PROBABILISTIC MONITORING OF STREAMS BELOW SMALL IMPOUNDMENTS IN TENNESSEE

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L&C Annex
401 Church Street
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David Stucki measures flow downstream of an impoundment on Savage Creek on the Cumberland Plateau.

Photo provided by Aquatic Biology Section, TDH.

Cover: Outfall of impoundment on Davis Branch in Sumner County, Spring 2004.
Photo provided by Aquatic Biology Section, TDH.

EXECUTIVE SUMMARY

The Division of Water Pollution Control receives requests to impound streams though the Aquatic Resources Alteration Permit Program (ARAP). The majority of these requests are on first to third order streams in headwater areas. Small impoundments are constructed for a variety of reasons including flood control, fishing, livestock, irrigation, industrial use, water supply, and aesthetics. Dams on these small streams not only affect the impounded stream segment but also have the potential to alter the physical, chemical and biological components of downstream reaches. The accumulative affect of multiple headwater impoundments can have an effect on flow regimes and sediment transport in larger downstream systems.

In 2003, the Tennessee Department of Environment and Conservation, Division of Water Pollution Control was awarded a 104(b)(3) grant to perform a probabilistic monitoring study of 75 streams below small impoundments. The study measured effects of the impoundments on aquatic life, nutrients, dissolved oxygen, pH, iron, manganese, habitat, flow and periphyton density in the downstream stream reaches.

Macroinvertebrate communities were adversely affected in most of the streams sampled. Of the 75 sites below impoundments, only four passed biological criteria guidelines or were comparable to first order references in both seasons sampled. The most frequent change in the benthic community structure was a loss of taxa in the generally intolerant orders, Ephemeroptera, Plecoptera and Trichoptera (EPT). Ninety-six percent of the samples failed to meet reference guidelines for the number of distinct EPT taxa. The abundance of EPT that were present was also reduced, with 86 percent of the samples having low EPT density. Higher numbers were generally due to the abundance of a single nutrient tolerant taxon. The loss of other taxa was also evident, 87 percent of the samples failed to meet taxa richness guidelines. A shift in the type of dominant organisms toward more tolerant taxa was also observed.

Lack of adequate flow was one of the biggest problems downstream of impoundments. Approximately one third of the perennial streams that were randomly selected for reconnaissance were dry. Of those with flow during the summer reconnaissance, one-fourth had dry channels by the fall sampling period. Thirty-nine percent of the dams with year-round discharge provided insufficient flow to supply adequate habitat for aquatic life during at least one season.

The Rosgen stream classification system was used to characterize the geomorphic effects on streams downstream of dams in the 14 ecoregions surveyed (Rosgen, 1996). Using this classification system it was apparent that many of the streams below the impoundments in the study had channel structures that were undergoing geomorphic change. Only about half of the streams appeared to have relatively stable channel structures typical of the ecoregion.

Disruption of habitat was a major concern below most of the impoundments. Sediment deposition was the most significant habitat problem in impounded streams with 80% failing to meet regional expectations. The sediment deposition parameter measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many aquatic organisms. Other frequently documented habitat problems included embeddedness of substrate, instability of banks, loss of stream sinuosity and disruption of bank vegetation.

The most frequently encountered chemical water quality problems below impoundments were elevated iron, manganese and nutrients as well as low dissolved oxygen concentrations. Elevated manganese was the number one problem. Ammonia was the most frequently elevated nutrient.

Dissolved oxygen in lakes and streams is critical to support fish and aquatic life. Low levels of dissolved oxygen may be caused by decay of organic material, respiration of algae, inflow of substantial amounts of ground water, or reduced stream flow. Dissolved oxygen was below criteria in at least one season at 21 of the impounded test sites. Many sites that passed dissolved oxygen criteria during daylight hours did not maintain saturation comparable to reference levels. Streams with dissolved oxygen saturation below this level may not be providing adequate oxygen to support benthic communities appropriate for the ecoregion.

Water temperature is an important component of the aquatic environment. Almost all facets of life history and distribution of aquatic macroinvertebrates are influenced by temperature. Eight of the impounded streams violated the temperature criterion at the time of sampling. Most of the test sites fell outside the temperature ranges found in regional reference streams.

Low pH, elevated alkalinity, or a significant change in the pH or acidity of the water over a relatively short period of time, can greatly impact aquatic life. The affects include respiratory or osmoregulatory failure, inability to molt and alteration of habitat through precipitation of iron. The majority of streams met pH criterion although iron and manganese precipitates were frequently observed.

Approximately half of the impounded test sites had elevated suspended solids (TSS) compared to regional reference streams. Total suspended solids (TSS) can include a wide variety of material, such as silt and decaying organic matter. High TSS can block light from reaching submerged vegetation. Particles can clog gills, reduce growth rates, decrease resistance to disease and prevent egg and larval development of benthic fauna. Suspended particles absorb heat from sunlight, which can result in higher water temperatures. Pollutants such as bacteria, nutrients, pesiticides and metals may attach to sediment particles and be transported to the water where they are released or carried further downstream.

High concentrations of heavy metals are toxic to aquatic life while precipitation of metals can render habitat unsuitable for colonization. Iron was above the recommended criterion of 1,000 ug/L at 61% of the impounded test sites. Manganese was above the 90th percentile of reference data at almost all sites.

Elevated nutrient concentrations are a common problem in surface waters in Tennessee. Impoundments have a tendency to trap nutrient runoff from surrounding land use, which can accelerate eutrophication. This nutrient rich water is then released to the stream. Nutrients can affect aquatic fauna through the stimulation of algal growth. This in turn can deplete dissolved oxygen levels and render substrates unusable for colonization by aquatic fauna. The presence of excessive nutrients can cause result in shifts of the benthic community toward organisms that feed on algae and fine organic matter.

Concentrations of total phosphorus, total ammonia, nitrate+nitrite and total Kjeldahl nitrogen (TKN) below each impoundment were compared to the reference database and first order reference streams to determine if excess nutrients were available for algal growth. Ammonia was the most frequently elevated nutrient followed by total phosphorus, TKN, and nitrate+nitrite.

When compared to ecoregion or first order reference sites, about half of the impounded streams had elevated periphyton density. Algae were abundant at more sites in the fall than in the summer probably due to lower canopy and less flow in the fall. More sites had elevated microalgal density than filamentous macroalgae. However the sites with filamentous algae had more severely impaired macroinvertebrate communities. Worms and midges dominated most of these samples. Macroalgae abundance showed a direct relationship with nutrients (TKN) and percent canopy.

Beasley Hollow Creek downstream of Shellcracker Lake had abundant filamentous algae and low dissolved oxygen in fall and summer.

Photo provided by Aquatic Biology Section, TDH.

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1. INTRODUCTION

Tennessee has over 60,000 miles of streams, many of which are headwater streams. These small streams are an important component of each watershed. They are the first locations in the upper reaches of the watershed where rainfall, runoff and groundwater merge to form a defined stream channel. Water contributed by headwater streams helps maintain summer base flow in downstream systems. They provide habitat to relatively distinct and diverse biota. Headwater streams are a key interface between the surrounding landscape and larger waterbodies. Disturbances not only affect the stream where the activities occur, but collectively have the potential to affect larger downstream systems.

The Division of Water Pollution Control receives requests to impound streams through the Aquatic Resources Alteration Permit Program (ARAP). Small impoundments are constructed for a variety of reasons including flood control, fishing, livestock, irrigation, industrial use, water supply, and aesthetics. Dams on small streams have the potential to cause adverse affects on aquatic life. The impoundment eliminates flowing stream segments in the flooded area making the habitat unsuitable for the native fluvial species, which are replaced by generally less diverse lotic species.

Not only is the impounded stream segment affected, the physical, chemical and biological components of downstream reaches may also be altered. Impoundments stop the natural flow and transfer of large particles, water and food sources downstream. Water retained in small stream impoundments is warmer due to increased exposure to sunlight resulting in elevated downstream water temperatures. Nutrients are accumulated from surrounding land uses and then released from impoundments where they become available for macrophyte or algal growth. Prolific algal growth affects dissolved oxygen levels and habitat availability.

Dams create barriers that can result in isolated populations of aquatic life that are less able to cope with environmental extremes. Many dams have no provision for minimum flow and provide inadequate flow downstream in the summer months or other low flow periods. Subsequently, low or no-flow events increase in frequency and magnitude and reduce the ability of aquatic populations to recover. All of these factors can lower biological integrity and result in altered water quality downstream of the impoundment.

Currently, 18 streams are listed as impaired due to small impoundments upstream (TDEC, 2005). Causes include habitat loss due to flow alteration or alteration in streamside or littoral vegetative cover, physical substrate habitat alteration, other anthropogenic substrate alteration, siltation, nutrients, ammonia, low dissolved oxygen and/or iron. There are likely many more streams affected as the majority of impounded headwater streams are generally not monitored after the dams are built to determine if aquatic life and water quality has been compromised. Additional streams will be added as a result of this study.

In 2003, the Tennessee Department of Environment and Conservation, Division of Water Pollution Control was awarded a 104(b)(3) grant to perform a probabilistic monitoring study of 75 streams below small impoundments. The probabilistic nature of the project will allow extrapolation to estimate the general condition of streams immediately below impoundments statewide. The study was designed to meet the following objectives:

1. Assess the effects of small impoundments on downstream aquatic life.

2. Measure the effects of small impoundments on downstream nutrient levels.

3. Document the effects of small impoundments on downstream dissolved oxygen levels.

4. Determine the effects of small impoundments on downstream pH levels.

5. Quantify the effects of small impoundments on iron and manganese levels.

6. Identify the effects of small impoundments on downstream channel structure and substrate.

7. Establish the effects of small impoundments on downstream habitat particularly embeddedness, sediment deposition, bank stability and erosion.

8. Determine if adequate flows are maintained in streams downstream of small impoundments.

9. Determine if periphyton levels are increased in streams below small impoundments.

10. Use data to better evaluate possible impacts of proposed impoundments during the permit review process.

11. Estimate the percentage of streams downstream of small impoundments that are likely to meet water quality standards based on probabilistic analysis.

2. DISTRIBUTION OF SMALL IMPOUNDMENTS IN TENNESSEE

Tennessee has over 195,00 small man-made lakes and ponds (Wilson et al, 2000). For the purpose of this study, small impoundments were defined as those encompassing 250 acres or less which have the potential for public access (Safe Dams database) or were built after 1992 and required an ARAP permit (Natural Resources database). There were 1,302 small impoundments that met this definition (Figure 1). Dams built prior to 1992 on private property with no potential for public access were not counted in the data set. The study also did not include small fishing lakes and ponds with an average size of 0.5 acre that are not built on streams and are dependent on surface runoff although they do affect the availability of rainwater to streams in the watershed and provide a source of pollutants through run-off.

Most of the small impoundments included in the study were constructed in Shelby County (7.3%), followed by Cumberland (5.2%), Williamson (4.4%), Fayette (3.8%) and Gibson (3.7%). There are records of small impoundments in every Tennessee county except Claiborne, Lake, Moore, Perry and Unicoi (Table 1). Dammed headwater streams occur in 49 of Tennessee's 55 HUC 8 watersheds. The majority of small impoundments are in the Lower Hatchie (6.1%), Lower Duck (6.0%), North Fork Forked Deer (5.7%), Harpeth (5.6%) and Wolf (5.3%) watersheds (Table 2). There are six Tennessee watersheds with no records of small impoundments. These are Clear Fork, Upper Cumberland, North Fork Holston, Upper French Broad, Powell and Clarks.

In order to assess the chemical, physical and biological components of the impounded streams, the ecoregion approach was used for characterization. Tennessee is divided into 25 ecoregions (Figure 2). Ecoregions were delineated based on similarity of climate, landform, soil, potential natural vegetation, hydrology and other ecologically relevant variables (Griffith et al, 1997). Reference conditions have been established for each ecoregion through reference stream monitoring. Most of the documented impoundments were in ecoregion 65e, the Southeastern Plains and Hills (Figure 3 and Table 3), followed by the Cumberland Plateau (68a) and the Loess Plains (74b). The proportion of available stream miles does not follow the relative percentage of impoundments (Figure 4). The greatest number of stream miles is in the Western Highland Rim (71f) with the Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f) being second.

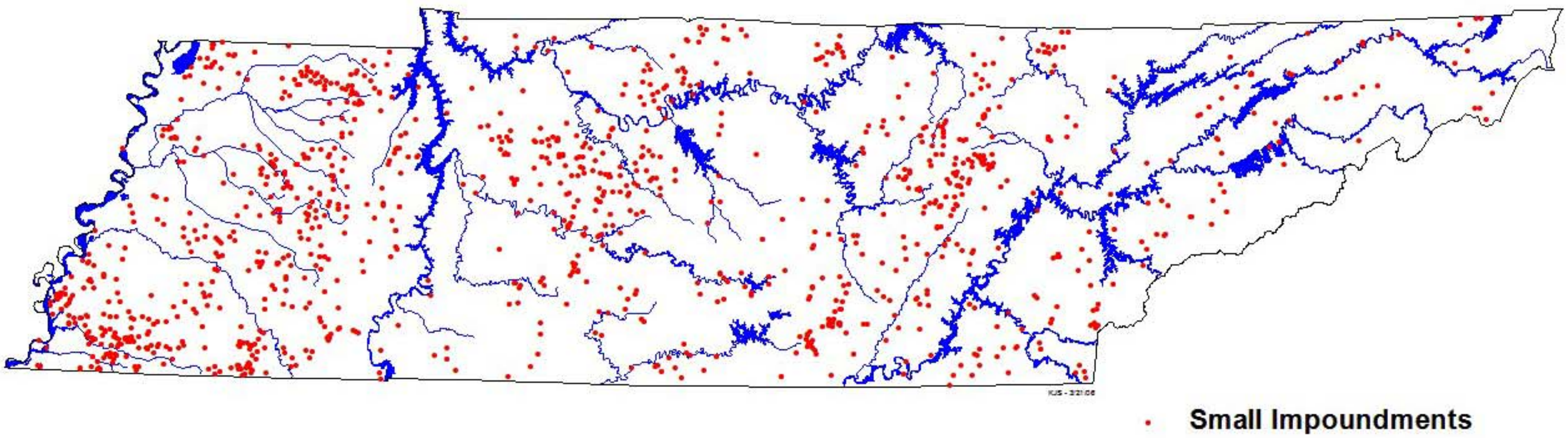

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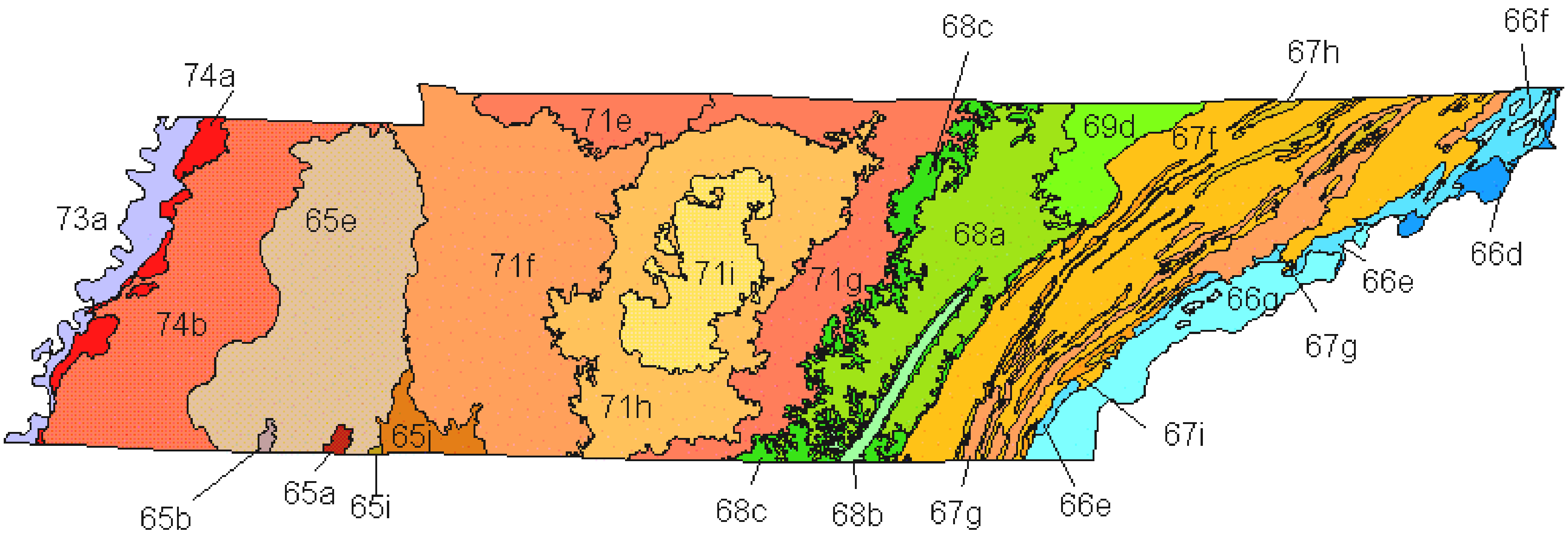
Figure 1: Location of small impoundments included in the study design.



65a Blackland Prairie
65b Flatwoods/Alluvial Prairie Margins
65e Southeastern Plains and Hills
65i Fall Line Hills
65j Transition Hills
66d Southern Igneous Ridges and Mtns
66e Southern Sedimentary Ridges
66f Limestone Valleys and Coves
66g Southern Metasedimentary Mtns.

67f Southern Limestone/Dolomite Valleys and Low Rolling Hills
67g Southern Shale Valleys
67h Southern Sandstone Ridges
67i Southern Dissected Ridges & Knobs
68a Cumberland Plateau
68b Sequatchie Valley
68c Plateau Escarpment
69d Cumberland Mountains

71e Western Pennyroyal Karst
71f Western Highland Rim
71g Eastern Highland Rim
71h Outer Nashville Basin
71i Inner Nashville Basin
73a Northern Mississippi Alluvial Plain
74a Bluff Hills
74b Loess Plains

Figure 2: Ecoregions in Tennessee.

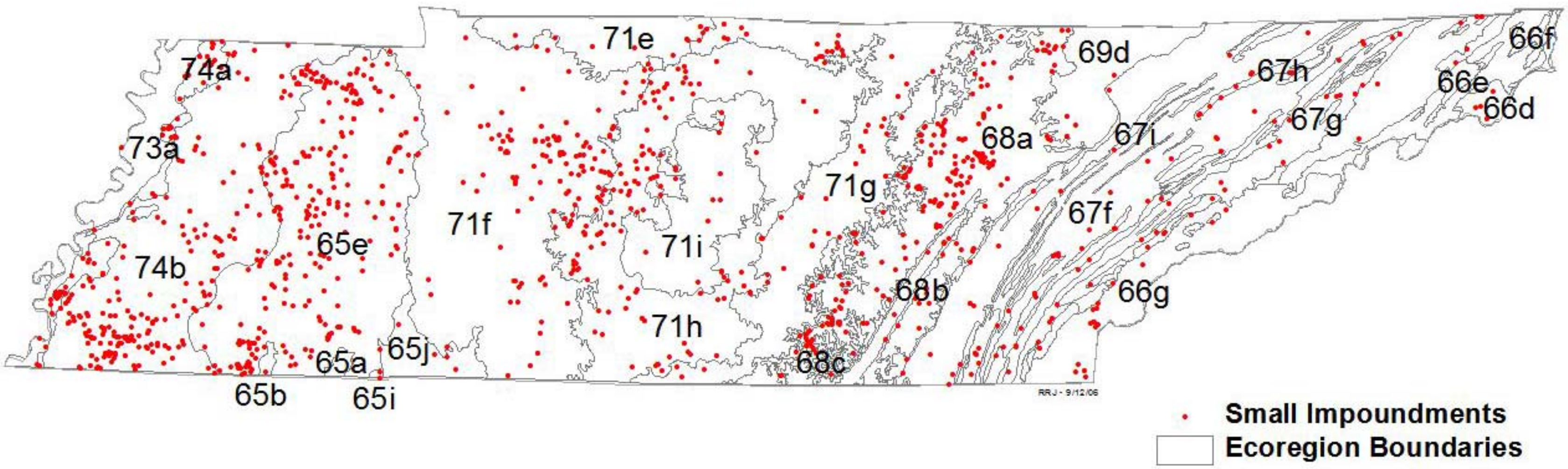


Figure 3: Ecoregion distribution of small impoundments included in the study design.

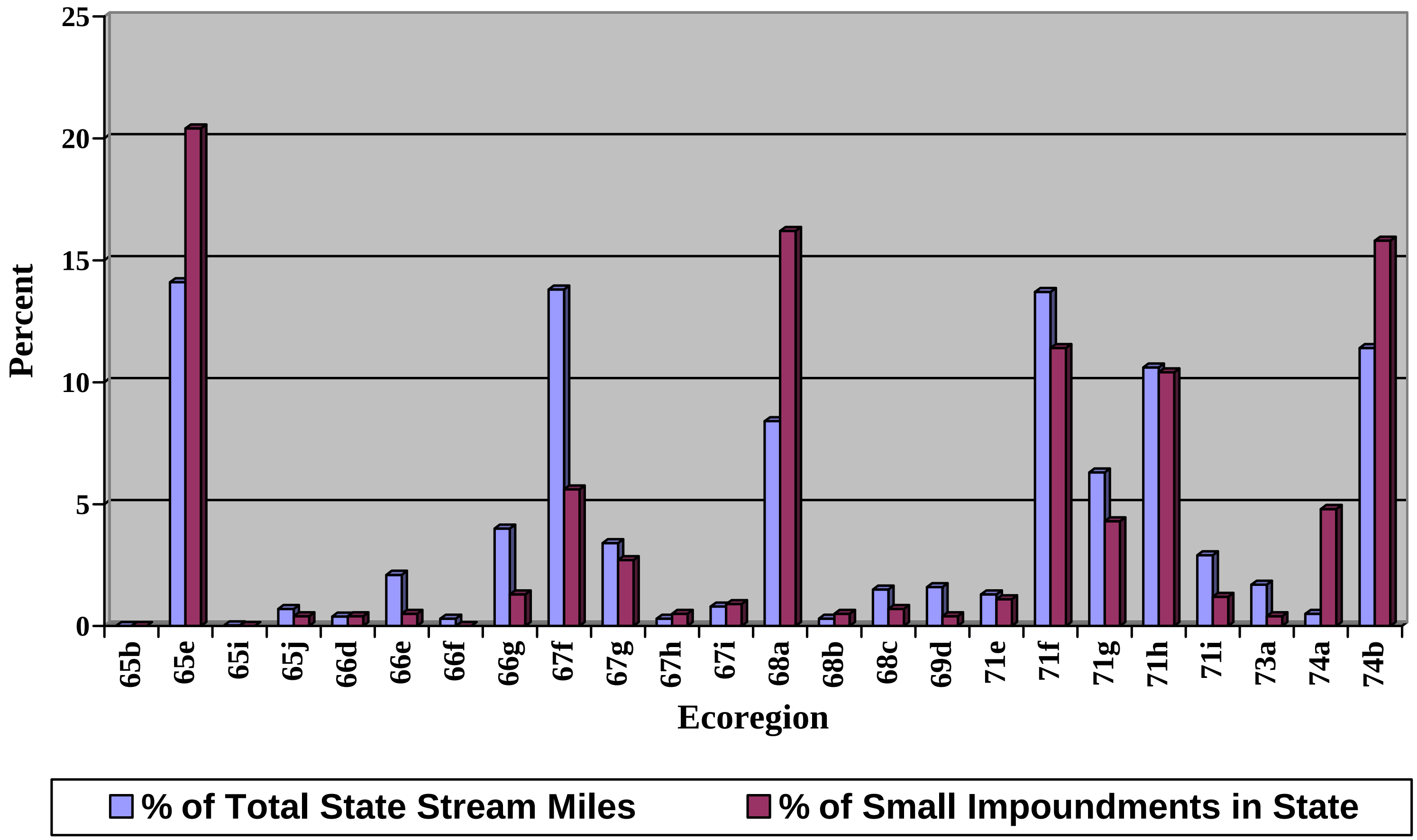


Figure 4: Comparison of the percentage of documented small impoundments by percent of stream miles in 24 Tennessee ecoregions. There were no small impoundments recorded in ecoregion 65a.

Table 1: Percent of documented small impoundments by county in Tennessee.

County	Percent of Dams < 250 acres	County	Percent of Dams < 250 acres	County	Percent of Dams < 250 acres
Anderson	0.2	Hamilton	1.1	Morgan	0.8
Bedford	0.8	Hancock	0.3	Obion	1.9
Benton	1.0	Hardeman	3.3	Overton	0.8
Bledsoe	1.3	Hardin	0.4	Perry	0.0
Blount	1.0	Hawkins	0.7	Pickett	0.2
Bradley	1.1	Haywood	2.1	Polk	0.5
Campbell	0.2	Henderson	1.5	Putnam	1.4
Cannon	0.2	Henry	2.5	Rhea	0.7
Carroll	1.9	Hickman	1.1	Roane	0.3
Carter	0.5	Houston	0.2	Robertson	0.5
Cheatham	0.5	Humphreys	1.2	Rutherford	0.6
Chester	1.1	Jackson	0.5	Scott	1.1
Claiborne	0.0	Jefferson	0.5	Sequatchie	0.8
Clay	0.2	Johnson	0.2	Sevier	0.4
Cocke	0.1	Knox	0.5	Shelby	7..3
Coffee	0.6	Lake	0.0	Smith	0.1
Crockett	0.3	Lauderdale	0.7	Stewart	0.1
Cumberland	5.2	Lawrence	1.2	Sullivan	0.5
Davidson	2.1	Lewis	0.8	Sumner	2.1
DeKalb	0.1	Lincoln	0.9	Tipton	1.2
Decatur	0.6	Loudon	0.4	Trousdale	0.1
Dickson	2.5	Macon	0.6	Unicoi	0.0
Dyer	1.7	Madison	2.8	Union	0.1
Fayette	3.8	Marion	1.0	Vanburen	0.3
Fentress	0.8	Marshall	0.6	Warren	0.9
Franklin	0.8	Maury	3.0	Washington	0.2
Gibson	3.7	McMinn	0.6	Wayne	0.4
Giles	0.4	McNairy	2.2	Weakley	2.0
Grainger	0.7	Meigs	0.1	White	1.2
Greene	0.8	Monroe	1.1	Williamson	4.4
Grundy	2.2	Montgomery	0.7	Wilson	0.5
Hamblen	0.2	Moore	0.0		

Table 2: Percent of documented small impoundments by watershed in Tennessee.

Watershed	Percent of Dams < 250 acres	Watershed	Percent of Dams < 250 acres	Watershed	Percent of Dams < 250 acres
Conasauga (TN03150101)	0.2	Upper French Broad (TN06010105)	0.0	Upper Kentucky (TN06040001)	2.7
Barren (TN05110002)	1.2	Pigeon (TN06010106)	0.1	Upper Duck (TN06040002)	1.8
Clear Fork (TN05130101)	0.0	Lower French Broad (TN06010107)	0.6	Lower Duck (TN06040003)	6.0
Upper Cumberland (TN05130103)	0.0	Nolichucky (TN06010108)	1.0	Buffalo (TN06040004)	1.2
South Fork Cumberland (TN05130104)	1.8	Upper Tennessee (TN06010201)	2.2	Lower Kentucky (TN06040005)	2.6
Obey (TN05130105)	1.2	Little Tennessee (TN06010204)	1.1	Clarks (TN06040006)	0.0
Cordell Hull (TN05130106)	1.4	Upper Clinch (TN06010205)	0.8	Mississippi (TN08010100)	0.7
Collins (TN05130107)	1.7	Powell (TN06010206)	0.0	Lower Obion (TN08010202)	3.6
Caney Fork (TN05130108)	4.3	Lower Clinch (TN06010207)	0.3	South Fork Obion (TN08010203)	5.2
Old Hickory (TN05130201)	1.2	Emory (TN06010208)	4.6	North Fork Forked Deer (TN08010204)	5.7
Cheatham (TN05130202)	2.5	Lower Tennessee (TN06020001)	2.1	South Fork Forked Deer (TN08010205)	3.8
Stones (TN05130203)	0.6	Hiwassee (TN06020002)	1.9	Forked Deer (TN08010206)	0.1
Harpeth (TN05130204)	5.6	Ocoee (TN06020003)	0.4	Upper Hatchie (TN08010207)	1.3
Barkley (TN05130205)	0.5	Sequatchie (TN06020004)	1.4	Lower Hatchie (TN08010208)	6.1
Red (TN05130206)	1.2	Guntersville (TN06030001)	2.0	Loosahatchie (TN08010209)	4.5
North Fork Holston (TN06010101)	0.0	Wheeler (TN06030002)	0.5	Wolf (TN09010210)	5.3
South Fork Holston (TN06010102)	0.6	Upper Elk (TN06030003)	1.8	Nonconnah (TN08010211)	1.1
Watauga (TN06010103)	0.7	Lower Elk (TN06030004)	0.5		
Holston (TN06010104)	1.4	Pickwick (TN06030005)	0.9		

Table 3: Percent of documented small impoundments by ecoregion in Tennessee.

Ecoregion	Percent of Impoundments less than 250 acres	Stream Miles in Each Ecoregion	Area of Ecoregion in Tennessee (sq miles)
65a	0.0	42	50
65b	0.1	23	36
65e	20.4	8720	4590
65i	0.1	20	9
65j	0.4	433	413
66d	0.4	238	235
66e	0.5	1291	799
66f	0.1	158	139
66g	1.3	2447	1338
67f	5.6	8543	5324
67g	2.7	2109	1433
67h	0.5	176	326
67i	0.9	481	585
68a	16.3	5164	3184
68b	0.5	179	250
68c	0.7	950	1379
69d	0.4	1008	896
71e	1.1	806	2
71f	11.4	8454	5871
71g	4.3	3909	2923
71h	10.4	6539	4414
71i	1.2	1785	1670
73a	0.4	1035	854
74a	4.8	315	486
74b	15.8	7021	4023

In Tennessee, more of the documented headwater impoundments were constructed in the 1960's than any other decade (Figure 5). Fifty small dams have been built during the last five years (2001 – 2005).

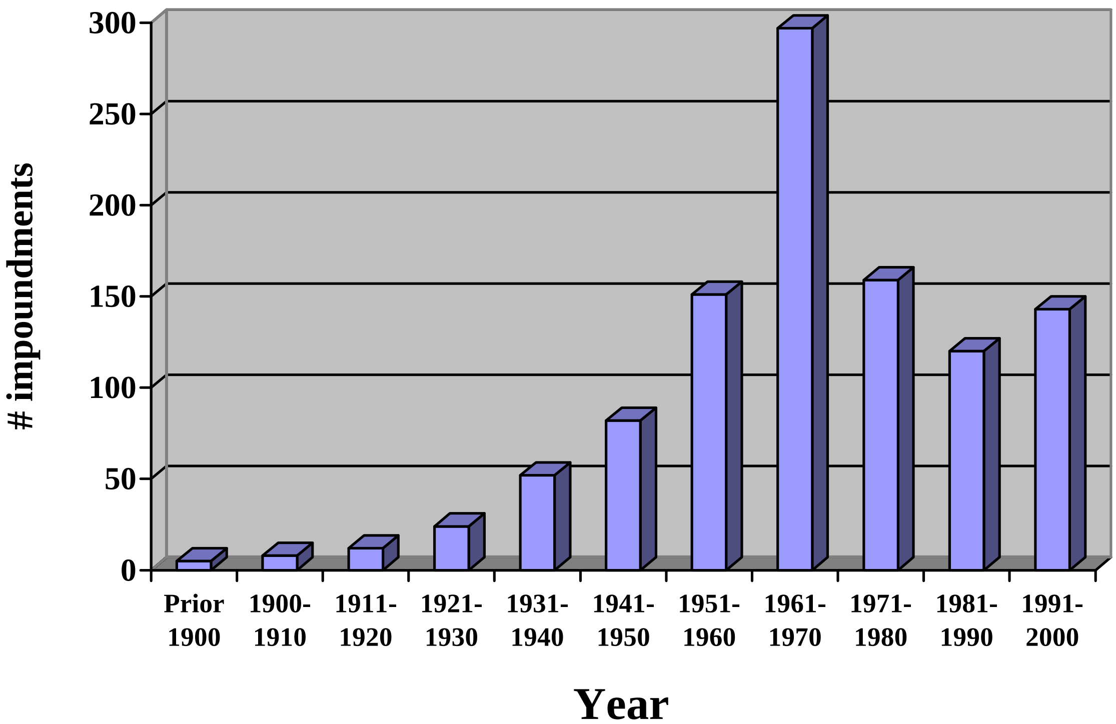


Figure 5: Number of documented impoundments less than 250 acres constructed in Tennessee by decade. Impoundment dates were unavailable for 199 sites.

3. DATA COLLECTION

3.1 Site Selection and Reconnaissance

The goal of the site selection process was to randomly select 75 streams with small impoundments for monitoring. A list of small impoundments in Tennessee was created by accessing the Aquatic Resources Alteration Permit and Safe Dams databases. The Aquatic Resources Alteration Permit database contained any dam that had received a construction permit after 1992. The Safe Dams database only contains those dams that were not considered farm ponds (no public access). Therefore, small impoundments without public access created prior to 1992 were excluded from the selection process. Combined, these two databases contained 1,302 impoundments of less than 250 acres. It is estimated that over 195,000 small man-made lakes and ponds actually occur in the state. Using a random number generator, 150 impoundments were selected for field reconnaissance and possible inclusion in the study.

In August and September 2003, field reconnaissance was conducted to determine which of the randomly selected sites met project requirements. To be eligible for monitoring the impounded streams must:

1. Have sufficient flow below the dam to support a benthic community.
2. Have suitable habitat (riffle or rooted bank) for use with TDEC's single habitat protocols.
3. Be a perennial (blue-line) stream with flow below the dam.
4. Have an impoundment.
5. Be comparable (order or drainage area) to existing ecoregion reference streams or a project-specific reference.
6. Have public access or landowner's permission.
7. Have minimal observable impacts that would interfere with the evaluation of the effects of the impoundment.
8. Have upstream drainage 80% within a single bioregion (A bioregion is one or more ecoregions with statistically similar benthic communities).
9. Impound no more than 250 acres.

In order to measure the effects of the dam without interference from other sources, monitoring stations were located in suitable macroinvertebrate habitat as close to the impoundment as possible. Distance from the impoundment at most sites ranged from 10 to 440 yards. One site was located 1000 yards downstream due to access problems. The median distance was 50 yards.

If other potential sources of impact were observed between the dam and the closest suitable sampling point, the site was removed from consideration. However, if the potential impact was related to the dam, such as reservoirs built for housing developments, recreational use or agricultural purposes, the site was included in the study.

Suitable sites were chosen in order of random selection with field reconnaissance ending after locating 75, which met the study conditions. One hundred and fifty sites were selected in the first draw. Over half did not meet study requirements. The most frequent problem was lack of flow below the impoundments (Figure 6). An additional 50 sites were randomly selected. All 50 of the additional sites were visited before 75 suitable sites were located.

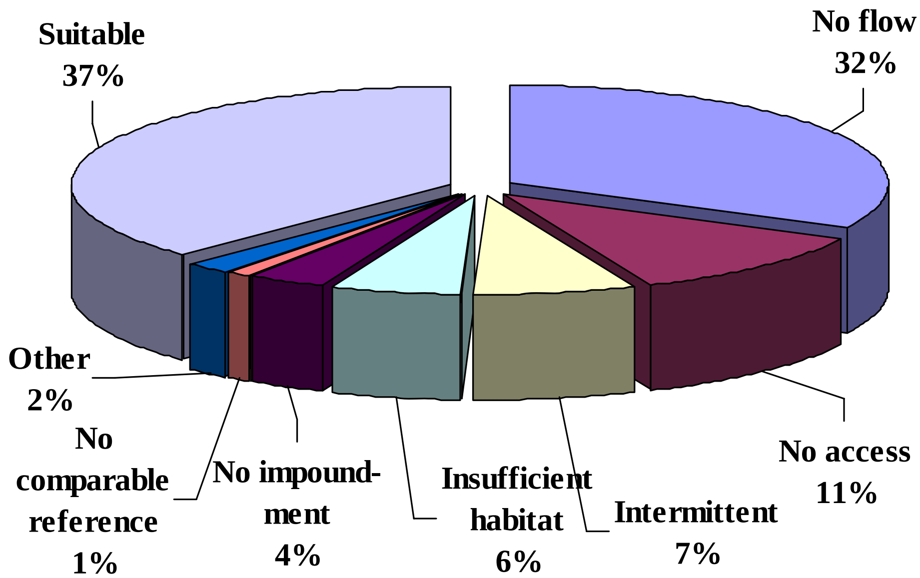


Figure 6: Results of reconnaissance in August and September 2003 at 200 randomly selected impounded streams in Tennessee.

Streams that were impounded for agricultural purposes were included in the study. These livestock pens were built on a dam at Sinking Creek in Cocke County. *Photo provided by Aquatic Biology Section, TDH.*

3.2 Distribution of Randomly Selected Subsample

Over half of the selected impounded test sites were located on second order streams. Twenty-eight percent were on first order streams and 19% were on third order. It is probable that a larger percentage of impoundments are on first order streams, but they were more likely to be dry during the reconnaissance period. Also, impoundments on second and third order streams generally flooded first order streams in the catchment area. Over 70 percent of the impoundments were less than 50 acres. The smallest was two acres and the largest impoundment was 250 acres. No drainage area was over 19 square miles.

Based on distribution within ecoregions, the 75 streams included in the subsample were representative of the entire population of impounded streams that met the study design (Table 4). Four of the five dominant ecoregions were the same in both sets. The exception is the Loess Plains (74b), which was the third most common ecoregion in the random selection with 22 sites. However, only two sites met monitoring requirements for inclusion in the study. Eleven sites had no discharge below the dam, six were intermittent streams and the owner's permission could not be obtained to access one site.

The North Fork Forked Deer and Wolf River watersheds were in the top five with impoundments but were not in the top five watersheds sampled. There were no sites in the North Fork Forked Deer watershed that met monitoring requirements for the study. Four sites were randomly selected but three had no discharge and owner permission could not be obtained for the fourth. Eight sites were randomly selected in the Wolf River watershed. Only one met study requirements. Four had no discharge, two were intermittent and the owner's permission could not be obtained at one.

Cumberland County was the only county in the top five for both the entire population of impounded streams and in the monitored subsample. Eight sites were selected in Shelby County but only one met monitoring requirements. Four impoundments had no discharge and three of the streams were intermittent. Only one dam was randomly selected in Gibson County and it had no discharge. Six sites were selected in Williamson County, but none met study requirements. Three had no discharge, staff could not obtain owner's permission to sample below two of the dams and one site appeared to be affected by construction from a new subdivision that would mask effects from the impoundment. Seven sites were randomly selected in Fayette County but four had no discharge, two were intermittent and owner's permission could not be obtained from one.

Since ecoregions, not watersheds or counties are used for assessments, the data set included in the study can be considered representative of small impoundments in the state. A comparison of the final site locations (Figure 2) to the locations of the total population (Figure 7) shows a similar geographical distribution. A complete list of monitored sites including ecoregion, watershed and county information is provided in Appendix A.

Table 4: Distribution of impounded streams in the total study population and randomly selected subsample in order of frequency. Only top five in each category is listed.

Frequency Rank	Ecoregions		Watersheds		Counties	
	Total Set	Random Sample	Total Set	Random Sample	Total Set	Random Sample
1	65e	68a	Hatchie	Emory Hatchie	Shelby	Cumberland
2	68a	65e	Lower Duck	Kentucky Lake	Cumberland	Hardeman
3	74b	71f	North Fork Forked Deer	Harpeth Guntersville	Williamson	Davidson Monroe
4	71f	71g	Harpeth	Barren Caney Fork Ft Loudoun Buffalo	Fayette	Benton Lewis Lincoln Overton
5	71h	71h	Wolf	Obey Cheatham Tennessee Hiwassee Wheeler Beech Lower Duck Obion South Fork Obion	Gibson	Cocke Dickson Franklin Henry Lawrence Madison Marion Obion Sumner Weakley

The majority of impounded streams in the study such as Mammy's Creek are on the Cumberland Plateau (68a).

Photo provided by Aquatic Biology Section, TDH.

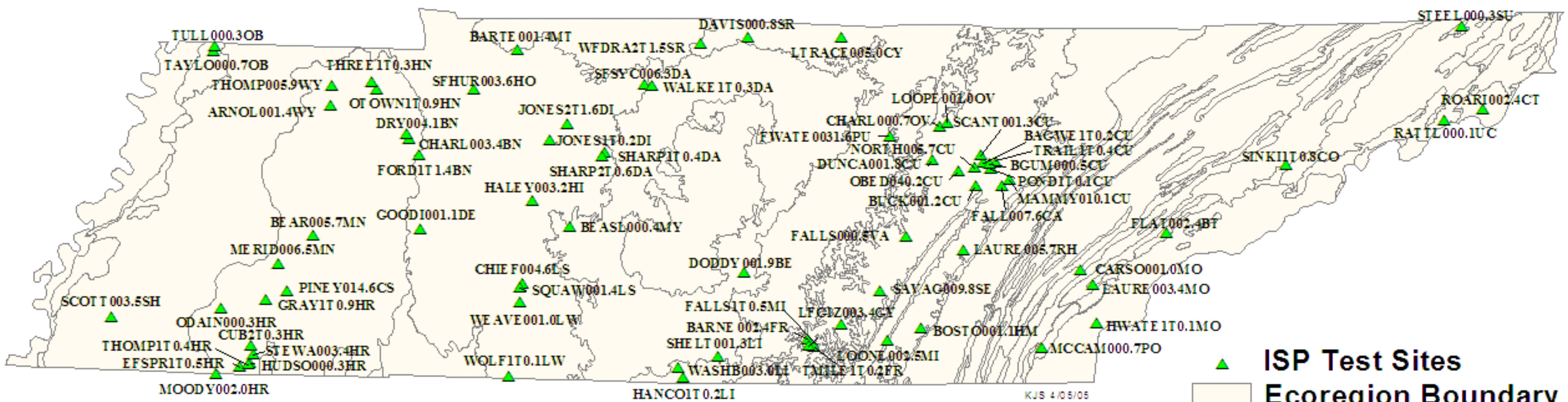


Figure 7: Location of 75 randomly selected test sites for the Tennessee impounded stream study.

3.3 Characterization of Study Sites

Comparable to the total study population, the greatest percentage (31%) of selected study sites were impounded in the 1960s (Figure 8). Only one impoundment had been constructed in the last five years.

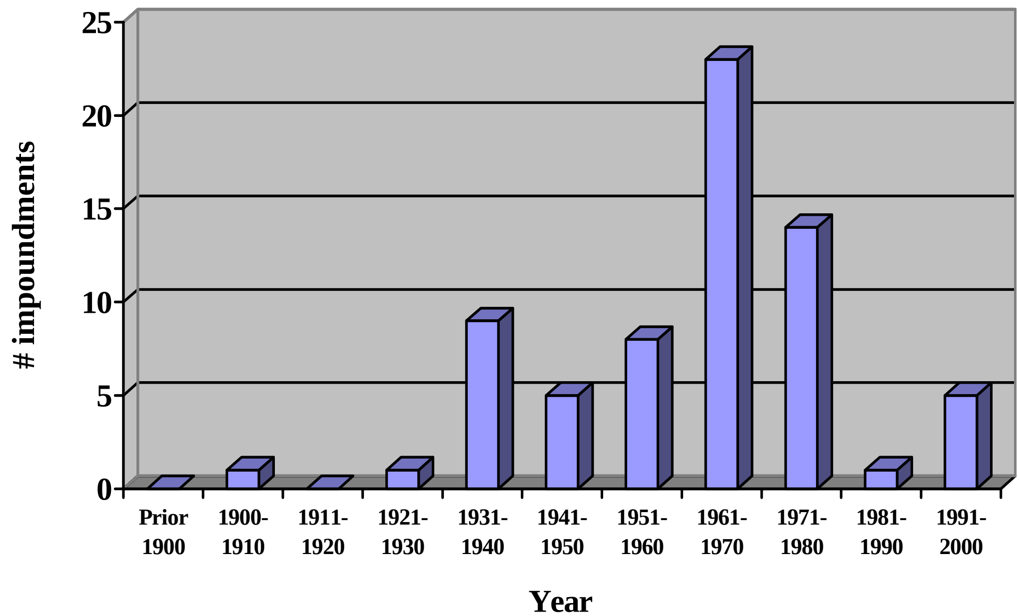


Figure 8: Distribution of randomly selected impoundments less than 250 acres constructed in Tennessee by decade. Dates were unavailable for seven sites.

The majority of selected test sites (69%) had surface discharge through either a spillway or standpipe. Thirteen percent of the sites had subsurface discharge through a toe drain or seepage. The rest had both surface and subsurface discharges. Each discharge type has the potential for different effects on the impounded stream. Surface waters are generally high temperature and have high nutrient levels while subsurface discharges may have low dissolved oxygen and/or elevated metals.

Land use, based on 1992 satellite imagery and over-flights, was calculated for the entire catchment area upstream of each dam (Table 5). The majority of sites (77%) were primarily forested in the upstream drainage area (Figure 9). The dominant land use at the remainder of sites was pasture. Pasture included both active grazing and fallow fields. If active grazing was observed during field reconnaissance, the site was dropped unless it was determined the purpose of the reservoir was livestock watering. Urban and cropland were relative minor portions of the drainage (Figure 10). The impounded areas covered 0.2 to 32% of the watershed upstream of the study sites.

Table 5: Land use for drainage area upstream of impounded study sites. Data based on 1992 satellite imagery and over-flights.

Station ID	Percent Land Use								Drainage Area (Square Miles)
	Open Water	Forest	Wetlands	Transitional	Pasture	Cropland	Urban	Strip Mines/ Quarries	
ARNOL001.4WY	1.87	16.83			66.45	14.86			1.72
BAGWE1T0.5CU	12.22	35.92			49.48	2.38			0.16
BARNE002.4FR	12.40	74.91			11.35	1.12	0.22		0.32
BARTE001.4MT	1.75	59.40			32.94	5.90			4.52
BEAR003.6WE	0.13	72.11	0.47	0.42	25.49	1.38			5.37
BEASL000.4MY	32.70	42.32			22.01	1.18		1.79	0.92
BGUM000.5CU	11.58	60.80			26.68	0.94			0.44
BOSTO001.1HM	4.89	87.86			7.23	0.02			1.07
BUCK001.2CU	0.18	31.05			64.18	4.58			2.76
CARSO000.1MO	5.00	13.29			77.29	4.43			0.59
CHARL000.7OV	7.02	86.40		0.20	6.38				0.61
CHARL003.4BN	*	77.44			22.56				0.13
CHIEF004.6LS	8.96	75.53	4.40		7.95	3.16			2.20
CUB2T0.3HR	6.04	62.69	2.30		28.86	0.11			1.32
DAVIS000.8SR	2.53	36.08			41.71	1.41	18.27		0.75
DODDY001.9BE	3.11	73.71	0.01		21.91	1.27			3.05
DRY004.1BN	8.26	59.80	1.39		30.03	0.52			0.56
DUNCA001.8CU	8.37	50.68			40.85	0.07	0.03		1.41
EFSPR1T0.5HR	15.06	76.36	0.38		7.77	0.43			0.51
FALL007.6CA	0.83	96.79			2.30	0.07			3.59
FALLS000.5VA	8.52	44.06	0.71	0.28	44.36	2.06			6.23
FALLS1T0.5MI	3.62	84.70			11.68				0.17
FLAT002.4BT	8.15	87.82			3.37	0.66			1.76
FORD1T0.4BN	11.84	53.57		1.21	31.11	2.28			0.16
FWATE0031.6PU	0.74	71.66	0.01	0.03	27.21	0.34	0.01		19.34
GOODI001.1DE	*	73.12			26.37	0.51			0.89
GRAY1T0.9HR	5.14	93.86			1.00				1.28
HALEY003.2HI	0.95	50.89	0.26		46.71	1.19			1.02
HANCO1T0.2LI	6.05	3.08		0.52	77.15	13.20			0.46
HUDSO000.3HR	1.88	84.16	4.30		9.65				1.75
JONES2T1.6DI	0.50	77.20			21.39	0.91			1.21
LAURE003.4MO	18.54	79.40			2.06				0.53
LAURE005.7RH	1.23	16.25			42.15	40.37			0.49
LFGIZ003.4GY	5.52	71.04			23.41	0.02			1.02
LOONE002.5MI	0.87	93.80			5.33				0.39
LOOPE001.0OV	9.52	61.45	0.53	0.06	26.24	2.19	0.01		1.64
LTRAC005.0CY	0.66	16.83	0.20	0.04	70.59	11.69			4.53
MAMMY010.1CU	0.49	82.67			16.58	0.26			2.13
MCCAM000.7PO	1.16	90.35			8.49				0.46
MERID006.5HM	2.49	53.64	0.32	0.08	37.32	6.15			3.98

Table 5 cont:

Station ID	Percent Land Use								Drainage Area (Square Miles)
	Open Water	Forest	Wetlands	Transitional	Pasture	Cropland	Urban	Strip Mines/ Quarries	
MOODY002.0HR**	2.65	62.40	6.19		13.28	15.49			4.03
NORTH005.7CU	15.90	28.76			51.92	0.49	2.93		1.24
OBED040.2CU	6.97	47.16			44.13	1.74			6.30
ODAIN000.3HR	2.20	52.87	2.72		38.24	3.96			11.97
OTOWN1T0.9HN	2.04	48.98			30.20		18.78		0.06
PINEY014.6CS	5.31	88.14	1.15		4.78	0.62			0.97
POND1T0.1CU	9.24	65.57			25.19				0.39
RATTL000.1UC	†	100.00							0.31
ROARI002.4CT	3.73	85.15			11.06	0.06			4.41
SAVAG009.8SE	2.65	84.88			11.67	0.76	0.03		6.03
SCANT001.3CU	15.07	46.62			35.63	2.68			0.34
SCOTT003.5SH	21.73	30.75	0.74		21.79	11.26	13.73		1.73
SFHUR003.6HO	2.90	8.86			83.15	5.10			0.42
SFSYC006.3DA	0.15	78.89		2.13	15.98	2.67	0.18		1.45
SHARP1T0.4DA	0.88	97.44			1.25	0.44			0.72
SHARP2T0.6DA	*	79.56	1.56		18.88				0.49
SHELT001.3LI	1.32	66.21	0.89		29.85	1.73			5.86
SINKI1T0.8CO	0.86	91.73			6.55		0.86		0.36
SQUAW001.4LS	3.33	72.16	4.00		18.83	1.69			2.83
STEEL000.3SU**	0.97	81.04	0.33		4.17	13.49			11.46
STEW003.4HR	1.67	91.54	0.56		6.22				2.19
TAYLO000.7OB	2.31	28.40		0.96	60.09	8.25			3.91
THOMP005.9WY	10.71	66.55	1.66		19.62	1.45			3.22
THOMP1T0.4HR	18.61	61.99			18.09	1.31			0.18
THREE1T0.3HN	2.49	66.98	1.81	0.95	22.53	5.25			0.28
TMILE1T0.5FR	9.04	90.78			0.17				0.14
TRAIL1T0.4CU	6.12	61.24			32.65				0.35
TULL000.2OB**	2.07	35.97	1.03		50.46	10.47			3.57
WALKE1T0.6DA	3.02	81.91			14.22	0.86			0.50
WASHB003.0LI	1.59	12.31	5.15		59.43	21.52			2.61
WEAVE001.0LW	3.38	74.23			18.35	4.03			0.93
WFDRA2T1.5SR	1.08	13.39		0.10	74.19	10.27	0.97		2.30
WOLF1T0.1LW	2.91	42.27			54.36	0.46			0.16

*Dam constructed after 1992 when land use data was compiled.
**Part of watershed drainage is located in another state.
†Not a permanent reservoir.

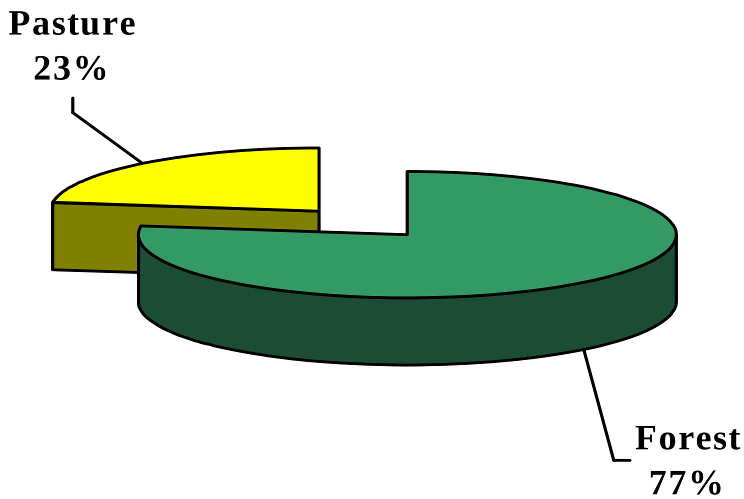


Figure 9: Dominant land use of drainage area upstream of 75 study sites. Data based on 1992 satellite imagery and over-flights.

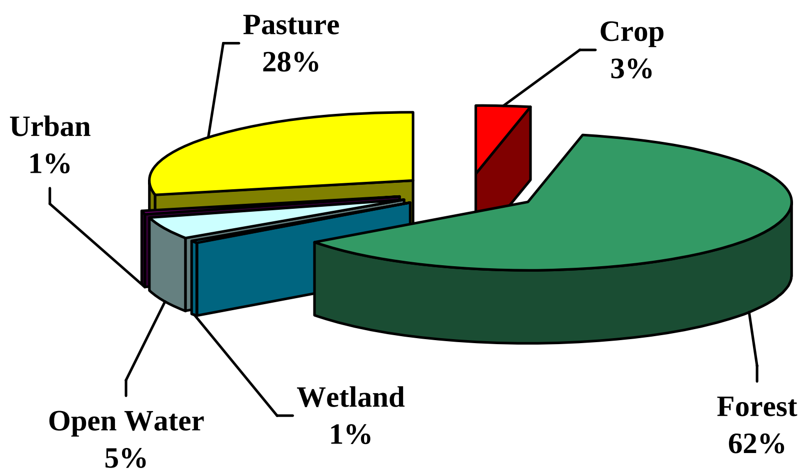


Figure 10: Overall land use upstream of 75 study sites. Data based on 1992 satellite imagery and over-flights.

Twenty-one of the impoundments are on streams that are considered Tier 2 (high quality) although some of the impoundments were in different areas of the stream. High quality streams meet one or more of the following criteria:

(a) Waters within state or national parks, wildlife refuges or management areas, forests, wilderness areas, or natural areas.

(b) State Scenic Rivers or Federal Wild and Scenic Rivers.

(c) Federally-designated critical habitat or other waters with documented populations of state or federally-listed threatened or endangered aquatic or semi-aquatic plants or animals, including those proposed for formal state or federal status.

(d) Waters within areas designated as Lands Unsuitable for Mining pursuant to the federal Surface Mining Control and Reclamation Act.

(e) Naturally reproducing trout streams.

(f) Waters with exceptional biological diversity as evidenced by a score of 40 or 42 on the Tennessee Macroinvertebrate Index (or a score of 28 or 30 in ecoregion 73a), provided that the sample is considered representative of overall stream conditions.

Most of the high quality segments with reservoirs were on public lands, including wildlife management areas, state parks and national forests and the reservoir is associated with recreation use. However one of the streams, Bear Creek in Wayne County, provides habitat for the state threatened saddled madtom. This fish is dependent on rocky riffles in clear creeks. The reservoir was constructed in 1969 and is 2.6 miles upstream of where the fish was documented in 1976.

An impoundment on the Obed is in the headwaters, over 17 miles upstream of the high quality reach where two endangered mussel species are found. However, the cumulative effects of multiple small impoundments in headwaters and tributaries could eventually have an effect on the flow and sedimentation of the downstream reaches.

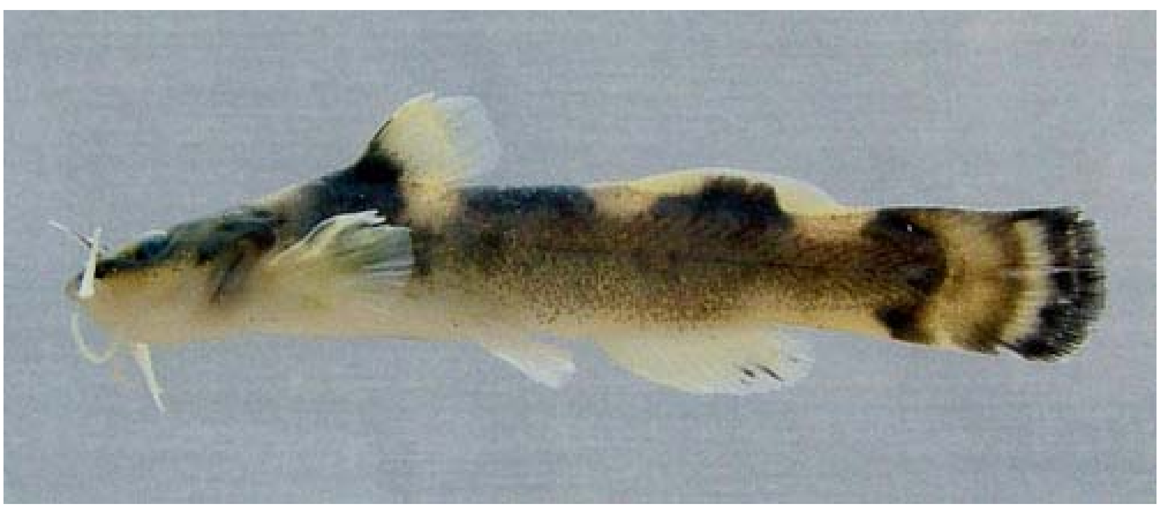
One of the test sites, Roaring Creek, was on a naturally reproducing trout stream. Four of the test sites were on tributaries to trout streams. A second site, Rattlesnake Creek, was a direct tributary to a naturally reproducing trout stream. Another test site, Laurel Creek in Monroe County, was located 2.6 miles upstream of one of the ecoregion reference sites for the Southern Sandstone Ridges (67h), which is considered high quality due to exceptional biological diversity.

Two reservoirs were just outside the boundaries of the Natchez Trace National Parkway. One was 0.7 miles upstream of Ozone Falls State Natural Area. A fourth was within the North Chickamauga Creek Gorge State Natural Area.

Ten of the test sites were located on stream segments that are on the 2004 303(d) list of waters that have violated water quality criteria (Table 6). Four of the sites were located on the Cumberland Plateau (68a), three in Southeastern Plains and Hills (65e), and three on the Interior Plateau in subregions 71f, 71g, and 71h. Eight of the stream segments are not supporting fish and aquatic life due to habitat loss or physical substrate alteration. The other two stream segments are not supporting of recreational uses due to high concentrations of *Eschericia coli*. The data collected for this study will be used in future assessment cycles to update the 303(d) list.

Population growth is related to the number of impoundments. Cumberland County experienced the largest growth rate between 1990 and 2000 of any county that was included in this study with a 34.7% growth rate. More than half the dams studied in this county were located in the town of Fairfield Glade. The population of Fairfield Glade in 1990 was 2209 and grew to 4885 in 2000 with a 121.1% growth rate. Eleven impoundments are located on these 12,700 acres of land. Six of these were randomly selected for this study.

The drainage area above impoundments in Cumberland County had a smaller percent of forested area (50.7%) compared to the average for the other eight counties studied in ecoregion 68a or the state as a whole. These statistics are based on land use determined in 1992. Due to the population growth, it is likely more development has occurred in Cumberland County since that time resulting in an additional decrease in forested areas in upstream watersheds.



The saddled madtom lives in rocky riffles, runs and flowing pools of clear creeks and small rivers. *Photo provided by David and Lynn Eisenhour.*

Table 6: Impounded test sites located on stream segments that have violated water quality criteria based on the 2004 303(d) list.

Ecoregion	Station ID	Impaired Use	Cause	Pollutant Source
65e	CUB2T0.3HR	Fish and Aquatic Life	Physical substrate habitat alteration	Channelization
65e	DRY004.1BN	Fish and Aquatic Life	Loss of biological integrity due to siltation. Habitat loss due to alteration in stream-side or littoral vegetative cover.	Nonirrigated Crop Production, Pasture Grazing
65e	THOMP005.9WY	Fish and Aquatic Life	Physical Substrate Habitat Alterations, Habitat loss due to stream flow alteration.	Upstream Impoundment, Channelized
68a	FALLS000.5VA	Fish and Aquatic Life	Habitat loss due to stream flow alteration, Iron, Physical substrate habitat alteration.	Upstream impoundment
68a	LFGIZ003.4GY	Recreation	*Escherichia coli*	Pasture Grazing, Septic Tanks
68a	OBED040.2CU	Fish and Aquatic Life	Habitat loss due to stream flow alterations, Physical Substrate Habitat Alteration	Discharges from MS4 area, Upstream Impoundment
68a	SAVAG009.8SE	Fish and Aquatic Life	Biological integrity loss due to undetermined cause.	Undetermined source
71h	WALKE1T0.3DA	Recreation	*Escherichia coli*	Undetermined source
71g	WASHB003.0LI	Fish and Aquatic Life	Habitat loss due to alteration in stream-side or littoral vegetative cover, Loss of biological integrity due to siltation.	Nonirrigated Crop Production
71f	WEAVE001.0LW	Fish and Aquatic Life	Habitat loss due to stream flow alteration, Low dissolved oxygen	Upstream Impoundment

3.4 Reference Sites

In order to determine whether the impoundments had any effect on the study streams, natural background conditions had to be determined. It was not practical to sample upstream at the majority of the sites for one or more of the following reasons.

1. The impoundment flooded the entire headwaters.
2. A second impoundment was located immediately upstream.
3. The drainage area at the upstream site was not 80% within the same bioregion and may naturally have a different biological community structure.
4. The stream order was smaller upstream.

For these reasons, the ecoregion reference stream database was used to determine natural conditions. The database includes information from over 100 reference streams monitored since 1996. This approach was developed by EPA and is regularly used by the division for stream assessments (TDEC, 2003). In five of the ecoregions included in the study (65e, 66g, 68a, 71f, 71g), first order guidelines have not been developed. In these regions, first order reference streams were selected and monitored in conjunction with the study sites. There was one first order study site in 67g, an unnamed tributary to Sinking Creek (SINKI1T000.8CO) that met conditions necessary to establish an upstream reference site.

3.5 Methodology and Quality Assurance for Sample Collection, Stream Monitoring and Sample Analyses

Sample collection and monitoring was conducted by experienced biologists with the Aquatic Biology Section, Tennessee Department of Health. Monitoring was conducted seasonally between August 2003 and November 2004. The Department of Environment and Conservation's QSSOP for Macroinvertebrate Surveys (TDEC, 2003) was followed for collections, sample processing, data reduction and quality assurance. Single habitat semi-quantitative macroinvertebrate samples were collected twice (Fall 2003 and Spring 2004) at each site. Riffles were the selected habitat except in ecoregions 65e and 74b where rooted bank samples were collected.

Duplicates were collected at ten percent of the sites. Samples were processed and macroinvertebrates identified by qualified taxonomists with the Tennessee Department of Health (TDH) and Third Rock Consultants in Lexington, Kentucky. Identifications were confirmed by a second taxonomist and sorting efficiency was checked on ten percent of samples. Any new taxa not already confirmed in the statewide reference collection, were verified by an outside expert and added to the collection. Sample debris and organisms will be maintained for five years. Chain of custody was maintained throughout the collection and analysis process.

Samples for the analysis of nitrate+nitrite, total phosphorus, ammonia, total kjeldahl nitrogen, suspended solids, iron and manganese were collected quarterly at each site. Sampling methods followed TDEC protocols (TDEC, 2004). Duplicates, trip blanks and field blanks were collected at ten percent of the sampling episodes. Samples were delivered to the state lab by field personnel with chain-of-custody maintained at all times. Samples were analyzed by chemists at the Nashville, Jackson or Knoxville state labs (TDH) using EPA approved methods and quality assurance protocols.

Abbreviated geomorphic measurements (stream profile and particle counts) were conducted quarterly (Rosgen, 1996). One hundred particles were randomly selected and measured along a transect in a typical run area. Elevations were measured along the flow transect to obtain a stream profile. Flow was measured using an electromagnetic flow meter at the same transect every quarter. Protocols followed TDEC requirements (TDEC, 2004).

Habitat was assessed quarterly following the 2003 TDEC QSSOP adapted from EPA'a rapid bioassessment protocols at each site. Scoring for each parameter was arbitrated by two trained biologists while at the site for QC purposes. Densiometer measurements of canopy were taken in the middle of each sample reach as well as at nine spots where periphyton were measured.

Dissolved oxygen, pH, conductivity and temperature were measured quarterly at each site using calibrated multiparameter probes. Duplicate measurements were taken at each site for QC purposes. A post-calibration was performed at the end of each sampling week to check for potential instrument drift.

Periphyton abundance was measured twice (summer and fall) at each site using field-based rapid periphyton protocols developed by Stevenson (Barbour et al, 1999). Periphyton were divided into two broad categories. Macroalgae included sessile, muti-cellular filamentous strands of long algae such as *Cladophora* spp. and *Spirogyra* spp. Microalgae included single celled algae, such as diatoms and blue-green algae, which coat the stream substrate. Three transects (riffle or run) with the least amount of canopy were surveyed. On each transect, percent substrate, algae type, thickness, abundance and percent canopy were recorded at three locations (right, middle and left). Duplicate surveys were conducted at ten percent of the sites.

4. MACROINVERTEBRATE COMMUNITIES BELOW IMPOUNDMENTS

The macroinvertebrate community was sampled below each impoundment to determine the health of the biotic community. The advantages of using macroinvertebrates as indicator organisms include:

a. Sensitivity to nutrients and metals.
b. Sensitivity to physical changes.
c. Dependency on stable habitat.
d. Limited mobility to avoid sources of pollution.
e. Abundance and diversity.
f. Vital position in the food chain.
g. Short life cycle.

Macroinvertebrate samples were assessed using the Tennessee Macroinvertebrate Index (TMI) developed for interpretation of biological criteria by Water Pollution Control (Arnwine and Denton 2001). This is a multi-metric index composed of seven biometrics. The index ranges from 0 to 42 with a score of 32 meeting expectations for the bioregion. Individual biometrics measure different aspects of the macroinvertebrate population including richness, community composition, pollution tolerance and habit.

a. Taxa Richness measures the total number of individual taxa without regard to abundance. Generally, the number decreases with increased pollution.

b. EPT Richness measures the diversity of these taxa without regard to abundance. This taxa group includes the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). They are often the first to disappear in response to stressors including habitat alterations, toxicants, sedimentation and nutrient enrichment.

c. The %EPT measures the relative abundance of Ephemeroptera, Plecoptera and Trichoptera. These three orders are generally reduced in numbers in stressed conditions.

d. The %OC measures the abundance of oligochaetes (aquatic worms) and chironomids (midge larvae). This metric usually increases in response to factors such as low dissolved oxygen and excessive sediment.

e. The NCBI (North Carolina Biotic Index) is a measure of the overall tolerance level of the entire benthic macroinvertebrate community. Taxa are rated on a scale of 0 to 10 with 10 being the most tolerant to pollution. A healthy population will include animals at all tolerance levels, however, the number of tolerant organisms should be comparatively low. The NCBI measures both the tolerance level of individual taxa and the overall abundance of those taxa.

f. The % Dominant (%DOM) is the relative abundance of the single most common taxon in the sample. The dominance of a single taxon demonstrates an imbalance in the structure of the macroinvertebrate community. An organism usually becomes dominant when it is able to tolerate a stressor that limits the survival or reproduction of other taxa.

g. The percent Clingers (%CLING) is generally a measure of physical aspects of the environment such as habitat disturbance, sedimentation, flow alteration and substrate stability. Clingers build fixed retreats or have adaptations to attach to surfaces in flowing water. They are dependent on availability of stable, sediment-free substrates.

An eighth biometric that is not part of the TMI was also used in this study. The percent nutrient tolerants (%NUTOL) is a metric developed by the state of Kentucky that combines 14 taxa that have been shown to be tolerant of elevated nutrients (Brumley, 2003). Subsequent testing in Kentucky indicates this metric is also sensitive to sedimentation.

Macroinvertebrate samples were collected in both spring and fall. At the majority of stations, data were compared to biocriteria guidelines developed for each bioregion (TDEC, 2003), the scores for each site are provided in Appendix B-1. If the stream size was smaller than the drainage area specified in the guidelines, a first order reference in the same bioregion was monitored and the expected values for each biometric were adjusted accordingly (Appendix B-2). If duplicates were collected, taxa lists were combined, adjusted to a 200-organism sample and rescored.

One site, an unnamed tributary to Sinking Creek in Cocke County, had an upstream reach with an appropriate reference that was free flowing, the same order as the downstream segment and 80% within the same bioregion. Sinking Creek is a small second order stream with a 4.5-acre impoundment. The upstream drainage area is approximately 0.4 square miles all within the Southern Shale Valleys (67g) ecoregion. The upstream site scored the highest possible score (42) in both the fall and the spring when compared to biocriteria guidelines. To help illustrate the suitability of using ecoregional references, the test site below the impoundment was compared to both the upstream reach and the established biocriteria guidelines for this bioregion. Comparisons to both types of reference data produced similar assessment results indicating an impaired benthic community. Scores downstream of the impoundment were slightly lower in the spring when compared to the upstream reference site than the regional biocriteria (Table 7).

Table 7: Comparison of biometric scores downstream of impoundment to upstream and regional reference sites. Test site is located on an unnamed tributary to Sinking Creek in Cocke County.

D/S test site compared to:	TR	EPT	%EPT	%OC	NCBI	%DOM	%CLING	TMI
U/S REF FALL	2	2	6	6	4	4	6	30
ECO REF FALL	2	2	6	6	4	4	6	30
U/S REF SPRING	4	0	2	6	4	6	6	28
ECO REF SPRING	4	2	2	6	4	6	6	30

Macroinvertebrate communities were adversely affected in most of the streams sampled below impoundments in the 2003 study (Figure 11). Of the 75 impounded sites, only four passed biological criteria guidelines or were comparable to first order references both seasons sampled. All of the passing streams were first and second order with less than four square mile drainages. The largest impoundment was 11 acres. The sampling stations were located near the dam (10 to 30 yards). They were all older impoundments built between 1935 and 1976. Three of the dams had surface discharge while one had both surface and subsurface.

South Fork Sycamore Creek was one of four impounded streams that supported a healthy macroinvertebrate community.

Photo provided by Aquatic Biology Section, TDH.

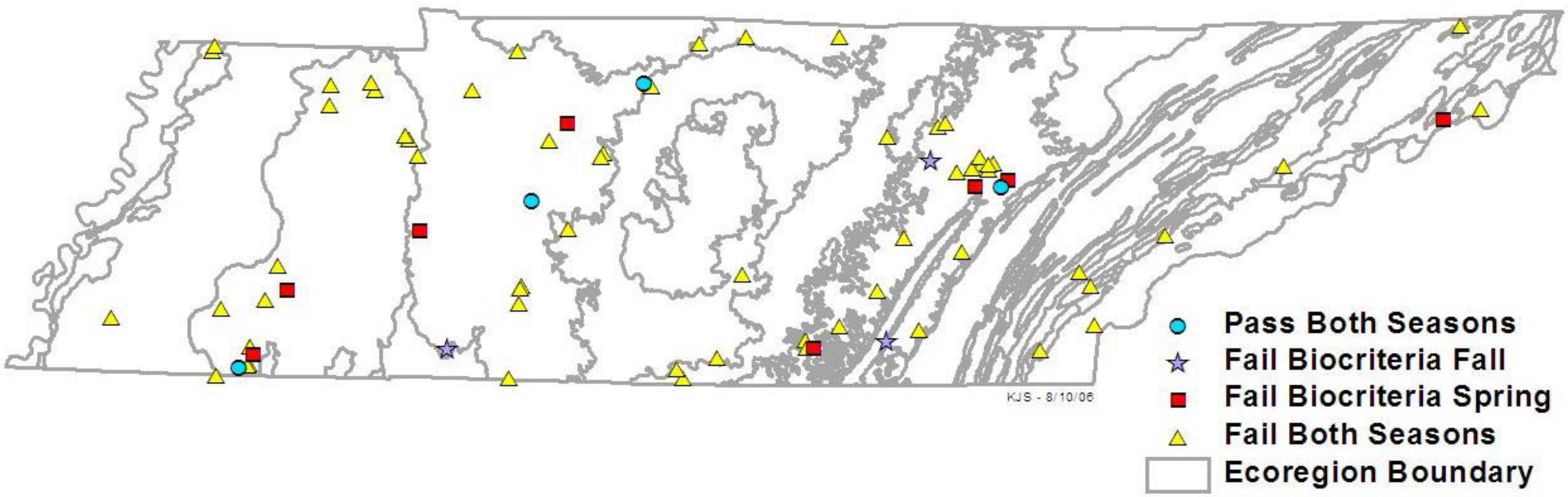


Figure 11: Location of impounded test sites showing comparison to biocriteria.

One site that was compared to a first order reference, an unnamed tributary to East Fork Spring Creek in Hardeman County (EFSPR1T0.5HR), is a small first order stream with a drainage area of 0.5 square miles in the Southeastern Plains and Hills (65e). The 11-acre impoundment was built in 1976. Discharge from the dam was good with stream flow meeting expectations for the ecoregion year round. The results should be viewed with caution since the first order reference stream used for comparison deteriorated in quality between the fall and spring sampling efforts due to livestock grazing and may have skewed the reference guidelines toward a more tolerant community. The impounded test site did not exhibit a healthy benthic community. The spring sample was dominated by hydra and only two EPT taxa were found. Worms and midges were dominant in fall.

Another stream that passed biocriteria was Fall Creek (FALL007.6CU) downstream of Ozone Lake on the Cumberland Plateau. This is a second order stream with a 3.6 square mile drainage. The reservoir was built in 1961 and impounds 7.6 acres in Camp Ozone just upstream of Ozone Falls. This dam had adequate discharge year round with stream flow meeting regional expectations in all seasons. There was good riparian and stable habitat below the dam except for a flash flooding area caused by the spillway.

The third impounded stream that passed regional guidelines for macroinvertebrate communities was South Fork Sycamore Creek (SFSYC006.3DA) in Davidson County. This is a first order stream with a 1.5 square mile drainage area in the Western Highland Rim (71f). A first order reference stream in the same ecoregion was used for comparison. Browns Lake was created in 1935 and is a seven-acre impoundment. There is a second, larger impoundment immediately upstream of this one. Discharge from Browns Lake provided adequate stream flow throughout the sampling year.

The final impounded stream with year round flow that passed biocriteria guidelines was Haley Creek (HALEY003.2HI) in Hickman County. This is a small second order stream with one square-mile drainage in the Western Highland Rim (71f). Boon-Dok Lake was created in 1966 and impounds 8.7 acres. Discharge from the dam was generally good although stream flow in the fall was slightly less than regional expectations.

Two streams, which were dry in the fall, were comparable to the reference in the spring. Both of these were first order tributaries in ecoregion 65e and results should be viewed with caution. They fall under the uncertain category in figure 12. As mentioned previously, the first order reference stream in this ecoregion was degraded by livestock in the spring and was no longer representative of least disturbed conditions. The macroinvertebrate population in the reference stream shifted toward a more pollution tolerant community dominated by chironomids and oligochaetes in the spring.

The first of these test sites was an unnamed tributary to Thompson Creek in Hardeman County. Ninety percent of the organisms found in the unnamed tributary below the impoundment were chironomids and oligochaetes. Only three EPT taxa were collected and they were also facultative or tolerant. The sample would only score 16 when compared to biocriteria guidelines developed for second order or larger streams. The impoundment is a 17-acre lake in a gated community and was built in 1977.

The other site was an unnamed tributary to Old Town Creek in Henry County. This stream also exhibited a primarily facultative benthic community. The dominant organism was *Nais* spp., a tolerant oligochaete. Only one EPT was found, the pollution tolerant mayfly *Caenis* spp. Habitat was poor with unstable banks. Iron precipitate was observed in the creek. Flow was low in winter and spring with no discharge from the dam in summer or fall.

Three sites with year round flow failed only in fall and eight failed only in spring. The majority of sites failed to meet biocriteria or were not comparable to first order reference streams in both the fall and spring sampling seasons (Figure 12). If only one season failed, it was generally spring.

Rattlesnake Creek in the Cherokee National Forest was one of the streams that only failed to meet biological guidelines in the spring. This creek is only impounded seasonally for swimming. The creek was impounded in spring when it failed biocriteria and was free-flowing in fall when it passed guidelines. There was good flow in the creek both seasons.

A site on Bear Creek in Wayne County provides habitat for the threatened Saddled Madtom. This site passed biocriteria in the spring, but had a slightly impaired macroinvertebrate community in the fall, scoring 30. This was not a flow issue as the dam had good discharge all four seasons. Excessive nutrients appeared to be a factor below the dam with total phosphorus elevated in the summer. Microalgae up to 0.5 mm thick coated from 76% to 86% of the substrate in both summer and fall. The nutrient tolerant *Cheumatopsyche* spp. dominated the fall sample making up almost half of the population.

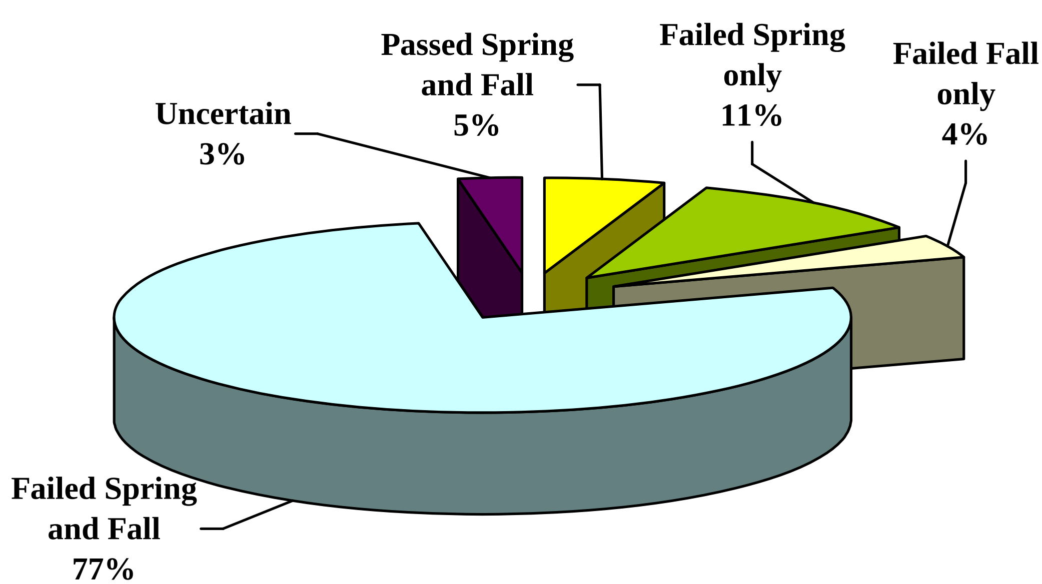


Figure 12: Percent of streams below impoundments failing to meet biocriteria by season.

The most frequent change in the benthic community structure downstream of small impoundments was a loss of EPT taxa (Figure 13). Ninety-six percent of the samples failed to meet reference guidelines for the number of distinct EPT taxa. The abundance of EPT was also reduced, with 86 percent of the samples failing to meet %EPT guidelines. A loss of other taxa was also documented below the impoundments. Eighty-seven percent of the samples failed to meet taxa richness guidelines.

An increase in the number of tolerant and facultative organisms was also evident below impoundments. Seventy-six percent of the samples failed to meet regional guidelines for the NCBI. Some of this was due to an increase in tolerant worms and midges - 58% of the samples failed to meet regional guidelines for %OC. There was also an increase in the 14 nutrient tolerant taxa that make up the %NUTOL biometric, which includes three facultative EPT, one crustacean, two snails, two beetles, one black fly, four midges and all worms. Fifty-three percent of the samples failed to meet guidelines for this metric

The abundance of clinger organisms was below guidelines in 67% of the samples. Clingers rely on sediment-free, stable habitat to thrive.

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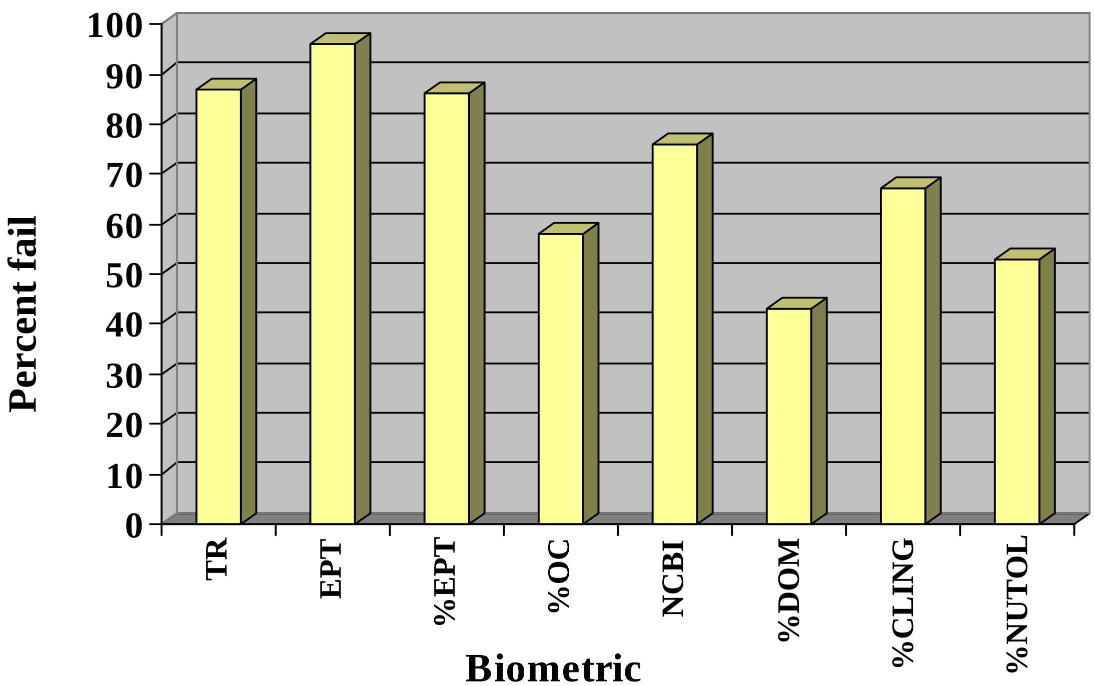

Figure 13: Percent of samples failing to meet regional biometric guidelines when compared to first order reference or regional biocriteria for larger streams.

The percent dominant metric was failed by the fewest number of samples (43%). Although the abundance of the most dominant animal did not always exceed guidelines, the type of dominant taxon was generally indicative of nutrient enrichment or sluggish flow. In the fall, the most prevalent organism below all the impoundments was the trichopteran *Cheumatopsyche* spp. This is a nutrient tolerant caddisfly that filters dead algae, colloidal material and detritus from the water column and thrives in areas where suspended materials are abundant. It was the dominant organism at 26% of the sites.

In spring, the prevalent taxa group was the midges, Chironomidae (Figure 14). Taxa from this family were dominant at 41% of the sites. This was also the dominant group at 23% of sites in the fall. Chironomids are generally tolerant of pollution. The most frequently encountered midge in the spring samples was *Parametriocnemus* spp. This midge is considered tolerant of low flow conditions (Commonwealth of Massachusetts, 2006).

There were regional as well as seasonal differences in the dominant taxa group below impoundments (Table 8 and Appendix B-3). In the west Tennessee bioregion comprising the Southeastern and Loess Plains (65abei-74b), chironomids were the dominant taxa group with *Glyptotendipes* spp. prevalent in fall and *Polypedilum* spp. most common in spring. *Glyptotendipes* is one of the most pollution tolerant benthic macroinvertebtates with an NCBI score of 9.47 (10.00 is the maximum score). It is generally found in eutrophic and slow moving water living in the sediment or in aquatic plants (Epler, 2001). At the two impounded test sites in the Bluff Hills bioregion (74a) of west Tennessee, *Glyptotendipes* spp. was dominant in the fall and isopods were prevalent in the spring

In the mountainous bioregion, 66deg, hydopsychid caddisflies including *Cheumatopsyche* and *Diplectrona* spp.were dominant in the fall. As mentioned earlier, *Cheumatopsyche* is tolerant of nutrient enriched conditions. *Diplectrona* is generally considered intolerant of pollution. It was dominant at two sites. Both of these sites passed biological guidelines in the fall but failed the spring. Facultative and tolerant chironomids were the dominant taxa group in the spring at all sites below impoundments in this bioregion.

In the ridge and valley bioregion (67fghi), *Cheumatopsyche* spp. was the dominant taxon at every impounded site in the fall. The riffle beetle, *Stenelmis* spp., was dominant at most sites in the spring. *Stenelmis* spp is nutrient tolerant and is often found downstream of sewage treatment plants.

Dipterans, including blackflies (Simuliidae), craneflies (Tipulidae) and midges (Chironomidae) were the dominant fall taxa below the 21 impoundments on the Cumberland Plateau bioregion (68a). Dipterans, primarily *Parametriocnemus spp.*, were also abundant in the spring

Cheumatopsyche spp. was the dominant fall taxon in the bioregion consisting of the Eastern and Western Highland Rims and the Outer Nashville Basin (71fgh). The nutrient tolerant isopod, Lirceus spp., was dominant in the spring. Adult *Lirceus* are omnivores that can take advantage of a wide variety of food sources. Juveniles are typically dependent on microbial foods such as algae and bacteria.

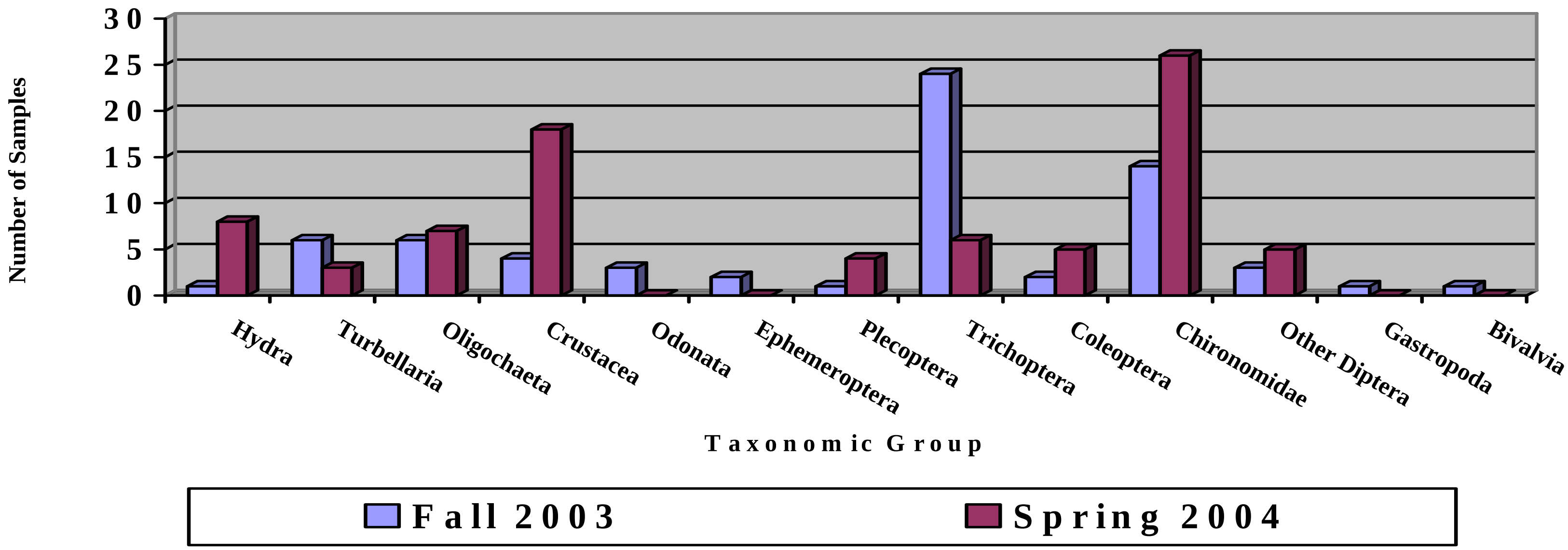

Figure 14: Dominant taxa groups downstream of 75 impoundments.

Table 8: Dominant taxon at study sites below impoundments.

Taxonomic Group	Genus	Number of Sites													
		65abei-74b		66deg		67fghi		68a		68c		71fgh		74a	
		Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Hydroida	*Hydra*		3					1	3				2		
Turbellaria	*Dugesia*	1	2									5	1		
Oligochaeta	*Nais*		2					1	1			1	2		
Oligochaeta	*Limnodrilus*		1					3	1			1			
Amphipoda	*Crangonyx*	1	1										1		
Isopoda	*Caecodotea*														2
Isopoda	*Lirceus*											3	13		1
Odonata	*Argia*	1													
Odonata	*Calopteryx*	1													

Table 8 cont:

Taxonomic Group	Genus	Number of Sites													
		65abei-74b		66deg		67fghi		68a		68c		71fgh		74a	
		Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Odonata	*Gomphidae*									1					
Ephemeroptera	*Habrophlebia*			1											
Ephemeroptera	*Isonychia*							1							
Plecoptera	*Amphinemura*								1						
Plecoptera	*Leuctra*				2				2						
Trichoptera	*Cheumatopsyche*	3		2	1	4		1	1		1	9	3		
Trichoptera	*Chimarra*							2							
Trichoptera	*Diplectrona*			2											
Trichoptera	*Oecetus*	1													
Coleoptera	*Neoporus*	1													
Coleoptera	*Stenelmis*						2					1	3		
Chironomidae	*Ablabesmyia*		1												
Chironomidae	*Chironomus*		1					1				1			
Chironomidae	*Constempellina*				1										
Chironomidae	*Cricotopus/Ortho.*		2												
Chironomidae	*Dicrotendipes*	1													
Chironomidae	*Diplocladius*							1							
Chironomidae	*Glyptotendipes*	3										1		1	
Chironomidae	*Nanocladius*		1												
Chironomidae	*Parametriocnemus*						1		5						
Chironomidae	*Polypedilum*	1	2		1			1	2			2	2		
Chironomidae	*Rheotanytarsus*								2						
Chironomidae	*Tanytarsus*								1				1		
Chironomidae	*Thienemannimyia*			1	1								1		
Chironomidae	*Zavrelimyia*								1						
Diptera	*Bezzia*		1												
Diptera	*Prosimulium*							1							
Diptera	*Simulium*		1				1		2						
Diptera	*Tipula*							2							
Gastropoda	*Elimia*											1			
Bivalvia	Sphaeriidae											1			

One site, Laurel Creek (LAURE003.4MO) in Monroe County was in the headwaters of an ecoregion reference stream for the Southern Sandstone Ridges (67h). The reference site is located approximately 2.6 miles downstream of the impoundment. Four small first order tributaries enter the stream between the two sites but do not change the stream order. The 51-acre Laurel Mountain Lake was constructed in 1965.

Dissolved oxygen saturation was low while temperature, suspended solids, iron, manganese and ammonia were elevated at the test site below the dam. Concentrations were comparable to levels found at two other regional reference streams 2.6 miles downstream. At the test site, the macroinvertebrate community failed to meet guidelines both seasons, scoring 26 in fall and 28 in spring. The downstream reference site scored 40 and 38 respectively. In fall, taxa richness increased from 11 taxa below the dam to 29 at the reference site while EPT taxa increased from 2 to 17. Nutrient tolerant organisms were more abundant at the test site (93.9%) than at the downstream reference site (21.3%). *Cheumatopsyche* spp, was the dominant species at the test site comprising 76.3% of the sample. Further downstream at the reference station, *Cheumatopsyche* was only nine percent of the sample. The facultative mayfly, *Stenonema* spp., was dominant but only comprised 20% of the community.

Spring also showed a big difference between the two sites although in different ways. There was still a marked increase in EPT taxa from 5 to 15 and a decrease in the percent of nutrient tolerant organisms from 41.6% to 20.7%. However, the biggest change was the percent of worms and midges, which decreased from 64% immediately below the dam to only 20.1% at the reference site. A midge species, *Parametriocnemus*, was dominant below the dam while a stonefly, *Amphinemura* spp. was dominant at the reference site. Although both of these species have similar pollution tolerance, their feeding habits are very different. The midge is a collector gatherer eating decomposing fine particulate matter. The stonefly is a shredder, primarily of leaf litter. Shredders tend to decrease with an increase in environmental disturbance (Barbour et. al., 1999).

Biological data were available at two of the 2003 probabilistic study sites prior to construction of the impoundments (Smith and Baker, 1997). These were unnamed tributaries to the South Harpeth River in Davidson County. One of the 1997 sites, SHARP1T0.6DA already had one impoundment, the 2003 test site was below both the existing impoundment and the second one constructed in 1998. The other 1997 site SHARP2T0.6DA, was on a previously un-impounded tributary. The impoundment was constructed in 1997. The location of the SHARP2T0.6DA station in 1997 was 50 yards upstream of the proposed dam site and is now under the impoundment.

Qualitative riffle kicks were collected at both sites in March 1997. Although the protocol was not directly comparable to the 2003 survey, the same habitat was sampled and the general community structure before and after impoundment can be compared. In 1997, SHARP2T0.6DA supported a diverse benthic community with intolerant taxa comprising over half the total taxa before the stream was impounded. Eight genera of mayflies, stoneflies and caddisflies (EPT) were common to very abundant while five were more infrequently collected. An intolerant stonefly, *Isoperla* spp. was very abundant.

The 2003 site was located 50 yards downstream of the dam that was constructed in 1997. There was a distinct loss in the number of EPT and intolerant taxa (Figure 15). EPT were only three percent of the sample. A single stonefly individual was collected, *Amphinemura* spp. This facultative stonefly is more tolerant of pollution than *Isoperla* spp, which was abundant in 1997. The only other EPT collected after the stream was impounded were two facultative members of the mayfly family Baetidae (*Plauditus* and *Acentrella* spp.). Worms, midges and blackfly larvae comprised almost half of the sample. None of these generally tolerant organisms were found in the riffle kick in the original sample. There were no intolerant taxa found in the spring 2003 sample.

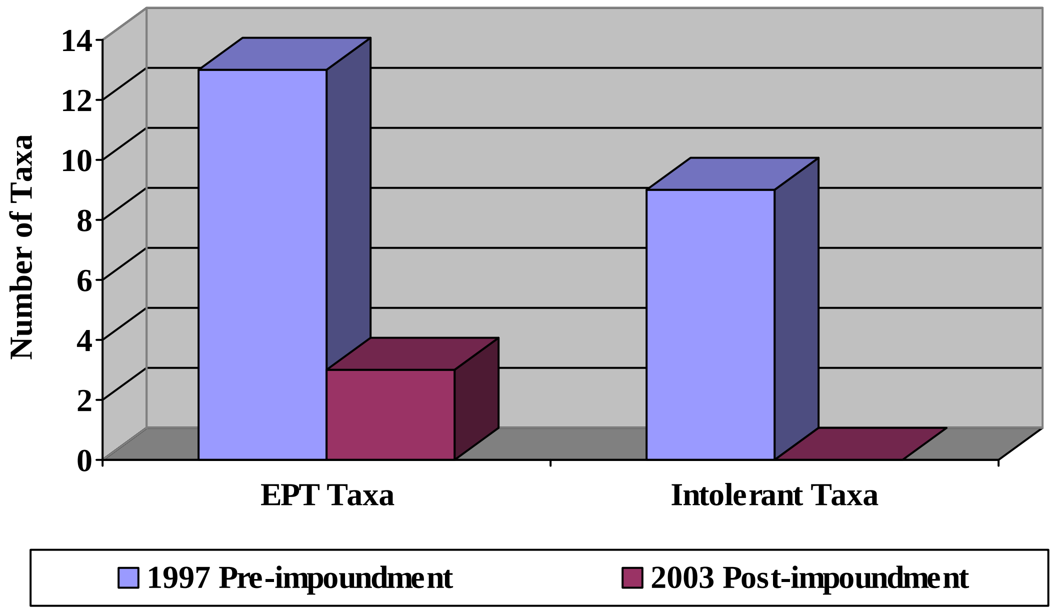

Figure 15: Comparison of EPT and intolerant taxa in riffle habitat before and after impoundment.

The other stream that was collected in both 1997 and 2003 was a second unnamed tributary to South Harpeth River. This creek already had one impoundment in 1997 and a second was proposed. In 1997, this tributary exhibited a more tolerant community structure than the nearby unimpounded stream. Both are first order streams with less than one square mile drainage all within the same ecoregion and should have similar biota. There were half as many EPT taxa found in the riffles and the abundance of the remaining taxa had dropped to few or rare. Worms and midges were common. Less than one fourth of the taxa were intolerant while a third were tolerant.

The sample collected in spring 2003, after the second impoundment was built, indicated conditions had worsened. Only four EPT were collected comprising 8% of the sample. There was only one intolerant taxon found, the trichopteran *Rhyacophila* spp, which was four percent of the sample. Facultative isopods, *Hydra* and pollution tolerant sphaerid clams comprised 70% of the macroinvertebrate community.

Other macroinvertebrate samples collected on small impounded streams in Tennessee during the same time period showed similar results to this probabilistic study. A survey was conducted on four small east Tennessee impoundments in 2003 and 2004 (Everett, 2005). This study focused on the macroinvertebrate community structure upstream and downstream of the impoundments. All of the streams showed a difference in benthic communities above and below the impounded reach. The intolerant trichopteran *Agapetus* spp. was collected upstream of every impoundment but was absent from the downstream stations. Conversely, the tolerant chironomid *Diamesa* spp. was found below dams but not upstream of the impoundments.

All of these streams had year-round flow downstream of the impoundments. The abundance of EPT taxa at all stations was depressed at least one season. The biggest discrepancies were observed in spring (March through May) (Figure 16). The number of nutrient tolerant organisms was elevated in the May below dams (Figure 17).

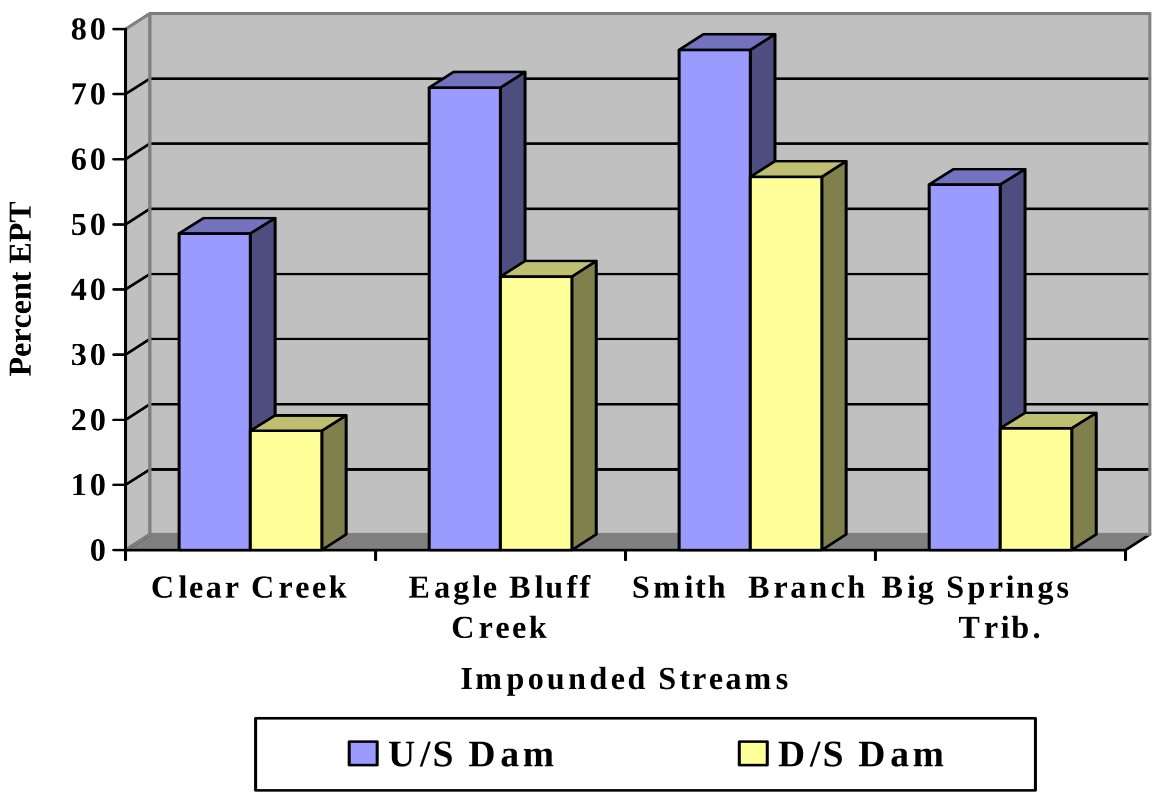

Figure 16: Percent abundance of EPT above and below four east Tennessee impoundments, May 2004 (March 2003 at Eagle Bluff Creek). *Data provided by Larry Everett, KEFO, WPC.*

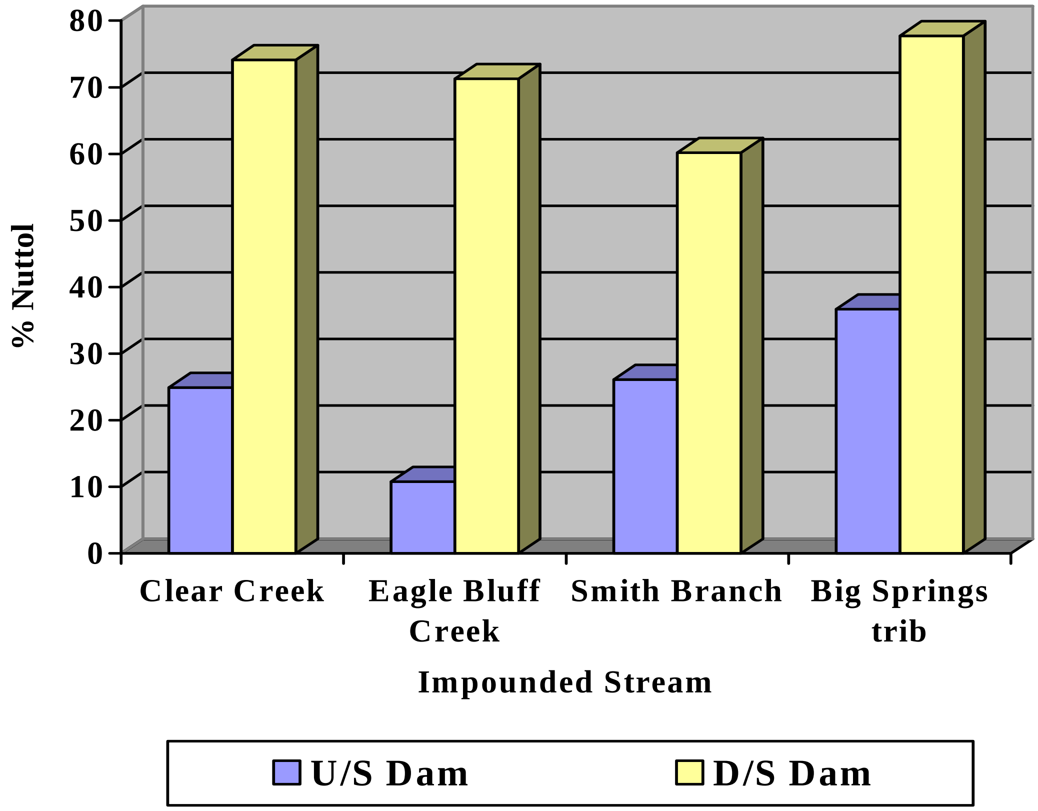

Figure 17: Percent abundance of nutrient tolerant taxa above and below four east Tennessee impoundments, May 2004. *Data provided by Larry Everett, KEFO, WPC.*

When compared to regional guidelines for first order streams developed in this project, data from a study conducted on Black Branch in Maury County supports the findings that macroinvertebrate communities are adversely affected when small streams are impounded (Pennington and Associates Inc., 2004). A macroinvertebrate sample was collected in August 1998 from a proposed dam site on this small first order stream prior to impoundment. This was a field survey and not directly comparable to TDEC protocols so an index score cannot be calculated. However, 17 distinct EPT genera were collected including four intolerant mayflies, two intolerant stoneflies and five intolerant caddisflies indicating a healthy stream community.

The dam was constructed in 1999 and the reservoir filled in 2001. Macroinvertebrate samples were collected at three locations in September 2003 and May 2004 with the same protocols used in this study and can be compared to the first order reference guidelines. One station was 100 feet below the dam, a second station was on an unimpounded first order tributary that entered Black Branch downstream of the first station. The third station was on Black Branch downstream of both the other stations and 1000 feet below the dam. Black Branch is a second order stream at this point but has a small drainage area.

The station immediately below the dam failed to meet regional guidelines for first order streams in the Western Highland Rim all three seasons it was sampled. Worms and midges were consistently more abundant than at other stations (Figure 18). In spring, worms and midges comprised 66% of the macroinvertebrate community. Tubificid worms were collected every season at this station and were not found at the other sites. As the abundance of worms and midges increased, the abundance of the less pollution tolerant EPT decreased. Thirteen EPT taxa were collected but the abundance was low (8.5%). Both the unnamed tributary and the other Black Branch station passed first order guidelines all three times. It is unlikely the Black Branch station would have shown recovery 1000 feet below the dam without the influence of the unnamed tributary. Based on flow data, the tributary contributes approximately 50% of the flow to Black Branch at this location.

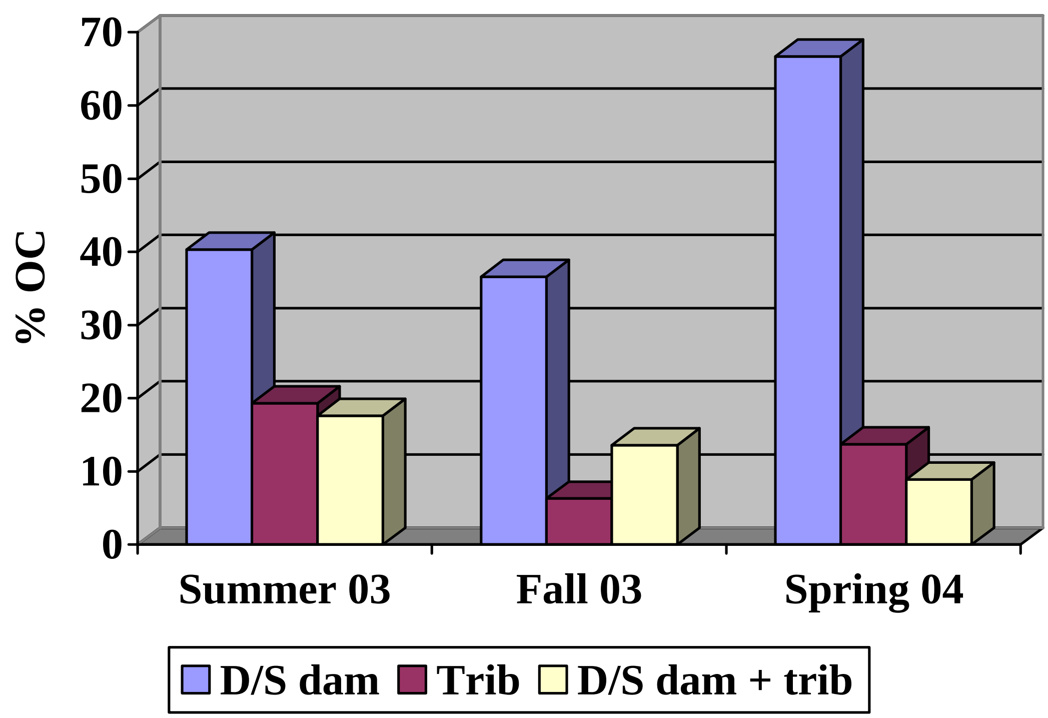

Figure 18: Abundance of worms and midges (%OC) in response to impoundment of Black Branch in Maury County. *Data provided by Pennington and Associates, Inc.*

5. FLOW BELOW IMPOUNDMENTS

It has been well documented that dams change the amount of flow downstream of impoundments (Grant et al, 2003, Brandt, 2000, Leopold, 1984, Williams and Wolman, 1984, Petts, 1980). This can result in periods where the stream below the impoundment has no flow and is reduced to isolated pools or a completely dry streambed. In streams that go dry under natural conditions, the duration or frequency of the dry periods can increase if the stream is impounded. During heavy rainfall, the streams can flash flood due to the quick release of large quantities of water from the reservoir.

Thirty two percent of the 200 randomly selected impoundments visited during the site selection process in summer 2003 had no discharge. This did not include an additional 7% of impoundments built on intermittent streams, based on topographic maps, that were counted separately. Of the 75 sites that summer flow in 2003, 23% were dry by the fall sampling period.

Over four times as many dams had surface discharges such as standpipes or spillways than subsurface discharge or multiple discharges. The type of discharge made little difference on whether water was released from the dam. Spillways, standpipes and subsurface discharge were equally likely to have no discharge (16-18%). Sixty-three percent of the dams with both surface and subsurface discharge did not release water at least one season. However, if water was released from the impoundment year round, subsurface discharges were more likely to maintain adequate stream flow all seasons (Table 9).

Table 9: Quality of stream flow downstream of impoundments grouped by discharge design.

Discharge Type	Total	Adequate stream flow maintained.	Inadequate stream flow at least one season.	No stream flow at least one season.
Standpipe	28	9	14	5
Spillway	23	8	11	4
Subsurface	12	6	4	2
Multiple	11	4	0	7
Unknown	1	0	1	0

Drainage area is a key factor in the amount of flow expected in a stream. There was a direct positive correlation for drainage area and high flow measurements ($p = 0.647$). The correlation was even stronger ($p = 0.855$) for first order streams alone. The size of the reservoir is another important factor. A large reservoir with a small drainage area can reduce downstream flow due to the amount of water retained. This is especially apparent in first order streams where a correlation ($p = 0.615$) was measured between low flow measurements and the drainage area/reservoir size ratio. A minimum of 10 acres in drainage area is generally recommended for each acre of lake (Dean et al, 1976). However, lake management is also a key issue. One of the lakes with no discharge had a drainage area to impoundment ratio of 286 to 1. All but five of the study lakes had at least a 10:1 ratio of upstream drainage to lake area.

Even if a site had measurable flow, it did not mean levels were adequate for maintenance of aquatic life. The channel flow status score of the field habitat assessment was compared to regional expectations, which are published in TDEC's QSSOP for Macroinvertebrate Stream Surveys. These expectations are based on 75% of the median reference score for the bioregion. First and second order test sites with small drainages were compared to first order reference streams collected during the study. The channel flow status score for each test site was determined in the field by estimating the percent of available channel that is filled with water and how much substrate is exposed. Possible scores range from 1 to 20 with higher scores being closer to optimal flow conditions. Scores for each site are provided in Appendix C-1.

Using this guideline, 52% of the sites had insufficient flow to sustain aquatic life during at least one season (Figure 19). One fourth of the streams were dry at least one season (Figure 20). Fall was the season most likely to have inadequate flow or no discharge from the impoundments. Even in the high flow seasons of winter and spring, 16 to 25% of the impounded streams had insufficient flow to sustain benthic communities. Many streams had inadequate flow for two or more seasons. Three of the streams with year-round flow were below expectations all four seasons. First order streams were least likely to maintain sufficient flow with 43% below three quarters of the median first order reference score (Figure 21). Second order streams were also likely to have inadequate flow (38%). Even larger impounded streams (21%) often had inadequate flow.

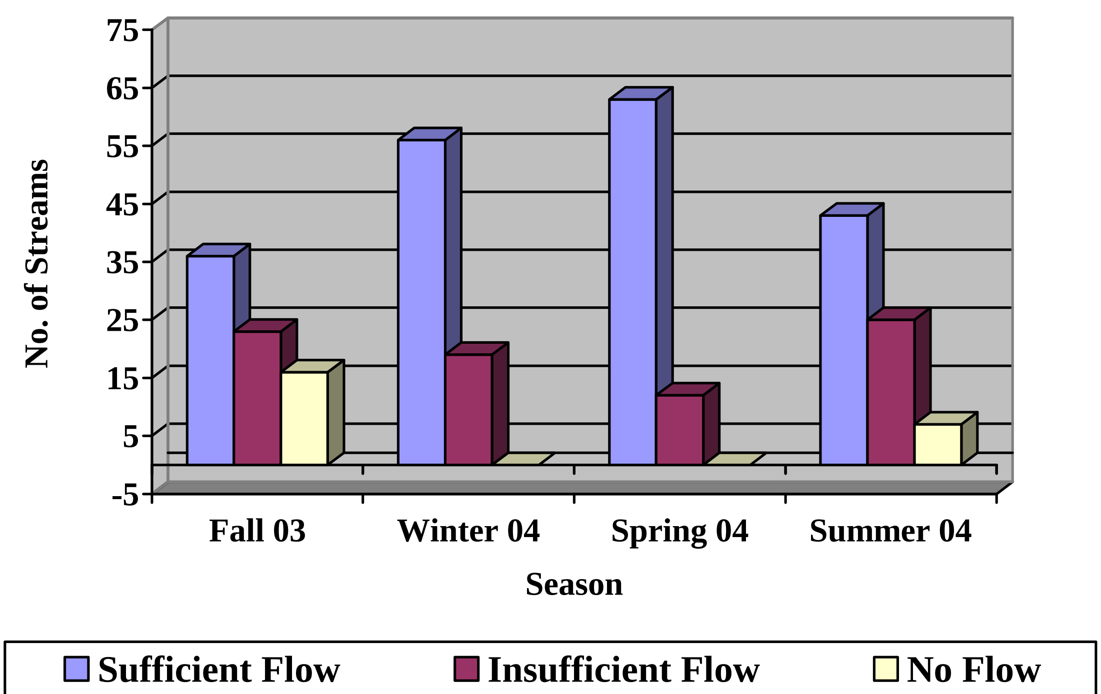

Figure 19: Comparison of stream flow below 75 randomly selected impoundments to regional expectations for maintenance of a healthy macroinvertebrate community. Number of sites based on qualitative assessment of channel flow status by experienced stream biologists.

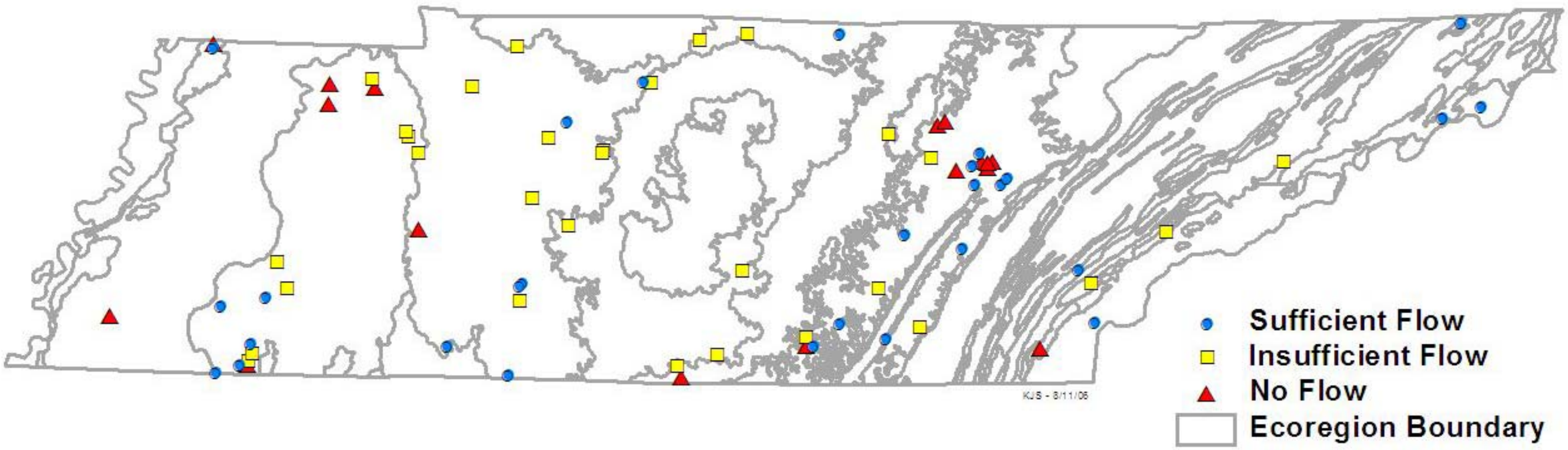

Figure 20: Location of impounded test sites without flow or with inadequate flow to sustain aquatic life at least one season.

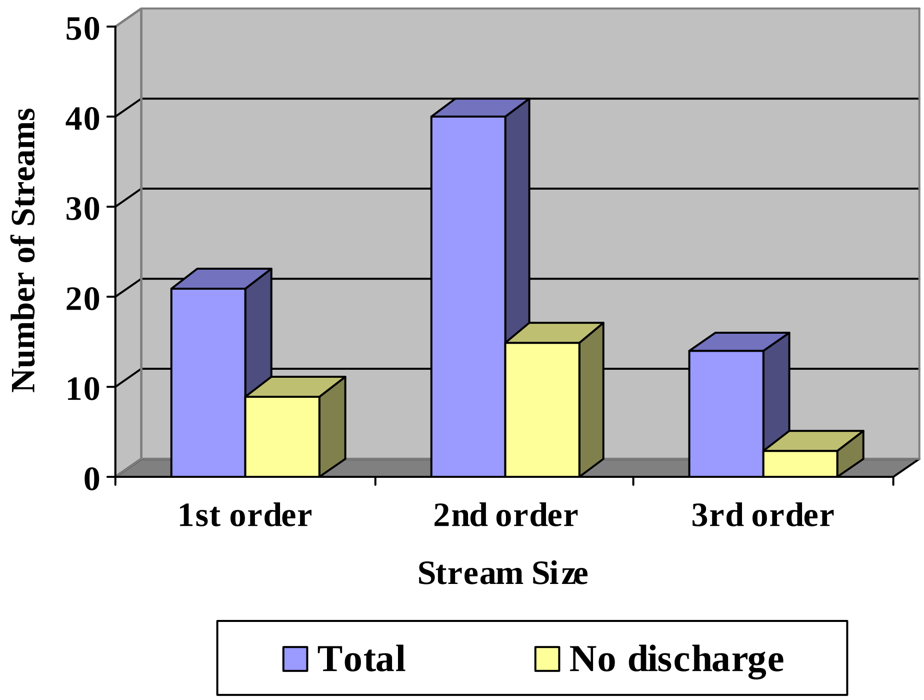

Figure 21: Number of impoundments with no discharge in at least one season grouped by stream size.

Another factor to consider in flow below impoundments is the alteration in the natural timing of changes in flow. For example, upstream and downstream stations were established at one reservoir on a first order tributary to Sinking Creek in Cocke County. The stations were only 0.2 miles apart and there were no other tributaries entering between the stations so flow should be comparable. Downstream there was no difference between winter and spring flow while upstream there was a 50% drop in these seasons (Table 10). An 80% drop in flow was measured between spring and summer downstream. Upstream the spring flow level was maintained in the summer probably due to the presence of springs. Summer flow downstream of the impoundment was only one third of the upstream level. (Table 10). Different macroinvertebrates hatch in different seasons, so an alteration in the timing of changes in flow and subsequent in-stream habitat availibility can cause shifts in the biological community structure.

Table 10: Comparison of flow upstream and downstream of an impoundment on a first order tributary to Sinking Creek in Cocke County, ecoregion 67g, Southern Shale Valleys.

Date	Flow Upstream Reservoir (cfs)	Flow Downstream Reservor (cfs)
10/29/2003	0.2	0.2
02/03/2004	0.6	0.5
05/04/2004	0.3	0.5
07/20/2004	0.3	0.1

It is possible that some of the smaller streams throughout the state may naturally have been dry or barely flowing for periods of the year without impoundments. However, the presence of dams that have no provisions for low flow discharge can increase the magnitude and duration of this period. Aquatic organisms such as fish and macroinvertebrates that are able to find refugia during short periods of no or minimal flow may not be able to do so if the time period or length of stream reach is extended. This can affect the ability of the stream to repopulate during periods of flow.

To help determine the likelihood of perennial streams being dry due to weather conditions instead of the influence of the impoundments, precipitation data for the period preceding and during site reconnaissance and sampling was compared to 25-year averages. Eight representative weather stations were selected to characterize precipitation in the vicinity of the impoundments (Figure 22). The weather stations were selected as having the best data quality control and closest proximity to the test sites. Most were located at major airports. TetraTech provided precipitation data for January 1978 through July 2004 for all weather stations and for 1978 through 2002 for Monterey. Precipitation measurements at the Montery station for 2003 and 2004 and for August 2004 for all stations except Huntsville were obtained from the National Oceanic and Atmospheric Administration (NOAA). The Alabama Office of State Climatology provided August 2004 precipitation totals for the Huntsville weather station.

It should be noted that all six of the first order reference streams monitored had flow throughout the study period. These reference streams represented the major regions including east Tennessee mountains, the ridge and valleys, the Cumberland Plateau, the interior plateau and the west Tennessee plains.

First order reference streams such as Douglas Branch (FECO68A01) on the Cumberland Plateau had good flow throughout the study period. Photograph was taken in July 2004.

Photo provided by Aquatic Biology Section, TDH.

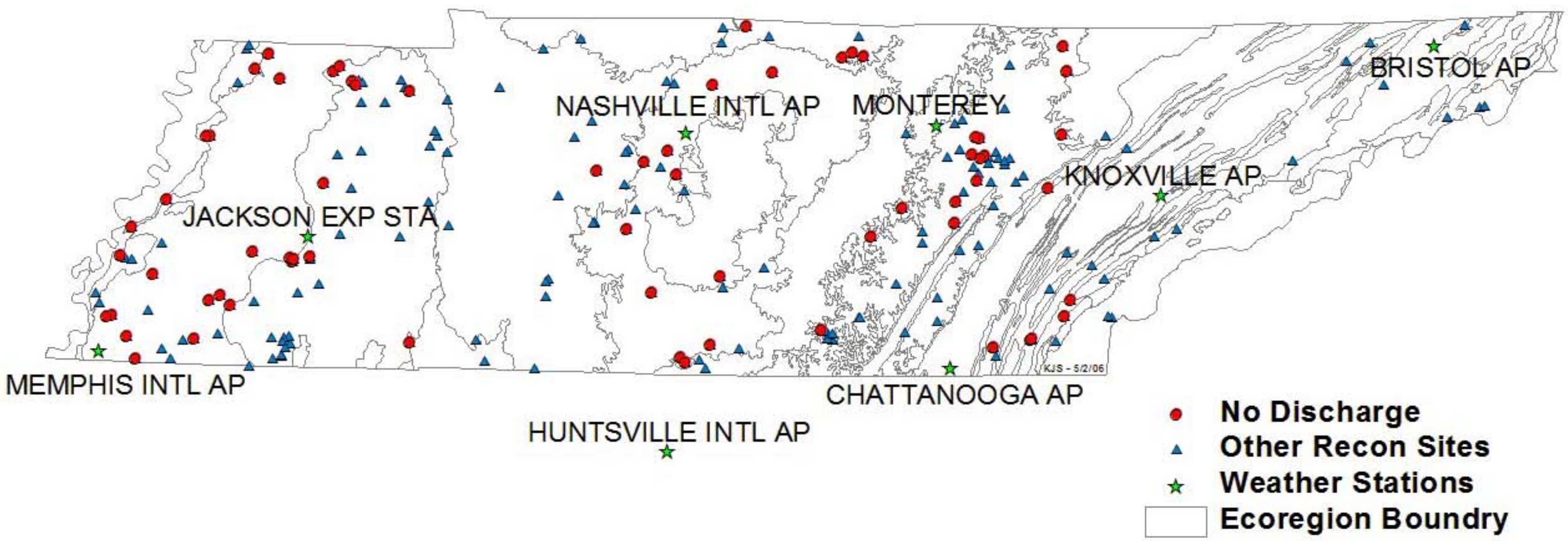

Figure 22: Proximity of reconnaissance sites to weather stations.

Seven streams were randomly selected for reconnaissance in the Bristol weather station area. None of them were eliminated from the study due to lack of flow. Precipitation was well above average April through September in this area (Figure 23). One second-order test site, Steele Creek, had good flow in early September, but was dry by the end of October. Precipitation in October was only slightly below the 25-year average. Steel Creek is a fairly large second order stream with approximately 11.5 square miles drainage area. The 43-acre impoundment had no discharge in October. It is likely this stream would have had flow without the influence of the impoundment. The other six streams in this area had sufficient flow to sustain aquatic life year round.

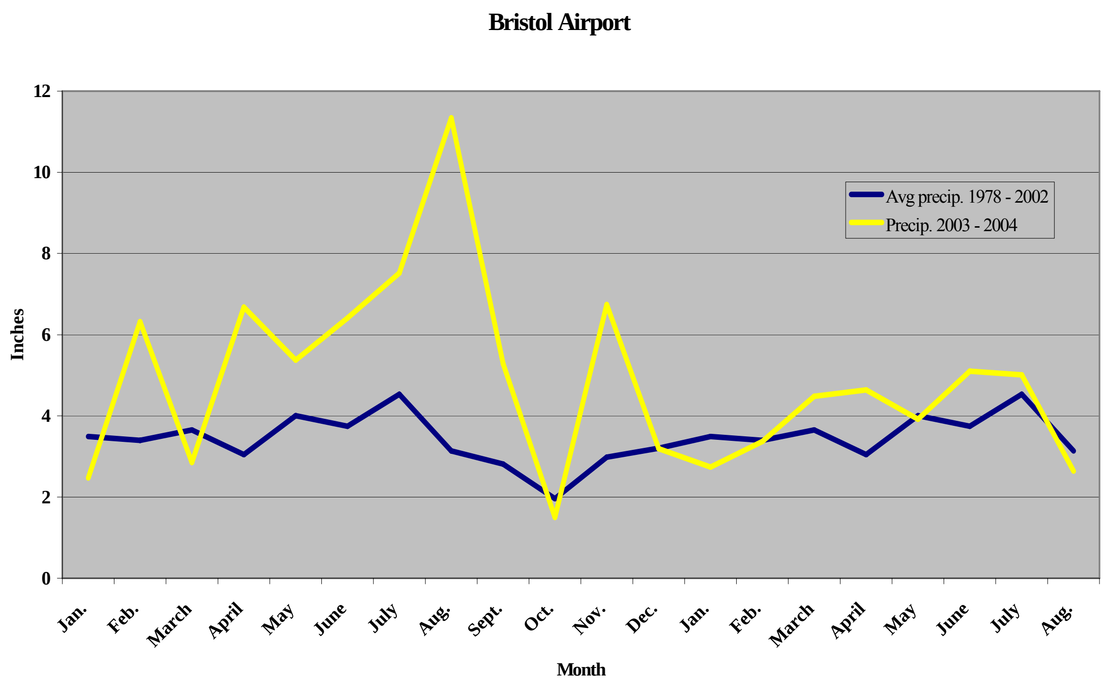

Figure 23: Monthly precipitation at the Bristol Airport 1978 – 2004.

Ten sites were selected for reconnaissance in the Knoxville weather station area. Only one first order stream was dry. Two first order reference streams in this area were monitored and had flow throughout the study period. Rainfall was at or above average for the four months preceding and the months during the reconnaissance period (Figure 24). Based on these factors, it is unlikely this stream would have been dry if it were free flowing.

Five of the reconnaissance sites met study requirements. All were small first and second order streams. Each had flow year–round although one had insufficient flow in the fall. A second order stream with a 54-acre impoundment had inadequate spring flow. April and May precipitation was well above average. Based on precipitation levels and reference stream flow, it is likely that both streams should have had adequate flow throughout the study period.

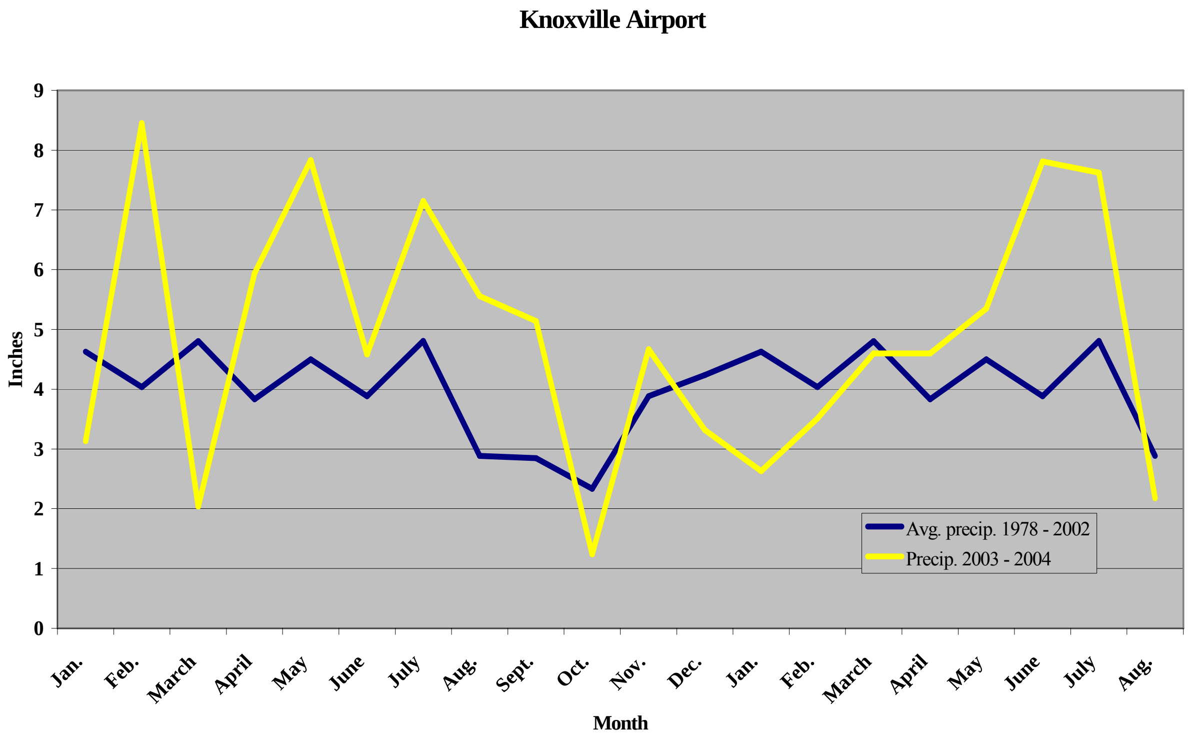

Figure 24: Monthly precipitation at the Knoxville Airport 1978 – 2004.

Twenty-five impounded streams in the Chattanooga weather station area were selected for reconnaissance in summer 2003. Three first order and four second order streams were dry. Precipitation was at or above normal for the four months prior to the reconnaissance (Figure 25). August precipitation was the same as the 25-year average while September was above. It is probable these perennial streams would have flow under natural conditions.

Eight streams met study requirements including summer flow. Five of these were either dry or had inadequate flow at least one season. The three streams with adequate year round flow were small first or second order even though precipitation levels were generally at or below average during the sampling period. A 75-acre impoundment on a relatively large third order stream had inadequate spring and summer discharge.

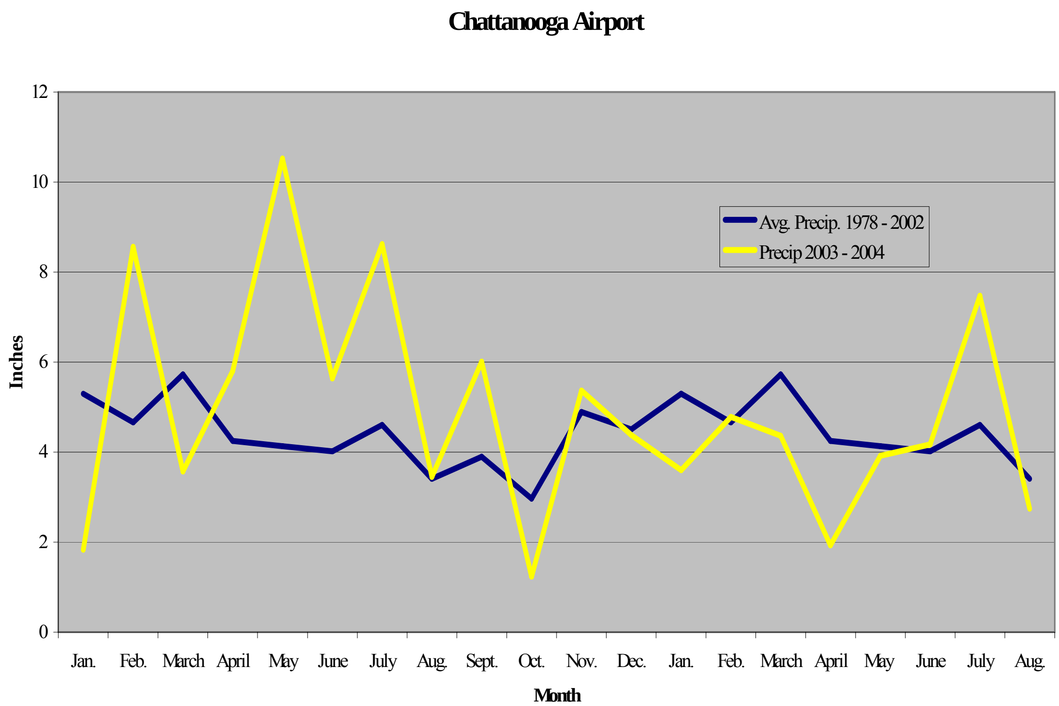

Figure 25: Monthly precipitation at the Chattanooga Airport 1978 – 2004.

Thirty-nine of the reconnaissance sites were closest to the Monterey weather station. Fourteen of the impoundments had inadequate flow or no discharge. It is not uncommon for small streams on the Cumberland Plateau to be dry in the late summer and early fall. However, a first order reference stream with a 0.5 square mile drainage area had flow throughout the study period. Six of the test streams were second order and three were third order. It is less likely that these would be dry without the presence of an impoundment especially considering precipitation at the Monterey weather station in the three months preceding the reconnaissance was above average (Figure 26). Rainfall levels in August were slightly below the 25-year average while September was above.

Seventeen impoundments met study objectives. Seven of these were no longer releasing water by the fall sampling period. Five impoundments were 25 acres or less on first order streams with less than one square mile drainage. Although these are similar in size to the reference stream, it is possible that these streams would have been dry even without flow alteration since October and November precipitation was below normal. Two of these streams along with a second order stream were dry the following summer (2004) although rainfall was above the 25-year average. Looper Branch, a larger second order stream, was also dry in the fall. There was no discharge from the eight-acre Pine Ridge Lake. The 209-acre Lake Holiday on the Obed River also had no discharge during the fall sampling period in November. The Obed is a third order stream at this location draining over 6 square miles.

Eight reservoirs had discharge year round with six of them maintaining adequate flow for aquatic life in all seasons. All were second or third order streams. Two of the impoundments with year round discharge did not maintain adequate flow downstream. Duncan Creek Lake, a 57-acre impoundment, did not maintain adequate spring flow. City Lake, a 62-acre impoundment on the Falling Water River did not maintain adequate discharge in the summer.

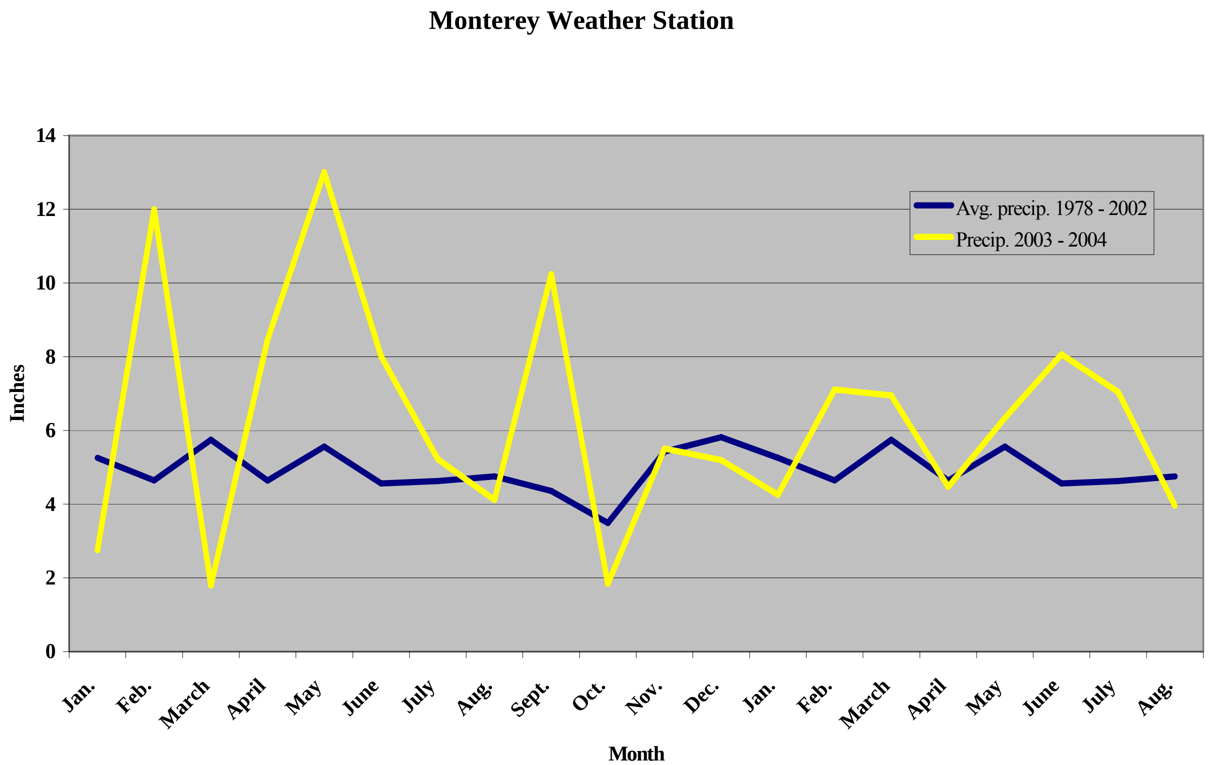

Figure 26: Monthly precipitation at the Monterey Weather Station 1978 – 2004.

Thirty of the reconnaissance sites were closest to the Nashville Airport weather station. Eleven of the impoundments had no discharge and the creek channels were dry when visited in August and September 2003. Ten of these were first order streams, while one was a larger third order. Rainfall was at or above normal in August and September although it was about 0.5 inches below the 25-year average in July (Figure 27).

Of the 15 sites selected for the study, all but one were still flowing during the fall sampling period. The site without flow is a seasonal impoundment for duck hunting and was not retaining water at the time. Therefore the creek's lack of flow was not a result of the impoundment. All but one of the impoundments with year-round discharge were on first or second order streams.

Although most of the dams in this area had some discharge year-round it was usually not sufficient to maintain aquatic life. Only two creeks had adequate year-round flow that met expectations for the ecoregion. Both of these were headwater streams with small impoundments. One was an unnamed tributary to Jones Creek downstream of the Hava-Lakatu Lake number 2, a four-acre reservoir in Dickson County and the other was South Fork Sycamore Creek downstream of Browns Lake, a seven-acre lake in Davidson County. The other streams had inadequate flow in the fall and/or summer. Seven creeks also had inadequate flow in winter and/or spring when most free-flowing streams are at their highest flow.

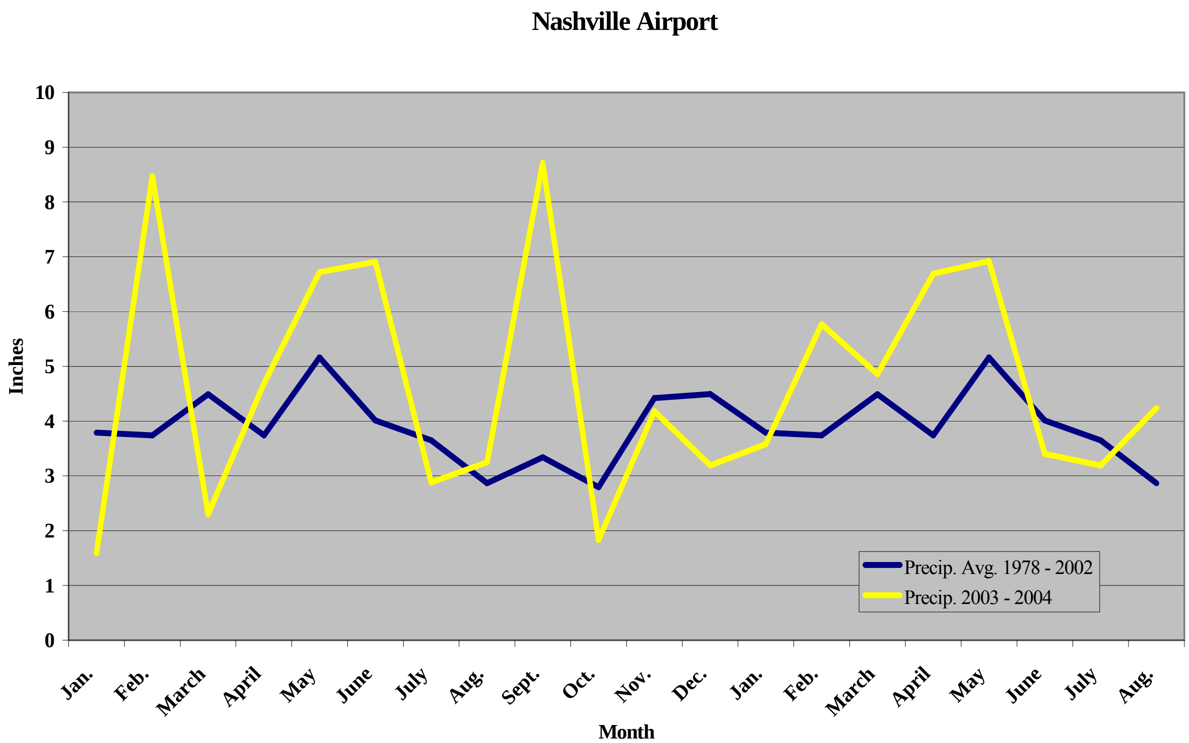

Figure 27: Monthly precipitation at the Nashville Airport 1978 – 2004.

Seventeen potential study sites were selected for reconnaissance in the Huntsville weather station area. Four impoundments had inadequate discharge for sampling. One was first order and three were second order. One of the impoundments was relatively large at 70 acres. Spring and early summer precipitation was at or above average (Figure 28). During the reconnaissance, August rainfall was slightly below average, while September was approximately two inches above.

Eight sites met study requirements. All but one had flow year round. One of the two first order streams was dry during the fall sampling trip in early November. October precipitation was approximately two inches below average. The stream had flow in winter and spring but was dry the following summer. A first order reference stream with a similar drainage area in this area had flow throughout the study period.

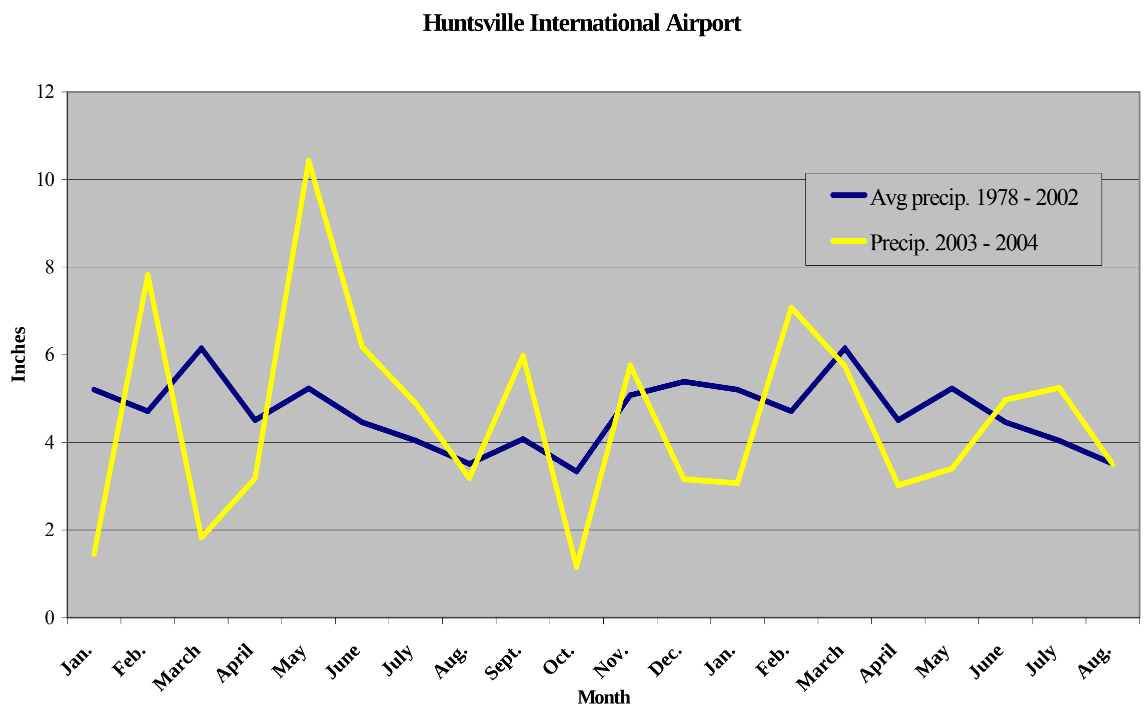

Figure 28: Monthly precipitation at the Huntsville Airport 1978 – 2004.

Fifty-two impounded streams in the Jackson weather station area were visited during the summer reconnaissance. Nineteen had little or no discharge. Ten of these were first order, seven second order and two were third order. Precipitation was at or above average the four months prior to the reconnaissance period (Figure 29). August rainfall levels were normal while September was approximately one inch below average. It is possible that at least the first order streams may have been dry even without the influence of the impoundment although a first order reference stream in this area retained flow throughout the study period. It is less likely that the second and especially the third order streams would have been dry without the impoundment.

Eighteen streams met study requirements. The majority were small first and second order streams. Five were dry by the fall sampling period. One of these was also dry the following summer. Thompson Creek is a larger second order stream with a 183-acre impoundment. Flow was low in summer and there was no discharge from the lake in the fall. Tull Creek, is a third order stream with a 58-acre impoundment. The creek had good flow when first visited in September although precipitation was approximately one inch below average. By the following month, the stream reach was reduced to one isolated pool immediately below the spillway. Over 100 dead and dying juvenile catfish were observed by field staff.

Stream flow was sufficient to support aquatic life below eight impoundments year-round. This included five small first and second order streams as well as three larger streams. Flow was inadequate in five streams for at least one season. None of these were first order. A six-acre impoundment on a second order tributary to Threemile Branch had insufficient discharge to provide adequate stream flow in any season. A 21-acre impoundment on Dry Creek in Benton County had inadequate discharge every season except summer.

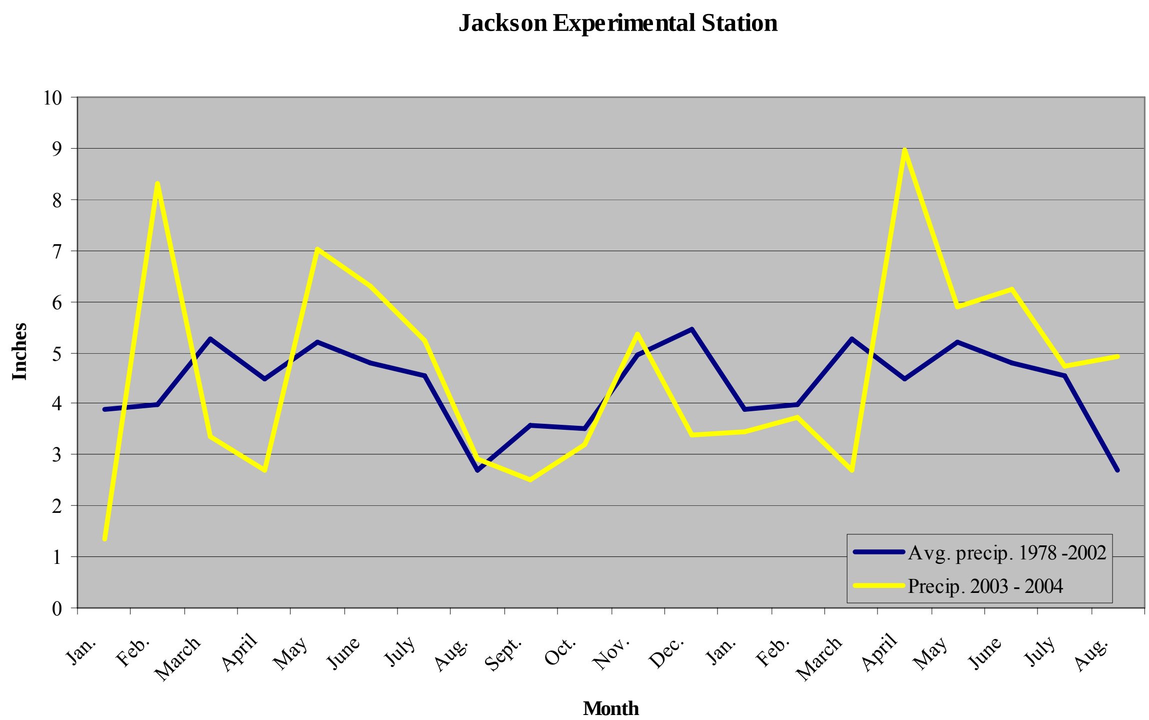

Figure 29: Monthly precipitation at the Jackson Experimental Station 1978 – 2004.

Twenty sites were selected for reconnaissance in the Memphis weather station area. Half of the sites were dry. Five of these were first order while five were second order. Although rainfall was well above average in the spring, July and August were approximately one inch below average (Figure 30). It is possible that at least the first order streams would have been dry even without the impoundments.

The only test site in this area that met requirements for inclusion in the study was Scotts Creek. This is a third order stream with a relatively large 237-acre impoundment. Although stream flow was adequate during the summer reconnaissance, there was no discharge from the impoundment the first week of October. Precipitation was average in September. This stream would likely have flow during the drier months if it were not impounded.

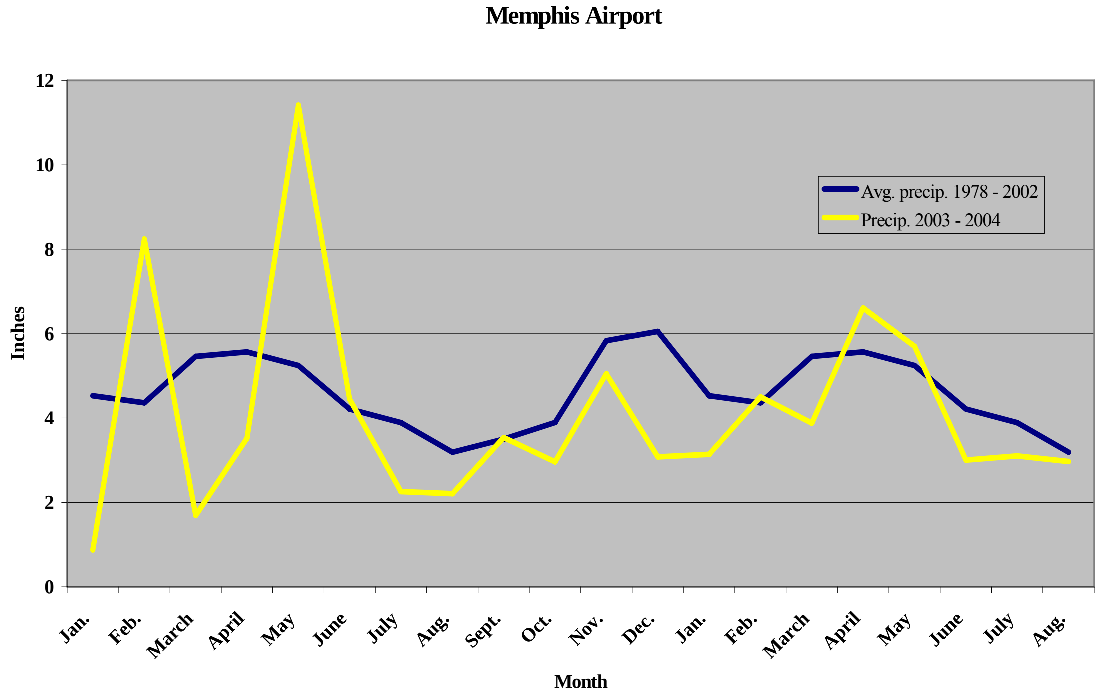

Figure 30: Monthly precipitation at the Memphis Airport 1978 – 2004.

6. GEOMORPHOLOGY BELOW IMPOUNDMENTS

Streams in most areas naturally change from one channel type to another. Alterations in natural flow patterns and channel structure such as those created by impoundments may accelerate this process or cause streams to change in ways not typical for the ecoregion or stream type. In natural stream channels, bankfull flow has been shown to be the dominant discharge for sediment transport and channel maintenance (Magilligan, 2003). A reduction in the frequency can contribute to narrowing of the channel, diminished sediment transport and reduced sinuosity.

The Rosgen stream classification system was used to characterize the geomorphologic effects on streams downstream of dams in the 14 ecoregions surveyed (Rosgen, 1996). This type of stream classification is based on physical processes and assumes that stream morphology is dependent on landscape position. There are four hierarchical levels of the Rosgen classification. The first level describes a stream's geomorphologic characterization. The second level is a morphologic description of the stream's characteristics. The third level assesses the stream condition and its stability. The fourth level is a confirmation of predictions made in Level III. Empirical relationships are developed at this level. Streams in this study were classified to Level II.

Level I classification is the least specific. The Level I classification provides a general characterization of valley types and landforms, and allows for a rapid initial delineation of stream types. The determination of valley type and corresponding fluvial and topographical features provides a foundation on which Level 1 stream classification is based. Aerial photos, topographic maps, and dam site photos were used for determinations at this level. Elevations were measured across the stream channel to determine channel shape. At this level, stream channel slope, shape, sinuosity, and patterns are determined. There are eight Level 1 categories in this classification system. Streams surveyed downstream dams in this project fell into five of these categories: "B", "C", "E", "F", or "G".

Type B: Streams are moderate to high gradient with a slope from 2 to 4%. They have riffle dominated channels that are wider and more sinuous than type A streams. These streams are moderately entrenched and flow through steep valleys. They lack a well-developed floodplain. This type stream is found in most Tennessee ecoregions.

Type C: Streams are low gradient with a slope less than 2%. These are riffle streams that tend to be wider and more sinuous than type B streams. They are slightly entrenched with well-developed floodplains and point bars within the active channel. Type C streams are found in most Tennessee ecoregions.

Type E: Streams are low gradient with a slope less than 2%. They tend to be narrow and highly sinuous. They are slightly entrenched and often develop within the main channel of Type C streams. This type stream is common downstream of dams.

Type F: Streams are low gradient with a slope less than 2%. They tend to be wide and deeply entrenched. These streams create new floodplain by increasing their width within the valley. High bank erosion rates yield a high sediment load. Type F streams are commonly found in West Tennessee.

Type G: Streams have a slope from 2 to 4%. They tend to be narrow and deeply entrenched. Sinuosity is low to moderate. High bank erosion rates result in a heavy sediment load. These streams can be found in a wide variety of landforms. This type stream is common downstream of dams.

Level II classification is more specific to a particular stream reach. The classification of a stream naturally changes along the river channel as elevation changes, geology changes, and as tributaries enter the stream. Stream classification can also change along the river channel due to anthropogenic stream alterations and placement or removal of impoundments. Stream characteristics such as channel cross-section, longitudinal profile, dominant bed material, and pattern features are parameters measured in the field that aid in the determination of stream classification at this level. Geomorphologic information for each test site is provided in Appendix C, Tables 2 and 3.

The calculated dominant bed material (D50) is the median substrate particle size based on measurements of 100 particles randomly selected across the flow transect. Knowing the size of the bed material helps determine the extent of sediment transport in a stream. This is particularly important downstream of impoundments because it aids in determining channel stability and availability of habitat for aquatic life.

The geomorphological characteristics of the test sites in this project were compared to the expected geomorphic conditions of established ecoregion reference streams (Arnwine et al, 2005). Many of the streams below the impoundments in the study had channel structures that were undergoing geomorphic change. Only about half of the streams appeared to have relatively stable channel structures typical of the ecoregion (Figure 31). Almost one fourth of the streams were becoming G-type streams with unstable banks that were sloughing. Cave-ins were common creating gullies and high sediment loads. Nineteen percent of the streams below impoundments were creating E-type channels. This type of stream is a response to lack of flow. A very small channel is cut within the original streambed creating a very narrow cross-section that helps the stream maintain some flow.

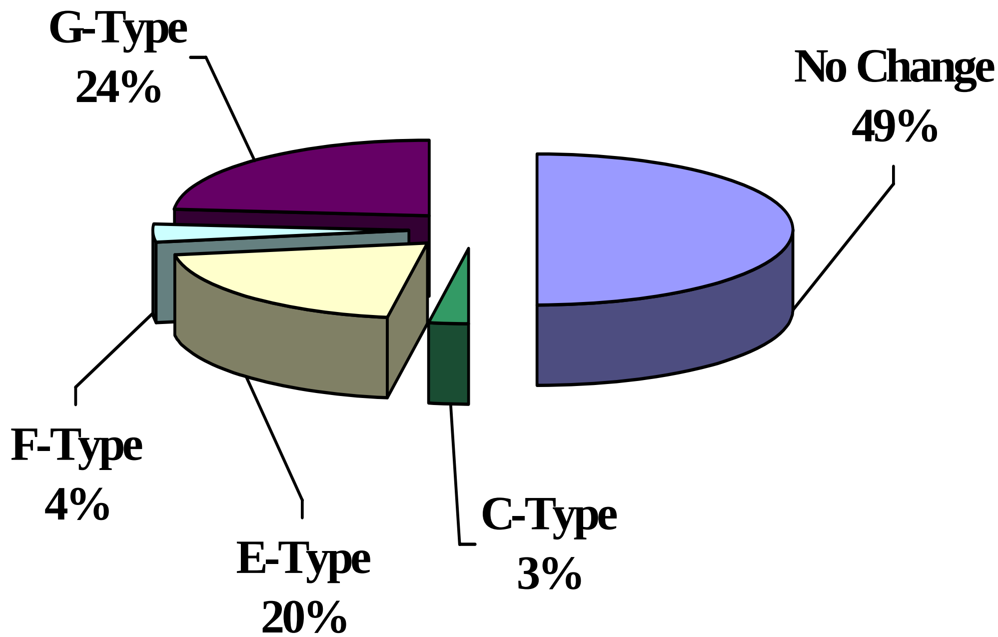

Figure 31: Geomorphic changes in streams below small impoundments. Stream type indicates stream is changing from original channel shape into the specified stream type.

Many streams below dams such as Meridian Creek in Madison County are becoming G-types with narrow, deeply entrenched channels. This stream type has high bank erosion potential and heavy sediment loads.

Photo provided by Aquatic Biology Section, TDH.

In addition to changes in the shape of the channel, many streams below impoundments had a smaller substrate size than typical for the ecoregion (Table 11). Silt was common in streams that should be sandy bottom. Gravel or sand was often dominant in streams that should have cobble or bedrock substrates.

Table 11: Dominant particle size of substrate in reference and impounded streams. Values are presented as percent of streams within dominant particle size.

Ecoregion	Station Type	# of Stations	Percent of Streams by Dominant Particle Size					
			Silt/Clay	Sand	Gravel	Cobble	Boulder	Bedrock
65e	Reference	6	17%	83%				
	Impounded	15	60%	33%	7%			
66d	Reference	5			20%	80%		
	Impounded	1			100%	0%		
66e	Reference	5			20%	40%	40%	
	Impounded	3			100%	0%	0%	
66g	Reference	1			100%			0%
	Impounded	1			0%			100%
67g	Reference	5		0%	40%			60%
	Impounded	2		50%	50%			0%
67h	Reference	2			100%			
	Impounded	1			100%			
67i	Reference	1			100%			
	Impounded	1			100%			
68a	Reference	9	0%	0%	33%	33%	33%	0%
	Impounded	21	5%	28%	33%	19%	5%	10%
68c	Reference	2			0%	100%		
	Impounded	1			100%	0%		
71f	Reference	7	0%		71%	14%		14%
	Impounded	15	7%		60%	0%		33%
71g	Reference	3			33%			66%
	Impounded	6			83%			17%
71h	Reference	3			33%	66%		0%
	Impounded	4			25%	25%		50%
74a	Reference	2		0%	100%			
	Impounded	2		100%	0%			
74b	Reference	2	0%	100%				
	Impounded	2	50%	50%				

6.1 Ecoregion 65e Southeastern Plains and Hills

The Southeastern Plains and Hills is a region of dissected, irregular plains and low, broad hills. The floodplains associated with this ecoregion tend to be fairly broad and have level terraces. Streams are low to moderate gradient with slopes less than 4%. These streams have sandy substrate and moderately stable stream banks. Based on data from five established reference streams, there are two types of cross-sections predominant in this ecoregion. One is a sloped C-type and the other is U-shaped with vertical banks and a flat bottom characteristic of an F-type stream. Both have sandy substrates. The stream banks can be low to high depending on the amount of erosion and riparian vegetation.

There were 11 test sites in this ecoregion that were comparable in size to the established reference streams. Three had the same C-type channel observed in the reference streams but two of these had a finer silt/clay substrate. Piney Creek (PINEY014.6CS) in Chickasaw State Park is located downstream of one of the oldest dams (1935) assessed in this ecoregion and demonstrates the final stages of morphologic change into an F-type stream. The substrate was sand.

Seven sites demonstrated changes in morphology that were not comparable to the reference. Two, Arnold Branch (ARNOL001.4WY) and Thompson Creek (THOMP005.9WY), had characteristics of an E-type stream with narrow, sinuous channels developing within the main C-type channel. Silt /clay was the dominant substrate, which is finer than that found in unimpaired streams in this region. Both sites were dry in the fall while Thompson Creek was also dry in the summer. Due to the lack of flow, these sites have a new channel down-cutting the streambed to form a smaller channel. This smaller channel develops in order to maintain a more consistent flow.

Five of the test sites showed characteristics of a G-type stream with narrow, deeply entrenched channels, low sinuosity and high erosion rates. These streams will likely evolve into the more sinuous F-types as down-cutting continues. Three of the streams had silt and clay as the dominant substrate due to more extensive erosion, including Gray's Creek tributary (GRAY1T0.9HR) in Chickasaw State Park. Despite the extensive riparian zone, vegetation on the stream bank has been lost due to erosion and down-cutting of the stream**.** Hudson Branch (HUDSO000.3HR) and Stewart Creek (STEWA003.4HR) also had silt and clay as the dominant substrate. Both sites had high erosion potential as evidenced by moderate to heavy deposits of fine sediment on bars and the presence of shelves along the banks.

Two of the G-type test sites still had sand as the dominant substrate. The Meridan Creek test site (MERID006.5MN) was located 250 yards downstream of the dam. Native vegetation was lacking on the stream banks due to kudzu on one side and a mowed field on the other which probably helped contribute to the increased erosion and accelerated change in stream structure. The stream has been diked at this location, however, the dike is eroding leaving moderate to heavy deposits of sediment.

An unnamed tributary to Threemile Branch (THREE1T0.3HN) was the other G-type stream with sand substrate. This site is only 30 yards downstream of the dam. Although the stream has relatively good riparian vegetation and is surrounded by woods, the banks are very unstable and are sloughing and caving in. This could be because the stream was channelized in the past but is now creating new meandors. There is moderate deposition of new gravel on the present gravel bars with moderate to heavy deposition of fine sediment within the channel and around the natural substrate.

One first order reference stream was assessed for channel structure and substrate size in this ecoregion during the study period. Although, this was the least impaired first order stream that could be located, it has been altered and may not be a good indicator of natural conditions. Bear Creek (BEAR005.7MN) has sand as the dominant substrate and is a C-type stream that is geomorphically changing to a G-type stream. This stream had been channelized in the past and is now being allowed to meander.

Four first order test sites are in this ecoregion. All of the test sites are C-type streams that are changing in geomorphology. One of these, East Fork Spring Creek, is similar to the first order reference, as it is also becoming a meandering G-type. This stream has the largest drainage area and maintained the most flow of all the first order test sites. However, siltation is a problem and the substrate is predominantly silt and clay instead of sand.

The three other first order test sites differ from the reference in that they are becoming E-type streams. Old Town Creek tributary (OTOWN1T0.9HR) has silt and clay as the dominant substrate. This stream has very unstable banks with many "raw" areas where sloughing has occurred. The banks have just a few trees and the rest is mowed to the stream. It was dry in the fall and summer. Because of the instability of the banks, this stream could become a G-type stream if the flow were to increase. Due to the lack of flow, the stream has created a new channel within the larger channel.

Thompson Creek tributary (THOMP1T0.4HR) is also a C-type stream that is becoming an E-type stream with a silt/clay substrate. This stream was dry in the fall although flow was adequate in other seasons. The stream channel is entrenched and the banks are moderately unstable and sloughing, leaving "raw" areas of erosion. The larger channel has caved in banks where the water level has been outside the banks of the smaller, highly incised channel.

Charlie Creek (CHARL003.4BN) is also developing into an E-type stream but was the only first order test site to have sand as the dominant substrate. The banks are moderately unstable with areas of sloughing and undercutting, especially at bends. The right bank is wooded but the left bank has a sparse tree line separating it from an open field. The stream had flow during the entire sampling period but was inadequate for macroinvertebarate colonization in the fall. The sand bars left from the old channel are now vegetated but new sediment is deposited within the smaller channel that is cut into the old channel.

6.2 Ecoregion 66d Southern Igneous Ridges and Mountains

The Southern Igneous Ridges and Mountains are low to high mountains with rounded domes, long straight ridges, and steep slopes. The ridges and mountains originated as igneous rock that has undergone metamorphic changes to form crystalline rock. Roan Mountain has the highest elevation in this ecoregion in Tennessee at 6286 feet. Typical streams have a gradient between 2 and 10%, are steep, entrenched, and confined, often forming cascading channels.

There are five established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material for all of the reference streams but one is cobble. The dominant bed material for Black Branch is gravel. There are two types of channel types at the reference streams. One is a relatively narrow V-shaped cross-section characteristic of A-type streams and the other is a broad U-shape found in B-type streams. Typical stream banks are moderately high due to entrenchment of the stream channel and steep side slopes.

One impounded test site is in this ecoregion. Roaring Creek (ROARI002.4CT) has gravel as the dominant substrate. The stream has a B-type morphologically changing into a C-type. Although this stream cascades, the presence of an island, gravel bar, and sand bars indicates that deposition and aggradation are changing the shape of the channel. These processes cause the stream to lose its gradient and become more characteristic of a C-type stream.

6.3 Ecoregion 66e Southern Sedimentary Ridges

Low mountains with rounded domes or long straight ridges and steep, long side slopes are typical of the Southern Sedimentary Ridges. Some of the foothills of the Blue Ridge Mountains are included in this ecoregion. Elevation is between 1000 and 4500 feet with local relief between 2000 and 3000 feet. The streams in this ecoregion are moderate to high gradient with slopes between 4% and 10%. They are clear, with cobble and gravel substrate and stable banks.

There are five established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material for two of them is cobble, two have boulder substrate and the fifth is gravel. All of the reference streams are B-type with a broad U-shaped cross-section.

There were three impounded test sites comparable in size to established reference streams in this ecoregion. Two of the sites maintain B-type characteristics similar to the references although both had the smaller gravel substrate dominant. They had moderately stable banks with infrequent areas of erosion.

McCamy Branch (MCCAM000.7PO) in the Chilhowee Recreation Area shows characteristics of an F-type stream. The stream had once been channelized immediately below the dam although it was long ago, possibly when the dam was built in 1938. The loss of natural meanders has created nearly vertical banks that are prone to sloughing. This type of stream cross-section is very atypical of streams in this region and is likely caused by the presence of the impoundment and channelization below the impoundment.

McCamey Branch in the Southern Sedimentary Ridges is typical of F-type streams with a high width to depth ratio and steep vertical banks. This is atypical of streams in this region and is a result of channelization and an upstream impoundment. *Photo provided by David Stucki, Aquatic Biology, TDH.*

6.4 Ecoregion 66g Southern Metasedimentary Mountains

The physiography of the Metasedimentary Mountains is high dissected mountains and steep slopes. Elevation is 1000 to 6600 feet with local relief from 2000 to 4000 feet. Clingmans Dome has the highest elevation in this ecoregion in Tennessee at 6643 feet. The geology consists of metamorphic and sedimentary rocks.

There was one first order test site in this ecoregion, an unnamed tributary to Hot Water Branch (HWATE1T0.1MO). This creek has bedrock as the dominant substrate. It is a B-type stream that is not geomorphologically changing. Since this was a first order stream and not comparable in size to established ecoregion references, a first order reference stream was also monitored during the study. Indian Branch (INDIA000.1MO) is also a B-type stream although gravel was the dominant substrate.

6.5 Ecoregion 67g Southern Shale Valleys

The Southern Shale Valleys are characterized by lowlands and rolling valleys with some slopes and hilly areas. Fine grain rock, particularly shale, is dominant. The elevation is between 800 and1500 feet with local relief between 100 and 400 feet. Typical streams tend to be moderate to low gradient with slopes less than 4%. Streams tend to have moderately stable banks.

There are four established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material is bedrock for each stream except Bent Creek, which is primarily cobble. There are two types of stream cross-sections commonly found in streams in this ecoregion. One is the sloped C-type and the other is the broad U-shaped cross-section characteristic of a B-type stream.

There was one test site in this ecoregion similar in size to the reference streams. Carson Branch (CARSO001.0MO) had a smaller substrate size with gravel dominant. The stream is a C-type morphologically changing to have characteristics of an E-type stream. The channel is very narrow and shallow with gravel bars present. A new smaller channel is being formed by down-cutting through the old channel.

One first order impounded test site on Sinking Creek (SINKI1T0.8CO) was randomly selected in this ecoregion. This was the only stream where a reach upstream of the reservoir met size and ecoregion requirements for comparison to the downstream site. The upstream station was a C-type stream with bedrock substrate (Figure 32). Even though the dam is relatively recent (1987) the downstream creek channel is geomorphologically changing to the more entrenched E-Type (Figure 33). The fact that the riparian zone has been cleared below the dam contributes to the problem.

The downstream segment of the creek has sand as the dominant substrate, which is probably covering the natural bedrock substrate found upstream. Flow, compared to the upstream site was the same in the fall and 40% higher in the spring. However, it was 17% lower in the winter and 33% lower in summer. If the stream was not impounded, flow would be expected to be the same at both sites since they are only 0.2 miles apart and there are no other tributaries entering between the two sites.

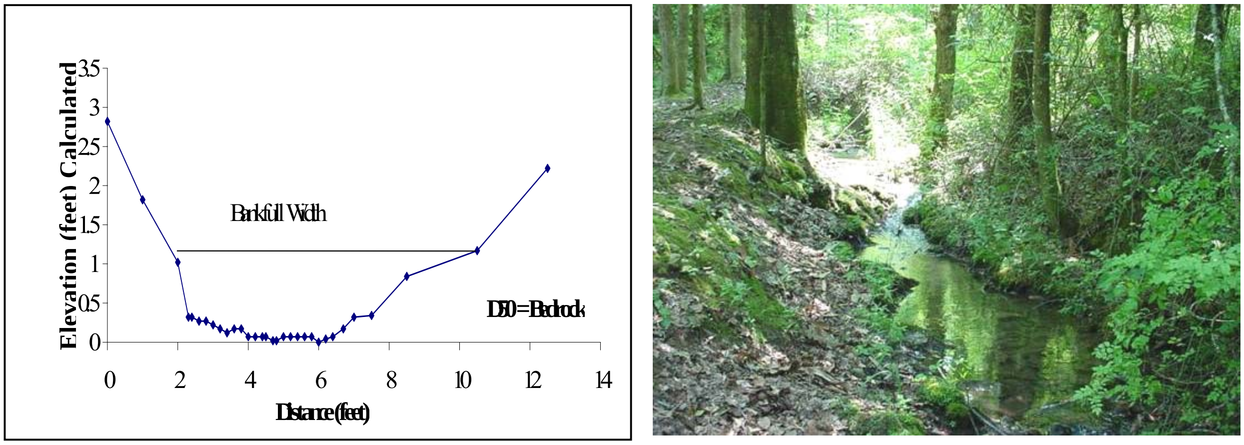

Figure 32: Cross-section and view of unnamed tributary to Sinking Creek upstream of reservoir. Profile is a typical sloping C-type. The channel width is approximately eight feet and the dominant substrate is bedrock. *Photo provided by Aquatic Biology Section, TDH.*

Figure 33: Cross-section and view of unnamed tributary to Sinking Creek 20 yards downstream of impoundment. Downcutting has resulted in an entrenched E-type channel. The channel width is approximately six feet and the dominant substrate is sand. *Photo provided by Aquatic Biology Section, TDH.*

6.6 Ecoregion 67h Southern Sandstone Ridges

Steep sandstone ridges among narrow intervening valleys are typical of the Southern Sandstone Ridges. The ridges to the west have more sandstone and the ridges in the central and eastern parts of the subregion have more shale. The elevation is between 900 and 3000 feet with local relief between 800 and 1200 feet. Typical streams are moderate gradient with slopes less than 4%.

There are two established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material is cobble or gravel. Streams may be either sloped C-type or U-shaped B-type.

There was only one impounded test site in this region. Laurel Creek (LAURE003.4MO) has gravel as the dominant substrate. The stream is a C-type stream developing into an E-type. The stream channel is very narrow and shallow with frequent gravel bars. This stream had very low flow conditions throughout the sampling period. Due to the lack of flow, a new channel is down-cutting the old channel to form a smaller channel. This smaller channel develops in order to maintain a more consistent flow. One of the ecoregion reference sites is 2.6 miles downstream of the test site. There are four first order tributaries between the two sites that contribute to flow. At this location, the channel has appeared to stabilize and is maintaining its C-type form. However, substrate size is smaller than the other reference stream.

6.7 Ecoregion 67i Southern Dissected Ridges and Knobs

The physiography of the Southern Dissected Ridges and Knobs is characterized by ridges, hills, and knobs. Ridges in the central to western part of this ecoregion are formed from sandstone beds that are resistant to weathering. The ridges in the east are mostly shale with some limestone. The elevation is between 800 and 2000 feet with local relief between 300 and 600 feet. Typical streams are moderate gradient with slopes less than 4%.

Mill Branch (ECO67I12) is the only established reference stream with geomorphologic data in this ecoregion. The estimated dominant bed material for this stream is gravel. The cross-section is sloped to one side and classified as a C-type stream. The impounded test site in this ecoregion, Steele Creek (STEEL000.3SU) was comparable geomophically to the reference stream.

6.8 Ecoregion 68a Cumberland Plateau

Undulating and rolling tablelands with some open low mountains, ravines, and gorges are characteristic of the Cumberland Plateau. Elevation is between 1200 and 2000 feet with local relief between 300 and 800 feet. Typical streams have a moderate gradient with slopes less than 4%. There are eight established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material for five of them is cobble while the other two are boulder. All of the reference streams have the broad U-shaped cross-section characteristic of a B-type stream.

Four impounded streams were comparable in size to the reference streams. Only one of them, Obed River (OBED40.2CU), had stable B-type geomorphology with cobble substrate. Buck Creek (BUCK001.2CU) is also classified as a B-type stream, however sand is the dominant substrate. The banks are moderately unstable with high erosion potential during floods. The dam was built in 1994 making it the newest of all test sites in this ecoregion. The sampling station is also located farthest downstream (350 yards) from the dam outfall of any site on the Cumberland Plateau. This stream may not yet show geomorphological changes to the streambed because of its age and location. Although the stream does not currently show a change in the expected shape of the cross-section, the dominant substrate size is smaller than the reference indicating a greater potential for erosion and sedimentation.

Falls Creek (FALLS000.5VA) is a B-type stream that is evolving into a C-type. The site is within Fall Creek Falls State Park. The stream banks are moderately stable with good riparian vegetation that has not been disturbed by human activities. There is slight deposition of new sediment in this stream, with the greatest amount of deposition occurring during lower flow. It appears that the streambed gradient has decreased due to gravel and sediment deposits in the channel.

Savage Creek (SAVAG009.8SE) is a C-type stream that shows characteristics of a G-type. Savage Creek has very unstable banks that are undercut and sloughing. There are gravel bars present from the movement of sediment from the banks into the channel, although there are not very many fine sediment deposits. The right bank is a mowed open area from the dam to the discharge. During heavy rainfall, the water flows quickly, down-cutting the streambed and causing the stream banks to gully.

There are many first order, impounded streams in the Cumberland Plateau ecoregion. Seventeen were randomly selected for this study. A first order reference stream was also monitored for comparison. The reference stream, Douglas Branch (FECO68A01) ias a C-type stream with cobble substrate.

Eleven of the first order reference streams had the B-type channel shape more typical of the larger streams than the first order reference. The majority of these had stable channels. Four of the streams had changing channel structure. Two, Charlie Branch (CHARL000.7OV) and Pond Branch (POND1T0.1CU) are becoming deeply entrenched G-type streams. These streams had sand or gravel instead of the typical larger particles as the dominant substrate indicating increased sediment transport. The stream banks were unstable with many eroded areas and sloughing. Pond Creek was dry in both the summer and fall while Charlie Branch had insufficient fall flow.

A third B-type stream, an unnamed tributary to Trail Branch (TRAIL1T0.4CU) may also be in the process of becoming a G-type. This site had moderately unstable banks with high erosion potential during floods. The stream is surrounded by a subdivision and there are obvious patches where the riparian vegetation has been disrupted or removed around the banks. Sand is the dominant substrate with moderate to heavy deposits of fine sediment at bends and pools in the stream. This stream was dry in the fall and had inadequate flow in the spring and summer. This impoundment was constructed in 1977 making it one of the youngest of the first order test sites in this ecoregion. There is evidence of shelves along the banks indicating that the stream may have G-type characteristics. Due to the age of the impoundment and its location within a narrow valley, it has not yet developed into a G-type stream although the potential is there.

Scantling Branch (SCANT001.3CU) has also undergone geomophologic changes since it was impounded in 1965 although it still maintains predominantly B-type characteristics. The substrate is primarily silt and clay. This stream had adequate flow only in the spring and had no flow during the fall and summer sampling periods. Banks were unstable with high erosion potential. More than likely, this reach of the stream will eventually become a C-type stream with sand bars due to the unstable silt and clay banks.

Four of the test sites are C-type streams similar to the first order reference. One stream, Little Fiery Gizzard Creek (LFGIZ003.4GY) downstream of Big Grundy Lake had a stable channel structure. The unnamed tributary to Falls Branch (FALLS1T0.5MI) is evolving into a G-type stream. Although the area is wooded with good riparian vegetation, the banks were moderately unstable. They were sloughing, undercut, and caving in, mostly at the bends in the creek. Gravel is the dominant substrate, which is smaller than that found in the reference stream.

Two are developing into the more narrowly entrenched E-type streams. At Looper Branch (LOOPE001.0OV) downstream of Pine Ridge Lake the stream banks were moderately stable with small areas of erosion although it appears that there is substantial movement of gravel and sediment during heavy flow from the impoundment. Gravel was the dominant particle size throughout the streambed. This site was dry in the fall but had adequate flow in other seasons. The stream is down-cutting the old channel to form a smaller channel. This smaller channel generally develops in an attempt to maintain a more constant flow.

The other site is Laurel Creek (LAURE005.7RH) downsteam of Sinclair Lake. Laurel Creek also had gravel as the dominant substrate. The banks were moderately stable with some small areas of erosion but there is high erosion potential during floods. There were moderate deposition of sediment on old and new gravel bars and islands. During most of the sampling period, the spillway was clogged and inhibited flow. The spillway was cleared in the spring to allow flow. Prior to the spillway being cleared, the flow was measured to be 0.07 cfs in the fall and 0.78 cfs in the winter. The flow was 9.5 cfs after the spillway was cleared. This stream still maintains many C-type characteristics, If the spillway is kept clear and discharge is maintained it may return to the natural channel form.

Two sites, a first order tributary to Bagwell Branch (BAGWE1T0.2CU) and Barnes Branch (BARNE002.4FR) were probably C-type streams at one time, but now have the characteristic of E-type channels and are no longer geomorphologically changing. The substrate at Bagwell Branch is sand, much smaller than the dominant particle size of the reference stream. There are heavy sediment deposits in the streambed creating a shifty sandy bottom atypical of the ecoregion. Winter was the only season this site had adequate flow and there was no flow in summer or fall. It appears this stream consistently has had low flow since the time the dam was closed in 1967, therefore creating a narrow channel within the original streambed.

Barnes Branch (BARNE002.4FR) has a gravel substrate that is also smaller than the reference stream. The banks are wooded but there is some disruption of the riparian vegetation where sloughing occurs. Unlike Bagwell Branch, Barnes Creek had some flow all year although it was too low in winter and summer. This is another old dam, built in 1955, and the channel has had time to create a smaller stream channel in response to altered flow regimes. However, it appears there is usually not enough flow to cover the substrate of even this smaller channel.

6.9 Ecoregion 68c Plateau Escarpment

Long, steep mountainsides, ravines, gorges, cliffs and many waterfalls characterize the Plateau Escarpment. The elevation is between 800 and 2400 feet with local relief between 900 and 1500 feet. Typical streams are moderate to high gradient having slopes between 2% and 10%.

There is one established reference stream with geomorphological data in this ecoregion. The estimated dominant bed material is cobble. The channel is a broad U-shaped cross-section that is characteristic of a B-type stream. There was only one impounded test site. The sample site on Looney Creek (LOONE002.5MI) is located at the base of the escarpment and has the C-type channel more typical of the more moderate gradient. The stream is first order and somewhat smaller than the second order reference. The dominant substrate is gravel. The channel is a C-type morphologically changing to have characteristics of an E- type stream. Although low, the stream had adequate flow for the ecoregion each time it was sampled. However, there is evidence the flow is not always adequate as the stream is down-cutting the old channel to form a narrower streambed.

6.10 Ecoregion 71f Western Highland Rim

The Western Highland Rim is a region of highly dissected rolling to steep, open hills with narrow winding ridges to moderately broad ridges. There are some level bottomlands along major streams. The elevation is from 400 to 1000 feet with local relief between 300 and 500 feet. Typical streams have a moderate gradient between 2% and 4%.

There are six established reference streams with geomorphological data in this ecoregion. All are B-type streams with bedrock, cobble and gravel substrate. There are eight impounded test sites in this size class. Five of the sites are B-type streams typical of the ecoregion. The other three are C-type streams with a somewhat lower gradient. These sites are located on Bear Creek (BEAR003.6WE), Goodin Branch (GOODI001.1DE), and Squaw Branch (SQUAW001.4LW). Only Bear Creek maintains characteristics of a C-type stream. Goodin Branch shows characteristics of an E-type stream. This stream was dry in the fall and had inadequate flow the following summer. Due to the lack of flow, the stream is cutting into the older, wider channel creating a small narrow channel.

Squaw Branch shows morphological characteristics of a G-type stream with shelves occurring within the channel. Water levels were high in this stream with at least 75% of the streambed filled in all seasons. The dam has a crank handle discharge at the top of the dam as well as subsurface seepage that forms a shallow five foot wide tributary entering upstream of the sample site on Squaw Branch. The shelving may be the result of episodic high flow when the crank valve is open and the tributary is flooded causing the stream to gully and shelf. The high water mark in the creek was approximately two feet above normal flow.

One first order reference stream was assessed for channel structure and substrate size, an unnamed tributary to Little Swan Creek (LSWAN1T0.1LS). This stream has bedrock as the dominant substrate and is a B-type stream. The banks are wooded with good riparian vegetative cover. The stream is embedded and the bedrock substrate armors the banks so the stream channel resists geomorphological change.

Seven first order impounded test sites were surveyed in this ecoregion. All of the test sites have characteristics of B or C-type streams. There is only one site that is geomorphologically changing and another site that appears to be at the beginning of geomorphologic change. Ford Creek tributary (FORD1T1.4BN) is a B-type stream that is evolving into a G-type. Silt and clay are the dominant substrate. This stream has unstable banks with many raw eroded areas where disruption of the natural vegetation has occurred. The stream is relatively straight and may have been channelized when the dam was constructed in 1960. The straight channel contributes to sloughing causing the banks to become vertical increasing silt and clay deposits. During the sampling period, there was only slight to moderate deposition of new fine sediments. Most of the sediment deposited in the channel has turned to hardpan clay.

The unnamed tributary to Jones Creek (JONES1T0.2DI) has gravel as the dominant substrate. It is a C-type stream that currently maintains this channel form. This a relatively new golf course impoundment constructed in 1997. Given time, the tributary will probably become a G-type stream because it is channelized. It also has unstable banks that are prone to sloughing and high erosion potential during high flow. There is obvious disruption of riparian vegetation by human activities due to the mowed golf course through which this stream runs. These factors contribute to the instability of the banks. There is moderate deposition of new gravel and sediment on old and new bars within the channel.

6.11 Ecoregion 71g Eastern Highland Rim

Weakly dissected plateau or tablelands, moderately dissected open hills and knobs to the north with some sinkholes and depressions characterize the Eastern Highland Rim. The elevation is between 800 and 1300 feet with local relief between 100 and 500 feet. Typical streams are low to moderate gradient with slopes less than 4%.

There are two established reference streams with geomorphological data in this ecoregion. The estimated dominant bed material is bedrock for Flat Creek and cobble for Hurricane Creek. The two streams have different channel shapes, one is the sloped C-type and the other is a broad U-shaped B-type stream.

Five impounded test sites are in this ecoregion. Two are B-type streams. Davis Branch (DAVIS000.8SR) maintains a B-type channel structure while West Fork Drakes Creek tributary #2 (WFDRA2T1.5SR) is evolving into a G-type stream with very unstable banks that are sloughing to form shelves. This reservoir was created in 1940 making it the oldest impounded stream sampled in the ecoregion.

Three of the impounded test sites are C-type streams. Only one, Little Trace Creek (LTRACE005.0CY), maintains the C-type characteristics. This site may not be showing any geomorphological effects of the dam because it is sampled furthest (~300yds) from the dam outfall of any site in this ecoregion.

Falling Water River (FWATE031.6PU) and Washburn Branch (WASHB003.0LI) show evidence of becoming G-type channels. Falling Water River had the highest flow of any stream in this ecoregion. The banks are unstable and have high erosion potential during flash floods. Over time, the stream's high flow has allowed erosion of the banks causing the stream to gully.

Washburn Branch had low flow every season except winter but there is evidence the stream periodically experiences flooding due to the presence of shelves and bank sloughing. The stream was channelized in the past, possibly when the dam was built, creating a narrow straight channel that does not allow the water to overflow the banks. The banks are being cut through and down into the streambed during high flow creating a gully.

One first order reference stream was assessed for channel structure and substrate size during the study. Flat Creek (FLAT008.0OV) has bedrock as the dominant substrate and is a C-type stream. One first order impounded test site was sampled. The unnamed tributary to Hancock Branch (HANCO1T0.2LI) has gravel as the dominant substrate. It is a C-type stream that is geomorphologically changing to an E-type. The tributary was dry in the fall and summer. A small very sinuous channel has developed in an effort to maintain a more consistant flow.

6.12 Ecoregion 71h Outer Nashville Basin

The Outer Nashville Basin is a region of highly dissected escarpments and gently rolling to steep open hills. The elevation is 500 to 1200 feet with local relief between 300 and 500 feet. Streams are moderately sinuous with a low gradient below 2%. The estimated dominant bed material at the three established reference streams was either cobble or gravel. The typical cross-section for streams is the C-type, which is sloped to one side.

Four impounded test sites were monitored in this ecoregion. Three were stable B or C-type streams. The fourth, Beasley Hollow (BEASL000.4MY), is changing from a C-type to an incised E-type stream. A lack of adequate flow is resulting in a smaller incised channel within the older streambed (Figure 34). The new channel is approximately five feet wide while the original channel was approximately 25 feet. Shellcracker Reservoir is large, 164 acres, for the 603 acre drainage area on this 2nd order stream, which is well within the 10:1 ratio generally needed to maintain good stream flow (Dean, 1976). Even within the smaller incised channel, the stream had inadequate flow compared to regional expectations in fall and winter.

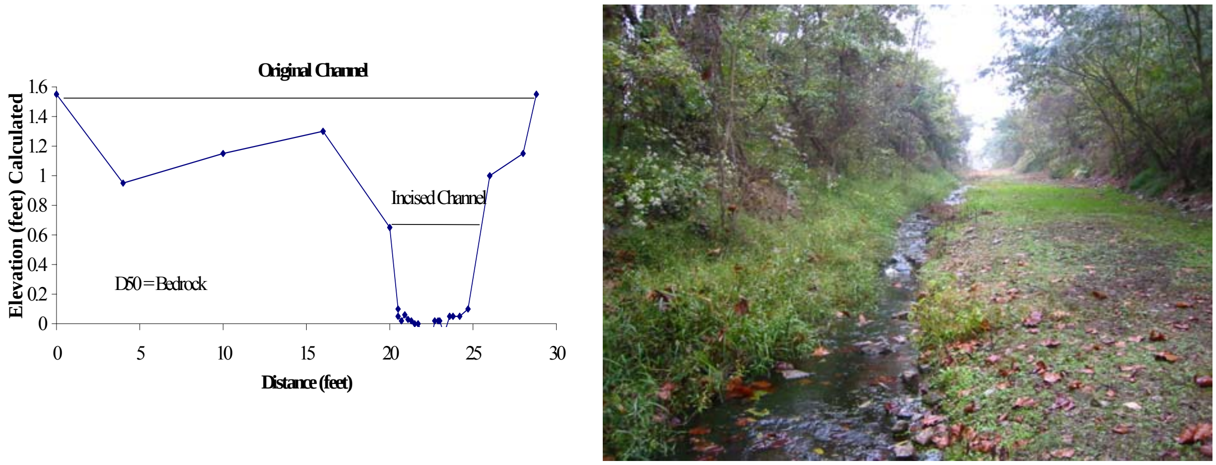

Figure 34: Cross-section and view of Beasley Hollow Creek downstream of Shellcracker Reservoir. *Photo provided by Aquatic Biology Section, TDH.*

6.13 Ecoregion 74a Bluff Hills

The Bluff Hills consist of irregular plains with dissected hills and ridges formed by wind blown deposits of fine-grained calcerous silt and clay. There are steeper hillsides and narrow hollows to the west, and smoother topography to the east. The valley bottoms tend to be narrower than those in surrounding ecoregions. Streams are moderate to low gradient with slopes less than 4%. Two established reference streams are both C-type with sloping channels and gravel substrate.

Two impounded test sites were monitored in this ecoregion. Taylor Creek (TAYLO000.7OB) and Tull Creek (TULL000.3OB) are C-type streams that are becoming entrenched G-types. The dominant substrate size is sand, which is finer than that found in reference streams. They have moderately unstable banks with high erosion potential and obvious sloughing.

6.14 Ecoregion 74b Loess Plains

The Loess Plains are characterized by irregular, level to gently rolling plains. The floodplains associated with this ecoregion tend to be wide and flat. Elevation is from 250 to 500 feet with local relief between 50 and 100 feet. Typical alluvial streams in this ecoregion have a gradient below 2%, low sinuosity, and are entrenched. They have moderately unstable stream banks. Two established wadeable reference streams are located in this ecoregion. The estimated dominant bed material for both streams is sand. They are F-type streams with the typical U-shaped channels, fairly flat bottoms and high, nearly vertical stream banks.

Two impounded test sites were monitored in the Loess Plains. The site on Moody Creek (MOODY002.0HR) is a C-type stream with silt and clay as the dominant substrate. It does not appear to be geomorphologically changing. This site was located furthest downstream from the impoundment of any site sampled in the study (1100 yards) and may not be as representative of the impoundment.

The site on Scotts Creek (SCOTT003.5SH) has sand as the dominant substrate and is an F-type stream that is becoming a G-type. The banks are very unstable, one bank is nearly vertical with sloughing and the other bank has shelves present. Lakeland Lake is a relatively large reservoir (237 acres) on a fairly small third order stream draining 1109 acres. The drainage area to reservoir ratio is only 5:1. Flow was inadequate every season except spring. There was no discharge from the dam in the fall. There is some evidence that the creek may have periodic floods, probably in the spring, despite the presence of the dam. The erratic flow regime is probably accelerating the evolution of this stream.

7. HABITAT BELOW IMPOUNDMENTS

Habitat assessments were conducted seasonally at each study site using EPA's Rapid Bioassessment technique (Barbour et al, 1999). Scores for each station are provided in Appendix C, Table 4. Assessments were conducted by two experienced stream biologists with scores arbitrated in the field. Seasonal scores for each parameter were averaged and compared to regional expectations (Figure 35). The expected scores were based on 75% of the median reference score over a ten-year period (TDEC, 2003). Over seventy percent of the streams failed habitat at least one season (Figure 36).

As described in section 3, lack of adequate flow was one of the biggest problems below dams. Changes in the natural flow regime can cause many habitat problems such as erosion and scouring. Banks that are normally covered with water become unstable when they are exposed to dessication, wind, or freeze and thaw cycles. When water returns in the form of surface runoff or increased flow, these banks have a higher likelihood of eroding. As sediment is eroded from the unstable banks or scoured from the streambed, it is carried farther downstream, and deposited in new areas covering benthic habitat.

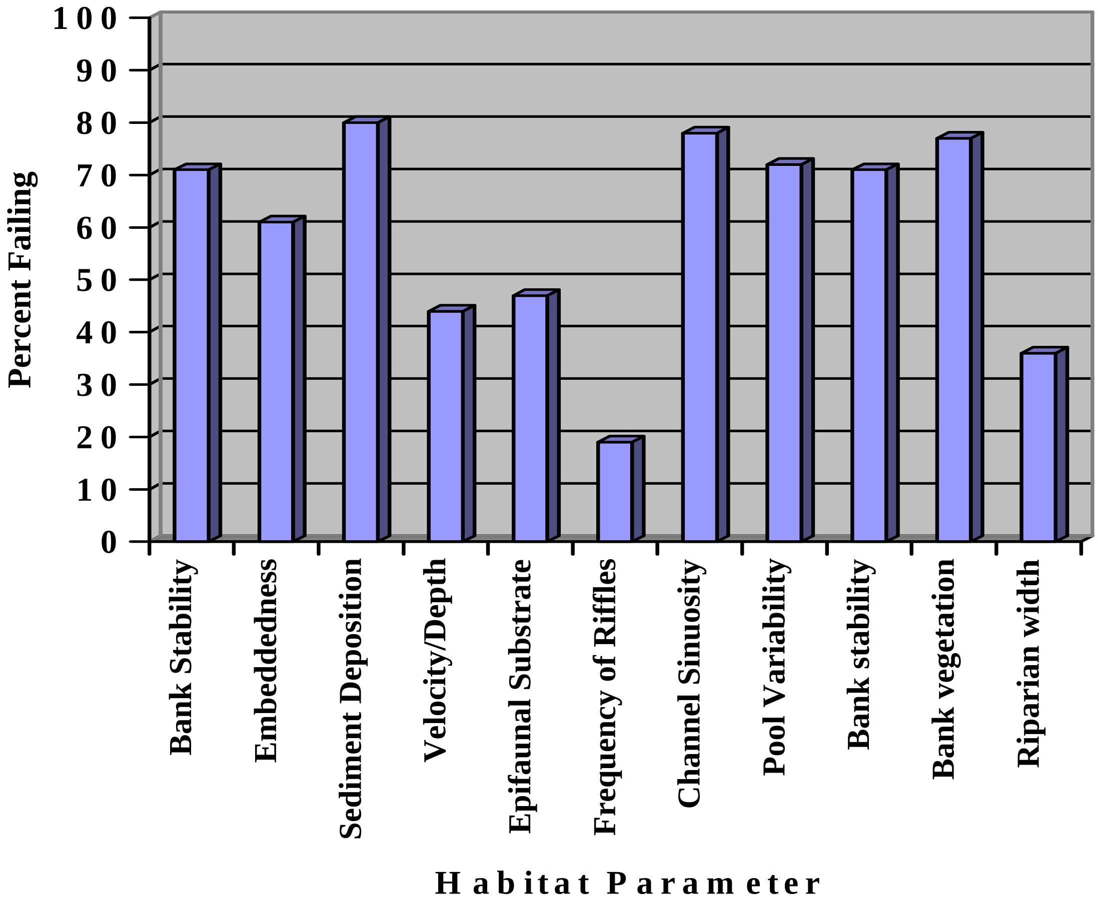

Figure 35: Percent of study reaches below 75 randomly selected small impoundments failing to meet regional expectations for 11 habitat parameters. Score for test site based on average of 4 seasons. Failing scores are based on comparison to regional expectations.

Three parameters in the field habitat assessment addressed factors related to bank stability and sedimentation. The bank stability parameter measures whether the stream banks are eroded or have the potential for erosion by estimating the amount of crumbling, unvegetated banks, exposed tree roots and exposed soil. Eroded banks indicate a problem of sediment movement and deposition and suggest a scarcity of cover and vegetative food sources. Seventy one percent of the sites below impoundments had eroded banks that failed to meet regional expectations.

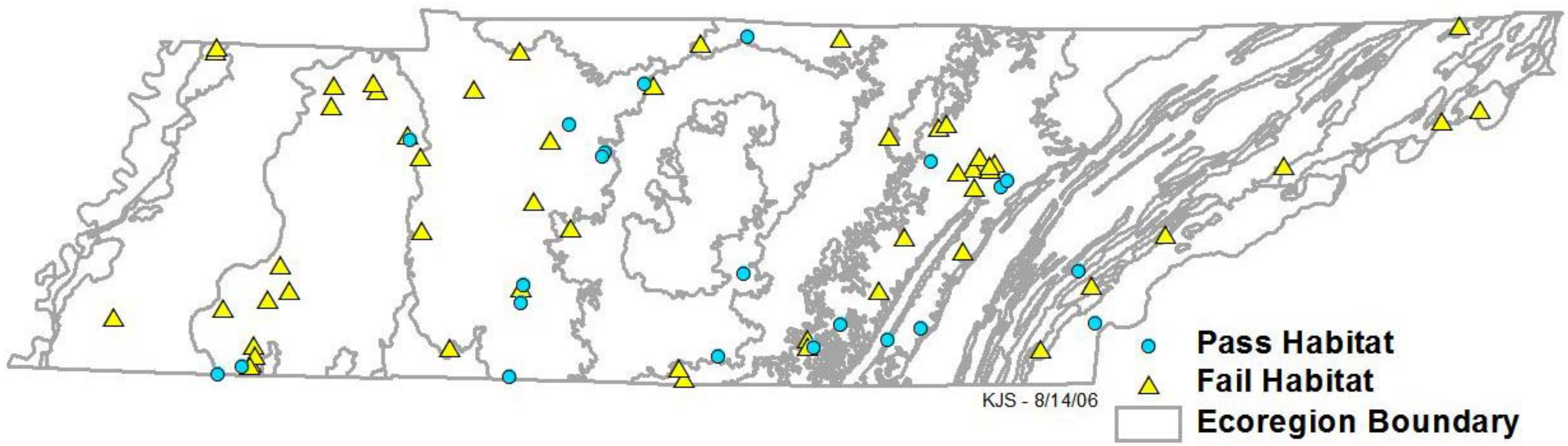

Figure 36: Location of impounded test sites showing comparison to regional habitat guidelines.

Embeddedness measures the extent to which the boulders, cobble and gravel on the streambed are surrounded by fine sediments such as silt, sand or mud. Fine sediments block the interstices between the rocks rendering them unsuitable for macroinvertebrate colonization. It is a result of large-scale sediment movement and deposition. Embeddedness was a substantial habitat problem downstream of small impoundments with 61 percent of the sites failing to meet regional guidelines. Dams block the natural movement of larger rocks that are colonized by benthic organisms while smaller particles can pass through during high flow periods.

Sediment deposition measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that is unsuitable for many aquatic organisms. Pools may disappear due to substantial sediment deposition. After lack of flow, this was the most significant habitat problem in impounded streams with 80 percent failing to meet regional expectations.

The amount and distribution of riffle, vegetated, deepwater, and other habitat types also changes downstream of impoundments as a result of water receding from the stream bank. Five habitat parameters were assessed to determine the changes in habitat type at the impounded test sites. These included the velocity /depth regime, availability of epifaunal substrate, frequency of riffles, channel sinuosity and pool variability.

Patterns of velocity and depth are important features of habitat diversity. Some aquatic animals prefer fast shallow riffles while others prefer quiet deep pools. The occurrence of a variety of velocity and depth combinations relates to the stream's ability to provide and maintain a stable aquatic environment for a variety of benthic organisms. In the most desirable situations, four velocity/depth regimes are present. These include slow-deep, slow-shallow, fast-deep and fast shallow. Poor quality streams are dominated by one velocity-depth, generally slow-deep. Impoundments have the tendency to reduce the variety of flow regimes due to reducing flow. Forty-four percent of the streams had fewer velocity/depth regimes than expected for the typical stream in the ecoregion.

Epifaunal substrate evaluates the quantity and variety of natural structures such as cobble, large rocks, snags, submerged logs and undercut banks. A diverse assortment of submerged structures provides the biota with multiple niches. As variety of cover decreases, so does biotic diversity and the potential for recovery following disturbances. When stream flow is reduced, many habitats are no longer submerged. Approximately half (47%) of the impounded streams did not provide adequate epifaunal substrate compared to regional expectations.

In moderate to high gradient streams, riffles provide high-quality habitat and diverse fauna. In headwaters, riffles are usually continuous and the presence of cascades or boulders provides a form of sinuosity and enhances the structure of the stream. Impoundments appeared to have little influence on downstream riffle frequency in moderate to high gradient streams. Only 19% of the moderate to high gradient test sites failed to meet regional expectations.

In low gradient streams, channel sinuosity is measured in place of riffle frequency. A high degree of sinuosity provides diverse habitat for macroinvertebrates and the stream is better able to handle surges in flow. Bends protect the stream from excessive erosion. Impoundments had a greater affect on the channel sinuosity of low gradient streams than the frequency of riffles in other streams. Seventy-eight percent of the low gradient impounded streams did not meet regional expectations for channel sinuosity. In some cases, the downstream area was channelized when the dam was erected.

Pool variability is another measure of habitat availability in low gradient streams. This parameter rates the overall mixture of pool types according to size and depth. A stream with many pool types will support a wide variety of aquatic species. Streams with monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse fauna. Most (67%) of the streams below impoundments in low gradient areas failed to meet regional expectations for this parameter. Partially due to a loss of sinuosity, streams often were reduced to a continuous run lacking pool areas.

Extreme low flows and rapidly fluctuating flow conditions can cause changes in riparian and aquatic vegetation. Many riparian species are adapted to the naturally occurring cycles of wet and dry periods and cannot reproduce successfully if conditions are not right for germination or seed dispersal. Replacement vegetation may not serve the same ecological functions. Although scores give an indication of the quality of stream vegetation, some low scores are due to riparian disturbances not associated with the impoundment.

The bank vegetative protection parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of in-stream scouring, the supply of food to shredders and the amount of stream shading which controls temperature and algal growth. Streams that have various types of native vegetation including trees, understory shrubs and non-woody macrophytes that provide full natural plant growth will score highest. This parameter also defines the native vegetation for the region and stream type. Vegetative protection failed to meet regional expectations at 77% of the test sites downstream of impoundments. Often this was due to a reduction in vegetative height by mowing to the creek bank below the dams or uses associated with the impoundment including recreation and agriculture.

However, even in wooded areas bank vegetation loss can be due to erosion. Even though an impounded stream in Chickasaw State Park was surrounded by forest, vegetation on the stream bank has been lost due to erosion and down-cutting of the stream. This is supported by the geomorphological measurements at this site (Section 5).

Bank side vegetation on the impounded unnamed tributary to Grays Creek in Chickasaw State Park is compromised by erosion. *Photo provided by Aquatic Biology Section, TDH.*

Although the quality of near-bank vegetation was often less than desirable there was generally little disturbance away from the banks. The riparian vegetative zone width measures the width of vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff and controls sediment runoff from surrounding land use. The most protective riparian zones are wider than 18 meters. Only 36% of the test sites had riparian zone widths less than expected for the ecoregion. Therefore, pollutants and sedimentation were generally not contributed by sources away from the immediate stream vicinity. At sites where riparian disturbance was documented it was generally due to the presence of fields and not bare soil or impermeable surfaces.

8. WATER QUALITY BELOW IMPOUNDMENTS

Impoundments have the potential to affect various aspects of water quality in the downstream reaches. To determine the changes in water quality, concentrations of key parameters at the test sites were compared to the 90th percentile of reference data (Appendix D-1) or to water quality criteria (TDEC, 2004). Values are provided in Appendix D, Table 2.

8.1 Dissolved Oxygen

Dissolved oxygen in lakes and streams is critical to support fish and aquatic life. Low levels of dissolved oxygen may be caused by decay of organic material, photosynthesis of algae, inflow of substantial amounts of ground water, or reduced stream flow. Discharge from the bottom of impoundments is usually low in dissolved oxygen.

According to Tennessee's water quality criteria, the dissolved oxygen concentration in most surface waters should not be less than 5.0 mg/L to support fish and aquatic life. The exceptions are trout streams where the minimum is 6.0 mg/L, streams in the Blue Ridge Mountains (7.0 mg/L) and naturally reproducing trout streams (8.0 mg/L).

Dissolved oxygen was below criteria at least one season in 21 of the 75 test sites (Figure 37). Two of the sites, Flat Creek and an unnamed tributary to Hot Water Branch are direct tributaries to trout streams in the Blue Ridge Mountains and fell below 7.0 mg/L. Two streams, an unnamed tributary to Sinking Creek and Shelton Creek, are direct tributaries to trout streams in other regions and fell below 6 mg/L. One site, Roaring Creek downstream of Ripshin Lake is a naturally reproducing trout stream (NRTS) and fell below 8 mg/L. Dissolved oxygen at the other 16 sites fell below 5 mg/L.

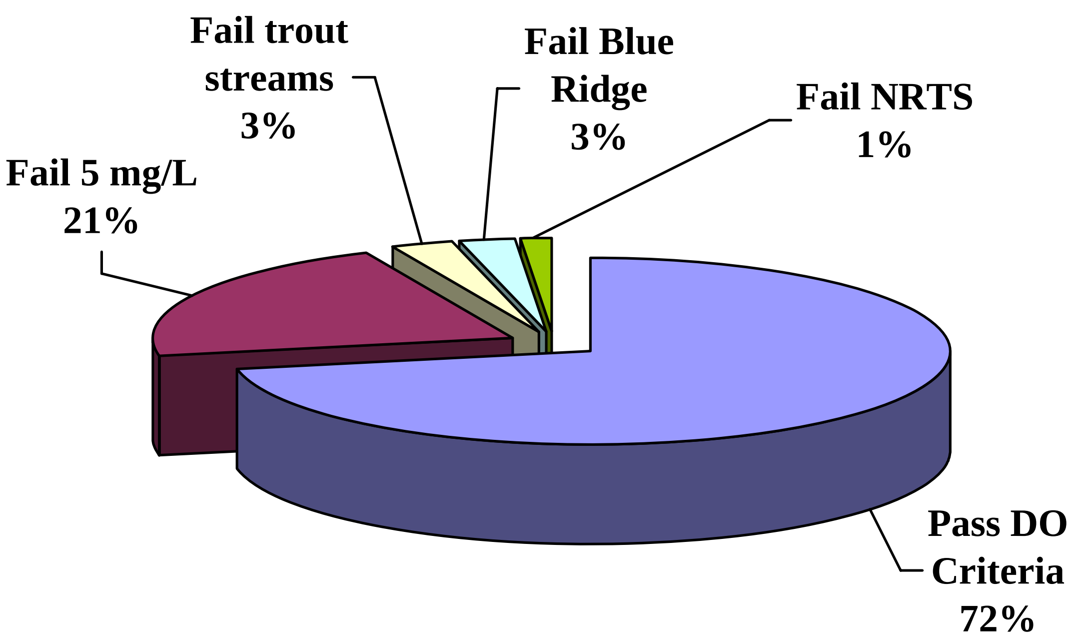

Figure 37: Distribution of impounded streams failing to meet dissolved oxygen criteria.

All but three of the sites below criteria received surface water discharge from the dams. There were two sites with low DO with dual discharge from surface and subsurface waters. All of the test sites with low DO also had elevated manganese, indicating that metal oxidation is occurring in these streams.

Dissolved oxygen was most likely to be below criteria in the summer and fall (Figure 38). None of the sites failed to meet criteria in the winter. Two streams had low dissolved oxygen in the spring. One of these was Scantling Branch downstream of Good Neighbor Lake on the Cumberland Plateau. This creek was dry in the summer. Dissolved oxygen was 5.3 mg/L during the day in the fall but may have been lower overnight. All of the fall flow was seepage from the bottom of the dam that is probably low in DO. Dissolved oxygen was 3.1 mg/L in the spring. The bedrock substrate was covered with iron precipitate in both the spring and fall, which may be oxidizing and consuming oxygen from the water. The macroinvertebrate population failed to meet biocriteria in both the fall and spring with a score of 12 both seasons. Worms and midges, which are tolerant of low dissolved oxygen, comprised over three quarters of the benthic population.

The other site that failed to meet criteria in the spring was South Fork Hurricane Creek downstream of Lakeview Circle Lake in the Western Highland Rim (71f), which had low DO in the fall, summer, and spring. Flow was slightly below expectations in the fall and spring. Iron ochre thickly covered the stream substrate during each season the site was sampled. This stream received mostly subsurface discharge from the dam, which may have had low dissolved oxygen concentrations. During the fall sampling period, a bacterial oil sheen was noted along the edges of the stream. In summer, dead algae were observed, which could have been consuming the oxygen as it decayed. In the spring, a smell of organic decay was recorded at the site. Macroinvertebrate index scores were very low both seasons sampled (10 and 14). Planarians dominated the site in the fall. These are omnivorous invertebrates that are tolerant of pollution. Predaceous hydra was the dominant spring taxon.

The lowest dissolved oxygen concentration recorded (1.9 mg/L) was during the summer at Squaw Branch in the Western Highland Rim (71f). This site also failed criteria in the fall (4.8 mg/L). The impoundment has a toe drain with subsurface discharge as well as subsurface seepage that forms a small tributary flowing into the main channel. Heavy iron deposits and iron fixing bacteria covered the substrate of the stream channel. Green algal masses as well as dead algae were observed in the stream during each season the site was sampled. The subsurface discharge from the lake has probably created conditions causing the low dissolved oxygen levels in the summer and fall. The site failed to meet biocriteria scoring 12 in the fall and 16 in the spring. Worms and midges dominated the samples.

Based on measurements of diurnal swings in reference streams, three sites that passed the 5.0 mg/L criteria during the daylight sampling hours may not pass the criterion at night. All of these sites failed to meet biocriteria in both seasons sampled. One is an unnamed tributary to Gray Creek downstream of Lake Lajoie in ecoregion 65e. The daylight dissolved oxygen measurement was 5.37 mg/L at three in the afternoon. This is likely the highest DO level for the day. Reference sites for this ecoregion indicate that dissolved oxygen levels have a natural diurnal swing of 1-2 mg/L (Arnwine and Denton, 2003).

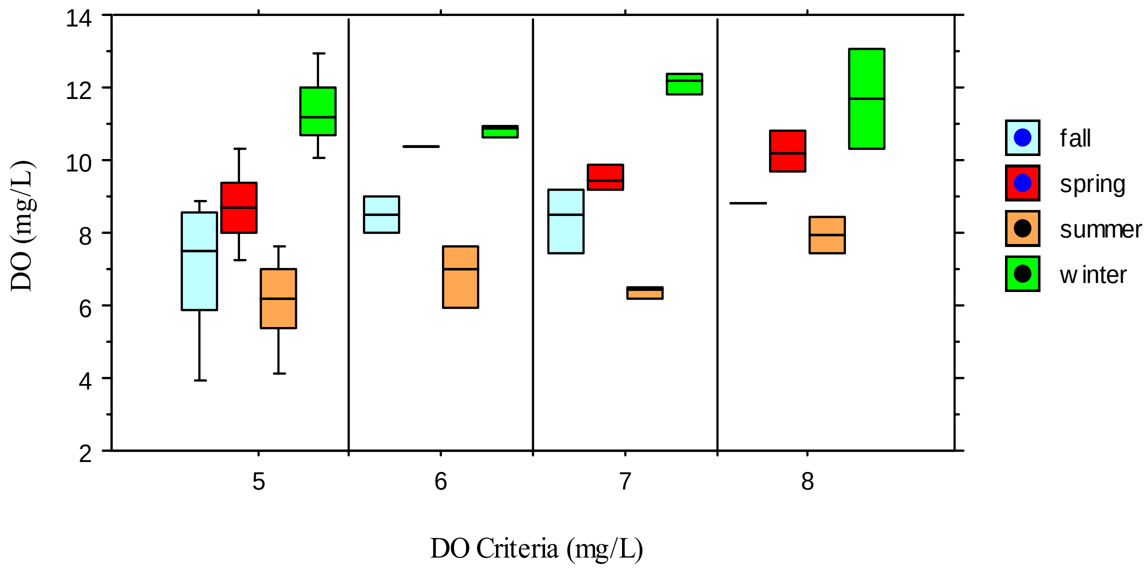

Figure 38: Seasonal ranges of daylight dissolved oxygen measurements from 75 impounded test sites compared to criteria.

The unnamed tributary to Sinking Creek, which is a tributary to a trout stream in ecoregion 67g also had relative high dissolved oxygen (6.61 mg/L) at 5:20 pm. Even with the typical diurnal swing of 2 mg/l recorded at reference streams, this site would fall below 6 mg/l. However filamentous algae were abundant at this site covering 100% of the substrate. It is highly probable that the diurnal swing is much greater as a result of photosynthesis. Daylight dissolved oxygen at the upstream site was never below 7.9 mg/L and algae were not present.

Little Trace Creek in ecoregion 71g had DO at 5.57 mg/L at 4:00 pm. This site also had abundant algae. Diurnal swings are 2 mg/L under normal conditions in this ecoregion. Worms and midges were abundant at this site.

The percent of oxygen saturation is an important component in determining whether there is an adequate supply of oxygen available to support a healthy aquatic community. Percent saturation is the measured DO divided by the maximum amount of oxygen the water can hold multiplied by 100. The percent saturation is affected by:

a. Temperature – Like all gases, oxygen is more soluble at lower temperatures. The colder the water, the more oxygen it can hold.

b. Elevation/Atmospheric Pressure – The higher the air pressure the more oxygen it can hold. Water at sea level can hold more oxygen than water on top of a mountain.

Because the same dissolved oxygen measurement can indicate a different percent saturation depending on factors such as temperature and elevation, it is important to look at both the dissolved oxygen value and the percent saturation.

The percent saturation was calculated for the test sites and compared to the tenth percentile of their respective ecoregion reference sites (Arnwine and Denton, 2003). Many sites that passed dissolved oxygen criteria during daylight hours did not maintain saturation comparable to background levels (Figure 39). Streams with dissolved oxygen saturation below this level may not be providing adequate oxygen concentrations to support benthic communities appropriate for the ecoregion. Although only 28% of the sites failed dissolved oxygen criteria, the 10th percentile was not met during at least one season at 77% of the impounded sites (Figures 40 and 41).

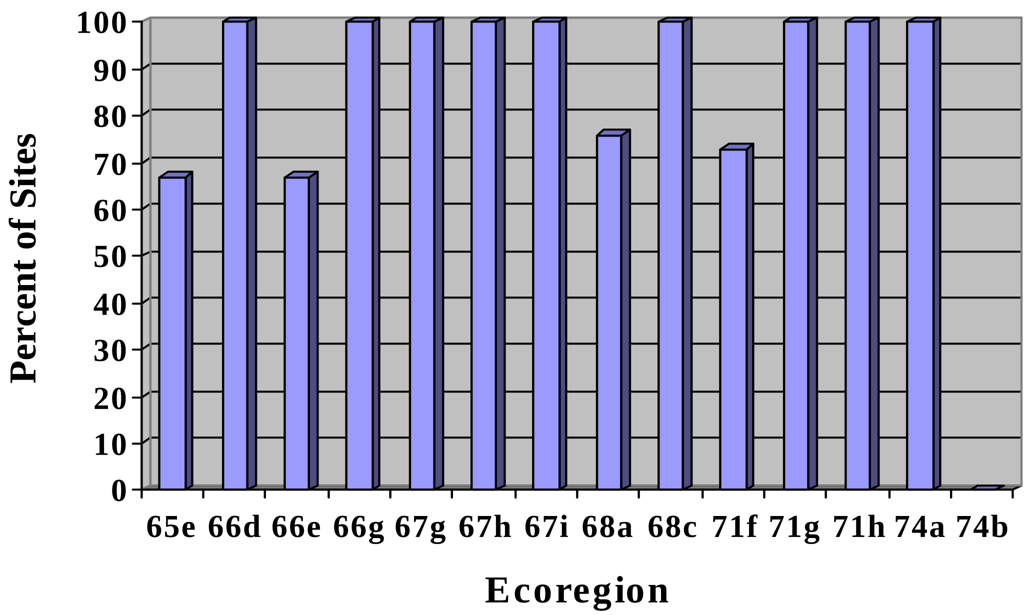

Figure 39: Percent of impounded streams with oxygen saturation below the 10th percentile of reference data.

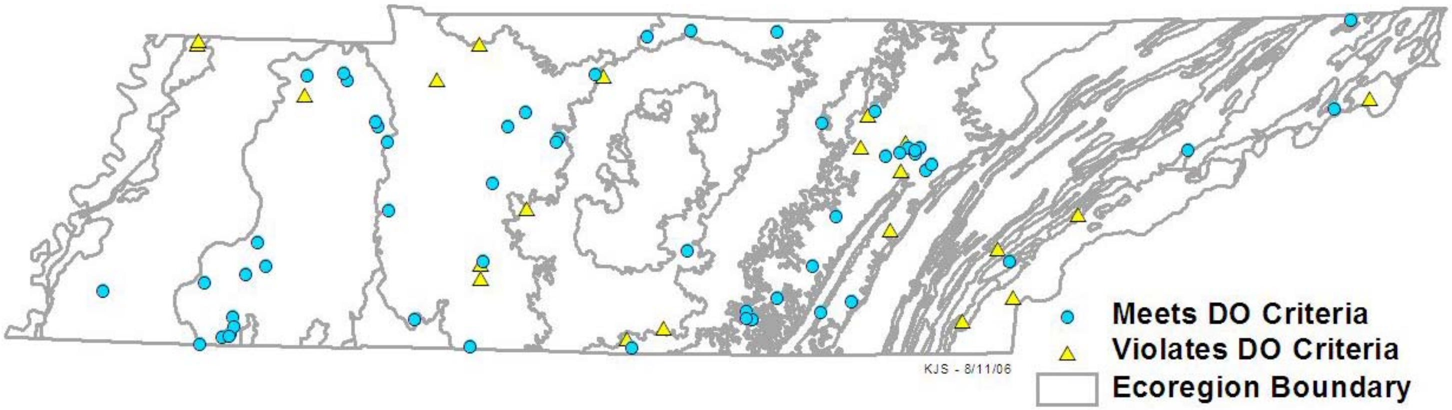

Figure 40: Location of impounded test sites showing comparison to dissolved oxygen criteria during daylight hours.

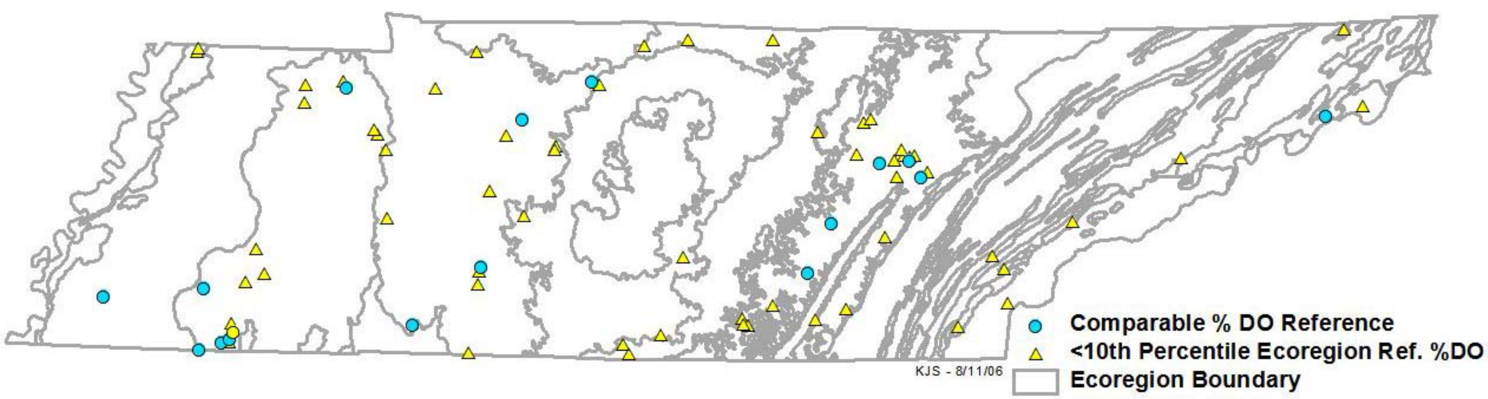

Figure 41: Location of impounded test sites showing comparison to 10^{th} percentile of reference dissolved oxygen saturation.

Although a minimum level of dissolved oxygen is necessary to support the aquatic community, high levels can also be dangerous. Super-saturated water, with saturation levels at or above 110% can cause a condition know as gas bubble trauma resulting in fish death. Macroinvertebrates are also known to be affected by super-saturated water, but most research has been conducted on fish. Thirteen of the 75 test sites (17.3%) had saturation above 100%. Two were above 110 percent in the spring. Both sites were in Lincoln County. One of these, the unnamed tributary to Hancock Creek downstream of Circle H Ranch Lake in the Eastern Highland Rim (71g) had 110% saturation. Filamentous algae were observed by field staff in spring. The site was dry in the summer and fall during the periphyton surveys. The spring macroinvertebrate sample failed to meet biocriteria. Dissolved oxygen at Shelton Creek downstream of Lincoln Lake in the Outer Nashville Basin (71h) was 122 percent. Microalgae was observed every season. Filamentous algae were growing on the bedrock in the spring. Macroinvertebrates failed biocriteria in spring and fall.

All of the sites with saturation above 100% had algae present in the stream. During the day, when the dissolved oxygen readings were taken, the algae were producing oxygen. This caused these streams to be supersaturated. It is likely these streams experience a high fluctuation in dissolved oxygen between the daylight and night-time hours causing a large diurnal swing.

Oxygen levels were supersaturated at Shelton Creek in the spring due to abundant algal growth. The site is located 80 yards downstream of Lincoln Lake. *Photo provided by Aquatic Biology Section, TDH.*

8.2 Water Temperature

Water temperature is an important component of the aquatic environment. Almost all facets of life history and distribution of aquatic macroinvertebrates are influenced by temperature. It is a key factor in determining their distribution, diversity and abundance. Most species have a preferred temperature range. Metabolism, growth, emergence and reproduction are directly related to temperature. Food availability, both quantity and quality, may be indirectly related through associated activity (Merrit and Cummins, 1996). Water temperature affects dissolved oxygen levels and the susceptibility of benthic fauna to parasites.

According to Tennessee's water quality criteria for the support of fish and aquatic life in wadeable streams, the temperature shall not exceed 30.5 ºC and the maximum rate of change should not exceed 2 ºC per hour. The maximum temperature change should not exceed 3 ºC relative to an upstream control point. For the support of trout in recognized trout streams, the temperature should not exceed 20 ºC. The presence of a dam on a stream can greatly influence the temperature downstream. Surface water discharges tend to be warm and can cause an unnatural increase in the temperature of the stream. Subsurface water discharges tend to be cold and can cause an unnatural decrease in the temperature of the stream.

Eight of the impounded streams had elevated water temperatures at the time of sampling, while six more were likely to exceed temperature criteria later in the day. Four impounded tributaries to trout streams had summer water temperatures well above 20 ºC. The tributary to Sinking Creek below the impoundment was 24.3 ºC. The water temperature at the site upstream of the impoundment did not exceed 16.9 ºC. The naturally reproducing trout stream, Roaring Creek, had water temperature of 19. 7 ºC at 9:00 am and was probably above 20 ºC by afternoon.

Four streams were above 30 ºC in July. These included Piney Creek in the Southeastern Plains and Hills (65e) and three creeks in the Western Highland Rim (71f). All but one of the sites received surface water discharge from the dams. There were five additional streams that were likely to exceed 30 ºC during the July sample. Carson Branch in 67g and a tributary to Gray's Creek in 65e measured 29.9 ºC. Beasley Hollow in 71h, Washburn Branch in 71g and the tributary to East Fork Spring in 65e all had water temperatures above 28 ºC in the morning hours.

Most of the sites with elevated temperatures had surface discharge. Only one, the unnamed tributary to Sinking Creek had subsurface discharge. All of the high temperatures were during the summer sampling period, except for one, on Shelton Creek (71h), where temperature was elevated in both spring and summer. This stream had good flow throughout the entire sampling period so the high temperatures are probably a result of the warming of the lake's surface.

The highest temperature recorded (31.6 ºC) was during the summer at the first order stream site on South Fork Sycamore Creek downstream of Brown Lake in Davidson County. There is another impoundment immediately upstream of this one. Although the site did not pass the temperature criteria in the summer, it did pass biology in both the spring and the fall. There was adequate flow throughout the year. This is a shallow bedrock stream. The benthic community is adapted to higher temperatures in this stream type.

Natural water temperatures are extremely variable in different ecoregions. Water temperatures that are acceptable in other parts of the state would not support many of the benthic macroinvertebrates and fish found in the mountain areas. Likewise, these streams would be too cold for lowland species to thrive. To determine if the test sites were within natural ranges, water temperatures were compared to the ecoregion and first order reference site temperature ranges between the 10th percentile and 90th percentile for each season (Table 12).

Table 12: Seasonal temperature ranges at ecoregion and first order reference sites.

Ecoregion	10th % Fall	90th % Fall	10th % Winter	90th% Winter	10th % Spring	90th% Spring	10th % Summer	90th% Summer
65e	7.94	17.88	2.64	13.42	11.34	22.08	17.02	23.85
66d	6.52	13.49	1.59	5.48	4.56	15.49	14.28	18.06
66e	4.02	13.69	1.23	8.78	5.95	14.37	16.62	20.02
66g	5.42	12.28	3.05	10.37	9.72	16.08	15.42	22.41
67g	4.25	10.14	5.01	13.49	12.20	17.34	18.17	23.42
67h	7.39	14.07	4.66	12.70	6.18	14.49	16.89	21.59
67i	13.78	13.78	10.98	15.61	16.20	16.20	18.76	19.28
68a	4.65	14.26	3.60	7.62	11.36	18.89	17.79	23.21
68c	10.63	12.94	8.20	11.72	11.80	14.91	15.93	21.19
71f	8.81	16.68	3.06	11.85	13.30	20.87	16.82	22.39
71g	6.15	12.02	5.04	11.12	12.61	19.51	18.09	22.84
71h	9.45	14.10	8.16	12.99	13.26	19.50	17.12	20.76
74a	6.62	19.16	5.78	12.65	10.93	18.87	22.12	25.02
74b	7.72	15.52	5.21	13.54	13.15	19.82	18.08	21.73

Many more sites (96%) fell outside the temperature range from the reference data than failed the criteria (Table 13). Only three sites fell within the seasonal temperature range for their ecoregion every season. These include Rattlesnake Creek (66e), and two first order streams Old Town Creek tributary (65e), and Pond Branch (68a).

Table 13: Number of impounded test sites in each ecoregion with water temperature above the 90th or below the 10th percentile of seasonal reference data.

Ecoregion	Total sites	Fall		Winter		Spring		Summer	
		< 10th	>90th	< 10th	>90th	< 10th	>90th	< 10th	>90th
65e	15	0	8	0	0	1	0	14	15
66d	1	0	0	0	0	0	0	1	1
66e	3	0	0	0	0	0	1	1	3
66g	1	0	1	0	0	0	1	0	1
67g	2	0	2	1	0	0	2	2	2
67h	1	0	1	0	0	0	0	1	1
67i	1	NA	NA	1	0	1	0	1	1
68a	21	0	10	2	0	0	9	9	21
68c	1	0	1	1	0	0	1	1	1
71f	15	0	11	0	0	10	0	10	15
71g	6	0	3	1	0	2	3	5	6
71h	4	0	4	4	0	0	1	4	4
74a	2	0	0	2	0	0	0	2	2
74b	2	0	1	0	0	0	0	2	2

The greatest divergence in water temperature was measured in the fall (Figure 42). Seventy two percent of the streams with flow had higher temperatures than the 90th percentile of reference sites. This is also the season with the lowest flows.

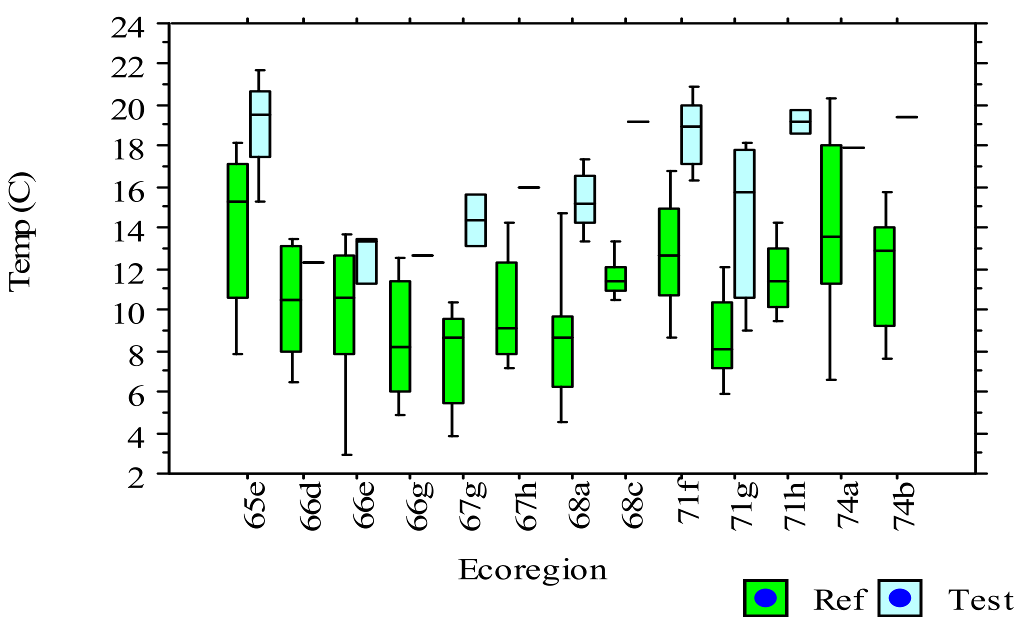

Figure 42: Fall water temperature ranges at reference and impounded test sites in 13 ecoregions.

In summer, 69% of the test sites had temperatures above the 90th percentile of reference data (Figure 43). This included streams in every ecoregion except the Southern Metasedimentary Mountains (66g) where only one site was sampled. Two sites had low summer temperatures. One of these, Duncan Creek on the Cumberland Plateau had subsurface seepage from the impoundment. The other, Rattlesnake Creek in the Blue Ridge Mountains, is only impounded in the summer.

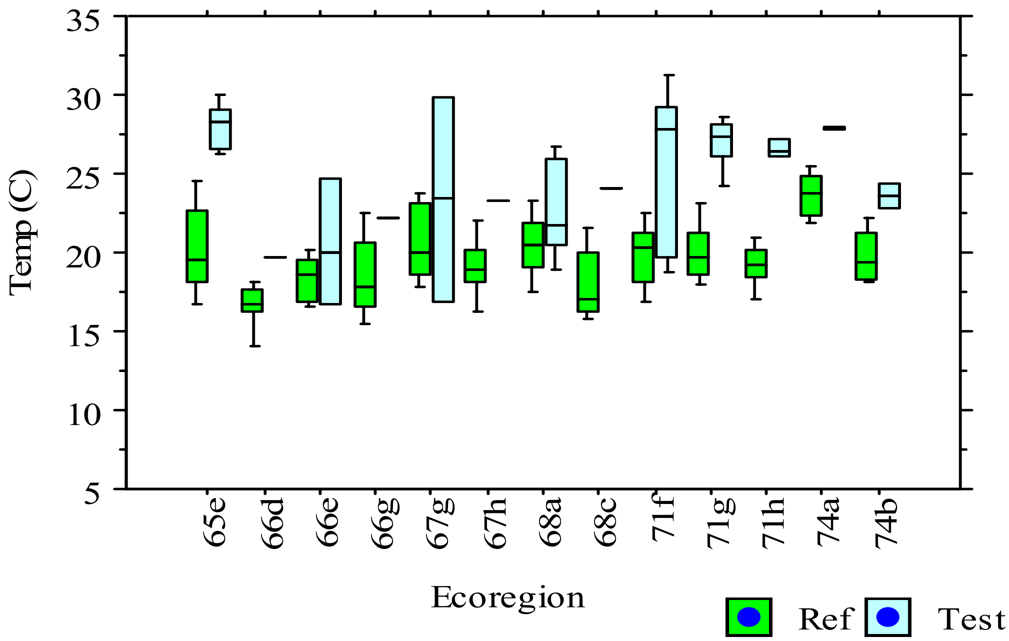

Figure 43: Summer water temperature ranges at reference and impounded test sites in 13 ecoregions.

Shelton Creek downstream of Elcan Lake in Lincoln County was the only site that had elevated temperatures in both spring and summer.

Photo provided by Aquatic Biology Section, TDH.

Approximately one fourth of the sites had elevated spring temperature despite the higher flow and cooler air temperatures (Figure 44). Thirteen sites, most of them in the Western Highland Rim (71f), had low water temperature in the spring. The three lowest were over 3 ºC below the 10th percentile of reference data. All three of these were below impoundments with subsurface discharge.

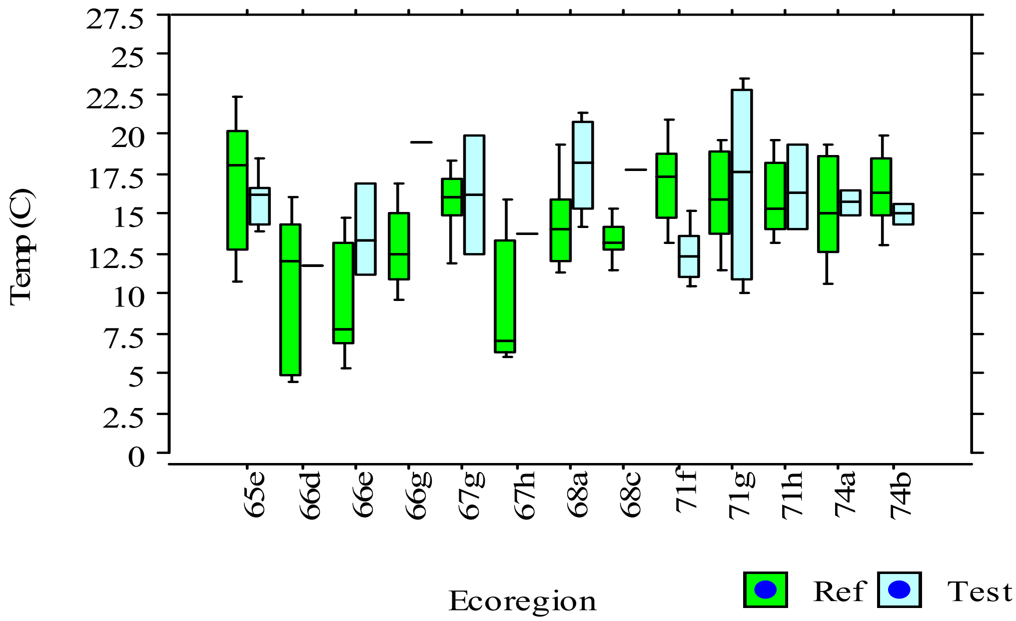

Figure 44: Spring water temperature ranges at reference and impounded test sites in 13 ecoregions.

None of the sites had elevated water temperature in winter. Water temperatures at 12 sites were below the 10th percentile of reference data. One of these was the unnamed tributary to Sinking Creek below Bryant Lake. The upstream site was over four degrees warmer. The discharge from Bryant Lake is subsurface discharge.

In general, it appears that most of the small impoundments had an affect on the water temperature of downstream stream reaches (Figures 45 and 46). A study on small impoundments with surface discharge in Michigan showed similar results (Lessard and Hayes, 2003). They found that mean summer temperatures were increased downstream of impoundments and the increase was maintained for at least 1 to 2 miles downstream. The study documented shifts in the macroinvertebrate and fish communities as a result of warming temperatures.

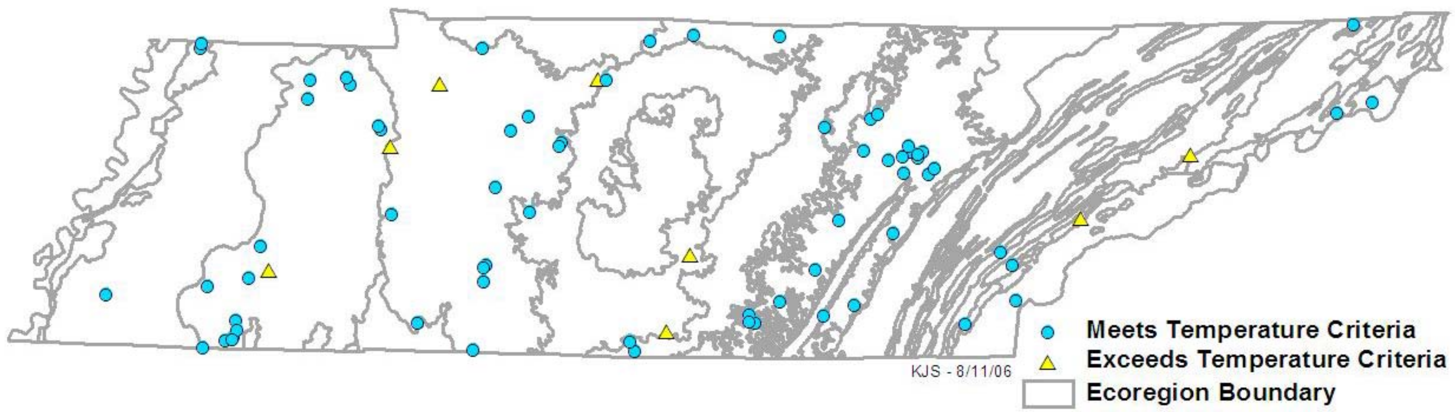

Figure 45: Location of impounded test sites showing comparison to water temperature criteria.

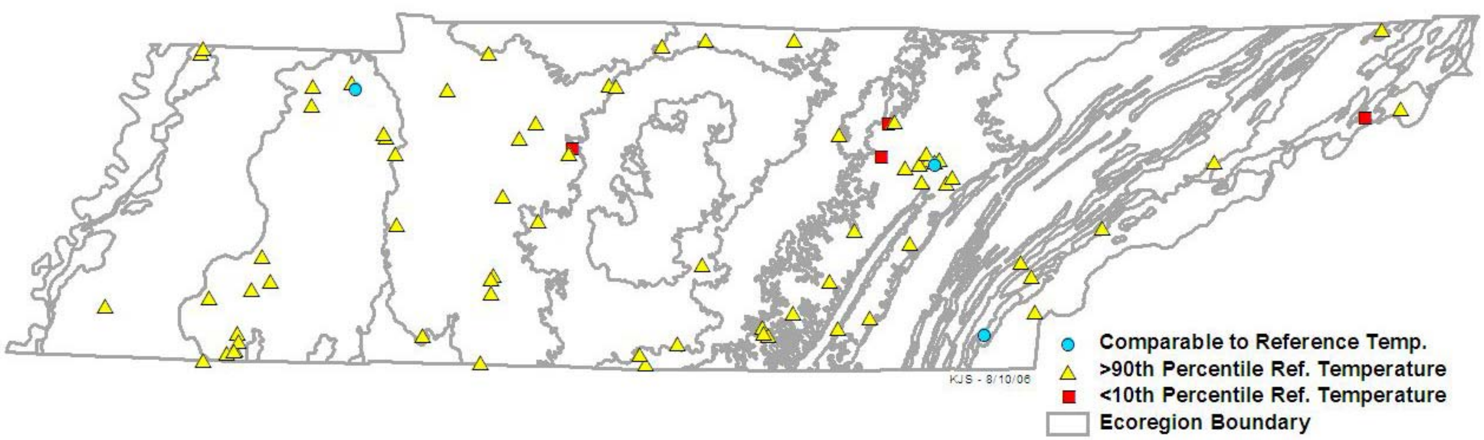

Figure 46: Location of impounded test sites showing comparison of water temperature to reference condition.

8.3 pH

Low pH, elevated alkalinity, or a significant change in the pH or acidity of the water over a relatively short period of time, can greatly impact aquatic life. The affects include respiratory or osmoregulatory failure, inability to molt and alteration of habitat through precipitation of metals. Generally, pH levels below 5.5 increase the toxicity of metals while pH above 9 increases the toxicity of ammonia. The statewide fish and aquatic life pH criterion for wadeable streams and rivers is 6.0 to 9.0.

Decreases of pH in streams below impoundments can be the result of disturbance of the natural substrate exposing rock formations. Increases can be the result of increased plankton productivity in the reservoir, which decreases carbon dioxide concentrations and boosts pH.

The majority of impounded streams met the pH criterion every season sampled (Figure 47). Most of the streams were also within the pH ranges recorded at reference streams for the ecoregion (Table 14 and Figure 48).

None of the sites had pH above 9.0. Four impounded test sites had pH below 6.0 (Table 15). Most of the sites had low pH in the spring although the largest stream, Savage Creek, had low winter pH. One reason all of these streams may have pH values on the acidic side could be due the to the type of soil found in these ecoregions. Each ecoregion where pH criteria was violated had the soil order ultisol in common. Ultisols are considered acidic soils (FAO Technical Paper, 1995).

Table 14: Minimum and maximum pH recorded at reference sites and impounded test sites.

Ecoregion	Minimum pH		Maximum pH	
	Reference	Impounded	Reference	Impounded
65e	5.6	5.9	7.7	7.8
66d	6.6	6.6	8.6	7.0
66e	6.2	5.7	8.3	7.0
66g	5.9	6.1	7.8	6.8
67g	6.7	7.6	8.8	8.0
67h	7.3	6.9	8.1	7.9
67i	7.8	7.4	8.0	8.1
68a	5.8	5.7	8.2	7.6
68c	7.2	7.3	8.8	7.7
71f	6.0	6.4	8.9	8.2
71g	7.3	6.6	8.6	7.9
71h	7.3	7.1	8.8	8.7
74a	6.3	7.3	8.3	8.1
74b	5.8	6.0	7.9	6.9

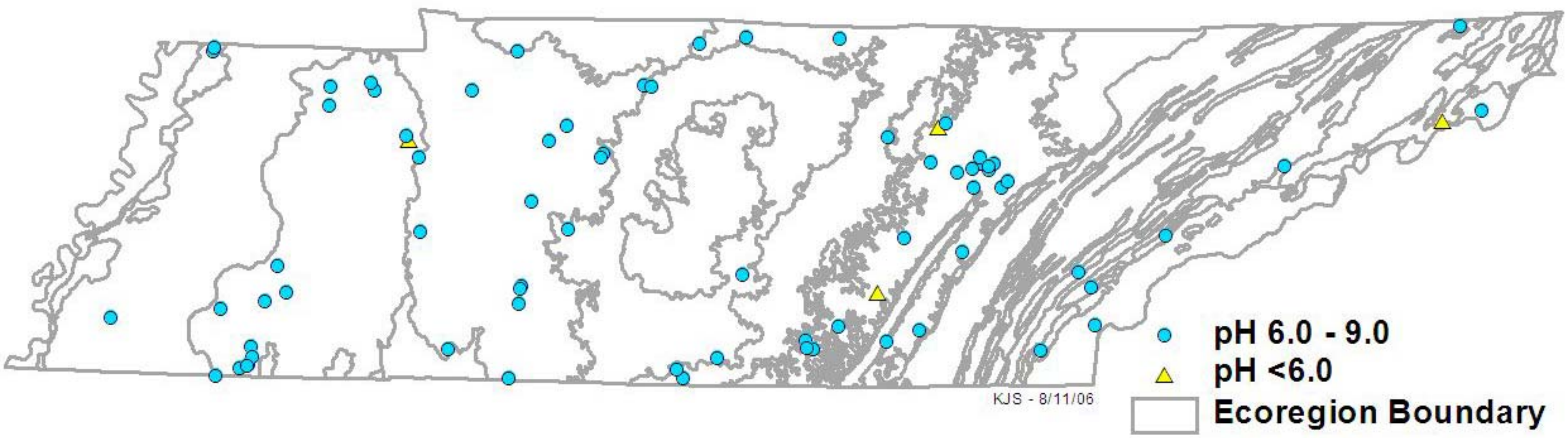

Figure 47: Location of impounded test sites showing comparison to pH criterion. Sites with pH below 6.0 fail to meet criteria.

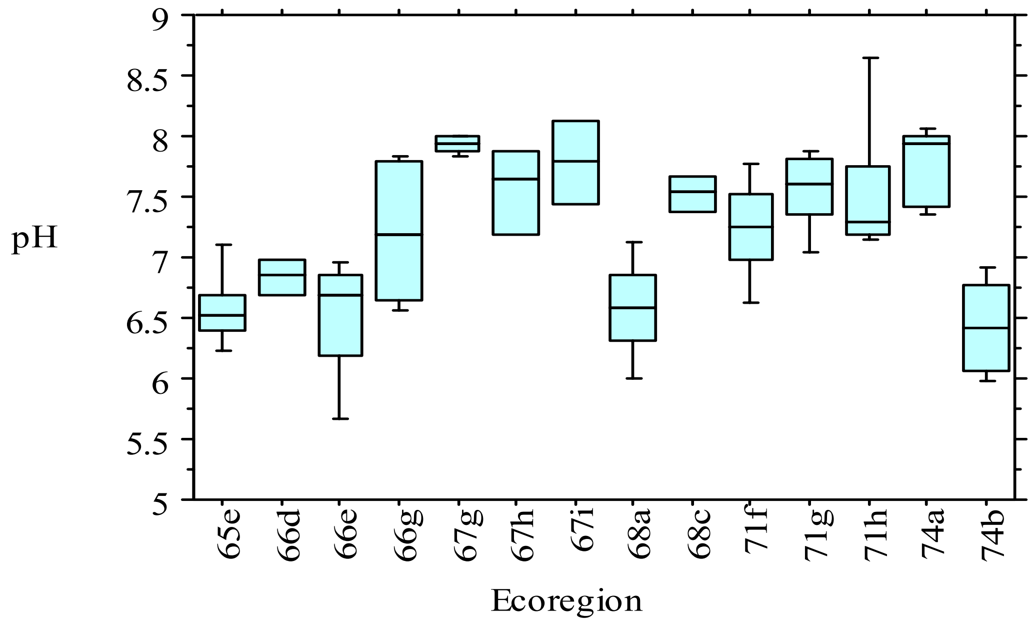

Figure 48: pH ranges at impounded stream sites.

Charlie Creek in the Southeastern Plains and Hills had a pH of 5.9 in the spring. Measurements as low as 5.6 have been recorded at reference sites in this region, so pH was probably not the primary factor in the low macroinvertebrate index scores. The same is true of Charlie Branch and Savage Creek on the Cumberland Plateau. The pH at both sites was only 0.1 below values recorded from ecoregion reference sites with healthy macroinvertebrate communities.

Although pH alone may not have been a factor on the poor quality of the macroinvertebrate communities, these three streams also had manganese levels above the 90^{th} percentile of reference data every season they were sampled. The toxicity of manganese is increased with decreasing pH. Manganese also precipitates out at lower pH levels and can make the substrate unuseable for aquatic life. Precipitate was observed at all of these sites.

Another stream on the Cumberland Plateau, Falls Creek downstream of Fall Creek Falls Reservoir, had pH within criteria during the entire sampling period. However, this stream was monitored 10 times the previous year and pH fell below 6 in five of the samples. The lowest measurement recorded was 5.2 in summer 2003.

Table 15: Seasonal pH at impounded test sites that did not meet pH criterion.

Station	Ecoregion	Order	pH			
			Fall	Winter	Spring	Summer
CHARL003.4BN	65e	1	Dry	6.3	5.9	6.2
RATTL000.1UC	66e	2	6.4	6.2	5.7	5.7
CHARL000.7OV	68a	1	6.0	6.8	5.7	6.0
SAVAG009.8SE	68a	3	6.3	5.7	6.0	6.2

The lowest pH was found in Rattlesnake Creek (66e) with values of 5.7 in the spring and summer. This value is lower than any recorded at a reference site in this region (6.2). This was the only stream with low pH more than one season. Rattlesnake is a direct tributary to the naturally reproducing trout stream Rock Creek. The impoundment is located in the Cherokee National Forest. The bottom of the impoundment is concrete so rock leachate is probably not a factor in the low pH. It is only used as a seasonal swimming area. The stream was free-flowing from September to February. This site passed biocriteria in the fall when pH was 6.4 and the stream was free-flowing, but not in the spring when the stream was impounded and pH was 5.7.

Rattlesnake Creek downstream of a seasonal swimming impoundment in the Cherokee National Forest had low pH in the spring and summer. *Photo provided by Aquatic Biology section, TDH.*

8.4 Total Suspended Solids

Total suspended solids (TSS) can include a wide variety of material, such as silt and decaying organic matter. High TSS can block light from reaching submerged vegetation. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die using up even more oxygen from the water. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. Pollutants such as bacteria, nutrients, pesticides and metals may attach to sediment particles and be transported to the water where they are released or carried further downstream.

Table 16: 90th percentile of reference total suspended solid data in 14 ecoregions.

Ecoregion	90th Percentile TSS (mg/l)
65e	23
66d	10
66e	10
66g	10
67g	13
67h	10
67i	50
68a	10
68c	12
71f	10
71g	12
71h	10
74a	13
74b	30

The decrease in water clarity caused by TSS can affect the ability of aquatic life to see and catch food. Suspended sediment can also clog gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a waterbody, they cause a reduction in habitat availability and can smother the eggs of fish and aquatic insects.

Dams act as sediment traps. During high flow they release fine particles and detain larger substrates from continuing downstream. This leads to greater erosion potential of the stream's banks below the dam. Tennessee has developed narrative criteria for sedimentation and siltation and ecoregional sediment expectations for healthy streams.

Total suspended solid concentrations of the test sites were compared to the 90th percentile of ecoregion reference data (Table 16). Approximately half of the impounded streams had higher suspended sediment concentrations than found in reference streams (Figure 49). These sites were located in eight of the 14 ecoregions studied.

The highest total suspended solid concentration was probably Thompson Creek downstream of Garret Lake in the Southeastern Plains and Hills. The concentration could not be quantified without dilution and the estimated concentration was 256 mg/L in the winter. Spring values were also elevated. The lake is in a wooded wildlife management area but creek banks are eroded and sloughing probably due to periodic high flows from the dam. The creek was dry in the fall and had very little flow the rest of the year.

West Fork Drakes Creek tributary #2 downstream of Willow Lake in the Eastern Highland Rim had the highest quantifiable total suspended sediment concentration (195 mg/L). The sample was collected in the summer. The lake is surrounded by a golf course and there is a plant nursery on the lakeshore. This site typically had excessive sediment deposits but the suspended sediment was undetected during the winter and spring. At the time of the summer sampling, new houses were being built around the lake. The removal of trees and topsoil for construction purposes made sediment available for transport through the impoundment. It was slightly raining the day of the sampling. Sediment and silt had been washed into the lake from the construction sites and were discharged through the mid-drain pipe into the creek. The lowest flow measured for this site was during the summer when the suspended sediment was at its greatest concentration.

Doddy Creek (71h) and Shelton Creek (71h) are direct tributaries to trout streams that had elevated suspended sediment concentrations in the spring. An unnamed tributary to Sinking Creek (67g) and Flat Creek (66e) are direct tributaries to trout streams that exceeded their respective ecoregion suspended sediment expectations in the summer.

West Fork Drakes Creek in Sumner County is affected by several factors associated with the Willow Lake impoundment including a golf course, lakefront homes and a nursery.

Photo provided by Aquatic Biology Section, TDH.

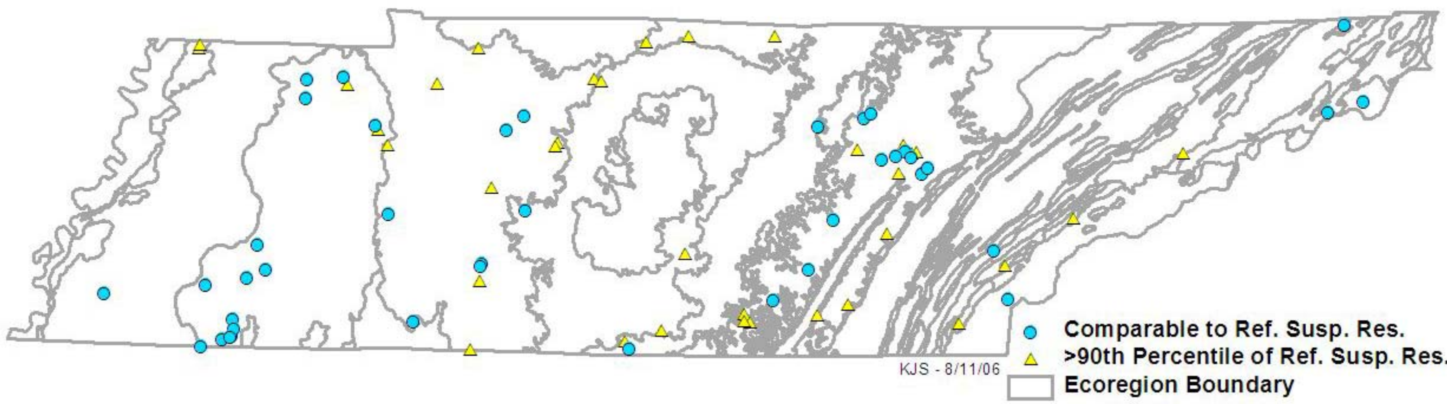

Figure 49: Location of impounded test sites showing comparison of total suspended solids concentrations to 90th percentile of reference data.

The lowest median values for suspended sediment concentration of test sites below impoundments were below the detection limit of 10 mg/L in 11 of the 14 ecoregions (Figure 50). The highest median concentration was 25 mg/L in ecoregion 74a. Ecoregion 74a was the only region sampled whose median concentration of suspended sediment was greater than the 90th percentile of regional reference data. This occurred during the winter/spring season.

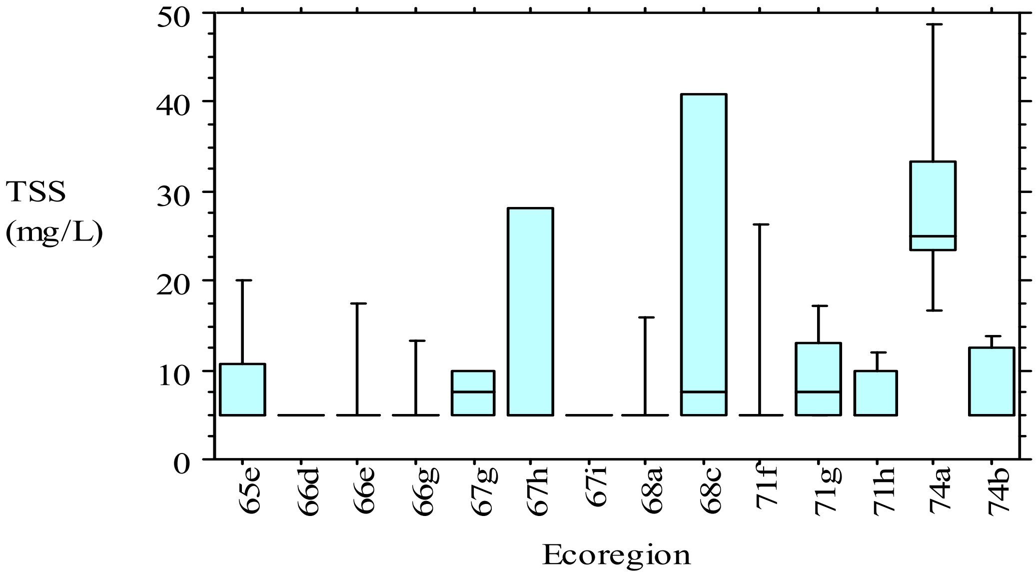

Figure 50: Distribution of total suspended solid concentrations below impoundments in 14 ecoregions.

8.5 Metals

Metals such as iron and manganese are naturally occurring in rocks. Impoundments have the potential to increase metal concentrations in downstream reaches due to disturbance of the overlying soil and increased surface area exposed to water. This potential is especially high in impoundments with subsurface discharge or seepage as the higher metal concentrations will be near the bottom. High concentrations of metals are toxic to aquatic life. The precipitation of metals in streams can render habitat unusable for colonization. Two commonly encountered metals, iron and manganese were measured in the streams below the impoundments.

8.5.1 Iron

EPA recommends and Tennessee has proposed an iron criterion of 1000 ug/L. Iron concentrations above this level were measured at 61% of the impounded test sites (Figure 51). These sites were located in 12 of the 14 ecoregions studied. The highest iron concentration recorded (266,000 ug/L) was during the fall on South Fork Hurricane Creek downstream of Lakeview Circle Lake in the Western Highland Rim (71f). During this sampling trip, there was a bacterial oil sheen visible along the edges of the stream and during every sampling event, the stream's substrate was heavily coated with iron fixing bacteria. This area is known for having high iron content in the rocks and has historical iron furnaces. There is some toe drain seepage and side seepage from the dam, although the main discharge is surface water through a standpipe. Most of the iron is likely from sediments in the lake that are leaching through the dam.

The highest median concentration was 1600 ug/L in the Loess Plains, 74b (Figure 52). Moody Creek and Scotts Creek were the only two test sites in this ecoregion. Moody Creek did not pass iron criteria during any season except summer. The creek had excessive silt and clay deposits covering the bottom substrate. The lake is spring fed and there is consistent subsurface water discharge to the downstream portion of the creek. The excessive sediment and iron deposits in the creek are probably due to the influence of groundwater and the subsurface drainage.

Scotts Creek was dry in the fall and had elevated iron concentrations the following three seasons. The creek had excessive sediment deposits. The lake is in a residential area and is surrounded by homes. Although the discharge is surface water, the water flows into the spillway through a road culvert. The iron deposits in the creek are most likely due to runoff and leaching of the soils.

The lowest median iron concentration of test sites below impoundments was 156 ug/L in the Southern Dissected Ridges and Knobs (67i). There was only one test site in this ecoregion, Steele Creek. The site was dry in the fall and there was no macroinvertebrate survey done. In the spring there was flow and the macroinvertebrate community was found to be healthy. The discharge is surface water over a spillway with no evidence of seepage through the dam. The iron in the lake settles to the bottom and does not travel through the dam because only surface water is allowed to pass into the creek.

Iron concentrations were much higher at the test site immediately downstream of Laurel Mountain Lake than at the ecoregion reference site 2.6 miles farther downstream. At the site closest to the dam, iron was 9,770 ug/L in summer 2004. The highest measurement recorded at the downstream reference site was 1,830 ug/L in summer 2003.

Two trout streams in the Blue Ridge Mountains had elevated iron concentrations. Flat Creek downstream of Lake in the Sky, a direct tributary to a trout stream, had elevated iron in the fall and summer. Roaring Creek downstream of Ripshin Lake is a naturally reproducing trout stream that did not pass iron criteria in the summer.

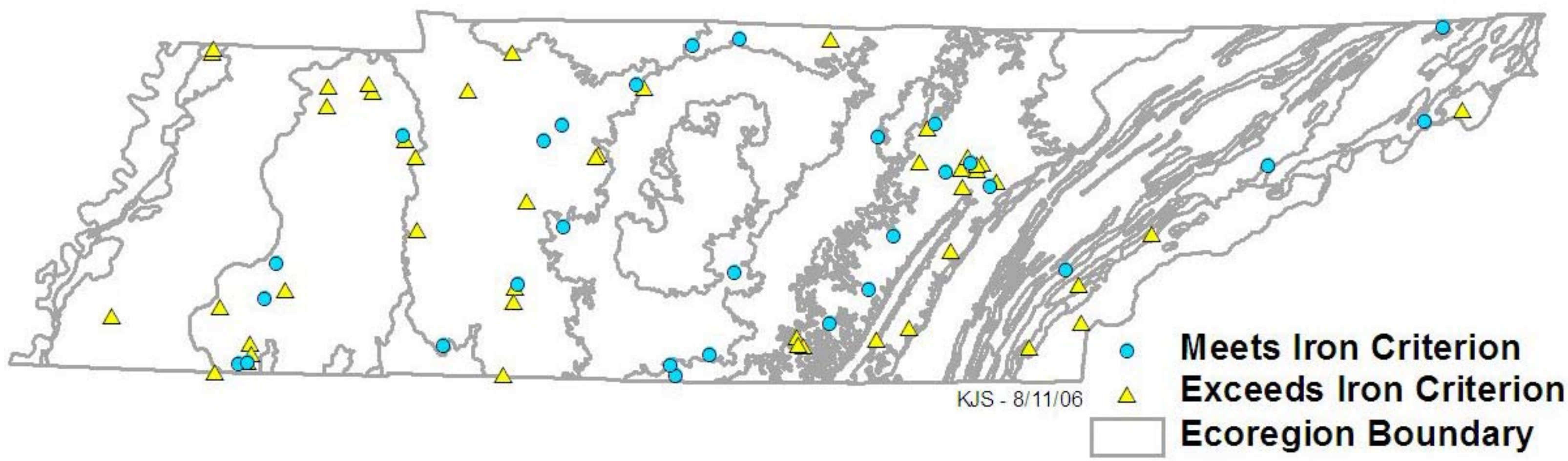

Figure 51: Location of impounded test sites showing comparison of iron concentrations to iron criterion.

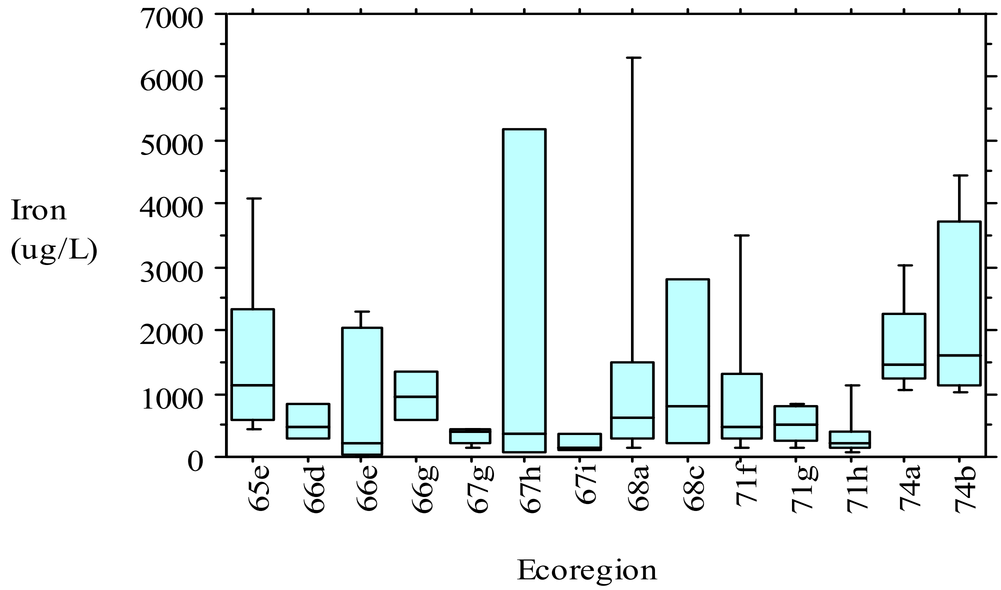

Figure 52: Distribution of iron concentrations below impoundments in 14 ecoregions.

Duncan Creek on the Cumberland Plateau (68a) had the highest concentration of iron (6710 ug/L) of any impounded site. The site failed to meet iron criteria each time it was sampled. A blanket of iron ochre covered the substrate each season. There was heavy equipment activity where trees had been cleared near the dam. This caused sediment loading to the creek. The sediments carrying iron were deposited in the creek leaving the iron ochre on the substrate. Likewise, there was visible seepage from the dam carrying iron ochre, which also contributed to the iron loading in this creek.

8.5.2 Manganese

Duncan Creek on the Cumberland Plateau had the highest iron concentrations of any impounded test stream.

Photo provided by Aquatic Biology Section, TDH.

Manganese concentrations at the test sites were compared to the 90th percentile of reference data (Table 17). Most of the streams below impoundments (93.3%) had manganese concentrations above this level (Figure 53). This included streams in all of the ecoregions in the study.

The highest concentration recorded (10,400 ug/L) was in the fall on Buck Creek on the Cumberland Plateau (68a). The primary lake discharge is surface water over a spillway but there is also a toe drain. It was raining during sampling but there was no water flowing over the spillway. The only source of water for the creek was seepage from the dam or from the toe drain. At the drain, ochre was covering the substrate. The stream has a heavy sediment load with one to two inches of sediment in pool areas. The sediments from the lake carry manganese and are deposited in the creek. This heavy sediment loading has yielded high manganese concentrations at this site every time it was sampled.

The lowest median concentration was 20 ug/L in ecoregion 66e in the Blue Ridge Mountains (Figure 54). The highest median concentration of test sites below impoundments was 467 ug/L in ecoregion 74a in the Bluff Hills of the Mississippi Valley Loess Plains.

Table 17: 90th percentile of reference manganese data in 14 ecoregions.

Ecoregion	90th Percentile Mn (ug/L)
65e	304
66d	16
66e	10
66g	14
67g	99
67h	33
67i	161
68a	33
68c	12
71f	13
71g	25
71h	25
74a	158
74b	339

The naturally reproducing trout stream, Rattlesnake Creek, had slightly elevated manganese in the fall (14 ug/L). The substrate was covered by a thick black ochre. Although this stream has a spillway, there is dual discharge from the subsurface. There also is a side stream that is created by dam seepage that was full of ochre.

The stream with the endangered Saddled Madtom, Bear Creek, had extremely elevated manganese levels all four seasons with concentrations as high as 815 ug/l. The 90th percentile for this ecoregion (71f) is 13 ug/l. Rocks were stained black and many dead corbicula clams were observed in Spring 2004.

Manganese concentrations downstream of the impoundment on Sinking Creek were consistently two to nine times greater than upstream levels. Concentrations exceeded the 90th percentile during the summer when there was a high concentration of suspended sediment. The elevated levels of metals are likely due to the subsurface water discharge.

Manganese was much more elevated at the site closest to the dam on Laurel Creek. Immediately below the dam, manganese was 5,550 ug/L in summer 2004. Two and a half miles downstream, the highest record over a two-year period was 366 ug/L in summer 2003.

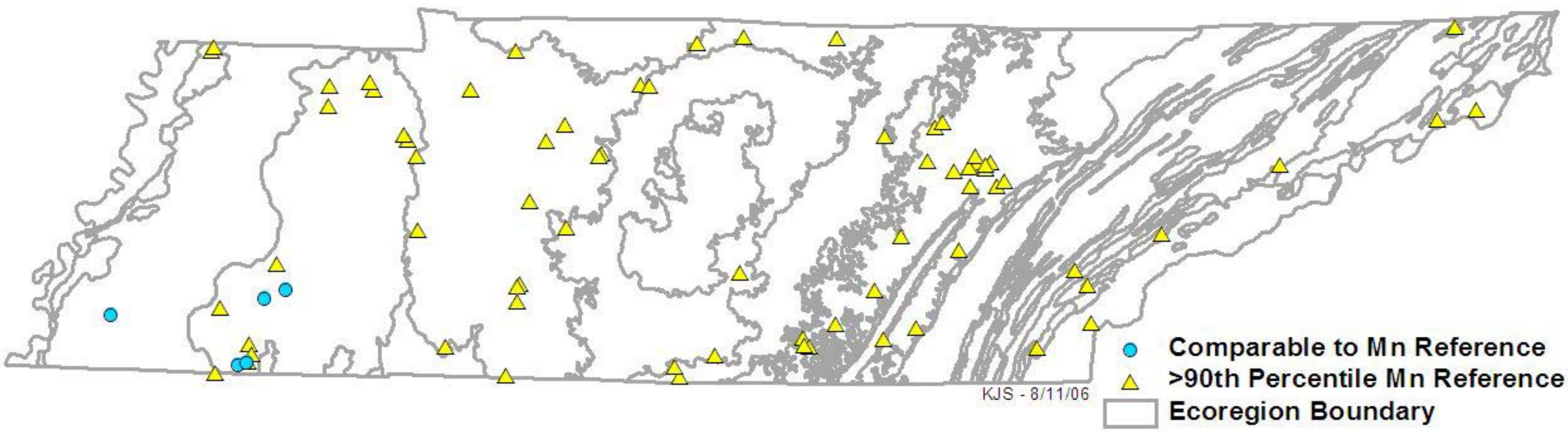

Figure 53: Location of impounded test sites showing comparison of manganese concentrations to the 90th percentile of reference data.

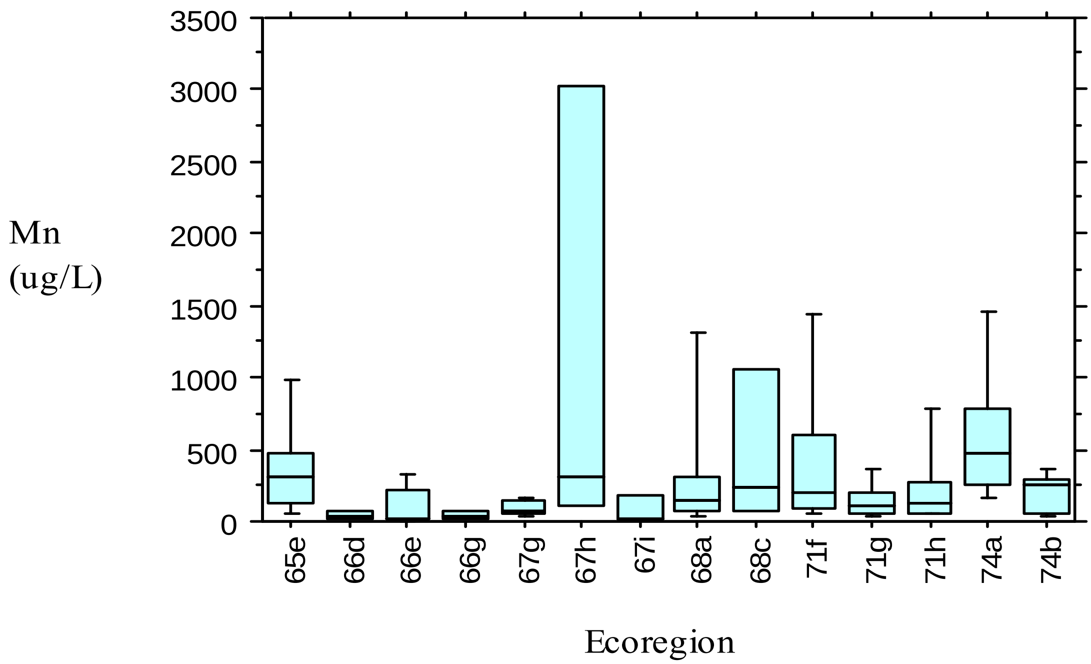

Figure 54: Distribution of manganese concentrations below impoundments in 14 ecoregions.

Buck Creek on the Cumberland Plateau had the highest manganese concentrations of any impounded test site.

Photo provided by Aquatic Biology Section, TDH.

8.6 Nutrients

Elevated nutrient concentrations are a common problem in surface waters in Tennessee. Impoundments have a tendency to trap nutrient run-off from surrounding land use which can accelerate eutrophication. Nutrients are intentionally added to some reservoirs to promote game fish production. This nutrient rich water is then released to the stream. Nutrients can affect aquatic fauna through the stimulation of algal growth. This in turn can deplete dissolved oxygen levels and can render substrates unusable for colonization by aquatic fauna. The presence of excessive nutrients can result in shifts of the benthic community towards organisms that feed on algae and fine organic matter.

Concentrations of total phosphorus, total ammonia, nitrate+nitrite and total Kjeldahl nitrogen (TKN) below each impoundment were compared to the reference database and first order reference streams to determine if excess nutrients were available for algal growth. Ammonia was the most frequently elevated nutrient followed by total phosphorus, TKN, and nitrate+nitrite (Figure 55).

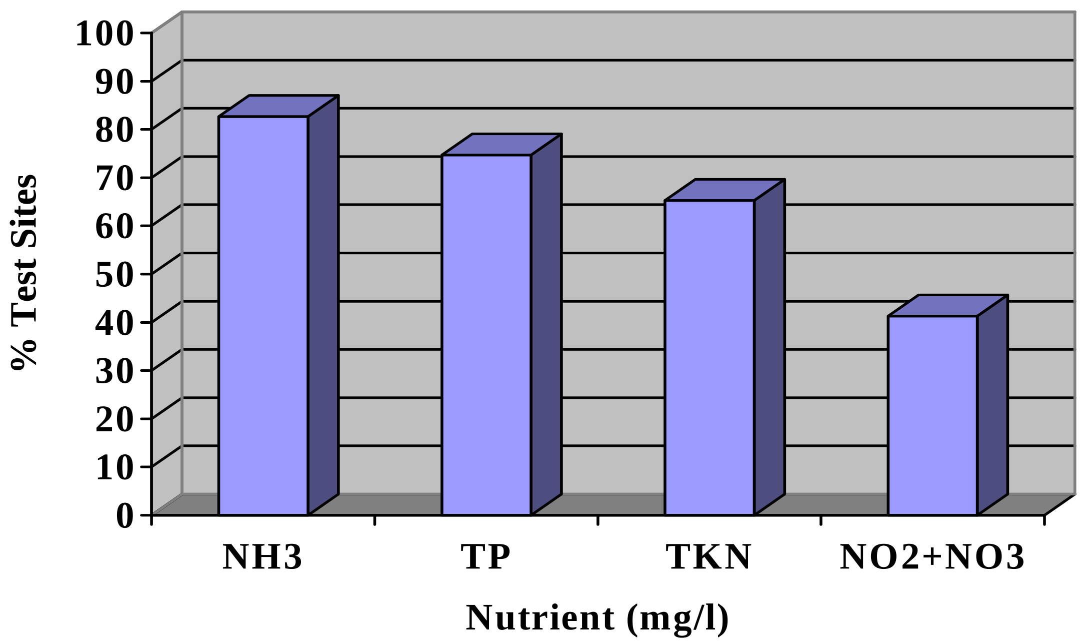

Figure 55: Percent of impounded test sites with elevated nutrient concentrations.

8.6.1 Total Ammonia

Total ammonia refers to a combination of ionized and unionized ammonia that is in equilibrium in water. Toxicity is in the unionized form. Ammonia is more toxic at higher pH. The EPA and proposed Tennessee criterion for ammonia takes this into account. The acute criterion (CMC) based on the pH for each sample was calculated using the following formulas:

For the six streams that were either trout streams or direct tributaries to trout streams:

$$CMC = \frac{0.275}{1 + 10^{7.204-pH}} + \frac{39.0}{1 + 10^{pH-7.204}}$$

For the other 69 streams:

$$CMC = \frac{0.411}{1 + 10^{7.204-pH}} + \frac{58.4}{1 + 10^{pH-7.204}}$$

Using these formulas, none of the sites had toxic levels of ammonia. However, when compared to reference data, ammonia levels were above the 90th percentile at 81% of the sites (Table 18). These sites were located in 13 of the 14 ecoregions studied (Figure 56). This indicates that although the ammonia may not have been present at acutely toxic levels, the impoundments were contributing more ammonia than would naturally be found in these streams. Although it is not the most useable form of nutrients, once the ammonia is broken down by microbial action, the nitrogen component is available for uptake by algae and can result in excess algal growth.

More than half the test sites had elevated ammonia levels during the summer and fall. The highest ammonia concentration (2.38mg/L) was during the summer on Squaw Branch (71f). This site also had ammonia levels above the 0.05 mg/L found in reference streams during the fall. The outfall is a subsurface water discharge and there is seepage from the dam forming a tributary to the main channel below the outfall. Most subsurface discharges are under anaerobic conditions and the nitrogen exists as the fully reduced forms ammonia and ammonium ion (Baird, 1999). Algal growth was recorded during each season. During the summer sampling, the dissolved oxygen concentration was below 2.0 mg/L.

Table 18: 90th percentile of reference ammonia data in 14 ecoregions.

Ecoregion	90th Percentile NH_3-N (mg/l)
65e	0.04
66d	0.02
66e	0.02
66g	0.02
67g	0.04
67h	0.02
67i	0.05
68a	0.02
68c	0.02
71f	0.05
71g	0.04
71h	0.02
74a	0.02
74b	0.04

The lowest median ammonia concentration was below 0.01 mg/L during the winter and spring in the Plateau Escarpment, 68c (Figure 57). Looney Creek was the only test site in this ecoregion although much of the drainage is from the Cumberland Plateau (68a) where many test sites were located. Ammonia was undetected in the spring and at the detection limit in winter, but above the 90^{th} percentile of ecoregion reference data during the fall and summer seasons with concentrations of 0.03 mg/L.

The highest median concentration of ammonia in test sites below impoundments was 0.24 mg/L during the summer and fall in the Loess Plains (74a). Taylor and Tull Creeks are the only two test sites in this ecoregion and both had elevated ammonia. They are part of the Indian-Reelfoot Lake system and feed North Reelfoot Creek. The streams had been channelized at one time and have excessive sediment deposits. They both are surrounded by cropland and had elevated nutrients except for nitrate+nitrite. The two impoundments that discharge to Taylor and Tull Creeks were eutrophic in 1991 (Hansel et al, 1991).

Taylor Creek had ammonia concentrations above background levels during the fall (0.66 mg/L) and summer (0.18 mg/L). Total kjeldahl nitrogen and total phosphorus were also above the 90^{th} percentile of reference data. The only season algae were not observed was in the winter. The site had low dissolved oxygen in the fall when macroalgae covered 66 percent of the substrate. A nutrient froth was noted during all seasons except fall.

Tull Creek had ammonia above background levels in the spring (0.10 mg/L) and summer (0.24 mg/L). This site also had other elevated nutrients with total kjeldahl nitrogen and total phosphorus above reference levels. The stream was stagnant in the fall with one isolated pool at the dam outfall and no chemical samples were taken. Macroalgae and microalgae were visible in the stream in spring and dead algae were observed in the summer. It is apparent the stream has similar nutrient problems as Taylor Creek.

Taylor Creek downstream of Reelfoot-Indian Lake #7 in the Bluff Hills had the highest ammonia levels in the study.

Photo provided by Aquatic Biology Section, TDH.

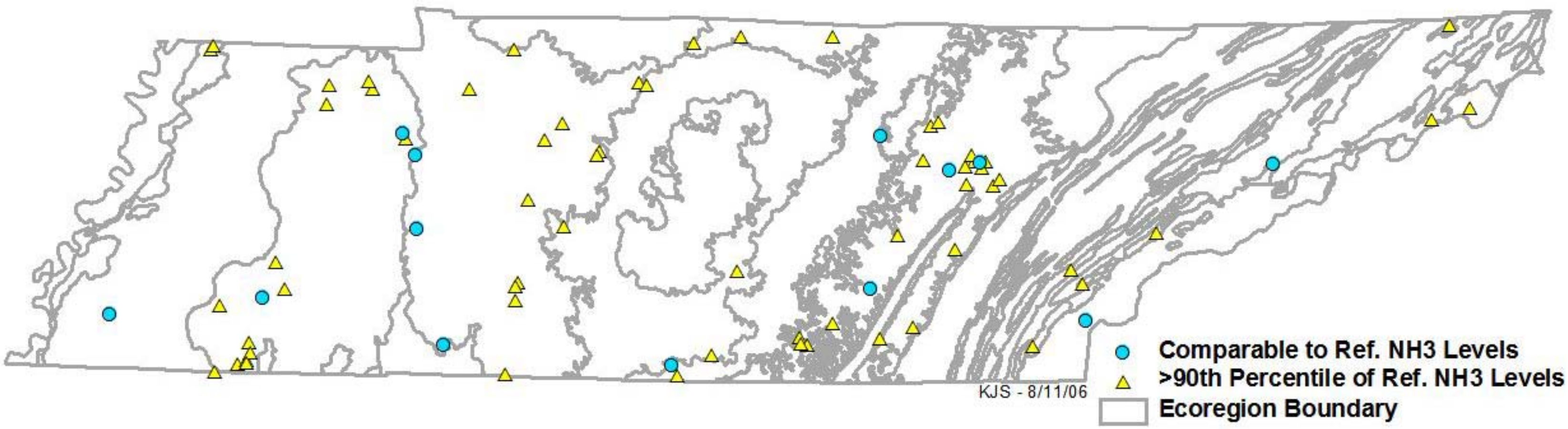

Figure 56: Location of impounded test sites showing comparisons of total ammonia concentrations to 90th percentile of reference data.

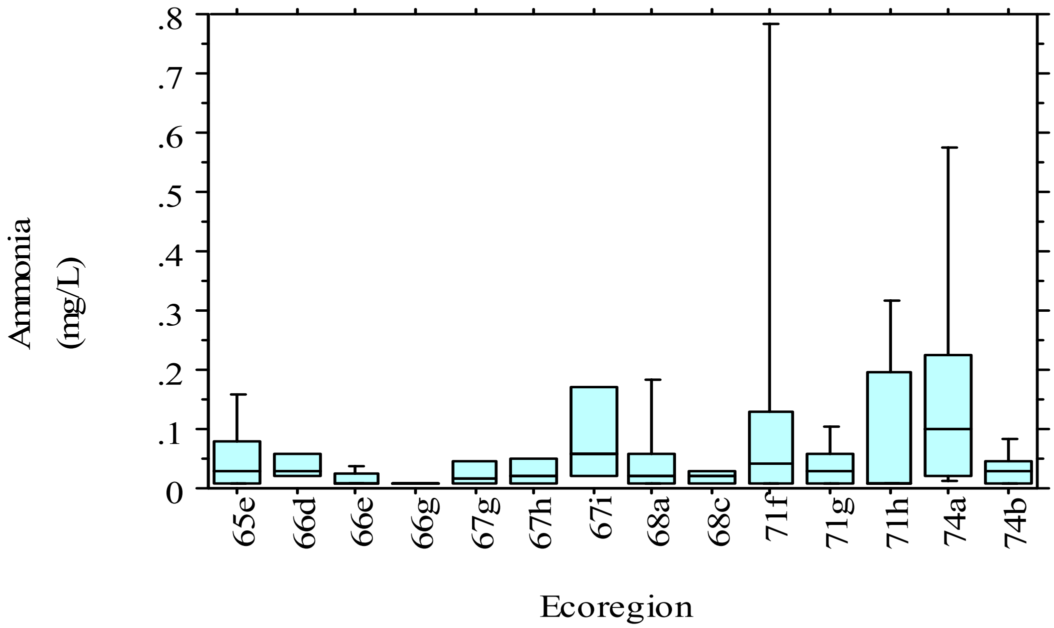

Figure 57: Distribution of ammonia concentrations below impoundments in 14 ecoregions.

Three of the sites that had ammonia above reference levels are direct tributaries to stocked trout streams, Doddy Creek (71h), Shelton Creek (71h) and Flat Creek (66e). Another site, Rattlesnake Creek (66e) is a direct tributary to a naturally reproducing trout stream. Roaring Creek (66d) also had elevated ammonia and is a naturally reproducing trout stream.

Doddy Creek was above reference levels in the fall (0.32 mg/L) and summer (0.04 mg/L) but ammonia was undetected in the winter and spring. Shelton Creek was only elevated in the summer (0.14 mg/L). Flat Creek and Rattlesnake Creek were slightly high in fall (0.03 mg/L) but ammonia was undetected during the other seasons. Roaring Creek was above reference condition in the fall (0.04 mg/L) and summer (0.08 mg/L). These levels are two times and four times as much as the expected amount of ammonia found in reference streams.

At the unnamed tributary to Sinking Creek levels were within the 90^{th} percentile of reference streams. However, ammonia was undetected in the upstream segment every season but was detectable in the downstream segment each time it was sampled. It appears that the lake is a sink for nitrite-nitrate and is discharging the ammonia from the subsurface water to the downstream segment**.**

A similar response was recorded at Laurel Creek. The site immediately downstream of the dam had low levels of ammonia in the fall and winter. Ammonia was not detected in any season over a two-year period 2.6 miles downstream.

8.6.2 Total Phosphorus

Total phosphorus concentrations at impounded test sites were compared to the nutrient criteria guidelines for each ecoregion (Denton et al, 2001). Approximately three quarters of the test sites exceeded the guidelines. These sites were located in 11 of the 14 ecoregions studied (Figure 58).

Over half the test sites had elevated phosphorus in summer and fall. However, the highest total phosphorus concentration (0.61mg/L) was during the winter on the unnamed tributary to Hancock Branch downstream of an impoundment on Circle H Ranch (71g). During the winter, the stream also did not meet ecoregional expectations for ammonia or total kjeldahl nitrogen. There were only standing pools of water in the fall and no flow in the summer so chemical samples were not collected. This is a small, 12-acre, agricultural pond and cows have access to the stream as it flows over the spillway through a field. The sample site was located 100 yards downstream of the impoundment outside the fenced cow pasture. A house is located near the stream and the lawn is mowed to the stream bank where there is just a narrow riparian zone of brush and shrubs.

The lowest median total phosphorus concentrations were below the detection limit in ecoregions 65e, 67h, 67i, and 68c during the winter/spring season (Figure 59). The highest median concentration (0.14 mg/L) was in the summer and fall in ecoregion 74a. Ecoregion 66d showed the greatest difference between the expected total phosphorus concentration and the median total phosphorus concentration found downstream of dams in any ecoregion.

Two of the four test sites that passed biology in spring and fall exceeded the ecoregion total phosphorus expectation both seasons. At Haley Creek, downstream of Boon-dok Lake in the Western Highland Rim, the percent of nutrient tolerant taxa, which is not included in the index, was above the 90^{th} percentile of reference streams. This metric is used by the state of Kentucky to indicate nutrient enrichment and sedimentation and is currently under review for inclusion in the Tennessee Macroinvertebrate Index. Periphyton were measured at the site in the summer and fall and visible in the winter and spring indicating nutrient enrichment.

The other site was Fall Creek downstream of Ozone Lake on the Cumberland Plateau. Nutrient tolerant taxa exceeded the 90^{th} percentile of first order reference streams in the fall. Microalgae density was also above reference condition in this season. The stream flows through a wooded area. The heavy canopy probably keeps algae levels down.

Flat Creek (66e) is a direct tributary to a trout stream, Rattlesnake Creek (66e) is a direct tributary to a naturally reproducing trout stream, and Roaring Creek (66d) is a naturally reproducing trout stream. They all failed to meet regional expectations for total phosphorus.

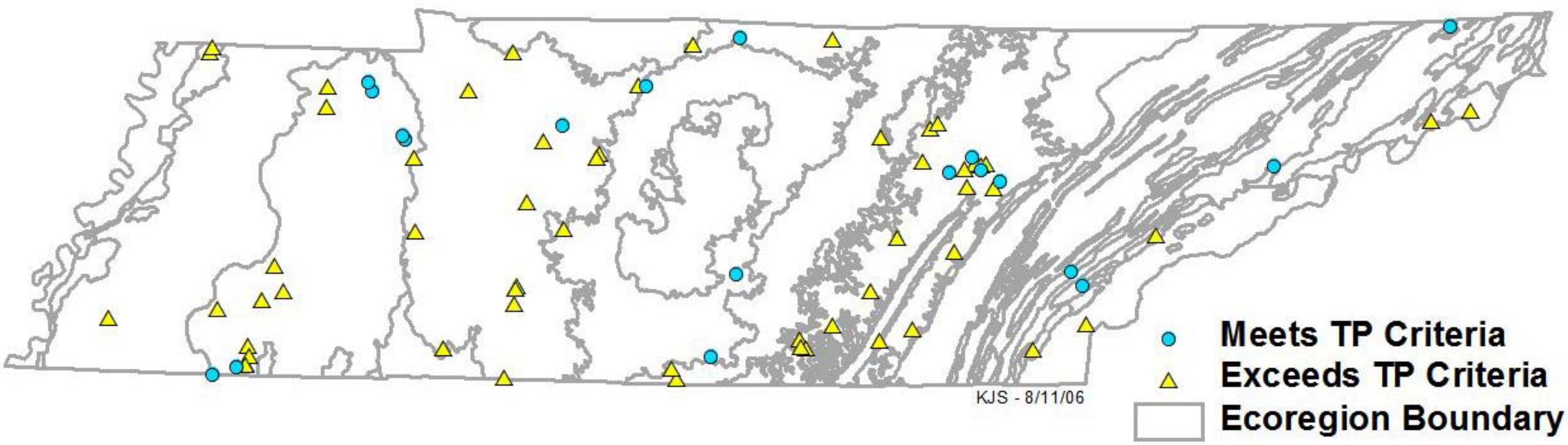

Figure 58: Location of impounded test sites showing comparison of total phosphorus concentrations to regional guidelines.

Roaring Creek was the most problematic of these streams for phosphorus. The spring sample for total phosphorus was undetected but the three other samples exceeded the ecoregion expectation of 0.01 mg/L. The total phosphorus concentration was 0.14 mg/L in the fall, 0.11 mg/L in winter, and 0.02 mg/L in the summer. These levels are as much as 14 times higher than the ecoregional expectation. This dam is one of the oldest built in 1946 and the lake may be eutrophic. It is located in a residential area with homes built around it and fertilizers on the lawns may have accumulated in the lake over the last 50 years. There were measurable amounts of microalgae during the fall periphyton survey and a nutrient froth was observed in the creek by the field staff in winter and summer.

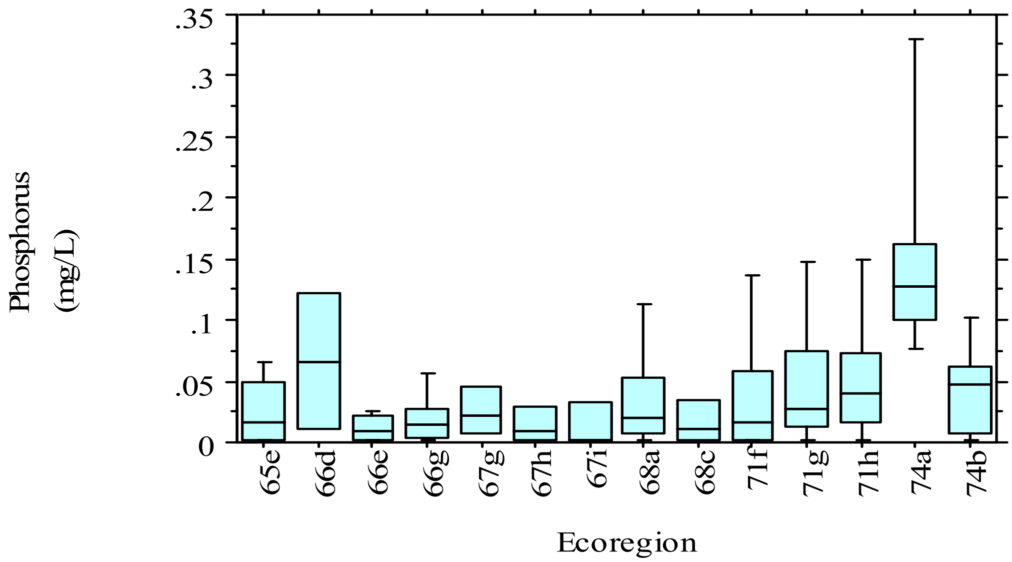

Figure 59: Distribution of total phosphorus concentrations below impoundments in 14 ecoregions.

Roaring Creek is a naturally reproducing trout stream. Total phosphorus levels were well above the regional guidelines every season except spring.

Photo provided by Aquatic Biology Section, TDH.

8.6.3 Total Kjeldahl Nitrogen

Total kjeldahl nitrogen (TKN) concentrations at the test sites were compared to the 90th percentile of reference data for each ecoregion (Table 19). Sixty-five percent of the sites had elevated TKN at least one season (Figure 60). These sites were located in 11 of the 14 ecoregions studied.

Three streams that exceeded regional background levels for TKN, Doddy Creek (71h), Shelton Creek (71h), and a tributary to Sinking Creek (67g) are direct tributaries to trout streams. Roaring Creek (66d), a naturally reproducing trout stream, also had elevated concentrations.

Table 19: 90th percentile of reference TKN data in 14 ecoregions.

Ecoregion	90th Percentile TKN (mg/l)
65e	0.3
66d	0.1
66e	0.1
66g	0.1
67g	0.2
67h	0.2
67i	0.2
68a	0.1
68c	0.1
71f	0.5
71g	0.2
71h	0.1
74a	0.3
74b	0.2

The highest TKN concentration recorded (2.61mg/L) was during the fall on South Fork Hurricane Creek (71f). This site also had elevated TKN in the spring. Ammonia was above reference levels every season sampled. A froth was noticed at the dam outfall every season but fall, when an iron fixing bacterial oil sheen was visible along the edges of the stream. The water had an organic decay odor when sampled during each season but winter. Filamentous macroalgae were above reference levels in the fall. The high nutrient loading is most likely from the reservoir due to eutrophication. There is some toe drain seepage and side seepage from the dam, although the main discharge is surface water through a standpipe.

The lowest median concentration for total kjeldahl nitrogen of test sites below impoundments was below the detection limit for ecoregions 66e, 67i, and 68c in winter/spring and in ecoregions 67i, 68a, 74a, and 74b in summer/fall. The highest median concentration was 0.42mg/L in winter/spring in ecoregion 74a and 0.26mg/L in summer/fall in ecoregion 71g (Figure 61). During the high flow winter/spring season, sites below impoundments in the Outer Nashville Basin (71h) had the greatest difference between reference TKN and the median test site TKN. In Sinking Creek, the site below the dam was above reference levels in the fall. The concentration was six times the amount measured upstream of the reservoir.

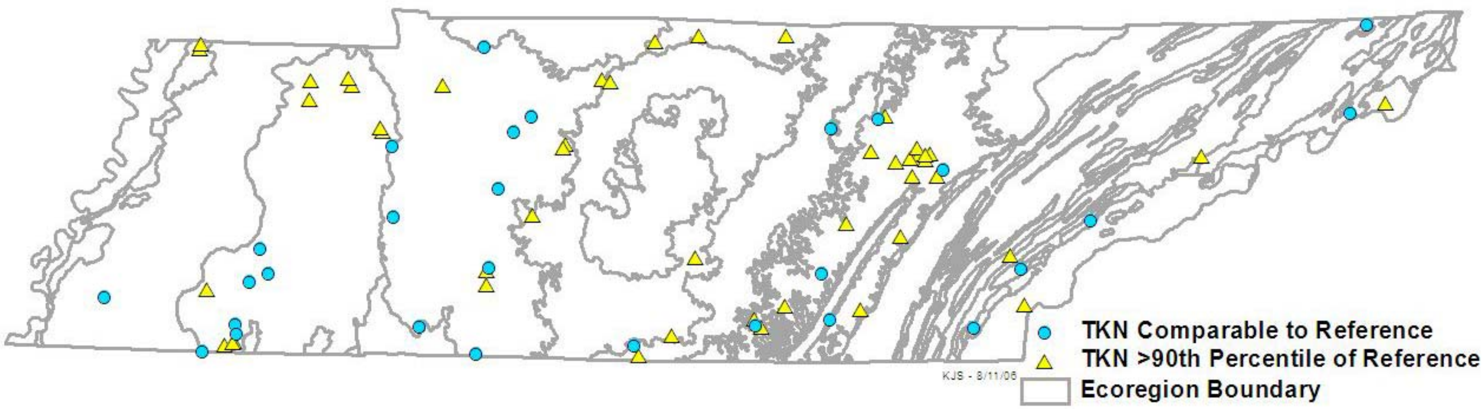

Figure 60: Location of impounded test sites showing comparison of TKN concentrations to 90th percentile of reference data.

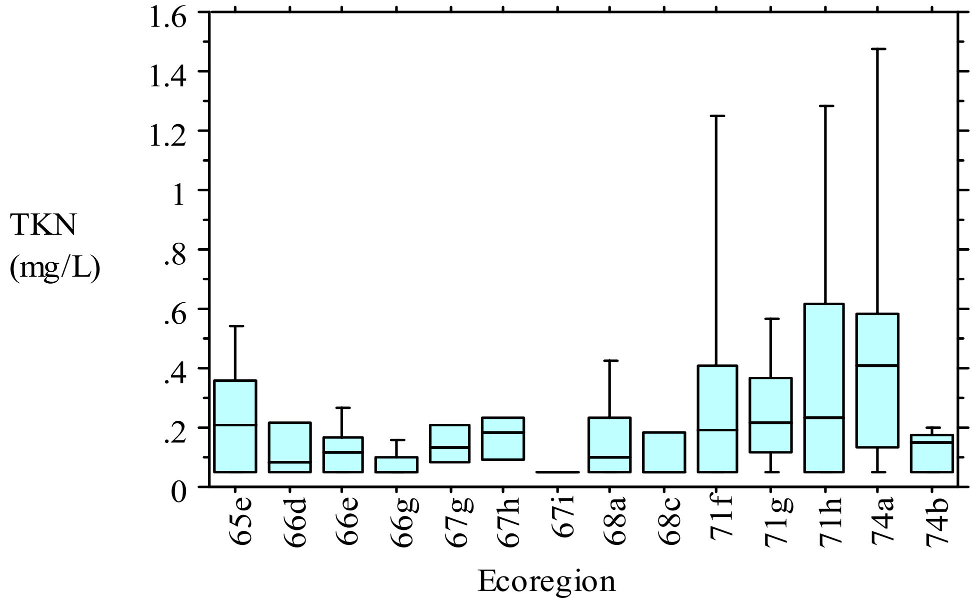

Figure 61: Distribution of TKN concentrations below impoundments in 14 Tennessee ecoregions.

The highest TKN concentrations were observed in South Fork Hurricane Creek downstream of Lakeview Circle Lake. The stream is located in the Western Highland Rim (71f) in Houston County. *Photo provided by Aquatic Biology Section, TDH.*

8.6.4 Nitrate+nitrite

Nitrate+nitrite concentrations at the test sites were compared to the nutrient criteria guidelines for each ecoregion (Denton et al, 2001). Forty one percent of the sites exceeded the guidelines. These sites were located in ecoregions 65e, 71f, 71h, 71g, 68a, and 67i (Figure 62). More than half the test sites that did not meet regional expectations failed during the winter and spring sampling periods when flow is highest.

The highest nitrate+nitrite concentration recorded (2.71 mg/L) was during the winter on Thompson Creek (THOMP005.9WY) in the Southeastern Plains and Hills. The creek had very little flow at the time (0.004 cfs). This site also failed to meet the ecoregion guidelines of 0.34 mg/L in the spring when the creek was almost stagnant. These were the only two seasons the creek had any flow. The site is located 80 yards downstream of the 183-acre Garret Lake. Garret is a TWRA fishing lake that is fertilized to promote fish production. The outfall from the dam is a surface water discharge. This site not only had elevated nitrate+nitrite problems but other nutrients were above background levels as well. The stream could not be surveyed for periphyton density since there was no summer or fall discharge from the lake, but a moderate level of algae was observed by field staff in the spring. An assessment of the lake and Thompson Creek was conducted ten years earlier. The lake was found to be eutrophic and the creek nutrient enriched (Arnwine, 1996).

The lowest median concentration of nitrate+nitrite below impoundments was 0.02 mg/L during the winter/spring season in ecoregion 66g (Figure 63). There was only one test site in this ecoregion, a first order tributary to Hot Water Branch. Although there was microalgae present during the summer sampling period and nitrate+nitrite was detected at each sampling event, the concentration was never above the ecoregion guidelines. Other nutrients were above ecoregion expectations including total kjeldahl nitrogen and total phosphorus which may be factors in the presence of the algae.

The highest median concentration was 1.63 mg/L in ecoregion 67i. This was the only ecoregion where the median was above the nitrate+nitrite criteria guidelines. Steele Creek was the only test site in this ecoregion. The lake is surrounded by a golf course, which may be one factor in the elevated levels of nitrate+nitrite. The site did not meet ecoregion guidelines during the winter or spring sampling periods when rainfall and runoff is highest. Filamentous algae were observed in the stream during the winter but not in other seasons. The stream was at bankfull in the spring with a measured flow of 109 cfs which may have washed the algae from the substrate. The lake was drained in the fall and the channel was dry. Flow was good the rest of the year. The site passed biocriteria in the fall but not in the spring when over 80% of the sample was comprised of nutrient tolerant taxa and only two EPT were found.

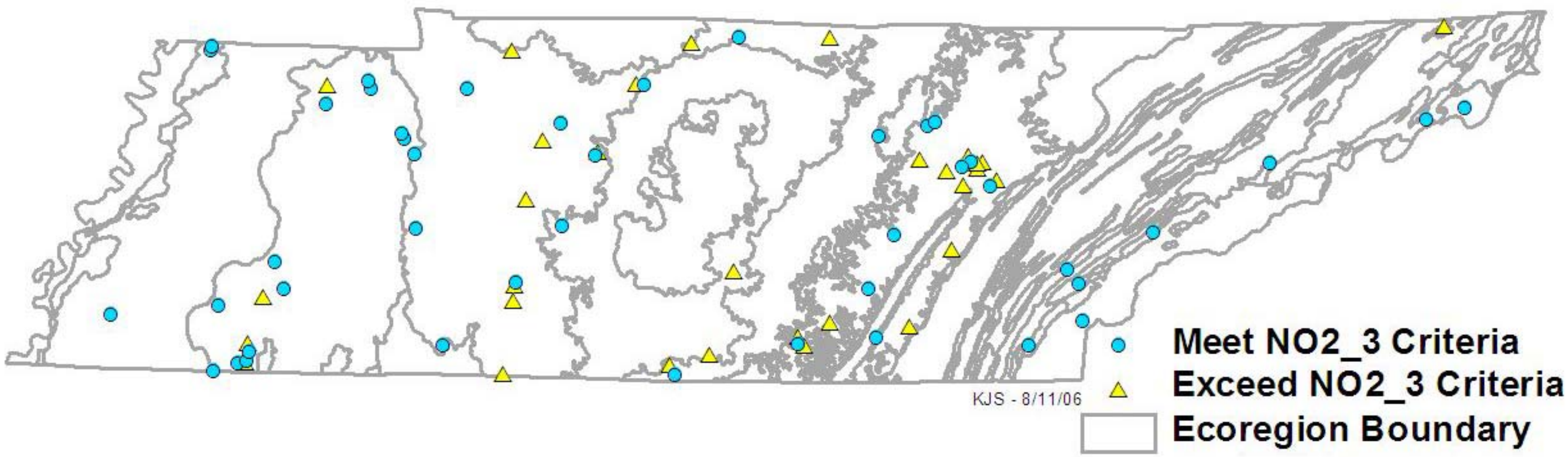

Figure 62: Location of impounded test sites showing comparison of nitrate+nitrite concentrations to regional guidelines.

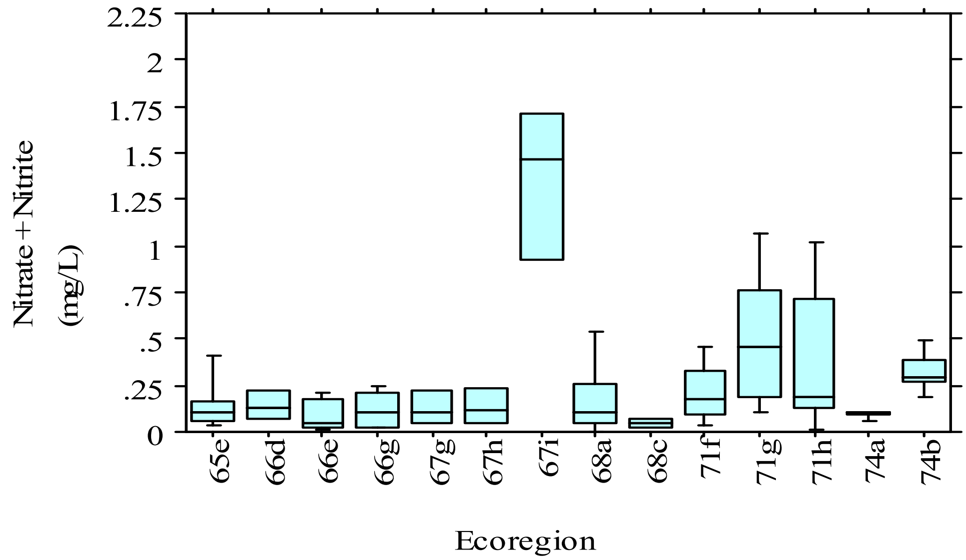

Figure 63: Regional distribution of nitrate+nitrite concentrations downstream of impoundments in 14 ecoregions.

Two sites that passed biocriteria in the spring did not meet nitrate+nitrite criteria in the spring. These sites include South Fork Sycamore Creek (71f) and Duncan Creek (68a). South Fork Sycamore Creek downstream of Browns Lake in the Western Highland Rim (71f) failed to meet nitrate+nitrite guidelines of 0.32 mg/L in the winter and spring. Both filamentous and microalgae were measured at the site in the summer and fall. The lake was choked with aquatic plant life at the spillway. The site passed biocriteria in the spring, but only scored 8 in the fall and was almost entirely composed of nutrient tolerant organisms. There were no EPT found. This is one of the oldest impoundments in the study, constructed in 1935. There is a larger impoundment upstream from this impoundment.

At Duncan Creek, a small amount of macroalgae were present in the fall when nitrate+nitrite concentrations were also elevated. This stream is over 90% shaded and does not provide enough sunlight for algae to proliferate despite high nutrient concentrations. However algal growth could become denser in downstream reaches if the canopy opens up. The macroinvertebrate community failed to pass biocriteria in the fall. Dredging and channelizing activity occurring in the creek immediately below the dam was probably a big factor. The macroinvertebrate community only scored a 12 in the fall with an abundance of tolerant organisms and few EPT. The site passed biocriteria in the spring although it still failed individual biometrics such as the number and abundance of EPT.

One of the sites that passed biology in the fall, Buck Creek on the Cumberland Plateau (68a), did not meet any nutrient guidelines. Macroalgae covered 31% of the substrate but the fall benthos were not affected. The site did fail to meet biocriteria in the spring with a loss of EPT taxa and an increase in worms and midges.

Haley Creek downstream of Boon-dok Lake in ecoregion 71f was one of the few sites that passed biocriteria in both spring and fall. The percent of nutrient tolerant taxa, which is not included in the index, was above the 90th percentile of reference streams. Nitrate+nitrite was slightly elevated in the winter with a concentration of 0.34 mg/L. Filamentous macroalgae was above reference levels when measured in the summer and fall. Algae were observed every season, indicating nutrient enrichment.

Two streams that failed to meet the regional guidelines are direct tributaries to stocked trout streams. The sites on Doddy and Shelton Creeks did not pass biocriteria when they were sampled in spring or fall. Both impoundments have surface water discharge. The elevated nitrate+nitrite in winter and total kjeldahl nitrogen in spring may have affected the biology of these streams in spring. Each time these sites were sampled, algae were observed. Filamentous algae were above reference conditions when measured in the summer and fall at Doddy Creek. Although periphyton was present in Shelton Creek, the summer and fall density was below reference conditions. However, a smell of organic decay was noted by field staff in the winter. The biologists indicated algae covered more of the substrate in the spring than during the fall and summer periphyton surveys.

At Laurel Creek, nitrate+nitrite was three times higher immediately below the dam than 2.6 miles downstream at the ecoregion reference station. One hundred percent of the substrate below the dam was covered by microalgae in the summer. Macroinvertebrates failed to meet biocriteria guidelines in the spring and fall.

The highest nitrate+nitrite concentrations were measured in the winter at Thompson Creek downstream of Garret Lake. The reservoir is in Weakley County in the Southeastern Plains and Hills (65e). *Photo provided by Aquatic Biology Section, TDH.*

9. PERIPHYTON DENSITY BELOW IMPOUNDMENTS

The periphyton community is comprised of sessile algae that inhabit the surfaces of underwater rocks and other stable substrates. They are the primary producers in the stream ecosystem turning nutrients into food for aquatic macroinvertebrates and fish. For the purposes of this study, periphyton were divided into two broad categories, macroalgae and microalgae. Macroalgae are long filamentous strands of green algae such as *Cladophora* or *Spirogyra* spp. Microalgae are primarily single celled algae which coat the substrate and are generally composed of diatoms or blue-green algae.

Excessive algal growth can reduce biodiversity by making rock habitat unsuitable for benthic fish and macroinvertebrates and by altering diurnal dissolved oxygen patterns. Dense algae levels are generally associated with an increase in tolerant macroinvertebrates.

Due to the sedentary nature of periphyton, the community composition and biomass are sensitive to changes in water quality. A diverse assemblage of periphyton can be found in healthy streams. Nuisance blooms are usually symptoms of a system stressed by factors such as excessive nutrients, elevated temperatures, or stagnant conditions.

Algal growth is influenced by canopy cover, time available to grow since the last flood, streambed stability, water velocity, nutrients and grazing by aquatic fauna. Impoundments have the potential to directly or indirectly affect these factors. By controlling the discharge of water, stream flow is artificially altered. Very low flow or stagnant conditions provide a good environment for algal growth. High fast flows dislodge and scour out algae. Streamside vegetation is often removed for the construction and maintenance of the dam as well as for recreation uses associated with the dam. This increases the amount of sunlight available to algae and promotes erosion. Impoundments often act as nutrient sinks concentrating runoff from surrounding land uses. Increased algae populations cause a shift in the macroinvertebrate community to grazers and other animals that eat algae.

Several nutrients and metals are required to complete the photosynthesis process and stimulate algal reproduction and growth (Figure 64). An increase in the availability of these components can result in an increase in periphyton density. Nitrogen is needed in the greatest amounts and is used in two primary areas. It is assimilated into the nicotinamide adenine dinucleotide phosphate (NADP) enzyme (Irrgang, 1999) and it is an important component of the chlorophyll structure (Whitmarsh and Govindjee, 1999). Phosphorus is another significant nutrient and is a key element in the production of adenosine triphosphate (ATP) synthase, an enzyme that carries energy through the photosynthesis process (Strotmann and Shavit, 1999).

Manganese and iron are essential metals in photosynthesis. Four manganese ions form a water-oxidizing complex, which splits water molecules and forms a free oxygen molecule (O_2). This allows the hydrogen molecules to be added to the carbohydrate (Renger, 1999). Iron clusters transfer electrons to $NADP^+$ (Fromme, 1999).

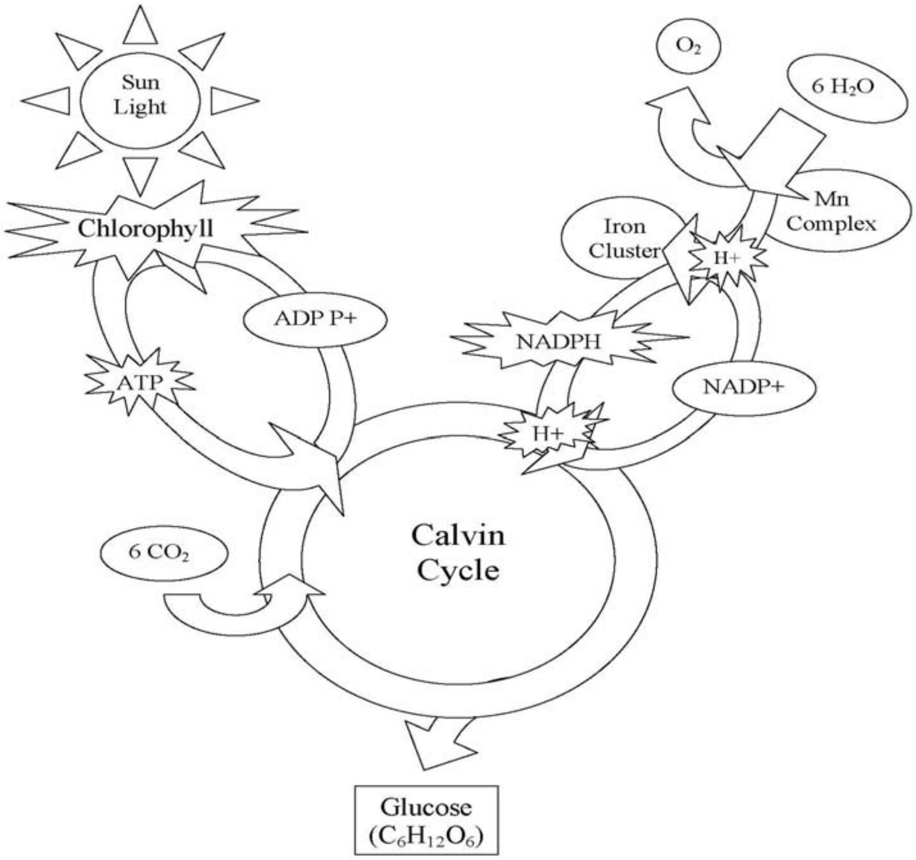

Figure 64: The role of nutrients and metals in the photosynthesis cycle.

Periphyton surveys were conducted at the impounded test sites in the low flow seasons, fall 2003 and summer 2004. Seventy-one of the sites had enough flow to conduct a survey at least one season. Periphyton surveys were conducted at least once at 71 sites (Appendix E). Four sites did not have flow in either of the survey seasons (Fall 2003 and Summer 2004). The density of algae on substrate at each site was statistically characterized by determining:

a. Percent of macroalgae present
b. Percent of substrate available for microalgae colonization
c. The maximum thickness rank of microalgae
d. The mean thickness rank (mean density) of microalgae
   Mean THR = $\Sigma\, d_i r_i / d_t$
   Where d_i = number of grid points (dots) over microalgae of different thickness ranks
   r_i = thickness rank of algae
   d_t = total number of grid points over suitable microalgae substrate at the site

The thickness rank represents the following algal density:

0	No microalgae
0.5	Substrate slimy, but no visible accumulation of microalgae
1	A thin layer of microalgae, less than 0.5 mm thick
2	Accumulation of microalgal layer from 0.5-1 mm thick
3	Accumulation of microalgal layer from 1 to 5 mm thick
4	Accumulation of microalgal layer from 5 mm to 2 cm thick
5	Accumulation of microalgal layer greater than 2 cm thick

Project specific first order reference streams and larger established reference streams were used to determine whether periphyton density at each impounded site were excessive or comparable to natural levels. The randomly selected test sites were in 14 ecoregions. Reference data were compiled and used to determine natural periphyton density for each ecoregion. Test data were compared only to the data from the ecoregion where the site was located and to reference streams of equivalent size.

Microalgae test data were compared to two measures; the maximum thickness rank recorded at any of the reference surveys and the average mean thickness rank of all the reference surveys in that ecoregion. Filamentous macroalgae test data were compared to the average amount of macroalgae measured at the ecoregion reference sites. If test sites were smaller than the established reference sites in a given ecoregion, first order project specific reference streams were monitored, insuring that streams of comparable size were evaluated.

For example, on the Cumberland Plateau (68a) six established ecoregion reference sites had existing periphyton data. The maximum thickness rank recorded at any Cumberland Plateau reference site was a slime layer with no visible accumulation (0.5). The average mean thickness rank of all the Cumberland Plateau ecoregion reference surveys was 0.12. Any creek of comparable size with more algae present than was found at the ecoregion reference sites was considered to have higher periphyton levels than natural conditions.

There were four impounded streams in the Cumberland Plateau within this size range. Buck Creek (BUCK001.2CU) had no microalgae present and Savage Creek (SAVAG009.8SE) had microalgae levels equal to the ecoregion reference sites. Falls Creek (FALLS000.5VA) had maximum and mean thickness ranks higher than the ecoregion reference sites. The Obed River (OBED040.2CU) had a higher mean thickness rank than the ecoregion reference sites (Figure 65). Graphical comparisons for all 14 ecoregions are provided in Appendix E.

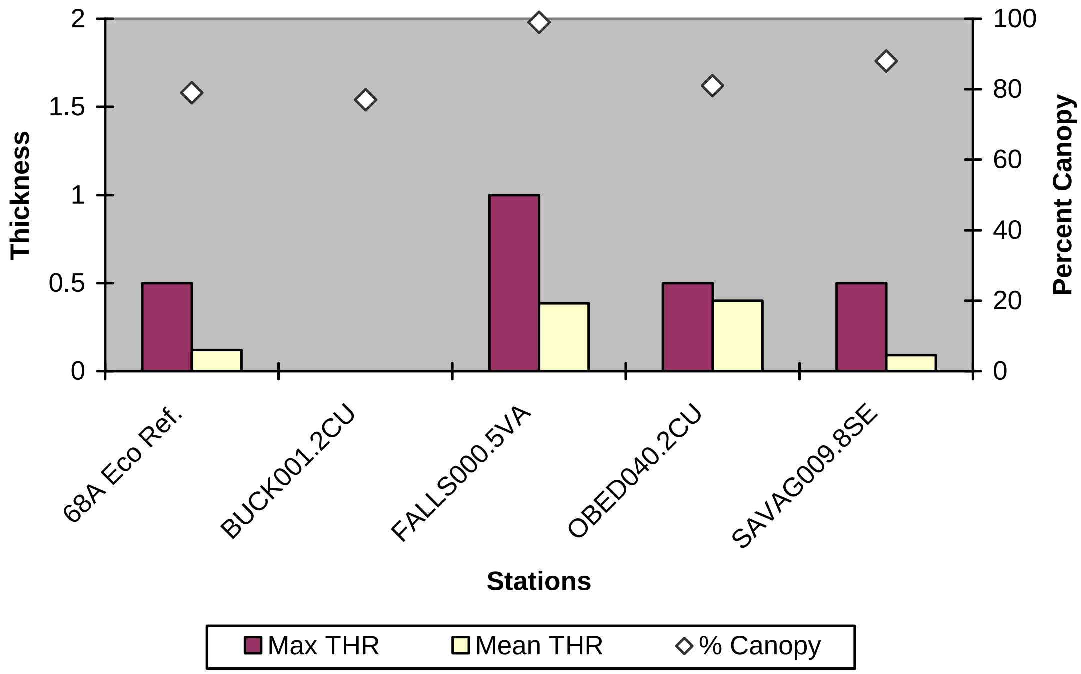

Figure 65: Microalgae and canopy at six ecoregion reference sites and four impounded test sites in 68a. The maximum thickness rank is the single highest reading and the mean thickness rank is the average value of all survey dates. Percent canopy is the date with the highest maximum thickness rank or with the highest percent of available substrate.

In the same ecoregion, 14 of the first and second order test streams had smaller drainage areas than the ecoregion reference streams. Therefore, a first order reference site in the same ecoregion, Douglas Creek (FECO68A01), was selected and surveyed for periphyton. Very little microalgae were recorded at this reference site. The maximum thickness rank was a slime layer with no visual accumulation (0.5) and the average mean thickness rank was only 0.01.

Microalgae were not observed at 71 percent of the first and second order impounded sites. Little Fiery Gizzard Creek (LFGIZ003.4GY) had about the same amount of microalgae as the first order reference creek. Fall Creek (FALL007.6CU) had a higher mean thickness rank. Looper Branch (LOOPE001.0OV) and Mammy's Creek (MAMMY010.1CU) had more microalgae than the first order reference sites (Figure 66).

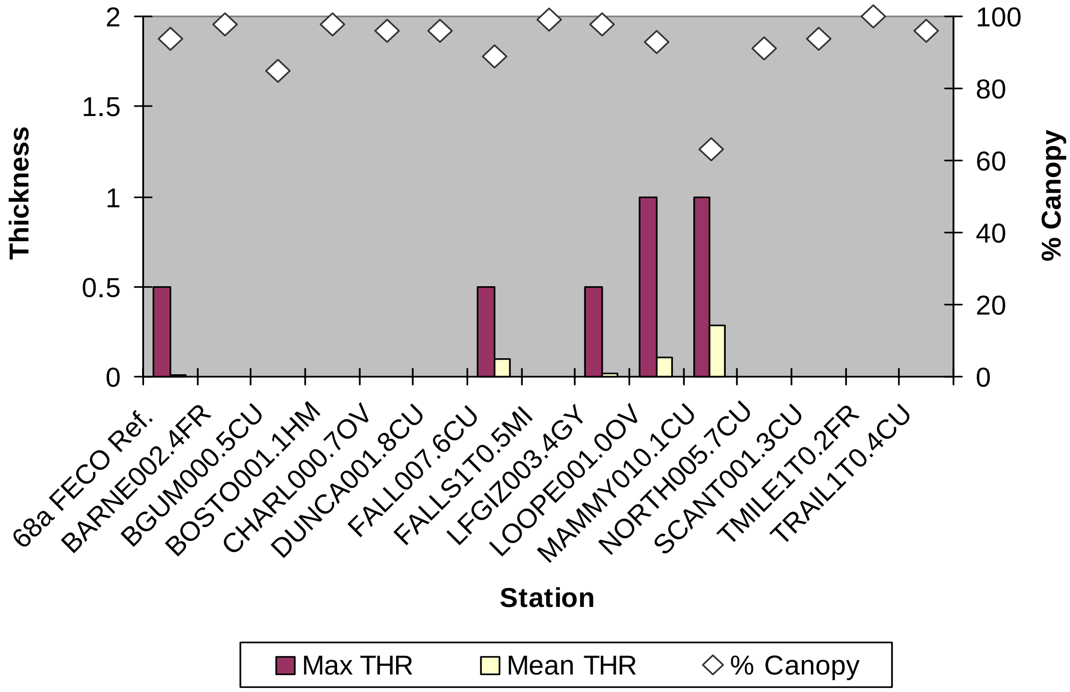

Figure 66: Microalgae and canopy at one first order reference site and 14 first and second order impounded sites in 68a. The maximum thickness rank is the single highest reading and the mean thickness rank is the average value of all survey dates. Percent canopy is the date with the highest maximum thickness rank or with the highest percent of available substrate.

Periphyton were observed in most of the 14 ecoregions included in this study (Table 20). Test sites in five ecoregions, Southern Igneous Ridges and Mountains (66d), Southern Metasedimentary Mountains (66g), Southern Dissected Ridges and Knobs (67i), Cumberland Escarpment (68c), and Loess Plains (74b) had periphyton densities comparable to the ecoregion reference sitess.

Half of the sites below impoundments had periphyton density comparable to reference sites (Figure 67). Microalgae were elevated at least one season at 22 sites while macroalgae were elevated at 14 sites (Figure 68). Ecoregion reference, first order reference, and test sites periphyton survey results are provided in Appendix E, Tables 1 and 2.

Table 20: Periphyton density at impounded test sites by ecoregion.

	Fall 2003			Summer 2004			Total		
Eco-region	Natural Algae Density	Elevated Micro-algae	Elevated Macro-algae	Natural Algae Density	Elevated Micro-algae	Elevated Macro-algae	Natural Algae Density	Elevated Micro-algae	Elevated Macro-algae
65e	7	4		12	1		19	5	
66d	1			1			2		
66e	2	1		2	1		4	2	
66g	1			1			2		
67g	1	1		2			3	1	
67h		1		1			1	1	
67i				1			1		
68a*	6	5	3	13	4		19	9	3
68c	1			1			2		
71f	8	4	3	7	5	3	15	9	6
71g	4	1		4			8	1	
71h	2		3	3		1	5		4
74a			1	2			2		1
74b	1			2			3		
* One site had both elevated microalgae and macroalgae									

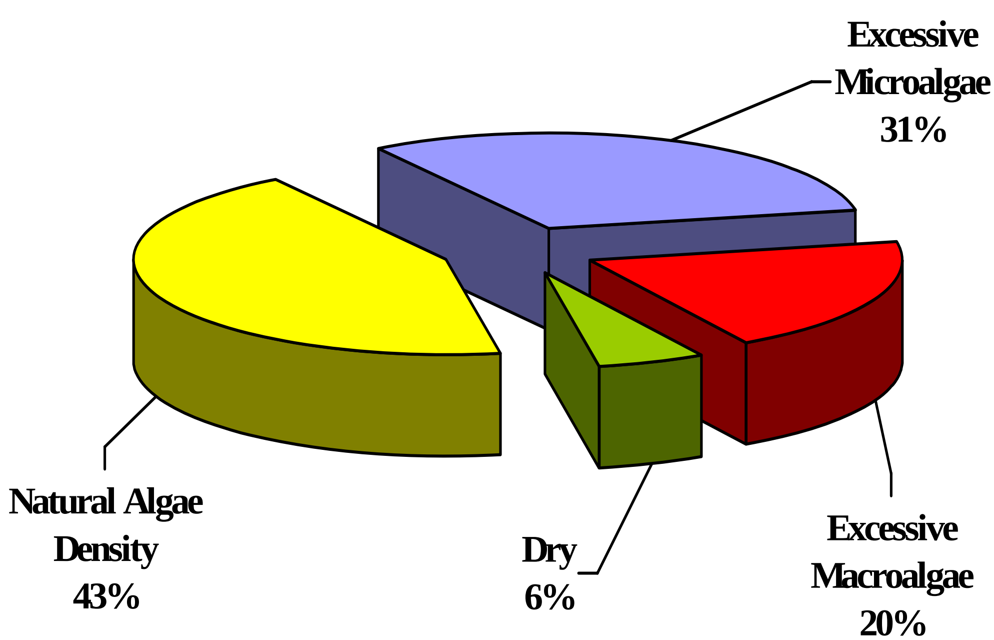

Figure 67: Periphyton density below impoundments.

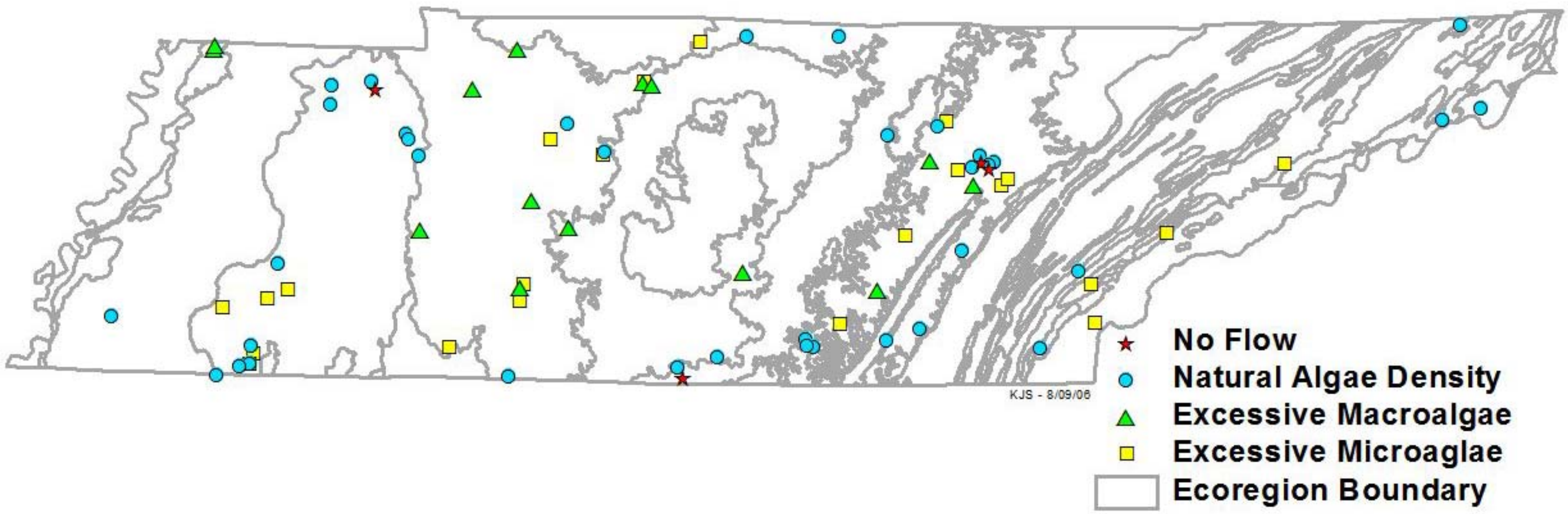

Figure 68: Results of periphyton abundance surveys at 71 streams below impoundments.

In fall, 82 percent (58) of the study sites had sufficient water levels to conduct periphyton surveys. Of these, almost half (43%) had periphyton densities higher than ecoregion reference streams. Of the remaining test sites with flow, almost twice as many had excessive microalgae than filamentous macroalgae (Figure 69).

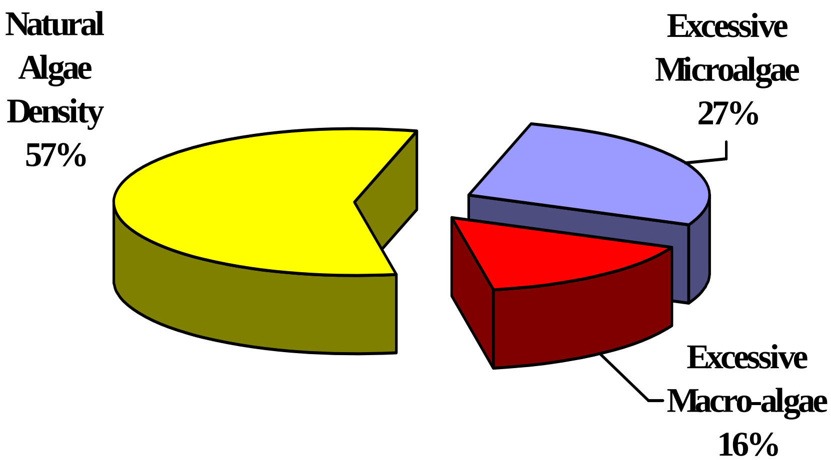

Figure 69: Fall 2003 periphyton density at 58 impounded streams with sufficient flow to conduct survey.

More of the study streams, 94 percent (67 sites), had enough flow to conduct periphyton surveys in summer 2004. A greater number of sites (78 percent) were comparable to the ecoregion reference streams (Figure 70). This may be due to the denser canopy cover in summer before leaves fall and the increased flow. Once again microalgae were more abundant than macroalgae.

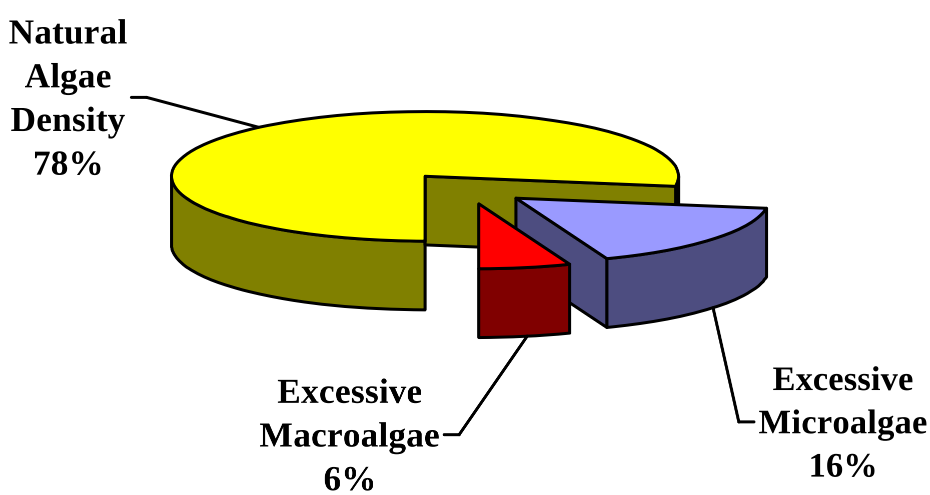

Figure 70: Summer 2004 periphyton density at 67 impounded streams with sufficient flow to conduct survey.

9.1 Macroalgae

Filamentous macroalgae density above reference levels were recorded at 13 impounded test sites in five ecoregions (Table 21). At three of these sites, macroalgae were abundant in both fall and summer. None of the reference sites in these regions had any macroalgae.

A reference site in ecoregion 71g had macroalgae in greater abundance that the test site on West Fork Drakes Creek. This was the only test site where algae was present but was not elevated. Most of the sites with elevated macroalgae were located in the Outer Nashville Basin (71f) and the Western Highland Rim (71h).

Beasley Hollow downstream of Shellcracker Lake in Maury County had the most macroalgae of any site covering over 80% of the available substrate in both fall 2003 and summer 2004. Dissolved oxygen was below 4 mg/L both seasons. *Glyptotendipes* spp. a midge tolerant of eutrophic conditions was the dominant organism in the fall at this site. One stream in the Bluff Hills (74a), Tull Creek (TULL000.3OB), had dead filamentous algae wrapped around trees above water line. Apparently, this site had abundant macroalgae that had been dislodged by recent high flows.

Manganese, an essential element in the photosynthesis process, was above the 90th percentile of reference data every time macroalgae were elevated (Figure 71). However, it should be noted that manganese was above the 90^{th} percentile of reference condition at most impounded sites whether algae were present or not. Iron was above 1000 ug/l at half the surveys with macroalgae.

Ammonia was the most abundant nutrient at these sites having concentrations above the 90th percentile of reference condition 76 percent of the time. In anaerobic conditions such as the bottom of lakes or stagnant water it is the most common form of nitrogen. Under natural conditions nitrate is generally more abundant in flowing waters (Baird, 1999). Another nutrient, total phosphorus, was elevated 65 percent of the time.

Dissolved oxygen saturation levels were below the levels needed to sustain aquatic life in 76 percent of the surveys where macroalgae were abundant. The necessary saturation level for each ecoregion was based on reference data (Arnwine and Denton, 2003). Dissolved oxygen was supersaturated (106%) at South Fork Sycamore Creek downstream of Browns Lake in Davidson County in the summer.

Table 21: Surveys with macroalgae density above reference condition.

Eco-region	Station	Date	% Macro-algae	% Canopy	% Substrate	Criteria Violations or Elevated Chemical Paramteters
68a	BUCK001.2CU	11/5/03	31	77	47	Mn, NH_3, TP, TKN, Fe, DO, %DO
68a	DUNCA001.8CU	11/12/03	1	96	97	Mn, NH_3, NO_2+NO_3, TP, Fe, DO, %DO
68a	SAVAG009.8SE	11/10/03	11	90	82	Mn
71f	BARTE001.4MT	7/13/04	2	49	24	Mn, NH_3, NO_2+NO_3, TP, Fe , %DO
71f	GOODI001.1DE	7/09/04	43	3	57	Mn, TP, Fe, %DO
71f	HALEY003.2HI	10/9/03	6	90	90	Mn, NH_3, TP, Fe, %DO
71f	HALEY003.2HI	7/15/04	8	90	24	Mn
71f	SFSYC006.3DA	10/10/03	5	67	95	Mn, NH_3, TP
71f	SFSYC006.3DA	7/13/2004	21	66	79	Mn, Temp., %DO
71f	SQUAW001.4LS	10/16/03	13	90	59	Mn, NH_3, TP, DO, %DO
71f	SFHUR003.6HO	7/8/2004	1	94	68	Mn, NH_3, TP, Fe, DO, Temp, %DO
71h	BEASL000.4MY	10/10/03	83	24	13	Mn,, NH_3, TP, TKN, DO, %DO
71h	BEASL000.4MY	7/15/04	94/69	67/56	31	Mn, NH_3, TKN, DO, %DO
71h	DODDY001.9BE	11/15/03	1	93	91	Mn, NH_3, TKN, %DO
71h	WALKE1T0.3DA	10/10/03	18	71	58	Mn, NH_3, TKN, Fe, %DO
74a	TAYLO000.7OB	10/08/03	66	65	6	Mn,, NH_3, TP, TKN, Fe, DO, %DO
74b	TULL000.3OB	07/07/04	Dead	94	4	Mn, NH_3, TP, Fe, %DO

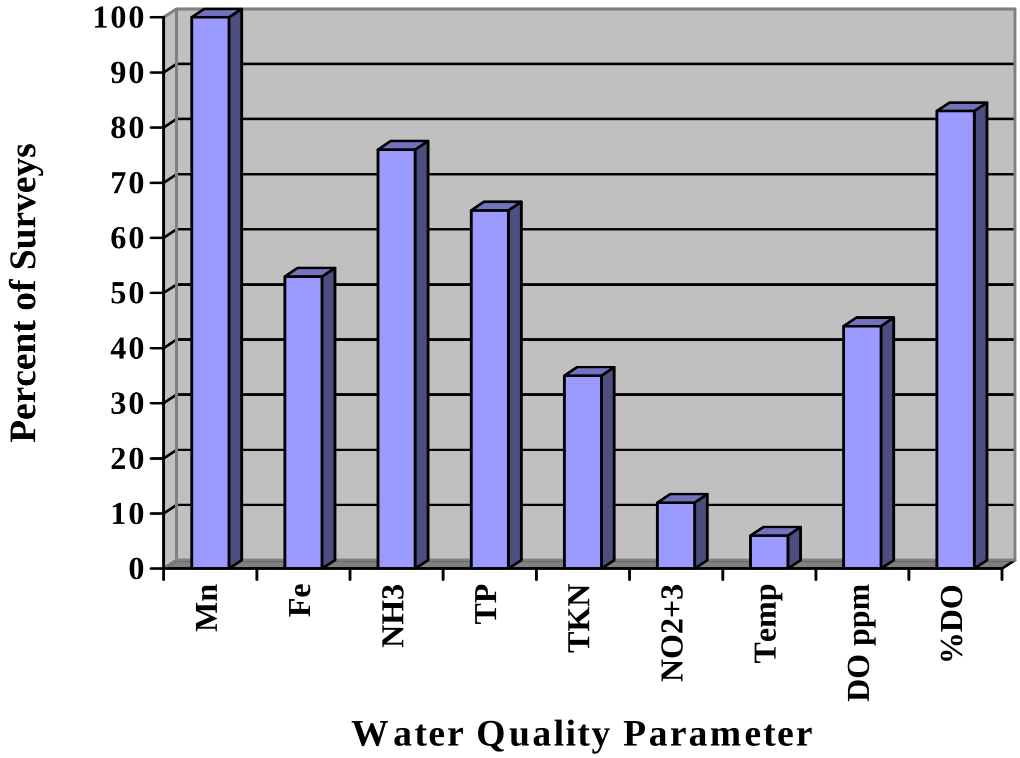

Figure 71: Percent of nine water quality parameters not meeting criteria or outside reference levels at 14 impounded sites with elevated macroalgae. The 90^{th} percentile of reference data was used for Mn, NH3 and TKN. The 10^{th} and 90^{th} percentiles were used for dissolved oxygen saturation (%DO).

Multiple linear regression analyses (adjusted R^2) were calculated to determine if a direct correlation existed between macroalgae density, water quality parameters (TKN, ammonia, nitrate+nitrite, manganese, and iron), and physical habitat components (percent substrate and percent canopy). The coefficient of determination (R^2) is the proportion of a dependent variable that is explained by the independent variables (maximum value of 1). For example, an R^2 of 0.70 means that 70% of the dependent variable's variation is explained by the independent variable.

When additional independent variables are assigned to an existing regression value the coefficient of determination is guaranteed to increase. Therefore, the R^2 was adjusted by applying a penalty to the value based on the number of variables assigned in multiple regression analysis (SAS, 1999). Correlations with a *p*-value less than 0.05 were considered statistically significant.

Only 17 surveys had measurable macroalgae present, therefore, visual interpretations of histograms were used to check for normalcy of data. Most of the tested parameters had normal distribution. Log transformations were used to normalize manganese and nitrate+nitrite data.

The strongest direct correlations with percent macroalgae were with nutrients and percent canopy. The most robust simple regression relationship was found between percent macroalgae and TKN with an R^2 of 0.502. The relationship between macroalgae and TKN was strengthened when percent canopy was considered, resulting in an adjusted R^2 of 0.741. The strongest correlations were found between macroalgae, nitrogen constituents (TKN and nitrate+nitrite), and the physical component (percent canopy) resulting in an adjusted R^2 of 0.774. When additional parameters were analyzed the correlations were reduced, so available nitrogen and the amount of sunlight have the strongest relationship with the amount of filamentous green algae able to grow in a stream. Sites with less than 70% canopy had the most abundant filamentous algae.

Taylor Branch downstream of Reelfoot-Indian Creek Dam #7 had 66% of the substrate covered with filamentous macroalgae.

Photo provided by Aquatic Biology Section, TDH.

9.2 Microalgae

Thirty one percent of the impounded streams had a higher abundance of microalgae in one or both of the surveys than was found at the ecoregion reference sites. Microalgae density was elevated below impoundments in seven of the ecoregions represented in this study. Over three quarters of the sites were located in three ecoregions: Southeastern Plains and Hills (65e), Cumberland Plateau (68a), and Western Highland Rim (71f).

Eighty-six percent of the sites with a high density of microalgae had elevated nitrogen levels in the form of ammonia, TKN or nitrate+nitrite (Table 22). Ammonia was the most commonly encountered form of nitrogen, occurring above background levels in 59 percent of the sites with high microalgae density (Figure 72). This form of nitrogen must be broken down to nitrate before utilization by algae for photosynthesis. Nitrate+nitrite was only elevated above regional guidelines at nine percent of the sites with elevated microalgae.

Total phosphorus was elevated at half of the sites with microalgae. No significant correlations were found between microalgae density and any combination of physical or chemical parameters. This may be due to the more diverse community structure of microalgae while macroalgae is usually dominated by one or two species.

Microalgae can grow in some shade as well as full sunshine. Many of the sites with dense microalgae had relatively good canopy cover. The minimum canopy measurement was 70 percent shade at 65 percent of the surveys with elevated microalgae. This may be explained by the dominance of diatoms at some sites. Diatoms have both chlorophyll *a* and *c*. Chlorophyll *c* requires less light for photosynthesis than chlorophyll *a* or *b*, the chlorophyll found in green macroalgae (Douglas et al, 2003). This allows diatoms to grow and reproduce in more shaded areas than filamentous or blue-green algae. However, un-shaded streams were more likely to have thicker algal layers. For example, an unnamed tributary to Jones Creek in Dickson County only had 45% canopy in the fall. It had the highest density of microalgae in the form of blue-green algae of any site with 100% of the substrate covered up to 2 cm thick. In summer, canopy was 93% and no periphyton were present in the same sample reach.

The unnamed tributary to Jones Creek (JONES1T0.2DI) in Dickson County downstream of Greystone Golf Course had the highest microalgae density recorded during the study period.

Photo provided by Aquatic Biology Section, TDH.

Table 22: Surveys with microalgae density above reference condition.

Station ID	Eco	Date	% Micro -algae	Max THR	Mean THR	Avg. % Canopy	Min. Canopy	Elevated Parameters
GRAY1T0.9HR	65E	10/8/03	53	0.5	0.27	93	85	NO_2+NO_3, TP, %DO
ODAIN000.3HR	65E	10/7/03	38	0.5	0.19	13	7	NH_3
PINEY014.6CS	65E	10/9/03	44	1	0.44	92	80	NH_3
STEWA003.4HR	65E	10/8/03	50	0.5	0.25	97	94	Mn, NH_3, TP, Fe
THOMP1T0.4HR	65E	7/7/04	23	0.5	0.11	75	56	NH_3., TP, %DO
FLAT002.4BT	66E	10/27/03	2	2	0.08	98	96	Mn, NH_3, TP, Fe, %DO
HWATE1T0.1MO	66G	7/20/04	100	0.5	0.06	82	52	Mn, Fe, DO, %DO
SINKI1T0.8CO	67G	10/29/03	100	1	0.84	40	0	TKN
LAURE003.4MO	67H	10/28/03	6	0.5	0.03	96	90	Mn, NH_3
FALLS000.5VA	68A	10/30/03	68	1	0.56	99	96	Mn, NH_3, TKN
FALLS000.5VA	68A	7/22/04	100	0.5	0.21	92	78	Mn, NH_3.
OBED040.2CU	68A	7/27/04	82	0.5	0.4	81	80	Mn
FALL007.6CU	68A	11/6/03	38	0.5	0.19	89	78	Mn, TP
LFGIZ003.4GY	68A	11/6/03	6	0.5	0.03	98	95	Mn, TKN, %DO
LOOPE001.0OV	68A	7/21/04	18	1	0.11	93	90	Mn, %DO
MAMMY010.1CU	68A	11/6/03	76	0.5	0.38	63	36	Mn, Fe
MAMMY010.1CU	68A	7/21/04	25	1	0.19	80	71	Mn, NO_2+NO_3, %DO
BEAR003.6WE	71F	10/13/03	76	1	0.46	93	71	Mn, %DO
BEAR003.6WE	71F	7/14/04	86	1	00.47	86	77	Mn, TP
CHIEF004.6LS	71F	10/13/03	63	2	0.44	19	0	Mn
CHIEF004.6LS	71F	7/12/04	94	2	0.77	14	0	Mn, NH_3, TP
WEAVE001.0LW	71F	7/13/04	82	0.5	0.41	95	91	Mn, NH_3, TP, TKN, DO, %DO
JONES1T0.2DI	71F	10/6/03	100	4	1.76	45	32	Mn, NH_3
SFSYC006.3DA	71F	10/10/03	13	1	0.07	67	42	Mn, NH_3, TP
SHARP2T0.6DA	71F	7/13/04	97	0.5	0.48	86	78	Mn, NH_3, TKN, TP, Fe, %DO
WFDRA2T1.5SR	71G	10/6/03	47	1	0.25	88	79	Mn, NH_3, TKN, TP

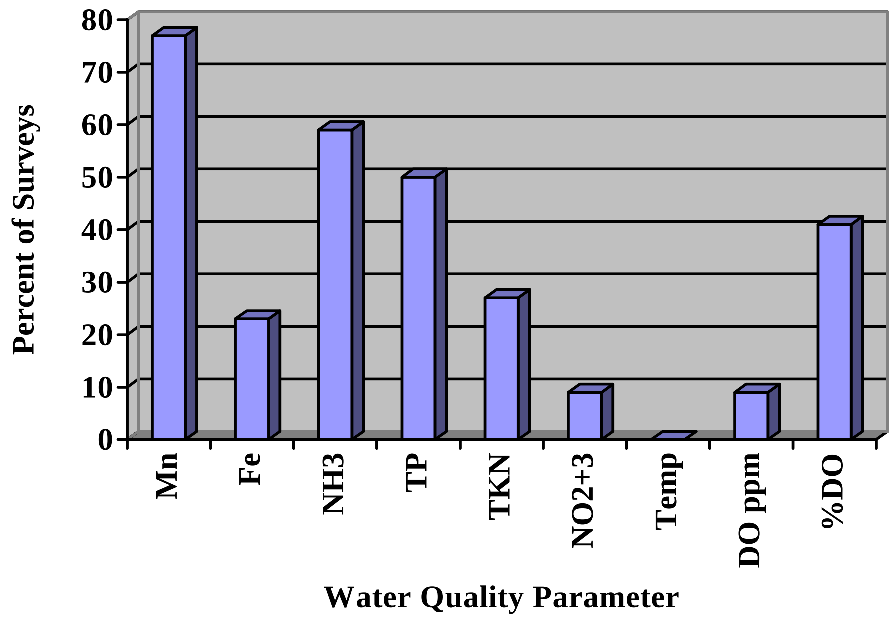

Figure 72: Percent of nine water quality parameters not meeting criteria or outside reference levels at 22 impounded sites with elevated microalgae. The 90th percentile of reference data was used for Mn, NH3 and TKN. The 10th and 90th percentiles were used for dissolved oxygen saturation (%DO).

9.3 Periphyton at Streams with Multiple Stations

At the test site located upstream of the ecoregion reference on Laurel Creek, a thin layer of microalgae covered a small percent of substrate immediately downstream of the dam in the fall. There was no microalgae at the reference site. Nitrate+nitrite below the dam reached 0.35 mg/L in the summer. The highest value recorded in ten years at the ecoregion reference site was 0.09 mg/L. Ammonia was never detected at the reference site. Concentrations below the dam were 0.07 mg/L in the winter.

As mentioned in previous sections, the unnamed tributary to Sinking Creek was the only stream with an upstream reach for comparison. Although, ample stable habitat for periphyton colonization was available at both sites, algae were only observed at the station downstream of the impoundment (Table 23). A thin layer of microalgae covered all available substrate. The canopy at the downstream site was much lower (40 percent) than the upstream site (90 percent) in the fall of 2003. Nutrient levels, especially ammonia and TKN were higher downstream than upstream. Ammonia was not detected upstream of the reservoir but was measurable downstream every season, although levels were within the 90th percentile of regional reference data. TKN (ammonia plus organic nitrogen) was above the 90th percentile of reference data in the fall.

Microalgae have been recorded in the ecoregion reference sites in the Southern Shale Valleys (67g). The maximum thickness rank at any of the ecoregion reference sites was a slime layer with no visual accumulation. The algal density downstream of the impoundment was higher when compared to either the upstream site or the ecoregion reference sites for 67g (Figure 73).

Table 23: Periphyton survey results for sites upstream and downstream of Bryant Reservoir on an unnamed tributary to Sinking Creek in the Southern Shale Valleys (67g).

Station ID	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mean THR	Avg. % Canopy
ECO67G01	8/27/02	0	63	0	0.0	0.0	
ECO67G05	8/27/02	0	82	5	0.5	0.0	
ECO67G08	8/20/02	0	83	25	0.5	0.1	
ECO67G09	8/20/02	0	69	35	0.5	0.2	
ECO67G10	8/22/02	0	96	48	0.5	0.2	
ECO67G11	8/11/04	0	92	10	0.5	0.0	82
SINKI1T1.0CO	10/27/03	0	98	0	0.0	0.0	90
SINKI1T1.0CO	7/19/04	0	70	0	0.0	0.0	93
SINKI1T0.8CO	10/29/03	0	41	100	1.0	0.8	40
SINKI1T0.8CO	7/20/04	0	24	0	0.0	0.0	66

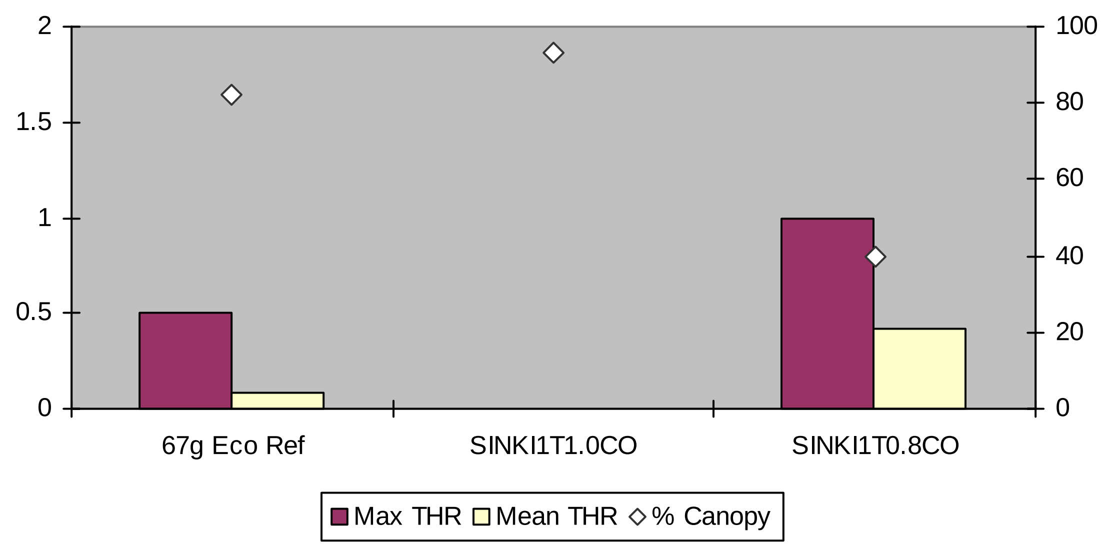

Figure 73: Microalgae and canopy at six ecoregion reference sites, one upstream reference site, and one test site in 67g. The maximum thickness rank is the single highest reading and the mean thickness rank is the average value of all survey dates.

Percent canopy is the date with the highest maximum thickness rank or the highest percent of available substrate.

The survey site on the unnamed tributary to Sinking Creek upstream of Bryant Reservoir had dense canopy and no periphyton.

Photo provided by Aquatic Biology Section, TDH .

The survey site on the unnamed tributary to Sinking Creek downstream of Bryant Reservoir had only 40 percent canopy and a measurable layer of microalgae on 100% of the substrate.

Photo provided by Aquatic Biology Section, TDH.

9.4 Periphyton and Macroinvertebrates

Seventy two percent of the samples that had elevated periphyton density in fall 2003 also failed to meet the target macroinvertebrate index score (TMI) of 32. Of the 16 sites with elevated microalgae, 70 percent failed biological macroinvertebrate criteria (Figure 74). The median macroinvertebrate index, including those that passed guidelines, was 28 of a possible 42 (Table 24).

Individual biometric scores were similar to those at all impounded sites except for the percent EPT and the percent clingers. Fewer sites with microalgae failed to meet regional criteria for these two parameters. That is due to the ability of the caddisfly larva *Cheumatopsyche spp*. to out compete other organisms when microalgae is abundant. The larvae collect and consume small algae particles. They are more tolerant of lower dissolved oxygen and high temperatures than many other EPT. *Cheumatopsyche spp*. was the dominant organisms at over half of the sites with microalgae. Even when it was not the dominant taxon, it was the dominant EPT at 75% of the streams.

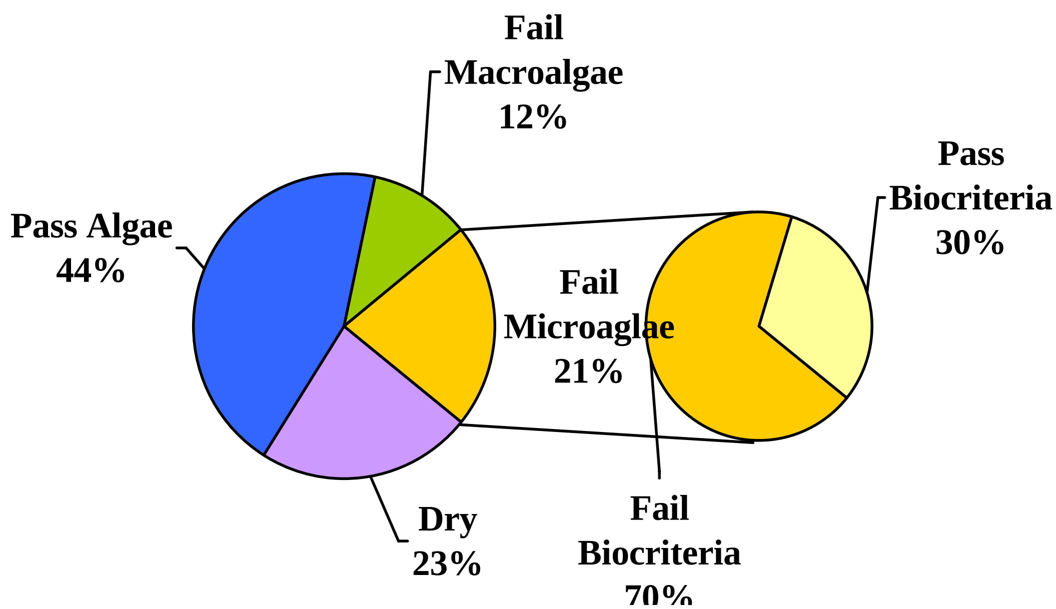

Figure 74: Percent of impounded test sites that met microalgae and macroinvertebrate regional expectations in the fall of 2003.

Table 24: Macroinvertebrate and periphyton data downstream of impounded streams with elevated microalgae fall 2003.

Station ID	Eco-region	% Macro-algae	% Sub-strate	% Micro-algae	Max THR	Mean THR	% Can-opy	Min. Can-opy	TMI	Dominant Taxon
GRAY1T0.9HR	65e	0	14	53	0.5	0.27	93	85	4	Glyptotendipes
ODAIN000.3HR	65e	0	20	38	0.5	0.19	13	7	26	Glyptotendipes
PINEY014.6CS	65e	0	10	44	1.0	0.44	92	80	32*	Cheumatopsyche Dugesia
STEWA003.4HR	65e	0	7	50	0.5	0.25	97	94	32*	Nanocladius
FLAT002.4BT	65e	0	89	2	2.0	0.08	98	96	28	Cheumatopsyche
SINKI1T0.8CO	67g	0	41	100	1.0	0.84	40	0	30	Cheumatopsyche
LAURE003.4MO	67h	0	98	6	0.5	0.03	96	90	26	Cheumatopsyche
FALL007.6CU	68a	0	98	38	0.5	0.19	89	78	38	Polypedilum
FALLS000.5VA	68a	0	94	68	1.0	0.56	99	96	14	Polypedilum Hydra
LFGIZ003.4GY	68a	0	96	6	0.5	0.03	98	95	24	Isonychia
MAMMY010.1CU	68a	0	98	76	0.5	0.38	63	36	36	Chimarra
BEAR003.6WE	71f	0	90	76	1.0	0.46	93	71	30	Cheumatopsyche
CHIEF004.6LS	71f	0	69	63	0.4	0.44	19	0	24	Cheumatopsyche
JONES1T0.2DI	71f	0	81	100	0.5	0.18	84	70	28	Lirceus
SFSYC006.3DA	71f	5	95	13	1.0	0.07	67	42	38	Elimia
WFDRA2T1.5SR	71g	6	76	47	1.0	0.25	88	79	26	Cheumatopsyche

* Questionable score, see Section 4

Only twelve percent of the survey sites had more filamentous macroalgae than the ecoregion reference sites, but most of those sites failed biological criteria in fall 2003 (Figure 75). Compared to the microalgae sites, the ones with elevated macroalgae had far more impacted macroinvertebrate communities, as indicated by lower index scores. The highest macroinvertebrate index score at a site that failed biocriteria and had macroalgae present was 14 out of a possible 42 (Table 25).

Worms and midges were more likely to be the dominant organisms below impoundments with abundant filamentous algae. Half the sites failed to meet guidelines for the %OC, which measures this component of the benthic community. The two streams with the most macroalgae had the lowest macroinvertebrate index scores. Eighty-three percent of the stream substrate in Beasley Creek (BEASL000.4MY) downstream of Shellcracker Reservoir in Maury County was covered with macroalgae and the macroinvertebrate index score was 2. Over 92 percent of the sample was composed of the chironomid larvae, *Glyptotendipes spp*. Sixty-six percent of the substrate of Taylor Creek (TAYLO000.7OB) downstream of Reelfoot-Indian Creek #7 was covered with macroalgae and it had a macroinvertebrate index score of 10. *Glyptotendipes spp*. was still the dominant taxon comprising 58 percent of the sample. This chironomid larvae eats filamentous algae and prefers to live in lentic or eutrophic conditions.

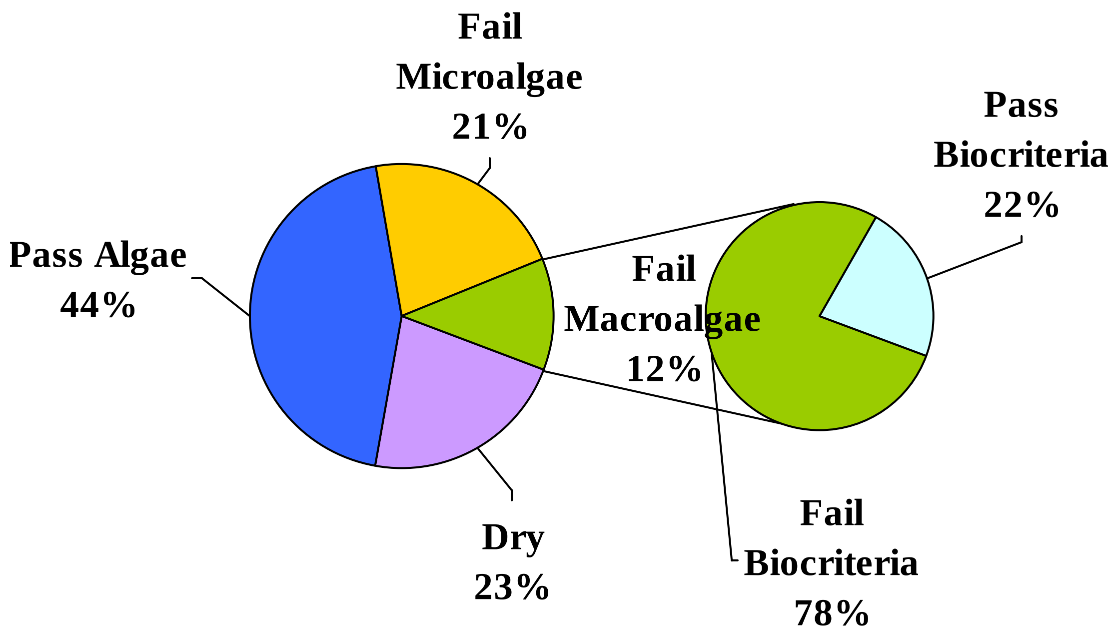

Figure 75: Percent of impounded test sites that met macroalgae and macroinvertebrate regional expectations fall 2003.

Table 25: Macroinvertebrate and periphyton data downstream of impounded streams with elevated macroalgae Fall 2003.

Station ID	Eco-region	% Macro-algae	% Sub-strate	% Micro-algae	Max THR	Mean THR	% Can-opy	Min. Can-opy	TMI	Dominant Taxon
BUCK001.2CU	68a	31	47	0	0.0	0.00	77	36	34	Chimarra
DUNCA001.8CU	68a	1	97	0	0.0	0.00	96	89	12	Chironomus
SAVAG009.8SE	68a	11	82	14	0.5	0.07	90	84	14	Nais
HALEY003.2HI	71f	6	90	35	1.0	0.25	90	85	32	Cheumatopsyche
SFSYC006.3DA	71f	5	95	13	1.0	0.07	67	42	38	Elimia
SQUAW001.4LS	71f	13	59	47	0.5	0.26	90	82	12	Thienemannimyia
BEASL000.4MY	71h	83	13	80	0.5	0.50	24	23	2	Glyptotendipes
DODDY001.9BE	71h	1	99	19	0.5	0.10	93	91	14	Polypedilum
WALKE1T0.3DA	71h	18	58	10	0.5	0.07	71	62	12	Dugesia
TAYLO000.7OB	74a	66	6	0	0.0	0.00	65	36	10	Glyptotendipes

In general, it appears that streams with an abundance of either microalgae or macroalgae affect macroinvertebrate populations in different ways (Figure 76). Microalgae are more likely to shift the population toward a higher abundance of a few facultative EPT taxa that filter or collect algae. Sites with an abundance of filamentous macroalgae support an increase in oligochaetes and chironomids. Macroinvertebrate index scores tend to be substantially lower in sites with abundant macroalgae.

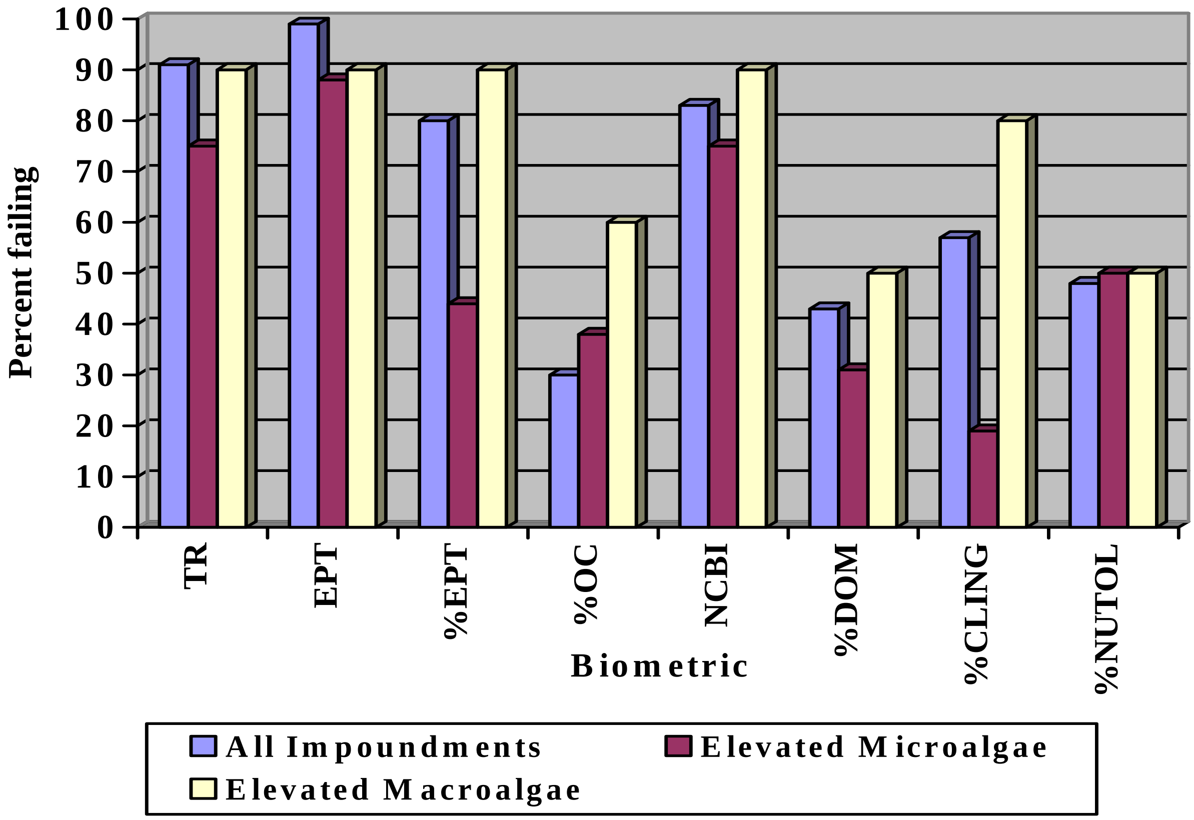

Figure 76: Percent of eight biometrics failing to meet regional guidelines at impounded sites with elevated periphyton.

10. HISTORIC DATA

In 1991, the division conducted a survey of forty lakes and reservoirs throughout the state as part of the Clean Lakes Program (Hansel et al, 1992). This was a continuation of a survey conducted in 1980 (TDPH, 1980). Thirty-three of the sites were impoundments less than 250 acres. Five of these were also randomly selected during the 2003 probabilistic study; Lake Lajoie, Lake Placid, Reelfoot Reservoir # 7 and Reelfoot Reservoir # 14 in west Tennessee, and Big Grundy Lake in southeast Tennessee.

The 1991 study was restricted to lake sampling and did not include the downstream reach. Monitoring included nutrient and chlorophyll analyses, a water column profile and secchi disc measurements. The Carlson Index was used to determine trophic status. Sixty-one percent of the small impoundments were either eutrophic or hypereutrophic. Only two showed improvement from the 1980 survey. Of the five lakes that were included in the 2003 probabilistic study, Lake Lajoie, Lake Placid, Reelfoot # 7 and Reelfoot # 14 were hypereutrophic in 1991, while Big Grundy Lake was oligotrophic.

In 2003, the downstream reaches of the four hypereutrophic lakes showed elevated nutrients, abundant algal growth and depressed macroinvertebrate communities. The unnamed tributary to Gray's Creek (GRAY1T0.9HR) below Lake Lajoie had elevated levels of total phosphorus and nitrate+nitrite. Microalgae covered 53% of the available substrate. The macroinvertebrate community was very depressed with an index score of 4 (out of 42) in the fall and 22 in the spring.

Piney Creek downstream of Lake Placid (PINEY014.6CS) supported macroinvertebrates in the fall, but only scored 16 in the spring indicating a degraded community. Temperature was elevated in the summer. Ammonia, total phosphorus and iron were also elevated. Microalgae were abundant covering 44% of the available substrate.

Taylor Creek, downstream of Reelfoot-Indian Creek Impoundment #7 had a stressed macroinvertebrate community in the spring and fall. Dissolved oxygen levels were low in the fall and summer. Suspended solids, ammonia, TKN, total phosphorus, iron and manganese were elevated at least two seasons. Filamentous microalgae were abundant.

Tull Creek, downstream of Reelfoot-Indian Lake #14 was dry in the fall although flow was sufficient to sustain aquatic life in the other seasons. The macroinvertebrate community only scored 10 in the spring. In some or all of the three seasons sampled, temperature, suspended solids, ammonia, TKN, nitrate+nitrite and manganese were elevated. Filamentous macroalgae were abundant but dead in the spring, probably due to scouring during a flash flood as strands were observed wrapped around trees.

In 2003, nutrient levels were also elevated downstream of the one lake (Big Grundy) that was oligotrophic in the 1991 study. Microalgae were only growing on 6% of the rocks, but canopy cover was dense. Manganese was above reference levels for the Cumberland

Plateau (68a) every season. The macroinvertebrate community failed to meet regional guidelines.

In 1996, another lake study was conducted on 13 TWRA fishing lakes and two municipal managed lakes (Arnwine, 1996). This study included both lake sampling and an abbreviated assessment of the macroinvertebrate community downstream of the dam. The lake samples included dissolved oxygen/temperature profiles, Secchi readings, chlorophyll analyses and nutrient analyses. The downstream surveys consisted of a screening level (biorecon) survey of the macroinvertebrate community and habitat assessments. Stream field measurements included flow, dissolved oxygen, conductivity, pH and temperature.

All but one of the lakes in the 1996 study were either eutrophic or hypereutrophic. The benthic communities in the receiving streams were comprised of only tolerant organisms, lacking EPT taxa. Many streams had low dissolved oxygen and habitat was generally buried by sediment. Two of the streams were dry.

Two lakes from the 1996 study, Bedford Lake on Doddy Creek and Garret Lake on Thompson Creek were randomly selected for the 2003 probabilistic study. Bedford Lake appeared to be in an advanced state of eutrophication in 1996. At that time, dissolved oxygen levels below the dam were low, a large amount of filamentous algae were observed and siltation was heavy. The macroinvertebrate community was depressed with only facultative and tolerant organisms present. In 2003, at least one nutrient parameter including TKN, total phosphorus and ammonia was elevated in the stream below the lake every season. Algae were not present but the stream was heavily shaded. Manganese was above ecoregion reference levels every season. Suspended solids were high in the spring and temperature was elevated in the summer. The macroinvertebrate community failed to meet regional guidelines scoring 14 in the fall and 12 in the spring.

Garret Lake was also eutrophic during the 1996 survey. According to the lake manager, the lake was being drained during the sampling effort. Dissolved oxygen levels were adequate during daylight hours downstream of the dam, however nutrient enrichment was indicated with bluegreen algae in pool areas and filamentous algae on submerged roots. Facultative organisms dominated the macroinvertebrate community. In 2003, Thompson Creek downstream of the dam was dry in the fall. Ammonia and total phosphorus levels were elevated every season with flow while nitrate+nitrite and TKN were elevated in the winter and spring. Periphyton were not recorded but most of the substrate was sand or gravel with only 13% rocks large enough to support algal growth. The stream also had a dense canopy. Iron and manganese were elevated every season with flow. The macroinvertebrate community failed to meet regional guidelines, scoring 14 out of 42.

11. IMPOUNDED TEST STREAMS WITH ADDITIONAL MONITORING STATIONS

Eighteen of the study sites were located on streams with established monitoring stations upstream or downstream. Eleven streams had additional biological monitoring stations but no water quality data (Table 26). Most of the surveys were screening level biorecons instead of the more intensive SQBANK or SQKICK samples collected for the 2003 study. However, all the biorecon sites scored either high enough or low enough to have confidence in the results.

Only one site, Carson Branch, downstream of Estes Kefauver Lake in Monroe County, failed the biorecon collected further downstream in 2006. This site was still fairly close to the dam (0.2 miles). A site below the dam on Arnold Branch in Weakley County failed to meet biological criteria in 2003, but passed a biorecon collected 0.3 miles further downstream in 2006. The rest of the sites that passed biorecons were between 1.2 and 10 miles downstream of the dam. One site, Haley Creek downstream of Boon-dok Lake in Hickman County, passed biocriteria at the dam and 2.5 miles further downstream.

Shelton Creek in Lincoln County had additional stations located 1.4 miles upstream of the dam and two miles downstream. The upstream station was sampled in January 2003 within the same time frame as the impounded stream study and passed the biorecon. The station 80 yards downstream of the dam failed to meet biocriteria both in November 2003 and April 2004. A site two miles downstream of the dam was collected in April 2001 and passed biorecon guidelines.

The biological results at these 11 sites indicate that dams affected the biological community for at least one-quarter mile. However, additional studies with multiple sites collected at the same time using the same techniques need to be conducted to fully understand the total stream length impacted by individual impoundments.

Three of the impounded streams had additional chemical monitoring stations without biological data. Little Fiery Gizzard Creek had one additional station 2.8 miles downstream of the impoundment on Big Grundy Lake. This station was collected two years after the impounded stream study from July 2005 to January 2006.

During the 2003 study, the station located 30 yards downstream of the impoundment had dissolved oxygen saturation below the 10^{th} percentile of reference data. All of the nutrients and manganese were elevated. At the station located 2.8 miles downstream, dissolved oxygen saturation was still slightly lower than the 90^{th} percentile of reference data. Ammonia and TKN were comparable to reference. Nitrate+nitrite and manganese concentrations were similar to those just below the dam. Total phosphorus samples were not collected. This site is influenced by run-off from Tracy City.

Table 26: Comparison of biological samples from multiple stations on 10 impounded streams.

STATION	LOCATION	DATE	BIOLOGY	TYPE
ARNOL001.4WY	60 YDS D/S DAM	04-05-04	FAIL	SQBANK
ARNOL001.1WY	0.3 MI D/S DAM	05-04-06	PASS	BIORECON
CARSO001.0MO	10 YDS D/S DAM	10-29-03	FAIL	SQKICK
CARSO001.0MO	10 YDS D/S DAM	04-22-04	FAIL	SQKICK
CARSO000.8MO	0.2 MI D/S DAM	01-04-06	FAIL	BIORECON
CHIEF004.6LS	160 YDS D/S CHIEF CREEK LAKE	10-14-03	FAIL	SQKICK
CHIEF004.6LS	160 YDS D/S CHIEF CREEK LAKE	04-13-04	FAIL	SQKICK
CHIEF001.9LS	3.3 MI D/S CHIEF CREEK LAKE AND 0.3 MI D/S NAPIER LAKE	12-03-99	PASS	BIORECON
DODDY001.9BE	20 YDS D/S DAM	11-05-03	FAIL	SQKICK
DODDY001.9BE	20 YDS D/S DAM	04-20-04	FAIL	SQKICK
DODDY000.7BE	1.2 MI D/S DAM	09-01-99	PASS	SQKICK
FLAT002.4BT	10 YDS D/S DAM	10-29-03	FAIL	SQKICK
FLAT002.4BT	10 YDS D/S DAM	05-04-04	FAIL	SQKICK
FLAT000.1BT	2.3 MI D/S DAM	10-23-00	PASS	BIORECON
HALEY003.2HI	20 YDS D/S DAM	10-09-03	PASS	SQKICK
HALEY003.2HI	20 YDS D/S DAM	04-16-04	PASS	SQKICK
HALEY000.7HI	2.5 MI D/S DAM	02-04-00	PASS	BIORECON
LTRAC005.0CY	20 YDS D/S DAM	11-14-03	FAIL	SQKICK
LTRAC005.0CY	20 YDS D/S DAM	05-13-04	FAIL	SQKICK
LTAC002.3CY	2.7 MI D/S DAM	03-06-05	PASS	BIORECON
LTRAC000.1CY	4.9MI D/S DAM	11-16-00	PASS	BIORECON
MAMMY010.1CU	80 YDS D/S DAM	11-06-03	PASS	SQKICK
MAMMY010.1CU	80 YDS D/S DAM	04-28-04	FAIL	SQKICK
MAMMY000.1CU	10 MI D/S DAM	06-18-02	PASS	BIORECON
SAVAG009.8SE	30 YDS D/S DAM	11-10-03	FAIL	SQKICK
SAVAG009.8SE	30 YDS D/S DAM	05-11-04	FAIL	SQKICK
SAVAG006.3SE	3.5 MI D/S DAM	12-06-02	PASS	BIORECON
STEWA003.4HR	0.25 MI D/S DAM	10-28-03	PASS	SQBANK
STEWA003.4HR	0.25 D/S DAM	04-07-04	FAIL	SQBANK
STEWA001.0HR	2.4 MI D/S DAM	05-03-04	PASS	BIORECON
SHELT001.3LI	80 YDS D/S DAM	11-04-03	FAIL	SQKICK
SHELT001.3LI	80 YDS D/S DAM	04-20-04	FAIL	SQKICK
SHELT002.7LI	1.4 MI U/S DAM	01-25-03	PASS	BIORECON
SHELT000.7LI	2 MI D/S DAM	04-23-01	PASS	BIORECON

The 2003 study site on Meridian Creek was located 30 yards downstream of the impoundment in Madison County. Dissolved oxygen saturation was below the 10th percentile of reference data while temperature, all the nutrients and manganese were above the 90th percentile. A station 5.5 miles downstream of the impoundments was sampled ten times from July 2001 to March 2002. Median dissolved oxygen, pH, nitrate+nitrite, and iron concentrations were higher than those measured below the dam. Median total kjeldahl nitrogen values were the same at both sites. Median temperature, ammonia, total phosphorus, and manganese concentrations were lower than those below the dam.

The 2003 study site on Scotts Creek in Shelby County was located 90 yards downstream of Lakeland Lake. Temperature and total phosphorus were above the 90th percentile of reference data. Iron concentrations were above the 1000 ug/L criterion. A monitoring station 1.8 miles farther downstream was sampled five times between November 2001 and March 2002. Median temperature, and total phosphorus concentrations were higher than those found at the test site. Iron and manganese were not sampled.

Both biological and chemical samples were collected at additional locations on four of the impounded streams. One site on Dry Creek (DRY000.7BN) in Benton County was located at river mile 0.7, which is 3.4 miles downstream of the test site below Cedar Creek Lake. In fall, winter and spring the two sites were sampled within one week of each other (Table 27). The site immediately below the dam failed to meet biological guidelines while the station 3.4 miles downstream passed guidelines. The impoundment site had elevated TKN in the fall. Levels were comparable to reference conditions father downstream.

Table 27: Comparison of stream conditions at two sites on Dry Branch (DRY004.1BN) 50 yards downstream Cedar Lake. DRY000.7BN is 3.4 miles downstream of the impoundment.

Station	Date	Biology	pH	DO	Temp	TSS	NH3	NO2+3	TKN	TP
DRY000.7BN	07/9/03		6.8	6.4	25.2	<10	0.06	0.05	0.0	<0.004
DRY000.7BN	09/4/03		6.5	8.5	21.1	17	<0.02	0.09	<0.1	0.029
DRY000.7BN	10/8/03	PASS	6.7	7.0	16.2	<10	0.05	0.09	0.21	0.023
DRY004.1BN	10/16/03	FAIL	6.5	7.5	14.4	10	0.03	0.05	0.36	<0.004
DRY000.7BN	01/7/04		7.2		1.2	<10	<0.02	0.06	<0.1	<0.004
DRY004.1BN	01/13/04		6.8	11.8	6.5	<10	0.03	0.22	0.24	<0.004
DRY000.7BN	03/11/04		7.3	10.3	9.7	<10	<0.02	0.04	<0.1	0.03
DRY000.7BN	04/07/04		7.0	10.5	11.4	12	<0.02	0.11	<0.1	<0.004
DRY004.1BN	04/07/04	FAIL	6.6	9.0	18.5	<10	<0.02	0.1	<0.1	0.017
DRY004.1BN	07/08/04		7.0	6.7	29.3	<10	<0.02	<0.01	<0.1	<0.004

There were four monitoring sites on Falling Water River in Putnam County in addition to the station 71 yards downstream of City Lake. The station below the dam had dissolved oxygen saturation below the 10th percentile of reference data. Temperature, total phosphorus and manganese were above the 90th percentile of reference data. Biocriteria were not met in fall or spring. A biological sample was collected 6.7 miles upstream of the impoundment in August 1998 and August 2002. This upstream site passed biological guidelines on both occasions. A chemical site 3.2 miles downstream of the dam, was sampled three times in July and August 2005. Dissolved oxygen, temperature and manganese were not measured. Total phosphorus concentrations were similar to those found below the dam in summer, spring and fall but were much lower than winter concentrations. Phosphorus was much higher than either of these two sites in August 2005 at a station located five miles further downstream.

An ambient monitoring station is located on the river at mile 10.5. This is more than 20 miles downstream of the impoundment. The station was sampled three times in the same period as the impounded stream study. Dissolved oxygen was readily available with saturation over 95%. Total phosphorus and manganese concentrations were similar to those found at the site close to the impoundment. The station has been collected 30 times between 1998 and 2006. Median dissolved oxygen, pH, ammonia, and iron values were less than those below the impoundment. Median temperature, suspended residue, nitrite-nitrate, and manganese values were higher.

A monitoring site on the Obed River is 19.4 miles downstream of the station located 200 yards below Holiday Lake in Cumberland County. This site was sampled four times between April and July 2003. The station at the impoundment had elevated nitrate+nitrite, TKN and manganese compared to the 90th percentile of reference data. This site was dry in the fall and failed to meet biocriteria in the spring. Nineteen miles downstream, the Obed River supported a healthy biological macroinvertebrate community. TKN and manganese were comparable to reference condition although nitrate+nitrite concentrations were higher than those below the dam.

12. CONCLUSIONS

The results of this study indicate that impoundments on small first to third order streams have adverse affects on physical, chemical and biological components downstream (Appendix F). Of the 75 randomly selected impounded sites, only four passed biological criteria guidelines or were comparable to first order references both seasons sampled. The most frequent change in the benthic community structure downstream of small impoundments was a loss of EPT. Ninety-six percent of the samples failed to meet reference guidelines for the number of distinct EPT taxa. The abundance of EPT that were present was also reduced, with 86% of the samples failing to meet %EPT guidelines. The loss of other taxa was also an issue below the impoundments. Eighty-seven percent of the samples failed to meet taxa richness guidelines. There was also a shift in the dominant organisms in streams below impoundments.

Results from 11 streams with multiple monitoring stations indicate that small impoundments affect the biological community for at least one-quarter mile downstream. However, additional studies with multiple sites collected at the same time using the same techniques need to be conducted to fully understand the stream length impacted by individual impoundments.

Lack of adequate flow was one of the biggest problems downstream of impoundments. Approximately one third of the sites that were randomly selected for reconnaissance were dry. Of those with flow during the summer reconnaissance, one-fourth had dry channels by the fall sampling period. Thirty-nine percent of the dams with year-round discharge provided insufficient flow to supply adequate habitat for aquatic life during at least one season.

Using the Rosgen classification system it was apparent that many of the streams below the impoundments in the study had channel structures that were undergoing geomorphic change. Only about half of the streams appeared to have relatively stable channel structures typical of the ecoregion. A fourth of the streams were becoming G-type channels with unstable banks and sloughing resulting in heavy sediment loads. Nineteen percent of the streams below impoundments were creating E-type channels due to lack of adequate flow. In these streams, a very small channel was cut within the original streambed creating a very narrow cross-section that helps the stream maintain some flow.

Disruption of habitat was a major concern below most of the impoundments. Sediment deposition was the most significant habitat problem in impounded streams with 80% failing to meet regional expectations. The sediment deposition parameter measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many aquatic organisms. Other frequently documented habitat problems included embeddedness of substrate, instability of banks, loss of stream sinuosity and disruption of bank vegetation.

The most frequently encountered chemical water quality problems below impoundments included elevated iron, manganese and nutrients as well as low dissolved oxygen concentrations (Figure 77). Elevated manganese was the number one problem. Only five sites had manganese concentrations comparable to reference levels. Four of the sites with low manganese were in the Southeastern Plains and Hills (65e) and one was in the Loess Plains (74b). Ammonia was the second most frequently elevated water quality parameter. Only thirteen sites had ammonia concentrations comparable to the regional reference.

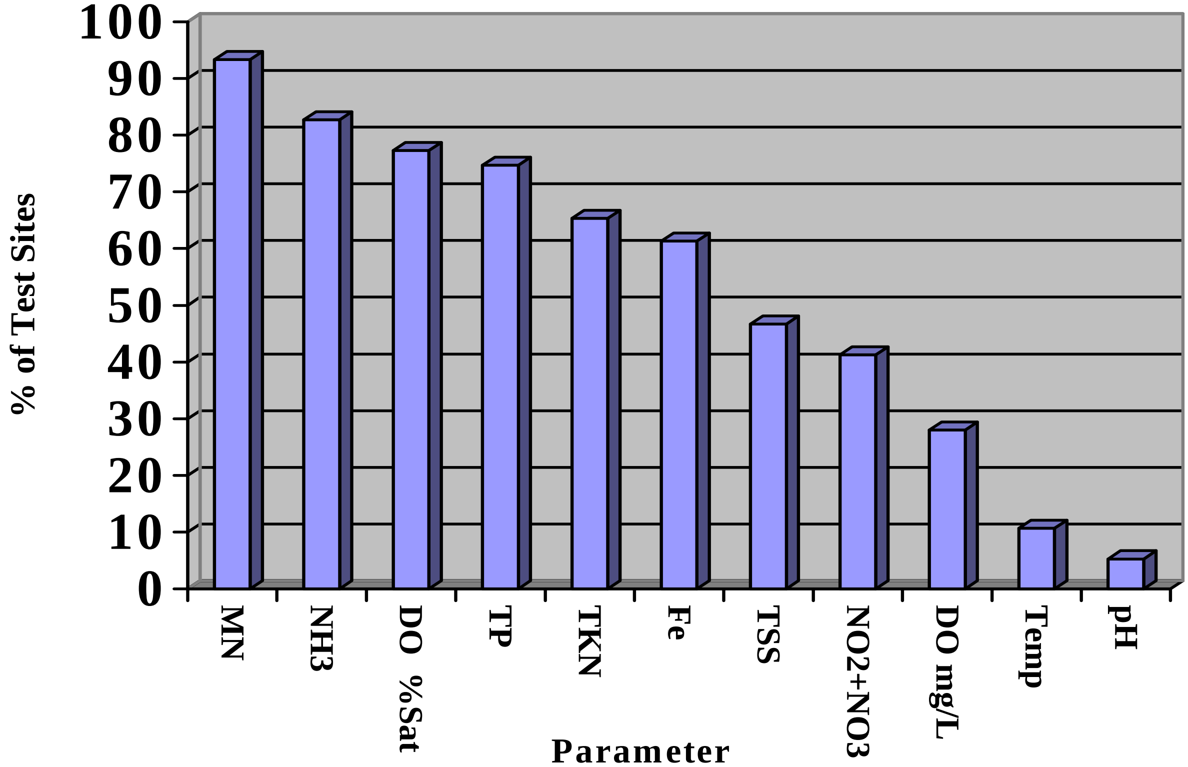

Figure 77: Percent of test sites below impoundments with water quality parameters not meeting expectations. Criteria were used for iron (Fe), DO mg/L, temperature and pH. The 90th percentile of reference data was used for manganese (MN) ammonia (NH3), DO (% Saturation), total phosphorus (TP), total kjeldahl nitrogen (TKN), total suspended solids (TSS) and nitrate+nitrite (NO2+NO3).

Streams below impoundments in the Bluff Hills (74a) in west Tennessee had the highest seasonal median values for the most parameters of any ecoregion (Table 28). These included total phosphorus, suspended solids and manganese in all seasons, ammonia in the summer/fall and total kjeldahl nitrogen in the winter/spring. Impounded streams in the Southern Igneous Ridges and Mountains (66d) had the lowest seasonal median values for the most parameters of any ecoregion. These included temperature and suspended solids all four seasons and dissolved oxygen in the winter.

Table 28: Lowest and highest median concentration for water quality parameters by season at impounded test sites.

Parameter	Season	Lowest Median	Ecoregion	Highest Median	Ecoregion
pH	All	6.41	74b	8.03	67i
Temp (^oC)	Winter	3.87	66d	7.70	74b
Temp (^oC)	Spring	11.77	66d	19.50	66g
Temp (^oC)	Summer	19.68	66d	28.28	65e
Temp (^oC)	Fall	12.27	66d	19.56	65e
DO (mg/L)	Winter	10.3	66d	13.0	67i
DO (mg/L)	Spring	8.3	68a	10.0	71f
DO (mg/L)	Summer	3.1	74a	7.5	74b
DO (mg/L)	Fall	2.5	74a	9.0	66g
NO2+NO3 (mg/L)	Winter/Spring	0.02	66g	1.62	67i
NO2+NO3 (mg/L)	Summer/Fall	0.04	66g	0.75	67i
NH3 (mg/L)	Winter/Spring	0.01	68c	0.04	67h
NH3 (mg/L)	Summer/Fall	0.01	66g	0.24	74a
TKN (mg/L)	Winter/Spring	0.05	66e, 67i, 68c	0.42	74a
TKN (mg/L)	Summer/Fall	0.05	67i, 68a, 74a, 74b	0.26	71g
TP (mg/L)	Winter/Spring	0.002	65e, 67h, 67i, 68c	0.140	74a
TP (mg/L)	Summer/Fall	0.015	66g	0.128	74a
TSS (mg/L)	All	5	65e, 66d, 66e, 66g, 67g, 67h, 67i, 68a, 71f, 71h, 74b	25	74a
Fe (ug/L)	All	156	67i	1600	74b
Mn (ug/L)	All	20	66e	467	74a

South Fork Hurricane Creek (71f) had the most frequent excursions above reference condition. Nine parameters were elevated a total of 23 times. These included dissolved oxygen, temperature, suspended residue, ammonia, total kjeldahl nitrogen, total phosphorus, iron, and manganese. Most discharge at normal lake levels was subsurface water from a toe drain, but a standpipe also discharges surface water when the lake level rises. The discharge from the dam was full of nutrient froth and iron ochre. Seepage from the dam created a side tributary that visibly carried large amounts of iron to the stream. The stream substrate was coated with iron and algae, and the macroinvertebrate community was found to be impaired. Another stream in the same ecoregion, Weaver Branch downstream of VFW Lake had elevated levels in eight of the nine parameters evaluated.

Two streams in the Cumberland Plateau, Buck Creek and Duncan Creek, had elevated concentrations of eight parameters. Duncan Creek, had concentrations above reference condition 21 times. These included dissolved oxygen, suspended residue, ammonia, nitrate-nitrite, total kjeldahl nitrogen, total phosphorus, iron, and manganese. This stream was channelized close to the dam and received surface water discharge over a spillway. Macroalgae were measurable in the fall and visible in the spring. The stream had excessive sediment deposition and iron ochre deposition on the substrate, The macroinvertebrate community failed to meet biocriteria guidelines in the fall.

The type of outfall at each dam was evaluated to see if it might have an affect on the downstream water chemistry. The percent above or below the expected value was calculated for each type of discharge. Table 29 shows the percent over the expected value for each parameter, except for dissolved oxygen, which shows the percent under the criteria. Sites with dual discharge have the most chemical water quality issues, except for dissolved oxygen where the subsurface discharges showed the greatest difference.

Table 29: Percent difference between reference condition and test sites for seven parameters divided by dam discharge type.

Parameter	Dual	Subsurface	Surface
Dissolved Oxygen	19	25	20
Nitrate+nitrite	140	102	121
Ammonia	982	438	597
Total Kjeldahl Nitrogen	312	132	236
Total Phosphorus	395	243	264
Iron	2227	73	228
Manganese	4607	1321	1512

Correlation Coefficients were calculated after data normalization to determine if there was a relationship between parameters. There was a relatively strong inverse relationship between dissolved oxygen and nutrients when both parameters failed to meet the criteria and guidelines (Table 30). There was an inverse relationship, although not a strong correlation, between dissolved oxygen and metals when both parameters failed to meet criteria and guidelines. As the levels of nutrients or metals increased in the stream, the concentration of dissolved oxygen decreased.

Table 30: Correlation between dissolved oxygen, nutrients and metals in 75 impounded test sites.

Parameter	Both Fail
DO + NH3	-0.748
DO + NO2+NO3	-0.489
DO + TKN	-0.824
DO + TP	-0.773
DO + FE	-0.452
DO + Mn	-0.487

Dissolved oxygen concentrations and flow measurements were compared to determine if low flow correlated to low dissolved oxygen. There was no evidence of a direct correlation between dissolved oxygen and flow. Metal concentrations were compared to pH when pH failed to meet criteria. There was no evidence of an inverse relationship between high metal concentrations and low pH values. Overall correlations between parameters were not determined because most of the data did not fit the normal curve under any transformation. Normality was determined using the Kolmogorov-Smirnov test for normality. Each time the data did not pass the normality test, it was transformed and tested again. Dissolved oxygen concentrations for every site were normally distributed and nitrate-nitrite concentrations for every site were normally distributed under log10 transformation. The dissolved oxygen concentrations were compared to the log10 transformation of the nitrate+nitrite concentrations, including those which passed guidelines, and there was no statistical relationship between them.

When compared to ecoregion or first order reference sites, about half of the impounded streams had elevated periphyton density. Algae were abundant at more sites in the fall than in the summer probably due to less canopy and lower flow in the fall. More sites had elevated microalgal density than filamentous macroalgae. However the sites with filamentous algae had more severely impaired macroinvertebrate communities. Worms and midges dominated most of these samples. Macroalgae abundance showed a direct relationship with nutrients (TKN) and percent canopy.

The net spinning trichopteran, Cheumatopsyche filters dead algae and detritus from the water column. It is a nutrient tolerant macroinvertebrate that is often found in abundance downstream of impoundments.

Photo provided by USEPA Region 3, Environmental Science Center, Fort Meade, Maryland, /www.epa.gov/bioindicators/html/photos_invertebrates_caddisflies.html

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APPENDIX A

Location of Study Sites
Impoundment Information

Table A-1: Location of Study Sites

Station ID	Impounded Stream	Sample Location	Segment ID	County	TOPO	Lat.dec	Long.dec	Order	ECO
ARNOL001.4WY	ARNOLD BRANCH	At bend off Tumbling Crek Rd 60 yds D/S Middle fork Obion #11 dam	TN08010203015_1100	WEAKLEY	444NE	36.235	-88.5613888	2	65E
BAGWE1T0.2CU	BAGWELL BRANCH TRIB	St George Drive 70 yds d/s Spring Lake	TN06010208015_0900	CUMBERLAND	117NW	35.99555556	-84.9202777	1	68A
BARNE002.4FR	BARNES BR/TRIB-LOST CK	Lake O'Donnel Rd 40 yds d/s O'Donnel Lake	TN06030001067_0400	FRANKLIN	94NW	35.201	-85.901	1	68A
BARTE001.4MT	BARTEE BRANCH	Clarksville Lake Rd D/S Cunningham Broadbent Lake	TN05130205110_0300	MONTGOMERY	300SE	36.5021	-87.5177	2	71F
BEASL000.4MY	BEASLEY HOLLOW	Hwy 247 100 yds d/s Shellcracker Lake (Williamsport Lakes TWRA)	TN06040003024_0999	MAURY	57NW	35.700	-87.218	2	71H
BGUM000.5CU	BLACK GUM BRANCH	Bainbridge Rd 200 yds D/S Lake Pomeroy	TN06010208015_1200	CUMBERLAND	117NE	35.99527778	-84.8555555	1	68A
BOSTO001.1HM	BOSTON BRANCH	Boston Branch Community 20 yds d/s Boston Branch Lake	TN06020001067_2000	HAMILTON	105NE	35.245	-85.2741666	2	68A
BUCK001.2CU	BUCK CREEK	Off Sawmill Rd d/s Pelfrey lake	TN06010208015_0700	CUMBERLAND	117NW	35.8895	-84.9642	3	68A
CARSO001.0MO	CARSON BRANCH	Kefauver Park Madisonville 10 yds d/s Estes Kefauver Lake	TN06020002082_0999	MONROE	132NW	35.49861111	-84.3902777	2	67G
CHARL000.7OV	CHARLIE BRANCH	Union B Rd d/s LAD lake	TN05130105019_0999	OVERTON	108NW	36.16166667	-85.1622222	1	68A
CHARL003.4BN	CHARLIE CREEK	McKeivy Drive 30 yds D/S Shannon Lake	TN06040005870_0210	BENTON	20SE	36.0892	-88.1156	1	65E
CHIEF004.6LS	CHIEF CREEK	Old Railroad Rd 160 yds d/s Chief Creek Lake	TN06040004013_0100	LEWIS	51NW	35.4375	-87.4722222	2	71F
CUB2T0.3HR	CUB CREEK TRIB 2	Lake Hardeman Rd 60 yds D/S Cub Creek #2A Dam	TN08010208001_0800	HARDEMAN	440NW	35.13555556	-88.9625	3	65E
DAVIS000.8SR	DAVIS BRANCH	Lake Rd d/s Westmoreland City Lake	TN05110002010_0300	SUMNER	316SW	36.57111111	-86.2319444	2	71G
DODDY001.9BE	DODDY CREEK	Green Cemetary Rd 20 yds d/s Bedford Lake	TN06040002030_0200	BEDFORD	78SE	35.500	-86.253	3	71H
DRY004.1BN	DRY CREEK	Cedar Drive 50 yards d/s Cedar Lake #2	TN06040005027_0300	BENTON	20SW	36.109	-88.131	2	65E

Table A-1 cont.

Station ID	Impounded Stream	Sample Location	Segment ID	County	TOPO	Lat.dec	Long.dec	Order	ECO
DUNCA001.8CU	DUNCAN CREEK	U/S Mayland Rd d/s Duncan Creek Lake	TN05130108036_200	CUMBERLAND	108SW	36.00666667	-85.2069444	2	68A
EFSPR1T0.5HR	UNNAMED TRIB-EAST FK SPRING CR	Crestwood Drive Candlewood Estates 30 yds d/s Spring Lake	TN08010208019_-0400	HARDEMAN	432SE	35.038	-89.021	1	65E
FALL007.6CU	FALL CREEK	Camp Ozone Rd 10 yds d/s Ozone Lake	TN06010201040_0510	CUMBERLAND	117NE	35.885	-84.816	2	68A
FALLS000.5VA	FALLS CREEK	Fall Creek Falls SP 35 yds d/s Fall Creek Falls Lake	TN05130108027_0600	VAN BUREN	103NE	35.66277778	-85.3569444	3	68A
FALLS1T0.5MI	FALLS BRANCH TRIB	Ravens Den Rd 40 yds D/S Tom McBee Lake	TN06030001057_0400	MARION	94NE	35.1625	-85.8638888	2	68A
FLAT002.4BT	FLAT CREEK	Flats Rd 10 yds d/s Lake in the Sky	TN06010201031-0200	BLOUNT	148NW	35.658	-83.907	2	66E
FORD1T1.4BN	FORD CREEK TRIB	Blackburn Rd 50 yds D/S Blackburn Lake	TN06040005020T_1000	BENTON	20SE	36.01444444	-88.0583333	1	71F
FWATE0031.6PU	FALLING WATER RIVER	Watson Rd D/S City Lake	TN05130108045_2000	PUTNAM	331SW	36.11861111	-85.4438888	3	71G
GOODI001.1DE	GOODIN BRANCH	Off Wylie Machayes Rd d/s Arnold Lake	TN06040001651_1000	DECATUR	22NE	35.6755	-88.0426	2	71F
GRAY1T0.9HR	TRIB-GRAY'S CREEK	Chickasaw State Park 35 yds d/s Lake Lajoie	TN08010208028_0999	HARDEMAN	439SW	35.346	-88.888	3	65E
HALEY003.2HI	HALEY CREEK	Greenhill Drive 20 yds d/s Boon-dok Lake	TN06040003009_0200	HICKMAN	49SW	35.819	-87.424	2	71F
HANCO1T0.2LI	TRIB-HANCOCK BRANCH	West Lincoln Rd 100 yds d/s Chricle H Ranch Lake	TN060300021216_0200	LINCOLN	73SE	35.025	-86.581	1	71G
HUDSO000.3HR	HUDSON BRANCH	Bishop Rd 30 yds d/s Porters Creek Lake #6	TN08010208024_0999	HARDEMAN	440SW	35.05444444	-88.9688888	3	65E
HWATE1T0.1MO	UNNAMED TRIB-HOT WATER BR	Epperson Rd 20 yds d/s Twin Lake #1	TN06020002018_0600	MONROE	132SE	35.260	-84.309	1	66G
JONES1T0.2DI	TRIB-JONES CREEK	Greystone Golf Course D/S Lake	TN05130204002_2000	DICKSON	48SE	36.095	-87.334	1	71F
JONES2T1.6DI	TRIB-JONES CREEK	Fowler Rd 35 yards d/s Hava-Lakatu Lake # 2	TN05130204002_0999	DICKSON	305NW	36.169	-87.233	2	71F
LAURE003.4MO	LAUREL CREEK	Co Hwy 775 off Big Creek Rd 25 yds d/s Laurel Mtn Lake	TN06010204056_1000	MONROE	132NE	35.43166667	-84.3252777	2	67h

Table A-1 cont.

Station ID	Impounded Stream	Sample Location	Segment ID	County	TOPO	Lat.dec	Long.dec	Order	ECO
LAURE005.7RH	LAUREL CREEK	Liberty Hill Rd1 mi past Harrison Rd 50 yds D/S Sinclair Lake	TN06020001048_0400	RHEA	110SE	35.59666667	-85.0369444	2	68A
LFGIZ003.4GY	L. FIERY GIZZARD	Lakes Rd Grundy Lakes Park 30 yds D/S Big Grundy Lake	TN06030001057_0815	GRUNDY	99SW	35.2649	-85.7186	2	68A
LOONE002.5MI	LOONEY'S CREEK	Ketner Cove Rd 10 yds D/S Ketner Cove Lake	TN06020004001_0200	MARION	105NW	35.19388889	-85.4583333	1	68C
LOOPE001.0OV	LOOPER BRANCH	Pine Ridge Lake Rd D/S Pine Ridge Lake	TN05130105019_0610	OVERTON	108NE	36.17972222	-85.1208333	2	68A
LTRACE005.0CY	LITTLE TRACE CREEK	Henson Rd 20 yds d/s Line Creek #3B Lake	TN05110002031_0200	CLAY	324SW	36.56861111	-85.7119444	3	71G
MAMMY010.1CU	MAMMY'S CREEK	Milestone Mountain Circle 80 yds D/S Lake Waldenesia	TN06010201040_0520	CUMBERLAND	117NE	35.91277778	-84.7791666	2	68A
MCCAM000.7PO	McCAMY BRANCH	Chilhowee Recreation Area 20 yds d/s McKamy Lake	TN06020003092_1000	POLK	126NE	35.149	-84.608	2	66E
MERID006.5MN	MERIDIAN CREEK	Medon Malesus Rd 30 yds d/s Meridian Creek Lake #1	TN08010205017_1000	MADISON	438SE	35.50638889	-88.8275	2	65E
MOODY002.0HR	MODDY CREEK	Upstream Hulder Rd 1000 yds d/s Indian Creek #8 lake	TN08010210019_0300	HARDEMAN	433NW	34.99861111	-89.15	2	74B
NORTH005.7CU	NORTH CREEK	Old Peavine Rd d/s Turner Lake	TN06010208015_0900	CUMBERLAND	117NW	35.974	-84.974	2	68A
OBED040.2CU	OBED RIVER	Holiday Drive 200 yds D/S Holiday Lake	TN06010208013_2000	CUMBERLAND	109NE	35.95555556	-85.0597222	3	68A
ODAIN000.3HR	OAK DAIN CREEK	Whiteville Lake Ln 50 yds D/S Oak Dain Creek	TN08010208015_0100	HARDEMAN	431SW	35.30055556	-89.1330555	2	65E
OTOWN1T0.9HN	OLD TOWN CREEK TRIB	Greenacres Drive 50 yds D/S Green Acres Lake	TN06040005024_0110	HENRY	8SE	36.30972222	-88.3077777	1	65E
PINEY014.6CS	PINEY CREEK	Lake Levee Rd 80 yds D/S Lake Placid	TN08010208027_1000	CHESTER	439NE	35.38833333	-88.7727777	2	65E
POND1T0.1CU	POND BRANCH	Malvern Rd 50 yds d/s Kirkstone Lake	TN06010208015_1100	CUMBERLAND	117NW	35.967	-84.883	1	68A
RATTL000.1UC	RATTLESNAKE CR	Off 395 Rock Creek Recreation Area Cherokee National Forest 15 yds d/s swimming area outfall	TN06010108029_1100	UNICOI	199NE	36.139	-82.348	2	66E

Table A-1 cont.

Station ID	Impounded Stream	Sample Location	Segment ID	County	TOPO	Lat.dec	Long.dec	Order	ECO
ROARI002.4CT	ROARING CREEK	Roaring Creek Rd 50 yds d/s Ripshin Lake	TN06010103012_0600	CARTER	208NW	36.18166667	-82.13	2	66D
SAVAG009.8SE	SAVAGE CREEK	Dunaway private game preserve off Tate Rd 30 yds d/s Dunaway Lake	TN05130107016_0150	SEQUATCHIE	99NE	35.41972222	-85.5038888	3	68A
SCANT001.3CU	SCANTLING BRANCH	Lakes Trailer Park on Laurel Point Rd 200 yds D/S Good Neighbor Lake	TN06010208007_0200	CUMBERLAND	116SW	36.02694444	-84.9336111	2	68A
SCOTT003.5SH	SCOTTS CREEK	Seed Tick Rd 80 yds d/s Lakeland Lake	TN08010209002_0100	SHELBY	416NW	35.24333333	-89.7375	3	74B
SFHUR003.6HO	SO FORK HURRICANE CREEK	Lakeview Circle 30 yds D/S Lakeview Circle Lake	TN06040005063_2000	HOUSTON	29SE	36.32111111	-87.7644444	1	71F
SFSYC006.3DA	SO FORK SYCAMORE CREEK	Browns Lake Rd 30 yds d/s Browns Lake	TN05130202014_0500	DAVIDSON	307SE	36.35555556	-86.8094444	1	71F
SHARP1T0.4DA	SOUTH HARPETH RIVER TRIB 1	Off South Harpeth Rd 20 uds D/S South Harpeth River Lake	TN05130204010_0200	DAVIDSON	305SE	36.04027778	-87.0263888	1	71F
SHARP2T0.6DA	S. HARPETH RIVER TRIB 2	Suddeth Farm off S. Harpeth Rd 50 yds d/s Elcan Lake	TN05130204010_1200	DAVIDSON	305SE	36.0261	-87.0392	1	71F
SHELT001.3LI	SHELTON CREEK	Lincoln Lake Rd D/S Lincoln Lake	TN06030003010_0400	LINCOLN	80SW	35.11944444	-86.3916666	3	71H
SINKI1T0.8CO	UNNAMED TRIB-SINKING CR	Brigadoon Way 20 yards d/s Bryant Lake	TN06010106002_0999	COCKE	173NW	35.959	-83.239	2	67G
SQUAW001.4LS	SQUAW BRANCH	Napier Rd 40 yds d/s Squaw Branch Lake	TN06040004013_0100	LEWIS	51NW	35.42416667	-87.4844444	2	71F
STEEL000.3SU	STEELE CREEK	Off Vance Rd @ Rooster Front Park 100 yds D/S Steele Creek Lake	TN06010102042_0300	SULLIVAN	206SW	36.56361111	-82.2266666	2	67I
STEWA003.4HR	STEWART BRANCH	Bowden Lane 0.25 mile D/S Porters Creek Lake #4	TN08010208024_0400	HARDEMAN	440SW	35.0925	-88.9519444	3	65E
TAYLO000.7OB	TAYLOR CREEK	Newman Glover Rd 50 yds D/S Reelfoot-Indian Creek #7 Dam	TN08010202036_0160	OBION	427NW	36.46722222	-89.2236111	2	74a

Table A-1 cont.

Station ID	Impounded Stream	Sample Location	Segment ID	County	TOPO	Lat.dec	Long.dec	Order	ECO
THOMP005.9WY	THOMPSON CREEK	Brann Rd 80 yds D/S Garret (Thompson Creek #4) Lake	TN08010203015_0600	WEAKLEY	443SE	36.3249	-88.5559	2	65E
THOMP1T0.4HR	THOMPSON CREEK TRIB	Woodrun Gated community 30 yds d/s Woodrun #1 lake	TN08010208024_0200	HARDEMAN	440SW	35.0476	-88.974	1	65e
THREE1T0.3HN	UNNAMED TRIB-THREEMILE BR	HWY 641/54 30 yds d/s Smith Lake	TN06040005024_0110	HENRY	8SE	36.345	-88.330	2	65E
TMILE1T0.2FR	UNNAMED TRIB-TWO MILE BR	Eva Rd 60 yds d/s Lake Eva	TN06030001067_0400	FRANKLIN	94NW	35.169	-85.895	1	68A
TRAIL1T0.4CU	UNNAMED TRIB-TRAIL BRANCH	St George Rd 20 yds d/s Sherwood Lake	TN06010208015_0999	CUMBERLAND	117NW	35.987	-84.884	1	68A
TULL000.3OB	TULL CREEK	Off Bane Rd 50 yds d/s Reelfoot-Indian Creek Lake #14	TN08010202036_0120	OBION	427NW	36.487	-89.215	3	74A
WALKE1T0.3DA	WALKERS CREEK TRIB	Licton Pike 20 yds D/S Lakewood Lake	TN05130202220_0200	DAVIDSON	307SE	36.34861111	-86.7647222	2	71H
WASHB003.0LI	WASHBURN BRANCH	Rebecca West Rd 50 yds d/s Rebecca Lake	TN060300021216_0210	LINCOLN	73NW	35.070	-86.612	2	71G
WEAVE001.0LW	WEAVER BRANCH	VFW Rd 40 yds d/s VFW Lake outflow	TN06040004013_0200	LAWRENCE	51SW	35.35638889	-87.4866666	2	71F
WFDRA2T1.5SR	W FORK DRAKES CK TRIB 2	Butler Rd 80 yds D/S Willow Lake	TN05110002008_0500	SUMNER	312SW	36.54166667	-86.4963888	2	71G
WOLF1T0.1LW	UNNAMED TRIB-WOLF CREEK	Wolf Creek Road 150 yards d/s McKinney Lake	TN06030005078_0400	LAWRENCE	43SE	35.021	-87.539	1	71F

Table A-2: Impoundment and Sample Information

Selection Rank	Dam	Year Impounded	Station ID	Impounded Stream	Eco-region	Order	Size (Acres)	Season Sampled			
								Fall 2003	Winter 2004	Spring 2004	Summer 2004
2	KIRKSTONE	1970	LOONE002.5MI	Looney's Creek	68c	1	2.0	X	X	X	X
10	LAUREL MOUNTAIN LAKE	1965	LAURE003.4MO	Laurel Creek	67h	2	51.4	X	X	X	X
15	SOUTH HARPETH RIVER	1998	SHARP1T0.4DA	So. Harpeth River Trib	71f	1	16.5	X	X	X	X
17	WILLOW LAKE	1940	WFDRA2T1.5SR	WF Drakes Ck Trib 2	71g	2	25.5	X	X	X	X
18	CITY LAKE	1948	FWATE0031.6PU	Falling Water R	71g	3	62.0	X	X	X	X
25	REELFOOT-INDIAN CREEK #7	1971	TAYLO000.7OB	Taylor Creek	74a	2	88.0	X	X	X	X
27	MIDDLE FORK OBION #11	1974	ARNOL001.4WY	Arnold Branch	65e	2	18.5		X	X	X
34	DUNAWAY	1965	SAVAG009.8SE	Savage Creek	68a	3	75.0	X	X	X	X
35	PELFEY	1994	BUCK001.2CU	Buck Creek	68a	3	64.0	X	X	X	X
38	WOODRUN #1	1977	THOMP1T0.4HR	Thompson Ck Trib	65e	1	17.0		X	X	X
41	CUNNINGHAM BROADBENT LAKE	1940	BARTE001.4MT	Bartee Branch	71f	2	40.0	X	X	X	X
49	ELCAN	1997	SHARP2T0.6DA	S. Harpeth River Trib	71f	1	12.8	X	X	X	X
52	INDIAN CREEK #8	1955	MOODY002.0HR	Moddy Creek	74b	2	13.0	X	X	X	X
53	ARNOLD	2001	GOODI001.1DE	Goodin Brach	71f	2	2.0		X	X	X
60	LINCOLN LAKE	1940	SHELT001.3LI	Shelton Creek	71h	3	40.0	X	X	X	X
61	LAKELAND	1950	SCOTT003.5SH	Scotts Creek	74b	3	237.0		X	X	X
62	CHIEF CREEK	1970	CHIEF004.6LS	Chief Creek	71f	2	96.0	X	X	X	X
63	LAD	1962	CHARL000.7OV	Charlie Branch	68a	1	17.6		X	X	X
65	LINE CREEK #3B	1965	LTRACE005.0CY	Little Trace Ck	71g	3	16.0	X	X	X	X
69	MERIDIAN CREEK # 1	1961	MERID006.5MN	Meridian Creek	65e	2	55.0	X	X	X	X
71	PINE RIDGE LAKE	1970	LOOPE001.0OV	Looper Branch	68a	2	74.4		X	X	X
73	VFW LAKE	1951	WEAVE001.0LW	Weaver Branch	71f	2	20.0	X	X	X	X
74	RIPSHIN LAKE	1946	ROARI002.4CT	Roaring Creek	66d	2	60.2	X	X	X	X
75	HOLIDAY	1959	OBED040.2CU	Obed River	68a	3	209.0		X	X	X
78	SINCLAIR	1950	LAURE005.7RH	Laurel Creek	68a	2	15.0	X	X	X	X
84	ESTES KEFAUVER	?	CARSO001.0MO	Carson Branch	67g	2	13.2	X	X	X	X
85	BROWNS	1935	SFSYC006.3DA	South Fork Sycamore Ck	71f	1	7.0	X	X	X	X

Table A-2 cont.

Selection Rank	Dam	Year Impounded	Station ID	Impounded Stream	Eco-region	Order	Size (Acres)	Season Sampled			
								Fall 2003	Winter 2004	Spring 2004	Summer 2004
86	PORTERS CREEK #6	1961	HUDSO000.3HR	Hudson Branch	65e	3	22.8	X	X	X	X
87	BOSTON BRANCH	1968	BOSTO001.1HM	Boston Branch	68a	2	18.4	X	X	X	X
90	STEELE CREEK	1963	STEEL000.3SU	Steele Creek	67i	2	42.5		X	X	X
92	LAKEWOOD	1976	WALKE1T0.3DA	Walkers Ck Trib	71h	2	12.0	X	X	X	X
98	WESTMORELAND CITY LAKE	1959	DAVIS000.8SR	Davis Branch	71g	2	12.0	X	X	X	X
100	LAKE PLACID	1935	PINEY014.6CS	Piney Creek	65e	2	39.5	X	X	X	X
104	BIG GRUNDY	1934	LFGIZ003.4GY	Little Fiery Gizzard Creek	68a	2	15.3	X	X	X	X
105	CUB CREEK #2A	1963	CUB2T0.3HR	Cub Ck Trib 2	65e	3	39.0	X	X	X	X
106	WEATHERFOROAD-BEAR CREEK 2	1969	BEAR003.6WE	Bear Creek	71f	2	25.0	X	X	X	X
108	SQUAW BRANCH	1963	SQUAW001.4LS	Squaw Branch	71f	2	56.0	X	X	X	X
112	DUNCAN CREEK	1980	DUNCA001.8CU	Duncan Creek	68a	2	57.0	X	X	X	X
113	GARRETT (THOMPSON CK. #4)	1960	TNOMP005.9WY	Thompson Creek	65e	2	183.0		X	X	X
114	GREEN ACRES	?	OTOWN1T0.9HN	Old Town Cr Trib	65e	2	2.3		X	X	X
116	LAKE POMEROY	1975	BGUM000.5CU	Black Gum Br	68a	1	25.2		X	X	X
118	TOM MCBEE	?	FALLS1T0.5MI	Falls Br Trib	68a	2	5.1	X	X	X	X
119	BLACKBURN	1960	FORD1T1.4BN	Ford Creek Trib	71f	1	10.1	X	X	X	X
129	SHANNON	1996	CHARL003.4BN	Charlie Creek	65e	1	3.0	X	X	X	X
133	LAKEVIEW CIRCLE	1972	SFHUR003.6HO	South Fork Hurricane Ck	71f	1	2.8	X	X	X	X
139	LAKE WALDENSIA	1900	MAMMY010.1CU	Mammy's Creek	68a	2	3.4	X	X	X	X
143	PORTERS CREEK #4	1961	STEWA003.4HR	Stewart Branch	65e	3	27.6	X	X	X	X
144	GOOD NEIGHBOR	1965	SCANT001.3CU	Scantling Branch	68a	2	22.9	X	X	X	X
145	FALL CREEK FALLS	1970	FALLS000.5VA	Falls Creek	68a	3	250.0	X	X	X	X
146	WHITEVILLE LAKE	1943	ODAIN000.3HR	Oak Dain Creek	65e	2	147.0	X	X	X	X
148	SPRING	1967	BAGWE1T0.2CU	Bagwell Br Trib	68a	1	9.2		X	X	X
152	GREYSTONE GOLF COURSE	1997	JONES1T0.2DI	Jones Ck Trib.	71f	1	5.5	X	X	X	X
153	O'DONNELL	1955	BARNE002.4FR	Barnes Branch	68a	1	21.0	X	X	X	X
156	KIRKSTONE	1980	POND1T0.1CU	Pond Br Trib	68a	1	21.0		X	X	X

Table A-2 cont.

Selection Rank	Dam	Year Impounded	Station ID	Impounded Stream	Eco-region	Order	Size (Acres)	Season Sampled			
								Fall 2003	Winter 2004	Spring 2004	Summer 2004
161	HAVA-LAKATU #2	1929	JONES2T1.6DI	Jones Ck Trib.	71f	2	4.1	X	X	X	X
164	MCKINNEY	1972	WOLF1T0.1LW	Wolf Ck Trib	71f	1	6.0	X	X	X	X
165	BRYANT	1987	SINKI1T0.8CO	Sinking Ck Trib.	67g	2	4.5	X	X	X	X
168	CEDAR LAKE #2	1977	DRY004.1BN	Dry Creek	65e	2	21.4	X	X	X	X
173	REBECCA LAKE	?	WASHB003.0LI	Washburn Branch	71g	2	32.0	X	X	X	X
178	BOON-DOK	1966	HALEY003.2HI	Haley Creek	71f	2	8.7	X	X	X	X
181	SHERWOOD	1977	TRAIL1T0.4CU	Trail Br Trib	68a	1	16.0	X	X	X	X
182	LAKE EVA	1969	TMILE1T02FR	Two Mile Br Trib.	68a	1	7.1		X	X	X
186	SPRING	1976	EFSPRI1T0.5HR	East Fork Spring Ck Trib.	65e	1	11.0	X	X	X	X
187	REELFOOT-INDIAN CREEK #14	1974	TULL000.3OB	Tull Creek	74a	3	57.5		X	X	X
188	TURNER LAKE	1973	NORTH005.7CU	North Creek	68a	2	105.0	X	X	X	X
189	CHILDRESS LAKE (CIRCLE H RANCH)	1955	HANCO1T0.2LI	Hancock Branch Trib	71g	1	12.0		X	X	X
190	BEDFORD LAKE	1940	DODDY001.9BE	Doddy Creek	71h	3	42.0	X	X	X	X
191	LAKE IN THE SKY	1966	FLAT002.4BT	Flat Creek	66e	2	52.5	X	X	X	X
192	MCKAMY LAKE	1938	MCCAM000.7PO	McCamy Branch	66e	2	7.8	X	X	X	X
193	TWIN LAKE #1	1962	HWATE1T0.1MO	Hot Water Br Trib.	66g	1	3.7	X	X	X	X
194	LAKE LAJOIE	1935	GRAY1T0.9HR	Gray's Ck Trib	65e	3	50.2	X	X	X	X
196	WILLIAMSPORT (SHELLCRACKER)	?	BEASL000.4MY	Beasley Hollow	71h	2	164.0	X	X	X	X
197	SMITH	?	THREE1T0.3HN	Threemile Br Trib.	65e	2	6.4	X	X	X	X
198	CHERIKEE NF	?	RATTL000.1UC	Rattlesnake Creek	66e	2	?	X	X	X	X
200	OZONE	1961	FALL007.6CA	Fall Creek	68a	2	7.6	X	X	X	X
NA	REFERENCE	NA	BEAR005.7MN	Bear Creek	65e	1	NA	X	X	X	X
NA	REFERENCE	NA	DOUGL000.2MG (FECO68A01)	Douglas Branch	68a	1	NA	X	X	X	X
NA	REFERENCE	NA	FLAT008.3OV	Flat Creek	71g	1	NA	X	X	X	X
NA	REFERENCE	NA	INDIA000.1MO	Indian Br	66g	1	NA	X	X	X	X
NA	REFERENCE	NA	LSWAN1T0.1LS	Little Swan Cr Trib.	71f	1	NA	X	X	X	X
NA	REFERENCE	NA	SINKI1T001.0CO	Sinking Creek Trib.	66g	1	NA	X	X	X	X

APPENDIX B

Macroinvertebrate Biometrics
First Order Guidelines
Dominant Taxon

Table B-1: Macroinvertebrate Biometric Results

STATION ID	METHOD	DATE	ECO-REGION	Totlnd	TotTaxa	EPTTax	%EPT	%OC	NCBI	%1Dom	%ClingP	%Nut Tol	TMI
ARNOL001.4WY	SQBANK	4/5/2004	65E	186	10	0	0	28.5	6.63	69.4	0	15.6	12
BAGWE1T0.2CU	SQKICK	5/13/2004	68A	183	26	0	0	84.2	7.71	49.2	3.8	62.8	10
BARNE002.4FR	SQKICK	11/5/2003	68A	232	16	3	3.9	70.7	6.83	34.9	4.3	2.2	14
BARNE002.4FR	SQKICK	4/21/2004	68A	179	16	4	69.3	25.7	1.66	67.6	70.9	5.6	30
BARTE001.4MT	SQKICK	10/6/2003	71F	226	15	1	62.8	17.7	6.35	62.8	73.5	86.7	26
BARTE001.4MT	SQKICK	4/15/2004	71F	178	19	3	6.7	32.6	6.59	44.4	10.1	53.4	12
BEAR003.6WE	SQKICK	10/13/2003	71F	167	17	4	81.4	13.8	5.33	48.5	85.6	58.1	30
BEAR003.6WE	SQKICK	4/14/2004	71F	205	24	9	47.8	42.9	5.3	26.8	56.6	42.4	32
BEASL000.4MY	SQKICK	10/10/2003	71H	214	10	1	0.5	97.2	9.38	92.1	0.5	6.1	2
BEASL000.4MY	SQKICK	4/13/2004	71H	170	16	0	0	21.8	6.74	50	27.6	91.2	16
BGUM000.5CU	SQKICK	5/12/2004	68A	194	31	6	17.5	60.3	4.29	26.3	37.6	30.9	26
BOSTO001.1HM	SQKICK	11/3/2003	68A	181	15	3	7.7	23.2	4.93	37	64.6	28.2	28
BOSTO001.1HM	SQKICK	4/21/2004	68A	165	15	1	1.2	37	4.68	55.2	57.6	58.2	22
BUCK001.2CU	SQKICK	11/5/2003	68A	167	32	9	53.9	24	4.36	34.7	50.3	4.8	34
BUCK001.2CU	SQKICK	5/11/2004	68A	173	28	5	12.7	77.5	5.34	23.1	20.2	21.4	20
CARSO001.0MO	SQKICK	10/29/2003	67G	176	14	3	34.7	33.5	5.71	21.6	61.4	64.8	26
CARSO001.0MO	SQKICK	4/22/2004	67G	178	19	1	3.4	40.4	6	26.4	56.2	83.7	22
CHARL000.7OV	SQKICK	5/10/2004	68A	192	17	1	1	91.1	6.8	50.5	2.1	21.9	8
CHARL003.4BN	SQBANK	10/14/2003	65E	149	23	1	0.7	28.9	7.71	28.2	0	38.9	20
CHARL003.4BN	SQBANK	4/7/2004	65E	161	11	0	0	96.9	9.13	66.5	0	93.2	4
CHIEF004.6LS	SQKICK	10/14/2003	71F	168	14	1	73.2	7.1	6.43	73.2	75.6	76.2	24
CHIEF004.6LS	SQKICK	4/13/2004	71F	177	25	3	6.8	53.7	6.9	29.9	5.6	26.6	14
CUB2T0.3HR	SQBANK	10/15/2003	65E	229	31	7	10	70.7	6.88	20.5	14	16.2	22
CUB2T0.3HR	SQBANK	4/7/2004	65E	183	34	6	6	73.8	6.55	32.2	7.7	19.7	18
DAVIS000.8SR	SQKICK	10/6/2003	71G	172	25	2	35.5	37.2	5.55	30.8	65.7	66.3	28
DAVIS000.8SR	SQKICK	4/14/2004	71G	172	29	3	6.4	73.3	6.85	27.3	23.3	58.1	18
DODDY001.9BE	SQKICK	11/5/2003	71H	167	26	4	6.6	83.2	6.83	20.4	15	56.3	14
DODDY001.9BE	SQKICK	4/20/2004	71H	193	19	3	3.1	46.6	7.27	40.9	16.1	69.9	12

Table B-1 cont.

STATION ID	METHOD	DATE	ECO-REGION	Totlnd	TotTaxa	EPTTax	%EPT	%OC	NCBI	%1Dom	%ClingP	%Nut Tol	TMI
DRY004.1BN	SQBANK	10/16/2003	65E	163	24	2	3.1	57.1	6.89	33.1	10.4	54	18
DRY004.1BN	SQBANK	4/7/2004	65E	129	20	3	2.3	69	6.51	23.3	20.9	44.2	20
DUNCA001.8CU	SQKICK	11/12/2003	68A	220	17	4	4.5	92.3	7.71	45.9	4.5	48.6	12
DUNCA001.8CU	SQKICK	4/29/2004	68A	189	18	6	37	28	3.19	31.7	65.1	37.6	32
EFSPR1T0.5HR	SQBANK	10/7/2003	65E	161	31	4	21.7	52.8	6.56	19.9	32.3	24.2	40
EFSPR1T0.5HR	SQBANK	4/6/2004	65E	204	22	2	2.9	39.2	6.4	54.4	6.9	27.5	32
FALL007.6CU	SQKICK	11/6/2003	68A	200	19	7	89.7	3.3	4.95	38.8	90.9	42.1	38
FALL007.6CU	SQKICK	4/28/2004	68A	189	28	13	38.1	50.8	4.62	21.7	36.5	29.6	34
FALLS000.5VA	SQKICK	10/30/2003	68A	171	21	2	1.8	63.2	5.57	19.3	5.8	36.3	14
FALLS000.5VA	SQKICK	5/11/2004	68A	229	13	0	0	24	5.73	73.4	0.4	9.2	14
FALLS1T0.5MI	SQKICK	11/5/2003	68A	172	22	3	61.6	24.4	6.15	52.9	67.4	59.3	32
FALLS1T0.5MI	SQKICK	4/12/2004	68A	175	24	4	9.7	77.7	5.22	20	25.1	33.7	18
FLAT002.4BT	SQKICK	10/29/2003	66E	173	17	6	82.1	6.9	5.86	72.3	86.7	79.8	28
FLAT002.4BT	SQKICK	5/4/2004	66E	191	10	1	63.4	31.9	5.99	63.4	66.5	94.8	22
FORD1T1.4BN	SQKICK	10/14/2003	71F	237	12	1	0.4	5.1	7.54	64.6	10.1	83.5	12
FORD1T1.4BN	SQKICK	4/7/2004	71F	216	11	1	0.5	4.6	7.58	87	6	94	10
FWATE031.6PU	SQKICK	12/3/2003	71G	173	17	2	11.6	38.2	6	29.5	35.3	64.2	20
FWATE031.6PU	SQKICK	4/29/2004	71G	164	20	5	11.6	47	5.6	28.7	26.8	51.2	22
GOODI001.1DE	SQKICK	4/14/2004	71F	177	17	4	5.1	16.4	7.22	74.6	5.6	76.8	14
GRAY1T0.9HR	SQBANK	10/8/2003	65E	215	16	3	6	90.7	8.87	84.2	6.5	0.5	4
GRAY1T0.9HR	SQBANK	4/6/2004	65E	190	28	5	7.9	41.6	6.86	25.8	5.3	16.8	22
HALEY003.2HI	SQKICK	10/9/2003	71F	165	26	6	50.9	17.6	5.44	33.9	67.9	58.2	32
HALEY003.2HI	SQKICK	4/16/2004	71F	202	34	9	40.6	27.7	5.09	26.2	43.6	42.6	32
HANCO1T0.2LI	SQKICK	4/20/2004	71G	187	23	3	8	45.5	5.4	24.6	55.6	62	26
HUDSO000.3HR	SQBANK	10/8/2003	65E	163	16	3	7.4	67.5	8.51	53.4	11	0.6	14
HUDSO000.3HR	SQBANK	4/7/2004	65E	176	29	4	5.1	49.4	6.98	26.1	11.9	4	22
HWATE1T0.1MO	SQKICK	10/28/2003	66G	103	31	8	41.7	16.5	4.73	14.6	48.5	13.6	34
HWATE1T0.1MO	SQKICK	5/5/2004	66G	220	13	3	52.7	28.6	3.27	45.9	69.1	39.5	30

Table B-1 cont.

STATION ID	METHOD	DATE	ECO-REGION	Totlnd	TotTaxa	EPTTax	%EPT	%OC	NCBI	%1Dom	%ClingP	%Nut Tol	TMI
JONES1T0.2DI	SQKICK	10/6/2003	71F	178	28	8	44.9	36.5	5.87	21.3	37.6	60.1	30
JONES1T0.2DI	SQKICK	4/8/2004	71F	222	24	5	30.2	17.6	5.19	28.8	23	51.4	26
JONES2T1.6DI	SQKICK	10/13/2003	71F	177	23	7	52.5	14.1	5.18	31.6	73.4	67.8	32
JONES2T1.6DI	SQKICK	4/13/2004	71F	175	25	4	16.6	60	5.11	13.7	42.3	28.6	22
LAURE003.4MO	SQKICK	10/28/2003	67H	198	11	2	77.3	15.7	6.08	76.3	93.9	93.9	26
LAURE003.4MO	SQKICK	5/5/2004	67H	161	22	5	31.7	64	4.5	26.7	43.5	41.6	28
LAURE005.7RH	SQKICK	10/30/2003	68A	193	11	0	0	95.9	8.18	33.7	0	90.2	10
LAURE005.7RH	SQKICK	4/22/2004	68A	179	27	1	1.7	64.8	6.77	27.4	3.9	36.9	16
LFGIZ003.4GY	SQKICK	11/6/2003	68A	163	22	5	39.3	33.7	5.5	19.6	16.6	18.4	24
LFGIZ003.4GY	SQKICK	4/21/2004	68A	190	19	3	66.3	28.4	4.19	50.5	11.1	12.6	28
LOONE002.5MI	SQKICK	11/6/2003	68C	156	25	4	25.6	18.6	4.93	21.2	36.5	14.1	28
LOONE002.5MI	SQKICK	4/21/2004	68C	229	32	7	61.1	17.9	4.33	25.8	55.5	31.9	40
LOOPE001.0OV	SQKICK	5/10/2004	68A	170	14	1	17.1	38.2	5.21	44.1	68.2	84.7	22
LTRAC005.0CY	SQKICK	11/14/2003	71G	213	29	7	27.2	53.1	5.67	23	42.3	54.5	26
LTRAC005.0CY	SQKICK	5/13/2004	71G	228	28	9	23.2	61.4	5.5	51.3	34.2	81.6	22
MAMMY010.1CU	SQKICK	11/6/2003	68A	175	16	7	73.7	23.4	3.63	35.4	78.9	12.6	36
MAMMY010.1CU	SQKICK	4/28/2004	68A	177	27	12	16.4	69.5	4.55	21.5	23.2	28.8	28
MCCAM000.7PO	SQKICK	10/29/2003	66E	190	24	7	56.8	36.8	2.96	23.2	14.7	5.3	26
MCCAM000.7PO	SQKICK	4/22/2004	66E	234	21	4	36.3	45.3	4.15	26.9	30.8	3	20
MERID006.5MN	SQBANK	10/9/2003	65E	118	26	2	7.6	30.5	7.43	16.9	27.1	23.7	22
MERID006.5MN	SQBANK	4/7/2004	65E	170	24	2	9.4	36.5	5.31	50.6	62.4	72.9	24
MOODY002.0HR	SQBANK	10/7/2003	74B	162	26	6	22.8	47.5	6.69	20.4	43.2	43.8	28
MOODY002.0HR	SQBANK	4/6/2004	74B	179	31	0	0	81.6	7.68	34.1	5.6	58.1	12
NORTH005.7CU	SQKICK	10/31/2003	68A	75	20	2	5.3	48	6.65	32	13.3	25.3	16
NORTH005.7CU	SQKICK	5/13/2004	68A	192	25	2	17.7	75.5	6.28	22.4	46.4	67.2	20
OBED040.2CU	SQKICK	5/14/2004	68A	208	20	3	1.9	27.4	6.04	55.3	9.6	24	16
ODAIN000.3HR	SQBANK	10/7/2003	65E	162	26	5	11.7	41.4	8	30.2	30.9	4.3	26
ODAIN000.3HR	SQBANK	4/5/2004	65E	191	28	3	7.9	18.8	7.23	22.5	24.1	7.9	26

Table B-1 cont.

STATION ID	METHOD	DATE	ECO-REGION	Totlnd	TotTaxa	EPTTax	%EPT	%OC	NCBI	%1Dom	%ClingP	%Nut Tol	TMI
OTOWN1T0.9HN	SQBANK	4/6/2004	65E	120	33	1	10.8	51.7	5.92	10.8	1.7	30.8	32
PINEY014.6CS	SQBANK	10/9/2003	65E	219	22	4	40.2	33.3	6.9	28.8	40.6	58.4	32
PINEY014.6CS	SQBANK	4/5/2004	65E	206	24	2	1.5	81.1	5.44	33	2.9	51	16
POND1T0.1CU	SQKICK	5/12/2004	68A	185	32	8	7	88.1	5.13	24.9	33	28.1	22
RATTL000.1UC	SQKICK	10/28/2003	66E	234	33	13	46.6	41.5	3.54	17.9	50.4	12	32
RATTL000.1UC	SQKICK	4/27/2004	66E	200	37	16	40.5	48.5	3.19	12.5	40	8.5	30
ROARI002.4CT	SQKICK	10/28/2003	66D	163	20	5	4.3	69.3	5.79	46.6	11.7	24.5	14
ROARI002.4CT	SQKICK	4/27/2004	66D	170	16	2	1.2	85.9	5.4	54.1	4.7	58.2	10
SAVAG009.8SE	SQKICK	11/10/2003	68A	217	15	1	0.5	47	6.73	37.8	25.3	70.5	14
SAVAG009.8SE	SQKICK	5/11/2004	68A	187	15	2	52.4	10.7	5.44	37.4	71.1	58.8	28
SCANT001.3CU	SQKICK	11/12/2003	68A	63	14	3	14.3	81	7.1	36.5	3.2	46	12
SCANT001.3CU	SQKICK	5/10/2004	68A	162	20	0	0	77.8	7.66	30.9	0.6	19.1	12
SCOTT003.5SH	SQBANK	4/5/2004	74B	163	17	1	1.2	87.1	5.63	27	14.1	23.9	16
SFHUR003.6HO	SQKICK	10/7/2003	71F	238	10	2	2.5	8.4	7.41	82.8	2.1	10.1	10
SFHUR003.6HO	SQBANK	4/6/2004	71F	201	20	1	0.5	41.8	6.2	42.3	2.5	15.9	14
SFSYC006.3DA	SQKICK	10/10/2003	71F	208	34	12	38	35.1	4.51	11.5	42.8	38	38
SFSYC006.3DA	SQKICK	4/14/2004	71F	184	37	12	19.6	47.8	5.51	18.5	27.7	54.3	32
SHARP1T0.4DA	SQKICK	10/17/2003	71F	162	12	0	0	92.6	7.46	49.4	0	73.5	8
SHARP1T0.4DA	SQKICK	4/15/2004	71F	193	19	4	8.3	16.6	6.57	30.1	7.8	38.9	20
SHARP2T0.6DA	SQKICK	10/16/2003	71F	239	19	1	0.4	18	7.15	55.2	1.3	23.4	16
SHARP2T0.6DA	SQKICK	4/13/2004	71F	197	24	3	3	30.5	6.8	47.7	14.7	77.7	18
SHELT001.3LI	SQKICK	11/4/2003	71H	203	17	2	26.1	24.3	6.83	40.9	34.3	39.1	18
SHELT001.3LI	SQKICK	4/20/2004	71H	190	24	2	21.1	36.8	5.93	20.5	45.8	58.4	24
SINKI1T0.8CO	SQKICK	10/29/2003	67G	178	17	5	75.3	5.6	5.28	49.4	83.1	65.7	30
SINKI1T0.8CO	SQKICK	4/27/2004	67G	192	22	4	22.9	14.6	4.89	20.8	61.5	59	30
SQUAW001.4LS	SQKICK	10/16/2003	71F	208	13	0	0	84.6	6.74	28.8	17.8	77.9	12
SQUAW001.4LS	SQKICK	4/13/2004	71F	180	18	4	9.4	57.2	5.45	30.6	10.3	15	16
STEEL000.3SU	SQKICK	7/19/2003	67I	203	23	6	66.5	21.2	5.12	35.5	77.8	59.1	32

Table B-1 cont.

STATION ID	METHOD	DATE	ECO-REGION	Totlnd	TotTaxa	EPTTax	%EPT	%OC	NCBI	%1Dom	%ClingP	%Nut Tol	TMI
STEEL000.3SU	SQKICK	4/26/2004	67I	191	14	2	6.8	8.4	4.37	77	81.2	86.9	22
STEWA003.4HR	SQBANK	10/28/2003	65E	163	39	6	25.2	54	6.55	13.5	39.3	30.7	32
STEWA003.4HR	SQBANK	4/7/2004	65E	188	28	5	6.4	67.6	6.23	14.4	24.5	20.7	22
TAYLO000.7OB	SQKICK	10/8/2003	74A	200	18	1	1.2	79.7	8.42	57.7	2.4	23.2	10
TAYLO000.7OB	SQKICK	4/5/2004	74A	184	16	0	0	29.3	7.78	36.4	2.7	44	18
THOMP005.9WY	SQBANK	4/6/2004	65E	225	19	1	0.4	25.8	6.35	59.1	0.4	7.1	14
THOMP1T0.4HR	SQBANK	4/6/2004	65E	185	25	3	3.8	89.7	6.41	20.5	9.7	63.2	38
THREE1T0.3HN	SQBANK	10/7/2003	65E	185	31	3	2.2	11.9	7.65	67.6	2.2	5.4	16
THREE1T0.3HN	SQBANK	4/6/2004	65E	228	27	1	0.9	29.8	7.1	51.8	0	13.6	18
TMILE1T0.2FR	SQKICK	4/21/2004	68A	195	12	2	12.3	40	3.6	34.9	57.4	29.7	24
TRAIL1T0.4CU	SQKICK	5/13/2004	68A	170	29	6	15.3	69.4	4.84	18.8	28.8	44.1	24
TULL000.3OB	SQBANK	4/5/2004	74A	229	8	0	0	7.9	8.64	67.7	0	27.5	10
WALKE1T0.3DA	SQKICK	10/2/2003	71H	185	10	1	3.8	16.2	7.37	73	5.4	25.4	12
WALKE1T0.3DA	SQKICK	10/10/2003	71H	184	12	1	5.4	4.3	7.13	72.3	8.2	23.4	12
WALKE1T0.3DA	SQKICK	4/8/2004	71H	230	15	3	1.7	22.2	7.51	64.3	0.9	80	12
WASHB003.0LI	SQKICK	11/4/2003	71G	211	19	1	1.9	14.7	5.36	76.8	82	82	20
WASHB003.0LI	SQKICK	4/20/2004	71G	239	25	4	2.5	23.8	5.52	63.6	72.8	78.2	24
WEAVE001.0LW	SQKICK	10/13/2003	71F	174	8	1	0.6	42.5	7.81	56.9	0.6	19.5	10
WEAVE001.0LW	SQKICK	4/13/2004	71F	195	20	1	2.1	51.8	6.21	40.5	2.6	45.6	14
WFDRA2T1.5SR	SQKICK	10/6/2003	71G	160	25	6	42.5	45	6.44	31.3	41.9	79.4	26
WFDRA2T1.5SR	SQKICK	4/14/2004	71G	177	14	3	8.5	31.6	7.83	51.4	13	88.1	12
WOLF1T0.1LW	SQKICK	10/13/2003	71F	167	25	3	6.6	44.3	5.91	31.1	11.4	40.7	20
WOLF1T0.1LW	SQKICK	4/14/2004	71F	207	22	2	1.9	15.5	7.17	74.9	5.8	86	14

Table B-2: First Order Guidelines (Guidelines for larger streams can be found in TDEC's QSSOP for Macroinvertebrate Stream Surveys, 2003)

Ecoregion 65e- ISP Project Specific Reference Target TMI Score January - June = 32			**Method = SQBANK Order = 1**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 21	15 – 21	7 – 14	< 7
EPT Richness	> 3	3	1 – 2	< 1
% EPT	> 4.0	2.7 – 4.0	1.3 – 2.6	< 1.3
% OC	< 90.4	90.4 – 93.5	93.6 – 96.7	> 96.7
NCBI	< 7.28	7.28 – 8.18	8.19 – 9.09	> 9.09
% Dominant	< 40.8	40.8 – 60.5	60.6 – 80.3	> 80.3
% Clingers	> 7.3	5.2 – 7.3	3.0 – 5.1	< 3.0
%Nuttol (not included in TMI)	< 32.0	32.0 – 54.6	54.7 – 77.3	> 77.3
Ecoregion 65e- ISP Project Specific Reference Target TMI Score June - December = 32			**Method = SQBANK Order = 1**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 24	17 - 24	8 - 16	< 8
EPT Richness (EPT)	> 3	3	1 - 2	< 1
% EPT	> 19.9	13.3 – 19.9	6.6 –13.2	< 6.6
% OC	< 73.1	73.1 – 82.1	82.2 – 91.1	> 91.1
NCBI	< 6.20	6.20 – 7.46	7.47 – 8.73	> 8.73
% Dominant	< 34.5	34.5 – 56.2	56.3 – 78.0	> 78.0
% Clingers	> 7.2	4.9 – 7.2	2.5 – 4.8	< 2.5
%Nuttol (not included in TMI)	< 33.1	33.1 – 55.3	55.4 – 77.7	> 77.7
Ecoregion 66g- ISP Project Specific Reference Target TMI Score Jan – December = 32			**Method = SQKICK Order = 1 and 2 with drainage less than 5 sq miles**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 32	22 - 32	11 - 21	< 11
EPT Richness (EPT)	> 13	9 - 13	5 - 8	< 5
% EPT	> 44.1	29.4 – 44.1	14.6 – 29.3	< 14.6
% OC	< 44.0	44.0 – 62.6	62.7 – 81.3	> 81.3
NCBI	< 4.90	4.90 – 6.70	6.71 – 8.50	> 8.50
% Dominant	< 39.1	39.1 – 58.1	58.2 – 79.1	> 79.1
% Clingers	> 42.3	28.2 – 42.3	14.0 - 28.1	< 14.0
%Nuttol (not included in TMI)	< 27.8	27.8 – 51.8	51.9 – 75.8	> 75.8

Table B-2 cont.

Ecoregion 68a- ISP Project Specific Reference Target TMI Score Jan – December = 32			**Method = SQKICK Order = 1 and 2 with drainage less than 5 sq miles**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 26	18 – 26	9 – 17	< 9
EPT Richness (EPT)	> 9	7 – 9	3 - 6	< 3
% EPT	> 58.3	39.0 – 58.3	19.6 – 38.9	< 19.6
% OC	< 32.6	32.6 – 55.0	55.1 – 77.5	> 77.5
NCBI	< 5.00	5.00 – 6.60	6.61 – 8.30	> 8.30
% Dominant	< 46.8	46.8 – 64.5	64.6 – 82.3	> 82.3
% Clingers	> 49.8	33.3 – 49.8	16.7 – 33.2	< 16.7
%Nuttol (not included in TMI)	< 39.4	39.4 – 59.5	59.6 – 79.7	> 79.7
Ecoregion 71f - ISP Project Specific Reference Target TMI Score Jan - December = 32			**Method = SQKICK Order = 1**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 25	17 – 25	9 – 16	< 9
EPT Richness (EPT)	> 10	7 - 10	4 - 6	< 4
% EPT	> 54.5	36.4 – 54.5	18.2 – 36.3	< 18.2
% OC	< 35.6	35.6 – 57.1	57.2 – 78.6	> 78.6
NCBI	< 4.00	4.00 – 5.98	5.99 – 7.98	> 7.98
% Dominant	< 37.1	37.1 – 58.0	58.1 – 79.0	> 79.0
% Clingers	> 39.7	26.2 – 39.7	13.4 – 26.1	< 13.4
%Nuttol (not included in TMI)	< 27.4	27.4 – 51.5	51.6 – 75.7	> 75.7
Ecoregion 71G - ISP Project Specific Reference Target TMI Score Jan – December = 32			**Method = SQKICK Order = 1**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 15	10 - 15	5 – 9	< 5
EPT Richness (EPT)	> 6	5 - 6	2 – 4	< 2
% EPT	> 33.1	22.0 - 33.1	10.9 - 21.9	< 10.9
% OC	< 26.8	26.8 – 51.1	51.2 – 75.5	> 75.5
NCBI	< 4.37	4.37 – 6.24	6.25 – 8.12	> 8.12
% Dominant	< 52.7	52.7 – 68.5	68.6 – 84.3	> 84.3
% Clingers	> 67.3	44.9 – 67.3	22.4 – 44.8	< 22.4
%Nuttol (not included in TMI)	< 32.4	32.4 – 55.0	55.1 – 77.6	> 77.6

Table B-2 cont.

Ecoregion 71G - ISP Project Specific Reference Target TMI Score Jan – December = 32			**Method = SQBANK Order = 3 OR Drainage area = 2-30 sq miles**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 31	21 - 31	10 - 20	< 10
EPT Richness (EPT)	> 3	2 - 3	1	< 1
% EPT	> 14.2	9.5 – 14.2	4.7 – 9.4	< 4.7
% OC	< 63.1	63.1 –75.4	75.5 – 87.6	> 87.6
NCBI	< 7.21	7.21 – 8.13	8.14 – 9.06	> 9.06
% Dominant	< 34.4	34.4 – 56.2	56.3 – 78.1	> 78.1
% Clingers	> 10.4	7.1 – 10.4	3.7 – 7.0	< 3.7
%Nuttol (not included in TMI)	< 43.4	43.4 – 62.3	62.4 – 81.1	> 81.1
UPSTREAM REFERENCE SINKI1T1.0CO Target TMI Score Jan – December = 32			**Method = SQKICK**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 31	22 - 31	11 - 21	< 11
EPT Richness (EPT)	> 13	9 - 13	5 – 8	< 5
% EPT	> 46.8	31.3 – 46.8	15.7 – 31.2	< 15.7
% OC	< 34.2	34.2 – 56.1	56.2 – 78.2	> 78.2
NCBI	< 4.51	4.51 – 6.34	6.35 – 8.18	> 8.18
% Dominant	< 36.6	36.6 – 57.7	57.8 – 78.8	> 78.8
% Clingers	> 38.4	25.7 – 38.4	12.9 – 25.6	< 12.9
%Nuttol (not included in TMI)	< 28.9	28.9 – 52.5	52.6 – 76.2	> 76.2

Table B-3: Dominant Taxon

Station ID	Eco-region	Method	DATE	Dominant Taxon	Order
ARNOL001.4WY	65e	SQBANK	4/5/2004	Hydra	Hydra
BAGWE1T0.2CU	68a	SQKICK	5/13/2004	Nais	Oligochaeta
BARNE002.4FR	68a	SQKICK	11/5/2003	Diplocladius	Diptera
BARNE002.4FR	68a	SQKICK	4/21/2004	Leuctra	Plecoptera
BARTE001.4MT	71f	SQKICK	10/6/2003	Cheumatopsyche	Trichoptera
BARTE001.4MT	71f	SQKICK	4/15/2004	Lirceus	Crustacea
BEAR003.6WE	71f	SQKICK	10/13/2003	Cheumatopsyche	Trichoptera
BEAR003.6WE	71f	SQKICK	4/14/2004	Cheumatopsyche	Trichoptera
BEASL000.4MY	71h	SQKICK	10/10/2003	Glyptotendipes	Diptera
BEASL000.4MY	71h	SQKICK	4/13/2004	Lirceus	Crustacea
BGUM000.5CU	68a	SQKICK	5/12/2004	Parametriocnemus	Diptera
BOSTO001.1HM	68a	SQKICK	11/3/2003	Prosimulium	Diptera
BOSTO001.1HM	68a	SQKICK	4/21/2004	Simulium	Diptera
BUCK001.2CU	68a	SQKICK	11/5/2003	Chimarra	Trichoptera
BUCK001.2CU	68a	SQKICK	5/11/2004	Parametriocnemus	Diptera
CARSO001.0MO	67g	SQKICK	10/29/2003	Cheumatopsyche	Trichoptera
CARSO001.0MO	67g	SQKICK	4/22/2004	Stenelmis	Coleoptera
CHARL000.7OV	68a	SQKICK	5/10/2004	Tanytarsus	Diptera
CHARL003.4BN	65e	SQBANK	10/14/2003	Neoporus	Coleoptera
CHARL003.4BN	65e	SQBANK	4/7/2004	Limnodrilus	Oligochaeta
CHIEF004.6LS	71f	SQKICK	10/14/2003	Cheumatopsyche	Trichoptera
CHIEF004.6LS	71f	SQKICK	4/13/2004	Crangonyx	Crustacea
CUB2T0.3HR	65e	SQBANK	10/15/2003	Dicrotendipes	Diptera
CUB2T0.3HR	65e	SQBANK	4/7/2004	Cricotopus/Orthocladius	Diptera
DAVIS000.8SR	71g	SQKICK	10/6/2003	Cheumatopsyche	Trichoptera
DAVIS000.8SR	71g	SQKICK	4/14/2004	Nais	Oligochaeta
DODDY001.9BE	71h	SQKICK	11/5/2003	Polypedilum	Diptera
DODDY001.9BE	71h	SQKICK	4/20/2004	Nais	Oligochaeta
DRY004.1BN	65e	SQBANK	10/16/2003	Polypedilum	Diptera
DRY004.1BN	65e	SQBANK	4/7/2004	Polypedilum	Diptera
DUNCA001.8CU	68a	SQKICK	11/12/2003	Chironomus	Diptera
DUNCA001.8CU	68a	SQKICK	4/29/2004	Leuctra	Plecoptera
EFSPR1T0.5HR	65e	SQBANK	10/7/2003	Oecetis	Trichoptera
EFSPR1T0.5HR	65e	SQBANK	4/6/2004	Hydra	Hydra
FALL007.6CU	68a	SQKICK	11/6/2003	Cheumatopsyche	Trichoptera
FALL007.6CU	68a	SQKICK	4/28/2004	Polypedilum	Diptera
FALLS000.5VA	68a	SQKICK	10/30/2003	Hydra	Hydra

Table B-3 cont.

Station ID	Eco-region	Method	DATE	Dominant Taxon	Order
FALLS000.5VA	68a	SQKICK	10/30/2003	Polypedilum	Diptera
FALLS000.5VA	68a	SQKICK	5/11/2004	Hydra	Hydra
FALLS000.5VA	68a	SQKICK	5/11/2004	Hydra	Hydra
FALLS1T0.5MI	68a	SQKICK	11/5/2003	Tipula	Diptera
FALLS1T0.5MI	68a	SQKICK	4/12/2004	Parametriocnemus	Diptera
FLAT002.4BT	66e	SQKICK	10/27/2003	Cheumatopsyche	Trichoptera
FLAT002.4BT	66e	SQKICK	10/29/2003	Cheumatopsyche	Trichoptera
FLAT002.4BT	66e	SQKICK	5/4/2004	Cheumatopsyche	Trichoptera
FORD1T1.4BN	71f	SQKICK	10/14/2003	Lirceus	Crustacea
FORD1T1.4BN	71f	SQKICK	4/7/2004	Lirceus	Crustacea
FWATE031.6PU	71g	SQKICK	12/3/2003	Polypedilum	Diptera
FWATE031.6PU	71g	SQKICK	4/29/2004	Polypedilum	Diptera
GOODI001.1DE	71f	SQKICK	4/14/2004	Lirceus	Crustacea
GRAY1T0.9HR	65e	SQBANK	10/8/2003	Glyptotendipes	Diptera
GRAY1T0.9HR	65e	SQBANK	4/6/2004	Bezzia	Diptera
HALEY003.2HI	71f	SQKICK	10/9/2003	Cheumatopsyche	Trichoptera
HALEY003.2HI	71f	SQKICK	10/9/2003	Cheumatopsyche	Trichoptera
HALEY003.2HI	71f	SQKICK	4/16/2004	Cheumatopsyche	Trichoptera
HALEY003.2HI	71f	SQKICK	4/16/2004	Hydra	Hydra
HANCO1T0.2LI	71g	SQKICK	4/20/2004	Stenelmis	Coleoptera
HUDSO000.3HR	65e	SQBANK	10/8/2003	Glyptotendipes	Diptera
HUDSO000.3HR	65e	SQBANK	4/7/2004	Ablabesmyia	Diptera
HWATE1T0.1MO	66g	SQKICK	10/28/2003	Diplectrona	Trichoptera
HWATE1T0.1MO	66g	SQKICK	5/5/2004	Leuctra	Plecoptera
JONES1T0.2DI	71f	SQKICK	10/6/2003	Limnodrilus	Oligochaeta
JONES1T0.2DI	71f	SQKICK	10/13/2003	Lirceus	Crustacea
JONES1T0.2DI	71f	SQKICK	4/8/2004	Lirceus	Crustacea
JONES1T0.2DI	71f	SQKICK	4/8/2004	Lirceus	Crustacea
JONES2T1.6DI	71f	SQKICK	10/13/2003	Cheumatopsyche	Trichoptera
JONES2T1.6DI	71f	SQKICK	4/13/2004	Tanytarsus	Diptera
LAURE003.4MO	67h	SQKICK	10/28/2003	Cheumatopsyche	Trichoptera
LAURE003.4MO	67h	SQKICK	5/5/2004	Parametriocnemus	Diptera
LAURE005.7RH	68a	SQKICK	10/30/2003	Tubificidae	Oligochaeta
LAURE005.7RH	68a	SQKICK	10/30/2003	Tubificidae	Oligochaeta
LAURE005.7RH	68a	SQKICK	4/22/2004	Tubificidae	Oligochaeta
LFGIZ003.4GY	68a	SQKICK	11/6/2003	Isonychia	Ephemeroptera
LFGIZ003.4GY	68a	SQKICK	4/21/2004	Amphinemura	Plecoptera

Table B-3 cont.

Station ID	Eco-region	Method	DATE	Dominant Taxon	Order
LOONE002.5MI	68c	SQKICK	11/6/2003	Gomphidae	Odonata
LOONE002.5MI	68c	SQKICK	4/21/2004	Cheumatopsyche	Trichoptera
LOOPE001.0OV	68a	SQKICK	5/10/2004	Simulium	Diptera
LTRAC005.0CY	71g	SQKICK	11/14/2003	Cheumatopsyche	Trichoptera
LTRAC005.0CY	71g	SQKICK	5/13/2004	Polypedilum	Diptera
MAMMY010.1CU	68a	SQKICK	11/6/2003	Chimarra	Trichoptera
MAMMY010.1CU	68a	SQKICK	4/28/2004	Polypedilum	Diptera
MCCAM000.7PO	66e	SQKICK	10/29/2003	Habrophlebia	Ephemeroptera
MCCAM000.7PO	66e	SQKICK	4/22/2004	Leucta	Plecoptera
MERID006.5MN	65e	SQBANK	10/9/2003	Argia	Odonata
MERID006.5MN	65e	SQBANK	10/9/2003	Cheumatopsyche	Trichoptera
MERID006.5MN	65e	SQBANK	4/7/2004	Simulium	Diptera
MOODY002.0HR	74b	SQBANK	10/7/2003	Calopteryx	Odonata
MOODY002.0HR	74b	SQBANK	4/6/2004	Chironomus	Diptera
NORTH005.7CU	68a	SQKICK	10/31/2003	Tipula	Diptera
NORTH005.7CU	68a	SQKICK	5/13/2004	Rheotanytarsus	Diptera
OBED040.2CU	68a	SQKICK	5/14/2004	Hydra	Hydra
ODAIN000.3HR	65e	SQBANK	10/7/2003	Glyptotendipes	Diptera
ODAIN000.3HR	65e	SQBANK	4/5/2004	Dugesia	Planaria
OTOWN1T0.9HN	65e	SQBANK	4/6/2004	Naididae	Oligochaeta
PINEY014.6CS	65e	SQBANK	10/9/2003	Cheumatopsyche	Trichoptera
PINEY014.6CS	65e	SQBANK	10/9/2003	Dugesia	Planaria
PINEY014.6CS	65e	SQBANK	4/5/2004	Dugesia	Planaria
PINEY014.6CS	65e	SQBANK	4/5/2004	Polypedilum	Diptera
POND1T0.1CU	68a	SQKICK	5/12/2004	Rheotanytarsus	Diptera
RATTL000.1UC	66e	SQKICK	10/28/2003	Diplectrona	Trichoptera
RATTL000.1UC	66e	SQKICK	4/27/2004	Constempellina	Diptera
RATTL000.1UC	66e	SQKICK	4/27/2004	Thienemannimyia	Diptera
ROARI002.4CT	66d	SQKICK	10/28/2003	Thienemannimyia	Diptera
ROARI002.4CT	66d	SQKICK	4/27/2004	Polypedilum	Diptera
SAVAG009.8SE	68a	SQKICK	11/10/2003	Nais	Oligochaeta
SAVAG009.8SE	68a	SQKICK	5/11/2004	Cheumatopsyche	Trichoptera
SCANT001.3CU	68a	SQKICK	11/12/2003	Limnodrilus	Oligochaeta
SCANT001.3CU	68a	SQKICK	5/10/2004	Zavrelimyia	Diptera
SCOTT003.5SH	74b	SQBANK	4/5/2004	Cricotopus/Orthocladius	Diptera
SFHUR003.6HO	71f	SQKICK	10/7/2003	Dugesia	Planaria
SFHUR003.6HO	71f	SQBANK	4/6/2004	Hydra	Hydra

Table B-3 cont.

Station ID	Eco-region	Method	DATE	Dominant Taxon	Order
SFSYC006.3DA	71f	SQKICK	10/10/2003	Elimia	Gastropoda
SFSYC006.3DA	71f	SQKICK	4/14/2004	Lirceus	Crustacea
SHARP1T0.4DA	71f	SQKICK	10/17/2003	Chironomus	Diptera
SHARP1T0.4DA	71f	SQKICK	4/15/2004	Lirceus	Crustacea
SHARP2T0.6DA	71f	SQKICK	10/16/2003	Sphaeriidae	Bivalvia
SHARP2T0.6DA	71f	SQKICK	4/13/2004	Lirceus	Crustacea
SHELT001.3LI	71h	SQKICK	11/4/2003	Dugesia	Planaria
SHELT001.3LI	71h	SQKICK	4/20/2004	Cheumatopsyche	Trichoptera
SHELT001.3LI	71h	SQKICK	4/20/2004	Stenelmis	Coleoptera
SINKI1T0.8CO	67g	SQKICK	10/29/2003	Cheumatopsyche	Trichoptera
SINKI1T0.8CO	67g	SQKICK	4/27/2004	Stenelmis	Coleoptera
SQUAW001.4LS	71f	SQKICK	10/16/2003	Nais	Oligochaeta
SQUAW001.4LS	71f	SQKICK	4/13/2004	Thienemannimyia	Diptera
STEEL000.3SU	67i	SQKICK	7/19/2003	Cheumatopsyche	Trichoptera
STEEL000.3SU	67i	SQKICK	4/26/2004	Simulium	Diptera
STEWA003.4HR	65e	SQBANK	10/28/2003	Cheumatopsyche	Trichoptera
STEWA003.4HR	65e	SQBANK	4/7/2004	Nanocladius	Diptera
TAYLO000.7OB	74a	SQKICK	10/8/2003	Glyptotendipes	Diptera
TAYLO000.7OB	74a	SQKICK	4/5/2004	Caecidotea	Crustacea
TAYLO000.7OB	74a	SQKICK	4/5/2004	Lirceus	Crustacea
THOMP005.9WY	65e	SQBANK	4/6/2004	Hydra	Hydra
THOMP1T0.4HR	65e	SQBANK	4/6/2004	Nais	Oligochaeta
THREE1T0.3HN	65e	SQBANK	10/7/2003	Crangonyx	Crustacea
THREE1T0.3HN	65e	SQBANK	4/6/2004	Crangonyx	Crustacea
TMILE1T0.2FR	68a	SQKICK	4/21/2004	Parametriocnemus	Diptera
TRAIL1T0.4CU	68a	SQKICK	5/13/2004	Parametriocnemus	Diptera
TULL000.3OB	74a	SQBANK	4/5/2004	Caecidotea	Crustacea
WALKE1T0.3DA	71h	SQKICK	10/2/2003	Dugesia	Planaria
WALKE1T0.3DA	71h	SQKICK	10/10/2003	Dugesia	Planaria
WALKE1T0.3DA	71h	SQKICK	4/8/2004	Lirceus	Crustacea
WALKE1T0.3DA	71h	SQKICK	4/8/2004	Lirceus	Crustacea
WASHB003.0LI	71g	SQKICK	11/4/2003	Stenelmis	Coleoptera
WASHB003.0LI	71g	SQKICK	4/20/2004	Stenelmis	Coleoptera
WEAVE001.0LW	71f	SQKICK	10/13/2003	Dugesia	Planaria
WEAVE001.0LW	71f	SQKICK	4/13/2004	Dugesia	Planaria
WFDRA2T1.5SR	71g	SQKICK	10/6/2003	Cheumatopsyche	Trichoptera
WFDRA2T1.5SR	71g	SQKICK	4/14/2004	Lirceus	Crustacea

Table B-3 cont.

Station ID	Eco-region	Method	DATE	Dominant Taxon	Order
WOLF1T0.1LW	71f	SQKICK	10/13/2003	Lirceus	Crustacea
WOLF1T0.1LW	71f	SQKICK	4/14/2004	Lirceus	Crustacea

APPENDIX C

Channel Flow Status
Rosgen Stream Classification
Cross-section and Particle Count Graphs
Habitat Scores

Table C-1: Channel Flow Status

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
ARNOL001.4WY	Jackson	2	65E	Fall 2003	0	14
ARNOL001.4WY	Jackson	2	65E	1/13/2004	12	14
ARNOL001.4WY	Jackson	2	65E	4/5/2004	10	14
ARNOL001.4WY	Jackson	2	65E	7/16/2004	7	14
BAGWE1T0.2CU	Monterey	1	68A	Fall 2003	0	12
BAGWE1T0.2CU	Monterey	1	68A	2/10/2004	16	12
BAGWE1T0.2CU	Monterey	1	68A	5/13/2004	7	12
BAGWE1T0.2CU	Monterey	1	68A	Summer 2004	0	12
BARNE002.4FR	Chattanooga	1	68A	11/5/2003	9	7
BARNE002.4FR	Chattanooga	1	68A	2/8/2004	10	12
BARNE002.4FR	Chattanooga	1	68A	4/21/2004	12	12
BARNE002.4FR	Chattanooga	1	68A	8/4/2004	0.1*	7
BARTE001.4MT	Nashville	2	71F	10/6/2003	10	11
BARTE001.4MT	Nashville	2	71F	1/15/2004	12	11
BARTE001.4MT	Nashville	2	71F	4/15/2004	17	11
BARTE001.4MT	Nashville	2	71F	7/12/2004	14	11
BEAR003.6WE	Huntsville	2	71F	10/13/2003	18	11
BEAR003.6WE	Huntsville	2	71F	1/14/2004	17	11
BEAR003.6WE	Huntsville	2	71F	4/14/2004	19	11
BEAR003.6WE	Huntsville	2	71F	7/14/2004	19	11
BEASL000.4MY	Huntsville	2	71H	10/10/2003	11	12
BEASL000.4MY	Huntsville	2	71H	1/21/2004	7	12
BEASL000.4MY	Huntsville	2	71H	4/13/2004	19	12
BEASL000.4MY	Huntsville	2	71H	7/15/2004	14	12
BGUM000.5CU	Monterey	1	68A	Fall 2003	0	7
BGUM000.5CU	Monterey	1	68A	2/10/2004	18	12
BGUM000.5CU	Monterey	1	68A	5/12/2004	13	12
BGUM000.5CU	Monterey	1	68A	7/26/2004	6	7
BOSTO001.1HM	Chattanooga	2	68A	11/3/2003	16	7
BOSTO001.1HM	Chattanooga	2	68A	2/4/2004	12	12
BOSTO001.1HM	Chattanooga	2	68A	4/21/2004	16	12
BOSTO001.1HM	Chattanooga	2	68A	Summer 2004	0.2*	7
BUCK001.2CU	Monterey	3	68A	11/5/2003	12	11
BUCK001.2CU	Monterey	3	68A	2/10/2004	18	14
BUCK001.2CU	Monterey	3	68A	5/11/2004	16	14
BUCK001.2CU	Monterey	3	68A	7/27/2004	20	11

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
CARSO001.0MO	Knoxville	2	67G	10/29/2003	11	11
CARSO001.0MO	Knoxville	2	67G	2/4/2004	15	11
CARSO001.0MO	Knoxville	2	67G	4/22/2004	18	11
CARSO001.0MO	Knoxville	2	67G	7/20/2004	0.3*	11
CHARL000.7OV	Monterey	1	68A	2/4/2004	17	12
CHARL000.7OV	Monterey	1	68A	5/10/2004	12	12
CHARL000.7OV	Monterey	1	68A	7/21/2004	7	7
CHARL000.7OV	Monterey	1	68A	7/21/2004	0	7
CHARL003.4BN	Jackson	1	65E	10/14/2003	5	6
CHARL003.4BN	Jackson	1	65E	1/19/2004	8	6
CHARL003.4BN	Jackson	1	65E	4/7/2004	6	6
CHARL003.4BN	Jackson	1	65E	7/8/2004	7	6
CHIEF004.6LS	Huntsville	2	71F	10/14/2003	18	11
CHIEF004.6LS	Huntsville	2	71F	1/15/2004	18	11
CHIEF004.6LS	Huntsville	2	71F	4/13/2004	19	11
CHIEF004.6LS	Huntsville	2	71F	7/13/2004	17	11
CUB2T0.3HR	Jackson	3	65E	10/15/2003	19	14
CUB2T0.3HR	Jackson	3	65E	1/14/2004	18	14
CUB2T0.3HR	Jackson	3	65E	4/7/2004	18	14
CUB2T0.3HR	Jackson	3	65E	7/7/2004	19	14
DAVIS000.8SR	Nashville	2	71G	10/6/2003	10	13
DAVIS000.8SR	Nashville	2	71G	1/16/2004	10	13
DAVIS000.8SR	Nashville	2	71G	4/14/2004	16	13
DAVIS000.8SR	Nashville	2	71G	7/12/2004	11	13
DODDY001.9BE	Nashville	3	71H	9/9/1999	9	12
DODDY001.9BE	Nashville	3	71H	11/5/2003	14	12
DODDY001.9BE	Nashville	3	71H	2/10/2004	15	12
DODDY001.9BE	Nashville	3	71H	4/20/2004	16	12
DRY004.1BN	Jackson	2	65E	10/16/2003	8	14
DRY004.1BN	Jackson	2	65E	1/13/2004	8	14
DRY004.1BN	Jackson	2	65E	4/7/2004	7	14
DRY004.1BN	Jackson	2	65E	7/8/2004	14	14
DUNCA001.8CU	Monterey	2	68A	11/12/2003	15	7
DUNCA001.8CU	Monterey	2	68A	2/11/2004	18	12
DUNCA001.8CU	Monterey	2	68A	4/29/2004	8	12
DUNCA001.8CU	Monterey	2	68A	7/22/2004	15	7

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
EFSPR1T0.5HR	Jackson	1	65E	10/7/2003	11	6
EFSPR1T0.5HR	Jackson	1	65E	1/13/2004	11	6
EFSPR1T0.5HR	Jackson	1	65E	4/6/2004	12	6
EFSPR1T0.5HR	Jackson	1	65E	7/7/2004	11	6
FALL007.6CU	Monterey	2	68A	11/6/2003	17	7
FALL007.6CU	Monterey	2	68A	2/9/2004	19	12
FALL007.6CU	Monterey	2	68A	4/28/2004	14	12
FALL007.6CU	Monterey	2	68A	7/2/2004	11	7
FALLS000.5VA	Monterey	3	68a	10/30/2003	13	11
FALLS000.5VA	Monterey	3	68a	2/5/2004	16	14
FALLS000.5VA	Monterey	3	68a	5/11/2004	16	14
FALLS000.5VA	Monterey	3	68a	5/11/2004	16	14
FALLS1T0.5MI	Chattanooga	2	68A	11/5/2003	13	7
FALLS1T0.5MI	Chattanooga	2	68A	2/11/2004	14	12
FALLS1T0.5MI	Chattanooga	2	68A	4/21/2004	16	12
FALLS1T0.5MI	Chattanooga	2	68A	8/4/2004	0.06*	7
FLAT002.4BT	Knoxville	2	66E	10/27/2003	12	14
FLAT002.4BT	Knoxville	2	66E	2/2/2004	13	14
FLAT002.4BT	Knoxville	2	66E	5/4/2004	20	14
FLAT002.4BT	Knoxville	2	66E	7/19/2004	0.85*	14
FORD1T1.4BN	Nashville	1	71F	10/14/2003	6	9
FORD1T1.4BN	Nashville	1	71F	1/13/2004	6	9
FORD1T1.4BN	Nashville	1	71F	4/7/2004	10	9
FORD1T1.4BN	Nashville	1	71F	7/8/2004	9	9
FWATE031.6PU	Monterey	3	71G	12/3/2003	19	13
FWATE031.6PU	Monterey	3	71G	2/11/2004	20	13
FWATE031.6PU	Monterey	3	71G	4/29/2004	13	13
FWATE031.6PU	Monterey	3	71G	7/22/2004	8	13
GOODI001.1DE	Nashville	2	71F	Fall 2003	0	11
GOODI001.1DE	Nashville	2	71F	1/15/2004	13	11
GOODI001.1DE	Nashville	2	71F	4/14/2004	19	11
GOODI001.1DE	Nashville	2	71F	7/9/2004	10	11
GRAY1T0.9HR	Jackson	3	65E	10/8/2003	15	14
GRAY1T0.9HR	Jackson	3	65E	1/12/2004	15	14
GRAY1T0.9HR	Jackson	3	65E	4/6/2004	17	14
GRAY1T0.9HR	Jackson	3	65E	7/8/2004	16	14

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
HALEY003.2HI	Nashville	2	71F	10/9/2003	10	11
HALEY003.2HI	Nashville	2	71F	1/14/2004	10	11
HALEY003.2HI	Nashville	2	71F	4/16/2004	17	11
HALEY003.2HI	Nashville	2	71F	7/15/2004	12	11
HANCO1T0.2LI	Huntsville	1	71G	Fall 2003	0	11
HANCO1T0.2LI	Huntsville	1	71G	2/11/2004	15	11
HANCO1T0.2LI	Huntsville	1	71G	4/20/2004	18	11
HANCO1T0.2LI	Huntsville	1	71G	Summer 2004	0	11
HUDSO000.3HR	Jackson	3	65E	10/8/2003	18	14
HUDSO000.3HR	Jackson	3	65E	1/13/2004	18	14
HUDSO000.3HR	Jackson	3	65E	4/7/2004	14	14
HUDSO000.3HR	Jackson	3	65E	7/7/2004	8	14
HWATE1T0.1MO	Knoxville	1	66G	10/28/2003	8	8
HWATE1T0.1MO	Knoxville	1	66G	2/3/2004	15	8
HWATE1T0.1MO	Knoxville	1	66G	5/5/2004	17	8
HWATE1T0.1MO	Knoxville	1	66G	7/20/2004	0.2*	8
JONES1T0.2DI	Nashville	1	71F	10/13/2003	11	9
JONES1T0.2DI	Nashville	1	71F	1/15/2004	7	9
JONES1T0.2DI	Nashville	1	71F	4/8/2004	8	9
JONES1T0.2DI	Nashville	1	71F	7/9/2004	6	9
JONES2T1.6DI	Nashville	2	71F	1/21/2004	11	11
JONES2T1.6DI	Nashville	2	71F	4/13/2004	16	11
JONES2T1.6DI	Nashville	2	71F	7/9/2004	13	11
JONES2T1.6DI	Nashville	2	71F	10/13/2003	11	11
LAURE003.4MO	Knoxville	2	67h	10/28/2003	10	11
LAURE003.4MO	Knoxville	2	67h	2/3/2004	10	11
LAURE003.4MO	Knoxville	2	67h	5/5/2004	7	11
LAURE003.4MO	Knoxville	2	67h	7/20/2004	0.01*	11
LAURE005.7RH	Monterey	2	68A	10/30/2003	12	7
LAURE005.7RH	Monterey	2	68A	2/10/2004	16	12
LAURE005.7RH	Monterey	2	68A	4/22/2004	20	12
LFGIZ003.4GY	Chattanooga	2	68A	11/6/2003	9	7
LFGIZ003.4GY	Chattanooga	2	68A	2/5/2004	14	12
LFGIZ003.4GY	Chattanooga	2	68A	4/21/2004	16	12
LFGIZ003.4GY	Chattanooga	2	68A	8/4/2004	3.07*	12
LOONE002.5MI	Chattanooga	1	68C	11/6/2003	16	9

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
LOONE002.5MI	Chattanooga	1	68C	2/4/2004	18	14
LOONE002.5MI	Chattanooga	1	68C	4/21/2004	18	14
LOONE002.5MI	Chattanooga	1	68C	8/4/2004	0.1*	9
LOOPE001.0OV	Monterey	2	68A	Fall 2003	0	7
LOOPE001.0OV	Monterey	2	68A	2/4/2004	18	12
LOOPE001.0OV	Monterey	2	68A	5/10/2004	13	12
LOOPE001.0OV	Monterey	2	68A	7/2/2004	11	7
LTRAC005.0CY	Monterey	3	71G	11/14/2003	16	13
LTRAC005.0CY	Monterey	3	71G	2/11/2004	20	13
LTRAC005.0CY	Monterey	3	71G	5/13/2004	16	13
LTRAC005.0CY	Monterey	3	71G	7/22/2004	16	13
MAMMY010.1CU	Monterey	2	68A	11/6/2003	16	7
MAMMY010.1CU	Monterey	2	68A	2/4/2004	18	12
MAMMY010.1CU	Monterey	2	68A	4/28/2004	14	12
MAMMY010.1CU	Monterey	2	68A	7/2/2004	9	7
MCCAM000.7PO	Chattanooga	2	66E	10/29/2003	6	14
MCCAM000.7PO	Chattanooga	2	66E	2/3/2004	18	14
MCCAM000.7PO	Chattanooga	2	66E	4/22/2004	15	14
MCCAM000.7PO	Chattanooga	2	66E	Summer 2004	0	14
MERID006.5MN	Jackson	2	65E	10/9/2003	10	14
MERID006.5MN	Jackson	2	65E	1/14/2004	7	14
MERID006.5MN	Jackson	2	65E	4/7/2004	16	14
MERID006.5MN	Jackson	2	65E	7/29/2004	18	14
MOODY002.0HR	Jackson	2	74B	10/7/2003	16	11
MOODY002.0HR	Jackson	2	74B	1/13/2004	14	11
MOODY002.0HR	Jackson	2	74B	4/6/2004	18	11
MOODY002.0HR	Jackson	2	74B	7/7/2004	19	11
NORTH005.7CU	Monterey	2	68A	10/31/2003	10	7
NORTH005.7CU	Monterey	2	68A	2/9/2004	20	12
NORTH005.7CU	Monterey	2	68A	5/13/2004	16	12
NORTH005.7CU	Monterey	2	68A	7/27/2004	16	7
OBED040.2CU	Monterey	3	68A	Fall 2003	0	11
OBED040.2CU	Monterey	3	68A	2/10/2004	19	14
OBED040.2CU	Monterey	3	68A	5/14/2004	15	14
OBED040.2CU	Monterey	3	68A	7/27/2004	20	11
ODAIN000.3HR	Jackson	2	65E	10/7/2003	19	14

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
ODAIN000.3HR	Jackson	2	65E	1/12/2004	20	14
ODAIN000.3HR	Jackson	2	65E	4/5/2004	19	14
ODAIN000.3HR	Jackson	2	65E	7/8/2004	19	14
OTOWN1T0.9HN	Jackson	1	65E	Fall 2003	0	6
OTOWN1T0.9HN	Jackson	1	65E	1/13/2004	6	6
OTOWN1T0.9HN	Jackson	1	65E	4/6/2004	6	6
OTOWN1T0.9HN	Jackson	1	65E	Summer 2004	0	6
PINEY014.6CS	Jackson	2	65E	10/9/2003	12	14
PINEY014.6CS	Jackson	2	65E	1/12/2004	12	14
PINEY014.6CS	Jackson	2	65E	4/5/2004	17	14
PINEY014.6CS	Jackson	2	65E	7/8/2004	15	14
POND1T0.1CU	Monterey	1	68A	Fall 2003	0	12
POND1T0.1CU	Monterey	1	68A	2/10/2004	17	12
POND1T0.1CU	Monterey	1	68A	5/12/2004	12	12
POND1T0.1CU	Monterey	1	68A	Summer 2004	0	12
RATTL000.1UC	Bristol	2	66E	10/28/2003	18	14
RATTL000.1UC	Bristol	2	66E	2/3/2004	17	14
RATTL000.1UC	Bristol	2	66E	4/27/2004	18	14
RATTL000.1UC	Bristol	2	66E	7/20/2004	16	14
ROARI002.4CT	Bristol	2	66D	10/28/2003	18	14
ROARI002.4CT	Bristol	2	66D	2/3/2004	17	14
ROARI002.4CT	Bristol	2	66D	4/27/2004	18	14
ROARI002.4CT	Bristol	2	66D	7/20/2004	14	14
SAVAG009.8SE	Chattanooga	3	68A	11/10/2003	16	11
SAVAG009.8SE	Chattanooga	3	68A	2/10/2004	18	14
SAVAG009.8SE	Chattanooga	3	68A	5/11/2004	6	14
SAVAG009.8SE	Chattanooga	3	68A	Summer 2004	6	14
SCANT001.3CU	Monterey	2	68A	11/12/2003	4	7
SCANT001.3CU	Monterey	2	68A	2/9/2004	6	12
SCANT001.3CU	Monterey	2	68A	5/10/2004	15	12
SCANT001.3CU	Monterey	2	68A	Summer 2004	0	
SCOTT003.5SH	Memphis	3	74B	Fall 2003	0	11
SCOTT003.5SH	Memphis	3	74B	1/12/2004	9	11
SCOTT003.5SH	Memphis	3	74B	4/5/2004	14	11
SCOTT003.5SH	Memphis	3	74B	7/6/2004	8	11
SFHUR003.6HO	Nashville	1	71F	10/7/2003	7	9

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
SFHUR003.6HO	Nashville	1	71F	1/15/2004	8	9
SFHUR003.6HO	Nashville	1	71F	4/6/2004	8	9
SFHUR003.6HO	Nashville	1	71F	7/8/2004	9	9
SFSYC006.3DA	Nashville	1	71F	10/10/2003	12	9
SFSYC006.3DA	Nashville	1	71F	1/22/2004	11	9
SFSYC006.3DA	Nashville	1	71F	4/14/2004	16	9
SFSYC006.3DA	Nashville	1	71F	7/13/2004	12	9
SHARP1T0.4DA	Nashville	1	71F	10/17/2003	7	9
SHARP1T0.4DA	Nashville	1	71F	1/21/2004	12	9
SHARP1T0.4DA	Nashville	1	71F	4/15/2004	15	9
SHARP1T0.4DA	Nashville	1	71F	7/13/2004	7	9
SHARP2T0.6DA	Nashville	1	71F	10/16/2003	7	9
SHARP2T0.6DA	Nashville	1	71F	1/21/2004	11	9
SHARP2T0.6DA	Nashville	1	71F	4/13/2004	16	9
SHARP2T0.6DA	Nashville	1	71F	7/13/2004	7	9
SHELT001.3LI	Huntsville	3	71H	11/4/2003	11	12
SHELT001.3LI	Huntsville	3	71H	2/11/2004	15	12
SHELT001.3LI	Huntsville	3	71H	4/20/2004	19	12
SHELT001.3LI	Huntsville	3	71H	4/20/2004	17	12
SINKI1T0.8CO	Knoxville	2	67G	10/29/2003	16	11
SINKI1T0.8CO	Knoxville	2	67G	2/3/2004	15	11
SINKI1T0.8CO	Knoxville	2	67G	4/27/2004	18	11
SINKI1T0.8CO	Knoxville	2	67G	7/20/2004	9	11
SQUAW001.4LS	Huntsville	2	71F	10/16/2003	14	11
SQUAW001.4LS	Huntsville	2	71F	1/15/2004	15	11
SQUAW001.4LS	Huntsville	2	71F	4/13/2004	18	11
SQUAW001.4LS	Huntsville	2	71F	7/13/2004	14	11
STEEL000.3SU	Bristol	2	67I	5/29/2003	20	11
STEEL000.3SU	Bristol	2	67I	2/2/2004	15	11
STEEL000.3SU	Bristol	2	67I	4/26/2004	20	11
STEEL000.3SU	Bristol	2	67I	7/19/2004	13	11
STEWA003.4HR	Jackson	3	65E	10/8/2003	15	14
STEWA003.4HR	Jackson	3	65E	1/14/2004	13	14
STEWA003.4HR	Jackson	3	65E	4/7/2004	16	14
STEWA003.4HR	Jackson	3	65E	7/8/2004	13	14
TAYLO000.7OB	Jackson	2	74a	10/8/2003	7	6

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
TAYLO000.7OB	Jackson	2	74a	1/12/2004	16	6
TAYLO000.7OB	Jackson	2	74a	4/5/2004	9	6
TAYLO000.7OB	Jackson	2	74a	7/7/2004	10	6
THOMP005.9WY	Jackson	2	65E	Fall 2003	0	14
THOMP005.9WY	Jackson	2	65E	1/13/2004	6	14
THOMP005.9WY	Jackson	2	65E	4/6/2004	6	14
THOMP005.9WY	Jackson	2	65E	7/7/2004	6	14
THOMP1T0.4HR	Jackson	1	65e	Fall 2003	0	6
THOMP1T0.4HR	Jackson	1	65e	1/13/2004	11	6
THOMP1T0.4HR	Jackson	1	65e	4/6/2004	17	6
THOMP1T0.4HR	Jackson	1	65e	7/7/2004	10	6
THREE1T0.3HN	Jackson	2	65E	10/7/2003	8	14
THREE1T0.3HN	Jackson	2	65E	1/13/2004	10	14
THREE1T0.3HN	Jackson	2	65E	4/6/2004	11	14
THREE1T0.3HN	Jackson	2	65E	7/7/2004	8	14
TMILE1T0.2FR	Chattanooga	1	68A	Fall 2003	0	12
TMILE1T0.2FR	Chattanooga	1	68A	2/5/2004	13	12
TMILE1T0.2FR	Chattanooga	1	68A	4/21/2004	18	12
TMILE1T0.2FR	Chattanooga	1	68A	Summer 2004	0	12
TRAIL1T0.4CU	Monterey	1	68A	Fall 2003	0	12
TRAIL1T0.4CU	Monterey	1	68A	2/10/2004	17	12
TRAIL1T0.4CU	Monterey	1	68A	5/13/2004	9	12
TRAIL1T0.4CU	Monterey	1	68A	7/26/2004	6	7
TULL000.3OB	Jackson	3	74A	Fall 2003	0	6
TULL000.3OB	Jackson	3	74A	1/12/2004	9	6
TULL000.3OB	Jackson	3	74A	4/5/2004	11	6
TULL000.3OB	Jackson	3	74A	7/7/2004	7	6
WALKE1T0.3DA	Nashville	2	71H	10/2/2003	8	12
WALKE1T0.3DA	Nashville	2	71H	1/22/2004	11	12
WALKE1T0.3DA	Nashville	2	71H	4/8/2004	12	12
WALKE1T0.3DA	Nashville	2	71H	7/13/2004	7	12
WASHB003.0LI	Huntsville	2	71G	11/4/2003	7	13
WASHB003.0LI	Huntsville	2	71G	2/11/2004	14	13
WASHB003.0LI	Huntsville	2	71G	4/20/2004	12	13
WASHB003.0LI	Huntsville	2	71G	Summer 2004	7	13
WEAVE001.0LW	Huntsville	2	71F	10/13/2003	8	11

Table C-1 cont.

STATION ID	Weather Station	ORDER	ECOIV	Date	Habitat Flow Score	Target Flow Score
WEAVE001.0LW	Huntsville	2	71F	1/14/2004	11	11
WEAVE001.0LW	Huntsville	2	71F	4/13/2004	17	11
WEAVE001.0LW	Huntsville	2	71F	7/13/2004	8	11
WFDRA2T1.5SR	Nashville	2	71G	10/6/2003	10	13
WFDRA2T1.5SR	Nashville	2	71G	1/16/2004	10	13
WFDRA2T1.5SR	Nashville	2	71G	4/14/2004	16	13
WFDRA2T1.5SR	Nashville	2	71G	7/12/2004	12	13
WOLF1T0.1LW	Huntsville	1	71F	10/13/2003	13	9
WOLF1T0.1LW	Huntsville	1	71F	1/14/2004	13	9
WOLF1T0.1LW	Huntsville	1	71F	4/14/2004	16	9
WOLF1T0.1LW	Huntsville	1	71F	7/14/2004	9	9

* Habitat assessment not available, flow measurement used to determine channel flow status

Table C-2: Rosgen Stream Classification

First Order Reference (FOR) and All Test Sites	Ecoregion	Dam Closed	Lake Acres	Stream Order	Discharge Type	Class Size D50	Stream Type	Stream Evolution	Valley Type
ARNOL001.4WY	*65E*	1974	18.5	2	Standpipe	Silt/clay	C6	E6	8
BAGWE1T0.2CU	68A	1967	9.2	1	Both	Sand	E5	E5	8
BARNE002.4FR	68A	1955	21.0	1	Standpipe	Gravel	E4	E4	8
BARTE001.4MT	71F	1940	40.0	2	Subsurface	Gravel	B4	B4	2
BEAR003.6WE	71F	1969	25.0	2	Subsurface	Gravel	C4	C4	8
BEAR005.7MN - (FOR)	65E	No Dam	NA	1	No Discharge	Sand	C5	G5	8
BEASL000.4MY	71H	>1951	164.0	2	Standpipe	Bedrock	C1	E1	8
BGUM000.5CU	68A	1975	25.2	1	Both	Gravel	B4	B4	2
BOSTO001.1HM	68A	1968	18.4	2	Standpipe	Cobble	B3	B3	2
BUCK001.2CU	68A	1994	64.0	3	Both	Sand	B5	B5	2
CARSO001.0MO	67G	<1972	13.2	2	Standpipe	Gravel	C4	E4	8
CHARL000.7OV	68A	1962	17.6	1	Both	Sand	B5	G5	2
CHARL003.4BN	65E	1996	3.0	1	Standpipe	Sand	C5	E5	8
CHIEF004.6LS	71F	1970	96.0	2	Subsurface	Gravel	B4	B4	2
CUB2T0.3HR	65E	1963	39.0	3	Subsurface	Silt/clay	C6	C6	8
DAVIS000.8SR	71G	1959	12.0	2	Spillway	Gravel	B4	B4	2
DODDY001.9BE	71H	1940	42.0	3	Spillway	Bedrock	B1	B1	2
DOUGL000.1MG – (FOR)	68A	No Dam	NA	1	No Discharge	Cobble	C3	C3	8
DRY004.1BN	65E	1977	21.4	2	Spillway	Gravel	C4	C4	8
DUNCA001.8CU	68A	1980	57.0	2	Spillway	Boulder	B2	B2	2
EFSPR1T0.5HR	65E	1976	11.0	1	Standpipe	Silt/clay	C6	G6	8
FALL007.6CA	68A	1961	7.6	2	Both	Cobble	B3	B3	2
FALLS000.5VA	68A	1970	250.0	3	Standpipe	Cobble	B3	C3	2
FALLS1T0.5MI	68A	<1972	5.1	2	Spillway	Gravel	C4	G4	8
FLAT002.4BT	66E	1966	52.5	2	Spillway	Gravel	B4	B4	2

Table C-2 cont.

First Order Reference (FOR) and All Test Sites	Ecoregion	Dam Closed	Lake Acres	Stream Order	Discharge Type	Class Size D50	Stream Type	Stream Evolution	Valley Type
FLAT008.3OV – (FOR)	71G	No Dam	NA	1	No Discharge	Bedrock	C1	C1	8
FORD1T1.4BN	71F	1960	10.1	1	Spillway	Silt/clay	B6	G6	2
FWATE0031.6PU	71G	1948	62.0	3	Spillway	Gravel	C4	G4	2
GOODI001.1DE	71F	2001	9.0	2	Subsurface	Gravel	C4	E4	8
GRAY1T0.9HR	65E	1935	50.2	3	Standpipe	Silt/clay	C6	G6	8
HALEY003.2HI	71F	1966	8.7	2	Standpipe	Bedrock	B1	B1	2
HANCO1T0.2LI	71G	1955	12.0	1	Spillway	Gravel	C4	E4	8
HUDSO000.3HR	65E	1961	22.8	3	Subsurface	Silt/clay	C6	G6	8
HWATE1T0.1MO	66G	1962	3.7	1	Standpipe	Bedrock	B1	B1	2
INDIA000.1MO – (FOR)	66G	No Dam	NA	1	No Discharge	Gravel	B4	B4	2
JONES1T0.2DI	71F	1997	5.5	1	Spillway	Gravel	C4	C4	8
JONES2T1.6DI	71F	1929	4.1	2	Spillway	Bedrock	B1	B1	2
LAURE003.4MO	67H	1965	51.4	2	Standpipe	Gravel	C4	E4	8
LAURE005.7RH	68A	1950	15.0	2	Spillway	Gravel	C4	E4	2
LFGIZ003.4GY	68A	1934	15.3	2	Both	Gravel	C4	C4	8
LOONE002.5MI	68C	1970	2.0	1	Standpipe	Gravel	C4	E4	8
LOOPE001.0OV	68A	1970	74.4	2	Both	Gravel	C4	E4	8
LSWAN1T0.1LS – (FOR)	71F	No Dam	NA	1	No Discharge	Bedrock	B1	B1	2
LTRAC005.0CY	71G	1965	16.0	3	Standpipe	Gravel	C4	C4	8
MAMMY010.1CU	68A	1900	3.4	2	Spillway	Bedrock	B1	B1	2
MCCAM000.7PO	66E	1938	7.8	2	Standpipe	Gravel	B4	F4	2
MERID006.5MN	65E	1961	55.0	2	Standpipe	Sand	C5	G5	10
MOODY002.0HR	74B	1955	13.0	2	Standpipe	Silt/clay	C6	C6	10
NORTH005.7CU	68A	1973	105.0	2	Spillway	Sand	B5	B5	2
OBED040.2CU	68A	1959	209.0	3	Spillway	Bedrock	B1	B1	2
ODAIN000.3HR	65E	1943	147.0	2	Spillway	Silt/clay	C6	C6	10

Table C-2 cont.

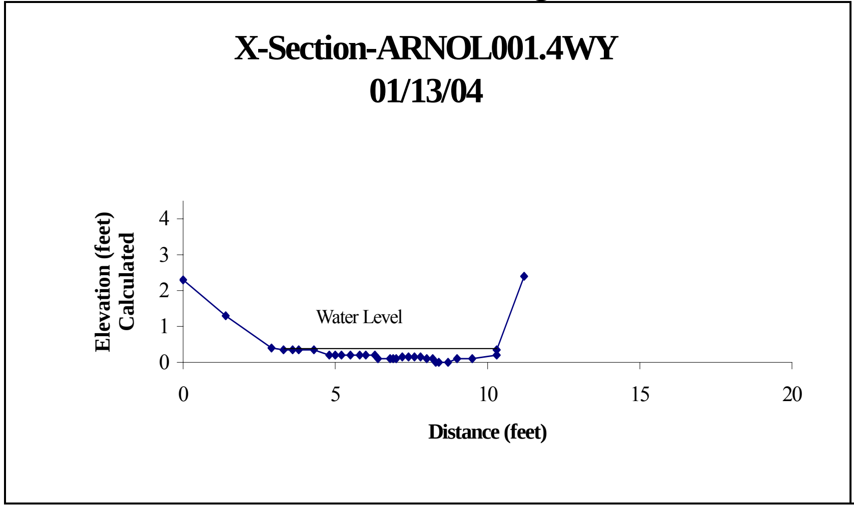
First Order Reference (FOR) and All Test Sites	Ecoregion	Dam Closed	Lake Acres	Stream Order	Discharge Type	Class Size D50	Stream Type	Stream Evolution	Valley Type
OTOWN1T0.9HN	65E	<1956	2.3	1	Spillway	Silt/clay	C6	E6	8
PINEY014.6CS	65E	1935	39.5	2	Standpipe	Sand	C5	F5	8
POND1T0.1CU	68A	1980	21.0	1	Both	Gravel	B4	G4	2
RATTL000.1UC	66E			2	Subsurface	Gravel	B4	F4	2
ROARI002.4CT	66D	1946	60.2	2	Both	Gravel	B4	C4	2
SAVAG009.8SE	68A	1965	75.0	3	Standpipe	Cobble	C3	G3	2
SCANT001.3CU	68A	1965	22.9	2	Both	Silt/clay	B6	B6	2
SCOTT003.5SH	74B	1950	237.0	3	Spillway	Sand	F5	G5	8
SFHUR003.6HO	71F	1972	2.8	1	Toe Drain	Gravel	C4	C4	8
SFSYC006.3DA	71F	1935	7.0	1	Spillway	Bedrock	B1	B1	2
SHARP1T0.4DA	71F	1998	16.5	1	Standpipe	Gravel	C4	C4	8
SHARP2T0.6DA	71F	1997	12.8	1	Standpipe	Bedrock	C1	C1	8
SHELT001.3LI	71H	1940	40.0	3	Spillway	Cobble	C3	C3	8
SINKI1T0.8CO	67G	1987	4.5	2	Toe Drain	Sand	C5	E5	8
SINKI1T1.0CO – (FOR)	67G	No Dam	NA	1	No Discharge	Bedrock	C1	C2	8
SQUAW001.4LS	71F	1963	56.0	2	Subsurface	Gravel	C4	G4	8
STEEL000.3SU	67I	1963	42.5	2	Spillway	Gravel	C4	C4	2
STEWA003.4HR	65E	1961	27.6	3	NA	Silt/clay	C6	G6	8
TAYLO000.7OB	74A	1971	88.0	2	Standpipe	Sand	C5	G5	8
THOMP005.9WY	65E	1960	183.0	2	Standpipe	Sand	C5	E5	8
THOMP1T0.4HR	65E	1977	17.0	1	Toe Drain	Silt/clay	C6	E6	8
THREE1T0.3HN	65E	<1956	6.4	2	Spillway	Sand	C5	G5	8
TMILE1T0.2FR	68A	1969	7.1	1	Standpipe	Sand	B5	B5	2
TRAIL1T0.4CU	68A	1977	16.0	1	Both	Sand	B5	B5	2
TULL000.3OB	74A	1974	57.5	3	Standpipe	Sand	C5	G5	8
WALKE1T0.3DA	71H	1976	12.0	2	Standpipe	Gravel	C4	C4	8

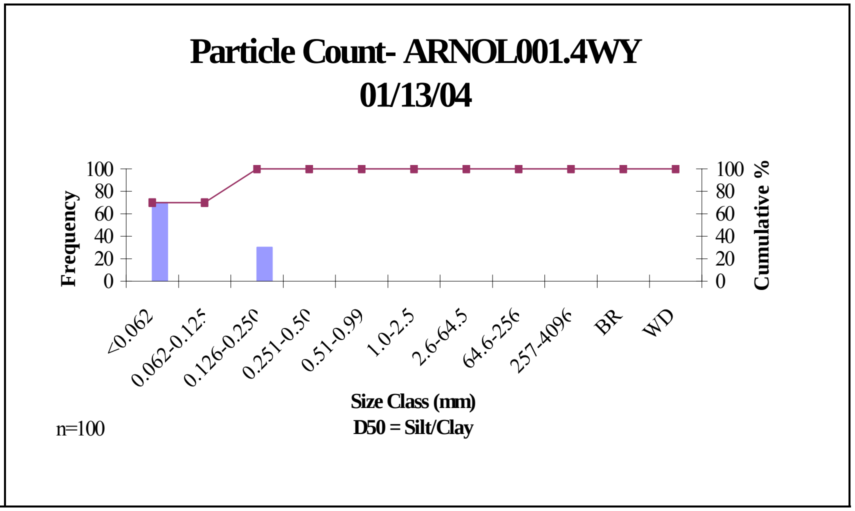
Table C-2 cont.

First Order Reference (FOR) and All Test Sites	Ecoregion	Dam Closed	Lake Acres	Stream Order	Discharge Type	Class Size D50	Stream Type	Stream Evolution	Valley Type
WASHB003.0LI	71G	1951-1978	32.0	2	Spillway	Gravel	C4	G4	8
WEAVE001.0LW	71F	1951	20.0	2	Standpipe	Bedrock	B1	B1	2
WFDRA2T1.5SR	71G	1940	25.2	2	Mid-surface	Bedrock	B1	G1	2
WOLF1T0.1LW	71F	1972	6.0	1	NA	Gravel	B1	B1	2

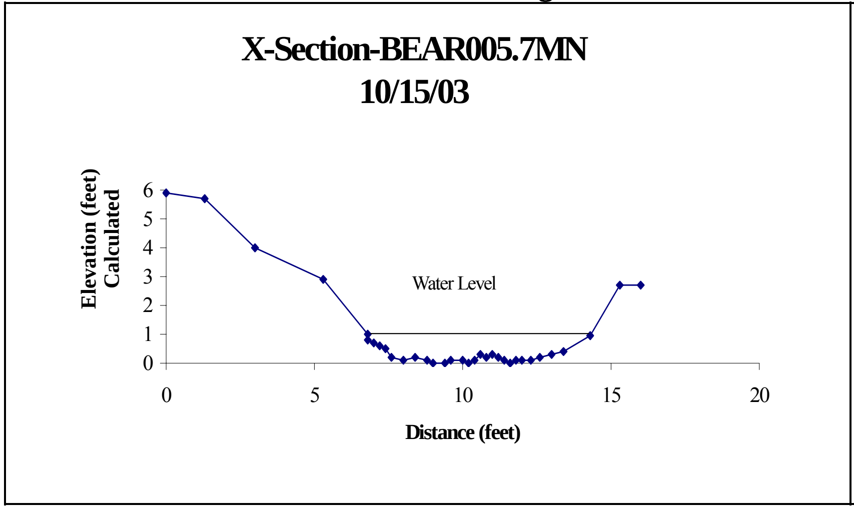
Table C-3: Cross Section and Particle Count Graphs

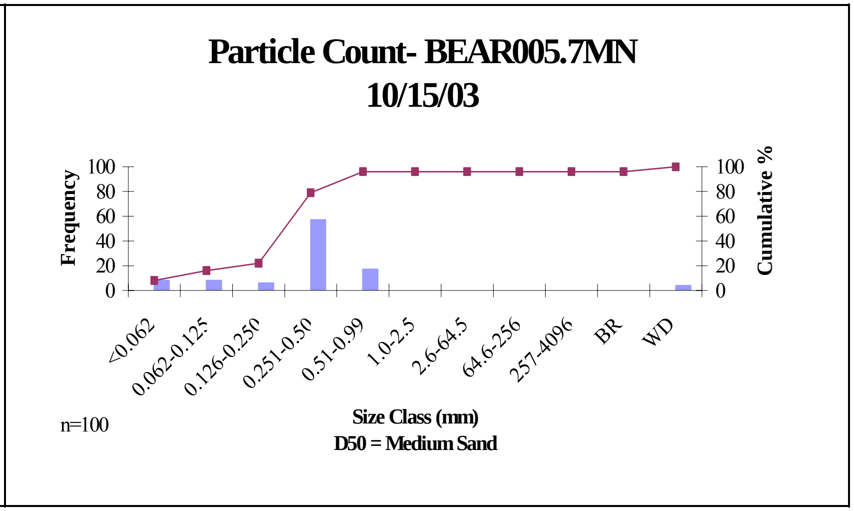
Ecoregion 65E - Arnold Branch - Middle Fork Obion Lake #11



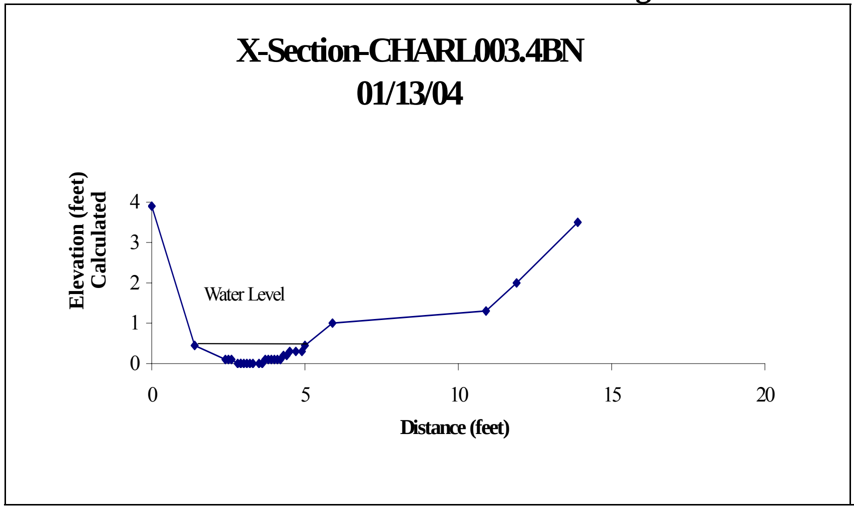


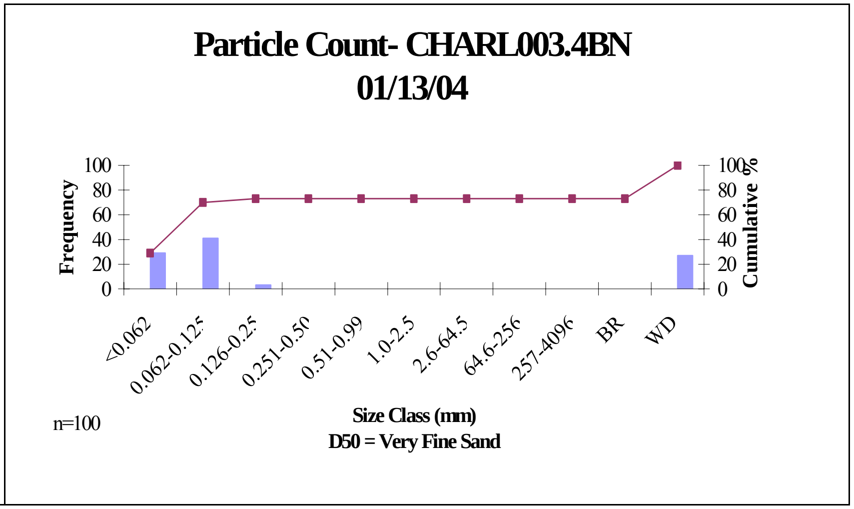
Ecoregion 65E – Bear Creek – First Order Reference Stream



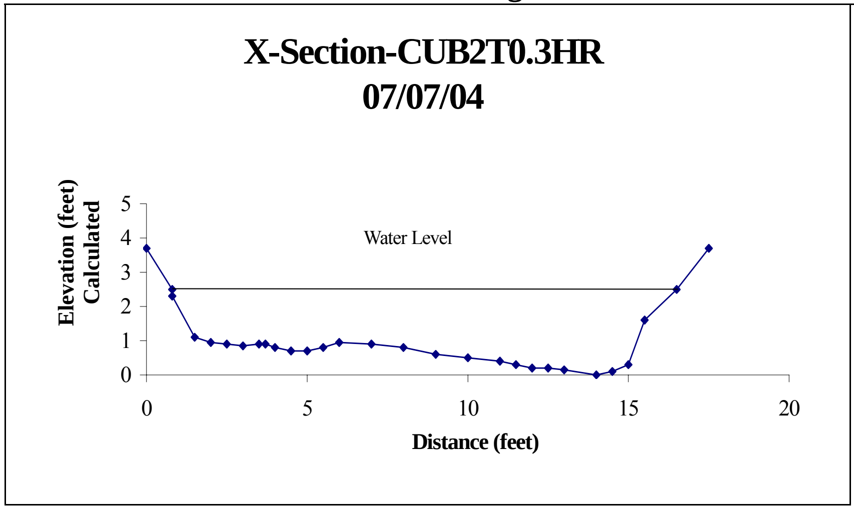


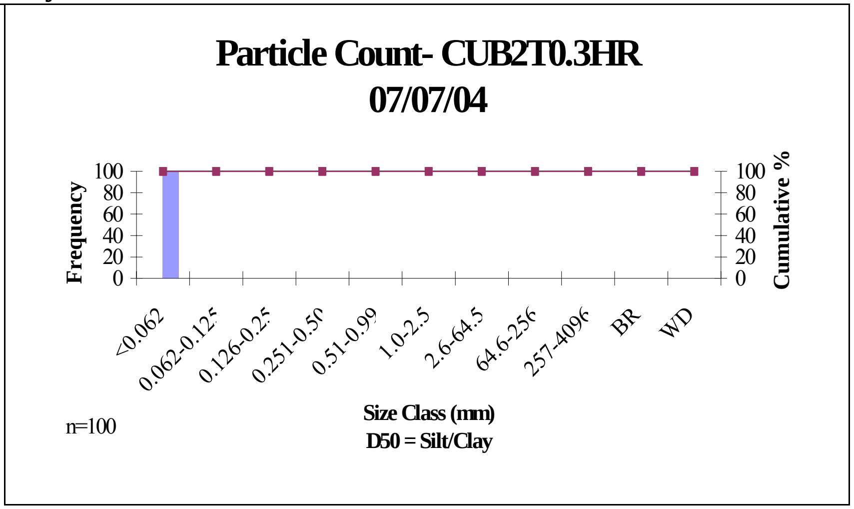
Ecoregion 65E – Charlie Creek – Shannon Lake



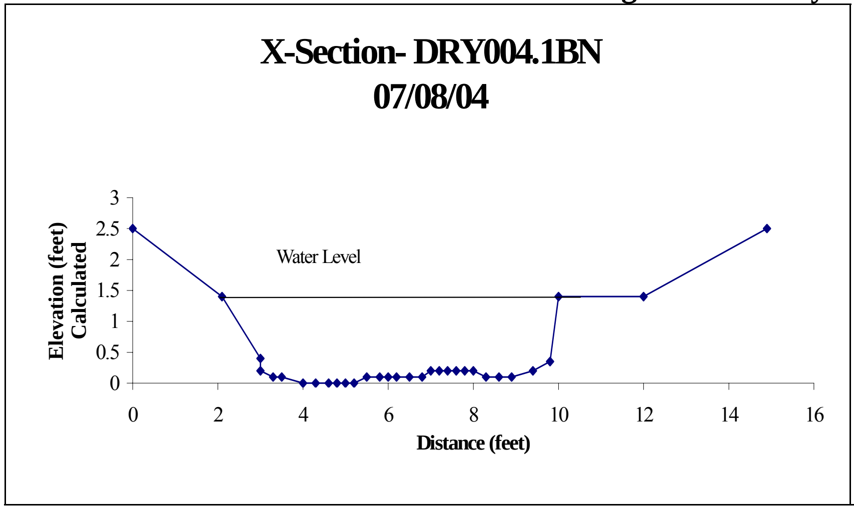


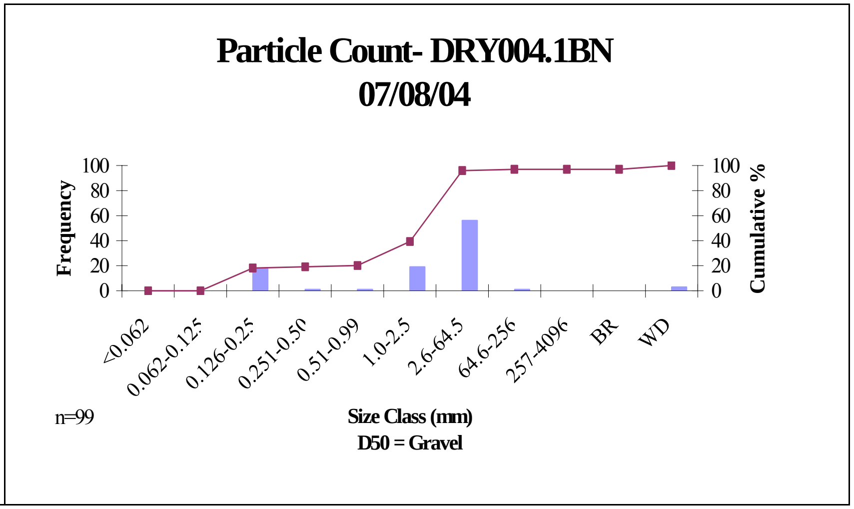
Ecoregion 65E – Cub Creek Tributary #2 – Cub Creek Dam # 2A



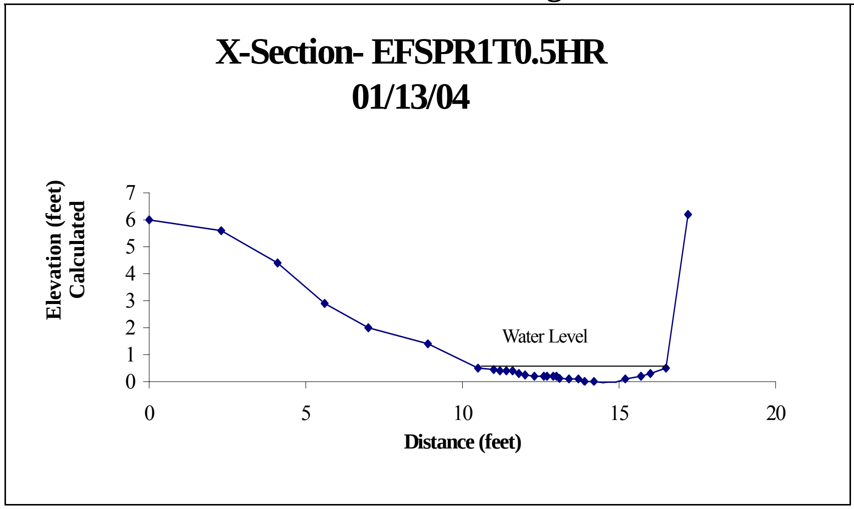


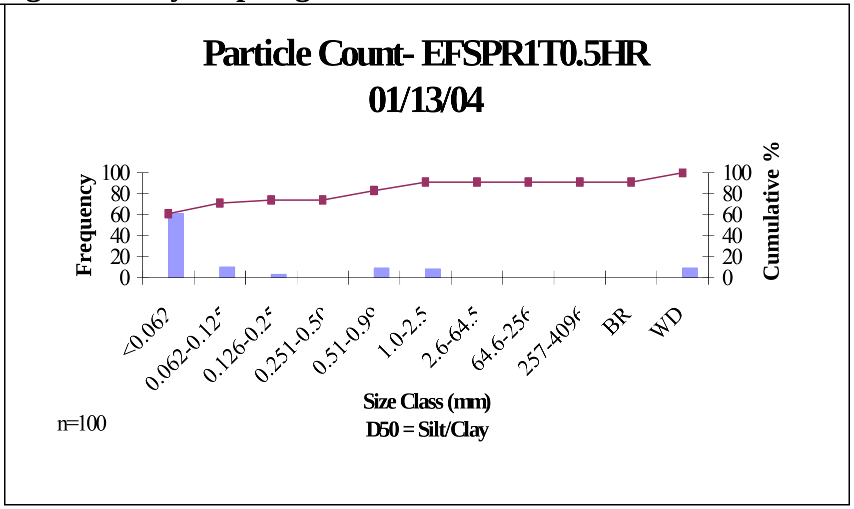
Ecoregion 65E – Dry Creek – Cedar Lake Dam #2



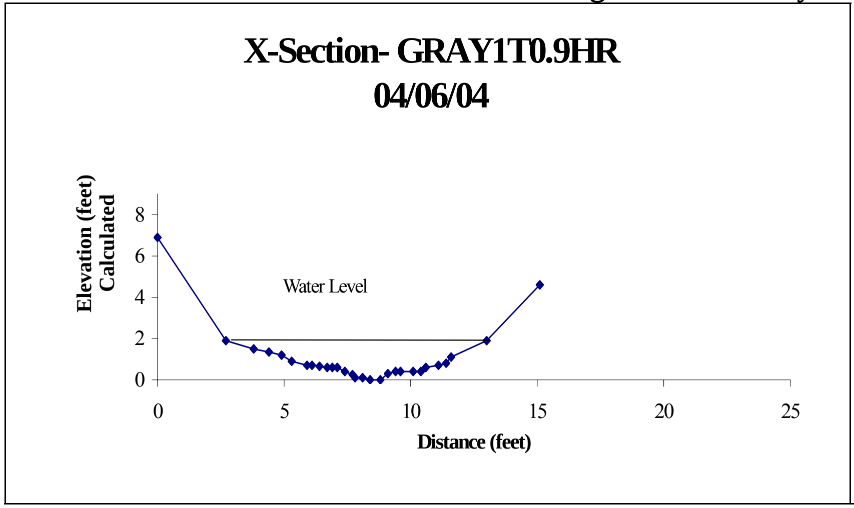


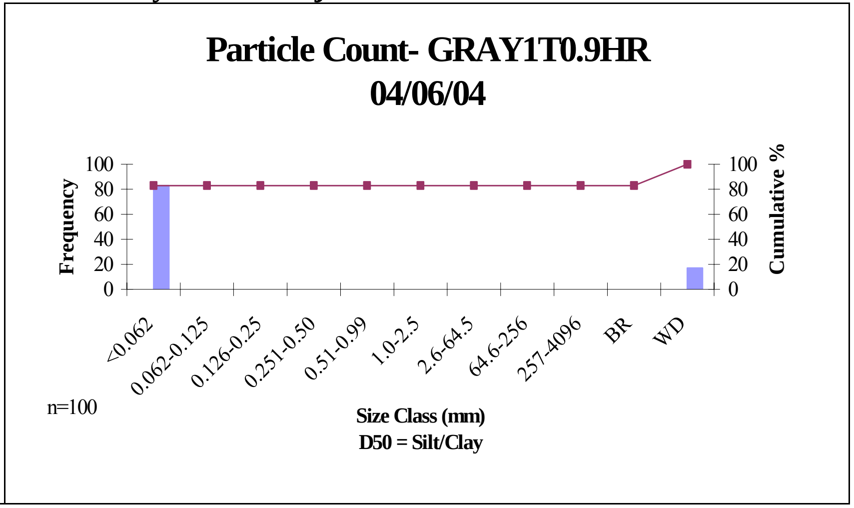
Ecoregion 65E – East Fork Spring Tributary – Spring Lake



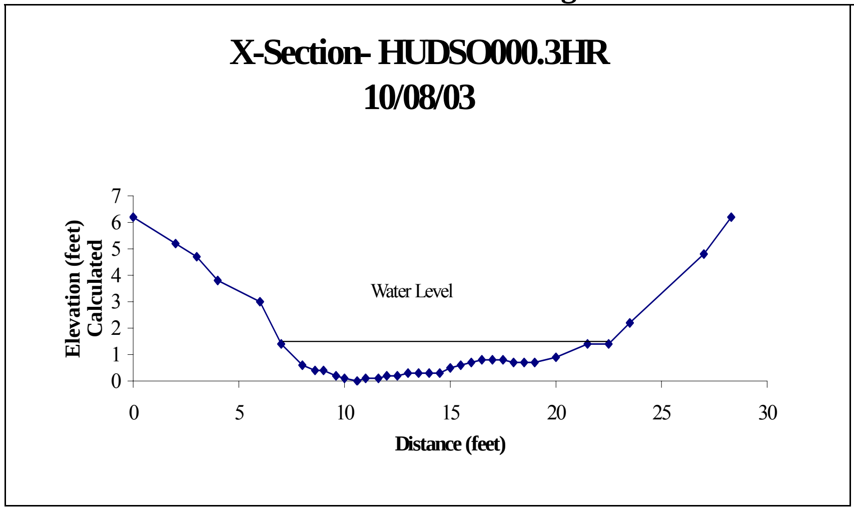


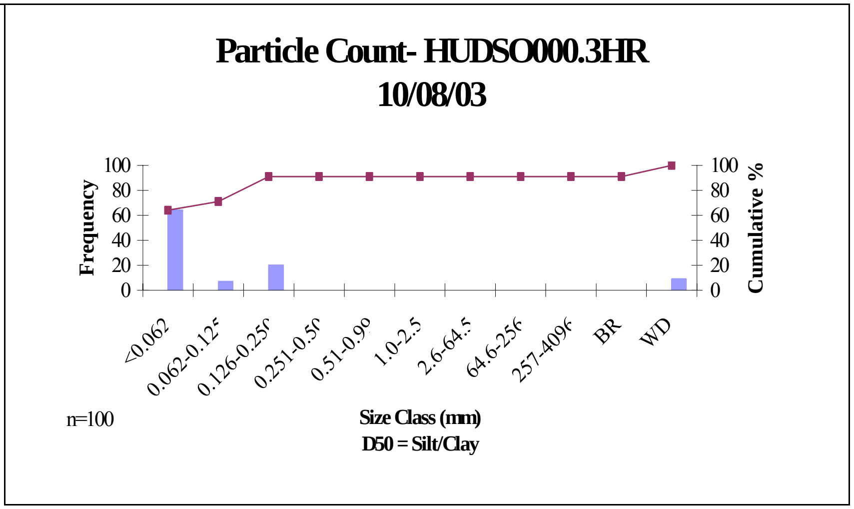
Ecoregion 65E – Grays Creek Tributary – Lake Lajoie



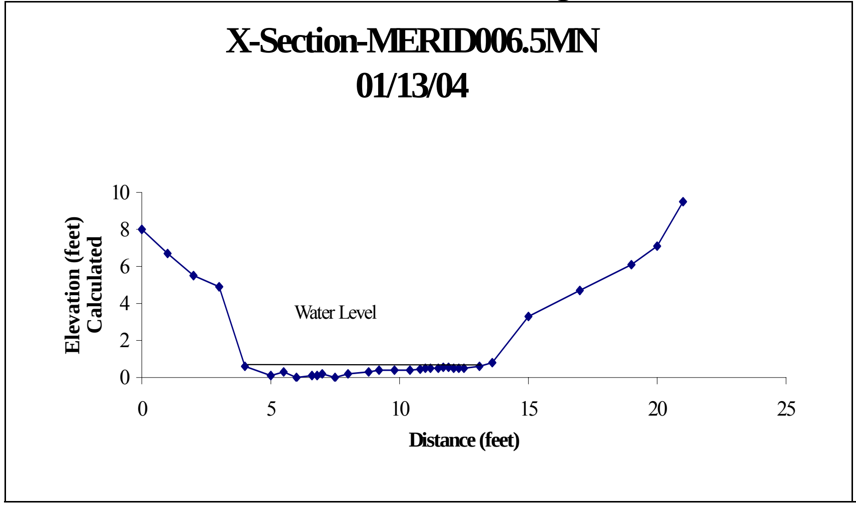


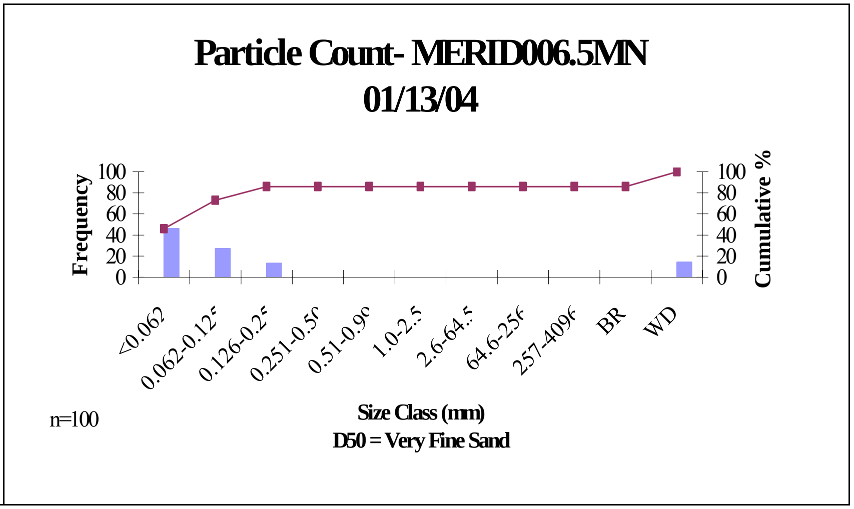
Ecoregion 65E – Hudson Branch – Porters Creek Dam #6



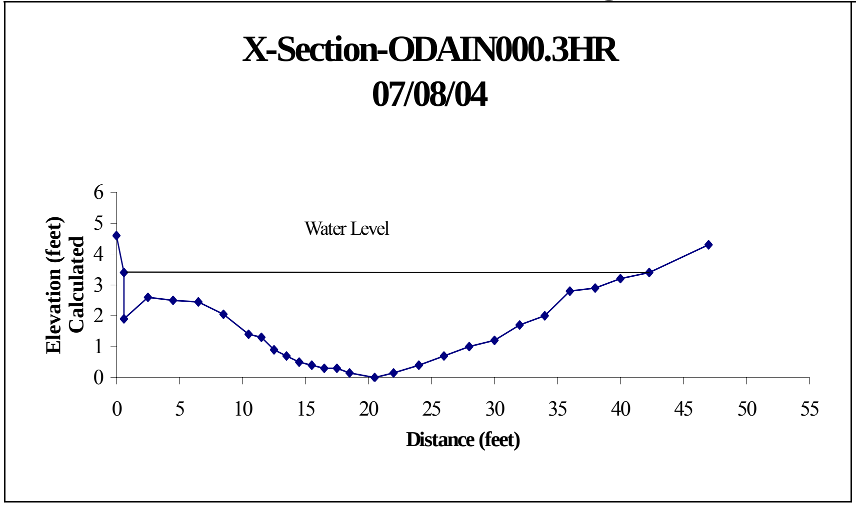


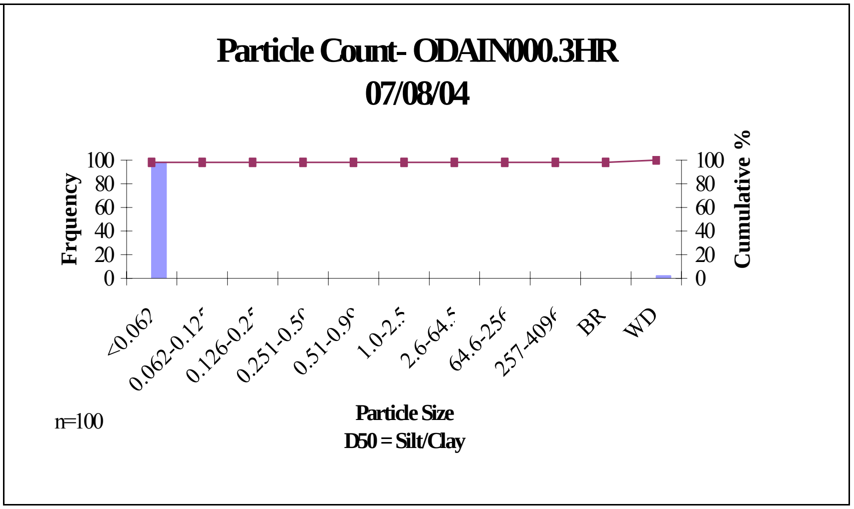
Ecoregion 65E – Meridian Creek – Meridian Creek Dam #1



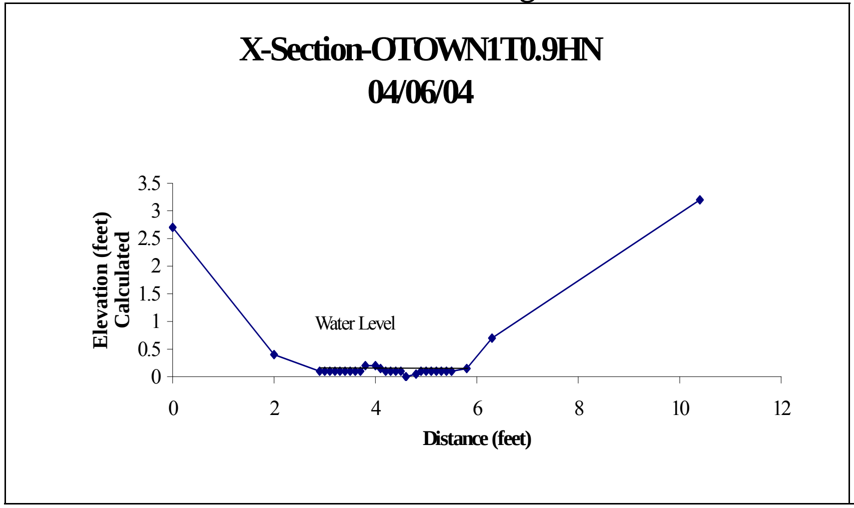


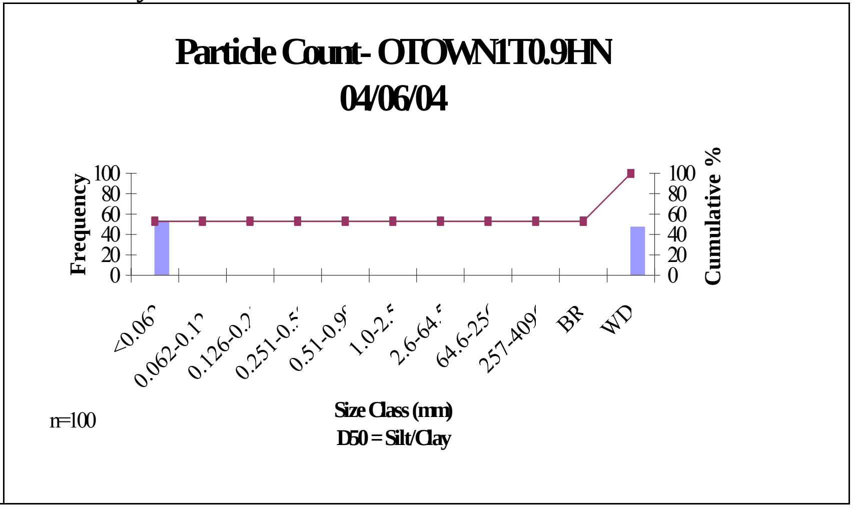
Ecoregion 65E – Oak Dain Creek – Whiteville Lake



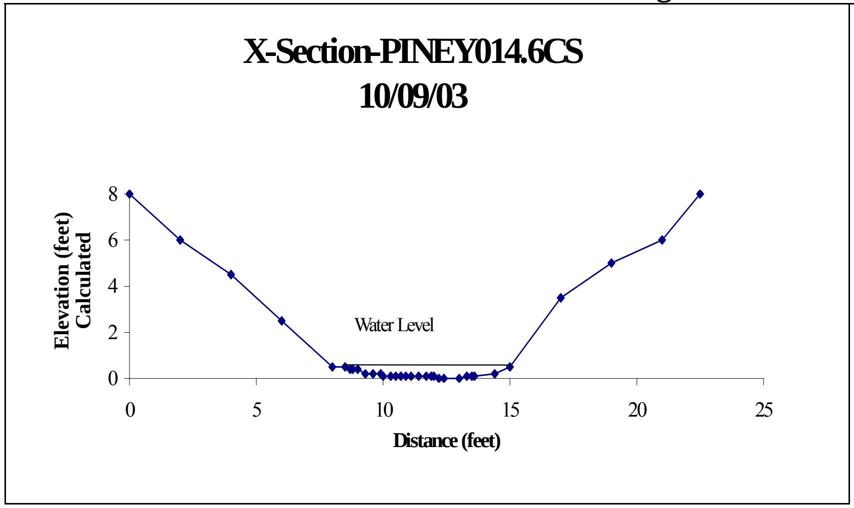


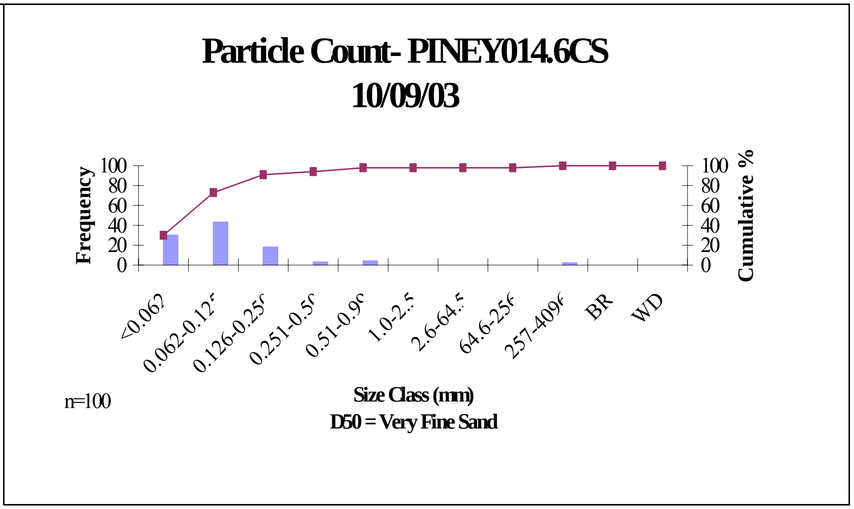
Ecoregion 65E – Old Town Creek Tributary – Green Acres Lake



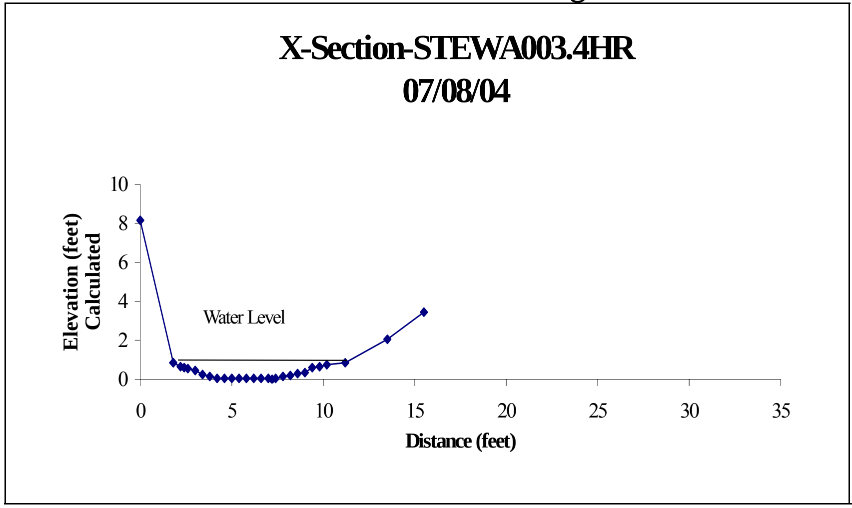


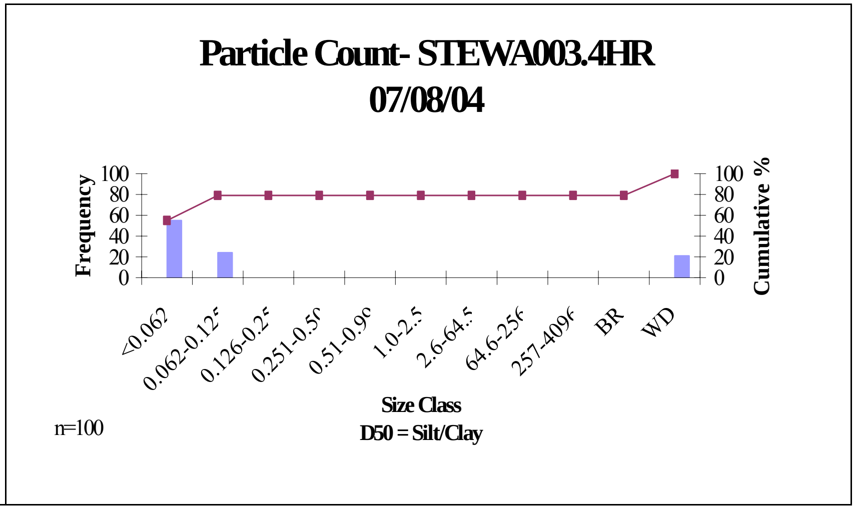
Ecoregion 65E – Piney Creek – Lake Placid



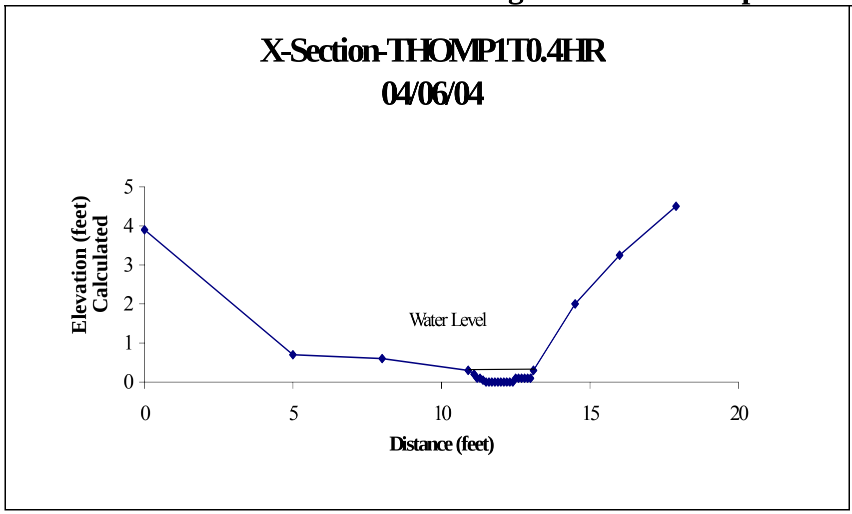


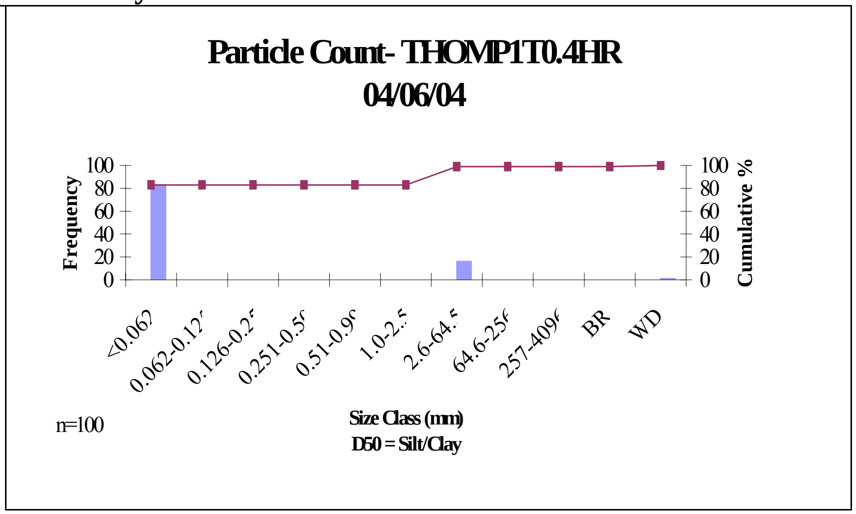
Ecoregion 65E – Stewart Branch – Porters Creek Dam #4



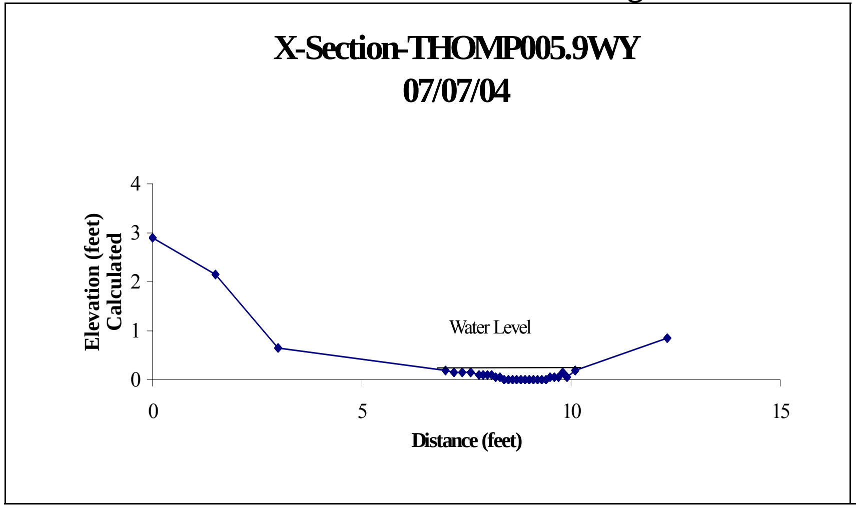


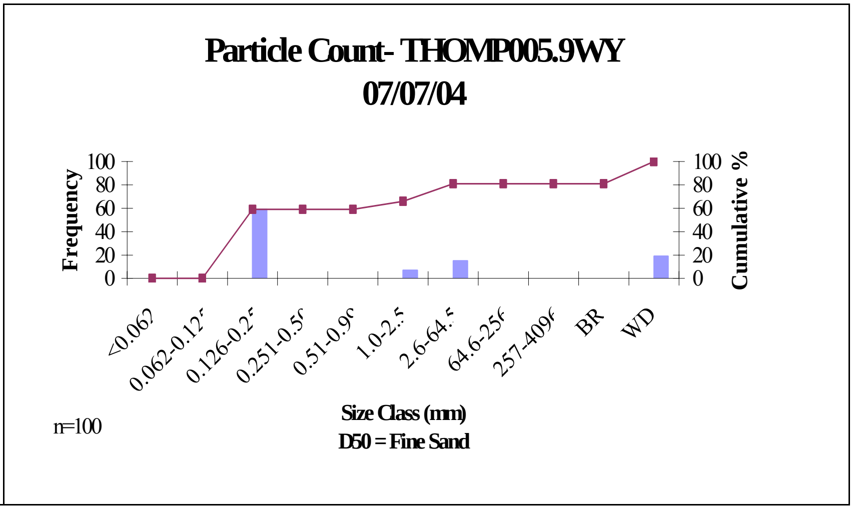
Ecoregion 65E – Thompson Creek Tributary – Woodrun Dam #1



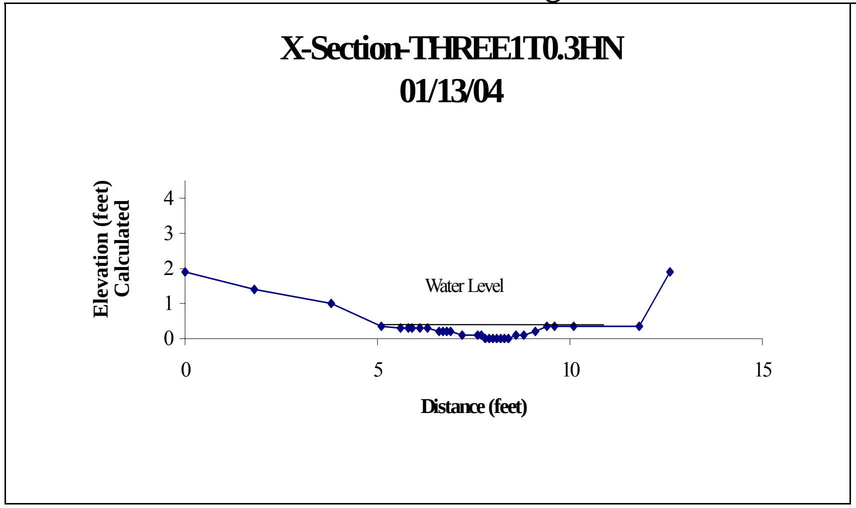


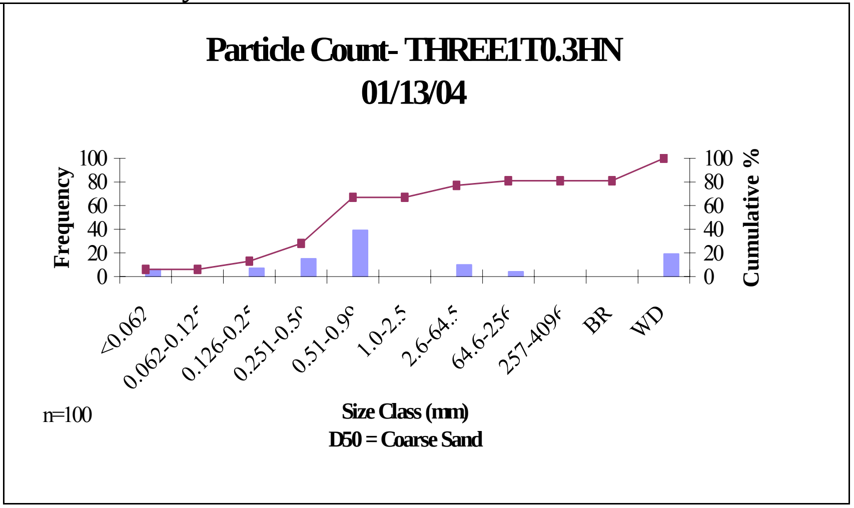
Ecoregion 65E – Thompson Creek – Garret Lake



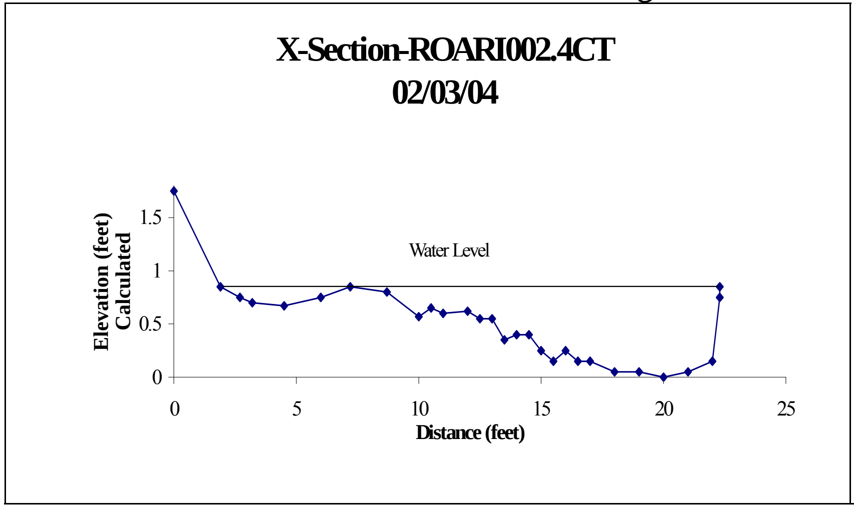


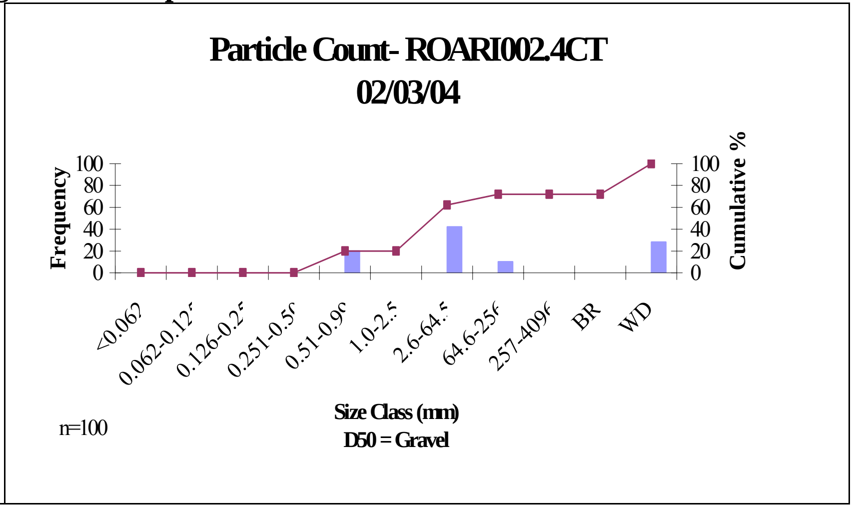
Ecoregion 65E – Threemile Branch Tributary – Smith Lake



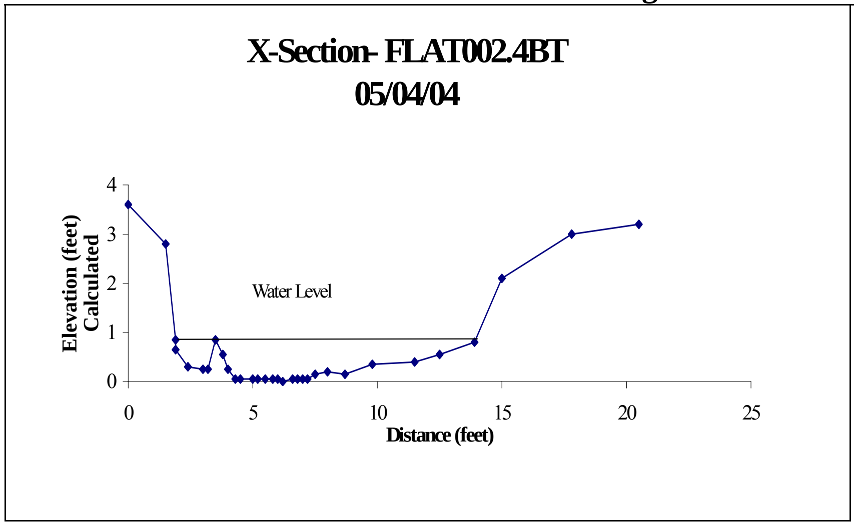


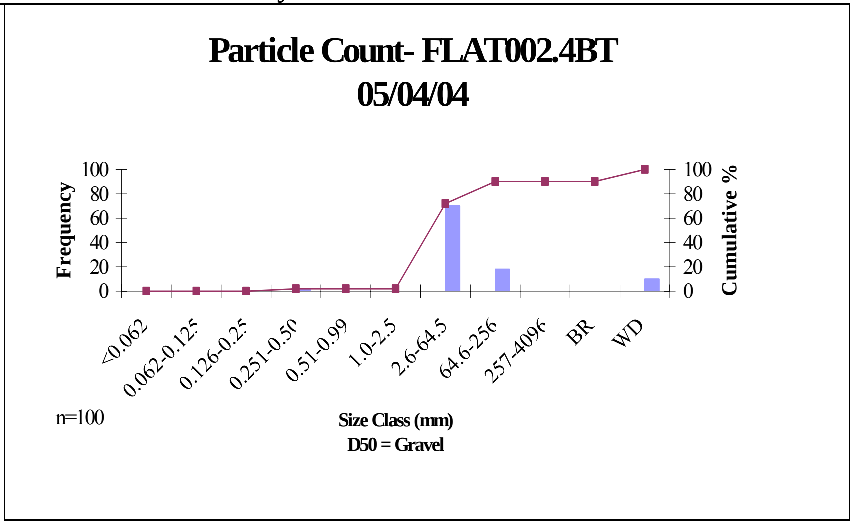
Ecoregion 66D – Roaring Creek – Ripshin Lake



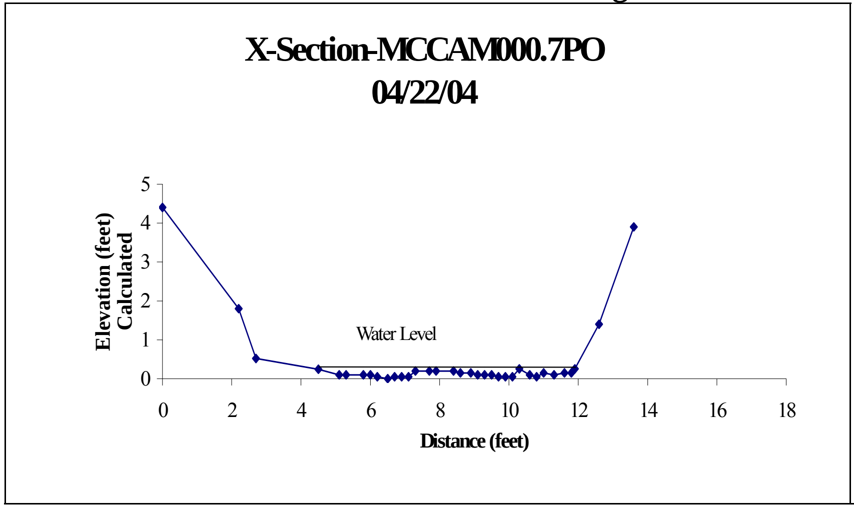


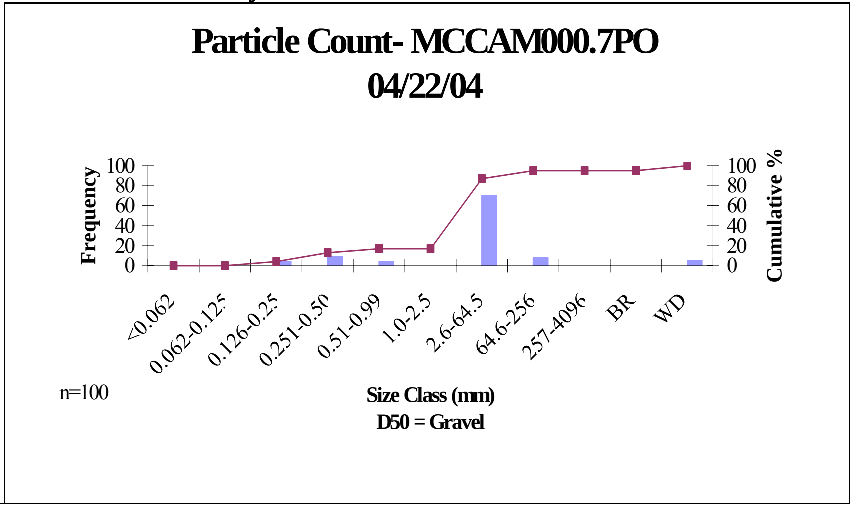
Ecoregion 66E – Flat Creek – Lake in the Sky



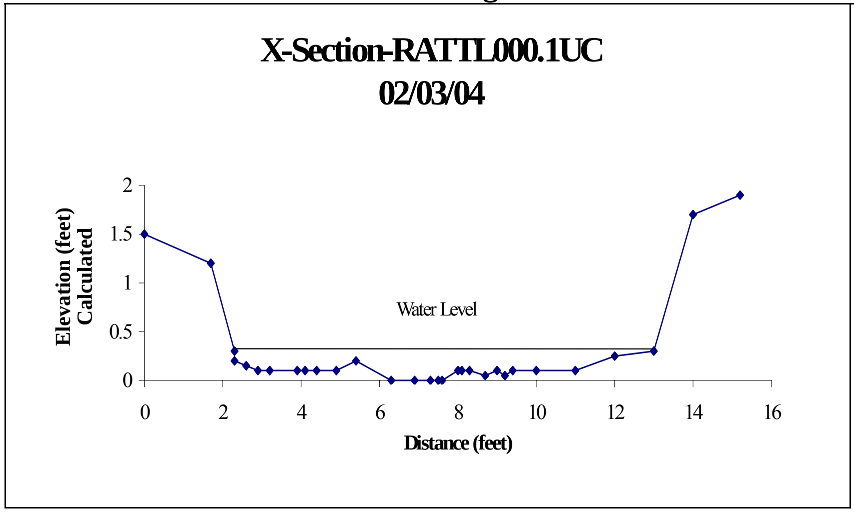


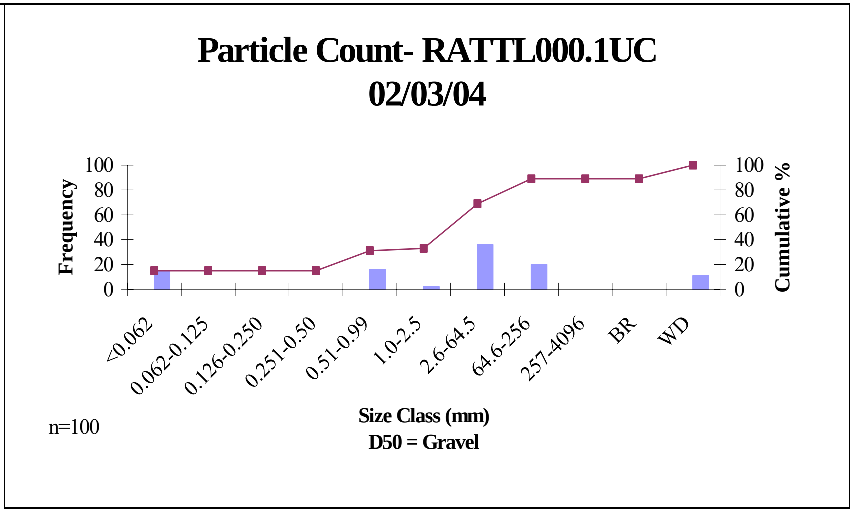
Ecoregion 66E – McCamy Branch – McCamy Lake



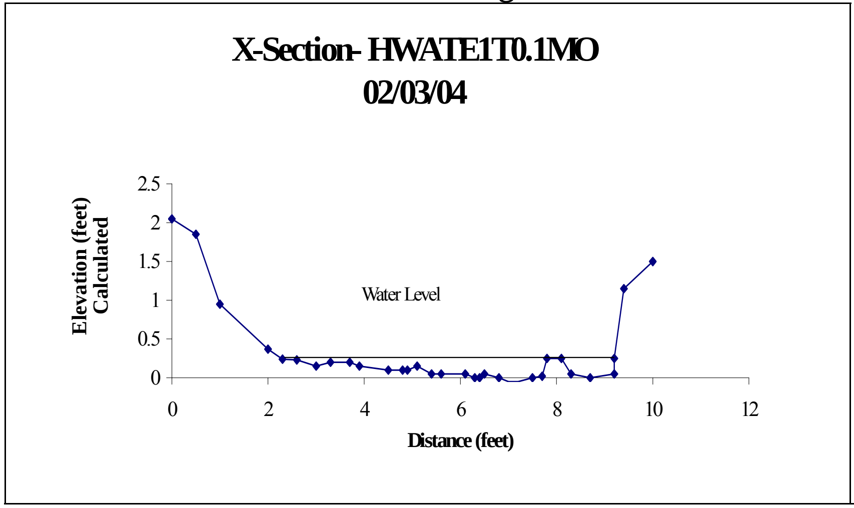


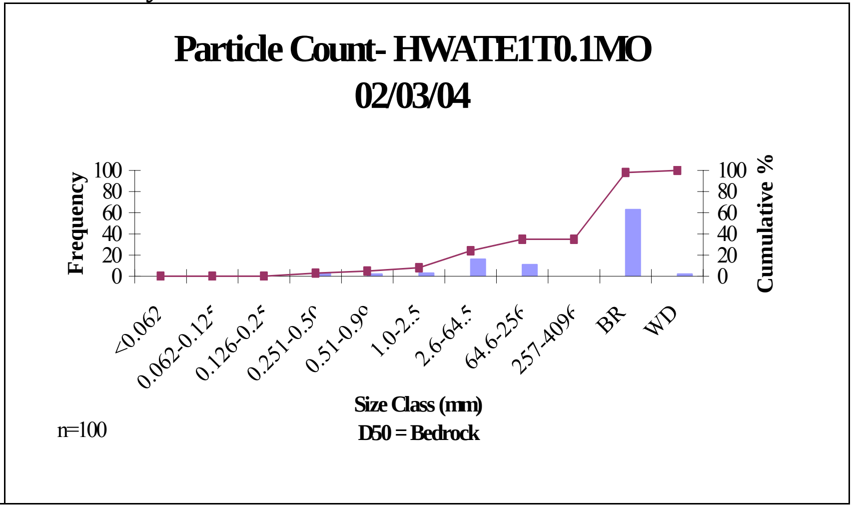
Ecoregion 66E – Rattlesnake Creek – Cherokee National Forest Dam



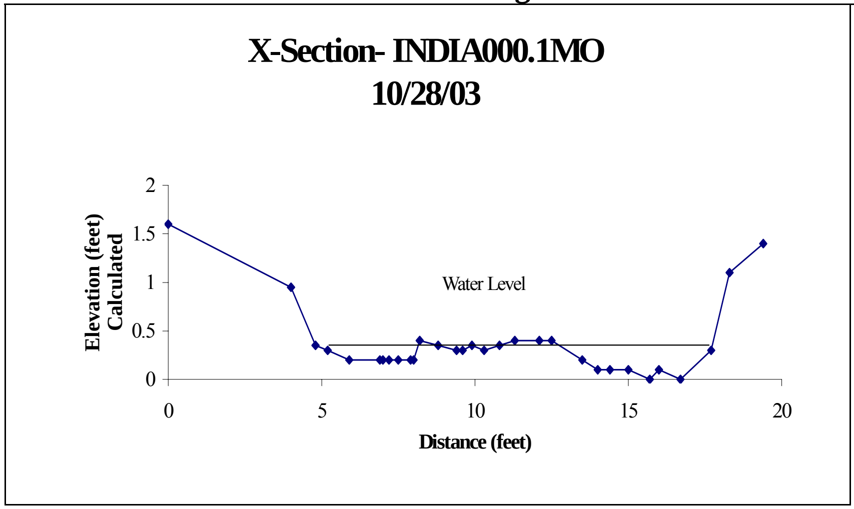


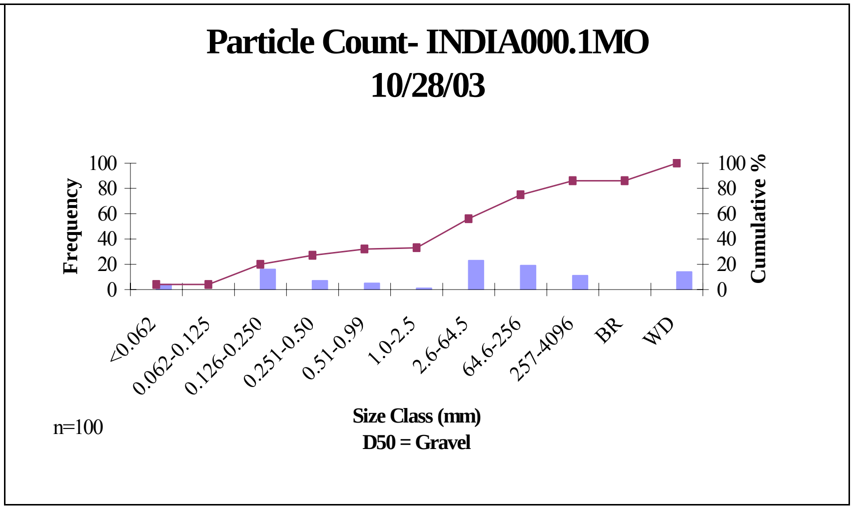
Ecoregion 66G – Hot Water Branch Tributary – Twin Lake Dam #2



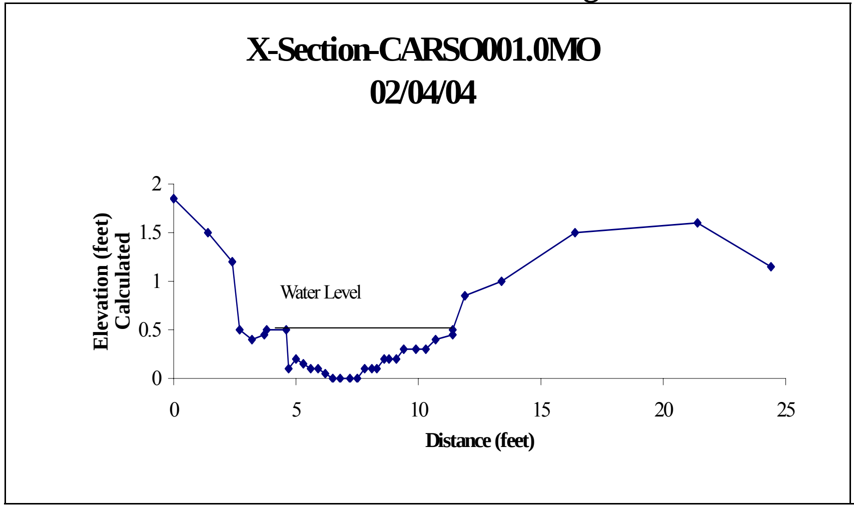


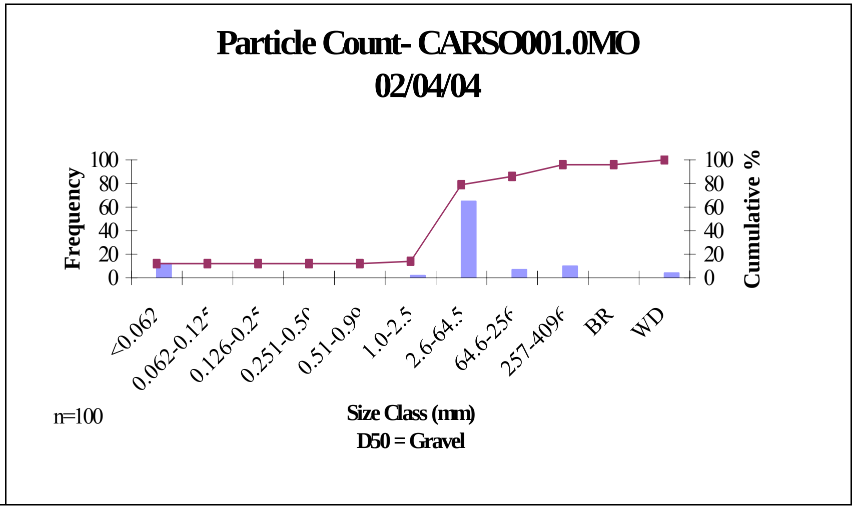
Ecoregion 66G – Indian Branch – First Order Reference Stream



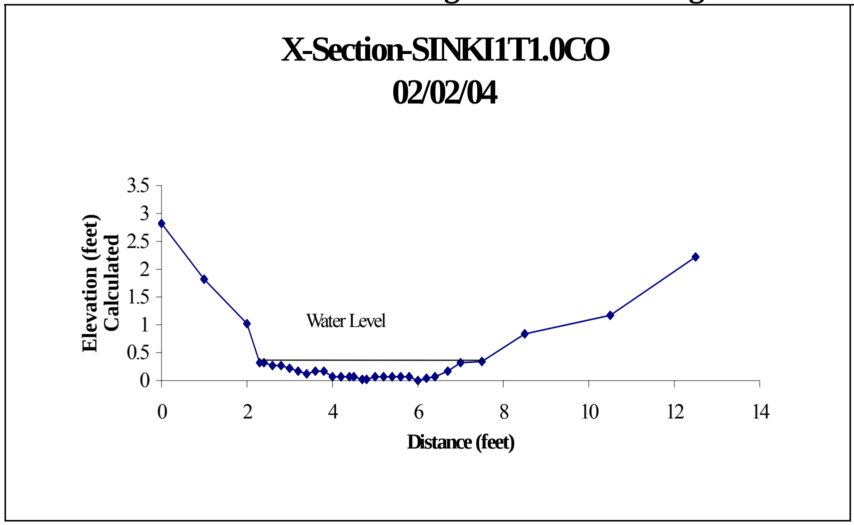


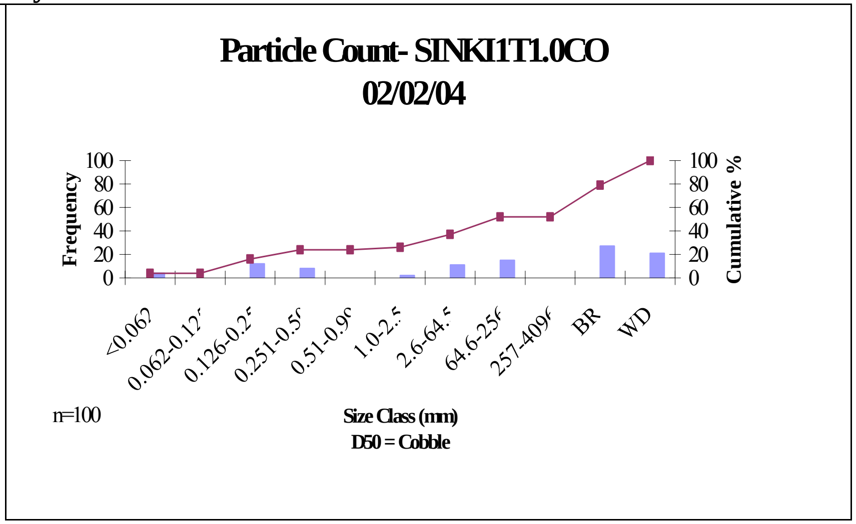
Ecoregion 67G – Carson Branch – Estes Kefauver Lake



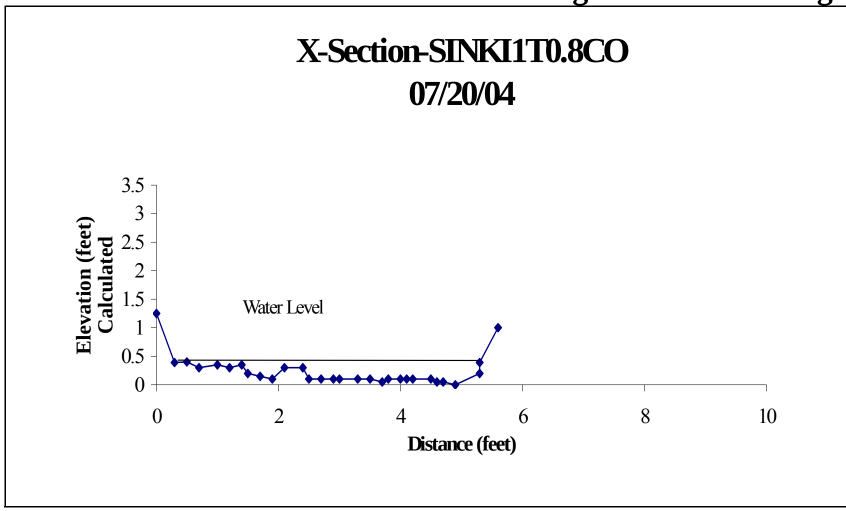


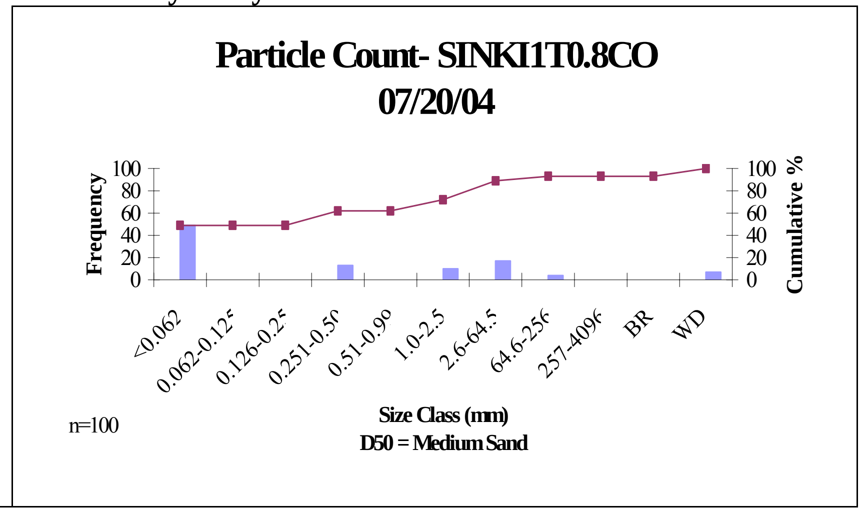
Ecoregion 67G – Sinking Creek Tributary – First Order Reference Stream



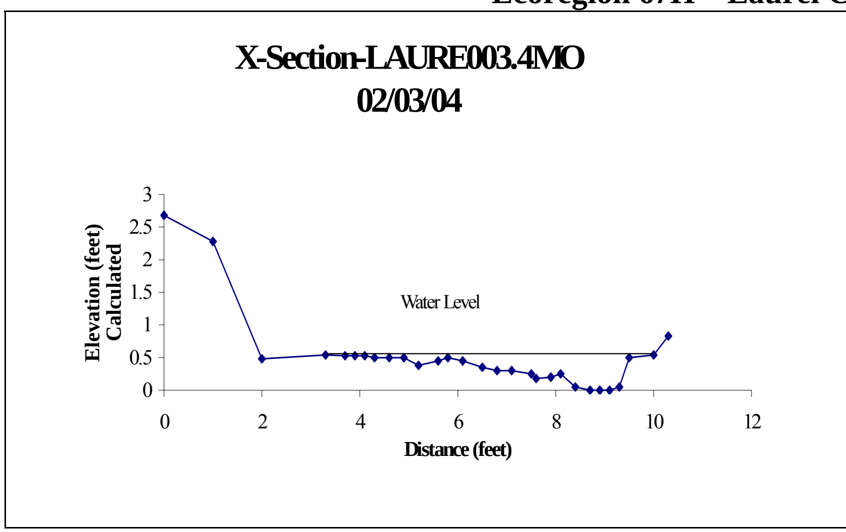


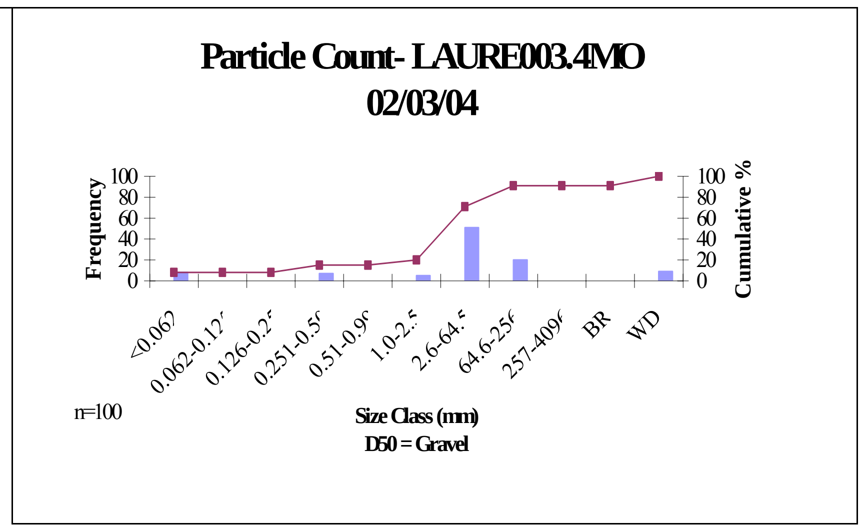
Ecoregion 67G – Sinking Creek Tributary – Bryant Lake



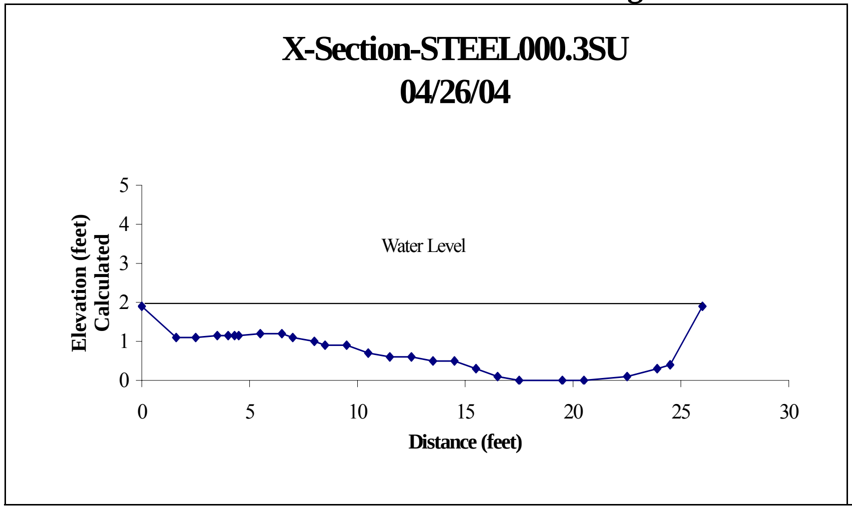


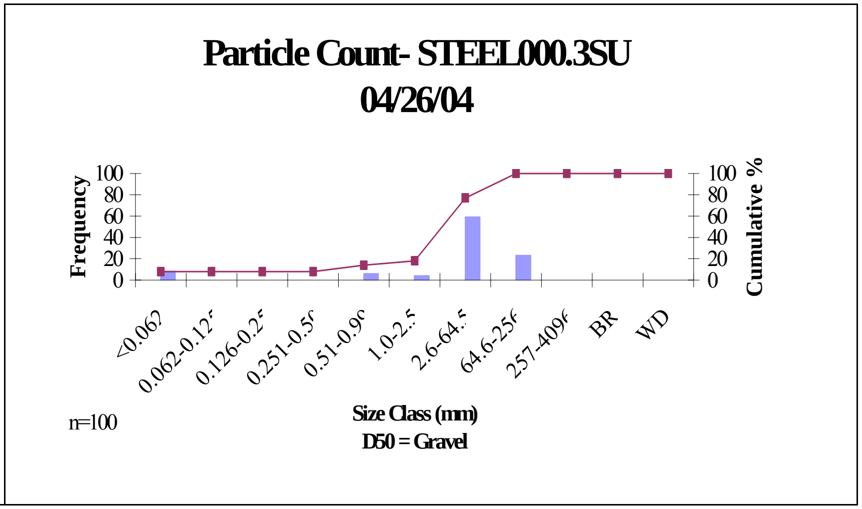
Ecoregion 67H – Laurel Creek – Laurel Mountain Lake



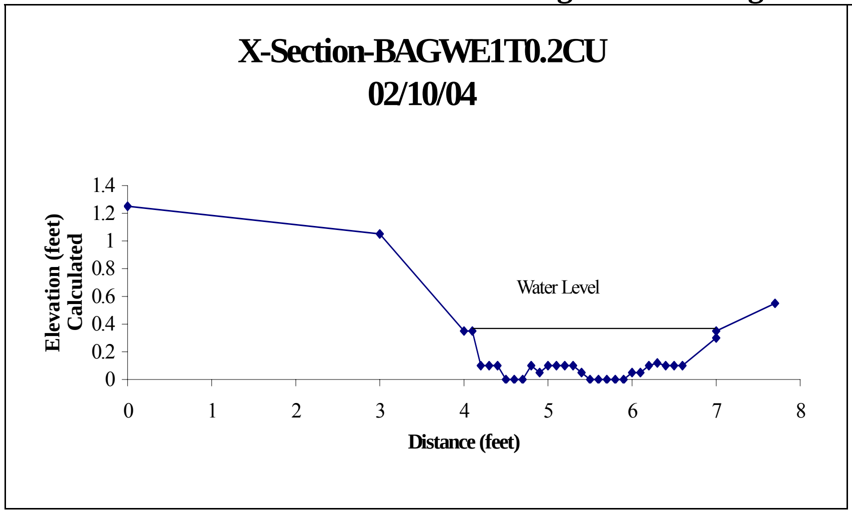


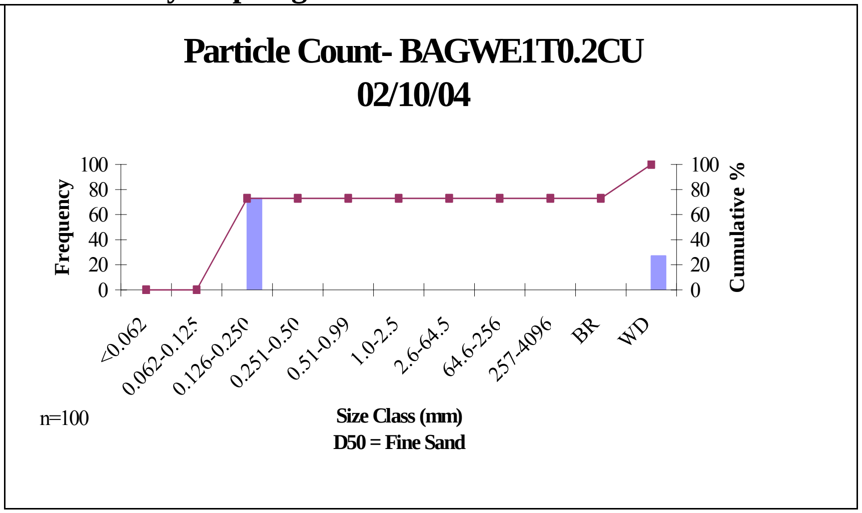
Ecoregion 67I – Steele Creek – Steele Creek Dam



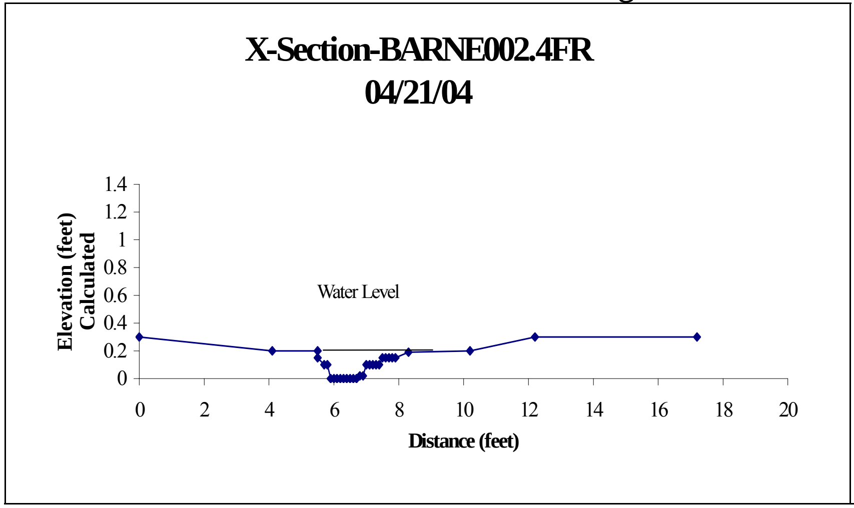


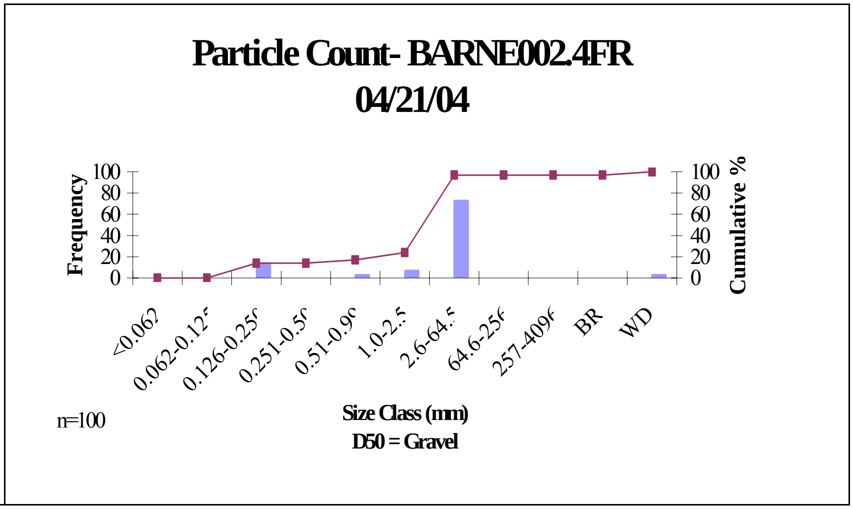
Ecoregion 68A – Bagwell Branch Tributary – Spring Lake



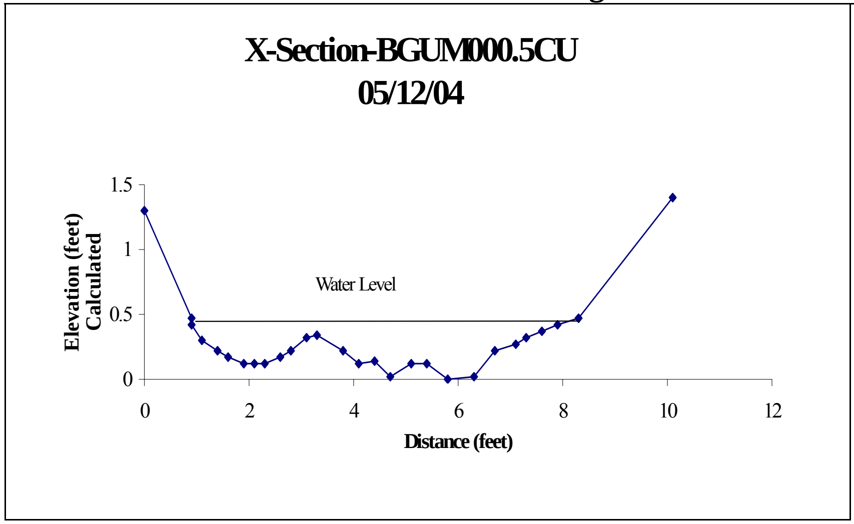


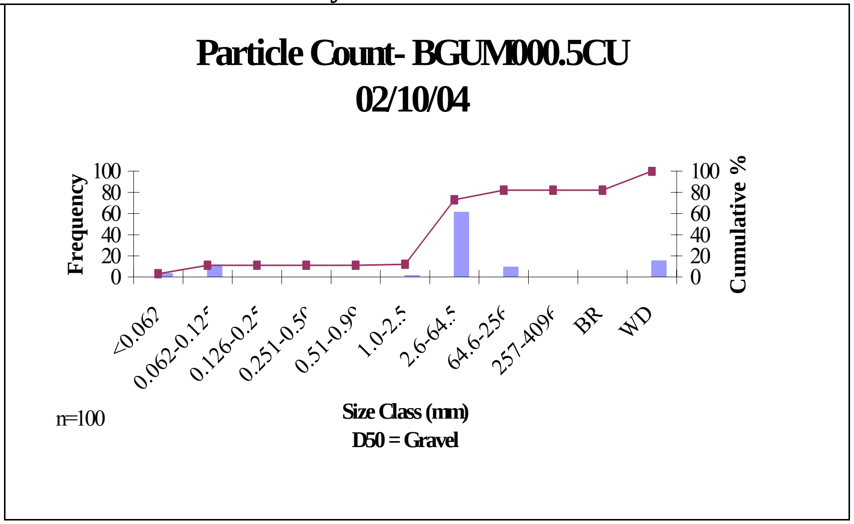
Ecoregion 68A – Barnes Branch – O'Donnell Lake



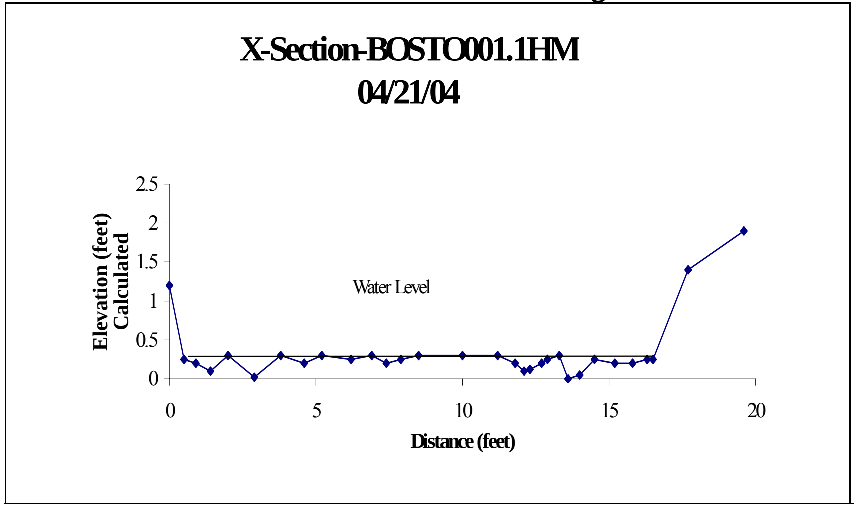


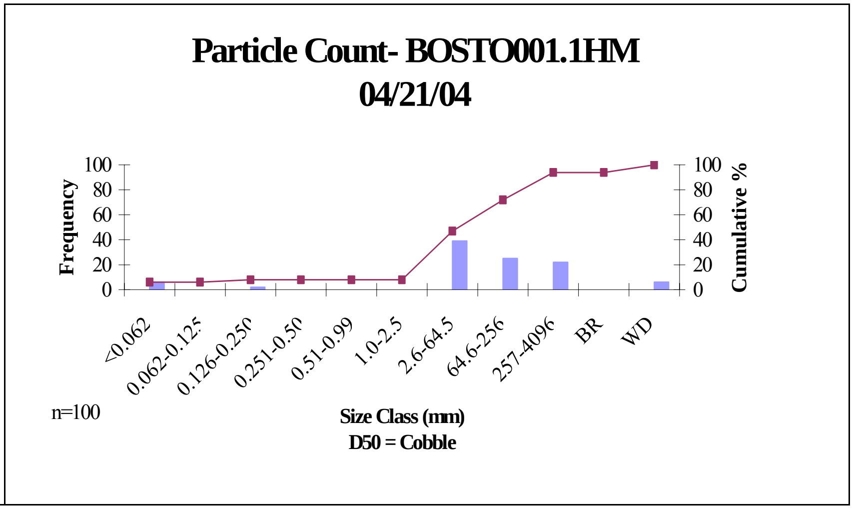
Ecoregion 68A – Black Gum Branch – Lake Pomeroy



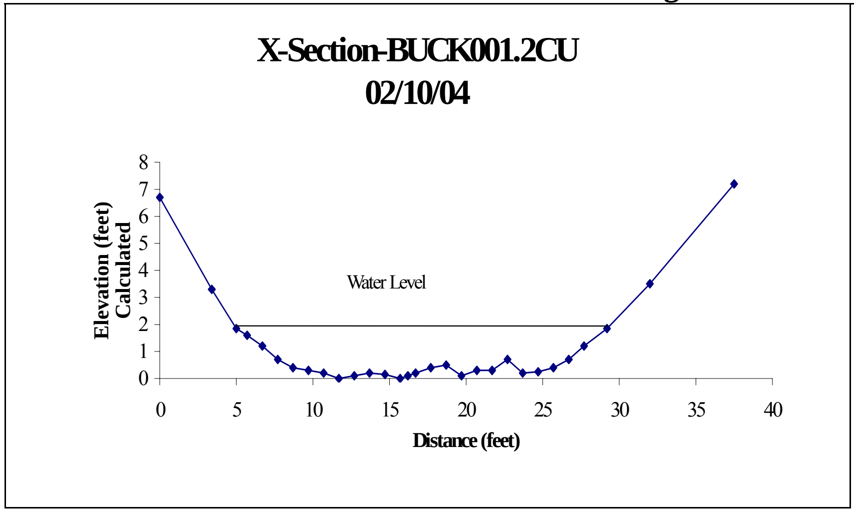


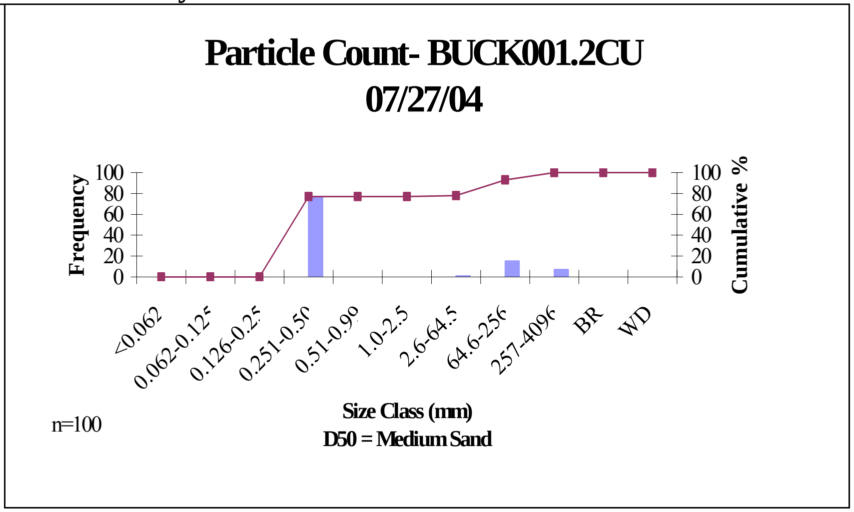
Ecoregion 68A – Boston Branch – Boston Branch Dam



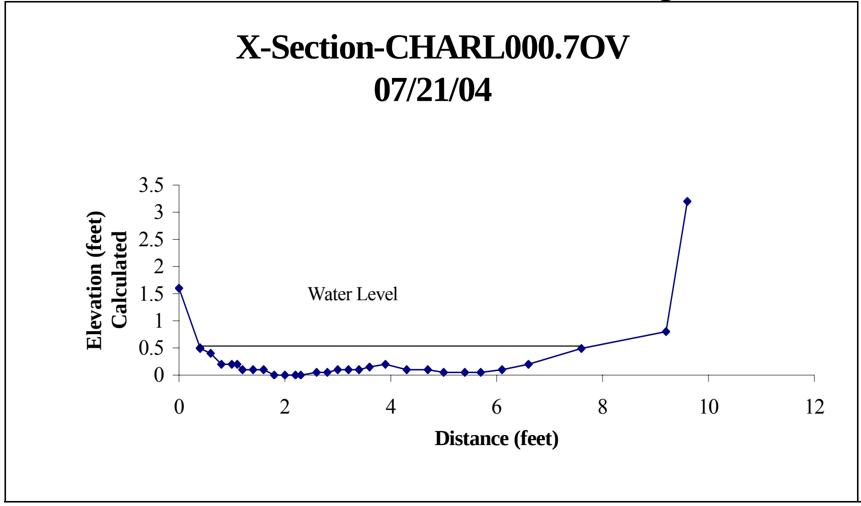


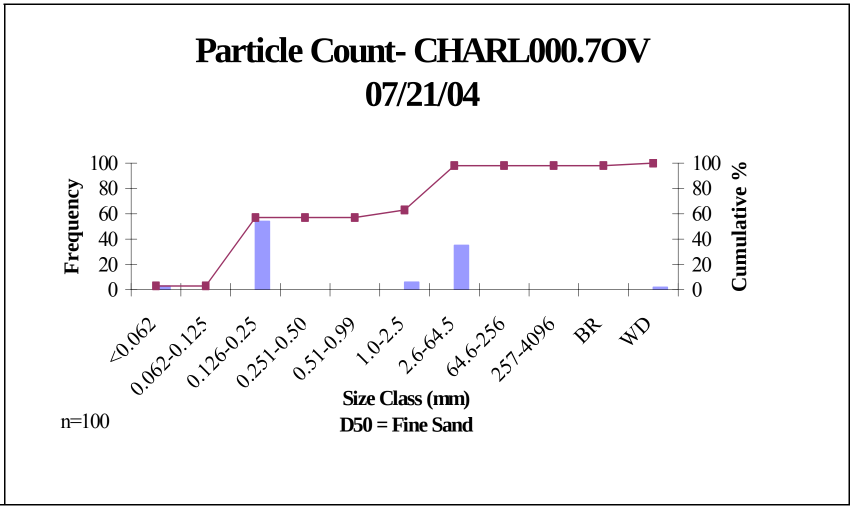
Ecoregion 68A – Buck Creek –Pelfey Lake



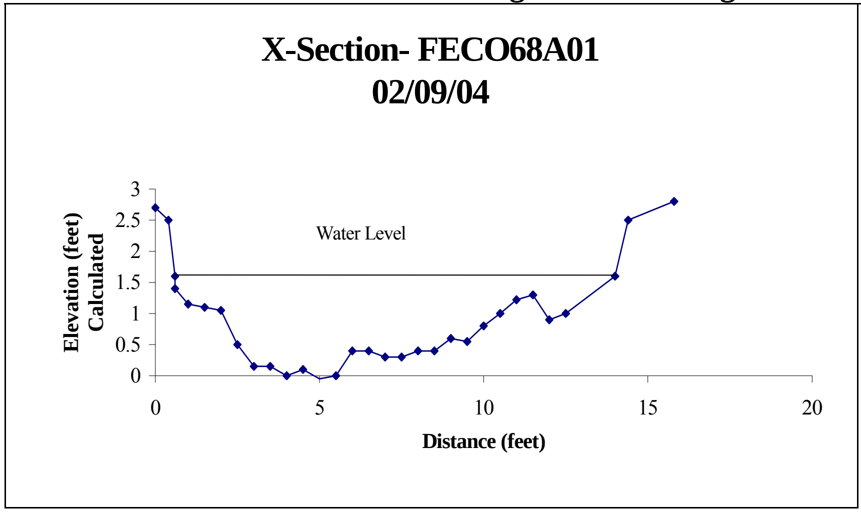


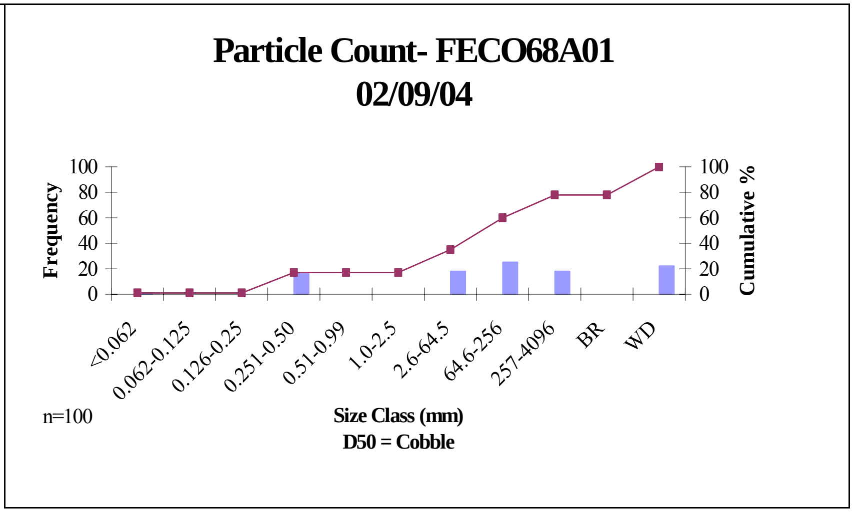
Ecoregion 68A – Charlie Branch – Lad Lake



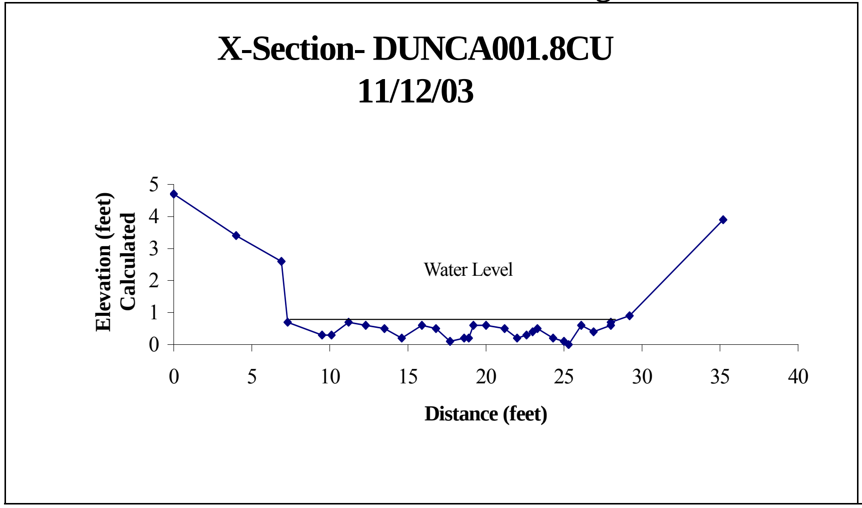


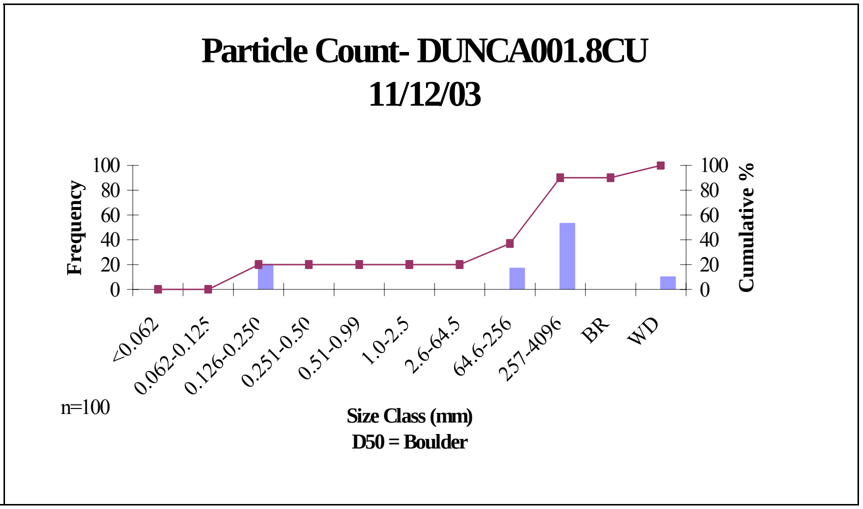
Ecoregion 68A – Douglas Branch – First Order Reference Stream



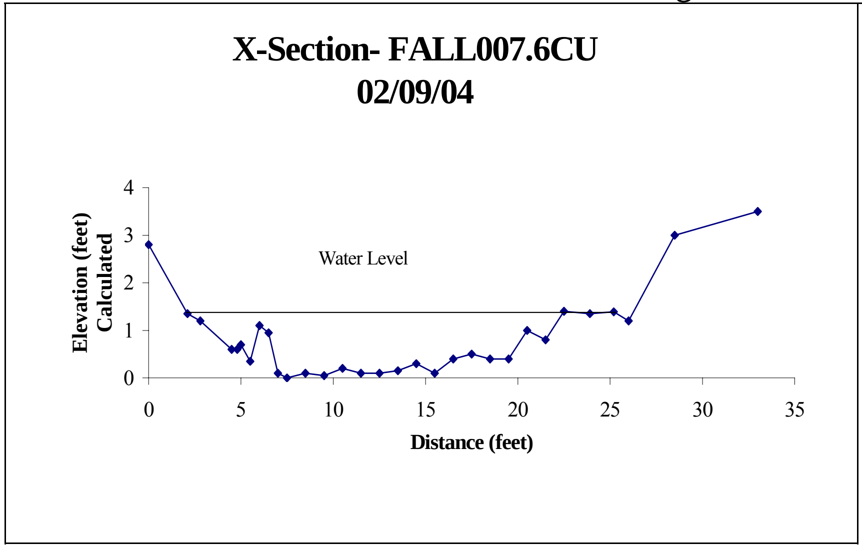


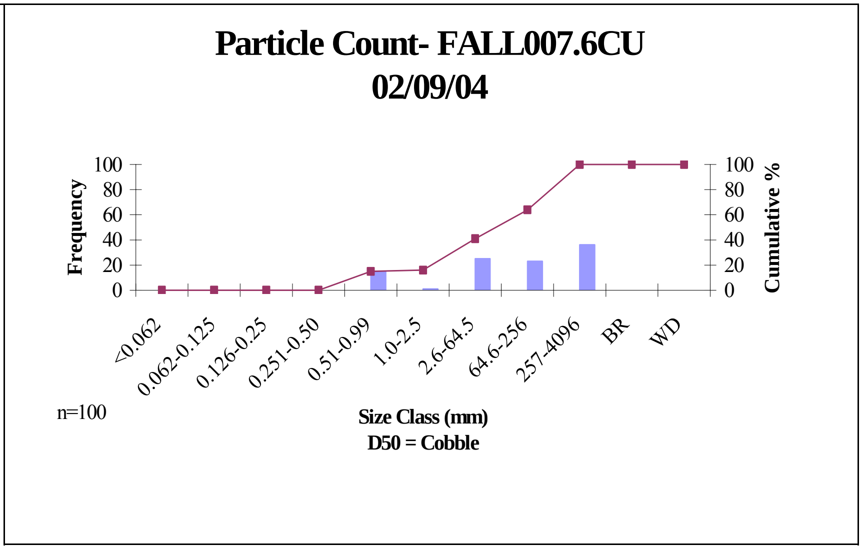
Ecoregion 68A – Duncan Creek – Duncan Creek Dam



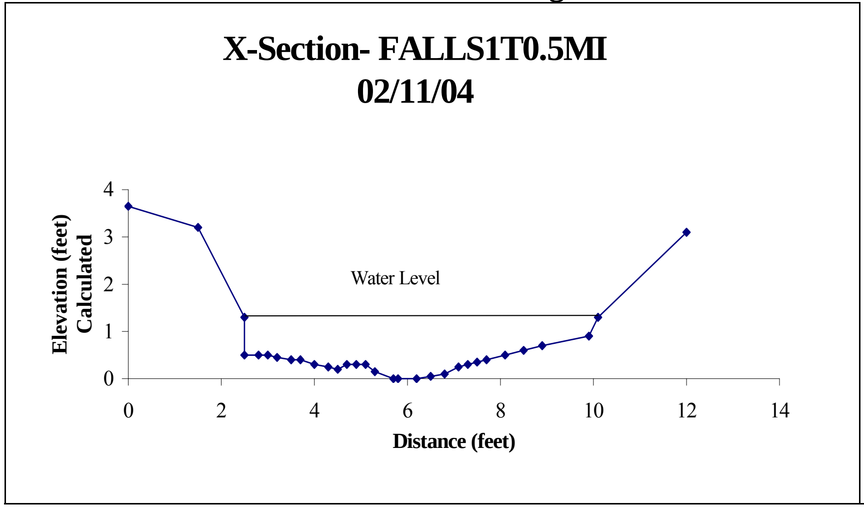


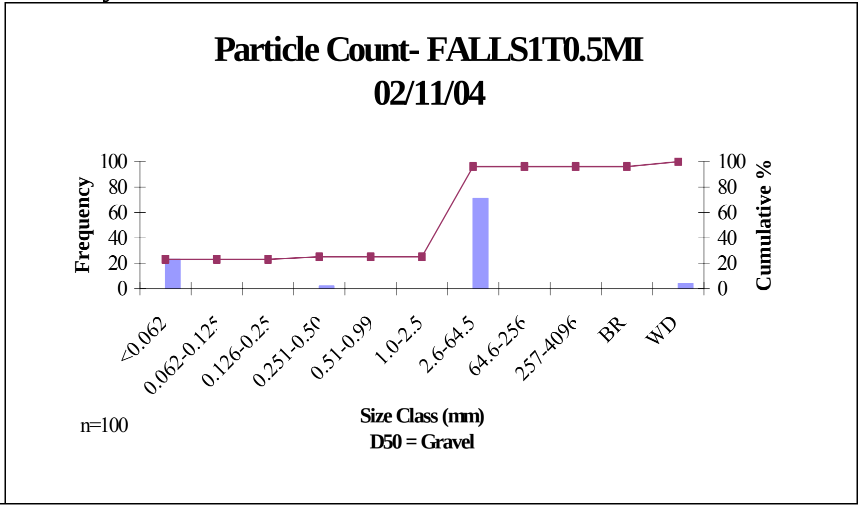
Ecoregion 68A – Fall Creek – Ozone Lake



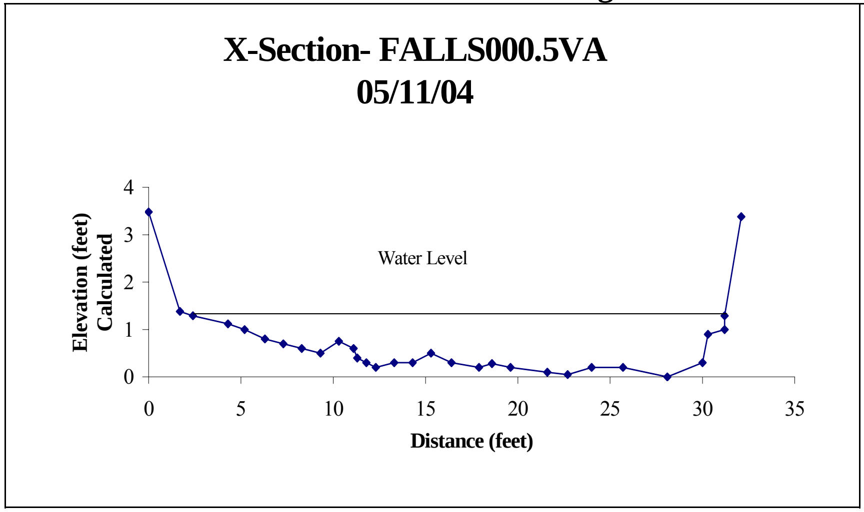


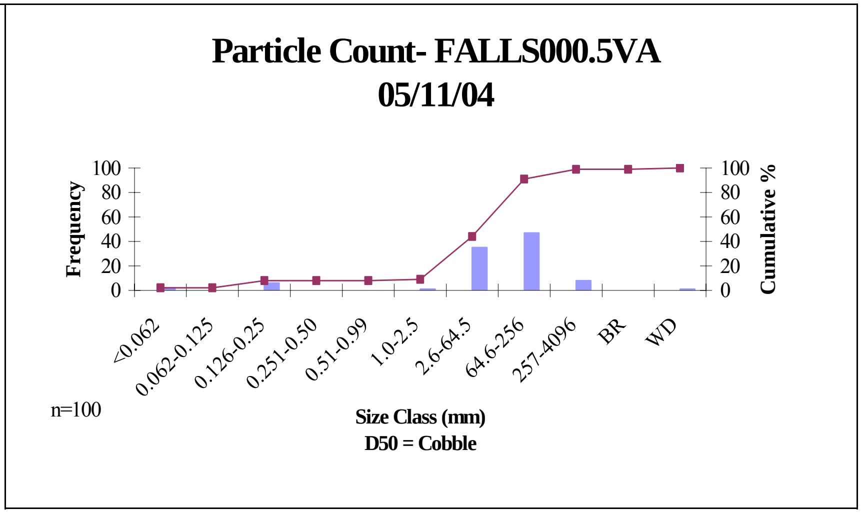
Ecoregion 68A – Falls Branch Tributary – Tom McBee Lake



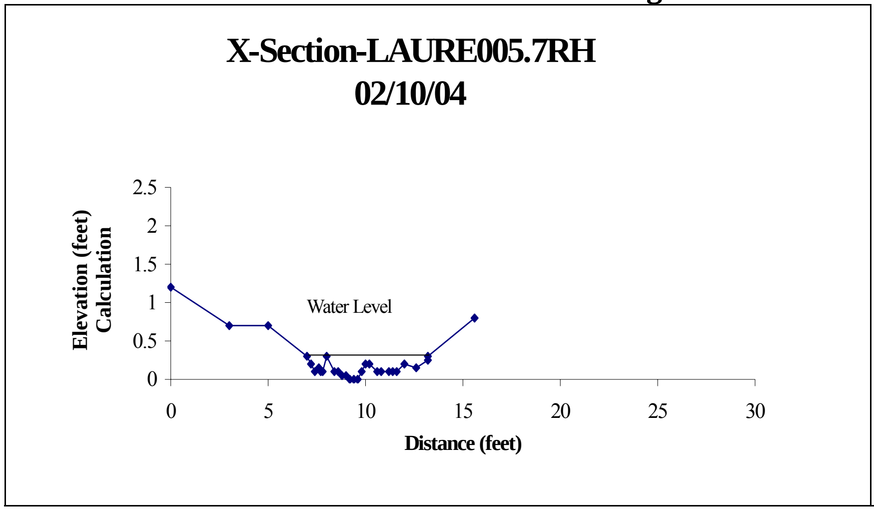


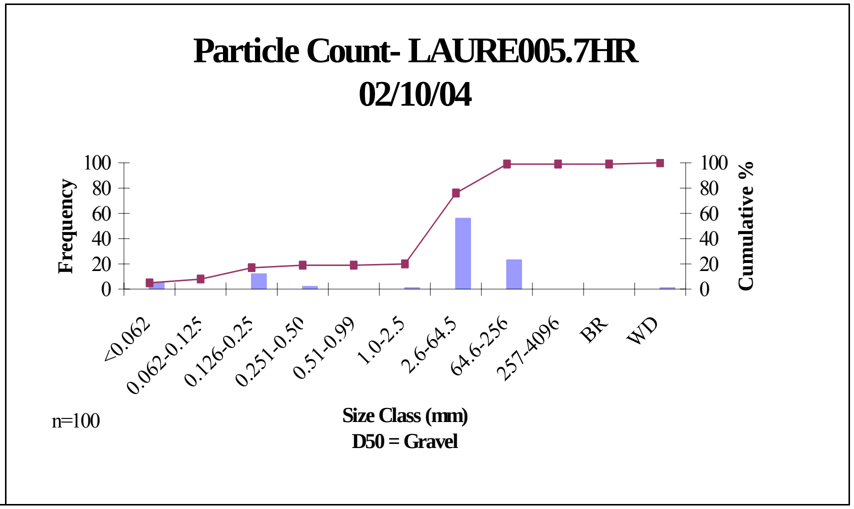
Ecoregion 68A – Falls Creek – Fall Creek Falls Lakes



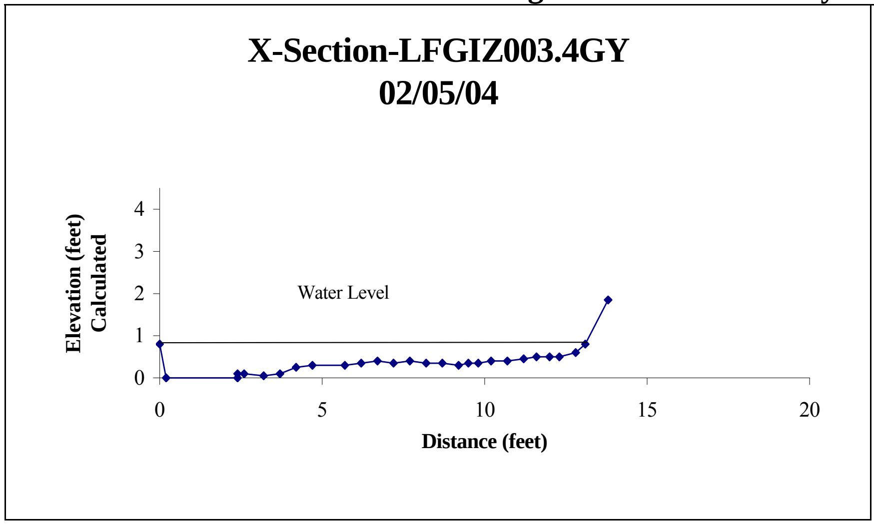


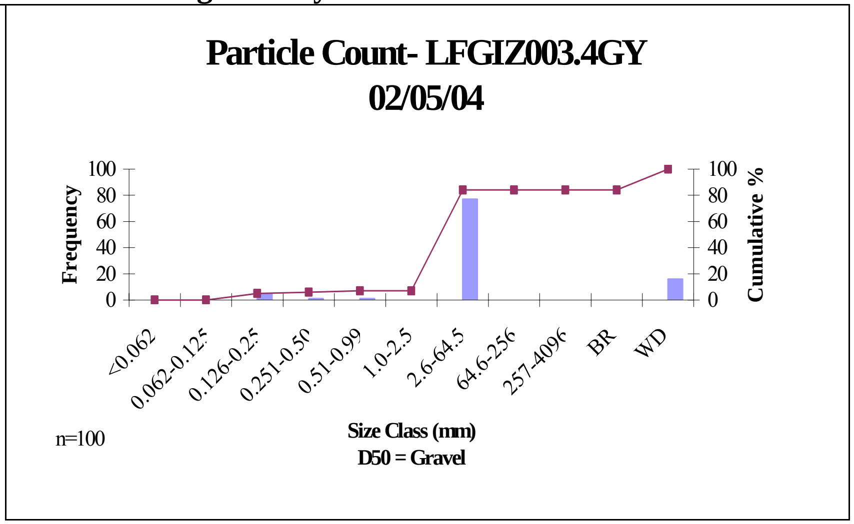
Ecoregion 68A – Laurel Creek – Sinclair Lake



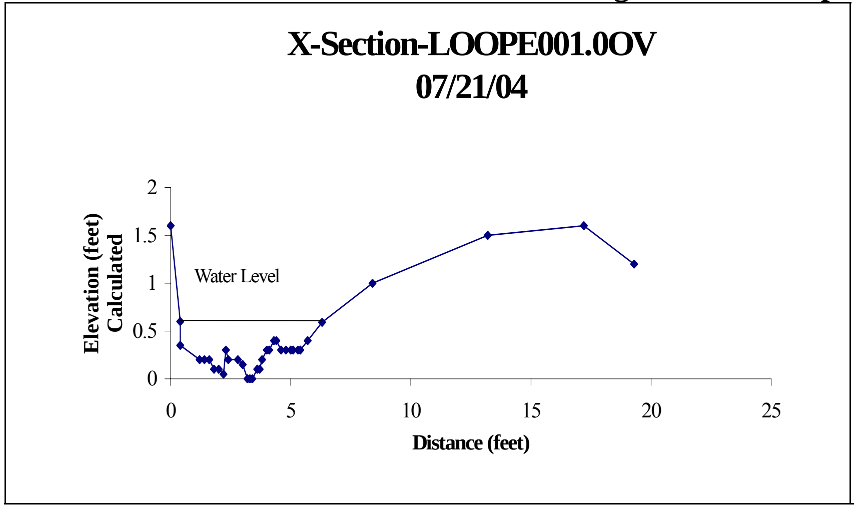


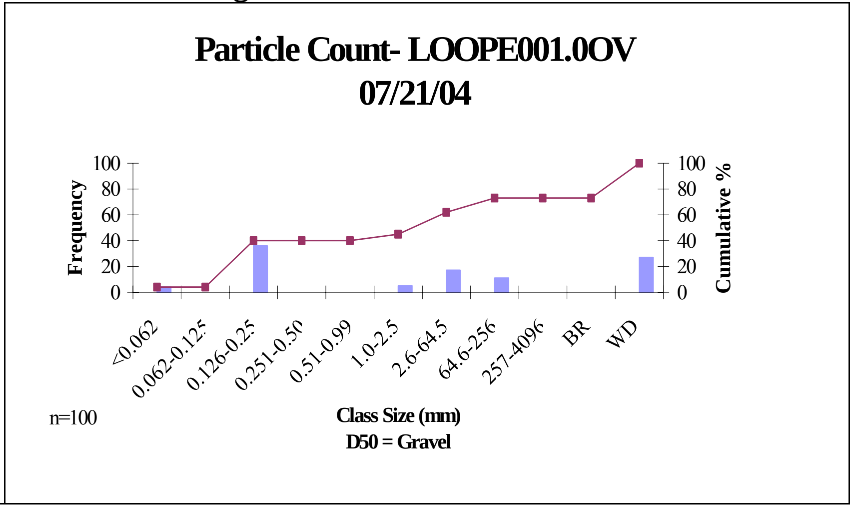
Ecoregion 68A – Little Fiery Gizzard Creek – Big Grundy Lake



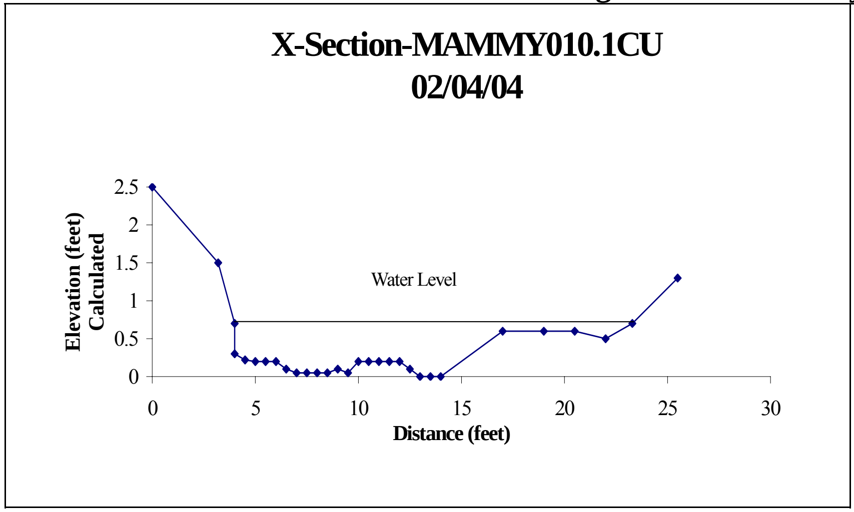


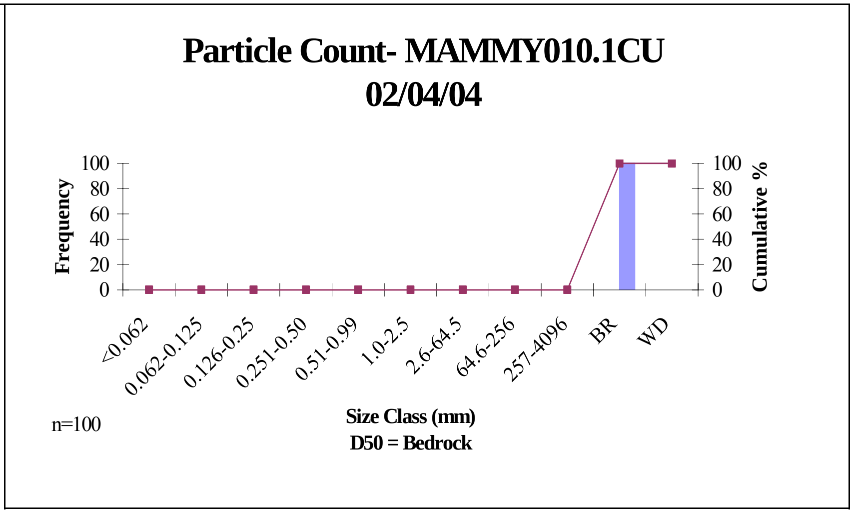
Ecoregion 68A – Looper Branch – Pine Ridge Lake



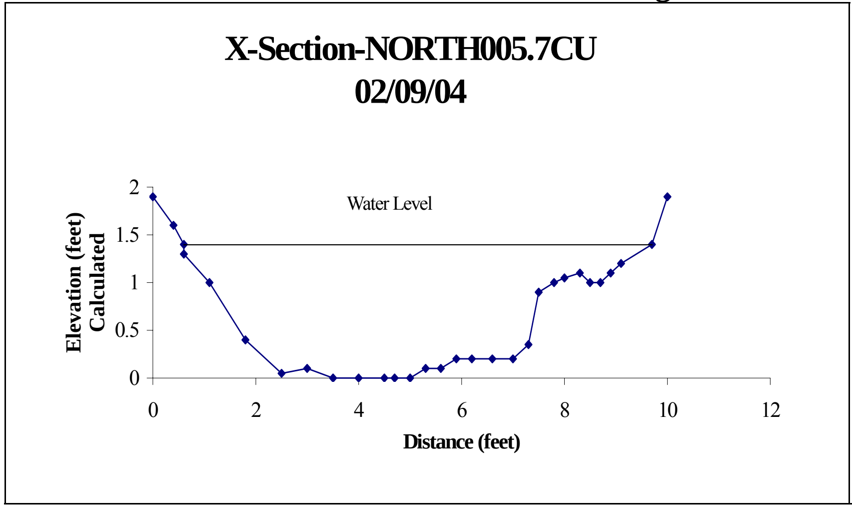


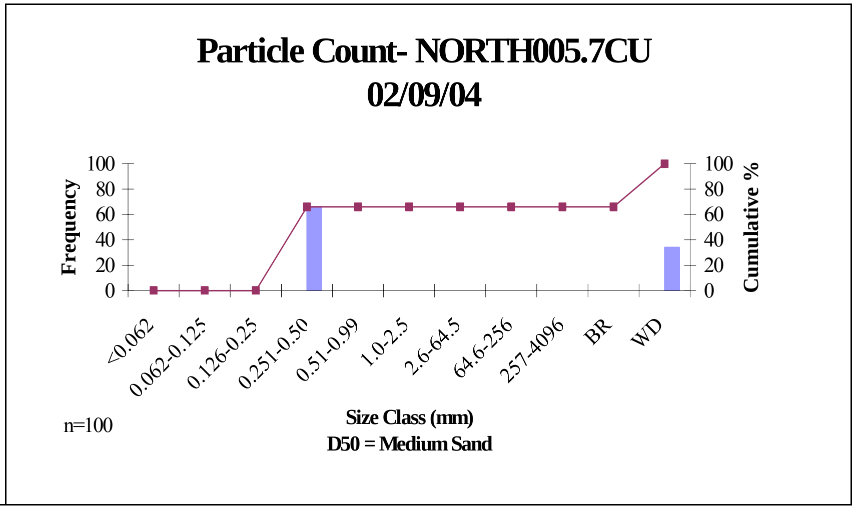
Ecoregion 68A – Mammy's Creek – Lake Waldensia



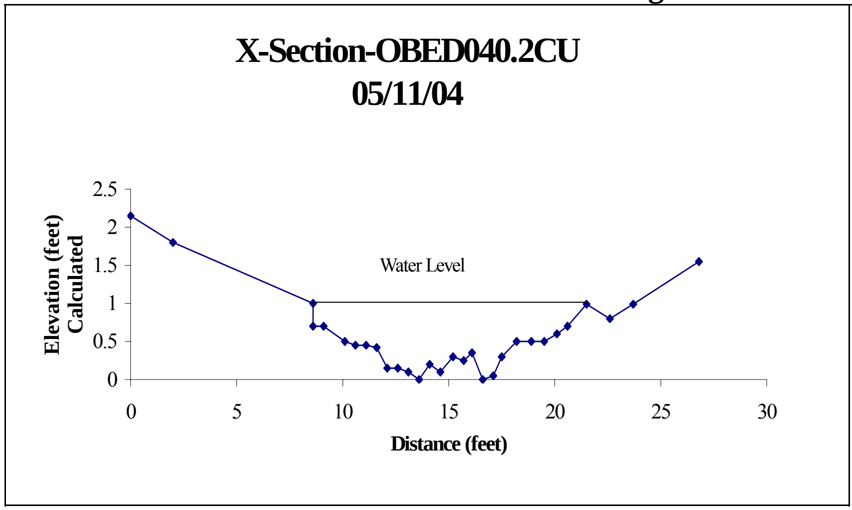


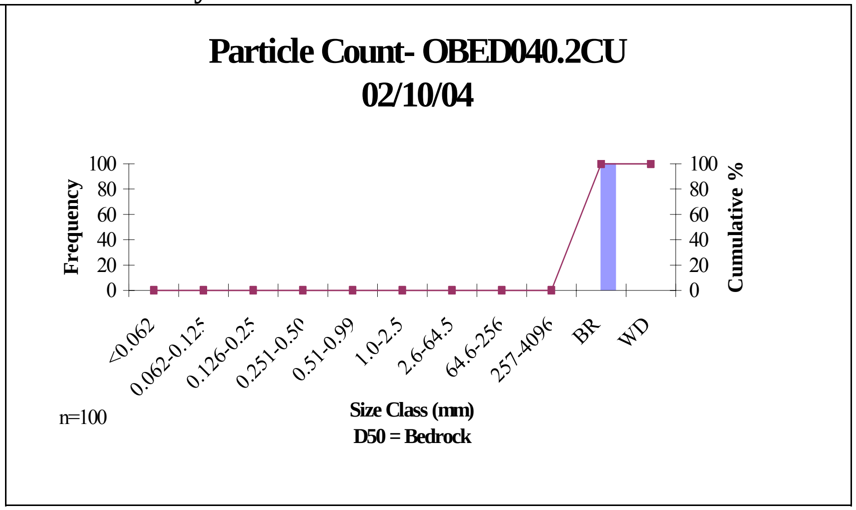
Ecoregion 68A – North Creek – Turner Lake



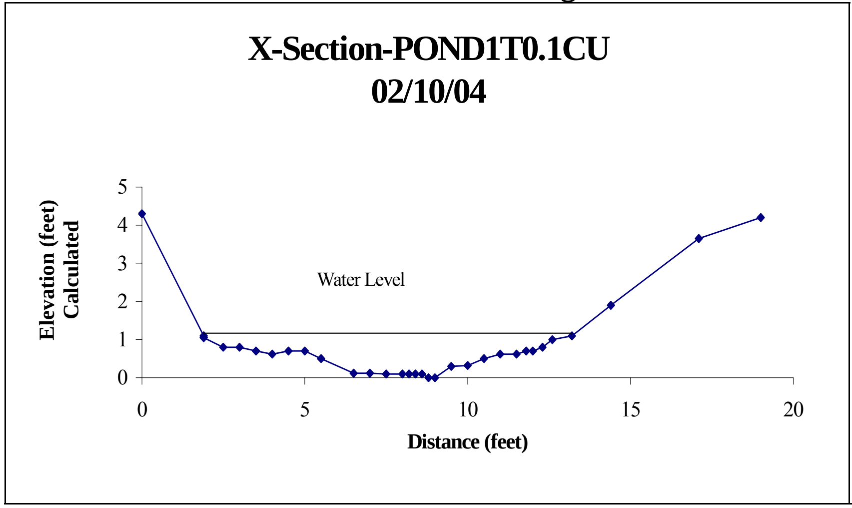


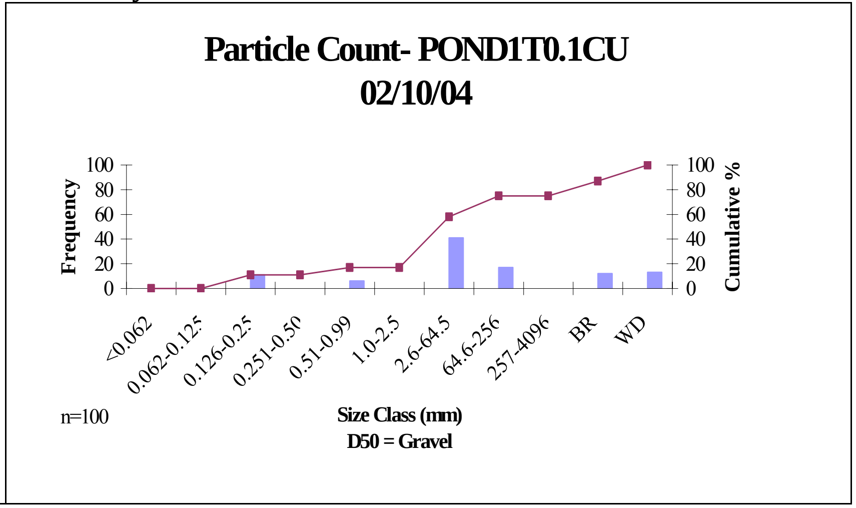
Ecoregion 68A – Obed River – Holiday Lake



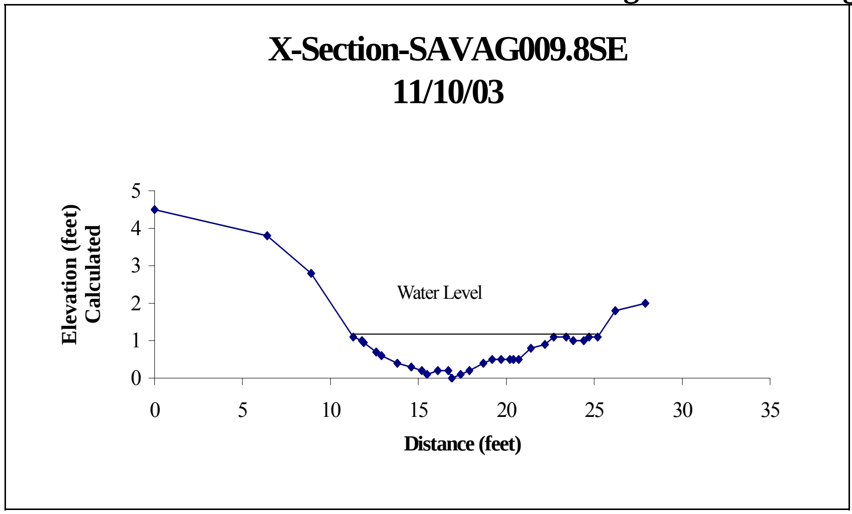


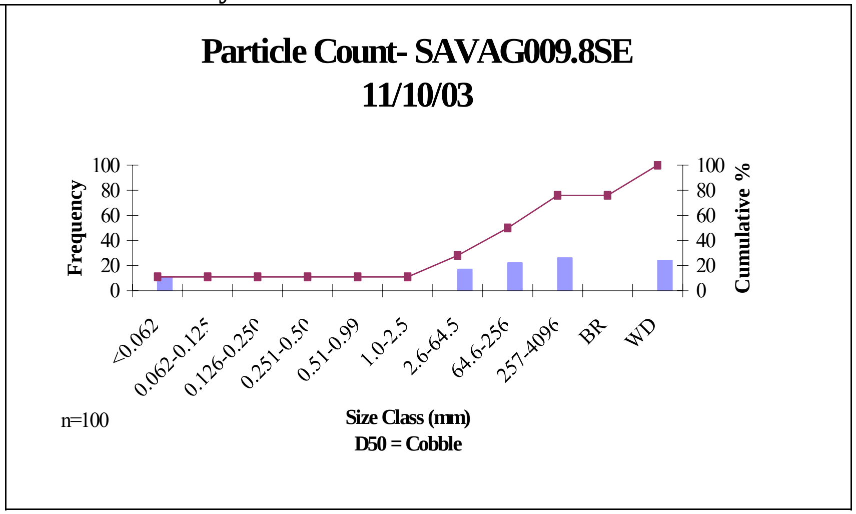
Ecoregion 68A – Pond Branch Tributary – Kirkstone Lake



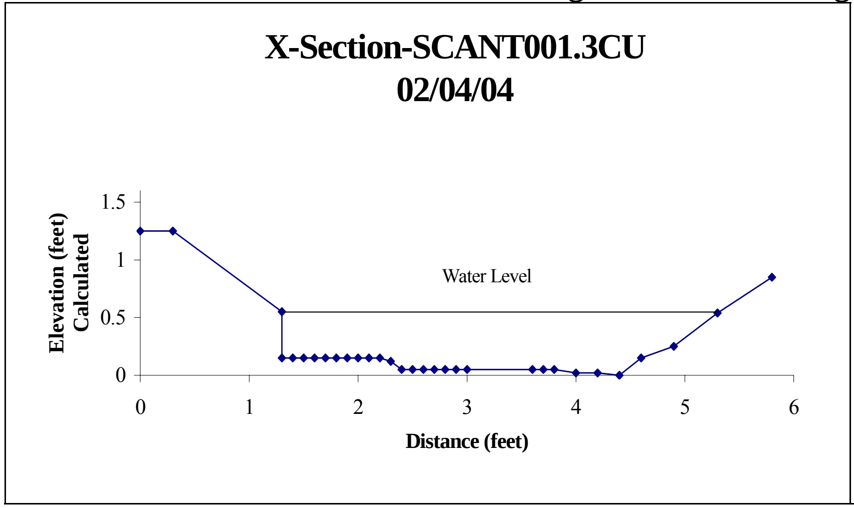


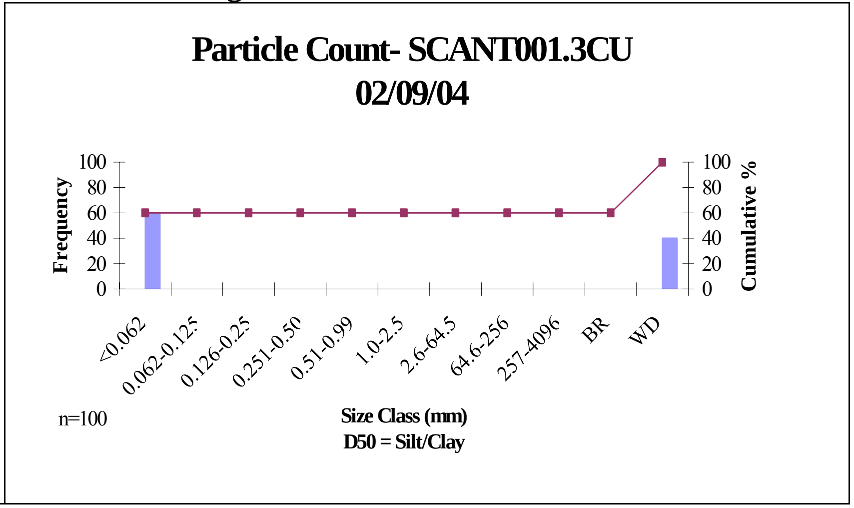
Ecoregion 68A – Savage Creek – Dunaway Lake



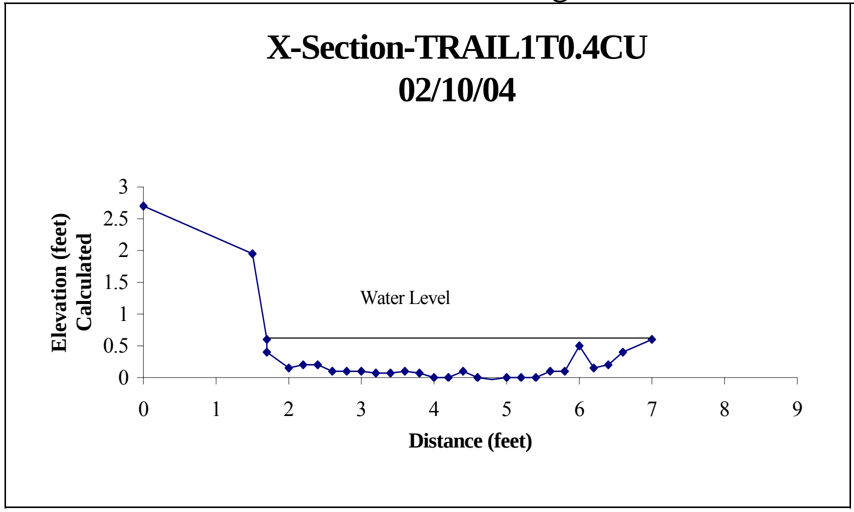


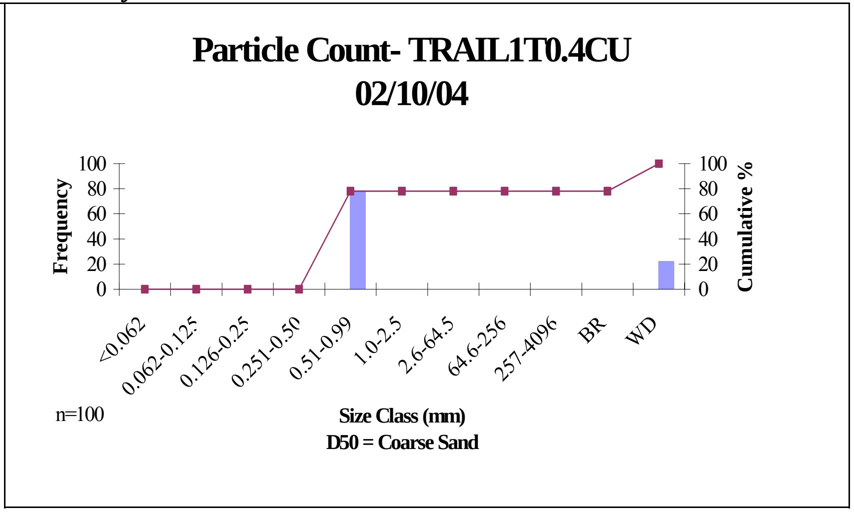
Ecoregion 68A – Scantling Branch – Good Neighbor Lake



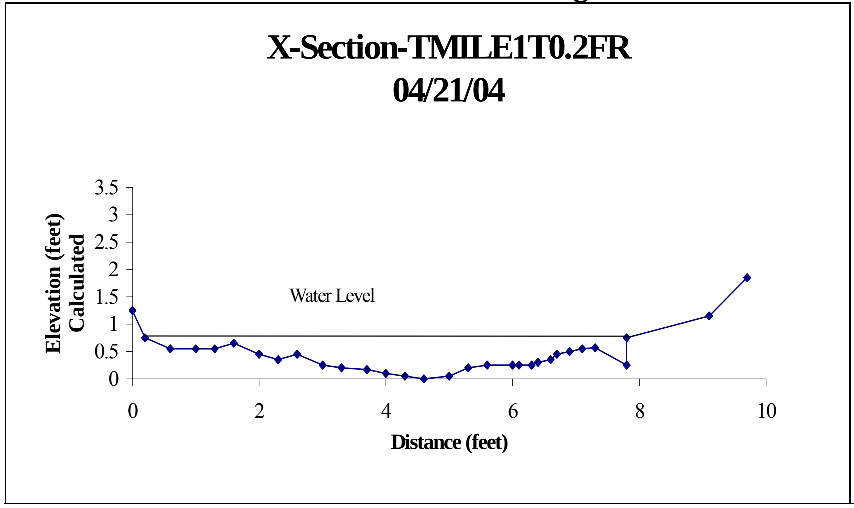


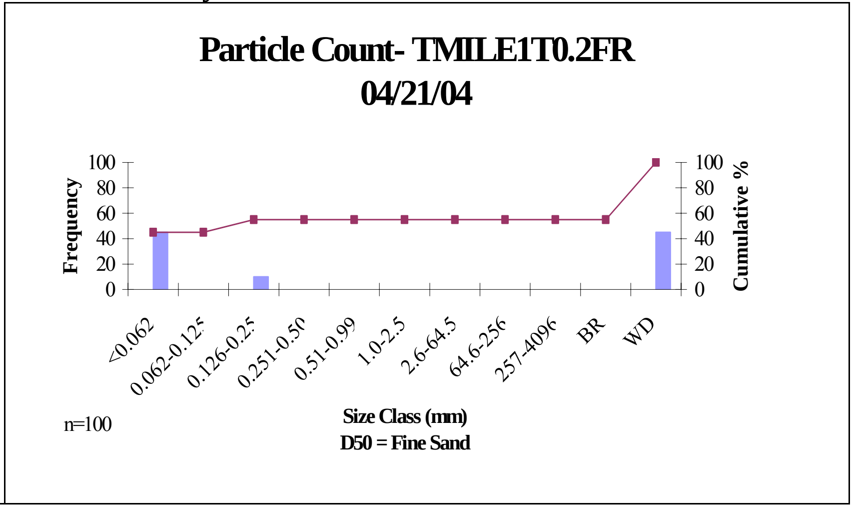
Ecoregion 68A – Trail Branch Tributary – Sherwood Lake



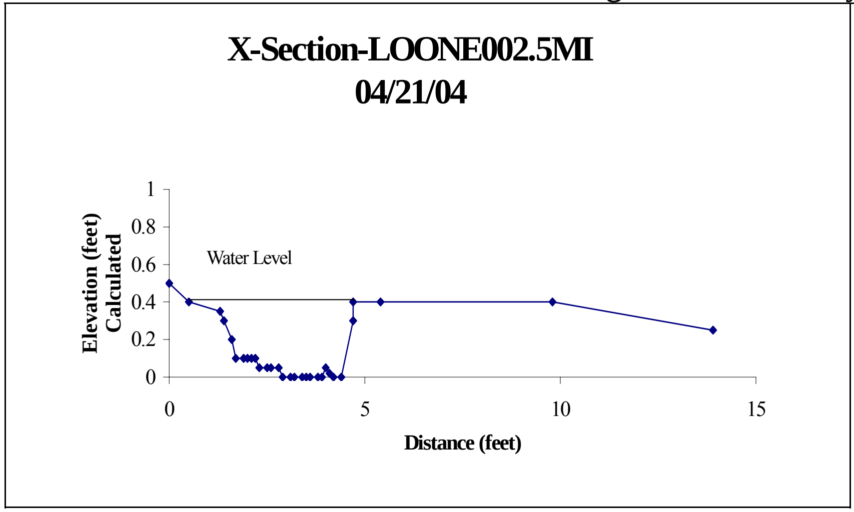


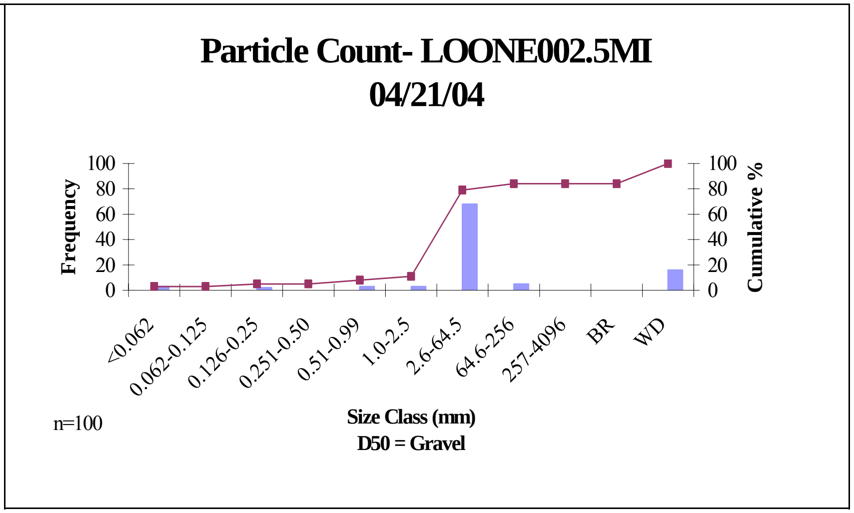
Ecoregion 68A – Two Mile Branch Tributary – Lake Eva



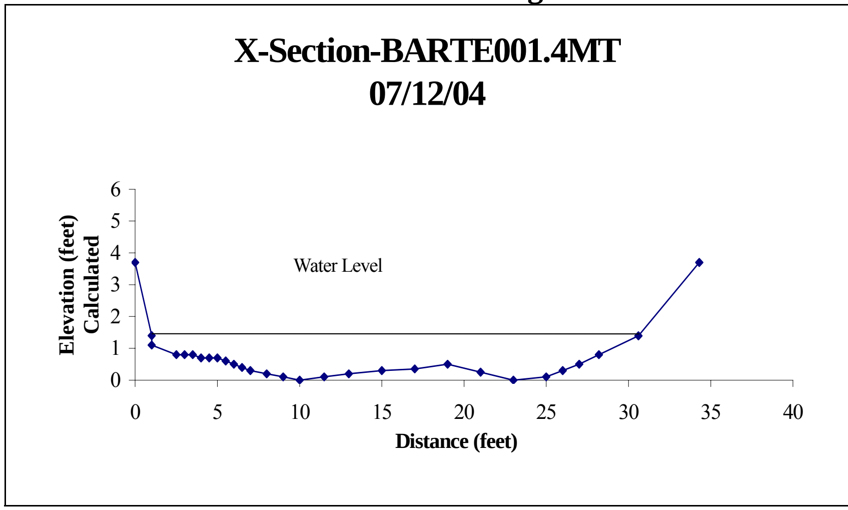


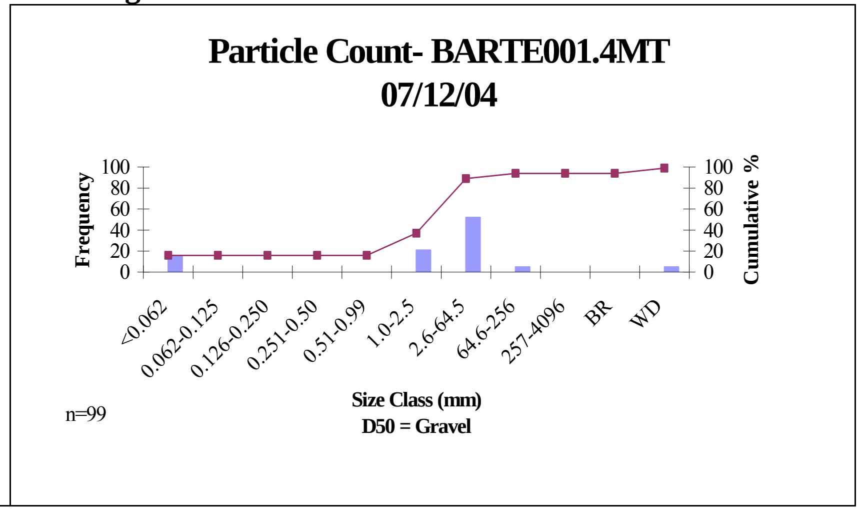
Ecoregion 68C – Looney's Creek – Kirkstone Lake



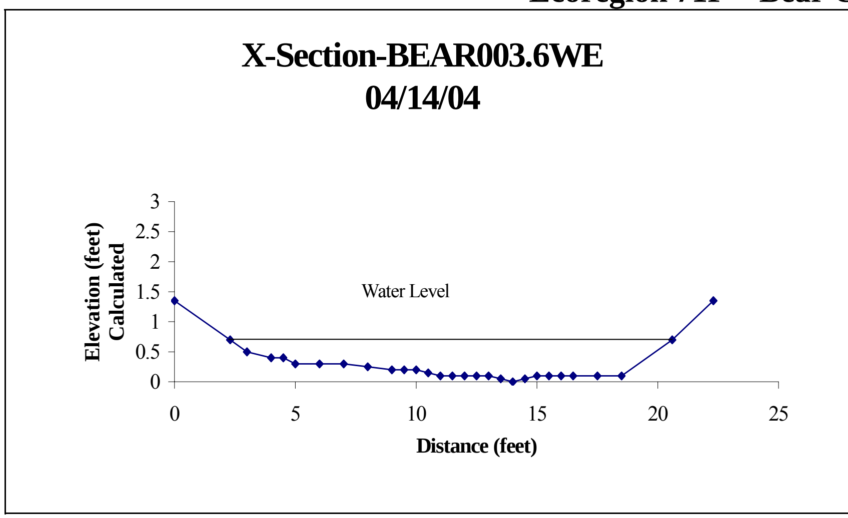


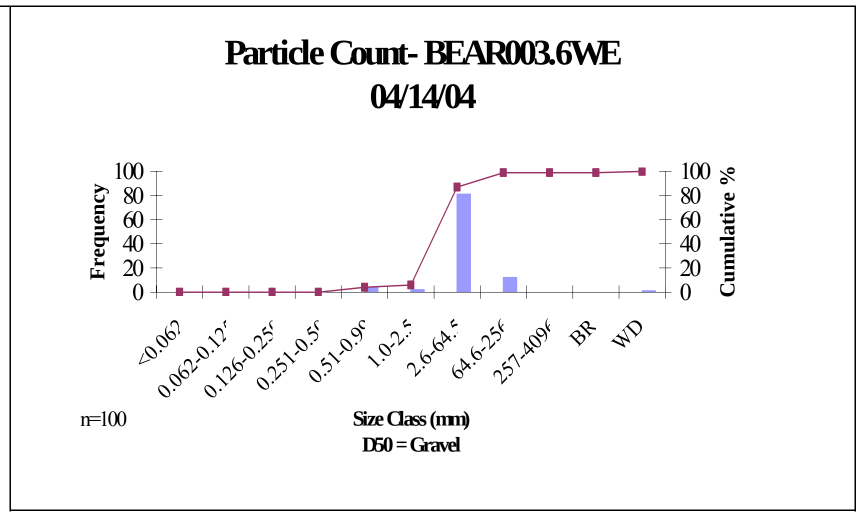
Ecoregion 71F – Bartee Branch – Cunningham Broadbent Lake



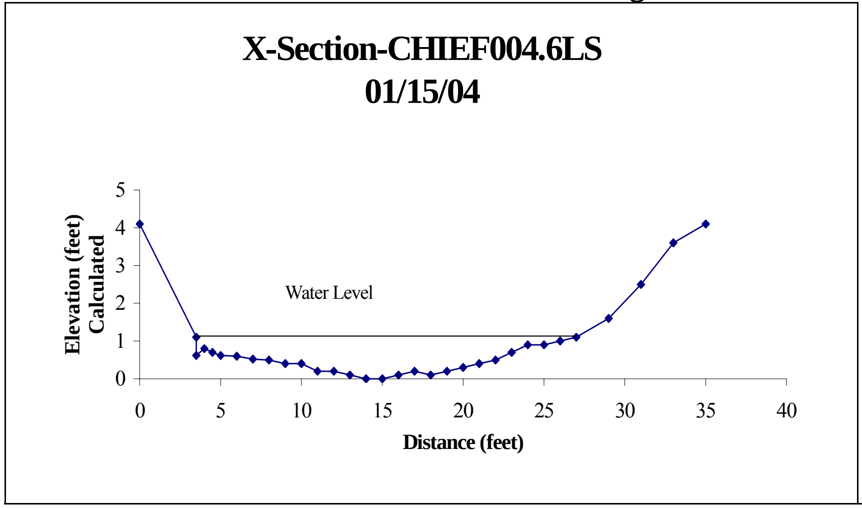


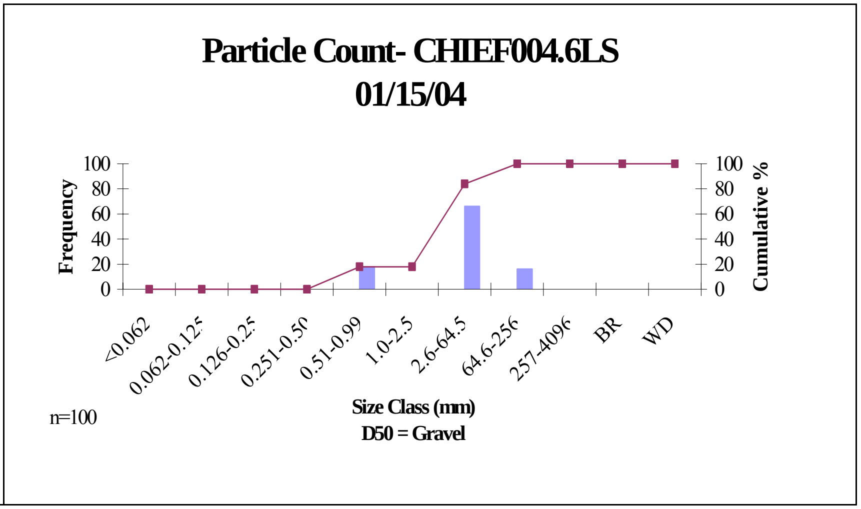
Ecoregion 71F – Bear Creek – Bear Creek Dam #2



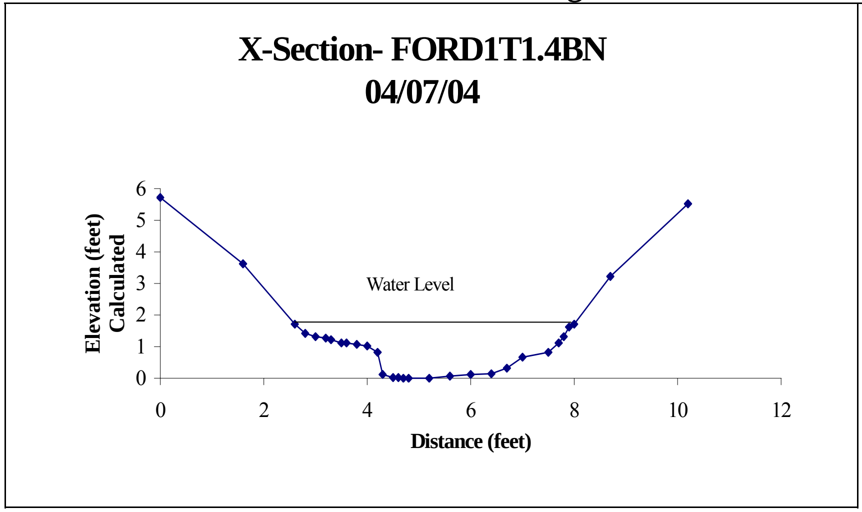


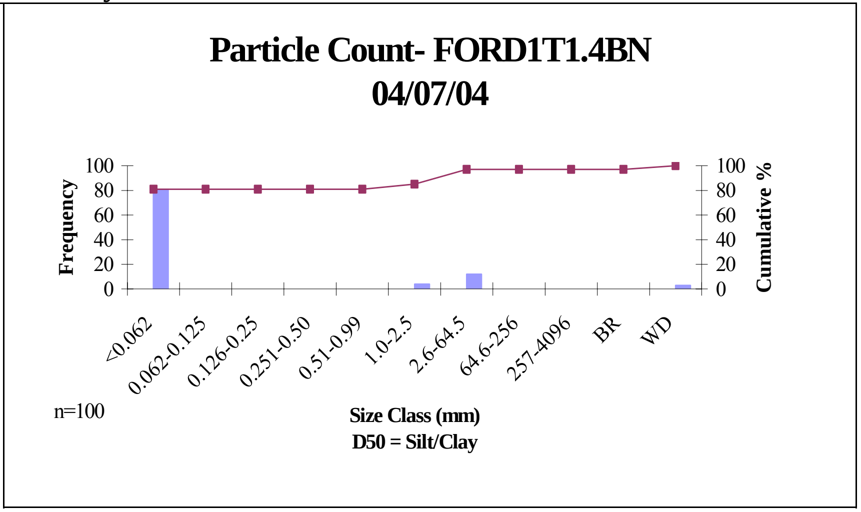
Ecoregion 71F – Chief Creek – Chief Creek Dam



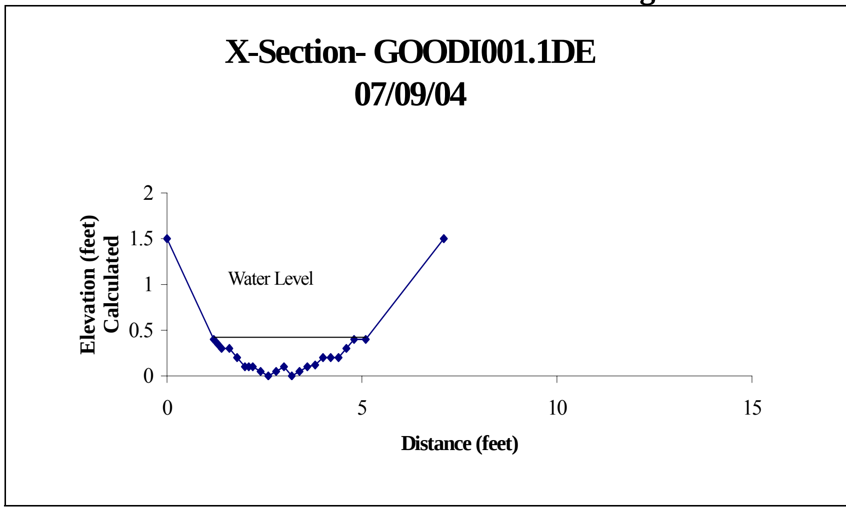


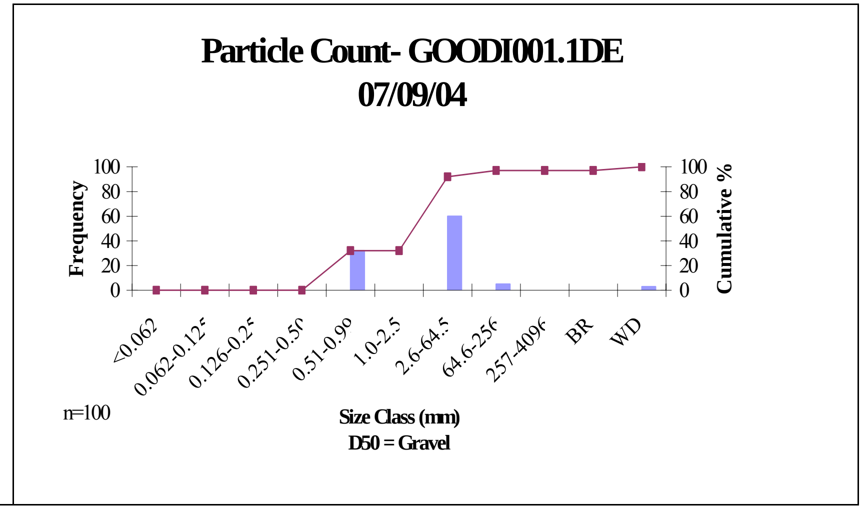
Ecoregion 71F – Ford Creek Tributary – Blackburn Lake



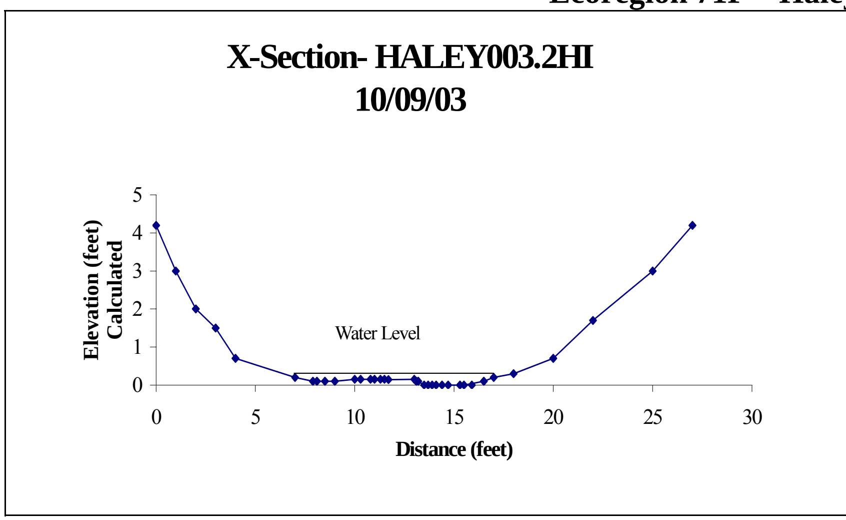


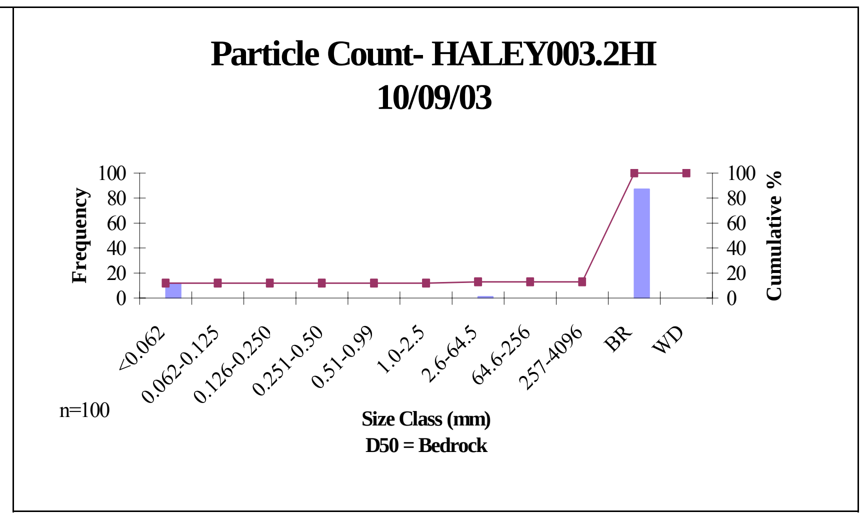
Ecoregion 71F – Goodin Branch – Arnold Lake



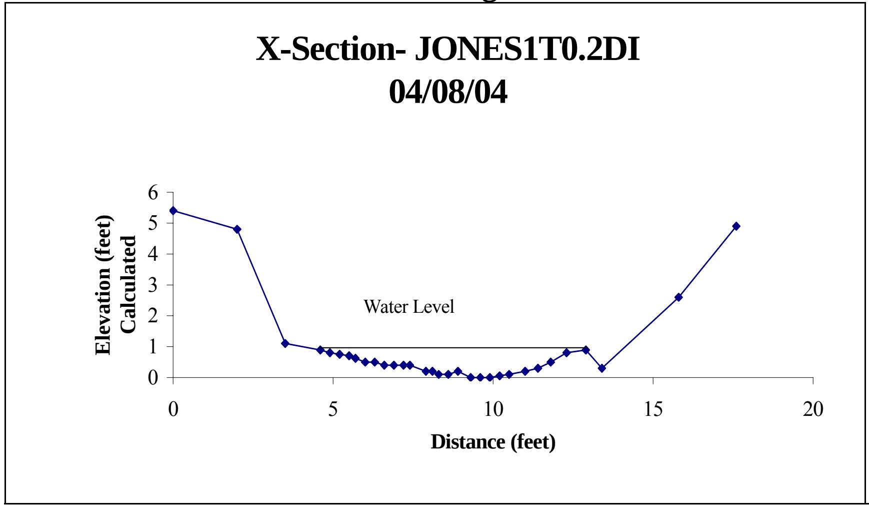


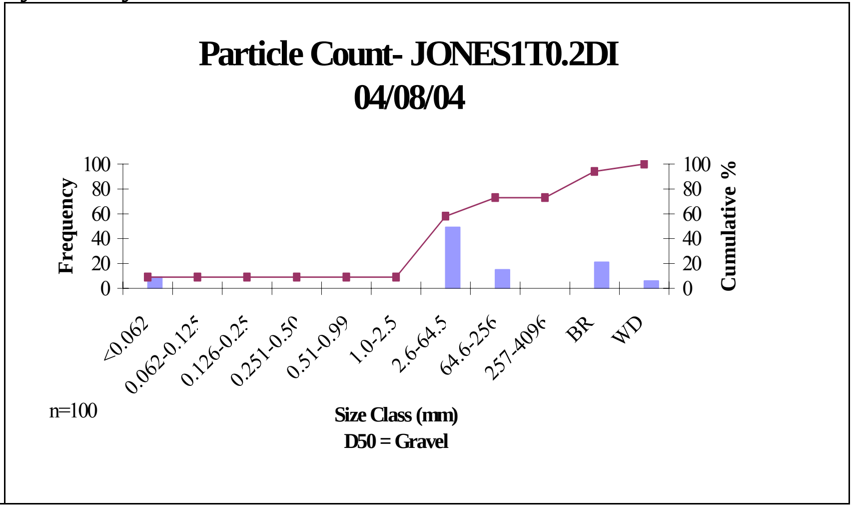
Ecoregion 71F – Haley Creek – Boon-Dok Lake



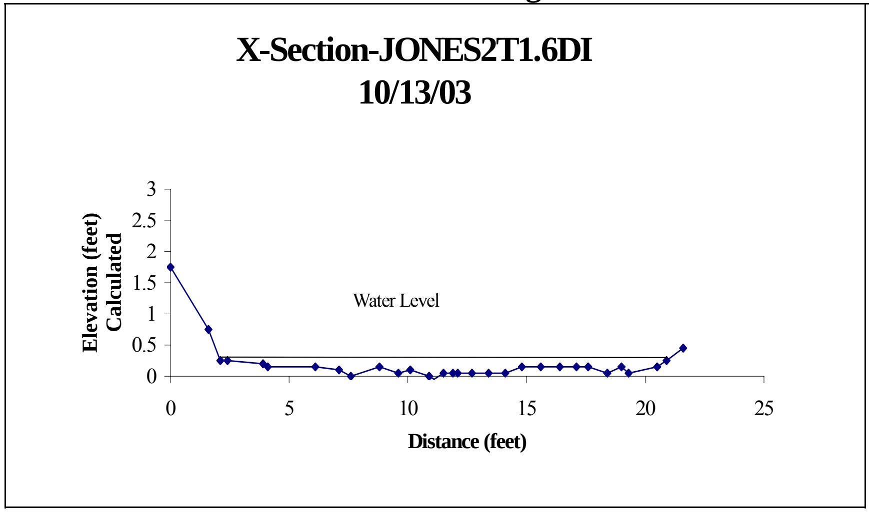


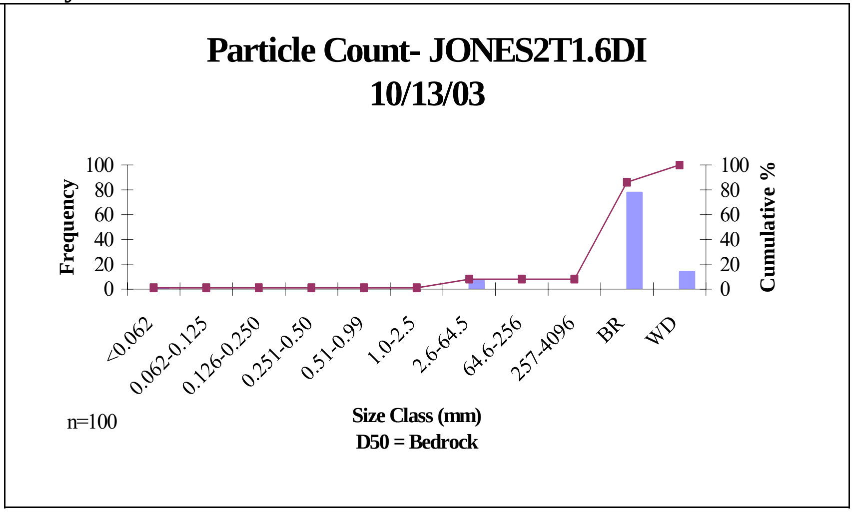
Ecoregion 71F – Jones Creek Tributary – Greystone Golf Course Dam



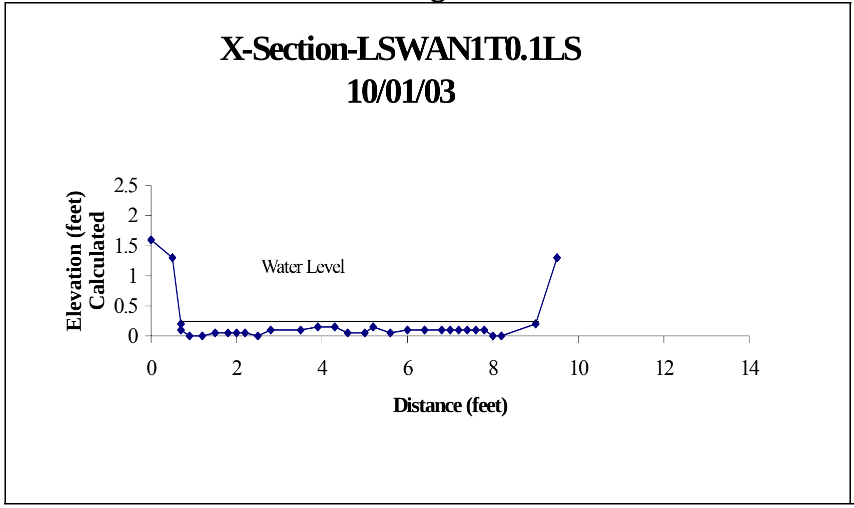


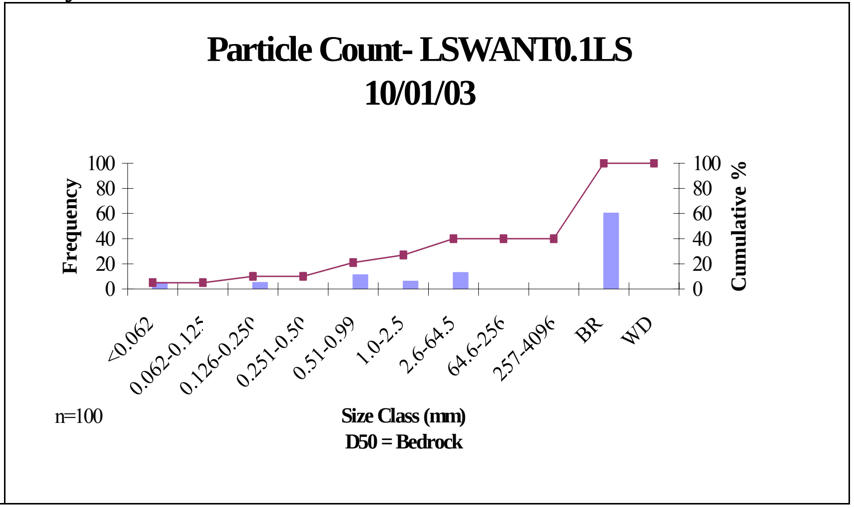
Ecoregion 71F – Jones Creek Tributary – Hava-Lakatu Dam #2



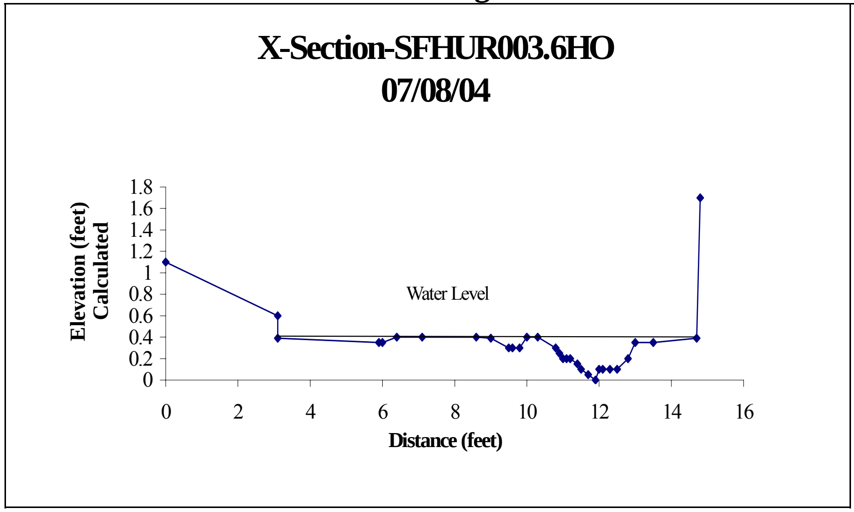


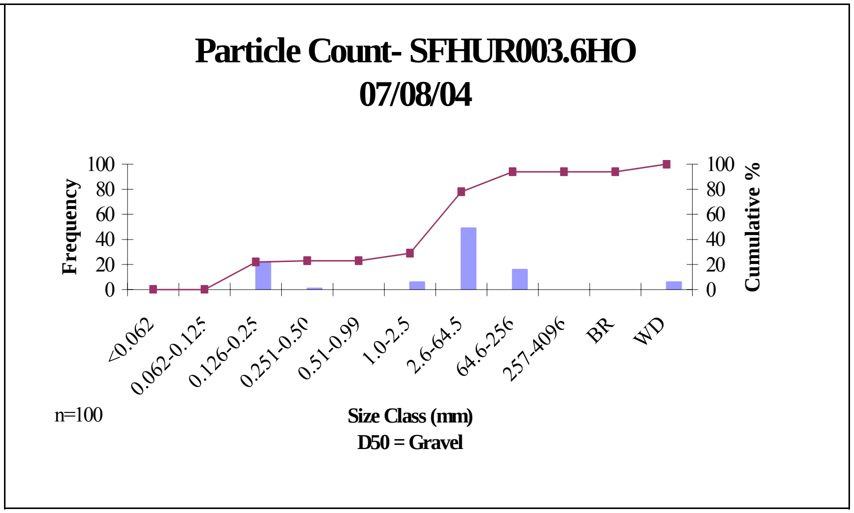
Ecoregion 71F – Little Swan Creek Tributary – First Order Reference Stream



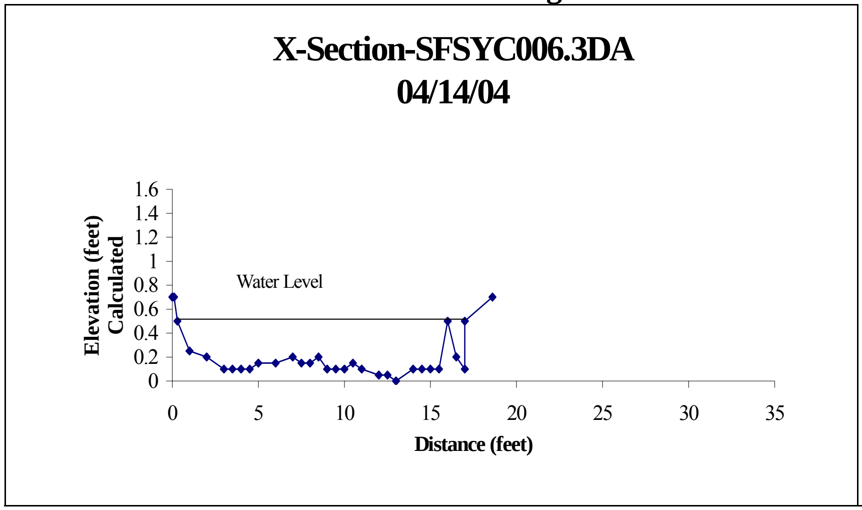


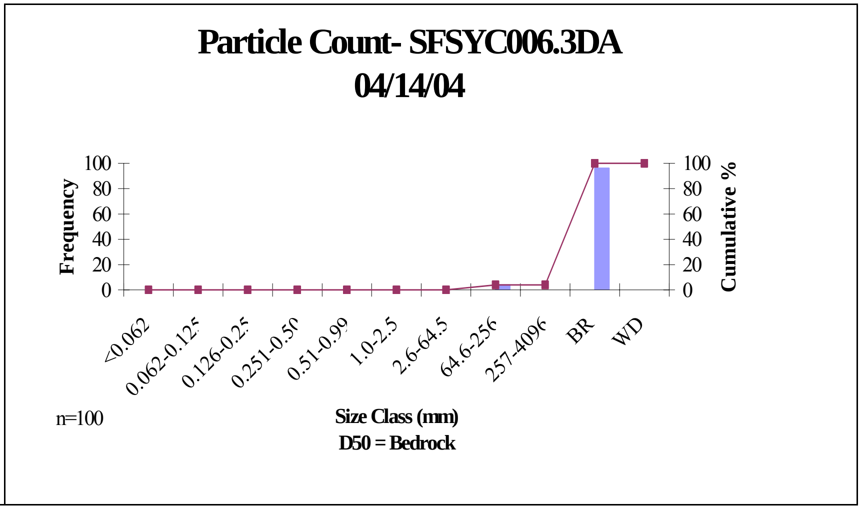
Ecoregion 71F – South Fork Hurricane Creek – Lakeview Circle Lake



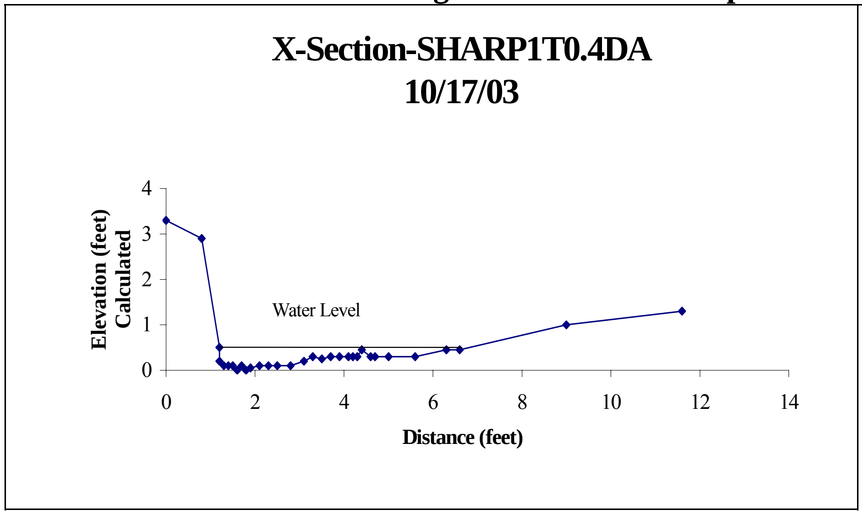


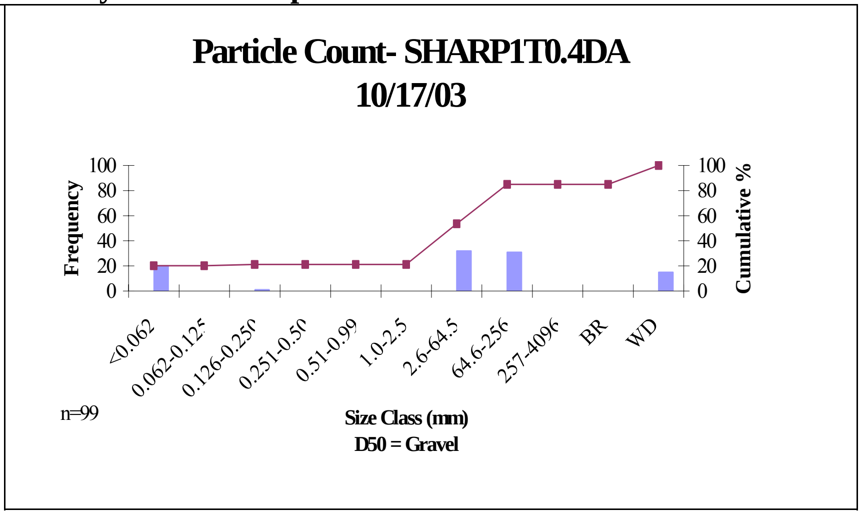
Ecoregion 71F – South Fork Sycamore Creek – Browns Lake



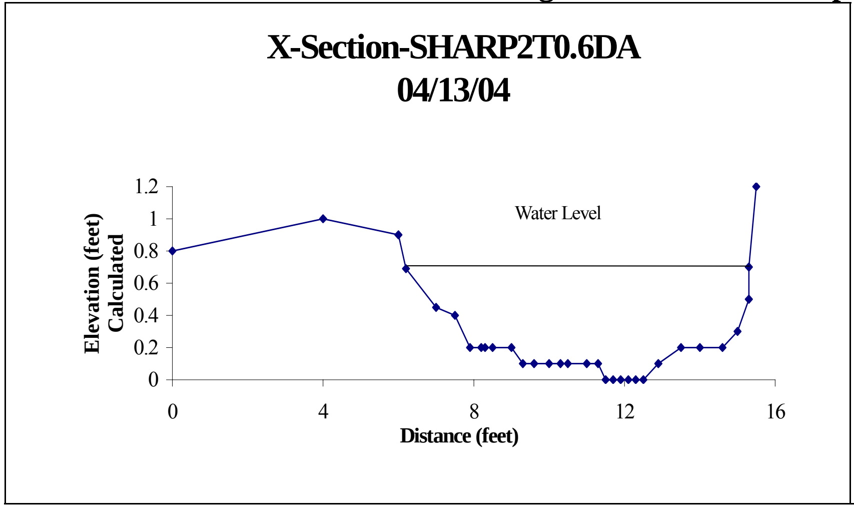


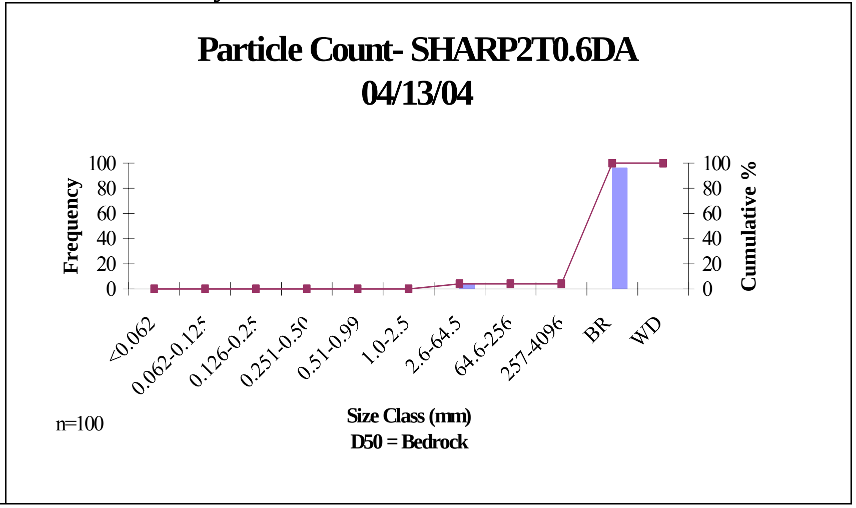
Ecoregion 71F – South Harpeth River Tributary – South Harpeth River Dam



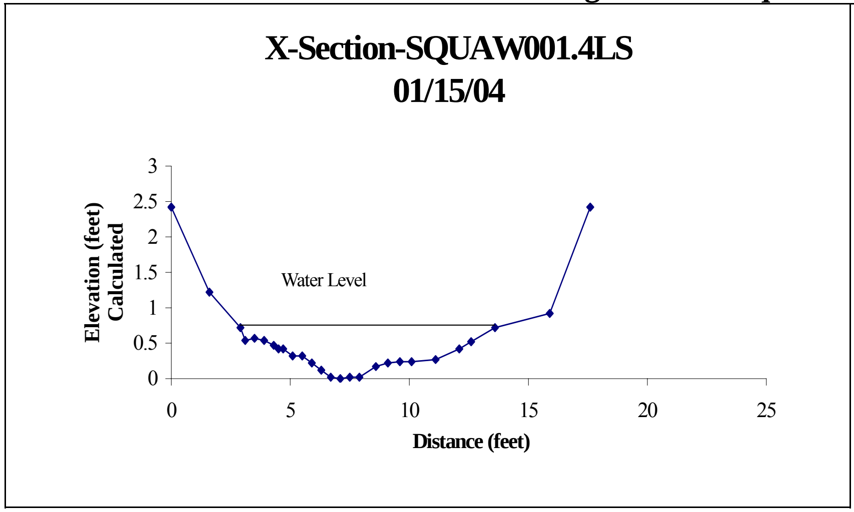


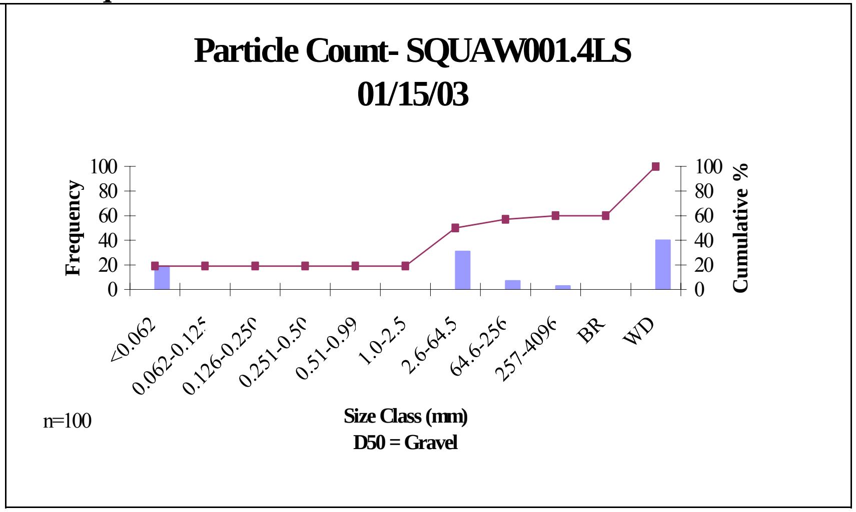
Ecoregion 71F – South Harpeth River Tributary – Elcan Lake



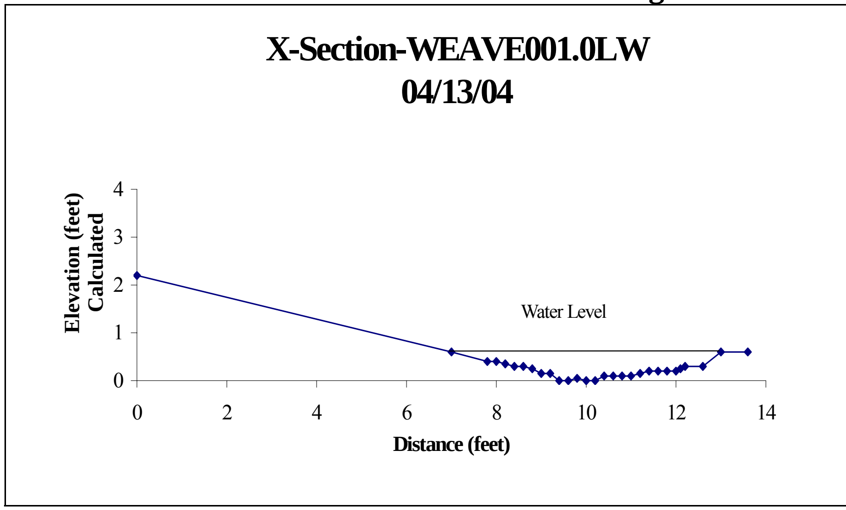


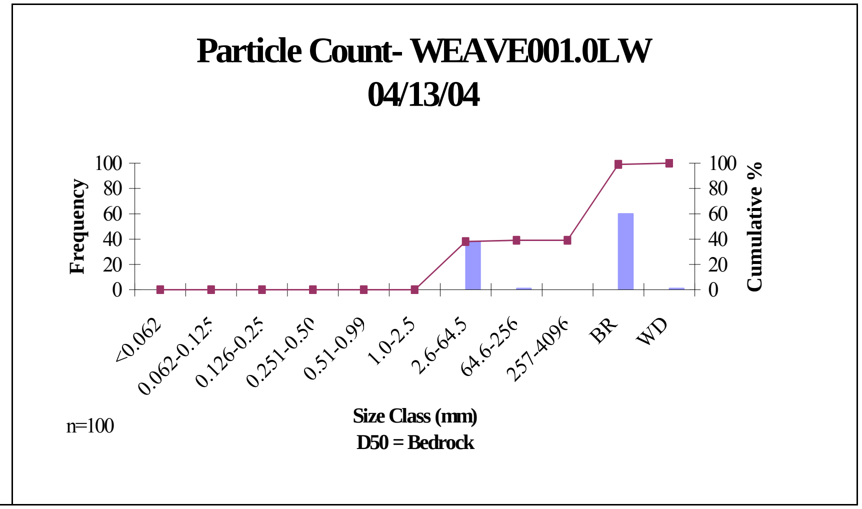
Ecoregion 71F – Squaw Branch – Squaw Branch Dam



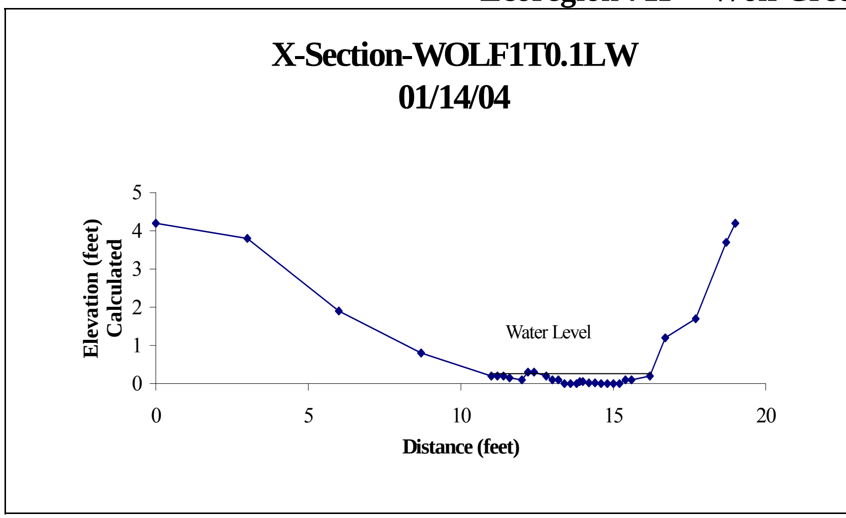


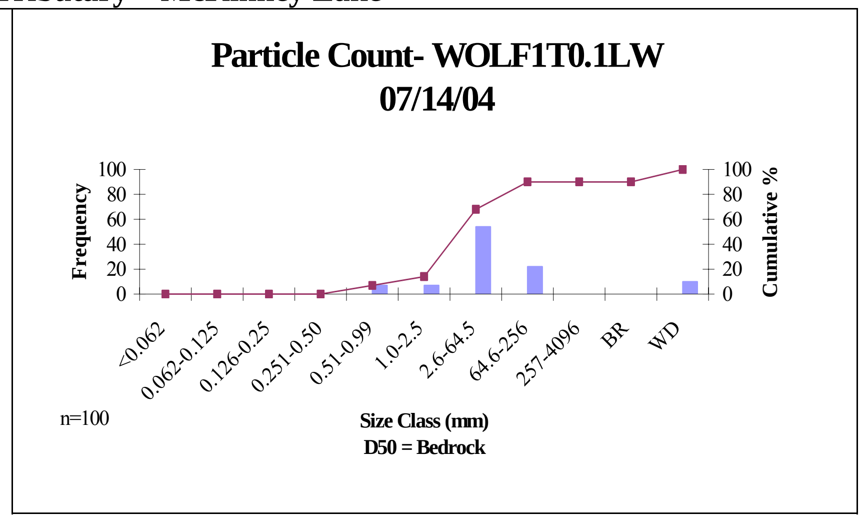
Ecoregion 71F – Weaver Branch – VFW Lake



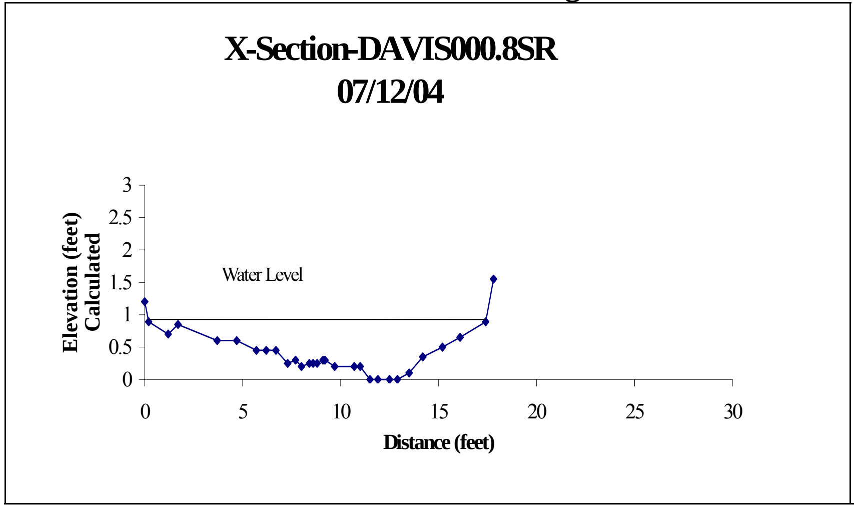


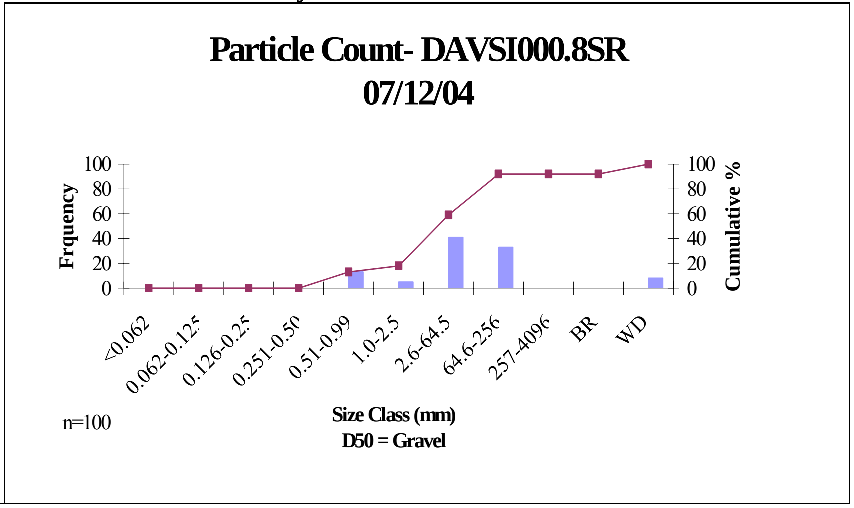
Ecoregion 71F – Wolf Creek Tributary – McKinney Lake



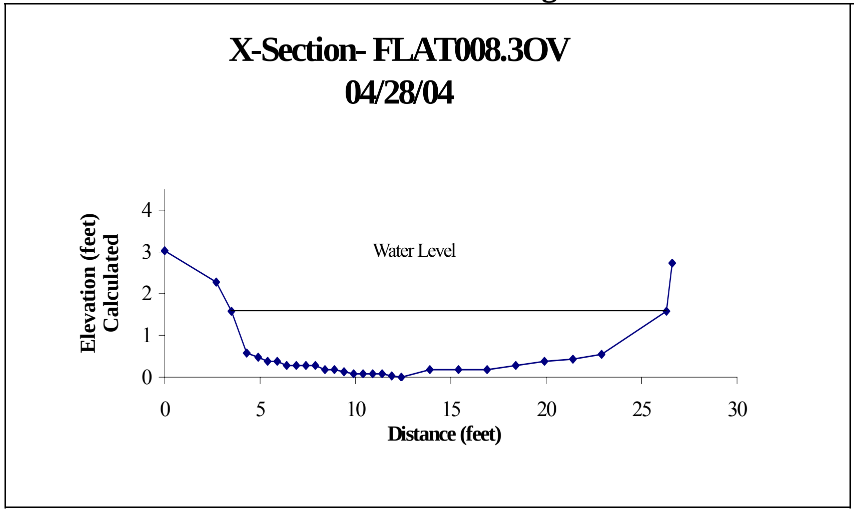


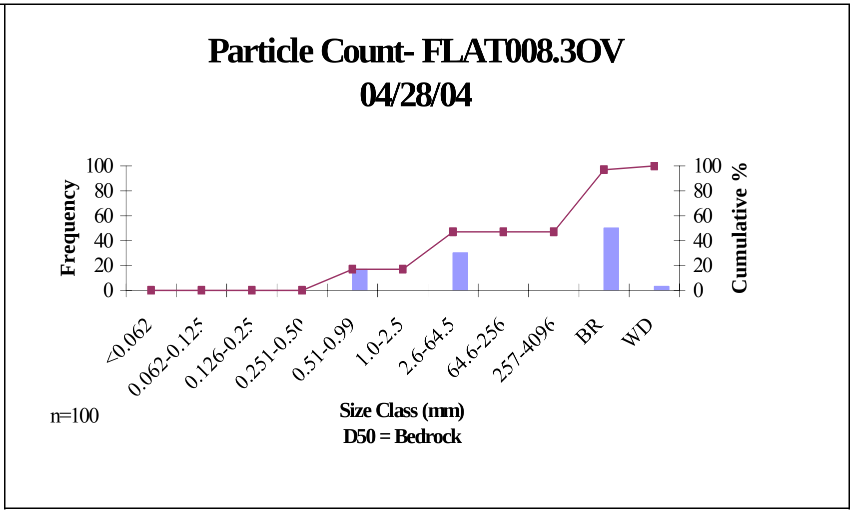
Ecoregion 71G – Davis Branch – Westmoreland City Lake



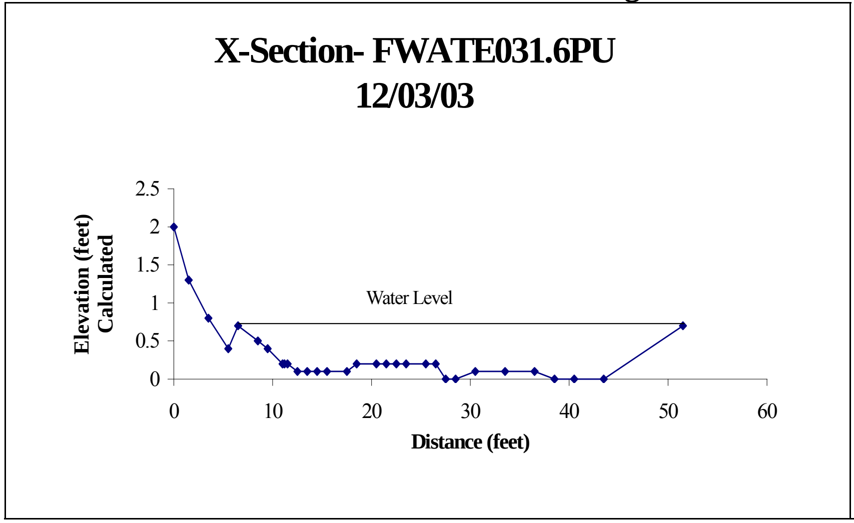


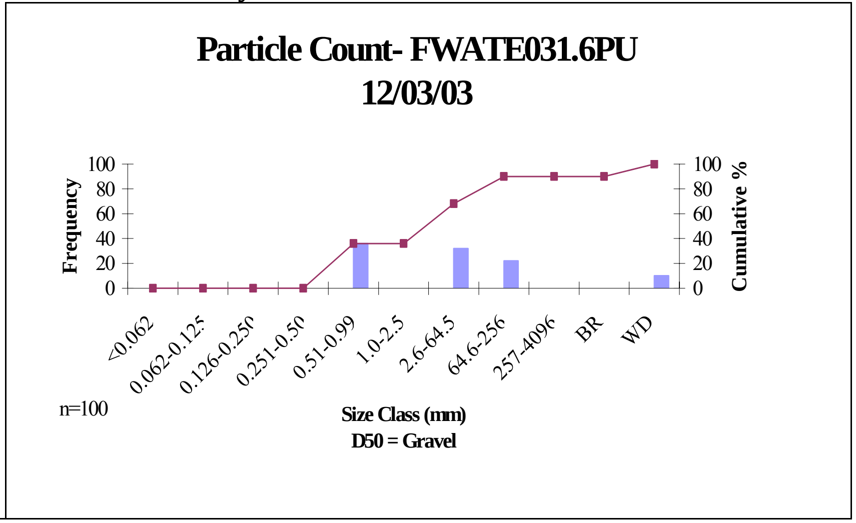
Ecoregion 71G – Flat Creek – First Order Reference Stream



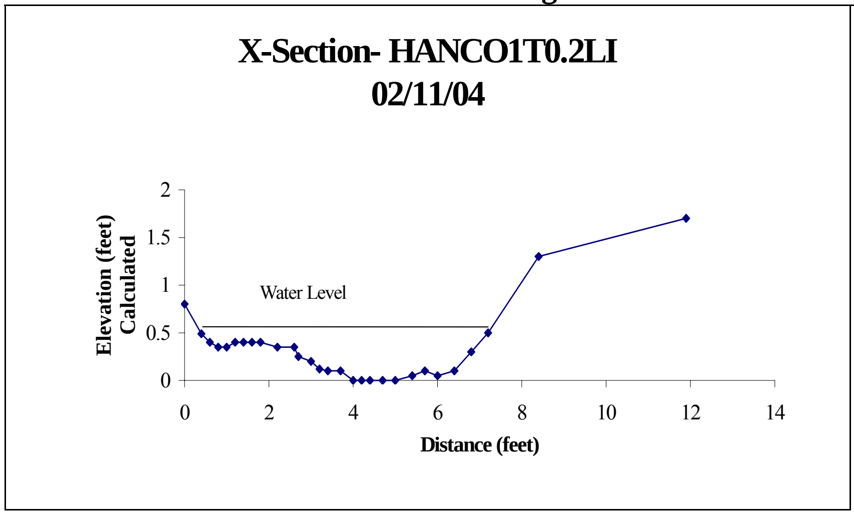


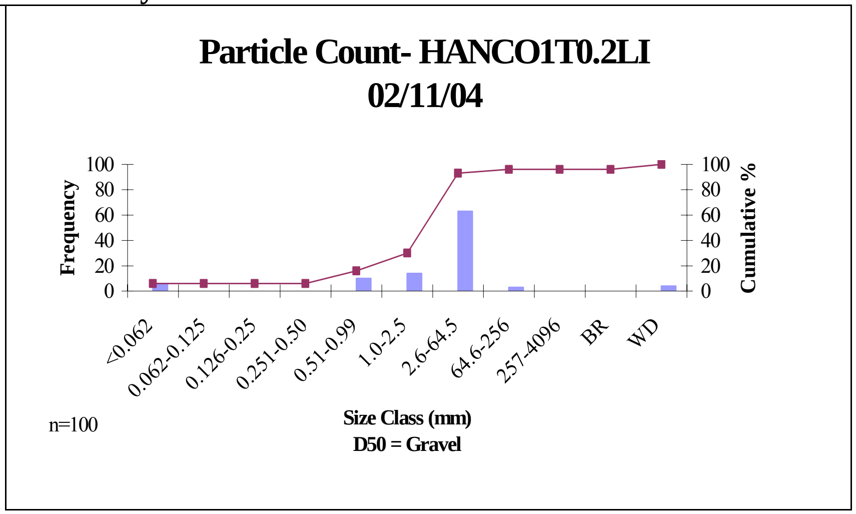
Ecoregion 71G – Falling Water River – City Lake



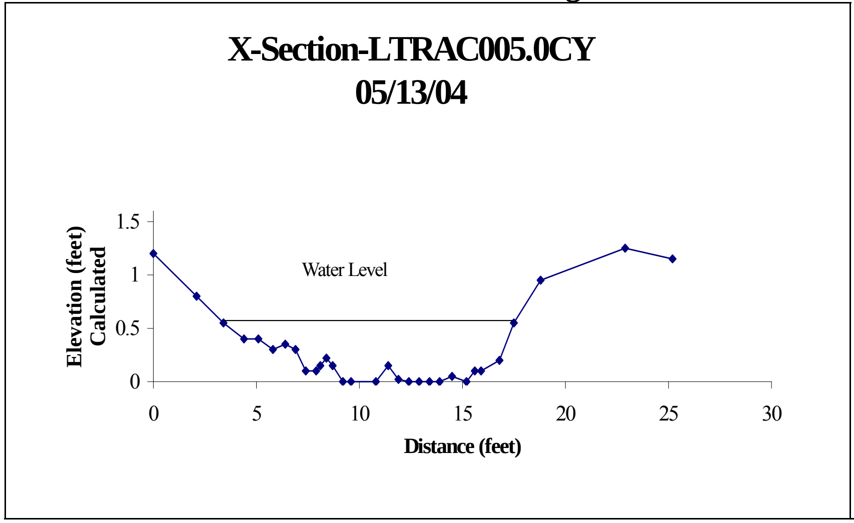


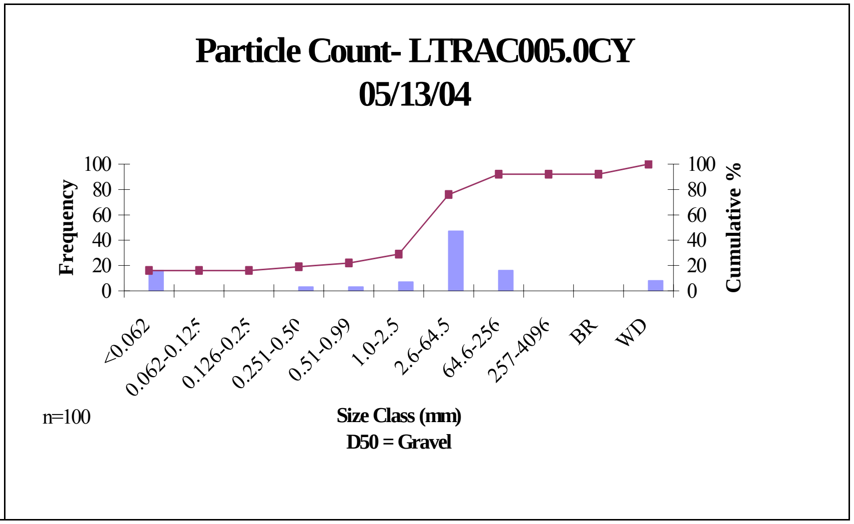
Ecoregion 71G Hancock Branch Tributary – Childress Lake



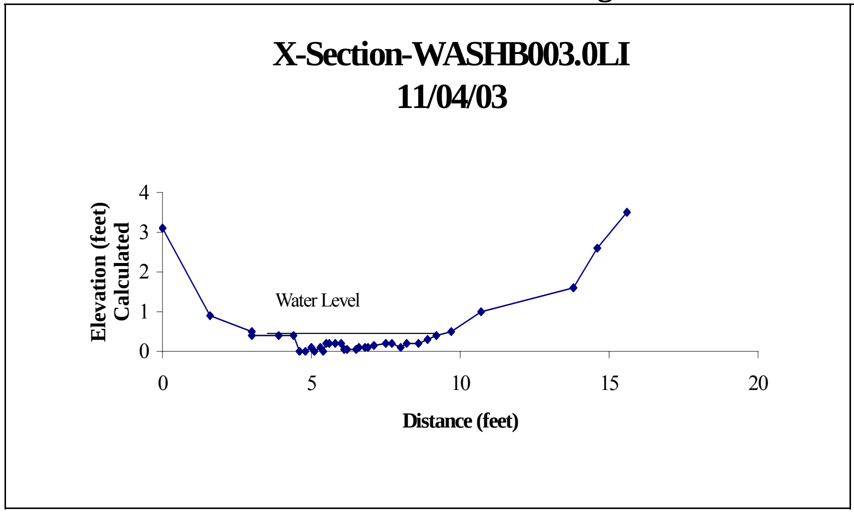


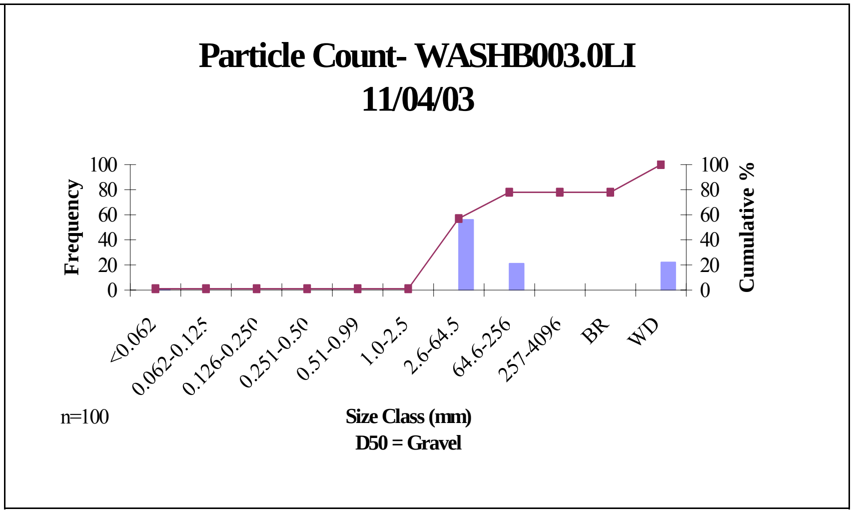
Ecoregion 71G- Little Trace Creek – Line Creek Dam #3B



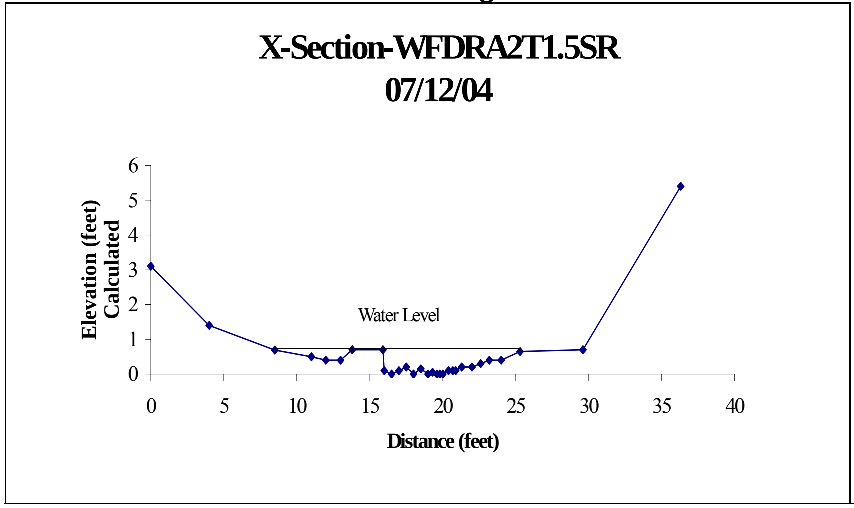


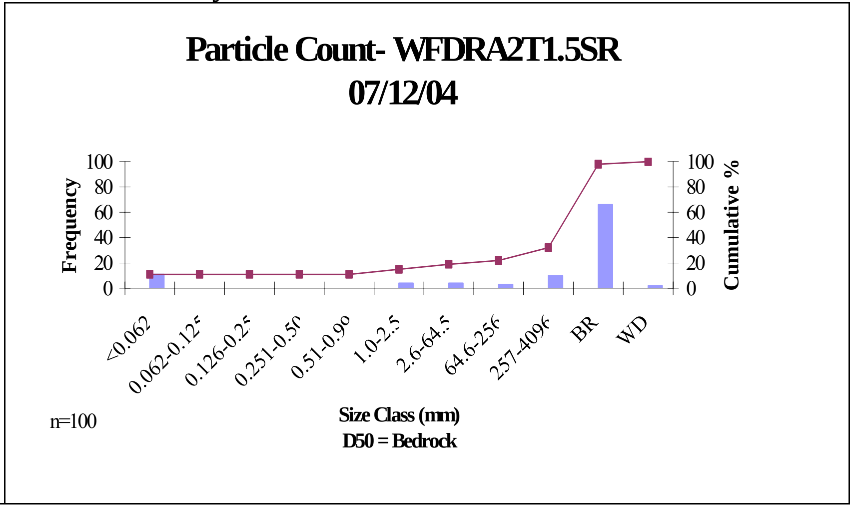
Ecoregion 71G – Washburn Branch – Rebecca Lake



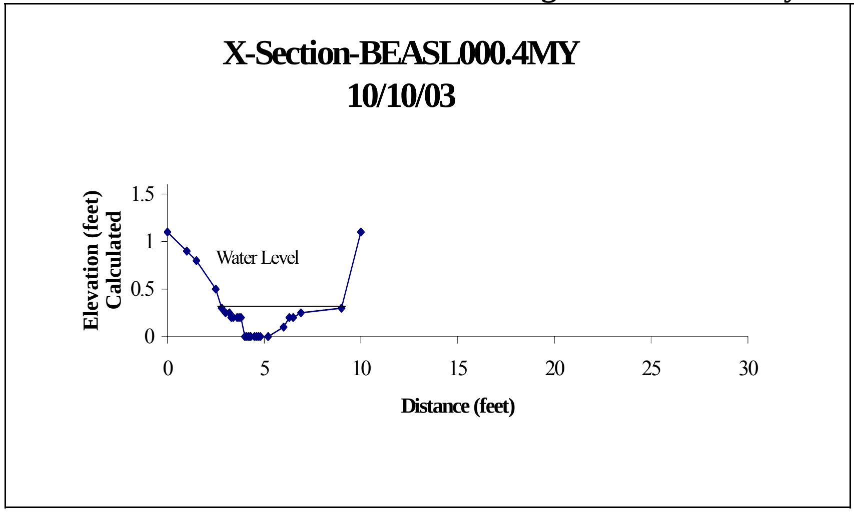


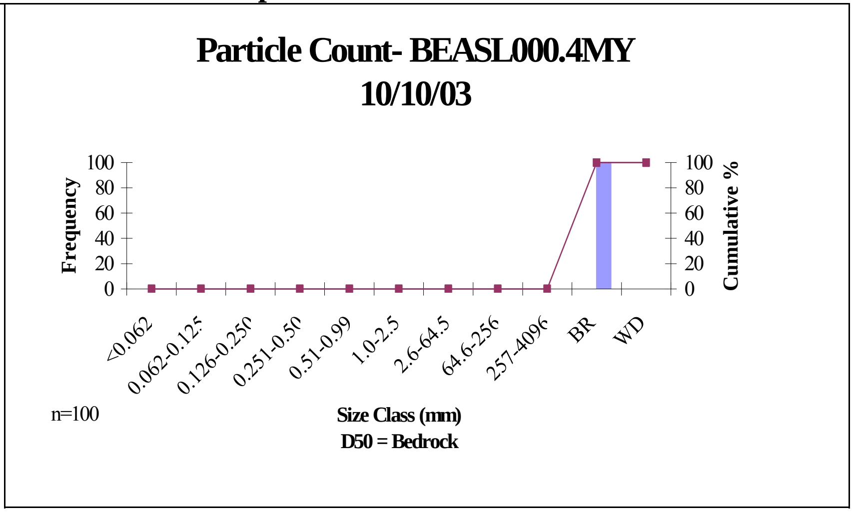
Ecoregion 71G – West Fork Drakes Creek Tributary #2 – Willow Lake



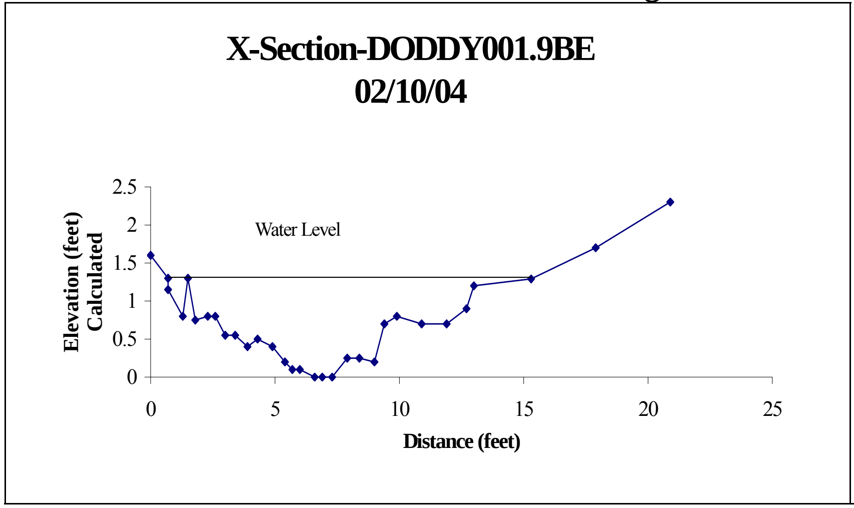


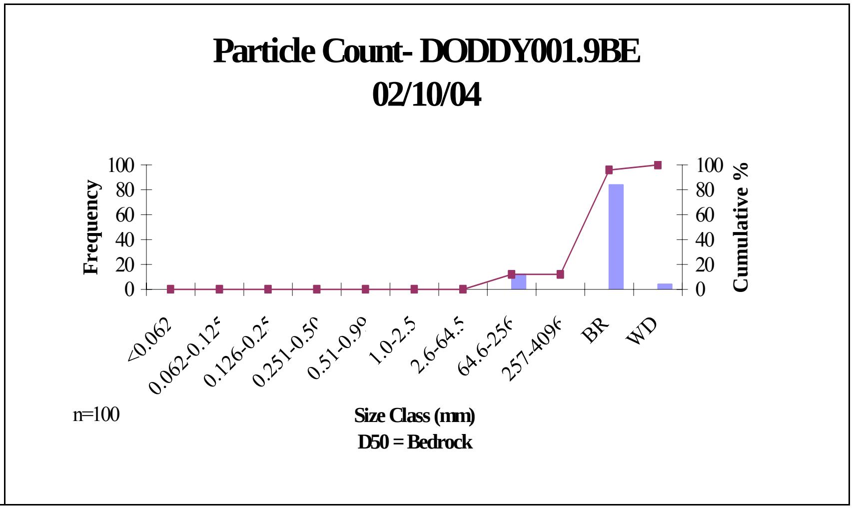
Ecoregion 71H – Beasley Hollow Creek – Williamsport Lake



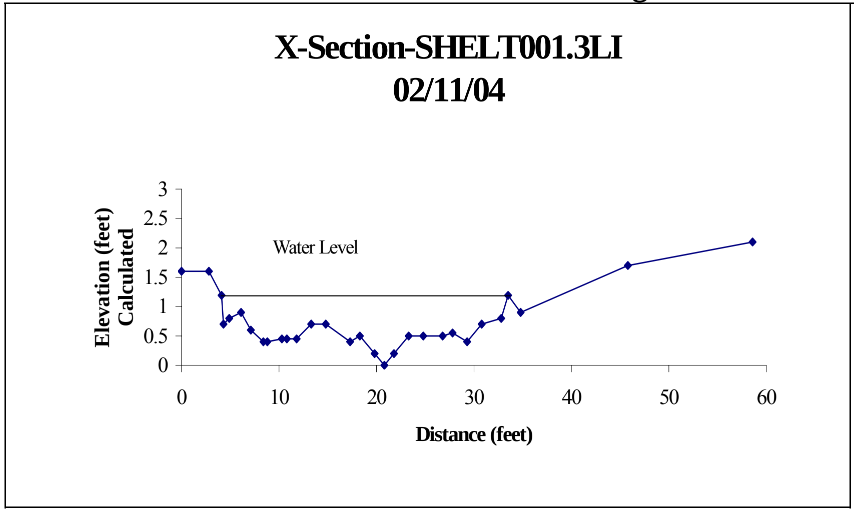


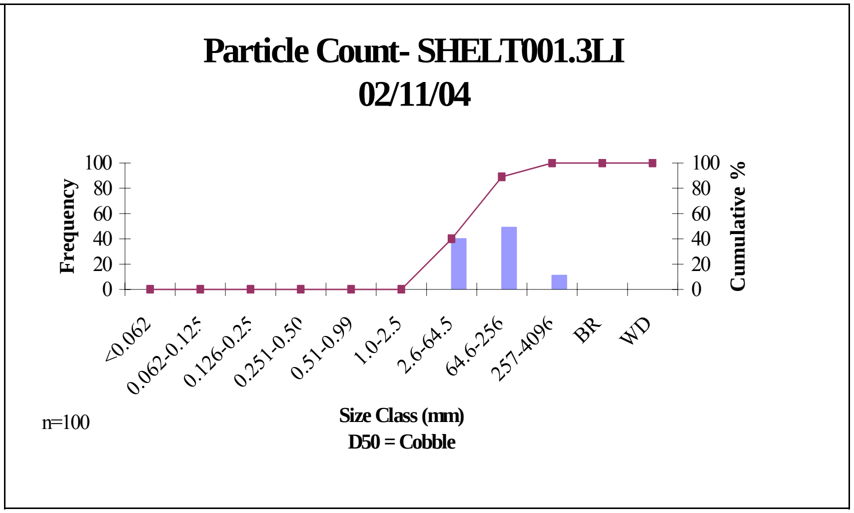
Ecoregion 71H – Doddy Creek – Bedford Lake



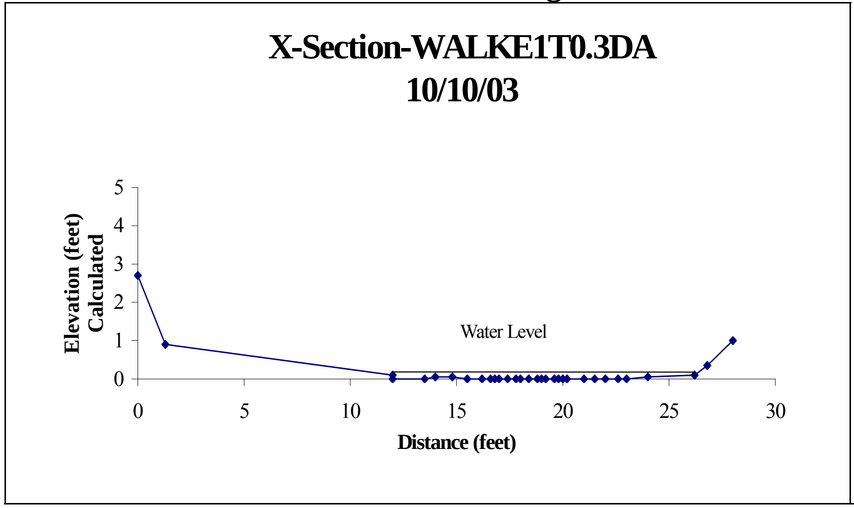


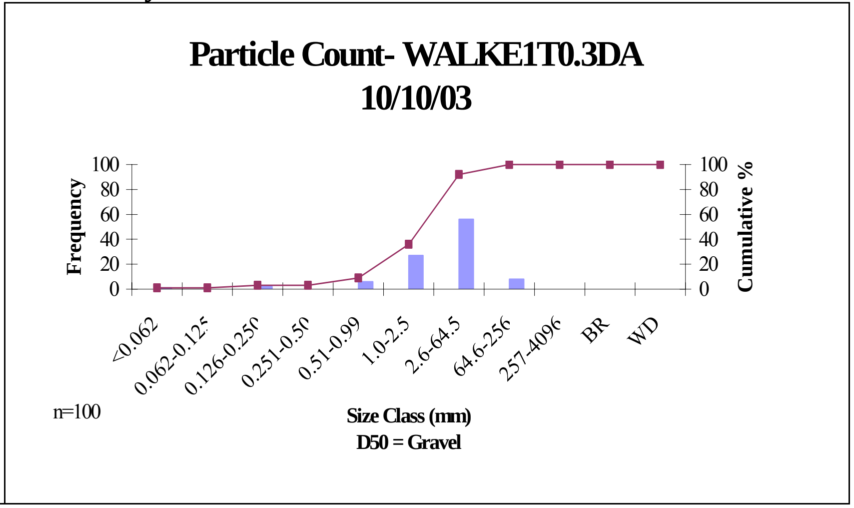
Ecoregion 71H – Shelton Creek – Lincoln Lake



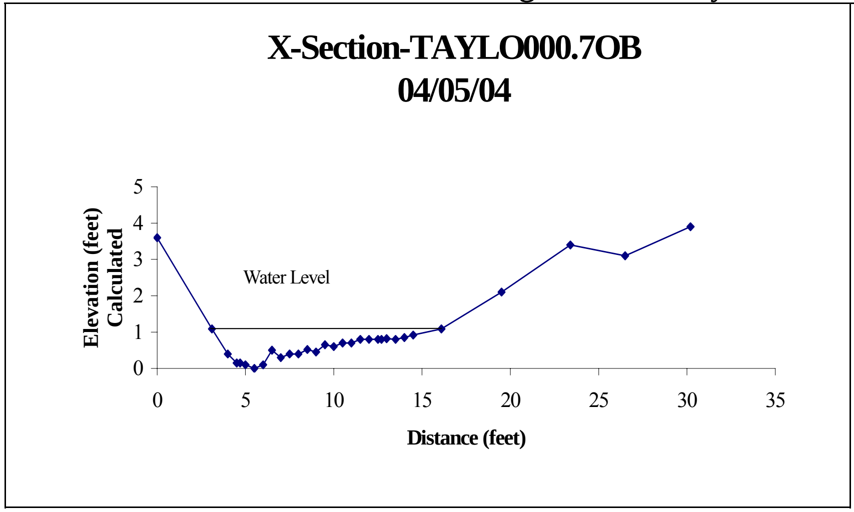


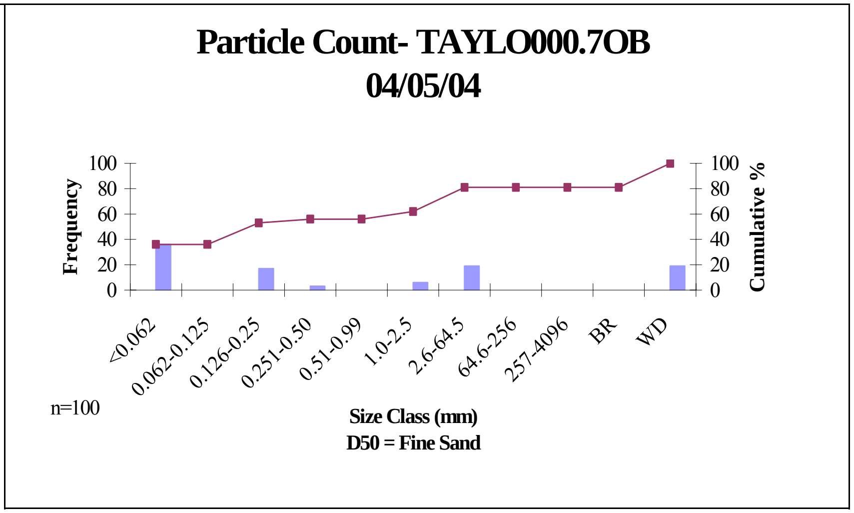
Ecoregion 71H – Walkers Creek Tributary – Lakewood Dam



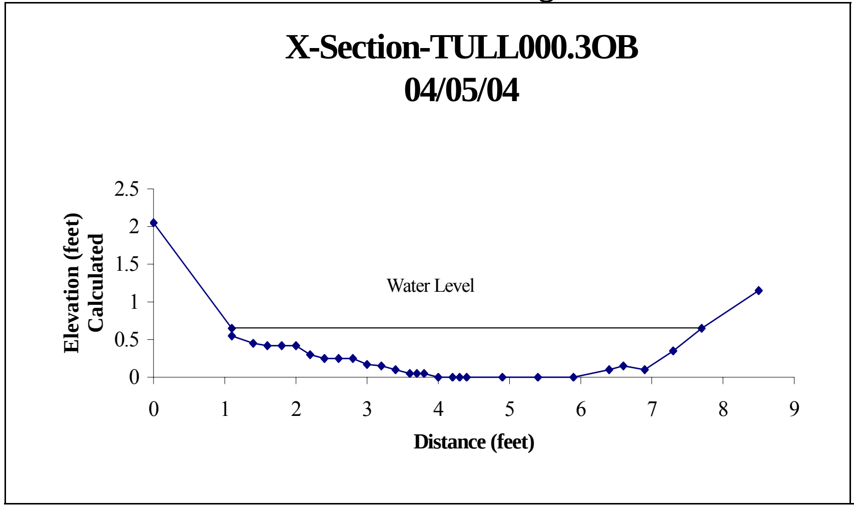


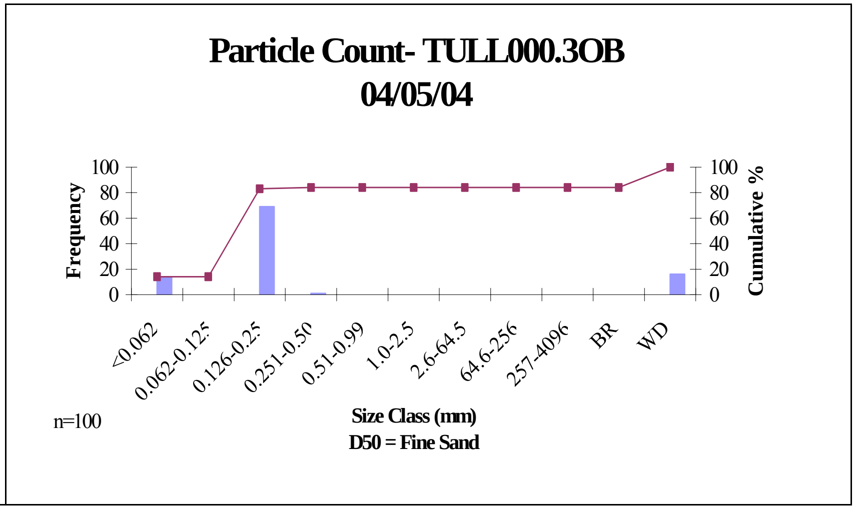
Ecoregion 74A – Taylor Creek – Reelfoot-Indian Creek Dam #7



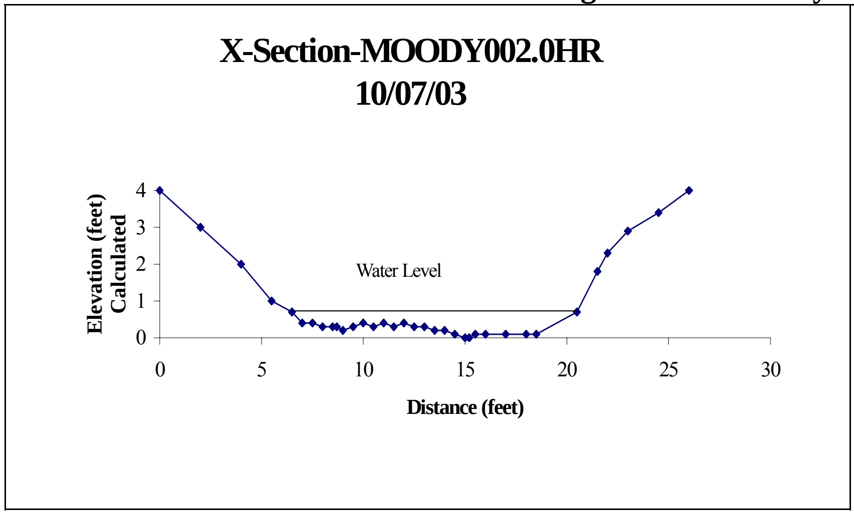


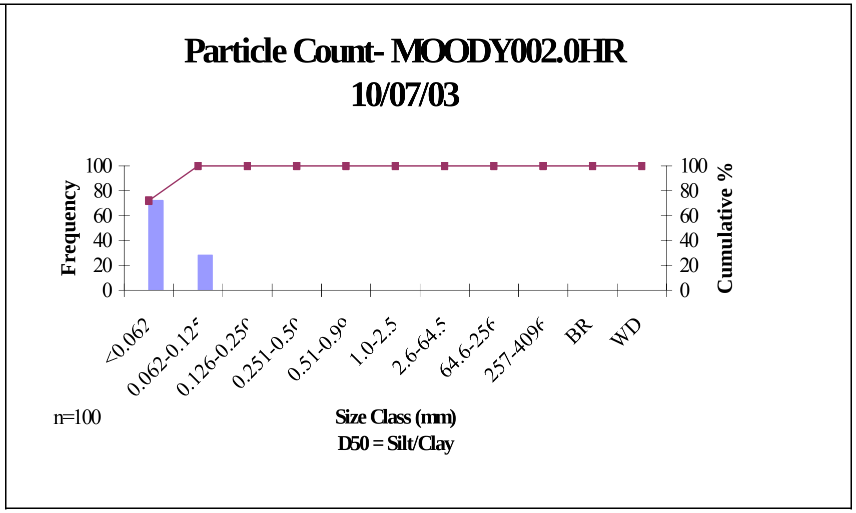
Ecoregion 74A – Tull Creek – Reelfoot-Indian Creek Dam #14



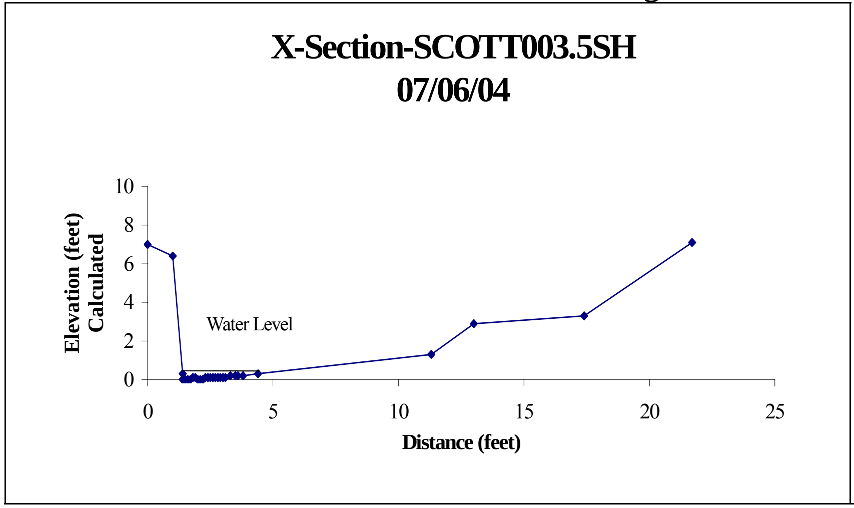


Ecoregion 74B – Moody Creek – Indian Creek Dam #8





Ecoregion 74B – Scotts Creek – Lakeland Dam



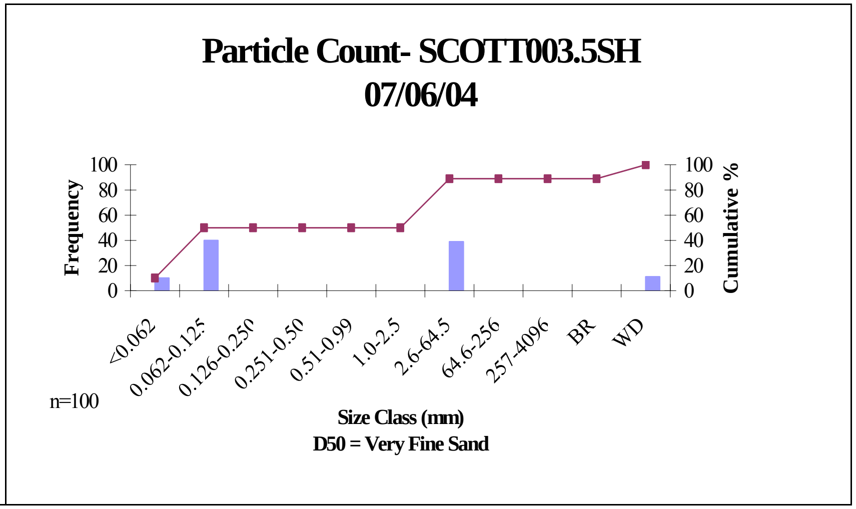


Table C-4: Habitat Scores

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
ARNOL001.4WY	1/13/2004	65E	GP	3	NA	NA	6	12	12	NA	3	3	6	6	4	4	3	2	10	74
ARNOL001.4WY	4/5/2004	65E	GP	9	NA	NA	10	10	17	NA	3	4	5	5	5	5	7	5	6	91
ARNOL001.4WY	7/16/2004	65E	GP	10	NA	NA	5	7	18	NA	5	5	6	6	5	5	3	2	17	94
BAGWE1T0.2CU	2/10/2004	68A	RR	3	3	9	2	16	18	8	3	3	3	3	3	4	NA	NA	NA	78
BAGWE1T0.2CU	5/13/2004	68A	RR	11	5	8	7	7	13	8	7	7	10	10	8	9	NA	NA	NA	110
BARNE002.4FR	11/5/2003	68A	RR	15	11	10	10	9	19	17	3	3	7	7	10	10	NA	NA	NA	131
BARNE002.4FR	2/8/2004	68A	RR	10	6	11	7	10	17	14	5	6	6	6	10	9	NA	NA	NA	117
BARNE002.4FR	4/21/2004	68A	RR	5	6	13	4	12	19	15	4	5	5	5	10	10	NA	NA	NA	113
BARTE001.4MT	10/6/2003	71F	RR	14	6	16	15	10	18	17	6	7	6	7	9	6	NA	NA	NA	137
BARTE001.4MT	1/15/2004	71F	RR	13	7	14	10	12	17	16	3	3	6	6	10	5	NA	NA	NA	122
BARTE001.4MT	4/15/2004	71F	RR	17	14	16	11	17	17	15	4	5	7	7	10	10	NA	NA	NA	150
BARTE001.4MT	7/12/2004	71F	RR	13	7	12	5	14	15	12	5	5	6	6	9	7	NA	NA	NA	116
BEAR003.6WE	10/13/2003	71F	RR	15	16	10	15	18	18	19	7	8	5	5	1	1	NA	NA	NA	136
BEAR003.6WE	1/14/2004	71F	GP	18	NA	NA	16	17	18	NA	8	5	2	2	0	0	19	9	10	124
BEAR003.6WE	4/14/2004	71F	RR	13	10	11	7	19	16	9	6	6	5	5	2	2	NA	NA	NA	111
BEAR003.6WE	7/14/2004	71F	RR	19	14	10	15	19	18	19	8	8	5	5	1	1	NA	NA	NA	142
BEAR005.7MN	10/15/2003	65E	GP	13	NA	NA	8	7	19	NA	2	1	3	2	3	2	10	13	14	97
BEAR005.7MN	1/14/2004	65E	GP	6	NA	NA	5	7	18	NA	2	2	3	3	3	2	7	8	7	73
BEAR005.7MN	4/7/2004	65E	GP	8	NA	NA	15	10	19	NA	1	1	4	4	2	2	8	9	15	98
BEAR005.7MN	7/8/2004	65E	GP	7	NA	NA	6	8	19	NA	3	3	5	5	2	3	7	8	11	87
BEAR005.7MN	10/6/2005	65E	GP	6	NA	NA	7	7	18	NA	5	2	5	2	4	1	7	8	14	86
BEAR005.7MN	4/11/2006	65E	GP	10	NA	NA	10	14	16	NA	6	4	6	3	6	0	11	12	14	112
BEAR005.7MN	4/11/2006	65E	RR	8	10	10	9	13	14	12	5	3	5	3	5	1	NA	NA	NA	98
BEASL000.4MY	10/10/2003	71H	RR	5	8	8	7	11	15	16	2	8	1	8	1	8	NA	NA	NA	98
BEASL000.4MY	1/21/2004	71H	RR	4	8	9	8	7	17	16	9	9	0	6	0	9	NA	NA	NA	102
BEASL000.4MY	4/13/2004	71H	RR	10	16	10	17	19	19	10	8	8	5	6	5	6	NA	NA	NA	139
BEASL000.4MY	7/15/2004	71H	RR	9	12	11	11	14	15	17	9	9	2	9	1	9	NA	NA	NA	128
BEASL000.4MY	7/15/2004	71H	RR	9	12	11	11	14	15	17	9	9	10	2	9	1	NA	NA	NA	129

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
BGUM000.5CU	2/10/2004	68A	RR	11	15	14	5	18	19	12	4	4	6	6	9	9	NA	NA	NA	132
BGUM000.5CU	5/12/2004	68A	RR	17	5	7	5	13	15	10	9	9	9	9	10	10	NA	NA	NA	128
BGUM000.5CU	7/26/2004	68A	RR	12	11	10	7	6	17	13	5	5	5	5	8	8	NA	NA	NA	112
BOSTO001.1HM	11/3/2003	68A	RR	12	8	11	14	16	19	12	7	7	8	8	10	10	NA	NA	NA	142
BOSTO001.1HM	2/4/2004	68A	RR	18	12	14	11	12	17	19	8	8	7	7	9	10	NA	NA	NA	152
BOSTO001.1HM	4/21/2004	68A	RR	18	5	11	6	16	19	17	8	9	6	6	10	10	NA	NA	NA	141
BUCK001.2CU	11/5/2003	68A	RR	17	12	15	7	12	20	13	6	6	8	8	10	10	NA	NA	NA	144
BUCK001.2CU	2/10/2004	68A	RR	11	16	16	13	18	19	13	5	5	6	6	10	10	NA	NA	NA	148
BUCK001.2CU	5/11/2004	68A	RR	18	8	18	15	16	16	8	3	5	7	7	10	9	NA	NA	NA	140
BUCK001.2CU	7/27/2004	68A	RR	13	11	15	9	19	20	10	7	7	5	5	10	10	NA	NA	NA	141
BUCK001.2CU	7/27/2004	68A	RR	13	12	15	10	20	20	8	7	7	5	5	10	10	NA	NA	NA	142
CARSO001.0MO	10/29/2003	67G	RR	12	7	14	8	11	17	16	6	6	6	6	6	2	NA	NA	NA	117
CARSO001.0MO	2/4/2004	67G	RR	16	13	12	10	15	17	15	8	8	6	6	5	4	NA	NA	NA	135
CARSO001.0MO	4/22/2004	67G	RR	13	8	12	6	18	17	16	5	5	6	6	6	2	NA	NA	NA	120
CHARL000.7OV	2/4/2004	68A	RR	5	9	10	5	17	18	9	2	3	3	3	10	10	NA	NA	NA	104
CHARL000.7OV	5/10/2004	68A	RR	18	3	8	5	12	17	17	5	2	7	7	10	10	NA	NA	NA	121
CHARL000.7OV	7/21/2004	68A	RR	8	4	9	4	7	15	10	4	3	6	6	8	10	NA	NA	NA	94
CHARL003.4BN	10/14/2003	65E	GP	7	NA	NA	6	5	19	NA	4	3	5	5	3	9	7	2	18	93
CHARL003.4BN	1/19/2004	65E	RR	5	6	5	5	8	18	16	5	5	4	7	4	9	NA	NA	NA	97
CHARL003.4BN	4/7/2004	65E	GP	5	NA	NA	7	6	18	NA	3	2	3	3	3	9	6	6	15	86
CHARL003.4BN	7/8/2004	65E	GP	6	NA	NA	6	7	17	NA	2	2	5	5	2	6	7	5	13	83
CHIEF004.6LS	0713-2004	71F	RR	19	12	18	13	17	18	18	7	9	6	9	8	9	NA	NA	NA	163
CHIEF004.6LS	10/14/2003	71F	RR	19	16	11	15	18	19	19	9	8	9	9	6	9	NA	NA	NA	167
CHIEF004.6LS	1/15/2004	71F	RR	19	16	14	15	18	19	19	9	8	9	9	6	9	NA	NA	NA	170
CHIEF004.6LS	4/13/2004	71F	RR	14	15	15	11	19	18	15	5	5	4	4	6	7	NA	NA	NA	138
CUB2T0.3HR	10/15/2003	65E	GP	7	NA	NA	5	19	6	NA	4	4	1	1	0	0	10	13	11	81
CUB2T0.3HR	1/14/2004	65E	GP	3	NA	NA	10	18	12	NA	2	2	1	1	0	0	6	12	8	75
CUB2T0.3HR	4/7/2004	65E	GP	4	NA	NA	3	18	11	NA	6	6	5	5	0	0	10	3	4	75

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
CUB2T0.3HR	7/7/2004	65E	GP	4	NA	NA	7	19	9	NA	5	5	1	1	0	0	8	11	8	78
DAVIS000.8SR	10/6/2003	71G	RR	15	11	10	12	10	16	17	6	6	7	7	9	10	NA	NA	NA	136
DAVIS000.8SR	1/16/2004	71G	RR	11	10	12	9	10	18	15	8	6	6	6	9	10	NA	NA	NA	130
DAVIS000.8SR	4/14/2004	71G	RR	18	15	18	13	16	16	16	6	6	8	8	9	10	NA	NA	NA	159
DAVIS000.8SR	7/12/2004	71G	RR	14	12	14	8	11	18	14	5	6	6	6	9	10	NA	NA	NA	133
DODDY001.9BE	9/9/1999	71H	RR	14	11	16	11	9	10	15	5	5	1	5	1	4	NA	NA	NA	107
DODDY001.9BE	11/5/2003	71H	RR	8	13	16	14	14	16	13	3	4	6	3	5	5	NA	NA	NA	120
DODDY001.9BE	2/10/2004	71H	RR	9	12	11	10	15	15	13	7	7	5	5	6	5	NA	NA	NA	120
DODDY001.9BE	4/20/2004	71H	RR	4	13	9	10	16	16	13	6	9	8	9	7	9	NA	NA	NA	129
DRY004.1BN	10/16/2003	65E	GP	13	NA	NA	12	8	16	NA	5	5	5	5	7	7	9	4	12	108
DRY004.1BN	1/13/2004	65E	GP	6	NA	NA	6	8	17	NA	4	4	7	7	9	9	6	3	9	95
DRY004.1BN	4/7/2004	65E	GP	12	NA	NA	14	7	17	NA	3	3	5	5	9	9	11	2	11	108
DRY004.1BN	7/8/2004	65E	GP	13	NA	NA	9	14	17	NA	5	5	3	3	7	8	8	8	6	106
DUNCA001.8CU	11/12/2003	68A	RR	12	11	16	8	15	9	11	5	5	8	8	10	10	NA	NA	NA	128
DUNCA001.8CU	2/11/2004	68A	RR	16	12	16	6	18	18	11	4	4	4	4	9	9	NA	NA	NA	131
DUNCA001.8CU	4/29/2004	68A	RR	15	3	17	19	8	14	14	7	7	5	5	8	10	NA	NA	NA	132
DUNCA001.8CU	7/22/2004	68A	RR	15	14	15	7	15	15	12	5	5	6	6	6	6	NA	NA	NA	127
EFSPR1T0.5HR	10/7/2003	65E	GP	9	NA	NA	9	11	18	NA	4	4	5	5	9	7	7	5	9	102
EFSPR1T0.5HR	1/13/2004	65E	GP	10	NA	NA	9	11	19	NA	5	2	6	6	9	8	8	16	14	123
EFSPR1T0.5HR	4/6/2004	65E	GP	9	NA	NA	5	12	13	NA	4	1	3	3	8	8	7	5	6	84
EFSPR1T0.5HR	7/7/2004	65E	GP	13	NA	NA	7	11	18	NA	6	2	7	2	10	8	13	7	10	114
FALL007.6CU	11/6/2003	68A	RR	17	15	15	13	17	20	14	9	9	10	10	10	10	NA	NA	NA	169
FALL007.6CU	2/9/2004	68A	RR	18	15	15	13	19	18	15	8	8	8	8	9	9	NA	NA	NA	163
FALL007.6CU	4/28/2004	68A	RR	16	5	16	16	14	18	17	9	9	8	8	8	10	NA	NA	NA	154
FALL007.6CU	7/2/2004	68A	RR	13	14	13	5	11	19	13	7	7	7	7	9	9	NA	NA	NA	134
FALLS000.5VA	10/30/2003	68A	RR	16	13	15	8	15	20	16	6	6	7	7	9	9	NA	NA	NA	147
FALLS000.5VA	10/30/2003	68A	RR	14	9	14	6	10	19	16	5	5	5	5	10	10	NA	NA	NA	128
FALLS000.5VA	2/5/2004	68A	RR	18	14	10	16	16	16	16	7	7	5	5	10	10	NA	NA	NA	150

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
FALLS000.5VA	5/11/2004	68A	RR	16	11	18	12	16	13	11	6	6	5	5	10	10	NA	NA	NA	139
FALLS000.5VA	5/11/2004	68A	RR	16	12	17	11	16	11	12	6	6	4	4	10	10	NA	NA	NA	135
FALLS1T0.5MI	11/5/2003	68A	RR	15	15	10	13	13	18	19	4	4	6	6	10	10	NA	NA	NA	143
FALLS1T0.5MI	2/11/2004	68A	RR	10	10	11	10	14	18	16	6	6	5	5	10	10	NA	NA	NA	131
FALLS1T0.5MI	4/21/2004	68A	RR	10	13	13	13	16	19	19	5	5	5	5	10	10	NA	NA	NA	143
FECO66G01	10/28/2003	66G	RR	19	10	10	15	8	19	19	8	8	8	8	10	8	NA	NA	NA	150
FECO66G01	2/3/2004	66G	RR	16	10	10	13	18	19	18	7	6	6	6	10	9	NA	NA	NA	148
FECO66G01	5/5/2004	66G	RR	11	5	12	6	19	19	19	10	9	10	10	10	10	NA	NA	NA	150
FECO66G01	4/14/2005	66G	RR	18	15	15	16	20	20	20	10	10	10	10	10	8	NA	NA	NA	182
FECO66G01	4/14/2005	66G	RR	19	15	15	17	20	20	20	10	10	10	10	10	8	NA	NA	NA	184
FECO66G01	4/14/2005	66G	RR	18	15	15	16	20	20	20	10	10	10	10	10	8	NA	NA	NA	182
FECO66G01	10/5/2005	66G	RR	15	12	17	10	10	20	20	10	8	10	9	10	8	NA	NA	NA	159
FECO66G01	4/11/2006	66G	RR	15	12	10	11	19	19	19	9	6	8	8	10	9	NA	NA	NA	155
FECO68A01	11/4/2003	68A	RR	18	17	14	15	8	20	14	8	8	8	8	10	10	NA	NA	NA	158
FECO68A01	2/9/2004	68A	RR	16	14	16	10	20	19	15	5	5	7	7	9	9	NA	NA	NA	152
FECO68A01	5/10/2004	68A	RR	16	15	14	16	13	18	10	8	9	8	8	10	10	NA	NA	NA	155
FECO68A01	7/21/2004	68A	RR	12	12	14	6	10	15	13	5	4	7	7	7	7	NA	NA	NA	119
FECO68A01	4/3/2006	68A	RR	10	19	18	19	20	18	18	9	9	9	9	9	9	NA	NA	NA	176
FECO71F01	10/1/2003	71F	RR	12	16	15	11	8	20	19	7	6	2	2	10	10	NA	NA	NA	138
FECO71F01	1/21/2004	71F	RR	13	16	15	14	17	20	18	6	6	9	9	10	10	NA	NA	NA	163
FECO71F01	4/13/2004	71F	RR	11	13	11	10	16	20	12	6	6	6	6	8	10	NA	NA	NA	135
FECO71F01	7/13/2004	71F	RR	14	16	14	13	9	20	18	9	9	9	9	9	10	NA	NA	NA	159
FECO71F01	10/7/2005	71F	RR	18	19	10	15	7	20	19	6	6	10	10	10	10	NA	NA	NA	160
FECO71F01	4/11/2006	71F	RR	14	14	11	15	12	20	18	8	9	10	10	8	10	NA	NA	NA	159
FECO71G01	11/3/2003	71G	RR	12	14	15	10	16	20	12	7	7	8	8	6	2	NA	NA	NA	137
FECO71G01	1/22/2004	71G	RR	19	13	17	14	15	19	18	9	5	8	4	8	1	NA	NA	NA	150
FECO71G01	4/28/2004	71G	RR	11	16	14	11	12	20	8	8	8	8	8	3	1	NA	NA	NA	128
FECO71G01	7/22/2004	71G	RR	16	16	16	11	15	20	13	6	5	6	4	6	2	NA	NA	NA	136

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
FECO71G01	10/11/2005	71G	RR	17	15	17	15	14	20	13	8	8	10	5	9	2	NA	NA	NA	153
FECO71G01	4/10/2006	71G	RR	19	15	18	17	17	19	17	10	8	10	5	10	0	NA	NA	NA	165
FLAT002.4BT	10/27/2003	66E	RR	19	13	16	16	8	18	16	7	7	8	8	9	10	NA	NA	NA	155
FLAT002.4BT	10/29/2003	66E	RR - QC	17	13	14	14	17	20	15	7	7	8	8	9	9	NA	NA	NA	158
FLAT002.4BT	2/2/2004	66E	RR	15	9	12	10	13	17	18	7	7	8	8	8	10	NA	NA	NA	142
FLAT002.4BT	5/4/2004	66E	RR	16	11	14	11	20	19	18	8	8	9	9	10	10	NA	NA	NA	163
FORD1T1.4BN	10/14/2003	71F	RR	12	7	11	11	6	18	14	3	3	5	5	2	2	NA	NA	NA	99
FORD1T1.4BN	1/13/2004	71F	RR	5	13	7	6	6	13	4	2	2	1	1	1	0	NA	NA	NA	61
FORD1T1.4BN	4/7/2004	71F	RR	9	8	11	8	10	18	4	2	2	3	3	1	0	NA	NA	NA	79
FORD1T1.4BN	7/8/2004	71F	RR	5	10	13	14	9	16	4	3	3	3	3	1	0	NA	NA	NA	84
FWATE031.6PU	12/3/2003	71G	RR	9	11	13	7	19	16	11	2	3	3	3	4	2	NA	NA	NA	103
FWATE031.6PU	2/11/2004	71G	RR	6	7	10	4	20	16	7	2	2	2	2	4	2	NA	NA	NA	84
FWATE031.6PU	4/29/2004	71G	RR	13	13	9	16	13	8	9	4	4	2	2	7	2	NA	NA	NA	102
FWATE031.6PU	7/22/2004	71G	RR	14	16	16	11	8	15	9	5	5	6	5	4	3	NA	NA	NA	117
GOODI001.1DE	1/15/2004	71F	GP	16	NA	NA	11	13	12	NA	3	3	2	2	1	2	16	16	10	107
GOODI001.1DE	4/14/2004	71F	RR	10	13	11	9	19	14	7	5	5	5	6	0	1	NA	NA	NA	105
GOODI001.1DE	7/9/2004	71F	RR	10	12	13	7	10	13	13	4	4	3	4	1	2	NA	NA	NA	96
GOODI001.1DE	7/9/2004	71F	RR	9	12	13	8	9	13	13	4	4	5	5	2	2	NA	NA	NA	99
GRAY1T0.9HR	10/8/2003	65E	GP	10	NA	NA	10	15	19	NA	6	6	7	7	10	10	8	6	8	122
GRAY1T0.9HR	1/12/2004	65E	GP	8	NA	NA	10	15	19	NA	6	6	7	7	10	10	10	6	8	122
GRAY1T0.9HR	4/6/2004	65E	GP	3	NA	NA	3	17	11	NA	3	3	2	2	10	10	9	3	8	84
GRAY1T0.9HR	7/8/2004	65E	GP	11	NA	NA	5	16	19	NA	3	3	4	4	10	10	12	10	7	114
HALEY003.2HI	10/9/2003	71F	RR	12	11	13	12	9	18	11	9	9	8	8	8	2	NA	NA	NA	130
HALEY003.2HI	10/9/2003	71F	RR	12	15	17	12	10	17	16	8	8	8	9	5	2	NA	NA	NA	139
HALEY003.2HI	1/14/2004	71F	RR	10	8	12	11	10	15	14	6	7	6	6	3	2	NA	NA	NA	110
HALEY003.2HI	4/16/2004	71F	RR	12	13	10	5	17	19	10	6	5	5	5	6	2	NA	NA	NA	115
HALEY003.2HI	4/16/2004	71F	RR	12	12	13	10	17	19	10	6	5	5	5	6	2	NA	NA	NA	122

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Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
HALEY003.2HI	7/15/2004	71F	RR	12	13	10	10	12	19	16	7	7	8	8	8	3	NA	NA	NA	133
HANCO1T0.2LI	2/11/2004	71G	RR	8	13	9	10	15	14	11	4	4	2	2	1	1	NA	NA	NA	94
HANCO1T0.2LI	4/20/2004	71G	RR	10	14	12	10	18	16	17	8	8	8	8	1	1	NA	NA	NA	131
HUDSO000.3HR	10/8/2003	65E	GP	11	NA	NA	11	18	17	NA	5	7	6	7	2	9	11	12	9	125
HUDSO000.3HR	1/13/2004	65E	GP	6	NA	NA	7	18	15	NA	5	5	6	6	2	9	7	13	8	107
HUDSO000.3HR	4/7/2004	65E	GP	4	NA	NA	3	14	12	NA	3	3	4	4	2	9	9	4	6	77
HUDSO000.3HR	7/7/2004	65E	GP	3	NA	NA	5	8	17	NA	4	6	5	7	2	8	7	5	6	86
HWATE1T0.1MO	10/28/2003	66G	RR	17	11	9	7	8	19	17	6	6	5	5	10	10	NA	NA	NA	130
HWATE1T0.1MO	2/3/2004	66G	RR	12	15	13	8	15	17	16	6	4	7	7	10	10	NA	NA	NA	140
HWATE1T0.1MO	5/5/2004	66G	RR	15	14	12	14	17	19	13	9	9	10	9	10	10	NA	NA	NA	161
JONES1T0.2DI	10/6/2003	71F	RR - QC	11	12	9	11	11	13	11	6	6	7	7	1	1	NA	NA	NA	106
JONES1T0.2DI	10/13/2003	71F	RR	14	7	11	10	11	11	11	6	6	3	3	2	2	NA	NA	NA	97
JONES1T0.2DI	1/15/2004	71F	RR	14	10	10	9	6	15	8	7	7	4	4	1	1	NA	NA	NA	96
JONES1T0.2DI	1/20/2004	71F	RR	12	11	10	11	8	15	11	5	5	2	2	1	1	NA	NA	NA	94
JONES1T0.2DI	4/8/2004	71F	RR	11	11	13	7	8	14	11	5	5	3	3	1	1	NA	NA	NA	93
JONES1T0.2DI	4/8/2004	71F	RR - QC	11	11	12	6	9	13	12	5	5	4	4	2	2	NA	NA	NA	96
JONES1T0.2DI	7/9/2004	71F	RR	9	11	9	7	6	13	10	4	6	3	5	2	2	NA	NA	NA	87
JONES1T0.2DI	7/9/2004	71F	RR	10	12	10	6	7	15	10	5	6	4	5	2	2	NA	NA	NA	94
JONES2T1.6DI	10/25/2001	71F	RR	15	11	15	11	16	16	17	4	4	5	1	5	1	NA	NA	NA	121
JONES2T1.6DI	10/13/2003	71F	RR	9	13	10	11	11	17	14	4	7	5	6	10	9	NA	NA	NA	126
JONES2T1.6DI	1/21/2004	71F	RR	11	14	10	12	11	18	11	8	8	7	7	9	9	NA	NA	NA	135
JONES2T1.6DI	4/13/2004	71F	RR	9	18	10	15	16	19	11	6	6	6	6	9	9	NA	NA	NA	140
JONES2T1.6DI	7/9/2004	71F	RR	10	12	15	11	13	19	10	7	7	6	6	8	5	NA	NA	NA	129
LAURE003.4MO	10/28/2003	67H	RR	12	13	14	15	10	20	19	7	7	7	7	10	10	NA	NA	NA	151
LAURE003.4MO	2/3/2004	67H	RR	16	13	10	10	10	17	17	5	4	6	6	10	10	NA	NA	NA	134
LAURE003.4MO	5/5/2004	67H	RR	10	7	7	5	7	13	15	7	7	8	8	10	10	NA	NA	NA	114

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
LAURE005.7RH	10/30/2003	68A	RR	10	3	11	5	8	19	16	7	7	6	6	4	4	NA	NA	NA	106
LAURE005.7RH	10/30/2003	68A	RR	11	6	14	4	15	16	8	4	3	4	4	6	6	NA	NA	NA	101
LAURE005.7RH	2/10/2004	68A	RR	10	13	8	10	16	16	11	5	5	4	4	4	3	NA	NA	NA	109
LAURE005.7RH	4/22/2004	68A	RR	7	14	11	10	20	18	15	5	5	5	5	6	5	NA	NA	NA	126
LFGIZ003.4GY	11/6/2003	68A	RR	15	16	10	11	9	16	16	4	4	5	5	9	3	NA	NA	NA	123
LFGIZ003.4GY	2/5/2004	68A	RR	15	16	16	13	14	16	16	6	8	7	8	3	4	NA	NA	NA	142
LFGIZ003.4GY	4/21/2004	68A	RR	15	11	16	11	16	19	18	8	7	8	7	8	7	NA	NA	NA	151
LOONE002.5MI	11/6/2003	68C	RR	7	10	9	12	16	19	12	8	8	9	9	10	10	NA	NA	NA	139
LOONE002.5MI	2/4/2004	68C	RR	10	8	10	8	18	17	16	8	8	7	7	10	10	NA	NA	NA	137
LOONE002.5MI	4/21/2004	68C	RR	15	13	9	13	18	19	18	8	8	7	6	10	10	NA	NA	NA	154
LOOPE001.0OV	2/4/2004	68A	RR	13	14	10	9	18	17	15	5	6	6	5	2	9	NA	NA	NA	129
LOOPE001.0OV	5/10/2004	68A	RR	16	6	16	8	13	16	15	7	7	7	7	2	10	NA	NA	NA	130
LOOPE001.0OV	7/2/2004	68A	RR	13	13	15	5	11	17	11	5	6	5	6	3	9	NA	NA	NA	119
LTRAC005.0CY	11/14/2003	71G	RR	12	9	15	10	16	20	11	5	5	3	3	3	2	NA	NA	NA	114
LTRAC005.0CY	2/11/2004	71G	RR	10	12	6	7	20	19	11	4	4	4	4	2	2	NA	NA	NA	105
LTRAC005.0CY	5/13/2004	71G	RR	11	15	9	13	16	17	16	8	7	8	7	4	2	NA	NA	NA	133
LTRAC005.0CY	7/22/2004	71G	RR	15	12	14	10	16	15	15	6	7	6	6	4	3	NA	NA	NA	126
MAMMY010.1CU	11/6/2003	68A	RR	16	15	15	14	16	20	16	8	8	7	7	10	10	NA	NA	NA	162
MAMMY010.1CU	2/4/2004	68A	RR	13	15	11	10	18	15	15	6	6	6	6	9	9	NA	NA	NA	139
MAMMY010.1CU	4/28/2004	68A	RR	13	6	16	13	14	13	9	8	6	7	6	9	7	NA	NA	NA	127
MAMMY010.1CU	7/2/2004	68A	RR	15	11	11	9	9	14	11	7	8	6	6	6	6	NA	NA	NA	119
MCCAM000.7PO	10/29/2003	66E	RR	11	11	6	6	6	7	10	1	1	5	5	10	10	NA	NA	NA	89
MCCAM000.7PO	2/3/2004	66E	RR	18	14	10	15	18	13	18	4	4	1	1	10	10	NA	NA	NA	136
MCCAM000.7PO	4/22/2004	66E	RR	17	13	9	10	15	8	18	3	3	2	2	10	10	NA	NA	NA	120
MERID006.5MN	10/9/2003	65E	GP	16	NA	NA	8	12	18	NA	5	3	5	4	7	1	12	16	10	117
MERID006.5MN	10/9/2003	65E	GP - QC	6	NA	NA	11	8	16	NA	2	2	3	3	7	2	12	1	10	83
MERID006.5MN	1/14/2004	65E	GP	6	NA	NA	6	7	14	NA	3	3	4	4	1	4	6	4	5	67

Table C-4 cont.

Station ID	Date	Eco-reg-ion	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
MERID006.5MN	4/7/2004	65E	GP	7	NA	NA	4	16	14	NA	3	3	4	4	5	2	9	4	7	82
MERID006.5MN	7/29/2004	65E	GP	9	NA	NA	6	18	18	NA	2	2	3	3	2	0	8	5	7	83
MOODY002.0HR	10/7/2003	74B	GP	14	NA	NA	7	16	19	NA	9	9	9	9	10	10	12	9	9	142
MOODY002.0HR	1/13/2004	74B	GP	5	NA	NA	7	14	19	NA	6	6	7	7	9	9	8	8	9	114
MOODY002.0HR	4/6/2004	74B	GP	9	NA	NA	4	18	14	NA	5	5	4	4	9	9	11	5	6	103
MOODY002.0HR	7/7/2004	74B	GP	13	NA	NA	5	19	19	NA	7	7	7	7	9	9	12	2	8	124
NORTH005.7CU	10/31/2003	68A	RR	8	3	8	4	10	17	14	6	6	5	5	9	9	NA	NA	NA	104
NORTH005.7CU	2/9/2004	68A	RR	6	15	10	6	20	14	9	3	3	5	5	5	5	NA	NA	NA	106
NORTH005.7CU	5/13/2004	68A	RR	18	8	12	10	16	17	15	7	7	6	6	8	8	NA	NA	NA	138
NORTH005.7CU	7/27/2004	68A	RR	5	8	14	5	16	19	9	3	3	4	5	5	5	NA	NA	NA	101
OBED040.2CU	2/10/2004	68A	RR	15	16	11	17	19	19	17	7	7	7	7	3	7	NA	NA	NA	152
OBED040.2CU	5/14/2004	68A	RR	15	14	15	17	15	5	9	10	10	5	5	6	6	NA	NA	NA	132
OBED040.2CU	7/27/2004	68A	RR	15	15	10	15	20	14	16	8	8	8	8	3	9	NA	NA	NA	149
ODAIN000.3HR	10/7/2003	65E	GP	17	NA	NA	11	19	16	NA	5	5	9	9	10	9	14	13	11	148
ODAIN000.3HR	1/12/2004	65E	GP	11	NA	NA	11	20	17	NA	4	6	9	9	10	6	14	15	13	145
ODAIN000.3HR	4/5/2004	65E	GP	4	NA	NA	4	19	15	NA	2	1	2	1	8	3	11	5	7	82
ODAIN000.3HR	7/8/2004	65E	GP	18	NA	NA	8	19	15	NA	5	5	7	5	10	3	15	13	9	122
OTOWN1T0.9HN	1/13/2004	65E	GP	4	NA	NA	5	6	16	NA	2	2	2	2	3	3	3	6	12	66
OTOWN1T0.9HN	4/6/2004	65E	GP	5	NA	NA	10	6	15	NA	1	1	2	2	2	2	6	6	11	69
PINEY014.6CS	10/9/2003	65E	GP	8	NA	NA	13	15	16	NA	5	3	5	2	8	1	8	4	7	95
PINEY014.6CS	10/9/2003	65E	GP - QC	7	NA	NA	13	10	13	NA	3	3	4	4	10	2	14	1	5	89
PINEY014.6CS	1/12/2004	65E	GP	10	NA	NA	9	12	17	NA	4	4	6	6	9	1	14	5	10	107
PINEY014.6CS	4/5/2004	65E	GP	10	NA	NA	7	17	12	NA	3	3	3	3	8	1	11	8	8	94
PINEY014.6CS	4/5/2004	65E	GP - QC	11	NA	NA	7	17	13	NA	3	3	3	3	8	1	12	8	8	97
PINEY014.6CS	7/8/2004	65E	GP	10	NA	NA	6	15	17	NA	4	1	5	2	9	0	8	6	7	90
POND1T0.1CU	2/10/2004	68A	RR	6	11	14	5	17	15	8	2	2	4	4	9	9	NA	NA	NA	106

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
POND1T0.1CU	5/12/2004	68A	RR	12	10	13	10	12	16	13	7	4	7	4	10	10	NA	NA	NA	128
RATTL000.1UC	10/28/2003	66E	RR	17	11	13	12	18	20	17	8	8	8	7	8	8	NA	NA	NA	155
RATTL000.1UC	2/3/2004	66E	RR	15	18	10	15	17	18	16	6	5	6	6	8	8	NA	NA	NA	148
RATTL000.1UC	4/27/2004	66E	RR	16	16	10	15	17	20	17	7	5	7	6	10	9	NA	NA	NA	155
RATTL000.1UC	4/27/2004	66E	RR - QC	16	17	10	15	18	20	16	8	5	8	5	9	9	NA	NA	NA	156
RATTL000.1UC	7/20/2004	66E	RR	12	14	10	10	17	19	16	8	7	7	6	6	5	NA	NA	NA	137
RATTL000.1UC	7/20/2004	66E	RR	11	13	10	10	16	17	17	7	6	7	7	4	3	NA	NA	NA	128
ROARI002.4CT	10/28/2003	66D	RR	16	8	15	11	18	19	17	8	8	7	7	5	5	NA	NA	NA	144
ROARI002.4CT	2/3/2004	66D	RR	17	16	15	15	17	19	16	8	8	8	8	3	9	NA	NA	NA	159
ROARI002.4CT	4/27/2004	66D	RR	17	17	16	14	18	14	16	7	7	8	8	2	10	NA	NA	NA	154
ROARI002.4CT	7/20/2004	66D	RR	16	15	15	13	14	18	16	7	7	8	8	3	10	NA	NA	NA	150
SAVAG009.8SE	11/10/2003	68A	RR	10	18	10	19	16	19	16	4	1	4	4	9	10	NA	NA	NA	140
SAVAG009.8SE	2/10/2004	68A	RR	11	15	10	14	18	18	12	2	5	6	5	10	9	NA	NA	NA	135
SAVAG009.8SE	5/11/2004	68A	RR	16	16	16	15	6	18	12	3	4	5	4	10	10	NA	NA	NA	135
SCANT001.3CU	11/12/2003	68A	RR	3	3	9	3	4	18	3	3	3	5	5	10	10	NA	NA	NA	79
SCANT001.3CU	2/9/2004	68A	RR	5	2	9	4	6	19	7	4	4	5	5	9	9	NA	NA	NA	88
SCANT001.3CU	5/10/2004	68A	RR	11	2	6	11	15	18	13	3	4	6	7	10	10	NA	NA	NA	116
SCOTT003.5SH	1/12/2004	74B	GP	12	NA	NA	8	9	19	NA	1	1	7	7	9	6	14	8	14	115
SCOTT003.5SH	4/5/2004	74B	GP	6	NA	NA	5	14	20	NA	1	2	3	3	9	5	10	6	8	92
SCOTT003.5SH	7/6/2004	74B	GP	6	NA	NA	6	8	18	NA	1	1	3	3	9	3	12	5	12	87
SFHUR003.6HO	10/7/2003	71F	RR	12	10	12	11	7	16	15	6	8	7	7	8	7	NA	NA	NA	126
SFHUR003.6HO	1/15/2004	71F	RR	13	4	11	7	8	18	15	6	5	6	6	9	8	NA	NA	NA	116
SFHUR003.6HO	4/6/2004	71F	RR	11	3	10	7	8	17	14	8	3	6	6	4	9	NA	NA	NA	106
SFHUR003.6HO	7/8/2004	71F	RR	11	8	9	7	9	18	12	5	4	5	5	8	5	NA	NA	NA	106
SFSYC006.3DA	10/10/2003	71F	RR	6	13	13	16	12	10	13	2	5	3	6	10	2	NA	NA	NA	111
SFSYC006.3DA	1/22/2004	71F	RR	11	14	10	14	11	18	15	3	8	5	6	10	2	NA	NA	NA	127
SFSYC006.3DA	4/14/2004	71F	RR	6	19	10	16	16	15	11	5	7	5	4	10	2	NA	NA	NA	126

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
SFSYC006.3DA	7/13/2004	71F	RR	10	13	12	10	12	16	13	6	6	7	5	10	2	NA	NA	NA	122
SHARP1T0.4DA	10/17/2003	71F	RR	14	7	9	7	7	19	15	2	8	8	8	10	2	NA	NA	NA	116
SHARP1T0.4DA	1/21/2004	71F	RR	13	10	10	11	12	18	16	3	6	7	5	10	1	NA	NA	NA	122
SHARP1T0.4DA	4/15/2004	71F	RR	17	18	10	15	15	18	16	3	8	7	7	10	2	NA	NA	NA	146
SHARP1T0.4DA	7/13/2004	71F	RR	14	8	14	10	7	17	14	3	6	6	6	10	2	NA	NA	NA	117
SHARP2T0.6DA	10/16/2003	71F	RR	15	9	10	10	7	19	17	7	8	7	7	2	10	NA	NA	NA	128
SHARP2T0.6DA	1/21/2004	71F	RR	10	12	10	8	11	19	14	6	7	6	6	2	10	NA	NA	NA	121
SHARP2T0.6DA	4/13/2004	71F	RR	15	17	10	15	16	17	15	7	7	6	6	2	10	NA	NA	NA	143
SHARP2T0.6DA	7/13/2004	71F	RR	11	14	10	11	7	18	14	6	6	7	7	2	9	NA	NA	NA	122
SHELT001.3LI	11/4/2003	71H	RR	12	13	13	11	11	18	15	7	7	8	6	9	2	NA	NA	NA	132
SHELT001.3LI	2/11/2004	71H	RR	13	12	14	11	15	17	12	6	5	7	6	5	2	NA	NA	NA	125
SHELT001.3LI	4/20/2004	71H	RR	14	13	12	10	19	19	10	8	6	8	5	5	2	NA	NA	NA	131
SHELT001.3LI	4/20/2004	71H	RR - QC	15	13	15	10	17	17	11	8	6	7	5	4	1	NA	NA	NA	129
SINKI1T0.8CO	10/29/2003	67G	RR	15	12	10	14	16	17	16	4	3	2	2	1	1	NA	NA	NA	113
SINKI1T0.8CO	2/3/2004	67G	RR	10	8	10	8	15	15	11	3	2	2	2	1	1	NA	NA	NA	88
SINKI1T0.8CO	4/27/2004	67G	RR	12	13	10	16	18	11	8	7	4	5	5	2	2	NA	NA	NA	113
SINKI1T0.8CO	7/20/2004	67G	RR	7	10	10	4	9	15	9	5	4	5	3	2	2	NA	NA	NA	85
SINKI1T1.0CO	10/27/2003	67G	RR	16	13	10	19	9	19	16	7	6	6	5	9	3	NA	NA	NA	138
SINKI1T1.0CO	2/2/2004	67G	RR	15	11	10	7	12	19	16	8	8	7	3	8	2	NA	NA	NA	126
SINKI1T1.0CO	5/4/2004	67G	RR	12	12	10	10	19	19	18	8	6	8	6	9	6	NA	NA	NA	143
SQUAW001.4LS	10/16/2003	71F	RR	18	10	15	10	14	20	19	7	9	9	9	8	9	NA	NA	NA	157
SQUAW001.4LS	1/15/2004	71F	RR	18	11	14	10	15	20	18	6	8	9	9	9	9	NA	NA	NA	156
SQUAW001.4LS	4/13/2004	71F	RR	15	13	10	8	18	15	11	4	4	2	2	10	8	NA	NA	NA	120
SQUAW001.4LS	7/13/2004	71F	RR	13	6	13	6	14	18	15	7	9	9	9	10	10	NA	NA	NA	139
STEEL000.3SU	12/21/1998	67I	RR	5	9	15	16	15	16	19	10	1	9	9	10	0	NA	NA	NA	134
STEEL000.3SU	5/29/2003	67I	RR	11	14	14	12	20	9	NA	6	9	2	8	1	6	NA	NA	NA	125
STEEL000.3SU	2/2/2004	67I	RR	15	14	14	15	15	19	16	6	6	5	7	10	6	NA	NA	NA	148

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
STEEL000.3SU	4/26/2004	67I	RR	12	17	10	17	20	13	16	8	10	8	8	8	10	NA	NA	NA	157
STEEL000.3SU	7/19/2004	67I	RR	11	11	10	5	13	18	14	7	5	5	4	6	10	NA	NA	NA	119
STEWA003.4HR	10/8/2003	65E	GP	14	NA	NA	13	15	20	NA	8	4	8	5	9	2	14	16	13	141
STEWA003.4HR	1/14/2004	65E	GP	7	NA	NA	7	13	19	NA	4	4	6	3	9	1	7	16	14	110
STEWA003.4HR	4/7/2004	65E	GP	3	NA	NA	4	16	12	NA	3	3	4	4	8	2	6	6	7	78
STEWA003.4HR	7/8/2004	65E	GP	11	NA	NA	7	13	19	NA	6	5	6	5	10	1	9	8	14	114
TAYLO000.7OB	10/8/2003	74A	RR	7	2	11	9	7	10	11	2	2	1	1	0	2	NA	NA	NA	65
TAYLO000.7OB	1/12/2004	74A	RR	9	7	14	6	16	15	7	5	5	3	3	0	5	NA	NA	NA	95
TAYLO000.7OB	4/5/2004	74A	RR	8	4	9	3	10	11	7	2	2	0	5	0	5	NA	NA	NA	66
TAYLO000.7OB	4/5/2004	74A	RR - QC	8	3	7	4	8	11	7	2	2	0	5	0	3	NA	NA	NA	60
TAYLO000.7OB	7/7/2004	74A	RR	12	7	11	9	10	17	11	3	3	3	3	3	1	NA	NA	NA	93
THOMP005.9WY	1/13/2004	65E	GP	3	NA	NA	2	6	15	NA	2	2	6	6	10	10	4	2	10	78
THOMP005.9WY	4/6/2004	65E	GP	2	NA	NA	13	6	16	NA	2	3	5	5	10	10	2	2	6	82
THOMP005.9WY	7/7/2004	65E	GP	5	NA	NA	6	6	18	NA	3	2	5	5	10	10	4	3	6	83
THOMP1T0.4HR	1/13/2004	65E	GP	14	NA	NA	16	11	18	NA	2	2	6	5	9	6	16	6	10	121
THOMP1T0.4HR	4/6/2004	65E	GP	8	NA	NA	5	17	15	NA	3	3	3	5	8	8	16	4	10	105
THOMP1T0.4HR	7/7/2004	65E	GP	12	NA	NA	6	10	16	NA	4	3	6	4	8	3	13	6	7	98
THREE1T0.3HN	10/7/2003	65E	GP	13	NA	NA	10	8	16	NA	2	2	6	6	9	9	13	10	5	109
THREE1T0.3HN	1/13/2004	65E	GP	10	NA	NA	4	10	15	NA	1	1	6	6	10	10	6	8	8	95
THREE1T0.3HN	4/6/2004	65E	GP	14	NA	NA	13	11	16	NA	3	3	4	4	10	10	12	2	6	108
THREE1T0.3HN	7/7/2004	65E	GP	13	NA	NA	7	8	16	NA	2	2	5	5	10	10	6	4	6	94
TMILE1T0.2FR	2/5/2004	68A	RR	10	5	11	8	13	16	14	6	6	8	8	9	10	NA	NA	NA	124
TMILE1T0.2FR	4/21/2004	68A	RR	14	8	13	5	18	19	16	5	6	8	8	10	10	NA	NA	NA	140
TRAIL1T0.4CU	2/10/2004	68A	RR	5	7	9	4	17	18	10	2	2	4	4	9	9	NA	NA	NA	100
TRAIL1T0.4CU	2/10/2004	68A	RR	5	7	9	4	17	18	10	2	2	4	4	9	9	NA	NA	NA	100
TRAIL1T0.4CU	5/13/2004	68A	RR	16	15	9	14	9	17	16	8	7	6	6	10	10	NA	NA	NA	143
TRAIL1T0.4CU	7/26/2004	68A	RR	11	11	10	7	6	19	6	5	5	5	5	6	6	NA	NA	NA	102

Table C-4 cont.

Station ID	Date	Eco-region	Type	Epi-fuanal Sub-strate	Embed-dedness	Velocity/ Deprth	Sediment Deopo-sition	Chan-nel Flow Status	Chan-nel Alter-ation	Fre-quency of Riffles	Bank Stab-ility Right	Bank Stab-ility Left	Vege-tative Prot-tection Left	Vege-tative Prot-tenction Right	Ripar-ian Width Left	Ripar-ian Width Right	Pool Sub-strate	Pool Varia-bility	Cjan-nel Sinu-osity	TMI
TULL000.3OB	1/12/2004	74A	GP	10	NA	NA	5	9	15	NA	3	3	3	3	10	4	15	3	8	91
TULL000.3OB	4/5/2004	74A	GP	7	NA	NA	10	11	16	NA	3	3	6	6	8	3	6	5	6	90
TULL000.3OB	7/7/2004	74A	GP	9	NA	NA	6	7	17	NA	2	2	5	4	9	3	12	3	10	89
WALKE1T0.3DA	10/2/2003	71H	RR - QC	9	6	7	5	7	19	18	7	3	6	9	2	9	NA	NA	NA	107
WALKE1T0.3DA	10/10/2003	71H	RR	11	9	12	4	10	8	15	8	9	7	7	2	10	NA	NA	NA	112
WALKE1T0.3DA	1/22/2004	71H	RR	13	8	10	8	11	16	12	7	8	7	7	1	9	NA	NA	NA	117
WALKE1T0.3DA	4/8/2004	71H	RR	15	10	10	13	11	17	16	6	7	8	8	10	1	NA	NA	NA	132
WALKE1T0.3DA	4/8/2004	71H	RR - QC	15	9	9	14	12	18	17	7	7	7	6	10	2	NA	NA	NA	133
WALKE1T0.3DA	7/13/2004	71H	RR	11	7	9	5	7	14	13	7	7	5	6	2	9	NA	NA	NA	102
WALKE1T0.3DA	7/13/2004	71H	RR	12	7	9	6	7	15	14	7	7	5	7	2	10	NA	NA	NA	108
WASHB003.0LI	11/4/2003	71G	RR	14	9	14	9	7	13	10	6	6	7	7	9	2	NA	NA	NA	113
WASHB003.0LI	2/11/2004	71G	RR	12	15	12	14	14	15	12	4	4	6	7	9	4	NA	NA	NA	128
WASHB003.0LI	4/20/2004	71G	RR	18	13	12	13	12	12	11	4	4	5	4	9	3	NA	NA	NA	120
WEAVE001.0LW	10/13/2003	71F	RR	18	10	13	7	8	19	18	8	6	8	8	9	9	NA	NA	NA	141
WEAVE001.0LW	1/14/2004	71F	RR	17	10	13	8	11	19	16	7	7	8	8	9	9	NA	NA	NA	142
WEAVE001.0LW	4/13/2004	71F	RR	12	13	13	7	17	18	13	4	4	3	4	10	10	NA	NA	NA	128
WEAVE001.0LW	7/13/2004	71F	RR	16	6	15	6	8	18	16	7	7	9	9	9	9	NA	NA	NA	135
WFDRA2T1.5SR	10/6/2003	71G	RR	18	11	16	16	10	17	17	2	1	6	6	9	10	NA	NA	NA	139
WFDRA2T1.5SR	1/16/2004	71G	RR	9	8	10	6	10	18	10	3	3	6	6	9	9	NA	NA	NA	107
WFDRA2T1.5SR	4/14/2004	71G	RR	16	14	17	15	16	16	16	8	2	5	5	10	10	NA	NA	NA	150
WFDRA2T1.5SR	7/12/2004	71G	RR	12	8	14	6	12	16	12	6	3	6	5	9	9	NA	NA	NA	118
WOLF1T0.1LW	10/13/2003	71F	RR	10	15	7	16	13	19	10	8	8	8	8	8	8	NA	NA	NA	138
WOLF1T0.1LW	1/14/2004	71F	RR	10	15	7	15	13	19	10	8	8	8	8	8	8	NA	NA	NA	137
WOLF1T0.1LW	4/14/2004	71F	RR	10	13	10	9	16	15	7	6	6	5	5	6	8	NA	NA	NA	116
WOLF1T0.1LW	7/14/2004	71F	RR	10	15	10	14	9	18	16	8	6	7	7	8	8	NA	NA	NA	136

APPENDIX D

90^{th} Percentile of Reference Water Quality Data
Test Site Water Quality Data

Table D-1: 90th percentile of reference data for select parameters by ecoregion

Ecoregion	Suspended Residue (mg/l)	NH3 (mg/L)	TKN (mg/L)	Mn (ug/L)
65e	113	0.04	0.7	431
65b	10	0.05	0.3	425
65e	23	0.04	0.3	304
65i	40	0.05	0.1	202
65j	10	0.02	0.1	32
66d	10	0.02	0.1	16
66e	10	0.02	0.1	10
66f	10	0.02	0.1	22
66g	10	0.02	0.1	14
67f	10	0.02	0.2	26
67g	13	0.04	0.2	99
67h	10	0.02	0.2	33
67i	50	0.05	0.2	161
68a	10	0.02	0.1	33
68b	10	0.02	0.3	70
68c	12	0.02	0.1	12
69d	10	0.02	0.1	36
71e	12	0.05	0.2	28
71f	10	0.05	0.5	13
71g	12	0.04	0.2	25
71h	10	0.02	0.1	25
71i	14	0.05	0.4	114
73a	56	0.52	0.9	912
74a	13	0.02	0.3	158
74b	30	0.04	0.2	339

Table D-2: Test site water quality data

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
ARNOL001.4WY	65e	01-13-2004	6.45	66.0	10.30	80	0.47	4.85	10.0U	0.07	0.05	0.54	0.065	2360	297
ARNOL001.4WY	65e	04-05-2004	6.54	67.9	8.70	84	0.49	13.90	10.0U	0.06	0.11	0.47	0.029	2590	391
ARNOL001.4WY	65e	07-06-2004	6.40	76.3	4.51	56	0.29	26.60	13.0	0.17	0.05	0.10U	0.082	4067	986
BAGWE1T0.2CU	68a	02-10-2004	6.90	95.9	10.37	84	0.23	6.14	10.0U	0.02U	0.15	0.76	0.522	668	103
BAGWE1T0.2CU	68a	05-13-2004	6.50	12.9	5.39	61	0.006	21.12	10.0U	0.06	0.13	0.25	0.043	180	11
BARNE002.4FR	68a	11-05-2003	6.78	91.5	5.58	58	0.04	17.12	10.0U	0.02U	0.02	0.10U	0.115	613	199
BARNE002.4FR	68a	02-05-2004	6.88	32.1	16.38	90	0.32	5.23	10.0U	0.05	0.20	0.17	0.004U	1630	123
BARNE002.4FR	68a	04-21-2004	6.40	42.9	9.00	87	0.09	13.90	16.0	0.02U	0.01U	0.11	0.014	919	158
BARNE002.4FR	68a	08-04-2004	6.85	68.5	7.06	80	0.01	21.73	10.0U	0.15	1.59	0.10U	0.067	1430	341
BARTE001.4MT	71f	10-06-2003	7.47	341.5	6.55	68	2.47	17.48	31.0	0.05	0.36	0.25	0.044	1230	291
BARTE001.4MT	71f	01-15-2004	7.61	321.5	10.07	82	12.44	6.55	10.0U	0.02	0.91	0.10U	0.004U	402	55
BARTE001.4MT	71f	04-15-2004	7.41	321.0	9.20	84	12.98	11.04	12.0	0.02U	0.17	0.19	0.061	1880	289
BARTE001.4MT	71f	07-13-2004	7.31	358.0	4.45	57	6.63	27.85	10.0U	0.09	0.45	0.10U	0.058	1370	359
BEAR003.6WE	71f	10-14-2003	7.08	40.5	8.90	100	2.09	21.08	10.0U	0.05	0.22	0.10U	0.004U	394	816
BEAR003.6WE	71f	01-14-2004	7.25	42.0	11.47	94	6.40	6.69	10.0U	0.02	0.23	0.13	0.008	233	198
BEAR003.6WE	71f	04-14-2004	6.81	39.0	11.27	99	11.11	9.57	10.0U	0.02U	0.12	0.26	0.004U	640	531
BEAR003.6WE	71f	07-13-2004	6.93	36.7	6.97	89	7.63	27.77	10.0U	0.05	0.10	0.10U	0.056	468	403
BEASL000.4MY	71h	10-10-2003	7.19	189.0	3.88	43	0.035	20.36	10.0U	0.92	0.41	1.57	0.249	54	301
BEASL000.4MY	71h	01-21-2004	7.38	282.0	11.75	92	0.97	4.82	10.0U	0.02U	0.84	0.86	0.042	65	63
BEASL000.4MY	71h	04-13-2004	7.81	309.0	9.20	89	1.20	13.63	10.0U	0.02U	0.43	0.30	0.153	439	213
BEASL000.4MY	71h	07-15-2004	7.19	156.3	2.89	37	0.27	28.05	10.0U	0.32	0.20	0.87	0.098	89	197
BGUM000.5CU	68a	02-10-2004	7.10	42.6	11.40	90	0.96	5.35	11.0	0.02U	0.06	0.39	0.162	1790	289

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
BGUM000.5CU	68a	05-12-2004	6.57	65.5	7.30	81	0.13	20.70	32.0	0.14	0.12	0.10	0.006	270	557
BGUM000.5CU	68a	07-26-2004	6.79	117.5	5.70	64	0.02	20.77	38.0	0.08	0.48	0.27	0.051	6300	1670
BOSTO001.1HM	68a	11-03-2003	6.42	65.7	7.09	70	0.21	14.91	11.0	0.37	0.17	0.59	0.004U	6360	1090
BOSTO001.1HM	68a	02-04-2004	6.84	31.2	12.40	94	1.99	3.85	10.0U	0.02U	0.10	0.10U	0.004U	219	47
BOSTO001.1HM	68a	04-21-2004	6.20	34.8	8.80	86	0.49	14.50	10.0U	0.02U	0.01U	0.10U	0.059	623	100
BOSTO001.1HM	68a	08-03-2004	6.32	54.5	6.19	66	0.02	18.80	24.0	0.17	0.43	0.10U	0.056	18500	1250
BUCK001.2CU	68a	11-05-2003	6.74	116.6	4.91	49	0.88	15.12	50.0	0.15	0.44	0.22	0.063	15300	10400
BUCK001.2CU	68a	02-10-2004	6.88	54.5	11.14	87	9.39	4.92	10.0U	0.02U	0.27	0.15	0.007	472	68
BUCK001.2CU	68a	05-11-2004	6.39	69.0	7.25	76	1.81	17.79	10.0U	0.03	0.10	0.10U	0.112	411	90
BUCK001.2CU	68a	07-26-2004	6.80	71.7	6.17	69	2.87	20.83	10.0U	0.02	0.14	0.20	0.035	734	217
CARSO001.0MO	67g	10-29-2003	7.93	303.3	7.87	79	0.41	15.58	10.0U	0.07	0.09	0.26	0.012	273	127
CARSO001.0MO	67g	02-04-2004	7.84	262.5	12.28	99	2.32	6.32	10.0U	0.02U	0.33	0.15	0.004U	398	62
CARSO001.0MO	67g	04-22-2004	7.90	290.0	8.80	97	0.95	19.90	10.0	0.02U	0.01U	0.12	0.033	418	59
CARSO001.0MO	67g	07-20-2004	8.00	308.0	4.93	65	0.31	29.85	10.0	0.02	0.12	0.10U	0.059	459	154
CHARL000.7OV	68a	02-04-2004	6.83	24.9	10.82	80	0.49	2.85	10.0U	0.02	0.04	0.10	0.004U	380	60
CHARL000.7OV	68a	05-10-2004	5.74	26.0	7.75	82	0.22	18.17	10.0U	0.02	0.01U	0.10U	0.106	653	178
CHARL000.7OV	68a	07-21-2004	5.97	47.4	5.34	58	0.28	19.63	10.0U	0.12	0.08	0.10U	0.041	2770	760
CHARL003.4BN	65e	10-13-2003	6.04	126.5	3.98	40	0.009	15.93	142	0.02U	0.07	0.41	0.004U	4970	3980
CHARL003.4BN	65e	01-15-2004	6.34	74.3	10.24	82	0.20	5.83	10.0U	0.05	0.09	0.14	0.004U	3980	1000
CHARL003.4BN	65e	04-07-2004	5.89	72.3	8.76	91	0.06	17.10	20.0	0.02U	0.09	0.20	0.029	2270	1350
CHARL003.4BN	65e	07-08-2004	6.22	53.4	6.41	82	0.49	28.24	11.0	0.03	0.16	0.18	0.032	2580	882
CHIEF004.6LS	71f	10-14-2003	7.36	50.7	8.39	92	14.17	20.04	10.0U	0.05	0.16	0.10U	0.004U	275	85

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
CHIEF004.6LS	71f	01-15-2004	7.40	51.1	11.22	90	15.79	5.76	10.0U	0.04	0.13	0.10U	0.04U	273	29
CHIEF004.6LS	71f	04-13-2004	6.62	51.8	9.37	89	42.40	13.01	10.0U	0.07	0.20	0.24	0.004U	551	309
CHIEF004.6LS	71f	07-13-2004	8.07	56.2	7.15	91	12.56	27.96	10.0U	0.13	0.04	0.10U	0.071	844	177
CUB2T0.3HR	65e	10-16-2003	6.71	35.3	8.52	90	4.69	17.94	10.0U	0.06	1.28	0.29	0.017	1210	166
CUB2T0.3HR	65e	01-14-2004	6.85	45.9	10.83	88	4.69	6.26	10.0U	0.06	0.09	0.16	0.004U	1430	280
CUB2T0.3HR	65e	04-07-2004	6.33	38.6	8.37	83	4.35	15.04	10.0U	0.01	0.10	0.18	0.004U	1410	331
CUB2T0.3HR	65e	07-07-2004	6.39	70.3	6.17	78	11.66	27.55	21.0	0.08	0.15	0.10U	0.051	1959	480
DAVIS000.8SR	71g	10-06-2003	7.35	292.4	7.54	76	0.40	15.78	13.0	0.09	0.61	0.22	0.021	229	112
DAVIS000.8SR	71g	01-16-2004	7.82	313.9	13.36	103	0.71	4.23	11.0	0.02U	0.76	0.12	0.004U	82	28
DAVIS000.8SR	71g	04-14-2004	7.51	295.0	10.91	97	5.57	9.94	10.0U	0.10	0.29	0.59	0.026	260	119
DAVIS000.8SR	71g	07-12-2004	7.69	297.0	6.50	82	0.67	27.37	10.0U	0.04	0.09	0.37	0.023	169	95
DODDY001.9BE	71h	11-05-2003	8.00	201.0	8.48	92	1.67	19.23	10.0U	0.32	0.06	1.32	0.033	130	423
DODDY001.9BE	71h	02-10-2004	7.10	160.0	10.85	90	9.52	7.06	10.0	0.02U	1.04	0.23	0.056	718	51
DODDY001.9BE	71h	04-20-2004	8.40	183.0	10.1	107	5.03	18.30	12.0	0.02U	0.01U	0.34	0.048	135	50
DODDY001.9BE	71h	08-03-2004	7.80	183.0	7.00	87	0.21	26.32	10.0U	0.04	0.83	0.10U	0.114	392	92
DRY004.1BN	65e	10-16-2003	6.52	88.3	7.47	73	0.03	14.37	10.0	0.03	0.05	0.36	0.004U	746	465
DRY004.1BN	65e	01-13-2004	6.76	87.4	11.82	96	0.48	6.51	10.0U	0.03	0.22	0.24	0.004U	489	166
DRY004.1BN	65e	04-07-2004	6.64	91.1	8.99	96	0.07	18.46	10.0U	0.02U	0.10	0.10U	0.017	843	352
DRY004.1BN	65e	07-08-2004	7.01	68.7	6.70	88	2.60	29.33	10.0U	0.02U	0.01U	0.10U	0.004U	614	304
DUNCA001.8CU	68a	11-12-2003	6.30	83.5	3.6	35	0.38	13.68	15.0	0.50	0.38	1.05	0.051	6710	2010
DUNCA001.8CU	68a	02-11-2004	6.77	39.1	11.38	87	4.35	3.88	10.0U	0.02U	0.74	0.32	0.200	1050	184
DUNCA001.8CU	68a	04-29-2004	6.55	47.0	7.97	76	2.22	13.28	10.0U	0.12	0.36	0.10U	0.004U	1350	397

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
DUNCA001.8CU	68a	07-22-2004	6.33	78.7	4.21	43	0.55	16.11	10.0	0.34	0.12	0.16	0.031	4360	1780
EFSPR1T0.5HR	65e	10-07-2003	7.05	53.9	7.86	91	0.30	22.37	10.0U	0.12	0.11	0.23	0.033	491	190
EFSPR1T0.5HR	65e	01-13-2004	7.11	56.8	11.18	91	0.47	6.60	10.0U	0.03	0.08	0.37	0.004U	577	83
EFSPR1T0.5HR	65e	04-06-2004	6.68	46.3	8.44	87	0.32	16.68	10.0U	0.02U	0.12	0.33	0.004U	518	111
EFSPR1T0.5HR	65e	07-07-2004	7.04	47.8	7.59	98	0.53	28.33	10.0U	0.02U	0.01U	0.10U	0.029	280	62
FALL007.6CU	68a	11-06-2003	7.01	46.7	8.55	87	3.62	16.40	10.0U	0.02U	0.04	0.10U	0.067	387	123
FALL007.6CU	68a	02-09-2004	6.28	24.0	11.39	91	23.77	5.59	10.0U	0.02U	0.07	0.41	0.024	71	25
FALL007.6CU	68a	04-28-2004	6.63	35.6	9.60	96	3.49	15.43	10.0U	0.07	0.07	0.10U	0.004U	263	105
FALL007.6CU	68a	07-21-2004	6.84	41.0	7.05	84	1.25	24.24	10.0U	0.02U	0.01	0.10U	0.036	387	148
FALLS000.5VA	68a	10-30-2003	6.86	32.0	8.36	84	20.03	15.50	10.0U	0.16	0.07	0.23	0.11	952	296
FALLS000.5VA	68a	02-05-2004	7.02	290.0	12.59	97	45.36	4.29	10.0U	0.10	0.07	0.28	0.004U	316	156
FALLS000.5VA	68a	05-11-2004	6.39	29.1	8.80	96	19.07	19.74	10.0U	0.02U	0.01U	0.10U	0.100	142	29
FALLS000.5VA	68a	07-22-2004	6.53	32.5	7.68	83	8.01	19.13	10.0U	0.08	0.05	0.10U	0.026	632	236
FALLS1T0.5MI	68a	11-05-2003	6.54	68.1	5.98	56	0.00	12.14	10.0U	0.02	0.09	0.15	0.093	2690	210
FALLS1T0.5MI	68a	02-11-2004	6.74	45.7	11.02	87	1.01	5.10	12.0	0.05	0.72	0.10U	0.033	770	48
FALLS1T0.5MI	68a	04-24-2004	6.30	52.4	8.20	85	0.29	17.00	10.0U	0.02U	0.01U	0.14	0.019	1460	188
FALLS1T0.5MI	68a	08-04-2004	6.50	53.9	5.90	73	0.06	26.21	10.0U	0.05	0.11	0.10U	0.021	916	125
FLAT002.4BT	66e	10-27-2003	6.84	30.8	8.07	77	0.83	13.44	10.0U	0.03	0.03	0.23	0.020	1860	230
FLAT002.4BT	66e	02-02-2004	6.81	26.2	12.47	95	3.09	4.13	10.0U	0.02	0.06	0.10U	0.004U	157	7
FLAT002.4BT	66e	05-04-2004	6.40	29.6	9.20	97	4.43	18.10	10.0U	0.02U	0.02	0.17	0.007	219	19
FLAT002.4BT	66e	07-19-2004	6.68	33.1	6.12	76	0.85	26.31	28.0	0.02U	0.14	0.12	0.004U	2330	203
FORD1T1.4BN	71f	10-14-2003	6.99	95.3	7.36	79	0.18	18.54	10.0U	0.02U	0.04	0.27	0.004U	370	148

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
FORD1T1.4BN	71f	01-13-2004	6.77	58.0	11.15	93	0.43	7.68	10.0U	0.03	0.11	0.19	0.004U	1310	350
FORD1T1.4BN	71f	04-07-2004	6.62	63.2	8.35	91	0.21	19.31	10.0U	0.02U	0.10	0.32	0.015	230	115
FORD1T1.4BN	71f	07-08-2004	7.58	57.8	6.86	92	0.64	31.10	20.0	0.02U	0.03	0.10U	0.054	460	398
FWATE031.6PU	71g	12-03-2003	7.74	259.1	11.68	101	25.14	9.00	10.0U	0.02U	0.81	0.16	0.130	502	45
FWATE031.6PU	71g	02-11-2004	7.86	183.6	10.90	93	21.06	8.61	11.0	0.02U	0.80	0.21	0.012	719	39
FWATE031.6PU	71g	04-29-2004	7.90	252.0	10.16	100	26.94	14.74	10.0U	0.03	0.45	0.10U	0.004U	811	55
FWATE031.6PU	71g	07-22-2004	7.81	292.7	6.24	75	34.70	24.28	10.0U	0.03	0.35	0.10U	0.028	129	56
GOODI001.1DE	71f	01-15-2004	7.32	79.5	10.87	88	0.83	6.17	10.0U	0.02	0.02	0.10U	0.004	264	78
GOODI001.1DE	71f	04-14-2004	6.61	59.1	10.28	98	5.49	13.24	10.0U	0.02U	0.01U	0.16	0.004U	299	48
GOODI001.1DE	71f	07-09-2004	6.61	117.4	5.82	67	0.26	22.69	10.0U	0.02	0.07	0.10U	0.062	1200	450
GRAY1T0.9HR	65e	10-08-2003	6.51	57.0	5.37	60	1.71	20.63	10.0U	0.10	1.38	0.29	0.046	838	274
GRAY1T0.9HR	65e	01-12-2004	6.68	27.0	11.22	92	0.08	6.67	10.0U	0.02U	0.06	0.25	0.004U	400	52
GRAY1T0.9HR	65e	04-06-2004	6.51	25.4	8.40	82	0.34	14.30	10.0U	0.03	0.54	0.31	0.004U	533	119
GRAY1T0.9HR	65e	07-08-2004	6.55	29.0	7.06	93	0.49	29.86	10.0U	0.03	0.03	0.10U	0.065	640	120
HALEY003.2HI	71f	10-05-2003	7.44	2.66	7.40	80	0.18	19.41	113	0.07	0.26	0.12	0.118	3640	897
HALEY003.2HI	71f	01-14-2004	7.76	240.1	10.89	90	0.60	7.00	10.0U	0.03	0.34	0.10U	0.004U	222	54
HALEY003.2HI	71f	04-16-2004	7.82	214.0	10.22	101	2.08	15.05	10.0U	0.02U	0.01U	0.19	0.042	476	172
HALEY003.2HI	71f	07-15-2004	7.50	255.4	7.22	88	0.49	25.29	10.0U	0.02U	0.12	0.13	0.004U	328	101
HANCO1T0.2LI	71g	02-11-2004	7.04	77.3	10.37	85	0.97	6.90	10.0U	0.06	0.34	0.56	0.613	704	142
HANCO1T0.2LI	71g	04-20-2004	7.60	92.4	9.30	110	0.15	23.60	10.0U	0.02	0.46	0.54	0.037	815	204
HUDSO000.3HR	65e	10-08-2003	6.63	23.8	8.56	95	1.76	20.53	10.0U	0.08	0.13	0.24	0.051	1700	368
HUDSO000.3HR	65e	01-13-2004	6.64	26.5	11.05	90	1.96	6.73	10.0U	0.10	0.05	0.29	0.004U	2070	291

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
HUDSO000.3HR	65e	04-07-2004	6.24	24.0	8.90	90	1.33	16.12	10.0U	0.02U	0.08	0.53	0.004U	2370	388
HUDSO000.3HR	65e	07-07-2004	6.58	33.1	7.77	101	1.30	28.71	10.0U	0.02U	0.01U	0.10U	0.072	925	525
HWATE1T0.1MO	66g	10-28-2003	6.77	25.0	8.99	85	0.06	12.69	10.0U	0.02U	0.03	0.15	0.019	1080	55
HWATE1T0.1MO	66g	02-03-2004	6.71	18.6	11.72	95	0.66	6.38	10.0U	0.02U	0.02	0.10U	0.004U	369	14
HWATE1T0.1MO	66g	05-05-2004	6.60	24.4	9.20	100	0.47	19.50	10.0U	0.02U	0.02	0.16	0.004	816	36
HWATE1T0.1MO	66g	07-20-2004	6.55	30.1	6.52	75	0.20	22.22	10.0U	0.02U	0.04	0.10U	0.011	1630	84
JONES1T0.2DI	71f	10-13-2003	7.80	381.0	8.50	91	0.35	18.82	10.0U	0.07	0.10	0.29	0.004U	48	109
JONES1T0.2DI	71f	01-20-2004	6.90	434.0	9.80	91	0.91	11.90	10.0U	0.06	0.17	0.10U	0.004U	25U	5U
JONES1T0.2DI	71f	04-08-2004	7.06	412.9	6.40	62	0.28	13.74	10.0U	0.02U	0.59	0.18	0.017	104	10
JONES1T0.2DI	71f	07-09-2004	7.08	404.0	6.92	73	0.34	17.70	10.0U	0.02U	0.51	0.10U	0.044	94	33
JONES2T1.6DI	71f	10-13-2003	7.27	381.0	6.99	91	0.61	20.45	30.0	0.02U	0.13	0.19	0.013	1000	136
JONES2T1.6DI	71f	01-21-2004	7.68	248.1	12.11	93	0.81	4.14	10.0U	0.02U	0.18	0.10U	0.004U	56	19
JONES2T1.6DI	71f	04-13-2004	7.42	241.0	10.40	97	7.50	12.29	10.0U	0.02U	0.09	0.28	0.012	131	82
JONES2T1.6DI	71f	07-09-2004	8.18	324.4	6.84	88	1.08	28.53	10.0U	0.03	0.03	0.10U	0.032	140	86
LAURE003.4MO	67h	10-28-2003	7.94	150.7	8.66	89	1.81	16.03	10.0U	0.03	0.01U	0.23	0.018	37	93
LAURE003.4MO	67h	02-03-2004	7.82	146.8	12.50	98	0.85	5.22	10.0U	0.07	0.10	0.23	0.004U	117	128
LAURE003.4MO	67h	05-05-2004	6.90	175.0	9.60	93	0.02	13.70	51.0	0.02U	0.13	0.14	0.004U	599	487
LAURE003.4MO	67h	07-20-2004	7.49	185.0	6.10	71	0.01	23.25	10.0U	0.02U	0.35	0.10U	0.039	9770	5550
LAURE005.7RH	68a	10-30-2003	6.59	117.6	3.80	38	0.07	15.50	23.0	0.28	0.19	0.51	0.008	4940	809
LAURE005.7RH	68a	02-10-2004	6.69	59.1	11.06	86	0.78	4.68	13.0	0.02U	0.81	0.16	0.012	1290	98
LAURE005.7RH	68a	04-22-2004	7.00	60.8	8.70	98	9.50	21.00	10.0U	0.02U	0.17	0.35	0.026	973	182
LAURE005.7RH	68a	08-03-2004	NA	NA	NA	NA	NA	NA	10.0U	0.23	0.52	0.10U	0.024	1610	982

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
LFGIZ003.4GY	68a	11-06-2003	7.34	206.0	7.44	79	1.02	18.06	10.0U	0.02U	0.05	0.2	0.004U	207	160
LFGIZ003.4GY	68a	02-05-2004	7.63	173.1	12.06	92	6.50	4.03	10.0U	0.03	0.62	0.17	0.009	132	67
LFGIZ003.4GY	68a	04-21-2004	7.40	176.0	8.40	89	2.64	18.20	10.0U	0.02U	0.53	0.10U	0.025	159	62
LFGIZ003.4GY	68a	08-04-2004	7.27	170.0	6.84	83	3.08	24.98	10.0U	0.02	0.14	0.10U	0.085	148	79
LOONE002.5MI	68c	11-06-2003	7.30	211.0	6.27	68	0.25	19.24	72.0	0.03	0.08	0.31	0.050	4210	1720
LOONE002.5MI	68c	02-04-2004	7.64	192.9	11.52	93	0.50	6.28	10.0U	0.02U	0.04	0.10U	0.004U	218	66
LOONE002.5MI	68c	04-21-2004	7.70	222.0	8.50	89	0.38	17.80	10.0	0.01U	0.01U	0.10U	0.004U	187	63
LOONE002.5MI	68c	08-04-2004	7.44	221.0	6.19	74	0.12	24.00	10.0U	0.03	0.05	0.10U	0.020	1370	411
LOOPE001.0OV	68a	02-04-2004	6.46	42.4	13.34	101	2.56	3.57	10.0U	0.06	0.08	0.21	0.004U	311	264
LOOPE001.0OV	68a	05-10-2004	6.84	50.9	7.70	86	0.47	20.74	10.0U	0.02U	0.01U	0.10U	0.116	112	58
LOOPE001.0OV	68a	07-21-2004	7.18	71.1	5.37	67	0.33	26.80	10.0U	0.02U	0.08	0.10U	0.020	263	103
LTRAC005.0CY	71g	11-14-2003	7.60	203.6	10.99	100	1.88	11.06	10.0U	0.02	0.55	0.30	0.004U	383	114
LTRAC005.0CY	71g	02-11-2004	7.04	72.5	12.42	100	13.33	6.09	14.0	0.02U	1.03	0.19	0.076	1590	51
LTRAC005.0CY	71g	05-13-2004	7.72	173.0	7.78	90	2.49	22.75	10.0U	0.04	0.64	0.10U	0.029	161	93
LTRAC005.0CY	71g	07-22-2004	7.88	194.2	5.57	70	2.98	26.79	10.0	0.05	0.17	0.29	0.042	268	215
MAMMY010.1CU	68a	11-06-2003	6.77	57.4	8.39	87	8.88	16.86	10.0U	0.02	0.10	0.10U	0.009	1250	184
MAMMY010.1CU	68a	02-04-2004	6.23	35.2	13.37	101	2.56	3.48	10.0U	0.04	0.25	0.10U	0.004	263	39
MAMMY010.1CU	68a	04-28-2004	6.72	34.6	9.91	97	1.60	14.38	10.0U	0.03	0.18	0.10U	0.008	510	82
MAMMY010.1CU	68a	07-21-2004	7.12	66.7	6.47	73	0.28	21.36	10.0U	0.02U	0.43	0.10U	0.017	750	96
MCCAM000.7PO	66e	10-29-2003	6.65	46.5	6.78	65	0.04	13.40	13.0	0.02U	0.03	0.16	0.012	2220	419
MCCAM000.7PO	66e	02-02-2004	6.95	36.6	12.18	94	0.75	4.24	10.0U	0.01	0.05	0.16	0.004U	237	21
MCCAM000.7PO	66e	04-22-2004	6.30	37.4	9.70	93	0.38	13.30	10.0U	0.02U	0.01U	0.10U	0.027	338	39

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
MCCAM000.7PO	66e	07-21-2004	6.78	54.8	6.42	71	0.00	20.06	10.0U	0.06	0.20	0.17	0.025	2290	293
MERID006.5MN	65e	10-05-2003	6.67	41.4	8.21	90	2.42	19.56	11.0	0.07	0.16	0.19	0.010	638	313
MERID006.5MN	65e	01-14-2004	6.64	31.1	11.07	89	2.93	6.15	10.0U	0.02U	0.15	0.10U	0.004U	543	109
MERID006.5MN	65e	04-07-2004	6.40	45.8	7.83	79	2.62	16.01	10.0U	0.02U	0.09	0.15	0.018	438	149
MERID006.5MN	65e	07-09-2004	6.63	50.4	7.24	91	8.83	27.35	17.0	0.04	0.07	0.10U	0.054	765	354
MOODY002.0HR	74b	10-07-2003	6.22	33.9	8.66	94	4.86	19.42	10.0U	0.09	0.52	0.15	0.015	1100	252
MOODY002.0HR	74b	01-13-2004	6.41	38.2	10.03	85	4.01	8.02	11.0	0.05	0.41	0.10U	0.004	1600	268
MOODY002.0HR	74b	04-06-2004	5.96	37.3	8.35	84	5.23	15.67	10.0U	0.04	0.33	0.16	0.004U	1190	296
MOODY002.0HR	74b	07-07-2004	6.01	39.1	7.38	86	4.49	22.78	10.0U	0.02U	0.29	0.10U	0.048	994	377
NORTH005.7CU	68a	11-12-2003	6.60	63.3	8.90	88	0.25	15.11	10.0U	0.04	0.06	0.45	0.004	1480	624
NORTH005.7CU	68a	02-09-2004	6.94	56.3	12.04	92	10.74	3.94	10.0U	0.03	0.07	0.35	0.012	218	322
NORTH005.7CU	68a	05-13-2004	6.39	68.5	6.84	81	0.58	23.98	10.0U	0.05	0.08	0.10	0.049	359	119
NORTH005.7CU	68a	07-27-2004	6.61	68.7	5.87	72	0.96	25.86	10.0U	0.02U	0.06	0.17	0.004U	1660	334
OBED040.2CU	68a	02-10-2004	7.12	57.0	11.99	92	13.67	4.10	10.0U	0.02U	0.31	0.10U	0.008	338	46
OBED040.2CU	68a	05-14-2004	7.05	67.2	8.38	95	1.19	21.65	10.0U	0.02	0.11	0.12	0.007	38	31
OBED040.2CU	68a	07-27-2004	7.34	69.5	6.58	82	4.00	26.74	10.0U	0.02U	0.04	0.10U	0.008	160	116
ODAIN000.3HR	65e	10-07-2003	6.51	40.4	8.80	95	8.63	18.89	10.0U	0.13	0.13	0.23	0.022	563	262
ODAIN000.3HR	65e	01-12-2004	6.48	35.5	11.16	91	7.98	6.68	10.0U	0.02U	0.18	0.10U	0.008	1310	101
ODAIN000.3HR	65e	04-05-2004	6.26	34.6	8.67	89	8.89	16.62	11.0	0.03	0.10	0.36	0.008	1130	141
ODAIN000.3HR	65e	07-08-2004	6.30	40.3	8.25	102	10.08	26.37	10.0U	0.02	0.04	0.10U	0.059	809	348
OTOWN1T0.9HN	65e	01-13-2004	6.36	122.7	9.68	78	0.02	6.36	16.0	0.09	0.33	0.29	0.015	1020	350
OTOWN1T0.9HN	65e	04-06-2004	6.17	161.4	8.71	85	0.002	14.25	30.0	0.02	0.24	0.58	0.007	4080	677

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
PINEY014.6CS	65e	10-05-2003	7.10	35.0	8.58	97	1.02	21.28	10.0U	0.06	0.09	0.21	0.008	738	101
PINEY014.6CS	65e	01-14-2004	6.41	26.0	11.36	90	1.46	5.60	10.0U	0.02U	0.03	0.18	0.004U	678	57
PINEY014.6CS	65e	04-05-2004	6.61	27.2	7.82	80	1.04	16.59	10.0U	0.03	0.10	0.20	0.004U	521	43
PINEY014.6CS	65e	07-08-2004	6.75	40.9	6.58	88	0.90	30.57	10.0U	0.03	0.04	0.10U	0.062	1560	301
POND1T0.1CU	68a	02-10-2004	6.48	29.8	10.98	87	3.29	5.65	10.0U	0.02U	0.29	0.22	0.004U	546	43
POND1T0.1CU	68a	05-12-2004	6.30	49.8	8.76	87	0.55	15.16	10.0U	0.03	0.20	0.30	0.022	1110	142
RATTL000.10UC	66e	10-28-2003	6.39	22.8	9.37	84	0.30	10.61	10.0U	0.03	0.04	0.36	0.004U	25U	14
RATTL000.10UC	66e	02-03-2004	6.16	21.6	13.06	99	0.27	3.60	10.0U	0.02U	0.24	0.10U	0.011	25U	10
RATTL000.10UC	66e	04-27-2004	5.66	20.1	10.16	91	1.24	10.55	10.0U	0.02U	0.20	0.10U	0.004U	25U	5U
RATTL000.10UC	66e	07-20-2004	5.66	19.4	8.44	85	1.79	15.68	10.0U	0.02U	0.10U	0.10U	0.022	26	10
ROARI002.4CT	66d	10-28-2003	6.96	30.8	8.84	83	6.26	12.27	10.0U	0.04	0.10	0.31	0.136	521	36
ROARI002.4CT	66d	02-03-2004	7.01	30.7	10.32	78	8.80	3.87	10.0U	0.02	0.29	0.12	0.110	416	40
ROARI002.4CT	66d	04-27-2004	6.62	29.1	9.52	88	14.14	11.77	10.0U	0.02	0.15	0.10U	0.004U	198	14
ROARI002.4CT	66d	07-20-2004	6.75	32.0	7.43	81	7.43	19.68	10.0U	0.08	0.04	0.10U	0.020	1140	98
SAVAG009.8SE	68a	11-10-2003	6.29	18.2	9.49	92	20.46	14.02	10.0U	0.02U	0.01U	0.10U	0.004U	231	65
SAVAG009.8SE	68a	02-10-2004	5.71	18.7	11.38	90	33.13	5.35	10.0U	0.02U	0.16	0.10	0.016	300	39
SAVAG009.8SE	68a	05-11-2004	6.00	19.0	9.05	97	3.10	18.96	10.0U	0.02U	0.01U	0.10U	0.118	271	98
SAVAG009.8SE	68a	07-21-2004	6.15	22.0	6.73	78	3.19	22.74	10.0U	0.02U	0.01U	0.10U	0.044	489	213
SCANT001.3CU	68a	11-12-2003	6.48	106.2	5.24	51	0.00	14.34	15.0	0.70	0.05	1.21	0.004U	7130	1860
SCANT001.3CU	68a	02-09-2004	6.73	81.8	9.04	72	0.25	5.57	10.0U	0.03	0.09	0.24	0.018	2080	140
SCANT001.3CU	68a	05-10-2004	6.20	109.0	3.12	31	0.01	15.60	12.0	1.01	0.59	0.10U	0.016	13600	1590
SCOTT003.5SH	74b	01-13-2004	6.94	65.7	11.21	93	0.94	7.39	10.0U	0.02U	0.27	0.18	0.112	4520	39

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
SCOTT003.5SH	74b	04-05-2004	6.58	73.4	8.84	86	0.23	14.30	14.0	0.02U	0.28	0.20	0.060	4150	50
SCOTT003.5SH	74b	07-06-2004	6.84	116.5	7.62	91	0.02	24.44	13.0	0.03	0.17	0.10U	0.063	2430	93
SFHUR003.6HO	71f	10-07-2003	6.77	221.9	1.99	20	0.03	16.32	54.0	1.67	0.11	2.61	0.372	3E+05	5680
SFHUR003.6HO	71f	01-15-2004	6.88	139.0	10.12	82	0.06	6.16	10.0U	0.17	0.20	0.53	0.079	3280	869
SFHUR003.6HO	71f	04-06-2004	6.47	203.9	4.00	40	0.002	15.22	21.0	1.09	0.13	1.58	0.059	10400	4580
SFHUR003.6HO	71f	07-08-2004	7.56	114.6	4.77	64	0.15	31.20	12.0	0.29	0.06	0.18	0.075	4170	833
SFSYC006.3DA	71f	10-10-2003	7.76	123.7	8.88	97	0.21	19.41	11.0	0.12	0.20	0.22	0.050	343	164
SFSYC006.3DA	71f	01-22-2004	7.17	110.2	13.52	102	1.38	3.61	10.0U	0.02U	0.44	0.10U	0.004U	196	48
SFSYC006.3DA	71f	04-14-2004	7.50	98.0	11.07	99	10.92	10.47	10.0U	0.02	0.48	0.75	0.029	286	66
SFSYC006.3DA	71f	07-13-2004	8.25	142.1	7.78	106	0.46	31.57	14.0	0.03	0.04	0.35	0.024	294	218
SHARP1T0.4DA	71f	10-17-2003	7.10	266.0	6.25	64	0.09	16.31	19.0	1.67	0.35	2.26	0.134	2980	2000
SHARP1T0.4DA	71f	01-21-2004	7.47	194.7	11.27	88	0.68	4.77	10.0U	0.20	0.41	0.52	0.004U	303	107
SHARP1T0.4DA	71f	04-15-2004	7.38	184.0	10.29	94	3.49	11.23	10.0U	0.13	0.05	0.27	0.014	1050	692
SHARP1T0.4DA	71f	07-13-2004	7.04	278.0	6.10	66	0.02	19.18	10.0U	1.96	0.29	1.98	0.177	1500	1660
SHARP2T0.6DA	71f	10-16-2003	6.79	150.0	5.68	58	0.02	16.47	10.0U	0.27	0.25	0.49	0.021	1260	939
SHARP2T0.6DA	71f	01-21-2004	7.05	114.3	13.86	107	0.46	4.61	10.0U	0.03	0.15	0.45	0.004U	351	144
SHARP2T0.6DA	71f	04-13-2004	7.11	112.0	10.03	92	5.58	11.61	10.0U	0.02	0.07	0.39	0.039	306	164
SHARP2T0.6DA	71f	07-13-2004	7.01	166.0	6.09	68	0.03	21.07	80.0	1.29	0.30	1.64	0.410	4250	3890
SHELT001.3LI	71h	11-04-2003	8.73	161.0	9.14	97	6.48	18.12	10.0U	0.02U	0.10	0.10U	0.004U	181	144
SHELT001.3LI	71h	02-11-2004	7.46	176.0	10.59	89	24.03	7.88	10.0U	0.02U	1.06	0.10U	0.008	243	64
SHELT001.3LI	71h	04-20-2004	8.70	171.0	11.00	122	17.53	20.30	10.0	0.02U	0.14	0.10U	0.029	161	80
SHELT001.3LI	71h	08-05-2004	7.63	164.0	5.59	69	5.96	26.39	10.0	0.14	0.19	0.10U	0.032	341	252

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
SINKI1T0.8CO	67g	10-29-2003	7.77	243.0	8.72	84	0.17	13.51	10.0U	0.02	0.04	0.30	0.055	131	64
SINKI1T0.8CO	67g	02-03-2004	7.70	207.0	13.42	104	0.54	4.74	10.0U	0.02	0.12	0.10U	0.021	440	85
SINKI1T0.8CO	67g	04-27-2004	8.05	205.0	9.15	95	0.52	17.35	10.0U	0.02	0.04	0.10U	0.004U	185	29
SINKI1T0.8CO	67g	07-20-2004	7.78	232.6	6.61	79	0.12	24.29	17.0	0.03	0.06	0.10U	0.018	398	159
SINKI1T1.0CO-R	67g	10-27-2003	7.81	256.8	8.41	80	0.22	13.08	17.0	0.02U	0.18	0.10U	0.066	114	20
SINKI1T1.0CO-R	67g	02-02-2004	7.76	214.9	10.99	96	0.58	9.27	10.0U	0.02U	0.22	0.10U	0.022	107	9
SINKI1T1.0CO-R	67g	05-04-2004	7.60	226.0	10.35	97	0.31	12.50	10.0U	0.02U	0.20	0.10U	0.033	189	18
SINKI1T1.0CO-R	67g	07-19-2004	7.85	259.0	7.87	81	0.32	16.93	10.0U	0.02U	0.25	0.10U	0.004U	392	72
SQUAW001.4LS	71f	10-16-2003	6.60	47.7	4.81	50	0.58	17.07	10.0U	0.32	0.04	0.49	0.210	973	287
SQUAW001.4LS	71f	01-15-2004	7.18	66.4	10.18	82	1.22	6.14	10.0U	0.03	0.16	0.19	0.004U	349	58
SQUAW001.4LS	71f	04-13-2004	6.64	73.5	6.66	60	0.80	10.45	10.0U	0.05	0.46	0.10U	0.009	1120	491
SQUAW001.4LS	71f	07-13-2004	6.40	101.7	1.91	21	1.49	18.82	10.0U	2.38	0.01U	2.23	0.550	5260	632
STEEL000.3SU	67i	02-02-2004	8.03	470.0	13.03	100	12.49	4.15	10.0U	0.06	1.79	0.10U	0.004U	86	23
STEEL000.3SU	67i	04-26-2004	8.14	413.0	9.30	97	109.35	17.20	10.0U	0.02U	1.46	0.10U	0.004U	156	21
STEEL000.3SU	67i	07-19-2004	7.44	431.1	5.18	60	8.27	23.02	10.0U	0.21	0.75	0.10U	0.044	456	239
STEWA003.4HR	65e	10-08-2003	6.48	25.8	8.82	98	4.05	20.66	10.0U	0.08	0.16	0.21	0.059	1970	501
STEWA003.4HR	65e	01-14-2004	6.62	31.3	11.10	90	1.72	6.55	10.0U	0.03	0.05	0.10U	0.004U	1530	319
STEWA003.4HR	65e	04-07-2004	6.34	29.0	8.67	89	1.53	16.46	10.0U	0.02U	0.07	0.24	0.004U	1210	327
STEWA003.4HR	65e	07-08-2004	6.40	33.1	7.75	96	2.67	26.55	10.0U	0.04	0.03	0.10U	0.047	1890	888
TAYLO000.7OB	74a	10-08-2003	7.32	263.3	2.54	27	0.24	17.96	25.0	0.66	0.05	1.68	0.372	1740	1610
TAYLO000.7OB	74a	01-12-2004	7.87	345.0	12.45	97	4.60	4.94	23.0	0.02	0.10	0.42	0.163	1260	204
TAYLO000.7OB	74a	04-05-2004	7.99	372.8	8.80	90	4.71	16.48	35.0	0.02	0.10	0.39	0.072	1450	395

Table D-2 cont.

Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (°C)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
TAYLO000.7OB	74a	07-07-2004	7.41	285.2	3.96	51	5.65	27.94	28.0	0.18	0.11	0.10U	0.094	3187	606
THOMP005.9WY	65e	01-13-2004	6.22	106.7	8.60	66	0.004	3.97	256	0.27	2.71	0.68	0.219	4570	1750
THOMP005.9WY	65e	04-06-2004	6.41	57.9	9.46	84	0.00	9.87	118	0.07	0.41	1.30	0.173	9270	1230
THOMP005.9WY	65e	07-07-2004	6.55	56.3	5.30	65	0.04	25.37	10.0U	0.14	0.26	0.10U	0.051	1036	482
THOMP1T0.4HR	65e	01-13-2004	7.33	73.1	10.64	89	0.20	7.83	10.0U	0.22	0.72	0.65	0.013	214	40
THOMP1T0.4HR	65e	04-06-2004	7.77	61.2	7.69	82	0.06	18.44	10.0U	0.03	0.13	0.50	0.004U	164	37
THOMP1T0.4HR	65e	07-07-2004	7.27	56.5	5.44	70	0.34	28.39	18.0	0.05	0.09	0.10U	0.054	182	94
THREE1T0.3HN	65e	10-07-2003	6.26	64.7	7.37	77	0.06	17.34	11.0	0.27	0.14	0.56	0.039	6500	713
THREE1T0.3HN	65e	01-13-2004	6.23	54.9	7.26	60	0.16	6.84	10.0U	0.16	0.18	0.43	0.019	4300	212
THREE1T0.3HN	65e	04-06-2004	6.22	58.2	8.20	81	0.15	14.64	10.0	0.18	0.14	0.43	0.004U	4000	250
THREE1T0.3HN	65e	07-07-2004	6.46	40.8	6.30	82	0.51	29.05	10.0U	0.04	0.06	0.18	0.019	2535	121
TMILE1T0.2FR	68a	02-05-2004	6.47	14.8	11.86	100	2.60	7.94	10.0U	0.02	0.05	0.10	0.004U	465	30
TMILE1T0.2FR	68a	04-21-2004	6.00	19.3	8.30	88	0.33	18.00	10.0U	0.02U	0.01U	0.10U	0.004U	673	91
TMILE1T0.2FR	68a	08-04-2004	6.39	25.9	5.88	74	0.00	27.01	16.0	0.04	0.04	0.10U	0.086	2890	278
TRAIL1T0.4CU	68a	02-10-2004	7.31	84.7	11.34	91	0.72	5.95	10.0U	0.02U	0.16	1.40	0.220	442	77
TRAIL1T0.4CU	68a	05-13-2004	6.61	104.6	7.60	84	0.09	20.27	10.0U	0.02	0.12	0.10U	0.021	610	268
TRAIL1T0.4CU	68a	07-26-2004	6.65	126.3	6.49	73	0.02	21.20	64.0	0.02U	1.33	0.10U	0.007	7940	2450
TULL000.3OB	74a	01-12-2004	7.46	382.0	12.63	98	4.04	4.77	15.0	0.02U	0.10	0.41	0.122	1030	152
TULL000.3OB	74a	04-05-2004	8.13	469.8	9.01	89	2.87	14.90	52.0	0.10	0.10	0.64	0.158	2430	467
TULL000.3OB	74a	07-07-2004	7.39	291.3	2.24	28	1.45	27.75	25.0	0.24	0.09	0.10U	0.128	1216	836
WALKE1T0.3DA	71h	10-10-2003	7.29	269.0	6.17	67	0.22	19.06	20.0	0.25	0.19	0.38	0.060	1190	818
WALKE1T0.3DA	71h	01-20-2004	7.22	260.0	10.26	83	1.01	6.36	10.0U	0.04	0.59	0.10U	0.004	165	60

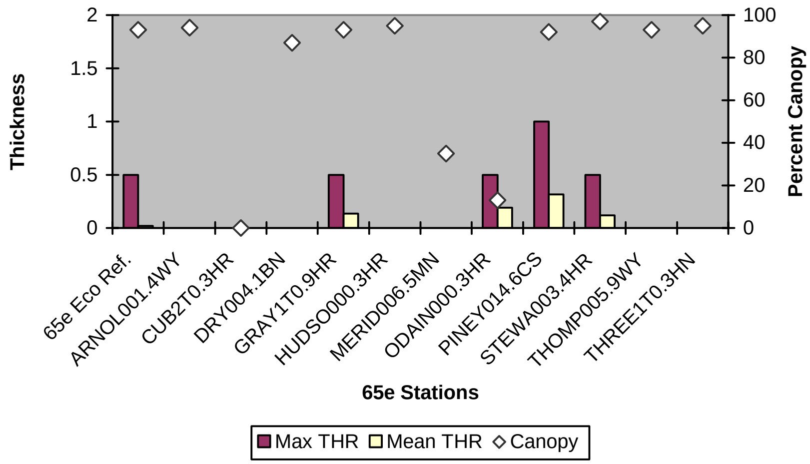
Table D-2 cont.

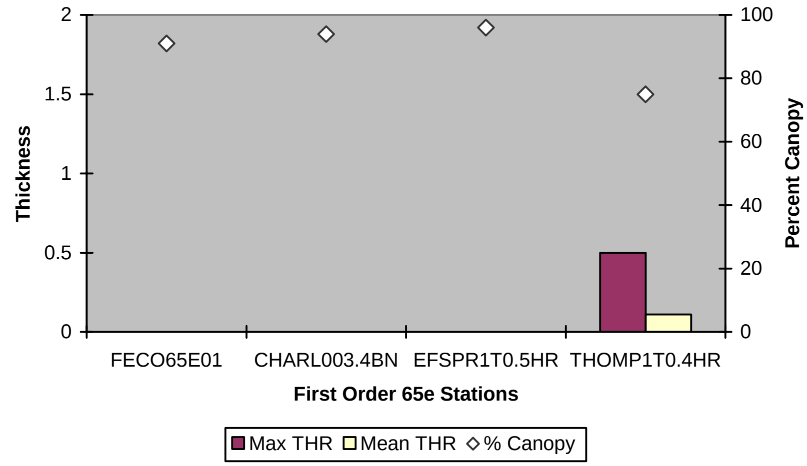
Station ID	Eco	Date	pH	Conduc-tivity (uMHO)	DO (mg/L)	DO % Sat	Flow (cfs)	Temp (ºC)	Sus Res (mg/L)	NH_3-N (mg/L)	NO_2+ NO_3 (mg/L)	TKN (mg/L)	Total-P (mg/L)	Fe (ug/L)	Mn (ug/L)
WALKE1T0.3DA	71h	04-08-2004	7.14	251.0	7.76	76	0.42	14.36	10.0U	0.02U	0.19	0.24	0.038	361	110
WALKE1T0.3DA	71h	07-13-2004	7.19	262.0	3.85	47	0.12	25.94	10.0U	0.02U	0.01U	0.10U	0.004U	25U	5U
WASHB003.0LI	71g	11-04-2003	7.35	108.0	4.81	51	0.26	18.17	17.0	0.02U	0.14	0.12	0.004U	264	162
WASHB003.0LI	71g	02-11-2004	6.59	45.3	10.44	82	5.12	6.48	12.0	0.02U	1.65	0.19	0.187	604	61
WASHB003.0LI	71g	04-20-2004	7.10	60.4	8.60	95	1.33	20.40	11.0	0.04	0.01U	0.10	0.024	832	358
WASHB003.0LI	71g	08-05-2004	7.31	86.8	4.30	56	0.34	28.59	18.0	0.03	0.19	0.10U	0.074	844	464
WEAVE001.0LW	71f	10-14-2003	6.97	63.7	7.04	79	0.60	20.95	15.0	0.09	0.29	0.10U	0.028	1350	197
WEAVE001.0LW	71f	01-14-2004	7.24	73.0	10.73	87	0.85	6.14	10.0U	0.18	0.46	0.51	0.004U	673	91
WEAVE001.0LW	71f	04-13-2004	7.16	64.1	9.83	93	2.04	12.87	10.0U	0.02U	0.23	0.10U	0.004	413	57
WEAVE001.0LW	71f	07-13-2004	8.24	66.2	3.75	49	0.65	29.48	10.0U	0.18	0.25	0.56	0.053	684	115
WFDRA2T1.5SR	71g	10-06-2003	7.39	178.5	7.57	80	1.13	17.75	17.0	0.17	0.4	0.57	0.083	687	355
WFDRA2T1.5SR	71g	01-16-2004	7.81	196.6	11.87	94	2.71	5.49	10.0U	0.03	1.16	0.23	0.004U	788	201
WFDRA2T1.5SR	71g	04-14-2004	7.59	198.0	10.61	96	10.72	10.88	10.0U	0.12	0.61	0.47	0.016	505	87
WFDRA2T1.5SR	71g	07-12-2004	7.59	214.0	6.12	78	0.84	28.06	195	0.07	0.12	0.35	0.041	279	131
WOLF1T0.1LW	71f	10-14-2003	7.68	229.4	8.40	91	0.27	19.21	187	0.04	0.67	0.10U	0.004U	2100	1610
WOLF1T0.1LW	71f	01-14-2004	7.94	226.0	10.58	89	0.26	7.97	10.0U	0.03	0.42	0.19	0.004U	1350	1190
WOLF1T0.1LW	71f	04-14-2004	7.77	213.0	10.48	97	0.48	11.91	10.0U	0.02U	0.20	0.41	0.006	341	446
WOLF1T0.1LW	71f	07-14-2004	7.68	253.3	8.62	93	0.53	19.15	10.0U	0.09	0.34	0.10U	0.138	703	765

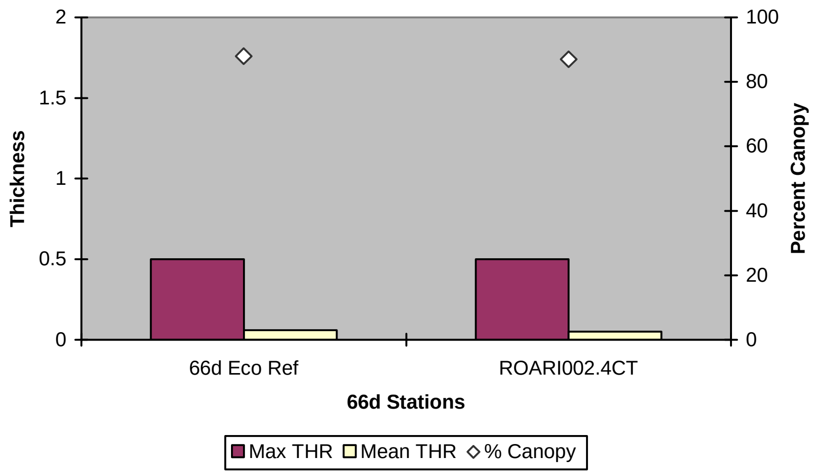
APPENDIX E

Periphyton Graphs by Ecoregion
Periphyton Data at Test Sites
Periphyton Data at Reference Site

Table E-1: Periphyton Graphs by Ecoregion







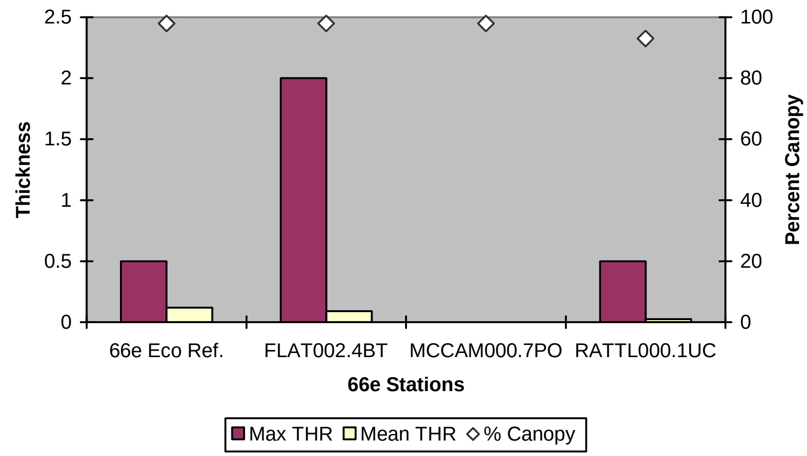
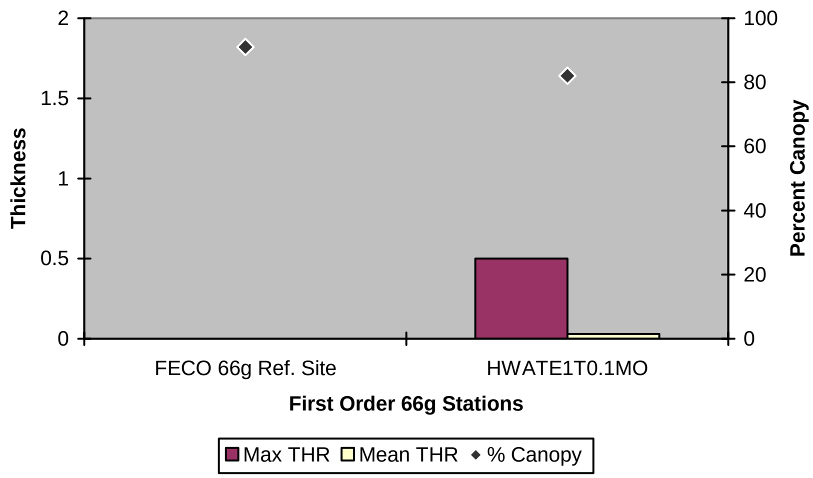
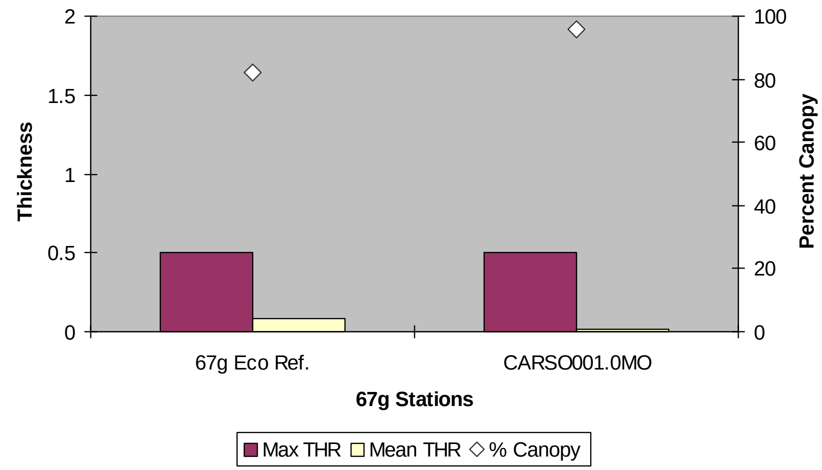
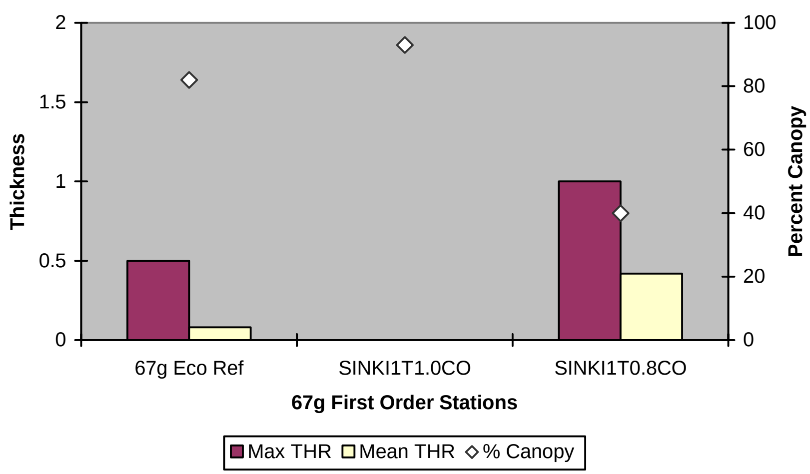


Table E-1 cont.







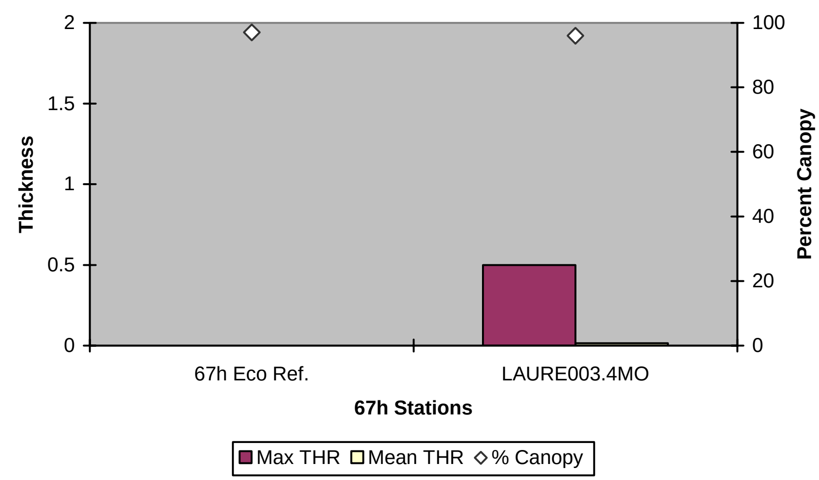
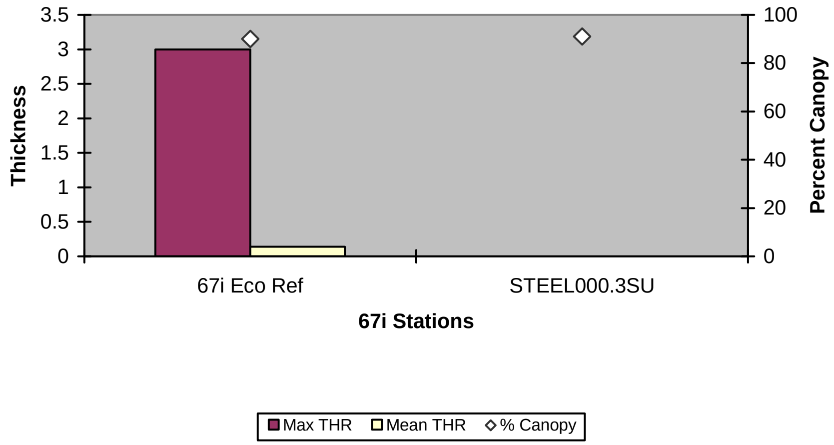
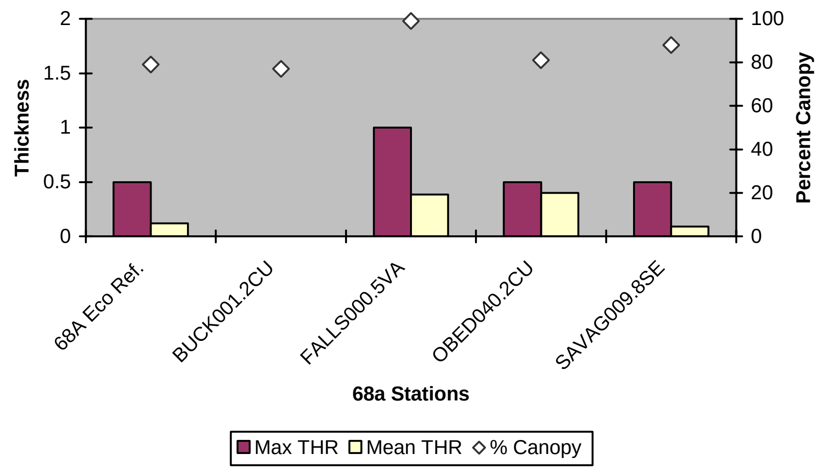
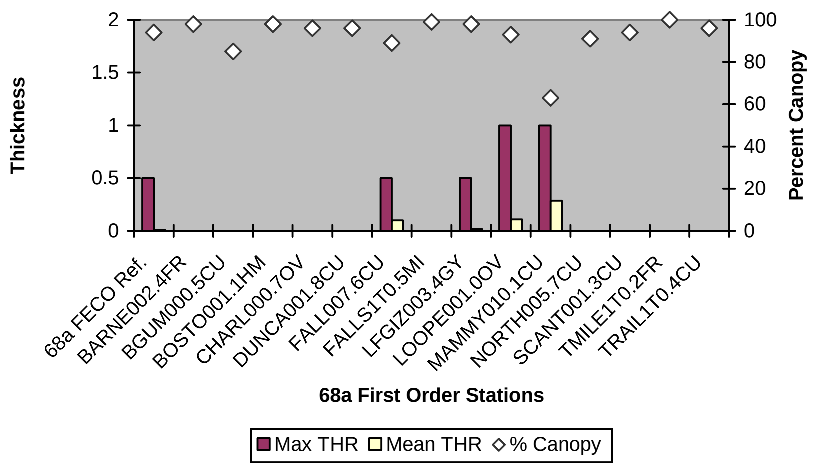


Table E-1 cont.







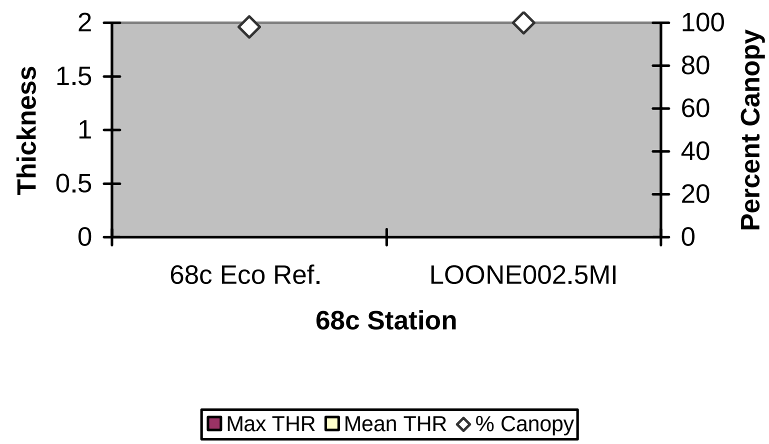
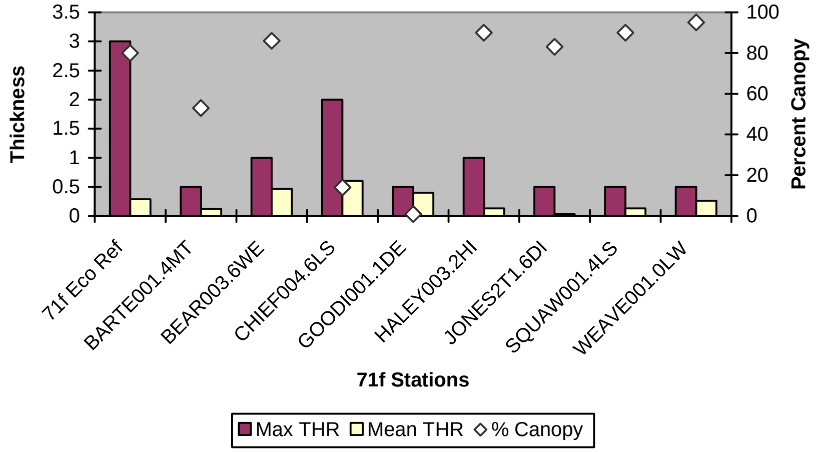
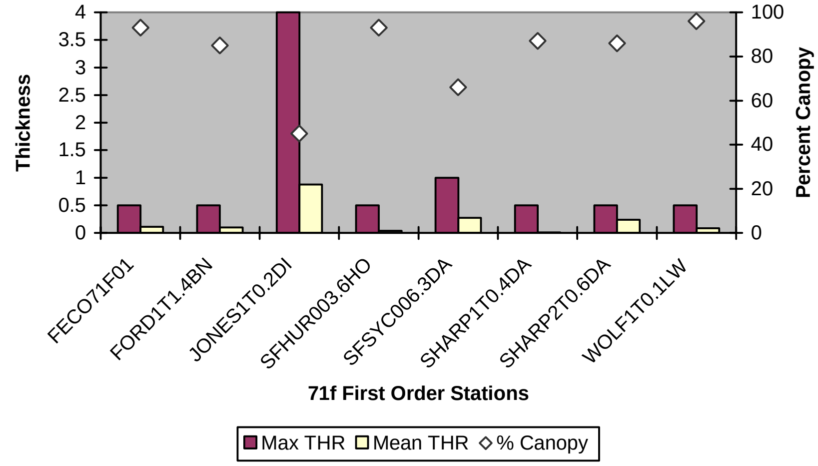
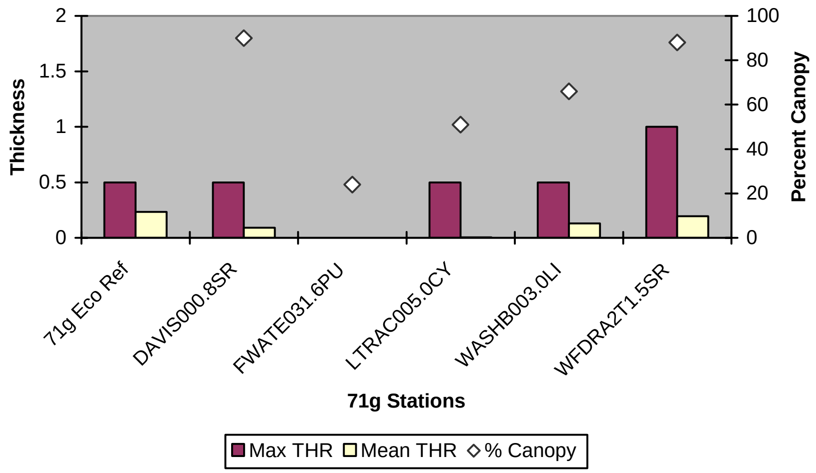


Table E-1 cont.







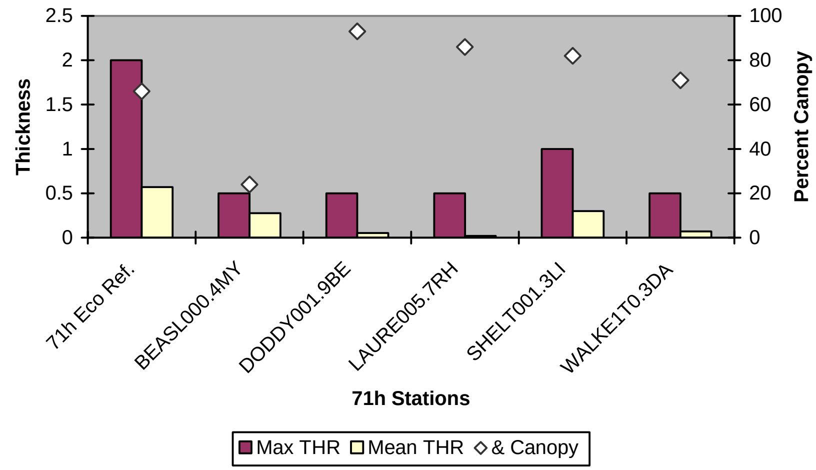
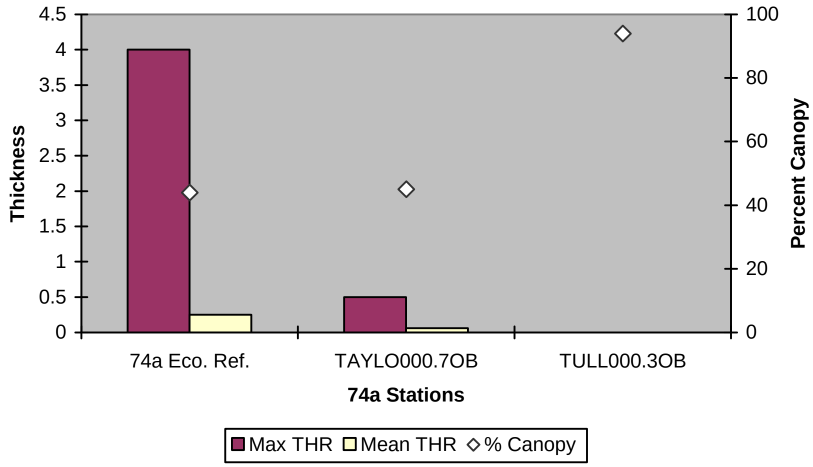


Table E-1 cont.



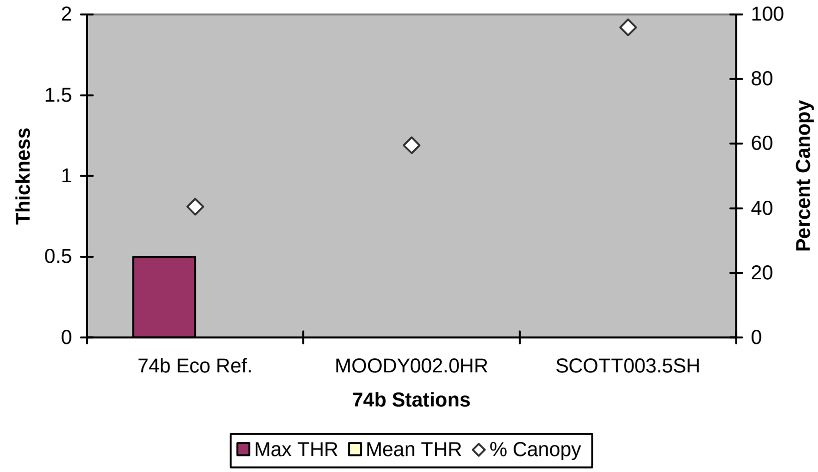


Table E-2: Periphyton Data at Test Sites

Station ID	Eco-region	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mn THR	Avg. % Canopy
ARNOL001.4WY	65e	7/6/04	0	0	0	0	0	94
BARNE002.4FR	68a	11/5/03	0	17	0	0	0	98
BARNE002.4FR	68a	8/4/04	0	0	0	0	0	96
BARTE001.4MT	71f	10/6/03	0	62	50	0.5	0.25	53
BARTE001.4MT	71f	7/12/04	2	24	0	0	0	49
BEAR003.6WE	71f	10/13/03	0	90	76	1	0.46	93
BEAR003.6WE	71f	7/14/04	0	100	86	1	0.47	86
BEASL000.4MY	71h	10/10/03	83	13	80	0.5	0.5	24
BEASL000.4MY	71h	7/15/04	69	31	11	0.5	0.05	56
BGUM000.5CU	68a	7/26/04	0	73	0	0	0	85
BOSTO001.1HM	68a	11/3/03	0	99	0	0	0	98
BOSTO001.1HM	68a	8/3/04	0	0	0	0	0	97
BUCK001.2CU	68a	11/5/03	31	47	0	0	0	77
BUCK001.2CU	68a	7/27/04	0	33	0	0	0	91
CARSO001.0MO	67g	10/29/03	0	83	0	0	0	92
CARSO001.0MO	67g	7/20/04	0	67	100	0.5	0.03	96
CHARL000.7OV	68a	7/21/04	0	50	0	0	0	96
CHARL003.4BN	65e	10/14/03	0	20	0	0	0	94
CHARL003.4BN	65e	7/8/04	0	2	0	0	0	90
CHIEF004.6LS	71f	10/13/03	0	69	63	2	0.44	19
CHIEF004.6LS	71f	7/13/04	0	100	94	2	0.77	14
CUB2T0.3HR	65e	10/15/03	0	0	0	0	0	0
CUB2T0.3HR	65e	7/7/04	0	0	0	0	0	0
DAVIS000.8SR	71g	10/6/03	0	66	30	0.5	0.15	90
DAVIS000.8SR	71g	7/12/04	0	88	6	0.5	0.03	90
DODDY001.9BE	71h	11/15/03	1	99	19	0.5	0.1	93
DODDY001.9BE	71h	8/3/04	0	31	0	0	0	96
DRY004.1BN	65e	10/16/03	0	32	0	0	0	87
DRY004.1BN	65e	7/8/04	0	21	0	0	0	91
DUNCA001.8CU	68a	11/12/03	1	97	0	0	0	96
DUNCA001.8CU	68a	7/22/04	0	100	0	0	0	96
EFSPR1T0.5HR	65e	10/7/03	0	0	0	0	0	92
EFSPR1T0.5HR	65e	7/7/04	0	50	0	0	0	96
FALL007.6CU	68a	11/6/03	0	98	38	0.5	0.19	89
FALL007.6CU	68a	7/21/04	0	96	0	0	0	95
FALLS000.5VA	68a	10/30/03	0	94	68	1	0.56	99
FALLS000.5VA	68a	7/22/04	0	89	100	0.5	0.21	92
FALLS1T0.5MI	68a	11/5/03	0	39	0	0	0	98
FALLS1T0.5MI	68a	8/4/04	0	38	0	0	0	99
FLAT002.4BT	66e	10/27/03	0	89	2	2	0.08	98
FLAT002.4BT	66e	7/19/04	0	98	100	0.5	0.1	98
FORD1T1.4BN	71f	10/14/03	0	100	0	0.5	0.2	85
FORD1T1.4BN	71f	7/18/04	0	0	0	0	0	93
FWATE031.6PU	71g	12/3/03	0	50	0	0	0	24
GOODI001.1DE	71f	7/9/04	27	67	80	0.5	0.4	1
GRAY1T0.9HR	65e	10/8/03	0	14	53	0.5	0.27	93
GRAY1T0.9HR	65e	7/8/04	0	24	0	0	0	97
HALEY003.2HI	71f	10/9/03	6	90	35	1	0.25	90
HALEY003.2HI	71f	7/15/04	8	24	3	0.5	0.01	90
HUDSO000.3HR	65e	10/8/03	0	0	0	0	0	84

Table E-2 cont.

Station ID	Eco-region	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mn THR	Avg. % Canopy
HUDSO000.3HR	65e	7/7/04	0	12	0	0	0	95
HWATE1T0.1MO	66g	10/28/03	0	91	0	0	0	87
HWATE1T0.1MO	66g	7/20/04	0	81	100	0.5	0.06	82
JONES1T0.2DI	71f	10/6/03	0	77	100	4	1.76	45
JONES1T0.2DI	71f	7/9/04	0	81	0	0	0	93
JONES2T1.6DI	71f	10/13/03	0	96	14	0.5	0.07	83
JONES2T1.6DI	71f	7/9/04	0	84	0	0	0	72
LAURE003.4MO	67h	10/28/03	0	98	6	0.5	0.03	96
LAURE003.4MO	67h	7/20/04	0	5	0	0	0	98
LAURE005.7RH	71h	10/30/03	0	32	3	0.5	0.02	86
LFGIZ003.4GY	68a	11/6/03	0	96	6	0.5	0.03	98
LFGIZ003.4GY	68a	8/4/04	0	100	0	0	0	88
LOONE002.5MI	68c	11/6/03	0	59	0	0	0	100
LOONE002.5MI	68c	8/4/04	0	57	0	0	0	97
LOOPE001.0OV	68a	7/21/04	0	62	18	1	0.11	93
LTRAC005.0CY	71g	11/14/03	0	38	3	0.5	0.01	51
LTRAC005.0CY	71g	7/22/04	0	68	0	0	0	87
MAMMY010.1CU	68a	11/6/03	0	98	76	0.5	0.38	63
MAMMY010.1CU	68a	7/21/04	0	97	25	1	0.19	80
MCCAM000.7PO	66e	10/29/03	0	93	0	0	0	98
MCCAM000.7PO	66e	7/21/04	0	0	0	0	0	94
MERID006.5MN	65e	10/9/03	0	3	0	0	0	16
MERID006.5MN	65e	7/9/04	0	7	0	0	0	35
MOODY002.0HR	74b	10/7/03	0	0	0	0	0	35
MOODY002.0HR	74b	7/7/04	0	0	0	0	0	84
NORTH005.7CU	68a	10/31/03	0	32	0	0	0	91
NORTH005.7CU	68a	7/27/04	0	4	0	0	0	91
OBED040.2CU	68a	7/27/04	0	24	82	0.5	0.4	81
ODAIN000.3HR	65e	10/7/03	0	20	38	0.5	0.19	13
PINEY014.6CS	65e	10/9/03	0	10	44	1	0.44	92
PINEY014.6CS	65e	7/8/04	0	43	0	0	0	97
RATTL000.1UC	66e	10/28/03	0	36	9	0.5	0.05	93
RATTL000.1UC	66e	7/20/04	0	45	0	0	0	95
ROARI002.4CT	66d	10/28/03	0	28	20	0.5	0.1	87
ROARI002.4CT	66d	7/20/04	0	57	0	0	0	94
SAVAG009.8SE	68a	11/10/03	11	82	14	0.5	0.07	90
SAVAG009.8SE	68a	7/21/04	0	87	100	0.5	0.11	88
SCANT001.3CU	68a	11/12/03	0	0	0	0	0	94
SCOTT003.5SH	74b	7/6/04	0	53	0	0	0	96
SFHUR003.6HO	71f	10/7/03	0	63	16	0.5	0.08	93
SFHUR003.6HO	71f	7/8/04	1	68	0	0	0	94
SFSYC006.3DA	71f	10/10/03	5	95	13	1	0.07	67
SFSYC006.3DA	71f	7/13/04	21	79	73	1	0.48	66
SHARP1T0.4DA	71f	10/17/03	0	100	0	0	0	70
SHARP1T0.4DA	71f	7/13/04	0	46	5	0.5	0.02	87
SHARP2T0.6DA	71f	10/16/03	0	81	0	0	0	72
SHARP2T0.6DA	71f	7/13/04	0	100	97	0.5	0.48	86
SHELT001.3LI	71h	11/4/03	0	96	29	1	0.22	82
SHELT001.3LI	71h	8/5/04	0	100	100	1	0.38	82
SINKI1T0.8CO	67g	10/29/03	0	41	100	1	0.84	40
SINKI1T0.8CO	67g	7/20/04	0	24	0	0	0	66

Table E-2 cont.

Station ID	Eco-region	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mn THR	Avg. % Canopy
SQUAW001.4LS	71f	10/16/03	13	59	47	0.5	0.26	90
SQUAW001.4LS	71f	7/13/04	0	96	0	0	0	95
STEEL000.3SU	67i	7/19/04	0	85	0	0	0	91
STEWA003.4HR	65e	10/8/03	0	7	50	0.5	0.25	97
STEWA003.4HR	65e	7/8/04	0	11	0	0	0	96
TAYLO000.7OB	74a	10/8/03	66	6	0	0	0	65
TAYLO000.7OB	74a	7/7/04	0	11	100	0.5	0.12	45
THOMP005.9WY	65e	7/7/04	0	13	0	0	0	93
THOMP1T0.4HR	65e	7/7/04	0	33	23	0.5	0.11	75
THREE1T0.3HN	65e	10/7/03	0	42	0	0	0	95
THREE1T0.3HN	65e	7/7/04	0	50	0	0	0	94
TMILE1T0.2FR	68a	8/4/04	0	0	0	0	0	100
TRAIL1T0.4CU	68a	7/26/04	0	57	0	0	0	96
TULL000.3OB	74a	7/7/04	Dead 0	0	0	0	0	94
WALKE1T0.3DA	71h	10/10/03	18	58	10	0.5	0.07	71
WALKE1T0.3DA	71h	7/13/04	0	50	13	0.5	0.07	85
WASHB003.0LI	71g	11/4/03	0	94	21	0.5	0.1	83
WASHB003.0LI	71g	8/5/04	0	47	100	0.5	0.16	66
WEAVE001.0LW	71f	10/13/03	0	69	24	0.5	0.12	99
WEAVE001.0LW	71f	7/13/04	0	100	82	0.5	0.41	95
WFDRA2T1.5SR	71g	10/6/03	6	76	47	1	0.25	88
WFDRA2T1.5SR	71g	7/12/04	0	91	28	0.5	0.14	92
WOLF1T0.1LW	71f	10/13/03	0	81	35	0.5	0.17	96
WOLF1T0.1LW	71f	7/14/04	0	100	0	0	0	98

Table E-3: Periphyton data at reference sites

Station ID	Eco-region	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mean THR	Avg. % Canopy
ECO65E04	65e	9/23/02	0	0	0	0	0.0	
ECO65E06	65e	9/23/02	0	0	0	0	0.0	
ECO65E08	65e	9/24/02	0	54	18	0.5	0.1	
ECO65E08	65e	10/5/04	0	0	0	0	0.0	96
ECO65E10	65e	10/1/02	0	0	0	0	0.0	
ECO65E11	65e	10/27/04	0	11	0	0	0.0	90
ECO66D01	66d	8/9/04	0	43	3	0.5	0.0	75
ECO66D03	66d	8/10/04	0	72	38	0.5	0.2	88
ECO66D05	66d	8/10/04	0	93	23	0.5	0.1	91
ECO66D06	66d	8/16/04	0	64	2	0.5	0.0	96
ECO66D07	66d	8/9/04	0	84	5	0.5	0.0	97
ECO66E04	66e	8/28/02	0	86	10	0.5	0.0	
ECO66E09	66e	8/17/04	0	95	54	0.5	0.3	98
ECO66E11	66e	8/27/02	0	90	6	0.5	0.0	
ECO66E17	66e	10/10/00	0	100	69	0.5	0.2	88
ECO66E18	66e	9/7/04	0	82	16	0.5	0.1	97
ECO67G01	67g	8/27/02	0	63	0	0	0.0	
ECO67G05	67g	8/27/02	0	82	5	0.5	0.0	
ECO67G08	67g	8/20/02	0	83	25	0.5	0.1	
ECO67G09	67g	8/20/02	0	69	35	0.5	0.2	
ECO67G10	67g	8/22/02	0	96	48	0.5	0.2	
ECO67G11	67g	8/11/04	0	92	10	0.5	0.0	82
ECO67H04	67h	9/15/04	0	51	0	0	0	97
ECO67H06	67h	9/7/04	0	27	0	0	0	95
ECO67I12	67i	8/31/04	0	64	5	3	0.14	90
ECO68A01	68a	9/5/02	0	86	7	0.5	0.0	
ECO68A03	68a	9/3/02	0	46	3	0.5	0.0	
ECO68A08	68a	9/15/04	0	74	0	0	0.0	62
ECO68A26	68a	9/5/02	0	91	93	0.5	0.5	
ECO68A27	68a	9/5/02	0	57	5	0.5	0.0	
ECO68A28	68a	8/31/04	0	97	42	0.5	0.2	79
ECO68C15	68c	07/11/06	0	75	0	0	0	98
ECO68C20	68c	07/11/06	0	50	0	0	0	99
ECO71F12	71f	6/21/02	0	80	74	1	0.5	80
ECO71F12	71f	10/9/02	0	78	44	1	0.3	
ECO71F12	71f	10/1/04	0	73	84	2	0.8	80
ECO71F16	71f	9/30/02	0	78	51	0.5	0.2	
ECO71F16	71f	9/29/04	0	94	14	0.5	0.1	55
ECO71F19	71f	9/30/02	0	85	54	0.5	0.2	
ECO71F19	71f	9/30/04	0	88	28	0.5	0.1	71
ECO71F27	71f	10/8/02	0	70	11	0.5	0.1	
ECO71F27	71f	10/22/04	0	96	0	0	0.0	94
ECO71F28	71f	9/30/04	0	94	88	3	0.4	72
ECO71F29	71f	9/29/04	0	84	73	0.5	0.4	77
ECO71G03	71g	9/30/02	21	83	1	0.5	0	
ECO71G04	71g	9/9/02	0	58	52	0.5	0.3	
ECO71G10	71g	8/13/02	0	52	81	0.5	0.4	
ECO71H06	71h	9/16/04	0	77	7	0.5	0.0	86
ECO71H09	71h	9/25/01	0	100	76	2	0.9	66
ECO71H09	71h	9/11/02	0	85	93	1	0.8	
ECO74A06	74a	10/26/04	0	78	14	4	0.5	44
ECO74A08	74a	11/8/04	0	31	0	0	0.0	75

Table E-3: cont.

Station ID	Eco-region	Date	% Macro-algae	% Substrate Available	% Micro-algae	Max THR	Mean THR	Avg. % Canopy
ECO74B01	74b	9/8/02	0	18	0	0	0.0	
ECO74B01	74b	11/23/04	0	49	0	0	0.0	36
ECO74B04	74b	11/16/04	0	15	12	0.5	0.0	45
FECO65E01	65e	10/15/03	0	0	0	0	0	96
FECO65E01	65e	7/8/04	0	0	0	0	0	91
FECO66G01	66g	10/28/03	0	78	0	0	0	93
FECO66G01	66g	7/20/04	0	62	100	0	0	91
FECO68A01	68a	11/4/03	0	87	4	0.5	0.02	94
FECO68A01	68a	7/21/04	0	68	0	0	0	96
FECO71F01	71f	10/1/03	0	90	0	0	0	95
FECO71F01	71f	7/13/04	0	80	46	0.5	0.23	93
SINKI1T1.0CO	67g	10/27/03	0	98	0	0	0	90
SINKI1T1.0CO	67g	7/19/04	0	70	0	0	0	93

ECO = Established Ecoregion Reference Station
FECO = Project Specific First Order Reference Station
SINKI1T1.0CO = Upstream Reference Station

APPENDIX F

Site Comparison to Criteria and Regional Reference Data

Table F-1: Site comparison to criteria and regional reference data. Fail, no-flow and low flow represent one or more seasons. Pass and good flow represent all 4 seasons sampled.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10^{th} Percen-tile	Temp Cri-teria	Temp > 90^{th} Percen-tile	Flow	TSS > 90^{th} Percen-tile	$NO_{2\text{-}3}$ Guide-lines	TKN > 90^{th} Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90^{th} percen-tile
ARNOL001.4WY	65e	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	**No**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
BAGWE1T0.2CU	68a	**Fail Both**	**Fail**	NA	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
BARNE002.4FR	68a	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
BARTE001.4MT	71f	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**
BEAR003.6WE	71f	**Fail Fall**	**Fail**	**Fail Micro-algae**	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**
BEASL000.4MY	71h	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Low**	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
BGUM000.5CU	68a	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**No**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
BOSTO001.1HM	68a	**Fail Both**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
BUCK001.2CU	68a	**Fail Spring**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
CARSO001.0MO	67g	**Fail Both**	Pass	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	Pass	Pass	**Fail**
CHARL000.7OV	68a	**Fail Both**	**Fail**	Pass	**Fail**	Pass	**Fail**	Pass	Pass	**No**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**
CHARL003.4BN	65e	**Fail Both**	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**	**Low**	**Fail**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10th Percen-tile	Temp Cri-teria	Temp > 90th Percen-tile	Flow	TSS > 90th Percen-tile	$NO_{2\text{-}3}$ Guide-lines	TKN > 90th Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90th percen-tile
CHIEF004.6LS	71f	**Fail Both**	Pass	**Fail Micro-**algae	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**
CUB2T0.3HR	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**
DAVIS000.8SR	71g	**Fail Both**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	Pass	**Fail**	**Fail**	Pass	Pass	**Fail**
DODDY001.9BE	71h	**Fail Both**	Pass	**Fail Macro-algae**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass	**Fail**
DRY004.1BN	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	Pass	Pass	**Fail**	Pass	Pass	Pass	**Fail**
DUNCA001.8CU	68a	**Fail Fall**	Pass	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	Pass	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
EFSPR1T0.5HR	65e	Pass Both	Pass	Pass	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	Pass	Pass	Pass
FALL007.6CU	68a	Pass Both	Pass	**Fail Micro-algae**	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
FALLS000.5VA	68a	**Fail Both**	**Fail**	**Fail Micro-algae**	**Fail**	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
FALLS1T0.5MI	68a	**Fail Spring**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
FLAT002.4BT	66e	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**
FORD1T1.4BN	71f	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**
FWATE0031.6PU	71g	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10th Percen-tile	Temp Cri-teria	Temp > 90th Percen-tile	Flow	TSS > 90th Percen-tile	NO_{2-3} Guide-lines	TKN > 90th Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90th percen-tile
GOODI001.1DE	71f	**Fail Spring**	**Fail**	**Fail Macro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**
GRAY1T0.9HR	65e	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	**Fail**	Pass	Pass	**Fail**	Pass	Pass
HALEY003.2HI	71F	Pass Both	**Fail**	**Rail Macro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**
HANCO1T0.2LI	71g	**Fail Both**	**Fail**	NA	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
HUDSO000.3HR	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	Pass	Pass	**Fail**	**Low**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
HWATE1T0.1MO	66g	**Fail Both**	Pass	**Fail Micro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	Pass	Pass	**Fail**	Pass	**Fail**	**Fail**	**Fail**
JONES1T0.2DI	71f	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	Pass	**Fail**	Pass	**Fail**	**Fail**	Pass	**Fail**
JONES2T1.6DI	71f	**Fail Spring**	Pass	Pass	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	Pass	**Fail**	Pass	Pass	**Fail**
LAURE003.4MO	67h	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	Pass	Pass	**Fail**	Pass	**Fail**	**Fail**
LAURE005.7RH	68a	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
LFGIZ003.4GY	68a	**Fail Both**	Pass	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	**Fail**	**Fail**	**Fail**	**Fail**	Pass	**Fail**
LOONE002.5MI	68c	**Fail Fall**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	**Fail**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10th Percen-tile	Temp Cri-teria	Temp > 90th Percen-tile	Flow	TSS > 90th Percen-tile	NO_{2-3} Guide-lines	TKN > 90th Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90th percen-tile
LOOPE001.0OV	68a	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**
LTRACE005.0CY	71g	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
MAMMY010.1CU	68a	**Fail Spring**	Pass	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	**Fail**	Pass	**Fail**	Pass	**Fail**	**Fail**
MCCAM000.7PO	66e	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	Pass	**No**	**Fail**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**
MERID006.5MN	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	Pass	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**
MOODY002.0HR	74b	**Fail Both**	Pass	Pass	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Fail**
NORTH005.7CU	68a	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
OBED040.2CU	68a	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	Pass	Pass	**Fail**	**No**	Pass	**Fail**	**Fail**	Pass	Pass	Pass	**Fail**
ODAIN000.3HR	65e	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	Pass	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
OTOWN1T0.9HN	65e	**Fail Both**	**Fail**	NA	Pass	Pass	Pass	Pass	Pass	**No**	**Fail**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Fail**
PINEY014.6CS	65e	**Fail Spring**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Low**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**	Pass
POND1T0.1CU	68a	**Fail Both**	**Fail**	NA	Pass	Pass	Pass	Pass	Pass	**No**	Pass	**Fail**	**Fail**	**Fail**	Pass	**Fail**	**Fail**
RATTL000.1UC	66e	**Fail Spring**	**Fail**	Pass	**Fail**	Pass	Pass	Pass	Pass	Good	Pass	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10th Percen-tile	Temp Cri-teria	Temp > 90th Percen-tile	Flow	TSS > 90th Percen-tile	NO_{2-3} Guide-lines	TKN > 90th Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90th percen-tile
ROARI002.4CT	66d	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
SAVAG009.8SE	68a	**Fail Both**	**Fail**	**Fail Macro-algae**	**Fail**	Pass	Pass	Pass	**Fail**	**Low**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**
SCANT001.3CU	68a	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	Pass	**Fail**	**Fail**
SCOTT003.5SH	74b	**Fail Both**	**Fail**	Pass	Pass	Pass	Pass	Pass	**Fail**	**No**	Pass	Pass	Pass	Pass	**Fail**	**Fail**	Pass
SFHUR003.6HO	71f	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
SFSYC006.3DA	71f	Pass Both	Pass	**Fail Micro & Macro-algae**	Pass	Pass	Pass	**Fail**	**Fail**	Good	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	Pass	**Fail**
SHARP1T0.4DA	71f	**Fail Both**	Pass	Pass	Pass	Pass	**Fail**	Pass	Pass	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
SHARP2T0.6DA	71f	**Fail Both**	Pass	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
SHELT001.3LI	71h	**Fail Both**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass	**Fail**
SINKI1T0.8CO	67g	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	Pass	Pass	Pass	**Fail**
SQUAW001.4LS	71f	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
STEEL000.3SU	67i	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	Pass	**Fail**	Pass	**Fail**	Pass	Pass	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10^{th} Percen-tile	Temp Cri-teria	Temp > 90^{th} Percen-tile	Flow	TSS > 90^{th} Percen-tile	NO_{2-3} Guide-lines	TKN > 90^{th} Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90^{th} percen-tile
STEWA003.4HR	65e	**Fail Spring**	**Fail**	**Fail Micro-algae**	Pass	Pass	Pass	Pass	**Fail**	**Low**	Pass	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**
TAYLO000.7OB	74a	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	Good	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
THOMP005.9WY	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
THOMP1T0.4HR	65e	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**No**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass
THREE1T0.3HN	65e	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	**Fail**
TMILE1T0.2FR	68a	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**No**	**Fail**	Pass	Pass	**Fail**	**Fail**	**Fail**	**Fail**
TRAIL1T0.4CU	68a	**Fail Both**	**Fail**	Pass	Pass	Pass	**Fail**	Pass	**Fail**	**No**	**Fail**	**Fail**	**Fail**	Pass	**Fail**	**Fail**	**Fail**
TULL000.3OB	74a	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	**No**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
WALKE1T0.3DA	71h	**Fail Both**	**Fail**	**Fail Macro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Low**	**Fail**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Fail**
WASHB003.0LI	71g	**Fail Both**	**Fail**	Pass	Pass	**Fail**	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	Pass	Pass	**Fail**	Pass	**Fail**
WEAVE001.0LW	71f	**Fail Both**	Pass	**Fail Micro-algae**	Pass	**Fail**	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
WFDRA2T1.5SR	71g	**Fail Both**	**Fail**	**Fail Micro-algae**	Pass	Pass	**Fail**	Pass	**Fail**	**Low**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	Pass	**Fail**

Table F-1 Cont.

Station ID	Eco-region	Bio-criteria	Habitat Guide-lines	Peri-phyton	pH 6–9	DO Cri-teria	% DO < 10th Percen-tile	Temp Cri-teria	Temp > 90th Percen-tile	Flow	TSS > 90th Percen-tile	NO_{2-3} Guide-lines	TKN > 90th Percen-tile	NH_3 Cri-teria*	TP Guide-lines	Fe < 1000 ug/L	Mn > 90th percen-tile
WOLF1T0.1LW	71f	**Fail Both**	Pass	Pass	Pass	Pass	**Fail**	Pass	**Fail**	Good	**Fail**	**Fail**	Pass	**Fail**	**Fail**	**Fail**	**Fail**

*** All sites passed proposed ammonia criteria.**