FINAL REPORT

BATIE SPRINGS: ASSESSMENT AND RESTORATION

BY

CATHIA FRAGO
TAMIM YOUNOS
AIDA MENDEZ
TERRI BROWN

SUBMITTED TO

VIRGINIA DIVISION OF SOIL AND WATER CONSERVATION

VIRGINIA WATER RESOURCES RESEARCH CENTER
10 SANDY HALL
VIRGINIA TECH
BLACKSBURG, VA 24061

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EXECUTIVE SUMMARY

The objectives of this study were to evaluate water quality problems associated with the Batie West and Batie East Springs and Batie Creek (Lee County, Virginia), and to make recommendations for the restoration of the creek. This goal was achieved by evaluating existing data available from various sources, a literature review, expert interviews, and limited water/sediment sampling and analyses for Batie Creek.

Batie Creek drains a portion of The Cedars, which is one of the Commonwealth's seven most significant karst regions identified by the Virginia Cave Board. Prior to the early 1980s, the Thompson Cedar Cave which provides water to Batie Springs was noted for its diverse and profuse aquatic life, including the isopod *Lirceus usdagalun,* an endangered crustacean species. During the late 1980s and early 1990s, researchers documented the progressive decline and disappearance of most of the original aquatic fauna in the Batie ecosystem. The number of tubificid worms, chironomid flies, and frogs increased significantly during this time. The decrease in biological diversity and increase in numbers of a few species indicate that the ecosystem was adversely impacted by nonpoint source pollution. Today, both the Batie West and East Springs and the creek formed at their confluence are characterized with a strong rotting odor, sludge deposits on their banks, and filamentous growth.

The major land use change responsible for the spring degradation occurred in 1985, when a sawmill operation moved to a site that surrounds the entrance of the Thompson Cedar Cave. By 1987, sawdust and other wood debris had been disposed of over the cave, blocking its entrance and contributing to the environmental degradation of the cave and the Batie West Spring. After an agreement with the Virginia Cave Board in 1988, the operators removed the sawdust from the cave entrance and constructed a clay berm to prevent direct entrance of sawdust to the cave. The condition of the springs has not improved noticeably since that time, however, due to the large concentration of sawdust stockpiled at the site.

The following parameters (from available data and limited additional analyses) were considered to characterize the existing condition of the springs and the creek, and to make recommendations for restoration: flow rate, turbidity, alkalinity, pH, conductivity, temperature, dissolved oxygen, TSS, TDS, COD, BOD, TOC, nitrogen, phosphorus, metals, pesticides, hydrocarbons, and tannins. For comparison purposes, analyses for several leachate seeps and sludge samples obtained in the vicinity of the springs are reported as well. The major findings of this report are summarized below.

The Batie West Spring is characterized as having a relatively low flow, bacterial slime, a heavy growth of sewage fungus on its substrate, and near zero levels of dissolved oxygen. The Batie East Spring has a more rapid flow rate, an average dissolved oxygen concentration of about 7.2 mg/L, and some filamentous growth on its bottom.

Average turbidity, alkalinity, and pH for both springs are within the normal ranges for limestone areas. The Batie West Spring was found to have a high concentration of organic matter derived from woody materials and not from animal waste or domestic sewage. The concentrations of nitrogen and phosphorus in the Batie West Spring were relatively low but in the range likely to cause eutrophication of Batie Creek.

Grab samples of the water and sediment of the Batie West and East Springs were tested for metals, pesticides, and hydrocarbons. Leachate from the old and new sawmill sites were also tested for these parameters.

It was found that the Batie West and East Springs are generally not contaminated with pesticides and hydrocarbons although storm sampling was not attempted. With the exception of iron and manganese, metal concentrations were comparable with those at background levels in nearby surface water streams sampled as control points. These springs are not currently used as a public or private source of drinking water. The metal concentrations in the Batie West and East Springs are well below the Virginia Water Control Board's criteria levels to protect aquatic life and human health.

Sediment samples from the Batie West and East Springs were found to be equal to, or below, background concentrations for cadmium, copper, and chromium. The springs' sediments were analyzed for cadmium, copper, chromium, nickel, zinc and lead in this study. Pre-existing background data for the sawmill leachate indicate that antimony, arsenic, beryllium, iron, magnesium, manganese, selenium, silver, thallium, and mercury concentrations were comparable to those in control samples. Lead, nickel, and zinc were not tested in the background samples.

The same data from above were used to determine whether the sediment or the leachate from the sawdust piles was contaminated for disposal purposes. It was determined that the sediment in the Batie West and East Springs was not contaminated at hazardous levels. Leachate from the old sawmill site (Mason Sinkhole) contained elevated levels of barium and manganese. Leachate from the new sawmill site contained elevated levels of barium only. Samples from both sites tested negative for pesticides. Both leachates contained dissolved petroleum levels below regulatory action levels.

Evaluation of the available data suggests that the loss of organism diversity, the rotting odors, and the overall degradation of Batie creek and adjacent caves is most likely a result of a high organic carbon content from woody materials and a low dissolved oxygen level. The decrease in species diversity observed in the cave and Batie Creek directly corresponds to the change in land use and subsequent decrease in groundwater and surface water quality.

Various physical and chemical techniques for remediating Batie Creek were reviewed. Based on available water and sediment analyses, and required conditions for organic matter decomposition, especially sawdust, dredging appears to be the most suitable and applicable restoration technique. An estimated 300 to 450 kg of bottom material would need to be dredged. However, in order to dredge the creek, a permit from the Virginia DEQ and the Virginia Army Corps of Engineers is required. Since Batie Creek discharges to the Powell River, which has been designated as an endangered species habitat, a permit from the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission would also be required. If dredging is selected as a remedial option, it is recommended that a joint permit application be filed with the agencies that have jurisdiction.

In addition, the massive sawdust piles, which are the source of the pollution problem, would need to be removed. Several wood products manufacturers located within 100 miles of the site may utilize the relatively new sawdust. The piles have been estimated to contain about 200,000yd^3 of decomposing sawdust. The sawdust that is deemed not usable by the wood waste users should be disposed of at a permitted landfill or compost facility. The determination of whether it would be classified as hazardous waste or solid waste would depend on the TCLP (Toxic Characteristic Leaching Potential) test. This analysis has not been conducted on the piles to date. However, since their leachate had contaminant concentrations that were close to background levels (with the exception of barium for which no background levels were available) it is likely that the piles would be classified as solid waste. In addition, generator knowledge might be helpful in determining the types and sources of materials that may be present in the sawdust.

TABLE OF CONTENTS

EXECUTIVE SUMMARY .... **I**

LIST OF FIGURES .... **IV**

LIST OF TABLES .... **V**

1. SITE DESCRIPTION **1**

1.1. BACKGROUND 1
1.2. LAND USE CLOSE TO BATIE SPRINGS 3
1.3 GEOLOGY AND TOPOGRAPHY 4
1.4 GROUNDWATER HYDROLOGY 5

2. BIOASSAYS AND WATER QUALITY STUDIES IN BATIE CREEK'S WATERSHED **6**

3. BIOLOGICAL AND QUALITATIVE INFORMATION **7**

4. PHYSICO-CHEMICAL PARAMETERS MEASURED IN BATIE CREEK AND ITS VICINITY **8**

4.1. FLOW RATE 8
4.2. DISSOLVED OXYGEN (DO), CHEMICAL OXYGEN DEMAND (COD), BIOCHEMICAL OXYGEN DEMAND (BOD), TOTAL ORGANIC CARBON (TOC), TANNINS AND CONDUCTIVITY (EC) 9
4.3. TURBIDITY, TOTAL DISSOLVED SOLIDS (TDS), AND TOTAL SUSPENDED SOLIDS (TSS) 15
4.4. FECAL AND TOTAL COLIFORM 16
4.5. ALKALINITY AND pH 17
4.6. WATER TEMPERATURE 17
4.7. NITROGEN AND PHOSPHORUS FORMS 18
4.8. METALS 19
4.8.1. Total Metal concentrations in Russell and Mason leachates *19*
4.8.2. Sediment and aquatic metal concentrations in Batie West and East *22*
4.9. PESTICIDES 29
4.10. HYDROCARBONS: VOLATILE, SEMIVOLATILE, DIESEL AND GASOLINE RANGE ORGANIC COMPOUNDS 29
4.11. OTHER POLLUTANTS AND POLLUTANT SOURCES 29
4.12. TOXICITY 29

5. REMEDIATION ALTERNATIVES **30**

5.1. SEDIMENT DREDGING OPERATIONS 31
5.1.1. Determination of sediment contamination for protection of aquatic life and human health *31*
5.1.2. Determination of sediment contamination for disposal purposes *31*
5.1.3. Sediment Dredging as a source of contamination *32*

6. SAWDUST DISPOSAL **32**

7. SAWDUST RECYCLING AND REUSE **35**

8. PROSPECTS FOR RECOVERY **37**

9. RECOMMENDATIONS **37**

10. LITERATURE CITED/LITERATURE CONSULTED **38**

APPENDIX A - HYDROGEOLOGIC INFORMATION

APPENDIX B - ENDANGERED AND THREATENED SPECIES

LIST OF FIGURES

Figure 1. Batie Creek's Watershed. 2
Figure 2. Dissolved Oxygen levels in Batie Creek 13
Figure 3. Dissolved Oxygen levels in Batie West and East compared to other water bodies in the watershed. 14
Figure 4. Background sediment metal concentrations 23
Figure 5. Average concentration of total metals in Batie East and West compared to background levels and other water bodies in the watershed. 24

LIST OF TABLES

Table 1. Estimated (Low)Flow Rates in the eastern half of The Cedars 9
Table 2. Summary of Historic Indicators measured at Batie West. 9
Table 3. Summary of Historic indicators measured at Batie East. 10
Table 4. Temperature, Dissolved Oxygen, pH and Conductivity at various sampling sites in the vicinity of Batie Creek. 10
Table 5. Dissolved Oxygen Profile of Batie Creek at various distances from the Confluence of Batie East and West. 11
Table 6. Total Dissolved, Suspended Solids Concentration and Turbidity in Batie West 16
Table 7. Suspended Solids Concentration and Turbidity in Batie 16
Table 8. Alkalinity and pH measured in Batie West Spring. 17
Table 9. pH measured in Batie East Spring. 17
Table 10. Water Temperature in Batie West. 18
Table 11. Water Temperature in Batie East. 18
Table 12. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN) and Phosphate values 18
Table 13. Eutrophication Potential of Rivers as a Function of Nutrient Concentration (DEQ, 1997c) 19
Table 14. Metals in Mason Sinkhole and Russell leachate. 21
Table 15. Total Metal Concentration in the Sediment (mg/Kg) 25
Table 16. Dissolved Metal Concentration in Water (µg/L). 25
Table 17. Batie East Average Dissolved Metal Concentrations vs. Criteria Values based on an average hardness of 208 mg/L as $CaCO_3$. 26
Table 18. Batie West Average Dissolved Metal Concentrations vs. Criteria Values based on an average hardness of 347 mg/L as $CaCO_3$. 26
Table 19. Dissolved Metal Concentration in Batie East 27
Table 20. Dissolved Metal Concentration in Batie West[40] 28
Table 21. Wood-Waste users located within 100 miles of Lee County. 34

1. Site Description

Batie Creek's watershed lies between 36°38'00"-36°45'00"N and 83°02'30" - 83°12'00"W. The watershed is located on the Hubbard Springs and Ben Hur 7.5 minutes Series topographic quadrangle maps (Figure 1). It is approximately 20 mi^2 (5140 ha) in areal extent. The town of Jonesville, Lee County's seat, is in the watershed. The largest roads crossing the watershed are US 58, alt. US 58, and Route 70.

Batie East and West springs surface near the center of the biologically and geologically important karst region known as The Cedars. The Cedars is a rocky, forested, karst lowland that is also the habitat for unique plant and animal species. About half of The Cedars lies within Batie Creek's watershed. The Batie East and West Springs are about one and half miles southwest of Jonesville, Virginia. The flow from these two springs merges at Batie Creek about 50 feet after surfacing. Batie Creek flows south for about 0.75 miles and joins the Powell River at River Mile 137.95(Smith, 1991).

As illustrated in Figure 1, water is primarily supplied to Batie Creek from several surface water sources, which sink into the karst aquifer and discharge at the Batie Springs. These include: McClure, Flanary and Fleenortown Creeks; Warner Spring, Sinking Creek, a spring which rises within the Jonesville town limits, Browning Spring, and springs on the Rajbansee and Baptist Church properties (Culver et al., 1992; Ewers et al., 1995; Brown, 1997). Tracer studies have shown that Fleenortown Creek most directly supplies Batie East Spring with some overflow into the Batie West Spring. Water from McClure and Flanary Creeks sinks into the aquifer and splits, with some portion flowing through the Thompson Cedar Cave to the Batie West Spring, with minor overflow into the Batie East Spring (Culver et al., 1992).

The Cedars is an extremely important conservation priority in the southern Appalachian region because of its remarkable natural diversity. It has also been rated as one of the seven most significant karst regions in Virginia. The Department of Conservation and Recreation (DCR) and the Virginia Cave Board are working with landowners to protect the habitats of rare and endangered species (terrestrial and aquatic) and unusual plant communities in this region. Thirteen of the 16 rare animal species of The Cedars inhabit one or more of the 10 caves of The Cedars. All of these 13 species are globally rare species (Smith, 1991).

1.1. Background

Lee County (281,600 acres) was surveyed in 1939 for the first time (USDA, 1953). The 1:24,000 maps that cover Batie Creek's watershed show that there was a quarry by Sinking Creek. The survey shows moderate to severe sheet erosion around Town Branch, and moderate sheet and gully erosion close to Sinking Creek (west of Jonesville) and Fleenortown. There were few residential areas in the county.

The main industry in the county prior to 1950 was agriculture (78.5 percent or 218,000 acres in 1945), which was dominated by grain, hay, tobacco, and livestock production. About 40

percent of the county's employees worked on farms. About 76,831 acres were available for crops, 23,790 acres for pasture, and 58,050 acres of woodland. Some portable and semiportable sawmills operated in the county sporadically. Coal mining occurred in the vicinity of St. Charles. The mining industry employed about 37 percent of the county's residents (total population 36,106). About 90 percent of the houses were built after 1900 as a result of booming coal and agricultural industries. However, by 1948, the economic development of the county was still substandard compared to the rest of the country. After World War II, the coal industry declined and agriculture became the mainstay of the community. Since the mid 1970s, the county has experienced a migration of the younger population due to lack of jobs. Small farms were taken over by larger farms and most of the agricultural lands have been converted to pasture (U.S. Department of Justice and Louis Berger & Associates, 1996).

Today, land use in Lee County consists of forests (68.7 percent, 191,600 acres), cultivated lands (28.7 percent, 80,100 acres), surface mines, quarries and other disturbed lands (1.1 percent, 3,200 acres), residential, commercial, and industrially developed lands (1.1 percent, 3,000 acres), and water bodies (0.4 percent, 1,100). In 1990 the county had a rural population of 24,496. Jonesville's resident population in 1990 was 927 (U.S. Department of Justice and Louis Berger & Associates, 1996).

1.2. Land use close to Batie Springs

In the early 1970s an oil refinery was located immediately to the west of Batie West Spring. It operated for one or two years. However, it did not require a Virginia Water Control Board (VWCB) (now Department of Environmental Quality) permit, since the operation did not discharge substances to a waterway (Kaurish, 1997). Later, when the oil refinery closed, a small sawmill began operating on the site. In 1983, Mr. Russell bought the property and in 1985, the family's large sawmill moved from its previous location on highway US 58 to the current site (Keith, 1997). In addition to the Thompson Cedar Cave several small sinkholes, "skylights", and a spring were reportedly located on the site. In spring or early summer 1987, the Thompson Cedar Cave entrance was blocked by sawdust, cedar bark, and other waste wood debris produced by the sawmill. As a consequence, the wood waste decomposing in the cave and the leachate from ridges of sawdust surrounding the cave polluted the cave stream and exterminated the pre-existing ecological community (Culver et al., 1992). At one point, the waste pile combusted spontaneously and smoldered for about a year until the fire was extinguished with a water spray. In 1988, the mill operator voluntarily removed sawdust from the cave's entrance and constructed a clay berm to prevent direct runoff into the cave. In 1994, the sawmill operation was upgraded to produce less sawdust; however, the sawdust was still being added to the pile at a rate of 30 tons/day (Russell, personal communication, 1995). Both the old sawmill on Rt. 58 and the newer sawmill near Thompson Cedar Cave appear to have impacted water quality off-site (Keith, 1997).

Other relevant land-use activities in the Batie Creek watershed include commercial development and urbanization on the west end of town (eastern tip of The Cedars); the pending construction of additional lanes along Route 58 and the Jonesville by-pass; a VDOT residency office, service stations, and a small bulk plant where petroleum products are stored and dispensed; livestock grazing and crop production; a commercial greenhouse; a water treatment plant; and a number of rural residential sites. VDCR and the Nature Conservancy are acquiring property in The Cedars in order to establish a natural area preserve. Some of these tracts may be managed through prescribed burning and other techniques, but will otherwise be maintained as is.

1.3 Geology and Topography

The Cedars is a mature karst terrane developed on very soluble limestone and dolomite of Middle Ordovician age (490 - 500 million years ago). The geologic, hydrologic, and climatic characteristics of The Cedars are the basis for the unusual diversity of rare plant and animal species found in this 17 square-kilometer area.

The specific region known as The Cedars extends southwestward from the town of Jonesville along a gently rolling valley approximately one mile wide and six miles long. The subdued topography is characterized by extensive exposures of limestone, sinking streams, caves, springs, "windows", and numerous sinkholes, ranging in depth from shallow depressions to dolines up to 20 m (75 ft) deep. The specific carbonate units responsible for this topography are the Hurricane Bridge and Martins Creek limestones, the underlying Poteet and Dot limestones, and the Mascot, Kingsport, and Longview dolomites, which are among the most cavernous formations in Virginia (Holsinger, 1975).

Surficial bedrock units in the study area are part of the Cumberland overthrust block, a regional "thrust sheet", which was deformed and transported for approximately five to five and one-half miles along the Pine Mountain Overthrust Fault (Miller and Brosge, 1954). As a result of these tectonic forces, the structural profile of The Cedars is that of a slightly down-warped basin known as The Cedars syncline. The Cedars syncline tilts slightly to the west, and separates the Chestnut Ridge anticline to the north, and the Sandy Ridge anticline to the south. Chestnut Ridge appears to be the source area for much of the groundwater that flows through The Cedars. Both of these structural folds have been speculatively explored for commercial oil and gas deposits, with limited success.

Bedrock is nearly horizontal along the trough of The Cedars syncline, and strikes 60° to 70° NE (Miller and Brosge, 1954). The mountain-building process superimposed distinct fracture and joint porosity upon the rock, primarily oriented N 18-20° West and due North. Therefore, groundwater flow and cave development occur preferentially along both strike and bedding planes, as well as along the joint orientations illustrated in Appendix A (Figure A), (Gathright, 1981). This has resulted in the development of a highly integrated subterranean drainage network in The Cedars.

The general structure and stratigraphy of The Cedars are illustrated in Appendix A (Figure B). The Hurricane Bridge formation contains limestone and calcareous units so pure that only a thin remnant of the unit remains along the axis of the syncline. The development and accumulation of residual soils have been negligible, and this unit tends to be forested with dense growths of cedar, oak, and pine trees anchored in humus and clay-filled bedrock fissures. Small calcareous shale barrens that provide habitat for the rare limestone clover (*Trifolium calcarium*) and other prairie-type plant species are scattered throughout The Cedars. The Hurricane Bridge formation is underlain by the cavernous Martins Creek limestone, which forms relatively deep, well-drained soils on terraces of the Powell River.

No surface streams completely cross The Cedars without being partially or completely pirated to the subsurface. Groundwater discharge occurs primarily at springs along the contact of the Hurricane Bridge and Martins Creek formations, and at base level along the Powell River (Culver et al., 1992). Between RM 123 and RM 138, The Cedars' average base flow contribution to the Powell River is estimated at approximately 36 MGD.

A soil survey of Lee County was conducted from 1938 to 1939 by the Soil Conservation Service, and was updated in the 1980s (USDA, 1953 and 1996). The most comprehensive geologic and hydrologic mapping of the area was conducted by Miller and Brosge, 1954;Gathwright, 1981; and Ewers et al., 1995.

1.4 Groundwater Hydrology

The Recovery Plan for the Lee County cave isopod (U.S. Fish and Wildlife Service, 1997) discusses the need for delineation of the groundwater drainage basins in order to protect the habitat of the troglobitic species. In recent years, much work has been completed by karst hydrology researchers such as Jones, 1990; Ewers, 1995; Idstein, 1995; and Rea, 1996. Accessible caves in The Cedars provide a glimpse of the solution-enlarged, underdrain system that captures and conveys water from sink points near Route 58 to the Powell River. These caves have formed very close to the surface, and some are directly affected by surface activities producing sediment, runoff, and chemical/bacterial pollutants.

Ewers estimates that four discrete groundwater sub-basins and several smaller discontinuous basins have developed in the study area (Ewers et al., 1995). Both Ewers and Rea found evidence that these basins overlap horizontally to some extent (personal communication, 1996). To date, the tests indicate that groundwater generally moves southwest and south (along geologic strike and joints, respectively) to the five major springs; Batie East and West Springs, Flanary Springs, Sims Spring, and Gollahon-Surgenor Spring. At least seven smaller springs draining portions of The Cedars emerge along the north bank of the Powell River, including Rock Wall Spring and Blue Hole Spring.

In most places in The Cedars, groundwater occurs in discrete conduits rather than as a continuous water table. Many residents of The Cedars report poor well yields and/or water quality related to low groundwater storage, and high turbidity and hydrogen sulfide concentrations. A significant percentage of these people either use treatment systems, purchase bottled water, or carry drinking water from local roadside springs. Other nearby residents, however, use wells (300 feet deep and less) that continuously yield sufficient quantities of fresh, potable groundwater. High concentrations of methane have been reported in some wells, and improperly-abandoned oil and gas exploration wells have created local contamination problems when salt brines intrude into shallow domestic wells.

During normal low-flow conditions, groundwater gradients between Route 58 and the Powell River range from approximately 7 m/km (36 ft/mi) to 16 m/km (83 ft/mi), with the vadose water table generally being less than 20 m (66 ft) below ground level. In 1990, William Jones (Environmental Data Systems, Inc.) conducted initial tracer tests from the Fleenortown Creek swallet and Thompson Cedar Cave to the Batie Springs. These tests indicated average groundwater flow rates of 40 m/hr during normal low-flow conditions. Groundwater velocities in the Sims Spring basin were estimated at 40 m/hr to 60 m/hr, based on tracer studies conducted by Ewers (1995) and Neely (FAA, 1997). Seasonal variations in groundwater velocity and the relationship between adjacent groundwater basins have been observed in The Cedars, and will be quantified in future studies based on quantitative tracer testing and discharge monitoring. Current dye studies are being conducted on the suspected source waters area located north of US Route 58.

2. Bioassays and water quality studies in Batie Creek's watershed

The first formal botanical work in The Cedars was conducted by Lloyd G. Carr (Carr, 1944 and 1965, cited by Smith, 1991). The biology of Thompson Cedar Cave has been the subject of extensive research over the last two decades (Holsinger and Bowman, 1973; and Holsinger and Culver, 1988). The aquatic fauna and benthic species of Batie and Town Branch Creeks were studied by the Tennessee Valley Authority (TVA) (Smollen, 1997). Lists of species that are rare or endangered at the state and federal levels are documented in Appendix B. The first and second tables list the natural heritage resources of The Cedars (Smith, 1991) and of the Powell River from Big Stone Gap to the Tennessee Line (VDCR, 1997). The third and fourth tables list the aquatic organisms in Batie Creek and Town Branch (Smollen, 1997).

In 1982, the flow rates for the Thompson-Cedar Cave stream, Batie East and West Springs, and McClure, Flanary, and Fleenortown Creeks were measured (Estes and Holsinger, 1982; cited by Culver et al., 1992). Water dye tracing experiments have been conducted in the area for several years, and a preliminary groundwater basin map has been developed (Culver et al., 1992; Ewers et al., 1995; Brown, 1997).

In 1988 and 1994, the Department of Environmental Quality (DEQ) and the Virginia Department of Conservation and Recreation (DCR) measured the pH, temperature (T), dissolved oxygen (DO), tannins, alkalinity, total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), conductivity (EC), turbidity, and biochemical oxygen demand (BOD) in Batie West Spring. In 1994, the DCR measured the pH, T, DO, and conductivity in Batie East Spring.

In 1996, the DEQ set up an eight week sampling routine for surface and subsurface streams feeding into Batie Creek, including several possible tributary streams that sink into the aquifer north of highway US 58. Recorded information includes measurements for DO, pH, EC, BOD_5, fecal coliform, tannins, phosphorus (P), ammonia (NH_3), total kjeldahl nitrogen

(TKN), and TSS (DEQ, 1997a). The same year, the DEQ staff measured the DO and temperature (T) at several intervals downstream in Batie East and West and Batie Creek (DEQ, 1997b).

In 1994, The Nature Conservancy contracted Environmental Monitoring Incorporated (EMI) to perform water analyses in The Cedars. Samples were collected at McClure and Flanary Creeks, the old sawmill (Masons sinkhole), Fleenortown Creek, Batie West Spring, and Chance window. The alkalinity, EC, DO, "methylene blue active substance (MBAS) - soap, anionic surfactants, and flocculent type compounds, nitrite and nitrate nitrogen (NO_2-N + NO_3-N), pH, TDS, TSS, and fecal coliform were analyzed for all the sites. Polyaromatic hydrocarbons (semivolatile organics) were measured in the Batie springs and at the old sawmill site.

During efforts to acquire the Mason tract, in 1996, The Nature Conservancy contracted EMI to analyze leachate from the old Russell sawmill (known as the "ancient pile") close to US 58 and the Mason sinkhole. Polyaromatic, volatile, diesel range, and gasoline range hydrocarbons were measured. The Russell and Mason leachates were also tested for pesticides and metals. Only the regulatory parameters required by law for landfill disposal of a contaminated substance were tested (Ketron, 1997).

In 1997, under contract with the DCR, the Virginia Water Resources Research Center (VWRRC) measured cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), and chemical oxygen demand (COD) in the sediment, and filtered waters of the Batie East and West Springs (VWRRC, 1997a). The pH, DO, T, conductivity, and salinity were also measured at Batie East and West in the field. Also, the VWRRC measured phosphate phosphorus (PO_4-P), NO_3-N, ammonium nitrogen (NH_4-N), TSS, total phosphorus (TP), filtered total phosphorus (FTP), TKN, filtered TKN (FTKN), total coliform, and E. Coli in the waters of Batie East and West Springs and the leachate of the new Russell sawdust pile (Warner Spring).

3. Biological and qualitative information on the Thompson Cedar Cave, Batie East and West Springs, Batie and Town Branch Creeks

Before being impacted by the sawdust piles, the Thompson Cedar Cave hosted a significantly diverse ecological community. Three major species of cave crustacean were present in the cave: the amphipod *Crangonyx antennatus*, and the isopods *Caecidotea recurvata* and *Lirceus usdagalun*. In addition, small numbers of the crayfish *Cambarus bartonii* and larvae of the northern spring salamander *Gyrinophilus porphyriticus* were present. The cave was one of the few known local habitats for the troglobitic isopod, *Lirceous usdagalun*, the Lee County cave isopod. At that time, this isopod presence was known only in one other location, approximately 6 miles to the southwest and was listed as an endangered species in December 1992 (Smith, 1991; Culver et al., 1992). The 5-7 mm-long isopod is of biological interest because of its morphological modifications to the cave environment that appear to be much more recent than other more common cave crustaceans (Culver, 1976). Drs. John R.

Holsinger and David C. Culver, karst biologists from Old Dominion University and American University, respectively, visited the Thompson Cedar Cave on an annual to semi-annual basis from 1967 through approximately 1992. In studying the distribution of the isopods and species interaction in the cave, they were able to document the condition of the cave and species present, prior to the sawdust contamination that became apparent in 1988 (Culver and Holsinger, 1990).

Less than three years after the sawmill operations began, the water in the cave was described as having a nearly black color and an extremely strong odor of rotting wood debris. The cave stream substrate was covered with a thick (>1cm) layer of bacterial slime. The original aquatic fauna had disappeared with the exception of *Gyrinophilus porphyriticus* and *Crangonyx antennatus*. The number of tubificid worms, chironomid flies, and frogs had increased with respect to past years. The apparent flow characteristics of the cave stream varied markedly: fresh mud on the walls indicated a higher water level than was observed in the previous ten years. Observations recorded in September 1991 found that the water in the stream was clear, the bacterial scum on gravel was less than 1 cm, sporadic chironomids and tubificids were found, and one adult *Caecidotea recurvata* was found in the stream (Culver et al., 1992). In 1986, Holsinger reported that the aquatic snails, *Fontigens nickliniana* and *Goniobasis simplex* inhabited Batie creek. By 1990, Holsinger observed that the *F. nickliniana* had disappeared and *G. simplex* had almost disappeared; crustaceans could not be found at the spring outlets; and most rooted aquatic vegetation had vanished from the springs (Holsinger, 1994).

In 1994, pockets of decomposing sawdust were observed inside the Thompson Cedar Cave (Brown, 1994). On August 25, 1994, the Batie East Spring had a strong "organic" odor and a heavy growth of sewage fungus on its substrate. The benthic community was relatively healthy and the spring was rated as "moderately impaired." Batie West Spring had a similarly strong organic odor and sewage fungus growth on the substrate. No vertebrates were observed and the benthic macroinvertebrates were limited primarily to colonies of tubificid worms. The spring was rated as severely impaired (Brown, 1994).

On July 10 and 11, 1996, the TVA's Aquatic and Biology Laboratory inventoried the fish and benthic species of Batie and Town Branch Creeks. TVA found that the habitat was poor in Batie Creek (IBI = 32) and poor/fair (IBI= 38) in Town Branch Creek (Smollen, 1997).

4. Physico-chemical Parameters Measured in Batie Creek and its Vicinity

4.1. Flow rate

Prior to the cave's blockade, Estes and Holsinger (1982) (as cited by Culver et al., 1992) reported an average maximum stream velocity of 14.96 ft/min (7.6 cm/s). The relative consistency of flow rate in the Thompson Cedar Cave stream is supported by Holsinger and others' annual qualitative observations for a period of more that 30 years. The estimated flow rates reported by Culver et al. (1992) and EMI (1994) are presented in Table 1.

Table 1. Estimated (Low) Flow Rates in the Eastern Half of The Cedars

Water Sources	Flow rate (gal/min)[1]	Date	Flow rate (gal/min)[2]	Date
Batie East Spring	4914	---[3]	---	---
Batie West Spring	444	---	200	12/02/1994
Thompson Cedar Cave	135	---	---	---
McClure Creek (Sink I3)	135	---	75	11/30/1994
Flanary Creek (Sink I4)	1506	---	65	11/30/1994
Fleenortown Creek	3646	---	399	11/30/1994
Chance Window	---	---	4993	12/02/1994

4.2. Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Organic Carbon (TOC), Tannins and Conductivity (EC)

In 1996, the DEQ developed dissolved oxygen profiles of Town Branch and Batie Creeks by testing water quality at frequent intervals from the confluence of the Batie Springs to the Powell River, 2500 feet downstream. The following values of DO, BOD_5, COD and conductivity have been recorded in the Batie West and East Springs:

Table 2. Summary of Historic Indicators Measured at the Batie West Spring

Date	5/3/88[4]	6/20/94[5]	8/25/94[6]	9/23/96[5]	4/17/97[6]	7/5/97[5]
DO(field) (mg/L)	4	2	5.72	0.97	0.65	0.06
BOD_5(lab) (mg/L)	5	>47	---	328	---	---
COD (mg/L)	---	---	---	---	241.7	---
TOC (mg/L)	---	135	---	---	---	---
Tannins (mg/L)	0.031	---	---	11.0	---	---
Tannins + Lignins (mg/L)	---	10.18	---	---	---	---
EC (μS/cm)	---	540	440	500	360[7]	415

[1] Culver et al. (1992).
[2] EMI (1994).
[3] No data.
[4] Brown (1994)
[5] DEQ (1997a).
[6] VWRRC (1997a).
[7] μmhos/cm

Table 3. Summary of Historic Indicators Measured at the Batie East Spring

Date	5/3/88[4]	6/20/94[5]	8/25/94[6]	9/23/96[5]	4/17/97[6]	7/5/97[5]
DO(field) (mg/L)	---	---	8.4	7.85	5.25	7.33
BOD_5(lab) (mg/L)	---	---	---	4	---	---
COD (mg/L)	---	---	---	---	5.8	---
Tannins (mg/L)	---	---	---	0.3	---	---
EC (µS/cm)	---	---	350	3250	280[7]	303

Dissolved oxygen (DO) and conductivity (EC) data for 13 other sampling points in the vicinity of Batie Creek are documented in Table 4. DO ranged from 4.33mg/L (Thompson Cedar Cave) to 9.65 mg/L where Town Branch joins Batie Creek. Figure 2 shows dissolved oxygen levels in Batie Creek along the traverse. The average DO concentration in was 0.28 mg/L in Batie West, compared with 7.64 mg/L in Batie East. The data from EMI (1996) are documented in table 5. Figure 3 compares the values of dissolved oxygen measured in Batie West and East to other water bodies in the area.

Table 4. Temperature, Dissolved Oxygen, pH and Conductivity at Various Sampling Sites in the Vicinity of Batie Creek

Sampling Site	Time	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µmhos)
Fleenortown Creek (Control)	0705	14.6	8.44	7.33	291
Fleenortown Creek (Swallet)	0720	15.3	8.30	7.52	276
Miner Window Main Pump Station	0735	15.9	6.61	7.24	360
Town Branch (Control #1)	0800	16.2	7.86	7.53	298
Town Branch upstream of STP	0815	17.3	7.91	7.67	310
Jonesville STP effluent	0820	21.7	5.01	6.86	598
Town Branch New Pump Station	0850	18.2	6.72	7.16	325
Town Branch Route 654 Bridge	0915	19.2	6.81	7.56	333
Browning Window	0930	15.7	7.71	6.89	300
Chance Window	0950	15.5	7.18	6.88	300
Batie Spring (East)	1030	16.0	7.33	6.83	303
Batie Spring (West)	1045	13.8	0.06	6.21	415
Warner Window	1110	15.2	7.58	6.79	340
Thompson Cedar Cave	1120	13.6	4.33	6.89	408
McClure/Flanary Creeks	1225	21.5	6.00	7.63	286
Field Measurements conducted by the DEQ on July 5, 1997.					

Table 5. Dissolved Oxygen Profile of Batie Creek at Various Distances from the Confluence of Batie East and West Springs

Distance (ft)	Dissolved Oxygen (mg/L)	Temp. (°C)	Description
10	7.69	14.4	East Spring
50	7.76	14.5	East Spring
0	7.47	14.4	Confluence of East and West Springs Easterly
15	0.28	14.1	West Spring
65	0.29	14.1	West Spring
0	0.36	14.1	Confluence of East and West Springs
50	6.92	14.4	Batie Creek
100	6.85	14.4	
150	6.3	14.5	
200	--[8]	14.5	
250	6.48	14.6	
300	6.22	14.6	
350	6.05	14.6	
400	5.91	14.7	
450	5.79	14.8	
500	5.53	14.8	
600	5.35	14.9	
700	4.84	15.1	
800	4.9	15.1	
900	4.93	15.4	
1000	5	15.5	
1100	4.63	15.6	
1200	4.57	15.6	
1300	4.53	15.7	
1400	4.53	15.8	
1500	4.64	15.8	
1600	4.48	16	
1700	5.05	16.1	
1800	6.36	16.7	
1900	5.28	16.6	
2000	5.4	16.1	
2100	5.31	16.7	
2200	5.09	16.9	
2300	5.04	16.9	
2400	5.06	16.8	
2465	5.16	17	

Sampled by the DEQ on September 26, 1996

[8] -- No data.

According to Chapman (1996), DO in natural waters vary with the temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure. Dissolved oxygen decreases as temperature, salinity, turbidity, and BOD/COD increase. Concentrations in unpolluted fresh waters are usually close to10 mg/L. Concentrations below 5 mg/L may adversely affect the functioning and survival of biological communities, and below 2 mg/L, will lead to the death of most fish. According to this information, the low dissolved oxygen content resulting from the excessive loading of organics to Batie West Spring alone could have caused the death of all aquatic organisms.

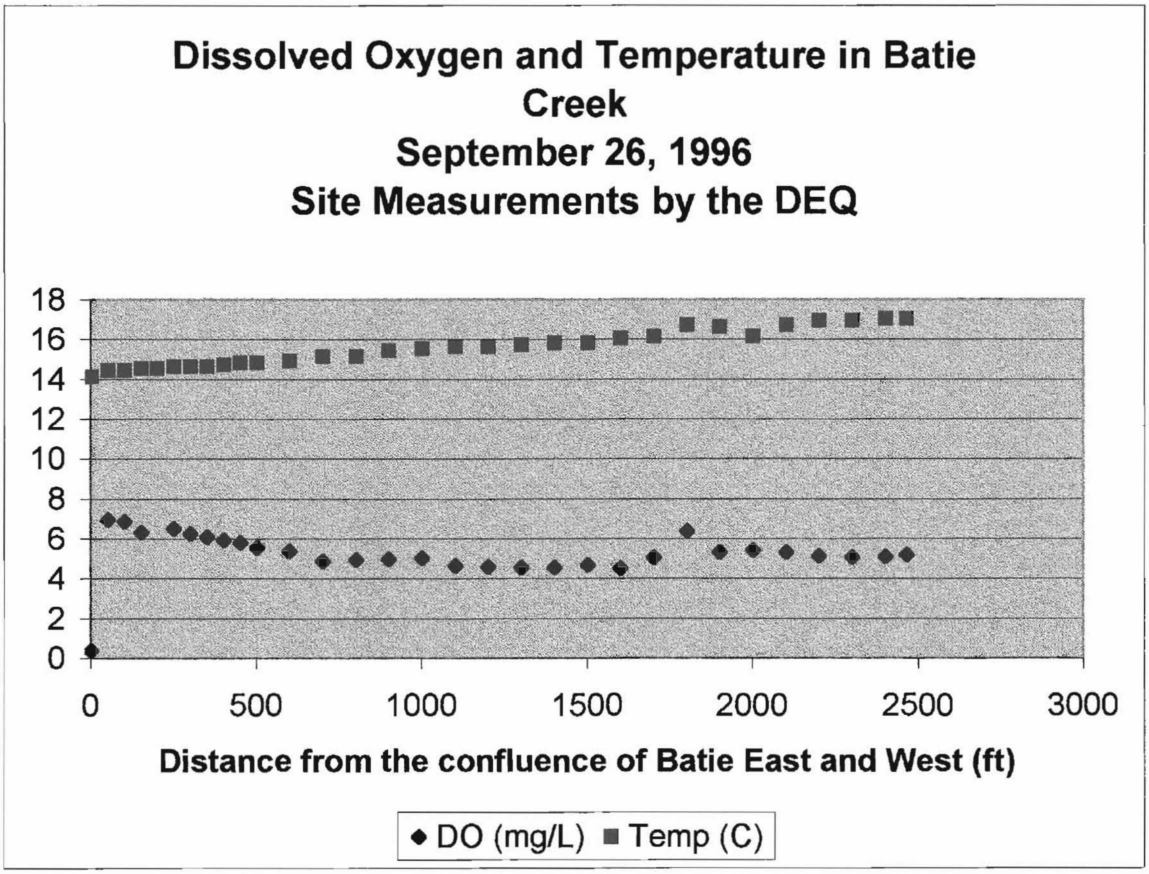


Figure 2. Dissolved Oxygen Levels in Batie Creek

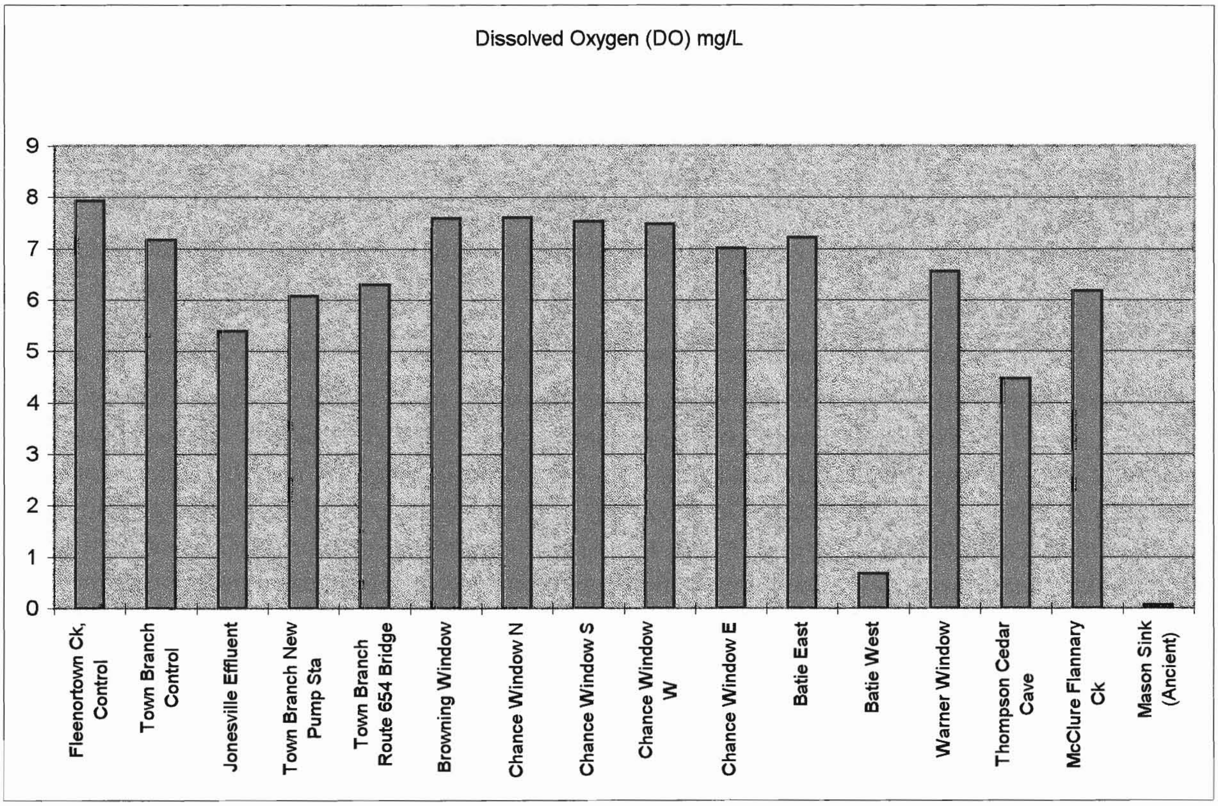


Figure 3. Dissolved Oxygen Levels in Batie West and East Springs Compared to Other Water Bodies in the Watershed[9]

[9] DEQ, field measurements conducted in July and August, 1997.

Other parameters that reflect the amount of available oxygen in the water are BOD_5, COD, TOC and EC. Normal BOD_5 values for domestic sewage are 250 mg/L. For industrial wastes, it may be as high as 30,000 mg/L. The BOD_5 in the Batie West Spring is two orders of magnitude higher than would be expected even from raw sewage discharge from a town of the size of Jonesville. The high concentration of tannins in the Batie West Spring suggests that the organic matter in the water is probably derived from woody material rather than from animal or human waste.

4.3. Turbidity, Total Dissolved Solids (TDS), and Total Suspended Solids (TSS)

Turbidity is a measure of how clear the water is, i.e., how much light can be transmitted through the water. Turbidity is a factor contributing to the degradation of Batie Creek. An increase in turbidity due to high solids content may interfere with the amount of light able to reach the vegetation in the stream resulting in the death of aquatic plants. In turn, this process would increase BOD and deplete oxygen levels as a result of microbial decomposition. In addition, deposition of sediment or particulates, such as sawdust, may cause these materials to accumulate on aquatic plants minimizing their photosynthesis, efficiency, and ability to transfer oxygen (Terrene Institute, 1996).

Normal turbidity values range from 1 to 1000 NTU (Chapman, 1996). Excessive turbidity levels caused by siltation and subsequent shifting of the stream bottom are cited as major factors in the decline of freshwater mussel biota (Williams et al., 1993, cited in TRS publication, 1997). Some rare and threatened fish species are vulnerable to turbidity above 25 NTU (Kundell and Rasmussen, 1995, cited by TRS, 1997). Under Virginia's discharge permit system, municipal dischargers with secondary treatment cannot exceed 30mg/L TSS for a 30-day average, nor 45 mg/L averaged over 7 days (DEQ, 1997c). The TSS levels in the Batie West Spring in 1994 were well above the expected values as shown in Table 6. However, measurements in subsequent years indicate that the TSS levels have dropped significantly. This may indicate that, for the most part, the solids have been deposited on the bottom of the creek and the low flow of the creek has not contributed to resuspension, or the elevated sample may have been related to a storm event. Dedicated stormwater sampling has not been conducted in the study area. For the events sampled, suspended solids were not a problem in the Batie East Spring as shown in Table 7.

Table 6. Turbidity, TDS and TSS Concentrations in the Batie West Spring

Date	6/20/94[10]	12/2/94[11]	9/23/96[12]	5/21/97[13]	Criteria[14]
TDS (mg/L)	244	264	---[15]	---	
TSS(mg/L)	266	18	20	9	<30mg/L (30 day average). <45 mg/L (7 day average).
Turbidity (NTU)	4.2	---	---	---	

Table 7. Turbidity, TSS Concentrations in the Batie East Spring

Date	9/23/96[16]	5/21/97[17]	Criteria[18]
TSS(mg/L)	3	6	<30mg/L (30 day average). <45 mg/L (7 day average).

4.4. Fecal and Total Coliform

Coliforms are used as indicators of the bacterial quality of water. The presence of coliforms in the water indicates that disease-causing organisms may be present in the sample. Tests for the presence of the E. coli organism is usually performed because it is found in the intestines of warm-blooded organisms. The use of total coliforms as in indicator may not be as useful in indicating the presence of pathogens because some types of coliform bacteria are naturally present in a wide range of environments.

Tests for fecal coliform bacteria in the Batie East and West Springs were performed by the DEQ in 1996. Tests indicated 210 and 30-colonies/100 ml in each spring, respectively. Both springs sampled again for fecal coliforms in 1997. There were less than 100 colonies/100ml and 300 colonies/100ml in the Batie West and East Springs, respectively (DEQ, 1997a). Both springs meet the goal of the Clean Water Act for swimmable waters (less than 1000 fecal coliform colonies/100 mL at any time, DEQ, 1994). The highest counts were found in McClure and Flanary Creeks (6500 colonies/100ml). The high count is probably associated with livestock wastes and/or on-site septic systems.

The VWRRC sampled the Batie East and West Springs and the Russell leachate for total coliforms and E. coli analysis in 1997. The Batie West Spring had 4000 and 1081 colonies/100 mL of total coliform and E. coli, respectively. Batie East Spring had 2400 and 1171 colonies/100 mL of total coliform and E. coli, respectively. The Russell leachate had 60,000 and 1802 colonies/100 mL of total coliform and E. coli, respectively. Both springs

[10] Brown(1994).
[11] EMI(1994).
[12] DEQ(1997a).
[13] VWRRC(1997b).
[14] Barron, A (1997) Level permitted to municipal discharges with secondary treatment.
[15] ---Not measured.
[16] DEQ(1997a).
[17] VWRRC(1996).
[18] Barron, A (1997) Level permitted to municipal discharges with secondary treatment.

had high counts of coliforms, possibly as a result of cattle dung, on-site wastewater systems, and runoff.

4.5. Alkalinity and pH

Summary of measurements for alkalinity and pH are documented in Tables 8 and 9.

Table 8. Alkalinity and pH Measured in the Batie West Spring

Date	5/3/88[19]	6/20/94[19]	8/25/94[19]	12/20/94[20]	23/9/96[21]	4/17/97[6]	7/5/97[21]
Alkalinity (ml/L)	---	244	---	241	---	---	---
pH (field)	7.95	6.0	8.8	6.69	5.96	7.0	6.21
pH (lab)	---	7.74	---	---	---	---	---

Table 9. pH Measured in the Batie East Spring

Date	5/3/88[19]	6/20/94[19]	8/25/94[19]	23/9/96[21]	4/17/97[6]	7/5/97[21]
pH (field)	---	---	6.78	7.12	8.0	6.83

Alkalinity data for other sampling points in the Batie Creek watershed ranged from 161 to 241 mg/L which are within the normal range for limestone groundwater. All surface water sources in the area had pH values between 6.0 and 8.5, which is the normal range for natural waters. The exception was the pH value recorded in the Batie West Spring in the summer of 1994 (pH = 8.8). This is attributed to sampling error or to some other unknown factor in the groundwater basin.

4.6. Water Temperature

Water temperature is influenced by latitude, altitude, season, time of day, air circulation, cloud cover, rate of groundwater recharge, and the flow and depth of the water body. Identifying trends in water temperature requires very frequent monitoring in conjunction with measurements of the previously mentioned variables. Water temperatures for the Batie West and East Springs were measured periodically and are shown in Tables 10 and 11, respectively. Water temperature in the Batie West Spring is generally a few degrees lower than in the Batie East Spring.

[19] Brown (1994)
[20] EMI(1994)
[21] DEQ(1997a)

Table 10. Water Temperature in Batie West Spring

Date	5/3/88[22]	5/3/88[22]	5/3/88[22]	12/20/94[23]	4/17/97[24]	4/17/97[24]	7/5/97[25]
T (°C)	17	18.6	14	12.0	13	13	13.8

Table 11. Water Temperature in Batie East Spring

Date	8/25/94[22]	4/17/97[24]	7/5/97[25]
T (°C)	18.9	14	16.0

4.7. Nitrogen and Phosphorus forms

Ammonia occurs naturally in water bodies. Unpolluted water contains small amounts of ammonia and ammonia compounds, usually less than 0.1 mg/L (Chapman, 1996). Ammonia concentrations detected in the Batie East and West Springs were less than the norm (DEQ, 1997a; VWRRC, 1997b).

The nitrate ion is the common form of nitrogen found in natural waters. Nitrate is an essential nutrient for aquatic plants, and plant growth and decay affect its seasonal fluctuations in water. Natural concentrations of NO_3-N seldom exceed 0.1 mg/L. When influenced by human activities, surface waters may contain nitrate concentrations up to 5 mg/L, but often less than 1.0 mg/L (Chapman, 1996). The Batie East Spring had a slightly elevated concentration of NO_3-N (1.48 mg/L).

Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate forms. In most natural surface waters, phosphorus ranges from 0.005 to 0.02 mg/L (Chapman, 1996). Phosphorus concentrations were relatively high in the Batie West and East Springs (0.11 and 0.05 mg/L, respectively) in 1996 (DEQ, 1997a) but were below detection level in both springs in 1997 (VWRRC, 1997b). The total phosphorus concentration detected in the Batie West Spring is above the recommended value for flowing waters, as established by the Committee on Nutrient Enrichment Problems in Virginia's Chesapeake Bay (Institute for Environmental Negotiation, 1987).

Table 12. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN) and Phosphate Values

Location	TP(mg/L as Phosphorus)	TKN (mg/L as Nitrogen)	Phosphate (mg/L as Phosphorus)
Batie West (09/23/96)	0.11	1.2	---[26]
(05/21/97)	BDL	0.08	BDL
Batie East (09/23/96)	0.05	0.1	---
(05/21/97)	BDL	0.175	BDL

[22] Brown (1994)
[23] EMI(1994)
[24] VWRRC(1997a)
[25] DEQ(1997a)
[26] Not measured

Virginia does not have a criteria for nitrogen and phosphorus concentrations in natural waters (DEQ, 1997c). However, it is known that phosphorus, while not the only cause, is a significant contributing factor to eutrophication usually the limiting one. Excess phosphorus as phosphate stimulates plant growth. It is believed that to prevent excess growth, total phosphorus should not exceed 0.1mg/L in streams not discharging directly to lakes or impoundments (USEPA, 1976). The Committee on Nutrient Enrichment recommended that the total phosphorus (TP) concentration is the most useful parameter in determining eutrophication and that the water quality standards for TP should range from 0.1mg/L to 0.2mg/L depending on the background conditions of the area.

Table 13 indicates the ratios of TP:TN and their significance to eutrophication (DEQ, 1997c). In September of 1996, TKN and TP values in the Batie West Spring were 1.2 mg/L and 0.11, respectively. The TP:TKN ratio (0.092) is well within the threshold value that may trigger eutrophication. This conditions most likely re-occurs each year during the late summer – early fall months.

Table 13. Eutrophication Potential as a Function of Nutrient Concentration

TP (mg - P/L)	TN (mg -N/L)	Significance
0.013	0.092	Problem threshold
0.13	0.92	Problem likely to exist
1.3	9.2	Severe problems possible

Symptoms of high nutrient loading include weedy proliferation and algal slimes. In general, slow flowing streams such as Batie Creek are most prone to eutrophication. Much of the plant proliferation and algal infestations die at the end of the summer for reasons not yet well understood (Terrene Institute, 1996). In the Batie Creek area, the die-off appears to be related to colder surface temperature and greater groundwater recharge rates. Under these conditions, an increase in BOD followed by a decrease in oxygen levels occurs.

4.8. Metals

4.8.1. Total Metal concentrations in Russell and Mason leachates

Metals and selected other constituents were analyzed in samples of leachate from both the new (Russell) and old (Mason tract) sawmill sites: Aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), boron (Bo), cadmium (Cd), chromium (Cr), copper (Cu), cyanide, iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), phosphorus (P), selenium (Se), silver (Ag), thallium (Tl), and zinc (Zn) (EMI, 1996). Table 14 summarizes the results and compares them to criteria values for solid waste disposal purposes. Russell leachate tested positive for Al, As, Ba, Bo, Cr, Cu, Fe, Mg, Mn, Ni, and Zn. According to the EPA guidelines for classification of Great Lakes Harbor sediment (USEPA, 1993), the Russell sludge would be classified as "not polluted" with As, Cr, Cu, Fe, Mg, Ni, and Zn, and "heavily polluted" with Ba (110 mg/Kg) from a disposal point of view. Leachate from the ancient pile, which collects on the Mason tract before sinking, tested positive for the same metals, as well, for Be and Pb. According to the same EPA solid waste disposal guidelines, leachate from the Mason tract would be classified as being "heavily polluted" with manganese and barium.

Virginia does not have solid waste disposal guidelines specifically pertaining to sediment. The determination of whether the leachate is hazardous would depend on the TCLP (Toxic Characteristic Leaching Potential) test. In addition, generator knowledge may be incorporated to determine whether the leachate would be classified as solid or hazardous waste. The present data seem to indicate that barium may be at higher than regulatory levels (100 mg/Kg in the TCLP test). Disposal issues are discussed in more detail in section 6.

Table 14. Metals in Mason Sinkhole and Russell leachate.

Metal	Mason Sinkhole Leachate (mg/Kg)	Russell Leachate (mg/Kg)	Guidelines [27] (mg/Kg)	Guidelines[28] (mg/Kg)	Guidelines[29] (mg/Kg)
Aluminum	4800	5100			
Antimony	BDL[30]	BDL			
Arsenic	2.73	2.1	10.00	57.00	<3
Barium	110	110			<40, >60[31]
Beryllium	0.52	BDL			
Boron	42.7	18.0			
Cadmium	BDL	BDL	1.0	5.10	--
Chromium	6.7	8.7	100.00	260.00	<25
Copper	5.40	8.30	100.00	390.00	<25
Cyanide	BDL	BDL			<0.10
Iron	14100	5200			<17000
Lead	8.1	BDL	50.00	450.00	<40
Magnesium	920	530			
Manganese	540	82.0			<300, >500[31]
Mercury	BDL	BDL	0.1	0.41	
Molybdenum	BDL	BDL			
Nickel	10	5.0	100		<20
Phosphorus	BDL	BDL			
Selenium	BDL	BDL			
Silver	BDL	BDL		6.10	
Thallium	BDL	BDL			
Zinc	67.3	55.0		410.00	<90
Date sampled: 3/11/96					

[27] Wisconsin Department of Natural Resources Interim Criteria for in-water disposal of dredged sediments.
[28] Washington State Department of Ecology marine sediment quality standards chemical criteria.
[29] EPA Guidelines for the Classification of Great Lakes Harbor Sediments (to be classified as not polluted unless otherwise indicated).
[30] BDL is Below Detection Level.
[31] Classified as heavily polluted sediments.

4.8.2. Sediment and Metal Concentrations in the Batie West and East Springs

Water and sediment samples were analyzed for Cd, Cr, Cu, Pb, Ni, and Zn in the Batie East and West Springs (VWRRC, 1997a). Results are summarized in Tables 15 and 16.

4.8.2.1. Total metal concentration in sediment

According to federal guidelines for the classification of sediment for disposal purposes (USEPA, 1993), the sediment in the Batie West and East Springs is not polluted. In this case, background data were provided by the DEQ from a Powell River monitoring station (Hurricane Bridge at river mile 138.91 on Route 654). This station is about 0.2 river miles upstream of the Batie Creek. Unfortunately, not all metals analysis for sediment in the Batie West and East Springs were the same as those analyzed for in the background samples. Figure 4 compares background levels to those found in both the Batie West and East Springs, and leachate from the old and new sawmills. The background values were derived from the average concentrations for two sets of data from July 1995 and 1996. Metal analysis for Batie East and West Springs that were available for comparison (i.e., cadmium, chromium, and copper) were not higher than the background levels. Even for Mason and Russell leachates, the metal concentrations were at or below background levels. This suggests that the sediment in Batie Creek is not contaminated with copper, cadmium, or chromium. In addition, since the sludge is not contaminated with aluminum, antimony, arsenic, beryllium, iron, and thallium, one may conclude that the sediment is less likely to be contaminated with these metals either. Lead, nickel and zinc were not tested in samples from the background site. These metals are further discussed in the following sections.

4.8.2.2. Dissolved metal concentration in water

Soluble metals concentrations in the Batie West and East Springs are compared to the EPA criteria in Tables 17 to 20. Where there are several values, the most stringent criteria apply. Some of these values are hardness dependent and were computed based on the average hardness values listed in each table. The values show that the concentrations in the Batie West and East Springs are well below the criteria levels.

According to Canadian guidelines (Chapman, 1996), the Cr, Pb, and Zn concentrations in the Batie West Spring may be toxic to some fish and aquatic life. The water in Batie Creek is not contaminated when compared to background levels of metals in nearby upstream water streams. Figure 5 illustrates the metal distribution in several areas, including the Batie East and West Springs and two background sites. Values in Figure 5 represent average values based on two to three samples per site. With the exception of iron and manganese, there is no apparent metal contamination present in the Batie West and East Springs as compared to control values.

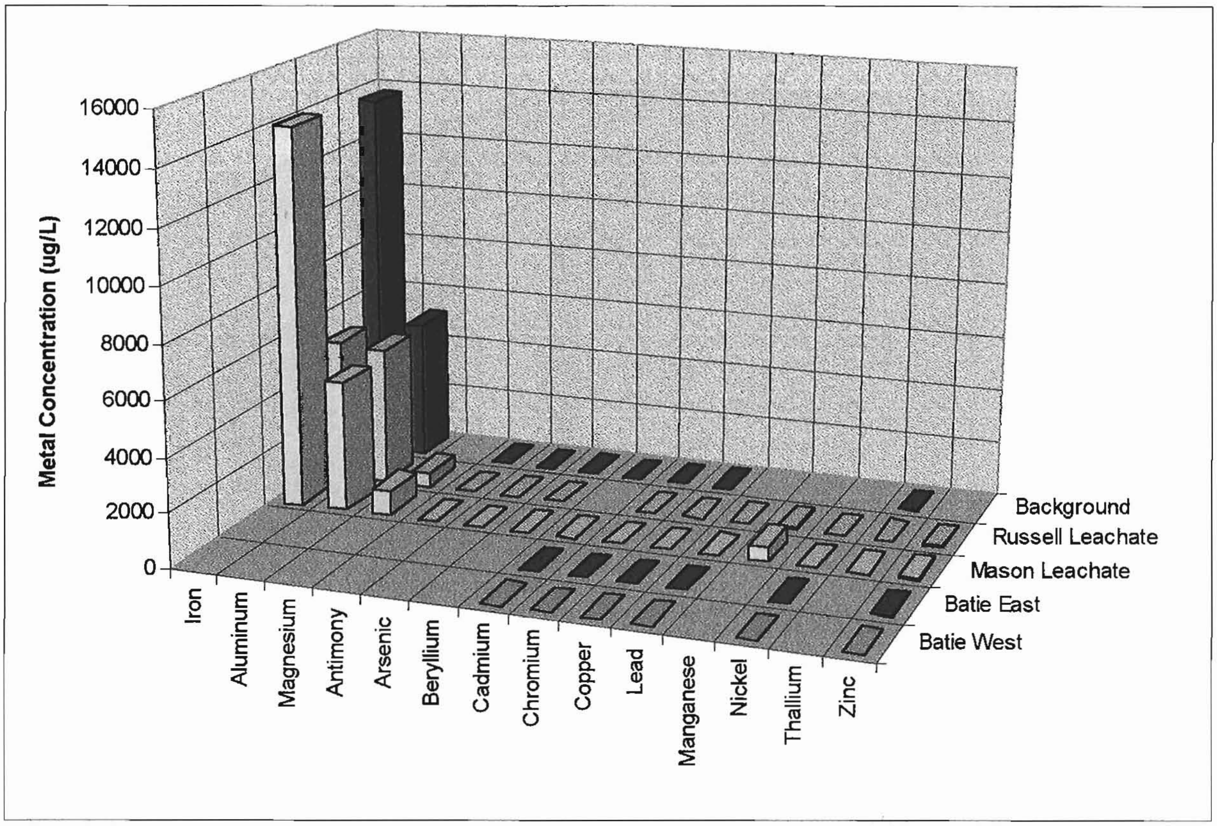


Figure 4. Background sediment metal concentrations

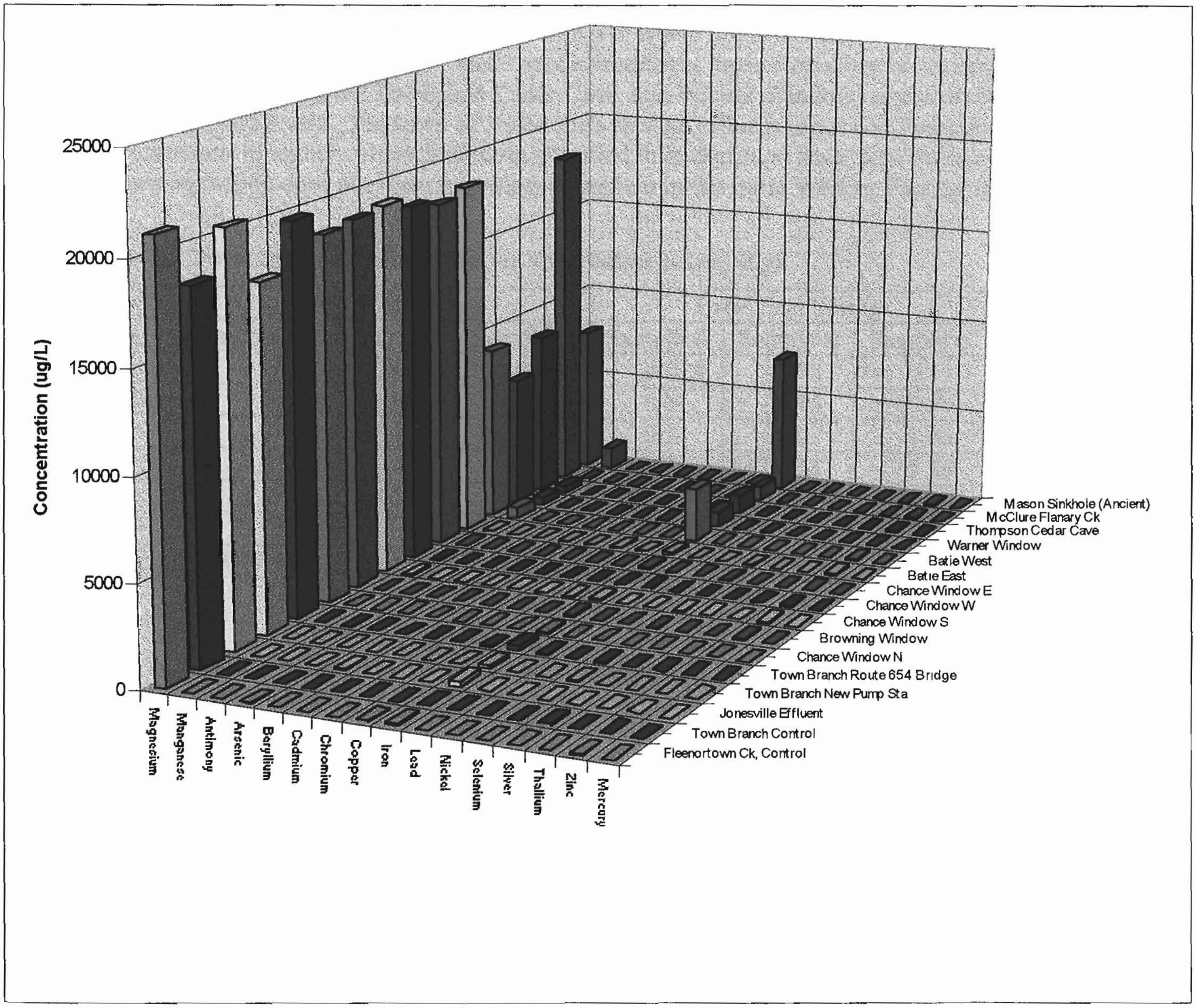


Figure 5. Average concentration of total metals in the Batie East and West Springs compared to background levels and other water bodies in the watershed.[32]

[32] DEQ, measured in July and August, 1997.

Conventionally, Fe and Mn are only of concern in determining the aesthetic quality, odor and taste of potable drinking water supplies. Batie creek water has not been used as a drinking water source, but it does flow into the Powell River where important aquatic species could be impacted. According to Figure 5, metal concentrations at those sites close to the sawdust piles (Mason Sinkhole, the Thompson Cedar Cave, and Warner Window) appear to be higher than background levels. The town of Jonesville's sewage effluent is not contributing to metal concentrations in higher values than those observed in background sites, with the exception of magnesium which does not seem to present a problem in the Batie West or East Springs.

Table 15. Total Metal Concentration in the Sediment (mg/Kg)

	Batie West Spring			Batie East Spring			Guidelines[33]
Metal	Sample A	Sample B	Sample C	Sample A	Sample B	Sample C	
Cadmium	0.065	0.07	0.06	0.015	0.02	0.11	--
Chromium	3.6	3.95	3.8	0.8	0.85	6.7	<25
Copper	0.9	1.05	0.95	0.2	0.2	1.65	<25
Nickel	1.2	1.4	1.35	0.5	0.55	5.55	<20
Lead	3.3	3.85	4.65	1.5	1.6	4.5	<40
Zinc	10	11	9	3.5	7.5	10	<90
Date sampled: 4/17/97							

Table 16. Dissolved Metal Concentration in Water (μg/L)

	Batie West Spring			Batie East Spring		
Metal	Sample A	Sample B	Sample C	Sample A	Sample B	Sample C
Cadmium	0.1	0.1	0.1	0.1	0.1	0.1
Chromium	1.8	2.0	1.5	0.2	1.6	0.2
Copper	BDL[34]	BDL	BDL	BDL	BDL	BDL
Nickel	3	5	2	BDL	BDL	BDL
Lead	1	2	2	1	2	2
Zinc	170	60	60	40	40	40
Date sampled: 4/17/97						

[33] EPA Guidelines for Classification of Great Lakes Harbor Sediments.

[34] BDL is below detection level of 0.1μg/L.

Table 17. Batie East Spring Average Dissolved Metal Concentrations vs. Criteria Values based on an average hardness of 208 mg/L as $CaCO_3$

	Average Value	Freshwater Aquatic Life		Human Health	
Metal		Acute	Chronic	Public Water Supplies[35]	All Other Surface Waters[36]
Cadmium (µg/L)	0.1	8.96	2.02	16	170
Chromium (µg/L)	0.67	3163.5[37]	377.1	33000	670000
		16.0[38]	11.0	170	3400
Copper (µg/L)	BDL	35.3	22.1	1300	---
Nickel (µg/L)	BDL	2635.3	293.0	607	4583
Lead (µg/L)	1.7	207.4	8.1	15	---
Zinc (µg/L)	40	217.7	197.1	5000[39]	---

Table 18. Batie West Spring Average Dissolved Metal Concentrations vs. Criteria Values based on an average hardness of 347 mg/L as $CaCO_3$

	Average Value	Freshwater Aquatic Life		Human Health	
Metal		Acute	Chronic	Public Water Supplies[35]	All Other Surface Waters[36]
Cadmium (µg/L)	0.1	15.96	3.01	16	170
Chromium (µg/L)	1.8	4810.7[37]	573.4	33000	670000
		16[38]	11	170	3400
Copper (µg/L)	BDL	57.2	33.6	1300	---
Nickel (µg/L)	3.3	4063.2	451.7	607	4583
Lead (µg/L)	1.7	397.9	15.5	15	---
Zinc (µg/L)	96.7	335.8	304.2	5000[39]	---

[35] These standards are aimed at protecting human health through drinking water and fish consumption.
[36] These standards are aimed at protecting human health through fish consumption.
[37] Values are for Chromium III.
[38] Values are for Chromium VI.
[39] To maintain acceptable taste, odor or aesthetic quality of drinking water.

Table 19. Dissolved Metal Concentration in the Batie East Spring[40]

				Freshwater Aquatic Life		Human Health	
METAL	8/12/97 (μg/L)	7/29//97 (μg/L)	7/15/97 (μg/L)	Acute	Chronic	Public Water Supplies[41]	All Other Surface Waters[42]
Antimony	BDL (10)[43]	BDL(10)	BDL (10)	---[44]	---	---	---
Arsenic	BDL (5)	BDL (5)	BDL (5)	---	---	50	---
Beryllium	BDL (5)	BDL (5)	BDL (5)	---	---	---	---
Cadmium	BDL (5)	BDL (5)	BDL (5)	8.96	2.02	16	170
Chromium	BDL (10)	BDL (10)	24	3163.5[45]	377.01	33000	670000
				16[46]	11	170	3400
Copper	BDL (10)	BDL (10)	BDL (10)	35.34	22.11	1300	---
Iron	133	97	110	---	---	300[47]	---
Lead	BDL (5)	BDL (5)	BDL (5)	207.41	8.08	15	---
Magnesium	19700	17700	18130	---	---	---	---
Manganese	27	25	26	---	---	50[47]	---
Nickel	BDL (10)	BDL (10)	BDL (10)	2635.31	292.97	607	4583
Selenium	BDL (10)	BDL (10)	BDL (10)	20	5.0	172	11200
Silver	BDL (10)	BDL (10)	BDL (10)	14.30	---	---	---
Thallium	BDL (10)	BDL (10)	BDL (10)	---	---	---	---
Zinc	BDL (50)	BDL (50)	BDL (50)	217.7	197.14	5000[47]	---
Mercury	BDL (.3)	BDL (.3)	BDL (.3)	2.4	.012	.144	---
Hardness	206 ppm[48]	207 ppm	211 ppm				

[40] Collection and analyses conducted by the DEQ.
[41] These standards are aimed at protecting human health through drinking water and fish consumption.
[42] These standards are aimed at protecting human health through fish consumption.
[43] Number in parenthesis indicates Minimum Detection Level. BDL is Below detection level.
[44] --- indicates that no data is available.
[45] Values are for Chromium III.
[46] Values are for Chromium VI.
[47] To maintain acceptable taste, odor or aesthetic quality of drinking water.
[48] Units of hardness in ppm are mg/L as Calcium Carbonate

Table 20. Dissolved Metal Concentration in Batie West Spring[40]

				Freshwater Aquatic Life		Human Health	
METAL	8/12/97 (μg/L)	7/29/97 (μg/L)	7/15/97 (μg/L)	Acute	Chronic	Public Water Supplies[49]	All Other Surface Waters[50]
Antimony	BDL (10)[51]	BDL(10)	BDL (10)	---[52]	---	---	---
Arsenic	BDL (5)	BDL (5)	BDL (5)	---	---	50	---
Beryllium	BDL (5)	BDL (5)	BDL (5)	---	---	---	---
Cadmium	BDL (5)	BDL (5)	BDL (5)	15.96	3.01	16	170
Chromium	BDL (10)	BDL (10)	24	4810.7[53]	573.4	33000	670000
				16[54]	11	170	3400
Copper	BDL (10)	BDL (10)	BDL (10)	57.2	34.2	1300	---
Iron	2473	3891	1982	---	---	300[55]	---
Lead	BDL (5)	BDL (5)	BDL (5)	397.9	15.5	15	---
Magnesium	8930	9620	8780	---	---	---	---
Manganese	527	787	417	---	---	50[55]	---
Nickel	BDL (10)	BDL (10)	BDL (10)	4063.2	451.7	607	4583
Selenium	BDL (10)	BDL (10)	BDL (10)	20	5.0	172	11200
Silver	BDL (10)	BDL (10)	BDL (10)	34.5	---	---	---
Thallium	BDL (10)	BDL (10)	BDL (10)	---	---	---	---
Zinc	BDL (50)	BDL (50)	BDL (50)	335.8	304.2	5000[55]	---
Mercury	BDL (.3)	BDL (.3)	BDL (.3)	2.4	.012	.144	---
Hardness	357 ppm[56]	364 ppm	321 ppm				

49 These standards are aimed at protecting human health through drinking water and fish consumption.
50 These standards are aimed at protecting human health through fish consumption.
51 Number in parenthesis indicates Minimum Detection Level. BDL is Below detection level.
52 --- indicates that no data is available.
53 Values are for Chromium III.
54 Values are for Chromium VI.
55 To maintain acceptable taste, odor or aesthetic quality of drinking water.
56 Units of hardness in ppm are mg/L as Calcium Carbonate

4.9. Pesticides

EMI (1996) analyzed the concentration of pesticides present in the Russell leachate and Mason seep. In both cases, pesticides tested negative for those sampling events. Pesticides would be detected in water samples only if a rainfall-runoff event occurs soon after pesticide application, or if a pesticide spill takes place somewhere in the basin.

4.10. Hydrocarbons: volatile, semivolatile, diesel and gasoline range organic compounds

EMI (1994) tested both Batie Springs and the Mason sinkhole for the presence of polyaromatic (semi-volatile) hydrocarbons. Results were negative for both sites. In 1996, EMI analyzed the Russell leachate and Mason seep for volatile, semivolatile, diesel, and gasoline range organic compounds. Both samples tested negative for volatile, semivolatile, and diesel range compounds, but tested positive for gasoline range hydrocarbons. However, in Virginia, sediment that contains less than 50 ppm of gasoline range hydrocarbons is considered not polluted and can be returned back to the ground (Ketron, 1997). According to this standard, both sites could be considered not contaminated for petroleum hydrocarbon compounds, although petroleum releases have occurred upgradient of the Batie Springs in the past.

4.11. Other pollutants and pollutant sources

Phenols were detected in the Russell leachate and Mason seep samples (8.21 and 40.3 mg/Kg, respectively). The USEPA (1980a) states that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 10.2 and 2.56 mg/L, and could occur at lower concentrations among species that are more sensitive than those tested. Phenols were at, or below, detection levels in water samples from the Batie West and East Springs, indicating that most of the phenolic compounds are not in dissolved form. Sulfates were detected in the Russell leachate and Mason seep samples (2600 and 3200 mg/Kg, respectively), which is considered relatively high according to Ketron (1997).

4.12. Toxicity

Data was not found on tolerance and sensitivity of the Batie Creek watershed (and the Powell River watershed) fauna to metals, phenols, sulfate, and gasoline range hydrocarbons (Anderson, 1997). However, the biotic diversity has been negatively impacted as attested by the decrease and disappearance of some rare and endangered plant and animal species, the rotting odors, low dissolved oxygen levels, and the overall degradation of the site.

5. Remediation Alternatives

As a result of this study, the Batie Creek degradation can be attributed to the wood residues from the sawdust mill. Strategies for abating the pollution of Batie Creek were evaluated under the assumption that the source of the organic load would be removed over an appropriate period of time. Without source removal, long-term treatment of the springs would be cost-prohibitive. The following remediation techniques address the concentration of decomposing organic matter in the cave, on the stream substrate, and in the spring resurgences.

I. No action: Source removal with no direct remediation of the groundwater and spring streams would result in very slow restoration of Batie Creek, but it is difficult to predict the rate of recovery. This technique is not suitable since organic matter decomposition, especially sawdust in anaerobic conditions takes longer than 20 years to decompose (Benfield, 1997). According to Melillo et al. (1983) decomposition of wood chips depends on their initial lignin and nitrogen content. The higher the lignin and the lower the nitrogen, the longer it will take for the wood chip to decompose. Coniferous material decomposes more slowly than deciduous. Melillo et al. (1983) predicted that it would take 75 years for a spruce wood chip to decompose in a ninth order stream.

II. Capping: Construction of an impervious cap over the stream bed is only done when the depth precludes removal. In addition, sufficient depth to put a cap over the sediment is required.

III. Chemical neutralization of heavy metals: The data indicate that the primary pollution problem is the organic matter and leachate impacting the cave and springs. The addition of chemicals such as lime might neutralize barium, chromium, lead and zinc, but further treatment of the springs would be necessary to remove the organic load.

IV. Aeration: The addition of oxygen would enhance the decomposition of organic matter. This procedure would cause resuspension of sediment that would flow downstream. It could increase the rate of recovery of the springs, but would also result in a temporary increase in the level of pollution in the Powell River.

V. Flushing of the cave and stream: This procedure would clean the springs but would move the pollutants downstream. The use of vacuum technology could be explored, however, these services are not known to exist in the area.

VI. Dredging: This operation would remove the contaminated layers of sediment from the creek's bottom and could be conducted by local contractors. The sediment would then either be land-applied or disposed in a permitted landfill or compost facility.

Based on the above review, dredging was selected as the most feasible active treatment option for Batie Creek. This does not imply that other techniques or treatments might not prove more cost-effective or efficient. These recommendations are intended as a starting point in the assessment of the most appropriate means to enhance the remediation of Batie Creek.

5.1. Sediment Dredging Operations

Sediments dredged under the purview of the US Army Corps of Engineers are subject to Virginia Solid Waste standards. The EPA has the enforcement authority for clean up of sediment under the following two conditions: (1) if the sediment is dredged and exhibits a hazardous waste characteristic or if it is mixed with a RCRA-listed hazardous waste; and (2) if the sediment contamination can be shown to have resulted by release from a specified solid waste management unit at a RCRA permitted or interim status hazardous waste facility (US Army Corps of Engineers, 1986).

In order to conduct a dredging project in Batie Creek, permits would be required from the Abingdon District Office of the Army Corps of Engineers, the U.S. Fisheries and Wildlife Service (USFWS), the Virginia Marine Resources Commission, and the Virginia DEQ. The USFWS and the Virginia Marine Resources Commission would have oversight authority because Batie Creek discharges to the Powell River which is classified as an endangered species habitat (Poor, 1997). It is recommended that a joint application to the interested agencies be submitted for approval.

5.1.1. Determination of sediment contamination for protection of aquatic life and human health

The determination of whether the sediment is contaminated depends on a number of factors. Historical information such as records or reports of a release of contaminants in the area may be useful in making this determination. Biological indicators such as diversity, number of benthic organisms, and fish kills may provide evidence of environmental stress. Odor or the release of gases from the sediments or water body may also indicate contamination. Finally, data from sediment samples may be used to compare to background concentrations or to criteria values. Guidelines for determining sediment contamination for the preservation of aquatic life and the designated use of the water body have not been finalized; therefore, a decision should be made on a case by case basis (USEPA, 1987).

Site-specific sediment quality criteria may be based on the toxicity of pollutants in the water where equilibrium sorption conditions can be assumed, laboratory measurements of the biological effects of contaminated sediments, or field bioassays that relate the impact of pollutants on the abundance of benthic organisms.

5.1.2. Determination of sediment contamination for disposal purposes

Standard procedures have been developed for the classification and regulation of dredged materials for disposal. These procedures typically involve a series of sediment tests to determine if open water disposal is feasible. Open water disposal involves depositing dredged material in an aquatic environment, which is not a local option.

Upland disposal allows placement of the dredged sediment in a diked containment area on dry land. Usually the solids are retained while the supernatant is allowed to drain into some type of collection system. Control options used to minimize impacts from the upland disposal of contaminated sediment include:

1. Effluent quality control techniques
2. Runoff control structures
3. Leachate control to minimize groundwater contamination
4. Monitoring and control of contaminant uptake by plants and animals
5. Stabilization of emissions and wind erosion

Upland disposal can be long-term or temporary prior to permanent disposal or beneficial use. Sediments may be allowed to dewater in a temporary upland facility prior to landfill disposal. The sediment would be classified as either hazardous or solid waste based on laboratory analyses and/or generator knowledge. If it is determined that the sediment is not contaminated, it may be used as fill material with certain restrictions. An estimated 300 to 450 kg of sediment would have to be removed from the bed of Batie Creek in order to remove most of the contamination. This value is a rough estimate based on: a sludge depth of about 2 inches, a sediment density of 2g/100ml (as per an analysis conducted on April 17, 1997 by the VWRRC), a total stream length of 200 ft, an average stream width of 13.3 ft, and factors of safety of 1.2 and 1.8, respectively. The proposed work zone includes both the Batie West and East Springs and Batie Creek up to Natural Bridge.

5.1.3. Sediment Dredging as a source of contamination

Dredging operations typically create temporary water pollution due to the release of interstitial water, suspension of solids, or desorption of re-suspended solids. In fact, re-suspension of solids may be the single most significant factor in the contamination of the water column since fine sediment has a tendency to stay suspended for long times. They also have a great capacity to grab contaminants such as organics and heavy metals (US Army Corps of Engineers, 1986). In most cases, silt screens are used to contain the re-suspended solids and avoid downstream contamination. In Batie Creek, however, the use of a silt screen would probably not be feasible because of the shallow depth of the creek. Temporary diversion of the creek may prove more practical.

6. Sawdust Disposal

The DEQ estimated that the sawdust piles at the active Russell sawmill contain about 200,000 yd^3 of material, distributed approximately evenly between the new pile and the old (Kaurish, DEQ, 1997b, personal communication.) The current DEQ policy requires that stockpiles of sawdust be dammed, with the leachate directed onto vegetated filtration strips. The filtration strips could be adjacent forested areas. Stockpiling is a temporary option, since eventually all sawdust should be removed from the site (White, 1997). Leachate disposal from new sawmills may be regulated under the storm water management regulations for industrial sites. The Standard Industrial Classification (SIC Code) Manual (Office of Management and Budget, 1997) lists all the industrial businesses and to which regulation each industry is subject to (Wise, 1997). For sawmills, the SIC Code is 2421 (Sawmills and Planning Mills, General).

Ideally, the sawdust should be utilized by an appropriate wood-waste user. A list of wood-waste users according to their distance from Lee County is given in Table 21. These users will probably be able to utilize only the relatively fresh and clean sawdust due to its higher BTU content. The old degraded sawdust should be landfilled or composted off-site in a permitted facility. The beneficial use of these materials in revegetating strip-mined areas should be explored with state agency and industry partners.

Virginia solid waste regulations require that the sawdust be analytically classified as either a solid waste or hazardous waste (Wentz, 1989). A hazardous waste is defined by its degree of ignitability, corrosivity, reactivity, or toxicity. The waste exceeds the regulatory limits if it fails the TCLP (Toxicity Characteristic Leaching Potential) test (Wentz, 1989). In this test, the leachate is subjected to acidic conditions and analyzed for specific parameters, and costs about $1500 per sample. This information, together with generator knowledge, may be used in determining whether the waste is hazardous.

The Russell sawdust piles were not analyzed for TCLP during this study. However, since the concentrations of regulated constituents in the leachate were close to background levels, it is likely that the sawdust would be categorized as a solid waste. In addition, information on the type of wood used by the mill might be helpful in determining the contamination of the sawdust. In addition to the hauling costs, disposal in a solid waste landfill is relatively inexpensive (less than $30.00/Ton), relative to manifesting and disposal in a permitted hazardous waste facility, which could run into thousands of dollars/Ton ($150.00 to $200.00 per 55-gal drum).

Table 21. Wood-Waste users located within 100 miles of Lee County.

Within 50 miles	Within 100 miles
• 123 SonnyLand Mulch Company P.O. Box 352 Abingdon, VA 24210 (540)628-2353 **Washington County** Takes hard wood bark and converts it to bagged mulch	• Harold Patterson 100 Patterson Chip Company, Inc. P.O. Box 647 Barbourville, KY 40905 (606) 523-9480 **Laurel County** Hardwood and Softwood slabs
• Bernie Smith 151 Williamette Kingsport, TN (423)392-2792 **Hawkins County** Produces wood chips	• Joe Stanford 128 Stanford Timber Products, Inc. Rt 1 Box 423 East Bernstadt, KY 40729 (606) 843-6122 **Laurel County** Round wood
• Mack English 38 English Lumber P.O. Box 60 Mooresburg, TN (423)272-4472 **Hawkins County** Produces bark	• Eric Hess 145 Webb Furniture Co. Galax, VA (540)236-6141 **Grayson County** Saw Dust
	• Eric Hess 145 Webb Particle board Jackson St. Galax, VA (54)236-6141 **Grayson County** Mixed

7. Sawdust Recycling and Reuse

Several wood users located within 100 miles of Jonesville may use the relatively new sawdust. A list of possible wood-waste users in the area is given in Table 21. Principal uses for sawdust include:

- Auxiliary industrial fuel.
- Horticultural and agricultural mulch.
- Manufacture of particulate board and paper

Site location and composition of the sawdust are local variables that affect the economic feasibility of a given sawdust recycling project (Lamb, 1997).

A. Use in commercial boilers to dry wood

This is the most common commercial use for sawdust. When sawdust is wet, it has to be combined with dry material. The wetter and older the sawdust, the lower its BTU and value. Transportation to the combustion site may be the most expensive aspect of this recycling option (White, 1997).

B. Application on forest and pasture land

Nitrogen must be added to the sawdust in order for soil microorganisms to decompose the woody material. As a soil amendment, sawdust improves soil moisture retention and adds bulk to the soil (Lofersky, 1997).

C. Combination with sewage sludge for composting and land application (Evanylo, 1997).

In a composting operation, water is added to the compost and the pile is aerated through a system of perforated pipes or by physically turning the piles. The aeration schedule depends on the pile temperature that is closely monitored and measured at several locations within the pile. In general, when the temperature rises to 140°F, in 24 to 48 hours, air is pumped into the pile. When organic matter decomposition is completed, the pile temperature drops to the ambient temperature.

Factors to consider when composting:

1) Microorganisms need a balanced diet to degrade the sawdust. To this end, N needs to be added to the sawdust, to balance the C/N ratio. P addition may also be necessary. The optimum C/P ratio is 150-200:1. N can be applied as digested poultry manure or sewage sludge, in accordance with Virginia Department of Health (VDH) and DEQ regulations.
2) The sawdust moisture content should be between 50-60 percent. If the sawdust pile moisture drops below 50 percent the microorganisms will die.
3) The sawdust pile temperature should be lower than 130-140 °F. If higher, the microorganisms will die.

4) All leachate and runoff must be controlled, collected, and treated to acceptable levels. For more detailed information on composting, see Rynk (1992).

D. Poultry bedding

Since this type of business is more common in eastern and central Virginia, the trucking costs would be relatively high. There may be poultry producers in Kentucky and Tennessee within a reasonable distance (Lofersky, 1997).

E. Sawdust pellets

Fuel pellets are used in special wood stoves, which cost about $1000 - $2000 in retail stores. The pellets are fabricated by machine and are composed of compressed sawdust and glue. Pellet manufactures are located in West Virginia (Glenn, 1996) and Oregon (Christianson, 1997). Christianson (1997) describes the production and characteristics of the sawdust pellets.

F. TRIX

It is a wood and plastic composite used to build furniture (Lofersky, 1997). It is fabricated in Winchester, Virginia. However, it would be expensive to haul the sawdust to Winchester.

G. Particleboard

It is mentioned as an alternative use of sawdust and wood chips (Glenn, 1997)

H. Paper Pulp

An alternative use for fine sawdust (less than ¾ in). The price per ton ranges from $25 to $30 delivered. A cost-benefit analysis would be required to determine the feasibility of hauling the sawdust to the paper mill.

I. Landfill Disposal

When the sawdust is produced faraway from a processing site, and is considered a nonprofitable waste, it may be dumped in a landfill. This is the least desirable option because the capacity and number of local landfills are limited. Currently, some commercial landfills have material recovery operations that separate, process, and sell the woody fraction of the waste stream (Steuteville, 1997).

J. Industrial recruitment

The economic benefits of having a sawdust-recycling industry locate in the area are (1) reduced disposal costs for the local wood products industry, (2) reduced water quality impacts on the community, (3) landfill space savings, and (4) reduced environmental liability. This solution would involve county and state economic development authorities which may offer incentives for wood-recyclers to locate in the area.

8. Prospects for Recovery

The complete recovery of the cave stream community in the Thompson Cedar Cave would be signaled by the physical recovery of the stream and the recolonization by aquatic troglobitic species. According to Culver et al. (1992), the appearance (color and odor) of the water and the appearance of the stream gravel improved from 1987 to 1991 but has reportedly decreased in recent years. Recolonization of the cave by *L. usdagalun* is problematic since the closest cave that is still populated by *L. usdagalun* appears to be physically and hydrologically remote. A recovery plan for the *L. usdagalun* has been completed by the USFWS and DCR (Roble et al., 1997).

Recolonization of the cave habitat is possible since microinvertebrates move from upstream to downstream. Cave isopod may still exist in certain upgradient uncontaminated segments of the karst system. The Lee County fish and other surface water species would move upstream from the Powell River to recolonize Batie Creek once it begins to recover sufficiently to support aquatic life.

9. Recommendations

The ultimate recovery of the Batie Springs and Batie Creek depends on the rate and efficiency of sawdust stockpile removal. This can only be accomplished with the full cooperation of the Russell Lumber Company, which may be limited by their available finances and production schedule. A partnership with the U.S. Fish and Wildlife Service or other federal agencies with funding to support habitat recovery activities may help ease the financial and logistical burden of sawdust removal. However, the true costs associated with this project depend on the method of sawdust disposal or re-use. Sawdust removal from the underlying cave may only be accomplished through natural flushing (once the source is removed), or may be enhanced using vacuum recovery from the surface. Dredging of the impacted surface stream segment between the Batie Springs and the Natural Bridge is recommended as an off-site restoration technique. In order to dredge the creek, a permit from the Army Corps of Engineers is required. Since Batie Creek discharges to the Powell River, which has been designated as an endangered species habitat, a permit from the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission would also be required. Once the sediment is removed from the stream, the stream water quality should be monitored for a period of years.

10. Literature cited

Anderson, K. 1997. Research Scientist, VA Tech. Memorandum. June 25, 1997.

Barron, A. DEQ. 1997c. Environmental Analyst. Personal Communication and Facsimile of criteria values.

Benfield, E. F. 1997. Professor of Ecology. Department of Biology. VA Tech. Personal communication.

Brown, T. 1994. Memorandum. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Blacksburg, VA. Sent to Dr. John Holsinger and Jun Zhang, Dept. of Biological Sciences, ODU. December 12, 1994.

Brown, T. 1997. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Personal communication.

Carr, L .G. 1944. A new species of *Houstonia* from the Cedar Barrens of Lee County, Virginia. Rhodora 46:306-310.

Carr, L. G. 1965. Floristic elements in Southwest Virginia. A phytogeographic consideration. Castanea 30(2):105-145.

Culver, D. C., W. K. Jones, and J. R. Holsinger. 1992. Biological and hydrological investigation of the Cedars, Lee county, Virginia, an ecologically significant and threatened karst area. Proceedings of the first international conference on ground water ecology. Jack A. Stanford and John J. Simmons, eds. Tampa, FL, April 26-29, 1992.

Chapman, D. (editor). 1996. Water Quality Assessments. Published on behalf of the UNESCO, WHO, and UNEP, E and FN SPON, London.

Christianson, R. 1997. Squeezing profits out of wood waste. Wood and wood products. June 1997. 121:124.

DEQ. 1994. Virginia Water Quality Assessment. 305(b) report to EPA administrator and congress for the period 1 July 1991 to 30 June 1993. Information bulletin #597.

DEQ. 1997a. Water quality parameters measured in Batie Creek's watershed.

DEQ. 1997b. DO measured in Batie Springs, Batie Creek, and Town branch.

Environmental Monitoring, Incorporated. 1994. Certificate of Analysis of Batie Creek for The Nature Conservancy. Project 560.4, Coeburn, Virginia. December 1994.

Environmental Monitoring, Incorporated. 1996. Certificate of Analysis of Russell Leachate Sludge for The Nature Conservancy. Project 560.6, Coeburn, Virginia. March 20, 1996.

Estes, J. A. and J. R. Holsinger. 1982. A comparison of the structure of two populations of the troglobitic isopod crustacean *Lirceus usdagalun* (Asellidae). Polskie Archiwum Hydrobiologii 29:453-461.

Ewers, R. O., P. J. Idstein, J. Jacobs and W. Keith. 1995. A hydrogeological investigation of "The Cedars", Lee county, Virginia. Ewers Water Consultants, Richmond, KY.

FAA. 1997. Delta Airport Consultants, Inc. April 1996. Environmental Assessment for Lee County Regional Airport, Jonesville, Virginia.

Glenn, J. 1996. Wood residuals find big uses in small pieces. Biocycle, December 1996, 35-37.

Gowan, D. 1997. The Nature Conservancy. Personal communication.

Helms, R. 1997. Wood Chemist at Virginia Tech Dept. Of Wood Sciences, College of Forestry and Wildlife. Phone conversation on Monday, 7 April 1997.

Holsinger, J. R. 1994. Old Dominion University The Cedars karst basin. Unpublished document.

Holsinger, J. R. and D. C. Culver. 1988. The invertebrate cave fauna of Virginia and part of eastern Tennessee: zoogeography and ecology. Brimleyana 14:1-162.

Holsinger, J.R., 1975. Descriptions of Virginia Caves. Va Div. Of Mineral Resources Bulletin No. 85, Charlottesville, VA, 450 pp.

Holsinger, J. R. and T. E. Bowman. 1973. A new troglobitic isopod of the genus Lirceus (Asellidae) from southwestern Virginia, with notes on its ecology and additional cave records for the genus in the Appalachians. International Journal of Speleology 5:261-271.

Institute for Environmental Negotiation. 1987. Division of Urban & Environmental Planning. University of Virginia. Nutrient Control Standards Workshop. May 14-15, 1987. Williamsburg, VA.

Jones, W.K. 1990. Preliminary Hydrological Investigation of The Cedars, Lee County, VA, unpublished proposal.

Ketron, G. 1997. EMI. Personal communication.

Kaurish, F. 1997 (b). Virginia DEQ. Personal communication.

Koch, L. 1997. U.S. Fish and Wildlife Service Facsimile of Recovery Plan draft for *Lirceus usdagalum*. 10 February 1997.

Kundell, J. and T. Rasmussen. 1995. Recommendations of the Georgia Board of Regents Scientific Panel on Evaluating the Erosion Measurement Standard Defined by the Georgia Erosion and Sedimentation Act. pp. 211-217. In: Proceedings 1995 Georgia Water Resources Conference. University of Georgia, Athens, GA.

Lawson, A. 1997. Memorandum of the Batie Creek Task Force. June 10, 1997.

Lofersky, J. 1997. Wood Science and Forest Products. Brooks Forest Products Center. VA Tech. Personal communication.

Melillo, J. M., R. J. Naiman, J. D. Aber, and K. N. Eshleman. 1983. The influence of substrate quality and stream size on wood decomposition dynamics. Oecologia (Berlin)58:281-285.

Miller, R. L. and W. P. Brosge. 1954. Geology and oil resources of the Jonesville district, Lee County, Virginia: U. S. Geological Survey Bulletin 990, 240p.

N'Dayegamiye, A. and D. Isfan. 1991. "Chemical and biological changes in compost of wood shavings, sawdust, and peat moss." *Canadian Journal of Soil Science*. 71: 475-484.

Office of Management and Budget, 1997. Standard Industrial Classification Manual. NTIS #PB87-100012.

Rea, J. 1996. Personal communication, Eastern Kentucky University, Bowling Geen, KY.

Roble, S., T. Brown, and L. Koch. 1997. Lee County Cave Isopod Recovery Plan, U.S. Fish & Wildlife Service, Hadley, Ma.

Rynk, R. 1992. On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service, Cooperative Extension, (NRAES-54), Ithaca, NY.

Smith, L. 1991. An overview of the natural heritage resources of the Cedars, Lee County, Virginia. Report, Division of Natural Heritage, Department of Conservation and Recreation, Richmond, VA.

Smith, W. 1997. Wood Science and Forest Products. Brooks Forest Products Center. VA Tech. List of industries that process wood waste.

Smollen. M.A. 1997. Draft of Batie Creek and Town Branch benthic and aquatic fauna. TVA.

Steuteville, R. 1997. Landfill diversion, large scale wood processing and marketing. Biocycle January 1997, 50-53.

TRS. 1997. Impact of suspended and deposited sediments. Watershed Protection Techniques. Technical notes. 2(3): 443- 444.

The Terrene Institute, USEPA, and US Department of Agriculture Forest Service. 1993. Proceedings. Technical Workshop on Sediments. Fev. 3-7, 1992. Corvallis, Oregon.

US Army Corps of Engineers. 1986. Guidelines for Selecting Control and Treatment Options for Contaminated Dredged Materials Requiring Restrictions. Environmental Lab. Dept. of the Army. Water Ways Experiment Station. Corps of Engineers, Vicksburg, MI.

USDA. 1953. Soil survey, Lee county Virginia, Series 1939, No. 17. USDA in cooperation with the Virginia Agricultural Experiment Station and the Tennessee Valley Authority.

U.S. Department of Justice Federal Bureau of Prisons and Louis Berger & Associates, Inc. 1996. United States Penitentiary, Lee Pennington Gap, Virginia., Washington, DC.

USEPA. 1973. Water quality criteria 1972. USEPA, EPA/R3/73/033.

USEPA. 1976. Water quality criteria, 1976. Facsimile from DEQ office, Oct. 1997.

USEPA. 1980a. Ambient water quality criteria for phenol. USEPA, Office of water regulations and standards, Criteria and Standards Division, Washington, DC, EPA 440/5-80-066.

USEPA. 1980b. Ambient water quality criteria for zinc. USEPA, Office of water regulations and standards, Criteria and Standards Division, Washington, DC, EPA.

USEPA. 1987. An Overview of Sediment Quality in the United States. Monitoring and Data Support Division Office of Water Regulations and Standards. Washington, DC.

USEPA. 1990. Contaminated sediments. Relevant statutes and EPA program activities Sediment oversight Technical committee (WH-553). EPA 506/6-90/003.

USEPA. 1993. Selecting remediation techniques for contaminated sediment, USEPA, Office of Water (WH-585), EPA-823-B93-001.

VWRRC. 1997a. Metals in Batie East and West water and sediment. COD, pH, T, in the Batie East and West Springs.

VWRRC, 1997b. Nitrogen and P compounds and Fecal and Total coliforms in the Batie East and West Springs, and the Russell sawdust leachate.

Wentz, C. 1989. Hazardous Waste Characterization and Site Assessment. In: Hazardous Waste Management. McGraw-Hill Publishing Company.

White, M. 1997. Wood Science and Forest Products. Brooks Forest Products Center. VA Tech. Personal communication.

Williams, J., M. Warren, K. Cummings, J. Harris, and R. Neves. 1993. Conservation Status of Freshwater Mussels of the United States and Canada. Fisheries 18(9):6-22.

Wise, L. 1997. DEQ, Roanoke. Personal communication.

11. Literature Consulted

Allen, H. E (editor). 1995. Metal Contaminated Aquatic Sediments. Ann Arbor Press, Chelsea, MI.

Averett, D. E., B.D. Perry, E.J. Torrey, J. A. Miller. 1990. Review of removal, containment, and treatment technologies for remediation of contaminated sediment in the Great Lakes, Miscellaneous Paper EL-90-25, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Baudo, R., J. P. Giesy, H. Muntau (editors).1990. Sediments: chemistry and toxicity of in-place pollutants. Lewis Publishers, Inc., Chelsea MI.

Benfield, E. F. 1996. Leaf Breakdown in Stream Ecosystems, 579-589. In: Methods in stream ecology. F. R. Hauer and G. A. Lamberti (Editors). Academic Press, San Diego.

Cairns, J. Jr. (editor). 1985. Multispecies Toxicity Testing. Pergamon press, NY..

Cullinane, M. J., D.E. Averett, R.A. Shafer, J.W. Male, C.L. Truitt, M.R. Bradbury. 1986. Guidelines for selecting control and treatment options for contaminated dredged material requiring restrictions, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Francingues, N. R., Jr., M. R. Palermo, C. R. Lee, and R. K. Peddicord. 1985. Management Strategies for disposal of dredged material: contaminant testing and controls, Miscellaneous Paper D-85-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Glenn, J. 1996. Wood residuals find big uses in small pieces. Biocycle December 1996, 35:38.

Biocycle . 1996. Products from bark and stumps. Biocycle December 1996, 35:38(?).

Osborne, L. L., P.B. Bayley, L.W. Higler, B. Statzner, F. Triska, and T.M. Iversen. 1993. Restoration of lowland streams: an introduction. Freshwater Biology, 29:187-194.

Rader, E. K. and N. H. Evans, editors. 1993. Geologic map of Virginia - expanded explanation: Virginia Division of Mineral Resources, 80p.

Shineldecker. C. L. 1992. Handbook of Environmental Contaminants: a guide for site assessment. Lewis Publishers, N. Y.

Statzner, B. and F. Sperling. 1993. Potential contribution of system-specific knowledge (SSK) to stream-management decisions: ecological and economic aspects. Freshwater Biology, 29:313-342.

Suthersan. S. S. 1996. Remediation Engineering Design Concepts. Lewis Publishers, N. Y.

USEPA. 1987. A compendium of technologies used in the treatment of hazardous wastes. Office of Research and Development, Washington, DC, EPA/625/8-97/014.

USEPA. 1991. Handbook: remediation of contaminated sediments. USEPA, Office of research and development, Washington, DC, EPA/625/6-91/028.

USEPA. 1990. Handbook on in situ treatment of hazardous waste-contaminated soils. Risk Reduction Engineering Laboratory, Cincinnati, OH, EPA/540/2-90/002.

USEPA. 1990.Workshop on innovative technologies for treatment of contaminated sediments June 13-14, 1990. Summary report. USEPA, Office of research and development, Washington, DC, EPA/600/2-90/054.

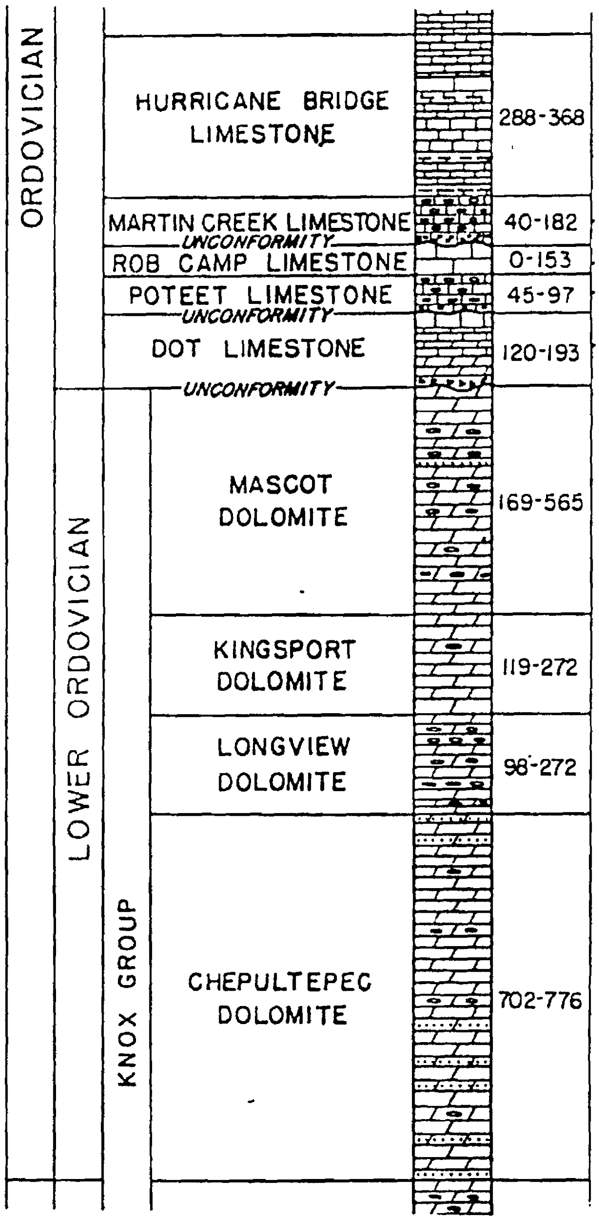
Webster, J. R. and E. F. Benfield. 1986. Vascular plant breakdown in freshwater ecosystems. Ann Rev. Ecol. Syst. 17:567-594.

Wolcott, L. T. 1990. Coal Waste Deposition and the Distribution of Freshwater Mussels in the Powell River, VA. Ms Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, VPI&SU, Blacksburg, VA.

Appendix A

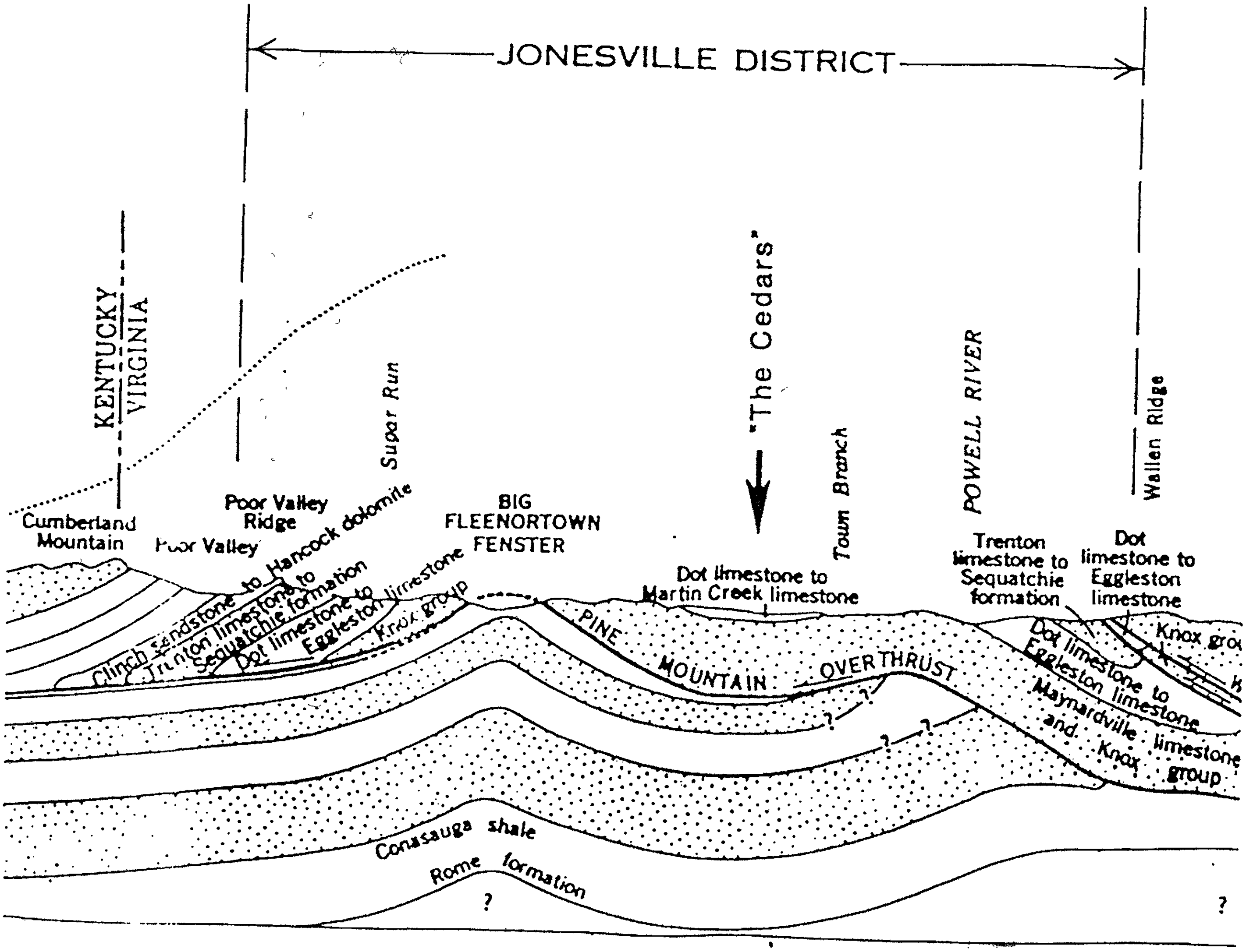
HYDROGEOLOGIC INFORMATION

Figure 1
Rocks Exposed in "The Cedars"

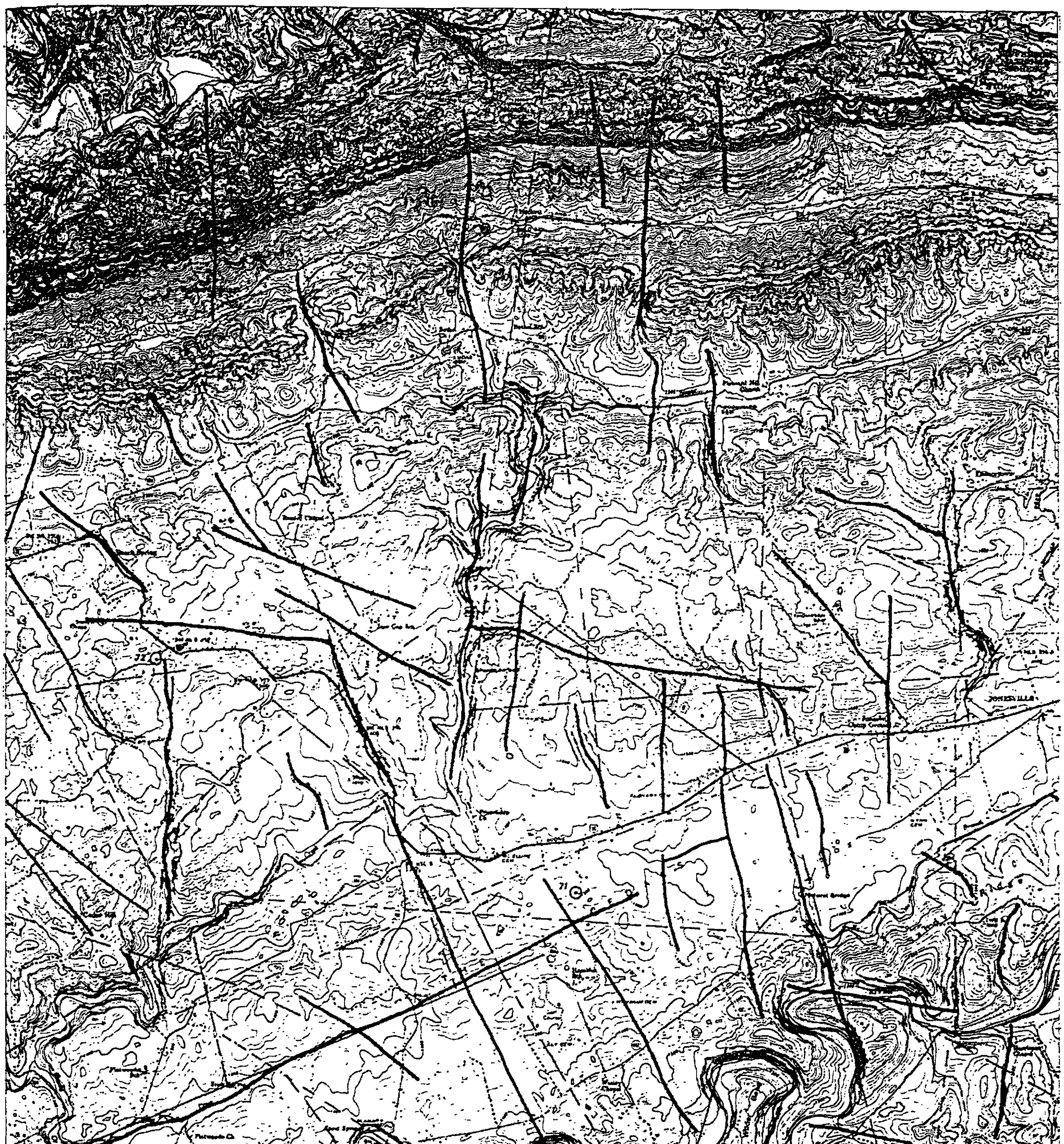


After Miller and Brosge, 1954

Figure 2
Geologic Cross-section of "The Cedars"



After Miller and Brosge, 1954


Control by USC&GS, USGS, and TVA
Topography by USGS and TVA from aerial photographs by stereophotogrammetric methods
Field examination by Tennessee Valley Authority, 1946
1000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue
SCALE 1:24000
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
QUADRANGLE LOCATION
PLATE 11
HUBBARD SPRINGS, VA.—KY.

Appendix B

LIST OF ENDANGERED AND THREATENED SPECIES

DEPARTMENT OF CONSERVATION & RECREATION
DIVISION OF NATURAL HERITAGE

NATURAL HERITAGE RESOURCES IN THE CEDARS MACROSITE

SCIENTIFIC NAME	COMMON NAME	GLOBAL RANK	STATE RANK	FEDERAL STATUS	STATE STATUS	EO RANK	LAST OBSERVATION	SURVEY SITE
GRAPTEMYS GEOGRAPHICA	MAP TURTLE	G5	S2S3			E	1992-10-06	FLETCHER BLUFFS
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	G4G5	S2	SOC	LT	B	1989-07-09	THE CEDARS
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	G4G5	S2	SOC	LT	B	1990-06-19	
BRACHORIA CEDRA	CEDAR MILLIPEDE	G1G2	S1			A	1990-05-10	NATURAL BRIDGE
BRACHORIA CEDRA	CEDAR MILLIPEDE	G1G2	S1			C	1990-05-30	JIM FULKS FARM
LIRCEUS USDAGALUN	LEE COUNTY CAVE ISOPOD	G1	S1	LE	LE	C	1996-12-01	SIMMS CREEK SPRING
LIRCEUS USDAGALUN	LEE COUNTY CAVE ISOPOD	G1	S1	LE	LE	B	1994-11-24	FLANNERY BRIDGE SP
LITOCAMPA COOKEI	A CAVE DIPLURAN	G?	S1			U		MOLLY WAGLE CAVE
MESODON ELEVATUS	PROUD GLOBE	G5	S2			E	1992-10-06	FLETCHER BLUFFS
PSEUDANOPHTHALMUS DELICATUS	DELICATE CAVE BEETLE	G2	S2			E	1980-	MOLLY WAGLE CAVE
SPELOBIA TENEBRARUM	A CAVE FLY	G4?	S1			U		THE CEDARS
CAMASSIA SCILLOIDES	WILD HYACINTH	G4G5	S2			C	1990-05-10	THE CEDARS
CAMASSIA SCILLOIDES	WILD HYACINTH	G4G5	S2			U	1979-05-20	THE CEDARS
CAMASSIA SCILLOIDES	WILD HYACINTH	G4G5	S2			BC	1995-06-08	THE CEDARS - SIMS
								LEE COUNTY AIRPORT
HOUSTONIA CANADENSIS	LONGLEAF BLUETS	G4G5	S2			A	1995-06-08	THE CEDARS - BEECH
								ROADSIDES; LEE COU
								AIRPORT
LITHOSPERMUM LATIFOLIUM	AMERICAN GROMWELL	G5	S2			E?	1986-10-07	THE CEDARS
LITHOSPERMUM LATIFOLIUM	AMERICAN GROMWELL	G5	S2			CD	1990-07-24	THE CEDARS
MANFREDA VIRGINICA	FALSE ALOE	G5	S1			A	1995-06-08	BEECH GROVE ROADSI
								THE CEDARS; BEECH
								CLIFF; THE CEDARS
								HAMBLIN
								SCHOOL; CEDAR GLAD
								NATURAL BRIDGE; LE
								COUNTY AIRPORT
MANFREDA VIRGINICA	FALSE ALOE	G5	S1			C	1990-	THE CEDARS
MANFREDA VIRGINICA	FALSE ALOE	G5	S1			BC	1990-	THE CEDARS
SCUTELLARIA PARVULA VAR PARVULA	SMALL SKULLCAP	G4T?	S1			A	1994-05-16	THE CEDARS - BEECH
								ROADSIDES
SENECIO MILLEFOLIUM	YARROW-LEAVED RAGWORT	G2?	S1	SOC		A	1995-06-08	BEECH GROVE ROADSI
								LEE COUNTY AIRPORT
SISYRINCHIUM ALBIDUM	WHITE BLUE-EYED-GRASS	G5?	S2			A	1995-06-08	BEECH GROVE ROADSI
								THE CEDARS; BEECH
								CLIFF; THE SCHOOL;
								GLADE AT NATURAL B
								LEE COUNTY AIRPORT
SPOROBOLUS COMPOSITUS VAR COMPOSITUS	LONGLEAF DROPSEED	G5T5	S1S2			E?	1985-09-23	THE CEDARS
SPOROBOLUS NEGLECTUS	SMALL DROPSEED	G5	S2			C	1990-09-09	THE CEDARS - HAMBL
								SCHOOL
TRIFOLIUM CALCARICUM	RUNNING GLADE CLOVER	G1	S1	SOC		A	1994-05-16	BEECH GROVE ROADSI
								THE CEDARS

DEPARTMENT OF CONSERVATION & RECREATION
DIVISION OF NATURAL HERITAGE

NATURAL HERITAGE RESOURCES IN THE CEDARS MACROSITE

SCIENTIFIC NAME	COMMON NAME	GLOBAL RANK	STATE RANK	FEDERAL STATUS	STATE STATUS	EO RANK	LAST OBSERVATION	SURVEY SITE
ALKALINE COLD SPRING & SPRING RUN						A	1990-05-15	THE CEDARS - SIMS
APPALACHIAN CAVE STREAM COMMUNITY		G2	S2			A	1990-05-17	THE CEDARS
OLIGOTROPHIC SCRUB						AB	1990-05-16	THE CEDARS
OLIGOTROPHIC WOODLAND						B	1990-05-16	THE CEDARS
OLIGOTROPHIC WOODLAND						C	1990-05-16	THE CEDARS
OLIGOTROPHIC WOODLAND						B	1990-05-17	THE CEDARS
OLIGOTROPHIC WOODLAND						B	1990-05-15	THE CEDARS
OLIGOTROPHIC WOODLAND						BC	1995-09-20	CEDARS PROPOSED AI
PERMESOTROPHIC FOREST						C	1990-05-17	THE CEDARS - SIMS
SUBMESOTROPHIC FOREST						BC	1995-09-20	CEDARS PROPOSED AI
SIGNIFICANT CAVE						U	1985-	MOLLY WAGLE CAVE

37 Records Processed

Table
Natural Heritage Resources of the Powell River from Big Stone Gap to the Tennessee Line

SPECIES NAME	COMMON NAME	GLOBAL RANK	STATE RANK	FEDERAL STATUS	STATE STATUS
APALONE SPINIFERA	SPINY SOFTSHELL	G5	S2		
DROMUS DROMAS	DROMEDARY PEARLYMUSSEL	G1	S1	LE	LE
EPIOBLASMA BREVIDENS	CUMBERLAND COMBSHELL	G2	S1	LE	LE
EPIOBLASMA CAPSAEFORMIS	OYSTER MUSSEL	G2	S1	LE	LE
EPIOBLASMA TRIQUETRA	SNUFFBOX	G3	S1	SOC	LE
ERIMYSTAX CAHNI	SLENDER CHUB	G1G2	S1	LT	LT
ETHEOSTOMA CAMURUM	BLUEBREAST DARTER	G4	S2		SC
ETHEOSTOMA CLARUM	WESTERN SAND DARTER	G3	S1		LT
ETHEOSTOMA MEADIAE	SPECKLED DARTER	G5	S2		
FUSCONAIA BARNESIANA	TENNESSEE PIGTOE	G2G3	S2S3		SC
FUSCONAIA COR	SHINY PIGTOE	G1	S1	LE	LE
FUSCONAIA CUNEOLUS	FINE-RAYED PIGTOE	G1	S1	LE	LE
GRAPTEMYS GEOGRAPHICA	MAP TURTLE	G5	S2S3		
HEMISTENA LATA	CRACKING PEARLYMUSSEL	G1	S1	LE	LE
IO FLUVIALIS	SPINY RIVERSNAIL	G2	S2	SOC	LT
LABIDESTHES SICCULUS	BROOK SILVERSIDE	G5	S2		SC
LEMIOX RIMOSUS	BIRDWING PEARLYMUSSEL	G1	S1	LE	LE
LEXINGTONIA DOLABELLOIDES	SLABSIDE PEARLYMUSSEL	G2G3	S2	SOC	LT
LIGUMIA RECTA	BLACK SANDSHELL	G5	S2		LT
MESODON ELEVATUS	PROUD GLOBE	G5	S2		
MOXOSTOMA CARINATUM	RIVER REDHORSE	G4	S2S3		SC
NECTURUS MACULOSUS	MUDPUPPY	G5	S2		
NOTROPIS ARIOMMUS	POPEYE SHINER	G3	S2S3		SC
PEGIAS FABULA	LITTLE-WINGED PEARLYMUSSEL	G1	S1	LE	LE
PERCINA AURANTIACA	TANGERINE DARTER	G3G4	S2S3		
PERCINA COPELANDI	CHANNEL DARTER	G4	S2		SC
PLETHOBASUS CYPHYUS	SHEEPNOSE	G3	S1		LT
PLEUROBEMA OVIFORME	TENNESSEE CLUBSHELL	G2G3	S2S3	SOC	
QUADRULA CYLINDRICA STRIGILLATA	ROUGH RABBITS FOOT	G4T2T3	S2	PE	LT

SPECIES NAME	COMMON NAME	GLOBAL RANK	STATE RANK	FEDERAL STATUS	STATE STATUS
QUADRULA INTERMEDIA	CUMBERLAND MONKEYFACE	G1	S1	LE	LE
QUADRULA SPARSA	APPALACHIAN MONKEYFACE	G1	S1	LE	LE
STERNOTHERUS MINOR	LOGGERHEAD MUSK TURTLE	G5	S2		
TRUNCILLA TRUNCATA	DEERTOE	G4	S1		LE
VILLOSA PERPURPUREA	PURPLE BEAN	G1	S1	LE	LE

Table 2. Abbreviated definitions of ranks used by the Virginia Natural Heritage Program to set protection priorities for rare species and natural communities. These ranks are not legal designations.

Global Rank	State Rank	Definition
G1	S1	Extremely rare; usually 5 or fewer populations or occurrences in the state (S1) or overall range (G1); or only a few remaining individuals are known; often especially vulnerable to extirpation.
G2	S2	Very rare; usually between 5 and 20 populations or occurrences; or with many individuals in fewer occurrences; often susceptible to extirpation.
G3	S3	Rare to uncommon; usually between 20 and 100 populations or occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.
G4	S4	Common; usually more than 100 occurrences, but may be fewer with many populations; may be restricted to only a portion of the state (S4) or overall range (G4); usually not susceptible to immediate threats.
G5	S5	Very common; demonstrably secure under present conditions.
–	SA	Occurs accidentally in the state.
GH	SH	Historically known from the state (SH) or the overall range (GH), but not verified for an extended period, usually more than 15 years; this rank is used primarily when inventory has been attempted recently.
–	SN	Regularly occurring migrants; transients; seasonal, nonbreeding residents. Usually no specific site can be identified within its range in the state. (Note that congregation and staging areas are monitored separately.)
GU	SU	Status uncertain, often because of low search effort or cryptic nature of the element.
GX	SX	Apparently extirpated from the state (SX) or overall range (GX).
Q		Denotes that the taxonomic status of the species is questionable.
T		Denotes that rank applies to a subspecies.

Draft

TVA 418 - 1 Batie Creek(mile 0.5) Below natural bridge 07/10/96

Return to Watershed Index | Return to Index | Location info. | Next Site | Prev Site | overall species list | IBI | Benthic | Habitat

IBI score: 32 poor

Common name	Scientific Name	Count	Anomalies
Central stoneroller	*Campostoma anomalum*	18	3
Striped shiner	*Luxilus chrysocephalus*	51	12
Bigeye chub	*Notropis amblops*	35	.
Telescope shiner	*Notropis telescopus*	2	.
Bluntnose minnow	*Pimephales notatus*	22	.
Blacknose dace	*Rhinichthys atratulus*	8	.
Creek chub	*Semotilus atromaculatus*	1	.
Black redhorse	*Moxostoma duquesnei*	1	.
Banded sculpin	*Cottus carolinae*	142	.
Rock bass(>= 5 in.)	*Ambloplites rupestris*	1	.
Redbreast sunfish	*Lepomis auritus*	1	.
		282	15

Problem with the dataComments

Return to Watershed Index | Return to Index | Location info. | Next Site | Prev Site | overall species list | IBI | Benthic | Habitat

revised: March 5, 1997

Draft

TVA 11496 - 1 Town Branch(mile 0.2) Above Batie Creek 07/11/96

Return to Watershed Index | Return to Index | Location info. | Next Site | Prev Site | overall species list | IBI | Benthic

IBI score: 38 poor/fair

Common name	Scientific Name	Count	Anomalies
Central stoneroller	*Campostoma anomalum*	132	.
Whitetail shiner	*Cyprinella galactura*	10	.
Spotfin shiner	*Cyprinella spiloptera*	Q	.
Striped shiner	*Luxilus chrysocephalus*	136	1
Warpaint shiner	*Luxilus coccogenis*	47	.
Mountain shiner	*Lythrurus lirus*	2	.
Sawfin shiner	*Notropis (undescribed)*	1	.
Bigeye chub	*Notropis amblops*	59	.
Tennessee shiner	*Notropis leuciodus*	16	.
Rosyface shiner	*Notropis rubellus*	1	.
Telescope shiner	*Notropis telescopus*	123	.
Mimic shiner	*Notropis volucellus*	2	.
Bluntnose minnow	*Pimephales notatus*	24	.
Blacknose dace	*Rhinichthys atratulus*	112	.
Banded sculpin	*Cottus carolinae*	38	.
Rock bass(< 5 in.)	*Ambloplites rupestris*	3	.
Rock bass(>= 5 in.)	*Ambloplites rupestris*	1	.
Snubnose darter	*Etheostoma simoterum*	2	.
		709	1

Problem with the dataComments

Return to Watershed Index | Return to Index | Location info. | Next Site | Prev Site | overall species list | IBI | Benthic

revised: March 5, 1997