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Tennessee Valley Authority

Water Management

AQUATIC ECOLOGICAL HEALTH DETERMINATIONS FOR TVA RESERVOIRS--1999

An Informal Summary of 1999 Vital Signs Monitoring Results
and Ecological Health Determination Methods

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Section 1. Reservoir Monitoring -- Overview of Approach, Methods, and 1999 Results

Introduction

The Tennessee Valley Authority (TVA) began a program to systematically monitor the ecological condition of its reservoirs in 1990. Previously, reservoir studies focused on reservoir specific assessments to meet specific needs as they arose.

Reservoir Monitoring is one of five components of TVA's overall river and reservoir monitoring effort, termed Vital Signs Monitoring. Objectives of Reservoir Monitoring are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee Valley reservoirs. Ecological monitoring activities provide the necessary information from key physical, chemical, and biological indicators to evaluate conditions in reservoirs and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions in TVA's reservoirs. Other components of Vital Signs Monitoring include: (1) examination of ecological conditions in tributary streams to the Tennessee River to evaluate their influences on observed conditions reservoirs and to provide a snapshot of overall watershed conditions; (2) monitoring of toxic contaminants in fish flesh to determine their suitability for consumption; (3) evaluating the number and size of important game fish species to help ensure their populations remain abundant and robust; and (4) sampling of bacteriological concentrations at recreational areas to evaluate their suitability for water contact recreation.

This document describes the monitoring and data evaluation process used to evaluate the overall ecological health of reservoirs. It summarizes 1999 data as an example of the mechanics of the ecological health scoring system used in the process. This document is prepared annually with the most recently published report covering calendar year (Dycus, et. al., 1999).

The reservoir ecological health evaluation process has been in use since 1990.. The scoring system is reviewed each year seeking opportunities for improvements. Initially, numerous improvements were made based on experienced gained from working with this new system and input from other professionals. Each year, progressively fewer changes have been needed.

Study Design Considerations

This monitoring program was designed based on several fundamental premises.

1. Ecological health evaluations must be based on physical, chemical, and biological components of the ecosystem.
2. Monitoring must provide current, useful information to resource managers and the public.
3. Monitoring program design must be dynamic and flexible, rather than rigid and static, and must allow adoption of new techniques as they develop.
4. Monitoring must be sustained for several years to document the status of the river/reservoir system, determine its year-to-year variability, and track changes through time.
5. Addressing specific cause/effect mechanisms is not the primary purpose of monitoring. While monitoring may provide information to identify cause/effect relationships, more detailed assessment investigations usually are required.

With these premises in mind, our challenge has been to develop a sustainable monitoring effort that collects the right kinds of physical, chemical, and biological data to provide enough information to reliably characterize ecological health. Study design must carefully consider selection of important ecological indicators, representative sampling locations, and frequency of sampling, all in light of available resources. Following are some of the basic study design decisions made in developing this program.

Ecological Indicators--Physical, chemical, and biological indicators (dissolved oxygen, chlorophyll, sediments, benthos, and fish) were selected to provide information from various habitats or ecological "compartments". For example, the open water or pelagic area in reservoirs is represented by chlorophyll and dissolved oxygen (DO) in midchannel. The shoreline or littoral area is evaluated by sampling the fish assemblage. The bottom or benthic compartment is evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments) and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

Sampling Locations--Three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam. Overbanks, basically the floodplain which was inundated when the dam was built, are included in transition zone and forebay areas. Embayments, another important type of reservoir area, also were considered. Previous studies (Meinert et.al., 1992) have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with little influence from the main body of the reservoir. Although these are important areas, monitoring of hundreds of embayments is beyond the scope of this program. As a result, only four, large embayments (all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres) are included in this monitoring effort.

Sampling Frequency--Sampling frequencies (indexing periods) must consider the expected temporal variation for each indicator. Indicators which vary in the short term (dissolved oxygen and chlorophyll) are monitored monthly from spring to autumn. Other indicators better integrate long-term variations and are sampled once each year. Sediments are monitored once in mid-summer. Fish assemblage sampling is conducted in autumn (September-November). From 1990 through 1994 benthic macroinvertebrate sampling was conducted in early spring (February-April) to avoid aquatic insect emergence. Beginning in 1995, sampling was switched to late autumn/early winter (November and December). The problem with spring benthos sampling was that results were reflective of conditions from the previous year. This caused results for this indicator to be out of synch with those from the other indicators. This change is more thoroughly discussed in Dycus and Meinert (1996).

Another design issue dealing with sampling frequency is year-to-year variation. Meteorological conditions (particularly runoff from rainfall and its influence on flows) have a great effect on reservoirs and can vary substantially from year-to-year. To account for this variation, our design specifies that a reservoir be sampled for five consecutive years. Following that, sampling occurs on an every other year basis.

Data Evaluation Considerations (Reference Condition and Classification Issues)

Like most evaluations, results for ecological integrity studies must be compared to some reference or yard stick to determine if monitoring results are indicative of good, fair, or poor conditions. In streams this is usually accomplished by studying a site that has had little or preferably no alterations due to human activities. Observations at that site provide the **reference conditions** or expectations of what represents a site with good/excellent ecological health. Given that reservoirs are not natural systems, this approach is inappropriate. Other potential approaches include historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. Preimpoundment conditions are inappropriate because of significant habitat alterations. For the most part, models are of limited value for many indicators because of spatial and temporal variations within and among reservoirs. Spatial variation exists within in the multiple zones (e.g., forebay, transition zone, inflow, and embayments) of a reservoir. Further, each zone responds differently to different stimuli. Temporal variations are introduced because reservoirs are controlled systems with planned annual drawdowns in elevations ranging from only a few feet to close to a hundred feet. This leaves best observed conditions and professional judgment as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. Our process uses a combination of these two approaches.

A preliminary step to developing reference conditions is to examine the need to separate the reservoirs under study into separate **reservoir classes** so that appropriate , "apples-to-apples" comparisons can be made. Like streams, important considerations for classifying reservoirs include size, gradient/depth, ecoregion, etc. In addition, reservoirs are managed systems and management objectives must be considered.

A lesson we learned early in this process was that the issue of classification and its influence on determining reference conditions differed among the environmental indicators. A fundamental question that had to be addressed separately for each indicator was – Should reservoir ecological health evaluations be based on:

1. ideal conditions (basically a subjective determination; for example, a very low DO concentration is an unacceptable ecological condition regardless of any classification issue); or
2. the best conditions expected/observed given the environmental and operational characteristics of the dam/reservoir (for example, very low DO concentrations are acceptable in many tributary reservoirs because they are expected due to water management practices, withdrawal schemes, stratification, etc.)?

Our response (opinion) was that ideal conditions should be expected for DO and Sediment Quality. That is, poor DO is unacceptable regardless of type of reservoir or dam operation. Sediments should not have high concentrations of metals, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota. In this situation, there is no need for classification because the same conditions are desired for all reservoirs.

For chlorophyll, the classification scheme that has evolved is somewhat of a combination of the two approaches. First the geological characteristics (primarily erodablility and nutrient level of soils) of the watershed were examination. Then a conceptual/subjective decision made as to the concentrations indicative of good, fair, and poor conditions. Two classes of reservoirs were developed – reservoirs in watersheds draining nutrient poor soils, basically those in the Blue Ridge Ecoregion (i.e., expected oligotrophic reservoirs); and reservoirs in watersheds draining soils which are not nutrient poor (i.e., expected mesotrophic reservoirs).

For benthic macroinvertebrates and fish assemblage, the "best expected/observed conditions" approach was selected initially. Basically, this means the data base from the existing population of reservoirs is examined to determine the range of conditions for each community characteristic or metric (e.g., number of taxa). The process is to first omit outliers (defined as more than three standard deviations from the mean), then trisect the remaining range of values (including zero if appropriate for a particular metric – see Sections 5.0 and 6.0 for details). These three ranges represent good, fair, and poor conditions and form the reference conditions or expectations for each metric. This is still the basic approach used for these two indicators, but experience has shown best results can be obtained by including professional judgment in the process. Cutoff points are examined closely and adjusted, if appropriate, based on professional judgment. This approach is discussed in detail in Dycus and Meinert (1998).

Reservoirs were divided into four classes to evaluate the benthos and fish. One class includes the reservoirs on the Tennessee River plus the two navigable reservoirs on tributaries to the Tennessee River (loosely termed run-of-river reservoir). This group of reservoirs has relatively short retention times and little winter drawdown. The remaining tributary reservoirs were separated into three classes: those in the Blue Ridge Ecoregion, those in the Ridge and Valley Ecoregion, and those on the Interior Plateau Ecoregion. The run-of-the-river reservoirs were not subdivided by ecoregion because most of the water flowing through each reservoir comes from upstream and does not originate within the ecoregion where the reservoir is physically located.

Ecological Health Rating Methods

We developed a methodology to evaluate the ecological health of reservoirs included in this program because none were available when the monitoring program began in 1990. The ecological health evaluation system examines each of five key indicators separately and then combines these ratings into a single, composite score for each reservoir.

Dissolved oxygen – The rating criteria represent a multidimensional approach that includes dissolved oxygen levels both throughout the water column (WC_{DO}) and near the bottom (B_{DO}) of the reservoir. The DO rating (ranging from 1 "poor" to 5 "good") at each sampling location is based on monthly measurements during April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs. This is the six-month period when maximum thermal stratification and maximum hypolimnetic anoxia are expected. The WC_{DO} Rating is the six-month average of the proportion of the reservoir cross-sectional area at the sample location that has a DO concentration less than 2.0 mg/L. The B_{DO} Rating is the six month average of the proportion of the reservoir cross-sectional bottom length that has a DO concentration less than 2.0 mg/L. The final DO rating is a combination of the WC_{DO} and B_{DO} results. (See Section 2.0 for details.)

Chlorophyll – Scoring criteria were developed separately for each of the two classes of reservoirs. Reservoirs expected to be oligotrophic receive highest ratings at low chlorophyll concentrations. Reservoirs expected to be mesotrophic receive highest ratings for an intermediate range of concentrations. For reservoirs expected to be mesotrophic, the rating is reduced at high chlorophyll concentrations and at low chlorophyll concentrations if an environmental factor (e.g., turbidity, toxicity, retention time) inhibits primary production. A sliding scale is used to evaluate the seasonal average chlorophyll concentration for each reservoir class. (See Section 3.0 for details.)

Sediment quality – Initially, the scoring criteria for sediment quality was based two components: sediment toxicity tests and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs. Since 1995, the sediment quality scoring criteria have been based only on sediment analyses for metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn), organochlorine pesticides, and PCBs. Sediment toxicity tests were discontinued primarily because of budget reductions, but also because frequent changes in toxicity testing methods made year-to-year comparisons difficult. The sediment quality rating compares results for metals analyses to sediment guidelines we adapted from EPA Region 5 (EPA, 1977). Presence of any of the organic analytes is deemed undesirable so results are compared to laboratory detection limits. If none of the metals exceed these guidelines and no PCBs or pesticides are detected, the site would receive the highest sediment quality rating. Occurrences of analytes above these standards lowers the rating. (See Section 4.0 for details.)

Benthic Macroinvertebrates – Seven metrics or characteristics are used to evaluate the benthic macroinvertebrates in all reservoirs. Scoring criteria for each metric were developed from the data base on TVA reservoirs. The benthic macroinvertebrate score is the total of these seven metrics. Some specific metrics vary between run-of-river reservoirs and tributary reservoirs due to differences in thermal stratification and dissolved oxygen concentrations. (See Section 5.0 for details.)

Fish Assemblage – Twelve metrics or characteristics are used to derived the Reservoir Fish Assemblage Index (RFAI) described in Hickman and McDonough (1995). The same 12 metrics are used for all classes of reservoirs although specific scoring ranges for each metric varies by reservoir class. (See Section 6.0 for details.)

The ecological health scoring process is designed such that four of the indicators (DO, chlorophyll-a, benthos, and fish) are given equal weights with each indicator assigned a rating ranging from 1 (poor) to 5 (excellent). The fifth indicator, sediment quality, is given half the weight of the other indicators and assigned a rating ranging from 0.5 (poor) to 2.5 (excellent). (Note: Prior to 1995, sediment quality had been rated on the 1 to 5 range, same as the other indicators. But, discontinuance of sediment toxicity testing, which had contributed half the sediment quality rating, resulted in the rating for this indicator being reduced by one half). Ratings for the five indicators are summed for each site. Thus, the maximum total rating for a sample site would be 22.5 (all indicators excellent) and the minimum 4.5 (all indicators poor).

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum possible rating for that reservoir, and expressed as a percentage. It is necessary to use a percentage basis because the number of sites monitored varies according to reservoir size and configuration. Only one site, the forebay, is sampled in small tributary reservoirs, and up to four sites (forebay, transition zone, inflow, and embayment) are sampled in selected run-of-the-river reservoirs. Also, the number of indicators varies from three to five at different sites. Chlorophyll and sediment quality are excluded at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. As a result, the number of scoring possibilities may be as few as 5 indicator ratings for a small reservoir sampled only at the forebay. Or, as many as 18 indicator ratings for a large reservoir sampled at the forebay, transition zone, inflow, and embayment. The total score for the small reservoir would be 22.5 if all indicators rated excellent, whereas, the total score for the large reservoir would be 82.5 if all indicators rated excellent. Hence, using a percentage basis allows easier comparison among reservoirs.

This approach provides a potential range of scores from 22 to 100 percent and applies to all reservoirs regardless of the number of indicators or sample sites. To complete the ecological health scoring process, the 22-100 percent scoring range must be divided into categories representing good, fair, and poor ecological health conditions.

As with other elements of this program, this has proven to be a challenging issue. The obvious approach would be to follow the same process as that used for individual indicators. Basically, this would mean trisecting the range between 22 and 100 and designating the three categories that result as good, fair, and poor. In attempting to use this approach we found that virtually all our reservoirs fell into the fair category — none rated poor and only a few rated good. This was not acceptable because there was such a large difference between reservoir conditions at the upper and lower ends of the fair range. We carefully examined the conditions which existed in each reservoir and were generally comfortable with the separation between fair and good categories, with only minor adjustment. However, the reservoirs at the lower end of the range exhibited conditions which we felt were truly representative of poor reservoir conditions. As a result, we initially made a subjective decision and adjusted the low end of the fair range up so that reservoirs with poor conditions actually rated poor. Originally, this adjustment differed between run-of-river reservoirs and tributary reservoirs.

The scoring ranges which resulted from this initial effort were used with slight modification from 1991 through 1997 and are shown below.

Run-of-the-River Reservoirs			Tributary, Storage Reservoirs		
Poor	Fair	Good	Poor	Fair	Good
<52	52-72	>72	<57	57-72	>72

A slightly difference approach to determine reservoir scoring ranges was instituted prior to evaluating the 1998 results and continued in 1999. One of the primary factors driving this change the absence of a justification for the difference in the poor range between the run-of-river reservoirs and tributary reservoirs. The scoring system itself should account for any differences if appropriate adjustments are made to scoring criteria for individual metrics for each indicator. If this is accomplished, final ecological health scores for reservoirs should be comparable, regardless of whether they are run-of-the river reservoir or tributary reservoirs.

The approach used was to first obtain a five-year average ecological health score for each reservoir. The average scores were then plotted and examined for natural breaks which coincided with known lake condition and which did not differ substantially that the previously used scoring ranges. The trisection of these average scores is shown in Figure 1 and summarized below. Incorporation of 1999 results and refiguring the five-year average did not change the trisection points.

Scoring Ranges for All Reservoirs in 1998 and 1999		
Poor	Fair	Good
<59	59-72	>72

An example that illustrates the overall reservoir health evaluation methodology is presented in Table 1 for Fort Loudoun Reservoir.

Reservoir Ecological Conditions--1999 Results

Meteorology and Hydrology – Meteorological conditions (sunlight, cloud cover, and the amount, frequency, and seasonal distribution of rainfall) significantly affect the hydrology (flows and retention times) and ecological conditions in reservoirs. As meteorology varies from year to year, so do its effects on reservoir hydrology and ecology.

Figure 2 shows the relative flow contributed by each of the major tributary rivers to the Tennessee River. Water quality characteristics vary greatly among these tributaries because of differences in geology, rainfall, and land use patterns among watersheds. For example, the French Broad and Holston rivers are moderately hard and rich in nutrients; the Little Tennessee and Hiwassee rivers are soft and nutrient-poor; the Clinch River is hard with moderate nutrients; while the other two large tributaries, the Elk and Duck rivers, are relatively hard and nutrient-rich, especially in phosphorus.

Like most years, 1999 had its share of meteorological extremes for both air temperatures and rainfall. In general, the year was characterized by hot and dry conditions. Eleven of the 12 months were warmer than normal (Figure 3), and nine months received less rain fall than normal. January and February were extremely mild (5 to 7°F above normal), ranking the 1998-1999 winter one of the warmest on record. March was the only month to be cooler than normal (by almost 4°F). April, July, August, November, and December were 2 to 4°F above normal, whereas May, June, September, and October were only slightly above normal (less than 0.5°F).

Rainfall patterns likewise exhibited extremes in 1999. A dry pattern persisted most of the year for the Tennessee Valley. Precipitation for the year was 40.4 inches or about 11 inches below the 100 year mean of 51.3 inches. Only two months (January and June) had above normal rainfall (Figures 4 and 4a). January was by far the wettest month of the year with an average of almost 8 inches of rain across the Tennessee Valley and greater amounts in some areas.

The ensuing period from February through May was much dryer than normal, which hindered filling of TVA reservoirs. Although individual storm events of 1 to 3 inches occurred during most of these months, these storms were generally isolated and as a result rainfall totals for each month were below normal. Of note was one strong storm event in early May which produced most of the rainfall for the entire month. That storm was particularly significant because it produced sufficient runoff to allow reservoir levels to rise an average of 4.4 feet over a 7 days period, with the most substantial rises at Fontana (11.8 feet), Hiwassee (9.1 feet), and Douglas (6.1 feet). Spillway releases were necessary on the lower portions of the main river despite minimum releases from the tributary projects and storing water above normal summer maximum levels at Fort Loudoun, Watts Bar, and Chickamauga.

The dry pattern returned in June with most rainfall gages receiving less than 2 inches of rain for most of the month. The pattern changed the last week of June when daily storms produced heavy rainfall totals. These storms provided enough rainfall to push the June total from 2 inches below normal before the week started to about one inch above normal by the end of June. The east central part of the basin received over two inches on June 24 and 25th. In the west and southwest basins, a storm June 28th brought three inch plus storm totals. This heavy rain in late June provided much needed water to the reservoir system.

Rainfall for July was almost two inches below normal below Chattanooga but near normal above Chattanooga due to afternoon convection rains in the mountains typical for July. There were only two rain events in July which were valley-wide. Otherwise, there were only localized events, a few of which were produced heavy rains. The last two weeks were dry with many sites below Chattanooga getting less than 0.5 inches.

The dry weather continued for the rest of 1999. August had the largest rainfall deficit for the year (3 inches below normal). Rainfall gages in the west and southwest portions of the Tennessee Valley recorded no rainfall while most stations recorded less than 0.5 inches during August. Substantial rainfall deficits existed during the other months also. In fact, this was the driest August-December period during the 1900's for the Tennessee Valley. The entire basin total from August to December 1999 was 10.0 inches which is 9.0 inches below the 100 year mean of 19.1 inches. By the end of 1999, reservoirs were at the lowest levels in the past 10 years due to the dry weather.

Although rainfall is an important consideration in evaluating meteorological influences on reservoir condition, what really matters is the runoff it produces. Runoff is greatest in high intensity rainfall events, especially if the ground is already saturated and spring growth of foliage has not yet occurred. Foliage increases surface area which enhances evaporation, and significant amounts of water move back to the atmosphere via plant transpiration.

On an average annual basis, runoff is highest January through early April and lowest August through October (Figure 5). The naturally low summertime runoff usually results in reduced stream flows which in turn decrease flows in the receiving reservoirs and thereby increase retention times. Retention time has a direct influence on physical, chemical, and biological conditions in reservoirs. Some of these effects are stressful to aquatic life. For example, lower reservoir flows allow stronger thermal stratification to develop. This in turn limits mixing of the water column diminishing reaeration and causing lower dissolved oxygen concentrations in bottom waters. Naturally warmer summer water temperatures further lower oxygen concentrations due to lower solubility of oxygen and higher rates of respiration and decomposition. In addition, low stream flows help to diminish turbidity and increase water clarity. In reservoirs in which algal productivity is not nutrient limited, which is typically the case for reservoirs on the main stem Tennessee River, greater water clarity means more light available for photosynthesis and higher algal populations.

As would be expected, the lack of rainfall described above resulted in less runoff than normal for the Valley during 1999. Total runoff for the year was 17.5 inches which is 5.2 inches below the 100 year mean of 22.7 inches (Figure 5a). As a result, reservoir flows were much lower than normal and retention times were much longer in 1999 than in years with more normal amounts of rainfall (Table 5). For example, the long-term average flow through Kentucky Dam (the downstream-most dam on the Tennessee River) is 66,850 cfs, whereas the flow in 1999 was only 48,000 cfs. Comparable low flows and increased retention times were experienced in reservoirs throughout the Tennessee Valley.

Periodicity of rainfall and resultant runoff is also an important factor. Of particular interest in 1999 were the storms in early May and late June. Both produced substantial runoff and, hence, provided much needed water to help fill the reservoirs and augment flows throughout the system. But, on the other hand, both would have introduced substantial nutrients to stimulate algal growth.

Clearly, the hot dry conditions in 1999 compounded by periodic heavy rainfall set the stage for potentially undesirable ecological conditions -- too much algal productivity and low dissolved oxygen levels. As seen below, these conditions were manifested in several reservoirs. Some had the highest chlorophyll levels found to date. Also, some reservoirs which usually do not suffer from low dissolved oxygen levels did so in 1999.

Physical/Chemical/Biological Conditions in 1999 – Full Vital Signs monitoring was conducted on 18 reservoirs (total of 33 sites) in 1999. Additional monitoring was conducted on several other reservoirs using selected Vital Signs Monitoring tools in 1999 to meet specific needs

(Table 2). These additional results are provided in the specific sections of this report as a means for making them available, but Reservoir Ecological Health scores were not developed for them.

The summary below clearly shows the negative influences of meteorological conditions in 1999, especially for chlorophyll and DO concentrations. Seasonal average chlorophyll concentrations were higher in 1999 than in previous years at 22 of the 33 sites monitored. Also, a greater amount of water with low DO concentrations occurred at 9 of the 33 sites in 1999. Results for the other three indicators were similar in 1999 compared to past years. These indicators are not expected to vary greatly due to seasonal influences, unless those influences are severe. Rather, they were selected to be more representative of more long-term changes.

Results for Each Indicator in 1999 Compared to Previous Years

Indicator	"Worse" Condition	# of Sites With No Change	"Better" Condition	Total Sites
Chlorophyll	22	11	0	33
DO	9	24	0	33
Fish	4	33	1	38
Benthos	4	30	4	38
Sediment	2	30	1	33

Notes: "Worse Conditions," "No Change," and "Better Conditions" were determined as follows:

- For Chlorophyll, the "No Change" column represents the number of sites in which the 1999 seasonal average chlorophyll concentration was +/-20% of the long-term seasonal average. "Worse Condition" was designated for sites which had higher chlorophyll concentrations and "Better Condition" for sites with lower concentrations than in the past.
- For Dissolved, the "No Change" column represents the number of sites in which the proportion of the water column with DO concentration <2.0 mg/l in 1999 was +/- 5% of the long-term average. "Worse Condition" was exemplified by an increase in the amount of water with low DO concentrations and "Better Condition" by a decrease in this amount.
- For Fish, the "No Change" column is represented by a 1999 index score which is +/- 9 points of the long-term average score. "Worse Condition" was exemplified by lower scores and "Better Condition" by higher scores.
- For Benthos, the "No Change" column is represented by a 1999 index score which is +/- 5 points of the long-term average score. "Worse Condition" was exemplified by lower scores and "Better Condition" by higher scores.
- For Sediment Quality, the "No Change" column is represented by a perusal of results for all years looking for notable increases or decreases in the number of pollutants above a predetermined concentration. "Worse Condition" was exemplified by an increase in the number of pollutants and "Better Condition" by a decrease in the number of pollutants.

Phytoplankton productivity in TVA reservoirs (as measured by chlorophyll concentrations in this monitoring program) is usually limited by a combination of three factors – nutrients, light, and retention time. In tributary reservoirs retention time is rarely a limiting factor because they have such a large volume relative to their inflow rate, which creates long retention times (100 - 300 days; Table 5). Longer retention times allow suspended particles to settle, increasing water clarity. As a result, light availability, which often limits algal productivity in main stream reservoirs, is rarely a problem during the summer in tributary reservoirs. Consequently, nutrient availability usually is the limiting factor in tributary reservoirs.

The heavy rainfall/runoff events in May and late June 1999 tended to supply and replenish ample amounts of nutrients. This tended to enhance algal productivity during spring and early summer. However, as runoff decreased during the dry summer/autumn period, algal productivity decreased in many reservoirs due to nutrient depletion, despite increased water clarity and retention time.

Most (6 of 9) of the reservoir sites which exhibited an increased amount of low DOs in 1999 were in tributary reservoirs and known to have DO problems regardless of meteorological conditions. However, two of the sites were forebays of run-of-the-river reservoirs – Fort Loudoun and Wheeler – and experience DO problems only in low flow years. The remaining site was on Chatuge Reservoir (a tributary reservoir). Low DOs at that site had been previously found only in 1998, which was also a hot, dry year.

In summary, ratings for three of the five ecological indicators (sediment quality, benthos, and fish) were generally about the same as in past years. Ratings for chlorophyll and DO were generally poorer in 1999 compared to previous years. Data and ratings for each of these indicators are summarized in Sections 2 through 6 of this document.

Reservoir Ecological Health Scores for 1999 – Combining all the aquatic ecosystem indicator ratings to determine the overall ecological health for each of the 18 reservoirs sampled in 1999 shows the following:

- 4 of the 18 rated good (2 run-of-river reservoirs and 2 tributary reservoirs);
- 6 of the 18 rated fair (3 run-of-river reservoirs and 3 tributary reservoirs); and
- 8 of the 18 rated poor (1 run-of-river reservoir and 7 tributary reservoirs).

The ecological health ratings for all reservoirs sampled in 1998 and/or 1999 are presented by classification unit in Table 3 and Figure 6. Main stem reservoirs scored higher (as in previous years) than any other class of reservoirs, while none of the reservoirs in the Interior Plateau Ecoregion scored better than fair. Comparisons of reservoir ecological health ratings with previous years (Table 4) shows that 12 of the 18 reservoirs sampled in 1999 scored within seven points of their long term average, 1 scored higher, and 5 scored lower than their long term average. The primary basis of selecting +/- 7 points to indicate comparability among years was that it spans the full scoring range of the fair category (<59 = Poor / 59-72 = Fair / >72 = Good). Professional judgment was also a consideration in this selection with special attention to the expected variation in the overall score as well as for the five indicators which constitute that score. Long-term is defined as the period for each reservoir for which comparable methods/locations exist thereby providing a true apples-to-apples comparison. Generally, this period was 1994 - 1999.

A summary of Vital Signs Monitoring results for each reservoir in 1999 is provided in Appendix A. Differences between 1999 and previous years are discussed and explained to the extent possible. Appendix A also includes ecological health scores for all years for which Vital Signs Monitoring data exist. Scores are provided as reported (calculated based on the methods in use at the time they were originally reported) and based on the latest (1999) scoring methods.

Important physical and operational characteristics of reservoirs and the dams that control them are summarized in Table 5.

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Table 1. Computional Method for Evaluation of Reservoir Health; Fort Loudounl Reservoir -- 1999 (Run-of-the-River Reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition	Inflow	Forebay	Transition	Inflow
Chlorophyll-a				1.0 (poor)	1.0 ~~(fair)~~ (poor)	No Rating
Summer Average, ug/l	21.0	20.5	No Sample			
Maximum Concentration	24.0	47.0	No Sample			
Dissolved Oxygen				1.5 (poor)	5.0 (good)	No Rating
Percent less than 2 mg/l :						
X-Sectional Area	10.8 (1)	0 (5)	No Sample			
Bottom X-Sectional Length	21.5 (2)	0 (5)	No Sample			
Sediment Quality				1.5 (fair)	1.0 (poor)	No Rating
Metals/Pesticides/PCBs	PCBs, Chlordane	Zinc, PCBs, Chlordane	No Sample			
Benthic Community				1 (poor)	3 (fair)	1 (poor)
Total Score - Seven Metrics	9	19	7			
Fish Community				4 (good)	3 (fair)	4 (good)
Total Score - Twelve Metrics	46	40	46			
	Sampling Location Sum			9.0 of 22.5	13.0 of 22.5	5.0 of 10
	Reservoir Sum			27.0 of 55 (49%)		
	Overall Reservoir Evaluation			"poor"		

Overall Reservoir Evaluation Key:

Less than 59 % -- poor (red)
59 % to 72 % -- fair (yellow)
Greater than 72 % -- good (green)

Table 2. Reservoir Vital Signs Monitoring Activities, 1999

Reservoir	River Mile	Sampling Schedule (Monthly or Annual) Water Chemistry	Sediment Chemistry	Benthos	Fish
Kentucky	TRM 23.0	M	A	A	A*
	TRM 85.0	M	A	A	A*
	TRM 200-206	-	-	A	A*
	Big Sandy 7.4	M	A	A	A*
Pickwick[1]	TRM 207.3	M	A	A	A
	TRM 230.0	M	A	A	A
	TRM 253-259	-	-	A	A
	Bear Creek 8.4	M	A	A	A
Wilson[1]	TRM 260.8	M	A	A	A
	TRM 273-274	-	-	A	A
Wheeler	TRM 277.0 S,B,F	M	A	A	A*
	TRM 295.9	M	A	A	A*
	TRM 347-348	-	-	A	A*
	Elk River 6.0	M	A	A	A*
Guntersville[1]	TRM 350.0	M	A	A	A
	TRM 375.2	M	A	A	A
	TRM 420-424	-	-	A	A
Nickajack	TRM 425.5	M	A	A	A**
	TRM 469-470 B,F	-	-	A	A***
Chickamuaga	TRM 472.3	M	A	A	A*
	TRM 490.5 S,B,F	M	A	A	A*
	TRM 518-529	-	-	A	A*
	Hiwassee 8.5	M	A	A	A*
Watts Bar[2]	TRM 531/532.5	M	A	A	A
	TRM 560.8	M	A	A	A
	TRM 600-601	-	-	A	A
	CRM 19-22	-	-	A	A
Fort Loudoun	TRM 605.5	M	A	A	A
	TRM 624.6	M	A	A	A****
	TRM 652	-	-	A	A
Tellico	LTRM 1.0	M	A	A	A**
	LTRM 15.0	M	A	A	A**
Melton Hill[2]	CRM 24.0	M	A	A	A
	CRM 45.0	M	A	A	A
	CRM 59-66	-	-	A	A
Norris	CRM 80.0	M	A	A	A
	CRM 125.0	M	A	A	A
	PRM 30.0 S,B,F	M	A	A	A
ɘs	FBRM 34.5 B,F	M	A	A	A*
	FBRM 51.0	M	A	A	A*

Reservoir	River Mile	Sampling Schedule (Monthly or Annual) Water Chemistry	Sediment Chemistry	Benthos	Fish
Cherokee[2]	HRM 53/55.0	M	A	A	A
	HRM 76.0	M	A	A	A
Ft.Pat Henry	SFHR 8.7	M	A	A	A
Boone	SFHR19.0	M	A	A	A
	SFHR 27.0	M	A	A	A
	WRM 6.5	M	A	A	A
South Holston[2]	SFHR 51.0	M	A	A	A
	SFHR 62.5	M	A	A	A
Watauga	WRM 37.4	M	A	A	A
	WRM 45.5	M	A	A	A
Fontana	LTRM 62.0	M	A	A	A
	LTRM 81.5	M	A	A	A
	TkRM 3.0	M	A	A	A
Apalachia	HiRM 67.0	M	A	A	A
Hiwassee[2]	HiRM 77/77.5	M	A	A	A
	HiRM 85.0	M	A	A	A
Chatuge	HiRM 122.0	M	A	A	A
	Shooting Cr 1.5	M	A	A	A
Nottely	NRM 23.5	M	A	A	A
	NRM 31.0	M	A	A	A
Blue Ridge	ToRM 54.1 S,B,F	M	A	A	A
Ocoee No.1	ORM 12.5	M	A	A	A*
Tims Ford	ERM 135.0	M	A	A	A
	ERM 150.0	M	A	A	A
Bear Creek	BCM 75.0 S,B,F	M	A	A	A*
L. Bear Creek	LBCM 12.5	M	A	A	A*
Cedar Creek	CCM 25.2	M	A	A	A*
Normandy	DRM 249.5	M	A	A	A
Beech[2]	BRM 36.0	M	A	A	A

Footnotes:

1=WQ Monitoring to support ADEM Tributary Nutrient
ɔading Study, full VS Monitoring not conducted

ʼQ Monitoring initiated in May due to drought
ɩditions; full VS Monitoring not conducted

S,B,F = QA Samples -- S=Sediment; B=Benthos; F=Fish

*Fish Tissue Site - 5 CHC and 5 LMB
**Fish Tissue Site - 5 CHC
***Fish Tissue Site - 5 CHC and 5 ʼ
****Fish Tussye Site - 10 CHC
(M)-Monthly, April-October (A)-Annual.
Shadded areas -- not sampled in 1999

Table 3. Ecological Health Scores for Reservoirs Monitored in 1998 and 1999 (All Scoring Based on the Latest, 1999, Criteria)

Reservoir	1997 Score/Rating	1998 Score/Rating	1999 Score/Rating
Reservoir Class: Mainstream Reservoirs			
Kentucky	78 - Good	NS	72 - Fair
Pickwick	NS	75 - Good	NS
Wilson	NS	78 - Good	NS
Wheeler	75 - Good	NS	60 - Fair
Guntersville	NS	84 - Good	NS
Nickajack	88 - Good	NS	85 - Good
Chickamauga	86 - Good	NS	82 - Good
Watts Bar		67 - Fair	NS
Ft. Loudoun	57 - Fair	62 - Fair	49 - Poor
Tellico	62 - Fair	NS	59 - Fair
Melton Hill	NS	70 - Fair	NS
Reservoir Class: Ridge and Valley Ecoregion			
Norris	67 - Fair	NS	70 - Fair
Douglas	54 - Poor	NS	56 - Poor
Cherokee	NS	50 - Poor	NS
Ft. Pat. Henry	56 - Poor	NS	56 - Poor
Boone	55 - Poor	NS	39 - Poor
South Holston	NS	54 - Poor	NS
Watauga	NS	60 - Fair	NS
Reservoir Class: Blue Ridge Ecoregion			
Apalachia	69-Good	61 - Fair	59 - Fair
Hiwassee	NS	69 - Fair	NS
Chatuge	NS	49 - Poor	49 - Poor
Blue Ridge	82 - Good	NS	84 - Good
Parksville	67 - Fair	NS	58 - Poor
Nottely	48 - Poor	NS	48 - Poor
Fontana	NS	69 - Fair	NS
Reservoir Class: Interior Plateau Ecoregion			
Tims Ford	NS	49 - Poor	NS
Normandy	NS	63 - Fair	NS
Bear	42 - Poor	NS	52 - Poor
Little Bear	64 - Fair	NS	69 - Fair
Cedar	69 - Fair	NS	73 - Good
Beech	NS	53 - Poor	NS

Table 4. Reservoir Ecological Health Scores for 1999 Comapred to Historic Mean for 199X* - 1998

	Res. Eco. Health Rating, as reported									Res. Eco. Health on 1999 Criteria									
Watershed / Reservoir	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991**	1992**	1993**	1994	1995	1996	1997	1998	Historic Mean*	1999
Kentucky Res. Watershed																			
Kentucky Reservoir	77	88	75	71	74	N/A	78	N/A	72	69	87	81	74	71	N/A	78	N/A	74	72
Beech Reservoir	N/A	N/A	65	56	46	51	N/A	53	N/A	N/A	N/A	69	54	50	51	N/A	53	52	N/A
Duck River Watershed																			
Normandy Reservoir	N/A	N/A	56	68	59	69	N/A	63	N/A	N/A	N/A	62	64	59	69	N/A	63	64	N/A
Pickwick/Wilson Watershed																			
Pickwick Reservoir	77	75	73	84	N/A	73	N/A	75	N/A	77	80	70	81	N/A	72	N/A	74	76	N/A
Wilson Reservoir	60	68	71	71	N/A	75	N/A	78	N/A	58	67	76	70	N/A	75	N/A	78	74	N/A
Bear Creek Resrvoir	N/A	N/A	60	56	46	47	42	N/A	52	N/A	N/A	64	60	51	47	42	N/A	50	52
Little Bear Creek Res.	N/A	N/A	64	64	69	64	64	N/A	69	N/A	N/A	68	64	64	64	64	N/A	64	69
Cedar Creek Reservoir	N/A	N/A	56	80	60	64	69	N/A	73	N/A	N/A	64	72	60	64	69	N/A	66	73
Wheeler/Elk Watershed																			
Wheeler Reservoir	89	80	72	75	69	N/A	76	N/A	~~59~~ 60	70	76	72	74	68	N/A	75	N/A	72	~~59~~ 60
Tims Ford Reservoir	N/A	60	58	58	56	53	N/A	49	N/A	N/A	63	60	58	56	53	N/A	49	54	N/A
Guntersville/Sequatchie WS																			
Guntersville Reservoir	66	83	78	83	N/A	86	N/A	84	N/A	84	85	79	81	N/A	86	N/A	82	83	N/A
Nickajack/Chickamauga																			
Nickajack Reservoir	89	83	88	90	92	N/A	88	N/A	85	87	81	87	91	89	N/A	88	N/A	89	85
Chickamauga Res.	90	73	83	87	81	N/A	88	N/A	82	83	88	86	85	78	N/A	86	N/A	83	82
Hiwassee River Watershed																			
Hiwassee Reservoir	82	69	58	68	N/A	62	N/A	69	N/A	72	71	69	62	N/A	62	N/A	67	64	N/A
Chatuge Reservoir	60	56	67	77	N/A	84	N/A	52	49	59	79	79	72	N/A	78	N/A	49	66	49
Nottely Reservoir	60	60	64	56	47	N/A	48	N/A	48	60	61	62	56	49	N/A	48	N/A	51	48
Blue Ridge Reservoir	87	73	72	86	84	N/A	82	N/A	84	87	83	91	80	84	N/A	82	N/A	82	84
Ocoee No. 1 Reservoir	47	53	52	60	71	N/A	71	N/A	58	74	74	67	67	67	N/A	67	N/A	67	58
Apalachia	N/A	N/A	N/A	N/A	N/A	N/A	73	66	59	N/A	N/A	N/A	N/A	N/A	N/A	69	61	65	59

* The time period included in the Historic Mean varies by reservoir due to varing periods of consistent record -- monitoring was not initiated on all reservoirs at the same time and sample locations within certain reservoirs have been moved.

** 1991, 1992, and 1993 are scored on 1999 criteria for 4 of the 5 indicators. A change in processing of benthic macroinvertebrate samples beginning in 1994 prevents appropriate scoring of the earlier results on the latter criteria.

Table 4. cont. Reservoir Ecological Health Score for 1999 Compared to Historic Mean for 199X* - 1998

Watershed / Reservoir	Res. Eco Health Rating, as reported									Res. Eco. Health on 1999 Criteria									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991**	1992**	1993**	1994	1995	1996	1997	1998	Historic Mean*	1999
Watts Bar/Ft. Loud./Mel. Hill																			
Watts Bar Reservoir	69	71	68	79	N/A	68	N/A	67	N/A	72	79	76	72	N/A	68	N/A	64	68	N/A
Fort Loudoun Reservoir	60	53	58	61	49	52	58	64	49	63	63	56	62	47	52	57	62	56	49
Melton Hill Reserovir	80	67	68	72	N/A	73	N/A	70	N/A	67	65	66	71	N/A	69	N/A	69	70	N/A
Clinch/Powell Watershed																			
Norris Reservoir	57	67	67	69	60	N/A	64	N/A	70	71	72	69	66	61	N/A	67	N/A	65	70
L' Tenn. River Watershed																			
Tellico Reservoir	48	48	63	71	53	N/A	62	N/A	59	61	57	63	72	53	N/A	62	N/A	62	59
Fontana Reservoir	N/A	N/A	64	67	72	62	N/A	69	N/A	N/A	N/A	71	77	72	62	N/A	68	70	N/A
French Broad River WS																			
Douglas Reservoir	42	56	58	64	45	N/A	54	N/A	56	60	54	60	62	45	N/A	54	N/A	54	56
Holston River Watershed																			
Cherokee Reservoir	50	53	64	53	51	49	N/A	50	N/A	57	57	66	51	54	49	N/A	50	51	N/A
Fort Pat. Henry Res.	N/A	N/A	72	60	51	59	56	N/A	56	N/A	N/A	86	60	51	55	56	N/A	56	56
Boone Reservoir	51	64	59	59	49	N/A	55	N/A	39	53	63	58	56	49	N/A	55	N/A	53	39
South Holston Res.	60	57	65	66	N/A	55	N/A	54	N/A	63	59	66	66	N/A	55	N/A	52	58	N/A
Watauga Reservoir	80	57	61	65	N/A	72	N/A	60	N/A	75	72	63	63	N/A	72	N/A	58	64	N/A

* The time period included in the Historic Mean varies by reservoir due to varing periods of consistent record -- monitoring was not initiated on all reservoirs at the same time and sample locations within certain reservoirs have been moved.

** 1991, 1992, and 1993 are scored on 1999 criteria for 4 of the 5 indicators. A change in processing of benthic macroinvertebrate samples beginning in 1994 prevents appropriate scoring of the earlier results on the latter criteria.

Table 5. Characteristics of Vital Signs Reservoirs

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres x K)	Depth at Dam[a] (ft)	Volume[a] (ac-ft x K)	Average Annual Drawdown[b] (ft)	Average Reservoir Flow - POR Thru 1999 (cfs)	Average Reservoir Flow CY 1999 (cfs)	Average Hydraulic Residence Time Jan-Dec 1999[a] (Days)	Average Hydraulic Residence Time April-Sept 1999[a] (Days)
Run-of-the-River Reservoirs										
Kentucky	40,200	184.3	160.3	88	2,839	5	66,853	48,048	29.8	45.2
Pickwick	32,820	52.7	43.1	84	924	6	55,772	42,922	10.9	15.2
Wilson	30,750	15.5	15.5	108	634	3	52,314	40,580	7.9	10.8
Wheeler	29,590	74.1	67.1	66	1,050	6	50,468	40,222	13.2	17.6
Guntersville	24,450	75.7	67.9	65	1,018	2	41,643	32,874	15.6	19.6
Nickajack	21,870	46.3	10.7	60	241	0	36,895	26,273	4.6	5.6
Chickamauga	20,790	58.9	35.4	83	628	7	34,812	26,190	12.1	14.5
Watts Bar	17,300	72.0/24.0[c]	39	105	1,010	6	27,606	20,476	24.9	28.7
Fort Loudoun	9,550	50	14.6	94	363	6	18,882	14,589	12.5	14.2
Melton Hill	3,343	44	5.7	69	120	0	5,089	3,202	18.9	22.9
Tellico	2,627	33.2	16.5	80	415	6	6,180[e]	5121[e]	40.9	46.0
Tributary River Reservoirs										
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,269	2,570	400.2	471.0
Douglas	4,541	43.1	30.4	127	1,408	48	6,779	4,841	146.6	163.4
Cherokee	3,428	54	30.3	163	1,481	28	4,580	2,735	273.0	305.0
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,667	1,613	8.4	8.5
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2559	1,542	61.8	61.8
South Holston	703	23.7	7.6	239	658	33	984	549	604.3	537.8
Watauga	468	16.3	6.4	274	569	26	717	443	647.6	510.4
Fontana	1,571	29	10.6	460	1,420	64	3,944	3,326	215.2	240.2
Hiwassee	968	22.2	6.1	255	422	45	2068	2,292	92.8	69.9
Chatuge	189	13	7.1	124	234	10	461	324	364.1	404.0
Nottely	214	20.2	4.2	167	170	24	416	251	341.5	439.5
Parksville	595	7.5	1.9	115	85	7	1419	861	49.8	50.8
Blue Ridge	232	11	3.3	156	193	36	611	326	298.5	281.8
Tims Ford	529	34.2	10.6	143	530	12	979	846	315.8	609.6
Bear Creek	232	16	0.7	74	10	11[e]	405	385	13.1	22.4
Cedar Creek	179	9	4.2	79	94	14[e]	310	250	189.6	460.1
Little Bear Creek	61	7.1	1.6	82	45	12[e]	108	90	252.1	487.9
Normandy	195	17	3.2	83	110	11	345	362	153.2	219.8
Beech	16	5.3	0.9	32	11	1[e]				

Footnotes: a. Estimates based on normal maximun pool; b. Tennessee River System Operations and Planning Review, Final EIS, TVA/RDG/EQS--91/1, 1990;
c. Major arms of reservoir; d. Estimated flow based on releases from Chilhowee Dam and adjusted based on drainage area between Chilhowee and Tellico Dams;
e. Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

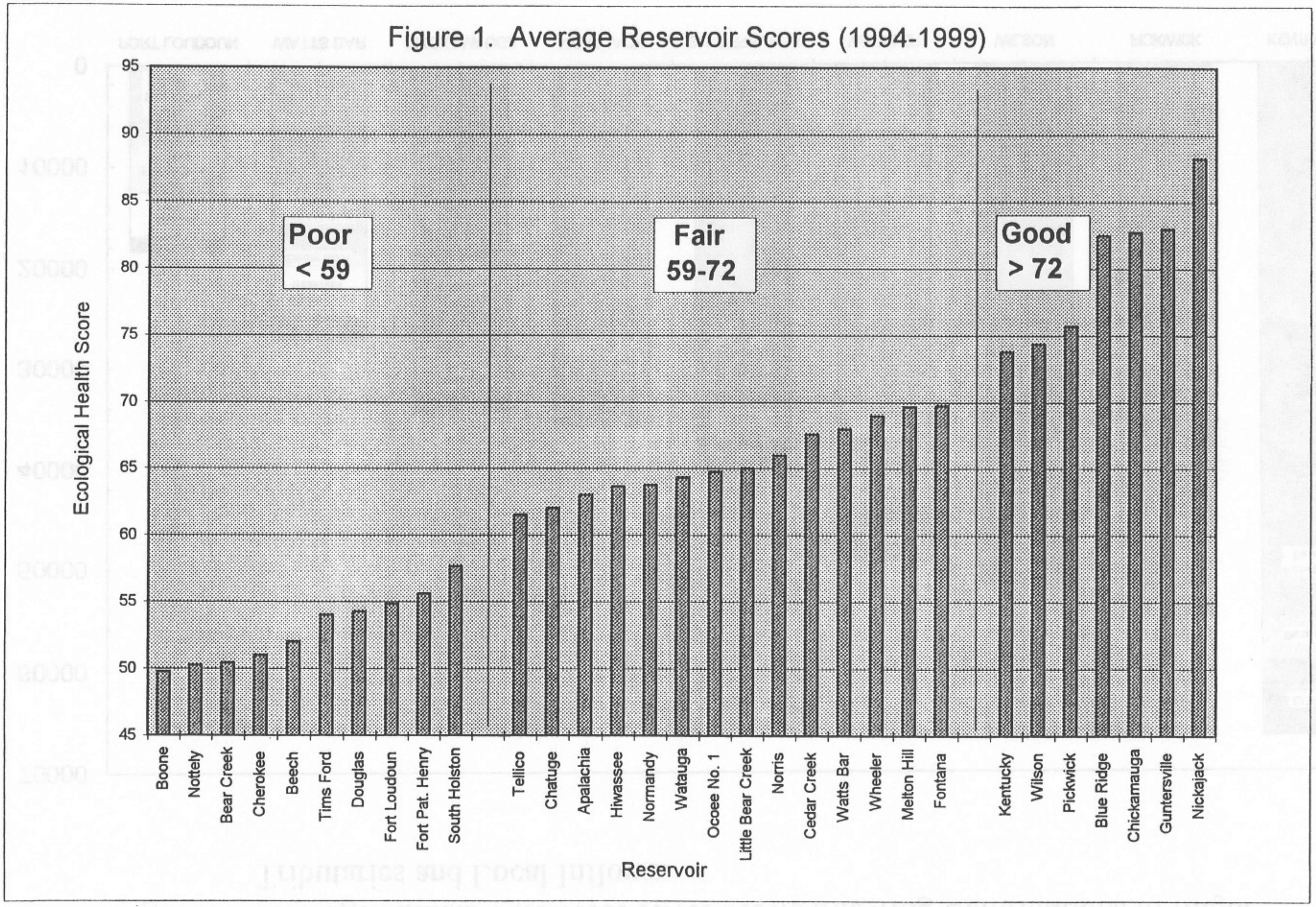


Figure 1. Average Reservoir Scores (1994-1999)
Poor
< 59
Fair
59-72
Good
> 72
Ecological Health Score
95
90
85
80
75
70
65
60
55
50
45
Boone
Nottely
Bear Creek
Cherokee
Beech
Tims Ford
Douglas
Fort Loudoun
Fort Pat. Henry
South Holston
Tellico
Chatuge
Apalachia
Hiwassee
Normandy
Watauga
Ocoee No. 1
Little Bear Creek
Norris
Cedar Creek
Watts Bar
Wheeler
Melton Hill
Fontana
Kentucky
Wilson
Pickwick
Blue Ridge
Chickamauga
Guntersville
Nickajack
Reservoir

Figure 2. Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

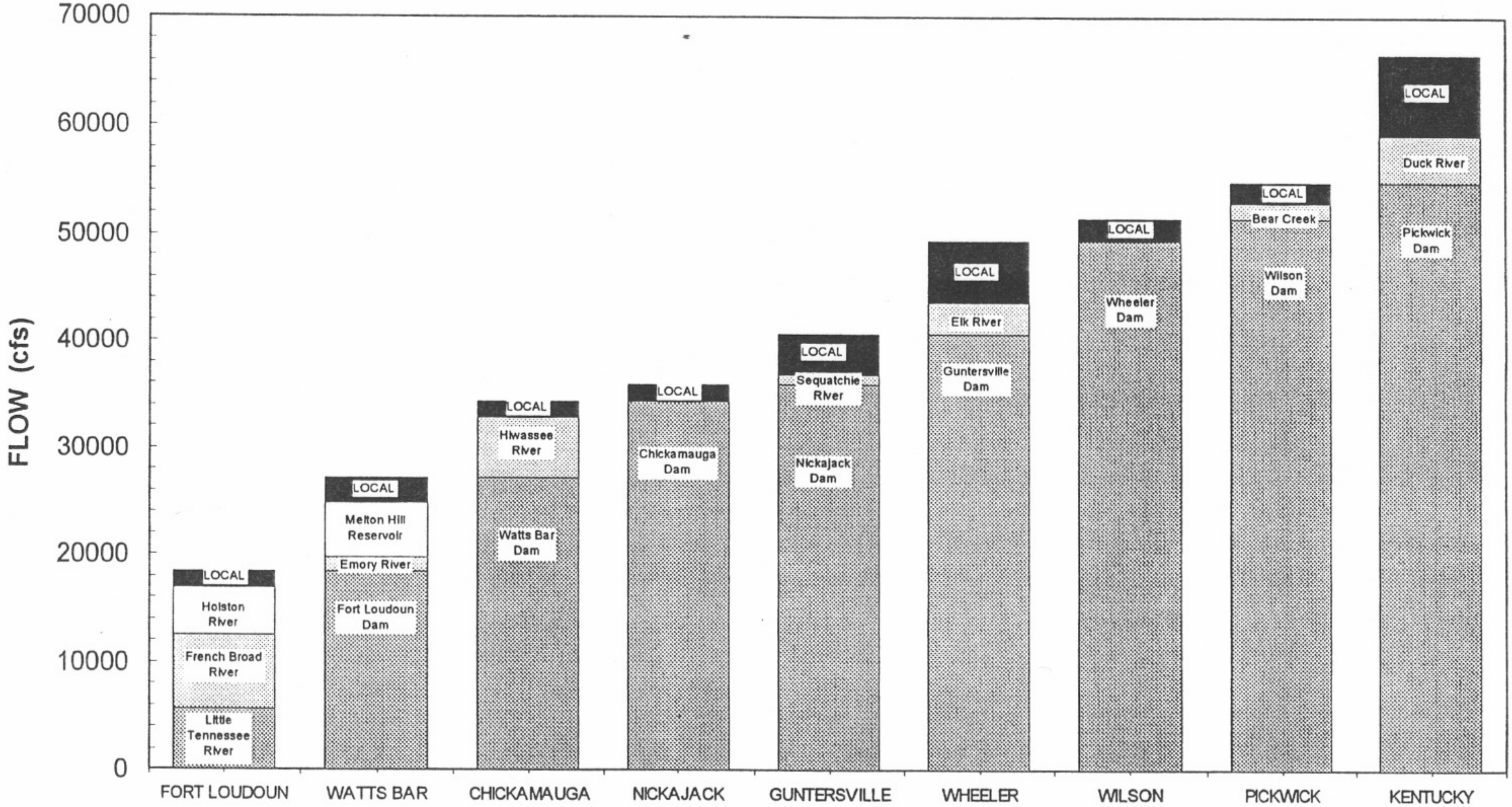


Figure 3. Temperature Departure From 30-Year Normal (deg F) in the TVA Region

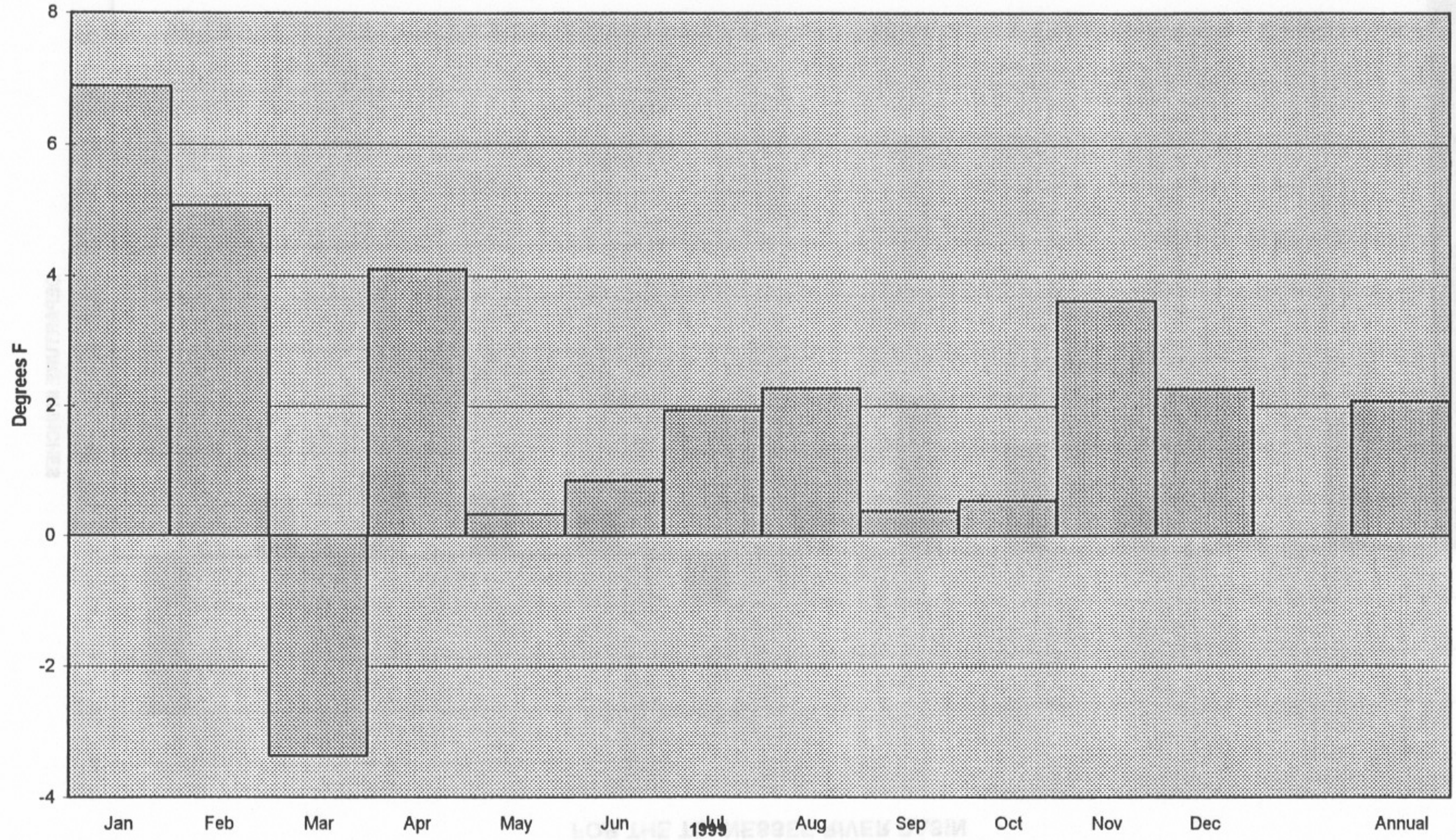


Figure 4. PRECIPITATION DEPARTURES FROM LONG-TERM MEAN (1899-1998) FOR THE TENNESSEE RIVER BASIN

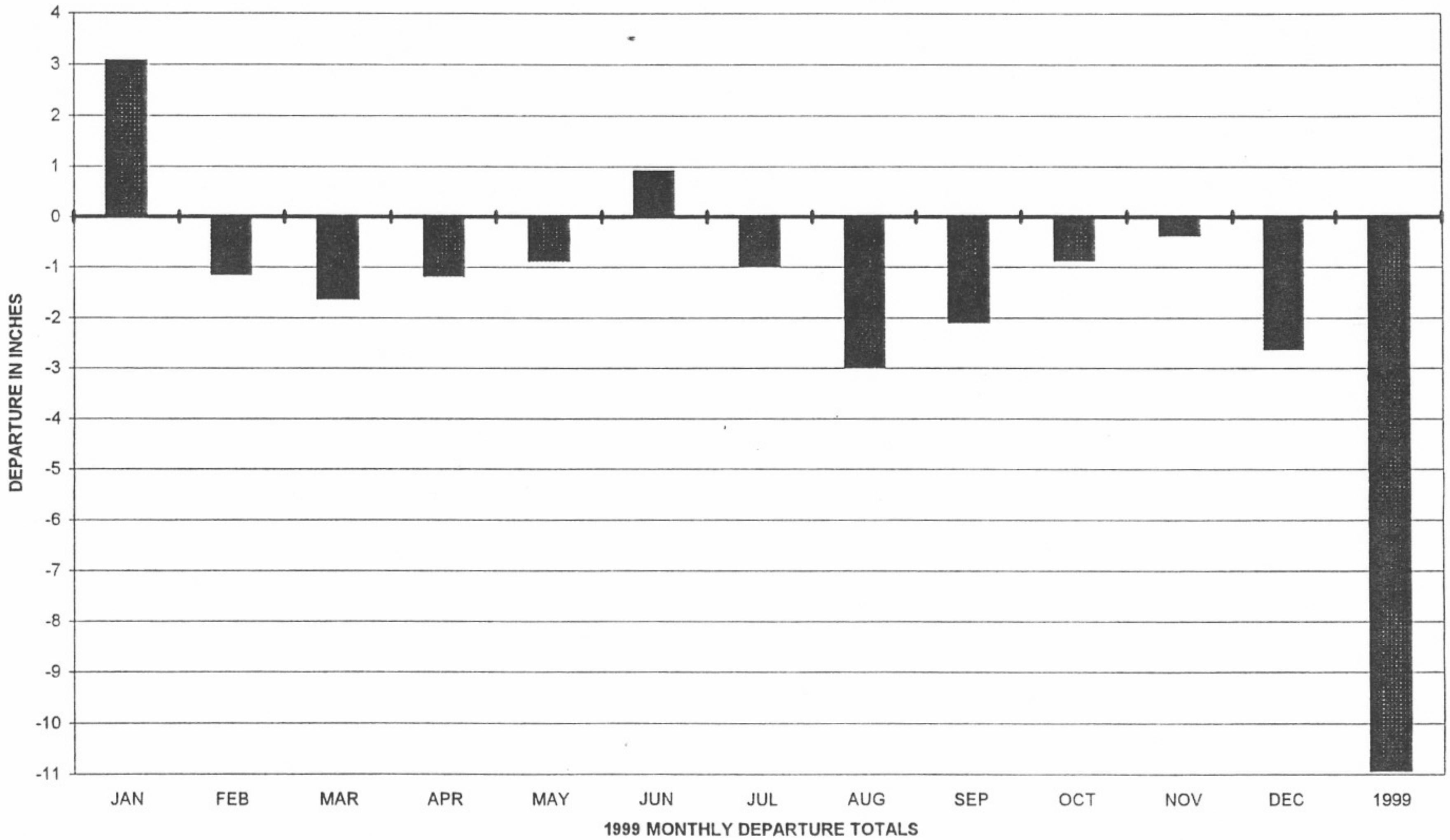


Figure 4a. PRECIPITATION FOR THE TENNESSEE RIVER BASIN - 1999

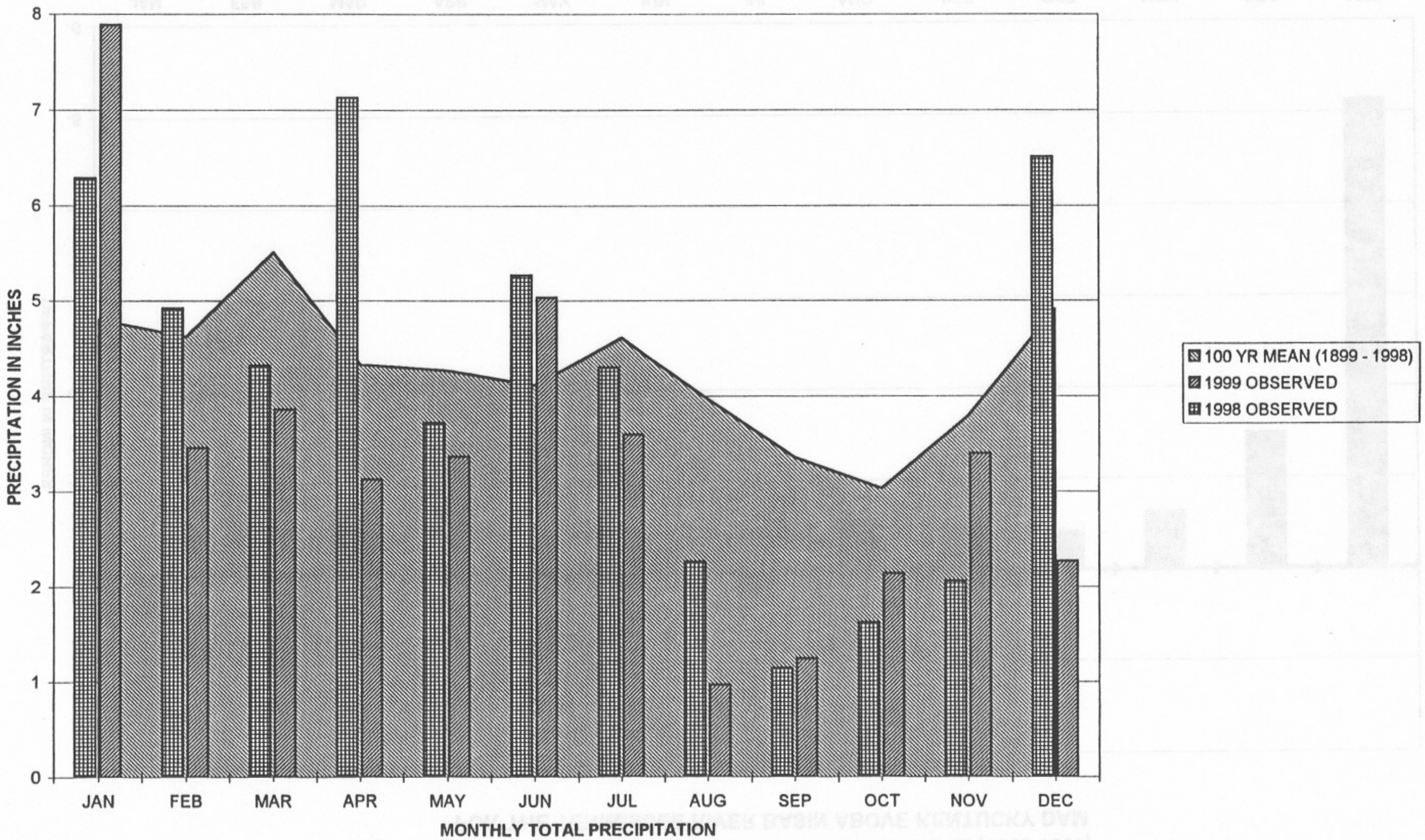


Figure 5. RUNOFF DEPARTURES FROM LONG-TERM MEAN (1899-1998)
FOR THE TENNESSEE RIVER BASIN ABOVE KENTUCKY DAM

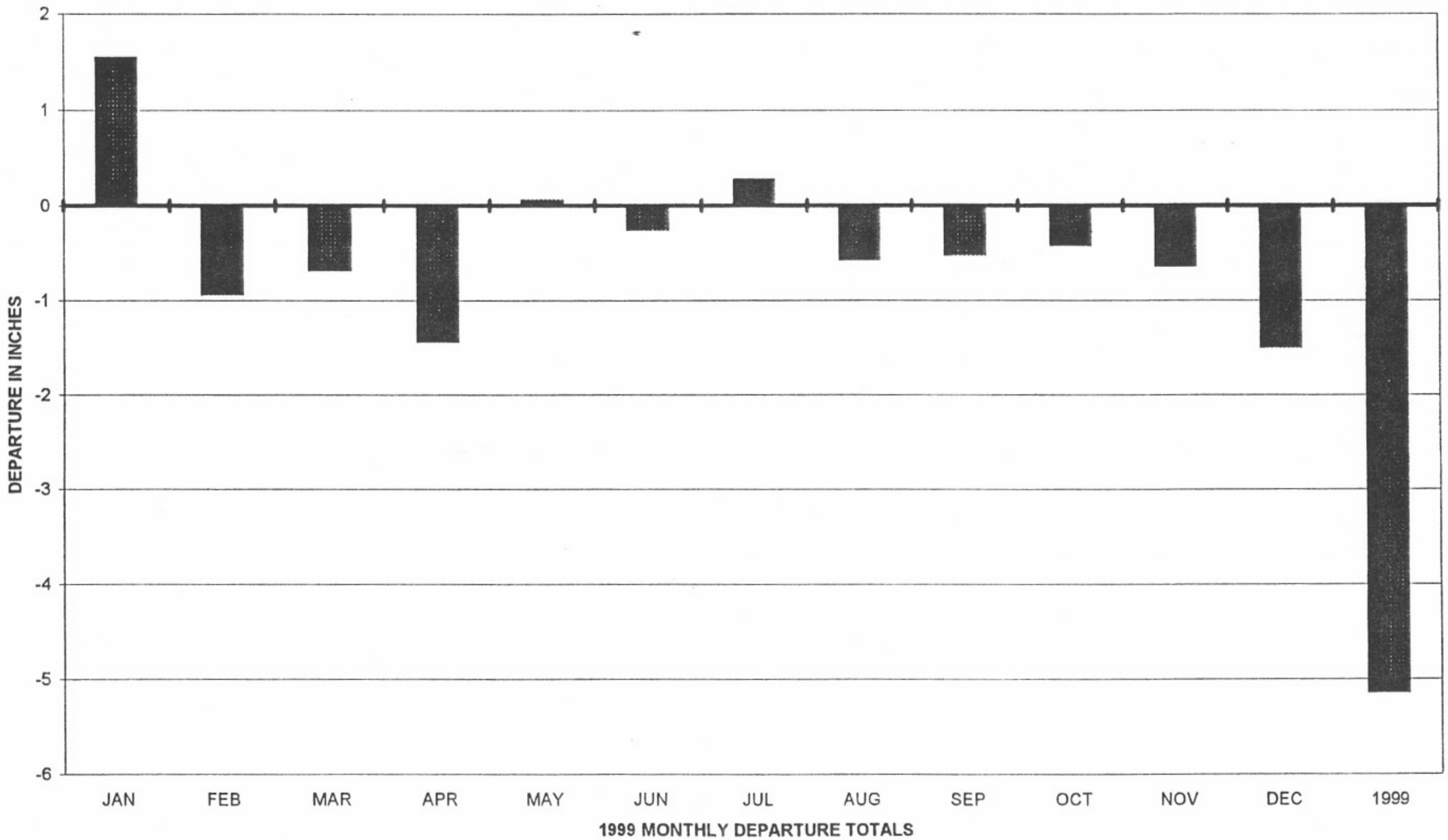
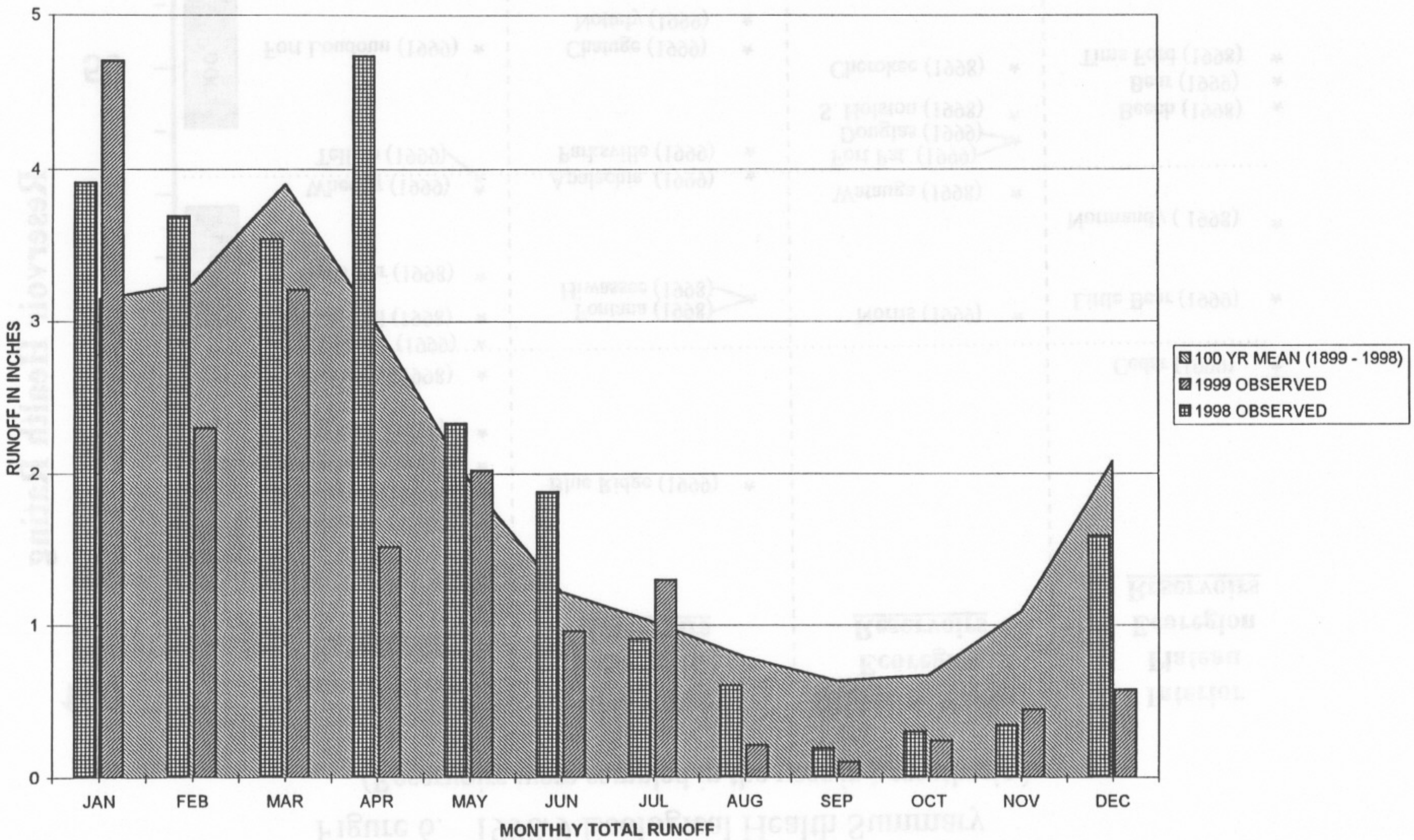


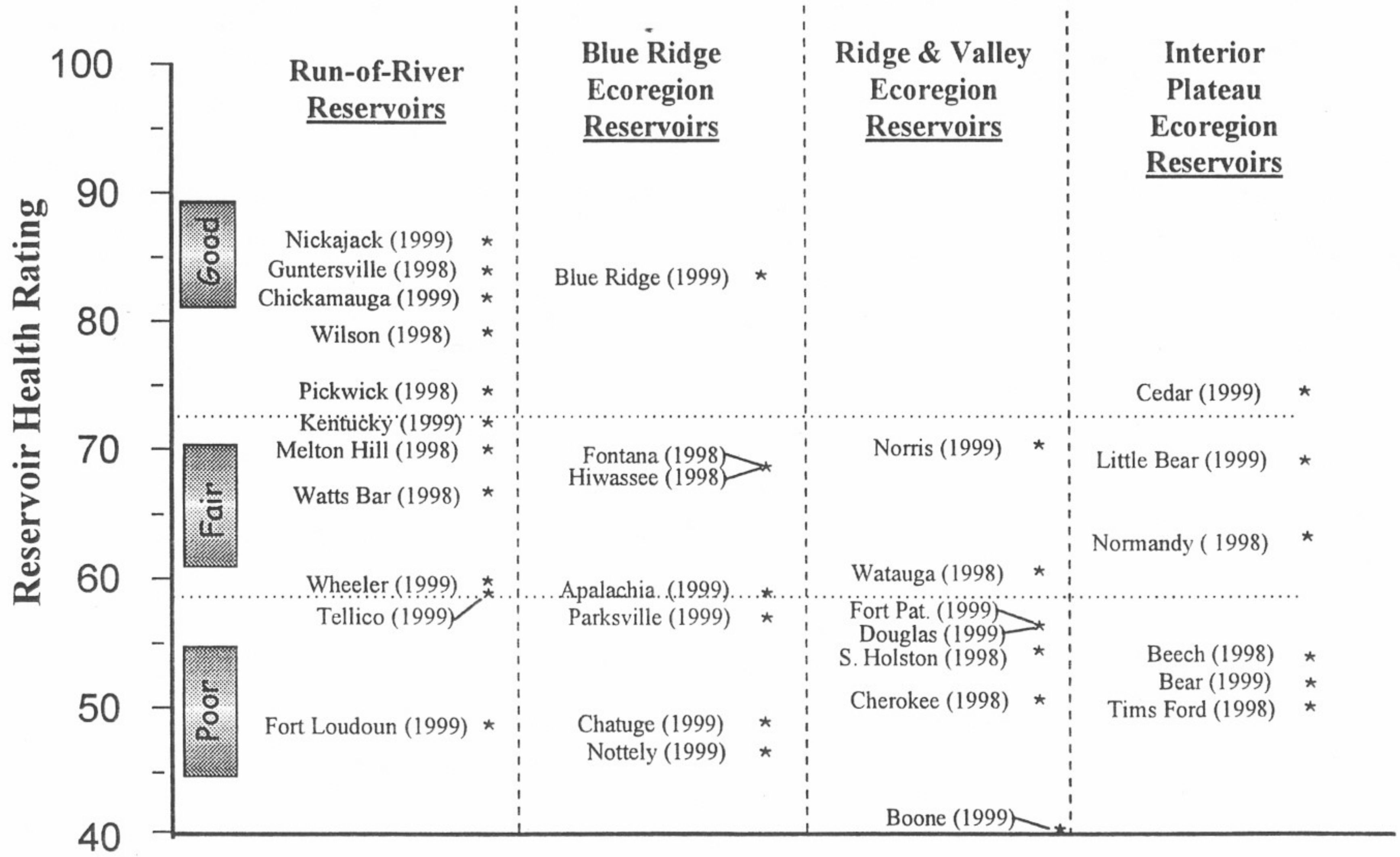
Figure 5a. RUNOFF ABOVE KENTUCKY DAM - 1999



99Section1,Figs3,4,4a,5,5a.xls,Fig 5a Runoff 99 Prepared by Edward A. Thornton 06/01/2000

Figure 6. 1998/9 Ecological Health Summary

(Reservoirs were sampled in the year in parenthesis.)



Section 2. Dissolved Oxygen (DO)

Philosophical Approach/Background

Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are below saturation in the metalimnion and hypolimnion of a reservoir or lake. This hypolimnetic and metalimnetic oxygen depletion is a common, but undesirable, occurrence in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia not only promotes the biochemical release of phosphorus which affects trophic conditions, but also promotes the release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, many of these reduced chemicals can cause chronic or acute toxicity to benthos.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions could result. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish health, growth, and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

A question fundamental to reservoir ecological health evaluation as well as reservoir classification issues is -- should reservoir ecological health evaluations be based on (1) ideal conditions, for example, low DO concentrations represent an unacceptable ecological condition; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir, for example, very low DO concentrations are acceptable in many tributary reservoirs because of withdrawal schemes, stratification, etc. The approach selected for this program is -- poor DO is unacceptable regardless of type of reservoir or dam operation. Hence, reservoirs were not separated into classes for DO evaluations/expectations because the expectation was the same for all reservoirs.

Data Collection Methods

DO data were collected monthly during the summer (April-October) of 1999, concurrently with chlorophyll, nutrients, and other physical/chemical samples. The 1999 sampling scheme included collection of physical/chemical water quality variables at 33 locations on 18 reservoirs for routine Vital Signs Monitoring. (See Table 2 in Section 1 for specific locations sampled in each reservoir.) Water quality sampling, as described in Table 2, included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and photic zone (defined as twice the Secchi depth or 4-meters, whichever is greater) composite samples for laboratory analysis of chlorophyll-a, nutrient (total phosphorus, ammonia-nitrogen, nitrate+nitrite-nitrogen, and organic nitrogen), and total dissolved carbon. Water quality profiles and sampling were conducted over the original river channel at the reservoir's maximum depth at each location. Physical/chemical water quality sampling was not conducted at reservoir inflow locations because many of these locations are free flowing (or tailwater areas of upstream dams) and are more representative of riverine processes (and the upstream reservoir), rather than conditions in the reservoir being assessed.

Two specific QA/QC activities were incorporated into the reservoir physical/chemical water sampling. These were: (1) collection and analysis of triplicate sets of water samples once during the year at seven locations to assess sample collection and handling, laboratory analysis, and natural sample variability; and (2) preparation and analysis of ten sets of nutrient container blanks (when the nutrient samples were collected) to assess the degree of contamination associated with the nutrient sample bottles.

DO Rating Scheme

A conceptual model was developed for dissolved oxygen rating criteria. The rating criteria represent a multidimensional approach that includes dissolved oxygen levels both throughout the water column (WC_{DO}) and near the bottom (B_{DO}) of the reservoir. The DO rating at each sampling location (ranging from 1 "poor" to 5 "good") is based on monthly summer water column and bottom water DO measurements. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.)

The final DO rating is the average of the water column DO (WC_{DO}) rating and the bottom DO rating (B_{DO}):

DO Rating = 0.5 (WC_{DO} rating + B_{DO} rating), where:

WC_{DO} (Water Column DO) Rating--a six-month average of the percent of the reservoir cross-sectional area (at the location where the sampling was conducted) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L. (See Figure 1).

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location*
<5%	5 (good);
≥5% but ≤10%	3 (fair);
>10%	1 (poor).

*Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows.

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length* (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

*The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Results from 1999 Monitoring

Table 1 summarizes DO results for each location monitored in 1999. The summary of DO results includes information on water column and bottom DO measurements and the final DO rating. This table includes DO results and ratings for all sites monitored in 1999. Most sites were monitored as part of routine Vital Signs Monitoring. Water quality measurements including DO were taken at several additional sites to meet specific needs. Reservoirs where this occurred as well as the specific reason the were included are footnoted in Table 1.

Isopleths for dissolved oxygen and temperature are provided in Appendix B for each sample location during the 1999 sampling season. Isopleths for sites included in rouitne Vitals Signs Monitoring in 1999 are provided first followed by isopleths for sites monitored to support specific needs.

References

Hutchinson, G. Evelyn, 1975. A Treatise on Limnology, Volume 1, Part 2 - Chemistry of Lakes, J. Wiley and Sons, New York.

Masters, A., and T.A. McDonough, April 1993. TVA Water Management, Chattanooga, Tennessee, Personal Communication.

Table 1

1999 Dissolved Oxygen Results -- Vital Signs Monitoring Data

(using average minimum winter pool elevations)

	Dissolved Oxygen						
	Water Column DO			Bottom DO			
Reservoir	Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section <2.0 mg/l	Rating	Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**
RUN-OF-THE-RIVER RESERVOIRS							
Kentucky							
Forebay(TRM 23.0)	No	3.7	5	No	7.1	4	**4.5**
T-Zone(TRM 85.0)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 200-206)	-	-	-	-	-	-	**(no rating)**
Embay(BSRM 7.4)	No	2.9	5	No	8.1	4	**4.5**
Pickwick[1]							
Forebay(TRM 207.3)	No	0.0	5	No	0.0	5	**5**
T-Zone(TRM 230.0)	Yes	0.0	4	No	0.0	5	**4.5**
Inflow(TRM 253-259)	-	-	-	-	-	-	**(no rating)**
Embay(BCM 8.4)	No	1.7	5	Yes	5.0	3	**4**
Wilson[1]							
Forebay(TRM 260.8)	No	7.0	3	Yes	49.1	1	**2**
Inflow(TRM 273-274)	-	-	-	-	-	-	**(no rating)**
Wheeler							
Forebay(TRM 277.0)	No	6.8	3	No	32.3	1	**2**
T-Zone(TRM 295.9)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 347-348)	-	-	-	-	-	-	**(no rating)**
Embay(ERM 6.0)	No	7.8	3	Yes	25.9	1	**2**
Guntersville[1]							
Forebay(TRM 350.0)	No	0.0	5	No	0.0	5	**5**
T-Zone(TRM 375.2)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 420-424)	-	-	-	-	-	-	**(no rating)**
Nickajack							
Forebay(TRM 425.5)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 469-470)	-	-	-	-	-	-	**(no rating)**
Chickamauga							
Forebay(TRM 472.3)	No	0.1	5	No	1.8	4	**4.5**
T-Zone(TRM 490.5)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 518-529)	-	-	-	-	-	-	**(no rating)**
Embay(HRM 8.5)	No	0.0	5	No	0.0	5	**5**

Table 1
1999 Dissolved Oxygen Results -- Vital Signs Monitoring Data
(using average minimum winter pool elevations)

	Dissolved Oxygen						
	Water Column DO			Bottom DO			
Reservoir	Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section <2.0 mg/l	Rating	Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**
Watts Bar[2]							
Forebay(TRM 531.0)	No	6.4	3	No	18.5	3	**3**
T-Zone(TRM 560.8)	No	0.0	5	No	0.0	5	**5**
Inflow(TRM 600-601)	-	-	-	-	-	-	**(no rating)**
Inflow(CRM 19-22)	-	-	-	-	-	-	**(no rating)**
Fort Loudoun							
Forebay(TRM 605.5)	No	10.8	1	No	21.5	2	**1.5**
T-Zone(TRM 624.6)	No	0.0	5	No	0.0	5	**5**
Tellico							
Forebay(LTRM 1.0)	No	0.8	5	No	3.5	4	**4.5**
T-Zone(LTRM 15.0)	No	0.0	5	No	0.0	5	**5**
Melton Hill[2]							
Forebay(CRM 24.0)	No	2.0	5	No	7.4	4	**4.5**
T-Zone(CRM 45.0)	No	1.6	5	No	2.6	4	**4.5**
TRIBUTARY RESERVOIRS							
Norris							
Forebay(CRM 80.0)	No	18.9	1	No	27.5	2	**1.5**
Mid-Res(CRM 125.0)	No	24.6	1	Yes	49.3	1	**1**
Mid-Res(PRM 30.0)	No	27.6	1	Yes	49.9	1	**1**
Cherokee[2]							
Forebay(HRM 55.0)	No	22.8	1	Yes	43.0	1	**1**
Mid-Res(HRM 77.0)	No	34.4	1	Yes	71.9	1	**1**
Douglas							
Forebay(FBRM 34.5)	No	32.3	1	Yes	61.3	1	**1**
Mid-Res(FBRM 51.0)	No	31.9	1	No	271.4	1	**1**
Ft. Patrick Henry							
Forebay(SFHRM 8.7)	No	1.8	5	No	6.4	4	**4.5**
Boone							
Forebay(SFHRM 19.0)	No	20.6	1	No	32.9	1	**1**
Mid-Res(SFHRM 27.0)	No	28.9	1	Yes	37.1	1	**1**
Mid-Res(WRM 6.5)	No	0.0	5	No	2.3	4	**4.5**
South Holston[2]							
Forebay(SFHRM 51.0)	No	6.6	3	No	24.0	2	**2.5**
Mid-Res(SFHRM 62.5)	No	22.0	1	Yes	52.6	1	**1**

Table 1

1999 Dissolved Oxygen Results -- Vital Signs Monitoring Data

(using average minimum winter pool elevations)

Reservoir	Dissolved Oxygen: Water Column DO: Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section <2.0 mg/l	Rating	Bottom DO: Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**
Watauga							
Forebay(WRM 37.4)							
Mid-Res(WRM 45.5)							
Fontana							
Forebay(LTRM 62.0)							
Mid-Res(LTRM 81.5)							
Mid-Res(TkRM 3.0)							
Blue Ridge							
Forebay(ToRM 54.1)	No	0.1	5	No	1.6	4	**4.5**
Apalachia							
Forebay(HiRM 67.0)	No	3.0	5	No	26.6	2	**3.5**
Hiwassee[2]							
Forebay(HiRM 77.5)	No	4.3	5	Yes	26.5	1	**3**
Mid-Res(HIRM 85.0)	No	0.2	5	No	6.5	4	**4.5**
Nottely							
Forebay(NRM 23.5)	No	17.0	1	No	30.0	2	**1.5**
Mid-Res(NRM 31.0)	No	21.6	1	No	55.7	1	**1**
Chatuge							
Forebay(HiRM 122.0)	No	10.1	1	No	20.5	2	**1.5**
Mid-Res(Shooting Cr 1.	No	14.0	1	No	24.6	2	**1.5**
Ocoee #1							
Forebay(ORM12.5)	No	0.0	5	No	0.0	5	**5**
Tims Ford							
Forebay(ERM 135.0)							
Mid-Res(ERM 150.0)							

Table 1
1999 Dissolved Oxygen Results -- Vital Signs Monitoring Data

(using average minimum winter pool elevations)

	Dissolved Oxygen						
	Water Column DO			Bottom DO			
Reservoir	Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section <2.0 mg/l	Rating	Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**
Normandy Forebay(DRM 249.5)							
Bear Creek Forebay(BCM 75.0)	No	24.3	1	Yes	63.7	1	1
Little Bear Creek Forebay(LBCM 12.5)	No	41.3	1	Yes	72.0	1	1
Cedar Creek Forebay(25.2)	No	30.6	1	Yes	74.0	1	1
Beech[2] Forebay(BRM 36.0)	No	39.8	1	Yes	76.6	1	1

Shaded monitoring locations were not sampled in 1999.

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not con

2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

Table 2

RESERVOIR "VITAL SIGNS" WATER QUALITY MONITORING
WATER QUALITY MEASUREMENTS -- 1999

Samples/ Measurements	Depths(s)[a] (meters)	Container	Preservation/Handling
		FIELD - each survey	
Secchi disc	(record depth)	--	--
Temp, pH, DO, cond	0.3, 1.5, 4, etc.	in situ[b]	--
Chlorophyll[c]	S_c	1-L cubitainer	Immediately add 1 mL of $MgCO_3$, place on ice, filter within 3 hours
		LABORATORY - each survey	
Nutrients -- (total phosphorus, ammonia, nitrate + nitrite, and organic nitrogen)	S_c	250-mL	Add 1 mL of 1 + 4 H_2SO_4, place on ice
Total Organic Carbon	S_c	125-mL	Add 1 mL of 1 + 4 H_2SO_4,
Blanks[d] and Triplicates[e]		(same containers as above -- for nutrients)	
		AQUATIC BIOLOGICAL - each survey	
Algal Assemblage[f] solution	S_c	125-mL, dark bottle	Add 2-mL of Lugol's or M3
Zooplankton Tow[g]	Bottom to Surface tow	250-mL	Add approx. 20mL buffered formalin per 250 mL of sample
		SEDIMENT - July survey	
Sediment[h] (metals, PCBs, and pesticides)	Top 3cm composite	1 - 1 liter glass wide mouth bottle	Immediately place on ice

a. S_c - indicates a surface composite sample (see Definitions).

b. Hydrolab measurements of temperature, pH, DO, and conductivity will be made at the depths shown and at 2-meter intervals (4-meter intervals on tributary reservoirs) to the bottom of the reservoir. Measurements will be made at intermediate depths any time the temperature changes $\geq$2°C or the DO changes $\geq$1 mg/L from the previous measurement.

c. Recommended chlorophyll filters -- Whatman GF/C, 47 mm, 1.2 µm pore size, MFR No.1822-047.

d. Container blanks will be prepared according to the schedule given in Table 2. (See Table 2).

e. Triplicate samples - Three separate and distinct samples, each collected separately and individually, will be collected, once during the year, at the locations and according to the schedule given in Table 2.

f. Algae samples will be placed in dark bottles and preservative with M3/Lugol's.

g. Zooplankton net should be retrieved at a constant rate of 0.5 to 0.7 meters per second.

h. All sediment samples (and duplicates) will be collected in July.

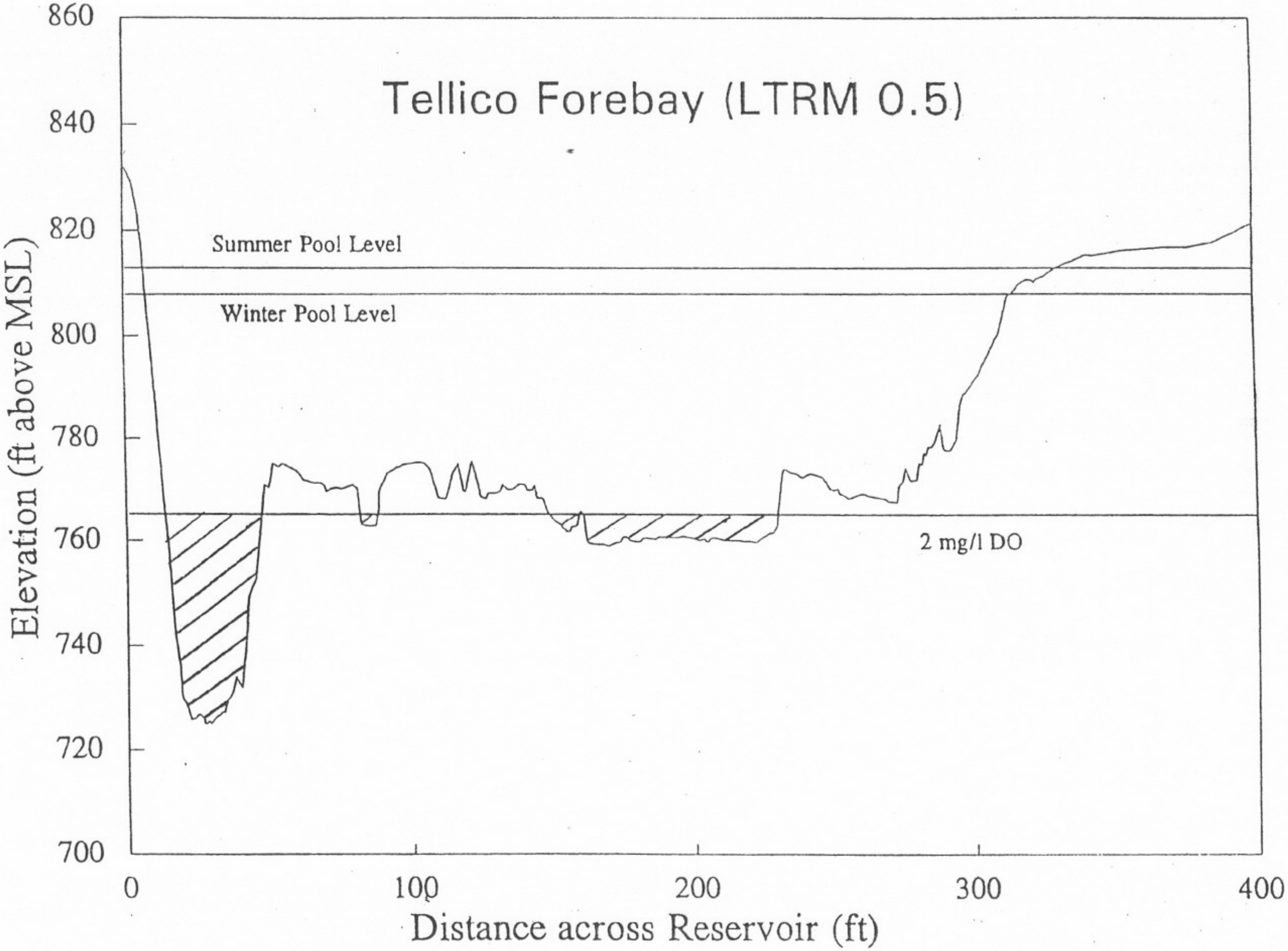


Figure 1. Cross-sectional Area of Tellico Reservoir Forebay Showing the Area with DO Less Than 2.0 mg/l.

Section 3. Chlorophyll and Nutrients

Philosophical Approach/Background

Algae are the base of the aquatic food chain; consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977).

Generally, lower chlorophyll concentrations in the oligotrophic range are thought of being indicative of good water quality conditions. Conversely, high chlorophyll concentrations are usually considered indicative of cultural eutrophication. However, care must be taken not to over generalize. For example, it would be inappropriate to expect all reservoirs in the Tennessee Valley to have low chlorophyll concentrations because some reservoirs are in watersheds which have nutrient rich, easily erodable soils. Most watersheds in the Tennessee Valley provide sufficient nutrients to expect chlorophyll concentrations in the mesotrophic range, even in absence of anthropogenic sources and cultural etrophication. However, two watersheds in the Tennessee Valley have soils (and consequently waters) with naturally low nutrient levels--the Little Tennessee and Hiwassee. The streams and rivers in these watersheds drain the Blue Ridge Ecoregion which is largely characterized by thin soils and is underlain mostly with hard crystalline and metasedimentary rocks.

Obviously, development of appropriate expectations is a critical step in evaluating implications of chlorophyll concentrations on the ecological health of a reservoir. The range of concentrations which are considered indicative of good, fair, and poor conditions must be tailored to reservoirs within each watershed based on knowledge of background or natural conditions. This leads to separating reservoirs into classes based upon these conditions.

The classification scheme used to develop expectations for chlorophyll in Tennessee Valley reservoirs was based on the "natural" nutrient level in a watershed.

Professional judgment was used to select concentrations considered indicative of good, fair, and poor conditions. Based on this approach, reservoirs were placed into one of two classes for chlorophyll expectations -- those expected to be oligotrophic because they are in watersheds with naturally low nutrient concentrations and those expected to be mesotrophic because the are in watersheds which naturally have greater nutrient availability. The reservoirs expected to be oligotrophic are those in the Blue Ridge Ecoregion. Included in this group are those in the Hiwassee River drainage--Hiwassee, Chatuge, Nottely, Blue Ridge, and Parksville reservoirs and those in the Little Tennessee River drainage--Tellico and Fontana. The remaining reservoirs, both mainstream reservoirs and tributary reservoirs, are expected to be mesotrophic.

The range of concentrations selected to represent good, fair, and poor conditions obviously will be much lower for reservoirs in nutrient-poor watersheds. For those reservoirs in watersheds with naturally low nutrient levels, the primary concern is early identification of cultural eutrophication. Appropriate actions can then be taken to control the nutrient loadings and prevent a shift to a higher trophic state. For reservoirs expected to be mesotrophic, the concern is that chlorophyll levels not become too great because of the associated undesirable conditions--occasional dense algal blooms, poor water clarity, low DOs, and the predominance of noxious bluegreen algae. In mesotrophic reservoirs where sufficient nutrients are available but chlorophyll concentrations remain low, there is likely something inhibiting this natural process, such as excessive turbidity, toxicity, etc. Consequently, the rating for chlorophyll-a may be lowered when such conditions are found.

Data Collection Methods

Water samples were collected monthly (April - September on run-of-river reservoirs and April-October on tributary reservoirs) from the photic zone (defined as twice the Secchi depth or 4-meters, whichever was greater) with a peristaltic pump. The water samples were collected from the entire photic zone, composited, and dispersed into bottles for laboratory analysis of chlorophyll, nutrients (total phosphorus, ammonia-nitrogen, nitrate+nitrite-nitrogen, and organic nitrogen), total organic carbon, and algal assemblage. In addition, in-situ water column profiles of temperature, dissolved oxygen, pH, conductivity; and Secchi depth measurements were made monthly. Zooplankton samples were also collected monthly with a 100 mm diameter net. Neither the zooplankton nor algal samples were processed as a routine part of this program. Rather, they were archived for later examination if the need arose.

In 1999, physical/chemical water quality variables for routine Vital Signs Monitoring were measured at the 33 locations on 18 reservoirs shown in Table 2, Section 1. Additional details on collection methods are given in Data Collection Methods, Section 2 and Table 2-Section 2.

Chlorophyll Rating Scheme

Chlorophyll ratings at each sampling location were based on the average summer concentration of monthly, composite photic zone samples collected from April through October (or September), using the criteria shown in Figure 1.

Results from 1999 Monitoring

Table 1 summarizes chlorophyll results for each location monitored as part of routine Vital Signs Monitoring in 1999. This summary includes the average chlorophyll concentration for the monitoring season, the maximum observed chlorophyll concentration, and the Final Chlorophyll-a Rating. Table 2 is a statistical summary of the physical/chemical and nutrient quality data for all locations monitored during the summer of 1999. Most sites were monitored as part of routine Vital Signs Monitoring. Water quality measurements including chlorophyll were taken at several additional sites to meet specific needs. Reservoirs where this occurred as well as the specific reason the were included are footnoted in Table 2.

References

Carlson, R.E., 1977. "A Trophic State Index for Lakes." Limnology and Oceanography, 22:361-369.

Table 1
1999 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date		Location	River Mile	Lab Chlorophyll-a Results		Average		Rating
April	6	Apalachia-FB	HIWASSEE RIVER 67.0	3	3			
May	4	Apalachia-FB	HIWASSEE RIVER 67.0	3	3			
June	2	Apalachia-FB	HIWASSEE RIVER 67.0	6	6			
July	7	Apalachia-FB	HIWASSEE RIVER 67.0	8	8			
August	3	Apalachia-FB	HIWASSEE RIVER 67.0	5	5			
September		Apalachia-FB	HIWASSEE RIVER 67.0	5	5		HMA	
October	6	Apalachia-FB	HIWASSEE RIVER 67.0	6	6			
						5.14		3.3
April	8	Bear-FB	BEAR CREEK 75.0	7	7			
May	13	Bear-FB	BEAR CREEK 75.0	11	11			
June	10	Bear-FB	BEAR CREEK 75.0	19	19			
July	13	Bear-FB	BEAR CREEK 75.0	28	28			
August	12	Bear-FB	BEAR CREEK 75.0	14	14			
September	10	Bear-FB	BEAR CREEK 75.0	11	11			
October	13	Bear-FB	BEAR CREEK 75.0	19	19			
						15.57		1.2
April	5	Blue Ridge-FB	TOCCOA RIVER 54.1	1	1			
May	3	Blue Ridge-FB	TOCCOA RIVER 54.1	1	1			
June	1	Blue Ridge-FB	TOCCOA RIVER 54.1	3	3			
July	6	Blue Ridge-FB	TOCCOA RIVER 54.1	3	3			
August	2	Blue Ridge-FB	TOCCOA RIVER 54.1	2	2			
September		Blue Ridge-FB	TOCCOA RIVER 54.1	2	2		HMA	
October	6	Blue Ridge-FB	TOCCOA RIVER 54.1	2	2			
						2.00		5.0
April	12	Boone-FB	SOUTH FORK HOLSTON 19.0	9	9			
May	10	Boone-FB	SOUTH FORK HOLSTON 19.0	22	22			
June	14	Boone-FB	SOUTH FORK HOLSTON 19.0	16	16			
July	12	Boone-FB	SOUTH FORK HOLSTON 19.0	15	15			
August	10	Boone-FB	SOUTH FORK HOLSTON 19.0	10	10			
September	14	Boone-FB	SOUTH FORK HOLSTON 19.0	11	11			
October	13	Boone-FB	SOUTH FORK HOLSTON 19.0	46				
						13.83	*	1.1
April	12	Boone-MRH	SOUTH FORK HOLSTON 27.0	37				
May	10	Boone-MRH	SOUTH FORK HOLSTON 27.0	30				
June	14	Boone-MRH	SOUTH FORK HOLSTON 27.0	20	20			
July	12	Boone-MRH	SOUTH FORK HOLSTON 27.0	37				
August	10	Boone-MRH	SOUTH FORK HOLSTON 27.0	25	25			
September	14	Boone-MRH	SOUTH FORK HOLSTON 27.0	12	12			
October	12	Boone-MRH	SOUTH FORK HOLSTON 27.0	30				
						19.00	*	1.0
April	12	Boone-MRW	WATAUGA RIVER 6.5	24	24			
May	10	Boone-MRW	WATAUGA RIVER 6.5	13	13			
June	14	Boone-MRW	WATAUGA RIVER 6.5	19	19			
July	12	Boone-MRW	WATAUGA RIVER 6.5	34				
August	10	Boone-MRW	WATAUGA RIVER 6.5	20	20			
September	14	Boone-MRW	WATAUGA RIVER 6.5	24	24			
October	12	Boone-MRW	WATAUGA RIVER 6.5	46				
						20.00	*	1.0
April	8	Cedar-FB	CEDAR CREEK 25.2	4	4			
May	13	Cedar-FB	CEDAR CREEK 25.2	9	9			
June	10	Cedar-FB	CEDAR CREEK 25.2	5	5			
July	13	Cedar-FB	CEDAR CREEK 25.2	5	5			
August	12	Cedar-FB	CEDAR CREEK 25.2	3	3			
September	10	Cedar-FB	CEDAR CREEK 25.2	2	2			
October	13	Cedar-FB	CEDAR CREEK 25.2	3	3			
						4.43		5.0
April	5	Chatuge-FB	HIWASSEE RIVER 122.0	4	4			
May	4	Chatuge-FB	HIWASSEE RIVER 122.0	2	2			
June	1	Chatuge-FB	HIWASSEE RIVER 122.0	3	3			
July	6	Chatuge-FB	HIWASSEE RIVER 122.0	8	8			
August	2	Chatuge-FB	HIWASSEE RIVER 122.0	3	3			
September		Chatuge-FB	HIWASSEE RIVER 122.0	3.8	3.8		HMA	
October	7	Chatuge-FB	HIWASSEE RIVER 122.0	3	3			

Table 1
1999 Chlorophyll-a Results – Vital Signs Reservoir Monitoring Data

Date		Location	River Mile	Lab Chlorophyll-a				Rating
				Results		Average		
						3.83		4.3
April	5	ChatugeSC-FB	SHOOTING CREEK 1.5	4	4			
May	4	ChatugeSC-FB	SHOOTING CREEK 1.5	2	2			
June	1	ChatugeSC-FB	SHOOTING CREEK 1.5	3	3			
July	6	ChatugeSC-FB	SHOOTING CREEK 1.5	11	11			
August	2	ChatugeSC-FB	SHOOTING CREEK 1.5	5	5			
September	7	ChatugeSC-FB	SHOOTING CREEK 1.5	3.5	3.5		HMA	
October	7	ChatugeSC-FB	SHOOTING CREEK 1.5	3	3			
						4.50		3.8
April	6	Chick-EM	HIWASSEE RIVER 8.5	3	3			
May	5	Chick-EM	HIWASSEE RIVER 8.5	14	14			
June	4	Chick-EM	HIWASSEE RIVER 8.5	15	15			
July	7	Chick-EM	HIWASSEE RIVER 8.5	5	5			
August	5	Chick-EM	HIWASSEE RIVER 8.5	6	6			
September	10	Chick-EM	HIWASSEE RIVER 8.5	6	6			
						8.17		4.9
April	8	Chick-FB	TENNESSEE RIVER 472.3	6	6			
May	5	Chick-FB	TENNESSEE RIVER 472.3	13	13			
June	4	Chick-FB	TENNESSEE RIVER 472.3	6	6			
July	7	Chick-FB	TENNESSEE RIVER 472.3	8	8			
August	5	Chick-FB	TENNESSEE RIVER 472.3	11	11			
September	10	Chick-FB	TENNESSEE RIVER 472.3	4	4			
						8.00		5.0
April	6	Chick-TZ	TENNESSEE RIVER 490.5	32				
May	5	Chick-TZ	TENNESSEE RIVER 490.5	18	18			
June	2	Chick-TZ	TENNESSEE RIVER 490.5	13	13			
July	7	Chick-TZ	TENNESSEE RIVER 490.5	13	13			
August	5	Chick-TZ	TENNESSEE RIVER 490.5	8	8			
September	10	Chick-TZ	TENNESSEE RIVER 490.5	3	3			
						11.00	*	2.5
April	13	Douglas-FB	FRENCH BROAD RIVER 34.5	11	11			
May	11	Douglas-FB	FRENCH BROAD RIVER 34.5	9	9			
June	15	Douglas-FB	FRENCH BROAD RIVER 34.5	11	11			
July	13	Douglas-FB	FRENCH BROAD RIVER 34.5	9	9			
August	10	Douglas-FB	FRENCH BROAD RIVER 34.5	6	6			
September	15	Douglas-FB	FRENCH BROAD RIVER 34.5	10	10			
October	13	Douglas-FB	FRENCH BROAD RIVER 34.5	6	6			
						8.86		4.6
April	13	Douglas-MR	FRENCH BROAD RIVER 51.0	14	14			
May	11	Douglas-MR	FRENCH BROAD RIVER 51.0	14	14			
June	15	Douglas-MR	FRENCH BROAD RIVER 51.0	10	10			
July	13	Douglas-MR	FRENCH BROAD RIVER 51.0	11	11			
August	10	Douglas-MR	FRENCH BROAD RIVER 51.0	13	13			
September	15	Douglas-MR	FRENCH BROAD RIVER 51.0	15	15			
October	13	Douglas-MR	FRENCH BROAD RIVER 51.0	30				
						12.83	*	1.6
April	12	Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	13	13			
May	10	Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	8	8			
June	14	Ft. Pat.-FB/T1	SOUTH FORK HOLSTON 8.7	27	triplicate			
June	14	Ft. Pat.-FB/T2	SOUTH FORK HOLSTON 8.7	30				
June	14	Ft. Pat.-FB/T3	SOUTH FORK HOLSTON 8.7	31	triplicate			
July	13	Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	28	28			
August	9	Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	25	25			
September		Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	20	20		HMA	
October	12	Ft. Pat.-FB	SOUTH FORK HOLSTON 8.7	17	17			
						18.50	*	1.0
April	14	FtLd-FB	TENNESSEE RIVER 605.5	17	17			
May	12	FtLd-FB	TENNESSEE RIVER 605.5	22	22			
June	16	FtLd-FB	TENNESSEE RIVER 605.5	24	24			
July	12	FtLd-FB	TENNESSEE RIVER 605.5	23	23			
August	11	FtLd-FB	TENNESSEE RIVER 605.5	19	19			
September	13	FtLd-FB	TENNESSEE RIVER 605.5	21	21			
						21.00		1.0

Table 1
1999 Chlorophyll-a Results – Vital Signs Reservoir Monitoring Data

Date		Location	River Mile	Lab Chlorophyll-a Results		Lab Chlorophyll-a Average		Rating
April	14	FtLd-TZ/T1	TENNESSEE RIVER 624.6	50	triplicate			
April	14	FtLd-TZ/T2	TENNESSEE RIVER 624.6	45	triplicate			
April	14	FtLd-TZ/T3	TENNESSEE RIVER 624.6	47				
May	12	FtLd-TZ	TENNESSEE RIVER 624.6	42				
June	16	FtLd-TZ	TENNESSEE RIVER 624.6	18	18			
July	12	FtLd-TZ	TENNESSEE RIVER 624.6	24	24			
August	11	FtLd-TZ	TENNESSEE RIVER 624.6	14	14			
September	13	FtLd-TZ	TENNESSEE RIVER 624.6	26	26			
						20.50	*	1.0
April	6	Kentucky-EM	BIG SANDY RIVER 7.4	24	24			
May	12	Kentucky-EM	BIG SANDY RIVER 7.4	11	11			
June	9	Kentucky-EM	BIG SANDY RIVER 7.4	12	12			
July	14	Kentucky-EM	BIG SANDY RIVER 7.4	29	29			
August	11	Kentucky-EM	BIG SANDY RIVER 7.4	43				
September	7	Kentucky-EM	BIG SANDY RIVER 7.4	31				
						19.00	*	1.0
April	6	Kentucky-FB/T1	TENNESSEE RIVER 23.0	20	triplicate			
April	6	Kentucky-FB/T2	TENNESSEE RIVER 23.0	16	triplicate			
April	6	Kentucky-FB/T3	TENNESSEE RIVER 23.0	19	19			
May	12	Kentucky-FB	TENNESSEE RIVER 23.0	11	11			
June	9	Kentucky-FB	TENNESSEE RIVER 23.0	15	15			
July	14	Kentucky-FB	TENNESSEE RIVER 23.0	9	9			
August	11	Kentucky-FB	TENNESSEE RIVER 23.0	17	17			
September	7	Kentucky-FB	TENNESSEE RIVER 23.0	9	9			
						13.33		2.3
April	6	Kentucky-TZ	TENNESSEE RIVER 85.0	10	10			
May	12	Kentucky-TZ	TENNESSEE RIVER 85.0	3	3			
June	9	Kentucky-TZ	TENNESSEE RIVER 85.0	11	11			
July	14	Kentucky-TZ	TENNESSEE RIVER 85.0	6	6			
August	11	Kentucky-TZ	TENNESSEE RIVER 85.0	10	10			
September	7	Kentucky-TZ	TENNESSEE RIVER 85.0	6	6			
						7.67		5.0
April	8	Little Bear-FB	LITTLE BEAR CREEK 12.5	6	6			
May	13	Little Bear-FB	LITTLE BEAR CREEK 12.5	6	6			
June	10	Little Bear-FB/T1	LITTLE BEAR CREEK 12.5	6	6			
June	10	Little Bear-FB/T2	LITTLE BEAR CREEK 12.5	7	triplicate			
June	10	Little Bear-FB/T3	LITTLE BEAR CREEK 12.5	6	triplicate			
July	13	Little Bear-FB	LITTLE BEAR CREEK 12.5	6	6			
August	12	Little Bear-FB	LITTLE BEAR CREEK 12.5	3	3			
September	10	Little Bear-FB	LITTLE BEAR CREEK 12.5	4	4			
October	13	Little Bear-FB	LITTLE BEAR CREEK 12.5	2	2			
						4.71		5.0
April	7	Nickajack-FB/T1	TENNESSEE RIVER 425.5	13	triplicate			
April	7	Nickajack-FB/T2	TENNESSEE RIVER 425.5	12	12			
April	7	Nickajack-FB/T3	TENNESSEE RIVER 425.5	11	triplicate			
May	6	Nickajack-FB	TENNESSEE RIVER 425.5	7	7			
June	3	Nickajack-FB	TENNESSEE RIVER 425.5	10	10			
July	8	Nickajack-FB	TENNESSEE RIVER 425.5	3	3			
August	4	Nickajack-FB	TENNESSEE RIVER 425.5	3	3			
September		Nickajack-FB	TENNESSEE RIVER 425.5	3	3		HMA	
						6.33		5.0
April	14	Norris-FB	CLINCH RIVER 80.0	6	6			
May	12	Norris-FB	CLINCH RIVER 80.0	9	9			
June	16	Norris-FB	CLINCH RIVER 80.0	4	4			
July	13	Norris-FB	CLINCH RIVER 80.0	6	6			
August	11	Norris-FB	CLINCH RIVER 80.0	2	2			
September	16	Norris-FB	CLINCH RIVER 80.0	3	3			
October	14	Norris-FB	CLINCH RIVER 80.0	2	2			
						4.57		5.0
April	13	Norris-MRC	CLINCH RIVER 125.0	7	7			
May	11	Norris-MRC	CLINCH RIVER 125.0	4	4			
June	15	Norris-MRC	CLINCH RIVER 125.0	10	10			
July	15	Norris-MRC	CLINCH RIVER 125.0	5	5			

Table 1
1999 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	River Mile	Lab Chlorophyll-a Results		Average		Rating
August 11	Norris-MRC	CLINCH RIVER 125.0	5	5			
September 16	Norris-MRC	CLINCH RIVER 125.0	4	4			
October 14	Norris-MRC	CLINCH RIVER 125.0	5	5			
					5.71		5.0
April 13	Norris-MRP	POWELL RIVER 30.0	4	4			
May 11	Norris-MRP	POWELL RIVER 30.0	5	5			
June 15	Norris-MRP	POWELL RIVER 30.0	4	4			
July 15	Norris-MRP	POWELL RIVER 30.0	11	11			
August 11	Norris-MRP	POWELL RIVER 30.0	4	4			
September 16	Norris-MRP	POWELL RIVER 30.0	6	6			
October 14	Norris-MRP	POWELL RIVER 30.0	4	4			
					5.43		5.0
April 5	Nottely-FB	NOTTELY RIVER 23.5	4	4			
May 3	Nottely-FB	NOTTELY RIVER 23.5	19	19			
June 1	Nottely-FB	NOTTELY RIVER 23.5	23	23			
July 6	Nottely-FB	NOTTELY RIVER 23.5	3	3			
August 2	Nottely-FB	NOTTELY RIVER 23.5	1	1			
September	Nottely-FB	NOTTELY RIVER 23.5	5	5		HMA	
October 7	Nottely-FB	NOTTELY RIVER 23.5	8	8			
					9.00		1.0
April 5	Nottely-MR	NOTTELY RIVER 31.0	13	13			
May 3	Nottely-MR	NOTTELY RIVER 31.0	5	5			
June 1	Nottely-MR/T1	NOTTELY RIVER 31.0	21	triplicate			
June 1	Nottely-MR/T2	NOTTELY RIVER 31.0	22	22			
June 1	Nottely-MR/T3	NOTTELY RIVER 31.0	22	triplicate			
July 6	Nottely-MR	NOTTELY RIVER 31.0	5	5			
August 2	Nottely-MR	NOTTELY RIVER 31.0	3	3			
September	Nottely-MR	NOTTELY RIVER 31.0	7	7		HMA	
October 7	Nottely-MR	NOTTELY RIVER 31.0	9	9			
					9.14		1.0
April 6	Ocoee-FB	OCOEE RIVER 12.5	2	2			
May 4	Ocoee-FB	OCOEE RIVER 12.5	2	2			
June 2	Ocoee-FB	OCOEE RIVER 12.5	3	3			
July 7	Ocoee-FB	OCOEE RIVER 12.5	3	3			
August 3	Ocoee-FB	OCOEE RIVER 12.5	2	2			
September	Ocoee-FB	OCOEE RIVER 12.5	1	1		HMA	
October 6	Ocoee-FB	OCOEE RIVER 12.5	1	1			
					2.00		5.0
April 14	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	10	10			
May 12	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	5	5			
June 16	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	14	14			
July 12	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	11	11			
August 11	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	12	12			
September 13	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	14	14			
					11.00		1.0
April 14	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	7	7			
May 12	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	7	7			
June 16	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	10	10			
July 12	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	10	10			
August 11	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	6	6			
September 13	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	6	6			
					7.67		1.3
April 5	Wheeler-EM	ELK RIVER 6.0	28	28			
May 10	Wheeler-EM	ELK RIVER 6.0	5	5			
June 7	Wheeler-EM	ELK RIVER 6.0	30				
July 12	Wheeler-EM	ELK RIVER 6.0	45				
August 9	Wheeler-EM	ELK RIVER 6.0	37				
September	Wheeler-EM	ELK RIVER 6.0	35			HMA	
					16.50	*	1.0
April 5	Wheeler-FB	TENNESSEE RIVER 277.0	25	25			
May 10	Wheeler-FB	TENNESSEE RIVER 277.0	12	12			
June 7	Wheeler-FB	TENNESSEE RIVER 277.0	23	23			
July 12	Wheeler-FB	TENNESSEE RIVER 277.0	14	14			

Table 1
1999 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	River Mile	Lab Chlorophyll-a Results		Lab Chlorophyll-a Average	Rating
August 9	Wheeler-FB	TENNESSEE RIVER 277.0	10	10		
September 8	Wheeler-FB	TENNESSEE RIVER 277.0	6	6		
					15.00	1.5
April 5	Wheeler-TZ	TENNESSEE RIVER 295.9	7	7		
May 10	Wheeler-TZ	TENNESSEE RIVER 295.9	2	2		
June 7	Wheeler-TZ	TENNESSEE RIVER 295.9	26	26		
July 12	Wheeler-TZ	TENNESSEE RIVER 295.9	7	7		
August 9	Wheeler-TZ	TENNESSEE RIVER 295.9	6	6		
September 8	Wheeler-TZ	TENNESSEE RIVER 295.9	5	5	8.83	4.6

* -- Astrisk indicates one (or more) chlorophyll-a results equaled or exceeded 30 ug/L

HMA -- Historical Monthly Average; actual sample data not usable because the acetone used for extration was not the appropriate concentration.

Shading indicates ratings for samples collected in nutrient limited watersheds

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	Kentucky Forebay (TRM 23.0)				Kentucky Transition (TRM 85.0)				Kentucky Embay (Big Sandy 7.4)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	84	25.4	12.9	30.9	71	25.6	14.5	30.6	47	25.1	12.7	31.4
Dissolved Oxygen (mg/L)	84	6.6	0.2	11.0	71	6.7	4.1	10.2	47	5.3	0.5	10.2
pH (s.u.)	84	7.5	6.9	8.8	71	7.4	7.1	8.6	47	7.4	6.7	9.0
Conductivity (us/cm)	84	154	138	210	71	165	151	192	47	111	58	212
Organic N (mg/L)	6	0.35	0.25	0.47	6	0.30	0.12	0.40	6	0.54	0.35	0.80
Ammonia N (mg/L)	5	0.01	0.01	0.02	6	0.11	0.07	0.21	6	0.03	0.01	0.08
Nitrate+Nitrite N (mg/L)	6	0.15	0.02	0.38	6	0.19	0.05	0.44	6	0.02	0.01	0.05
Total Nitrogen (mg/L)	6	0.51	0.40	0.64	6	0.60	0.47	0.87	6	0.58	0.38	0.83
Total Phosphorus (mg/L)	6	0.062	0.040	0.150	5	0.064	0.050	0.080	6	0.062	0.020	0.160
TN / TP Ratio	6	9.8	4.3	12.4	5	9.4	7.1	12.4	6	14.1	2.6	31.0
Chlorophyll-a (ug/L)	6	13.5	9.0	20.0	6	7.7	3.0	11.0	6	25.0	11.0	43.0
TOC	6	3.1	2.4	4.2	6	3.1	2.4	4.4	6	4.3	3.9	5.1
Secchi Depth (m)	6	1.20	1.00	1.50	6	0.92	0.70	1.00	6	0.95	0.60	1.40

	Pickwick Forebay (TRM 207.3)[1]				Pickwick Transition (TRM 230.0)[1]				Pickwick Embayment (BCM 8.4)[1]			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	93	24.9	13.9	30.6	61	25.0	14.7	30.7	39	24.8	14.3	30.4
Dissolved Oxygen (mg/L)	93	7.0	3.7	13.5	61	6.5	3.8	12.2	39	5.5	0.7	9.1
pH (s.u.)	93	7.4	7.0	9.2	61	7.3	6.2	8.8	39	7.5	7.0	8.9
Conductivity (us/cm)	93	156	143	177	61	164	150	181	39	132	92	154
Organic N (mg/L)	6	0.30	0.07	0.50	6	0.32	0.25	0.37	6	0.38	0.24	0.49
Ammonia N (mg/L)	6	0.04	0.01	0.10	6	0.05	0.01	0.10	6	0.03	0.01	0.07
Nitrate+Nitrite N (mg/L)	6	0.16	0.02	0.39	6	0.23	0.05	0.45	6	0.11	0.01	0.29
Total Nitrogen (mg/L)	6	0.50	0.14	0.76	6	0.60	0.36	0.89	6	0.51	0.44	0.64
Total Phosphorus (mg/L)	5	0.050	0.030	0.070	5	0.054	0.040	0.080	5	0.044	0.030	0.070
TN / TP Ratio	5	9.74	2.33	18.00	5	10.69	6.00	15.00	5	12.23	7.71	16.00
Chlorophyll-a (ug/L)	6	15.2	3	30	6	9.7	4	16	6	15.3	9	22
TOC	6	3.2	2.4	4.9	6	3.2	2.5	4.5	6	3.7	2.6	5.1
Secchi Depth (m)	6	1.18	0.90	1.50	6	1.32	1.10	1.50	6	0.98	0.50	1.50

	Wilson Forebay (TRM 260.8)[1]			
	N	Mean	Min	Max
Temperature (deg C)	95	24.9	12.1	31.7
Dissolved Oxygen (mg/L)	95	6.2	0.1	13.5
pH (s.u.)	95	7.5	6.8	9.0
Conductivity (us/cm)	95	163	149	176
Organic N (mg/L)	6	0.38	0.23	0.50
Ammonia N (mg/L)	6	0.02	0.01	0.06
Nitrate+Nitrite N (mg/L)	6	0.17	0.02	0.45
Total Nitrogen (mg/L)	6	0.57	0.27	0.90
Total Phosphorus (mg/L)	6	0.050	0.030	0.110
TN / TP Ratio	6	13.18	6.75	30.00
Chlorophyll-a (ug/L)	6	21.0	12	33
TOC	6	3.6	2.6	5.2
Secchi Depth (m)	6	1.58	0.90	1.90

	Wheeler Forebay (TRM 277.0)				Wheeler Transition (TRM 295.9)				Wheeler Embayment (ERM 6.0)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	56	25.5	14.1	30.6	42	25.0	15.4	30.5	40	24.2	14.9	30.6
Dissolved Oxygen (mg/L)	56	6.7	0.5	13.1	42	7.0	5.0	11.7	40	5.8	0.1	14.9
pH (s.u.)	56	7.7	7.0	9.2	42	7.5	7.3	8.9	40	7.9	7.1	9.4
Conductivity (us/cm)	56	168	151	231	42	168	153	181	40	206	162	245
Organic N (mg/L)	6	0.38	0.28	0.62	6	0.27	0.16	0.42	6	0.48	0.22	0.65
Ammonia N (mg/L)	6	0.03	0.01	0.07	6	0.04	0.01	0.07	6	0.05	0.01	0.11
Nitrate+Nitrite N (mg/L)	6	0.15	0.01	0.44	6	0.27	0.12	0.60	6	0.26	0.03	0.80
Total Nitrogen (mg/L)	6	0.56	0.35	0.74	6	0.58	0.40	0.78	6	0.79	0.61	1.20
Total Phosphorus (mg/L)	6	0.047	0.030	0.080	6	0.052	0.040	0.070	6	0.162	0.090	0.350
TN / TP Ratio	6	13.0	8.8	24.3	6	11.5	8.1	15.0	6	5.6	3.4	8.7
Chlorophyll-a (ug/L)	6	15.0	6.0	25.0	6	8.8	2.0	26.0	5	29.0	5.0	45.0
TOC	6	3.4	2.6	5.6	6	3.1	2.2	4.5	6	3.7	1.9	5.3
Secchi Depth (m)	6	1.37	0.70	1.80	5	1.22	0.90	1.50	6	0.78	0.50	0.90

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted

2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	Guntersville Forebay (TRM 350.0)[1]				Guntersville Transition (TRM 375.2)[1]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	62	24.9	13.2	31.4	38	25.1	15.8	30.4
Dissolved Oxygen (mg/L)	62	7.1	2.2	11.2	38	6.9	5.4	10.8
pH (s.u.)	62	7.7	6.9	8.7	38	7.5	7.2	8.5
Conductivity (us/cm)	62	160	145	172	38	175	159	189
Organic N (mg/L)	6	0.23	0.02	0.36	6	0.18	0.12	0.23
Ammonia N (mg/L)	6	0.02	0.01	0.04	6	0.03	0.01	0.08
Nitrate+Nitrite N (mg/L)	6	0.14	0.02	0.46	6	0.27	0.17	0.39
Total Nitrogen (mg/L)	6	0.39	0.28	0.61	6	0.47	0.39	0.59
Total Phosphorus (mg/L)	6	0.033	0.020	0.040	6	0.030	0.030	0.030
TN / TP Ratio	6	12.14	8.75	17.00	6	15.78	13.00	19.67
Chlorophyll-a (ug/L)	5	15.8	10	28	5	6.6	2	15
TOC	6	2.5	2.1	2.9	6	2.4	2.2	2.5
Secchi Depth (m)	6	1.74	1.25	2.25	6	1.69	1.25	2.35

	Nickajack Forebay (TRM 425.5)			
	N	Mean	Min	Max
Temperature (deg C)	58	24.2	13.0	29.2
Dissolved Oxygen (mg/L)	58	6.4	4.8	11.6
pH (s.u.)	58	7.3	7.0	8.8
Conductivity (us/cm)	58	176	152	195
Organic N (mg/L)	6	0.24	0.14	0.61
Ammonia N (mg/L)	6	0.07	0.01	0.16
Nitrate+Nitrite N (mg/L)	6	0.22	0.17	0.31
Total Nitrogen (mg/L)	6	0.53	0.35	0.84
Total Phosphorus (mg/L)	6	0.032	0.020	0.050
TN / TP Ratio	6	18.4	7.0	31.0
Chlorophyll-a (ug/L)	5	7.2	3.0	13.0
TOC	6	2.2	2.0	2.4
Secchi Depth (m)	6	2.00	1.50	2.50

	Chickamauga Forebay (TRM 472.3)				Chickamauga Transition (TRM 490.5)				Chickamauga Embay (HiRM 8.5)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	65	24.3	13.0	30.2	49	23.1	12.7	28.9	32	21.6	16.2	27.0
Dissolved Oxygen (mg/L)	65	6.4	1.5	10.8	49	6.8	3.8	11.8	32	7.5	4.8	9.5
pH (s.u.)	65	7.4	6.9	8.2	49	7.5	7.0	8.5	32	7.4	7.0	8.0
Conductivity (us/cm)	65	172	151	194	49	180	154	198	32	188	112	282
Organic N (mg/L)	6	0.20	0.14	0.34	6	0.26	0.15	0.33	6	0.28	0.19	0.35
Ammonia N (mg/L)	6	0.04	0.01	0.08	6	0.03	0.01	0.06	6	0.05	0.02	0.09
Nitrate+Nitrite N (mg/L)	6	0.16	0.06	0.36	6	0.19	0.08	0.37	6	0.21	0.13	0.31
Total Nitrogen (mg/L)	6	0.40	0.29	0.51	6	0.48	0.28	0.67	6	0.54	0.39	0.64
Total Phosphorus (mg/L)	6	0.027	0.020	0.040	6	0.037	0.020	0.060	6	0.052	0.020	0.080
TN / TP Ratio	6	16.1	8.8	25.5	6	13.9	8.2	17.3	6	12.8	7.6	30.0
Chlorophyll-a (ug/L)	6	8.0	4.0	13.0	6	14.5	3.0	32.0	6	8.2	3.0	15.0
TOC	6	2.2	2.0	2.6	6	2.4	2.1	2.5	6	3.0	2.1	3.9
Secchi Depth (m)	6	1.62	1.40	2.00	6	1.52	1.30	1.80	6	0.81	0.70	1.00

	Watts Bar Forebay (TRM 532.5)[2]				Watts Bar Transition (TRM 560.8)[2]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	83	23.4	13.3	30.8	46	23.4	15.9	28.9
Dissolved Oxygen (mg/L)	83	5.6	0.2	10.5	46	7.2	3.2	11.7
pH (s.u.)	83	7.8	6.9	9.3	46	7.8	7.3	8.8
Conductivity (us/cm)	83	174	143	210	46	189	153	213
Organic N (mg/L)	5	0.44	0.30	0.80	5	0.32	0.19	0.40
Ammonia N (mg/L)	5	0.01	0.01	0.01	5	0.02	0.01	0.04
Nitrate+Nitrite N (mg/L)	5	0.04	0.01	0.18	5	0.13	0.04	0.22
Total Nitrogen (mg/L)	5	0.50	0.32	0.99	5	0.47	0.32	0.63
Total Phosphorus (mg/L)	5	0.022	0.020	0.030	5	0.034	0.030	0.040
TN / TP Ratio	5	23.57	13.33	49.50	5	14.30	8.00	21.00
Chlorophyll-a (ug/L)	5	15.4	8	27	5	16.4	10	20
TOC	5	2.6	2.1	3.0	5	2.4	2.1	2.7
Secchi Depth (m)	5	1.72	1.30	2.40	5	1.40	1.25	1.60

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted
2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted
(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	Fort Loudoun Forebay (TRM 605.5)				Fort Loudoun Transition (TRM 624.6)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	97	22.1	10.7	28.7	69	21.7	12.9	27.6
Dissolved Oxygen (mg/L)	97	5.6	0.4	12.5	69	7.7	4.7	20.0
pH (s.u.)	97	7.7	7.0	9.0	69	7.9	7.4	9.2
Conductivity (us/cm)	97	203	113	275	69	221	164	272
Organic N (mg/L)	6	0.36	0.18	0.46	6	0.42	0.30	0.55
Ammonia N (mg/L)	6	0.02	0.01	0.04	6	0.03	0.01	0.05
Nitrate+Nitrite N (mg/L)	6	0.13	0.01	0.40	6	0.19	0.06	0.33
Total Nitrogen (mg/L)	6	0.51	0.41	0.59	6	0.63	0.45	0.85
Total Phosphorus (mg/L)	6	0.032	0.030	0.040	6	0.038	0.006	0.050
TN / TP Ratio	6	16.2	13.7	19.7	6	31.0	9.0	115.0
Chlorophyll-a (ug/L)	6	21.0	17.0	24.0	6	29.0	14.0	50.0
TOC	6	2.8	2.5	3.2	6	2.7	1.6	3.3
Secchi Depth (m)	6	1.34	1.10	1.70	6	0.99	0.75	1.20

	Tellico Forebay (LTRM 1.0)				Tellico Transition (LTRM 15.0)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	101	16.2	8.9	27.1	75	18.1	10.4	29.3
Dissolved Oxygen (mg/L)	101	6.1	1.0	10.5	75	7.9	2.3	10.2
pH (s.u.)	101	7.2	6.4	8.6	75	7.4	6.5	8.7
Conductivity (us/cm)	101	75	33	184	75	48	27	78
Organic N (mg/L)	6	0.30	0.10	0.57	6	0.19	0.09	0.44
Ammonia N (mg/L)	6	0.01	0.01	0.01	6	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	6	0.09	0.02	0.24	6	0.05	0.01	0.17
Total Nitrogen (mg/L)	6	0.40	0.28	0.60	6	0.25	0.11	0.46
Total Phosphorus (mg/L)	6	0.018	0.007	0.030	6	0.015	0.007	0.030
TN / TP Ratio	6	27.1	11.0	45.7	6	20.9	3.7	28.6
Chlorophyll-a (ug/L)	6	11.0	5.0	14.0	6	7.7	6.0	10.0
TOC	6	2.2	1.6	3.0	6	2.2	1.4	3.2
Secchi Depth (m)	6	1.93	1.40	2.75	6	1.93	1.60	2.20

	Melton Hill Forebay (CRM 24.0)[2]				Melton Hill Transition (CRM 45.0)[2]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	67	19.1	13.4	30.3	42	18.8	12.5	27.4
Dissolved Oxygen (mg/L)	67	6.9	0.6	14.1	42	7.9	1.8	11.7
pH (s.u.)	67	7.9	7.4	8.8	42	7.9	7.5	8.7
Conductivity (us/cm)	67	273	218	297	42	274	240	292
Organic N (mg/L)	4	0.28	0.12	0.48	4	0.26	0.11	0.41
Ammonia N (mg/L)	4	0.01	0.01	0.01	4	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	4	0.17	0.02	0.38	4	0.45	0.19	0.70
Total Nitrogen (mg/L)	5	0.40	0.19	0.62	5	0.68	0.51	0.91
Total Phosphorus (mg/L)	4	0.015	0.010	0.020	4	0.023	0.010	0.040
TN / TP Ratio	5	31.50	18.00	62.00	5	39.95	15.25	91.00
Chlorophyll-a (ug/L)	4	11.3	9	15	5	11.8	3	24
TOC	5	2.5	1.9	2.8	5	2.2	1.5	3.0
Secchi Depth (m)	5	1.93	1.40	2.50	5	0.99	0.75	1.30

	Norris Forebay (CRM 80.0)				Norris Mid-Res (CRM 125.0)				Norris Mid-Res (PRM 30.0)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	162	14.4	5.1	29.4	85	19.6	8.1	29.5	98	18.9	8.2	30.1
Dissolved Oxygen (mg/L)	162	6.7	0.3	14.5	85	5.8	0.2	13.9	98	5.5	0.2	12.7
pH (s.u.)	162	7.9	7.2	8.8	85	8.0	7.2	8.7	98	7.9	7.1	8.7
Conductivity (us/cm)	162	268	231	309	85	290	262	321	98	318	270	394
Organic N (mg/L)	7	0.23	0.09	0.30	7	0.22	0.08	0.28	7	0.17	0.11	0.22
Ammonia N (mg/L)	7	0.01	0.01	0.01	7	0.01	0.01	0.02	7	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	7	0.06	0.01	0.19	7	0.14	0.01	0.67	7	0.18	0.01	0.69
Total Nitrogen (mg/L)	7	0.29	0.22	0.37	7	0.37	0.21	0.95	7	0.36	0.16	0.86
Total Phosphorus (mg/L)	7	0.009	0.003	0.020	7	0.009	0.004	0.020	7	0.010	0.005	0.020
TN / TP Ratio	7	50.8	11.0	86.7	7	50.0	14.0	95.0	7	45.1	9.0	88.0
Chlorophyll-a (ug/L)	7	4.6	2.0	9.0	7	5.7	4.0	10.0	7	5.4	4.0	11.0
TOC	7	2.6	1.9	3.1	7	2.2	1.8	2.6	7	1.9	1.7	2.1
Secchi Depth (m)	7	2.94	1.20	4.40	7	2.36	1.80	3.10	7	2.48	1.90	3.10

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted

2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	Cherokee Forebay (HRM 55.0)[2]				Cherokee Mid-Res (HRM 76.0)[2]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	122	18.5	8.3	30.0	90	21.2	11.2	30.6
Dissolved Oxygen (mg/L)	122	5.1	0.2	10.9	90	3.8	0.1	16.3
pH (s.u.)	122	7.9	7.2	8.8	90	7.8	7.2	8.9
Conductivity (us/cm)	122	299	256	356	90	313	265	376
Organic N (mg/L)	6	0.31	0.23	0.40	6	0.39	0.34	0.43
Ammonia N (mg/L)	6	0.01	0.01	0.01	6	0.04	0.01	0.16
Nitrate+Nitrite N (mg/L)	6	0.09	0.01	0.41	6	0.10	0.01	0.20
Total Nitrogen (mg/L)	6	0.41	0.25	0.82	6	0.53	0.43	0.72
Total Phosphorus (mg/L)	5	0.013	0.007	0.020	5	0.032	0.020	0.050
TN / TP Ratio	5	33.90	12.50	42.00	5	17.21	10.20	26.00
Chlorophyll-a (ug/L)	6	9.2	6	16	6	14.2	8	28
TOC	6	3.0	2.2	3.7	6	3.1	2.4	3.5
Secchi Depth (m)	7	2.06	1.50	3.25	6	1.56	1.00	2.25

	Douglas Forebay (FBRM 34.5)				Douglas Mid-Res (FBRM 51.0)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	104	20.3	7.6	30.1	79	21.6	11.0	30.7
Dissolved Oxygen (mg/L)	104	5.0	0.1	11.0	79	5.3	0.2	11.1
pH (s.u.)	104	7.7	6.8	9.4	79	7.9	6.7	9.3
Conductivity (us/cm)	104	163	144	216	79	166	138	235
Organic N (mg/L)	7	0.26	0.18	0.40	7	0.34	0.22	0.41
Ammonia N (mg/L)	7	0.02	0.01	0.06	7	0.02	0.01	0.05
Nitrate+Nitrite N (mg/L)	7	0.14	0.01	0.54	7	0.10	0.01	0.36
Total Nitrogen (mg/L)	7	0.42	0.28	0.73	7	0.46	0.34	0.77
Total Phosphorus (mg/L)	7	0.014	0.010	0.020	6	0.023	0.010	0.030
TN / TP Ratio	7	29.6	21.0	36.5	6	21.9	13.0	43.0
Chlorophyll-a (ug/L)	7	8.9	6.0	11.0	7	15.3	10.0	30.0
TOC	7	2.6	2.2	2.9	7	2.8	2.5	3.0
Secchi Depth (m)	7	2.01	1.25	2.75	7	1.34	0.90	1.60

	Fort Patrick Henry(SFHRM 8.7)			
	N	Mean	Min	Max
Temperature (deg C)	73	16.6	9.3	26.7
Dissolved Oxygen (mg/L)	73	7.8	1.9	20.0
pH (s.u.)	73	7.9	7.3	9.1
Conductivity (us/cm)	73	222	174	270
Organic N (mg/L)	7	0.36	0.15	0.57
Ammonia N (mg/L)	7	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	7	0.31	0.07	0.84
Total Nitrogen (mg/L)	7	0.68	0.53	1.00
Total Phosphorus (mg/L)	7	0.029	0.020	0.050
TN / TP Ratio	7	26.8	13.0	50.0
Chlorophyll-a (ug/L)	6	19.7	8.0	28.0
TOC	7	2.7	2.0	3.3
Secchi Depth (m)	7	1.35	1.00	2.00

	Boone Forebay (SFHRM19.0)				Boone Mid-Res (SFHRM 27.0)				Boone Mid-Res (WRM 6.5)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	134	16.6	7.3	27.3	110	18.1	8.8	27.4	86	18.3	7.7	27.5
Dissolved Oxygen (mg/L)	134	5.6	0.2	14.9	110	5.4	0.1	16.9	86	7.9	0.9	13.2
pH (s.u.)	134	7.8	7.1	9.6	110	7.9	7.4	9.3	86	8.0	7.1	9.3
Conductivity (us/cm)	134	200	131	279	110	257	171	349	86	158	130	211
Organic N (mg/L)	7	0.38	0.28	0.53	7	0.49	0.33	0.82	7	0.44	0.24	0.56
Ammonia N (mg/L)	7	0.01	0.01	0.02	7	0.02	0.01	0.04	7	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	7	0.11	0.01	0.64	7	0.11	0.01	0.66	7	0.15	0.01	0.56
Total Nitrogen (mg/L)	7	0.50	0.35	0.93	7	0.62	0.35	1.12	7	0.59	0.42	0.81
Total Phosphorus (mg/L)	7	0.019	0.010	0.020	7	0.033	0.020	0.060	7	0.033	0.020	0.040
TN / TP Ratio	7	27.7	17.5	46.5	7	19.2	11.7	25.0	7	19.3	10.5	27.0
Chlorophyll-a (ug/L)	7	18.4	9.0	46.0	7	27.3	12.0	37.0	7	25.7	13.0	46.0
TOC	7	3.7	2.1	4.8	7	4.1	2.8	5.1	7	3.1	2.2	3.8
Secchi Depth (m)	7	1.39	0.75	2.10	7	1.10	0.60	1.50	7	1.26	1.00	1.50

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted

2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	South Holston Forebay (SFHRM 51.0)[2]				South Holston Mid-Res (SFHRM 62.5)[2]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	173	12.7	6.5	28.4	113	16.6	7.1	28.6
Dissolved Oxygen (mg/L)	173	6.2	0.3	14.3	113	5.1	0.1	14.1
pH (s.u.)	173	7.7	7.1	9.0	113	7.8	7.2	9.2
Conductivity (us/cm)	173	208	188	355	113	216	182	271
Organic N (mg/L)	6	0.30	0.17	0.72	6	0.33	0.21	0.58
Ammonia N (mg/L)	6	0.01	0.01	0.01	6	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	6	0.18	0.10	0.40	6	0.12	0.01	0.54
Total Nitrogen (mg/L)	6	0.49	0.29	1.13	6	0.46	0.25	1.13
Total Phosphorus (mg/L)	6	0.007	0.004	0.010	6	0.016	0.007	0.030
TN / TP Ratio	6	86.78	29.00	226.00	6	38.39	12.50	113.00
Chlorophyll-a (ug/L)	6	4.3	3	5	6	9.3	6	16
TOC	6	2.4	1.9	2.8	6	2.5	1.9	3.1
Secchi Depth (m)	6	3.98	2.25	5.90	6	2.49	1.50	4.75

	Apalachia Forebay (HiRM 67.0)			
	N	Mean	Min	Max
Temperature (deg C)	100	16.1	7.7	27.8
Dissolved Oxygen (mg/L)	100	7.2	0.5	11.8
pH (s.u.)	100	6.7	6.1	8.3
Conductivity (us/cm)	100	26	22	49
Organic N (mg/L)	7	0.09	0.05	0.15
Ammonia N (mg/L)	7	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	7	0.13	0.10	0.16
Total Nitrogen (mg/L)	7	0.23	0.18	0.31
Total Phosphorus (mg/L)	7	0.009	0.003	0.020
TN / TP Ratio	7	47.5	9.5	103.3
Chlorophyll-a (ug/L)	6	5.2	3.0	8.0
TOC	7	1.4	1.2	1.7
Secchi Depth (m)	7	3.79	2.75	5.00

	Hiwassee Forebay (HiRM 77.5)[2]				Hiwassee Mid-Res (HiRM 85.0)[2]			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	147	17.0	9.1	28.5	98	18.6	10.2	29.1
Dissolved Oxygen (mg/L)	147	6.3	0.2	11.7	98	7.2	1.7	12.7
pH (s.u.)	147	6.7	6.1	9.1	98	7.0	6.2	9.4
Conductivity (us/cm)	147	27	23	40	98	29	23	169
Organic N (mg/L)	6	0.11	0.05	0.14	6	0.11	0.08	0.13
Ammonia N (mg/L)	6	0.01	0.01	0.02	6	0.02	0.01	0.04
Nitrate+Nitrite N (mg/L)	6	0.08	0.02	0.16	6	0.05	0.01	0.12
Total Nitrogen (mg/L)	6	0.20	0.13	0.28	6	0.18	0.14	0.24
Total Phosphorus (mg/L)	6	0.011	0.003	0.020	6	0.011	0.004	0.020
TN / TP Ratio	6	33.39	6.50	93.33	6	22.67	8.50	60.00
Chlorophyll-a (ug/L)	5	5,6	2	12	5	9.0	3	15
TOC	6	1.5	1.2	2.0	6	1.6	1.2	2.0
Secchi Depth (m)	6	3.50	2.60	4.50	6	3.33	2.75	4.25

	Chatuge Forebay (HiRM 122.0)				Chatuge Forebay (SCM 1.5)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	106	17.0	7.5	31.2	105	17.2	7.5	30.9
Dissolved Oxygen (mg/L)	106	6.4	0.3	11.1	105	6.3	0.3	11.2
pH (s.u.)	106	6.8	5.8	8.7	105	6.8	5.8	8.8
Conductivity (us/cm)	106	21	17	59	105	21	18	50
Organic N (mg/L)	7	0.10	0.04	0.14	7	0.12	0.07	0.22
Ammonia N (mg/L)	7	0.01	0.01	0.01	7	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	7	0.04	0.01	0.11	7	0.04	0.01	0.11
Total Nitrogen (mg/L)	7	0.15	0.07	0.21	7	0.17	0.09	0.24
Total Phosphorus (mg/L)	7	0.010	0.003	0.040	7	0.020	0.004	0.090
TN / TP Ratio	7	29.1	5.0	70.0	7	24.4	2.1	60.0
Chlorophyll-a (ug/L)	6	3.8	2.0	8.0	6	4.7	2.0	11.0
TOC	7	1.6	1.3	2.2	7	1.6	1.3	2.1
Secchi Depth (m)	7	2.83	2.00	4.00	6	2.88	2.30	3.75

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted
2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

	Nottely Forebay (NoRM 23.5)				Nottely Mid-Res (NoRM 31.0)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	122	16.7	7.6	30.1	79	18.7	7.9	30.9
Dissolved Oxygen (mg/L)	122	6.0	0.3	11.0	79	5.5	0.2	11.2
pH (s.u.)	122	6.7	5.8	9.1	79	6.6	5.9	7.6
Conductivity (us/cm)	122	27	23	73	79	29	24	75
Organic N (mg/L)	7	0.14	0.08	0.22	7	0.16	0.09	0.44
Ammonia N (mg/L)	7	0.01	0.01	0.01	7	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	7	0.04	0.01	0.17	7	0.04	0.01	0.15
Total Nitrogen (mg/L)	7	0.20	0.13	0.30	7	0.29	0.11	0.70
Total Phosphorus (mg/L)	7	0.015	0.003	0.040	7	0.032	0.006	0.160
TN / TP Ratio	7	23.0	6.5	46.7	7	22.0	1.6	55.0
Chlorophyll-a (ug/L)	6	9.7	1.0	23.0	6	9.3	3.0	21.0
TOC	7	2.0	1.5	2.7	7	1.7	1.3	2.2
Secchi Depth (m)	7	2.06	0.90	2.75	7	1.58	0.70	2.00

	Blue Ridge Forebay (ToRM 54.1)			
	N	Mean	Min	Max
Temperature (deg C)	130	17.0	5.4	29.4
Dissolved Oxygen (mg/L)	130	7.6	0.4	11.5
pH (s.u.)	130	6.6	5.8	8.5
Conductivity (us/cm)	130	17	15	30
Organic N (mg/L)	7	0.07	0.03	0.12
Ammonia N (mg/L)	7	0.01	0.01	0.01
Nitrate+Nitrite N (mg/L)	7	0.04	0.01	0.11
Total Nitrogen (mg/L)	7	0.14	0.10	0.17
Total Phosphorus (mg/L)	6	0.005	0.002	0.010
TN / TP Ratio	6	38.3	11.4	80.0
Chlorophyll-a (ug/L)	6	2.0	1.0	3.0
TOC	7	1.2	1.0	1.7
Secchi Depth (m)	7	3.81	2.75	4.50

	Ocoee No. 1 Forebay (ORM 12.5)			
	N	Mean	Min	Max
Temperature (deg C)	102	16.3	7.8	29.6
Dissolved Oxygen (mg/L)	102	8.1	5.1	10.9
pH (s.u.)	102	6.5	5.9	8.0
Conductivity (us/cm)	102	56	46	65
Organic N (mg/L)	7	0.10	0.02	0.32
Ammonia N (mg/L)	7	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	7	0.07	0.05	0.10
Total Nitrogen (mg/L)	7	0.17	0.11	0.38
Total Phosphorus (mg/L)	7	0.005	0.002	0.010
TN / TP Ratio	7	48.8	12.0	80.0
Chlorophyll-a (ug/L)	6	2.2	1.0	3.0
TOC	7	1.2	1.0	1.4
Secchi Depth (m)	7	3.92	2.50	5.00

	Beech Forebay (BRM 36.0)[2]			
	N	Mean	Min	Max
Temperature (deg C)	36	24.8	19.0	32.0
Dissolved Oxygen (mg/L)	36	4.6	0.2	9.4
pH (s.u.)	36	6.8	5.8	8.0
Conductivity (us/cm)	36	62	44	172
Organic N (mg/L)	6	0.36	0.18	0.50
Ammonia N (mg/L)	6	0.03	0.01	0.08
Nitrate+Nitrite N (mg/L)	6	0.01	0.01	0.01
Total Nitrogen (mg/L)	6	0.40	0.21	0.52
Total Phosphorus (mg/L)	6	0.027	0.020	0.040
TN / TP Ratio	6	16.17	10.50	26.00
Chlorophyll-a (ug/L)	6	16.7	10	30
TOC	6	4.1	3.3	5.6
Secchi Depth (m)	6	1.17	0.90	1.80

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted
2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1999 Vital Signs Reservoir Monitoring Summary

Bear Creek Forebay (BCM 75.0)

	N	Mean	Min	Max
Temperature (deg C)	66	22.0	12.4	30.7
Dissolved Oxygen (mg/L)	66	4.1	0.1	9.8
pH (s.u.)	66	6.9	6.1	8.9
Conductivity (us/cm)	66	74	46	197
Organic N (mg/L)	6	0.36	0.26	0.50
Ammonia N (mg/L)	7	0.02	0.01	0.06
Nitrate+Nitrite N (mg/L)	7	0.18	0.01	0.67
Total Nitrogen (mg/L)	7	0.51	0.12	0.97
Total Phosphorus (mg/L)	7	0.030	0.020	0.060
TN / TP Ratio	7	20.3	6.0	36.5
Chlorophyll-a (ug/L)	7	15.6	7.0	28.0
TOC	7	3.2	2.2	4.3
Secchi Depth (m)	7	1.23	1.00	1.50

Little Bear Creek Forebay (LBCM 12.5)

	N	Mean	Min	Max
Temperature (deg C)	97	18.3	10.5	31.0
Dissolved Oxygen (mg/L)	97	3.9	0.1	10.1
pH (s.u.)	97	7.1	6.1	8.9
Conductivity (us/cm)	97	110	94	151
Organic N (mg/L)	7	0.19	0.12	0.32
Ammonia N (mg/L)	7	0.02	0.01	0.03
Nitrate+Nitrite N (mg/L)	7	0.09	0.01	0.36
Total Nitrogen (mg/L)	7	0.30	0.19	0.54
Total Phosphorus (mg/L)	7	0.015	0.008	0.030
TN / TP Ratio	7	25.4	9.5	54.0
Chlorophyll-a (ug/L)	7	4.9	2.0	7.0
TOC	7	2.7	2.0	4.1
Secchi Depth (m)	7	2.69	1.70	4.70

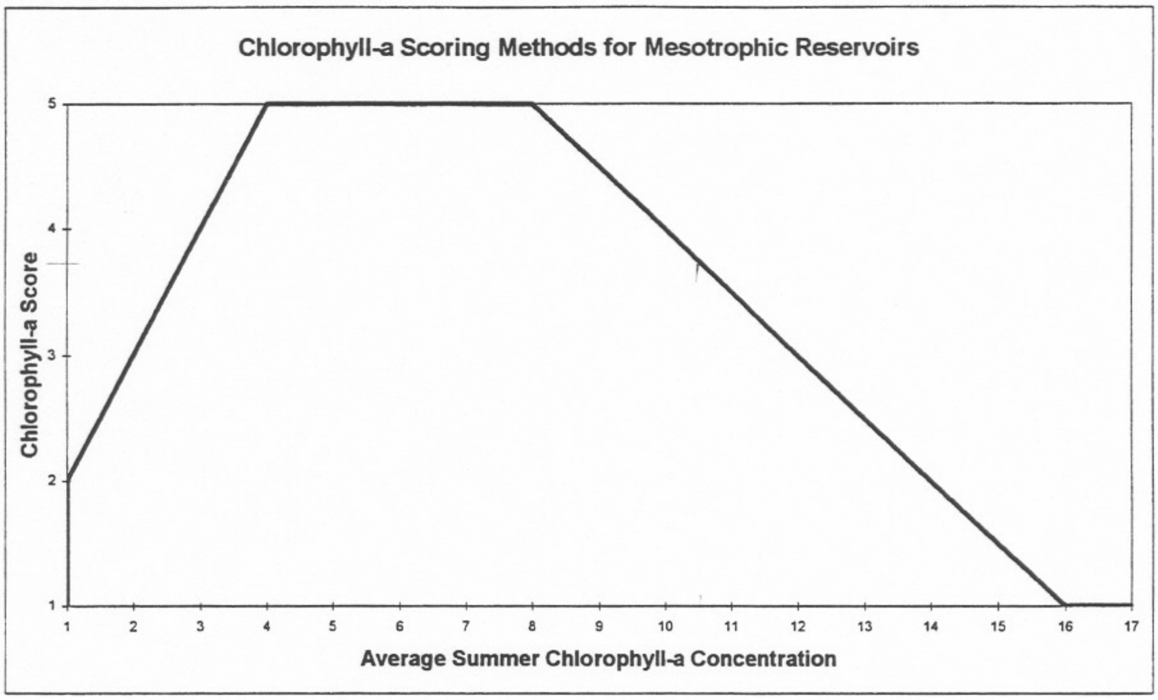
Cedar Creek Forebay (CCM 25.2)

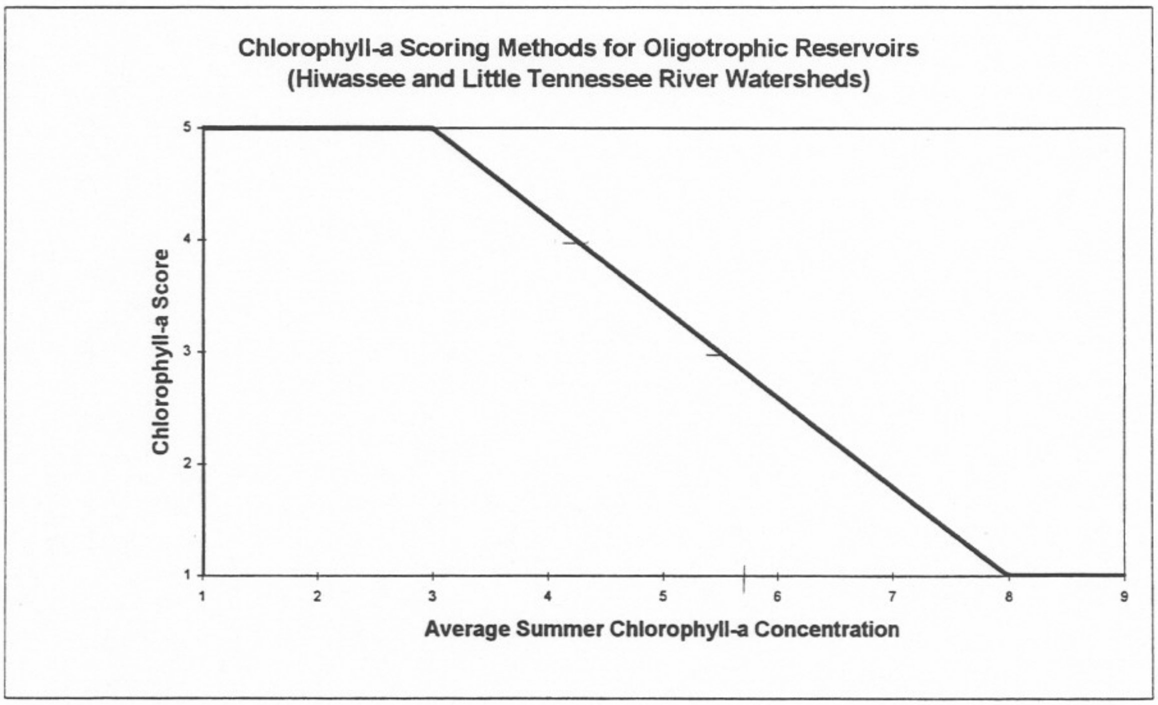
	N	Mean	Min	Max
Temperature (deg C)	96	20.2	10.7	30.7
Dissolved Oxygen (mg/L)	96	3.8	0.1	9.9
pH (s.u.)	96	7.6	6.7	8.6
Conductivity (us/cm)	96	239	209	478
Organic N (mg/L)	7	0.21	0.15	0.33
Ammonia N (mg/L)	7	0.01	0.01	0.02
Nitrate+Nitrite N (mg/L)	7	0.06	0.01	0.29
Total Nitrogen (mg/L)	7	0.28	0.17	0.50
Total Phosphorus (mg/L)	7	0.011	0.005	0.020
TN / TP Ratio	7	33.3	8.5	55.6
Chlorophyll-a (ug/L)	7	4.4	2.0	9.0
TOC	7	3.0	2.3	4.2
Secchi Depth (m)	7	2.13	1.50	2.60

1=Water Quality Monitoring to support ADEM Tributary Nutrient Loading Study; full Vital Signs Monitoring not conducted
2=Water Quality Monitoring initiated in May due to drought conditions; full Vital Signs Monitoring not conducted

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Figure 1. Chlorophyll-a Scoring Methods for Reservoirs





Chlorophyll-a Rating – The chlorophyll-a rating at each sampling location is based on the average summer concentration (of monthly photic zone composite samples). If triplicate samples are collected at a sampling location, only the median value of the triplicate is used in the calculation of the summer average and the maximum. If a monthly chlorophyll-a sample has a concentration that exceeds 30 ug/l, the value is not included in the calculation of the summer average, however, the final chlorophyll-a rating is decreased one unit, (i.e. 5 to 4, or 4 to 3, etc.) for each sample that exceeds 30 ug/l.

* If nutrients are present (e.g. total phosphorus greater than about 0.01 mg/L and nitrate+nitrite-nitrogen greater than about 0.05 mg/L) but chlorophyll-a concentrations are generally low (e.g. < 3ug/L), other limiting or inhibiting factors (e.g., high streamflows, turbidity, toxicity, etc.) must be considered. When these conditions exist, the chlorophyll-a rating is decreased one unit.

Section 4.0. Sediment Quality

Philosophical Approach/Background

Sediments at the bottoms of reservoirs serve as a repository for a variety of materials, especially chemicals which a have low solubility in water. If contaminated, bottom sediments can be long-term sources of toxic substances to the aquatic environment and can have adverse impacts on bottom fauna. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. Thus, examination of reservoir sediments is useful to determine if toxic chemicals are present and if chemical composition is changing through time.

There are several sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). Prior to 1995, TVA's approach used two sediment assessment methods--one biological (toxicity tests), the other chemical (direct chemical analysis of sediments)--to evaluate sediment quality. In 1995 and subsequent years only sediment chemical analysis of heavy metals, pesticides, and PCBs has been used. The primary reason for excluding toxicity tests in 1995 was budget reductions. Another important reason was that toxicity testing protocols had changed often during the four years they had been part of this monitoring program precluding year to year comparisons. Test media had changed from sediment elutriate to sediment pore water. Test procedures/organisms had changed from Microtox®, to Microtox® plus Rototox®, and later to Rototox® plus 24-hour acute test using Ceriodaphnia. Protocols were to change again in 1995 to the newly approved EPA methods using whole sediments and amphipods and midge larvae.

As discussed in Section 1 of this report, an initial question concerning evaluation of sediment monitoring results and implications of sediment quality on overall reservoir ecological health is essentially a classification issue -- should evaluations of sediment results be based on: (1) ideal conditions; for example, sediments should not have high concentrations of metals compared to background, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir; for example, high concentrations of reduced metals are acceptable in tributary reservoirs due to anoxic conditions resulting from long retention times and thermal stratification. The approach taken for these studies accepts only ideal conditions. That is, metal concentrations should not be elevated and pesticides should not be present. In this situation, there is no need for classification because the same conditions are desired for all reservoirs.

Sediment Collection Methods

Sediment samples were collected during the summer of 1999 from 33 locations, i.e., the forebays and transition zones (or mid-reservoir) of 6 run-of-river reservoirs and12 tributary reservoirs as shown in Table 2 of Section 1. In addition, 5 of the 33 locations were randomly selected for replicate QA/QC sampling. Unfortunately, replicate samples were collected at only three sites due to oversight by the sampling crew. Replicate samples were collected, handled, and processed independently from the other samples at each respective site. Results from these three sets of replicates were used to assess field methods consistency, variations in laboratory physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect approximately the top three centimeters of sediment. Each sediment sample was a composite of at least three subsamples independently collected at each sampling location from the original stream channel. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency. Samples were placed on ice immediately after collection and compositing, and were shipped or carried to the laboratory where they were analyzed for 13 metals and 26 selected organics (organochlorine pesticides and PCBs), as shown in Tables 1 and 1a.

Sediment Rating Scheme

As described above, sediment quality evaluations were based on both results of toxicity tests (S_{TOX}) and chemical analysis (S_{CHM}) prior to 1995. The Sediment Quality Rating scheme used during this period was the result of average rating of the sample's toxicity and its sediment chemistry:

$$\textbf{Sediment Quality Rating} = 0.5\ (S_{TOX}\ \textbf{rating} + S_{CHM}\ \textbf{rating}).$$

Since both the sediment toxicity rating and the sediment chemistry rating could range from 1 (poor quality) to 5 (excellent quality), this resulted in an final, Sediment Quality Rating ranging from 1 (poor quality) to 5 (excellent quality) for a given reservoir location. To arrive at an overall ecological health score for a reservoir location, this Sediment Quality Rating was then combined with ratings for the other four indicators (DO, chlorophyll, benthos, and fish). Together, all five indicators carried equal weight and each indicator could range from 1 to 5. This methodology is described in more detail in Section 1.

With the elimination of sediment toxicity testing beginning in 1995, it seemed inappropriate that the Sediment Quality Rating (based only on the results of chemical analyses) should carry equal weight with the other four ecological indicators. It was decided that the Sediment Quality Rating would be revised and carry only half the weight as the other four indicators of reservoir ecological health, and equal one half the sediment chemistry rating. Consequently, the revised Sediment Quality Rating ranges from 1 (poor quality) to 2.5 (excellent quality).

Sediment Quality Rating = 0.5 (S_{CHM} rating).

When this monitoring began in 1990 there were no sediment guidelines for this region of the country to use as the basis for evaluating sediment chemistry results. However, guidelines for metals had been suggested by EPA Region V for the Great Lakes (EPA, 1977). A comparison of sediment chemistry results from this monitoring program to those guidelines found that, except in known polluted areas (and except for zinc as described below), results from Tennessee Valley reservoirs rarely exceeded the values suggested by EPA, Region V. Thus, these guidelines for cadmium, chromium, copper, lead, mercury, and nickel were accepted as the standard for comparison of sediment chemistry (metals) concentrations resulting from this monitoring program (Table 1).

The initial comparison of metals concentrations from Tennessee Valley reservoirs to guidelines suggested by EPA, Region V found numerous areas where zinc concentrations exceeded the suggested guideline of 200 ug/kg. This indicated that the EPA, Region V suggested guideline of 200 ug/kg for zinc may not be an appropriate measure of "back-ground" conditions for the Tennessee Valley. Because the suggested guideline of 200 ug/kg did not allow for discrimination among sites, a detailed review of all available zinc results for the Tennessee Valley was conducted (based on a STORET retrieval at that time). As a result of that review, a concentration of 300 ug/kg was selected because it effectively separated areas with known or suspected sources from those considered to be representative of "background" conditions.

Arsenic was added to the list of metal analytes for this monitoring program beginning in 1994. A comparison of arsenic concentrations in sediments from Tennessee Valley reservoirs to the EPA, Region V suggested guideline for arsenic (8.0 ug/kg) resulted in the same problem described above for zinc – this concentration did not effectively discriminate among sites. After thorough consideration of all sediment results from this region, a concentration of 15 ug/kg was accepted as the "back-ground" value for purposes of evaluating Vital Signs results.

The approach to evaluating results from laboratory analysis of sediment samples for organochlorine pesticides and PCBs was different from that for heavy metals. Metals are a natural component of soil and sediment so there is a "back-ground" concentration which must be considered acceptable. This is not the case for the organochlorine pesticides and PCBs because these are man-made chemicals. Therefore, the approach taken for evaluating these results was that presence of any of these chemicals was indication of an undesirable condition and thus caused the sediment quality rating to be lowered. This approach means that the laboratory detection limit is the "guideline" for these chemicals (Table 1 and 1a).

Each sampling location's sediment chemistry is rated as follows:

Sediment Chemistry S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

*Analytes (i.e., heavy metals, pesticides, and PCBs) and guidelines are listed in Tables 1 and 1a.

Results from 1999 Monitoring

Table 2 provides sediment chemistry rating, Final Sediment Quality Rating, and comments for each location examined in 1999. Table 3 presents the actual sediment chemistry data which resulted in the sediment chemistry rating for each location.

It should be noted that an improved digestion procedure (Hotblock) was used beginning in 1999. Digestion techniques used during the years have changed from Glass (1990-1994) to Teflon (1995-1998) to Hotblock (1999). The Hotblock procedure provides better digestion and extraction for all metals but has particular implications for arsenic because it provides better conversion of all arsenic states to As^{-6}. As a result, arsenic concentrations increased at many sites compared to previous years, but few exceeded the guideline of 15 ug/kg.

References

Environmental Protection Agency, 1992. Sediment Classification Methods Compendium. EPA 823-R-92-006, USEPA, Washington, D.C.

Environmental Protection Agency, 1977. "Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments." USEPA, Region V, Chicago.

Table 1

Physical/Chemical Measurements of Sediment, Reservoir Vital Signs Monitoring, 1999

Description, units	Detection Limits (dry weight)	Sediment Quality Guidelines[a]
Metals		
Aluminum, mg/kg	5 mg/kg	--
Arsenic, mg/kg	0.5 mg/kg	15 mg/kg
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/kg	10 mg/kg	--
Chromium, mg/kg	5 mg/kg	75 mg/kg[b]
Copper, mg/kg	1 mg/kg	50 mg/kg[b]
Iron, mg/kg	1 mg/kg	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/kg	1 mg/kg	--
Manganese, mg/kg	0.5 mg/kg	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	1 mg/kg	300 mg/kg
Organochlorine Pesticides and PCB's		
Aldrin, µg/kg	10 µg/kg	10 µg/kg
α-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
β-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
γ-Benzene Hexachloride (Lindane), µg/kg	10 µg/kg	10 µg/kg
δ-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
Chlordane, µg/kg	10 µg/kg	10 µg/kg
Dieldrin, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDT, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDD, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDE, µg/kg	10 µg/kg	10 µg/kg
α-Endosulfan, µg/kg	10 µg/kg	10 µg/kg
β-Endosulfan, µg/kg	10 µg/kg	10 µg/kg
Endosulfan Sulfate, µg/kg	10 µg/kg	10 µg/kg
Endrin, µg/kg	10 µg/kg	10 µg/kg
Endrin Aldehyde, µg/kg	10 µg/kg	10 µg/kg
Heptachlor, µg/kg	10 µg/kg	10 µg/kg
Heptachlor Epoxide, µg/kg	10 µg/kg	10 µg/kg
Methoxychlor, µg/kg	10 µg/kg	10 µg/kg
PCB-1221, µg/kg	25 µg/kg	25 µg/kg
PCB-1232, µg/kg	25 µg/kg	25 µg/kg
PCB-1242, µg/kg	25 µg/kg	25 µg/kg
PCB-1248, µg/kg	25 µg/kg	25 µg/kg
PCB-1254, µg/kg	25 µg/kg	25 µg/kg
PCB-1260, µg/kg	25 µg/kg	25 µg/kg
PCB-1016, µg/kg	25 µg/kg	25 µg/kg
PCB's, Total, µg/kg	25 µg/kg	25 µg/kg
Toxaphene, µg/kg	500 µg/kg	500 µg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

Table 1a

Analytical Methodology for Vital Signs Sediments, 1999

Parameter	Reference	Method Description	Minimum Detectable Concentration
Pesticides/PCBs:	EPA, SW 846: Methods 3550A & 8080A	CH_2CL_2, Kuderna-Danish/Mercury (KD/Hg), Gas Chromatograph/Electron Capture (GC/EC)	
Pesticides			10 ug/Kg
Toxaphene			500 ug/Kg
PCB's			25 ug/Kg
Metals:	EPA, SW 846: Methods 3050A & 6010A	HNO_3, Inductively Coupled Argon Plasma (ICAP)	
Iron			1 mg/Kg
Manganese			0.5 mg/Kg
Calcium			10 mg/Kg
Magnesium			1 mg/Kg
Copper			1 mg/Kg
Zinc			1 mg/Kg
Aluminum			5 mg/Kg
Nickel			5 mg/Kg
Cadmium			0.5 mg/Kg
Chromium			5 mg/Kg
Lead			5 mg/Kg
Arsenic:	EPA, SW 846: Method 7060A	HNO_3, Atomic Absorption Spectrophotometry (AAS), Heated Graphite Atomizer (HGA)	0.5 mg/Kg
Mercury:	EPA, SW 846: Method 7471A	$HNO_3/KMNO_4$, Cold Vapor (CV)–AAS	0.10 mg/Kg
Residue: (Solids)	EPA, SW 846: Method 3550A	Gravimetry	
Total			0.1 %
Volatile			0.1 %

Reference:

Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW 846, United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC 20460, Third Edition, Updates I, II, and IIA, September 1994.

Table 2

1999 Sediment Ratings -- Vital Signs Reservoir Monitoring

Chemistry
5 - no analytes
3 - 1 or 2 analytes
1 - 3 or more analytes

Toxicity
5 - no toxicity
3 - some toxicity
1 - significant toxicity

No Toxicity Testing in 1999

Sediment Quality Rating = 0.5 (SED CHM)

(Note: if an analyte was found at the detection limit, 0.5 points was added to the Final Sediment Rating; or if an organic compound was detected on the primary column yet not confirmed on the secondary column, 0.5 was added to the Final Sediment Rating.)

Reservoir	Mile	Comment	Collection Date yymmdd	# Pest.	# Metals	SED-CHM RATING	SED-TOX RATING	FINAL SEDIMENT QUALITY RATING	COMMENTS (ppb, dry weight)
Kentucky	TRM 23.0		990714	0		5		2.5	
	TRM 85.0		990714	0		5		2.5	
	Big Sandy 7.4		990714	0	1	3		1.5	As=21
Wheeler	TRM 277.0		990712	0		5		2.5	
	TRM 295.9		990712	0		5		2.5	
	Elk River 6.0		990712	0		5		2.5	
Nickajack	TRM 425.5		990708	1		3		1.5	PCB-1254=80,PCB-1260=31
Chickamauga	TRM 472.3		990707	0	1	3 (4)		1.5 (2)	Zinc=300
	TRM 490.5	Dup-1	990707	0		5		2.5	
		Dup-2	990707						
	Hiwassee 8.5		990707	1	1	3		1.5	Chlordane=12, Zinc=550
Fort Loudoun	TRM 605.5		990712	2		3		1.5	PCB-1254=30, Chlordane=24
	TRM 624.6		990712	2	1	1 (2)		0.5 (1)	PCB-1254=30, Chlordane=23 Zinc=300
Tellico	LTRM 1.0		990712	0		5		2.5	
	LTRM 15.0		990712	0		5		2.5	
Norris	CRM 80.0		990713	1	2	1 (2)		0.5 (1)	As=25,Chlordane=10, Lead=72
	CRM 125.0		990715	0		5		2.5	
	PRM 30.0	Dup-1	990715	0		5		2.5	
		Dup-2	990715	1		3		1.5	Chlordane=13
Douglas	FBRM 33/34.5		990713	1		3		1.5	Chlordane=19
	FBRM 51.0		990713	1		3		1.5	Chlordane=19
Ft.Pat Henry	SFHR 8.7		990713	1	1	3 (4)		1.5 (2)	Chlordane=23, Copper=50

Table 2

1999 Sediment Ratings – Vital Signs Reservoir Monitoring

Chemistry
5 - no analytes
3 - 1 or 2 analytes
1 - 3 or more analytes

Toxicity
5 - no toxicity
3 - some toxicity
1 - significant toxicity

No Toxicity Testing in 1999

Sediment Quality Rating = 0.5 (SED CHM)

(Note: if an analyte was found at the detection limit, 0.5 points was added to the Final Sediment Rating; or if an organic compound was detected on the primary column yet not confirmed on the secondary column, 0.5 was added to the Final Sediment Rating.)

Reservoir	Mile	Comment	Collection Date yymmdd	# Pest.	# Metals	SED-CHM RATING	SED-TOX RATING	FINAL SEDIMENT QUALITY RATING	COMMENTS (ppb, dry weight)
Boone	SFHR 19.0		990712	1		3		1.5	Chlordane=29
	SFHR 27.0		990712	1		3		1.5	Chlordane=37
	WRM 6.5		990712	1	2	1		0.5	Chlordane=47, Copper=65 Zinc=330
Apalachia	HiRM 67.0		990707	0		5		2.5	
Chatuge	HiRM 122.0		990706		1	3		1.5	Copper=79
	Shooting Cr. 1.5		990706		3	1		0.5	Chromium=94, Copper=67 Nickel=53
Nottely	NRM 23.5		990706	0		5		2.5	
	NRM 31.0		990706	0		5		2.5	
Blue Ridge	ToRM 54.1	Dup-1	990706	0		5		2.5	
		Dup-2	990706						
Ocoee No. 1	ORM 12.5		990707	1	4	0		0.0	PCB-1254=110, Copper=1400 As=23, Lead=450, Zinc=1200
Bear Creek	BCM 75.0		990713	0		5		2.5	
L. Bear Creek	LBCM 12.5		990713	0		5		2.5	
Cedar Creek	CCM 25.2		990713	0		5		2.5	

Shaded (Duplicate/Precision) samples were not used to determine the Sediment Quality Ratings

Table 3
1999 Vital Signs Reservoir Monitoring Sediment Data

Reservoir	Mile	Comment	Sample Date yymmdd	Metals (mg/kg, dry weight) Aluminum	Arsenic	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Zinc
--------																
Kentucky	TRM 23.0		990714	30000	8.8	<0.5	8300	40	23	31000	21	3300	3300	0.17	35	120
Kentucky	TRM 85.0		990714	16000	5.7	<0.5	3300	23	13	19000	14	2000	1600	0.1	19	74
Kentucky	BSRM 7.4		990714	6000	21	<0.5	460	7.6	3.6	33000	4.5	580	960	0.12	6.2	19
Wheeler	TRM 277.0		990712	36000	8.8	<0.5	3800	44	31	36000	29	3300	2200	0.16	39	180
Wheeler	TRM 295.9		990712	28000	8.6	<0.5	3100	40	29	30000	26	3700	3300	0.18	32	170
Wheeler	ERM 6.0		990712	21000	5.8	<0.5	8800	25	14	36000	20	3000	2200	<0.10	30	80
Nickajack	TRM 425.5		990708	23000	8	<0.5	8200	41	38	29000	43	3200	2900	0.42	30	290
Chickamauga	TRM 472.3		990707	25000	11	<0.5	3400	38	49	37000	38	3400	5800	0.31	31	300
Chickamauga	TRM 490.5	Dup-1	990707	20000	7.5	<0.5	3300	34	35	30000	33	3300	3100	0.43	28	280
Chickamauga	TRM 490.5	Dup-2	990707	26000	6.8	<0.5	3500	37	36	34000	38	3600	3300	0.35	32	250
Chickamauga	HIRM 8.5		990707	18000	6	0.7	3000	28	48	28000	29	2800	1400	0.27	21	550
Fort Loudoun	TRM 605.5		990712	35000	10	0.6	5400	46	40	43000	42	4600	2700	0.14	36	280
Fort Loudoun	TRM 624.6		990712	28000	7.2	0.9	8000	39	38	36000	39	5100	3100	0.15	31	300
Tellico	LTRM 1.0		990712	37000	12	<0.5	2100	40	32	46000	35	3300	3700	0.13	32	150
Tellico	LTRM 15.0		990712	32000	8	<0.5	1500	36	29	37000	24	3600	3200	0.13	29	120
Norris	CRM 80.0		990713	30000	25	<0.5	3800	36	33	37000	72	3200	5400	0.18	38	150
Norris	CRM 125.0		990715	24000	6.5	<0.5	7300	36	28	33000	31	4400	960	<0.10	36	140
Norris	PRM 30.0	Dup-1	990715	24000	10	<0.5	7500	29	29	31000	51	4000	1300	0.11	36	200
Norris	PRM 30.0	Dup-2	990715	25000	11	<0.5	7300	30	29	33000	51	4000	1500	<0.10	37	190
Douglas	FBRM 34.5		990713	45000	7.7	<0.5	3200	56	40	46000	33	4900	800	0.13	40	200
Douglas	FBRM 51		990713	23000	2	<0.5	3000	38	25	25000	23	4300	450	<0.10	23	170
Ft Pat Henry	SFHRM 8.7		990713	31000	8.4	<0.5	6800	42	50	32000	32	4900	1400	0.18	30	210
Boone	SFHRM 19.0		990712	39000	10	<0.5	4700	50	43	39000	41	5500	1200	0.14	37	210
Boone	SFHRM 27.0		990712	25000	7.4	<0.5	36000	38	34	26000	34	4600	1100	0.13	29	130
Boone	WRM 6.5		990712	36000	6.4	<0.5	6400	46	65	38000	45	6600	850	0.15	34	330
Apalachia	HiRM 67.0		990707	58000	14	<0.5	850	47	43	68000	28	3800	1400	0.13	31	160
Chatuge	HiRM 122.0		990706	47000	9.2	<0.5	580	68	79	50000	17	3000	450	0.10	35	98
Chatuge	HiRM 122.0	Precision	990706	60000	8.7	<0.5	550	68	57	56000	16	2800	470	0.11	40	100
Chatuge	SCM 1.5		990706	54000	11	<0.5	690	94	67	60000	17	2500	600	0.11	53	99

Table 3
1999 Vital Signs Reservoir Monitoring Sediment Data

Metals (mg/kg, dry weight)

Reservoir	Mile	Comment	Sample Date yymmdd	Aluminum	Arsenic	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Zinc
--------																
Nottely	NoRM 23.5		990706	36000	5.1	<0.5	730	33	27	35000	12	2700	510	<0.10	17	83
Nottely	NoRM 23.5	Precision	990706	50000	4.8	<0.5	650	33	28	40000	15	2500	540	<0.10	20	85
Nottely	NoRM 31.0		990706	46000	6.3	<0.5	1200	52	44	44000	15	5300	500	<0.10	26	140
Nottely	NoRM 31.0	Precision	990706	59000	6.1	<0.5	1100	52	46	47000	18	5000	520	<0.10	31	140
Blue Ridge	ToRM 54.1	Dup-1	990706	53000	7.4	<0.5	550	45	40	46000	23	3800	500	<0.10	28	120
Blue Ridge	ToRM 54.1	Dup-2	990706	60000	4.8	<0.5	590	47	42	54000	27	3600	530	0.11	28	120
Ocoee	ORM 12.5		990707	43000	23	1.3	1300	39	1400	81000	450	3100	2600	0.20	26	1200
Bear Creek	BCM 75.0		990713	27000	6.8	<0.5	1300	36	20	31000	21	2400	1200	<0.10	32	98
Little Bear Creek	LBCM 12.5		990713	34000	14	<0.5	2500	54	20	41000	21	2700	940	0.12	39	160
Cedar Creek	CCM 25.2		990713	32000	13	<0.5	9300	50	15	33000	17	3300	1400	<0.10	34	110

Results for Metals Digestion Blank (99/08554):				<5	< 0.5	<0.5	<10	<5	<1	<1	<5	<1	<0.5	<0.10	<5	<1
Results for Sediment Reference Material (99/08561):																
			Reported Values	625	119	85.1	1928	127	80.9	758	78.1	128	213	2.7	94.5	68.7
			Percent Recovery,%	139%	116%	96%	97%	96%	95%	137%	90%	109%	114%	94%	99%	96%
			Certified Values	450	103	89	1988	132	85	553	87	117	187	3	95	72
			Approx. 95% C.I.													
VS-MS (Metals Spike)			Reported Values	2420	37	12	7684	54	57	1234	106	443	1900	0.97	92	255
			Percent Recovery,%	87%	92%	108%	92%	121%	115%	91%	111%	112%	83%	97%	112%	123%

Table 3

1999 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCBs (ug/kg, dry weight)

Reservoir	Mile	Comment	Sample Date yymmdd	ALDRIN	Benzene Hexachloride (BHC) ALPHA	BHC BETA	BHC DELTA	BHC GAMMA	CHLORDANE	DIELDRIN	DDT's p,p DDD	DDT's p,p DDE	DDT's p,p DDT	Endosulfan ALPHA	Endosulfan BETA	Endosulfan SULFATE	ENDRIN
Kentucky	TRM 23.0		990714	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Kentucky	TRM 85.0		990714	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Kentucky	BSRM 7.4		990714	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Wheeler	TRM 277.0		990712	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Wheeler	TRM 295.9		990712	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Wheeler	ERM 6.0		990712	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Nickajack	TRM 425.5		990708	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chickamauga	TRM 472.3		990707	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chickamauga	TRM 490.5	DUP-1	990707	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chickamauga	TRM 490.5	DUP-2	990707	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chickamauga	HIRM 8.5		990707	<10.	<10.	<10.	<10.	<10.	12	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Fort Loudoun	TRM 605.5		990712	<10.	<10.	<10.	<10.	<10.	24	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Fort Loudoun	TRM 624.6		990712	<10.	<10.	<10.	<10.	<10.	23	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Tellico	LTRM 1.0		990712	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Tellico	LTRM 15.0		990712	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Norris	CRM 80.0		990713	<10.	<10.	<10.	<10.	<10.	10	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Norris	CRM 125.0		990715	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Norris	PRM 30.0	DUP-1	990715	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Norris	PRM 30.0	DUP-2	990715	<10.	<10.	<10.	<10.	<10.	13	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Douglas	FBRM 34.5		990713	<10.	<10.	<10.	<10.	<10.	19	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Douglas	FBRM 51		990713	<10.	<10.	<10.	<10.	<10.	19	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Ft Pat Henry	SFHRM 8.7		990713	<10.	<10.	<10.	<10.	<10.	23	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Boone	SFHRM 19.0		990712	<10.	<10.	<10.	<10.	<10.	29	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Boone	SFHRM 27.0		990712	<10.	<10.	<10.	<10.	<10.	37	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Boone	WRM 6.5		990712	<10.	<10.	<10.	<10.	<10.	47	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chatuge	HIRM 122.0		990706	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chatuge	HIRM 122.0	Precision	990706	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Chatuge	SCM 1.5		990706	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Nottely	NoRM 23.5		990706	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.

Table 3
1999 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCBs (ug/kg, dry weight)

Reservoir	Mile	Comment	Sample Date yymmdd	ALDRIN	Benzene Hexachloride (BHC) ALPHA	BHC BETA	BHC DELTA	BHC GAMMA	CHLORDANE	DIELDRIN
Nottely	NoRM 23.5	Precision	990706	<10.	<10.	<10.	<10	<10	<10	<10.
Nottely	NoRM 31.0		990706	<10.	<10.	<10.	<10.	<10	<10	<10.
Nottely	NoRM 31.0	Precision	990706	<10.	<10.	<10	<10.	<10.	<10	<10.
Ocoee	ORM 12.5		990707	<10.	<10.	<10.	<10	<10.	<10.	<10.
Blue Ridge	ToRM 54.1	DUP-1	990706	<10.	<10.	<10.	<10	<10	<10.	<10.
Blue Ridge	ToRM 54.1	DUP-2	990706	<10.	<10.	<10	<10	<10	<10.	<10.
Apalachia	HiRM 67.0		990707	<10.	<10	<10.	<10.	<10.	<10	<10.
Bear Creek	BCM 75.0		990713	<10.	<10.	<10.	<10.	<10	<10.	<10.
Little Bear Creek	LBCM 12.5		990713	<10.	<10.	<10.	<10.	<10.	<10	<10.
Cedar Creek	CCM 25.2		990713	<10.	<10.	<10.	<10.	<10	<10	<10.

Results from Organic Extraction Blank				<10.	<10.	<10	<10.	<10	<10.	<10.
VS-MS (ORG PEST SPK)			Reported Values	147	--	--	--	137	--	195
			Percent Recovery	92%	--	--	--	86%	--	122%
VS-MS (ORG CHLOR SPIKE)			Reported Values	--	--	--	--	--	636	--
			Percent Recovery	--	--	--	--	--	95%	--

Reservoir	Mile	Comment	Sample Date yymmdd	DDT's p,p DDD	DDT's p,p DDE	DDT's p,p DDT	Endosulfan ALPHA	Endosulfan BETA	Endosulfan SULFATE	ENDRIN
Nottely	NoRM 23.5	Precision	990706	<10	<10	<10.	<10.	<10.	<10.	<10.
Nottely	NoRM 31.0		990706	<10	<10.	<10.	<10.	<10	<10.	<10.
Nottely	NoRM 31.0	Precision	990706	<10	<10.	<10.	<10.	<10	<10	<10.
Ocoee	ORM 12.5		990707	<10	<10	<10	<10.	<10	<10	<10
Blue Ridge	ToRM 54.1	DUP-1	990706	<10.	<10.	<10	<10.	<10	<10.	<10.
Blue Ridge	ToRM 54.1	DUP-2	990706	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Apalachia	HiRM 67.0		990707	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Bear Creek	BCM 75.0		990713	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Little Bear Creek	LBCM 12.5		990713	<10.	<10.	<10	<10.	<10.	<10	<10.
Cedar Creek	CCM 25.2		990713	<10.	<10.	<10.	<10.	<10.	<10	<10.

Results from Organic Extraction Blank				<10.	<10.	<10	<10.	<10.	<10	<10
VS-MS (ORG PEST SPK)			Reported Values	--	--	114	--	--	--	231
			Percent Recovery	--	--	71%	--	--	--	144%
VS-MS (ORG CHLOR SPIKE)			Reported Values	--	--	--	--	--	--	--
			Percent Recovery	--	--	--	--	--	--	--

Table 3
Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCB's (ug/kg dry weight)

Reservoir	Mile	Comment	Sample Date yymmdd	ENDRIN ALDEHYDE	HEPTACHLOR	HEPTACHLOR EPOXIDE	METHOXYCHLOR	Polychlorinated Biphenyls (PCB's)								TOXAPHENE
								1016	1221	1232	1242	1248	1254	1260	TOTAL	
Kentucky	TRM 23.0		990714	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Kentucky	TRM 85.0		990714	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Kentucky	BSRM 7.4		990714	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Wheeler	TRM 277.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Wheeler	TRM 295.9		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Wheeler	ERM 6.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Nickajack	TRM 425.5		990708	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	80	31	111	<500.
Chickamauga	TRM 472.3		990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Chickamauga	TRM 490.5	Dup-1	990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Chickamauga	TRM 490.5	Dup-2	990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Chickamauga	HIRM 8.5		990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Fort Loudoun	TRM 605.5		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	30	<25.	30	<500.
Fort Loudoun	TRM 624.6		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	30	<25.	30	<500.
Tellico	LTRM 1.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Tellico	LTRM 15.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Norris	CRM 80.0		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Norris	CRM 125.0		990715	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Norris	PRM 30.0	Dup-1	990715	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Norris	PRM 30.0	Dup-2	990715	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Douglas	FBRM 34.5		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Douglas	FBRM 51		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Ft Pat Henry	SFHRM 8.7		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Boone	SFHRM 19.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Boone	SFHRM 27.0		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Boone	WRM 6.5		990712	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Apalachia	HIRM 67.0		990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Chatuge	HIRM 122.0		990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Chatuge	HIRM 122.0	Precision	990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.

Table 3
Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCB's (ug/kg dry weight)

Reservoir	Mile	Comment	Sample Date yymmdd	Endrin Aldehyde	Heptachlor	Heptachlor Epoxide	Methoxychlor	Polychlorinated Biphenyls (PCB's) 1016	1221	1232	1242	1248	1254	1260	Total	Toxaphene
Chatuge	SCM 1.5		990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Nottely	NoRM 23.5		990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Nottely	NoRM 23.5	Precision	990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Nottely	NoRM 31.0		990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Nottely	NoRM 31.0	Precision	990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Ocoee	ORM 12.5		990707	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	110	<25.	110	<500.
Blue Ridge	ToRM 54.1	Dup-1	990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Blue Ridge	ToRM 54.1	Dup-2	990706	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Bear Creek	BCM 75.0		990713	<10	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25.	<25.	<25.	0	<500.
Little Bear Creek	LBCM 12.5		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25	<25.	<25	<25.	<25.	0	<500.
Cedar Creek	CCM 25.2		990713	<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25	<25	<25.	<25.	0	<500.
....																
Results for Organics Extraction Blank (99/08553)				<10.	<10.	<10.	<10.	<25.	<25.	<25.	<25.	<25	<25.	<25.	0	<500.
VS-MS (ORG PCB SPK)			Reported Values	--	--	--	--	--	--	--	--	--	577	--	--	--
			Percent Recovery, %	--	--	--	--	--	--	--	--	--	87%	--	--	--
VS-MS (ORG PEST SPK)			Reported Values	--	134	--	--	--	--	--	--	--	--	--	--	--
			Percent Recovery, %	--	84%	--	--	--	--	--	--	--	--	--	--	--
VS-MS (ORG TOX SPK)			Reported Values	--	--	--	--	--	--	--	--	--	--	--	--	670
			Percent Recovery, %	--	--	--	--	--	--	--	--	--	--	--	--	67%

Section 5. Benthic Macroinvertebrates

Philosophical Approach/Background

Benthic macroinvertebrates are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have limited capability of movement thereby preventing them from avoiding undesirable conditions. The assemblage of macroinvertebrates in a reservoir is expected to be vastly different from that in a free-flowing river. Also, substantial differences are expected along a longitudinal gradient with organisms adapted to a more riverine environment expected at the upper end or inflow of a reservoir and organisms adapted to a lacustrine environment expected in the pool near the dam. Other factors to consider in evaluating the benthos in reservoirs include reservoir operational characteristics (e.g., depth of withdrawal for discharge, water depth, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability) and physical/chemical features owing to geological characteristics of different ecoregions.

One of the most important factors to consider is that reservoirs are artificial systems. This is a significant issue because it influences the approach to be taken in interpretation of the data once collected. Because reservoirs are man-made systems, it is not possible to follow the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to set the yard stick or expectations (termed reference conditions) of what a "good" benthic macroinvertebrate assemblage would be in a reservoir unaffected by human impacts. Other approaches must be used to develop the criteria by which the results will be compared to determine if they represent good, fair, or poor conditions. These include: historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. The state of the science of benthic macroinvertebrate assemblages in reservoirs is insufficient for predictive models to be effective. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for these organisms in reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment is the best approach. Use of best observed conditions requires an extensive database to determine expectations, and use of professional judgment requires substantial experience with the group of reservoirs under consideration. To use this concept, results in the data base which approach desired conditions for a given characteristic (metric) are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing scoring ranges are provided later in this section.

Another important consideration in evaluating benthic macroinvertebrate results is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 31 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics.

	Tributary Reservoirs		
Run-of-River	Blue Ridge	Ridge & Valley	Interior Plateau
Kentucky	Apalachia*	Cherokee	Normandy
Pickwick	Hiwassee	Ft. Patrick Henry*	Bear Creek
Wilson	Chatuge	Boone	Little Bear Creek
Wheeler	Nottely	South Holston	Cedar Creek
Guntersville	Parksville*	Douglas	Beech*
Nickajack	Blue Ridge	Norris	
Chickamauga	Fontana	Tims Ford**	
Watts Bar	Watauga		
Fort Loudoun			
Tellico***			
Melton Hill			

* These reservoirs are included in their respective classes because they are physically located within the specified ecoregion; however, results were excluded from developing scoring ranges: Apalachia and Ft. Patrick Henry because of their nominal drawdown and short retention times are uncharacteristic of other reservoirs their in class; Beech because its physical attributes (primarily its shallow nature and bowel shape) are quite different from the other reservoirs in that class; and Parksville because of known pollution (very high metal concentrations), which would be expected to cause a degraded benthic macroinvertebrate community.

** Tims Ford is in the Interior Plateau ecoregion but due to operational and morphological characteristics was considered more similar to and classified with Ridge and Valley reservoirs. Results from Tims Ford were excluded from developing reference conditions for either class.

*** Tellico is essentially in a class by itself - it has a nominal drawdown like the other run-of-river reservoirs to allow for navigation yet it typically stratifies in summer like a tributary reservoir due to its physical characteristics, in particular its relatively long retention time. For these reasons, results for Tellico were excluded from developing scoring criteria for all reservoir classes and was scored against run-of-river reservoir scoring criteria.

Once reservoirs have been appropriately classified, scoring criteria (i.e., those values for each characteristic or metric which will be considered good, fair, or poor) must be developed. When using best observed conditions, a data base must exist and decisions made as to how best separate data for each metric into the three scoring ranges. TVA's approach is, for each metric, to first omit outliers, then trisect the range of the remaining values (including zero if appropriate for a particular metric). Cutoff points between the ranges are examined closely and adjusted as needed based on professional judgment. These three ranges represent good, fair, and poor conditions and form the reference conditions or expectations for each metric. More details of TVA's approach to developing scoring ranges are provided under the Benthic macroinvertebrate Invertebrate Rating Scheme below.

Sample Collection Methods

Benthic macroinvertebrate samples were collected in the late fall/early winter (November-December) at 38 locations on 18 TVA reservoirs in 1999 (Table 1, Section 1). This was the fifth year for sample collection to occur during the late fall/early winter time frame. Previous to 1995, sample collection had occurred during late winter/early spring (February-March). The problem with using late winter/early spring benthic macroinvertebrate information is that the results are an indication of the conditions which existed during the summer and autumn of the previous year. This had the undesirable effect of causing results for benthic macroinvertebrates to be out of synch with the rest of the monitoring data for a particular year because Vital Signs monitoring results are summarized and reported on a calendar year cycle. Benthos sampling was initially conducted in late winter/early spring because the required reporting date of mid-January did not allow sample processing time in the laboratory. Also, there was concern that insect instars would be so small that they could pass through the collection screen and/or be difficult to identify.

Thorough evaluation of the 1993—1994 results showed late fall/early winter collection and use of field identification to the Family and Order levels would negate most of the problems resulting from late winter/early spring sampling and would improve the contribution of this important assemblage to the overall reservoir evaluation. The basis for these changes is documented in Section 4, Appendix A of Dycus, 1995. Evaluation of data resulting from use of these methods is discussed in Dycus and Meinert, 1996 (summarizing 1995 results), Dycus and Meinert, 1997 (summarizing 1996 results), and Dycus, Meinert, and Baker, 1999 (summarizing 1998 results).

At each sample location, a line-of-sight transect was established across the width of the reservoir, and one Ponar grab sample collected at 10 equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Care was taken to collect samples only from the permanently wetted bottom portion of the reservoir (i.e., below the elevation of the minimum winter pool level). Samples were washed, counted, and identified in the field to either Family or Order level as appropriate (i.e., the lowest practical in the field). Samples were then transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution.

The Quality Control (QC) element of the benthic macroinvertebrate evaluation includes two components. One examines how the final benthic score is affected by the change from laboratory processing to field processing. The other examines the reproducibility of benthic macroinvertebrate sampling results. To fulfill the first component, samples from seven sites (about 20% of the sampling locations) were processed in the field (described above) and later sent to the benthic laboratory for processing as in previous years (sorted and quantified at the lowest practical taxon). Benthic scores were developed for both sets of sample results and compared.

To examine the reproducibility of the collection and analysis procedure, the same seven sites selected above were sampled a second time. This was achieved by collecting the first set of 10 samples, leaving the sampling location, and then returning as near as possible to the original transect site (usually on the same day) and repeating the collection of a second (replicate) set of 10 samples. In this effort, both sets of samples were field processed and benthic scores developed for each set of samples and compared. All classes of reservoirs and types of locations (i.e., forebay, transition zone, embayment, and inflow) were included in the QC effort.

Benthic Macroinvertebrate Rating Scheme

Selection of specific metrics and their associated reference conditions (expectations) are obviously important steps in developing a rating scheme for an indicator. Basically, this means selecting the characteristics (metrics) of an indicator, in this case benthic macroinvertebrates, which will form the basis of the evaluation and further deciding the scoring range for each metric which will be used to identify good, fair, and poor conditions. Generally, a numeric value is then assigned to each metric depending on where it falls in the scoring range with good = 5, fair = 3, and poor = 1. The metrics are then summed to provide an overall evaluation or rating for the indicator.

The number of metrics used by this monitoring program to evaluate benthic macroinvertebrate results varied between six and eight the first few years with seven being used the last four years. Through 1997 the same metrics were used for all classes of reservoirs sampled, although scoring ranges differed by reservoir class and type of sample location. Beginning in 1998 and continued into 1999, certain metrics differed between the run-of-river reservoirs and tributary reservoirs, although seven metrics were used in both cases. The need for this change was identified by the QC component of this program and discussed in Dycus and Meinert, 1998. The problem was that scores for repeat sets of samples from tributary reservoirs were occasionally quite different from one another. The primary contributing factor appeared to be presence/absence of one or two EPT organisms in one sample set yet not in the repeat set. EPT organisms are relatively rare in tributary reservoirs due to physical constraints. As a result, scoring criteria were comparably low for the EPT metric as well as the Long-lived metric (EPT organisms are the primary contributor to this metric in tributary reservoirs). If it happened that just one or two mayflies, for example, were found in a sample set, the rating for the EPT metric could shift from poor (1 point) to good (5 points). If it happened that the mayfly was greater than 10 mm in length, it would also count as a Long-lived taxon and result in a shift from 1 to 5 points for that metric. Absence of mayflies in the repeat set could cause up to 10 point difference in the Benthic Macroinvertebrate Score between the sample sets. This was considered unacceptable.

This situation arose because metrics to evaluate the benthic community was first developed for use on results from the run-of-river reservoirs where EPT organisms, especially mayflies, are common. The same metrics were later applied to results from the tributary reservoirs with the assumption that simply adjusting the scoring range would be sufficient to account for differences between the two groups of reservoirs. The QC program demonstrated this assumption was not valid and some type of change was needed.

One of the potential solutions described in Dycus and Meinert (1998) was to determine if other metrics might be more appropriate for tributary reservoirs. Experience has shown that the benthic macroinvertebrate fauna in tributary reservoirs is dominated by chironomids and oligochates with other taxa present on a case by case basis. Therefore, the metrics chosen for use must accept the fact that the benthos present in tributary reservoirs are ecologically poor by any other comparison. After careful evaluation it was determined that five of the seven metrics which had been used previously still had validity for use on tributary reservoir benthos data. However, the EPT Taxa and Long-Lived Taxa metrics were not appropriate. Two new metrics were chosen as replacements. One was Non-Chironomid & Oligochaete Taxa and the other was Chironomid Density. The first accepts the fact that presence (survival) of any taxon in addition to chironomid and oligochaete taxa is indicative of improved conditions compared to their absence. The second accepts that increasing density of chironomids indicates conditions are better than conditions where chironomids cannot survive at all.

The metrics used to evaluate 1998 and 1999 benthic macroinvertebrate results are identified in the table below and then described in more detail in the following paragraphs.

Metric	Run-of-River Reservoirs	Tributary Reservoirs*
Taxa Richness	X	X
EPT Taxa	X	
Long - Lived Taxa	X	
Non-Chironomid & Oligochaete Density	X	X
Percent Oligochaetes	X	X
Dominance	X	X
Zero Samples	X	X
Non-Chironomid & Oligochaete Taxa		X
Chironomid Density		X

*Rather than eliminating use of EPT organisms in tributary reservoirs, it was decided to allow "bonus points" (up to 2) if any EPT organism was found at the site, as long as the resulting benthic score did not exceed 35, the maximum possible benthic score as discussed later.

- **Taxa richness** (Used on both Run-of-River and Tributary Reservoirs)—This metric is calculated by averaging the total number of taxa present in each sample at a site. Taxa generally means Family or Order level because samples are processed in the field. For chironomids, taxa refers to obviously different organisms (i.e., separated by body size, head capsule size and shape, color, etc.). An increase in taxa richness indicates better conditions than low taxa richness.

- **EPT** (Used on Run-of-River Reservoirs only)—This metric is calculated by averaging the number of Ephemeroptera, Plecoptera, and Trichoptera taxa present in each sample at a site. Higher diversity of these taxa indicates good water quality and other habitat conditions in streams. A similar use is incorporated here despite expected lower numbers of these organisms in reservoirs than in streams.
- **Long-lived organisms** (Used on Run-of-River Reservoirs only)—This is a presence/absence metric which is evaluated based on the proportion of samples with at least one long-lived organism (Corbicula, Hexagenia, mussels, and snails) present. The presence of long-lived taxa is indicative of conditions which allow long-term survival.
- **Percentage as Oligochaetes** (Used on both Run-of-River and Tributary Reservoirs)—This metric is calculated by averaging the percentage of oligochaetes in each sample at a site. Oligochaetes are considered tolerant organisms so a higher proportion indicates poor water quality.
- **Percentage as dominant taxa** (Used on both Run-of-River and Tributary Reservoirs)—This metric is calculated by selecting the two most abundant taxa in a sample, summing the number of individuals in those two taxa, dividing that sum by the total number of animals in the sample, and converting to a percentage for that sample. The percentage was then average for the 10 samples at each site. Often, the most abundant taxa differed among the 10 samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples a site. This metric is used as an evenness indicator. Dominance of one or two taxa indicates poor conditions.
- **Density excluding Chironomids and Oligochaetes** (Used on both Run-of-River and Tributary Reservoirs)—This metric is calculated by first summing the number of organisms excluding chironomids and oligochaetes present in each sample and then averaging these densities for the 10 samples at a site. This metric examines the community excluding taxa which often dominate under adverse conditions. A higher

abundance of non-chironomids and oligochaetes indicates good water quality conditions.

- **Zero-samples (Proportion of samples with no organisms present)** (Used on both Run-of-River and Tributary Reservoirs)—This metric is the proportion of samples at a site which have no organisms present. "Zero-samples" indicate living conditions unsuitable to support aquatic life (i.e. toxicity, unsuitable substrate, etc.). Any site having one empty sample was assigned a score of three, and any site with two or more empty samples received a score of one. Sites with no empty samples were assigned a score of five.
- **Non-Chironomid & Oligochaete Taxa** (Used on Tributary Reservoirs only)—This metric is calculated by summing the total number of taxa, excluding chironomid and oligochaete taxa, present in each sample at a site. It is similar to the Taxa Richness metric above, but it is not considered redundant with that metric. The Taxa Richness metric on tributary reservoirs will be mostly chironomid and oligochaete taxa, whereas this new metric highlights presence (survival) of any additional taxa and recognizes their presence is indicative of improved conditions compared to their absence.
- **Chironomid Density** (Used on Tributary Reservoirs only)— This metric is calculated by averaging the density of chironomids in each sample at a site. It accepts that, for tributary reservoirs, increasing density of chironomids indicates conditions are better than conditions where chironomids cannot survive at all.

Scoring Criteria for each of the metrics were developed using the ~~five~~ six years of Vital Signs monitoring which provide results from samples processed in the field (1994 - 1999). Scoring ranges were developed as follows:

- Individual criteria were developed for each type of sampling location (forebay, transition zone/mid-reservoir, and inflow) for each of the four classes of reservoirs.
- Results from the 10 samples along a transect for each year were combined (averaged for most metrics) and outliers deleted.
- Results were then trisected with the third of the range representing desirable conditions assigned a value of 5 (good), the middle one-third assigned a 3 (fair), and

the third representing undesirable conditions assigned a 1 (poor). Prior to 1998, trisection for all metrics was performed on the actual observed range of values. Beginning in 1998 the approach changed for all metrics except for the Percentage as Dominance Taxa metric. The approach for this metric was the same as in the past – trisection was conducted on actual observed values. For example, if the average Dominance at a particular type location in a particular reservoir class ranged from 50 to 95 percent, the range (45) was trisected (15) and the resulting scoring ranges would be 50 - 65 percent = good, 66 - 80 percent = fair, and 81 - 95 percent = poor. A slightly different approach was used for the other metrics beginning in 1998. For these metrics, the trisection included the entire possible (theoretical) range from the highest observed value to zero. In the above example there may have been an observed range in the number of taxa for all locations from 3 to 9. For the new approach 9 would have been trisected rather than 6 providing scoring ranges of ≤3 = poor, 4 - 6 = fair, and ≥7 = good. Values down to and including zero were included in the trisection even if they were not observed because zero represents an actual condition which could occur and would represent the worse-case condition.

Following publication of the report summarizing 1998 results we realized we had incorrectly implemented the change described above. We found we had trisected the observed range rather than the maximum theoretical range as desired. We then incorrectly applied the trisected values or "cut-offs' to the maximum theoretical range. Using the observed example, where the number of taxa ranged from 3 to 9, we incorrectly trisected the observed range (6) which provided "cut-offs" of 2 units each. We then incorrectly applied those cut-offs to the maximum theoretical range (0 - 9) which resulted in scoring ranges of ≤2 = poor, 3 - 5 = fair, and ≥6 = good. This error made the benthic community scores presented in the 1998 report for field processed samples appear higher than they should have been. Prior to analyzing results for 1999, new scoring ranges were correctly developed and data for all years for which the field processed method has existed (1994 - 1999) were "rescored". These new scores are presented below in the Results section of this report.

- Professional judgment and observations on the entire data base were used to adjust the cutoffs for the range of each metric, as appropriate.

Scoring criteria which resulted from these efforts are detailed by reservoir class for each metric in Table 1. Two versions of Table 1 (a and b) are provided. Table 1a provides scoring criteria for results for field processed samples. These criteria were developed based on samples collected 1994 through 1999. Table 1b provides scoring criteria for results from laboratory processed samples collected for QC purposes in 1999. These criteria were developed based on laboratory processing of samples collected 1994 through 1999.

As described above, sample results at each site were scored using the appropriate scoring ranges for each metric and assigned a value of either 5 (good), 3 (fair), or 1 (poor). Numerical ratings for the seven metrics were then summed. This resulted in a minimum score of 7 if all metrics at a site were poor, and a maximum score of 35 if all metrics were good.

One use of the benthic macroinvertebrate score is to help establish the overall ecological health score for a reservoir (see Section 1). The benthic macroinvertebrate community is one of five indicators which are summed to arrive at an overall Ecological Health Index for a reservoir.

To arrive at an evaluation of the condition of the benthic macroinvertebrate community at a sample location, scores were evaluated as follows:

Benthic Community Score	7-12	13-18	19-23	24-29	30-35
Community Condition	Very Poor	Poor	Fair	Good	Excellent
Contribution to Reservoir Ecological Health Score	1	2	3	4	5

Benthic community results along with results from the other four indicators and overall ecological health scores for each reservoir are used to keep the public informed on the conditions of Tennessee Valley reservoirs. In documents intended for the public, results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good), yellow (fair), or red (poor). This necessitates dividing scores for each indicator into three ranges. The benthic macroinvertebrate scores are categorized as follows:

Benthic Community Score	7-16	17-26	27-35
Color	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1999 Monitoring

Results and Benthic Community Scores

Results from 1999 benthos sampling are summarized for each sample location, separated by reservoir class and reservoir zone, in Table 2. This table includes final benthic scores, ratings for each of the seven metrics, and the data for each metric which drove the rating. Results for 1994, 1995, 1996, 1997, 1998, and 1999 were scored on the new criteria (as described above) and included in Table 2. All results in Table 2 are from field-processed samples. Results for lab-processed (QC) samples for 1999 are in Table 3. Appendix C provides mean density for each taxon at each location in 1999; first for field-processed samples, followed by lab-processed samples.

Table 4 provides benthic community scores for 1994 through 1999 at all monitoring locations. Scores shown are for field processed samples based on the latest (1999) scoring criteria. This table provides an "apples to apples" comparison through time. The 1999 scores for most locations (30 of 38) were similar to past scores(+/- 5 points of the long-term average benthic index score, see Section 1 for more detailed description of comparisons among years).

Evaluation of QC Results

As described earlier, QC efforts for benthic macroinvertebrates include two components. One is aimed at evaluating implications of developing scores for the benthic community based on field processed samples begun in 1995, rather than on lab processed samples as in previous years. (Note: In 1994 all samples were processed in both the field and lab but reported only for the lab. Beginning in 1995 the protocol changed to all field processing with only a subset of samples sent to the lab for verification.) Results (scores and metric ratings) from lab processed samples for this QC component in 1999 are in Table 3. They are not reported in Table 2 because different scoring criteria are used for lab processed samples, as discussed above.

The other QC component deals with how well the benthic scores can be repeated and is accomplished by collecting a second set of samples (also processed in the field) at selected locations. Results of this component for 1994, 1995, 1996, 1997, 1998, and 1999 are provided in Table 2 and identified with a "Q".

Determination of acceptable differences for QC results is an important issue and must consider study design and planned use of results. Given that the primary use of these results is to help evaluate the overall condition of a reservoir, the acceptable difference was defined in terms of impact on the Reservoir Ecological Health Score. The Reservoir Ecological Health Score is developed by summing the points (ratings) for the five indicators (chlorophyll, DO, sediment quality, benthos, and fish assemblage) and expressing as a percentage of the maximum points possible (see Section 1). The benthic macroinvertebrate community contributes from 1 to 5 points for each sample site to the overall Reservoir Ecological Health Score. A benthic community score between 7-12 contributes 1 point; 13-18 2 points; 19-23 3 points; 24-29 4 points; and 30-35 5 points. For reservoirs with only one sample location, a shift of 1 point changes the Reservoir Ecological Health Score 4.4 percent, a shift of 2 points results in an 8.8 percent change, etc. The former was deemed acceptable but the latter unacceptable. Therefore, for both components of the benthos QC effort, the difference in contribution between the original sample and the QC sample should be no more than 1 point.

When this reasoning is applied to the benthic score itself, replicate scores for QC sample sets should be no more than 6 points apart. Differences greater than this could cause a 2 point shift in the benthic community contribution to Ecological Health Score.

QC Results: Comparison of scores – field processed samples vs lab processed samples in 1999

Run-of-the-River Reservoirs	Benthic Community Scores		
	Field Score	Lab Score	Difference
Wheeler Forebay	17 (Poor)	19 (Fair)	-2
Chickamauga Transition Zone	31 (Excellent)	23 (Fair)	+8
Nickajack Inflow	29 (Good)	27 (Good)	+2
Tributary Reservoirs			
	Field Score	Lab Score	Difference
Blue Ridge Ecoregion			
Blue Ridge Forebay	23 (Fair)	27 (Good)	-4
Ridge and Valley Ecoregion			
Douglas Forebay	19 (Fair)	17 (Poor)	+2
Norris Powell Mid-reservoir	33 (Excellent)	27 (Good)	+6
Interior Plateau Ecoregion			
Bear Creek Forebay	21 (Fair)	23 (Fair)	-2

Note: Field processed samples are scored on expectations appropriate for that level of taxonomic discernment as shown in Table 1a; whereas lab processed samples are scored on a different set of expectations appropriate for that level of discernment as shown in Table 1b.

Differences in all but one sample set were less than the desired maximum of 6. The maximum observed difference between scores from field processed and lab processed samples was 8 (1 set) and the minimum was 2 (4 sets). The mean difference (1.4) for the seven "paired" scores and associated 95 percent confidence interval ($\pm$ 4.1) provide a range (-0.2 to 5.5), also below the desired maximum of 6. There appeared to be no bias in these 7 pairs of scores. That is, scores from samples processed in the laboratory were higher those when processed in the field for 4 pairs and lower for 3 pairs. These QC results indicate that field processing of samples provides a satisfactory evaluation of the reservoir benthic community.

One concern in previous years has been a bias in benthic index scores between field and lab processed samples. For the 1994 - 1996 results there was a bias toward higher scores from the samples when processed in the lab. As a result, adjustments in scoring criteria were made in prior to scoring 1997 results. These adjustments had the desired effect of eliminating the bias observed in 1994 - 1996, but may have gone too far and caused a possible bias in the other direction – scores for both 1997 and 1998 tended to be higher based on the field derived results than the lab derived results. (See the annual summary report for each of those years for detailed explanation of suspected problems and adjustments made to correct those problems - references cited above.)

Results for paired scores for 1999 are encouraging. Results from this component of the QC effort will continue to be examined each year to determine if additional changes to scoring criteria are needed. However, further changes to the scoring criteria are undesirable because continued changes could allow degradation to occur undocumented due to a continued lowering of criteria. From the inception of this monitoring program, we had established a maximum of five years to establish a data base from which to develop scoring criteria. The five-year period was almost reached in 1995 when the decision was made to switch to field processing of samples from the previous method of all laboratory processing. This necessitated "starting over" to develop new scoring criteria suitable for taxonomic discernment appropriate for samples processed in the field with the naked eye. This second five-year period has now been reached and several changes in scoring criteria, as well as in the metrics themselves, have been required to reach what appears to be reliable scoring criteria for field process samples (as indicated by the 1999 QC sample data). Hopefully, the nominal difference among paired sets of samples and absence of bias will continue in future years.

QC Results: Scores for original samples compared to scores for repeat sampling in 1999

Run-of-the-River Reservoirs	Benthic Community Scores		
	Field Score Original	Field Score Repeat	Difference
Wheeler Forebay	17 (Poor)	19 (Fair)	2
Chickamauga Transition Zone	31 (Excellent)	25 (Good)	6
Nickajack Inflow	29 (Good)	31 (Excellent)	2

Tributary Reservoirs	Benthic Community Scores		
	Field Score Original	Field Score Repeat	Difference
Blue Ridge Ecoregion			
Blue Ridge Forebay	23 (Fair)	23 (Fair)	0
Ridge and Valley Ecoregion			
Douglas Forebay	19 (Fair)	19 (Fair)	0
Norris Powell Mid-reservoir	33 (Excellent)	33 (Excellent)	0
Interior Plateau Ecoregion			
Bear Creek Forebay	21 (Fair)	21 (Fair)	0

Note: + and - signs are not provided for these differences because there is no basis for bias – neither would be expected to be higher or lower than the other; therefore, the absolute rather than the relative difference should be considered.

Scores from all paired sample sets compared favorably. Replicate sample sets from all seven sites had scores that differed by 6 points or less. Replicate sample sets from four sites had identical scores, and scores for replicate sample sets at two sites differed by only 2 points. None of replicate sample sets had scores which differed by more than 6 points. The mean difference (1.4) for all QC sites in 1999 and associated 95 percent confidence limits (± 2.1) provide a range (-0.7 - 3.5) which does not include 6.

Year	Maximum Observed Difference	Mean	95% CL	Lower Limit	Upper Limit
1994	12	2.3	± 2.0	0.3	4.3
1995	8	4.0	± 2.2	1.8	6.2
1996	12	4.5	± 3.7	0.8	8.2
1997	8	2.9	± 2.6	0.3	5.5
1998	6	2.3	± 1.9	0.4	4.2
1999	6	1.4	± 2.1	-0.7	3.5

The mean difference in scores between the original and repeat sample sets in 1999 was the smallest to date. This improvement is likely due to one or a combination of two factors: field crews are becoming better at processing samples (picking animals from debris and identifying to appropriate taxonomic level) in the field and/or the changes made in metrics for tributary reservoir results (discussed above) achieved their desired effect. These QC results are encouraging and indicate the methods used provide reproducible results.

Reference

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Table 1a. Scoring Criteria for Benthic Macroinvertebrate Community; Field Processed Samples, Reservoir Vital Signs Monitoring - 1999

Run-of-the-River Reservoirs

Benthic Community Metrics	Forebay			Transition Zone			Inflow		
	1	3	5	1	3	5	1	3	5
Taxa Richness	≤2.4	2.5-4.7	≥4.8	≤2.1	2.2-4.3	≥4.4	≤2.8	2.9-5.7	≥5.8
EPT	≤0.4	0.5-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8
Long-lived	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8	≤0.3	0.4-0.7	≥0.8
Non Chiron &Oligo Density	≤118	119-235	≥236	≤291	292-580	≥581	≤568	569-1152	≥1153
Percent Oligochaetes	≥29.7	14.9-29.6	≤14.8	≥28.0	14.0-27.9	≤13.9	≥40.0	20.1-39.9	≤20.0
Dominance	≥90.7	81.4-90.6	≤81.3	≥87.8	78.8-87.7	≤78.7	≥85.0	78.8-84.9	≤78.7
Zero Samples	≥0.2	0.1	0	≥0.2	0.1	0	≥0.2	0.1	0

Blue Ridge Tributary Reservoirs*

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	≤1.3	1.4-2.7	≥2.8	-	-	-	≤1.1	1.2-2.3	≥2.4
Sum of Non Chiron & Oligo Taxa	≤4	5-8	≥9	-	-	-	≤1	2-4	≥5
Non Chiron and Oligo Density	≤66	67-131	≥132	-	-	-	≤3.0	3.1-6.1	≥6.2
Chironomid Density	≤96	97-191	≥192	-	-	-	≤185	186-369	≥370
Percent Oligochaetes	≥57.9	29.0-57.8	≤28.9	-	-	-	≥64.2	32.2-64.1	≤32.1
Dominance	≥95.0	89.8-94.9	≤89.7	-	-	-	≥98.7	97.3-98.6	≤97.2
Zero Samples	≥0.3	0.1-0.2	0	-	-	-	≥0.3	0.1-0.2	0

Table 1a. Cont', Scoring Criteria for Benthic Macroinvertebrate Community; Field Processed Samples, Reservoir Vital Signs Monitoring - 1999

Interior Plateau Tributary Reservoirs*									
Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	≤1.3	1.4-2.6	≥2.7	-	-	-	-	-	-
Sum of Non Chiron & Oligo Taxa	≤1	2-3	≥4	-	-	-	-	-	-
Non Chiron and Oligo Density	≤11.0	11.1-21.0	≥21.1	-	-	-	-	-	-
Chironomid Density	≤205	206-408	≥409	-	-	-	-	-	-
Percent Oligochaetes	≥61	31-60	≤30	-	-	-	-	-	-
Dominance	≥97.7	95.4-97.6	≤95.3	-	-	-	-	-	-
Zero Samples	≥0.3	0.1-0.2	0	-	-	-	-	-	-

Ridge and Valley Tributary Reservoirs*									
Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	≤0.8	0.9-1.7	≥1.8	-	-	-	≤1.5	1.6-3.1	≥3.2
Sum of Non Chiron & Oligo Taxa	≤1	2	≥3	-	-	-	≤2	3-6	≥7
Non Chiron and Oligo Density	≤34	35-68	≥69	-	-	-	≤10.0	10.1-20.0	≥20.1
Chironomid Density	≤100	101-199	≥200	-	-	-	≤321	322-642	≥643
Percent Oligochaetes	≥64.5	33.3-64.4	≤33.2	-	-	-	≥56.0	28.1-55.9	≤28.0
Dominance	≥99.0	97.8-98.9	≤97.7	-	-	-	≥97.0	94.0-96.9	≤93.9
Zero Samples	≥0.3	0.1-0.2	0	-	-	-	≥0.3	0.1-0.2	0

*Two points were added to total score if any EPT were present as long as the adjusted score did not exceed 35.

Table 1b. Scoring Criteria for Benthic Macroinvertebrate Community; Lab Processed Samples, Reservoir Vital Signs Monitoring - 1999

Run-of-the-River Reservoirs									
Benthic Community Metrics	Forebay			Transition Zone			Inflow		
	1	3	5	1	3	5	1	3	5
Taxa Richness	<2.8	2.8-5.5	>5.5	<3.3	3.3-6.6	>6.6	<4.2	4.2-8.3	>8.3
EPT	<0.6	0.6-0.9	>0.9	<0.6	0.6-1.4	>1.4	<0.9	0.9-1.9	>1.9
Long-lived	<0.6	0.6-0.8	>0.8	<0.6	0.6-0.9	>0.9	<0.6	0.6-0.8	>0.8
Percent Oligochaetes	>41.9	41.9-21.0	<21.0	>21.9	21.9-11.0	<11.0	>23.9	23.9-12.0	<12.0
Dominance	>90.3	90.3-81.7	<81.7	>87.9	87.9-77.8	<77.8	>86.2	86.2-73.1	<73.1
Non Chiron & Oligo Density	<125.0	125.0-249.9	>249.9	<305.0	305.0-609.9	>609.9	<400.0	400.0-799.9	>799.9
Zero Samples	>0	-	0	>0	-	0	>0	-	0

Blue Ridge Tributary Reservoirs*									
Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5	1	3	5	1	3	5
Taxa Richness	<1.8	1.8-3.5	>3.5	-	-	-	<1.8	1.8-3.5	>3.5
Sum of Non Chiron & Oligo Taxa	<5	5 - 9	>9				<5	6 - 10	>10
Non Chiron & Oligo Density	<25.0	25.0-49.9	>49.9	-	-	-	<15.0	15.0-29.9	>29.9
Chironomid Density	<91.1	91.1-182.9	>182.9				<167.1	167.1-334	≥334
Percent Oligochaetes	>47.9	47.9-24.0	<24.0	-	-	-	>53.9	53.9-27.0	<27.0
Dominance	>96.0	96.0-92.2	<92.2	-	-	-	>95.5	95.5-92.4	<92.4
Zero Samples	>0	-	0	-	-	-	>0	-	0

Table 1b. Cont', Scoring Criteria for Benthic Macroinvertebrate Community; Lab Processed Samples, Reservoir Vital Signs Monitoring - 1999

Interior Plateau Tributary Reservoirs*

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5	1	3	5	1	3	5
Taxa Richness	<1.7	1.7-3.4	>3.4	-	-	-	-	-	-
Sum of Non Chiron & Oligo Taxa	<6	6 - 10	>10						
Non Chiron & Oligo Density	<25.0	25.0-49.9	>49.9	-	-	-	-	-	-
Chironomid Density	<56.1	56.1-112.0	>112.0						
Percent Oligochaetes	>61.9	61.9-31.0	<31.0	-	-	-	-	-	-
Dominance	>95.3	95.3-91.4	<91.4	-	-	-	-	-	-
Zero Samples	≥0	-	0	-	-	-	-	-	-

Ridge and Valley Tributary Reservoirs*

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5	1	3	5	1	3	5
Taxa Richness	<1.2	1.2-2.4	>2.4	-	-	-	<2.0	2.0-3.9	>3.9
Sum of Non Chiron & Oligo Taxa	<4	4 - 6	>6				<5	6-10	>10
Non Chiron & Oligo Density	<40.0	40.0-79.9	>79.9	-	-	-	<21.0	21.0-41.9	>41.9
Chironomid Density	<82.1	82.1-163.9	>163.9				<218.1	218.1-435.9	>435.9
Percent Oligochaetes	>61.9	61.9-31.0	<31.0	-	-	-	>41.9	41.9-21.0	<21.0
Dominance	>98.3	98.3-97.0	<97.0	-	-	-	>98.1	98.1-96.6	<96.6
Zero Samples	>0	-	0	-	-	-	>0	-	0

*Two points were added to total score if any EPT were present as long as the adjusted score did not exceed 35.

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Forebay Sites

Reservoir	Q	Mile	Year	Score	TAXA		LLIVED		EPT		%OLIGO		DOMN		TOTNONCT		ZEROS	
Chickamauga	Q	472.3	94	31	5.9	5	1	5	0.5	3	26.3	3	78.6	5	298.3	5	0	5
Chickamauga		472.3	94	31	5.3	5	1	5	1	5	13.8	5	82.3	3	151.7	3	0	5
Chickamauga		472.3	95	27	4.3	3	0.9	5	0.4	1	14.9	5	85.3	3	310.0	5	0	5
Chickamauga		472.3	97	29	5.5	5	0.9	5	0.3	1	6.1	5	81.7	3	353.3	5	0	5
Chickamauga		472.3	99	25	5.1	5	0.9	5	0.3	1	15.5	3	84.0	3	141.7	3	0	5
Fort Loudoun		605.5	94	13	3	3	0.1	1	0.1	1	34.6	1	99.3	1	7.6	1	0	5
Fort Loudoun		605.5	95	13	3.2	3	0.1	1	0.1	1	43.1	1	96.5	1	11.7	1	0	5
Fort Loudoun		605.5	96	11	2.9	3	0.1	1	0.1	1	38.0	1	99.5	1	3.3	1	0.1	3
Fort Loudoun	Q	605.5	97	15	2.7	3	0.3	1	0.3	1	20.6	3	99.0	1	41.7	1	0	5
Fort Loudoun		605.5	97	15	3.2	3	0.4	3	0.4	1	38.0	1	99.3	1	30.0	1	0	5
Fort Loudoun		605.5	98	13	3.5	3	0.1	1	0.1	1	32.6	1	98.6	1	5.0	1	0	5
Fort Loudoun		605.5	99	9	2.4	1	0.1	1	0	1	36.3	1	100.0	1	3.3	1	0.1	3
Guntersville		350	94	27	4.9	5	1	5	0.6	3	20.0	3	86.6	3	143.3	3	0	5
Guntersville		350	96	35	6	5	1	5	0.8	5	12.8	5	72.6	5	246.7	5	0	5
Guntersville	Q	350	98	35	7	5	1	5	1	5	5.0	5	74.4	5	283.3	5	0	5
Guntersville		350	98	35	7.1	5	1	5	1.1	5	4.1	5	71.9	5	328.3	5	0	5
Kentucky		7.4	94	19	6.2	5	0.2	1	0	1	5.9	5	94.1	1	60.0	1	0	5
Kentucky		7.4	95	19	4.9	5	0.1	1	0	1	8.7	5	93.5	1	78.3	1	0	5
Kentucky		7.4	97	23	5.6	5	0.5	3	0.1	1	2.4	5	93.7	1	128.3	3	0	5
Kentucky		7.4	99	21	6.3	5	0.3	1	0.3	1	10.6	5	89.6	3	86.7	1	0	5
Kentucky		23	94	27	6	5	0.9	5	0.2	1	25.6	3	81.0	5	173.3	3	0	5
Kentucky		23	95	23	4.4	3	0.7	3	0.2	1	17.4	3	85.4	3	523.3	5	0	5
Kentucky		23	97	27	6	5	0.7	3	0	1	7.2	5	86.3	3	328.3	5	0	5
Kentucky		23	99	21	5	5	0.6	3	0	1	15.1	3	85.7	3	106.7	1	0	5
Melton Hill		24	94	17	3.5	3	0.4	3	0.5	3	15.0	3	94.0	1	18.3	1	0.1	3
Melton Hill	Q	24	96	19	2.5	3	0.3	1	0.5	3	11.0	5	94.0	1	28.3	1	0	5
Melton Hill		24	96	11	2.4	1	0.3	1	0.4	1	18.1	3	98.3	1	18.3	1	0.1	3
Melton Hill		24	98	17	2.9	3	0.6	3	0.6	3	4.1	5	96.9	1	30.0	1	0.2	1
Nickajack	Q	425.5	94	31	4.8	5	0.9	5	1.1	5	11.3	5	82.4	3	151.7	3	0	5
Nickajack		425.5	94	31	4.8	5	0.8	5	1.5	5	4.5	5	82.8	3	138.3	3	0	5
Nickajack	Q	425.5	95	25	3.9	3	0.9	5	0.6	3	14.9	3	82.8	3	196.7	3	0	5
Nickajack		425.5	95	29	4.2	3	0.9	5	0.8	5	16.3	3	76.3	5	171.7	3	0	5
Nickajack		425.5	97	33	5.9	5	1	5	1	5	6.3	5	81.9	3	331.7	5	0	5
Nickajack		425.5	99	35	5.5	5	0.9	5	0.9	5	4.7	5	78.7	5	518.3	5	0	5
Pickwick		8.4	94	17	5	5	0	1	0	1	20.5	3	99.6	1	3.3	1	0	5
Pickwick		8.4	96	15	4.3	3	0.1	1	0	1	20.8	3	96.5	1	13.3	1	0	5
Pickwick		8.4	98	17	3.9	3	0	1	0	1	5.2	5	100.0	1	1.7	1	0	5
Pickwick		207.3	94	29	4.9	5	0.5	3	0.5	3	12.2	5	78.8	5	213.3	3	0	5
Pickwick		207.3	96	29	5	5	0.6	3	0.9	5	14.5	5	84.4	3	228.3	3	0	5
Pickwick		207.3	98	29	4.4	3	1	5	0.7	3	5.4	5	90.2	3	271.7	5	0	5
Tellico		1	94	7	0.8	1	0	1	0	1	55.6	1	100.0	1	0.0	1	0.4	1
Tellico		1	95	7	0.9	1	0	1	0	1	61.9	1	100.0	1	1.7	1	0.3	1
Tellico		1	97	9	1.8	1	0.1	1	0.1	1	28.5	3	98.1	1	11.7	1	0.2	1
Tellico		1	99	7	0.9	1	0.1	1	0	1	48.9	1	100.0	1	1.7	1	0.4	1

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Seperated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Forebay Sites (Con't)

Reservoir	Q	Mile	Year	Score	TAXA		LLIVED		EPT		%OLIGO		DOMN		TOTNONCT		ZEROS	
Watts Bar		531	94	13	3.8	3	0.2	1	0.3	1	24.0	3	92.0	1	20.0	1	0.1	3
Watts Bar	Q	531	96	13	3.1	3	0.2	1	0.4	1	44.4	1	94.8	1	10.0	1	0	5
Watts Bar		531	96	11	3	3	0.1	1	0.1	1	32.7	1	95.2	1	10.0	1	0.1	3
Watts Bar	Q	531	98	15	4.3	3	0.3	1	0.3	1	24.0	3	94.7	1	38.3	1	0	5
Watts Bar		531	98	13	4.1	3	0.2	1	0.2	1	33.1	1	94.8	1	40.0	1	0	5
Wheeler		277	94	19	4.8	5	0.4	3	0	1	19.1	3	93.1	1	41.7	1	0	5
Wheeler		277	95	15	3	3	0.2	1	0	1	15.7	3	95.9	1	21.7	1	0	5
Wheeler		277	97	23	4.8	5	0.6	3	0	1	10.0	5	88.7	3	80.0	1	0	5
Wheeler		277	99	17	3.9	3	0.6	3	0.2	1	19.3	3	92.1	1	70.0	1	0	5
Wheeler	Q	277	99	19	4.2	3	0.5	3	0	1	22.9	3	89.4	3	105.0	1	0	5
Wilson		260.8	94	17	4.6	3	0	1	0	1	9.1	5	94.1	1	78.3	1	0	5
Wilson		260.8	96	15	3.8	3	0	1	0	1	40.4	1	90.1	3	21.7	1	0	5
Wilson		260.8	98	15	4	3	0.2	1	0.1	1	27.1	3	91.9	1	45.0	1	0	5

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Transition Sites

Reservoir	Q	Mile	Year	Score	TAXA		LLIVED		EPT		%OLIGO		DOMN		TOTNONCT		ZEROS	
Chickamauga	Q	8.5	94	17	2.6	3	0.4	3	0.4	3	39.2	1	85.2	3	61.7	1	0.1	3
Chickamauga		8.5	94	17	2.9	3	0.5	3	0.6	3	21.7	3	89.4	1	203.3	1	0.1	3
Chickamauga		8.5	95	27	5.5	5	0.9	5	0.9	5	33.8	1	75.9	5	166.7	1	0	5
Chickamauga		8.5	97	25	5.9	5	0.6	3	0.8	5	37.0	1	78.4	5	191.7	1	0	5
Chickamauga		8.5	99	21	4.6	5	0.6	3	0.6	3	54.3	1	81.7	3	81.7	1	0	5
Chickamauga	Q	490.5	94	33	5.5	5	1	5	1	5	5.0	5	73.7	5	480.0	3	0	5
Chickamauga		490.5	94	33	5.7	5	0.9	5	1	5	10.8	5	70.8	5	373.3	3	0	5
Chickamauga		490.5	95	29	5.4	5	0.9	5	0.9	5	23.0	3	74.6	5	170.0	1	0	5
Chickamauga		490.5	97	31	5.9	5	1	5	0.7	3	10.4	5	69.7	5	428.3	3	0	5
Chickamauga		490.5	99	31	5.5	5	1	5	0.9	5	13.7	5	78.6	5	270.0	1	0	5
Chickamauga	Q	490.5	99	25	5.5	5	1	5	0.3	1	11.9	5	80.3	3	266.7	1	0	5
Fort Loudoun		624.6	94	17	3.9	3	0.4	3	0.4	3	28.6	1	92.8	1	21.7	1	0	5
Fort Loudoun		624.6	95	23	4.9	5	0.7	3	0.7	3	15.3	3	86.2	3	76.7	1	0	5
Fort Loudoun		624.6	96	23	4.6	5	0.4	3	0.4	3	12.7	5	91.0	1	83.3	1	0	5
Fort Loudoun		624.6	97	27	5.5	5	1	5	1	5	12.4	5	89.2	1	140.0	1	0	5
Fort Loudoun	Q	624.6	98	23	4.2	3	0.7	3	0.7	3	2.9	5	85.5	3	91.7	1	0	5
Fort Loudoun		624.6	98	23	4.7	5	0.6	3	0.6	3	5.5	5	91.8	1	96.7	1	0	5
Fort Loudoun		624.6	99	19	5.4	5	0.3	1	0.4	3	5.3	5	92.9	1	58.3	1	0.1	3
Guntersville		375.2	94	33	6.3	5	1	5	1	5	7.4	5	78.8	3	610.0	5	0	5
Guntersville		375.2	96	33	5.5	5	1	5	0.8	5	4.1	5	82.7	3	733.3	5	0	5
Guntersville		375.2	98	33	5.2	5	1	5	1	5	5.6	5	86.2	3	768.3	5	0	5
Kentucky	Q	85	94	27	5.8	5	0.9	5	0.8	5	14.7	3	79.7	3	253.3	1	0	5
Kentucky		85	94	29	5.3	5	1	5	0.8	5	9.9	5	81.0	3	255.0	1	0	5
Kentucky		85	95	29	3.9	3	1	5	0.9	5	1.6	5	85.8	3	433.3	3	0	5
Kentucky	Q	85	97	35	6.1	5	1	5	0.8	5	13.3	5	76.6	5	760.0	5	0	5
Kentucky		85	97	35	6.4	5	1	5	1	5	3.7	5	76.9	5	790.0	5	0	5
Kentucky		85	99	31	6	5	1	5	0.8	5	16.5	3	75.0	5	301.7	3	0	5
Melton Hill		45	94	15	3.2	3	0.3	1	0.3	1	26.0	3	96.7	1	8.3	1	0	5
Melton Hill		45	96	17	3.2	3	0.4	3	0.4	3	41.8	1	90.8	1	26.7	1	0	5
Melton Hill		45	98	17	3.4	3	0.7	3	0.7	3	36.9	1	89.0	1	35.0	1	0	5
Pickwick		230	94	31	6	5	1	5	0.8	5	18.4	3	74.6	5	294.8	3	0	5
Pickwick	Q	230	96	33	5.2	5	0.9	5	0.9	5	3.5	5	80.2	3	758.3	5	0	5
Pickwick		230	96	33	5.2	5	1	5	0.8	5	3.7	5	83.7	3	871.7	5	0	5
Pickwick		230	98	31	5.2	5	1	5	0.8	5	8.5	5	82.8	3	403.3	3	0	5
Tellico		15	94	11	1.5	1	0.3	1	0.3	1	11.3	5	100.0	1	6.7	1	0.2	1
Tellico	Q	15	95	13	1.3	1	0.2	1	0.2	1	8.3	5	100.0	1	3.3	1	0.1	3
Tellico		15	95	15	2	1	0.4	3	0.4	3	33.8	1	99.0	1	10.0	1	0	5
Tellico		15	97	7	1.8	1	0	1	0.2	1	32.6	1	100.0	1	8.3	1	0.2	1
Tellico		15	99	9	0.7	1	0.1	1	0	1	23.3	3	100.0	1	3.3	1	0.5	1
Watts Bar		560.8	94	29	4.5	5	0.9	5	1	5	2.7	5	90.2	1	356.7	3	0	5
Watts Bar		560.8	96	25	4.2	3	0.9	5	0.9	5	1.0	5	89.7	1	148.3	1	0	5
Watts Bar		560.8	98	23	4	3	0.7	3	0.7	3	11.3	5	94.8	1	355.0	3	0	5
Wheeler		6	94	15	4.6	5	0.1	1	0	1	28.4	1	98.9	1	8.3	1	0	5
Wheeler	Q	6	95	13	3.5	3	0	1	0	1	45.2	1	90.4	1	25.0	1	0	5
Wheeler		6	95	13	2.8	3	0	1	0	1	54.5	1	95.2	1	10.0	1	0	5
Wheeler		6	97	15	6	5	0.1	1	0	1	52.0	1	92.3	1	80.0	1	0	5
Wheeler		6	99	15	4.6	5	0	1	0	1	38.9	1	93.0	1	38.3	1	0	5
Wheeler		295.9	94	33	5.6	5	1	5	0.8	5	10.4	5	77.3	5	316.7	3	0	5
Wheeler		295.9	95	25	3.3	3	1	5	0.6	3	6.6	5	82.2	3	131.7	1	0	5
Wheeler		295.9	97	31	5.9	5	1	5	1	5	10.1	5	79.5	3	393.3	3	0	5
Wheeler		295.9	99	31	5.6	5	1	5	0.9	5	3.5	5	83.5	3	511.7	3	0	5

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Inflow Sites

Reservoir	Q	Mile	Year	Score	TAXA		LLIVED		EPT		%OLIGO		DOMN		TOTNONCT		ZEROS	
Chickamauga		518	94	19	2.6	1	1	5	0	1	5.3	5	95.7	1	411.7	1	0	5
Chickamauga	Q	518	95	23	4.5	3	0.9	5	0.3	1	2.9	5	79.5	3	155.5	1	0	5
Chickamauga		518	95	31	6.4	5	0.9	5	1	5	3.5	5	68.1	5	249.1	1	0	5
Chickamauga		518	97	25	5.5	3	1	5	0.5	3	1.5	5	84.8	3	345.6	1	0	5
Chickamauga		518	99	21	3.7	3	0.8	5	0.1	1	2.5	5	86.4	1	222.7	1	0	5
Fort Loudoun		652	94	7	1.2	1	0.1	1	0	1	40.5	1	99.2	1	10.9	1	0.3	1
Fort Loudoun		652	95	11	1.7	1	0	1	0	1	25.0	3	94.7	1	19.1	1	0.1	3
Fort Loudoun		652	96	7	1.4	1	0	1	0	1	59.9	1	97.1	1	11.7	1	0.2	1
Fort Loudoun		652	97	9	2.4	1	0.1	1	0.2	1	24.3	3	90.9	1	73.3	1	0.2	1
Fort Loudoun		652	98	13	2.5	1	0	1	0	1	35.4	3	94.6	1	11.7	1	0	5
Fort Loudoun		652	99	7	1.5	1	0.2	1	0	1	48.2	1	95.8	1	3.3	1	0.2	1
Guntersville		420	94	21	3.3	3	0.9	5	0.1	1	2.0	5	87.3	1	281.8	1	0	5
Guntersville		420	96	27	4.7	3	1	5	0.5	3	3.1	5	84.1	3	629.1	3	0	5
Guntersville		420	98	23	4.1	3	0.9	5	0.6	3	3.6	5	91.0	1	364.5	1	0	5
Kentucky		15	94	23	5.4	3	1	5	0.7	3	18.1	5	86.4	1	214.5	1	0	5
Kentucky		200	94	27	5.2	3	0.9	5	0.4	3	12.7	5	75.8	5	80.9	1	0	5
Kentucky		200	95	21	3.1	3	0.8	5	0	1	0.6	5	88.3	1	92.7	1	0	5
Kentucky	Q	200	97	21	4.3	3	0.8	5	0.3	1	5.5	5	86.8	1	170.9	1	0	5
Kentucky		200	97	27	4.2	3	0.9	5	0.6	3	12.0	5	78.0	5	113.6	1	0	5
Kentucky		200	99	21	3.8	3	1	5	0.3	1	0.2	5	88.0	1	258.3	1	0	5
Melton Hill		58.8	94	11	1.2	1	0	1	0	1	9.0	5	100.0	1	0.0	1	0.2	1
Melton Hill		58.8	96	7	1.5	1	0.1	1	0.2	1	40.0	1	98.4	1	5.5	1	0.2	1
Melton Hill		58.8	98	7	1.8	1	0	1	0	1	43.2	1	93.7	1	2.7	1	0.3	1
Nickajack	Q	469	94	27	5.8	5	1	5	2.1	5	0.0	5	85.3	1	457.3	1	0	5
Nickajack		469	94	31	7.6	5	1	5	2.4	5	0.5	5	82.2	3	693.6	3	0	5
Nickajack		469	95	31	8.5	5	1	5	2.2	5	2.1	5	79.7	3	1086.4	3	0	5
Nickajack		469	97	33	7	5	1	5	1.7	5	1.6	5	82.3	3	1420.0	5	0	5
Nickajack		469	99	29	6.3	5	1	5	0.7	3	1.1	5	79.9	3	591.8	3	0	5
Nickajack	Q	469	99	31	6.1	5	1	5	1	5	4.0	5	77.3	5	436.4	1	0	5
Pickwick	Q	253.2	94	21	3.6	3	0.6	3	0.5	3	10.4	5	91.4	1	183.6	1	0	5
Pickwick		253.2	94	25	4.2	3	0.4	3	1	5	5.4	5	79.7	3	95.5	1	0	5
Pickwick		253.2	96	21	3.8	3	0.7	3	0.6	3	0.7	5	85.4	1	131.8	1	0	5
Pickwick	Q	253.2	98	21	3.6	3	0.9	5	0.3	1	2.2	5	88.9	1	120.0	1	0	5
Pickwick		253.2	98	23	3.7	3	0.9	5	0.5	3	1.0	5	88.1	1	109.1	1	0	5
Watts Bar		19	94	13	1.8	1	0.3	1	0.2	1	0.0	5	96.1	1	38.2	1	0.1	3
Watts Bar		19	96	15	1.4	1	0.1	1	0	1	7.0	5	99.0	1	43.6	1	0	5
Watts Bar		19	98	15	2.1	1	0	1	0.3	1	16.4	5	97.9	1	34.5	1	0	5
Watts Bar		600	94	17	2.9	3	0.2	1	0.2	1	4.3	5	89.9	1	65.5	1	0	5
Watts Bar		600	96	13	2.5	1	0	1	0.6	3	0.2	5	89.2	1	77.3	1	0.2	1
Watts Bar		600	98	15	2.7	1	0.3	1	0.3	1	0.0	5	83.1	3	43.6	1	0.1	3
Wheeler		347	94	31	6.1	5	0.9	5	1	5	0.9	5	68.7	5	308.2	1	0	5
Wheeler		347	95	21	4.5	3	1	5	0.1	1	0.4	5	86.0	1	407.3	1	0	5
Wheeler		347	97	25	5.2	3	1	5	0.7	3	1.1	5	91.9	1	610.0	3	0	5
Wheeler		347	99	23	4.9	3	1	5	0.2	1	0.5	5	90.2	1	580.0	3	0	5
Wilson		273	94	25	5.5	3	1	5	0.6	3	1.9	5	80.4	3	359.7	1	0	5
Wilson	Q	273	96	29	5.2	3	1	5	0.9	5	0.5	5	85.4	1	1295.0	5	0	5
Wilson		273	96	27	4.2	3	1	5	0.6	3	0.2	5	90.8	1	1730.0	5	0	5
Wilson		273	98	33	6	5	1	5	0.8	5	2.7	5	83.7	3	1176.7	5	0	5

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Blue Ridge Ecoregion – Forebay Sites

Reservoir	Q	Mile	Year	SCORE	TAXA		%OLIGO		DOMN		TOTNONC		ZEROS		SumTaxa		XCHI		EPT	
Apalachia		67	96	19	2.4	3	51.7	3	94.3	3	18.3	1	0	5	6	3	51.7	1	0	0
Apalachia		67	97	17	1.6	3	49.1	3	98.9	1	15.0	1	0	5	6	3	8.2	1	0	0
Apalachia		67	98	11	1.2	1	77.8	1	100.0	1	11.7	1	0.1	3	3	1	1.8	1	0.2	2
Apalachia		67	99	17	1.8	3	42.1	3	96.5	1	21.7	1	0.1	3	8	3	22	1	0.1	2
Blue Ridge	Q	54.1	94	21	2.7	3	38.7	3	90.5	3	105.0	3	0.2	3	8	3	80.0	1	0.4	2
Blue Ridge		54.1	94	13	1.5	3	40.5	3	94.8	3	15.0	1	0.5	1	2	1	78.3	1	0	0
Blue Ridge		54.1	95	29	3.5	5	47.4	3	84.6	5	161.7	5	0.1	3	13	5	95.0	1	0.3	2
Blue Ridge		54.1	97	29	4	5	35.1	3	91.2	3	341.7	5	0	5	12	5	62.7	1	0.1	2
Blue Ridge		54.1	99	23	2.4	3	34.5	3	98.1	1	198.3	5	0	5	8	3	32	1	0.1	2
Blue Ridge	Q	54.1	99	23	2.4	3	38.8	3	96.0	1	135.0	5	0.1	3	10	5	17	1	0.1	2
Chatuge		1.5	94	17	1.9	3	23.4	5	98.6	1	4.2	1	0.2	3	3	1	81.7	1	0.1	2
Chatuge		1.5	96	17	1.5	3	40.4	3	98.3	1	6.7	1	0	5	4	1	16.7	1	0.3	2
Chatuge		1.5	98	21	2.4	3	2.1	5	98.4	1	11.7	1	0.1	3	3	1	286.4	5	0.1	2
Chatuge		1.5	99	13	1.3	1	25.0	5	100.0	1	8.3	1	0.3	1	4	1	37	1	0.2	2
Chatuge		122	94	17	1.5	3	45.1	3	100.0	1	5.0	1	0	5	2	1	22.4	1	0.2	2
Chatuge	Q	122	96	7	0.9	1	64.3	1	100.0	1	1.7	1	0.3	1	1	1	5.0	1	0	0
Chatuge		122	96	17	1.6	3	34.1	3	100.0	1	8.3	1	0	5	3	1	33.3	1	0.2	2
Chatuge		122	98	21	2.2	3	6.5	5	100.0	1	3.3	1	0.1	3	1	1	250.9	5	0.1	2
Chatuge		122	99	11	0.9	1	26.7	5	100.0	1	1.7	1	0.5	1	1	1	22	1	0	0
Fontana		62	95	7	0.6	1	86.7	1	100.0	1	3.3	1	0.6	1	2	1	0.0	1	0	0
Fontana		62	96	7	0.2	1	66.7	1	100.0	1	0.0	1	0.9	1	0	1	1.7	1	0	0
Fontana		62	98	9	0.3	1	33.3	3	100.0	1	1.7	1	0.7	1	1	1	0.9	1	0	0
Hiwassee		77	94	7	0.3	1	66.7	1	100.0	1	0.0	1	0.7	1	0	1	1.7	1	0	0
Hiwassee		77	96	9	1	1	75.0	1	99.2	1	25.0	1	0.2	3	2	1	3.3	1	0	0
Hiwassee	Q	77	98	9	1	1	50.0	3	100.0	1	6.7	1	0.3	1	3	1	3.6	1	0	0
Hiwassee		77	98	13	1.5	3	63.9	1	99.0	1	10.0	1	0	5	3	1	5.5	1	0	0
Nottely		23.5	94	17	1.7	3	41.5	3	100.0	1	0.0	1	0.1	3	0	1	200.2	5	0	0
Nottely		23.5	95	15	2.6	3	40.4	3	100.0	1	0.0	1	0.1	3	0	1	126.7	3	0	0
Nottely		23.5	97	15	2.2	3	46.4	3	100.0	1	0.0	1	0	5	0	1	60.9	1	0	0
Nottely		23.5	99	13	1.4	3	45.0	3	100.0	1	0.0	1	0.2	3	0	1	17	1	0	0
Parksville-Ocoee No. 1	Q	12.5	94	7	0.4	1	100.0	1	100.0	1	0.0	1	0.6	1	0	1	0.0	1	0	0
Parksville-Ocoee No. 1		12.5	94	7	0.8	1	82.5	1	100.0	1	3.3	1	0.3	1	1	1	1.7	1	0	0
Parksville-Ocoee No. 1	Q	12.5	95	7	1	1	69.1	1	98.0	1	15.0	1	0.3	1	2	1	3.3	1	0	0
Parksville-Ocoee No. 1		12.5	95	15	1.5	3	63.4	1	96.7	1	18.3	1	0	5	6	3	3.3	1	0	0
Parksville-Ocoee No. 1		12.5	97	17	1.4	3	50.4	3	100.0	1	23.3	1	0.1	3	5	3	3.6	1	0.1	2
Parksville-Ocoee No. 1		12.5	99	9	0.4	1	50.0	3	100.0	1	1.7	1	0.6	1	1	1	2	1	0	0
Watauga		37.4	94	7	0.5	1	60.0	1	100.0	1	1.8	1	0.5	1	2	1	0.0	1	0	0
Watauga		37.4	96	7	1.2	1	69.5	1	100.0	1	6.7	1	0.4	1	1	1	28.3	1	0	0
Watauga		37.4	98	9	1.8	3	84.3	1	100.0	1	0.0	1	0.3	1	0	1	19.1	1	0	0

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Blue Ridge Ecoregion -- Mid-Reservoir Sites

Reservoir	Q	Mile	Year	Score	TAXA		%OLIGO		DOMN		TOTNONCT		ZEROS		SumTaxa		XCHI		EPT	
Fontana		3	94	17	1.9	3	39.1	3	100.0	1	0.0	1	0.2	3	0	1	398.3	5	0	0
Fontana		3	96	9	1.2	3	96.2	1	100.0	1	0.0	1	0.3	1	0	1	11.7	1	0	0
Fontana		3	98	19	3	5	31.1	5	100.0	1	0.0	1	0.1	3	0	1	307.3	3	0	0
Fontana		81.5	94	19	2	3	28.2	5	100.0	1	0.0	1	0.1	3	0	1	402.4	5	0	0
Fontana		81.5	96	11	1.2	3	96.1	1	100.0	1	0.0	1	0.1	3	0	1	6.7	1	0	0
Fontana		81.5	98	15	1.9	3	2.3	5	100.0	1	0.0	1	0.2	3	0	1	169.1	1	0	0
Hiwassee	Q	85	94	9	1.3	3	93.7	1	100.0	1	0.0	1	0.4	1	0	1	65.0	1	0	0
Hiwassee		85	94	9	1	1	63.0	3	100.0	1	0.0	1	0.5	1	0	1	13.3	1	0	0
Hiwassee		85	96	11	1.5	3	90.0	1	99.6	1	3.3	3	0.4	1	1	1	40.0	1	0	0
Hiwassee		85	98	15	1.7	3	45.5	3	97.2	5	1.7	1	0.4	1	1	1	97.3	1	0	0
Nottely	Q	31	94	29	2.2	3	2.9	5	99.3	1	9.1	5	0	5	5	5	237.3	3	0.4	2
Nottely		31	94	29	2.6	5	8.2	5	99.0	1	5.5	3	0	5	6	5	252.7	3	0.2	2
Nottely	Q	31	95	23	1.3	3	24.4	5	95.8	5	1.7	1	0.2	3	1	1	186.7	3	0.1	2
Nottely		31	95	15	1.2	3	37.4	3	100.0	1	1.7	1	0.1	3	1	1	243.3	3	0	0
Nottely	Q	31	97	31	3.4	5	16.9	5	96.1	5	3.3	3	0	5	2	3	202.7	3	0.1	2
Nottely		31	97	21	2.9	5	15.5	5	99.2	1	1.7	1	0	5	1	1	200.0	3	0	0
Nottley		31	99	25	2.5	5	0.5	5	100.0	1	1.7	1	0	5	1	1	553	5	0.1	2
Watauga	Q	45.5	94	19	1.3	3	7.3	5	100.0	1	1.7	1	0.1	3	1	1	386.7	5	0	0
Watauga		45.5	94	21	1.6	3	16.8	5	98.7	1	151.7	5	0.1	3	3	3	151.7	1	0	0
Watauga	Q	45.5	96	19	2.1	3	23.7	5	100.0	1	5.0	3	0.2	3	1	1	308.3	3	0	0
Watauga		45.5	96	13	1.8	3	32.4	3	100.0	1	0.0	1	0.3	1	0	1	291.7	3	0	0
Watauga		45.5	98	11	1.9	3	33.4	3	100.0	1	0.0	1	0.3	1	0	1	46.4	1	0	0

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Interior Plateau Tributary Reservoirs -- Forebay Sites

Reservoir	Q	Mile	Year	Score	TAXA		%OLIGO		DOMN		TOTNONCT		ZEROS		SumTaxa		XCHI		EPT	
Bear Creek		75	94	21	1.8	3	4.1	5	100.0	1	3.3	1	0	5	2	3	100.0	1	0.1	2
Bear Creek		75	95	19	1.8	3	14.6	5	100.0	1	0.0	1	0	5	0	1	213.3	3	0	0
Bear Creek		75	96	17	1.6	3	7.3	5	100.0	1	0.0	1	0	5	0	1	180.0	1	0	0
Bear Creek		75	97	11	1.3	1	47.9	3	100.0	1	0.0	1	0.2	3	0	1	6.4	1	0	0
Bear Creek		75	99	21	1.8	3	6.9	5	100.0	1	0.0	1	0	5	0	1	613	5	0	0
Bear Creek	Q	75	99	21	1.6	3	2.7	5	100.0	1	0.0	1	0	5	0	1	562	5	0	0
Beech		36	94	35	4.3	5	11.9	5	96.5	3	23.3	5	0	5	11	5	801.7	5	0.3	2
Beech		36	95	27	3.1	5	11.0	5	98.7	1	6.7	1	0	5	3	3	535.0	5	0.1	2
Beech	Q	36	96	29	3.1	5	4.2	5	98.2	1	23.3	5	0.1	3	6	5	236.7	3	0.2	2
Beech		36	96	35	3.7	5	4.8	5	93.0	5	38.3	5	0	5	11	5	240.0	3	0.4	2
Beech		36	98	33	3.6	5	5.1	5	97.2	3	23.3	5	0	5	8	5	320.0	3	0.1	2
Cedar Creek		25.2	94	27	2.4	3	25.7	5	96.5	3	31.7	5	0.1	3	5	5	68.3	1	0.3	2
Cedar Creek		25.2	95	11	1.2	1	5.7	5	100.0	1	0.0	1	0.3	1	0	1	71.7	1	0	0
Cedar Creek		25.2	96	17	1.6	3	31.8	3	100.0	1	3.3	1	0.1	3	2	3	66.7	1	0.1	2
Cedar Creek		25.2	97	15	1.5	3	13.9	5	100.0	1	0.0	1	0.1	3	0	1	49.1	1	0	0
Cedar Creek		25.2	99	29	2	3	4.8	5	97.5	3	15.0	3	0	5	5	5	213	3	0.1	2
Little Bear Cr	Q	12.5	94	21	1.9	3	76.7	1	99.7	1	30.0	5	0	5	2	3	123.3	1	0.1	2
Little Bear Cr		12.5	94	15	2.2	3	65.7	1	99.3	1	10.0	1	0	5	1	1	48.3	1	0.2	2
Little Bear Cr		12.5	95	15	3.9	5	72.1	1	100.0	1	1.7	1	0.1	3	1	1	41.7	1	0.1	2
Little Bear Cr		12.5	96	17	1.4	3	83.6	1	96.9	3	15.0	3	0.1	3	3	3	15.0	1	0	0
Little Bear Cr	Q	12.5	97	15	1.7	3	90.1	1	99.4	1	1.7	1	0	5	1	1	15.5	1	0.1	2
Little Bear Cr		12.5	97	9	1.3	1	86.9	1	100.0	1	0.0	1	0.1	3	0	1	13.6	1	0	0
Little Bear Creek		12.5	99	19	2	3	78.6	1	97.3	3	11.7	3	0	5	2	3	63	1	0	0
Normandy		249.5	94	15	1.4	3	47.1	3	100.0	1	0.0	1	0	5	0	1	26.7	1	0	0
Normandy	Q	249.5	95	7	0.7	1	81.7	1	100.0	1	0.0	1	0.4	1	0	1	5.0	1	0	0
Normandy		249.5	95	7	0.9	1	73.4	1	100.0	1	0.0	1	0.3	1	0	1	13.3	1	0	0
Normandy		249.5	96	13	1.7	3	66.3	1	99.3	1	1.7	1	0	5	1	1	30.0	1	0	0
Normandy		249.5	98	19	2.5	3	19.0	5	100.0	1	0.0	1	0.1	3	0	1	419.1	5	0	0
Upper Bear Creek		115.4	98	23	2.5	3	45.2	3	100.0	1	36.7	5	0	5	2	3	322.7	3	0	0

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Ridge and Valley Ecoregion Tributary Reservoirs -- Forebay Sites

Reservoir	Q	Mile	Year	Score	TAXA		%OLIGO		DOMN		TOTNONCT		ZEROS		SumTaxa		XCHI		EPT	
Boone		19	94	17	2.4	5	86.4	1	98.6	3	1.7	1	0	5	1	1	43.0	1	0	0
Boone		19	95	11	1.1	3	99.6	1	100.0	1	1.7	1	0.1	3	1	1	1.7	1	0	0
Boone	Q	19	97	11	1.5	3	78.0	1	100.0	1	1.7	1	0.1	3	1	1	17.3	1	0	0
Boone		19	97	13	1.4	3	90.0	1	100.0	1	3.3	1	0.2	3	2	3	8.2	1	0	0
Boone		19	99	15	2.1	5	68.4	1	98.4	3	1.7	1	0.1	3	1	1	23	1	0	0
Cherokee		53	94	25	2.4	5	43.7	3	99.6	1	3.3	1	0	5	2	3	200.0	5	0.1	2
Cherokee		53	95	19	2.2	5	51.5	3	100.0	1	0.0	1	0.1	3	0	1	290.0	5	0	0
Cherokee		53	96	17	1.9	5	55.6	3	100.0	1	0.0	1	0.1	3	0	1	103.3	3	0	0
Cherokee	Q	53	98	21	2.1	5	14.6	5	100.0	1	0.0	1	0.2	3	0	1	234.5	5	0	0
Cherokee		53	98	21	2.5	5	25.3	5	100.0	1	0.0	1	0.2	3	0	1	297.3	5	0	0
Douglas		33	94	17	2.2	5	56.6	3	100.0	1	0.0	1	0.1	3	0	1	125.0	3	0	0
Douglas		33	95	11	1.5	3	81.5	1	100.0	1	0.0	1	0.2	3	0	1	48.3	1	0	0
Douglas		33	97	21	2.5	5	47.2	3	100.0	1	0.0	1	0	5	0	1	206.4	5	0	0
Douglas		33	99	19	2	5	20.3	5	100.0	1	0.0	1	0.3	1	0	1	268	5	0	0
Douglas	Q	33	99	19	1.8	5	20.4	5	100.0	1	0.0	1	0.3	1	0	1	247	5	0	0
Ft Pat Henry		8.7	94	19	2.3	5	54.8	3	99.6	1	1.7	1	0	5	1	1	133.3	3	0	0
Ft Pat Henry		8.7	95	15	1.9	5	72.6	1	100.0	1	0.0	1	0	5	0	1	33.3	1	0	0
Ft Pat Henry		8.7	96	17	1.8	5	61.0	3	100.0	1	3.3	1	0	5	1	1	35.0	1	0	0
Ft Pat Henry		8.7	97	15	2.5	5	55.2	3	100.0	1	0.0	1	0.1	3	0	1	51.8	1	0	0
Ft. Pat Henry		8.7	99	19	2.6	5	31.7	5	100.0	1	0.0	1	0.1	3	0	1	120	3	0	0
Norris		80.4	94	19	1.3	3	77.4	1	99.0	1	40.9	3	0	5	3	5	2.7	1	0	0
Norris	Q	80.4	95	21	1.1	3	78.9	1	100.0	1	101.7	5	0	5	3	5	0.0	1	0	0
Norris		80.4	95	21	1.2	3	73.0	1	100.0	1	65.0	3	0	5	4	5	0.0	1	0.1	[illegible]
Norris		80.4	97	25	2.2	5	68.7	1	97.7	5	8.3	1	0	5	3	5	21.8	1	0.[illegible]	[illegible]
Norris		80	99	13	1.1	3	66.7	1	100.0	1	5.0	1	0.1	3	2	3	5	1	0	[illegible]
South Holston		51	94	19	1.3	3	73.5	1	96.6	5	4.5	1	0.3	1	3	5	10.9	1	0.1	2
South Holston	Q	51	96	7	0.7	1	85.7	1	100.0	1	0.0	1	0.3	1	0	1	3.3	1	0	0
South Holston		51	96	9	0.5	1	73.7	1	100.0	1	3.3	1	0.6	1	2	3	0.0	1	0	0
South Holston		51	98	7	0.4	1	75.0	1	100.0	1	0.0	1	0.6	1	0	1	0.9	1	0	0
Tims Ford		135	94	7	0.8	1	92.5	1	100.0	1	0.0	1	0.4	1	0	1	3.3	1	0	0
Tims Ford		135	95	11	0.9	3	81.3	1	100.0	1	0.0	1	0.2	3	0	1	3.3	1	0	0
Tims Ford		135	96	11	0.9	3	80.0	1	100.0	1	0.0	1	0.2	3	0	1	6.7	1	0	0
Tims Ford	Q	135	98	7	0.8	1	90.5	1	100.0	1	0.0	1	0.3	1	0	1	3.6	1	0	0
Tims Ford		135	98	9	0.8	1	100.0	1	100.0	1	0.0	1	0.2	3	0	1	0.0	1	0	0

Table 2. Results and Ratings for individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Ridge and Valley Ecoregion Tributary Reservoirs -- Mid-Reservoir Sites

Reservoir	Q	Mile	Year	Score	TAXA		%OLIGO		DOMN		TOTNONCT		ZEROS		SumTaxa		XCHI		EPT	
Boone		6.5	94	13	2	3	76.7	1	100.0	1	0.0	1	0	5	0	1	32.1	1	0	0
Boone		6.5	95	9	1.3	1	83.9	1	100.0	1	1.7	1	0.1	3	1	1	8.3	1	0	0
Boone		6.5	97	13	2.4	3	74.5	1	98.8	1	1.7	1	0	5	1	1	43.6	1	0	0
Boone		6.5	99	9	1.5	1	65.4	1	100.0	1	0.0	1	0.1	3	0	1	20	1	0	0
Boone		27	94	15	2.2	3	47.6	3	99.7	1	0.9	1	0	5	1	1	123.6	1	0	0
Boone		27	95	11	1.7	3	60.5	1	100.0	1	0.0	1	0.1	3	0	1	70.0	1	0	0
Boone		27	97	9	2.1	3	57.1	1	99.5	1	1.7	1	0.3	1	1	1	108.2	1	0	0
Boone		27	99	15	2.4	3	41.9	3	99.1	1	6.7	1	0.2	3	3	3	48	1	0	0
Cherokee		76	96	15	2.3	3	13.6	5	100.0	1	0.0	1	0.1	3	0	1	198.3	1	0	0
Cherokee		76	98	19	3.6	5	4.1	5	100.0	1	0.0	1	0	5	0	1	272.7	1	0	0
Douglas		51	94	17	2.1	3	27.9	5	100.0	1	0.0	1	0	5	0	1	150.0	1	0	0
Douglas		51	95	15	1.9	3	36.1	3	100.0	1	0.0	1	0	5	0	1	118.3	1	0	0
Douglas	Q	51	97	19	3.6	5	14.8	5	100.0	1	0.0	1	0	5	0	1	300.9	1	0	0
Douglas		51	97	17	3.1	3	9.3	5	99.7	1	3.3	1	0	5	1	1	275.5	1	0	0
Douglas		51	99	21	2.8	3	2.6	5	100.0	1	0.0	1	0	5	0	1	675	5	0	0
Norris		30	94	31	3.9	5	40.3	3	95.7	3	28.3	5	0	5	7	5	365.0	3	0.1	2
Norris		30	95	23	1.9	3	39.7	3	90.8	5	23.3	5	0.2	3	6	3	40.0	1	0	0
Norris		30	97	27	4.2	5	25.7	5	97.1	1	25.0	5	0	5	9	5	273.6	1	0	0
Norris		30	99	33	4.2	5	7.6	5	96.9	3	30.0	5	0	5	7	5	963	5	0	0
Norris	Q	30	99	33	4	5	8.7	5	98.6	1	30.0	5	0	5	8	5	895	5	0.1	2
Norris		125	94	25	3.1	3	22.9	5	98.8	1	11.7	3	0	5	4	3	373.3	3	0.2	2
Norris		125	95	19	2.8	3	30.9	3	96.5	3	13.3	3	0.1	3	3	3	143.3	1	0	0
Norris		125	97	23	3.6	5	21.8	5	97.0	1	18.3	3	0.1	3	6	3	375.5	3	0	0
Norris		125	99	23	4.6	5	4.7	5	99.4	1	8.3	1	0.1	3	4	3	725	5	0	0
South Holston		62.5	94	15	2.7	3	30.9	3	99.3	1	1.8	1	0	5	1	1	70.5	1	0	0
South Holston		62.5	96	7	0.8	1	66.7	1	100.0	1	0.0	1	0.3	1	0	1	6.7	1	0	0
South Holston	Q	62.5	98	11	2	3	30.2	3	100.0	1	0.0	1	0.3	1	0	1	130.0	1	0	0
South Holston		62.5	98	13	3.1	3	30.3	3	100.0	1	0.0	1	0.2	3	0	1	150.9	1	0	0
Tims Ford		150	94	11	0.7	1	25.0	5	100.0	1	0.0	1	0.4	1	0	1	16.7	1	0	0
Tims Ford		150	95	7	0.6	1	66.7	1	100.0	1	0.0	1	0.4	1	0	1	8.3	1	0	0
Tims Ford		150	96	7	0.9	1	76.1	1	100.0	1	0.0	1	0.4	1	0	1	10.0	1	0	0
Tims Ford		150	98	9	1.1	1	57.4	1	100.0	1	0.0	1	0.1	3	0	1	10.9	1	0	0

Table3. Results and Ratings for Individual Metrics and Final Benthic Scores for QA/QC Samples Processed in the Laboratory

Tributary Reservoirs																									
CLASS	AREA	RESERVOIR	MILE	YEAR	LAB SCORE	Taxa		SumTaxa		EPT		%OLIGO		DOMN		TOTNONC/O		ZERO		Xchi	
BR	Forebay	Blue Ridge	54.1	99	27	3.4	3	11	5	0.1	2	41.5	1	92.8	1	188.3	5	0	5	63.3	5
IP	Forebay	Bear Creek	75	99	23	2.6	3	4	1	0.1	2	8.3	5	98.7	1	6.7	1	0	5	736.7	5
RV	Forebay	Douglas	33	99	17	2.2	3	2	1	0	0	14.6	5	99.6	1	5	1	0.1	1	316.7	5
RV	Mid-Res	Norris	30	99	27	4.1	5	7	3	0	0	14.4	5	98.3	1	35	3	0	5	1272	5

Run-of-River Reservoirs																			
CLASS	AREA	RESERVOIR	Mile	YEAR	LAB SCORE	TAXA		LLIVED		EPT		%OLIGO		DOMN		TOTNONC/O		ZERO	
Main	Forebay	Wheeler	277	99	19	2.8	3	0.6	3	0.2	1	11.8	5	92.6	1	70	1	0	5
Main	Transition	Chickamauga	490.5	99	23	5.4	3	1	5	0.9	3	27.6	1	76.1	5	285	1	0	5
Main	Inflow	Nickajack	469	99	27	7.7	3	1	5	1.4	3	0.8	5	75	3	776.4	3	0	5

Table 4. Benthic Community Scores for 1994 through 1999 Based on Field Processed Samples Collected in Late Autumn/Early Winter and Scored Against 1999 Criteria

Run-of-the-River Reservoirs

Reservoir		Mile	1994*	1995*	1996*	1997*	1998*	1999*
Chickamauga	Forebay	472.3	31	27	.	29	.	25
Chickamauga	Transition	490.5	33	29	.	31	.	31
Chickamauga	Inflow	518	19	31	.	25	.	21
Chickamauga	Embayment	8.5	17	27	.	25	.	21
Fort Loudoun	Forebay	605.5	13	13	11	15	13	9
Fort Loudoun	Transition	624.6	17	23	23	27	23	19
Fort Loudoun	Inflow	652	7	11	7	9	13	7
Guntersville	Forebay	350	27	.	35	.	35	.
Guntersville	Transition	375.2	33	.	33	.	33	.
Guntersville	Inflow	420	21	.	27	.	23	.
Kentucky	Forebay	23	27	23	.	27	.	21
Kentucky	Transition	85	29	29	.	35	.	31
Kentucky	Inflow	200	27	21	.	27	.	21
Kentucky	Embayment	7.4	19	19	.	23	.	21
Melton Hill	Forebay	24	17	.	11	.	17	.
Melton Hill	Transition	45	15	.	17	.	17	.
Melton Hill	Inflow	58.8	11	.	7	.	7	.
Nickajack	Forebay	425.5	31	29	.	33	.	35
Nickajack	Inflow	469	31	31	.	33	.	29
Pickwick	Forebay	207.3	29	.	29	.	29	.
Pickwick	Transition	230	31	.	33	.	31	.
Pickwick	Inflow	253.2	25	.	21	.	23	.
Pickwick	Embayment	8.4	17	.	15	.	17	.
Tellico	Forebay	1	7	7	.	9	.	7
Tellico	Transition	15	11	15	.	7	.	9
Watts Bar	Forebay	531	13	.	11	.	13	.
Watts Bar	Transition	560.8	29	.	25	.	23	.
Watts Bar	Inflow	19	13	.	15	.	15	.
Watts Bar	Inflow	600	17	.	13	.	15	.
Wheeler	Forebay	277	19	15	.	23	.	17
Wheeler	Transition	295.9	33	25	.	31	.	31
Wheeler	Inflow	347	31	21	.	25	.	23
Wheeler	Embayment	6	15	13	.	15	.	15
Wilson	Forebay	260.8	17	.	15	.	15	.
Wilson	Inflow	273	25	.	27	.	33	.

*Note: Results for all years are scored on 1999 scoring protocols. Scores for 1991 - 1993 are excluded from this table because they are based on lab processed results.

Evaluation Criteria:

Benthic Community Score	7-12	13-18	19-23	24-29	30-35
Community Condition	Very Poor	Poor	Fair	Good	Excellent

Table 4. Cont.'

Blue Ridge Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*	1998*	1999*
Apalachia	Forebay	67	.	.	19	17	11	17
Blue Ridge	Forebay	54.1	13	29	.	29	.	23
Chatuge	Forebay	122	17	.	17	.	21	11
Chatuge	Forebay	1.5	17	.	17	.	21	13
Fontana	Forebay	62	7	.	9	.	13	.
Fontana	Mid-reservoir	81.5	19	.	11	.	15	.
Fontana	Mid-reservoir	3	17	.	9	.	19	.
Hiwassee	Forebay	77	7	.	9	.	13	.
Hiwassee	Mid-reservoir	85	9	.	11	.	15	.
Nottely	Forebay	23.5	17	15	.	15	.	13
Nottely	Mid-reservoir	31	29	15	.	21	.	25
Parksville	Forebay	12.5	7	15	.	17	.	9
Watauga	Forebay	37.4	7	.	7	.	9	.
Watauga	Mid-reservoir	45.5	21	.	13	.	11	.

Interior Plateau Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*	1998*	1999*
Bear Creek	Forebay	75	21	19	17	11	.	21
Beech Lake	Forebay	36	35	27	35	.	33	.
Cedar Creek	Forebay	25	27	11	17	15	.	29
Little Bear Cr.	Forebay	12.5	15	15	17	9	.	19
Normandy	Forebay	249.5	15	7	13	.	19	.

Ridge and Valley Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*	1998*	1999*
Boone	Forebay	19	17	11	.	13	.	15
Boone	Mid-reservoir	27	15	11	.	9	.	15
Boone	Mid-reservoir	6.5	13	9	.	13	.	9
Cherokee	Forebay	53	25	19	17	.	21	.
Cherokee	Mid-reservoir	76	.	.	15	.	19	.
Douglas	Forebay	33	17	11	.	21	.	19
Douglas	Mid-reservoir	51	17	15	.	17	.	21
Fort Pat. Henry	Forebay	8.7	19	15	17	15	.	19
Norris	Forebay	80.4	19	21	.	25	.	13
Norris	Mid-reservoir	125	25	19	.	23	.	23
Norris	Mid-reservoir	30	31	23	.	27	.	33
South Holston	Forebay	51	19	.	9	.	7	.
South Holston	Mid-reservoir	62.5	15	.	7	.	13	.
Tims Ford	Forebay	135	7	11	11	.	9	.
Tims Ford	Mid-reservoir	150	11	7	7	.	9	.

*Note: Results for all years are scored on 1999 scoring protocols. Scores for 1991 - 1993 are excluded from this table because they are based on lab processed results.

Evaluation Criteria:

Benthic Community Score	7-12	13-18	19-23	24-29	30-35
Community Condition	Very Poor	Poor	Fair	Good	Excellent

Section 6. Fish Community

Philosophical Approach/Background

Many of the same considerations discussed for the benthic macroinvertebrate community (Section 5) also apply for the fish community. These are repeated here, as appropriate, in case the reader does not have access to that information.

Fish are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have a long life cycle which allows them to integrate conditions over time. In streams, fish community monitoring often has found environmental degradation when physical and chemical monitoring have failed to do so. Fish are also important to the public for aesthetic, recreational, and commercial reasons.

Reservoir fish communities are vastly different from that in the river prior to impoundment due to significant habitat alterations. Also, differences are expected along a longitudinal gradient with a more riverine community expected at the upper end or inflow of a reservoir and a more lacustrine community expected in the pool near the dam. Other factors to consider in evaluating biotic communities in reservoirs include reservoir operational characteristics (e.g., water depth, water level fluctuation, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability, and depth of withdrawal for discharge) and physical/chemical features owing to geological characteristics of different ecoregions.

All these factors, plus the fact that a reservoir is an artificial system, must be considered in selecting community characteristics or expectations that will be used to evaluate aquatic resource conditions. Given that reservoirs are artificial systems, it is not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to determine characteristics or expectations of a reservoir unaffected by human impacts. By definition, IBI specifies reference conditions should be developed from natural, unaltered habitats (Karr and Dudley, 1981 after Frey 1975). Therefore, other approaches must be used; such as, using historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. Like benthic macroinvertebrates, the state of the understanding of fish communities in reservoirs simply is insufficient for models to effectively predict species composition and relative abundance. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment as the best approach. Use of best observed conditions requires an extensive database to determine expectations for each metric, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept, results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed conditions. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided later in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only those in the same ecoregion and comparable physical characteristics should be compared. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 31 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics. Fish assemblage expectations for each metric (discussed later) have been developed for each of these four reservoir categories.

	Tributary Reservoirs		
Run-of-River Reservoirs	Blue Ridge Ecoregion	Ridge & Valley Ecoregion	Interior Plateau Ecoregion
Kentucky	Apalachia	Cherokee	Tims Ford
Pickwick	Hiwassee	Ft. Patrick Henry	Normandy
Wilson	Chatuge	Boone	Bear Creek
Wheeler	Nottely	South Holston	Little Bear Creek
Guntersville	Parksville	Douglas	Cedar Creek
Nickajack	Blue Ridge	Norris	Beech
Chickamauga	Fontana		
Watts Bar	Watauga		
Fort Loudoun			
Tellico			
Melton Hill			

Sample Collection Methods

Shoreline electrofishing samples were collected during daylight hours from forebay and transition (mid-reservoir) zones of most reservoirs during autumn (September through November 1999). In addition, inflow areas (generally the tailwater area of the upstream data) were sampled on most run-of-the river reservoirs. Only the forebay was sampled on very small reservoirs or reservoirs where zones were indistinguishable. Location of collection sites in 1999 are identified in Section 1, Table 1.

A total of 15 electrofishing runs, each covering 300m of shoreline, was collected from each of the sampled zones. All habitats were sampled in proportion to their occurrence in the zone. Twelve experimental gill nets with five 6.1m panels (mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7 cm) were set for one overnight period in forebay and transition zones. Excessive current prevented use of gill nets in mainstream inflow areas limiting sampling to only electrofishing in these locations. Nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets.

Total length (mm) and weight (g) were obtained for sport species and channel catfish. Remaining species captured were enumerated prior to release. During electrofishing, fish observed but not captured were included if positive identification could be made and counts were estimated when high densities of identifiable fish were encountered. Young-of-year fish were counted separately and, as in stream IBI calculations (Karr 1981), were excluded from proportional and abundance metrics due to sampling inefficiencies. Only fish examined closely as a result of obtaining length and weight measurements were inspected externally for signs of disease, parasites, and anomalies. Other species groups often included several individuals which were observed, but not captured, thus the ratio of diseased, etc. was not obtainable for these groups. Natural hybrids (i.e., those known not to be part of a fisheries management program) were included as an anomaly. Field data loggers or data sheets were used to record all results.

It is important for a monitoring program to demonstrate that the data it produces are reproducible. This is particularly true in this case because it is necessary to use two field crews so all the required sampling can be completed within the desired time frame to minimize seasonal effects—generally the reservoirs to be monitored in a particular year are split equally between the two crews. To evaluate the reproducibility of the RFAI results, 15 - 20 percent of the sites to be monitored in a particular year are selected to be resampled as part of the Quality Control program. An attempt is made to select sites representative of all reservoir classes and reservoir reaches. Selected sites are revisited by a second field crew several days or weeks after the initial sampling to collect a second set of samples. A RFAI score is then developed separately for each of the two sample sets. In 1999, 7 of the 38 sites monitored were selected for resampling as part of the Quality Control program. For a variety of reasons (primarily because of a very tight schedule), only 6 sites were revisited.

Reservoir Fish Assemblage Index (RFAI)

The RFAI uses 12 fish community metrics from five general categories (Hickman and McDonough, 1995). The 12 metrics include:

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.
2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.
3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and suitable sediment quality in littoral areas.
4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs.
5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.
6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.

7. **Percentage dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.

9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners spawn over rocky substrate and do not provide parental care. This guild is expected to be sensitive to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

Fish Health

12. **Percentage individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Establishing scoring criteria (i.e., expectations or reference conditions) requires a substantial data base for each class of reservoir and assumes the data base contains reservoirs with conditions ranging from poor to good for each metric. The smaller the number of reservoirs within a class, the less likely these assumptions can be met and the greater the need for sound professional judgment based on extensive knowledge of reservoir communities being studied. One way to help alleviate this problem is to use several years of results from reservoirs within a class. This not only helps establish baseline conditions for each reservoir, but also has the desirable effect of increasing the data base from which scoring criteria can be developed. However, care must be taken to keep this time period as short as possible; otherwise, constantly changing criteria will prevent recognition of improvements or degradation, if they occur. This potential problem was realized as this monitoring program was being conceived. As a result, it was decided that the maximum desired period to establish baseline conditions and provide the data base to develop scoring criteria would be five years, assuming variations of low, normal, and high flows were experienced in that time frame. This proved to be the case. In practice, scoring criteria for RAFI metrics were reevaluated each year from 1990 through 1994 as new data were added. Scoring criteria have not been adjusted since 1994.

In developing scoring criteria, a slightly different approach was used for species richness metrics than for abundance and proportional metrics. For species richness metrics, a list was made of all species collected from comparable locations within a reservoir class from 1990 - 1994. This species list was adjusted using inferences of experienced biologists knowledgeable of the reservoir system, resident fish species, susceptibility of each species to collection methods being used, and effects of human-induced impacts on these species. This effort resulted in a list of the maximum number of species expected to occur at a sampling location and be captured by collection devices in use. Given that only one collection effort is exerted each year, this maximum number of species would not be expected to be represented in that one collection. Therefore, the range from zero to 95% of the maximum was trisected to provide the three scoring ranges (good, fair, and poor). Although even 95% of the maximum number of species at a site would not be expected to be collected in one sampling event, this "high" expectation was adopted to keep these metrics conservative in light of potential uncertainties introduced by relying heavily on professional judgment.

Scoring criteria for proportional metrics and the abundance metric were determined by trisecting observed ranges after omitting outliers. Next, cutoff points between the three ranges were adjusted based on examination of frequency distributions of observed data for each metric along with professional judgment. In some cases, the narrow range of observed conditions required further adjustment based on knowledge of metric responses to human-induced impacts observed in other reservoir classes. Scoring criteria for the fish health metric are those described by Karr et.al. (1986). Scoring criteria are detailed in Table 1.

Scoring criteria are used to separate results for each metric into three categories assumed to represent relative degrees of condition of the fish assemblage ranging from good to poor. Each category has a corresponding value: good = 5; fair = 3; and poor = 1. The sum of the 12 metrics constitutes the RFAI score.

Scoring criteria were applied differently to results from the two collections methods (electrofishing and experimental gill netting) depending on the type metric. For the taxa richness, reproductive composition, and fish health metrics, sampling results were pooled prior to scoring. For abundance and proportional metrics, electrofishing and gill netting results were scored separately, then the two scores averaged to arrive at a final metric value.

To arrive at an evaluation of the condition of the fish assemblage at a sample location, scores were evaluated as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Community Condition	Very Poor	Poor	Fair	Good	Excellent

The contribution of the fish community results for each sample site to the overall reservoir Ecological Health Index was as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Contribution to Reservoir Ecological Health Index	1	2	3	4	5

Fish assemblage results along with results from the other four indicators and overall the ecological health score for each reservoir are used to keep the public informed on the conditions of Tennessee Valley reservoirs. In publications intended for the public, results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good), yellow (fair), or red (poor). This necessitated dividing the RFAI scores into three ranges as follows:

RFAI Score	12-28	29-44	45-60
Color	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1999 Monitoring

RFAI scores for 1990 through 1999 are summarized by reservoir class and type of location in Table 2. (Note: 10 electrofishing runs were used from 1990 to 1992 and 15 were used from 1993 to 1999.) Appendix D summarizes results and ratings for individual metrics and final RFAI scores for each sample location based on 1999 data. Appendix E provides mean catch per effort by species for electrofishing and gill netting efforts at each location in 1999.

An important step in evaluating results is to determine the reproducibility of the RFAI scores. The RFAI scores from the original and repeat sampling form the basis of this comparison as described above. The first step in evaluating the QC results is to determine the magnitude of difference between the two scores which is acceptable. We have chosen 10 (out of a maximum RFAI score of 60) as the desired maximum difference between the two sample sets. A difference greater than this could cause the RAFI to change two rating categories (e.g., very poor-1 point to fair-3 points or fair-3 points to good-5 points). A shift of two categories in the RFAI could cause a change of 2 points contributed to the overall Reservoir Ecological Health Score. For reservoirs with only one sample location, a 2 point change translates into a change of 8.8 percent change in the Ecological Health Score, which is deemed unacceptable.

Comparison of Scores from Initial and Repeat Sampling in 1999:

	Initial Score	QC Score	Difference
Run-of-the-River Reservoirs			
Wheeler Transition Zone	30[a] (Poor)	41[b] (Good)	11
Chickamauga Transition Zone	41[a] (Good)	40[b] (Fair)	1
Nickajack Inflow	46[a] (Good)	54[b] (Excellent)	8
Tributary Reservoirs			
Blue Ridge Ecoregion			
Blue Ridge Forebay	(Site included for re-sampling per QA plan, but re-sampling did not occur.)		
Ridge and Valley Ecoregion			
Douglas Forebay	42[b] (Good)	30[a] (Poor)	12
Norris Mid-Reservoir	53[b] (Excellent)	41[a] (Good)	12
Interior Plateau Ecoregion			
Bear Creek Forebay	44[a] (Good)	47[b] (Good)	3

a. = Crew A; b = Crew B

The maximum observed difference in RAFI scores between the original and repeat collection efforts was 12 (2 sample sets). Only 3 of the 6 QA sample sets had a difference less than the desired maximum of 10. The mean difference for all reservoirs in 1999 and associated 95 percent confidence limits were 7.8±5.0 (2.8 - 12.8). Means and 95 percent confidence limits for other years are shown below.

Year	Maximum Observed Difference	Mean	95% CL	Lower Limit	Upper Limit
1994	10	2.6	± 1.8	0.8	4.3
1995	6	3.1	± 1.9	1.2	5.0
1996	12	4.4	± 3.5	0.8	8.0
1997	14	4.3	± 5.5	-1.2	9.8
1998	16	5.3	± 4.9	0.4	10.2
1999	12	7.8	± 5.0	2.8	12.8

Differences in scores from repeat sample sets were greater in 1999 than in any previous year. Half of the sample sets as well as the 95% confidence limits exceeded the desired maximum of 10 points. Mean differences were relatively low in 1994 and 1995. There was a slight increase in 1996 and 1997, yet the differences were still acceptable. Results for 1998 marked the first time that the upper limit of the 95% CL included 10, the maximum difference deemed acceptable. Discussion of the greater differences in 1998 QC results focused on differences in repeat sample sets at run-of-river-reservoir inflow sites because the maximum difference between replicate sets of samples in 1996, 1997, and especially 1998 occurred at those sites each year, whereas, this had not been the case in 1994 and 1995.

1994 Pickwick Inflow	Difference = 2
1995 Chickamauga Inflow	Difference = 4
1996 Wilson Inflow	Difference = 12
1997 Kentucky Inflow	Difference = 14
1998 Pickwick Inflow	Difference = ~~18~~ 16
1999 Nickajack Inflow	Difference = 8

The tendency toward a greater difference in repeat sample sets from the inflow site did not hold true in 1999. Rather, of the three sites which had a difference greater than 10, two were on tributary reservoirs where inflows are not sampled and the other was from a run-of-river-reservoir transition zone site. The only consistent observation on the 1999 repeat scores was that the lower of the paired scores always came from the same field crew. There are a variety of implications from this observation, all of which will be taken into consideration prior to initiating the monitoring cycle in 2000 in an effort to eliminate as many sources of differences between the two crews as possible. However, the immediate issue deals with the 1999 RFAI scores – are they reliable? One way to address this question is to compare the 1999 results to the long-term results for each site. Basically, all things being equal, there should be no bias for either higher or lower scores compared to past results. Crew A sampled 9 reservoirs with a total of 18 sites in 1999. Of those 18 sites, 10 had a RFAI score within the long-term range, 8 sites had RFAI scores lower (generally by one point) than had ever been measured before, and none of the sites had a score in 1999 which exceeded the highest found to date. Crew B also sampled 9 reservoirs with a combined total of 20 sites in 1999. Of those 20 sites, 16 had a RFAI score within the long-term range, one site had a score lower than had ever been measured before, and 3 sites had a score in 1999 which exceeded the highest found to date.

This tally indicates that Crew B did not have a bias, yet Crew A did have a slight negative (lower score) bias. The next step in this process is determine if this bias in the RFAI scores has important implications to the overall ecological health scores for those 9 reservoirs sampled by Crew A.

The 18 sites at which Crew A conducted fish assemblage sampling in 1999 were distributed among the 9 reservoirs as follows: 1 site each on Apalachia, Bear Creek, Little Bear Creek, Cedar Creek, and Parksville reservoirs, 2 sites on Nickajack Reservoir; 3 sites on Chickamauga Reservoir (Crew B sampled the 4th site on Chickamauga); and 4 sites each on Kentucky and Wheeler reservoirs. Five of these 9 reservoirs had RFAI scores similar to past years indicating little, if any, potential impact of the possible bias on the overall ecological health scores. These 5 reservoirs include Bear Creek, Cedar Creek, Chickamauga, Kentucky, and Little Bear Creek. For the remaining 4 reservoirs (Apalachia, Nickajack, Parksville, and Wheeler), RFAI scores were generally lower than in past years. For each site in each of these reservoirs, the RFAI was lower than in the past by one scoring category (e.g., "Fair" in 1999 compared to a long-term average in the "Good" category). A shift of one rating category would decrease the contribution of RFAI to the overall reservoir ecological score by 1 point per site. When this difference is figured into the overall reservoir ecological health score, it would have had the potential to reduce the score for Apalachia and Parksville by 4 points (each of these have one sample location so 1 point divided by 22.5 maximum points = 0.04 or 4 percentage points); for Wheeler Reservoir by 5 points (1 point for each of 4 sample locations divided by maximum of 77.5 points = 0.05 or 5 percentage points); and for Nickajack Reservoir 6 points (1 point for each of 2 sample locations divided by maximum of 32.5 points = 0.05 or 6 percentage points).

As discussed above and detailed in Section 1, the overall ecological health score is divided into three categories - Poor (scores 22.5 - 58); Fair (scores 59 - 72); and Good (scores (73 - 100). If the percentage points described above for each reservoir were added to the reservoir ecological health score for 1999 and compared to these categories, only one reservoir (Parksville) would change categories:

Reservoir	Initial 1999 Score / Initial Category	RFAI Points to Add	New Reservoir Score / New Category
Apalachia	59 - Fair	4	63 - Fair
Parksville	58 - Poor	4	62 - Fair
Wheeler	60 - Fair	5	65 - Fair
Nickajack	85 - Good	6	91 - Good

From this evaluation it appears that RFAI scores for a few reservoirs may have been negatively influenced by the possible bias of one field crew. Fortunately, the magnitude of influence was relatively small and buffered by the other four indicators. As a result, the influence on the possible bias on the overall reservoir ecological scores was negligible when compared to the ultimate rating categories of Good-Fair-Poor.

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Table 1. Scoring criteria for forebay and transition sections of mainstream reservoirs in the Tennessee River valley. Lower mainstream reservoirs include: Kentucky, Pickwick, Wilson and Wheeler Reservoirs. Upper mainstream reservoirs include: Guntersville, Nickajack, Chickamauga, Watts Bar and Fort Loudoun Reservoirs. Other reservoirs include: Melton Hill and Tellico Reservoirs.

			Scoring Criteria					
			Forebay			Transition		
Metric	Reservoir Group	Gear	1	3	5	1	3	5
1. Number of species	Lower mainstream	Combined	<14	14-27	>27	<16	16-30	>30
	Upper mainstream	Combined	<14	14-27	>27	<15	15-29	>29
	Other reservoirs	Combined	<13	13-24	>24	<13	13-26	>26
2. Number of Lepomid sunfish species	Lower mainstream	Combined	<2	2-3	>3	<2	2-3	>3
	Upper mainstream	Combined	<2	2-4	>4	<2	2-4	>4
	Other reservoirs	Combined	<2	2-4	>4	<2	2-4	>4
3. Number of sucker species	Lower mainstream	Combined	<4	4-6	>6	<4	4-7	>7
	Upper mainstream	Combined	<4	4-7	>7	<4	4-7	>7
	Other reservoirs	Combined	<4	4-6	>6	<4	4-6	>6
4. Number of intolerant species	Lower mainstream	Combined	<2	2-4	>4	<3	3-4	>4
	Upper mainstream	Combined	<2	2-4	>4	<2	2-4	>4
	Other reservoirs	Combined	<2	2-3	>3	<2	2-4	>4
5. Percent tolerant individuals	All	Electrofishing	>45%	20-45%	<20%	>50%	25-50%	<25%
	All	Gill netting	>40%	20-40%	<20%	>40%	20-40%	<20%
6. Percent dominance	All	Electrofishing	>60%	40-60%	<40%	>60%	40-60%	<40%
	All	Gill netting	>50%	30-50%	<30%	>50%	30-50%	<30%
7. Number of piscivore species	Lower mainstream	Combined	<4	4-7	>7	<4	4-7	>7
	Upper mainstream	Combined	<4	4-7	>7	<4	4-7	>7
	Other reservoirs	Combined	<4	4-7	>7	<4	4-7	>7
8. Percent omnivores	All	Electrofishing	>45%	20-45%	<20%	>50%	25-50%	<25%
	All	Gill netting	>45%	30-45%	<30%	>45%	30-45%	<30%
9. Percent invertivores	All	Electrofishing	<35%	35-70%	>70%	<30%	30-60%	>60%
	All	Gill netting	<5%	5-15%	>15%	<7%	7-15%	>15%
10. Number of Lithophilic spawning species	Lower mainstream	Combined	<4	4-6	>6	<4	4-7	>7
	Upper mainstream	Combined	<3	3-6	>6	<4	4-7	>7
	Other reservoirs	Combined	<4	4-7	>7	<4	4-7	>7
11. Total number of individuals	All	Electrofishing	<50	50-100	>100	<50	50-100	>100
	All	Gill netting	<15	15-35	>35	<15	15-35	>35
12. Percent anomalies	All	Combined	<2%	2-5%	>5%	<2%	2-5%	>5%

Table 1, continued. Scoring criteria for inflow sections of Mainstream Reservoirs in the Tennessee River valley. Lower mainstream reservoirs include: Kentucky, Pickwick, Wilson and Wheeler Reservoirs. Upper mainstream reservoirs include: Guntersville, Nickajack, Chickamauga, Watts Bar and Fort Loudoun Reservoirs.

			Scoring Criteria		
Metric	Reservoir Group	Gear	1	3	5
1. Number of species	Lower mainstream	Electrofishing	<14	14-27	>27
	Upper mainstream	Electrofishing	<14	14-27	>27
	Melton Hill	Electrofishing	<13	13-24	>24
2. Number of Lepomid sunfish species	Lower mainstream	Electrofishing	<2	2-4	>4
	Upper mainstream	Electrofishing	<3	3-4	>4
	Melton Hill	Electrofishing	<3	3-4	>4
3. Number of sucker species	Lower mainstream	Electrofishing	<4	4-7	>7
	Upper mainstream	Electrofishing	<3	3-6	>6
	Melton Hill	Electrofishing	<3	3-6	>6
4. Number of intolerant species	Lower mainstream	Electrofishing	<3	3-6	>6
	Upper mainstream	Electrofishing	<2	2-4	>4
	Melton Hill	Electrofishing	<2	2-4	>4
5. Percent tolerant individuals	All	Electrofishing	>55%	30-55%	<30%
6. Percent dominance	All	Electrofishing	>60%	40-60%	<40%
7. Number of piscivore species	Lower mainstream	Electrofishing	<4	4-7	>7
	Upper mainstream	Electrofishing	<3	3-6	>6
	Melton Hill	Electrofishing	<4	4-7	>7
8. Percent omnivores	All	Electrofishing	>55%	30-55%	<30%
9. Percent invertivores	All	Electrofishing	<25%	25-50%	>50%
10. Number of Lithophilic spawning species	Lower mainstream	Electrofishing	<4	4-7	>7
	Upper mainstream	Electrofishing	<4	4-7	>7
	Melton Hill	Electrofishing	<3	3-5	>5
11. Total number of individuals	All	Electrofishing	<50	50-100	>100
12. Percent anomalies	All	Electrofishing	<2%	2-5%	>5%

Table 1, continued. Scoring criteria for reservoirs in the Interior Plateau Ecoregion of the Tennessee River valley. Other reservoirs include: Beech, Bear Creek, Little Bear Creek, and Cedar Creek Reservoirs.

			Scoring Criteria					
			Forebay			Transition		
Metric	Reservoir Group	Gear	1	3	5	1	3	5
1. Number of species	Normandy	Combined	<8	8-17	>17	<8	8-17	>17
	Tims Ford	Combined	<10	10-20	>20	<11	11-20	>20
	Other reservoirs	Combined	<10	10-19	>19			
2. Number of Lepomid sunfish species	Normandy	Combined	<2	2-3	>3	<2	2-3	>3
	Tims Ford	Combined	<2	2-3	>3	<2	2-3	>3
	Other reservoirs	Combined	<2	2-3	>3			
3. Number of sucker species	Normandy	Combined	<3	3-4	>4	<2	2-2	>2
	Tims Ford	Combined	<4	4-6	>6	<4	4-6	>6
	Other reservoirs	Combined	<3	3-5	>5			
4. Number of intolerant species	Normandy	Combined	<2	2-2	>2	<2	2-2	>2
	Tims Ford	Combined	<2	2-2	>2	<2	2-2	>2
	Other reservoirs	Combined	<2	2-2	>2			
5. Percent tolerant individuals	All	Electrofishing	>30%	15-30%	<15%	>30%	15-30%	<15%
	All	Gill netting	>35%	20-35%	<20%	>35%	20-35%	<20%
6. Percent dominance	All	Electrofishing	>60%	40-60%	<40%	>60%	40-60%	<40%
	All	Gill netting	>50%	30-50%	<30%	>50%	30-50%	<30%
7. Number of piscivore species	Normandy	Combined	<3	3-6	>6	<3	3-6	>6
	Tims Ford	Combined	<4	4-6	>6	<4	4-6	>6
	Other reservoirs	Combined	<3	3-6	>6			
8. Percent omnivores	All	Electrofishing	>25%	10-25%	<10%	>25%	10-25%	<10%
	All	Gill netting	>60%	40-60%	<40%	>60%	40-60%	<40%
9. Percent invertivores	All	Electrofishing	<60%	60-80%	>80%	<50%	50-70%	>70%
	All	Gill netting	<3%	3-6%	>6%	<3%	3-6%	>6%
10. Number of Lithophilic spawning species	Normandy	Combined	<3	3-6	>6	<3	3-6	>6
	Tims Ford	Combined	<4	4-6	>6	<4	4-6	>6
	Other reservoirs	Combined	<3	3-6	>6			
11. Total number of individuals	All	Electrofishing	<40	40-80	>80	<40	40-80	>80
	All	Gill netting	<10	10-18	>18	<10	10-18	>18
12. Percent anomalies	All	Combined	<2%	2-5%	>5%	<2%	2-5%	>5%

Table 1, continued. Scoring criteria for reservoirs in the Ridge and Valley Ecoregion of the Tennessee River valley.

		Scoring Criteria					
		Forebay			Transition		
Metric	Gear	1	3	5	1	3	5
1. Number of species	Combined	<10	10-19	>19	<11	11-20	>20
2. Number of Lepomid sunfish species	Combined	<2	2-3	>3	<2	2-3	>3
3. Number of sucker species	Combined	<3	3-5	>5	<3	3-6	>6
4. Number of intolerant species	Combined	<2	2-2	>2	<2	2-2	>2
5. Percent tolerant individuals	Electrofishing	>30%	15-30%	<15%	>30%	15-30%	<15%
	Gill netting	>50%	30-50%	<30%	>50%	30-50%	<30%
6. Percent dominance	Electrofishing	>60%	40-60%	<40%	>60%	40-60%	<40%
	Gill netting	>50%	30-50%	<30%	>50%	30-50%	<30%
7. Number of piscivore species	Combined	<3	3-6	>6	<4	4-6	>6
8. Percent omnivores	Electrofishing	>25%	10-25%	<10%	>25%	10-25%	<10%
	Gill netting	>60%	40-60%	<40%	>60%	40-60%	<40%
9. Percent invertivores	Electrofishing	<60%	60-80%	>80%	<50%	50-70%	>70%
	Gill netting	<3%	3-6%	>6%	<3%	3-6%	>6%
10. Number of Lithophilic spawning species	Combined	<2	2-4	>4	<3	3-6	>6
11. Total number of individuals	Electrofishing	<40	40-80	>80	<40	40-80	>80
	Gill netting	<15	15-30	>30	<15	15-30	>30
12. Percent anomalies	Combined	<2%	2-5%	>5%	<2%	2-5%	>5%

Table 1, continued. Scoring criteria for reservoirs in the Blue Ridge Ecoregion of the Tennessee River valley.

		Scoring Criteria					
		Forebay			Transition		
Metric	Gear	1	3	5	1	3	5
1. Number of species	Combined	<8	8-15	>15	<8	8-15	>15
2. Number of Lepomid sunfish species	Combined	<2	2-3	>3	<2	2-3	>3
3. Number of sucker species	Combined	<2	2-3	>3	<2	2-3	>3
4. Number of intolerant species	Combined	<2	2-2	>2	<2	2-2	>2
5. Percent tolerant individuals	Electrofishing	>30%	15-30%	<15%	>30%	15-30%	<15%
	Gill netting	>20%	10-20%	<10%	>20%	10-20%	<10%
6. Percent dominance	Electrofishing	>60%	40-60%	<40%	>60%	40-60%	<40%
	Gill netting	>50%	30-50%	<30%	>50%	30-50%	<30%
7. Number of piscivore species	Combined	<3	3-5	>5	<3	3-5	>5
8. Percent omnivores	Electrofishing	>10%	5-10%	<5%	>10%	5-10%	<5%
	Gill netting	>30%	15-30%	<15%	>30%	15-30%	<15%
9. Percent invertivores	Electrofishing	<75%	75-85%	>85%	<75%	75-85%	>85%
	Gill netting	<3%	3-6%	>6%	<3%	3-6%	>6%
10. Number of Lithophilic spawning species	Combined	<3	3-4	>4	<3	3-4	>4
11. Total number of individuals	Electrofishing	<30	30-60	>60	<30	30-60	>60
	Gill netting	<10	10-18	>18	<10	10-18	>18
12. Percent anomalies	Combined	<2%	2-5%	>5%	<2%	2-5%	>5%

Table 2. Summary of RFAI Scores for 1990-1999 Based on 1994 Scoring Methods.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Apalachia	Forebay	.	.	.	.	.	.	32	27	36	26
Bear Creek	Forebay	.	.	47	45	44	38	48	45	.	44
Beech Lake	Forebay	.	.	.	.	29	27	28	.	32	.
Blue Ridge	Forebay	.	40	37	39	42	44	.	36	.	45
Boone	Forebay	.	30	35	24	34	35	.	32	.	32
	Mid-res. So. Holston	.	41	30	36	36	27	.	36	.	34
	Mid-res. Watauga	.	34	34	34	37	39	.	40	.	31
Cedar Creek	Forebay	.	.	42	41	50	44	48	51	.	42
Chatuge	Forebay	.	35	43	40	43	.	36	.	28	40
	Shooting Creek	.	.	.	40	39	.	41	.	25	38
Cherokee	Forebay	38	42	35	42	38	37	32	.	36	.
	Mid-reservoir	39	36	34	38	38	32	35	.	32	.
Chickamauga	Forebay	45	44	46	45	41	47	.	38	.	41
	Inflow	48	48	42	56	52	44	38	52	.	44
	Transition	45	45	41	51	43	50	44	40	.	41
	Sequoyah	.	.	.	.	.	.	48	.	.	43
	Hiw. R. Embayment	.	.	.	48	42	39	.	44	.	47
Douglas	Forebay	41	33	39	40	42	36	.	46	.	42
	Mid-reservoir	41	42	38	43	44	37	.	49	.	[illegible]
Fontana	Forebay	.	.	.	42	43	.	29	.	37	
	Mid-res. L'Tenn. R.	.	.	.	44	42	37	36	.	47	.
	Mid-res. Tuck. River	.	.	.	40	40	33	40	.	41	.
Fort Loudoun	Forebay	39	35	41	41	37	36	33	42	49	46
	Inflow	40	32	24	34	36	32	26	22	40	46
	Transition	33	33	33	34	38	27	38	37	41	40
	Little R. Embayment	.	.	.	.	.	35	.	.	.	.
Fort Patrick Henry	Forebay	.	.	.	46	33	20	26	27	.	26
Guntersville	Forebay	42	46	39	46	30	.	44	.	39	.
	Inflow	52	46	40	38	42	.	46	.	32	.
	Transition	40	33	40	38	35	.	36	.	30	.
Hiwassee	Forebay	.	42	39	48	52	.	51	.	49	.
	Mid-reservoir	.	49	40	47	43	.	50	.	47	.
Kentucky	Forebay	37	44	38	42	38	41	.	41	.	39
	Embayment	.	.	.	31	31	28	.	34	.	32
	Inflow	44	46	36	38	34	36	.	38	.	42
	Transition	48	44	49	44	43	42	.	44	.	40
Little Bear Creek	Forebay	.	.	42	45	46	42	46	52	.	47
Melton Hill	Forebay	37	42	31	40	49	.	41	.	51	.
	Inflow	40	20	18	22	28	.	36	.	36	.
	Transition	40	36	30	43	43	.	38	.	41	

Table 2. Continued

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Nickajack	Forebay	46	45	36	49	45	44	.	35	.	34
	Inflow	54	48	48	58	50	54	.	46	.	46
	Transition	43	40	.	.	.	.	.	.	.	.
Normandy	Forebay	.	.	41	53	48	45	58	.	53	.
	Mid-reservoir	.	.	51	.	.	.	.	.	.	.
Norris	Forebay	33	34	34	34	43	31	.	38	.	38
	Mid-res. Clinch River	44	40	43	47	51	39	.	45	.	51
	Mid-res. Powell River	48	48	44	48	52	41	.	45	.	53
Nottely	Forebay	.	37	35	37	38	36	.	35	42	39
	Mid-reservoir	.	.	.	40	37	37	.	43	41	39
Parksville-Ocoee no 1	Forebay	.	32	36	34	42	37	.	37	.	25
Pickwick	Forebay	43	40	34	50	43	.	42	.	44	.
	Bear Cr. Embayment	.	.	.	42	44	.	51	.	40	.
	Inflow	48	44	42	50	46	.	48	.	42	.
	Transition	45	45	40	47	47	.	53	.	37	.
South Holston	Forebay	.	34	39	51	43	.	42	.	47	.
	Mid-reservoir	.	41	40	44	44	.	39	.	40	.
Tellico	Forebay	37	38	36	36	47	37	.	45	.	46
	Transition	36	31	31	41	44	37	.	46	.	45
Tims Ford	Forebay	.	.	40	46	50	33	42	.	46	.
	Mid-reservoir	.	.	48	51	47	49	44	.	49	.
Upper Bear Creek	Forebay	.	.	31	34	.	.	.	.	31	.
Watauga	Forebay	.	33	29	30	31	.	37	.	26	.
	Mid-reservoir	.	32	31	42	35	.	43	.	46	.
Watts Bar	Forebay	42	42	35	39	43	.	41	.	44	39
	Inflow Tennessee	34	40	42	38	46	.	40	.	50	.
	Inflow Clinch	46	40	34	44	40	.	48	.	46	.
	Transition	46	46	44	53	46	.	42	.	48	.
Wheeler	Forebay	40	43	40	49	41	50	.	41	.	39
	Inflow	44	44	40	44	48	42	.	50	.	36
	Transition	40	36	31	47	43	37	.	38	.	30
	Elk River Embayment	.	.	.	41	50	39	.	46	.	38
Wilson	Forebay	33	44	39	44	45	.	42	.	47	.
	Inflow	38	38	46	54	40	.	46	.	44	.

Table 3. Core Fish Species List with Trophic Guild, Tolerance, and Reproductive Designations* for use in Reservoir Fish Assemblage Index (RAFI) for TVA Reservoirs

Species	Tropic Guild	Tolerance	Lithophilic Spawner
Chestnut Lamprey	PS		L
Spotted Gar	PI		
Longnose Gar	PI	TOL	
Shortnose Gar	PI	TOL	
Bowfin	PI		
American Eel	PI		
Skipjack Herring	PI	INT	
Gizzard Shad	OM	TOL	
Threadfin Shad	PL		
Mooneye	IN		L
Chain Pickerel	PI		
Central Stoneroller	HB		
Common Carp	OM	TOL	
Goldfish	OM	TOL	
Silver Chub	IN	INT	
Golden Shiner	OM	TOL	
Emerald Shiner	IN		
Ghost Shiner	IN		
Spotfin Shiner	IN		
Mimic Shiner	IN	INT	
Steelcolor Shiner	IN		
Pugnose Minnow	IN		
Bluntnose Minnow	OM		
Fathead Minnow	OM		
Bullhead Minnow	IN		
River Carpsucker	OM		
Quillback	OM		
Northern Hog Sucker	IN	INT	L
Smallmouth buffalo	OM		
Bigmouth Buffalo	PL		
Black Buffalo	OM		
Spotted Sucker	IN	INT	L
Silver Redhorse	IN		L
Shorthead Redhorse	IN		L
River Redhorse	IN	INT	L
Black Redhorse	IN	INT	L
Golden Redhorse	IN		

Table 3. Continued

Species	Tropic Guild	Tolerance	Lithophilic Spawner
Blue Catfish	OM		
Black Bullhead	OM	TOL	
Yellow Bullhead	OM	TOL	
Brown Bullhead	OM	TOL	
Channel Catfish	OM		
Flathead Catfish	PI		
Blackstripe Topminnow	IN		
Blackspotted Topminnow	IN		
Mosquitofish	IN	TOL	
Brook Silverside	IN		
White Bass	PI		L
Yellow Bass	PI		L
Rock Bass	PI	INT	
Redbreast Sunfish	IN	TOL	
Green Sunfish	IN	TOL	
Warmouth	IN		
Orangespotted Sunfish	IN		
Bluegill	IN		
Longear Sunfish	IN	INT	
Redear Sunfish	IN		
Spotted Sunfish	IN		
Smallmouth Bass	PI		
Spotted Bass	PI		
Largemouth Bass	PI		
White Crappie	PI		
Black Crappie	PI		
Yellow Perch	IN		
Logperch	IN		L
Sauger	PI		L
Walleye	PI		L
Freshwater Drum	IN		

*Designations:

Trophic Guild: HB = Herbivore; PS = Parasitic; PL = Planktivore; OM = Omnivore
IN = Insectivore: PI = Piscivore

Tolerance: TOL = Tolerant; INT = Intolerant

Lithophilic Spawning Species = L