LONG TERM EVALUATION OF SEDIMENT AND POLLUTANT SOURCES TO LAKE LURE: YEAR THIRTEEN REPORT

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Acknowledgments

Maintaining healthy streams and lakes is clearly very important to the Lake Lure community. Fortunately, there are many people who are willing to give much of their personal time and effort to ensure water quality is preserved. In 2008 Dean Givens, the new Lake Operations Director for the Town of Lake Lure, took over coordination of the VWIN program and has been instrumental in ensuring that all samples were collected and delivered every month. Dean also monitors the lake sites for temperature and dissolved oxygen and collecting nutrient samples. In this new position created by the Town of Lake Lure Dean has provided excellent coordination of lake management activities.

Of course, the program would not exist without volunteers to collect samples every month. These dedicated people include Rod Anderson, Lloyd Joslin, Bob Keith, Craig Mullikin, Chuck Watkins, and Jerry Webb. Special thanks also go to the Town of Lake Lure for providing cold storage for the samples until they are delivered. This program would also not exist if it were not for the continued funding by the Town of Lake Lure. Few other area governments have exhibited such concern for our natural resources. Along with the town management of Chimney Rock, they have also played a key role in the formation and support of the Upper Broad River Watershed Protection Committee. The communities of Chimney Rock, Lake Lure, and Bat Cave have shown great foresight in working together to monitor pollutant levels and control the sources of pollution to the watershed. In recent years their efforts have gained much recognition. Residents of the area are fortunate to have such leaders in their community.

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. A wide variety of organizations provide administrative support. Some of these include the Town of Lake Lure, the Environmental Conservation Organization (ECO), the Pacolet Area Conservancy (PAC), Haywood Waterways Association, the Madison County Soil and Water Conservation District, the Friends of Lake Glenville, the Lake James Environmental Association, the Hiawassee River Watershed Coalition, and the Watershed Association of the Tuckasegee River. The UNC-Asheville Environmental Quality Institute (EQI) has provided 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 that 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, many other groups have joined and expanded the range of testing to include much of Western North Carolina as well as parts of northern Georgia and eastern Tennessee. Monthly sampling of these sites provides extensive water quality information for the French Broad, Broad, Catawba, Little Tennessee, and Hiawassee River watersheds. In October 2009, sampling was halted when UNC-Asheville closed EQI due to budget cuts. Laboratory services are expected to resume in the summer of 2010 when EQI reopens as a nonprofit organization.

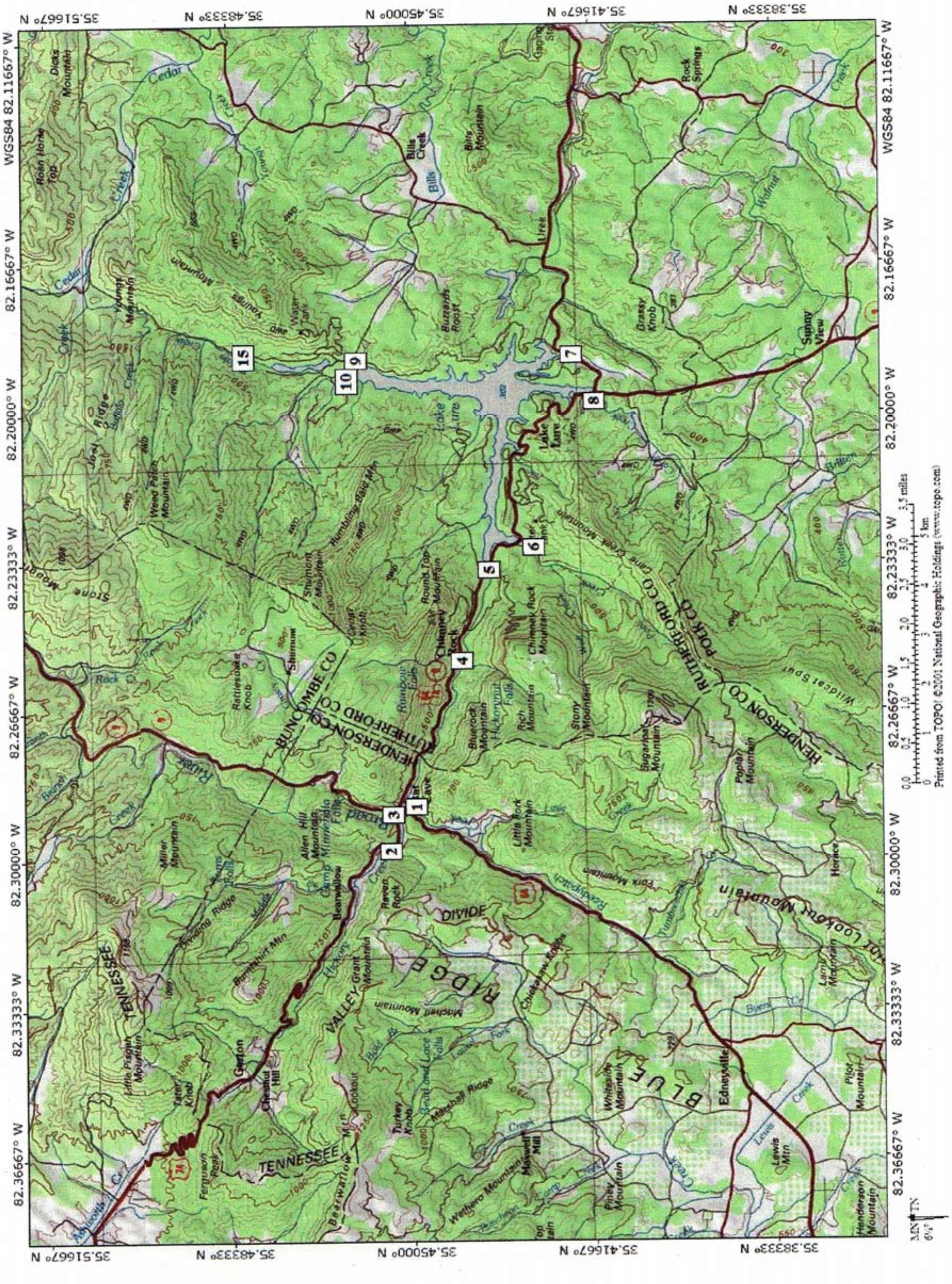
The Lake Lure VWIN Program

In July 1996, the Town of Lake Lure began a VWIN program to monitor ten selected stream sites and four lake sites in order to assess water quality conditions in streams flowing into Lake Lure and to provide continuous assessment of the health of Lake Lure. 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 lakes cycles and trends as well as identifying problems as they arise. In September 2006 another site was added on Buffalo Creek upstream from Bald Mountain Lake. 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. As a matter of clarification, it should be noted that the boulder-strewn section of the Broad River between Bat Cave and Lake Lure is locally referred to as the Rocky Broad River. This report represents statistical analyses and interpretation of data gathered by VWIN volunteers from July 1996 through October 2009.

Table 1: Description of Lake Lure VWIN Monitoring Sites

1. Reedypatch Creek at Hwy 64 (Bat Cave)
2. Hickory Creek at Hwy 74 (Bat Cave)
3. Broad River at Hwy 9 (Bat Cave)
4. Rocky Broad River at Chimney Rock
5. Rocky Broad River at Lake Lure
6. Pool Creek at Hwy 64/74/9
7. Public Golf Course Creek at Hwy 64/74
8. Cane Creek 1/4 mile above Tryon Bay
9. Buffalo Creek above Lake Lure
10. Fairfield Mountains Creek at Fairfield Mountains
11. Lake Lure Main Channel at Center of Lake - one meter from the top
12. Lake Lure Main Channel at Center of Lake - one meter from the bottom
13. Lake Lure at the Dam - one meter from the top
14. Lake Lure at Dam – one meter from the bottom
15. Buffalo Creek upstream from Bald Mountain Lake

Figure 1: Lake Lure 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 Lure 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 thirteen years of data gathered between July 1996 and October 2009. With each additional year of continuous stream and lake monitoring, trends in water quality become more evident, and a clearer picture of actual existing conditions 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 the Lake Lure area (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 mg/L, 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 three-year period from November 2006 through October 2009 (Table 2). Using only the past three years of data allows streams to show the most current water quality status. Thus, streams that may show improved water quality as a result of newly implemented management practices will reflect improvement in their grade. Likewise, streams where water quality has been deteriorating will show lower grades than past years. 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, 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 fields 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 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.

Table 2: Classification Grades Based on Parameters and Ranges

Site	Description	pH	Alkalinity	Turbidity	TSS	Cond	Copper	Lead	Zinc	Ortho P	Ammonia-N	Nitrate-N
1	Reedypatch Crk at Hwy 64 (Bat Cave)	A	B	C	A	C	A	A	A	B	A	B
2	Hickory Crk at Hwy 74 (Bat Cave)	A	C	B	A	B	A	A	A	B	A	A
3	Broad River at Hwy 9 (Bat Cave)	A	C	B	A	B	A	A	A	B	A	A
4	Rocky Broad River at Chimney Rock	A	C	C	B	B	A	A	A	B	A	A
5	Rocky Broad River at Lake Lure	A	C	B	B	B	A	A	A	B	A	A
6	Pool Creek at Hwy 64/74/9	A	D	A	A	A	A	A	B	A	A	A
7	Public Golf Course Crk at Hwy 64/74	A	B	C	A	B	A	A	A	A	A	B
8	Cane Creek 1/4 mile above Tryon Bay	A	B	B	A	B	A	A	A	B	B	A
9	Buffalo Creek at Lake Lure	A	C	B	A	A	A	A	A	A	B	A
10	Fairfield Mountains Crk at Lake Lure	A	C	A	A	B	A	A	B	B	A	A
15	Buffalo Creek at Bald Mt Lake	A	D	C	B	A	A	A	A	B	A	A

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 over the past three years and also includes the median values for each site over the entire period of the study. With this expanded information, changes in median values over time can be seen.

The data from over 200 sites in the Western North Carolina counties in the VWIN program are used in this report to compare water quality from the stream sites in the Lake Lure 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 in this study compared with all sites analyzed throughout the region, and with average median levels for sites in mostly undeveloped forested watersheds. 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. The averages for sites in mainly forested watersheds are included to show typical water quality in streams that are relatively unaffected by human disturbance. With most parameters, sites that show median values closer to the forested stream averages exhibit better water quality, but this is not necessarily the case with pH and alkalinity because areas of lower rainfall naturally exhibit higher pH and alkalinity levels.

A statistical analysis of the effects of stream water level, temporal changes, and seasonality on the water quality parameters at individual sites has also been 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 statistically 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. When inspecting for trends in one variable, the statistical methodology adjusts for changes in the other variables. For example, when a chemical parameter has a significant increase over time it indicates that it would have been expected to increase over that ten-year time period if there were not changes in flows during that time and there were equal numbers of samples taken each season. Statistical trend analysis is normally carried out on sites with five or more years of monitoring. Since the upstream site on Buffalo Creek has been monitored for only three years there are very few trends at this time.

Flow measurements from nearby US Geological Survey gauging stations are used to analyze trends related to flow. This method presents some problems since gauging stations can only truly represent the streams on which they are located, but it has been found to be the most reliable and least costly method of determining these trends. The USGS gauging station on Cove Creek (USGS-02149000 - a tributary of the Broad River just downstream from Lake Lure) was utilized to determine relative flow for the sites in the Lake Lure area. 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 Lure monitoring program in 1996 to present.

Appendix F and G are summaries of trends related to flow and time by site. 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 values in area streams are generally 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. High alkalinity waters are considered 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. Many 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 the Lake Lure monitoring sites compared to the regional median and the median at sites in largely undisturbed forested 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. For this reason, the standard for trout-designated waters is 10 NTU while the standard to protect other aquatic life is 50 NTU. TSS quantifies solids by weight and is heavily influenced by the combination of stream flow and land disturbing activities. Mountain streams in undisturbed forested areas remain clear even after a moderately heavy rainfall event, but streams in areas with disturbed soil will become highly turbid after even a relatively small 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

Figure 2: Median pH levels at each monitoring site compared to the regional average median for all VWIN sites in Western NC and with the average median at largely undisturbed forested sites

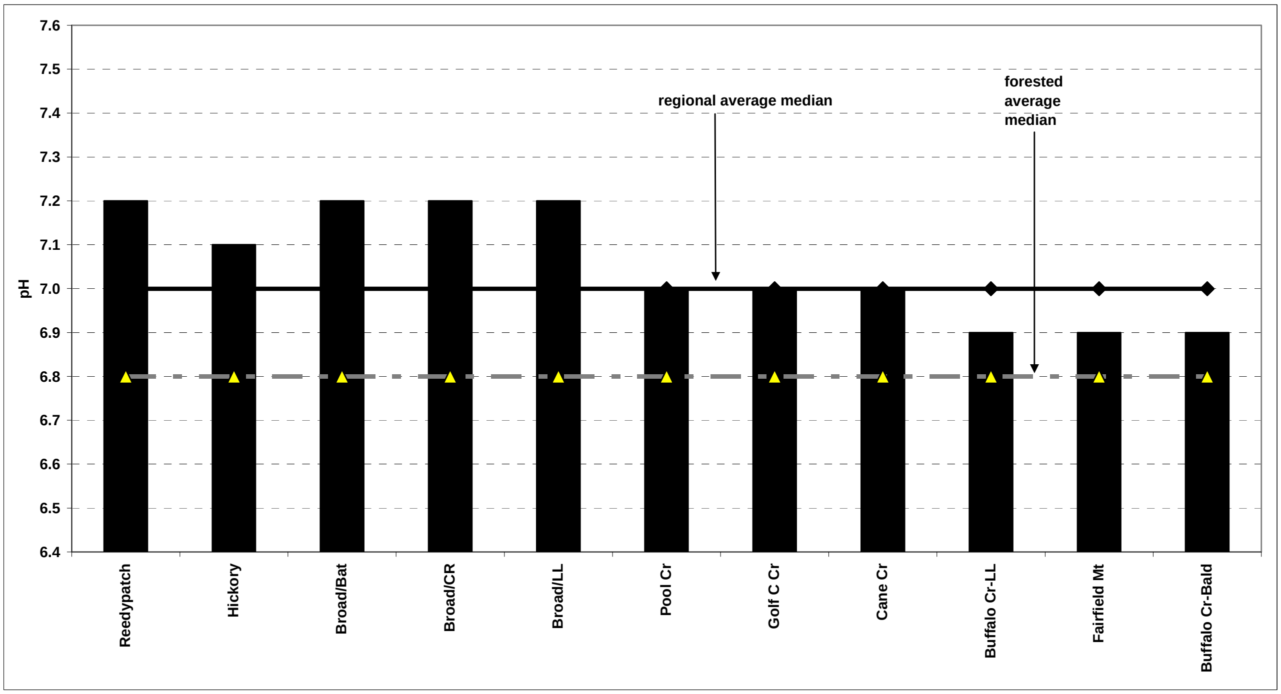
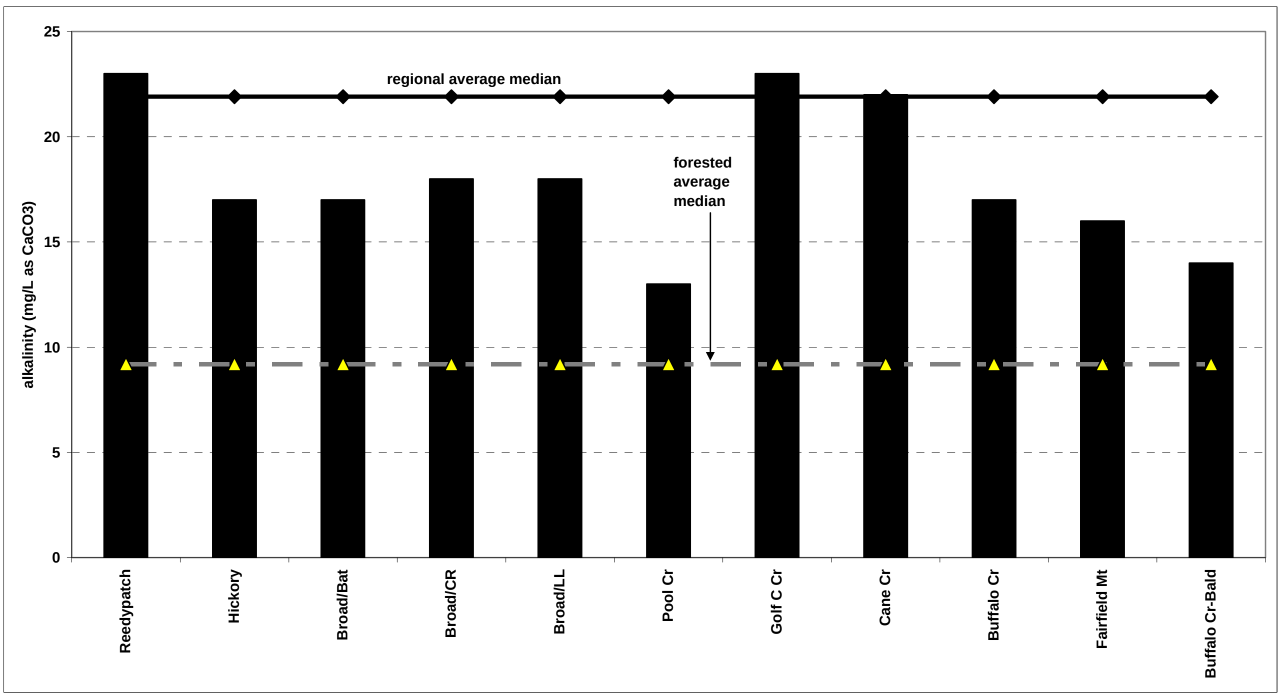
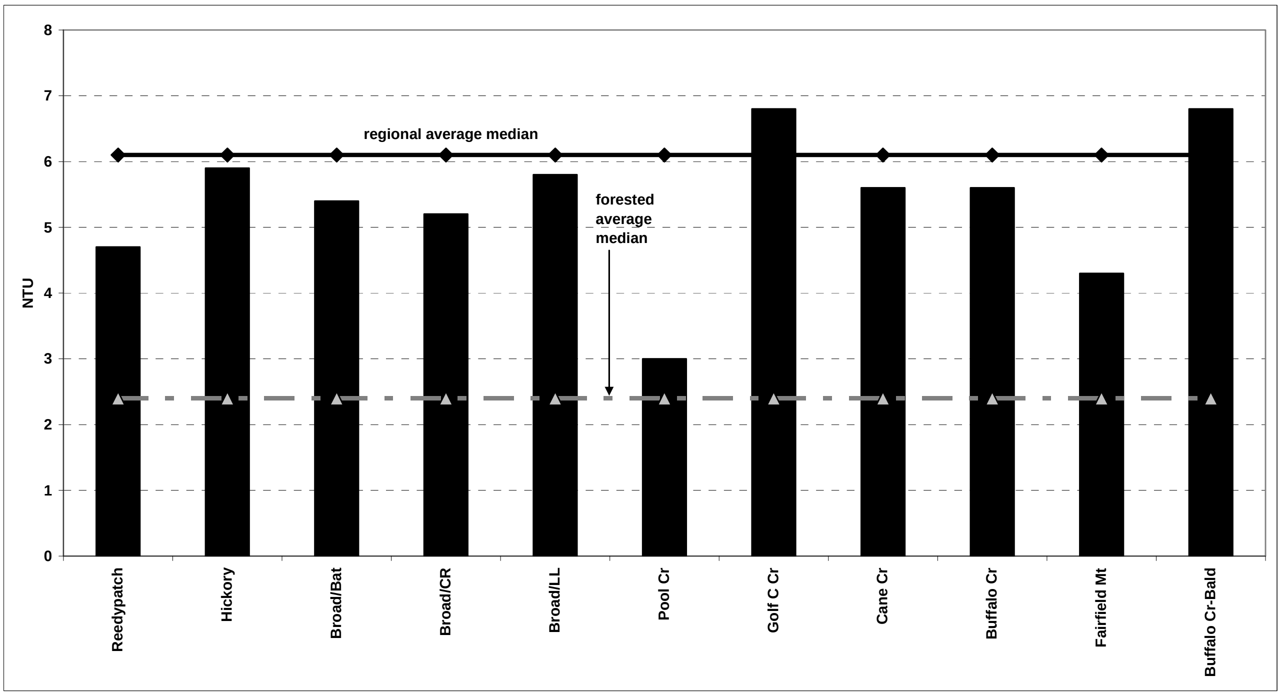


Figure 3: Median alkalinity levels at each monitoring site compared to the regional average median for all VWIN sites in Western NC and to the average median at largely undisturbed forested sites



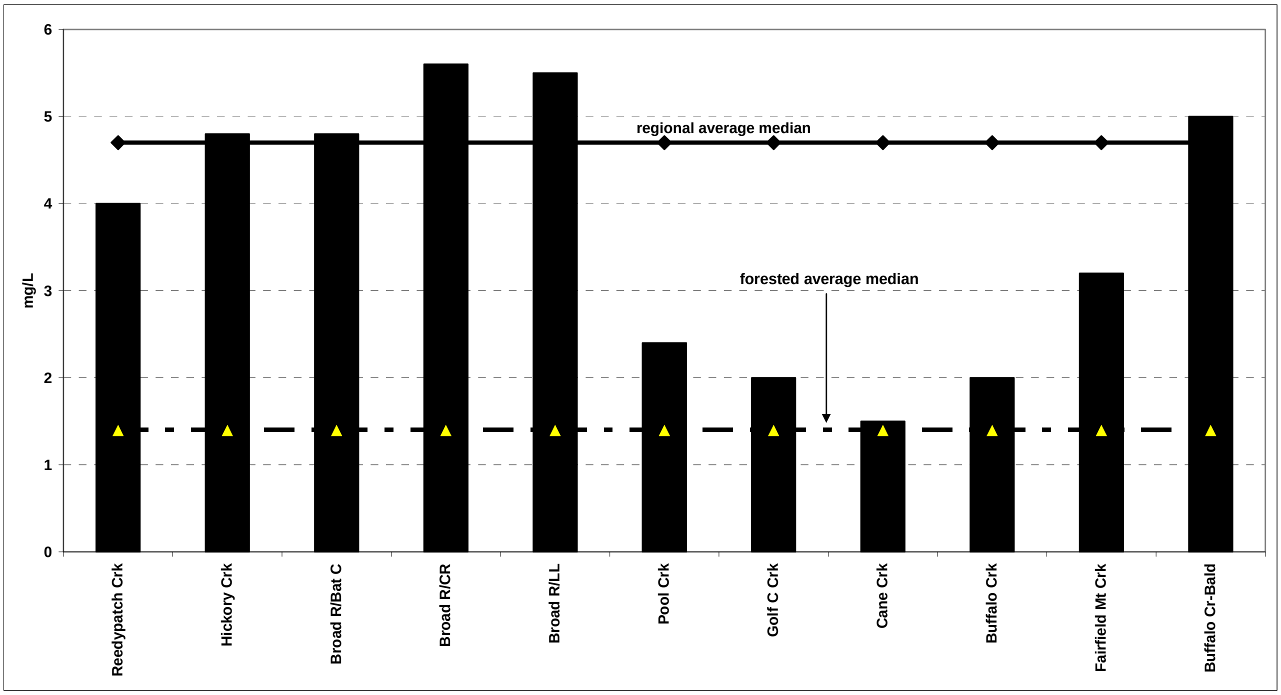
is destroyed by stream siltation. The absence of these species reduces the diversity of the ecosystem. In addition, small amounts of bottom-deposited sediment can severely reduce the hatch rate of trout eggs. There is no legal standard for TSS, but values below 30.0 mg/l are generally considered low, and values above 100 mg/l are considered high. A good measure of the upstream land use conditions is how much TSS rises after a heavy rainfall.
levels in winter.   Figures 4 and 5 show median turbidity and total suspended solids levels at the Lake Lure monitoring sites compared to the regional median and the median at sites in largely undisturbed forested areas.

Figure 4: Median turbidity levels at each monitoring site compared to the regional average median for all VWIN sites in Western NC and to the average median at largely undisturbed forested sites



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 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 within the clay that ionize more readily in water. Figure 6 shows median conductivity levels at the Lake Lure monitoring sites compared to the regional median and the median at sites in largely undisturbed forested areas.

Figure 5: Median total suspended solids concentrations at each monitoring site compared to the regional average median for all VWIN sites in Western NC and to the average median at largely undisturbed forested sites



Metals are found 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/1 kg fertilizer.

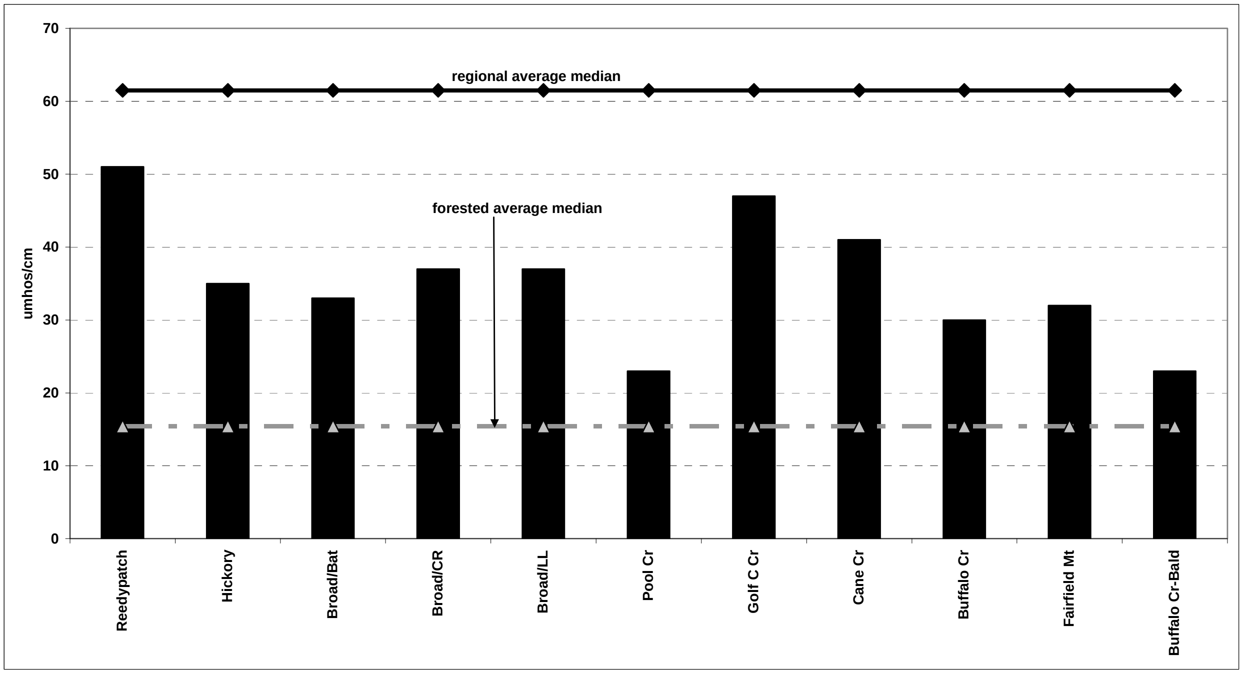
Copper: The standard of 7.0 ug/l has been established to protect aquatic life. In most areas, ambient levels are usually below 1.0 ug/l. Wear of brake linings has been shown to contribute concentrations of copper, lead, and zinc. Copper has a relatively high content in brake linings. Copper is also present 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. Zinc is a byproduct of the auto tire vulcanization process.

Figure 6: Median conductivity levels at each monitoring site compared with the average median at all VWIN sites in Western NC and with the average median at sites in largely undisturbed forested areas



D. Nutrients (Orthophosphate (PO_4^{3-}), Ammonia-Nitrogen (NH_3), and Nitrate/Nitrite-Nitrogen (NO_3^-/NO_2^-)

Orthophosphate: 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 algae 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 and lawn, 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. **In this report orthophosphate (PO_4^{3-}) is reported as concentrations of PO_4^{3-}. To isolate phosphorus (P) from the measurement, divide the reported amount by three. Note that the four lake samples are also analyzed for total phosphorus. The median results are reported as both PO_4^{3-} and as P.** Orthophosphate is a measure of the dissolved phosphorus that is immediately available to plants or algae. Orthophosphate is also referred to as phosphorus in solution. There is no legal water quality standard, but generally levels must be below 0.05 mg/l to prevent downstream eutrophication. The normal ambient level of orthophosphate in undisturbed streams is about 0.01 to 0.03 mg/l. Total phosphorus is the measure of all the chemical forms of phosphorus including dissolved orthophosphate, phosphorus bound to particulate matter, and phosphorus locked up biologically in algae and bacteria.

Ammonia Nitrogen (NH_3) and Nitrate/nitrite Nitrogen (NO_3^-/NO_2^-): Ammonia-nitrogen 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 where extensive trout farming occurs also show elevated ammonia-nitrogen concentrations.

Like phosphorus, nitrate/nitrite-nitrogen serves as an algal nutrient contributing to excessive stream and reservoir algae 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, fertilizer runoff from agricultural land and domestic lawns, and livestock. 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 concentrations at each monitoring site compared to the regional average median for all VWIN sites in Western NC and to the average median at largely undisturbed forested sites.

Figure 7: Median orthophosphate concentrations at each monitoring site compared with the average median at all VWIN sites in Western NC and with the average median at sites in largely undisturbed forested areas

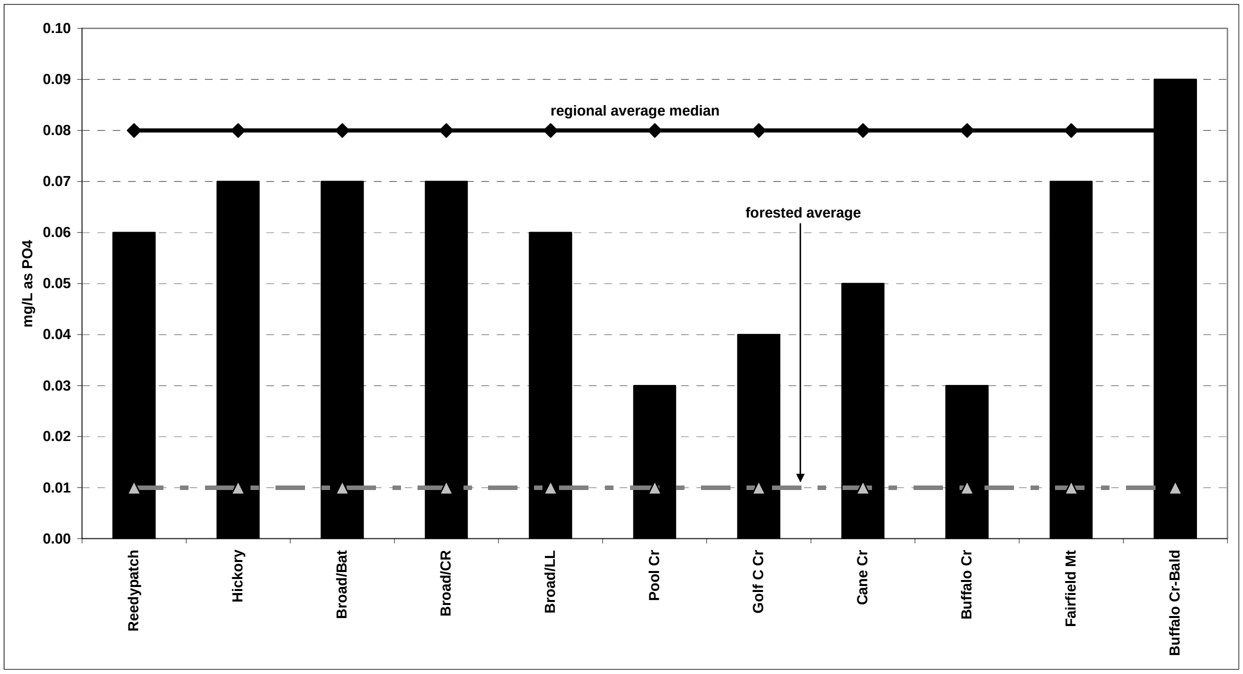


Figure 8: Median ammonia-nitrogen concentrations at each monitoring site compared with the average median at all VWIN sites in Western NC and with the average median at sites in largely undisturbed forested areas

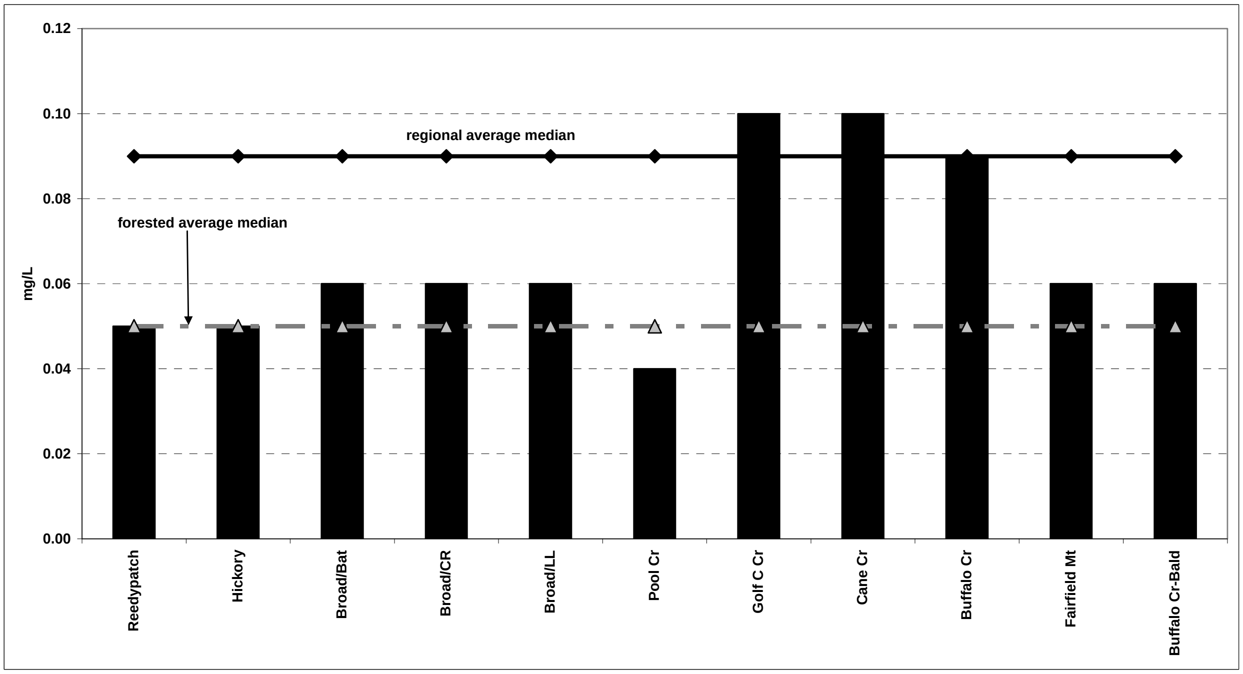
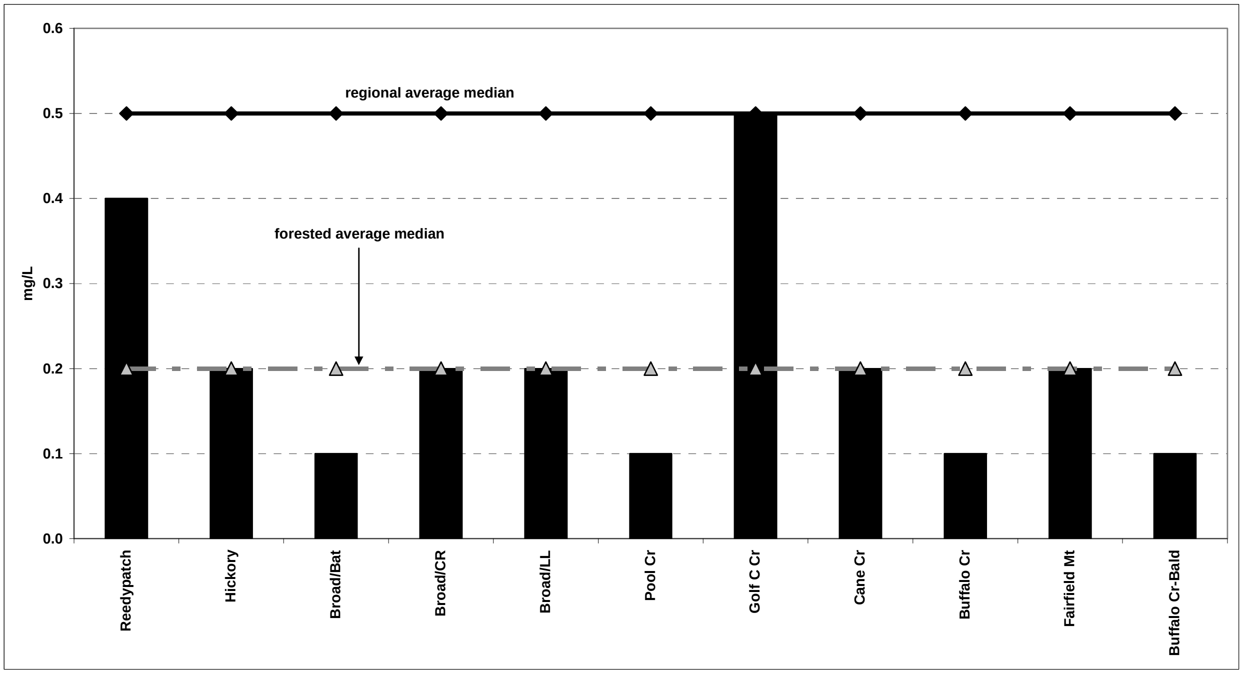


Figure 9: Median nitrate/nitrite-nitrogen concentrations at each monitoring site compared with the average median at all VWIN sites in Western NC and with the average median at sites in largely undisturbed forested areas



E. Lake Lure Monitoring Results:

Analysis of Lake Lure includes measurements for temperature and dissolved oxygen (DO) at four locations on the lake at one or two meter intervals, and measurements of total phosphorus, orthophosphate, ammonia-nitrogen and nitrate-nitrogen at two locations on the lake at one meter from the surface and one meter from the bottom. Temperature, dissolved oxygen, and nutrient measurements as well as secchi depth are taken from a point near the center of the lake, a point near the dam, at Tryon Bay, and at Buffalo Bay. Secchi depth measurements were begun in July 1999. Secchi depth is a measure of lake water transparency. A standardized black and white disc is lowered into the water until it can no longer be seen. Then it is pulled back up and, at the point it becomes visible again, the depth is measured. This is usually approximately one-half the distance of light penetration through the water. Algae growth occurs within this "photic zone" and algae growth, along with suspended sediment, can reduce Secchi depth.

Although the reporting year ends in June, this report includes DO and temperature measurements through October 2009 so that a more complete analysis of the lake cycle is available. Lake analysis is temporarily discontinued during the winter months. Lakes in this area undergo almost continuous turnover and mixing of the water column during the winter months, thus temperature and DO measurements tend to remain constant throughout the water column, so continuous winter measurements are not as necessary. Temperature and dissolved oxygen are key parameters to understanding lake conditions. All animal life needs oxygen, and the oxygen concentration determines 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 less dense layers of warmer water near the surface. Because these lower layers no longer mix with surface water, 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 and settling on the bottom, the more oxygen is used in decomposition. This is a natural process but can be accelerated when large amounts of organic matter enter the lake from outside sources, or if 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 and temperature into consideration.

The lake temperature profile for the 2009 monitoring period showed slightly lower temperatures than the 12-year average (Figures 10, 11, and 12). The dissolved oxygen profile for that period followed a similar pattern from previous years, and by September there was very little oxygen in the lake water below 8-10 meters (Figures 13, 14, and 15). Appendix I shows temperature and dissolved oxygen concentrations at the site near the dam each month since monitoring began. Data from the other three sites monitored on the lake are available upon request.

Figure 10: Temperature profile at the dam and main channel sites in May compared to the average temperature for May

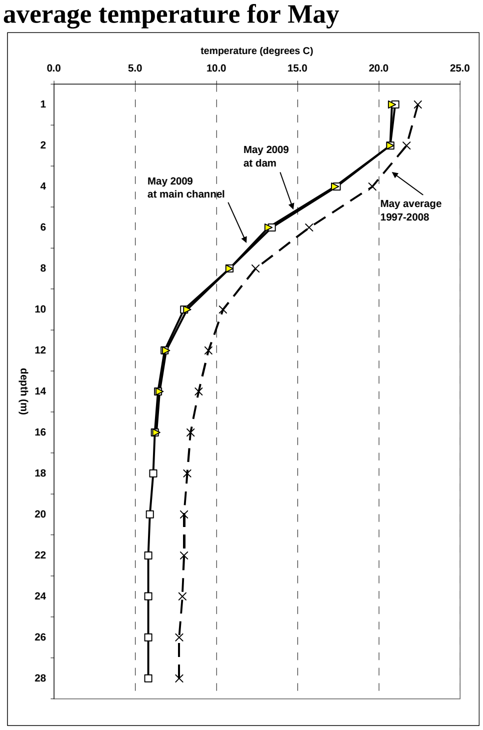


Figure 11: Temperature profile at the dam and main channel sites in July compared to the average temperature for July

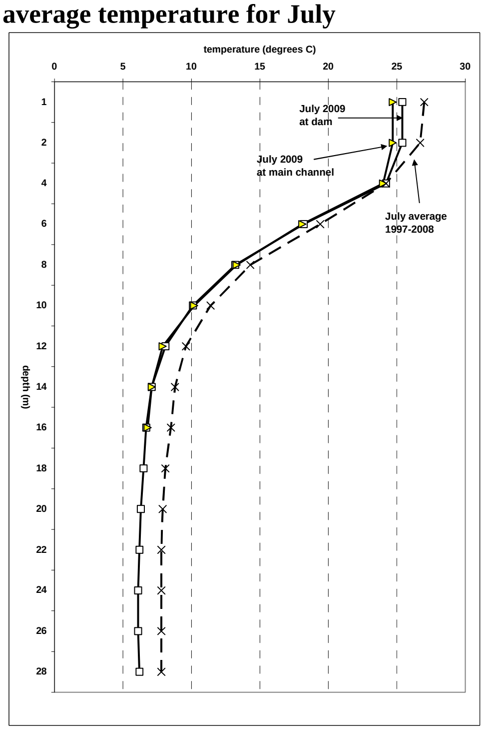


Figure 12: Temperature profile at the dam and main channel sites in September compared to the average temperature for September

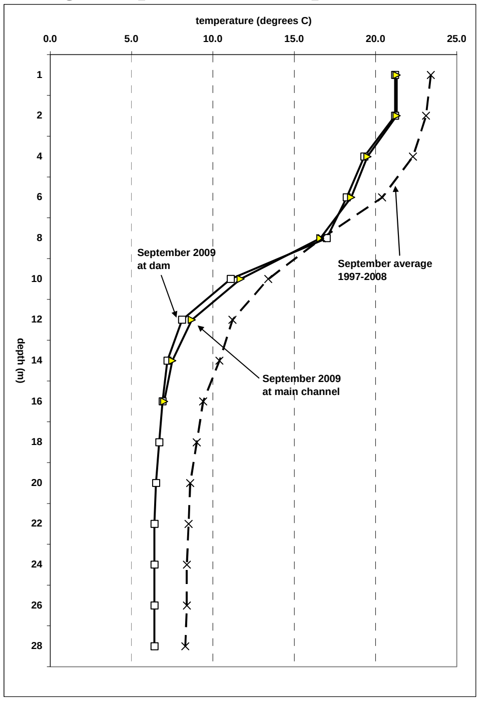


Figure 13: Dissolved oxygen profile at the dam and main channel sites in May compared to the average dissolved oxygen concentration in May

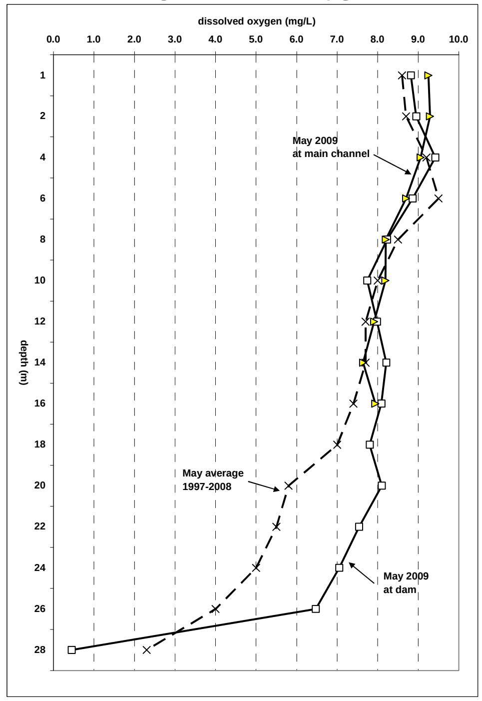


Figure 14: Dissolved oxygen profile at the dam main channel sites in July compared to the average DO concentration for July

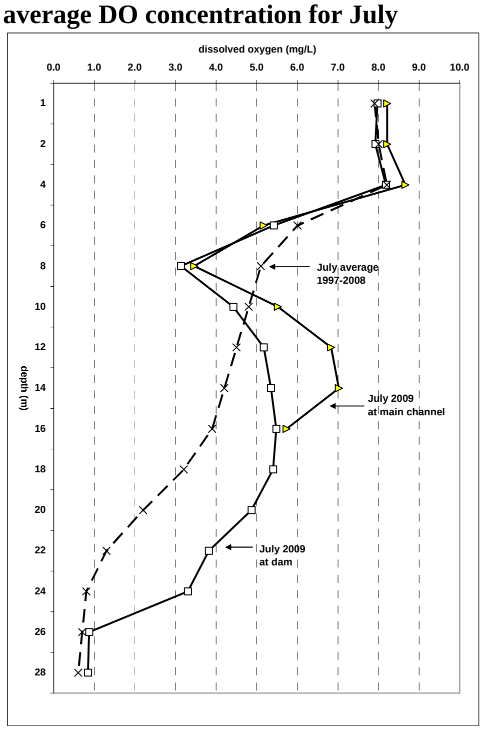
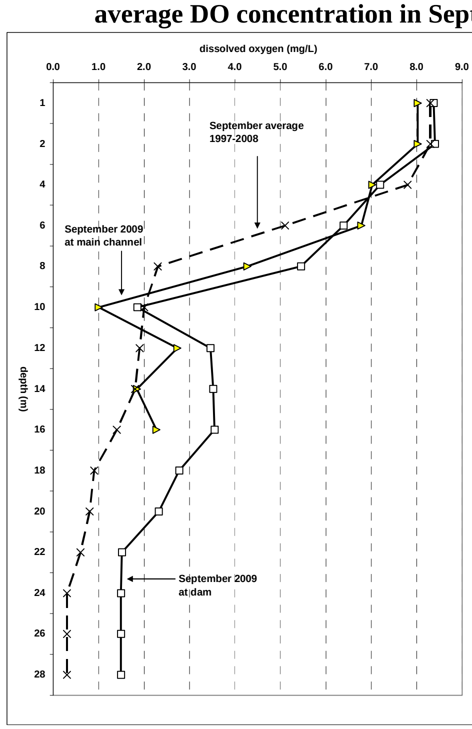


Figure 15: Dissolved oxygen profile at the dam and main channel sites in September compared to the average DO concentration in September



Secchi depths in 2009 were similar to recent years, despite having higher monthly flows. Appendix J shows secchi depths at the four lake monitoring sites, and average stream flow at the Cove Creek USGS monitoring site each month since lake secchi depth monitoring began.

In 2009, total phosphorus concentrations were equal to or lower than the average of previous years at the main channel (Figure 16). Despite higher rainfall in 2009, the annual total phosphorus remained the same as the previous two years (Figure 17). Appendix K lists total phosphorus concentrations one meter from the surface at the site near the dam and in the main channel from 1997 through 2009.

Figure 16: Total phosphorus concentrations each month in 2009 in the main channel compared to the twelve-year average total phosphorus concentration each month

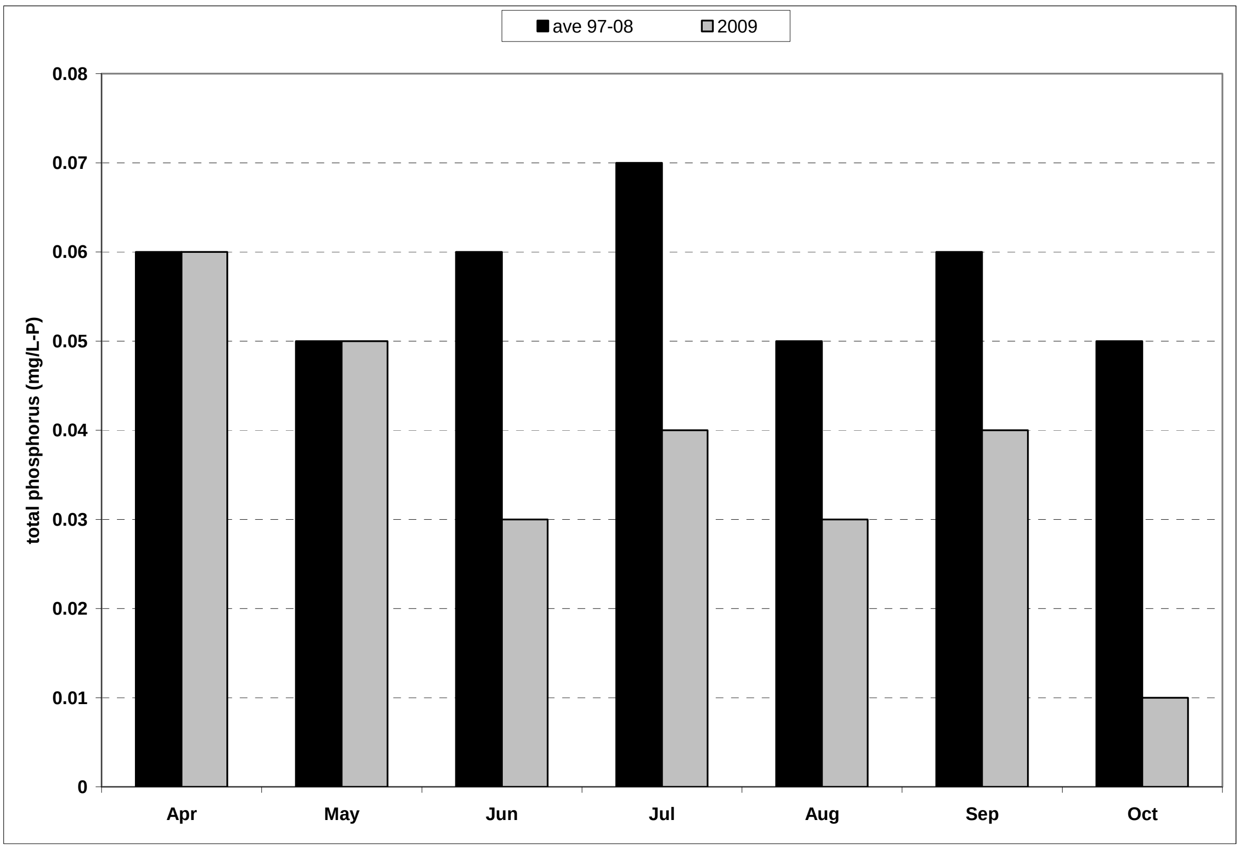
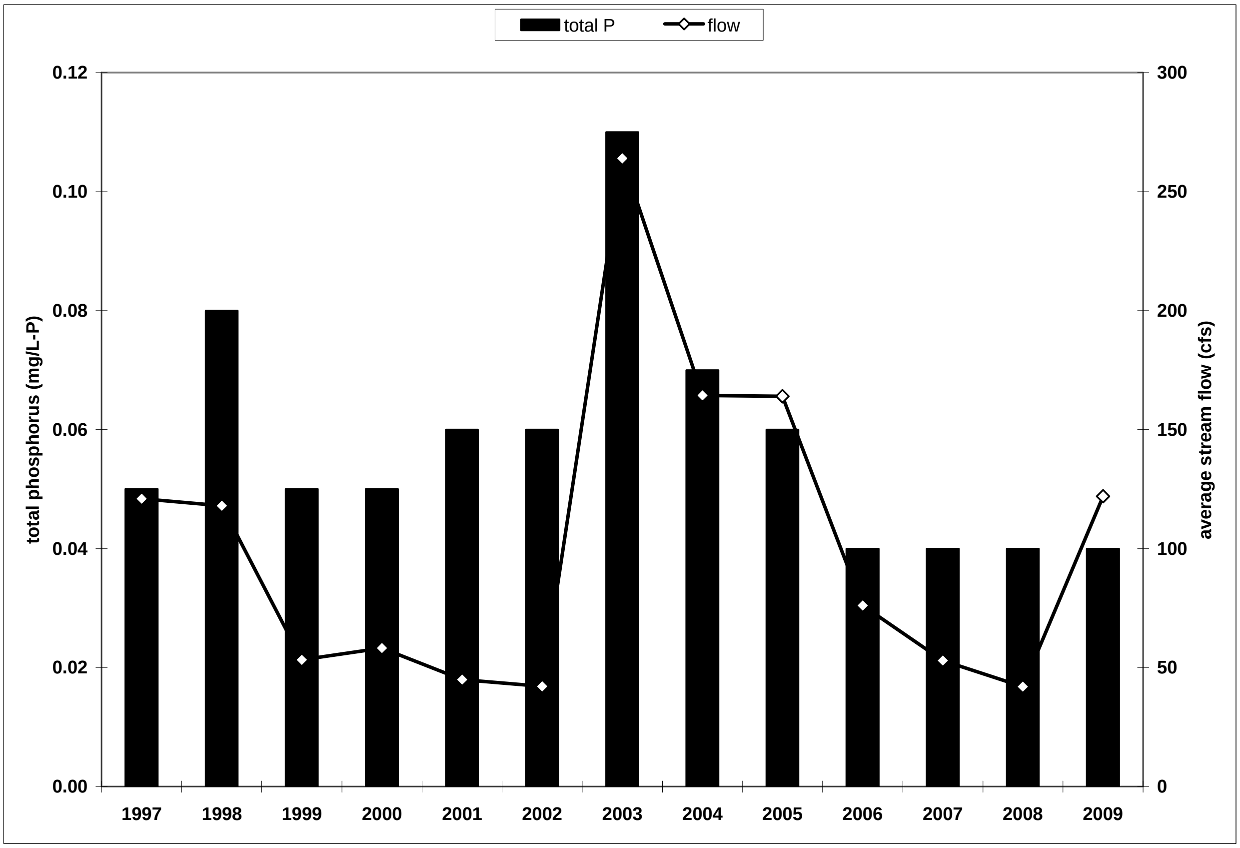


Figure 17: Average total phosphorus concentrations each year at the main channel site compared to average stream flow during the months of lake monitoring each year



IV. Summary and Conclusions

Understanding the water quality of the streams that flow into Lake Lure is vital to understanding the water quality of the lake itself. As development continues around the lake, however, activities on the land immediately adjacent to the lake will be an increasingly important factor in the health of the lake.

Chemical analysis of samples collected at the Lake Lure sites are intended to characterize the water quality relative to the parameters established by the Volunteer Water Information Network program. Concerned groups and individuals can use the information from the program to help identify problems and evaluate solutions. Characterizing water quality 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 data from over 200 VWIN sites throughout Western North Carolina are used to compare Lake Lure stream sites with all other sites in the program. Ranking of water quality for all of these sites is found in Appendix D. Summarized observations and trends for Lake Lure stream sites are presented below. Summaries of trends are presented in Appendices F, G, and H.

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 3 is a summary of ranking of

Lake Lure stream sites by water quality parameters. With this information it is easier to focus on related water quality problems.

Table 3: Index rating for Lake Lure stream monitoring sites

site #	site name	sediment	metals	nutrients	overall	rating
	VWIN - WNC Regional Average	**74**	**86**	**85**	**82**	
1	Reedypatch Crk at Hwy 64 (Bat Cave)	75	88	83	82	**good**
2	Hickory Crk at Hwy 74 (Bat Cave)	88	94	92	91	**excellent**
3	Broad River at Hwy 9 (Bat Cave)	88	94	92	91	**excellent**
4	Rocky Broad River at Chimney Rock	63	94	92	83	**good**
5	Rocky Broad River at Lake Lure	75	94	92	87	**good**
6	Pool Creek at Hwy 64/74/9	100	94	100	98	**excellent**
7	Public Golf Course Crk at Hwy 64/74	75	94	92	87	**good**
8	Cane Creek 1/4 mile above Tryon Bay	88	94	83	88	**good**
9	Buffalo Creek at Lake Lure	88	100	92	93	**excellent**
10	Fairfield Mountains Crk at Lake Lure	100	88	92	93	**excellent**
15	Buffalo Creek at Bald Mtn Lake	63	100	92	85	**good**
	average for Lake Lure stream sites	**82**	**94**	**91**	**89**	
	percent sites below regional average	**18%**	**0%**	**18%**	**0%**	

The Broad River and Tributaries

All sites continue to rate either **good** or **excellent**. Sites rating **good** include Reedypatch Creek, the Rocky Broad River at Chimney Rock and at Lake Lure, the Public Golf Course creek, Cane Creek, and Buffalo Creek upstream from Bald Mountain Lake. Sites rating **excellent** include Hickory Creek, the Broad River at Bat Cave, Pool Creek, Buffalo Creek at Lake Lure, and the creek at Fairfield Mountains. For the sites that rate **good** it is mostly stream sedimentation that brings the rating down. Although median turbidity and total suspended solids levels are low at these sites, maximum levels are quite elevated. This is an indication of extensive sediment runoff into these streams during storms.

Trend analysis shows turbidity and total suspended solids levels increase as stream flow increases at all sites except Pool Creek and both sites on Buffalo Creek. Surface runoff during rain events is less evident in the more protected Pool Creek watershed. There are practically no parameters showing increased levels over time. Orthophosphate is the only parameter showing decreasing concentrations over time at almost all sites. Although TSS levels still increase during rain events, concentrations increase above 10mg/L with less frequency in recent years compared to the early years of monitoring. Although drought in recent years is a factor, generally TSS levels have remained lower in both wet and dry years since 2002. Most sites show at least some seasonal trends, and levels of most parameters are higher in summer. Summer storms often produce greater surface runoff because the storms are generally more intense, and more land disturbing activities occur in summer.

Lake Lure

The temperature profile in 2009 was almost identical to the average profile from all past years of VWIN lake monitoring. By late July in the cool water below 6 meters there was insufficient oxygen for fish to survive at any of the four monitored sites. This has usually been the case, however, over the past 13 years of monitoring. Secchi depths did not respond much to the increased flow in 2009. Total phosphorus concentrations did not appear to be influenced by increased rainfall in 2009, and trend analysis did not detect a change related to flow or time.

Appendix A: Chain of Custody form

Volunteer Water Information Network

Lake Lure

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) Stream Flow Measurement no longer needed – using USGS gauging stations in the watershed

11) 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	
Total P	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 occasional increases in pollutant level 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
J = Jackson/Lake Glenville
LJ = Lake James
LL = Lake Lure
M = Madison County
NOT=Nottely River Watershed
P = Polk County
TOE = Toe River Watershed
TU = Tuckasegee River watershed

	site #	site description	Excellent
1	B28	Bent Creek below Lake Powhatan	100
2	H11	Green River below Lake Summit	100
3	H12	Green River at Terry's Creek Rd	100
4	H7	North Fork Mills River	100
5	H9	Mills River at SR 191 (Davenport Bridge)	100
6	HW1	Upper Hiawassee River	100
7	HW11	Hog Creek	100
8	HW2	Martin's Creek	100
9	HW3	Hightower Creek	100
10	HW8	Lower Shooting Creek	100
11	HY1	West Fork Pigeon River/Bethel	100
12	HY2	East Fork Pigeon River/Bethel	100
13	J1	Hurricane Creek/Norton Br Rd (Tuckasegee R wtrshd)	100
14	J2	Norton Creek at Norton Rd br (Tuckasegee R wtrshd)	100
15	J5	Cedar Creek at Beetree Rd (Tuckasegee R wtrshd)	100
16	J7	Norton Creek/up Grassy Cmp (Tuckasegee R wtrshd)	100
17	NOT5	Coosa Creek	100
18	Toe3	South Toe River	100
19	TU1	East Fork Tuckasegee River	100
20	B9A	Beetree Creek (Swannanoa River watershed)	98
21	HW7	Upper Shooting Creek	98
22	HY13	Allens Creek (Richland Creek watershed)	98
23	**LL6**	**Pool Creek (Broad River watershed)**	**98**
24	B22	Ivy Creek at Dillingham Road	97
25	J3	Mill Creek/dnstrm Norton br (Tuckasegee R wtrshd)	97
26	NOT9	Conley Creek	97
27	B31	Swannanoa River at Grassy Branch confluence	96

Appendix D: Stream Ranking Index - continued

28	H10	Mills River at Hooper Lane	96
29	H19	Green River at Old Hwy 25 S	96
30	HW4	Scataway Creek	96
31	HW9	Upper Bell Creek	96
32	HY3	East Fork Pigeon River/Cruso	96
33	NOT3	Nottely River	96
34	NOT8	Ivy Log Creek	96
35	B12A	Bent Creek at SR 191	95
36	HW12	Woods Creek	95
37	J6	Glenville Creek at Tator Knob Rd (Tuckasegee R)	95
38	B24	Swannanoa River at confluence with North Fork	94
39	LJ5	Linville River at Hwy 126	94
40	NOT1	Nottely River upstream	94
41	H24	Little Willow Creek at River Road	93
42	HW5	Geisky Creek	93
43	**LL10**	**Fairfield Mts Creek (Broad River watershed)**	**93**
44	**LL9**	**Buffalo Creek (Broad River watershed)**	**93**
45	NOT7	Young Cane Creek	93
46	B17A	Swannanoa River at NC 81	92
47	B33	North Fork Swannanoa River at Grovestone Quarry	92
48	LJ1	Catawba River at SR 1501	92
49	P13	Green River at Hwy 9	92
50	P6	Horse Creek at SR 1516 (River Rd) (N Pacolet River wtrshd)	92
51	TU3	Caney Fork (Tuckasegee River watershed)	92
52	B20	Ivy Creek at Buckner Branch Road	91
53	B5B	Reems Creek at Ox Creek	91
54	H13	Big Hungry River below dam (Green River watershed)	91
55	HY10	Richland Creek at West Waynesville	91
56	**LL2**	**Hickory Creek at Bat Cave (Broad River watershed)**	**91**
57	**LL3**	**Broad River at Bat Cave**	**91**
			Good
58	H23	Big Willow Creek at Patterson Rd	89
59	H26	Brittain Creek at Patton Park (Mud Creek watershed)	89
60	B38	Swannanoa River at Bull Creek	88
61	H21	Mud Creek at Berea Church Road	88
62	LJ2	Catawba River at US 221A	88
63	**LL8**	**Cane Creek upstream from Tryon Bay (Broad Rvr wtrshd)**	**88**
64	NOT2	Arkaqua Creek	88
65	P1	White Oak Creek at SR 1137/Houston Road	88
66	Toe1	Cane Creek at Bakersville	88
67	Toe5	Cane River at MH High Sch	88
68	TU10	Barker's Creek (Tuckasegee River watershed)	88
69	TU14	Deep Creek (Tuckasegee River watershed)	88
70	TU5	Tuckasegee River upstream from Scott's Creek	88
71	B1A	Big Ivy Creek at Forks of Ivy	87
72	B43	Ross Creek at Swannanoa River (Swannonoa R wtrshd)	87
73	H3	Mud Creek at Erkwood Road	87
74	**LL5**	**Broad River at Lake Lure**	**87**
75	**LL7**	**Public Golf Course Creek at Hwy 64/74 (Broad Rvr wtrshd)**	**87**
76	B16A	Cane Creek at Mills Gap Road	86
77	H15	Bat Fork Creek at Tabor Road (Mud Creek watershed)	86
78	TU4	Cullowhee Creek (Tuckasegee River watershed)	86

Appendix D: Stream Ranking Index - continued

79	B30	Grassy Branch (Swannanoa River watershed)	85
80	B5A	Ox Creek at Reems Creek (Reems Creek watershed)	85
81	H29	Brandy Branch at Mills River Village (Mills River watershed)	85
82	J4	Pine Creek/Pine Creek Rd br (Tuckasegee R wtrshd)	85
83	LJ12	North Fork of the Catawba River below Limekiln Creek	85
84	**LL15**	**Buffalo Creek at Bald Mtn Lake (Broad R watershed)**	**85**
85	P5	Horse Creek at SR 1516 (River Road) N Pacolet R wtrshd)	85
86	TU2	West Fork Tuckasegee River	85
87	Toe2	Cane Creek at Loafer's Glory	84
88	H14	Boylston Creek at Ladson Road	83
89	H5	Clear Creek at Nix Road (Mud Creek watershed)	83
90	H8	South Fork Mills River	83
91	HY11	Richland Creek at Lake Junaluska	83
92	HY9	Plott Creek in Hazelwood (Richland Crk watershed)	83
93	LJ4	Catawba River at Resistoflex	83
94	**LL4**	**Broad River at Chimney Rock**	**83**
95	NOT6	Anderson Creek	83
96	P15	North Pacolet River at Melrose	83
97	P16	North Pacolet River at Rte 108	83
98	TU11	Connelley Creek (Tuckasegee River watershed)	83
99	TU12	Tuckasegee River downstream from Bryson City	83
100	TU9	Tuckasegee River at Barker's Creek	83
101	B15A	Cane Creek at Hwy 74 (FBR watershed)	82
102	B23	French Broad River at Jean Webb Park - Asheville	82
103	H22	Hoopers Creek at Jackson Rd (Cane Creek watershed)	82
104	H28	Shaw Creek at Hunters Glen	82
105	HY31	Beaverdam Creek just downstream from I-40	82
106	**LL1**	**Reedypatch Creek at Bat Cave (Broad River watershed)**	**82**
107	P9	Joels Creek upstream (N. Pacolet Rvr watershed)	82
108	TU15	Oconoluftee River (Tuckasegee River watershed)	82
109	B21	Paint Fork at Barnardsville (Ivy River watershed)	81
110	H1	French Broad River at Banner Farm Road in Horseshoe	81
111	HY12	Jonathan Creek near confluence with Pigeon River	81
112	HY27	Jonathan Creek at Maggie Valley	81
113	P7	North Pacolet River at SR 1516 (S River Rd)	81
114	TU7	Savannah Creek (Tuckasegee River watershed)	81
115	B40	Ross Creek at Lower Chunns Cove Rd(Swannanoa R wtrshd)	80
116	B41	Ross Creek at Tunnel Road (Swannanoa River watershed)	80
117	H20	Clear Creek at Apple Valley Rd (Mud Crk watershed)	80
118	LJ3	North Fork of the Catawba River at SR 1552	80

			Average
119	B15B	Ashworth Creek at Hwy 74 & Cane Crk Rd (Cane Ck wtrshd)	79
120	M4	East Fork Bull Creek (Ivy River watershed)	79
121	TU13	Kirkland Creek (Tuckasegee River watershed)	79
122	TU8	Green's Creek (Tuckasegee River watershed)	79
123	B10	Bull Creek at Swannanoa River (Swannanoa R wtrshd)	78
124	B35	Smith Mill Creek at Louisiana Blvd.	78
125	B6B	Reems Creek at French Broad River	78
126	HY6	Rush Fork at Crabtree (Crabtree Creek watershed)	78
127	P4	White Oak Creek at SR 1322 (Moore Road)	78
128	P8	Demannu Creek at SR 1140 and Hwy 9 (Green River wtrshd)	78
129	B27	Flat Creek at NC 19/23	77

Appendix D: Stream Ranking Index - continued

130	H27	Mill Pond Creek at South Rugby Road	77
131	H30	Devils Fork at Dana Road (Mud Creek watershed)	77
132	HY25	Raccoon Creek downstream (Richland Creek watershed)	77
133	M11	Bull Creek (Ivy River watershed)	77
134	P2	White Oak Creek at SR 1531 (Fox Mt Rd)	77
135	B12B	French Broad River at Bent Creek	76
136	B17B	Haw Creek at NC 81 (Swannanoa River watershed)	76
137	B2	Lower Sandymush Creek	76
138	B34	Lower Hominy Creek at NC 191	76
139	B9B	Swannanoa River at Beetree Creek	76
140	H18	Mud Creek at 7th Avenue	76
141	HY24	Raccoon Creek upstream (Richland Creek watershed)	75
142	HY26	Crabtree Creek at Crabtree Rd	75
143	B47	Reed Creek at entrance to UNCA	74
144	B7A	Reed Creek at UNCA Botanical Gardens	74
145	B8	Beaverdam Creek at Beaver Lake	74
146	HY8	Eaglenest Creek in Hazelwood (Richland Creek watershed)	74
147	LJ13	North Fork of the Catawba River at Old Linville Rd	74
148	B25	South Turkey Creek (Sandymush Creek watershed)	73
149	H2	French Broad River at Butler Bridge Road	73
150	M15	Paint Fork at Beech Glen (Ivy River watershed)	73
151	P14	White Oak Creek at Briar Hill Farm	73
152	P18	Camp Creek (Green River watershed)	73
153	B26	North Turkey Creek (Sandymush Creek watershed)	72
154	H25	Gash Creek at Etowah School Road	72
155	HY32	Beaverdam Creek upstream	72
156	HY4	Pigeon River downstream from Canton	72
157	M13	California Creek at Beech Glen (Ivy River watershed)	72
158	NOT4	Butternut Creek	72
159	B1B	Little Ivy Creek (Ivy River watershed)	71
160	Toe4	North Toe River at Red Hill	71
161	B7B	Glenn Creek at UNCA Bot Gardens (Reed Ck wtrshd)	70
162	M12	Grapevine Creek (Ivy River watershed)	70
163	M14	Middle Fork at Beech Glen (Ivy River watershed)	70

			Below Average
164	B14	Lower Flat Creek	69
165	B42	Ross Creek at Upper Chunns Cove (Swannanoa R wtrshd)	69
166	M19	Laurel Valley Creek (Laurel River watershed)	69
167	M20	Puncheon Fork (Laurel River watershed)	69
168	M3	French Broad River at Hot Springs	69
169	HY7	Fines Creek downstream	68
170	B32	French Broad River at Walnut Island Park	67
171	B6A	French Broad River at the Ledges Park	67
172	HY19	Fines Creek upstream	67
173	HY23	Ratcliff Cove Branch (Raccoon Creek watershed)	67
174	Toe6	Bald Creek at Bald Crk Elem	67
175	TU6	Scott's Creek (Tuckasegee River watershed)	67
176	HY5	Pigeon River at Hepco Bridge	66
177	H4	Mud Creek at North Rugby Road	65
178	HY28	Hyatt Creek left branch	65
179	B4	Lower Newfound Creek	64
180	HY15	Fines Creek midstream	64

Appendix D: Stream Ranking Index - continued

181	B13	French Broad River at Corcoran Park (Hend/Bunc line)	62
182	H16	Cane Creek at Howard Gap Road	62
183	B37	Newfound Creek at Leicester Hwy	61
184	M17	Gabriel's Creek at Ivy River	61
185	B36	Newfound Creek at Dark Cove Road	60
186	B3B	Sandymush Creek at Willow Creek	60
187	HY14	Rush Fork upstream (Crabtree Crk watershed)	60
188	M2	French Broad River at Barnard Bridge	60
189	P10	Joels Creek downstream (N Pacolet River watershed)	60

			Poor
190	HY20	Cove Creek at NC 209 (Fines Creek watershed)	58
191	B48	South Creek Pond/Beaver Lake (Beaverdam Crk wtrshd)	56
192	HY22	Hyatt Creek downstream (Richland Creek watershed)	56
193	HY29	Hyatt Creek Owl Ridge branch	56
194	M1	Ivy River at NC 25/70	56
195	HY30	Hyatt Creek Green Valley branch	52
196	HY21	Hyatt Creek upstream (Richland Creek watershed)	51
197	B39	South Creek at Beaver Lake (Beaverdam Crk watershed)	49

Percent -	**Excellent**	**Good**	**Average**	**Below Average**	**Poor**
Buncombe	20	22	36	18	4
Henderson	29	46	18	7	0
Haywood	18	17	24	24	17
Hiawassee	100	0	0	0	0
Jackson/Lake Glenville	86	14	0	0	0
Lake James	29	57	14	0	0
Lake Lure	**45**	**55**	**0**	**0**	**0**
Madison	0	0	50	42	8
Nottely	67	22	11	0	0
Polk	14	43	36	7	0
Tuckasegee River	13	67	13	7	0
Toe	17	50	17	16	0
TOTAL	29	31	23	13	4

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	6.8	7.2	7.8	159	7.3
2	35	6.5	7.1	8.9	158	7.2
3	35	6.7	7.2	7.9	158	7.2
4	36	6.7	7.2	7.6	159	7.2
5	32	6.6	7.2	7.4	156	7.1
6	32	6.4	7.0	7.3	156	7.0
7	21	6.6	7.0	7.3	142	7.1
8	36	6.4	7.0	7.2	156	7.1
9	35	6.5	6.9	7.2	157	6.9
10	35	6.7	6.9	7.2	157	7.0
15	34	6.3	6.9	7.2	36	6.9

Alkalinity - Last 3 Years/rep. limit 1 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	15	23	32	159	22
2	35	10	17	24	158	16
3	35	10	17	26	158	16
4	36	10	18	26	159	18
5	32	11	18	27	156	18
6	32	7	13	20	156	14
7	21	16	23	35	144	21
8	36	14	22	34	156	20
9	35	9	17	31	157	16
10	35	10	16	24	157	16
15	34	6	14	23	36	14

Turbidity (NTU) - Last 3 Years/rep. limit 1 NTU					All Results	
site	sample #	low	median	high	sample #	median
1	36	1.2	4.7	85	159	4.3
2	35	1.3	5.9	21	158	5.2
3	35	1.0	5.4	27	158	5.1
4	36	1.3	5.2	90	159	5.0
5	32	1.8	5.8	27	156	5.2
6	32	1.2	3.0	13	156	3.4
7	21	3.2	6.8	70	144	6.0
8	36	2.8	5.6	38	156	6.2
9	35	2.6	5.6	21	157	4.4
10	35	1.7	4.3	23	157	4.4
15	34	1.0	6.8	80	36	6.8

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	60.8	160	3.6
2	35	<4	4.8	21.6	159	6.8
3	35	<4	4.8	27.6	159	5.6
4	36	<4	5.6	97.6	160	6.4
5	32	<4	5.5	27.2	157	5.2
6	32	<4	2.4	39.6	157	3.2
7	21	<4	2.0	46.3	145	2.8
8	36	<4	1.5	31.6	157	2.8
9	35	<4	2.0	22.8	158	3.0
10	35	<4	3.2	30.8	158	4.0
15	34	<4	5.0	118.8	36	5.0

Appendix E: Data Summary (continued)

Conductivity - Last 3 Years/rep. limit 10 umhos/cm					All Results	
site	sample #	low	median	high	sample #	median
1	36	42	51	65	159	50
2	35	29	35	47	158	34
3	35	27	33	43	158	31
4	36	30	37	49	159	35
5	32	31	37	52	156	36
6	32	20	23	35	156	25
7	21	44	47	59	144	46
8	36	27	41	67	156	39
9	35	21	30	60	157	28
10	35	26	32	46	157	31
15	34	18	23	30	36	24

Copper (ppb) - Last 3 Years/rep. limit 2 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<2	0.4	2.5	157	0.5
2	35	<2	0.6	<2	156	0.5
3	35	<2	0.5	<2	156	0.5
4	36	<2	0.5	7.0	157	0.4
5	32	<2	0.5	<2	154	0.5
6	32	<2	0.3	3.0	154	0.4
7	21	<2	0.4	2.5	142	0.4
8	36	<2	0.4	<2	154	0.5
9	35	<2	0.3	<2	155	0.2
10	35	<2	0.3	4.0	155	0.3
15	34	<2	0.2	5.0	36	0.1

Lead (ppb) - Last 3 Years/rep. limit 2 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<2	0.3	<2	159	0.2
2	35	<2	0.4	<2	158	0.3
3	35	<2	0.3	3.7	158	0.2
4	36	<2	0.3	<2	159	0.3
5	32	<2	0.3	<2	156	0.3
6	32	<2	0.3	<2	156	0.2
7	21	<2	0.3	2.1	144	0.2
8	36	<2	0.2	<2	156	0.2
9	35	<2	0.1	<2	157	0.1
10	35	<2	0.2	<2	157	0.1
15	34	<2	0.3	3.7	36	0.3

Zinc - Last 3 Years/rep. limit 20 ppb					All Results	
site	sample #	low	median	high	sample #	median
1	36	<20	0.6	<20	158	0.6
2	35	<20	1.5	34.2	157	0.9
3	35	<20	1.1	36.1	157	0.3
4	36	<20	0.8	<20	157	0.5
5	32	<20	1.4	<20	155	1.1
6	32	<20	1.6	69.5	154	0.5
7	21	<20	1.3	<20	142	1.0
8	36	<20	0.3	<20	154	0.3
9	35	<20	0.2	<20	155	0.1
10	35	<20	0.4	55.3	154	0.1
15	34	<20	0.2	<20	36	0.2

Appendix E: Data Summary (continued)

Orthophosphate (mg/L as PO_4)-Last 3 Yrs/rep. lim. 0.02 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	<0.02	0.06	0.17	159	0.07
2	35	<0.02	0.07	0.19	158	0.09
3	35	0.02	0.07	0.19	158	0.08
4	36	<0.02	0.07	0.14	159	0.08
5	32	<0.02	0.06	0.20	156	0.07
6	32	<0.02	0.03	0.10	156	0.04
7	21	<0.02	0.04	0.12	144	0.06
8	36	<0.02	0.05	0.17	156	0.06
9	35	<0.02	0.03	0.11	157	0.04
10	35	<0.02	0.07	0.23	157	0.08
11	21	<0.02	0.02	0.11	109	0.04
12	21	<0.02	0.03	0.09	108	0.05
13	21	<0.02	0.03	0.13	109	0.04
14	21	<0.02	0.03	0.18	108	0.04
15	34	0.03	0.09	0.17	36	0.09

Total P (mg/L as PO4)-Last 3 Yrs/rep. lim. 0.02 mg/L						All Results		
site	sample #	low	med (PO_4)	med (as P)	high	sample #	med (PO_4)	med (as P)
1	0					36	0.18	0.06
2	0					36	0.18	0.06
3	0					36	0.20	0.07
4	0					36	0.17	0.06
5	0					36	0.20	0.07
6	0					36	0.15	0.05
7	0					36	0.17	0.06
8	0					35	0.17	0.06
9	0					35	0.16	0.05
10	0					36	0.20	0.07
11	21	0.04	0.12	0.04	0.18	107	0.16	0.05
12	21	0.05	0.11	0.04	0.23	104	0.16	0.05
13	21	0.05	0.11	0.04	0.21	106	0.16	0.05
14	21	0.03	0.12	0.04	0.23	104	0.16	0.05
15	0					0		

Ammonia-nitrogen (mg/L) - Last 3 Years/rep. lim. 0.02 mg/L					All Results	
site	sample #	low	median	high	sample #	median
1	36	<0.02	0.05	0.17	159	0.05
2	35	<0.02	0.05	0.13	158	0.05
3	35	<0.02	0.06	0.30	158	0.06
4	36	0.02	0.06	0.24	159	0.05
5	32	0.02	0.06	0.22	156	0.06
6	32	<0.02	0.04	0.17	156	0.04
7	21	0.05	0.10	0.18	144	0.09
8	36	0.05	0.10	0.51	156	0.11
9	35	0.03	0.09	0.60	157	0.09
10	35	<0.02	0.06	0.17	157	0.06
11	21	0.03	0.06	0.09	108	0.05
12	21	0.03	0.05	0.10	107	0.05
13	21	0.03	0.05	0.08	108	0.05
14	21	0.03	0.06	0.49	107	0.17
15	34	<0.02	0.06	0.34	36	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	0.4	1.6	159	0.4
2	35	<0.1	0.2	0.5	158	0.2
3	35	<0.1	0.1	0.4	158	0.1
4	36	0.1	0.2	1.0	159	0.2
5	32	<0.1	0.2	0.4	156	0.2
6	32	<0.1	0.1	0.5	156	0.1
7	21	0.2	0.5	0.7	144	0.5
8	36	<0.1	0.2	0.8	156	0.2
9	35	<0.1	0.1	0.5	157	0.1
10	35	<0.1	0.2	0.4	157	0.2
11	21	<0.1	0.1	0.1	109	0.1
12	21	0.1	0.2	0.3	108	0.2
13	21	<0.1	0.1	0.2	109	0.1
14	21	<0.1	0.2	0.4	108	0.2
15	34	<0.1	0.1	0.4	36	0.1

Appendix F: Trends for Each Site Related to Flow

		increases as flow increases												decreases as flow increases											
site #	site name	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total Phos	Ammonia-N	Nitrate-N	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total Phos	Ammonia-N	Nitrate-N
1	Reedypatch Crk at Hwy 64 (Bat Cave)			X	X							X	X		X			X				X			
2	Hickory Crk at Hwy 74 (Bat Cave)			X	X			X				X	X		X			X							
3	Broad River at Hwy 9 (Bat Cave)			X	X				X			X	X		X			X							
4	Rocky Broad River at Chimney Rock			X	X							X	X		X			X							
5	Rocky Broad River at Lake Lure			X	X							X	X		X			X							
6	Pool Creek at Hwy 64/74/9														X			X							
7	Public Golf Course Crk at Hwy 64/74			X		X							X												
8	Cane Creek 1/4 mile above Tryon Bay	X		X	X							X			X			X				X			
9	Buffalo Creek at Lake Lure														X			X							
10	Fairfield Mountains Crk at Lake Lure			X	X							X			X			X							
11	Lake Lure main channel near surface																								
12	Lake Lure main channel near bottom																								
13	Lake Lure near dam near surface																								
14	Lake Lure near dam near bottom																								
15	Buffalo Creek upstream of Bald Mt Lake																	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 Phos	Ammonia-N	Nitrate-N	pH	Alkalinity	Turbidity	TSS	Conductivity	Copper	Lead	Zinc	Ortho-phos	Total Phos	Ammonia-N	Nitrate-N
1	Reedypatch Crk at Hwy 64 (Bat Cave)																					X			
2	Hickory Crk at Hwy 74 (Bat Cave)																X					X			
3	Broad River at Hwy 9 (Bat Cave)																					X			
4	Rocky Broad River at Chimney Rock																					X			
5	Rocky Broad River at Lake Lure																		X			X			
6	Pool Creek at Hwy 64/74/9												X					X	X			X		X	
7	Public Golf Course Crk at Hwy 64/74																					X			
8	Cane Creek 1/4 mile above Tryon Bay													X			X		X			X			X
9	Buffalo Creek at Lake Lure	X																	X			X		X	
10	Fairfield Mountains Crk at Lake Lure																					X			
11	Lake Lure main channel near surface																					X			
12	Lake Lure main channel near bottom																					X			
13	Lake Lure near dam near surface																					X			
14	Lake Lure near dam near bottom																					X		X	X
15	Buffalo Creek upstream of Bald Mt Lake									X					X										

Appendix H: Seasonal Trends

Lake Lure Sites (11 stream sites, lake sites not included)

parameter	hi winter	hi spring	hi summer	hi fall	lo winter	lo spring	lo summer	lo fall	trend sites	% sites showing trend
pH			9		9				9	81.8%
alkalinity			2	7	5	4			9	81.8%
turbidity	1		7		7			1	8	72.7%
total susp sol			8		7			1	8	72.7%
conductivity			3	8	4	7			11	100.0%
copper			2		2				2	18.2%
lead	1		5		3	1		2	6	54.5%
zinc			1		1				1	9.1%
orthophos.			4		3	1			4	36.4%
ammonia-N			7	2	9				9	81.8%
nitrate-N	2		8		3		1	6	10	90.9%

All VWIN sites in Western North Carolina (177 total sites analyzed for trends)

parameter	hi winter	hi spring	hi summer	hi fall	lo winter	lo spring	lo summer	lo fall	trend sites	% sites showing trend
pH	0	2	88	35	104	19	0	2	125	70.6%
alkalinity	0	0	42	94	61	75	0	0	136	76.8%
turbidity	2	28	91	0	60	1	0	60	121	68.4%
total susp sol	0	39	95	1	82	0	0	53	135	76.3%
conductivity	12	4	47	78	22	111	4	4	141	79.7%
copper	1	13	42	0	41	1	1	13	56	34.4%
lead	1	9	30	0	18	2	0	20	40	24.5%
zinc	9	7	17	0	8	5	3	17	33	20.2%
orthophos.	0	9	64	5	55	19	0	4	78	44.1%
ammonia-N	1	6	92	11	91	10	1	8	110	62.1%
nitrate-N	77	9	39	0	11	12	24	78	125	70.6%

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009

Lake Lure at dam			mean monthly flow for April = 175cfs										
date	4/26/97	4/25/98	4/24/99	4/29/00	4/28/01	4/27/02	4/26/03	4/24/04	4/23/05	4/23/06	4/22/07	4/27/08	average	4/27/09
flow (cfs)	203	243	95	121	70	59	332	126	184	80	164	75	146	123
secchi (ft)				6.00	7.50	8.50	7.42	12.75		10.17		6.42	8.39	no test
depth (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	16.0	17.0	18.0	15.0	19.0	19.0	17.0			18.8		17.1	17.4	
2	16.0	15.0	18.0	15.0	18.0	19.0	16.0			18.7		17.0	17.0	
4	15.0	14.0	17.0	15.0	16.0	17.0	13.0			17.5		16.2	15.6	
6	13.0	12.0	14.0	14.0	13.0	14.0	12.0			12.9		13.1	13.1	
8	13.5	10.0	12.0	12.0	10.0	11.5	10.0			11.3		9.6	11.1	
10	11.5	9.0	10.0	12.0	10.0	10.0	8.0			10.0		8.6	9.9	
12	10.0	9.0	9.0	10.0	9.0	9.0	8.0			9.6		8.2	9.1	
14	9.0	8.0	9.0	9.0	9.0	8.5	7.0			8.8		8.0	8.5	
16	9.0	8.0	8.0	8.0	9.0	8.0	7.0			8.4		7.7	8.1	
18	8.0	8.0	8.0	8.0	9.0	8.0	7.0			8.1		7.5	8.0	
20	8.0	8.0	8.0	8.0	8.0	8.0	7.0			7.9		7.4	7.8	
22	7.5	8.0	8.0	7.0	8.0	8.0	7.0			7.7		7.3	7.6	
24	7.5	8.0	8.0	7.0	8.0	8.0	7.0			7.6		7.3	7.6	
26	7.5	7.5	8.0	7.0	8.0	8.0	7.0			7.5		7.2	7.5	
28	7.5	7.0	8.0	7.0	8.0	8.0	7.0			7.5		7.2	7.5	

Lake Lure at dam			mean monthly flow for May = 142cfs										
date	5/24/97	5/23/98	5/23/99	5/30/00	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/28/06	5/26/07	5/24/08	average	5/24/09
flow (cfs)	151	181	68	77	41	39	284	89	110	64	101	41	104	177
secchi (ft)				6.92	9.08	9.00	7.42	10.42	7.67	8.25	7.75	8.67	8.35	8.42
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	22.0	25.5	24.0	25.0	23.0	22.0	19.0		21.3	21.5	22.7	20.0	22.4	21.0
2	20.0	23.0	24.0	25.0	22.0	22.0	19.0		21.2	20.8	22.1	20.0	21.7	20.7
4	18.0	19.3	20.0	22.0	22.0	21.0	16.0		21.0	18.4	19.2	19.1	19.6	17.4
6	15.0	14.5	16.0	17.0	14.0	17.0	15.0		15.5	16.5	15.1	17.0	15.7	13.4
8	13.0	11.8	14.0	14.0	11.0	12.0	11.0		12.1	13.6	11.3	12.6	12.4	10.8
10	12.0	10.0	11.0	12.0	10.0	10.0	9.0		10.0	10.5	9.9	10.4	10.4	8.0
12	12.0	8.9	10.0	10.0	9.0	9.0	8.0		9.2	9.6	9.2	9.3	9.5	6.8
14	10.0	8.5	9.0	9.0	9.0	9.0	8.0		8.8	9.1	8.8	8.5	8.9	6.4
16	8.0	8.2	9.0	8.0	9.0	8.5	8.0		8.5	8.8	8.4	8.1	8.4	6.2
18	9.0	8.0	8.0	8.0	9.0	8.0	7.0		8.3	8.5	8.1	7.9	8.2	6.1
20	8.5	8.0	8.0	8.0	9.0	8.0	7.0		8.1	8.2	7.6	7.9	8.0	5.9
22	8.5	7.9	8.0	8.0	9.0	8.0	7.0		8.1	7.9	7.7	7.9	8.0	5.8
24	8.0	7.9	8.0	8.0	9.0	8.0	7.0		8.0	7.7	7.6	7.9	7.9	5.8
26	7.0	7.8	8.0	8.0	8.0	8.0	7.0		8.0	7.7	7.6	7.9	7.7	5.8
28	7.0	7.9	8.0	8.0	8.0	8.0	7.0		7.9	7.7	7.4	7.9	7.7	5.8

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for June = 125cfs										
date	6/28/97	6/27/98	6/26/99	6/24/00	6/23/01	6/22/02	6/28/03	6/26/04	6/25/05	6/24/06	6/23/07	6/29/08	average	6/29/09
flow (cfs)	151	116	51	46	41	34	253	135	159	71	72	25	96	98
secchi (ft)				6.92	14.00	11.83	8.00	7.33	8.17	9.33	7.92	7.00	8.94	9.50
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	25.0	29.0	26.0	28.0	24.0	26.0	26.0		25.1	26.1	25.5	25.2	26.0	26.8
2	25.0	29.0	25.0	28.0	23.0	26.0	25.0		24.7	26.0	25.4	25.2	25.7	26.7
4	21.0	26.0	23.0	26.0	23.0	26.0	20.0		19.6	24.0	23.4	24.6	23.3	20.7
6	18.0	18.0	19.0	18.0	17.0	20.0	17.0		15.4	18.9	17.0	17.8	17.8	16.0
8	15.5	14.0	15.0	12.0	11.0	14.0	13.0		12.4	13.5	11.9	13.7	13.3	13.0
10	14.0	10.0	12.0	10.0	9.0	11.0	10.0		10.4	10.9	9.6	11.5	10.8	9.3
12	13.0	9.0	10.0	9.0	8.0	10.0	9.0		9.6	9.6	8.9	9.6	9.6	7.3
14	12.0	9.0	9.0	9.0	8.0	9.0	8.0		9.2	8.9	8.5	8.8	9.0	6.8
16	11.0	8.0	9.0	8.0	7.0	9.0	8.0		8.9	8.7	8.2	8.4	8.6	6.5
18	11.0	8.0	8.0	8.0	7.0	8.0	8.0		8.7	8.2	7.8	8.1	8.3	6.3
20	10.5	8.0	8.0	8.0	7.0	8.0	8.0		8.5	8.0	7.5	7.9	8.1	6.2
22	11.0	7.0	8.0	8.0	7.0	8.0	7.0		8.3	7.9	7.3	7.7	7.9	6.1
24	9.0	7.0	8.0	8.0	7.0	8.0	7.0		8.1	7.8	7.2	7.6	7.7	6.0
26	8.5	7.0	8.0	8.0	7.0	8.0	7.0		8.2	7.8	7.1	7.6	7.7	6.0
28	8.5	7.0	8.0	8.0	7.0	8.0	7.0		8.2	7.8	7.0	7.6	7.6	6.0

Lake Lure at dam				mean monthly flow for July = 99cfs										
date	7/26/97	7/25/98	7/24/99	7/22/00	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	7/27/08	average	7/26/09
flow (cfs)	101	82	50	48	57	25	308	94	304	52	53	23	100	48
secchi (ft)			6.75	5.67	10.00	11.92	8.08	8.58	4.83	5.92	10.00	7.00	7.88	7.08
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	27.0	28.0	30.0	27.0	22.0	30.0	26.0	28.2	26.2	27.7	25.4	26.5	27.0	25.4
2	26.0	28.0	29.0	27.0	22.0	30.0	26.0	28.2	24.8	27.5	25.3	26.5	26.7	25.4
4	21.0	27.0	24.0	27.0	21.0	29.0	22.0	25.6	20.0	23.1	24.9	26.3	24.2	24.2
6	18.0	22.0	21.0	20.0	18.0	24.0	17.0	19.7	16.7	18.4	20.2	18.2	19.4	18.2
8	15.0	15.0	16.0	15.0	12.0	16.0	11.0	13.8	14.4	16.2	13.0	14.3	14.3	13.2
10	12.0	10.0	12.0	12.0	10.0	12.0	11.0	10.8	11.2	13.7	10.5	11.4	11.4	10.1
12	10.0	9.0	10.0	10.0	8.0	10.0	9.0	9.8	9.6	10.4	9.1	9.8	9.6	8.1
14	10.0	8.0	9.0	9.0	8.0	9.0	8.0	9.2	9.0	9.2	8.6	9.0	8.8	7.1
16	9.0	8.0	9.0	9.0	7.0	9.0	8.0	8.8	8.7	8.9	8.2	8.5	8.5	6.7
18	8.5	7.0	8.0	8.0	7.0	9.0	8.0	8.5	8.5	8.6	7.9	8.1	8.1	6.5
20	8.0	8.0	8.0	8.0	7.0	8.0	7.0	8.3	8.4	8.4	7.6	7.9	7.9	6.3
22	8.0	8.0	8.0	8.0	7.0	8.0	7.0	8.1	8.3	8.2	7.3	7.8	7.8	6.2
24	8.0	8.0	8.0	8.0	7.0	8.0	7.0	7.9	8.3	8.1	7.2	7.6	7.8	6.1
26	8.0	8.0	8.0	8.0	7.0	8.0	7.0	7.9	8.3	8.1	7.1	7.6	7.8	6.1
28	8.0	8.0	8.0	8.0	7.0	8.0	7.0	7.8	8.4	8.1	7.1	7.6	7.8	6.2

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for August = 107cfs									
date	8/23/97	8/22/98	8/28/99	8/26/00	8/25/01	8/24/02	8/23/03	8/28/04	8/27/05	8/26/06	8/27/07	8/25/08	average	8/23/09
flow (cfs)	73	75	30	43	34	21	396	81	168	92	45	56	93	42
secchi (ft)			6.17	6.50	10.08	12.83	6.83	8.08	8.25	8.17	8.08	5.67	8.07	7.00
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	23.0	28.0	28.0	27.0	24.0	29.0	27.0	27.2	26.3	26.4	25.3	26.1	26.4	26.6
2	22.0	27.0	27.0	27.0	24.0	29.0	27.0	27.0	26.2	26.1	25.3	25.8	26.1	26.7
4	20.0	25.0	26.0	26.0	23.0	28.0	21.0	26.0	21.8	26.0	25.0	25.4	24.4	25.1
6	16.0	19.0	22.0	22.0	19.0	22.0	18.0	21.7	18.5	20.9	20.1	20.1	19.9	20.0
8	12.0	15.0	17.0	17.0	14.0	16.0	15.0	15.0	14.8	17.1	12.8	14.7	15.0	14.0
10	11.0	12.0	12.0	13.0	10.0	12.0	11.0	11.6	12.0	13.9	10.5	11.0	11.7	9.8
12	10.0	10.0	10.0	11.0	8.0	10.0	9.0	10.3	10.3	11.3	9.0	9.2	9.8	7.9
14	9.0	9.0	9.0	10.0	8.0	9.0	8.0	9.3	9.2	9.8	8.6	8.7	9.0	7.1
16	8.0	9.0	9.0	9.0	8.0	9.0	8.0	8.9	8.8	9.0	8.1	8.4	8.6	6.7
18	9.0	8.0	8.0	9.0	7.0	9.0	8.0	8.5	8.6	8.6	8.0	8.1	8.3	6.5
20	8.0	8.0	8.0	8.0	7.0	9.0	8.0	8.3	8.4	8.3	7.7	7.9	8.1	6.3
22	8.0	8.0	8.0	8.0	7.0	9.0	8.0	8.2	8.3	8.2	7.5	7.8	8.0	6.2
24	8.0	8.0	8.0	8.0	7.0	8.0	7.0	8.0	8.2	8.1	7.3	7.7	7.8	6.2
26	8.0	8.0	8.0	8.0	7.0	8.0	7.0	7.9	8.1	8.1	7.0	7.7	7.7	6.3
28	8.0	8.0	8.0	8.0	7.0	8.0	7.0	7.9	8.1	8.1	7.1	7.7	7.7	6.3

Lake Lure at dam				mean monthly flow for Sept = 100cfs									
date	9/27/97	9/26/98	9/25/99	9/23/00	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/24/07	9/29/08	average	9/27/09
flow (cfs)	77	55	31	42	38	59	152	486	89	114	33	40	101	126
secchi (ft)			5.83	7.00	12.08	11.25	8.42	1.92	8.25	6.08	8.42	7.50	7.68	5.00
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	25.3	26.0	22.0	24.0	24.0	24.0	23.0	21.0	24.5	21.7	24.0	21.3	23.4	21.2
2	25.0	25.0	22.0	24.0	23.0	23.0	23.0	20.7	24.5	21.2	24.1	21.3	23.1	21.2
4	22.5	25.0	22.0	23.0	23.0	23.0	23.0	19.3	22.2	19.1	24.1	21.2	22.3	19.3
6	19.5	22.0	22.0	23.0	23.0	21.0	19.0	18.2	18.4	18.7	19.5	20.5	20.4	18.2
8	16.0	17.0	19.0	18.0	16.0	19.0	15.0	17.5	14.8	17.2	13.0	18.4	16.7	17.0
10	13.5	14.0	13.0	14.0	12.0	15.0	11.0	17.1	13.2	14.6	9.6	13.7	13.4	11.1
12	12.0	11.0	11.0	11.0	10.0	11.0	9.0	16.7	9.9	12.5	9.5	10.7	11.2	8.1
14	10.8	10.0	10.0	10.0	10.0	10.0	9.0	15.8	9.6	10.9	8.5	9.6	10.4	7.2
16	10.0	9.0	9.0	9.0	9.0	9.0	8.0	14.7	9.2	9.5	8.1	8.8	9.4	6.9
18	9.8	8.0	9.0	9.0	9.0	9.0	8.0	11.8	8.8	8.9	8.1	8.4	9.0	6.7
20	9.4	8.0	9.0	9.0	9.0	9.0	8.0	9.7	8.6	8.4	7.5	8.1	8.6	6.5
22	9.0	8.0	9.0	8.0	9.0	9.0	8.0	9.3	8.4	8.3	7.5	8.0	8.5	6.4
24	9.0	8.0	9.0	8.0	9.0	9.0	8.0	9.1	8.4	8.2	7.0	7.8	8.4	6.4
26	9.0	8.0	9.0	8.0	9.0	9.0	8.0	8.9	8.3	8.2	7.0	7.8	8.4	6.4
28		8.0	9.0	8.0	9.0	9.0	8.0	8.8	8.2	8.1	7.0	7.7	8.3	6.4

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for October = 107cfs										
date	10/25/97	10/24/98	10/23/99	10/28/00	10/27/01	10/26/02	11/1/03	10/23/04	10/22/05	10/27/06	10/27/07	10/26/08	average	10/26/09
flow (cfs)	88	75	47	32	33	58	123	140	112	60	35	33	70	92
secchi (ft)			6.42	11.58	12.67	11.67		7.42	9.50	6.08	6.67	9.00	9.00	8.00
DEPTH (m)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)	temp(C)
1	17.0	18.0	17.0	18.0	16.0	18.0		17.5	20.0	15.3	17.3	16.6	17.3	14.7
2	17.0	18.0	17.0	18.0	16.0	18.0		17.4	20.0	15.0	16.1	16.6	17.2	14.8
4	17.0	18.0	17.0	18.0	16.0	18.0		17.1	19.0	14.8	15.8	16.5	17.0	14.8
6	17.0	18.0	17.0	18.0	16.0	18.0		16.6	18.0	14.7	15.8	16.5	16.9	14.7
8	16.0	17.0	18.0	17.0	16.0	17.0		16.3	16.0	14.4	12.6	16.2	16.0	14.2
10	14.0	13.0	18.0	14.0	14.0	15.0		16.0	12.0	13.0	9.2	14.2	13.9	12.7
12	12.0	10.0	14.0	12.0	12.0	12.0		15.4	11.0	12.1	9.0	11.3	11.9	10.1
14	10.0	9.0	12.0	10.0	10.0	10.0		14.5	10.0	10.3	8.5	9.4	10.3	7.6
16	10.0	9.0	10.0	9.0	10.0	9.0		12.8	9.0	9.4	8.1	8.7	9.5	7.1
18	9.0	8.0	10.0	9.0	9.0	9.0		10.0	9.0	8.8	8.4	8.3	9.0	6.9
20	9.0	8.0	9.0	8.0	9.0	9.0		9.3	9.0	8.5	7.5	8.1	8.6	6.8
22	9.0	8.0	8.0	8.0	9.0	9.0		9.0	8.0	8.4	7.7	8.1	8.4	6.6
24	9.0	8.0	8.0	8.0	9.0	9.0		8.8	8.0	8.4	7.0	7.8	8.3	6.6
26	9.0	8.0	8.0	8.0	9.0	9.0		8.6	8.0	8.2	7.0	7.8	8.2	6.5
28	9.0	8.0	8.0	8.0	9.0	9.0		8.6	8.0	8.2	7.0	7.7	8.2	6.5

Lake Lure at dam				mean monthly flow for April = 175cfs										
date	4/26/97	4/25/98	4/24/99	4/29/00	4/28/01	4/27/02	4/26/03	4/24/04	4/23/05	4/23/06	4/22/07	4/27/08	average	4/27/09
flow (cfs)	203	243	95	121	70	59	332	126	184	80	364	75	163	123
secchi (ft)				6.00	7.50	8.50	7.42	12.75		10.17	no test	6.42	8.39	no test
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	10.0	9.4	9.1	9.6	9.1	9.0	7.4			10.6		8.6	9.2	
2	9.6	8.8	8.9	10.0	9.3	8.6	8.9			10.4		8.8	9.3	
4	9.6	8.8	9.0	10.0	9.5	9.4	9.0			11.0		9.1	9.5	
6	8.5	8.0	8.6	9.2	9.0	10.2	9.9			11.8		9.2	9.4	
8	8.2	8.0	8.1	8.8	8.3	9.6	10.9			10.4		8.8	9.0	
10	7.6	7.8	7.8	8.4	8.2	8.8	10.8			9.7		8.1	8.6	
12	7.6	7.8	7.6	8.1	8.3	8.8	10.6			9.4		7.7	8.4	
14	7.0	7.8	7.3	8.0	8.0	8.6	11.0			8.7		7.5	8.2	
16	7.0	7.8	7.4	8.0	8.0	8.4	11.1			8.4		7.1	8.1	
18	6.4	7.8	7.3	7.8	7.8	8.0	11.4			8.2		6.7	7.9	
20	6.4	7.8	7.1	7.6	7.7	7.8	11.1			7.9		6.5	7.8	
22	6.0	7.8	6.9	7.6	7.4	7.6	11.0			8.0		6.1	7.6	
24	5.8	7.8	6.6	7.5	7.0	7.4	10.8			7.5		5.8	7.4	
26	5.4	7.8	6.5	7.3	6.7	7.5	10.6			7.2		5.4	7.2	
28	4.8	7.4	5.8	6.9	6.2	7.2	2.0			6.2		0.2	5.2	

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for May = 142cfs									
date	5/24/97	5/23/98	5/23/99	5/30/00	5/26/01	5/25/02	5/24/03	5/22/04	5/28/05	5/28/06	5/26/07	5/24/08	average	5/24/09
flow (cfs)	151	181	68	77	41	39	284	89	110	64	101	41	104	177
secchi (ft)				6.92	9.08	9.00	7.42	10.42	7.67	8.25	7.75	8.67	8.35	8.42
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	8.0	8.3	7.5	7.8	8.4	8.3	8.2		8.9	9.8	9.4	9.5	8.6	8.8
2	8.2	9.0	7.5	7.8	8.6	8.3	8.4		8.9	9.7	9.5	9.5	8.7	9.0
4	8.8	10.8	8.4	8.6	8.5	8.3	8.4		9.0	10.5	10.7	9.6	9.2	9.4
6	8.6	11.2	8.8	8.9	9.0	9.2	9.3		9.8	10.4	10.8	8.3	9.5	8.9
8	7.4	7.7	7.3	7.9	9.0	10.6	9.6		7.4	9.8	9.5	7.8	8.5	8.2
10	7.0	7.6	6.0	7.0	9.0	10.8	9.7		6.9	7.9	8.0	7.8	8.0	7.7
12	6.4	7.7	5.8	6.7	9.0	10.6	9.6		6.8	7.0	7.8	7.8	7.7	8.0
14	6.2	7.8	5.9	6.5	8.8	10.5	9.5		7.2	7.0	7.6	7.3	7.7	8.2
16	5.8	7.8	5.7	6.4	8.6	10.2	9.3		6.7	6.8	7.3	7.0	7.4	8.1
18	5.0	8.0	5.6	6.3	8.2	10.2	9.4		6.4	6.5	5.4	6.3	7.0	7.8
20	5.0	7.2	5.3	6.1	8.0	9.2	9.2		5.8	5.8	2.1	0.2	5.8	8.1
22	4.8	6.2	4.6	5.8	7.6	8.7	8.8		5.2	4.5	4.6	0.1	5.5	7.5
24	4.4	4.7	4.1	5.5	7.0	8.4	8.4		4.3	4.3	3.4	0.1	5.0	7.1
26	4.0	3.8	2.5	4.4	6.0	6.4	8.0		2.6	3.1	2.6	0.1	4.0	6.5
28	4.0	1.7	0.9	2.5	4.2	0.6	7.2		0.2	2.2	1.6	0.1	2.3	0.5

Lake Lure at dam				mean monthly flow for June = 125cfs									
date	6/28/97	6/27/98	6/26/99	6/24/00	6/23/01	6/22/02	6/28/03	6/26/04	6/25/05	6/24/06	6/23/07	6/29/08	average	6/29/09
flow (cfs)	151	116	51	46	41	34	253	135	159	71	72	25	96	98
secchi (ft)				6.92	14.00	11.83	8.00	7.33	8.17	9.33	7.92	7.00	8.94	9.50
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	7.8	8.0	7.7	7.2	7.6	7.8	6.2		8.9	7.8	8.3	8.8	7.8	7.7
2	8.2	8.0	8.0	7.2	8.0	7.7	7.9		9.0	7.8	8.2	8.8	8.1	7.6
4	7.9	9.4	8.0	8.1	6.0	7.7	8.1		8.8	9.5	9.8	9.2	8.4	8.8
6	7.0	10.6	7.8	9.4	7.0	8.7	7.6		6.6	11.0	11.1	8.8	8.7	5.2
8	5.8	9.0	6.4	7.2	7.0	9.6	7.2		5.6	8.5	8.8	6.0	7.4	5.1
10	4.5	6.4	4.8	6.1	6.4	10.4	7.5		5.5	6.2	6.5	5.6	6.4	5.9
12	4.5	6.4	4.6	5.7	6.0	8.8	7.8		5.4	5.4	6.2	5.5	6.0	6.4
14	4.5	6.2	4.9	5.3	5.8	8.2	8.0		5.6	4.9	6.1	5.5	5.9	6.7
16	4.5	6.2	4.5	5.1	5.6	7.4	8.2		6.0	4.6	5.9	5.3	5.8	6.5
18	4.2	6.2	3.7	4.8	5.2	6.8	8.1		5.4	3.3	5.5	4.5	5.2	6.3
20	4.2	6.2	3.8	4.7	4.8	6.2	7.4		4.9	2.9	4.8	3.2	4.8	6.2
22	3.4	6.0	2.9	3.8	4.0	5.8	6.8		3.1	1.5	4.3	2.4	4.0	5.4
24	0.8	5.8	2.3	2.6	3.4	5.5	6.4		0.2	0.2	3.6	0.3	2.8	5.0
26	0.5	5.2	1.4	1.1	3.2	3.4	5.6		0.1	0.1	2.1	0.1	2.1	3.0
28	0.2	5.0	0.6	0.6	3.0	1.4	1.0		0.1	0.1	0.5	0.9	1.2	0.7

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for July = 99cfs									
date	7/26/97	7/25/98	7/24/99	7/22/00	7/28/01	7/27/02	7/26/03	7/24/04	7/23/05	7/22/06	7/28/07	7/27/08	average	7/26/09
flow (cfs)	101	82	50	48	57	25	308	94	304	52	53	23	100	48
secchi (ft)			6.75	5.67	10.00	11.92	8.08	8.58	4.83	5.92	10.00	7.00	7.88	7.08
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	7.5	7.8	6.9	7.1	9.6	7.0	7.9	7.7	8.5	8.3	8.1	8.4	7.9	8.0
2	8.6	7.4	6.7	7.0	9.6	7.2	7.9	7.6	9.2	8.2	8.1	8.3	8.0	7.9
4	7.8	8.3	8.5	7.0	10.0	7.0	7.8	8.9	6.9	10.2	8.1	8.2	8.2	8.2
6	4.0	9.4	5.1	6.8	10.0	8.2	3.6	4.4	4.0	1.9	9.5	5.2	6.0	5.4
8	3.2	5.5	3.4	5.5	11.4	8.9	4.0	3.6	3.6	2.8	5.7	3.1	5.1	3.1
10	3.4	4.2	3.2	4.7	10.0	9.9	4.2	3.1	4.1	3.3	4.6	3.4	4.8	4.4
12	3.2	4.0	3.2	4.3	8.4	7.6	4.5	2.9	4.5	3.5	4.5	3.9	4.5	5.2
14	3.0	3.8	3.3	4.2	7.6	6.4	4.6	3.0	4.5	1.7	4.1	3.9	4.2	5.4
16	2.4	3.8	3.1	3.9	7.0	5.7	4.8	3.0	4.4	1.6	4.3	3.3	3.9	5.5
18	2.0	3.2	2.6	2.9	5.6	4.4	4.8	2.2	3.6	1.0	3.4	2.3	3.2	5.4
20	1.2	1.6	2.1	2.8	3.8	3.0	4.6	1.3	2.6	0.3	2.4	0.8	2.2	4.9
22	0.5	1.6	0.8	1.8	2.8	1.4	3.6	1.0	0.9	0.1	0.2	0.2	1.3	3.8
24	0.4	0.6	0.4	0.9	2.4	1.0	2.6	0.7	0.1	0.1	0.0	0.2	0.8	3.3
26	0.4	0.4	0.4	0.6	2.2	0.9	1.0	0.7	1.1	0.2	0.1	0.2	0.7	0.9
28	0.2	0.4	0.3	0.5	2.0	0.9	0.5	0.6	1.6	0.1	0.1	0.1	0.6	0.8

Lake Lure at dam				mean monthly flow for August = 107cfs									
date	8/23/97	8/22/98	8/28/99	8/26/00	8/25/01	8/24/02	8/23/03	8/28/04	8/27/05	8/26/06	8/27/07	8/25/08	average	8/23/09
flow (cfs)	73	75	30	43	34	21	396	81	168	92	45	56	93	42
secchi (ft)			6.17	6.50	10.08	12.83	6.83	8.08	8.25	8.17	8.08	5.67	8.07	7.00
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	7.8	5.8	7.2	7.3	11.6	7.2	6.6	8.2	8.5	8.0	8.2	9.2	8.0	7.7
2	7.8	5.8	7.4	7.1	11.6	7.2	7.4	8.1	8.3	7.9	8.2	9.4	8.0	7.7
4	8.0	6.2	7.6	7.6	13.0	7.4	7.8	8.6	8.4	7.8	8.1	9.0	8.3	8.6
6	2.6	4.0	6.4	3.2	12.0	8.3	3.2	1.7	0.9	1.5	8.5	2.1	4.5	3.7
8	2.0	2.4	3.0	2.0	9.6	8.4	2.6	0.5	0.6	0.2	5.5	0.5	3.1	1.4
10	2.0	1.8	2.0	2.4	9.0	6.8	3.9	1.5	1.6	1.1	4.6	1.8	3.2	3.8
12	2.2	1.4	1.8	2.5	8.0	4.2	4.8	1.7	2.5	1.3	4.5	2.5	3.1	4.5
14	1.7	1.7	2.0	2.6	7.0	2.4	5.2	1.2	2.7	0.3	4.2	2.0	2.7	5.1
16	1.2	1.3	1.6	2.5	6.6	1.5	5.4	1.0	1.5	0.2	4.1	1.1	2.3	4.7
18	0.6	1.1	0.8	1.6	5.4	0.9	5.2	0.1	0.5	0.2	4.0	0.2	1.7	4.3
20	0.6	0.4	0.5	0.8	3.8	0.7	4.2	0.1	0.1	0.1	3.4	0.2	1.2	2.8
22	0.4	0.2	0.5	0.5	3.0	0.6	3.0	0.1	0.1	0.1	2.4	0.2	0.9	1.6
24	0.4	0.1	0.5	0.4	2.6	0.6	1.4	0.1	0.1	0.1	0.4	0.2	0.6	0.8
26	0.4	0.1	0.5	0.4	2.4	0.5	1.2	0.1	0.1	0.1	0.1	0.2	0.5	0.8
28	0.2	0.1	0.5	0.4	2.2	0.5	1.0	0.1	0.1	0.1	0.1	0.2	0.5	0.7

Appendix I: Temperature and dissolved oxygen concentrations at the site near the dam from 1997 through 2009-continued

Lake Lure at dam				mean monthly flow for Sept = 100cfs										
date	9/27/97	9/26/98	9/25/99	9/23/00	9/22/01	9/28/02	9/27/03	9/25/04	9/24/05	9/23/06	9/24/07	9/29/08	average	9/27/09
flow (cfs)	77	55	31	42	38	59	152	486	89	114	33	40	101	126
secchi (ft)			5.83	7.00	12.08	11.25	8.42	1.92	8.25	6.08	8.42	7.50	7.68	5.00
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	8.2	9.6	8.1	8.2	8.0	8.0	7.2	9.0	8.0	8.7	8.2	8.0	8.3	8.4
2	8.2	9.3	8.0	7.9	8.2	8.0	8.0	8.9	7.9	8.8	8.1	8.0	8.3	8.4
4	7.0	8.4	7.9	8.0	8.0	7.8	8.2	7.6	8.9	6.1	8.1	7.6	7.8	7.2
6	2.5	4.7	7.3	5.1	6.6	7.8	4.0	7.2	0.9	3.0	8.2	4.3	5.1	6.4
8	0.4	0.7	1.0	1.1	3.6	6.0	2.0	6.0	0.1	1.0	6.0	0.1	2.3	5.5
10	0.7	0.4	0.7	0.9	2.6	4.8	2.4	6.2	0.4	0.6	4.4	0.1	2.0	1.9
12	0.8	0.5	0.7	1.1	1.8	3.2	3.0	5.2	1.0	0.6	4.5	0.7	1.9	3.5
14	0.6	0.8	0.6	1.4	1.7	2.0	3.2	4.5	1.0	0.6	4.2	1.0	1.8	3.5
16	0.3	0.4	0.5	1.4	1.2	1.4	3.2	2.7	0.8	0.4	4.0	0.8	1.4	3.6
18	0.2	0.3	0.5	1.0	0.8	1.0	2.6	0.2	0.2	0.2	4.0	0.1	0.9	2.8
20	0.2	0.3	0.4	0.6	0.6	1.0	2.2	0.1	0.1	0.2	3.3	0.1	0.8	2.3
22	0.2	0.3	0.4	0.5	0.6	0.9	1.2	0.1	0.1	0.2	2.4	0.1	0.6	1.5
24	0.2	0.2	0.4	0.4	0.4	0.8	0.9	0.1	0.1	0.2	0.1	0.1	0.3	1.5
26	0.2	0.2	0.4	0.4	0.3	0.8	0.8	0.1	0.1	0.1	0.1	0.1	0.3	1.5
28		0.2	0.3	0.4	0.3	0.7	0.7	0.1	0.1	0.2	0.1	0.1	0.3	1.5

Lake Lure at dam				mean monthly flow for October = 107cfs										
date	10/25/97	10/24/98	10/23/99	10/28/00	10/27/01	10/26/02	11/1/03	10/23/04	10/22/05	10/27/06	10/27/07	10/26/08	average	10/26/09
flow (cfs)	88	75	47	32	33	58	123	140	112	60	35	33	70	92
secchi (ft)			6.42	11.58	12.67	11.67		7.42	9.50	6.08	6.67	9.00	9.00	8.00
DEPTH (m)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)	DO(mg/L)
1	7.7	8.5	8.1	9.1	9.2	8.8		9.9	8.8	8.6	8.2	8.0	8.6	8.2
2	7.8	8.2	6.8	8.8	9.0	8.8		9.6	8.8	8.5	8.2	8.0	8.4	8.1
4	7.4	8.2	6.6	8.9	9.0	8.7		7.3	8.3	8.1	8.1	7.9	8.0	8.1
6	7.4	7.8	6.9	8.2	9.0	8.6		6.5	3.8	7.8	7.8	7.6	7.4	7.8
8	1.2	6.0	6.2	6.1	8.0	6.4		5.3	0.2	5.8	7.7	5.6	5.3	6.3
10	0.6	1.1	1.1	1.4	2.8	4.2		4.9	0.1	1.2	4.5	1.2	2.1	2.0
12	0.6	0.7	0.6	0.8	1.6	1.5		3.3	0.3	0.6	4.3	0.2	1.3	1.3
14	0.6	0.6	0.5	0.7	0.8	0.8		1.7	0.3	0.3	4.0	0.2	1.0	2.1
16	0.6	0.5	0.4	0.6	0.4	0.6		0.1	0.1	0.2	3.9	0.1	0.7	1.9
18	0.4	0.5	0.4	0.6	0.4	0.5		0.1	0.1	0.2	3.9	0.1	0.7	1.4
20	0.4	0.4	0.4	0.5	0.4	0.4		0.1	0.1	0.2	2.1	0.1	0.5	1.1
22	0.4	0.4	0.4	0.5	0.4	0.4		0.1	0.1	0.2	2.1	0.1	0.5	1.0
24	0.4	0.4	0.4	0.5	0.4	0.4		0.1	0.1	0.2	0.1	0.1	0.3	1.0
26	0.4	0.4	0.3	0.5	0.3	0.3		0.1	0.1	0.1	0.1	0.1	0.2	1.0
28	0.4	0.4		0.4	0.2	0.3		0.1	0.0	0.2	0.1	0.1	0.2	1.0

Appendix J: Secchi depths (in inches) at four sites on Lake Lure from 1999 - 2009 (mean flow in cfs)

	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT
1999 Dam					81	74	70	77
2000 Dam		72	83	83	68	78	84	139
2001 Dam	45	90	109	168	120	121	145	152
2002 Dam		102	108	142	143	154	135	140
2003 Dam		89	89	96	97	82	101	
2004 Dam		153	125	88	103	97	23	89
2005 Dam	89		92	98	58	99	99	114
2006 Dam		122	99	112	71	98	73	73
2007 Dam	92		93	95	120	97	101	80
2008 Dam		77	104	84	84	68	90	108
2009 Dam			101	114	85	84	60	96
1999 Main Channel					77	82	82	78
2000 Main Channel		85	83	81	62	78	90	123
2001 Main Channel	45	98	109	146	111	113	135	125
2002 Main Channel		105	112	142	146	142	120	133
2003 Main Channel		88	91	86	94	70	88	
2004 Main Channel		151	112	102	99	95	30	86
2005 Main Channel	102		87	92	56	108	105	110
2006 Main Channel		113	105	115	85	94	67	70
2007 Main Channel	81		87	125	96	96	95	70
2008 Main Channel		89	89	77	90	75	90	108
2009 Main Channel			84	80	75	72	48	102
1999 Buffalo Bay					70	73	67	73
2000 Buffalo Bay		77	74	68	62	57	83	86
2001 Buffalo Bay	43	81	80	120	96	109	116	125
2002 Buffalo Bay		102	106	129	124	125	105	122
2003 Buffalo Bay		92	89	78	58	76	86	
2004 Buffalo Bay		112	108	87	96	77	26	75
2005 Buffalo Bay	89		92	90	58	93	85	87
2006 Buffalo Bay		111	98	91	70	85	59	70
2007 Buffalo Bay	88		93	86	73	80	86	75
2008 Buffalo Bay		96	89	77	77	65	90	114
2009 Buffalo Bay			89	85	62	72	48	84
1999 Tryon Bay					68	72	77	64
2000 Tryon Bay		70	74	79	54	64	68	129
2001 Tryon Bay	40	78	102	122	90	102	133	120
2002 Tryon Bay		98	117	121	140	137	112	125
2003 Tryon Bay		94	75	82	94	72	104	
2004 Tryon Bay		136	101	75	102	85	25	89
2005 Tryon Bay	86		66	86	57	91	98	95
2006 Tryon Bay		120	102	85	80	86	66	72
2007 Tryon Bay	74		81	95	95	94	97	72
2008 Tryon Bay		72	84	79	79	60	90	108
2009 Tryon Bay			77	113	72	72	48	96
1999 mean mo flow		95	68	51	50	30	31	47
2000 mean mo flow		121	77	46	48	43	42	32
2001 mean mo flow	117	70	41	41	57	34	38	33
2002 mean mo flow		59	39	34	25	21	59	58
2003 mean mo flow		332	284	253	308	396	152	123
2004 mean mo flow		126	89	135	94	81	486	140
2005 mean mo flow	199	187	114	162	319	168	89	112
2006 mean mo flow		80	64	71	52	92	114	60
2007 mean mo flow	164	101	72	51	42	33	34	32
2008 mean mo flow		75	41	25	23	56	40	33
2009 mean mo flow		123	177	98	48	42	126	92

Appendix K: Total Phosphorus (as P) one meter from the surface at the dam and in the main lake channel - 1997 – 2009

	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	yr ave
1997 Dam	0.08	0.06	0.03	0.05	0.04	0.05	0.03	**0.05**
1998 Dam	0.10	0.09	0.08	0.05	0.07	0.06	0.06	**0.07**
1999 Dam	0.04		0.05	0.03	0.09	0.05	0.06	**0.05**
2000 Dam	0.08	0.06	0.06	0.06			0.04	**0.06**
2001 Dam	0.07	0.05	0.02	0.05	0.04	0.03	0.07	**0.05**
2002 Dam	0.06	0.07	0.05	0.05	0.07	0.07	0.08	**0.07**
2003 Dam	0.06	0.12	0.29	0.07	0.09	0.14	0.07	**0.12**
2004 Dam	0.03	0.05	0.06	0.09	0.05	0.06	0.04	**0.05**
2005 Dam		0.06	0.08	0.07	0.05	0.06	0.05	**0.06**
2006 Dam	0.03	0.06	0.10	0.05	0.06	0.03	0.04	**0.05**
2007 Dam		0.03	0.05	0.02	0.04	0.04	0.02	**0.03**
2008 Dam	0.03	0.04	0.05	0.03	0.04	0.07	0.04	**0.04**
2009 Dam	0.07	0.06	0.03	0.04	0.02	0.04	0.03	**0.04**
1997 Main	0.04	0.06	0.06	0.09	0.04	0.03	0.02	**0.05**
1998 Main	0.10	0.07	0.10	0.11	0.06	0.07	0.05	**0.08**
1999 Main	0.04	0.03	0.03	0.05	0.12	0.05	0.04	**0.05**
2000 Main	0.07		0.06	0.05			0.03	**0.05**
2001 Main	0.06	0.06	0.01	0.12	0.05	0.03	0.07	**0.06**
2002 Main	0.06	0.05	0.07	0.05	0.03	0.06	0.08	**0.06**
2003 Main	0.09	0.10	0.11	0.07	0.09	0.21	0.08	**0.11**
2004 Main	0.10	0.06	0.07	0.04	0.07	0.07	0.06	**0.07**
2005 Main		0.07	0.08	0.08	0.06	0.05	0.06	**0.06**
2006 Main	0.03	0.03	0.07	0.06	0.02	0.05	0.03	**0.04**
2007 Main		0.03	0.05	0.04	0.04	0.04	0.02	**0.04**
2008 Main	0.02	0.03	0.06	0.03	0.02	0.04	0.05	**0.04**
2009 Main	0.06	0.05	0.03	0.04	0.03	0.04	0.01	**0.04**