Evaluation of Sediment and Pollutant Sources to Lake James: Year Seven Report

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TABLE OF CONTENTS

Acknowledgments

The Lake James Environmental Association was formed in 1973 to protect the environment and ecology of the lake and its tributaries. It has worked tirelessly since that time to reduce pollution levels and protect the land around the lake. In 2001 this dedicated organization realized the need to learn more about the water quality of the tributaries entering the lake as well as the water quality of the lake itself. With this goal they joined with the Environmental Quality Institute/University of North Carolina-Asheville to begin monthly monitoring of the lake and its main tributaries.

We especially wish to thank the board of Directors of LJEA including past and current officers Eric Jenkins, Robert Long (who is also serving as the coordinator for the project), Ken Harris, Jimmy Blanton, and the late Art Bonham, as well as all the members of the organization for providing the funding and administrative organization to run the program. We would also like to thank the family foundation of James and John Rostan for providing grant funds to purchase lake monitoring equipment.

The success of this project is highly dependent on volunteers. Many LJEA members have participated in sample collection. In the past year Jimmy Blanton, Bob Long, Al Pinkul, and Bill Hendley have largely taken on the duties of stream monitoring, and Robert and Anne Long, Bruce Whipple, George Johnson, Warren Klutz, and Phil Howerton have served as lake monitors.

This project has also been facilitated by the addition of lake morphometric data provided by Larry Olmstead and Bill Foris of Duke Energy.

I. Introduction

VWIN's History

The Volunteer Water Information Network (VWIN) is a partnership of groups and individuals dedicated to preserving water quality in western North Carolina. Organizations such as the Lake James Environmental Association, the Environmental Conservation Organization (ECO), the Pacolet Area Conservancy (PAC), the Town of Lake Lure, and many others provide administrative support. The UNC-Asheville Environmental Quality Institute (EQI) provides technical assistance through laboratory analysis of water samples, statistical analysis of water quality results, and written interpretation of the data. Volunteers venture out once per month to collect water samples from designated sites along streams and rivers in the region.

An accurate and on-going water quality database, as provided by VWIN, is essential for good environmental planning. The data gathered by the volunteers provides an increasingly accurate picture of water quality conditions and changes in these conditions over time. Communities can use this data to identify streams of high water quality, which need to be preserved, as well as streams that cannot support further development without significant water quality degradation. In addition, the information allows planners to assess the impacts of increased development and the success of pollution control measures. Thus, this program provides the water quality data for evaluation of current management efforts and can help guide decisions affecting future management actions. The VWIN program also encourages involvement of citizens in the awareness, ownership and protection of their water resources.

In February of 1990, volunteers began monthly sampling 27 stream sites in Buncombe County. The program expanded to 45 sites by November of 1990. Since that time, monitoring has expanded to over 200 sites throughout Western North Carolina and beyond. Monthly sampling of these sites provides extensive water quality information for the French Broad, Broad, Catawba, Little Tennessee, Watauga, and Hiawassee River Watersheds in North Carolina.

The Lake James VWIN Program

In May 2001, the Lake James Environmental Association began a VWIN program to monitor five selected stream sites and six lake sites in order to assess water quality conditions in streams flowing into Lake James, and to provide continuous assessment of the health of the lake. Because problems were noticed almost immediately at the site on the North Fork of the Catawba River, two more sites were quickly added to assess this problem. With sedimentation and potential eutrophication of the lake a growing concern, many citizens realize the need for continuous monitoring of the streams flowing into the lake as a means of trying to pinpoint sources of problems. Continuous monitoring of the lake itself is vital to understanding the lake cycles and trends as well as identifying problems as they arise. The approximate location of all the monitoring sites can be found on the map in Figure 1. Table 1 is a list of the monitoring sites and their locations. This report represents statistical analyses and interpretation of data gathered by VWIN volunteers from May 2001 through April 2008.

Table 1: Lake James Monitoring Sites

1. **Catawba River at SR-1501**
2. **Catawba River at US-221A**
3. **North Fork of the Catawba River at SR-1552**
4. **Catawba River at Restoflex Road**
5. **Linville River at NC Hwy 126**
6. **Lake James at Plantation Point – Catawba arm near Catawba River**
7. **Lake James at Big Island – mid Catawba arm**
8. **Lake James at Marion Lake Club - lower Catawba arm**
9. **Lake James at Paddy Creek dam - Linville arm**
10. **Lake James at upper Linville arm**
11. **Lake James at lower Linville arm**
12. **North Fork of the Catawba River downstream from Limekiln Creek**
13. **North Fork of the Catawba River at Old Linville Road**

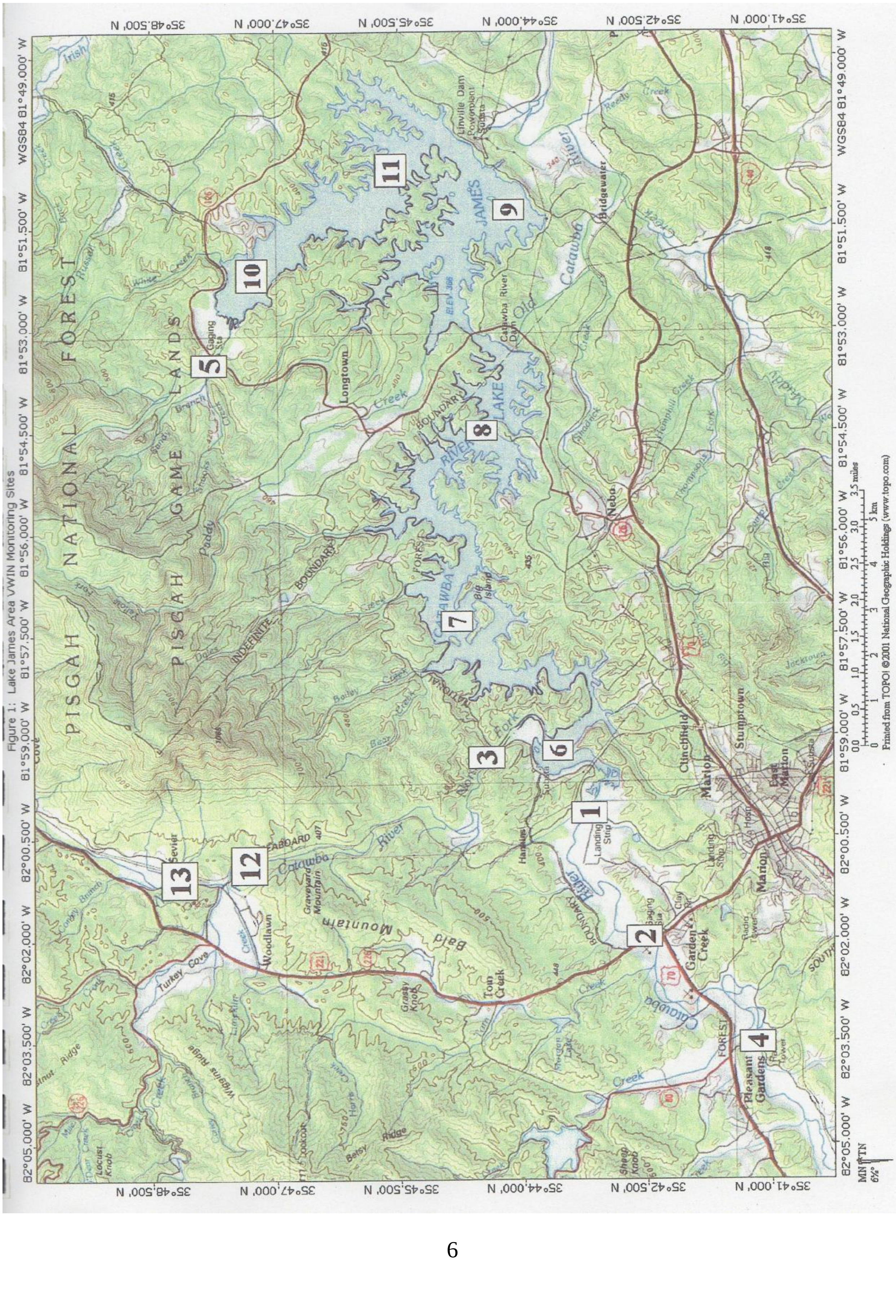


Figure 1: Lake James Area VWIN Monitoring Sites

II. Methodology

A water monitoring coordinator provides hands-on instruction and experience in sample collection to all volunteers prior to their first day of sample collection. The Lake Lames monitoring samples are collected on the fourth Saturday of each month. Water samples are collected in six 250 mL polyethylene bottles. In order to assure consistent sampling techniques, each bottle is labeled with the site number and the parameter for which the water from that particular bottle will be analyzed. Each set of samples includes a chain-of-custody form to be completed by the volunteer. This form includes site number and site location, the time and date of sample collection, the name of the person collecting the sample, and the weather conditions prior to sample collection. Appendix A is a copy of the chain-of-custody form used by the volunteers.

After collection, the volunteer takes the samples and data sheet to a designated drop point where the samples are refrigerated. It is the job of the volunteer coordinator to pick up the samples from the drop point and deliver them or ship them to the EQI laboratory for analysis within two days of collection. A description of the laboratory analysis methodology is contained in Appendix B. Following analysis of samples the empty bottles are cleaned in the laboratory and then packed together with blank chain-of-custody forms for use next month.

Various statistical analyses are performed on the data and are intended to:

1) Characterize the water quality of each stream site relative to accepted or established water quality standards;

2) Identify effects of precipitation, stream water level, seasonality, land use, and temporal trends on water quality, after sufficient data have been collected.

III. Results and Discussion

This discussion is based on seven years of data gathered from May 2001 through April 2008, but also includes the lake data from May through September 2008. With each additional year of continuous monitoring, trends in water quality become more evident, and a clearer picture of actual conditions existing in various streams, lakes, and watersheds is available. Continuing water quality data collection over time provides updated information on changing conditions. With this information financial resources and policies can be focused on areas of greatest concern.

A discussion of the stream sites relative to specific water quality parameters follows. To better understand the parameters, explanations, standards and sources of contamination, some definitions of units and terms have been provided.

The amount of a substance in water is referred to in units of concentration. Parts per million (ppm) is equivalent to mg/L. This means that if a substance is reported to have a concentration of 1 ppm, then there is one milligram of the substance in each liter (1000 grams) of water. The parameter total suspended solids (TSS) illustrates the weight/volume concept of concentration. According to the statistical summary data for Lake James stream sites (Appendix E), site 1 had a median TSS concentration of 4.0 mg/L, which is equivalent to 4.0 ppm. Thus if you filter one liter of water from site 1 on average you will collect sediments that weigh 4.0 mg. The same conversion applies for parts per billion (ppb), which is equivalent to micrograms per liter (ug/L). Concentrations of the VWIN parameters in water samples are compared to normal ambient levels. Ambient levels are estimates of the naturally occurring concentration ranges of a substance. For instance, the ambient level of copper in most streams is less than 1 ug/L (1 ppb). Ambient water quality standards, on the other hand, are used to judge acceptable concentrations. The ambient water quality standard for ammonia-nitrogen to protect trout populations is 1.0 to 2.0 mg/L (seasonally dependent), but the normal ambient level for most trout waters is about 0.1 mg/L.

A classification grade was assigned to each site based on the results of analysis. This report shows site-specific grades for each parameter for the most recent three-year period of this study (Table 2). The grades are designed to characterize the water quality at each site with regard to individual parameters. Water quality standards were used where applicable to assess the possible impacts these levels could have on human health and organisms in the aquatic environment. For example, the 7 ppb water quality standard for copper was used to determine grades for the sites. A grade of "A" would be assigned to a site if, over the last three years, or in this case the whole project period of two years, no samples had a concentration that exceeded this standard. In contrast, due to the detrimental effects decreases in pH can have on the organisms that live in streams, a site could receive an "A" if minimum pH value was never lower than 6.0. Appendix C describes the criteria used for the grading system for each parameter.

Appendix D is a list of all VWIN stream sites monitored in Western North Carolina indexed and ranked using the grading system previously discussed and shown in Table 2. This indexing system was developed to facilitate comparisons of specific problem areas such as sediment, nutrients, or chemical and heavy metal pollutants. Parameters were grouped into these three categories and number grades were assigned to each parameter (A=100, B=75, C=50, D=25). The numbers were added, and the total divided by the number of parameters in the

Table 2: Classification grades based on parameters and ranges

Site	Description	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho P	Ammonia-N	Nitrate-N
1	CR1 - Catawba River at SR-1501	A	B	C	A	B	A	A	A	A	A	A
2	CR2 - Catawba River at US-221A	A	B	C	B	B	A	A	A	A	A	A
3	NF1 - North Fork of the Catawba River at SR-1552	A	A	C	B	D	B	A	A	C	A	B
4	CR5 - Catawba River at Restoflex Rd	A	B	C	B	C	A	A	A	A	A	A
5	LR1 - Linville River at Hwy 126	A	C	A	A	B	B	A	A	A	A	A
12	NF1A - North Fork/Catawba River below Limekiln Crk	A	A	C	B	D	B	A	A	C	A	B
13	NF2 - North Fork/Catawba River at Old Linville Rd	A	A	C	B	D	B	A	A	C	A	C

A Excellent
B Good
C Fair
D Poor

dimension. For example, a site with a B in turbidity and a C in total suspended solids would receive a sediment index of (75 + 50)/2 = 62.5 (rounded to 63). Index ratings for each of the three groupings were added and the total divided by 3 to determine the overall index rating for each site. A maximum score of 100 and a minimum of 25 are possible.

It is important and useful to compare sites within the mountain area to understand how water quality from each stream ranks, not only within the county, but also within the region. With this information local governments, organizations, and individuals can compare areas with similar problems or successes and share information or even develop region-wide plans. It will also be helpful to note changes in rankings over time as stream water quality improves or deteriorates relative to the many other mountain streams tested in the VWIN program. Many factors such as population density, industrial development, topography, and land use patterns can affect water quality. All of these factors must be taken into consideration when comparing stream water quality.

Appendix E contains summarized statistical data collected over the course of this study. It is a list of minimum, maximum, and median concentrations or values.

The data for over 200 sites throughout Western North Carolina in the VWIN program are used in this report to compare water quality from the stream sites in the Lake James area with water quality from the mountain region in general. Some of the graphs in this discussion section include averages of median values for all sites analyzed throughout the region. It should be noted that, although there are always some sites in each county that are relatively unaffected by human activities, most VWIN sites are generally chosen to measure the effects of human activities on stream water quality. For this reason, forest streams are under-represented and the averages in all areas are weighted somewhat toward streams that experience various degrees of pollution. To illustrate water quality in more pristine areas the averages for sites in mainly forested watersheds are also included.

When more than five years of monitoring are completed, trend analysis is included in each report. A statistical analysis of the effects of stream water level, temporal changes, and seasonality on the water quality parameters at individual sites is included in this discussion. This analysis is used to determine if changes in concentrations or levels of a parameter relate to changes in water levels, (i.e. flow), increases or decreases over time (i.e. temporal change), and changes of the seasons in Western North Carolina (i.e. seasonality). Trends are observed in the data, and interpretations of what might be causing the trends are suggested. Trends are considered significant if the p-value is less than 0.05. The p-value is the probability of obtaining as much trend as observed in the data if, in fact, there was no true underlying trend.

Trends related to flow are determined using flow measurements from nearby U.S. Geological Survey gauging stations. Although this method may present some problems as gauging stations can only truly represent the streams on which they are located, the method has been found to be the most effective for the least cost. With this method the control for flow allows for more precise examination of the effects of other factors. The USGS gauging stations on the Catawba River at Pleasant Gardens (02137727) was utilized to estimate relative flow for the Lake James monitoring sites. The logarithm of the ratio of the measured flow to the long-term average flow for each date was used as the predictor variable for flow. Corresponding flow data were found for all sample collection dates from the beginning of the Lake James monitoring program in 2001 to present. Appendix F is a summary of trends related to flow, Appendix G shows trends related to time, and Appendix H shows trends related to season.

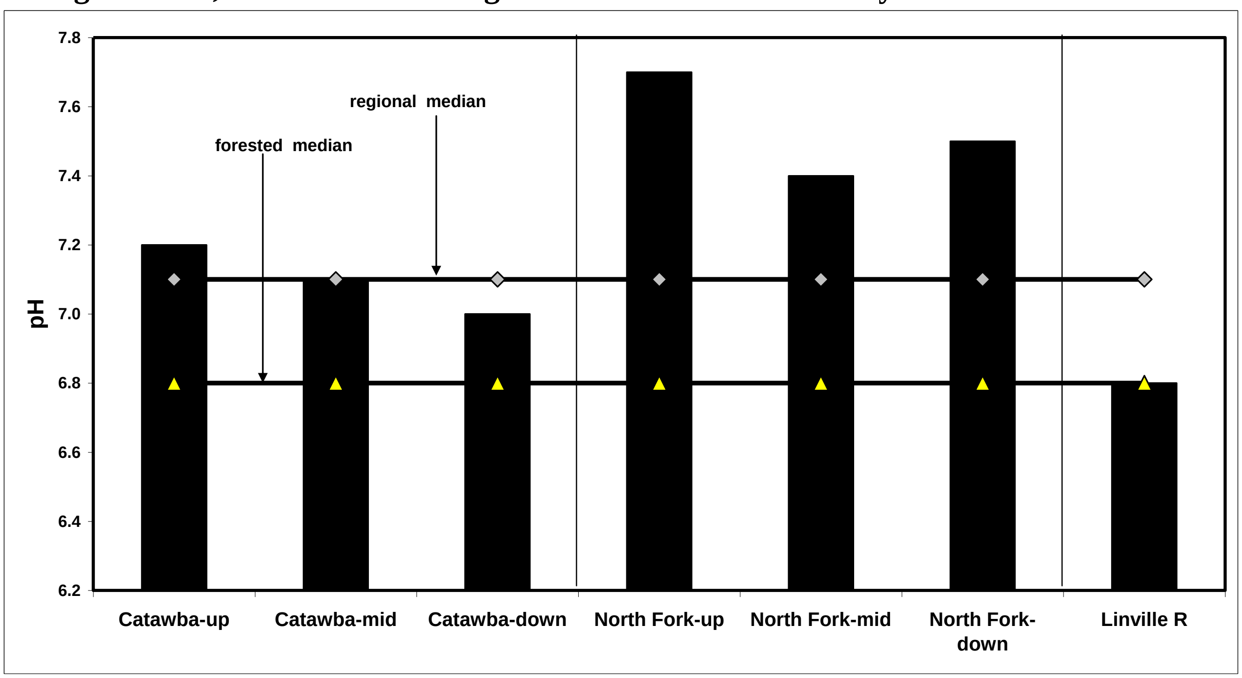
A. Acidity (pH) and Alkalinity: pH is used to measure acidity. The pH is a measure of the concentration of hydrogen ions in a solution. If the value of the measurement is less than 7.0, the solution is acidic. If the value is greater than 7.0, the solution is alkaline (more commonly referred to as basic). The ambient water quality standard is between 6.0 and 9.0. Natural pH in area streams should be in the range of 6.5 - 7.2. Values below 6.5 may indicate the effects of acid rain or other acidic inputs, and values above 7.5 may be indicative of an industrial discharge.

Because organisms in aquatic environments have adapted to the pH conditions of natural waters, even small pH fluctuations can interfere with the reproduction of those organisms or can even kill them outright. The pH is an important water quality parameter because it has the potential to seriously affect aquatic ecosystems. It can also be a useful indicator of specific types of discharges.

Alkalinity is the measure of the acid neutralizing capacity of a water or soil. Waters with high alkalinity are considered to be protected (well buffered) against acidic inputs. Streams that are supplied with a buffer are able to absorb and neutralize hydrogen ions introduced by acidic sources such as acid rain, decomposing organic matter and industrial effluent. For example, water can leach calcium carbonate (a natural buffer) from limestone soils or bedrock and then move into a stream, providing that stream with a buffer. As a result, pH levels in the stream are held constant despite acidic inputs. Unfortunately, natural buffering materials can become depleted due to excessive acidic precipitation over time. In that case, further acidic precipitation inputs can cause severe decreases in stream pH. Potential future stream acidification problems can be anticipated by alkalinity measurement. There is no legal standard for alkalinity, but waters with an alkalinity below 30 mg/l are considered to have low alkalinity. Western NC streams tend to have low alkalinity because of generally thin soils and because the underlying granitic bedrock does not contain many acid-neutralizing compounds such as calcium carbonate.

Figures 2 and 3 show median pH and alkalinity levels at each site for the past three years compared to median levels for all VWIN sites in Western North Carolina and for sites in largely undisturbed, forested areas.

Figure 2: Median pH levels at Lake James monitoring sites compared with the regional average median, and with the average median at sites in relatively undisturbed areas

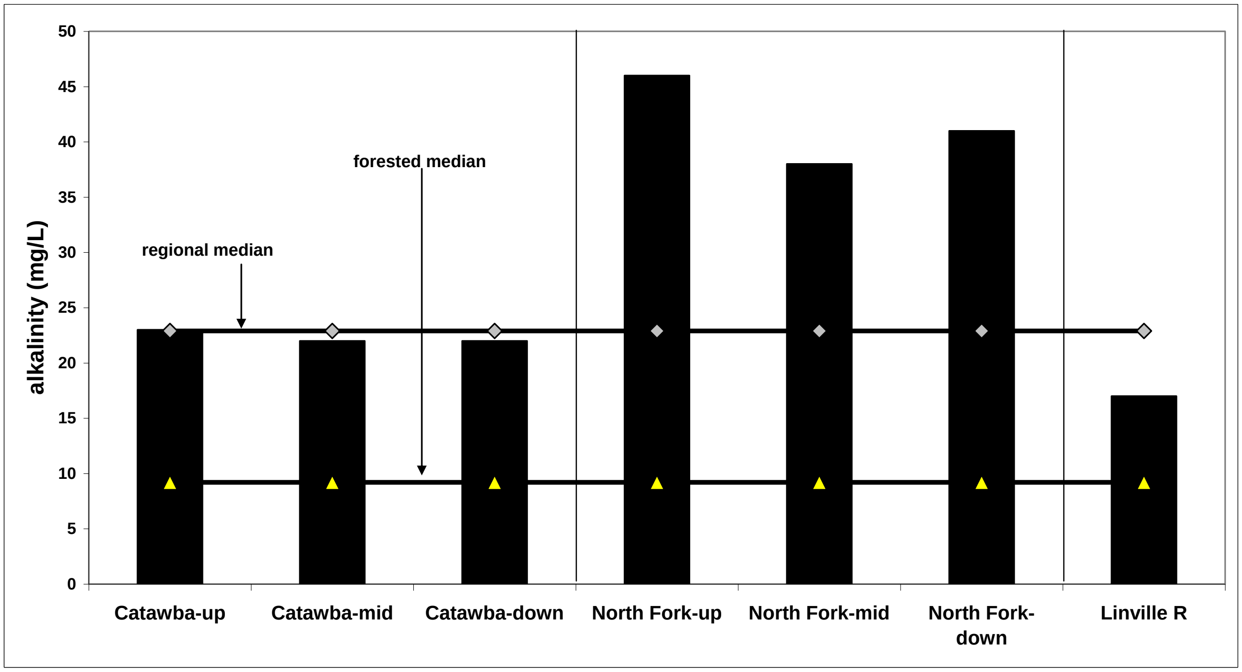


B. Turbidity and Total Suspended Solids (TSS): Turbidity is a measurement of the visual clarity of a water sample and indicates the presence of fine suspended particulate matter. The unit used to measure turbidity is NTU (nephelometric turbidity units), which measures the absorption and reflection of light when it is passed through a sample of water. Because particles can have a wide variety of sizes, shapes and densities, there is only an approximate relationship between the turbidity of a sample and the concentration (i.e. weight) of the particulate matter present. This is why there are separate tests for NTU turbidity and suspended solids.

Turbidity is an important parameter for assessing the viability of a stream for trout propagation. Trout eggs can withstand only small amounts of silt before hatching success is greatly reduced. Fish that are dependent on sight for locating food are also at a great disadvantage when water clarity declines. For this reason, the standard for trout-designated waters is 10 NTU while the standard to protect other aquatic life is 50 NTU.

Mountain streams in undisturbed forested areas remain clear even after a moderately heavy rainfall event, but streams in areas with disturbed soil may become highly turbid after even

Figure 3: Median alkalinity levels at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas



a relatively light rainfall. Deposition of silt into a stream bottom can bury and destroy the complex bottom habitat. Consequently, the habitat for most species of aquatic insects, snails, and crustaceans is destroyed by stream siltation. The absence of these species reduces the diversity of the ecosystem. In addition, small amounts of bottom-deposited sediment can severely reduce the hatch rate of trout eggs. There is no legal standard for TSS, but values below 30.0 mg/l are generally considered low, and values above 100 mg/l are considered high. TSS quantifies solids by weight and is heavily influenced by the combination of stream flow and land disturbing activities. A good measure of the upstream land use conditions is how much TSS rises after a heavy rainfall.

Figures 4 and 5 show median turbidity and total suspended solids levels at each site for the past three years compared to median levels for all VWIN sites in Western North Carolina and for sites in largely undisturbed, forested areas.

C. Conductivity and Heavy Metals (Copper, Lead, and Zinc):

Conductivity is measured in micromhos per centimeter (umho/cm) and is used to measure the ability of a water sample to conduct an electrical current. Pure water will not conduct an electrical current. However, samples containing dissolved solids and salts will form positively and negatively charged ions that will conduct an electrical current. The concentration of

Figure 4: Median turbidity levels at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas

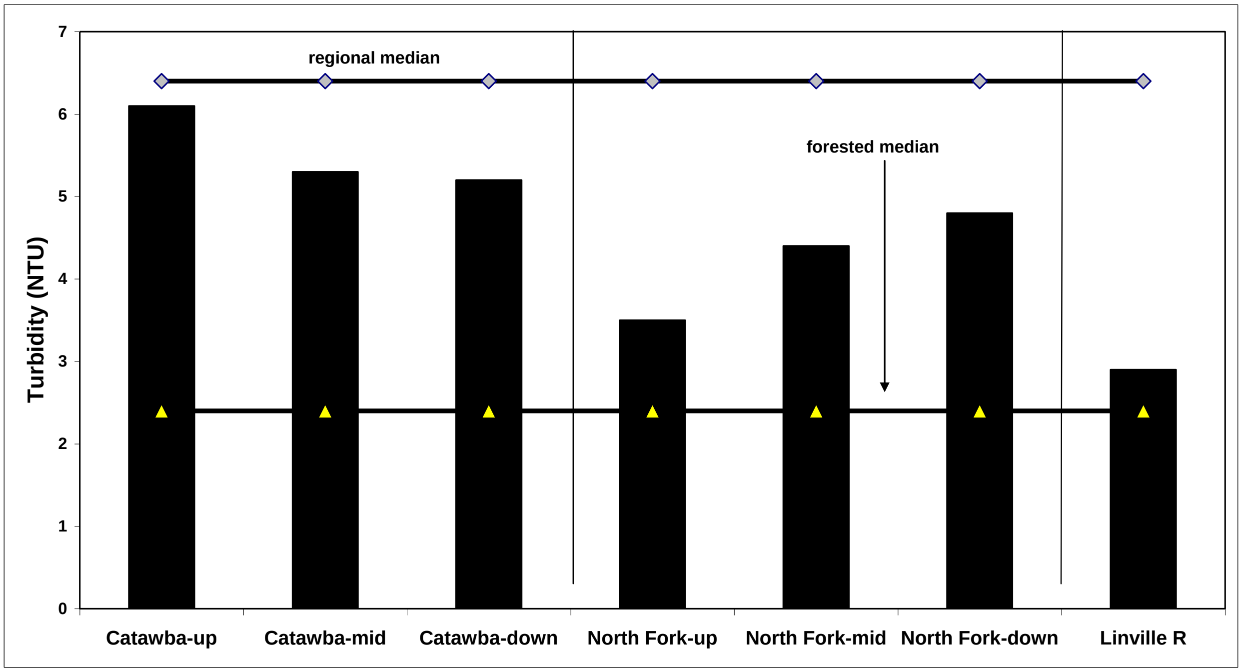
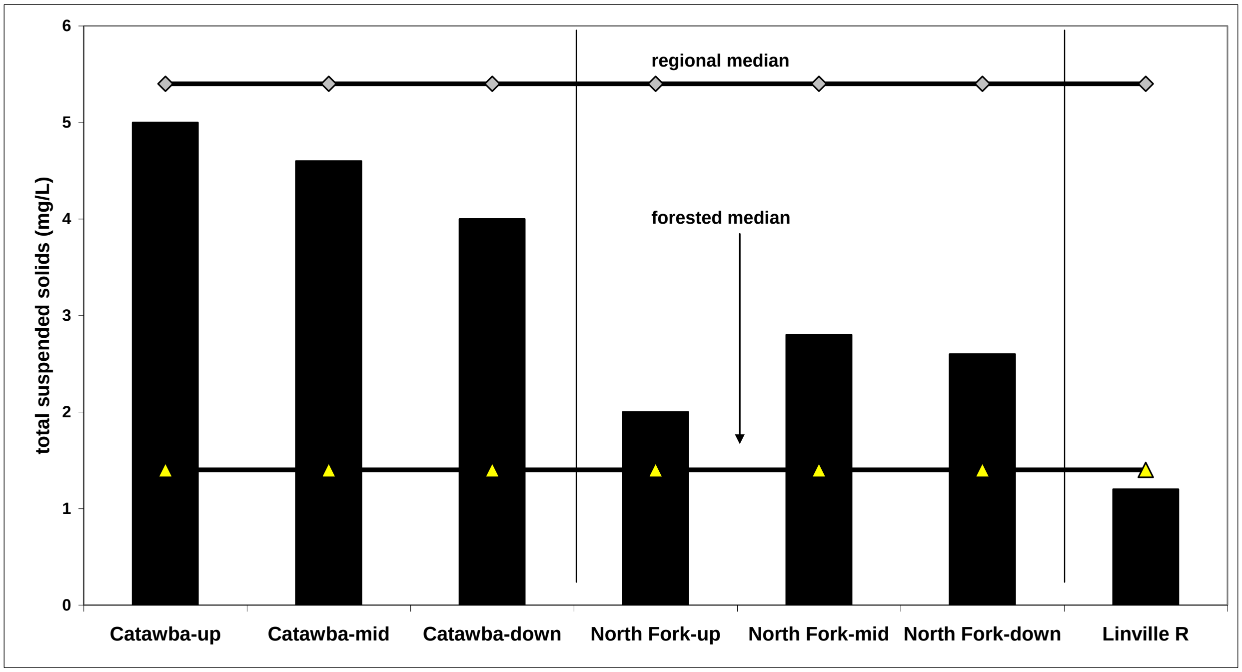


Figure 5: Median total suspended solids concentrations at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas



dissolved ions in a sample determines conductivity. Inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum affect conductivity levels. Geology of an area can affect conductivity levels. Streams that run through areas with granitic bedrock tend to have lower conductivity because granitic rock is composed of materials that do not ionize in water. Streams that receive large amounts of runoff containing clay particles generally have higher conductivity because of the presence of materials in clay that ionize more readily in water.

Metals are naturally occurring in surface waters in minute quantities as a result of chemical weathering and soil leaching. However, concentrations greater than those occurring naturally can be toxic to human and aquatic organisms. Elevated levels are often indicative of industrial pollution, wastewater discharge, and urban runoff, especially from areas with high concentrations of automobiles. Airborne contaminants from coal-fired power plants may also contribute metals to the atmosphere, which are then carried to land by precipitation and dry fallout. Because metals sorb readily to many sediment types, they may easily enter streams in areas with high sediment runoff. Another source of heavy metals can be runoff from agricultural fields using sewage sludge as fertilizer, which sometimes is permitted to contain up to 1500 mg metal/kg fertilizer.

Copper: The standard of 7.0 ug/l has been established to protect aquatic life. In most areas, ambient levels are usually below 1.0 ug/l. Wear of brake linings has been shown to contribute concentrations of copper, lead, and zinc. Copper has a relatively high content in brake linings. Copper is also present in leaded, unleaded, and diesel fuel emissions.

Lead: A standard of 25.0 ug/l has been established to protect aquatic life, while the normal ambient level is usually below 1.0 ug/l. Lead may be present in industrial wastewater and was once common in road runoff from the use of leaded gasoline. Roadside soils still generally contain high lead levels, resulting in elevated stream concentrations if these soils are subject to erosion.

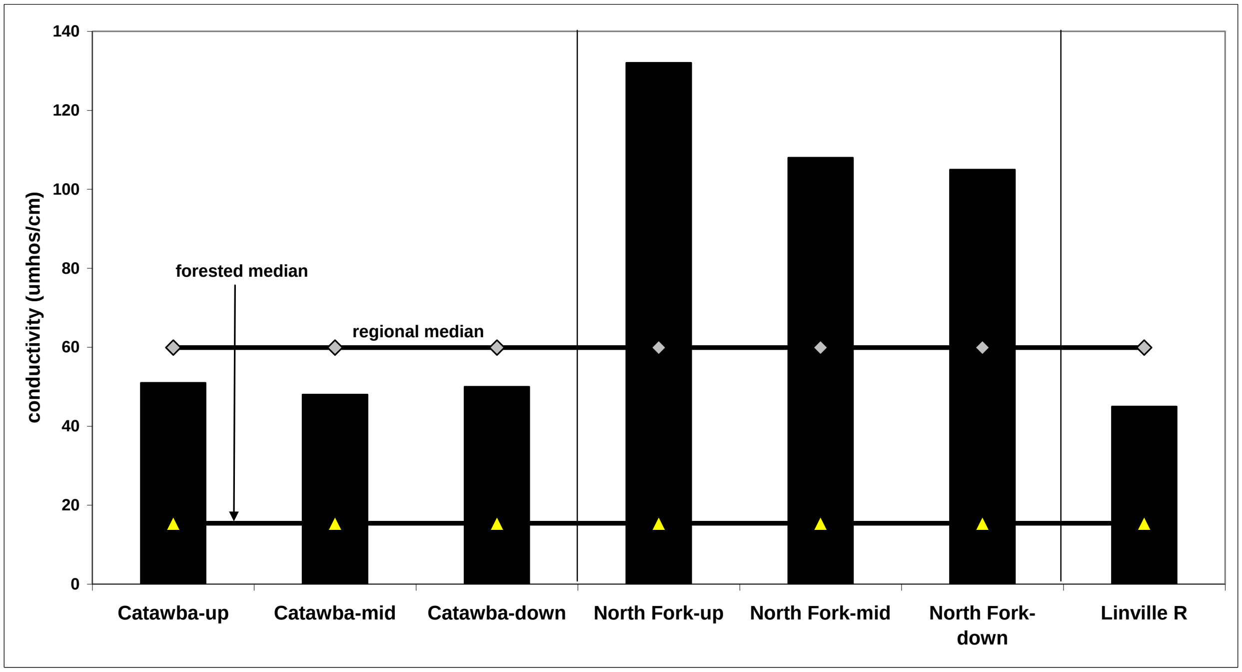
Zinc: The surface water standard is 50.0 ug/l. Typical ambient levels of zinc are approximately 5.0 ug/l. Zinc is a major metal component of tire rubber, brake linings, and galvanized crash barriers. Studies have been conducted linking this to zinc contamination from urban runoff. Because zinc is a by-product of the auto tire vulcanization process as well as the galvanization of iron, its presence in water may also result from industrial or domestic wastewater.

Elevated levels of conductivity and heavy metals are most often seen in streams receiving industrial or domestic wastewater or urban runoff. These substances also occur naturally in soils and may show higher levels in streams where severe erosion and runoff are occurring.

Figures 6 shows median conductivity levels at each site for the past three years compared to median levels for all VWIN sites in Western North Carolina and for sites in largely undisturbed, forested areas.

D. Nutrients (Total Phosphorus (P), Orthophosphate (PO_4^{3-}), Ammonia-Nitrogen (NH_4^+/NH_3-N), and Nitrate/Nitrite-Nitrogen (NO_3^-/NO_2^--N): Phosphorus is an essential nutrient for aquatic plants and algae. It occurs naturally in water and is, in fact, usually the limiting nutrient in most aquatic systems. In other words, plant growth is restricted by the availability of phosphorus in the system. Excessive phosphorus inputs stimulate the growth of algae and diatoms on rocks in a stream and cause periodic algal blooms in reservoirs downstream. Slippery green mats of algae in a stream, or blooms of algae in a lake are usually the result of an introduction of excessive phosphorus into the system that has caused algae or aquatic plants to grow at abnormally high rates. Eutrophication is the term used to describe this growth of algae due to an over abundance of a limiting nutrient. Sources of phosphorus include soil, disturbed land, wastewater treatment plants, failing septic systems, runoff from fertilized crops

Figure 6: Median conductivity levels at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas



and lawns, and livestock waste storage areas. Phosphates have an attraction for soil particles, and phosphorus concentrations can increase greatly during rains where surface runoff is a problem. Phosphorus commonly enters streams from agricultural fertilization, animal waste runoff, or treated sewage discharges. **In this report orthophosphate (PO_4^{3-}) is reported in the form of orthophosphate (PO_4^{3-}). To isolate phosphorus (P) from the measurement, divide the reported amount by 3.07. Total phosphorus is also reported in the (PO_4^{3-}) form, but median levels of the P form are also provided.**

Orthophosphate: This is a measure of the dissolved phosphorus that is immediately available to plants or algae. Orthophosphate is also referred to as phosphorus in solution.

Total Phosphorus: Total phosphorus is the measure of all the chemical forms of phosphorus in a system. Total phosphorus includes dissolved orthophosphate, phosphorus bound to particulate materials, as well as phosphorus locked up biologically in algae and bacteria. Some of the particulate-bound phosphorus may eventually become chemically available to organisms as orthophosphate.

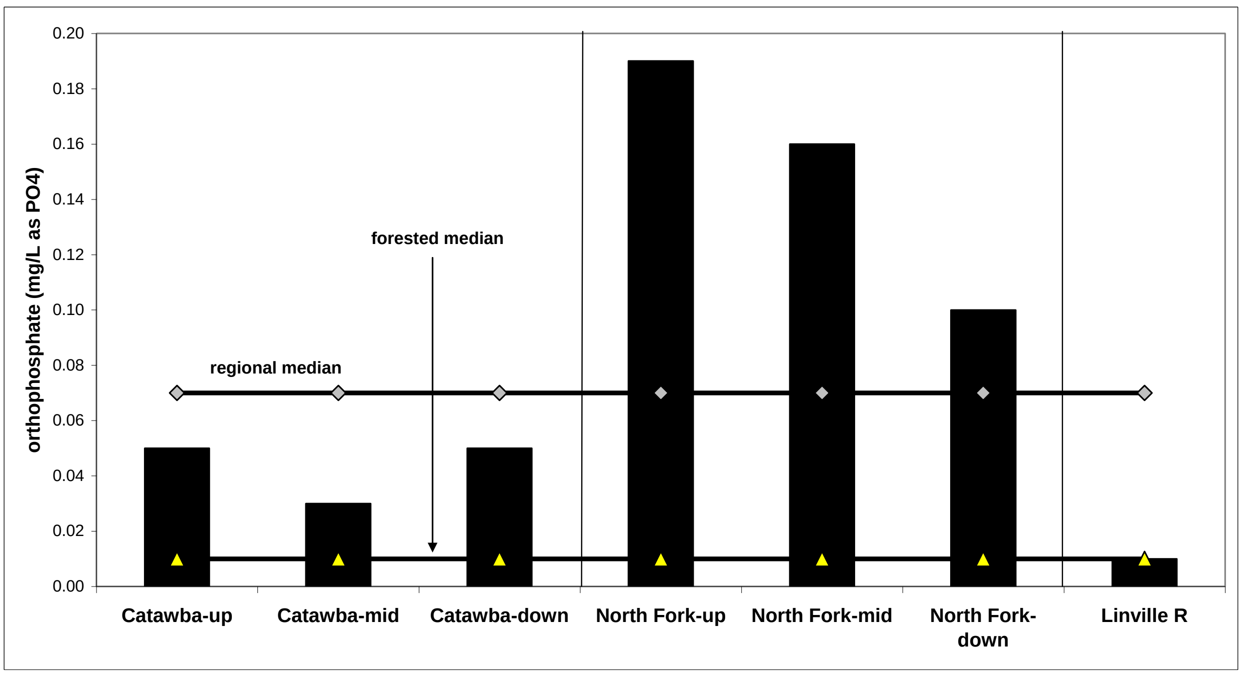
Ammonia-Nitrogen (NH_4^+/NH_3-N) is contained in the remains of decaying wastes of plants and animals. Some species of bacteria and fungi decompose these wastes and NH_3 is formed. The normal ambient level is approximately 0.10 mg/l, and elevated levels of NH_3 can be toxic to fish.

Although the actual toxicity depends on the pH of the water, the proposed ambient standard to protect trout waters is 1.0 mg/l in summer and 2.0 mg/l in winter. The most probable sources of ammonia nitrogen are agricultural runoff, livestock farming, septic drainage and sewage treatment plant discharges. In Western North Carolina, streams with extensive trout farming also show elevated ammonia-nitrogen concentrations.

Like phosphorus, **nitrate/nitrite-nitrogen (NO_3/NO_2-N)** serves as an algal nutrient contributing to excessive stream and reservoir algal growth. In addition, nitrate is highly toxic to infants and the unborn causing inhibition of oxygen transfer in the blood stream at high doses. This condition is known as "blue-baby" disease. This is the basis for the 10 mg/L national drinking water standard. The ambient standard to protect aquatic ecosystems is 10 mg/L as well. The most probable sources are septic drainage and fertilizer runoff from agricultural land and domestic lawns. Nitrates from land sources end up in streams more quickly than other nutrients such as phosphorus because they dissolve in water more readily and can travel with ground water into streams. Consequently, nitrates are a good indicator of the possibility of sources of pollution from sewage or animal waste during dry weather.

Figures 7, 8, and 9 show median orthophosphate, ammonia-nitrogen, and nitrate/nitrite-nitrogen levels at each site for the past three years compared to median levels for all VWIN sites in Western North Carolina and for sites in largely undisturbed, forested areas.

Figure 7: Median orthophosphate concentrations at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas



E. Lake Monitoring Results

Six sites on Lake James, from the Catawba River side and three from the Linville River side, have been monitored from May through September since 2001 for temperature, dissolved oxygen (DO) at one to two meter depth intervals; and total phosphorus, orthophosphate,

Figure 8: Median ammonia-nitrogen concentrations at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas

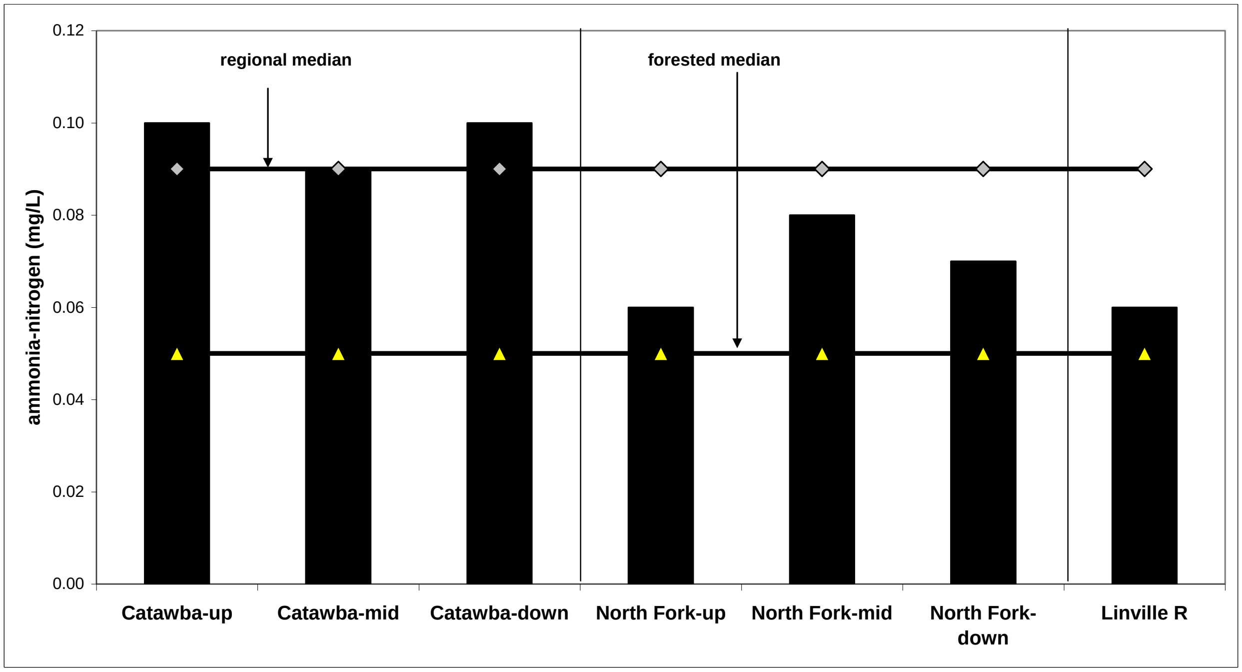
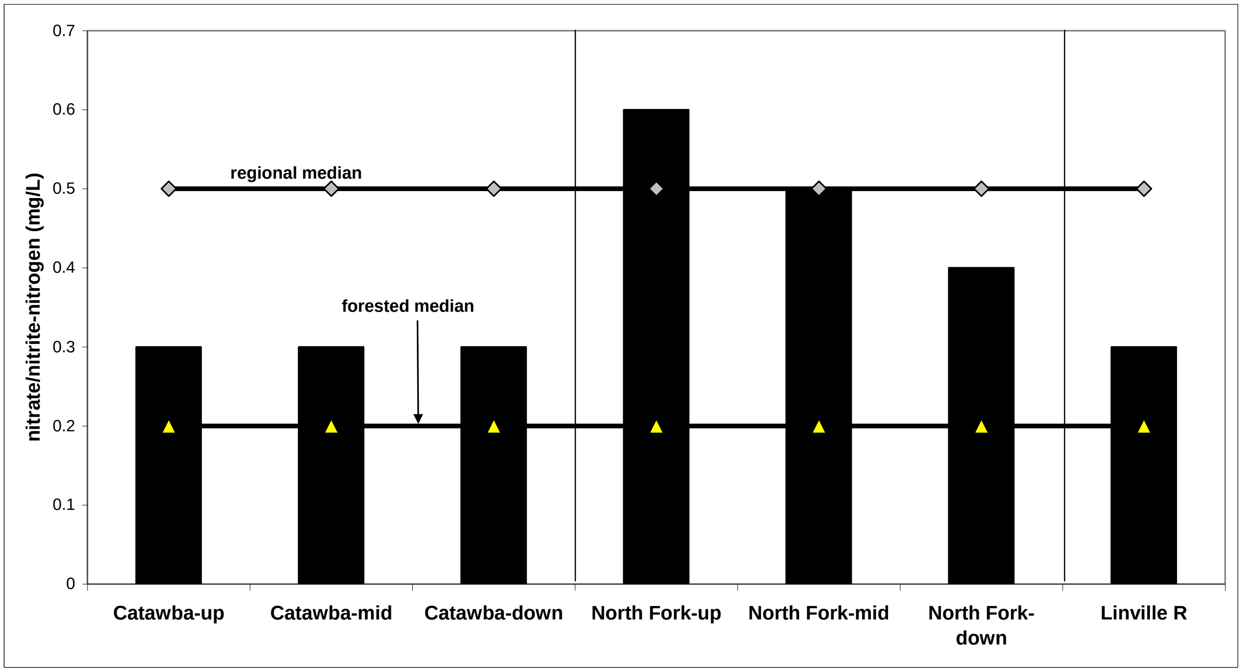


Figure 9: Median nitrate/nitrite-nitrogen concentrations at Lake James monitoring sites compared with the regional median, and with the median at sites in relatively undisturbed areas



ammonia-nitrogen and nitrate-nitrogen near the surface. In 2008 the sites at Plantation Pointe and upper Linville were eliminated. Secchi depth is also measured at each location. Secchi depth is a measure of lake water transparency and gives an estimate of the distance of light penetration through the water. This area of light penetration is called the photic zone and is the area where algae will grow if sufficient nutrients are available. The area of light penetration is usually approximately twice the secchi depth. Samples are currently collected and measurements are taken near Big Island, and Marion Lake Club on the Catawba side, and at the lower lake and near the Paddy Creek dam on the Linville side.

Although the reporting year ends in April, this report also includes lake monitoring data from May through September 2008, so comparisons are made for eight years of lake monitoring. Lake analysis is temporarily discontinued during the winter months. Lakes in this area generally undergo continuous turnover (complete mixing) during the winter months. During this mixing period temperature and dissolved oxygen levels remain consistent throughout the water column, and it becomes less necessary to continue testing of the entire lake water column.

Temperature and dissolved oxygen are key parameters to understanding lake conditions. All animal life needs oxygen in various amounts, and oxygen concentrations determine which species will survive. As air temperatures warm in the spring, surface water temperatures warm as well. Colder, denser water in the deeper layers becomes trapped under the lighter layers of warmer water near the surface. Because these lower layers no longer mix with surface water, and thus are no longer exposed to air at the surface, oxygen levels begin to decline and carbon dioxide levels increase as a result of bacterial decomposition of organic matter. The greater the amount of organic matter falling through the water column towards the bottom, the more oxygen is used by decomposition of this organic matter, and the more carbon dioxide is produced by organisms consuming the dead algae. The carbon dioxide combines with water to form carbonic acid causing pH levels to decline. This is a natural process but is accelerated when organic matter in excess of natural amounts enters the lake from outside sources, or excessive algae growth occurs as a result of nutrient loading. That is the reason phosphorus and nitrogen concentrations are important parameters for assessing lake water quality.

Another important concept to understand is oxygen saturation. The amount of oxygen that can be dissolved in water is dependent on temperature. More oxygen will dissolve in cold water than in warm water. When comparing dissolved oxygen concentrations from one month to the next or one year to the next, it is important to take both dissolved oxygen concentrations and temperature into consideration and express this as the percent oxygen saturation.

With two major river systems, the Catawba and Linville, providing water to two sections of the lake separated by a shallow narrow channel, Lake James functions almost as two different lakes. The outflow is on the Linville side of Lake James, and water from the Catawba side flows into the Linville side through a narrow channel. Because the channel is shallow (about 10 to 12 meters deep depending on the water level of the lake at any given time), the water flowing through the channel from the Catawba side into the Linville side is largely the warmer, well-oxygenated surface water. With the warmer, less dense water remaining at the surface, the deeper, colder, and denser waters on the Catawba side of the lake become trapped in place throughout the warm months.

On the Linville side of the lake the dynamics are often quite different. The outflow from the lake is taken from the hypolimnion (the deeper, colder layer) while the warmer surface water from the Catawba side pours through into the Linville side. This creates a very different temperature profile for each side of the lake. The complex inflow and outflow dynamics on the Linville side of the lake probably account for many of the differences from one year to the next. The hypolimnetic withdrawals and the turbulence they may cause on the Linville side can result in significant disruption of temperature stratification.

The two river systems flowing into the separate sides of the lake are also quite different. The Catawba River and the North Fork of the Catawba River feed the Catawba side. An estimated 45.3% of the inflow into Lake James is from the Catawba River and 21.8% is from the North Fork of the Catawba River (average flow estimates provided courtesy of Duke Power Company). About 92% of the water on the Catawba side of the lake flows in from these two water bodies and the rest is from smaller streams and surface runoff. Approximately 22.3% of the water in Lake James flows in from the Linville River on the Linville side of the lake. Most (an average of 72.5%) of the water entering the Linville side of the lake is flowing through the narrow channel from the Catawba arm. As previously mentioned, during the warmer months this is largely warm, well-oxygenated surface water.

Summer 2008 was dryer than normal and the lake displayed the attributes that have been more typical of drought years. In the eight years that the lake has been monitored, four of them have been during close to average or above average rainfall seasons, and four have been during below average rainfall seasons. During the four dry seasons average flow for the Catawba River at Pleasant Gardens was less than 90cfs, and during the four wet seasons average flow exceeded 170cfs. Minimum monthly flow during the dry years was 32cfs (8/02 and 7/08) and maximum flow was 155cfs (8/08). Minimum monthly flow during the wet years was 98cfs (7/06) and maximum flow was 1,418cfs (9/04). During dry periods secchi depths are generally greater on both sides of the lake, and during wet years total phosphorus concentrations are slightly higher than average on the Catawba side of the lake, and especially at the Big Island site, which is closer to the Catawba River and North Fork outflow (Table 3).

Table 3: Average secchi depths and total phosphorus concentrations during years of dry weather compared to years of wet weather, and average monthly flow of the Catawba River at Pleasant Gardens during those periods

secchi depth (ft) - dry seasons						Total Phosphorus (mg/L-P)-dry seasons				
year	Big Island	Marion Lake Club	Lower Linville	Paddy Creek Dam	ave flow (cfs)	year	Big Island	Marion Lake Club	Lower Linville	Paddy Creek Dam
2001	11.58	12.97	18.48	19.45	84.9	2001	0.04	0.05	0.03	0.03
2002	11.70	13.33	14.23	14.52	85.6	2002	0.04	0.03	0.05	0.03
2007	10.30	12.48	14.85	14.68	88.2	2007	0.05	0.03	0.02	0.03
2008	11.73	14.55	16.31	17.13	88.8	2008	0.03	0.03	0.02	0.04
ave	**11.33**	**13.33**	**15.97**	**16.44**		**ave**	**0.04**	**0.04**	**0.03**	**0.03**
secchi depth - wet seasons						**Total Phosphorus (mg/L-P)-wet seasons**				
2003	7.75	8.08	12.03	11.80	433.4	2003	0.10	0.05	0.05	0.05
2004	8.55	10.42	10.92	11.79	400.6	2004	0.07	0.04	0.04	0.03
2005	8.73	10.15	11.56	12.78	373.6	2005	0.08	0.04	0.03	0.04
2006	10.52	13.58	12.70	12.90	174.8	2006	0.04	0.04	0.04	0.03
ave	**8.89**	**10.56**	**11.80**	**12.32**		**ave**	**0.07**	**0.04**	**0.04**	**0.04**

The temperature profile on the Catawba side of the lake shows a distinct thermocline (region of rapid temperature change) during both wet and dry years (Figure 10), but the epilimnion (upper layer) is generally warmer during dry years, thus the thermocline is even more pronounced. The thermocline almost disappears during wet years on the Linville side of the lake (Figure 11). Lake temperatures decline only slightly and very gradually from the surface to the bottom, particularly closer to the Paddy Creek Dam. During dry years a more distinct thermocline develops, but is still much less distinct compared to the thermocline on the Catawba side of the lake. The temperature remains more uniform from surface to bottom on the Linville side because the colder water is withdrawn from deep in the lake. During wet years more water is withdrawn and there is much more mixing with surface water, thus temperature changes little from surface to bottom.

Figure 10: September temperature profile on Catawba side of lake during dry seasons (solid lines) and wet seasons (dashed lines)

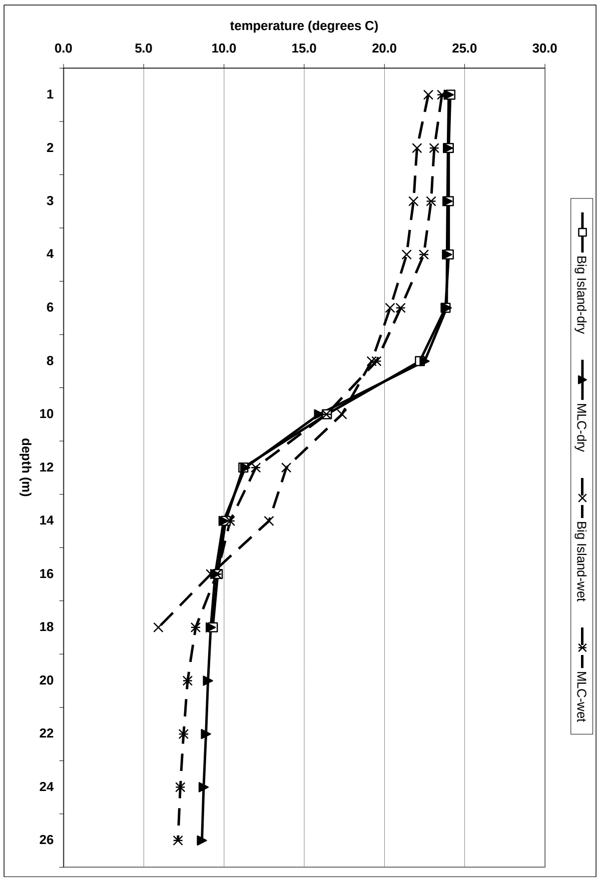
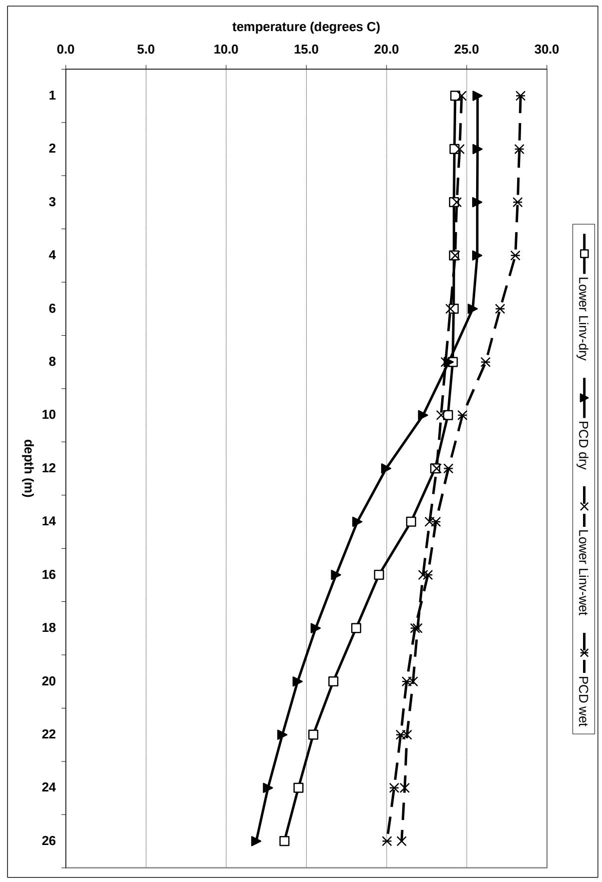


Figure 11: September temperature profile on Linville side of lake during dry seasons (solid lines) and wet seasons (dashed lines)



Since the 2008 lake monitoring season was dryer than usual the temperature profile was typical of dry seasons and there was a more distinct metalimnion (middle layer) and a greater loss off oxygen than generally occurs in wet seasons on the Linville side of the lake. The metalimnetic oxygen decline began to develop early in the season and was quite distinct by September (Figures 12, 13, and 14). On the Catawba side of the lake the rapid decline in oxygen

Figure 12: May 2008 dissolved oxygen saturation at Paddy Creek Dam site compared with the May average from 2001-2007 at that site

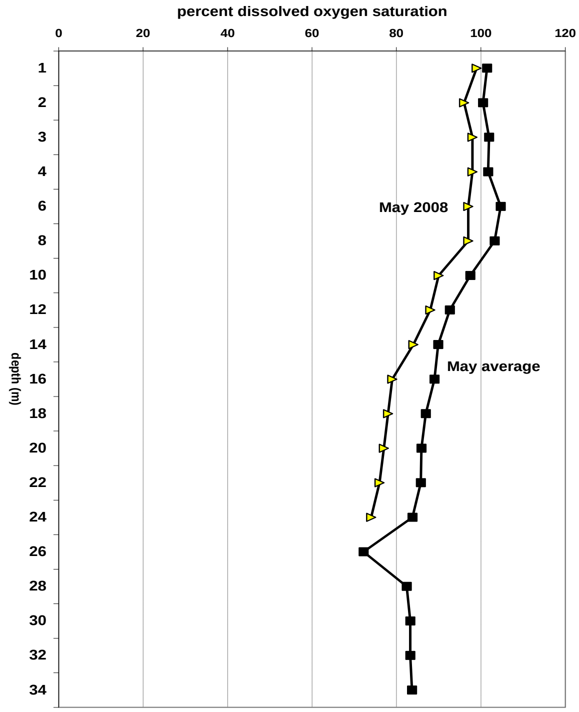


Figure 13: July 2008 percent dissolved oxygen saturation at the Paddy Creek Dam site compared with the July average from 2001-2008 at that site

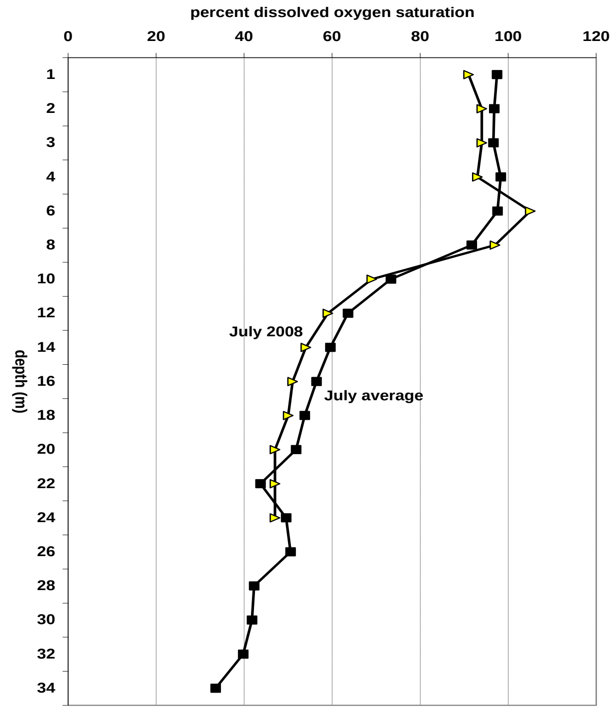


Figure 14: September 2008 percent dissolved oxygen saturation at the Paddy Creek Dam site compared with the September average from 2001-2007 at that site

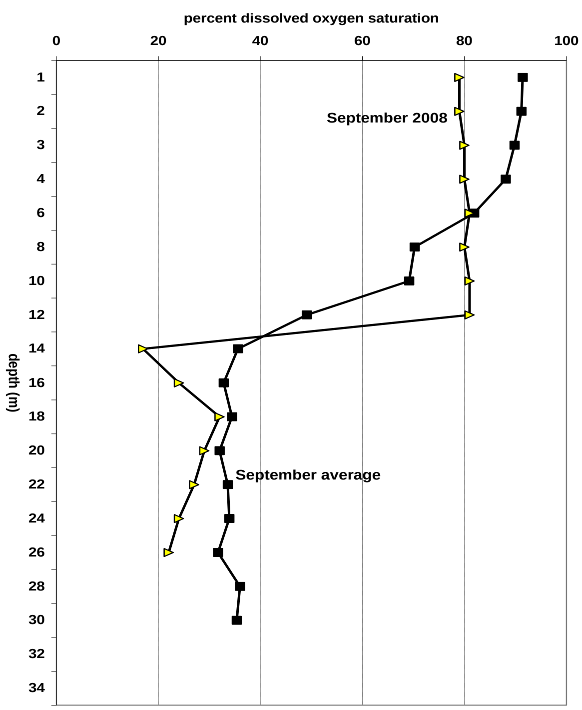


Figure 15: May 2008 dissolved oxygen saturation at Marion Lake Club site compared with the May average from 2001-2007 at that site

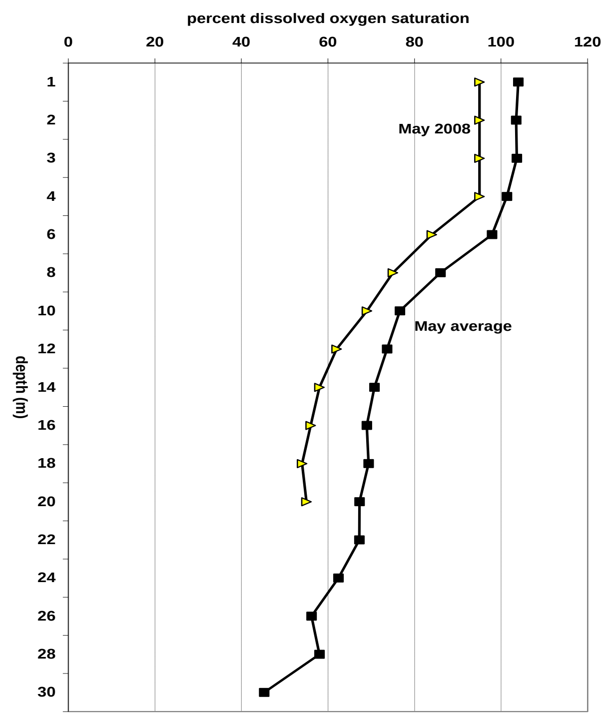


Figure 16: July 2008 percent dissolved oxygen saturation at the Marion Lake Club site compared with the July average from 2001-2007 at that site

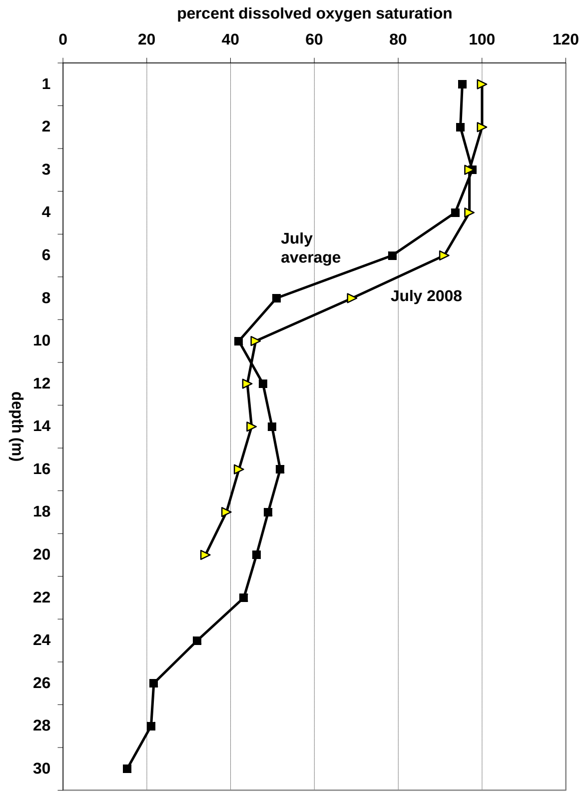
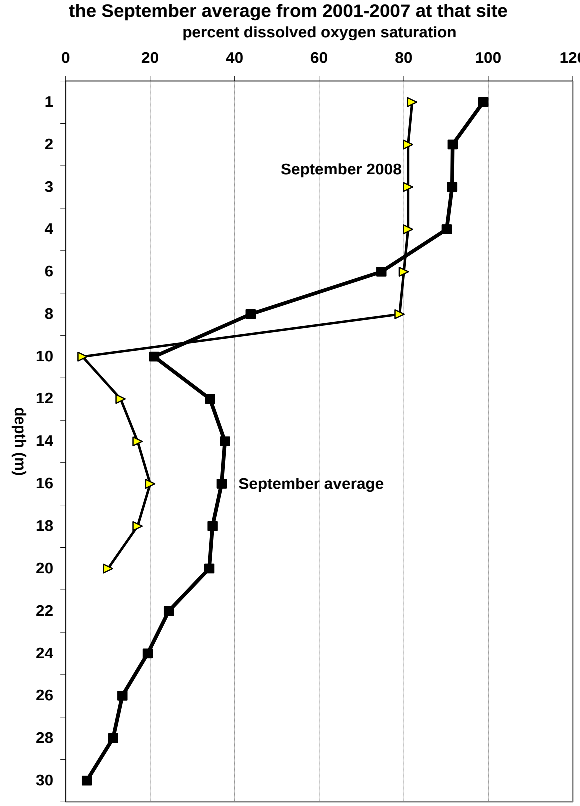


Figure 17: September 2008 percent dissolved oxygen saturation at the Marion Lake Club site compared with the September average from 2001-2007 at that site



occurred at a shallower level, was already well-developed by mid-summer, and was extreme by September (Figures 15, 16, and 17). These patterns of oxygen loss for both sides of the lake were similar to those that occurred in past years. Appendix I is a table of temperatures and dissolved oxygen saturation levels at the Big Island, Marion Lake Club, Upper Linville, and Paddy Creek Dam sites in May, July, and September from 2001 through 2008.

IV: Summary and Conclusions

Understanding the water quality of the streams that flow into Lake James is vital to understanding the water quality of the lake itself. As development continues on the lakeshore, however, activities on the land adjacent to the lake will also be an important factor in the health of the lake. But a major source of pollutants to the lake will likely continue to be the major rivers flowing into Lake James.

Chemical analysis of samples collected at the Lake James monitoring sites are intended to characterize the water quality relative to the parameters established by the Volunteer Water Information Network program. Information from the program can be used by concerned groups and individuals to help identify problems and evaluate solutions. Characterizing the water quality of the county is a complex task, and interpretation of the data can be difficult due to many factors. With continued long term monitoring, however, various trends become more evident. The VWIN program is currently monitoring over 200 sites throughout Western North Carolina. A comparison of Lake James stream sites with all other sites in the program is presented in

Appendix D. Summarized observations and trends for Lake James stream and lake sites are presented below.

The stream ranking system allows grouping by parameters into categories. This system permits comparison of specific water quality problems such as stream sedimentation, urban runoff of chemicals and heavy metals, and nutrient loading. Table 4 is a summary of ranking of Lake James stream sites by water quality issues.

Table 4: Index ratings for Lake James stream monitoring sites

site #	site name	sediment	metals	nutrients	overall	rating
	VWIN - WNC Regional Average	**70**	**86**	**86**	**81**	
	Catawba River					
4	CR5 - Catawba River at Restoflex Rd	63	88	100	83	good
2	CR2 - Catawba River at US-221A	63	94	100	85	good
1	CR1 - Catawba River at SR-1501	75	94	100	90	excellent
	North Fork of the Catawba River					
13	NF2 - North Fork at Old Linville Rd	63	75	67	68	below average
12	NF1A - North Fork below Limekiln Crk	63	75	75	71	average
3	NF1 - North Fork at SR-1552	63	75	75	71	average
	Linville River					
5	LR1 - Linville River at Hwy 126	100	88	100	96	excellent
	average for Lake James stream sites	**70**	**84**	**88**	**81**	
	percent sites below regional average	**71%**	**43%**	**43%**	**43%**	

The Catawba River

There are three sites on the Catawba River, the most upstream at Restoflex Rd, the middle site at US 221A, and the most downstream at SR 1501. Dry weather often results in improved water quality ratings because there is less runoff, thus fewer pollutants entering streams. The 2007/2008 monitoring year was quite dry and ratings for most sites either remained the same as the previous monitoring year or improved slightly. In the case of the three sites on the Catawba River, ratings at the two upstream sites at Restoflex Road and at US-221A remained the same (**good**), and the rating for the site on SR-1501 improved from **good** to **excellent**. Median and maximum turbidity and total suspended solids levels are highest at the upstream site on Restoflex Road and decline at each downstream site. Median levels of most other parameters do not change greatly from upstream to downstream, but maximum levels are usually highest at the Restoflex Road site. Many other pollutants are often carried into the river attached to sediment, so higher levels of other pollutants are typical. Lower concentrations of pollutants at the downstream site indicate some degree of settling in the stream bed between the upstream and downstream sites.

Trend analysis shows that turbidity, total suspended solids, lead, and to some extent nutrient levels are greatly affected by stream flow with levels increasing as flow increases. Conductivity and alkalinity levels decline as stream flow increases. Parameters that increase are affected by stormwater runoff, and parameters that decrease are affected by dilution of naturally occurring substances, or pollutants originating from a point-source. Orthophosphate concentrations are decreasing over time at all three sites, and total phosphorus is decreasing at the downstream site (the only site on the Catawba River that is analyzed for total phosphorus). Median total phosphorus concentrations are still slightly higher than they should be for a stream discharging into a lake. All of the sites show stark seasonal variations with turbidity, total suspended solids, conductivity, and nutrient levels higher in summer. Surface runoff is usually greater in summer when land disturbance is at its greatest and intense thunderstorms cause more particles to break away from the land surface.

The North Fork of the Catawba River

Three sites are monitored on the North Fork. The most upstream is at Old Linville Road, the next site downstream is just downstream from the confluence with Limekiln Creek, and the most downstream site is at SR 1552. Ratings at these three sites have not changed in the past year. The upstream site at Old Linville Road continues to rate **below average**, and the sites at Limekiln Creek and SR1552 continue to rate **average**.

Median levels of pH, alkalinity, conductivity, and orthophosphate are above average to well above average for the region at all three sites, and median levels of zinc and nitrate/nitrite-nitrogen exceed the regional average at the most upstream site on Old Linville Road. Maximum levels of most of these parameters are also unusually elevated. Median turbidity and total suspended solids levels are low for the region, but maximum levels are quite elevated. Median pH, alkalinity, conductivity, zinc, orthophosphate, and nitrate/nitrite-nitrogen are highest at the upstream site and decline at each successive site downstream. Turbidity and TSS increase from upstream to downstream. Orthophosphate and nitrate/nitrite-nitrogen concentrations decrease as flow increases at the two upstream sites indicating probable point-source pollution.

As a major contributor of flow into Lake James, phosphorus concentrations are of specific concern. Although the average flow of the North Fork is about half that of the Catawba River, the median orthophosphate concentration at the downstream site on the North Fork is double that of the downstream site on the Catawba River. Thus the North Fork is as significant a contributor of orthophosphate (the form of phosphorus that is readily available to plants) to Lake James as is the Catawba River. The main source of orthophosphate is upstream from the site on Old Linville Road. Concentrations decline downstream from that site. Trend analysis shows orthophosphate concentrations declining as flow increases at all three sites on the North Fork. This decline is evident during years of higher stream flow (Figure 18) and in all years during months of higher stream flow (Figure 19), but there are some variations. Figures 18 and 19 show median annual and monthly orthophosphate concentrations at the site on the North Fork at Old Linville Road and, for comparison, at the site on the Linville River. The Linville River site was

Figure 18: Median annual orthophosphate concentrations at the site on the North Fork at Old Linville Road and at the site on the Linville River compared with average annual stream flow for the Catawba River at Pleasant Gardens – 2001 through 2008

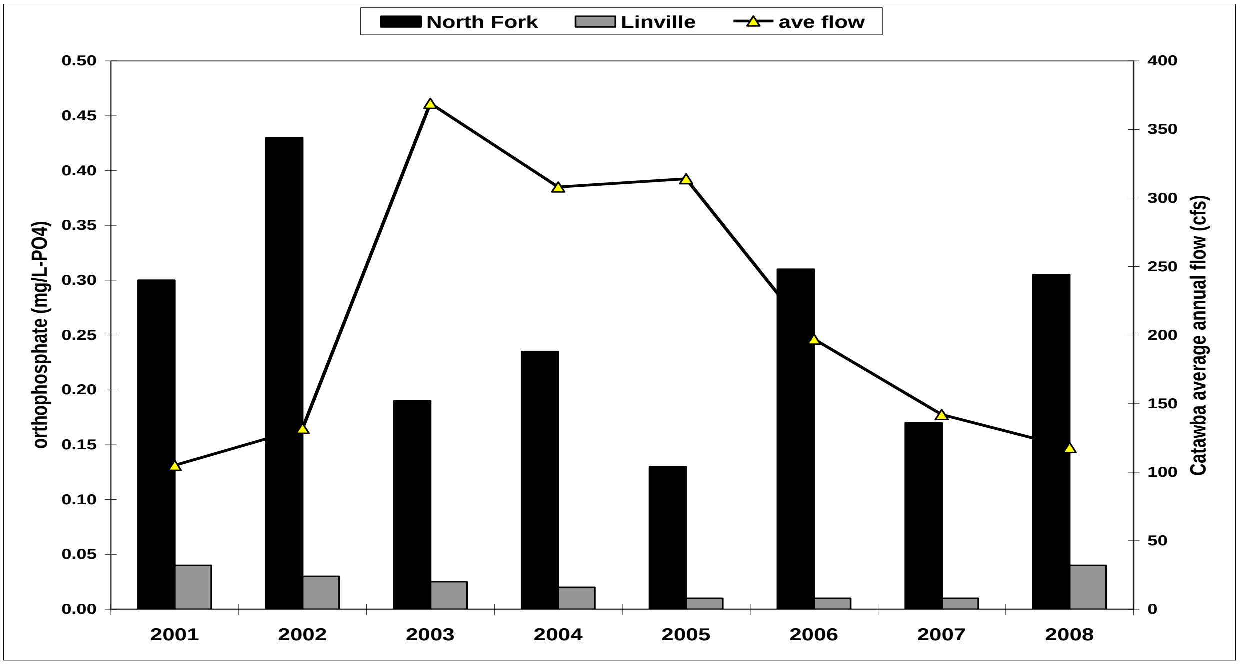
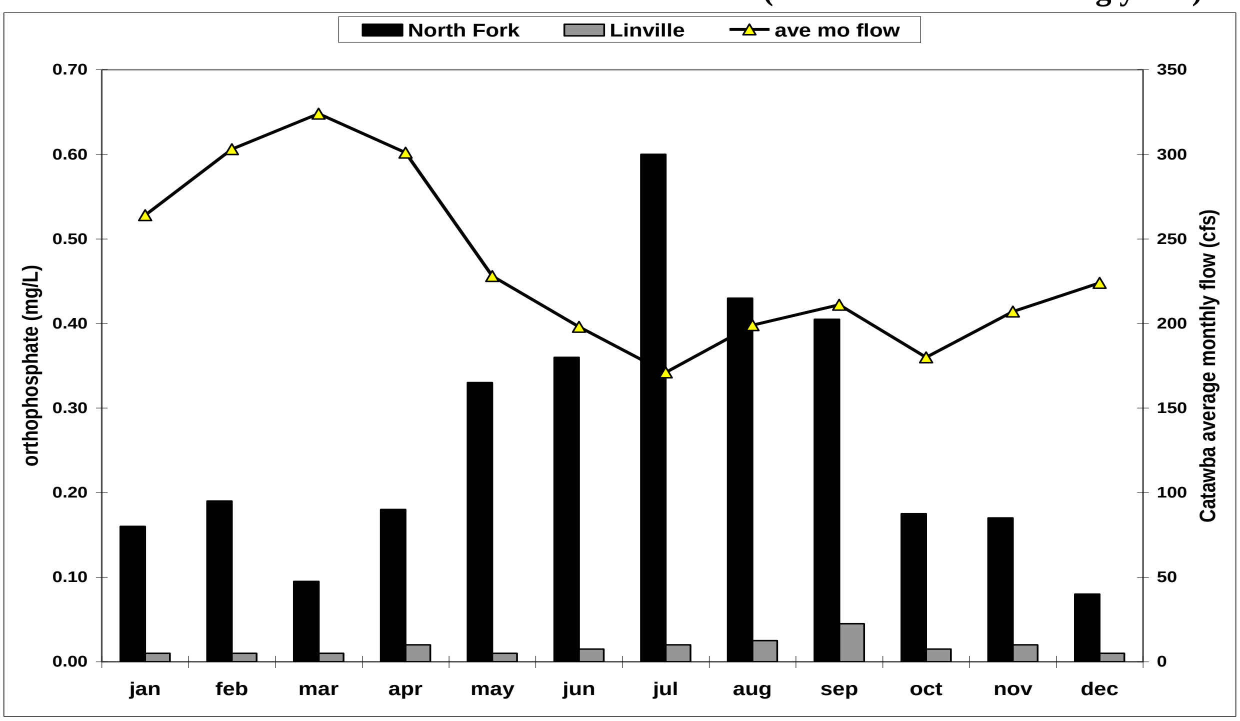


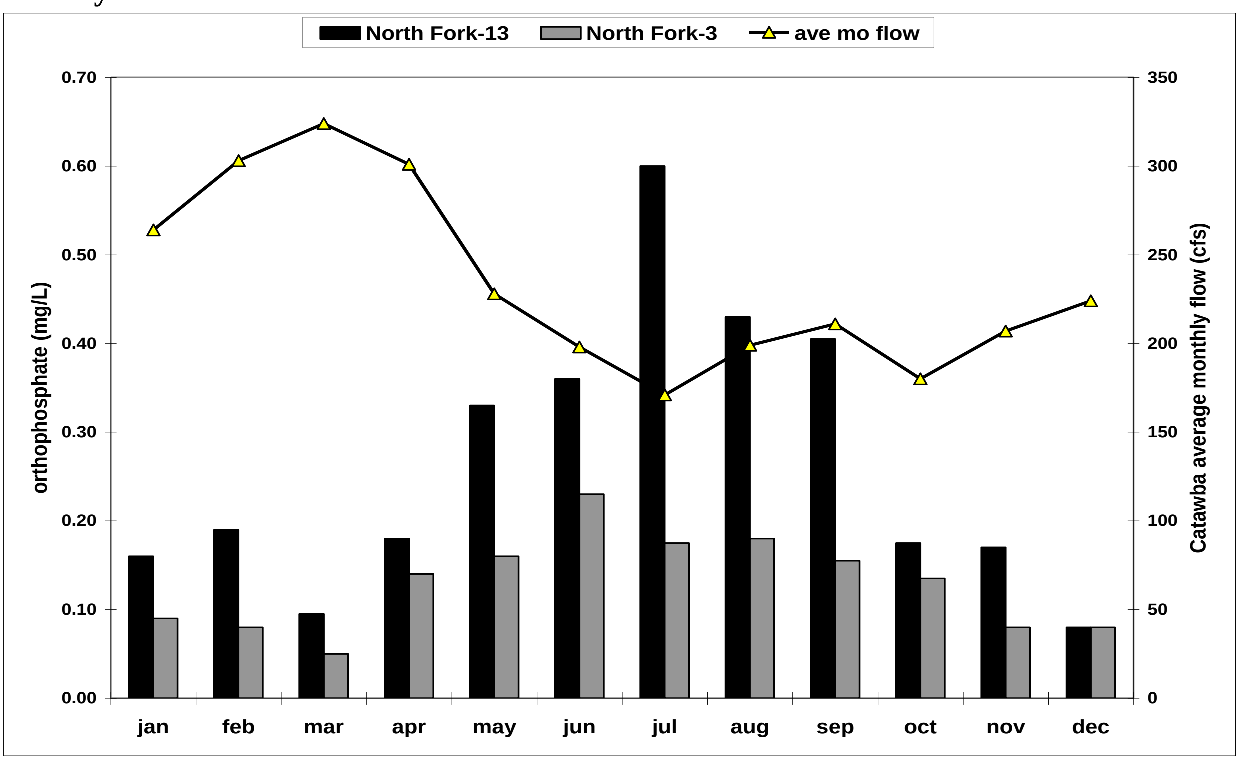
Figure 19: Median monthly orthophosphate concentrations at the site on the North Fork at Old Linville Road and at the site on the Linville River compared with average monthly stream flow for the Catawba River at Pleasant Gardens (data from all monitoring years)



selected for comparison because it only exhibits natural background concentrations of orthophosphate. Both sites show highest concentrations during the three driest years of analysis, 2001, 2002, and 2008 (note: although most of this report only includes data through April 2008, this chart and the monthly chart include data from all of 2008). Concentrations decline during the years of high flow from 2003 though 2005, and remain low at the Linville River site through 2007 even though flow rates decline. This pattern of somewhat delayed response of orthophosphate concentrations to long periods of lower or higher stream flow commonly occurs at VWIN stream monitoring sites. Although the site on the North Fork also adheres to this pattern to a certain degree, there are some exceptions. These exceptions could be related to variations in wastewater effluent flow in certain years, and to occasional problems with wastewater treatment over extended periods.

The chart showing monthly median concentrations over the period 2001 through 2008 are of greater concern because it shows orthophosphate concentrations much greater from May through September, which is when the potential for algae production peaks. Although concentrations decline considerably at the downstream site compared to the upstream site (Figure 20), they are still well above normal background levels, and above levels considered acceptable for streams flowing into lakes. Stream flow typically declines during the summer months, thus continued wastewater effluent output at the same rate would result in higher concentrations of

Figure 20: Median monthly orthophosphate concentrations at the site on the North Fork at Old Linville Road (13) and at the site on the North Fork at SR 1552 compared with average monthly stream flow for the Catawba River at Pleasant Gardens



phosphorus during those months because there is less dilution. But stream flow is also typically lower in fall, yet orthophosphate concentrations decline. This would seem to indicate there are seasonal variations for the source of this pollutant.

Trend analysis shows that nutrient concentrations are declining over time at the site near Limekiln Creek and at SR 1552, but the site on Old Linville Road does not show this trend. Conductivity levels are also declining over time at the site near Limekiln Creek. Trend analysis shows total suspended solids concentrations increasing over time at the Old Linville Road site. Seasonal trends at the North Fork sites are similar to those of the Catawba River sites.

The Linville River

The site on the Linville River at Highway 126 continues to rate **excellent**. Median levels of most parameters are near normal background levels for relatively undisturbed streams, and maximum levels are also quite low. Conductivity levels are somewhat higher than most other streams in the region that are in undisturbed areas, but in this case the higher levels could be from natural sources. Trend analysis shows conductivity and alkalinity levels have increased slightly in recent years, and orthophosphate and pH levels have decreased slightly. The Linville River has not been shown to be a significant contributor of pollutants to Lake James.

Lake James

Unlike many reservoirs in the area that are fed by one main river system, Lake James is fed by three large rivers, and the lake is largely divided into two very different sections, one referred to as the Catawba arm and the other as the Linville arm. A narrow, shallow channel connects the two sections, and the outflow for the lake is from relatively deep in the lake on the Linville side. The Linville River has not been shown to be a significant contributor of pollutants to Lake James. The main waterway pollutant contributors are the Catawba River and the North Fork of the Catawba River.

In 2008 Lake James followed the typical pattern it has established for temperature and dissolved oxygen concentrations in previous years, particularly years when the summer months produced abnormally low rainfall. Oxygen loss below 8 meters was quite extreme on the Catawba side of the lake by mid-summer, and more pronounced than usual on the Linville side by September. Secchi depths and total phosphorus concentrations were similar to previous years of monitoring during drought years. Secchi depths are typically 2 to 4 feet greater in dry seasons than in wet seasons. There is little difference in total phosphorus concentrations between wet and dry seasons on the Linville side of the lake, but concentrations are generally slightly higher on the Catawba side of the lake during wet seasons, particularly at the sites closer to the outflow points of the Catawba and North Fork Rivers. Both secchi depths and total phosphorus concentrations are influenced by the amount of sediment flowing into the lake, and more sediment flows into the lake when rainfall increases.

Although total phosphorus concentrations were somewhat lower in 2008 because of the drought, they are typically at or above what they should be to control algal growth, particularly on the Catawba side of the lake where the Catawba River and the North Fork contribute to the phosphorus load. Although only orthophosphate is analyzed at the Linville River site, concentrations are typically quite low. In fact median concentrations are equal to or less than median concentrations at the lake monitoring sites on the Linville side of the lake.

Controlling phosphorus in the lake will involve controlling surface runoff into both the Catawba River and the North Fork, and controlling phosphorus concentrations in wastewater effluent, especially during the warmer months when algae production peaks.

Appendix A: Chain of Custody form

Volunteer Water Information Network

Lake James

1) Sample Site Number ____ .

2) Sample Site Name ____.

3) Collection Date _________________________ Day ____________________.

4) Time Collected ____.

5) Temperature at drop-off site (in cooler)___________________________________.

6) Volunteer's Name ____.

7)Volunteer's Phone# &/or Email: ______________________________________.

______________________ (please provide current mailing address if there has been a change)

8) Water Flow Rate (please circle one) Very High High Normal Low

9) Type of Rain in past 3 days (please circle one) Heavy Medium Light Dry

10) General Observations (turbidity, waste matter, dead animals upstream, anything out of the ordinary) ____ .

____ .

____ .

Parameter Results (For Lab Use Only)

Parameter and Result		Date of Analysis
NH3	mg/L	
NO3	mg/L	
Po	mg/L	
Turb	NTU	
TSS	mg/L	
Cond	umhos/cm	
Alk	mg/L	
Cu	ug/L	
Zn	ug/L	
Pb	ug/L	
pH		

Appendix B: Laboratory Analysis

Samples are kept refrigerated until they are delivered to the EQI laboratory on the Monday morning following Saturday collections. Methods follow EPA or Standard Methods for the Examination of Water and Wastewater-18th-20th Edition techniques and the EQI laboratory is certified by the State of North Carolina for water and wastewater analysis of orthophosphate, total phosphorus, ammonia-nitrogen, turbidity, total suspended solids, pH, conductivity, copper, lead, and zinc. All samples are kept refrigerated until the time of analysis. Shipped samples are sent on ice. Analysis for nitrogen, phosphorus, pH, turbidity, and conductivity are completed within 48 hours of the collection time. As pH cannot be tested on site, the holding time for pH is exceeded. When immediate analysis does not occur, such as for total phosphorus and heavy metals, the samples are preserved by acidification.

Explanations about the procedures and instruments used in the EQI lab are quite technical in nature and will be omitted from this report. Detailed information is available on request. The reporting limits for each parameter have been provided.

Approximate Analytical Reporting Limits
for VWIN Water Quality Parameters.

PARAMETER	REPORTING LIMIT	UNITS
Ammonia Nitrogen	0.02	mg/L
Nitrate/nitrite Nitrogen	0.1	mg/L
Total Phosphorus (as PO_4^{3-})	0.02	mg/L
Orthophosphate (as PO_4^{3-})	0.02	mg/L
Alkalinity	1.0	mg/L
Total Suspended Solids	4.0	mg/L
Conductivity	10.0	umhos/cm
Turbidity	1.0	NTU
Copper	2.0	ug/L
Zinc	20.0	ug/L
Lead	2.0	ug/L
pH	n/a	n/a

Appendix C: Parameters and Ranges for Stream Quality Classifications

pH -

- Grade A= never less than 6.0
- Grade B= below 6.0 in less than 10% of samples, never below 5.0
- Grade C= never less than 5.0
- Grade D= at least one sample was less 5.0.

Alkalinity -

- Grade A= median greater than 30 mg/L (indicates little vulnerability to acidic inputs)
- Grade B= median 20-30 mg/L (indicates moderate vulnerability to acidic inputs)
- Grade C= median less than 20 mg/L (considered to be vulnerable to acidic inputs).
- Grade D= median less than 15 mg/L (very vulnerable to acidic inputs)

Turbidity -

- Grade A= median less than 5 NTU and exceeded the standard for trout waters of 10 NTU in less than 10% of samples, but never exceeded 50 NTU
- Grade B= median less than 7.5 NTU and never exceeded the 50 NTU standard
- Grade C= median less than 10 NTU and exceeded 50 NTU in less than 10% of samples
- Grade D= median greater than 10 NTU or exceeded 50 NTU in more than 10% of samples.

Total Suspended Solids -

- Grade A= median less than 5 mg/L and maximum less than 100 mg/L - not measurably disturbed by human activities
- Grade B= median less than 7.5 mg/L and exceeded 100 mg/L in less than 10% of samples - low to moderate disturbance
- Grade C= median less than 10 mg/L and exceeded 100 mg/L in less than 10% of samples - moderate to high disturbance.
- Grade D= median greater than 10 mg/L or maximum exceeded 100 mg/L in more than 10% of samples - high level of land disturbance

Conductivity -

- Grade A= median less than 30 umhos/cm, never exceeded 100 umhos/cm
- Grade B= median less than 50 umhos/cm, exceeded 100 umhos/cm in less than 10% of samples
- Grade C= median greater than 50 umhos/cm, exceeded 100 umhos/cm in less than 10% of samples
- Grade D= exceeded 100 umhos/cm in more than 10% of samples.

Total Copper -

- Grade A= never exceeded water quality standard of 7 ug/L
- Grade B= exceeded 7 ug/L in less than 10% of samples
- Grade C= exceeded 7 ug/L in 10 to 20% of samples
- Grade D= exceeded 7 ug/L in more than 20% of samples

Appendix C (continued)

Total Lead -

Grade A= never exceeded water quality standard of 10ug/L
Grade B= exceeded 10 ug/L in less than 10% of samples
Grade C= exceeded 10 ug/L in 10 to 20% of samples
Grade D= exceeded 10 ug/L in more than 20% of samples

Total Zinc -

Grade A= median less than 5 ug/L, never exceeded water quality standard of 50 ppb
Grade B= median less than 10 ug/L, exceeded 50 ppb in less than 10% of samples
Grade C= median less than 10 ug/L, exceeded 50 ppb in 10 - 20% of samples.
Grade D= Median greater than 10 ug/L or concentration exceeded 50 ppb in more than 20% of samples

Total Phosphorous (as P)-

Grade A= median not above 0.03 mg/L
Grade B= median greater than 0.03 mg/L but less than 0.07 mg/L.
Grade C= median greater than 0.07 mg/L but less than 0.10 mg/L
Grade D= median greater then 0.10 mg/L

Orthophosphate (as PO_4^{3-}) -

Grade A= median less than ambient level of 0.05 mg/L
Grade B= median between 0.05 mg/L but less than 0.10 mg/L
Grade C= median greater than 0.10 mg/L but less than 0.20 mg/L
Grade D= median greater then 0.20 mg/L.

Ammonia Nitrogen -

Grade A= never exceeded 0.50 mg/L
Grade B= never exceeded the proposed ambient standard for trout waters in the summer of 1 mg/L
Grade C= exceeded 1 mg/L in less than 10% of samples, but never exceeded 2mg/L
Grade D= exceeded 1 mg/L in more than 10% of samples, or at least one sample had a concentration greater than the proposed ambient standard for trout waters in the winter of 2.0 mg/L.

Nitrate Nitrogen -

Grade A= median does not exceed 0.3 mg/L, no sample exceeded 1.0 mg/L
Grade B= less than 10% of samples exceeded 1.0 mg/L, none exceeded 5 mg/L
Grade C= no samples exceeded 5 mg/L
Grade D= at least one sample exceeded 5 mg/L

Appendix D: Stream Ranking Index

Excellent	Median and maximum pollutant levels in all parameters show little effect from human disturbances
Good	One or more parameters show minor or only occassional increases in pollutant levels from human disturbances
Average	Exhibits constant low levels of one or more pollutants or sudden significant, but short term increases.
Below Ave	Median pollutant levels are abnormally high in one or more parameters, or exhibits very high pollutant levels during certain weather conditions
Poor	Pollutant levels are consistently higher than average in several parameters and/or show extreme levels during certain weather conditions

B = Buncombe County
H = Henderson County
HW=Hiawassee River Watershed
HY = Haywood County
LG = Lake Glenville
LJ = Lake James
LL = Lake Lure
M = Madison County
NOT=Nottely River Watershed
P = Polk County
TOE = Toe and Cane River watersheds
TU = Tuckasegee River watershed

	site #	site description	Excellent
1	B28	Bent Creek below Lake Powhatan	100
2	H9	Mills River at SR 191 (Davenport Bridge)	100
3	H10	Mills River at Hooper Lane	100
4	HW1	Upper Hiawassee River	100
5	HW2	Martin's Creek	100
6	HW4	Scataway Creek	100
7	HW5	Geisky Creek	100
8	HW6	Eagle Fork Creek	100
9	HW8	Lower Shooting Creek	100
10	HY1	West Fork Pigeon River/Bethel	100
11	HY2	East Fork Pigeon River/Bethel	100
12	LG1	Hurricane Creek/Norton Br Rd (Tuckasegee R wtrshd)	100
13	LG5	Cedar Creek at Beetree Rd (Tuckasegee R wtrshd)	100
14	LG7	Norton Creek/up Grassy Cmp (Tuckasegee R wtrshd)	100
15	LL6	Pool Creek (Broad River watershed)	100
16	NOT9	Conley Creek	100
17	TOE3	South Toe River	100
18	TU1	East Fork Tuckasegee River	100
19	HW7	Upper Shooting Creek	98
20	HY3	East Fork Pigeon River/Cruso	98
21	HY13	Allens Creek (Richland Creek watershed)	98
22	**LJ5**	**Linville River at Hwy 126**	**98**
23	NOT1	Nottely River upstream	98
24	NOT3	Nottely River	98
25	B12A	Bent Creek at SR 191	97

Appendix D: Stream Ranking Index - continued

26	B22	Ivy Creek at Dillingham Road	97
27	H7	North Fork Mills River	97
28	LG2	Norton Creek at Norton Rd br (Tuckasegee R wtrshd)	97
29	LG3	Mill Creek/dnstrm Norton br (Tuckasegee R wtrshd)	97
30	LL9	Buffalo Creek (Broad River watershed)	97
31	H19	Green River at Old Hwy 25 S	96
32	H11	Green River below Lake Summit	96
33	HW3	Hightower Creek	96
34	HW9	Upper Bell Creek	96
35	NOT5	Coosa Creek	96
36	NOT10	Young Cane Creek upstream	96
37	H12	Green River at Terry's Creek Rd	95
38	HY11	Richland Creek at Lake Junaluska	95
39	LG6	Glenville Creek at Tator Knob Rd (Tuckasegee R)	95
40	LL8	Cane Creek upstream from Tryon Bay (Broad Rvr wtrshd)	94
41	HW11	Hog Creek	93
42	LL2	Hickory Creek at Bat Cave (Broad River watershed)	93
43	HW12	Woods Creek	92
44	NOT8	Ivy Log Creek	92
45	P1	White Oak Creek at SR 1137/Houston Road	92
46	TU3	Caney Fork (Tuckasegee River watershed)	92
47	B20	Ivy Creek at Buckner Branch Road	91
48	H13	Big Hungry River below dam (Green River watershed)	91
49	HY10	Richland Creek at West Waynesville	91
50	LL3	Broad River at Bat Cave	91
51	LL7	Public Golf Course Creek at Hwy 64/74 (Broad Rvr wtrshd)	91
52	LL10	Fairfield Mts Creek (Broad River watershed)	91
53	B30	Grassy Branch (Swannanoa River watershed)	90
54	H8	South Fork Mills River	90
55	H15	Bat Fork Creek at Tabor Road (Mud Creek watershed)	90
56	**LJ1**	**Catawba River at SR 1501**	**90**
57	P13	Green River at Hwy 9	90

			Good
58	NOT7	Young Cane Creek	89
59	H23	Big Willow Creek at Patterson Rd	88
60	M8	Little Laurel Creek (Laurel River watershed)	88
61	P6	Horse Creek at SR 1516 (River Rd) (N Pacolet River wtrshd)	88
62	TOE1	Cane Creek at Bakersville	88
63	TOE5	Cane River at Mtn Heritage HS	88
64	TU5	Tuckasegee River upstream from Scott's Creek	88
65	TU10	Barker's Creek (Tuckasegee River watershed)	88
66	TU14	Deep Creek (Tuckasegee River watershed)	88
67	B5B	Reems Creek at Ox Creek	87
68	B31	Swannanoa River at Grassy Branch confluence	87
69	B43	Ross Creek at Swannanoa River (Swannonoa R wtrshd)	87
70	H14	Boylston Creek at Ladson Road	87
71	H21	Mud Creek at Berea Church Road	87
72	H28	Shaw Creek at Hunters Glen	87
73	M9	Shelton Laurel Creek (Laurel River watershed)	87
74	NOT2	Arkaqua Creek	87
75	P15	North Pacolet River at Melrose	87
76	TU4	Cullowhee Creek (Tuckasegee River watershed)	86

Appendix D: Stream Ranking Index - continued

77	B17A	Swannanoa River at NC 81	85
78	H20	Clear Creek at Apple Valley Rd (Mud Crk watershed)	85
79	LG4	Pine Creek/Pine Creek Rd br (Tuckasegee R wtrshd)	85
80	**LJ2**	**Catawba River at US 221A**	**85**
81	P5	Horse Creek at SR 1516 (River Road) N Pacolet R wtrshd)	85
82	P16	North Pacolet River at Rte 108	85
83	TU2	West Fork Tuckasegee River	85
84	B40	Ross Creek at Lower Chunns Cove Rd(Swannanoa R wtrshd)	84
85	TOE2	Cane Creek at Loafer's Glory	84
86	H18	Mud Creek at 7th Avenue	83
87	HY12	Jonathan Creek near confluence with Pigeon River	83
88	**LJ4**	**Catawba River at Resistoflex**	**83**
89	LL4	Broad River at Chimney Rock	83
90	LL5	Broad River at Lake Lure	83
91	TU9	Tuckasegee River at Barker's Creek	83
92	TU11	Connelley Creek (Tuckasegee River watershed)	83
93	TU12	Tuckasegee River downstream from Bryson City	83
94	M7	Spring Creek	82
95	TU15	Oconoluftee River (Tuckasegee River watershed)	82
96	B1A	Big Ivy Creek at Forks of Ivy	81
97	B9A	Beetree Creek (Swannanoa River watershed)	81
98	B16A	Cane Creek at Mills Gap Road	81
99	B17B	Haw Creek at NC 81 (Swannanoa River watershed)	81
100	H1	French Broad River at Banner Farm Road in Horseshoe	81
101	H5	Clear Creek at Nix Road (Mud Creek watershed)	81
102	H27	Mill Pond Creek at South Rugby Road	81
103	H29	Brandy Branch at Mills River Village (Mills River watershed)	81
104	HY9	Plott Creek in Hazelwood (Richland Crk watershed)	81
105	HY27	Jonathan Creek at Maggie Valley	81
106	LL1	Reedypatch Creek at Bat Cave (Broad River watershed)	81
107	LL15	Buffalo Creek at Bald Mtn Lake (Broad R watershed)	81
108	M10	Laurel River	81
109	P2	White Oak Creek at SR 1531 (Fox Mt Rd)	81
110	P4	White Oak Creek at SR 1322 (Moore Road)	81
111	P7	North Pacolet River at SR 1516 (S River Rd)	81
112	P8	Demannu Creek at SR 1140 and Hwy 9 (Green River wtrshd)	81
113	TU7	Savannah Creek (Tuckasegee River watershed)	81
114	P9	Joels Creek upstream (N. Pacolet Rvr watershed)	80

			Average
115	TU8	Green's Creek (Tuckasegee River watershed)	79
116	TU13	Kirkland Creek (Tuckasegee River watershed)	79
117	B8	Beaverdam Creek at Beaver Lake	78
118	B10	Bull Creek at Swannanoa River (Swannanoa R wtrshd)	78
119	B35	Smith Mill Creek at Louisiana Blvd.	78
120	H3	Mud Creek at Erkwood Road	78
121	H22	Hoopers Creek at Jackson Rd (Cane Creek watershed)	78
122	H26	Brittain Creek at Patton Park (Mud Creek watershed)	78
123	M11	Bull Creek (Ivy River watershed)	78
124	M14	Middle Fork at Beech Glen (Ivy River watershed)	78
125	P14	White Oak Creek at Briar Hill Farm	78
126	H30	Devils Fork at Dana Road (Mud Creek watershed)	77
127	M12	Grapevine Creek (Ivy River watershed)	77

Appendix D: Stream Ranking Index - continued

128	B5A	Ox Creek at Reems Creek (Reems Creek watershed)	76
129	B6B	Reems Creek at French Broad River	76
130	B9B	Swannanoa River at Beetree Creek	76
131	B15A	Cane Creek at Hwy 74 (FBR watershed)	76
132	B15B	Ashworth Creek at Hwy 74 & Cane Crk Rd (Cane Ck wtrshd)	76
133	B24	Swannanoa River at confluence with North Fork	76
134	B33	North Fork Swannanoa River at Grovestone Quarry	76
135	B38	Swannanoa River at Bull Creek	76
136	B41	Ross Creek at Tunnel Road (Swannanoa River watershed)	76
137	HY6	Rush Fork at Crabtree (Crabtree Creek watershed)	76
138	M1	Ivy River at NC 25/70	76
139	M13	California Creek at Beech Glen (Ivy River watershed)	76
140	M4	East Fork Bull Creek (Ivy River watershed)	75
141	NOT6	Anderson Creek	75
142	B12B	French Broad River at Bent Creek	74
143	HY4	Pigeon River downstream from Canton	74
144	HY8	Eaglenest Creek in Hazelwood (Richland Creek watershed)	74
145	M15	Paint Fork at Beech Glen (Ivy River watershed)	74
146	HY25	Raccoon Creek downstream (Richland Creek watershed)	73
147	NOT4	Butternut Creek	73
148	P18	Camp Creek (Green River watershed)	73
149	B21	Paint Fork at Barnardsville (Ivy River watershed)	72
150	H16	Cane Creek at Howard Gap Road	72
151	HY28	Hyatt Creek left branch	72
152	M3	French Broad River at Hot Springs	72
153	M6	Big Pine Creek	72
154	B14	Lower Flat Creek	71
155	HY26	Crabtree Creek at Crabtree Rd	71
156	**LJ3**	**North Fork of the Catawba River at SR 1552**	**71**
157	**LJ12**	**North Fork of the Catawba River below Limekiln Creek**	**71**
158	TOE4	North Toe River at Red Hill	71

			Below Average
159	HY5	Pigeon River at Hepco Bridge	69
160	P10	Joels Creek downstream (N Pacolet River watershed)	69
161	B26	North Turkey Creek (Sandymush Creek watershed)	68
162	**LJ13**	**North Fork of the Catawba River at Old Linville Rd**	**68**
163	B7A	Reed Creek at UNCA Botanical Gardens	67
164	HY19	Fines Creek upstream	67
165	HY23	Ratcliff Cove Branch (Raccoon Creek watershed)	67
166	HY24	Raccoon Creek upstream (Richland Creek watershed)	67
167	M20	Puncheon Fork (Laurel River watershed)	67
168	TOE6	Bald Creek at Bald Creek Elementary School	67
169	TU6	Scott's Creek (Tuckasegee River watershed)	67
170	B7B	Glenn Creek at UNCA Bot Gardens (Reed Ck wtrshd)	66
171	B25	South Turkey Creek (Sandymush Creek watershed)	66
172	HY7	Fines Creek downstream	66
173	B23	French Broad River at Jean Webb Park - Asheville	65
174	B36	Newfound Creek at Dark Cove Road	65
175	B42	Ross Creek at Upper Chunns Cove (Swannanoa R wtrshd)	65
176	B47	Reed Creek at entrance to UNCA	65
177	B27	Flat Creek at NC 19/23	64

Appendix D: Stream Ranking Index - continued

178	B2	Lower Sandymush Creek	63
179	B37	Newfound Creek at Leicester Hwy	63
180	H4	Mud Creek at North Rugby Road	63
181	H25	Gash Creek at Etowah School Road	63
182	M19	Laurel Valley Creek (Laurel River watershed)	63
183	B34	Lower Hominy Creek at NC 191	62
184	H2	French Broad River at Butler Bridge Road	61
185	M17	Gabriel's Creek at Ivy River	61
186	B3B	Sandymush Creek at Willow Creek	60
187	HY14	Rush Fork upstream (Crabtree Crk watershed)	60
188	HY15	Fines Creek midstream	60
189	HY29	Hyatt Creek Owl Ridge branch	60

			Poor
190	B32	French Broad River at Walnut Island Park	59
191	B13	French Broad River at Corcoran Park (Hend/Bunc line)	58
192	HY20	Cove Creek at NC 209 (Fines Creek watershed)	58
193	HY30	Hyatt Creek Green Valley branch	58
194	B6A	French Broad River at the Ledges Park	57
195	B48	South Creek Pond/Beaver Lake (Beaverdam Crk wtrshd)	56
196	HY22	Hyatt Creek downstream (Richland Creek watershed)	56
197	M2	French Broad River at Barnard Bridge	55
198	B1B	Little Ivy Creek (Ivy River watershed)	54
199	B4	Lower Newfound Creek	53
200	HY21	Hyatt Creek upstream (Richland Creek watershed)	51
201	B39	South Creek at Beaver Lake (Beaverdam Crk watershed)	44

Percent -	**Excellent**	**Good**	**Average**	**Below Average**	**Poor**
Buncombe	10	18	31	27	14
Henderson	33	37	19	11	0
Haywood	22	11	22	30	15
Hiawassee	100	0	0	0	0
Lake Glenville	86	14	0	0	0
Lake James	**29**	**28**	**29**	**14**	**0**
Lake Lure	64	36	0	0	0
Madison	0	24	53	17	6
Nottely	60	20	20	0	0
Polk	14	65	14	7	0
Toe/Cane	17	50	16	17	0
Tuckasegee River	13	67	13	7	0
TOTAL	28	28	22	16	6

Appendix E: Data Summary

Site	the number assigned to the VWIN site
Sample #	the number of samples collected for each parameter
Low	minimum value of any sample(s)
Median	median value for each site for last 3 years and then for all years monitored
High	maximum value of any sample(s)

pH - Last 3 Years					All Results	
site	sample #	low	median	high	sample #	median
1	36	6.6	7.0	7.4	80	7.0
2	36	6.8	7.1	7.5	80	7.1
3	36	7.0	7.5	8.3	83	7.6
4	36	6.7	7.2	7.6	80	7.2
5	36	6.0	6.8	7.4	83	6.9
12	35	6.7	7.4	8.0	74	7.6
13	35	7.0	7.7	8.2	73	7.7

Alkalinity - Last 3 Years/rep. limit 1 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	13	22	35	80	22
2	36	15	22	33	80	21
3	36	24	41	78	83	38
4	36	14	23	34	80	21
5	36	9	17	22	83	15
12	35	10	38	76	74	40
13	35	25	46	103	72	44

Turbidity (NTU) - Last 3 Years/rep. limit 1 NTU					All Results	
site	sample #	low	median	high	sample #	median
1	36	2.1	5.2	95	80	5.7
2	36	2.4	5.3	100	80	5.7
3	36	1.5	4.8	220	83	4.8
4	36	2.3	6.1	180	80	6.3
5	36	1.0	2.9	15	83	2.8
12	35	1.1	4.4	170	74	4.7
13	35	0.7	3.5	190	73	3.1

TSS (mg/L) - Last 3 Years/rep. limit 4 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	<4	4.0	72.4	80	4.4
2	36	<4	4.6	109.6	80	5.2
3	36	<4	2.6	177.6	83	3.2
4	36	<4	5.0	142.6	80	5.4
5	36	<4	1.2	32.0	83	1.6
12	35	<4	2.8	211.4	74	3.3
13	35	<4	2.0	181.9	72	2.0

Conductivity - Last 3 Years/rep. limit 10 umhos/cm					All Results	
site	sample #	low	median	high	sample #	median
1	36	39	50	89	80	49
2	36	37	48	78	80	47
3	36	64	105	186	83	99
4	36	41	51	88	80	50
5	36	35	45	57	83	41
12	35	69	108	222	74	121
13	35	73	132	331	73	130

Copper (ppb) - Last 3 Years/rep. limit 2 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<2	0.9	2.9	77	0.9
2	36	<2	0.8	4.7	77	0.7
3	36	<2	1.0	11.5	80	1.0
4	36	<2	0.9	5.9	77	0.9
5	36	<2	0.7	3.8	80	0.7
12	35	<2	1.7	11.7	71	2.0
13	35	<2	1.1	9.2	70	1.0

Appendix E: Data Summary (continued)

Lead (ppb) - Last 3 Years/rep. limit 2 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<2	0.4	3.1	80	0.4
2	36	<2	0.3	3.4	80	0.3
3	36	<2	0.2	6.1	83	0.1
4	36	<2	0.4	4.3	80	0.4
5	36	<2	0.2	<2	83	0.2
12	35	<2	0.2	6.5	74	0.2
13	35	<2	0.5	4.7	73	0.2

Zinc - Last 3 Years/rep. limit 20 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<20	2.3	33.6	80	2.3
2	36	<20	2.2	22.1	80	2.1
3	36	<20	0.4	25.9	83	0.4
4	36	<20	3.8	37.0	80	3.3
5	36	<20	0.9	<20	83	0.7
12	35	<20	0.7	26.8	74	1.1
13	35	<20	4.7	27.1	73	4.7

Orthophosphate (mg/L as PO4)-Last 3 Yrs/rep. lim. 0.02 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	<0.02	0.05	0.10	80	0.06
2	36	<0.02	0.03	0.12	80	0.05
3	36	<0.02	0.10	0.21	83	0.14
4	36	<0.02	0.05	0.17	80	0.06
5	36	<0.02	0.01	0.16	83	0.02
6	15	<0.02	0.03	0.11	34	0.03
7	15	<0.02	0.02	0.08	35	0.02
8	15	<0.02	0.02	0.07	35	0.02
9	15	<0.02	0.01	0.05	35	0.01
10	15	<0.02	0.02	0.03	35	0.01
11	15	<0.02	0.01	0.05	35	0.01
12	35	0.02	0.16	0.40	74	0.21
13	35	0.03	0.19	1.77	73	0.20

Total P (mg/L as PO4)-Last 3 Yrs/rep. lim. 0.02 mg/L						All Results		
site	sample #	low	med (PO4)	med (as P)	high	sample #	med (PO4)	med (asP)
1	36	0.06	0.19	0.06	0.46	73	0.22	0.07
2	0					0		
3	36	0.12	0.21	0.07	0.76	77	0.29	0.09
4	0					0		
5	0					19	0.10	0.03
6	15	0.16	0.27	0.09	0.36	34	0.28	0.09
7	15	0.06	0.14	0.05	0.30	35	0.14	0.05
8	15	0.04	0.11	0.04	0.18	35	0.11	0.04
9	15	0.02	0.08	0.03	0.25	35	0.08	0.03
10	15	0.02	0.10	0.03	0.18	35	0.10	0.03
11	15	<0.02	0.11	0.04	0.28	35	0.09	0.03
12	0					0		
13	0					0		

Appendix E: Data Summary (continued)

Ammonia-nitrogen (mg/L) - Last 3 Years/rep. lim. 0.02 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	0.04	0.10	0.21	80	0.11
2	36	0.03	0.09	0.21	80	0.09
3	36	0.02	0.07	0.18	83	0.07
4	36	0.04	0.10	0.33	80	0.10
5	36	0.02	0.06	0.19	83	0.06
6	15	0.09	0.15	0.24	34	0.15
7	15	0.02	0.05	0.09	35	0.05
8	15	0.03	0.04	0.08	35	0.04
9	15	0.02	0.04	0.06	35	0.04
10	15	<0.02	0.04	0.09	35	0.04
11	15	0.02	0.04	0.06	35	0.04
12	35	0.03	0.08	0.24	74	0.09
13	35	0.02	0.06	0.20	73	0.06

Nitrate/nitrite-nitrogen (mg/L)- Last 3 Years/rep. limit 0.1 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	0.2	0.3	1.0	80	0.3
2	36	0.1	0.3	0.8	80	0.3
3	36	0.1	0.4	1.6	83	0.4
4	36	0.1	0.3	1.0	80	0.3
5	36	0.1	0.3	0.5	83	0.3
6	15	<0.1	0.2	0.3	34	0.2
7	15	<0.1	0.1	0.2	35	0.1
8	15	<0.1	0.0	0.2	35	0.1
9	15	<0.1	0.0	0.2	35	0.0
10	15	<0.1	0.0	0.2	35	0.0
11	15	<0.1	0.1	0.2	35	0.1
12	35	0.2	0.5	1.4	74	0.5
13	35	0.2	0.6	1.5	73	0.7

Appendix F: Trends for Each Site Related to Flow

increases as flow increases

site	site name	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total P	Ammonia-N	Nitrate-N
1	CR1 - Catawba River at SR-1501			X	X			X			X		X
2	CR2 - Catawba River at US-221A			X	X			X				X	X
3	NF1 - North Fork at SR-1552			X	X			X					
4	CR5 - Catawba River/Restoflex Rd			X	X			X				X	
5	LR1 - Linville River at Hwy 126			X				X				X	X
6	Lake James/Plantation Point												
7	Lake James/Big Island										X	X	
8	Lake James/Marion Lake Club											X	
9	Lake James/Paddy Creek dam										X	X	
10	Lake James/upper Linville arm										X	X	
11	Lake James/lower Linville arm											X	
12	NF1A - North Fork at Limekiln Crk												
13	NF2 - North Fork/Old Linville Rd												

decreases as flow increases

site	site name	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total P	Ammonia-N	Nitrate-N
1	CR1 - Catawba River at SR-1501		X			X							
2	CR2 - Catawba River at US-221A		X			X							
3	NF1 - North Fork at SR-1552	X	X			X				X			
4	CR5 - Catawba River/Restoflex Rd		X			X							
5	LR1 - Linville River at Hwy 126	X	X			X							
6	Lake James/Plantation Point												
7	Lake James/Big Island												
8	Lake James/Marion Lake Club												
9	Lake James/Paddy Creek dam												
10	Lake James/upper Linville arm												
11	Lake James/lower Linville arm												
12	NF1A - North Fork at Limekiln Crk		X			X				X			X
13	NF2 - North Fork/Old Linville Rd		X			X				X			X

Appendix G: Trends for Each Site Related to Time

		increasing over time												decreasing over time											
site	site name	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total P	Ammonia-N	Nitrate-N	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total P	Ammonia-N	Nitrate-N
1	CR1 - Catawba River at SR-1501	X																				X	X		
2	CR2 - Catawba River at US-221A																					X			
3	NF1 - North Fork at SR-1552													X					X			X	X		X
4	CR5 - Catawba River/Restoflex Rd		X																			X			
5	LR1 - Linville River at Hwy 126		X			X								X								X			
6	Lake James/Plantation Point																								
7	Lake James/Big Island																								
8	Lake James/Marion Lake Club																								X
9	Lake James/Paddy Creek dam																								
10	Lake James/upper Linville arm																								
11	Lake James/lower Linville arm																								
12	NF1A - North Fork at Limekiln Crk													X				X	X			X		X	
13	NF2 - North Fork/Old Linville Rd				X			X																	

Appendix H: Number of Sites Exhibiting Seasonal Trends

Lake James Stream Sites

parameter	hi winter	hi spring	hi summer	hi fall	lo winter	lo spring	lo summer	lo fall	trend sites	% sites showing trend
pH			2		2				2	28.6%
alkalinity			1	5	2	4			6	85.7%
turbidity			7		5			2	7	100.0%
total susp sol			7		7				7	100.0%
conductivity			7		1	6			7	100.0%
copper			1		1				1	14.3%
lead			1					1	1	14.3%
zinc			1		1				1	14.3%
orthophos.			4		4				4	57.1%
ammonia-N			7		7				7	100.0%
nitrate-N	1		6		2			5	7	100.0%

All VWIN sites in Western North Carolina (176 total sites analyzed for trends, except 162 for metals)

Alkalinity	hi winter	hi spring	hi summer	hi fall	lo winter	lo spring	lo summer	lo fall	trend sites	% sites showing trend
pH		5	74	34	95	15		3	113	64.2%
alkalinity		1	37	92	43	87			130	73.9%
turbidity	7	26	89		51	1		70	122	69.3%
total susp sol	1	34	103		73	10		55	138	78.4%
conductivity	9	4	41	82	20	109	5	2	136	77.3%
copper		2	36	3	31	4		6	41	25.3%
lead		6	41	1	30	1		17	48	29.6%
zinc	8	6	21		10	6	6	13	35	21.6%
orthophos.		1	76	4	54	20		7	81	46.0%
ammonia-N	2	3	78	5	68	8	1	11	88	50.0%
nitrate-N	85	9	35		7	9	18	95	129	73.3%

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles

Lake Percent Oxygen Saturation in May

Big Island

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	102	107	107	123	108	111	99	**108**	95
2	104	106	106	131	111	110	106	**111**	97
3	106	107	106	132	110	113	106	**111**	97
4	106	105	100	128	109	113	110	**110**	95
6	82	94	88	99	88	89	79	**88**	87
8	77	64	79	83	67	53	71	**70**	68
10	62	51	69	71	63	56		**62**	57
12	56	45	57	68	66	42		**56**	47
14	49	41	55	58	52	34		**48**	36
16	39	40	57	40	1			**35**	33
18	37	40	53	39				**42**	
20			48					**48**	

Marion Lake Club

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	103	102	102	116	104	103	97	**104**	95
2	101	103	104	116	104	101	96	**103**	95
3	100	103	106	111	108	99	99	**104**	95
4	97	103	92	117	105	99	97	**101**	95
6	91	100	71	118	110	99	96	**98**	84
8	82	91	65	112	80	85	87	**86**	75
10	75	76	63	92	70	79	81	**77**	69
12	68	70	64	87	73	77	77	**74**	62
14	67	65	63	83	71	71	76	**71**	58
16	68	60	67	80	69	67	72	**69**	56
18	68	63	68	80	72	68	67	**69**	54
20	67	62	68	74	71	64	65	**67**	55
22	65	66	72	73	71	60	64	**67**	
24	61	61	71	68	63	56	57	**62**	
26	59	59	69	64	49	51	43	**56**	
28	56	53	64	59				**58**	
30	31	48	60	42				**45**	

Lower Linville

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	101	108	103	110	103	105	101	**104**	98
2	101	109	100	109	97	104	102	**103**	97
3	99	107	100	108	104	104	103	**104**	97
4	100	107	100	107	102	104	107	**104**	97
6	101	107	99	116	90	105	105	**103**	93
8	104	103	89	115	94	102	102	**101**	90
10	99	98	87	109	85	102	97	**97**	88
12	97	94	86	105	81	98	93	**94**	86
14	94	90	84	105	80	88	91	**90**	83
16	92	89	84	100	80	99	90	**91**	82
18	89	87	86	98	77	99	89	**89**	78
20	86	86	85	97	77	98	86	**88**	
22	85	79	85	96	98	91	86	**89**	
24	82	74	86		71	85	82	**80**	
26	80	70	81		68	80	8	**65**	
28	80		75		68			**74**	

Paddy Creek Dam

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	100	98	97	113	98	98	106	**101**	99
2	102	102	89	112	97	96	105	**100**	96
3	101	102	94	114	97	99	107	**102**	98
4	99	103	91	115	98	99	107	**102**	98
6	99	109	91	122	101	100	111	**105**	97
8	103	107	86	128	98	96	105	**103**	97
10	96	100	80	122	90	98	97	**97**	90
12	90	96	76	115	82	97	93	**93**	88
14	89	92	73	111	79	96	89	**90**	84
16	87	91	77	109	78	94	87	**89**	79
18	87	87	76	106	78	90	85	**87**	78
20	85	83	76	104	79	89	85	**86**	77
22	84	82	78	104	79	88	86	**86**	76
24	83	80	75	102	77	86	84	**84**	74
26	83	80	73	99	78	10	83	**72**	
28	83	79	76	97	77			**82**	
30	83	78	76	96				**83**	
32	83	78	75	97				**83**	
34	82	73		96				**84**	

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles (continued)

Lake Temperature (degrees C) in May

Big Island

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	22.2	21.0	19.2	26.0	21.7	22.7	24.0	**22.4**	20.9
2	22.2	20.7	19.0	24.9	21.6	22.5	23.5	**22.1**	20.6
3	22.0	19.9	18.6	23.6	21.1	20.3	22.4	**21.1**	19.5
4	22.0	19.5	18.2	21.6	20.9	19.3	21.2	**20.4**	19.2
6	18.4	19.0	16.4	17.8	17.4	17.7	18.4	**17.9**	17.2
8	12.4	17.2	14.6	13.0	14.0	15.2	12.0	**14.1**	14.4
10	10.3	11.7	11.3	10.5	11.1	11.7		**11.1**	13.0
12	9.4	9.5	6.8	9.4	10.6	10.4		**9.4**	11.3
14	8.7	8.7	6.6	8.8	9.6	9.9		**8.7**	10.3
16	8.7	8.5	6.4	8.4	9.6			**8.3**	9.9
18	8.6	8.3	6.3	8.2				**7.9**	
20		8.2	6.3	8.1				**7.5**	

Marion Lake Club

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	21.8	21.1	18.9	25.7	22.1	23.3	23.6	**22.4**	20.7
2	21.7	20.7	18.7	25.6	22.1	22.2	23.5	**22.1**	20.7
3	21.7	20.0	18.6	23.9	21.8	21.2	22.4	**21.4**	20.3
4	21.6	19.7	18.2	21.5	21.3	20.3	21.3	**20.6**	19.6
6	18.4	19.4	16.3	17.7	17.0	18.3	17.3	**17.8**	16.7
8	13.6	16.2	14.3	13.3	13.7	13.8	11.7	**13.8**	14.5
10	10.5	11.5	10.5	10.5	11.4	11.4	10.5	**10.9**	12.6
12	9.6	9.1	7.8	9.5	9.9	10.4	10.0	**9.5**	11.1
14	9.0	8.6	6.8	8.8	9.6	9.9	9.8	**8.9**	10.4
16	8.7	8.4	6.6	8.5	9.4	10.0	9.6	**8.7**	9.9
18	8.6	8.2	6.4	8.2	9.2	9.5	9.5	**8.5**	9.6
20	8.5	8.1	6.2	8.0	9.2	9.4	9.4	**8.4**	9.5
22	8.4	8.1	6.1	7.8	9.1	9.2	9.2	**8.3**	
24	8.3	7.9	6.0	7.7	9.0	9.1	9.1	**8.2**	
26	8.3	7.8	5.9	7.6	8.8	9.0	9.0	**8.1**	
28	8.2	7.8	5.9	7.5				**7.4**	
30	8.1	7.7	5.9	7.4				**7.3**	

Lower Linville

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	22.0	20.8	19.3	25.5	21.9	22.1	23.8	**22.2**	20.9
2	22.0	20.4	19.1	25.4	22.0	22.1	23.4	**22.1**	20.7
3	21.6	20.3	19.1	24.8	21.6	22.1	23.0	**21.8**	20.4
4	21.6	20.2	19.0	23.5	21.0	22.0	21.6	**21.3**	19.9
6	20.1	19.8	18.9	18.4	19.0	20.9	19.3	**19.5**	18.9
8	14.6	19.3	17.6	15.9	16.4	19.7	14.5	**16.9**	16.8
10	12.5	16.6	16.9	13.6	15.0	19.2	12.3	**15.2**	15.0
12	11.5	13.9	16.0	12.2	14.1	18.6	11.5	**14.0**	13.7
14	10.8	12.2	14.6	11.5	13.6	15.7	11.2	**12.8**	12.6
16	10.5	11.5	13.9	10.9	12.8	16.1	11.0	**12.4**	11.8
18	10.0	11.1	13.4	10.4	12.0	15.4	10.9	**11.9**	10.7
20	9.5	10.7	12.8	10.0	11.1	12.8	10.7	**11.1**	10.4
22	9.4	10.4	12.3	9.8	10.5	11.7	10.6	**10.7**	10.3
24	9.3	10.0	12.0		10.4	11.0	10.5	**10.5**	10.2
26	9.2	9.8	11.7		10.2	10.8	10.4	**10.4**	10.1
28	9.2		11.3		10.2			**10.2**	

Paddy Creek Dam

depth (m)	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/27/06	5/26/07	average	5/24/08
1	21.6	20.4	19.1	25.4	22.0	21.8	23.5	**22.0**	20.8
2	21.4	20.3	19.0	25.2	22.1	21.7	23.3	**21.9**	20.6
3	21.4	20.2	19.0	24.6	22.1	21.7	22.9	**21.7**	20.6
4	21.3	19.9	19.0	23.6	21.5	21.7	21.8	**21.3**	20.4
6	21.3	19.7	18.3	19.1	18.5	19.7	18.3	**19.3**	19.7
8	15.5	19.3	17.8	16.3	16.6	18.5	14.8	**17.0**	17.3
10	13.3	16.6	17.0	13.3	15.4	17.4	12.4	**15.1**	15.3
12	11.9	14.0	15.7	12.0	14.5	14.7	11.6	**13.5**	14.4
14	11.0	12.8	14.7	11.4	13.7	13.2	11.2	**12.6**	13.0
16	10.4	11.9	13.9	10.8	12.8	12.6	10.9	**11.9**	11.5
18	10.0	11.0	13.2	10.5	11.9	12.0	10.7	**11.3**	10.9
20	9.6	10.4	12.8	10.1	11.2	11.5	10.6	**10.9**	10.5
22	9.4	10.0	12.4	9.8	10.6	11.1	10.5	**10.5**	10.3
24	9.4	9.9	12.0	9.6	10.4	10.9	10.5	**10.4**	10.2
26	9.3	9.8	11.7	9.6	10.4	10.8	10.5	**10.3**	
28	9.3	9.8	11.1	9.5	10.4			**10.0**	
30	9.3	9.7	10.4	9.5				**9.7**	
32	9.3	9.7	9.4	9.5				**9.5**	
34	9.2	9.6		9.4				**9.4**	

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles (continued)

Lake Percent Oxygen Saturation in July

Big Island

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	109	106	93	123	102	114	107	**108**	103
2	107	106	95	122	130	114	109	**112**	101
3	104	109	92	124	123	113	103	**110**	99
4	104	106	80	124	79	113	99	**101**	99
6	88	59	66	66	74	45	69	**67**	74
8	18	3	61	0	68	2	1	**22**	39
10	7	1	49	0	25	7	19	**15**	6
12	11	5	52	0	32	10	13	**18**	3
14	7	1	48	0	17	13	1	**12**	3
16	4	1	47	0	17	6	1	**11**	3
18	4	1	50		3	2	1	**10**	
20					1	2		**2**	

Marion Lake Club

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	98	104	97	70	94	105	99	**95**	100
2	97	101	97	69	93	104	103	**95**	100
3	97	101	101	70	113	101	101	**98**	97
4	96	101	101	69	84	113	91	**94**	97
6	96	88	68	70	62	79	87	**79**	91
8	60	45	48	68	49	46	41	**51**	69
10	28	29	40	49	38	52	58	**42**	46
12	38	37	54	26	51	57	71	**48**	44
14	41	43	62	25	52	60	66	**50**	45
16	47	47	67	24	56	60	62	**52**	42
18	50	42	70	16	59	48	58	**49**	39
20	50	44	73	9	52	47	48	**46**	34
22	48	47	78	7	40	39	43	**43**	
24	46	42	76	6	23	19	12	**32**	
26	38	23	76	7	1	5	2	**22**	
28	26	5	46	7				**21**	
30	6		33	7				**15**	

Lower Linville

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	100	112	107	73	106	102	96	**99**	94
2	100	109	109	71	103	96	98	**98**	93
3	100	108	109	69	105	102	96	**98**	93
4	100	108	104	70	112	100	96	**99**	96
6	100	105	110	67	102	78	96	**94**	96
8	99	105	83	53	56	56	79	**76**	95
10	95	101	62	47	55	65	79	**72**	76
12	90	87	55	29	58	34	76	**61**	71
14	83	77	52	21	57	21	74	**55**	68
16	71	71	52	23	57	33	63	**53**	64
18	69	69	51	20	2	1	65	**40**	61
20	66	57	50	19		0	54	**41**	
22	61	48	48	16				**43**	
24	52		42	1				**32**	
26	23		35					**29**	
28			26						

Paddy Creek Dam

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	99	105	108	70	103	100	97	**97**	91
2	100	105	108	69	101	99	96	**97**	94
3	99	105	108	70	102	99	93	**97**	94
4	99	105	108	69	114	101	92	**98**	93
6	99	109	94	70	110	110	91	**98**	105
8	98	105	84	68	86	113	88	**92**	97
10	88	93	60	49	57	85	81	**73**	69
12	79	81	48	26	59	81	71	**64**	59
14	66	72	52	25	56	76	70	**60**	54
16	63	65	48	24	57	70	68	**56**	51
18	63	58	46	16	60	70	63	**54**	50
20	63	59	46	9	54	68	64	**52**	47
22	61	63	43	7	0	69	63	**44**	47
24	59	64	42	6		66	60	**50**	47
26	62	64	43	7		69	58	**51**	
28	58	63	41	7				**42**	
30	57	63	40	7				**42**	
32	56	61	35	7				**40**	
34	47	54	26	7				**34**	

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles (continued)

Lake Temperature (degrees C) in July

Big Island

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	26.5	29.3	27.7	29.8	26.6	29.3	26.8	**28.0**	28.6
2	26.5	29.0	27.7	29.5	24.2	29.2	26.8	**27.6**	28.4
3	26.5	28.8	26.7	29.4	21.8	29.1	26.7	**27.0**	28.3
4	26.5	28.7	24.3	29.0	20.9	28.6	26.5	**26.4**	28.3
6	26.3	26.5	21.6	27.0	19.5	25.6	26.0	**24.6**	27.0
8	22.4	20.9	18.9	24.5	14.3	20.1	19.9	**20.1**	20.2
10	14.5	13.7	13.3	17.3	10.3	13.4	11.8	**13.5**	14.4
12	10.0	9.6	8.6	12.4	9.6	10.9	10.6	**10.2**	12.2
14	7.3	8.9	7.4	11.1	9.5	7.1	10.0	**8.8**	11.3
16	8.9	8.7	7.0	10.8	9.4	9.8	9.7	**9.2**	10.4
18	8.8	8.5	6.8		9.4	9.6	9.7	**8.8**	10.1
20					9.3	9.7		**9.5**	10.2
									10.3
									10.3

Marion Lake Club

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	26.4	28.9	27.7	29.7	28.4	29.1	26.9	**28.2**	28.6
2	26.4	28.8	27.7	29.7	28.6	29.1	27.0	**28.2**	28.5
3	26.4	28.8	27.5	29.7	23.3	29.1	26.9	**27.4**	28.4
4	26.4	28.8	25.0	29.6	22.0	28.7	26.8	**26.8**	28.4
6	26.4	26.5	22.2	26.9	20.5	25.5	25.7	**24.8**	26.6
8	23.0	21.6	19.3	22.5	19.3	19.9	18.4	**20.6**	20.1
10	15.2	13.1	14.2	14.8	12.8	13.0	12.4	**13.6**	14.3
12	10.7	9.7	8.8	11.7	10.2	10.8	10.4	**10.3**	12.2
14	9.5	8.9	7.3	10.8	9.7	10.0	10.0	**9.5**	10.1
16	9.0	8.6	6.9	10.5	9.4	9.7	9.7	**9.1**	10.2
18	8.7	8.4	6.7	10.1	9.3	9.5	9.5	**8.9**	9.8
20	8.5	8.3	6.6	9.9	9.2	9.3	9.4	**8.7**	9.6
22	8.5	8.1	6.4	9.8	9.1	9.2	9.2	**8.6**	9.3
24	8.4	8.0	6.3	9.8	8.9	9.1	9.1	**8.5**	9.1
26	8.3	8.0	6.2	9.7	8.8	9.0	9.0	**8.4**	9.0
28	8.2	7.9	6.2	9.6				**8.0**	
30	8.1		6.3	9.5				**8.0**	

Lower Linville

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	26.1	28.7	28.0	33.9	29.5	29.0	26.8	**28.9**	28.1
2	26.1	28.6	27.8	33.3	29.3	29.0	26.8	**28.7**	28.1
3	26.1	28.6	27.7	33.0	29.1	29.0	26.7	**28.6**	28.1
4	26.1	28.5	27.6	32.8	28.0	29.0	26.7	**28.4**	28.1
6	26.1	27.6	24.9	31.4	26.0	27.1	26.2	**27.0**	27.8
8	23.0	24.3	22.9	29.1	24.2	22.8	22.7	**24.1**	20.8
10	19.1	21.5	21.5	27.2	23.3	20.0	18.0	**21.5**	17.8
12	16.3	19.2	20.7	25.5	22.5	18.3	15.2	**19.7**	16.2
14	14.3	17.8	20.2	23.8	22.0	17.0	13.9	**18.4**	15.4
16	13.1	16.5	19.7	22.0	21.5	15.8	13.1	**17.4**	14.3
18	12.2	15.5	19.3	20.9	20.9	15.2	12.3	**16.6**	13.4
20	11.6	14.5	19.0	20.3		15.3	11.7	**15.4**	12.3
22	10.8	13.6	18.7	19.6			11.4	**14.8**	11.5
24	10.5		18.5	18.0			11.3	**14.6**	10.9
26	10.0		18.1					**14.1**	10.8
28			17.7					**17.7**	

Paddy Creek Dam

depth (m)	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	average	7/26/08
1	26.1	28.6	27.8	34.8	29.3	28.7	27.0	**28.9**	27.9
2	26.1	28.5	27.7	34.4	29.1	28.7	27.0	**28.8**	28.1
3	26.1	28.4	27.7	34.0	29.0	28.7	26.9	**28.7**	28.1
4	26.1	28.4	27.4	33.8	27.6	28.7	26.9	**28.4**	28.1
6	26.1	27.2	25.0	32.9	26.2	26.7	26.0	**27.2**	26.7
8	23.1	24.2	23.1	31.9	24.4	23.6	22.3	**24.7**	21.1
10	19.6	21.4	21.6	28.5	23.2	20.5	18.0	**21.8**	17.7
12	15.8	19.1	21.0	26.3	22.5	19.0	15.3	**19.9**	15.9
14	13.9	17.6	20.2	25.0	21.8	18.1	14.0	**18.7**	14.8
16	12.9	16.3	19.7	24.3	21.4	16.6	13.1	**17.8**	13.9
18	12.2	15.5	19.3	22.2	21.1	15.5	12.1	**16.8**	12.8
20	11.6	14.5	19.0	21.1	20.8	14.8	11.8	**16.2**	11.7
22	11.0	13.5	18.8	21.0	20.4	14.1	11.4	**15.7**	11.2
24	10.3	12.8	18.5	20.9		13.7	11.2	**14.6**	10.9
26	10.1	11.9	18.2	20.8		13.0	11.0	**14.2**	10.8
28	9.9	11.2	17.7	20.7				**14.9**	
30	9.8	10.8	17.2	20.5				**14.6**	
32	9.7	10.6	16.0	20.4				**14.2**	
34	9.7	10.3	16.3	20.3				**14.2**	

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles (continued)

Lake Percent Oxygen Saturation in September

Big Island

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	100	91	115	138	101	93	94	**105**	85
2	98	90	112	91	101	92	94	**97**	86
3	94	88	111	83	108	92	91	**95**	84
4	94	85	109	78	99	88	95	**93**	106
6	93	77	75	77	64	77	89	**79**	80
8	92	64	68	77	47	60	2	**59**	80
10	8	23	39	65	52	1	2	**27**	4
12	6	2	2	79	47	1	1	**20**	4
14	4	1	2	74	44	1	1	**18**	4
16	3	1	1	52		1	1	**10**	4
18	3		1	2			1	**2**	
20									

Marion Lake Club

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	103	84	100	122	105	89	89	**99**	82
2	94	82	93	96	104	82	90	**92**	81
3	92	82	96	88	103	89	90	**91**	81
4	91	82	88	85	110	87	88	**90**	81
6	89	80	57	72	66	72	87	**75**	80
8	56	57	43	87	19	43	1	**44**	79
10	10	9	8	90	1	2	27	**21**	4
12	13	20	17	89	21	35	44	**34**	13
14	20	23	27	77	39	35	43	**38**	17
16	33	27	31	48	45	40	34	**37**	20
18	35	28	35	40	38	36	31	**35**	17
20	35	28	39	40	39	31	26	**34**	10
22	32	26	40	35	15	18	5	**24**	
24	27	19	41	36	9	2	2	**19**	
26	19	3	36	26	7	2	1	**13**	
28	10	2	19	15	10			**11**	
30			2	11	2			**5**	

Lower Linville

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	96	85	79	116	100	84	84	**92**	74
2	94	85	83	122	101	84	86	**94**	78
3	93	88	84	114	102	84	86	**93**	74
4	93	88	85	95	104	84	89	**91**	76
6	90	86	83	72	75	83	88	**82**	77
8	90	84	82	74	19	84	86	**74**	79
10	89	83	79	69	3	83	68	**68**	78
12	74	71	65	67	9	83	22	**56**	65
14	29	73	37	67	6	70	24	**44**	24
16	36	43	16	69	35	70	21	**41**	28
18	39	41	14	69	32	44	30	**38**	26
20	39	41	15	69	37	55	16	**39**	22
22	37	44	20	68	13	14	12	**30**	16
24	20	39	19	68	0			**29**	8
26	19	32	9	66	0			**25**	12
28			8	61				**35**	

Paddy Creek Dam

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	93	85	73	123	99	82	85	**91**	79
2	94	86	75	116	100	81	86	**91**	79
3	94	88	78	107	96	82	84	**90**	80
4	94	88	79	90	100	82	84	**88**	80
6	94	88	78	77	70	80	86	**82**	81
8	93	87	74	43	27	80	88	**70**	80
10	90	92	79	46	20	76	81	**69**	81
12	42	75	54	48	32	65	28	**49**	81
14	35	46	34	44	21	44	25	**36**	17
16	25	35	30	43	36	31	30	**33**	24
18	25	36	29	44	41	32	34	**34**	32
20	30	36	27	40	33	25	33	**32**	29
22	35	36	26	39	33	28	38	**34**	27
24	39	38	27	39	29	29	36	**34**	24
26	41	45	24		19	28	33	**32**	22
28	38	49	21					**36**	
30	38	51	17					**35**	
32									
34									

Appendix I: Lake James Percent Oxygen Saturation and Temperature Profiles (continued)

Lake Temperature (degrees C) in September

Big Island

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	24.6	23.8	23.9	17.8	26.5	22.7	24.9	**23.5**	22.9
2	24.5	23.8	23.7	15.3	26.4	22.7	24.8	**23.0**	22.9
3	24.4	23.8	23.6	14.8	26.1	22.7	24.8	**22.9**	22.9
4	24.4	23.7	23.5	14.5	24.8	22.7	24.8	**22.6**	22.9
6	24.2	23.4	22.8	13.8	22.5	22.3	24.7	**22.0**	22.9
8	23.7	21.8	20.4	13.1	22.3	21.0	20.4	**20.4**	22.9
10	19.5	17.0	18.3	12.4	22.3	16.4	12.2	**16.9**	16.9
12	11.2	10.5	10.6	11.4	22.2	11.3	10.5	**12.5**	12.7
14	9.5	9.5	7.7	11.0	22.2	10.3	10.1	**11.5**	11.1
16	9.0	8.8	7.4	9.8		10.3	9.9	**9.2**	10.6
18	8.8		7.1	4.7			9.8	**7.6**	
20									

Marion Lake Club

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	24.7	23.7	23.8	20.6	26.7	23.2	24.8	**23.9**	22.8
2	24.6	23.6	23.8	18.8	26.6	23.2	24.8	**23.6**	22.8
3	24.5	23.6	23.7	18.1	26.6	23.2	24.8	**23.5**	22.8
4	24.5	23.6	23.5	17.6	25.5	23.2	24.7	**23.2**	22.8
6	24.4	23.6	22.7	16.7	22.6	22.0	24.7	**22.4**	22.8
8	23.7	23.0	20.7	16.2	20.6	20.5	20.5	**20.7**	22.8
10	18.0	14.9	17.7	15.3	15.9	16.6	12.6	**15.9**	18.2
12	10.9	10.4	10.9	14.4	11.2	11.4	10.6	**11.4**	13.4
14	9.5	9.1	8.0	13.4	9.9	10.2	10.1	**10.0**	11.2
16	8.9	8.6	7.3	11.6	9.5	9.8	9.8	**9.4**	10.5
18	8.7	8.5	6.9	7.1	9.3	9.6	9.5	**8.5**	10.0
20	8.5	8.3	6.8	5.5	9.2	9.4	9.4	**8.2**	9.8
22	8.4	8.2	6.6	4.8	9.2	9.3	9.3	**8.0**	9.6
24	8.4	8.1	6.5	4.2	9.3	9.1	9.2	**7.8**	9.2
26	8.3	8.1	6.4	3.8	9.3	9.0	9.0	**7.7**	9.1
28	8.2	8.0	6.5	3.5				**6.6**	
30			6.5	3.3				**4.9**	

Lower Linville

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	24.9	24.1	24.4	23.2	26.9	24.2	25.1	**24.7**	23.2
2	24.8	24.0	24.4	22.8	26.9	24.1	25.0	**24.6**	23.3
3	24.7	23.9	24.3	22.2	26.9	24.1	25.0	**24.4**	23.3
4	24.7	23.9	24.3	21.8	26.9	24.1	25.0	**24.4**	23.3
6	24.6	23.9	24.1	21.4	26.3	24.1	25.0	**24.2**	23.3
8	24.5	23.9	24.0	21.1	25.5	24.1	25.0	**24.0**	23.3
10	24.4	23.5	23.9	20.9	24.7	24.1	24.0	**23.6**	23.2
12	23.8	22.8	23.5	20.7	24.2	24.1	22.0	**23.0**	22.9
14	22.3	21.5	22.9	20.4	23.8	23.6	20.1	**22.1**	21.6
16	20.2	20.2	22.3	20.0	23.2	23.6	17.8	**21.0**	20.6
18	18.9	18.4	21.9	20.0	23.0	22.8	16.0	**20.1**	19.1
20	17.6	17.4	21.5	19.9	22.8	22.4	14.6	**19.5**	17.2
22	15.8	16.7	21.4	19.8	22.6	21.3	13.6	**18.7**	15.8
24	14.6	15.7	21.2	19.7	22.5		12.7	**17.7**	14.9
26	13.7	14.8	20.9	19.5	22.4		12.5	**17.3**	13.6
28			20.5	19.3				**19.9**	

Paddy Creek Dam

depth (m)	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/22/07	average	9/27/08
1	26.1	28.6	27.8	34.8	26.7	24.1	24.9	**27.6**	23.1
2	26.1	28.5	27.7	34.4	26.9	24.1	25.0	**27.5**	23.1
3	26.1	28.4	27.7	34.0	26.9	24.1	25.0	**27.5**	23.1
4	26.1	28.4	27.4	33.8	26.8	24.1	25.0	**27.4**	23.1
6	26.1	27.2	25.0	32.9	26.3	24.1	25.0	**26.7**	23.2
8	23.1	24.2	23.1	31.9	25.6	24.1	25.0	**25.3**	23.2
10	19.6	21.4	21.6	28.5	24.7	24.1	24.9	**23.5**	23.2
12	15.8	19.1	21.0	26.3	24.2	23.9	21.8	**21.7**	23.2
14	13.9	17.6	20.2	25.0	23.7	23.4	19.4	**20.5**	21.8
16	12.9	16.3	19.7	24.3	23.4	22.9	17.7	**19.6**	20.5
18	12.2	15.5	19.3	22.2	23.0	22.6	15.9	**18.7**	18.7
20	11.6	14.5	19.0	21.1	22.8	22.1	14.7	**18.0**	17.0
22	11.0	13.5	18.8	21.0	22.7	21.0	13.5	**17.4**	16.0
24	10.3	12.8	18.5	20.9	22.6	19.9	12.5	**16.8**	14.8
26	10.1	11.9	18.2	20.8	22.4	18.7	11.9	**16.3**	13.6
28	9.9	11.2	17.7	20.7				**14.9**	
30	9.8	10.8	17.2	20.5				**14.6**	
32	9.7	10.6	16.0	20.4				**14.2**	
34	9.7	10.3	16.3	20.3				**14.2**	