32	14	7	2	6.3	2	14	2.0	2.0	2.4	3.9	6.1
Iron	32	0	1000	2	6.3	97	1800	160	220	295	490	881
Lead	32	32	25	0	.	10	10	10	10	10	10	10
Manganese	0	0	.	.	.	.	.	.	.	.	.	.
Nickel	32	32	88	0	.	10	10	10	10	10	10	10
Aluminum	32	0	.	.	.	69	1400	98	135	170	250	470
Mercury	32	32	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

Table 57. Summary of water quality parameters collected from the Cashie River (Station N8950000; Class C Sw) during the period 09/01/1994 to 08/31/1999.

Parameter	N	N < RL	Ref.	N > Ref.	% > Ref.	Min.	Max.	Percentiles 10	25	50	75	90
Field												
Temperature (^{o}C)	33	.	.	.	.	1	27	5	11	17	22	25
Conductivity	33	.	.	.	.	36.3	120	63	71	80	94	106
Dissolved Oxygen	33	.	5	21	63.6	0.1	12.7	0.2	0.5	3.1	6.1	9.5
pH (s.u.)	33	.	<6;>9	14	42.4	5.2	6.4	5.6	5.9	6.0	6.2	6.3
Other												
Total Residue	0	0	.	.	.	.	.	.	.	.	.	.
Total Sus. Solids	21	0	.	.	.	1	33	2	5	8	9	18
Hardness	22	0	.	.	.	9	100	21	24	28	36	66
Chloride	0	0	230	.	.	.	.	.	.	.	.	.
Turbidity (NTU)	22	0	50	1	4.5	2.4	73.0	3.1	4.7	7.8	11.0	25.4
Bacteria												
Total coliform	1	0	.	.		600	600	.	.	600	.	.
Fecal coliform	23	2	200	5	21.7	10	1054	10	32	91	200	396
Nutrients												
NH_3 as N	36	5	.	.	.	0.01	0.29	0.01	0.02	0.04	0.08	0.11
TKN as N	36	0	.	.	.	0.2	0.9	0.3	0.4	0.5	0.6	0.7
NO_2+NO_3 as N	36	17	.	.	.	0.01	0.22	0.01	0.01	0.02	0.04	0.11
Total Phosphorus	36	0	.	.	.	0.04	0.46	0.05	0.10	0.18	0.26	0.33
Metals (total)												
Arsenic	34	34	50	0	.	10	10	10	10	10	10	10
Cadmium	33	33	2	0	.	2	2	2	2	2	2	2
Chromium	33	33	50	0	.	25	25	25	25	25	25	25
Copper	31	19	7	1	3.2	2	7.5	2.0	2.0	2.0	3.0	4.7
Iron	32	0	1000	26	81.3	330	8100	797	1400	2750	4450	5300
Lead	33	33	25	0	.	10	10	10	10	10	10	10
Manganese	1	0	.	.	.	220	220	.	.	220	.	.
Nickel	33	33	88	0	.	10	10	10	10	10	10	10
Aluminum	32	1	.	.	.	50	2700	147	185	270	365	930
Mercury	34	34	0.012	N/A	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Abbreviations:

N	Total number of samples.
N < RL	Number of samples less than the Division analytical reporting level (RL).
Ref	Water quality reference (standard or action level); see NC Administrative Code 15A NCAC 2B .0200.
N > Ref	Number of samples greater than (or less than) the reference.
% > Ref	Proportion (%) of samples greater than the reference.
Min	Minimum.
Max	Maximum.
N/A	Not applicable because all samples were less than the reporting level.

Units of Measurement

As noted. Conductivity = µmhos/cm; bacteria = no. colonies/100 ml; metals = µg/l; all others = mg/l.

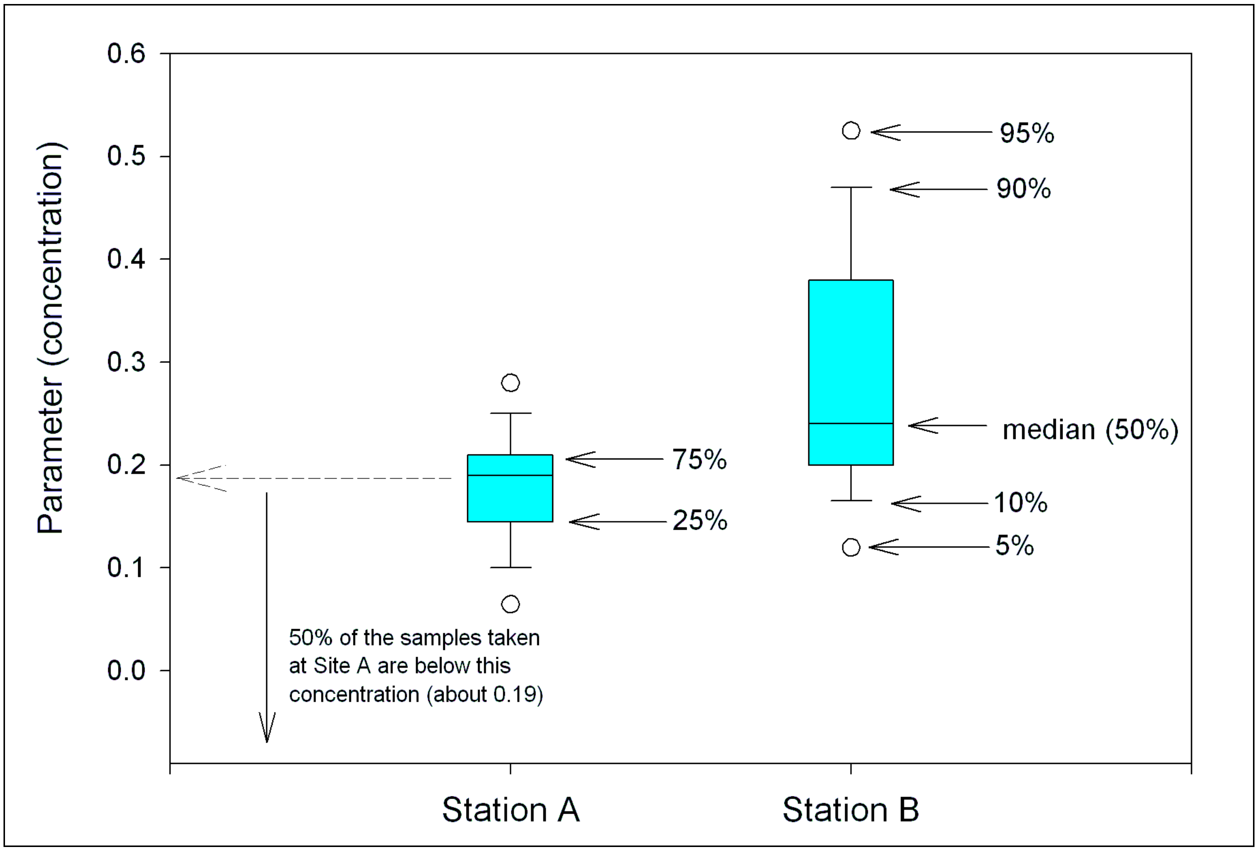

Figure 55. **Explanation of box plots. Box plots (or box and whisker plots) show the distribution of measurements of a parameter. Here the distribution of measurements of a hypothetical parameter are compared between Station A and Station B. The percentage of measurements at or below a particular concentration are indicated on the figure. Note that the median and variation of measurements taken at Station B are greater than the median of Station A.**

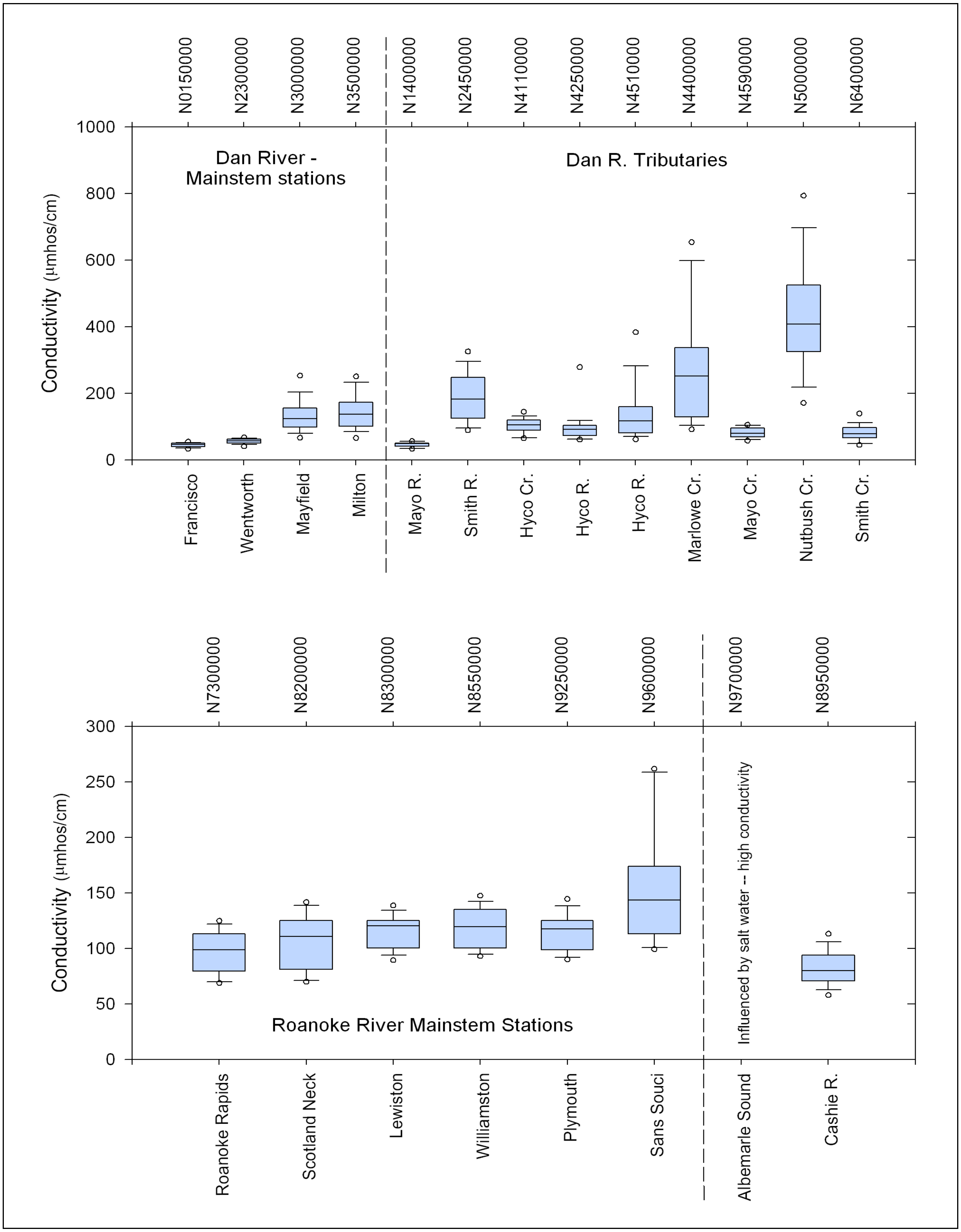

Figure 56. Box plots of conductivity in the Roanoke River basin, 1980 - 1999.

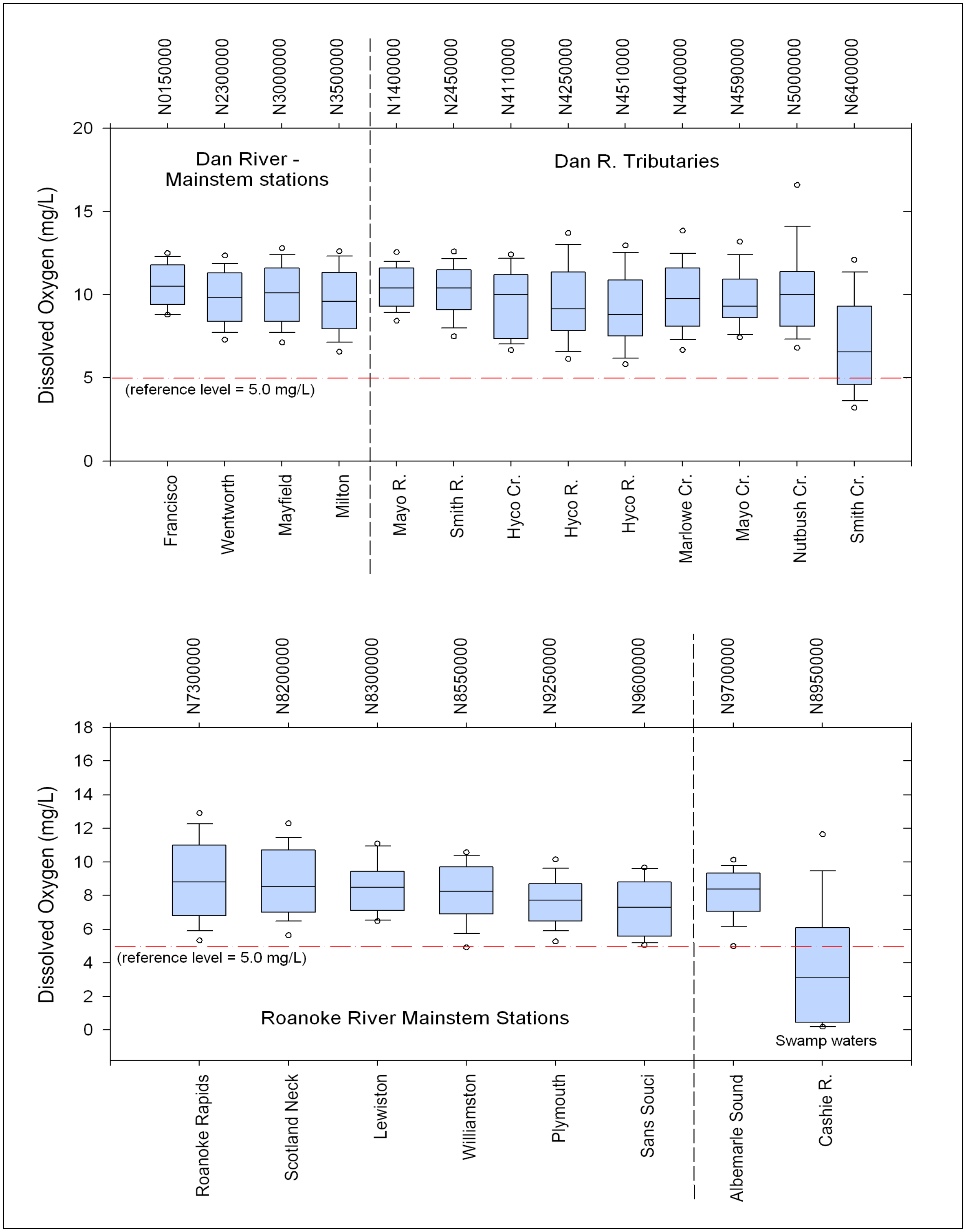

Figure 57. Box plots of dissolved oxygen in the Roanoke River basin, 1980 - 1999.

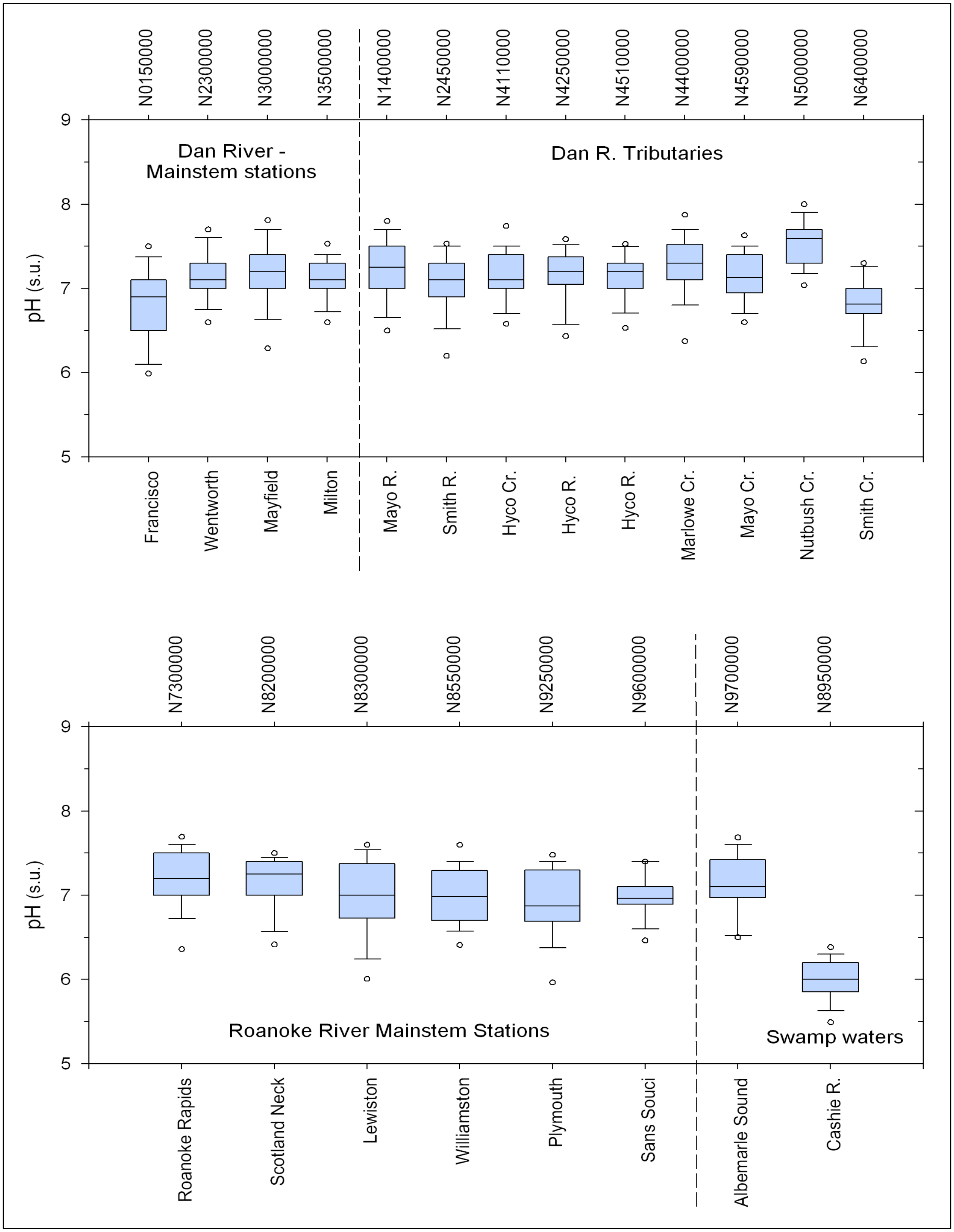

Figure 58. Box plots of pH in the Roanoke River basin, 1980 - 1999.

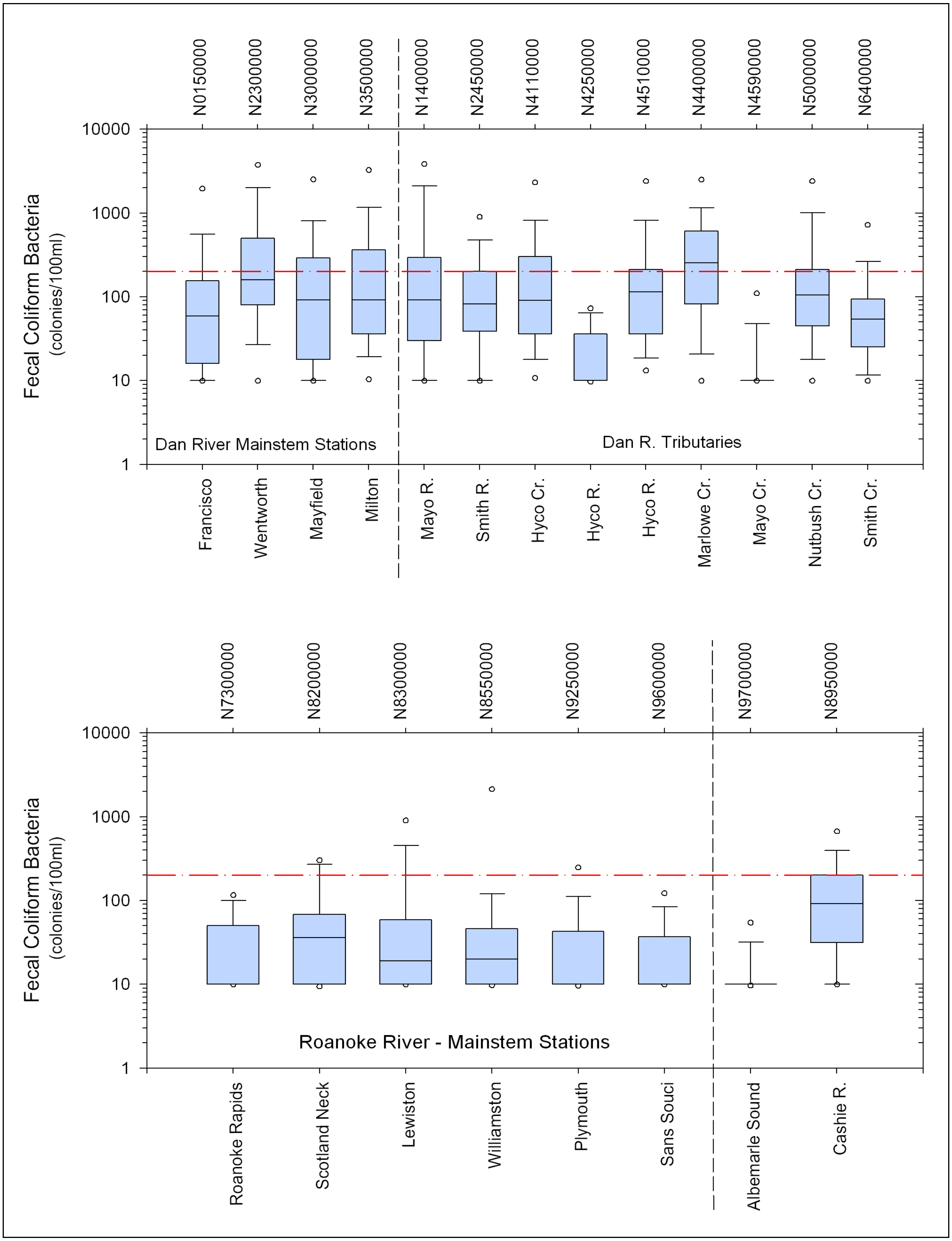

Figure 59. **Box plots of fecal coliform bacteria. Dashed line at 200 colonies/100 ml represents a reference level.**

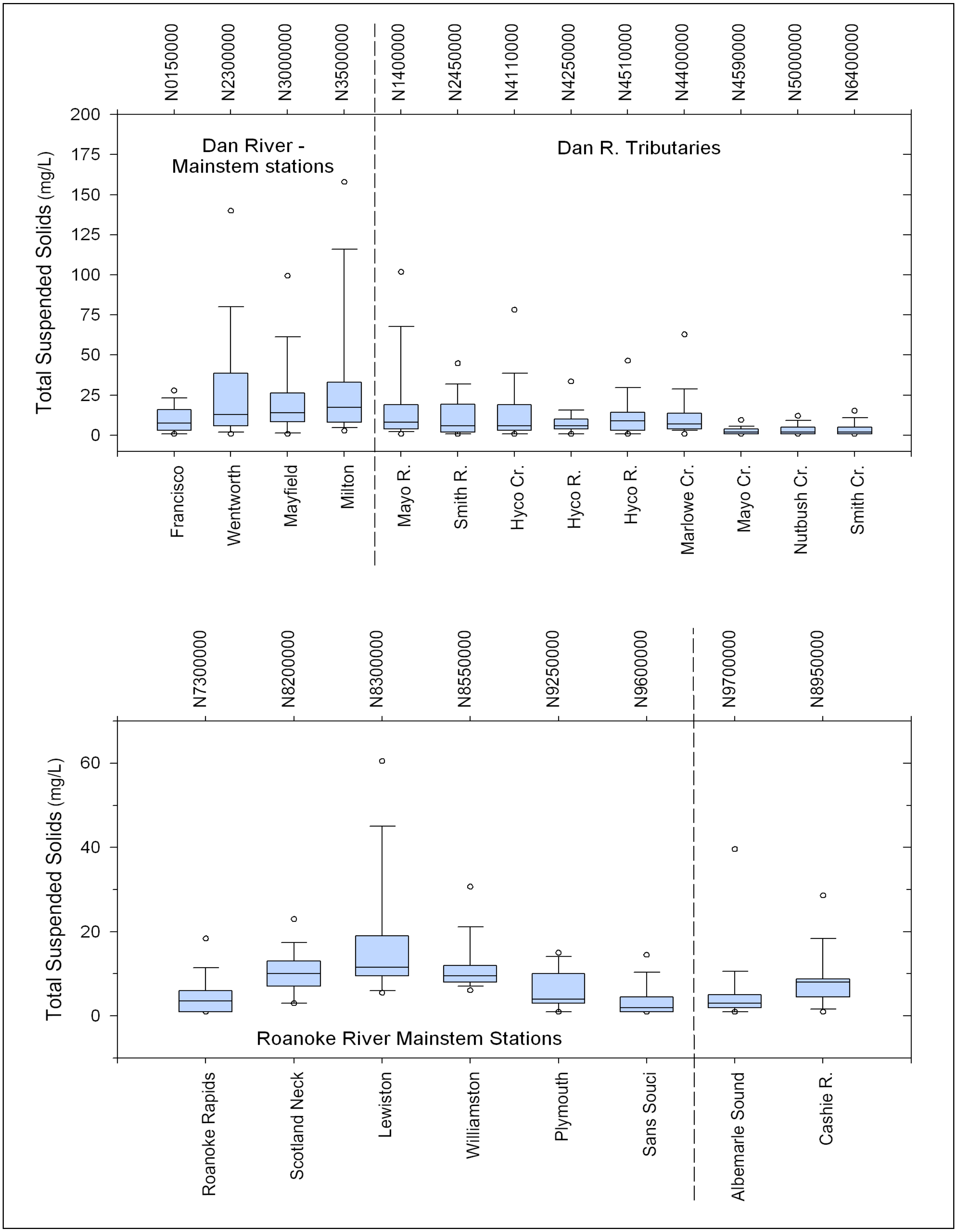

Figure 60. Box plots of total suspended solids in the Roanoke River basin, 1980 - 1999.

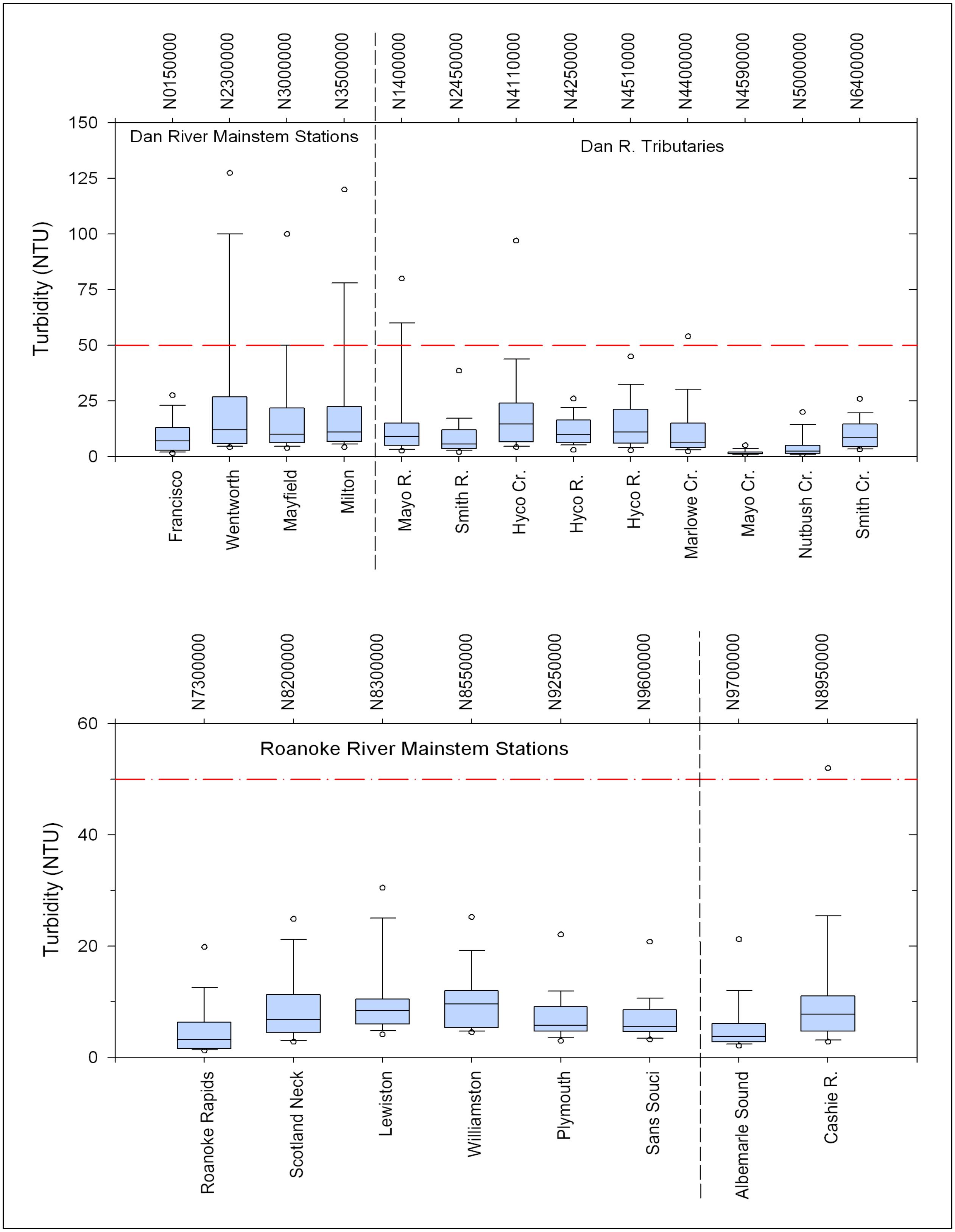

Figure 61. Box plots of turbidity in the Roanoke River basin, 1980 - 1999.

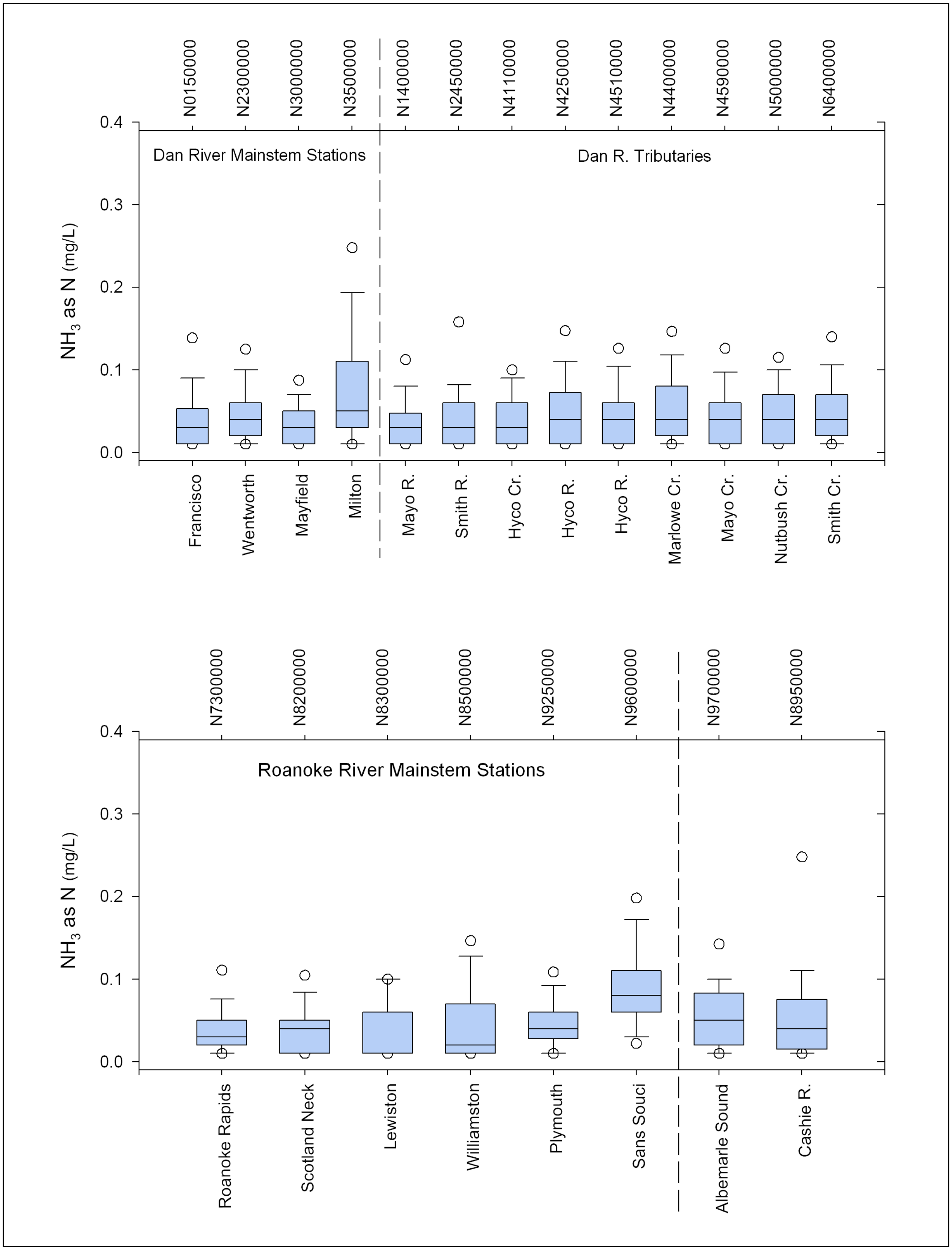

Figure 62. **Box plots of ammonia nitrogen in the Roanoke River basin, 1980 - 1999.**

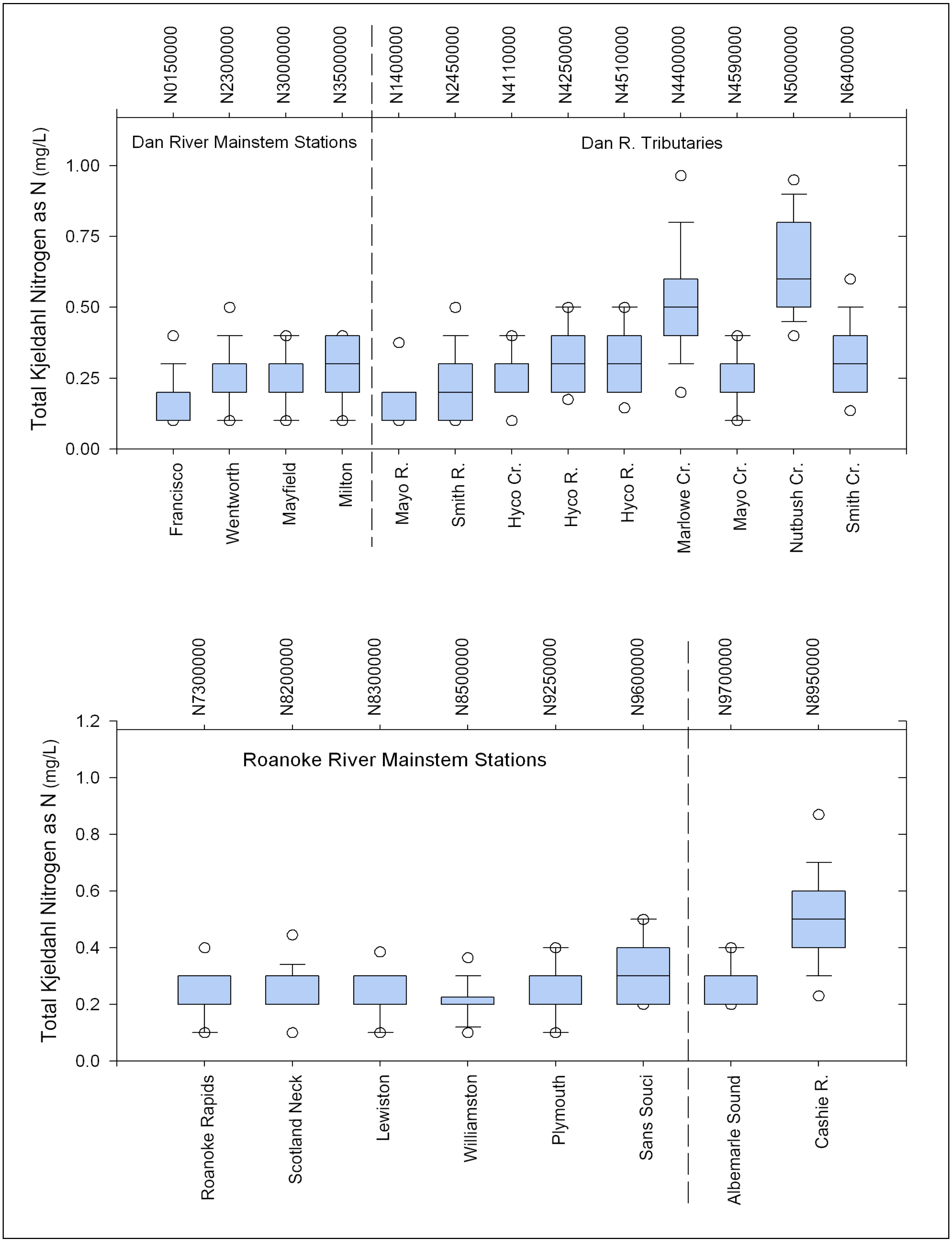

Figure 63. Box plots of total Kjeldahl nitrogen in the Roanoke River basin, 1980 - 1999.

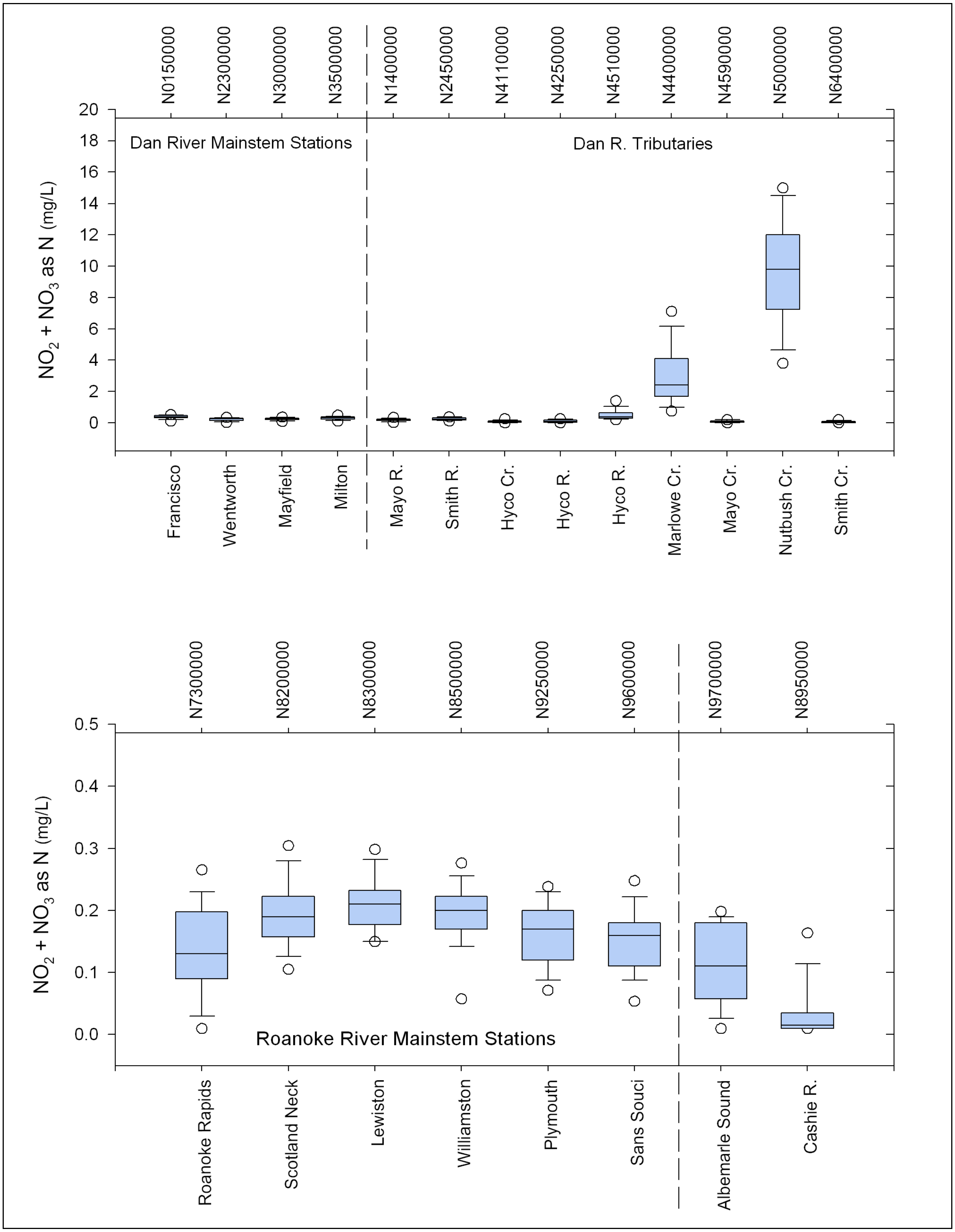

Figure 64. **Box plots of total nitrate+nitrite nitrogen in the Roanoke River basin, 1980 - 1999.**

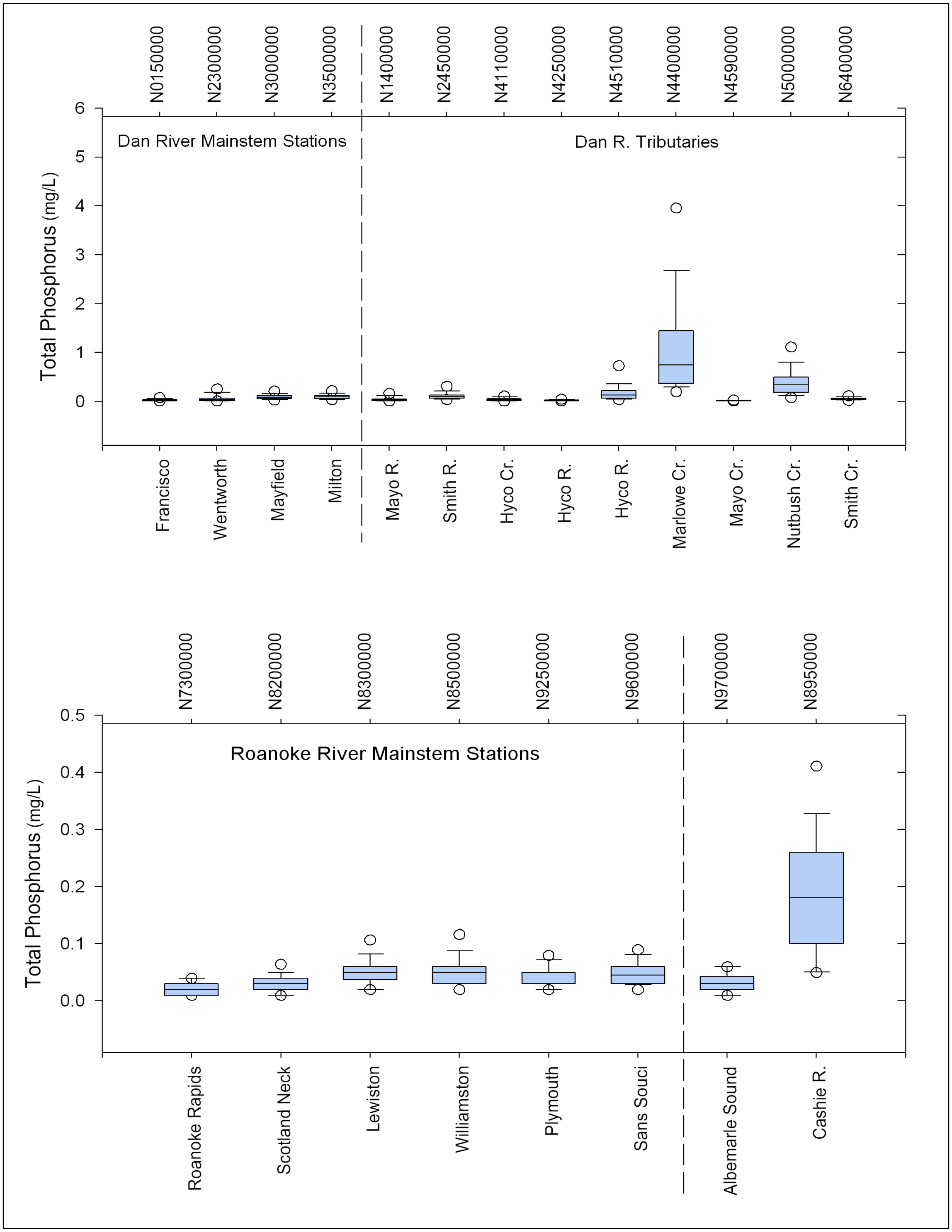

Figure 65. Box plots of total phosphorus in the Roanoke River basin, 1980 - 1999.

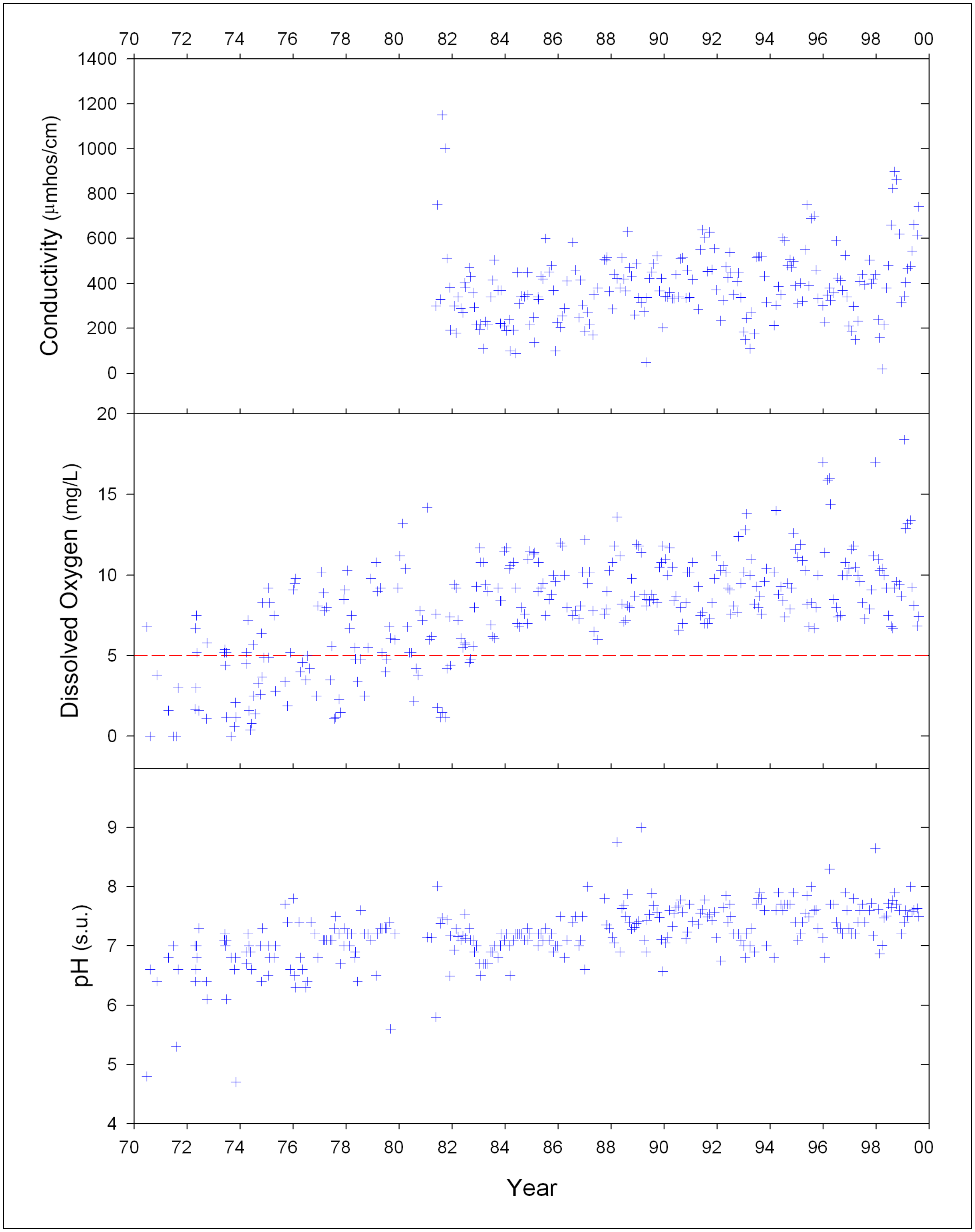

Figure 66. Temporal patterns of conductivity, dissolved oxygen, and pH at Nutbush Creek near Henderson (Station N5000000). Dashed line represents water quality standard.

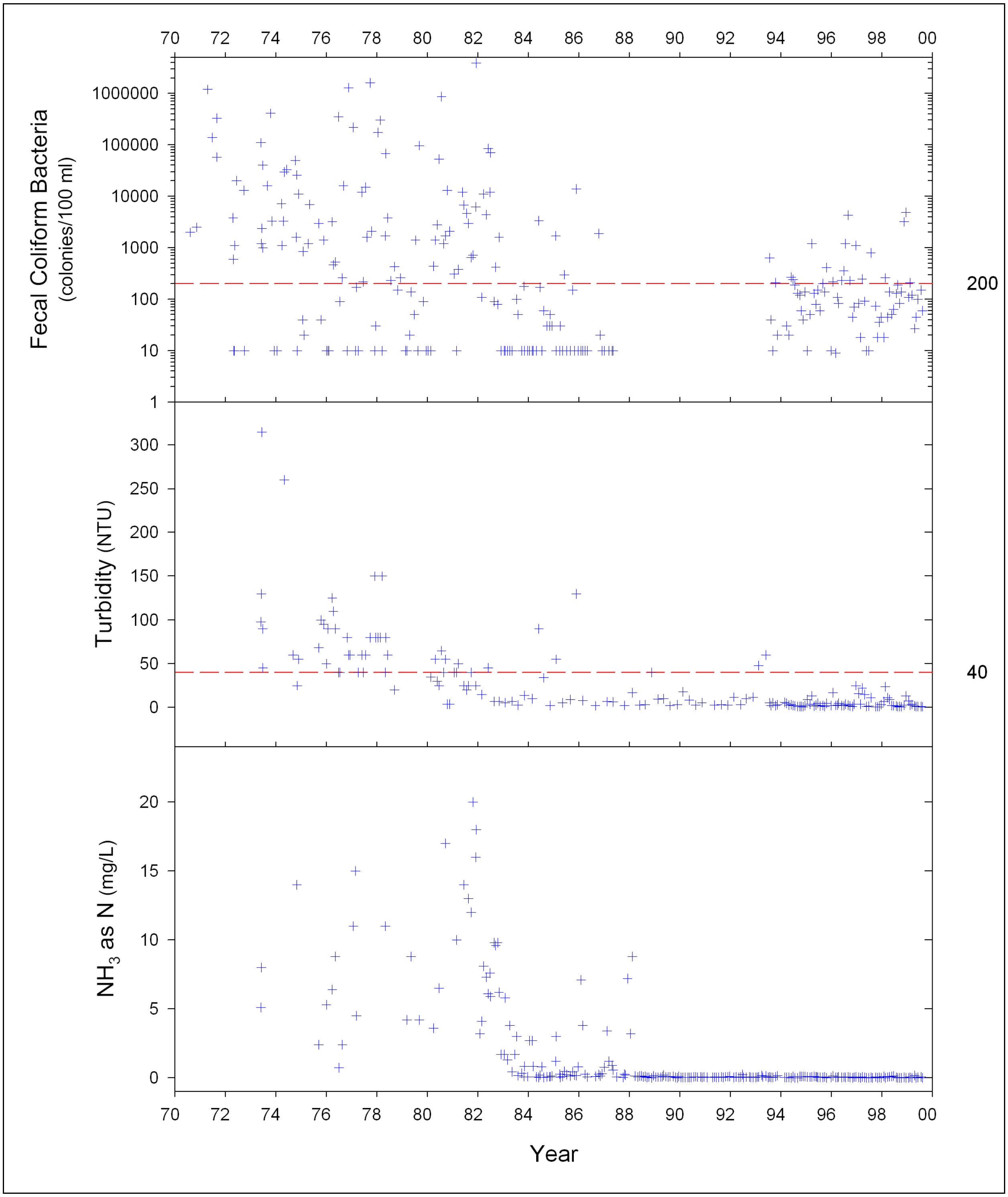

Figure 67. **Temporal patterns of fecal coliform bacteria, turbidity and ammonia as nitrogen (NH_3) at Nutbush Creek near Henderson (Station N5000000). Dashed lines at 200 colonies/100ml and 40 NTU represent the reference levels or standards.**

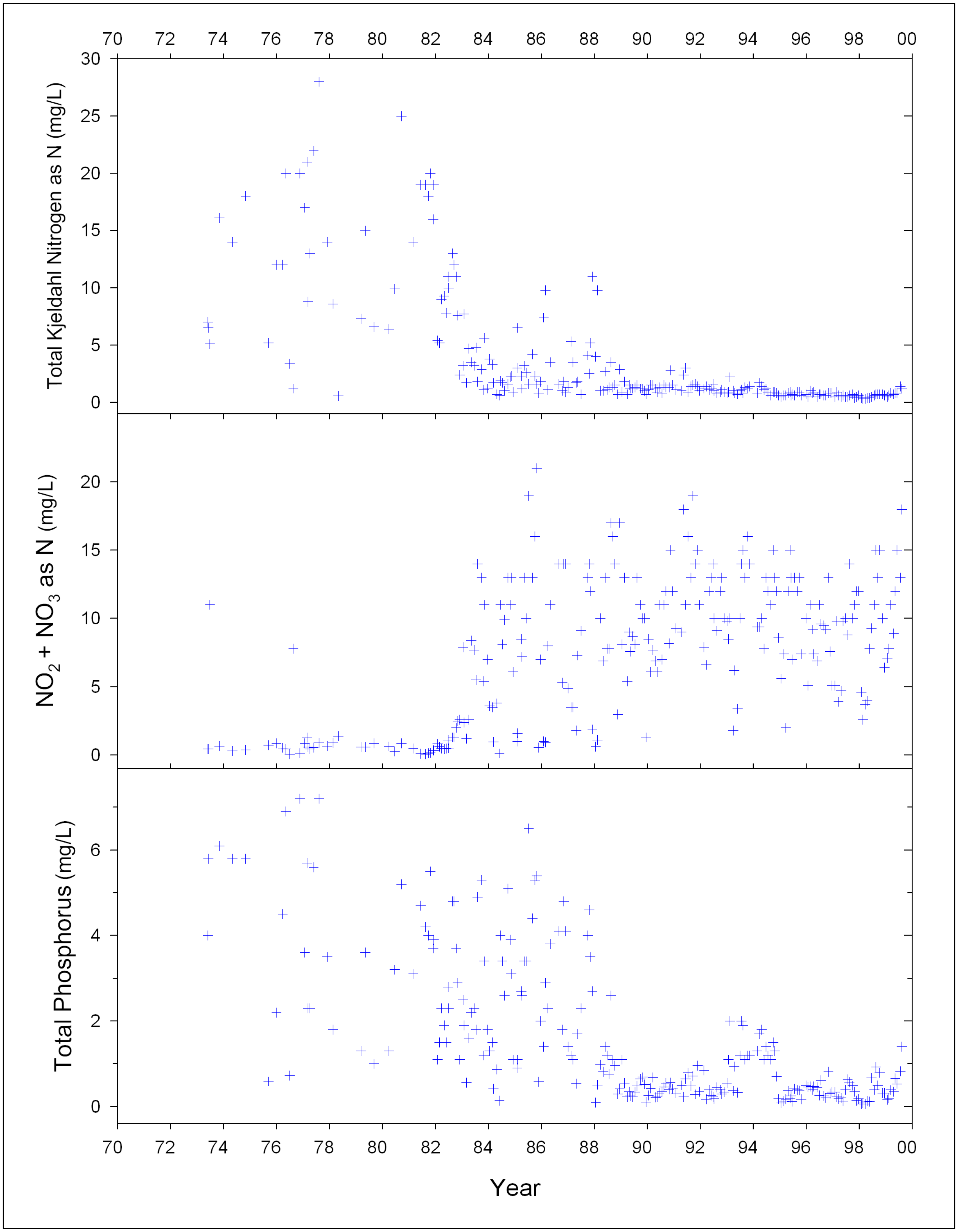

Figure 68. **Temporal patterns of total Kjeldahl nitrogen, nitrite+nitrate (NO_2+NO_3) as nitrogen, and total phosphorus at Nutbush Creek near Henderson (Station N5000000).**

Aquatic Toxicity Monitoring

Twenty-nine facility permits in the Roanoke River basin currently require whole effluent toxicity (WET) monitoring (Figure 69 and Table 58).

Twenty-seven facility permits have a WET limit; the other two facilities have episodic discharges and their permits specify monitoring but with no limit.

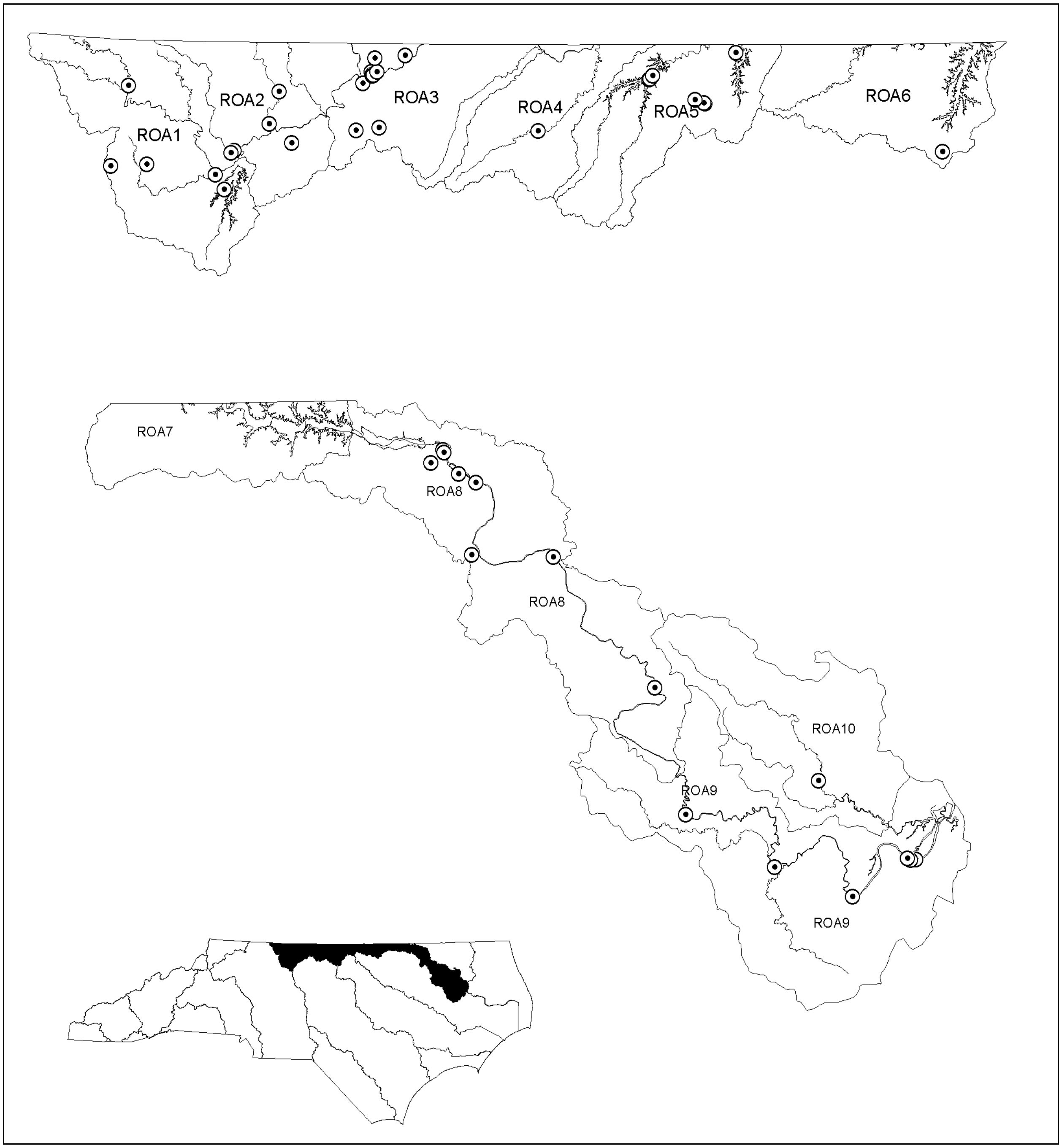

Figure 69. Facilities required to perform toxicity testing in the Roanoke River basin.

Table 58. Facilities in the Roanoke River basin required to perform whole effluent toxicity testing.

Subbasin/Facility	NPDES Permit No.	Receiving Stream	County	Flow (MGD)	IWC (%)	7Q10
01						
Briarwood Subdivision-Rayco Utilities	NC0028746/001	UT Brushy Fork Cr	Stokes	0.05	49	0.08
Duke Power-Belews Creek/003	NC0024406/003	Dan R	Stokes	7.7	33	24
Kobe Copper Products, Inc.	NC0035173/001	UT Dan R	Stokes	0.025	34	0.07
Stokes Co. Board Of Education	NC0044954/001	Little Neatman Cr	Stokes	0.017	9	0.27
Stokes Co. Board of Education	NC0044962/001	UT Dan R	Stokes	0.011	23	0.06
02						
Mayodan WWTP	NC0021873/001	Mayo R	Rockingham	3.0	6	75
Stoneville WWTP	NC0028011/001	Mayo R	Rockingham	0.250	0.66	58.6
03						
Duke Power-Dan River	NC0003468/002	Dan R	Rockingham	1.8	0.88	314
Eden WWTP/Mebane Bridge	NC0025071/001	Dan R	Rockingham	13.5	6.30	386
Eden-Dry Creek WWTP	NC0025151/001	Dan R	Rockingham	0.5	0.24	313
Miller Brewing Co.	NC0029980/001	Dan R	Rockingham	5.2	2.51	313
04						
Yanceyville WWTP	NC0040011/001	Country Line Cr	Caswell	0.45	37	1.2
05						
Cogentrix-Roxboro/003	NC0065081/003	UT Mitchell Cr	Person	Variable	100	0.0
CP&L-Mayo Steam Electric Plant	NC0038377/002	Mayo Reservoir	Person	NA	NA	NA
CP&L-Roxboro/003	NC0003425/003	Hyco Lake	Person	NA	NA	NA
CP&L-Roxboro/006	NC0003425/006	Hyco Lake	Person	NA	NA	NA
Roxboro WWTP	NC0021024/001	Marlowe Cr	Person	5.0	99.87	0.0
06						
Henderson Nutbush Cr. WWTP	NC0020559/001	Nutbush Cr	Vance	4.14	97	0.2
07						
Champion International Roanoke	NC0000752/001	Roanoke R	Halifax	28	4.2	1500
Dept. of Corrections (Caledonia)	NC0027626/001	Roanoke R	Halifax	0.8	0.12	1000
Halifax WWTP	NC0066192/001	Quankey Cr	Halifax	0.075	14	0.7
Panda-Rosemary Corp.	NC0079014/001	S. Sewer -UT Chockoyotte Cr	Halifax	0.054	100	0.0
Perdue Inc. Lewiston	NC0028835/001	Roanoke R	Bertie	3.0	0.42	1102
Roanoke Rapids WWTP	NC0024201/001	Chockoyotte Cr	Halifax	8.34	1.3	1000
Weldon WWTP	NC0025721/001	Roanoke R	Halifax	1.2	0.19	1000
08						
Alamac Knit Fabrics-Hamilton(WP Pepp)	NC0001961/001	Roanoke R	Martin	1.5	0.21	1122
Liberty Fabrics, Inc.	NC0023710/001	Roanoke R	Martin	0.45	0.06	1200
Weyerhaeuser-Plymouth(Roanoke)	NC0000680/001	Roanoke R	Martin	55	6.8	1160
Williamston WWTP	NC0020044/001	Roanoke R	Martin	2.0	0.26	1170
09						
Windsor WWTP	NC0026751/001	UT Cashie R	Bertie	1.15	100	0.0

The number of facilities monitoring for whole effluent toxicity has increased steadily since 1987, the first year that whole effluent toxicity limits were written into permits in North Carolina (Figure 70) In addition, the compliance rate of those facilities has risen since the inception of the program. Since 1993, the compliance rate has also stabilized at approximately 90-95% (Figure 70 and Table 59).

The Cogentrix Corporation's Roxboro plant (Subbasin 05) has experienced problems meeting its whole effluent toxicity limit in 1997 and the latter half of 1999. The 1997 failures were traced to a change in a water treatment chemical applied to the facility's cooling towers. The late 1999 toxicity problems are also associated with the facility's cooling tower blowdown discharge. Areas of investigation as of January 2000 include cooling tower chemicals and the Roxboro water supply.

The City of Henderson WWTP (Subbasin 06) has experienced problems with whole effluent toxicity for quite some time. The facility's Special Order by Consent (SOC) expired on September 30, 1999 and the City submitted an application for extension of the SOC. Toxicity reduction activities performed included refractory toxicity testing that targeted at least two industrial contributors as sources of toxicity.

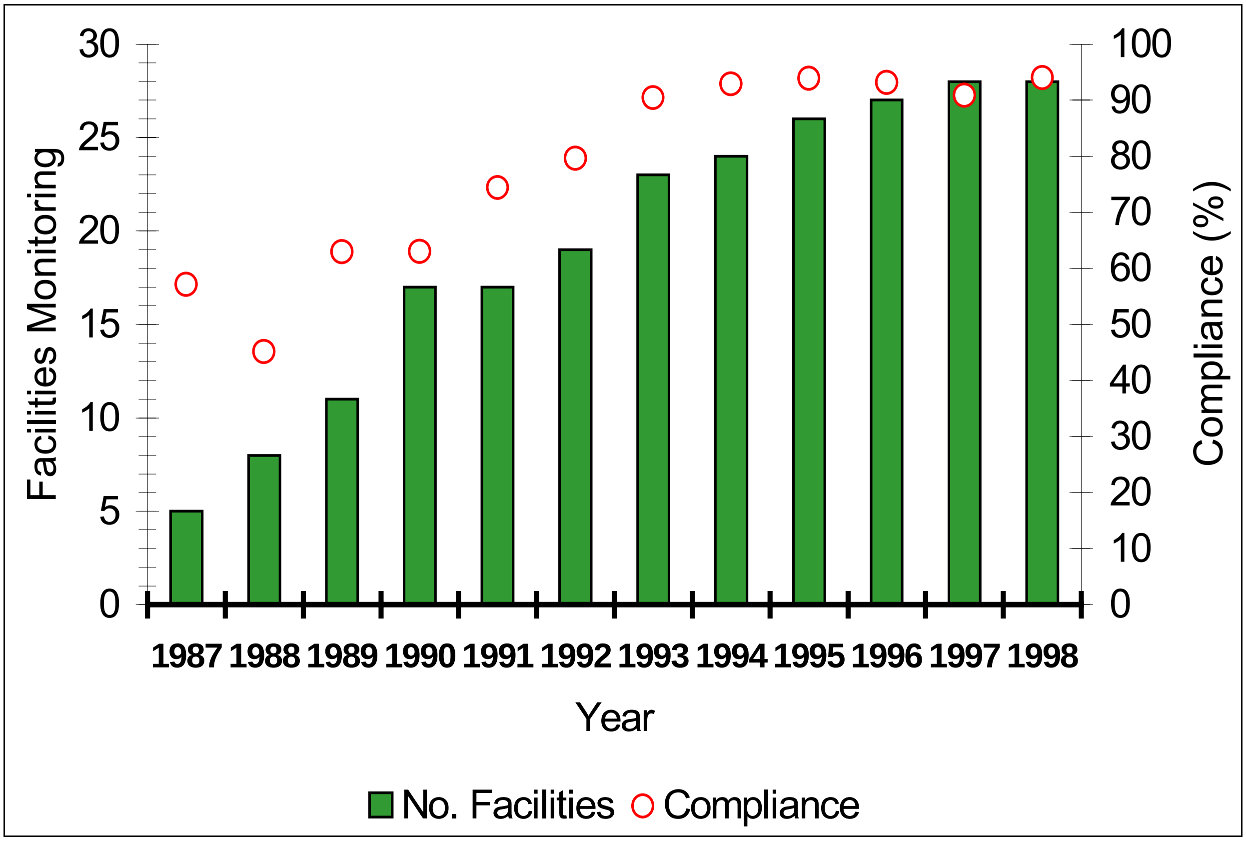

Figure 70. **Whole effluent toxicity monitoring in the Roanoke River basin, 1987-1998. The compliance values were calculated by determining whether a facility was meeting its ultimate permit limit during the given time period, regardless of any SOCs in force.**

Table 59. Compliance record of facilities performing whole effluent toxicity testing in the Roanoke River basin.

Subbasin/Facility	NPDES Permit No.	Pre 1999 Passes[1]	Pre 1999 Fails	1999 Passes	1999 Fails
01					
Briarwood Subdivision-Rayco Utilities	NC0028746/001	13	5	4	0
Duke Power-Belews Creek/003	NC0024406/003	36	1	4	0
Kobe Copper Products, Inc.	NC0035173/001	25	26	4	0
Stokes Co. Board Of Education	NC0044954/001	23	2	4	0
Stokes Co. Board of Education	NC0044962/001	8	3	4	1
02					
Mayodan WWTP	NC0021873/001	26	2	2	0
Stoneville WWTP	NC0028011/001	39	5	3	0
03					
Duke Power-Dan River	NC0003468/002	37	0	3	0
Eden WWTP/Mebane Bridge	NC0025071/001	35	1	3	0
Eden-Dry Creek WWTP	NC0025151/001	33	2	4	0
Miller Brewing Co.	NC0029980/001	23	0	3	0
04					
Yanceyville WWTP	NC0040011/001	23	3	4	1
05					
Cogentrix-Roxboro/003	NC0065081/003	33	27	3	4
CP&L-Mayo Steam Electric Plant	NC0038377/002	11	0	4	0
CP&L-Roxboro/003	NC0003425/003	21	0	3	0
CP&L-Roxboro/006	NC0003425/006	9	0	1	0
Roxboro WWTP	NC0021024/001	43	11	3	0
06					
Henderson Nutbush Cr WWTP	NC0020559/001	39	92	3	8
08					
Champion International Roanoke	NC0000752/001	40	0	3	0
Dept of Corrections (Caledonia)	NC0027626/001	26	4	4	0
Halifax WWTP	NC0066192/001	24	4	4	1
Panda-Rosemary Corp.	NC0079014/001	11	7	0	1
Perdue Inc. Lewiston	NC0028835/001	40	7	4	0
Roanoke Rapids WWTP	NC0024201/001	24	0	4	0
Weldon WWTP	NC0025721/001	17	1	4	0
09					
Alamac Knit Fabrics-Hamilton(WP Pepp)	NC0001961/001	52	12	3	0
Liberty Fabrics, Inc.	NC0023710/001	39	28	3	0
Weyerhaeuser-Plymouth(Roanoke)	NC0000680/001	36	1	4	0
Williamston WWTP	NC0020044/001	34	4	3	0
10					
Windsor WWTP	NC0026751/001	30	16	4	3

[1]Note that "pass" denotes meeting a permit limit or, for those facilities with a monitoring requirement, meeting a target value. The actual test result may be a "pass" (from a pass/fail acute or chronic test), LC_{50}, or chronic value. Conversely, "fail" means failing to meet a permit limit or target value.

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GLOSSARY

7Q10	A value which represents the lowest average flow for a seven day period that will recur on a ten year frequency. This value is applicable at any point on a stream. 7Q10 flow (in cfs) is used to allocate the discharge of toxic substances to streams.
Bioclass	Criteria have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample based on the number of taxa present in the intolerant groups (EPT) and the Biotic Index value.
cfs	Cubic feet per second, generally the unit in which stream flow is measured.
CHL *a*	Chlorophyll *a*.
Division	The North Carolina Division of Water Quality.
D.O.	Dissolved Oxygen.
Ecoregion	An area of relatively homogeneous environmental conditions, usually defined by elevation, geology, and soil type. Examples include mountains, piedmont, coastal plain, sandhills, and slate belt.
EPT	The insect orders (Ephemeroptera, Plecoptera, Trichoptera); as a whole, the most intolerant insects present in the benthic community.
EPT N	The abundance of Ephemeroptera, Plecoptera, Trichoptera insects present, using values of 1 for Rare, 3 for Common and 10 for Abundant.
EPT S	Taxa richness of the insect orders Ephemeroptera, Plecoptera and Trichoptera. Higher taxa richness values are associated with better water quality.
HQW	High Quality Waters.
IWC	Instream Waste Concentration. The percentage of a stream comprised of an effluent calculated using permitted flow of the effluent and 7Q10 of the receiving stream.
Major Discharger	Greater than or equal to one million gallons per day discharge (≥ 1 MGD).
MGD	Million Gallons per Day, generally the unit in which effluent discharge flow is measured.
Minor Discharger	Less than one million gallons per day discharge (< 1 MGD).
NPDES	National Pollutant Discharge Elimination System.
NCBI (EPT BI)	North Carolina Biotic Index, EPT Biotic Index. A summary measure of the tolerance values of organisms found in the sample, relative to their abundance. Sometimes noted as the NCBI or EPT BI.
NCIBI	North Carolina Index of Biotic Integrity (NCIBI); a summary measure of the effects of factors influencing the fish community.
NSW	Nutrient Sensitive Waters.
NTU	Nephelometric Turbidity Unit.

GLOSSARY (continued)

ORW	Outstanding Resource Waters.
Parametric Coverage	A listing of parameters measured and reported.
SOC	A consent order between an NPDES permittee and the Environmental Management Commission that specifically modifies compliance responsibility of the permittee, requiring that specified actions are taken to resolve non-compliance with permit limits.
Total S (or S)	The number of different taxa present in a benthic macroinvertebrate sample.
UT	Unnamed tributary.
WWTP	Wastewater treatment plant.
Web Sites	Basinwide planning -- http://h2o.enr.state.nc.us/basinwide/basinwide/default.html
	Biological monitoring -- http://www.esb.enr.state.nc.us/bau.html
	Fish kills -- http://www.esb.enr.state.nc.us/fishkill/fishkill00.html
	North Carolina Administrative Code that relates to the Division of Water Quality and water quality protection -- http://h2o.enr.state.nc.us/rules/ruleindex.html

Appendix B1. Benthic macroinvertebrate sampling and criteria for freshwater wadeable and flowing waters.

Benthic macroinvertebrates can be collected using two sampling procedures. The Division's standard qualitative sampling procedure includes 10 composite samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leafpack sample, and visual collections from large rocks and logs (NCDEHNR 1997b).

An abbreviated method (4-sample EPT) includes one kick-net sample, one bank sweep, one leaf pack sample, and visual collections from large rocks and logs. Only EPT groups are collected and identified, and only EPT criteria are used to assign a bioclassification. "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera, insect groups that are generally intolerant of many kinds of pollution. Higher EPT taxa richness values usually indicate better water quality.

The purpose of these collections is to inventory the aquatic fauna and produce an indication of relative abundance for each taxon. Organisms are classified as Rare (1-2 specimens), Common (3-9 specimens), or Abundant (≥ 10 specimens).

Several data-analysis summaries (metrics) can be produced to detect water quality problems (Tables B1 – B3).

Table B1. Benthos classification criteria for flowing water systems in the mountain ecoregion.

Metric	Sample type	Bioclass	Score
EPT S	10-sample Qualitative	Excellent	> 41
		Good	32 - 41
		Good-Fair	22 - 31
		Fair	12 - 21
		Poor	0 - 11
	4-sample EPT	Excellent	> 35
		Good	28 - 35
		Good-Fair	19 - 27
		Fair	11 - 18
		Poor	0 - 10
Biotic Index (range 0 – 10)	10-sample Qualitative	Excellent	< 4.05
		Good	4.06 - 4.88
		Good-Fair	4.89 - 5.74
		Fair	5.75 - 7.00
		Poor	> 7.00

Table B2. Benthos classification criteria for flowing water systems in the piedmont ecoregion.

Metric	Sample type	Bioclass	Score
EPT S	10-sample Qualitative	Excellent	> 31
		Good	24 – 31
		Good-Fair	16 - 23
		Fair	8 – 15
		Poor	0 - 7
	4-sample EPT	Excellent	> 27
		Good	21 - 27
		Good-Fair	14 - 20
		Fair	7 - 13
		Poor	0 - 6
Biotic Index (range 0 – 10)	10-sample Qualitative	Excellent	< 5.19
		Good	5.19 - 5.78
		Good-Fair	5.79 - 6.48
		Fair	6.49 - 7.48
		Poor	> 7.48

Table B3. Benthos classification criteria for flowing water systems in the coastal plain ecoregion.

Metric	Sample type	Bioclass	Score
EPT S	10-sample Qualitative	Excellent	> 27
		Good	21 - 27
		Good-Fair	14 - 20
		Fair	7 - 13
		Poor	0 - 6
	4-sample EPT	Excellent	> 23
		Good	18 - 23
		Good-Fair	12 - 17
		Fair	6 –11
		Poor	0 - 5
Biotic Index (range 0 – 10)	10-sample Qualitative	Excellent	< 5.47
		Good	5.47 - 6.05
		Good-Fair	6.06 - 6.72
		Fair	6.73 - 7.73
		Poor	> 7.73

These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

EPT taxa richness (EPT S) is used with criteria to assign water quality ratings (bioclassifications). Water quality ratings also are based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI). Tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions.

Water quality ratings assigned with the biotic index numbers are combined with EPT taxa richness ratings to produce a final bioclassification, using criteria for Mountain. Piedmont, or Coastal Plain streams. EPT abundance (EPT N) and total taxa richness calculations also are used to help examine between-site differences in water quality. If the EPT taxa richness rating and the biotic index differ by one bioclassification, the EPT abundance value is used to determine the final site rating.

The expected EPT taxa richness values are lower in small high-quality mountain streams (< 4 m wide or with a drainage area < 3.5 mi^2). For these small mountain streams, an adjustment to the EPT taxa richness values is made prior to applying taxa richness criteria.

EPT taxa richness and biotic index values also can be affected by seasonal changes. Criteria for assigning bioclassification are based on summer sampling: June-September. For samples collected outside summer, EPT taxa richness can be adjusted by subtracting out winter/spring Plecoptera or other adjustment based on resampling of summer site. The biotic index values also are seasonally adjusted for samples outside the summer season.

Criteria have been developed to assign bioclassifications ranging from Poor to Excellent to each benthic sample. These bioclassifications primarily reflect the influence of chemical pollutants. The major physical pollutant, sediment, is not assessed as well by a taxa richness analysis.

Swamp Streams

Recent extensive work on swamp streams suggested that different criteria should be used for slow flowing, swamp-like systems. Draft swamp stream rating criteria evaluate a stream based on benthic macroinvertebrate data collected in winter, fish community data, and a habitat score. Benthos data collected outside of the winter high flow period are not used to assign ratings. At least two of the data types must be collected to assign a rating. Each of these components is assigned a point value of 10 (Good), 5 (Fair) or 1 (Poor), and the points are averaged to assign an overall site rating (OSR): Good-Excellent (>7.5), Fair-Good (5.0-7.5), Fair (2.0-4.9), and Poor (<2.0). Ratings for the benthos are based entirely on the biotic index value: Good < 6.99, Fair 7.75-7.00, Poor >7.75. Deep (nonwadeable) coastal rivers with little or no visible current have different EPT criteria (Coastal B) that are being used on a provisional basis until more data can be gathered.

The draft swamp criteria were developed after collecting data for over four years. That data appeared to indicate that the BI values could separate differences in impact, but only during winter high flow conditions. In the summer, all sites were too similar to provide meaningful data. However, even now, there has been insufficient sampling of reference swamp streams to use the ratings without reservation for such things as use support. It must be stressed that the criteria are draft and will remain so until we better evaluate such things as: year to year variation at reference swamp sites, variation among reference swamp sites, the effect of small changes in pH on the benthos community, whether the habitat evaluation can be improved, and the role fisheries data should play in the evaluation. In this light, the ratings should be used for comparative purposes only, and should not be used for use support. To this end, swamp streams are not rated in this report.

Flow Measurement

Changes in the benthic macroinvertebrate community are often used to help assess between-year changes in water quality. Some between-year changes in the macroinvertebrates, however, may be due largely to changes in flow. High flow years magnify the potential effects of nonpoint source runoff, leading to scour, substrate instability, and reduced periphyton. Low flow years may accentuate the effect of point source dischargers by providing less dilution of wastes.

For these reasons, all between-year changes in the biological communities are considered in light of flow conditions (high, low, or normal) for one month prior to the sampling date. Daily flow information is obtained from the closest available USGS monitoring site and compared to the long-term mean flows. High flow is defined as a mean flow > 140% of the long-term mean for that time period, usually July or August. Low flow is defined as a mean flow < 60% of the long-term mean, while normal flow is 60-140% of the mean. While broad scale regional patterns are often observed, there may be large geographical variation within the state, and large variation within a single summer period.

Habitat Evaluation

The Division has developed a habitat assessment form to better evaluate the physical habitat of a stream. The habitat score has a potential range of 1 - 100, based on evaluation of channel modification, amount of instream habitat, type of bottom substrate, pool variety, bank stability, light penetration, and riparian zone width. Higher numbers suggest better habitat quality, but no criteria have been developed to assign impairment ratings.

Appendix B2 **Benthic macroinvertebrate data collected in the Roanoke River basin, 1983 - 1999. Current basinwide monitoring sites have the Map Number bolded.**

Subbasin/Stream	Location	County	Map No.	Index No.	Date	S/ EPT S	NCBI/ EPT BI	Bio Class[1]
01								
Dan R	NC 704	Stokes	**B-1**	22-(1)	08/99	85/41	4.19/3.30	G
					08/94	57/28	3.84/3.51	G
					07/90	94/48	4.48/3.68	E
					07/88	89/38	4.06/2.98	G
					07/86	84/37	4.00/3.17	G
					08/84	86/36	4.66/3.58	G
Dan R	SR 1695	Stokes	**B-2**	22-8	08/99	72/37	4.57/3.95	G
					08/94	45/20	4.75/3.87	G-F
North Double Cr	SR 1504	Stokes	**B-3**	22-10	08/99	-/25	-/3.97	G-F
					08/94	-/17	-/4.63	F
UT Cascade Cr (family cabins)		Stokes	B-4		06/95	37/15	4.34/1.96	G-F
Cascade Cr	SR 2012	Stokes	B-5	22-12-(2)	06/95	54/26	2.96/1.98	G
					09/90	-/23	-/2.99	G-F
Cascade Cr	Near SR 1001	Stokes	B-6	22-12-(2)	03/91	-/26	-/2.94	G
					09/90	-/26	-/3.48	G
Cascade Cr (above swimming lake)		Stokes	B-7	22-12-1	06/95	69/31	3.35/1.77	E
					03/93	-/34	-/1.61	E
					08/91	-/26	-/1.59	G
					03/91	-/35	-/1.69	E
					09/90	-/22	-/1.88	G
Indian Cr (above trail)		Stokes	B-8	22-13-(1)	03/93	-/30	-/1.47	E
					03/91	-/25	-/1.38	G
Indian Cr (below trail)		Stokes	B-9	22-13-(1)	03/93	-/34	-/1.54	E
					03/91	-/27	-/1.22	E
					09/90	-/26	-/2.57	E
Indian Cr	SR 1001	Stokes	B-10	22-13-(2)	09/90	-/22	-/2.33	G
Indian Cr	SR 1487	Stokes	B-11	22-13-(2)	09/90	-/27	-/2.76	G
Snow Cr	SR 1673	Stokes	**B-12**	22-20	08/99	-/18	-/4.37	F
					08/94	-/22	-/4.00	G-F
Town Fk Cr	SR 1970	Stokes	B-13	22-25	09/95	-/7	-/5.95	P
Town Fk Cr	SR 1961	Stokes	B-14	22-25	09/95	89/26	5.17/4.77	G-F
Town Fk Cr	SR 1955	Stokes	B-15	22-25	09/95	-/26	-/4.69	G-F
Town Fk Cr	US 311	Stokes	B-16	22-25	02/88	-/19	-/4.43	G-F
Town Fk Cr	SR 1917	Stokes	B-17	22-25	08/94	-/15	-/4.59	G-F
					02/88	-/24	-/4.21	G-F
Neatman Cr	SR 1961	Stokes	B-18	22-25-6	09/95	-/29	-/4.27	G
UT Dan R,	US 311	Stokes	B-19	22-(28.5)	02/87	-/21	-/4.00	G-F
UT Dan R (near raceway)		Stokes	B-20	22-(28.5)	02/87	-/15	-/4.40	F
02								
Mayo R	SR 1358	Rockingham	**B-1**	22-30-(1)	08/99	70/32	4.26/3.44	G
					08/94	64/38	3.60/3.24	G
					08/89	79/42	4.78/4.02	G
					03/89	96/54	3.72/2.85	G
					07/87	87/40	4.78/4.10	G
					07/86	102/37	5.07/3.95	G
Mayo R	NC 770	Rockingham	B-2	22-30-(1)	03/89	-/37	-/3.49	G-F
Mayo R	US 220 Bus	Rockingham	B-3	22-30-(1)	03/89	-/44	-/3.29	G-F
Mayo R	NC 135	Rockingham	B-4	22-30-(10)	08/89	-/28	-/4.12	G
Mayo R	SR 2177	Rockingham	**B-5**	22-30-(10)	08/99	52/21	5.22/4.25	G-F
					09/94	71/33	4.70/4.33	G
03								
Dan R	SR 2150	Rockingham	B-1	22-(31.5)	08/89	64/26	5.50/4.66	G
					07/87	92/32	5.67/4.61	G
Dan R	SR 1761	Rockingham	B-2	22-(39)	08/91	55/26	5.07/4.30	E
					07/87	68/26	5.14/4.15	G
					07/86	61/20	5.87/4.64	G-F
					09/84	56/17	5.71/4.41	G-F
					08/83	65/22	5.53/4.70	G
Smith R (near NC/VA state line)	VA 922		B-3	22-40-(1)	09/84	63/21	5.74/4.42	G-F

Appendix B2 (continued).

Subbasin/Stream	Location	County	Map No.	Index No.	Date	S/ EPT S	NCBI/ EPT BI	Bio Class[1]
03								
Smith R	NC 14	Rockingham	**B-4**	22-40-(3)	09/99	51/18	5.23/3.67	F
					08/94	58/18	5.66/4.43	F
					07/90	81/31	5.52/4.18	G-F
					07/88	69/24	6.03/5.08	F
					07/86	57/18	6.14/4.71	F
Wolf Island Cr	NC 700	Caswell	B-5	22-48	07/88	82/24	5.81/4.82	G
					07/85	68/25	5.40/4.69	G
					08/83	76/24	5.52/4.53	G
UT Hogans Cr	VA 736	Pittsylvania	B-6	22-50	06/98	44/16	4.94/4.04	NR
					11/96	48/12	6.15/4.71	NR
UT Hogans Cr (above ponds)	Off SR 1503	Caswell	B-7	22-50	06/98	43/13	5.25/4.61	NR
					11/96	36/10	6.13/4.92	NR
UT Hogans Cr (below ponds)	Off SR 1503	Caswell	B-8	22-50	06/98	48/12	5.89/5.67	NR
					11/96	41/7	6.42/3.95	NR
Jones Cr	SR 2632	Rockingham	B-9	22-50-3	01/92	-/29	-/4.56	G
Jones Cr	SR 2571	Rockingham	B-10	22-50-3	12/87	83/27	5.55/4.50	G
04								
Dan R	NC 57	Caswell	**B-1**	22-39	08/99	66/32	5.42/4.54	G
Country Line Cr	NC 57	Caswell	B-2	22-56-(3.7)	08/94	-/14	-/4.42	G-F
					07/90	73/26	5.51/4.52	G
					07/87	78/26	5.77/4.95	G
					08/83	72/19	5.80/4.34	G-F
05								
Hyco Cr (North Hyco Cr)	US 158	Caswell	B-1	22-58-1	08/94	-/10	-/5.93	F
					07/90	65/20	5.91/5.27	G-F
					07/87	74/23	5.86/5.15	G-F
					07/86	78/21	5.88/5.07	G-F
Marlowe Cr	SR 1322	Person	**B-2**	22-58-12-6	08/99	53/9	6.34/5.74	F
					08/94	33/5	6.90/6.49	P
06								
Island Cr	SR 1445	Granville	B-1	23-4	08/94	-/17	-/5.10	G-F
L Island Cr	SR 1342	Vance	B-2	23-4-3	05/88	-/21	-/4.88	G-F
Nutbush Cr (above WWTP)	NC 39	Vance	B-3	23-8-(1)	11/94	58/12	6.89/6.13	F
					10/94	54/12	6.96/5.77	F
					05/88	44/6	7.40/6.75	F
Nutbush Cr (below WWTP)	Off NC 39	Vance	B-4	23-8-(1)	11/94	48/7	7.19/6.20	F
Nutbush Cr	SR 1317	Vance	**B-5**	23-8-(1)	08/99	41/8	6.72/6.75	F
					10/94	50/8	6.74/6.31	F
					08/94	44/8	6.83/6.88	F
					05/88	35/3	8.14/6.45	P
Anderson Swamp Cr	I-85	Vance	B-6	23-8-6-(1)	02/90	49/13	6.98/5.71	NR
UT Anderson Swamp Cr	US 1/158	Vance	B-7	23-8-6-(1)	02/90	18/2	7.55/7.75	NR
07								
Smith Cr	US 1	Warren	**B-1**	23-10	07/99	59/12	6.56/5.51	F
					08/94	53/6	6.94/6.15	F
					07/89	59/12	6.75/5.06	F
					07/86	56/10	6.22/5.13	F
					08/84	56/12	6.42/5.36	F
Sixpound Cr	SR 1306	Warren	**B-2**	23-13	07/99	54/14	5.50/5.04	G-F
					08/94	-/12	-/5.32	F
08								
Deep Cr	US 158	Halifax	**B-1**	23-24-(1)	07/99	58/11	6.40/5.17	NR
					08/94	64/13	6.36/5.70	F
Roanoke R (below Weldon)	US 158	Halifax	B-2	23-(26)	09/94	45/16	5.29/4.68	G
Roanoke R (boat access),		Halifax	**B-3**	23-(26)	03/99	76/28	5.26/4.36	G
Roanoke R	US 258	Halifax	**B-4**	23-(26)	07/99	41/19	5.21/4.76	G
					03/99	67/30	5.37/4.72	G
					09/94	45/16	4.90/4.28	G
					07/87	46/12	5.98/5.03	F
					07/85	49/16	5.92/4.88	G-F
Quankey Cr	NC 903	Halifax	**B-5**	23-30	02/99	40/9	6.66/5.92	NR
Quankey Cr	NC 561	Halifax	B-6	23-30	09/99	-/9	-/5.51	F
Quankey Cr (above WWTP)		Halifax	B-7	23-30	12/92	51/7	6.55/5.69	F
Quankey Cr (below WWTP)		Halifax	B-8	23-30	12/92	57/9	6.41/5.28	F

Appendix B2 (continued).

Subbasin/Stream	Location	County	Map No.	Index No.	Date	S/ EPT S	NCBI/ EPT BI	Bio Class[1]
08								
Oconeechee Cr	SR 1126	Northampton	**B-9**	23-31	02/99	22/4	6.48/6.85	NR
Conoconnara Swp	NC 561,	Halifax	**B-10**	23-33	02/99	31/5	6.44/6.80	NR
					07/84	39/3	7.49/6.26	NR
Kehukee Swp	SR 1804	Halifax	**B-11**	23-42	09/99	-/6	-/6.19	NR
					02/99	59/8	7.10/6.44	NR
09								
Roanoke R (below Hamilton),	NC 125/903	Martin	**B-1**	23-(26)	03/99	61/23	5.82/4.80	G-F
					09/94	51/19	5.21/4.39	G
Roanoke R (below Williamston)	US 17	Martin	**B-2**	23-(26)	07/99	45/17	5.96/4.77	G-F
					03/99	73/23	6.32/5.07	G-F
					09/94	53/17	5.70/4.80	G-F
Indian Cr	SR 1108	Bertie	B-3	23-47	03/97	30/1	7.40/7.78	NR
Conoho Cr	NC 125/903	Martin	**B-4**	23-49	02/99	29/3	7.28/7.56	NR
					08/94	23/0	7.49/-	NR
Conoho Cr	SR 1417	Martin	**B-5**	23-49	02/99	39/5	6.26/4.80	NR
Hardison Mill Cr	NC 171	Martin	**B-6**	23-50-3	02/99	24/2	7.69/7.65	NR
Hardison Mill Cr	SR 1528	Martin	**B-7**	23-50-3	02/99	27/3	7.28/7.65	NR
Deep Run Swp	NC 171	Martin	**B-8**	23-52-1-1	02/99	21/1	7.61/7.78	NR
Welch Cr	SR 1552	Martin	**B-9**	23-55	02/99	32/3	7.20/6.92	NR
Roanoke R	NC 45	Bertie	**B-10**	23-(53)	07/99	59/9	7.35/6.56	NR
					09/94	52/9	7.52/6.08	NR
					06/92	60/8	7.48/5.82	NR
					07/90	51/10	7.48/6.23	NR
					07/88	60/7	7.93/6.62	NR
					07/86	50/8	7.68/6.77	NR
					07/85	37/4	8.16/6.50	NR
					07/84	42/6	7.63/6.18	NR
					07/83	38/6	8.07/5.42	NR
Conaby Cr	SR 1114	Washington	B-11	23-56	04/94	68/5	7.015.89	NR
Conaby Cr	SR 1325	Washington	B-12	23-56	04/94	41/0	7.44/-	NR
10								
Cashie R (above WWTP)	off NC 11	Bertie	B-1	24-2-(1)	06/84	37/0	8.61/-	NR
Cashie R (below WWTP)	off NC 11	Bertie	B-2	24-2-(1)	06/84	41/0	8.39/-	NR
Cashie R	SR 1219	Bertie	**B-3**	24-2-(1)	02/99	41/6	7.47/7.23	NR
					06/84	43/2	8.247.00	NR
					07/83	34/2	8.54/7.00	NR
Cashie R	SR 1257	Bertie	**B-4**	24-2-(1)	02/99	34/7	6.78/6.09	NR
Hoggard Mill Cr	SR 1301	Bertie	**B-5**	24-2-6	02/99	46/7	6.74/6.37	NR
Wading Place Cr	NC 308	Bertie	**B-6**	24-2-8	03/99	35/3	7.35/7.42	NR
Roquist Swp	US 13/17	Bertie	**B-7**	24-2-8	02/99	31/4	6.98/5.48	NR
Cashie R	SR 1500	Bertie	B-8	24-2-(9)	09/94	56/9	8.10/6.34	NR

[1] E = Excellent, G = Good, G-F = Good-Fair, F = Fair, P = Poor, and NR = Not Rated.

Appendix FT1. Fish tissue criteria.

In evaluating fish tissue analysis results, several different types of criteria are used. Human health concerns related to fish consumption are screened by comparing results with federal Food and Drug Administration (FDA) action levels (USFDA 1980), Environmental Protection Agency (USEPA) recommended screening values, and criteria adopted by the North Carolina State Health Director (Table FT1). Individual parameter results which appear to be of potential human health concern are evaluated by the N.C. Division of Occupational and Environmental Epidemiology by request from the Water Quality Section.

The FDA levels were developed to protect humans from the chronic effects of toxic substances consumed in foodstuffs and thus employ a "safe level" approach to fish tissue consumption. Presently, the FDA has only developed metals criteria for mercury.

The US EPA has recommended screening values for target analytes which are formulated from a risk assessment procedure (USEPA 1995). These are the concentrations of analytes in edible fish tissue that are of potential public health concern. The DWQ compares fish tissue results with US EPA screening values to evaluate the need for further intensive site specific monitoring.

The North Carolina State Health Director has adopted a selenium limit of 5 µg/g for issuing an advisory. Although the USEPA has suggested a screening value of 0.7 ppt (pg/g) for dioxins, the State of North Carolina currently uses a value of 3.0 ppt in issuing an advisory.

Table FT1. Fish tissue criteria. All wet weight concentrations are reported in parts per million (ppm, µg/g), except for dioxin which is in parts per trillion (ppt, pg/g).

Contaminant	FDA Action Levels	US EPA Screening Values	NC Health Director
Metals			
Cadmium		10.0	
Mercury	1.0	0.6	
Selenium		50.0	5.0
Organics			
Aldrin	0.3		
Chlorpyrifos		30	
Total chlordane		0.08	
Cis-chlordane	0.3		
Trans-chlordane	0.3		
Total DDT[1]		0.3	
o,p DDD	5.0		
p, p DDD	5.0		
o,p DDE	5.0		
p,p DDE	5.0		
o,p DDT	5.0		
p,p DDT	5.0		
Dieldrin		0.007	
Dioxins (total)		0.7	3.0
Endosulfan (I and II)		60.0	
Endrin	0.3	3.0	
Heptachlorepoxide		0.01	
Hexachlorobenzene		0.07	
Lindane		0.08	
Mirex		2.0	
Total PCBs		0.01	
PCB-1254	2.0		
Toxaphene		0.1	

[1]Total DDT includes the sum of all its isomers and metabolites (i.e. p,p DDT, o,p DDT, DDE, and DDD).
[2]Total chlordane includes the sum of cis-and trans- isomers as well as nonachlor and oxychlordane.

Appendix FT2. **Wet weight concentrations of mercury (Hg), arsenic (As), and cadmium (Cd) in fish tissue from the Roanoke River basin, 1994 - 1999.**

Subbasin/ Site	County	Date	Species	Total Length (cm)	Weight (g)	Hg (µg/g)	As (µg/g)	Cd (µg/g)
03								
Dan River near Eden	Rockingham	08/31/1999	*Lepomis macrochirus*	16	77	0.05	ND[1]	ND[1]
			Ictalurus punctatus	35.5	358	0.10	ND	ND
			Moxostoma erythrurum	37.8	335	0.36	ND	ND
			Moxostoma erythrurum	33	387	0.17	ND	ND
			Moxostoma erythrurum	31.2	300	0.27	ND	ND
			Moxostoma erythrurum	33.5	378	0.23	ND	ND
			Moxostoma erythrurum	37.1	476	0.37	ND	ND
			Moxostoma erythrurum	34.3	426	0.17	ND	ND
			Micropterus salmoides	30	374	0.20	ND	ND
			Micropterus salmoides	28.2	304	0.13	ND	ND
			Micropterus salmoides	27.5	260	0.12	ND	ND
			Carpiodes cyprinus	38.2	796	0.29	ND	ND
			Lepomis auritus	16.3	88	0.07	ND	ND
			Lepomis auritus	13.2	44.2	0.10	ND	ND
			Lepomis microlophus	15.7	73.5	0.04	ND	ND
			Moxostoma erythrurum	37.8	414	0.22	ND	ND
			Ameiurus brunneus	30.1	369	0.03	ND	ND
			Ameiurus brunneus	31	346	0.03	ND	ND
			Ameiurus catus	29	334	0.16	ND	ND
06								
Kerr Lake at mouth of Nutbush Cr	Vance	05/20/1999	*Lepomis macrochirus*	18.4	125	0.12	ND	ND
			Esox niger	57	1552	0.39	ND	ND
			Esox niger	53	1219	0.31	ND	ND
			Micropterus salmoides	46.5	1470	0.56	ND	ND
			Micropterus salmoides	42	1121	0.51	ND	ND
			Micropterus salmoides	43.8	984	0.65	ND	ND
			Micropterus salmoides	38	671	0.41	ND	ND
			Micropterus salmoides	38.5	767	0.59	ND	ND
			Micropterus salmoides	31	500	0.35	ND	ND
			Micropterus salmoides	33.6	477	0.52	ND	ND
			Micropterus salmoides	30.5	412	0.34	ND	ND
			Micropterus salmoides	31.5	423	0.26	ND	ND
			Micropterus salmoides	29.5	401	0.28	ND	ND
			Lepomis microlophus	27.5	377	0.06	ND	ND
			Lepomis microlophus	26.8	419	0.11	ND	ND
			Lepomis microlophus	22	179	0.08	ND	ND
			Ameiurus catus	27	241	0.34	ND	ND
		01/28/1999	*Morone saxatilis*	70				
			Morone saxatilis	467				
			Morone saxatilis	48.2				
			Morone saxatilis	42.5				
			Morone saxatilis	73.2				
			Morone saxatilis	41				
			Morone saxatilis	77.1				
			Morone saxatilis	65				
			Morone saxatilis	44.6				
			Morone saxatilis	67				
			Morone saxatilis	41.7				
			Morone saxatilis	44.3				
			Morone saxatilis	74.8				
			Morone saxatilis	39.5				
			Morone saxatilis	42.4				
			Morone saxatilis	70.1				
			Morone saxatilis	72.2				
			Morone saxatilis	44.5				
			Morone saxatilis	78.2				

Appendix FT2 (continued).

Subbasin/ Site	County	Date	Species	Total Length (cm)	Weight (g)	Hg (µg/g)	As (µg/g)	Cd (µg/g)
07								
Lake Gaston near Henrico	Halifax	07/08/1999	*Lepomis macrochirus*	17.5	104.6	0.05	ND	ND
			Lepomis macrochirus	18.1	119.3	0.05	ND	ND
			Lepomis macrochirus	14.8	76.5	0.03	ND	ND
			Ictalurus punctatus	49.2	1096	0.05	ND	ND
			Ictalurus punctatus	48.2	1013	0.21	ND	ND
			Ictalurus punctatus	48.5	1172	0.05	ND	ND
			Ictalurus punctatus	43.5	804	0.10	ND	ND
			Ictalurus punctatus	47.8	1136	0.07	ND	ND
			Micropterus salmoides	25	212	0.07	ND	ND
			Micropterus salmoides	29.5	343	0.10	ND	ND
			Micropterus salmoides	31.1	423	0.07	ND	ND
			Micropterus salmoides	36.2	612	0.29	ND	ND
			Micropterus salmoides	42.6	962	0.37	ND	ND
			Micropterus salmoides	38.2	797	0.19	ND	ND
			Micropterus salmoides	37.4	728	0.14	ND	ND
			Micropterus salmoides	40.1	979	0.24	ND	ND
			Micropterus salmoides	45.3	1077	0.20	ND	ND
			Micropterus salmoides	45	1585	0.27	ND	ND
			Perca flavescens	19.7	87.3	0.05	ND	ND
			Perca flavescens	24.4	169	0.12	ND	ND
08								
Roanoke River at Weldon	Halifax	05/19/99	*Lepomis macrochirus*	14.9	66.6	0.07	ND	ND
			Lepomis macrochirus	15.7	77.5	0.06	ND	ND
			Pomoxis nigromaculatus	25.1	254	0.28	ND	ND
			Micropterus salmoides	43.1	1193	0.57	ND	ND
			Micropterus salmoides	40.7	1095	0.33	ND	ND
			Micropterus salmoides	38.2	657	0.43	ND	ND
			Micropterus salmoides	30.2	371	0.29	ND	ND
			Micropterus salmoides	32.3	412	0.43	ND	ND
			Micropterus salmoides	29.3	330	0.33	ND	ND
			Micropterus salmoides	25.3	244.5	0.23	ND	ND
			Micropterus salmoides	21.9	139.5	0.18	ND	ND
			Lepomis auritus	17	92	0.10	ND	ND
			Morone saxatilis	47.5	1256	0.20	ND	ND
			Morone saxatilis	43.8	986	0.21	ND	ND
			Morone saxatilis	45.3	907	0.24	ND	ND
			Morone saxatilis	42.8	732	0.20	ND	ND
			Morone saxatilis	39.7	661	0.19	ND	ND
			Morone saxatilis	43.1	1540	0.51	ND	ND
			Ameiurus catus	37.5	575	0.07	ND	ND
			Ameiurus catus	33.8	528	0.15	ND	ND
			Perca flavescens	23.8	188	0.17	ND	ND
		09/20/1995	*Amia calva*	39.5	621	0.13		
			Amia calva	42	686	0.13		
			Amia calva	46	992	0.11		
			Amia calva	53.5	1223	0.67		
			Amia calva	64	2701	0.68		
			Amia calva	57.5	2394	0.56		
		11/16/1994	*Amia calva*	62	2011	0.79	ND	ND
			Amia calva	71	3261	1.8	ND	ND
			Amia calva	59	1442	0.85	ND	ND
			Amia calva	59.5	1695	0.64	ND	ND
			Micropterus salmoides	35	617	0.16	ND	ND
			Micropterus salmoides	25	210	0.13	ND	ND
			Micropterus salmoides	23.5	176	0.13	ND	ND

Appendix FT2 (continued).

Subbasin/ Site	County	Date	Species	Total Length (cm)	Weight (g)	Hg (µg/g)	As (µg/g)	Cd (µg/g)
08								
Roanoke River at Scotland Neck	Halifax	05/19/99	*Amia calva*	58	1847	0.52	ND	ND
			Amia calva	55	1417	0.47	ND	ND
			Amia calva	60.1	2010	1.1	ND	ND
			Amia calva	50	1100	0.39	ND	ND
			Amia calva	54.9	1429	0.41	ND	ND
			Amia calva	49.5	1349	0.57	ND	ND
			Lepomis macrochirus	17.5	116	0.14	ND	ND
			Ictalurus punctatus	54.8	1654	0.15	ND	ND
			Ictalurus punctatus	43.5	641	0.10	ND	ND
			Micropterus salmoides	40.2	966	0.71	ND	ND
			Micropterus salmoides	32.5	533	0.46	ND	ND
			Micropterus salmoides	31.2	412	0.52	ND	ND
			Lepomis auritus	18.9	167	0.06	ND	ND
			Morone saxatilis	49	1245	0.26	ND	ND
			Morone saxatilis	45.2	1004	0.28	ND	ND
			Morone saxatilis	48	1128	0.20	ND	ND
			Morone saxatilis	47	1082	0.11	ND	ND
			Morone saxatilis	45	1054	0.18	ND	ND
			Morone saxatilis	43.2	835	0.15	ND	ND
			Morone saxatilis	43.5	901	0.10	ND	ND
			Morone saxatilis	41.1	652	0.26	ND	ND
			Ameiurus catus	36	712	0.42	ND	ND
			Ameiurus catus	28.7	305.5	0.19	ND	ND
09								
Roanoke River at Plymouth	Washington	07/21/1999	*Amia calva*	55.5	1738	0.56	ND	ND
			Amia calva	52.5	1321	0.47	ND	ND
			Amia calva	45.7	837	0.50	ND	ND
			Amia calva	42.5	690	0.31	ND	ND
			Lepomis macrochirus	17.9	133.6	0.07	ND	ND
			Esox niger	47.8	640	0.64	ND	ND
			Micropterus salmoides	41.6	1165	0.44	ND	ND
			Micropterus salmoides	44.1	1282	0.53	ND	ND
			Micropterus salmoides	39.3	924	0.68	ND	ND
			Micropterus salmoides	37.6	759	0.48	ND	ND
			Micropterus salmoides	37.2	797	0.40	ND	ND
			Micropterus salmoides	37.1	821	0.64	ND	ND
			Micropterus salmoides	39	619	0.84	ND	ND
			Micropterus salmoides	37.6	703	0.49	ND	ND
			Micropterus salmoides	33.2	484	0.42	ND	ND
			Micropterus salmoides	28.9	342	0.45	ND	ND
			Micropterus salmoides	36.2	639	0.36	ND	ND
			Lepomis microlophus	25.5	313	0.13	ND	ND
			Lepomis microlophus	26.1	338	0.22	ND	ND
			Lepomis microlophus	19.4	140	0.12	ND	ND
			Perca flavescens	23.6	190.3	0.20	3.9	ND
			Perca flavescens	20.1	119	0.16	ND	ND
		07/06/1995	*Amia calva*	44.8	900	0.43		
			Amia calva	54	1500	0.37		
			Amia calva	54.7	1700	0.45		
			Amia calva	52.1	1200	0.6		
			Amia calva	67.1	3000	1		
			Amia calva	69.5	3500	1.5		
			Amia calva	72.6	3900	1.2		

Appendix FT2 (continued).

Subbasin/ Site	County	Date	Species	Total Length (cm)	Weight (g)	Hg (µg/g)	As (µg/g)	Cd (µg/g)
09								
Roanoke River at US-17	Martin	07/06/1999	*Amia calva*	57.3	1815	0.65	ND	ND
			Amia calva	57	1959	0.76	ND	ND
			Amia calva	65.1	2633	1.3	ND	ND
			Lepomis macrochirus	23	290	0.30	ND	ND
			Lepomis macrochirus	18.8	150.5	0.30	ND	ND
			Lepomis macrochirus	17.6	132	0.17	ND	ND
			Lepomis macrochirus	16.8	99	0.27	ND	ND
			Micropterus salmoides	44.8	1226	1.3	ND	ND
			Micropterus salmoides	42.1	1090	1.4	ND	ND
			Micropterus salmoides	36.5	853	0.86	ND	ND
			Micropterus salmoides	39.7	894	0.94	ND	ND
			Micropterus salmoides	37.1	850	0.76	ND	ND
			Micropterus salmoides	35.1	692	0.94	ND	ND
			Micropterus salmoides	33	574	0.82	ND	ND
			Micropterus salmoides	33.8	704	0.75	ND	ND
			Micropterus salmoides	33	525	0.68	ND	ND
			Micropterus salmoides	26.4	253	0.44	ND	ND
			Micropterus salmoides	22.5	155	0.35	ND	ND
			Lepomis microlophus	20.9	187	0.19	ND	ND
			Ameiurus catus	38	768	0.64	ND	ND
			Ameiurus catus	35	588	0.67	ND	ND
			Ameiurus catus	36.2	610	0.39	ND	ND
			Ameiurus catus	33.1	518	0.67	ND	ND
			Ameiurus catus	33.2	408	0.31	ND	ND
		07/06/1995	*Amia calva*	51.1	110	0.85		
			Amia calva	53	1200	0.84		
			Amia calva	54.5	1300	0.85		
			Amia calva	53.3	1300	0.84		
			Amia calva	54.1	1200	0.98		
			Amia calva	69.5	2800	2.4		
			Amia calva	58.1	1700	1.2		
			Amia calva	67.3	2400	2.2		
		11/14/1994	*Micropterus salmoides*	32	436	0.62	ND	ND
			Micropterus salmoides	40	945	0.82	ND	ND
			Micropterus salmoides	44	1369	0.93	ND	ND
			Micropterus salmoides	51	2056	1.4	ND	ND
		06/16/1994	*Amia calva*	56	1878	0.43		
			Amia calva	51	1345	0.38		
			Amia calva	51	1442	0.57		
			Amia calva	53.3	1507	0.64		
			Amia calva	53	1619	0.59		
			Amia calva	62	2102	1.3		
			Amia calva	65	2672	0.93		
			Amia calva	53.5	1669	0.47		
			Amia calva	61.5	1914	2		
			Amia calva	61	2202	1.3		
			Amia calva	57	1747	0.82		
			Amia calva	66.5	2851	1.1		
			Amia calva	65	2316	1.4		
			Amia calva	69.5	3030	1.5		
			Amia calva	68	2687	2		
			Amia calva	74	3295	2.5		
			Amia calva	68	3030	1.5		
			Amia calva	75.5	4039	2.9		
			Ameiurus nebulosus	40	890	0.13		
			Ameiurus nebulosus	38.5	859	0.18		
			Ameiurus nebulosus	37.7	779	0.24		
			Ameiurus nebulosus	36.5	887	0.17		
			Micropterus salmoides	30	400	0.44		
			Micropterus salmoides	33	460	0.23		
			Micropterus salmoides	29.5	408	0.22		
			Micropterus salmoides	33.5	495	0.69		

Appendix FT2 (continued).

Subbasin/ Site	County	Date	Species	Total Length (cm)	Weight (g)	Hg (µg/g)	As (µg/g)	Cd (µg/g)
09								
Roanoke River at US-17	Martin	06/16/1994	*Micropterus salmoides*	33	595	0.43		
			Micropterus salmoides	34.5	733	0.61		
			Micropterus salmoides	35.5	804	0.76		
			Micropterus salmoides	37	812	0.76		
			Micropterus salmoides	35	658	0.98		
			Micropterus salmoides	32.5	565	0.64		
			Micropterus salmoides	35.5	803	0.7		
			Micropterus salmoides	39	1032	0.97		
			Micropterus salmoides	41.5	1178	0.86		
			Micropterus salmoides	45	1286	0.63		
			Micropterus salmoides	44	1361	0.88		
10								
Cashie River at Windsor	Bertie	07/21/1999	*Amia calva*	54.5	1426	1.5	ND	ND
			Amia calva	53	1495	1.5	ND	ND
			Amia calva	53	1468	1.3	ND	ND
			Amia calva	50.5	1239	1.0	ND	ND
			Amia calva	41	663	0.69	ND	ND
			Amia calva	41.5	649	0.67	ND	ND
			Lepomis macrochirus	22.1	202	0.68	ND	ND
			Lepomis macrochirus	16.8	205	0.31	ND	ND
			Lepomis macrochirus	15.5	78	0.20	ND	ND
			nigromaculatus	22.1	183.5	0.45	ND	ND
			nigromaculatus	19.9	118	0.24	ND	ND
			Ameiurus nebulosus	37.5	694.3	0.17	ND	ND
			Esox niger	39.6	435	0.80	ND	ND
			Micropterus salmoides	50.7	2201	1.4	ND	ND
			Micropterus salmoides	51.5	2185	1.9	ND	ND
			Micropterus salmoides	42	1088	0.64	ND	ND
			Micropterus salmoides	33.7	503	1.1	ND	ND
			Micropterus salmoides	29	350	0.58	ND	ND
			Micropterus salmoides	30.1	420	0.44	ND	ND
			Micropterus salmoides	27	285	0.42	ND	ND
			Micropterus salmoides	29.8	325	0.65	ND	ND
			Micropterus salmoides	27.4	279	0.44	ND	ND
			Micropterus salmoides	25.1	219	0.49	ND	ND
			Ameiurus natalis	32.3	498	0.56	ND	ND

[1]ND = non detect; detection level for arsenic = 1.0 µg/g and for cadmium = 0.1 µg/g.

Appendix FT3. **Wet weight concentrations of chromium, copper (Cu), lead, nickel, and zinc (Zn) in fish tissue from the Roanoke River basin, November 14 and 16, 1994.**[1]

Subbasin Site	County	Date	Species	Total Length (cm)	Weight (g)	Cu (µg/g)	Zn (µg/g)
03							
Roanoke River at Weldon	Halifax	11/16/1994	*Amia calva*	62	2011	1.2	4.2
			Amia calva	71	3261	0.62	4.7
			Amia calva	59	1442	0.61	5.1
			Amia calva	59.5	1695	0.52	4.7
			Micropterus salmoides	35	617	0.37	4.7
			Micropterus salmoides	25	210	0.39	8.5
			Micropterus salmoides	23.5	176	0.48	7
Roanoke River at US-17	Martin	11/14/1994	*Micropterus salmoides*	32	436	0.26	5.4
			Micropterus salmoides	40	945	0.29	4.8
			Micropterus salmoides	44	1369	0.19	3.7
			Micropterus salmoides	51	2056	0.2	3.8

[1]All total chromium, lead, and nickel concentrations were less than the detection levels of 0.25, 0.5, and 0.5 µg/g; respectively.

Appendix FT4. **Wet weight concentrations of PCBs in fish tissue from John H. Kerr Reservoir at the mouth of Nutbush Creek, Vance County.**

Date Sampled	Species	Total Length (mm)	Weight (g)	PCB (µg/g)[1]
01/28/1999	*Morone saxatilis*	467	---	ND
01/28/1999	*Morone saxatilis*	482	---	ND
01/28/1999	*Morone saxatilis*	425	---	ND
01/28/1999	*Morone saxatilis*	732	---	ND
01/28/1999	*Morone saxatilis*	410	---	ND
01/28/1999	*Morone saxatilis*	771	---	ND
01/28/1999	*Morone saxatilis*	650	---	ND
01/28/1999	*Morone saxatilis*	446	---	ND
01/28/1999	*Morone saxatilis*	670	---	ND
01/28/1999	*Morone saxatilis*	417	---	ND
01/28/1999	*Morone saxatilis*	443	---	ND
01/28/1999	*Morone saxatilis*	748	---	ND
01/28/1999	*Morone saxatilis*	395	---	ND
01/28/1999	*Morone saxatilis*	424	---	ND
01/28/1999	*Morone saxatilis*	701	---	ND
01/28/1999	*Morone saxatilis*	722	---	ND
01/28/1999	*Morone saxatilis*	445	---	ND
01/28/1999	*Morone saxatilis*	782	---	0.162
01/28/1999	*Morone saxatilis*	700	---	0.222
05/20/1999	*Micropterus salmoides*	465	1470	ND
05/20/1999	*Micropterus salmoides*	420	1121	ND
05/20/1999	*Micropterus salmoides*	438	984	ND
05/20/1999	*Micropterus salmoides*	380	671	ND
05/20/1999	*Micropterus salmoides*	385	767	ND

[1]ND = not detected; detection level was 0.125 µg/g.

Appendix L1. Lake Assessment Program

Numerical indices are often used to evaluate the trophic state of lakes. An index was developed specifically for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NCDNRCD 1982). The North Carolina Trophic State Index (NCTSI) is based on total phosphorus (TP in mg/l), total organic nitrogen (TON in mg/l), Secchi depth (SD in inches), and chlorophyll *a* (CHL in µg/L). Lakewide means for these parameters are used to produce a NCTSI score for each lake, using the equations:

$$TON_{Score} = ((\text{Log}\ (TON) + 0.45)/0.24)*0.90$$

$$TP_{Score} = ((\text{Log}\ (TP) + 1.55)/0.35)*0.92$$

$$SD_{Score} = ((\text{Log}\ (SD) - 1.73)/0.35)*-0.82$$

$$CHL_{Score} = ((\text{Log}\ (CHL) - 1.00)/0.48)*0.83$$

$$NCTSI = TON_{Score} + TP_{Score} + SD_{Score} + CHL_{Score}$$

In general, NCTSI scores relate to trophic classifications (Table L1). When scores border between classes, best professional judgment is used to assign an appropriate classification. NCTSI scores may be skewed by highly colored water typical of dystrophic lakes. Some variation in the trophic state of a lake between years is not unusual because of the potential variability of data collections which usually involve sampling a limited number of times during the growing season.

Table L1. Lakes classification criteria.

NCTSI Score	Trophic classification
< -2.0	Oligotrophic
-2.0 – 0.0	Mesotrophic
0.0 – 5.0	Eutrophic
> 5.0	Hypereutrophic

Lakes are classified for their “best usage” and are subject to the state’s water quality standards. Primary classifications are C (suited for aquatic life propagation /protection and secondary recreation such as wading), B (primary recreation, such as swimming, and all class C uses), and WS-I through WS-V(water supply source ranging from highest watershed protection level I to lowest watershed protection V, and all class C uses).

Lakes with a CA designation represent water supplies with watersheds that are considered Critical Areas (i.e., an area within 0.5 mile and draining to water supplies from the normal pool elevation of reservoirs, or within 0.5 mile and draining to a river intake).

Supplemental classifications may include SW (slow moving Swamp Waters where certain water quality standards may not be applicable), NSW (Nutrient Sensitive Waters subject to excessive algal or other plant growth where nutrient controls are required), HQW (High Quality Waters which are rated excellent based on biological and physical/chemical characteristics), and ORW (Outstanding Resource Waters which are unique and special waters of exceptional state or national recreational or ecological value). A complete listing of these water classifications and standards can be found in Title 15 North Carolina Administrative Code, Chapter 2B, Section .0100 and .0200.

Appendix L2. **Surface waters data collected from the lakes in the Roanoke River basin, 1994 - 1999.[1]**

Subbasin/Lake	Date	Station	Dissolved oxygen	Temperature	pH	Conductivity	Secchi depth
01							
Hanging Rock Lake	08/31/99	ROA003A	7.3	23.5	6.0	12	3.1
	07/20/99	ROA003A	7.8	27.7	7.8	19	3.8
	06/23/99	ROA003A	7.7	23.4	7.4	20	3.8
	08/30/94	ROA003A	8.0	24.1	6.1	14	3.8
Kernersville Reservoir	08/04/99	ROA0092A	7.6	30.6	7.6	103	1.1
	07/20/99	ROA0092A	8.1	28.6	7.1	98	1.5
	06/21/99	ROA0092A	7.5	22.0	7.0	96	0.8
	08/30/94	ROA0092A	7.9	27.2	7.3	89	1.0
Belews Lake	08/25/99	ROA009E	6.7	32.5	7.5	94	3.9
	08/25/99	ROA009G	6.6	31.4	7.6	93	4.1
	08/25/99	ROA009H	6.9	30.4	7.5	94	3.8
	08/25/99	ROA009J	5.5	35.0	7.5	94	3.8
	07/08/99	ROA009E		33.1	7.6	87	2.5
	07/08/99	ROA009G	7.4	31.0	7.5	90	3.2
	07/08/99	ROA009H	7.2	31.0	7.6	91	3.6
	07/08/99	ROA009J	7.2	35.3	7.6	90	3.1
	06/09/99	ROA009E	6.8	32.9	7.4	91	3.2
	06/09/99	ROA009G	7.4	31.1	7.5	90	3.1
	06/09/99	ROA009H	7.1	31.4	7.4	91	3.3
	06/09/99	ROA009J	6.7	34.6	7.4	91	3.1
	08/16/94	ROA009E	7.0	31.5	6.7	78	3.0
	08/16/94	ROA009G	7.4	29.8	6.7	79	2.5
	08/16/94	ROA009H	7.6	29.6	6.7	79	2.8
	08/16/94	ROA009J	6.8	32.6	7.2	78	2.5
04							
Farmer Lake	08/03/99	ROA027G	6.7	30.1	7.7	65	0.4
	08/03/99	ROA027J	7.8	30.0	8.0	86	1.8
	08/03/99	ROA027L	7.4	29.7	7.6	83	2.5
	07/07/99	ROA027G	8.4	31.6	8.1	98	0.7
	07/07/99	ROA027J	7.2	31.3	8.0	88	1.4
	07/07/99	ROA027L	7.6	31.3	7.2	82	2.0
	06/10/99	ROA027G	7.8	29.2	7.7	97	0.4
	06/10/99	ROA027J	8.6	28.8	7.9	83	1.7
	06/10/99	ROA027L	8.4	28.8	7.8	80	1.6
	08/23/94	ROA027G	9.1	26.9	7.6	72	0.4
	08/23/94	ROA027J	8.4	26.5	7.1	66	0.8
	08/23/94	ROA027L	7.7	26.5	6.9	66	1.1
05							
Hyco Lake	08/17/99	ROA030C	5.9	34.4	7.2	103	1.5
	08/17/99	ROA030E	6.7	33.6	7.4	103	1.8
	08/17/99	ROA030F	6.2	33.4	7.3	103	1.7
	08/17/99	ROA030G	6.4	32.0	7.4	102	1.9
	07/20/99	ROA030C	6.8	33.4	7.4	78	2.3
	07/20/99	ROA030E	7.3	32.3	7.5	78	2.5
	07/20/99	ROA030F	7.2	32.5	6.9	78	2.3
	07/20/99	ROA030G	7.3	31.4	7.0	78	2.5
	06/01/99	ROA030C	7.3	28.2	6.9	94	1.5
	06/01/99	ROA030E	8.0	27.8	6.9	93	1.7
	06/01/99	ROA030F	7.6	27.8	6.9	93	1.4
	06/01/99	ROA030G	7.8	27.1	6.9	92	1.8
	08/18/94	ROA030E	7.2	31.7	7.2	92	1.3
	08/18/94	ROA030F	6.9	31.2	7.2	92	1.4
	08/18/94	ROA030G	6.6	30.1	7.2	91	1.5

Appendix L2 (continued).

Subbasin/Lake	Date	Station	Dissolved oxygen	Temperature	pH	Conductivity	Secchi depth
05							
Lake Roxboro	08/03/99	ROA030DA	8.0	30.3	8.0	92	0.9
	08/03/99	ROA030DC	7.5	30.2	82.0	91	1.4
	08/03/99	ROA030DE	7.7	29.2	8.0	91	1.3
	07/07/99	ROA030DA	9.0	32.7	8.4	91	1.0
	07/07/99	ROA030DC	8.4	31.6	8.3	81	1.4
	07/07/99	ROA030DE	7.7	32.1	7.9	87	1.5
	06/10/99	ROA030DA	8.3	30.3	7.8	91	1.5
	06/10/99	ROA030DC	8.1	29.7	7.6	88	2.1
	06/10/99	ROA030DE	8.5	28.9	7.7	8.6	1.8
	08/04/94	ROA030DA	10.5	28.2	8.3	70	0.9
	08/04/94	ROA030DC	10.0	28.1	8.3	71	1.0
	08/04/94	ROA030DE	9.6	8.2	28.0	70	1.1
Roxboro Lake	08/17/99	ROA031C	9.9	30.1	8.9	89	0.6
	08/17/99	ROA031E	9.4	29.8	9.0	75	0.7
	08/17/99	ROA031H	9.2	30.3	9.0	75	0.8
	07/20/99	ROA031C	9.1	30.2	7.6	64	0.8
	07/20/99	ROA031E	9.7	30.5	8.0	57	0.8
	07/20/99	ROA031H	9.5	30.7	7.9	57	0.8
	06/08/99	ROA031C	8.1	28.0	7.7	72	0.8
	06/08/99	ROA031E	8.5	27.9	8.2	67	1.5
	06/08/99	ROA031H	8.6	18.3	8.2	66	1.9
	08/02/94	ROA031C	8.8	26.9	7.2	69	0.8
	08/02/94	ROA031E	10.2	28.2	8.4	64	1.2
	08/02/94	ROA031H	10.3	28.0	8.5	63	1.2
Mayo Reservoir	08/17/99	ROA0341A	7.9	29.6	7.8	92	2.6
	08/17/99	ROA0342A	7.7	29.3	7.7	94	2.7
	08/17/99	ROA0343A	7.8	29.3	7.7	99	3.5
	07/20/99	ROA0341A	8.3	29.6	7.2	7	2.4
	07/20/99	ROA0342A	8.0	29.6	7.4	71	2.6
	07/20/99	ROA0343A	8.5	29.2	7.2	75	2.9
	06/01/99	ROA0341A	9.4	24.6	7.2	81	2.4
	06/01/99	ROA0342A	9.1	24.8	7.7	84	2.3
	06/01/99	ROA0343A	9.0	25.3	7.2	87	3.5
	08/18/94	ROA0341A	7.3	27.2	7.2	80	2.2
	08/18/94	ROA0342A	7.1	26.9	7.7	83	2.8
	08/18/94	ROA0343A	7.6	26.8	7.3	86	3.7
06							
John H. Kerr Reservoir	08/12/99	ROA037A	7.4	30.2	8.1	130	0.8
	08/12/99	ROA037E	7.4	29.7	8.0	121	1.2
	08/12/99	ROA037I	7.4	29.1	7.9	121	2.1
	08/12/99	ROA037IJ	7.3	28.9	8.0	125	2.1
	07/13/99	ROA037A	9.0	28.3	8.2	118	1.5
	07/13/99	ROA037E	8.8	28.4	8.2	116	1.7
	07/13/99	ROA037I	8.5	28.3	8.1	116	2.3
	07/13/99	ROA037IJ	8.4	28.5	8.2	121	2.6
	06/08/99	ROA037A	8.5	22.5	8.4	130	0.8
	06/08/99	ROA037E	9.0	21.9	8.0	112	1.3
	06/08/99	ROA037I	8.9	22.4	8.1	110	1.9
	06/08/99	ROA037IJ	8.4	23.1	8.1	113	2.0
	08/09/94	ROA037A	7.9	26.5	7.8	101	1.0
	08/09/94	ROA037E	7.3	26.6	7.2	100	1.9
	08/09/94	ROA037I	7.1	26.4	7.2	103	2.3
	08/09/94	ROA037IJ	7.3	26.7	7.5	111	2.4

Appendix L2 (continued).

Subbasin/Lake	Date	Station	Dissolved oxygen	Temperature	pH	Conductivity	Secchi depth
07							
Lake Gaston	08/05/99	ROA0382A	3.6	24.5	6.7	121	2.0
	08/05/99	ROA038A	8.0	29.6	7.6	114	1.8
	08/05/99	ROA039	8.2	29.2	7.5	114	1.9
	08/05/99	ROA039B	8.5	29.3	8.2	113	2.1
	07/22/99	ROA0382A	3.7	23.7	6.8	115	1.8
	07/22/99	ROA038A	8.3	28.6	7.5	110	1.7
	07/22/99	ROA039	8.7	28.9	7.9	109	2.1
	07/22/99	ROA039B	8.4	29.5	7.9	108	2.4
	06/02/99	ROA0382A	6.7	17.6	7.9	114	1.2
	06/02/99	ROA038A	8.5	23.2	7.9	111	1.2
	06/02/99	ROA039	9.0	23.9	8.0	109	1.8
	06/02/99	ROA039B	8.9	24.2	8.4	108	2.2
	08/09/94	ROA0382A	3.1	23.7	7.1	123	1.6
	08/09/94	ROA038A	6.4	26.1	7.0	111	1.1
	08/09/94	ROA039	8.1	26.9	7.3	100	1.6
	08/09/94	ROA039B	7.3	26.5	7.1	97	2.2
08							
Roanoke Rapids Lake	08/05/99	ROA039C	6.4	27.2	6.9	114	1.7
	08/05/99	ROA039D	8.2	30.6	8.0	113	1.4
	08/05/99	ROA039E	7.9	30.8	7.8	113	1.8
	07/22/99	ROA039C	6.7	27.8	7.1	110	2.2
	07/22/99	ROA039D	8.4	30.0	7.8	109	2.2
	07/22/99	ROA039E	8.4	29.9	7.9	109	2.1
	06/02/99	ROA039C	8.4	23.3	8.4	108	2.0
	06/02/99	ROA039D	8.6	23.8	8.6	108	1.6
	06/02/99	ROA039E	9.1	24.1	9.0	109	1.5
	08/09/94	ROA039C	5.3	26.2	7.0	101	2.2
	08/09/94	ROA039D	7.5	26.8	7.1	98	1.7
	08/09/94	ROA039E	7.5	27.7	7.1	97	1.6

[1]Units of measure are dissolved oxygen (mg/l), temperature (^{o}C), pH (s.u.), conductivity (µmhos/cm), and Secchi depth (m).

Appendix L3. **Photic zone data collected from lakes in the Roanoke River basin, 1994 - 1999.[1]**

Subbasin/Lake	Date	Station	TP	TKN	NH_3	NO_x	TN	TON	TIN	Chl a	Total Solids	Susp. Solids	Turbidity
01													
Hanging Rock Lake	08/31/99	ROA003A	0.01	0.2	0.10	0.01	0.21	0.10	0.11	16	36	1.0	1.5
	07/20/99	ROA003A	0.02	0.2	0.07	< 0.01	0.21	0.13	0.08	18	13	2.0	1.4
	06/23/99	ROA003A	0.02	0.2	< 0.01	< 0.01	0.21	0.20	0.01	17	22	1.0	< 1.0
	08/30/94	ROA003A	0.02	0.3	0.09	0.05	0.35	0.21	0.14	10	55	7.0	3.6
Kernersville Res.	08/04/99	ROA0092A	0.03	0.4	< 0.01	< 0.01	0.41	0.40	0.01	35	83	7.0	6.2
	07/20/99	ROA0092A	0.03	0.2	0.08	< 0.01	0.21	0.12	0.09	—	61	8.0	3.8
	06/21/99	ROA0092A	0.03	0.5	0.11	0.01	0.51	0.39	0.21	82	81	6.0	10.0
	08/30/94	ROA0092A	0.04	0.4	0.08	0.36	0.76	0.32	0.44	4	100	10.0	9.9
Belews Lake	08/25/99	ROA009E	< 0.01	0.2	0.08	0.01	0.21	0.12	0.09	4	83	< 1.0	1.2
	08/25/99	ROA009G	0.01	0.2	0.08	0.01	0.21	0.12	0.21	7	89	< 1.0	1.2
	08/25/99	ROA009H	< 0.01	0.3	0.10	< 0.01	0.31	0.20	0.11	7	77	< 1.0	< 1.0
	08/25/99	ROA009J	0.01	0.3	0.08	0.03	0.33	0.22	0.11	5	67	1.0	< 1.0
	07/08/99	ROA009E	0.01	0.3	0.01	0.08	0.38	0.29	0.09	9	69	2.0	1.5
	07/08/99	ROA009G	< 0.01	0.1	< 0.01	< 0.01	0.11	0.10	0.01	9	74	2.0	1.6
	07/08/99	ROA009H	< 0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	8	76	1.0	1.5
	07/08/99	ROA009J	< 0.01	0.2	0.01	0.05	0.25	0.18	0.06	9	73	1.0	2.3
	06/09/99	ROA009E	< 0.01	0.2	0.02	0.06	0.26	0.18	0.08	3	60	< 1.0	1.1
	06/09/99	ROA009G	< 0.01	0.2	0.02	0.06	0.26	0.18	0.08	8	65	< 1.0	< 1.0
	06/09/99	ROA009H	0.01	0.2	0.02	0.06	0.26	0.18	0.08	2	65	2.0	1.2
	06/09/99	ROA009J	< 0.01	0.2	0.03	0.06	0.26	0.17	0.09	2	67	< 1.0	1.0
	08/16/94	ROA009E	0.01	0.2	0.05	0.10	0.30	0.15	0.15	< 1	77	< 1.0	1.0
	08/16/94	ROA009G	0.01	0.2	0.06	0.09	0.29	0.14	0.15	< 1	60	2.0	< 1.0
	08/16/94	ROA009H	0.02	0.2	0.04	0.09	0.29	0.16	0.13	< 1	100	< 1.0	< 1.0
	08/16/94	ROA009J	0.02	0.2	0.05	0.10	0.30	0.15	0.15	< 1	53	6.0	1.1
04													
Farmer Lake	08/03/99	ROA027G	0.07	0.4	< 0.01	< 0.01	0.41	0.40	0.01	71	150	66.0	24.0
	08/03/99	ROA027J	0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	31	82	1.0	4.2
	08/03/99	ROA027L	< 0.01	0.2	0.01	0.03	0.23	0.19	0.04	30	75	1.0	2.0
	07/07/99	ROA027G	0.03	0.4	< 0.01	0.01	0.41	0.40	0.02	46	120	22.0	11.0
	07/07/99	ROA027J	< 0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	28	82	7.0	3.4
	07/07/99	ROA027L	< 0.01	0.3	0.01	< 0.01	0.31	0.29	0.02	17	74	1.0	1.9
	06/10/99	ROA027G	0.06	0.3	0.01	< 0.01	0.31	0.29	0.02	10	95	22.0	1.4
	06/10/99	ROA027J	0.02	0.3	< 0.01	< 0.01	0.31	0.30	0.01	6	61	3.0	3.6
	06/10/99	ROA027L	0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01	8	54	3.0	2.1
	08/23/94	ROA027G	0.06	0.7	0.03	0.03	0.73	0.67	0.06	11	130	18.0	18.0
	08/23/94	ROA027J	0.03	0.3	0.02	0.01	0.31	0.28	0.03	4	110	5.0	3.9
	08/23/94	ROA027L	0.02	0.3	0.06	< 0.01	0.31	0.24	0.07	5	99	4.0	2.4
05													
Hyco Lake	08/17/99	ROA030C	< 0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	11	97	1.0	1.8
	08/17/99	ROA030E	< 0.01	0.4	0.12	< 0.01	0.41	0.28	0.13	17	91	1.0	1.7
	08/17/99	ROA030F	< 0.01	0.6	< 0.01	< 0.01	0.61	0.60	0.01	3	92	1.0	1.4
	08/17/99	ROA030G	< 0.01	0.3	0.02	< 0.01	0.31	0.28	0.03	8	95	4.0	1.4
	07/20/99	ROA030C	0.01	0.2	0.08	< 0.01	0.21	0.12	0.09	17	80	1.0	1.2
	07/20/99	ROA030E	0.02	0.4	0.01	< 0.01	0.41	0.39	0.02	34	75	4.0	1.8
	07/20/99	ROA030F	0.01	0.1	0.05	< 0.01	0.11	0.05	0.06	13	76	2.0	1.4
	07/20/99	ROA030G	0.01	0.1	0.06	< 0.01	0.11	0.04	0.07	12	70	1.0	1.2
	06/01/99	ROA030C	< 0.01	0.1	0.01	0.08	0.18	0.09	0.09		94	1.0	3.7
	06/01/99	ROA030E	< 0.01	0.3	< 0.01	0.04	0.34	0.30	0.05	4	94	1.0	2.6
	06/01/99	ROA030F	< 0.01	0.2	< 0.01	0.07	0.27	0.20	0.08	6	94	2.0	4.3
	06/01/99	ROA030G	< 0.01	0.1	< 0.01	0.08	0.18	0.10	0.09	3	95	3.0	3.5
	08/18/94	ROA030E	0.03	0.3	0.04	0.03	0.33	0.26	0.07	4	67	5	3.7
	08/18/94	ROA030F	0.03	0.2	0.06	0.09	0.29	0.14	0.15	2	80	4	4.5
	08/18/94	ROA030G	0.02	0.2	0.07	0.1	0.30	0.13	0.17	1	77	2	4.5

Appendix L3 (continued)[1].

Subbasin/Lake	Date	Station	TP	TKN	NH_3	NO_x	TN	TON	TIN	Chl a	Total Solids	Susp. Solids	Turbidity
05													
Lake Roxboro	08/03/99	ROA030DA	0.02	0.4	0.04	< 0.01	0.41	0.36	0.05	55	81	4.0	5.6
	08/03/99	ROA030DC	0.01	0.5	0.05	< 0.01	0.51	0.45	0.06	36	82	1.0	4.3
	08/03/99	ROA030DE	0.01	0.4	0.06	0.05	0.45	0.34	0.11	9	78	2.0	3.4
	07/07/99	ROA030DA	0.02	0.4	< 0.01	< 0.01	0.41	0.40	0.01	51	85	8.0	5.3
	07/07/99	ROA030DC	0.01	0.5	< 0.01	< 0.01	0.51	0.50	0.01	14	74	5.0	3.9
	07/07/99	ROA030DE	< 0.01	0.5	< 0.01	< 0.01	0.51	0.50	0.01	12	71	1.0	4.3
	06/10/99	ROA030DA	0.02	0.4	< 0.01	< 0.01	0.41	0.40	0.01	25	66	2.0	4.1
	06/10/99	ROA030DC	0.03	0.3	< 0.01	< 0.01	0.31	0.30	0.01	12	56	5.0	2.7
	06/10/99	ROA030DE	0.02	0.3	< 0.01	< 0.01	0.31	0.30	0.01	6	58	2.0	2.7
	08/04/94	ROA030DA	0.05	0.4	0.04	< 0.01	0.41	0.36	0.05	12	76	7	8.1
	08/04/94	ROA030DC	0.03	0.4	0.06	< 0.01	0.41	0.34	0.07	9	76	4	6.3
	08/04/94	ROA030DE	0.02	0.4	0.03	< 0.01	0.41	0.37	0.04	8	63	3	4.2
Roxboro Lake	08/17/99	ROA031C	< 0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	48	98	5.0	4.3
	08/17/99	ROA031E	< 0.01	0.5	0.07	< 0.01	0.51	0.43	0.08	51	81	3.0	3.6
	08/17/99	ROA031H	< 0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01	61	84	5.0	4.3
	07/20/99	ROA031C	0.03	0.3	0.05	< 0.01	0.31	0.25	0.06	87	67	3.0	5.3
	07/20/99	ROA031E	0.02	0.4	0.05	< 0.01	0.41	0.35	0.06	58	60	5.0	3.3
	07/20/99	ROA031H	0.02	0.4	0.06	0.03	0.43	0.34	0.09	46	64	5.0	4.8
	06/08/99	ROA031C	0.03	0.3	0.01	< 0.01	0.31	0.29	0.02	4	74	5.0	4.9
	06/08/99	ROA031E	0.02	0.3	0.01	< 0.01	0.31	0.29	0.02	1	65	3.0	2.2
	06/08/99	ROA031H	0.02	0.3	< 0.01	0.01	0.31	0.30	0.02	12	65	5.0	2.4
	08/02/94	ROA031C	0.05	0.5	0.14	< 0.01	0.51	0.36	0.15	9	66	4	5.0
	08/02/94	ROA031E	0.01	0.5	0.02	< 0.01	0.51	0.48	0.03	10	60	5	4.0
	08/02/94	ROA031H	0.01	0.5	0.03	< 0.01	0.51	0.47	0.04	10	59	4	3.6
Mayo Res.	08/17/99	ROA0341A	< 0.01	0.4	0.04	< 0.01	0.41	0.36	0.05	12	75	< 1	1.7
	08/17/99	ROA0342A	< 0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01	6	78	< 1	1.1
	08/17/99	ROA0343A	< 0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	7	80	< 1	< 1.0
	07/20/99	ROA0341A	0.01	0.2	0.06	< 0.01	0.21	0.14	0.07	8	58	1.0	1.9
	07/20/99	ROA0342A	0.01	0.3	0.05	< 0.01	0.31	0.25	0.06	7	50	1.0	< 1.0
	07/20/99	ROA0343A	0.01	0.2	0.05	< 0.01	0.21	0.15	0.06	9	65	1.0	1.4
	06/01/99	ROA0341A	< 0.01	0.1	< 0.01	< 0.01	0.11	0.10	0.01	1	73	< 1	1.0
	06/01/99	ROA0342A	< 0.01	0.1	< 0.01	0.01	0.11	0.10	0.02	3	73	< 1	1.4
	06/01/99	ROA0343A	< 0.01	0.1	< 0.01	< 0.01	0.11	0.10	0.01	4	78	< 1	1.3
	08/18/94	ROA0341A	0.02	0.2	0.06	0.02	0.22	0.14	0.08	3	56	2	1.6
	08/18/94	ROA0342A	0.01	0.1	0.07	0.02	0.12	0.03	0.09	2	55	< 1	1.0
	08/18/94	ROA0343A	0.01	0.1	0.05	0.02	0.12	0.05	0.07	< 1	60	2	< 1
06													
J. H. Kerr Res.	08/12/99	ROA037A	0.04	0.4	< 0.01	< 0.01	0.41	0.40	0.01	29	110	9.0	7.3
	08/12/99	ROA037E	0.01	0.4	0.07	< 0.01	0.41	0.33	0.08	32	90	5.0	4.3
	08/12/99	ROA037I	< 0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	14	87	2.0	2.6
	08/12/99	ROA037IJ	< 0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	14	120	6.0	2.3
	07/13/99	ROA037A	0.01	0.3	0.05	< 0.01	0.31	0.25	0.06	20	81	2.0	3.1
	07/13/99	ROA037E	0.01	0.4	0.04	< 0.01	0.41	0.36	0.05	23	85	2.0	2.3
	07/13/99	ROA037I	0.01	0.3	0.05	< 0.01	0.31	0.25	0.06	15	83	3.0	2.2
	07/13/99	ROA037IJ	0.01	0.4	0.03	< 0.01	0.41	0.37	0.04	28	73	2.0	1.2
	06/08/99	ROA037A	0.03	0.2	0.07	0.05	0.25	0.13	0.12	17	92	< 1	4.8
	06/08/99	ROA037E	0.01	0.2	0.04	< 0.01	0.21	0.20	0.05	7	90	< 1	3.2
	06/08/99	ROA037I	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	10	87	1.0	3.4
	06/08/99	ROA037IJ	0.03	0.1	< 0.01	< 0.01	0.11	0.10	0.01	8	100	< 1	3.3
	08/09/94	ROA037A	0.04	0.3	0.02	< 0.01	0.31	0.28	0.03	6	80	6.0	4.1
	08/09/94	ROA037E	0.02	0.2	0.04	0.03	0.23	0.16	0.07	2	89	3.0	2.3
	08/09/94	ROA037I	0.03	0.3	0.02	0.05	0.35	0.28	0.07	2	93	3.0	1.5
	08/09/94	ROA037IJ	0.02	0.3	< 0.01	0.03	0.33	0.30	0.04	2	92	3.0	1.6

Appendix L3 (continued)[1].

Subbasin/Lake	Date	Station	TP	TKN	NH_3	NO_x	TN	TON	TIN	Chl a	Total Solids	Susp. Solids	Turbidity
07													
Lake Gaston	08/05/99	ROA0382A	< 0.01	0.2	0.05	0.02	0.22	0.15	0.07	7	76	1.0	2.6
	08/05/99	ROA038A	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	14	86	1.0	1.7
	08/05/99	ROA039	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	11	88	2.0	1.4
	08/05/99	ROA039B	0.01	0.7	0.27	< 0.01	0.71	0.43	0.28	14	78	4.0	2.1
	07/22/99	ROA0382A	0.01	0.3	0.05	0.09	0.39	0.25	0.14	7	94	3.0	2.5
	07/22/99	ROA038A	0.02	0.2	0.01	0.01	0.21	0.19	0.02	22	86	4.0	2.4
	07/22/99	ROA039	0.01	0.2	0.03	< 0.01	0.21	0.17	0.04	20	85	3.0	2.0
	07/22/99	ROA039B	0.01	0.3	0.03	< 0.01	0.31	0.27	0.04	9	80	4.0	1.2
	06/02/99	ROA0382A	0.01	0.1	0.02	0.19	0.29	0.08	0.21	3	92	< 1.0	3.0
	06/02/99	ROA038A	0.01	0.2	0.01	0.11	0.31	0.19	0.12	6	94	1.0	3.7
	06/02/99	ROA039	0.01	0.1	0.02	0.08	0.18	0.08	0.10	5	88	< 1.0	3.2
	06/02/99	ROA039B	0.01	0.2	0.04	0.08	0.28	0.16	0.12	6	83	2.0	2.5
	08/09/94	ROA0382A	0.03	0.2	0.12	0.07	0.27	0.08	0.19	< 1	97	4.0	4.8
	08/09/94	ROA038A	0.02	0.3	0.04	0.06	0.36	0.26	0.10	3	96	4.0	4.1
	08/09/94	ROA039	0.02	0.3	0.01	0.05	0.35	0.29	0.06	4	100	3.0	2.5
	08/09/94	ROA039B	0.02	0.2	0.03	0.05	0.25	0.17	0.08	2	84	2.0	1.5
08													
Roanoke Rapids Lake	08/05/99	ROA039C	0.01	0.3	< 0.01	< 0.01	0.31	0.30	0.01	22	90	7.0	2.6
	08/05/99	ROA039D	0.01	0.4	< 0.01	< 0.01	0.41	0.40	0.01	10	81	6.0	2.6
	08/05/99	ROA039E	0.01	0.2	< 0.01	< 0.01	0.21	0.20	0.01	15	79	4.0	2.3
	07/22/99	ROA039C	0.01	0.3	0.04	0.05	0.35	0.26	0.09	9	81	5.0	1.7
	07/22/99	ROA039D	0.01	0.2	0.04	0.02	0.22	0.16	0.06	10	71	3.0	1.9
	07/22/99	ROA039E	0.01	0.2	0.04	< 0.01	0.21	0.16	0.05	12	76	2.0	2.3
	06/02/99	ROA039C	0.01	0.2	< 0.01	0.10	0.30	0.20	0.11	5	77	3.0	2.8
	06/02/99	ROA039D	< 0.01	0.2	< 0.01	0.11	0.31	0.20	0.12	6	88	3.0	3.0
	06/02/99	ROA039E	0.03	0.3	0.02	0.07	0.37	0.28	0.09	9	85	2.0	3.0
	08/09/94	ROA039C	0.02	0.2	0.02	0.07	0.27	0.18	0.09	1	79	3.0	1.7
	08/09/94	ROA039D	0.02	0.2	0.01	0.04	0.24	0.19	0.05	2	96	4.0	2.4
	08/09/94	ROA039E	0.02	0.2	0.02	0.04	0.24	0.18	0.06	2	88	3.0	2.2

[1]Abbreviations are TP = total phosphorus, TKN = total Kjeldahl nitrogen, NH_3 = ammonia nitrogen, No_x = nitrate + nitrite nitrogen, TON = total organic nitrogen, TIN = total inorganic nitrogen, and Chl *a* = chlorophyll *a*. Units of measure are mg/l, except for chlorophyll *a* which is µg/l and turbidity which is NTU.