TOTAL MAXIMUM DAILY LOAD (TMDL)

For

pH and Iron

In The

Bear Creek Subwatershed

Located In The

South Fork Cumberland River Watershed

(HUC 05130104)

Scott County, Tennessee

FINAL

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LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
CCC	Criteria Continuous Concentration
CFR	Code of Federal regulations
CFS	Cubic Feet per Second
CMC	Criteria Maximum Concentration
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
RM	River Mile
TDEC	Tennessee Department of Environment & Conservation
TMDL	Total Maximum Daily Load
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation

SUMMARY SHEET

Total Maximum Daily Load (TMDL) for pH and Iron in South Fork Cumberland River Watershed (05130104)

Impaired Waterbody Information

State: Tennessee
Counties: Scott
Watershed: South Fork Cumberland River (HUC 05130104)
Constituents of Concern: pH and Iron

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN05130104050 – 1000	BEAR CREEK*	2.6
TN05130104050 – 0100	EAST FORK BEAR CREEK	5.7

*Portions of this waterbody lie in another state. This TMDL only address the portion of Bear Creek located in Tennessee.

Designated Uses:

The designated use classifications for waterbodies in the South Fork Cumberland River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004*:

The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

Derived from *National Recommended Water Quality Criteria (USEPA, 2006)*:

Iron, total* 1000 μg/L

*Tennessee does not have a numeric water quality criterion for iron. However, TDEC believes that meeting the above criteria will satisfy the requirement that "waters shall not contain substances or a combination of substances including disease-causing agents which, by way of either direct exposure or indirect exposure through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict of impair growth in fish or aquatic life or their offspring".

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) list as impaired due to pH and iron.

Portions of Bear Creek are located in Kentucky. This TMDL only addresses the portion of Bear Creek located in Tennessee. Kentucky surface water standards for pH and iron are similar to the criteria applied in this TMDL. Therefore, TDEC believes that meeting the Tennessee water quality criteria will also enable Bear Creek to meet the Kentucky surface water standards at the Tennessee/Kentucky state line.

Analysis of monitoring data for Bear Creek and East Fork Bear Creek suggests that they are still impaired for pH and iron. Analysis of monitoring data for West Fork Bear Creek suggests that it is also impaired for pH and iron. At this time, listing is suggested West Fork Bear Creek for pH and iron.

Analysis/Methodology:

Net alkalinity was used as a surrogate for pH. The net alkalinity TMDL for impaired waterbodies in the Bear Creek subwatershed was developed using a load duration curve methodology to assure compliance with the target net alkalinity of 10.8 mg/L (see Figure S-1 and Appendices C & D), which will provide a pH within the criteria range of 6.0 – 9.0. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads.

The TMDLs for net alkalinity and iron in the South Fork Cumberland River watershed are summarized in the following table.

Critical Conditions:

Water quality data collected over a period of 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

The 10-year period used for LSPC model simulation period for development of load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Implicit (conservative modeling assumptions) and explicit (10% of the water quality criteria for each individual metal for each impaired subwatershed or drainage area).

Summary of TMDLs, WLAs[a], & LAs expressed as daily loads for Impaired Waterbodies in the Bear Creek Subwatershed (part of HUC 05130104)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS	LAs
			[lbs/day]	[lbs/day]	[lbs/day]
Bear Creek (mainstem)	TN05130104050 – 1000	Net Alkalinity	$5.81 \times 10^1 * Q$	NA[b]	$5.81 \times 10^1 * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$
East Branch Bear Creek	TN05130104050 – 0100	Net Alkalinity	$5.81 \times 10^1 * Q$	NA[b]	$5.81 \times 10^1 * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$
West Branch Bear Creek	TN05130104050 – 0200	Net Alkalinity	$5.81 \times 10^1 * Q$	NA[b]	$5.81 \times 10^1 * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$

Notes: NA = Not Applicable.
Q = Mean Daily Flow (cfs).

a. There are currently no point sources in the Bear Creek Subwatershed; therefore, there is no required load reduction for point sources (WLA). Any future point sources must meet instream water quality standards at the point of discharge as specified in their NPDES permit.
b. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.2).

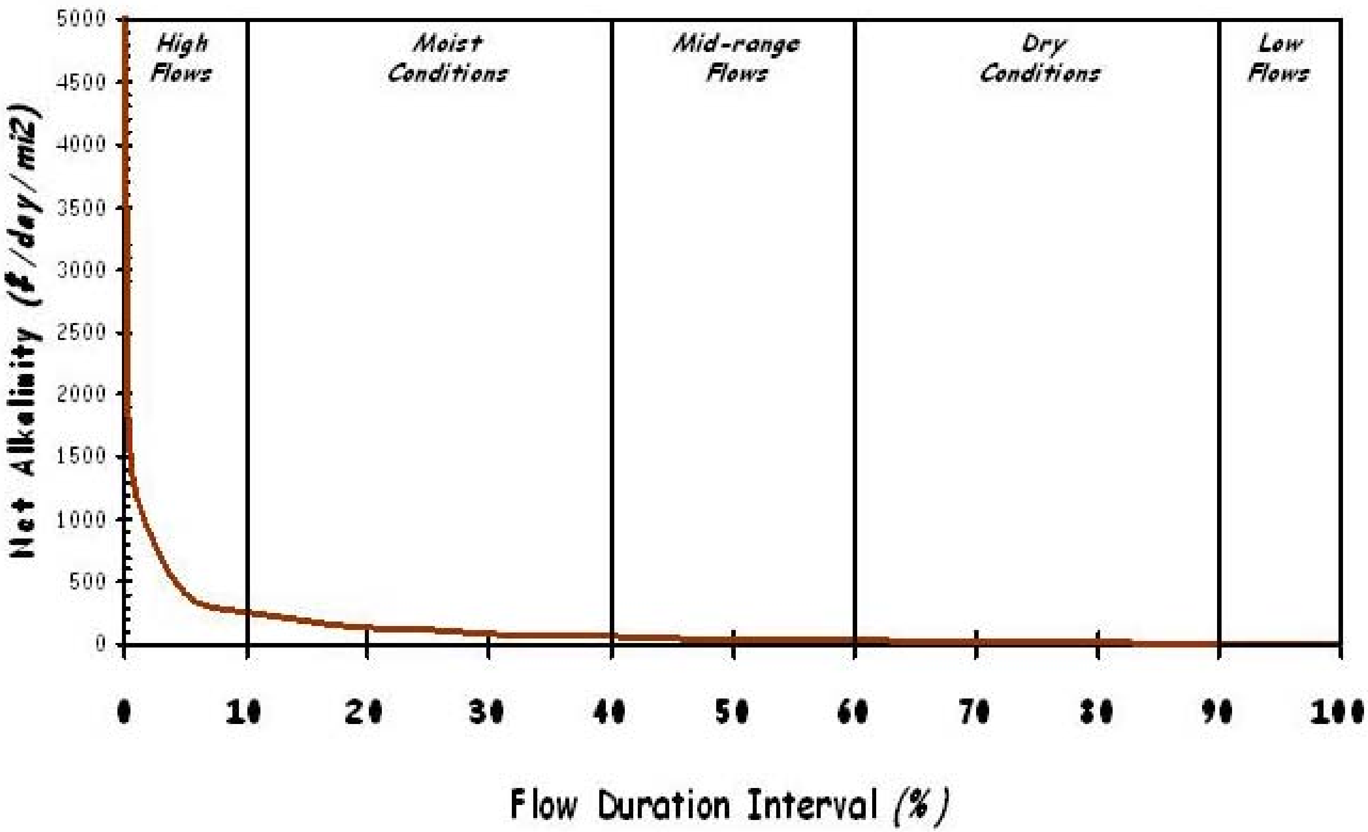

Figure S-1. Target Net Alkalinity Load Duration Curve

pH and IRON TOTAL MAXIMUM DAILY LOAD (TMDL) SOUTH FORK CUMBERLAND RIVER WATERSHED (HUC 05130104)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting designated uses. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991a).

2.0 WATERSHED DESCRIPTION

The South Fork Cumberland River Watershed (HUC 05130104), also referred to as the Big South Fork Watershed, is located in middle and eastern Tennessee and Kentucky (Figure 1). This document addresses only the portion of the watershed located in Tennessee. The South Fork Cumberland River Watershed falls within three Level III ecoregions (Southwestern Appalachians, Central Appalachians, and Interior Plateau) and contains four Level IV subecoregions (USEPA, 1997) as shown in Figure 2:

- **Cumberland Plateau (68a)** tablelands and open low mountains are about 1000 feet higher than the Eastern Highland Rim (71g) to the west, and receive slightly more precipitation with cooler annual temperatures than the surrounding lower-elevation ecoregions. The plateau surface is less dissected with lower relief compared to the Cumberland Mountains (69d) or the Plateau Escarpment (68c). Elevations are generally 1200-2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvanian-age conglomerate, sandstone, siltstone, and shale is covered by well-drained, acid soils of low fertility. Bituminous coal that has been extensively surface and underground mined underlies the region. Acidification of first and second order streams is common. Stream siltation and mine spoil bedload deposits continue as long-term problems in these headwater systems. Pockets of severe acid mine drainage persist.

- **Plateau Escarpment (68c)** is characterized by steep, forested slopes and high velocity, high gradient streams. Local relief is often 1000 feet or more. The geologic strata include Mississippian-age limestone, sandstone, shale, and siltstone, and Pennsylvanian-age shale, siltstone, sandstone, and conglomerate. Streams have cut down into the limestone, but the gorge talus slopes are composed of colluvium with huge angular, slabby blocks of sandstone. Vegetation community types in the ravines and gorges include mixed oak and chestnut oak on the upper slopes, mesic forests on the middle and lower slopes (beech-tulip poplar, sugar maple-basswood-ash-buckeye), with hemlock along rocky streamsides and river birch along floodplain terraces.

- The **Cumberland Mountains (69d)**, in contrast to the sandstone-dominated Cumberland Plateau (68a) to the west and southwest, are more highly dissected, with narrow-crested steep slopes, and younger Pennsylvanian-age shales, sandstones, siltstones, and coal. Narrow, winding valleys separate the mountain ridges, and relief is often 2000 feet. Cross Mountain, west of Lake City, reaches 3534 feet in elevation. Soils are generally well-drained, loamy, and acidic, with low fertility. The natural vegetation is a mixed mesophytic forest, although composition and abundance vary greatly depending on aspect, slope position, and degree of shading from adjacent land masses. Large tracts of land are owned by lumber and coal companies, and there are many areas of stripmining.

- **Eastern Highland Rim (71g)** has level terrain, with landforms characterized as tablelands of moderate relief and irregular plains. Mississippian-age limestone, chert, shale and dolomite predominate, and karst terrain sinkholes and depressions are especially noticeable between Sparta and McMinnville. Numerous springs and spring-associated fish fauna also typify the region. Natural vegetation for the region is transitional between the oak-hickory type to the west and the mixed mesophytic forests of the Appalachian ecoregions to the east. Bottomland hardwoods forests were once abundant in some areas, although much of the original bottomland forest has been inundated by several large impoundments. Barrens and former prairie areas are now mostly oak thickets or pasture and cropland.

The South Fork Cumberland River Watershed, located in Anderson, Campbell, Fentress, Morgan, Pickett, and Scott Counties, Tennessee, has a drainage area of approximately 976 square miles (mi^2) in Tennessee. The entire watershed, including portions of Tennessee and Kentucky, drains approximately 1,374 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the South Fork Cumberland River Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the South Fork Cumberland River Watershed is summarized in Table 1 and Figure 3. The Bear Creek subwatershed, located in McCreary (KY) and Scott (TN) Counties, has a drainage area of approximately 23 square miles, 16 square miles of which are in Tennessee. Land use for the Bear Creek subwatershed is also summarized in Table 1.

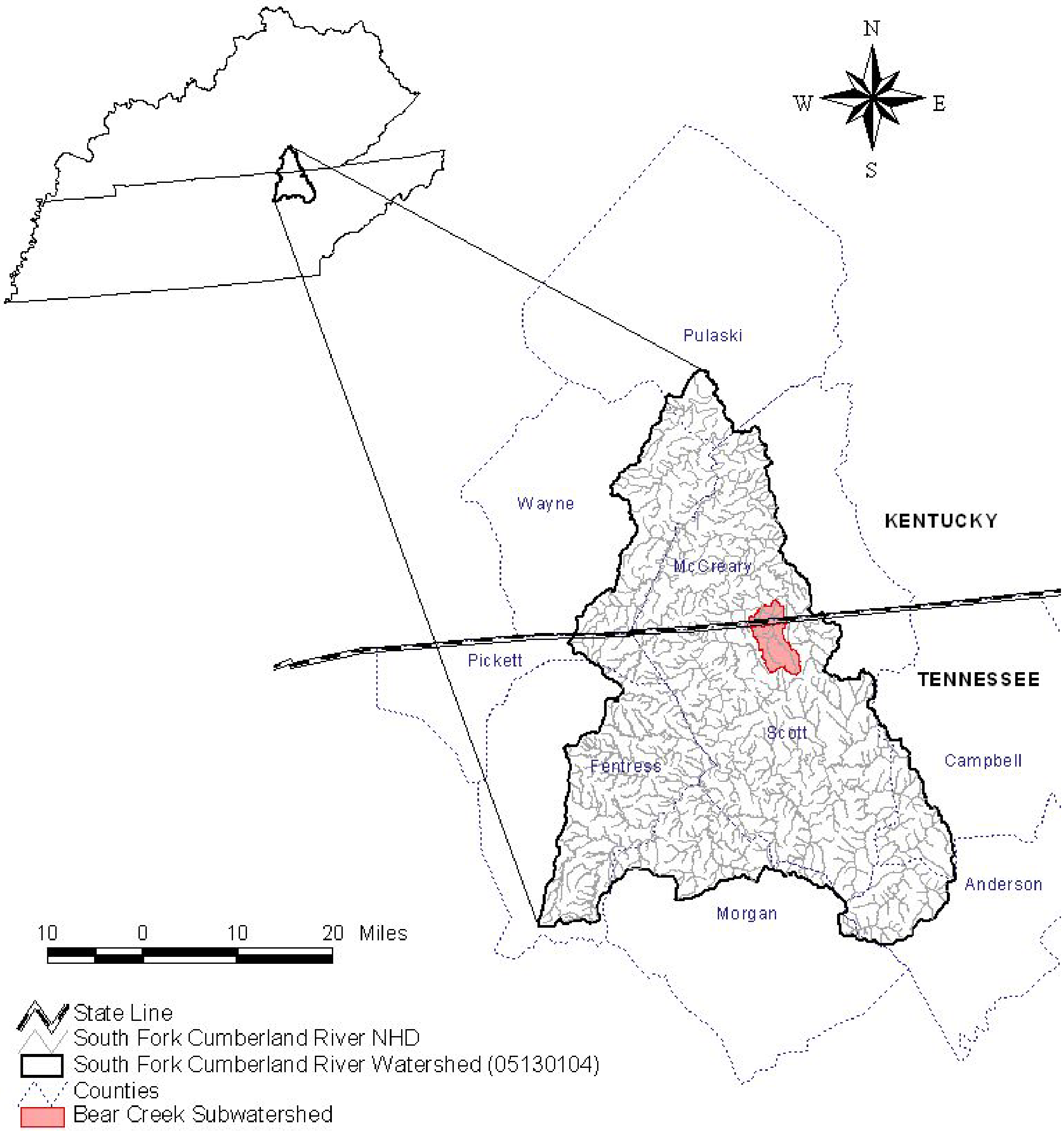

Figure 1 Location of South Fork Cumberland River Watershed

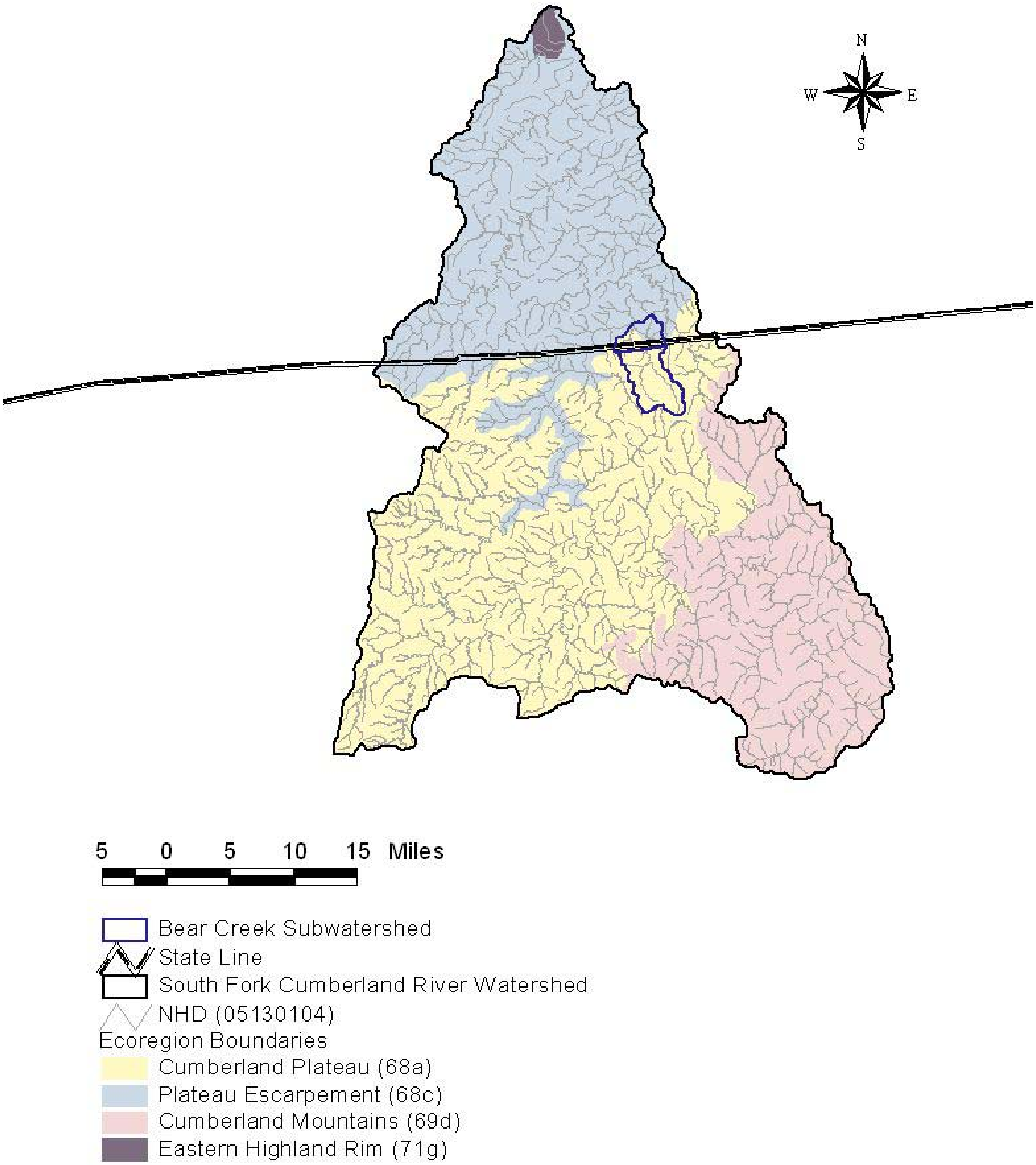

Figure 2 South Fork Cumberland River Watershed Ecoregion Designation

Table 1 MRLC Land Use Distribution – South Fork Cumberland River Watershed & Bear Creek Subwatershed

Land use	Bear Creek Subwatershed (TN only) (051301040405)		Bear Creek Subwatershed (KY & TN)		S. Fork Cumberland River Watershed (KY & TN) (05130104)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Deciduous Forest	5,284	50.9	6,760	45.1	511,970	58.2
Emergent Herbaceous Wetlands	0	0	0	0	37	0
Evergreen Forest	1,609	15.5	3,233	21.6	120,469	13.7
High Intensity Commercial/Industrial/ Transportation	25	0.2	25	0.2	1,693	0.2
High Intensity Residential	16	0.1	16	0.1	151	0
Low Intensity Residential	27	0.3	27	0.2	3,391	0.4
Mixed Forest	3,155	30.4	4,624	30.9	196,148	22.3
Open Water	6	0.1	8	0.1	3,641	0.4
Other Grasses (Urban/recreational)	0	0	0	0	1,925	0.2
Pasture/Hay	194	1.9	202	1.3	32,408	3.7
Quarries/Strip Mines/Gravel Pits	0	0	0	0	296	0
Transitional	44	0.4	44	0.3	1,899	0.2
Row Crops	0	0	0	0	5,258	0.6
Woody Wetlands	0	0	0	0	393	0
Total	10,392	100.0	14,970	100.0	879,679	100.0

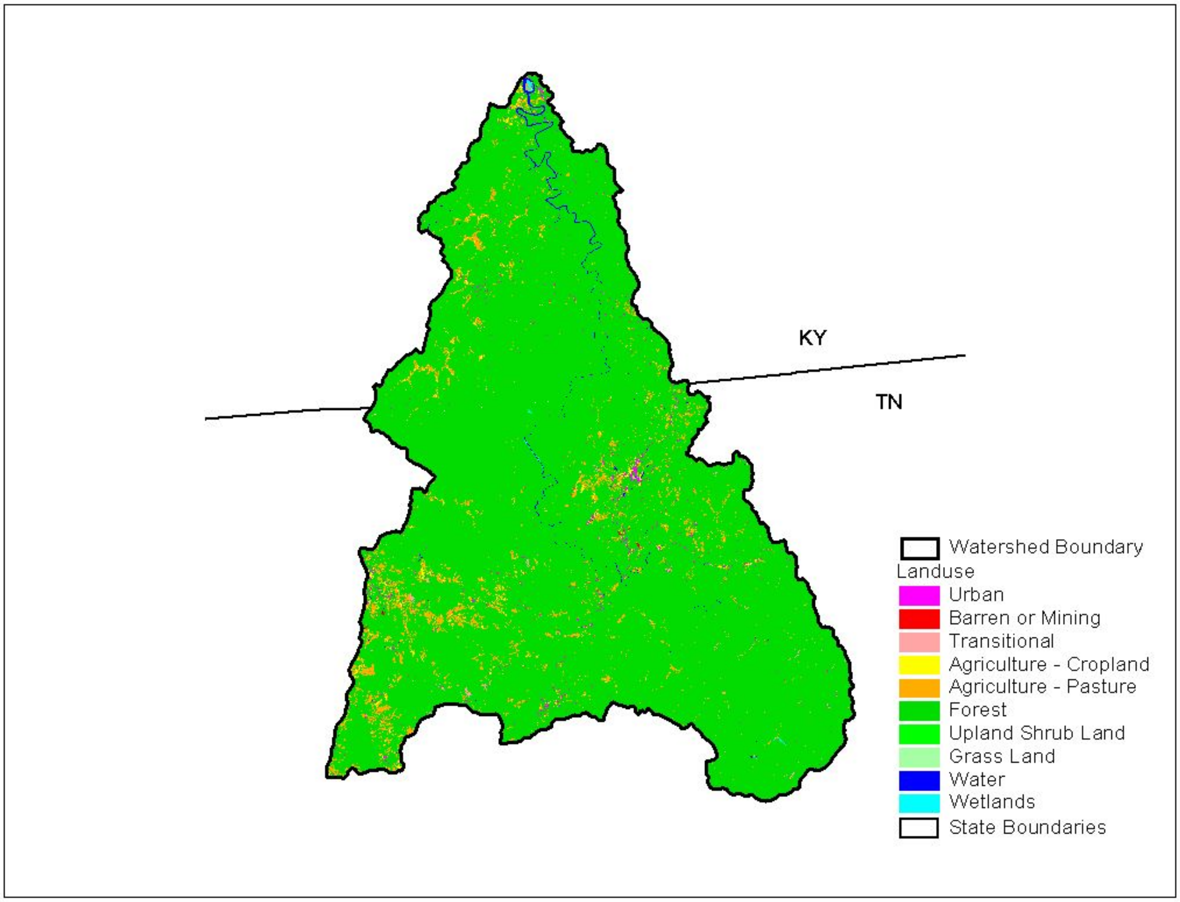

Figure 3 South Fork Cumberland River Watershed Land Use Distribution

3.0 PROBLEM DEFINITION

The State of Tennessee's Final 2006 303(d) list (TDEC, 2006) was approved by the U.S. Environmental Protection Agency (EPA), Region IV, in October of 2006. The list identified several waterbodies in the South Fork Cumberland River watershed as not supporting designated use classifications due, in part, to pH and iron associated with abandoned mines and resource extraction. Information regarding formation of acid mine drainage (AMD) is contained in Appendix A. An excerpt from the 2006 303(d) list is presented in Table 2. Impaired segments in the South Fork Cumberland River Watershed are shown in Figure 4.

Table 2 2006 303(d) List – South Fork Cumberland River Watershed

Waterbody ID	Impacted Waterbody	County	Miles/Acres Impaired	Cause	Pollutant Source
TN05130104 050 – 1000	Bear Creek	Scott	2.6	pH Loss of biological integrity due to siltation	Abandoned Mining
TN05130104 050 – 0100	East Branch Bear Creek	Scott	5.7	Iron pH Loss of biological integrity due to siltation	Abandoned Mining

The designated use classifications for Bear Creek and East Fork Bear Creek and their tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Bear Creek has been void of aquatic life since the late 1800s when coal mines were opened in the area.

Bear Creek was also identified on the State of Kentucky's final 2004 303(d) list as not supporting designated use classifications due to low pH associated with resource extraction (surface and subsurface mining). Kentucky surface water standards for pH and iron are similar to the water quality criteria applied in this TMDL. Therefore, TDEC believes that meeting the Tennessee water quality criteria will enable Bear Creek to meet the Kentucky surface water standards at the Tennessee/Kentucky state line.

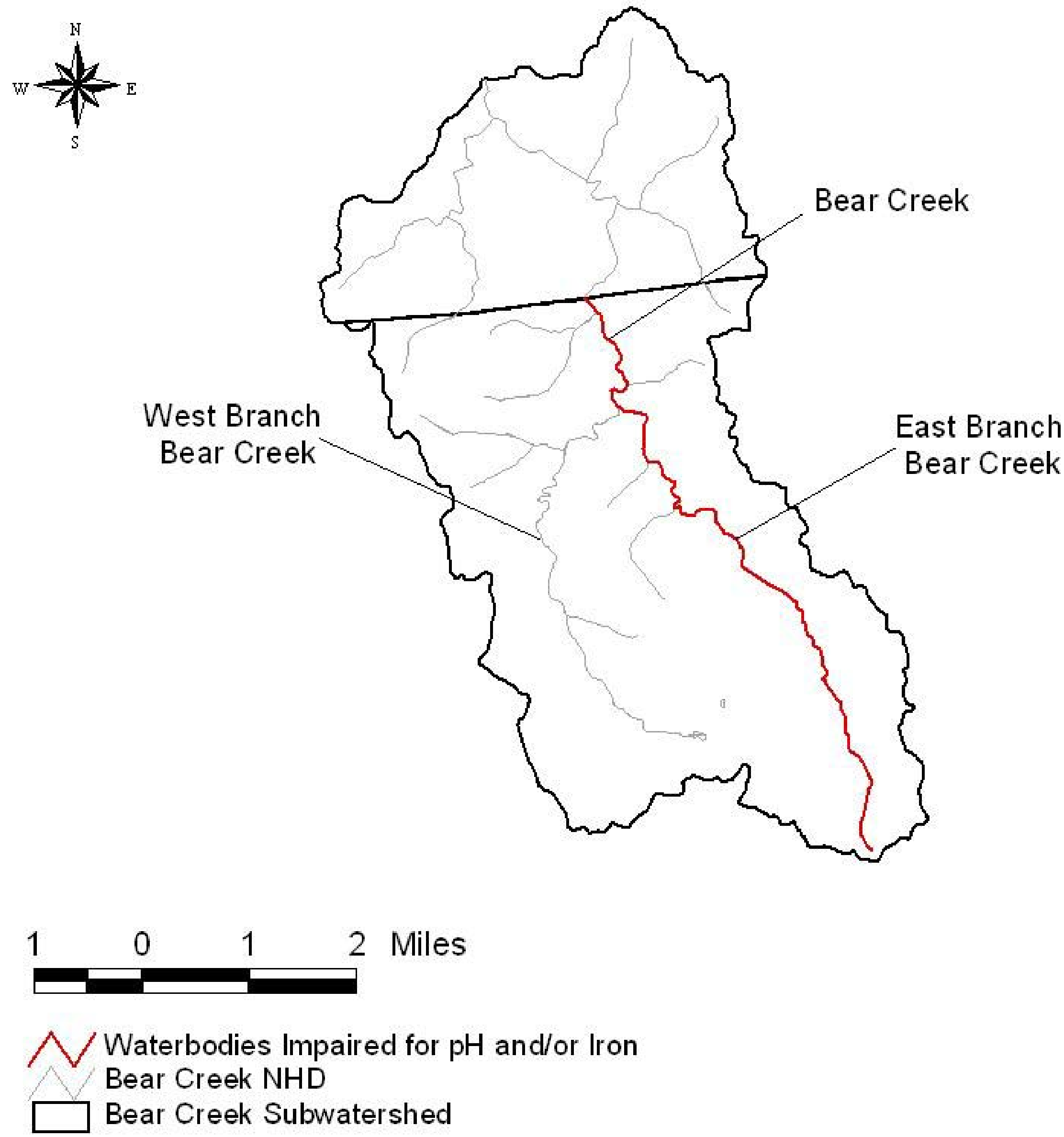

Figure 4 Bear Creek Subwatershed pH- and Iron-Impaired Segments

4.0 TARGET IDENTIFICATION

The allowable instream range of pH for the South Fork Cumberland River watershed, is established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, January, 2004 (Revised)* (TDEC, 2004) for applicable use classifications. The Fish & Aquatic Life criteria pH range for "all other wadeable streams" of 6.0 to 9.0 is the most stringent for the waterbodies covered by this TMDL. The criteria were approved by the Environmental Protection Agency (EPA) in September 2004.

According to the Pennsylvania Department of Environmental Protection (PDEP, 1998), the "acidity or net alkalinity of a solution, not the pH, is probably the best single indicator of the severity of AMD." In order to facilitate analysis of existing pollutant loads and load reductions required to restore the South Fork Cumberland River watershed to fully supporting all of its designated use classifications, net alkalinity will be used as a surrogate parameter for TMDL development. For the purposes of this TMDL, the following terms are defined:

Acidity	The quantitative capacity of a water to react with a strong base to a designated pH. Expressed as milligrams per liter calcium carbonate.
Total Alkalinity	A measure of the ability of water to neutralize acids. Expressed as milligrams per liter calcium carbonate.
Net Alkalinity	The total alkalinity minus the acidity. Expressed as milligrams per liter calcium carbonate.

Since there is no specified numerical criterion for net alkalinity, a net alkalinity of 10.8 mg/l $CaCO_3$, was selected as the numerical target for this TMDL based on analysis of all available monitoring data for Tennessee (see Appendix C). In order to characterize net alkalinity (as $CaCO_3$) over the range of flow conditions encountered in the subwatershed, the target net alkalinity (as $CaCO_3$) is expressed by means of a target load duration curve. The target load duration curve, developed in Appendix D, is presented in Figure 5. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the Beer Creek subwatershed meet, or exceed, the loads per unit area specified in the target load duration curve.

There is currently no numerical criterion for iron established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, January 2004 (Revised)* (TDEC, 2004). U.S.EPA has published National Recommended Water Quality Criteria (USEPA, 2006). The recommended Criterion Continuous Concentration (CCC) for iron for the protection of fish & aquatic life is 1000 μg/L (1.0 mg/L) and has been selected as the appropriate numeric target for the Bear Creek subwatershed. TDEC believes that meeting this criterion will satisfy the requirement that "waters shall not contain substances or a combination of substances including disease-causing agents which, by way of either direct exposure or indirect exposure through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict of impair growth in fish or aquatic life or their offspring".

In accordance with the guidance in *Technical Support Document For Water Quality-based Toxics Control* (USEPA, 1991b), fish & aquatic life criteria are interpreted to mean that the 1-hour average exposure should not exceed the Criterion Maximum Concentration (CMC) and the 4-day average exposure should not exceed the Criterion Continuous Concentration (CCC). Excursions of CMCs & CCCs should not exceed a frequency of once every three years.

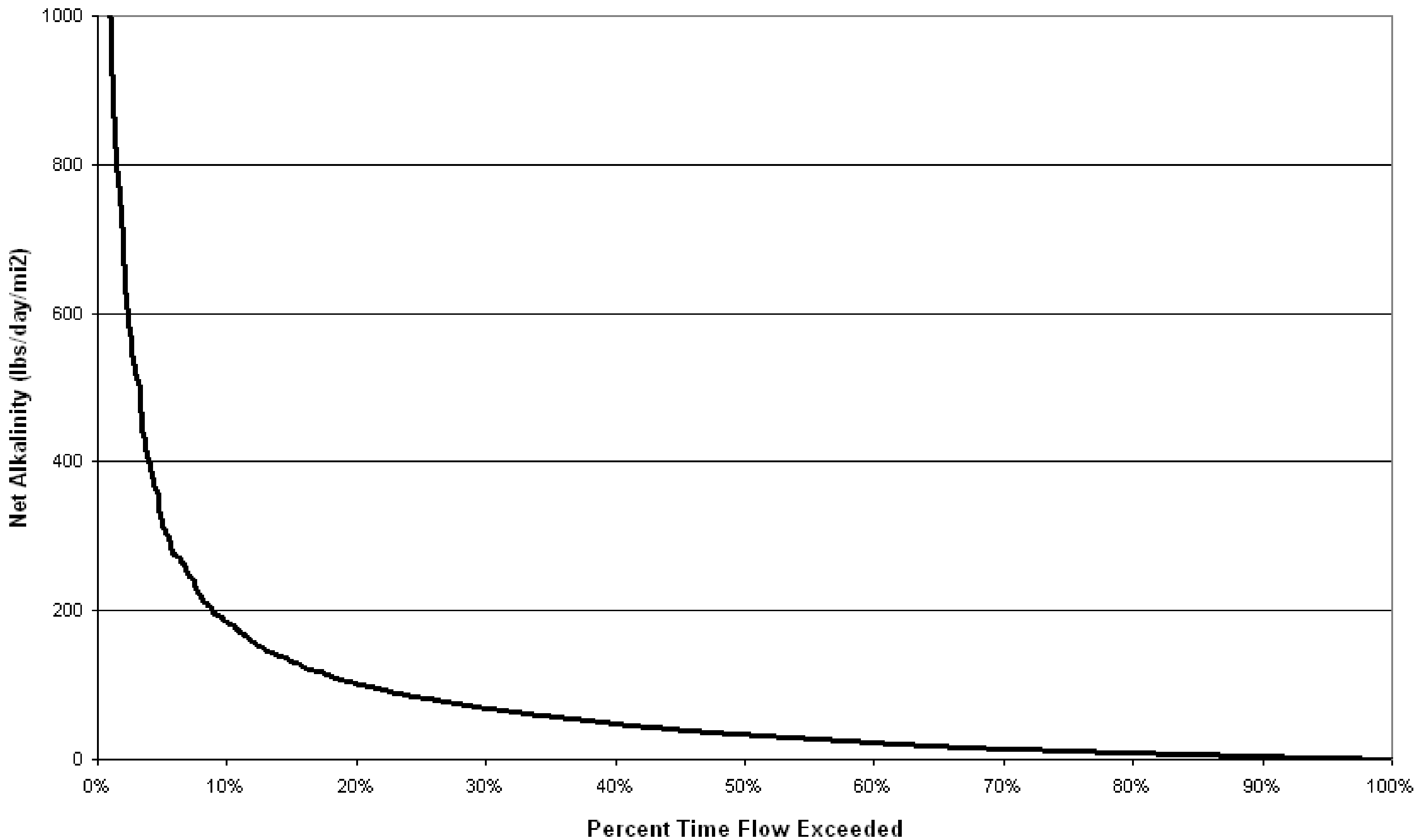

Figure 5 Target Net Alkalinity Load Duration Curve

5.0 WATER QUALITY ASSESSMENT AND DIFFERENCE FROM TARGET

Water quality monitoring of the Bear Creek Subwatershed has been conducted by a variety of entities. In the 1980s, monitoring was conducted by personnel from the National Park Service. (See Table B-1 and Figure B-1.) In 1995, monitoring was conducted by personnel from the Fish & Wildlife Service as part of an environmental assessment of the Bear Creek Watershed (USDA, 1997). (See Table B-2 and Figure B-1.) Personnel from the Office of Surface Mining have conducted monitoring during the period from 3/21/00 through 5/16/06 as part of a reclamation effort. (See Table B-3 and Figure B-2.)

The locations of all monitoring stations were compared and, whenever possible, sites were paired to allow for comparison of historic monitoring data with more recent monitoring data. The following monitoring stations, grouped by drainage area, were compared to determine whether improvement had occurred (see Figure 6 and Appendix F).

Mainstem Bear Creek

- Bear Creek d/s of confluence of East Branch & West Branch Bear Creek 36°34'57''N, 84°31'04"W
  BISO_NPS_BR-3 36°35'35''N, 84°31'09"W
- Bear Creek at USGS gage 36°37'37''N, 84°32'00"W
  BISO_NPS_BR-1 36°37'32''N, 84°32'01"W

East Branch Bear Creek

- 1 – Chick House Out 36°32'51''N, 84°29'49"W
  CH3G 36°32'51''N, 84°29'50"W
- 13 – Chick House Road (Previt Branch) 36°33'22''N, 84°30'49"W
  PB1 36°33'34''N, 84°31'09"W
  PB2 36°33'31''N, 84°30'58"W
- 15 – East Phase 5 Out 36°32'55''N, 84°29'50"W
  CH6 36°32'55''N, 84°29'51"W

West Branch Bear Creek

- 5 – Atomic School Road 36°32'26''N, 84°31'39"W
  WB1 36°32'26''N, 84°31'40"W
- 8 – West 4 Out 36°33'17''N, 84°31'23"W
  WB8 36°33'08''N, 84°31'21"W
- 10 – Phillips 10 36°32'46''N, 84°31'20"W
  WB6 36°32'47''N, 84°31'20"W
- 11 – Phillips 11 36°32'34''N, 84°31'11"W
  WB4 36°32'35''N, 84°31'11"W
- 12 – Phi 12/West 3 36°32'28''N, 84°31'04"W
  WB3 36°32'28''N, 84°31'05"W

Statistics for recent water quality monitoring results are summarized in Table 3. The linkage between pH and net alkalinity is presented in Table 4. Exceedances of the pH criterion are indicated in red. Note that 90% of the time, when a pH exceedance occurred, the net alkalinity was less than the target net alkalinity.

Bear Creek and East Branch Bear Creek were identified on the Final 2006 303(d) list as impaired due to pH and iron (East Branch only). Analysis of monitoring data for Bear Creek and East Branch Bear Creek suggests that they are still impaired. At this time, Bear Creek and East Branch Bear Creek should remain listed. Analysis of monitoring data for West Branch Bear Creek suggests that it is impaired for pH and iron. At this time, listing is suggested for West Branch Bear Creek.

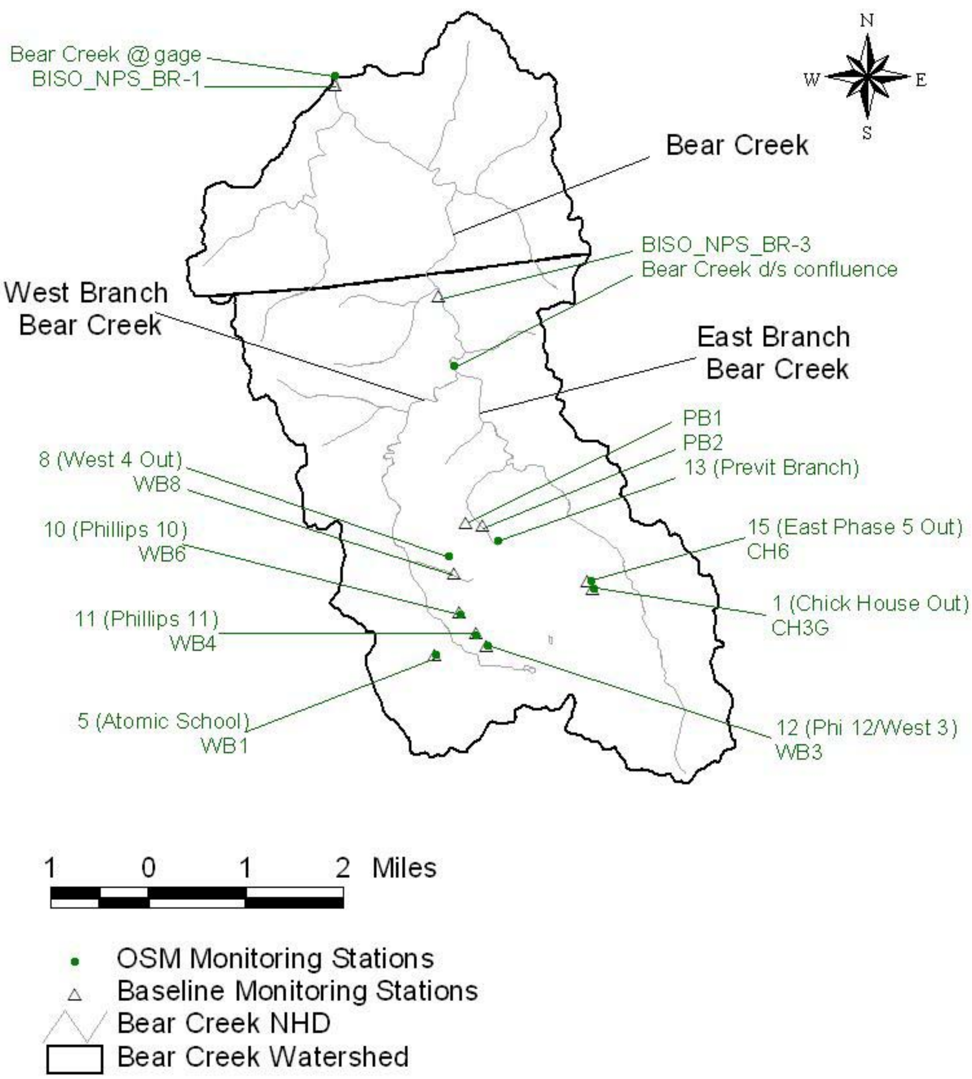

Figure 6 Bear Creek Subwatershed Monitoring Stations

Table 3 Summary of OSM Water Quality Monitoring Data

Monitoring Station No.	Monitoring Station Description	Date Range	Parameter	Data Pts.	Target (µg/L)	Min. (µg/L)	Avg. (µg/L)	Max. (µg/L)	No. Exceed. Target
	Bear Creek at USGS gage (in KY)	2001 – 2006	pH [a]	9	6.0-9.0	5.47	6.05	7.09	2
			Iron	9	1000	90	333	1370	1
	Bear Creek (confluence of East Branch & West Branch)	2001 – 2003	pH [a]	3	6.0-9.0	5.59	5.74	6.15	2
			Iron	4	1000	80	195	390	0
13	Chick House Rd. (Previt Branch)	2001 – 2006	pH [a]	12	6.0-9.0	3.54	4.13	5.70	12
			Iron	12	1000	390	2033	12900	4
15	East Phase 5 Out	2001 – 2006	pH [a]	12	6.0-9.0	3.58	4.11	6.69	11
			Iron	12	1000	160	1509	4040	7
1	Chick House Out	2000 – 2006	pH [a]	14	6.0-9.0	3.8	4.63	6.45	10
			Iron	14	1000	350	2001	2410	6
5	Atomic School Road	2000 – 2006	pH [a]	14	6.0-9.0	3.59	4.19	6.99	13
			Iron	14	1000	280	2213	9800	8
8	West 4 Out	2000 – 2006	pH [a]	14	6.0-9.0	2.69	3.34	4.96	14
			Iron	13	1000	11	8502	26000	12
10	Phillips 10	2001 – 2006	pH [a]	10	6.0-9.0	3.51	4.16	7.06	4
			Iron	10	1000	1380	3468	12000	10
11	Phillips 11	2001 – 2006	pH [a]	10	6.0-9.0	3.60	4.58	6.47	4
			Iron	10	1000	3100	22495	69750	10
12	Phi 12/West 3	2001 – 2006	pH [a]	11	6.0-9.0	3.51	4.36	6.85	6
			Iron	12	1000	50	1019	3900	3

[a] pH is expressed in standard units (s.u.); average is calculated by converting to microequivalents per liter of the hydrogen ion concentration.

Table 4 Comparison of Bear Creek Subwatershed pH & Net Alkalinity

Monitoring Site	Parameter	Units	Sample Date 3/21/00	9/13/00	2/12/01	5/7-9/01	1/28-29/02	6/11-12/02	11/4-5/02	2/20-25/03	6/16-17/03	8/27-28/03	1/26-27/04	7/12/04	5/24-25/05	5/15-16/06
Bear Creek	pH	--				5.47	5.95		6.30	6.15	7.09	6.58	6.10		6.02	6.58
(@ gage)	Net Alkalinity	mg/L[a]				-13.00	13.00		-35.00	-1.00	-11.00	7.00	-16.00		-4.00	7.00
Bear Creek	pH	--				5.65	6.15					5.59				
(@ confluence)	Net Alkalinity	mg/L[a]				-16.00	21.00			17.00		-10.00				
Site 13	pH	--			4.99	4.12	3.54	4.95	5.54	4.48	4.28	5.70	5.10	4.32	3.87	3.64
(Previt Branch	Net Alkalinity	mg/L[a]			-50.00	-40.00	-30.00	-87.00	-22.00	-25.00	-20.00	-46.00	-33.00	-42.00	-36.00	-35.00
Site 15	pH	--			4.30	5.82	3.62	5.37	4.42	4.06	3.72	6.69	3.58	4.59	4.82	4.96
(East Phase 5 Out)	Net Alkalinity	mg/L[a]			-110.00	19.00	-70.00	-25.00	-80.00	-64.00	-70.00	40.00	-72.00	-50.00	-21.00	24.00
Site 1	pH	--	3.80	5.28	4.40	4.96	4.45	6.07	5.96	4.61	4.34	6.45	6.20	5.71	6.09	5.54
(Chick House Out)	Net Alkalinity	mg/L[a]	-40.00	-66.00	-55.00	-19.00	-64.00	-4.00	21.00	-70.00	-20.00	190.00	20.00	25.00	11.00	18.00
Site 5	pH	--	3.80	3.81	3.98	4.16	3.59	4.66	4.52	5.18	6.99	4.60	4.66	4.96	5.99	4.35
(Atomic School Rd.)	Net Alkalinity	mg/L[a]	-36.00	-68.00	-60.00	-70.00	-15.00	-50.00	-39.00	-32.00	13.00	-40.00	-37.00	-13.00	-19.00	-25.00
Site 8	pH	--	3.40	3.80	3.32	3.06	3.27	3.76	3.10	3.93	3.76	3.75	3.96	4.96	3.37	2.69
(West 4 Out)	Net Alkalinity	mg/L[a]		-115.00	-130.00	-140.00	-76.00	-28.00	-340.00	-100.00	-51.00	-130.00	-67.00	-10.00	-84.00	-56.00
Site 10	pH	--			3.84	4.80	3.51	3.64	6.82	7.04			7.06	6.57	6.73	6.93
(Phillips 10)	Net Alkalinity	mg/L[a]			-50.00	-63.00	-50.00	-70.00	70.00	56.00			40.00	71.00	75.00	80.00
Site 11	pH	--			3.60	6.20	5.40	6.47	6.27	6.30	5.79		5.99		6.49	6.50
(Phillips 11)	Net Alkalinity	mg/L[a]			-350.00	50.00	-83.00	34.00	7.00	65.00	-34.00		30.00		27.00	75.00
Site 12	pH	--			0.05	6.44	3.51	6.79	5.92	5.02	4.26	6.75	4.03	5.25	6.67	6.85
(Phi 12/West 3)	Net Alkalinity	mg/L[a]			-29.00	15.00	-27.00	34.00	20.00	-4.00	-20.00	106.00	-20.00	-11.00	-9.00	12.00

[a] mg/L $CaCO_3$

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of individual sources, or source categories, of low pH and high metals in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources. A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Non-point sources include all other sources of pollution.

6.1 Point Sources

There are 32 facilities in the South Fork Cumberland River Watershed that have NPDES permits authorizing the discharge of wastewater due to mine operations. None of these facilities are located in the Bear Creek subwatershed.

6.2 Non-point Sources

There are a number of abandoned surface mining sites in the South Fork Cumberland River watershed that are susceptible to the formation of acid mine drainage as discussed in Appendix A. In the 2006 303(d) List (ref.: Table 2), abandoned mining was identified as the source of low pH and high metals in several impaired waterbodies in the watershed.

7.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or <u>other appropriate measure</u>.

7.1 TMDL Representation

In general, waterbodies become impaired due to excessive loading of particular pollutants that result in concentrations that violate instream water quality standards. A TMDL establishes the maximum load that can be assimilated by the waterbody, without violating standards, and allocates portions of this load to point and non-point sources. This normally involves reductions in loading from existing levels, with WLAs & LAs of zero load reduction as the ideal.

The use of net alkalinity as a surrogate parameter, however, requires a different approach. Existing levels of net alkalinity in impaired subwatersheds may be negative, while target values are positive. The concept of a “maximum net alkalinity load” does not appropriately represent the desired target condition with respect to AMD caused impairment. Net alkalinity targets can be achieved by reducing acidity, increasing total alkalinity, or some combination of both.

The net alkalinity TMDL for the South Fork Cumberland River watershed is considered to correspond to the target load duration curve (see Figure 5) as developed in Appendix D.

7.2 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions. These include: 1) the use of a 10-year continuous simulation that incorporates a wide range of meteorological events, 2) the use of the load duration curve, which addresses pollutant loading over the entire range of flow, and 3) the use of a positive net alkalinity target of 10.8 mg/L based on analysis of all available monitoring data for Tennessee (see Appendix C).

For development of iron TMDLs, an explicit MOS, equal to 10% of the water quality targets (ref.: Section 4.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum for Iron MOS = 100 mg/L

7.3 Determination of Total Maximum Daily Loads

The TMDLs for net alkalinity and iron in the South Fork Cumberland River watershed are presented in Table 5. The TMDLs can also be represented by the target load duration curves developed in Appendix D (ref: Figures D-2 thru D-4). The target load duration curves were developed on a unit area basis and are applicable for all impaired subwatersheds.

7.4 Determination of WLAs, & LAs

As previously stated, the TMDL can be expressed as the sum of all Waste Load Allocations (WLAs), Load Allocations (LAs), and an appropriate margin of safety (MOS).

For waterbodies with no active mining operations, the WLA and the LA for pH are equal to the TMDL for pH. The TMDL, WLA, and LA for pH, using net alkalinity as a surrogate for pH, are summarized in Table 5 and presented as a load duration curve in Figure 5.

For waterbodies with no active mining operations, there is no WLA and the LA for each metal is equal to the TMDL - MOS. The TMDLs and LAs for iron in the Bear Creek subwatershed are summarized in Table 5.

7.5 Seasonal Variation

The target load duration curves, the TMDLs, and LAs are applicable over the entire range of flow for all waterbodies in the Bear Creek subwatershed in all seasons.

Table 5 TMDLs, WLAs[a], & LAs expressed as daily loads for Impaired Waterbodies in the Bear Creek Subwatershed (part of HUC 05130104)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS	LAs
			[lbs/day]	[lbs/day]	[lbs/day]
Bear Creek (mainstem)	TN05130104050 – 1000	Net Alkalinity	$5.81 \times 10^{1} * Q$	NA[b]	$5.81 \times 10^{1} * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$
East Branch Bear Creek	TN05130104050 – 0100	Net Alkalinity	$5.81 \times 10^{1} * Q$	NA[b]	$5.81 \times 10^{1} * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$
West Branch Bear Creek	TN05130104050 – 0200	Net Alkalinity	$5.81 \times 10^{1} * Q$	NA[b]	$5.81 \times 10^{1} * Q$
		Iron	$5.38 * Q$	$5.38 \times 10^{-1} * Q$	$4.842 * Q$

Notes: NA = Not Applicable.
Q = Mean Daily Flow (cfs).

a. There are currently no point sources in the Bear Creek Subwatershed; therefore, there is no required load reduction for point sources (WLA). Any future point sources must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

b. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.2).

8.0 IMPLEMENTATION PLAN

Monitoring was conducted in 2000 thru 2006 for a number of waterbodies in the South Fork Cumberland River watershed identified as impaired due to low pH and/or high metals. This condition is a result of AMD from land disturbance caused by current and past coal mining activities. Analysis of monitoring data for Bear Creek and East Fork Bear Creek suggests that, although improvement is occurring, they are still impaired for pH and iron. Analysis of monitoring data for West Fork Bear Creek suggests that it is also impaired for pH and iron. At this time, listing is suggested West Fork Bear Creek for pH and iron.

Impaired subwatersheds were analyzed for individual metals using load duration curves. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of period monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired subwatersheds and an overall load reduction calculated to meet individual target concentrations according to the methods described in Appendix D.

Individual metal load reductions were calculated for impaired segments using Load Duration Curves to evaluate compliance with the target concentrations according to the procedure in Appendix D. The load reductions at each monitoring site within the drainage area (East Branch, West Branch, mainstem Bear Creek) were compared and the largest required load reduction was selected as the load reduction for that drainage area. The load reductions for the Bear Creek Subwatershed are summarized in Table 6.

Required LAs will be implemented in several steps to reduce acidity and/or increase total alkalinity so as to result in an increase of instream net alkalinity. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the Bear Creek subwatershed meet, or exceed, the loads per unit area specified in the target load duration curve (ref.: Figure 5).

Step 1: Once sites have been identified, remediation plans will be developed utilizing primarily passive treatment schemes (versus treatment by chemical addition) to provide a long-term solution to stream impairment. Remediation measures that have proved successful include, but are not limited to:

- Regrading of spoil
- Isolation of acid producing material from water contact
- Anoxic limestone drains
- Constructed wetlands.

The Abandoned Mine Lands Section and the NPS Section of the DWPC have expertise in the development of AMD remediation plans and have completed a number of reclamation projects on abandoned mines in the Tennessee coalfield. A number of these projects have included measures designed to remediate acid production caused by land disturbance due to past mining.

Bear Creek watershed project planning for acid mine remediation for abandoned coal mine sites in Scott County began in 1991. Eleven agencies and groups have provided funding and support for ten sites that have been reclaimed which represent treatment on over half of the acres needing treatment. Initial reclamation demonstration projects – land reshaping reclamation, installing anoxic drains, and constructing artificial (buffer) wetlands – were completed at the end of FY 1992.

The BMPs were partially funded with three $25,000 section 319 grants to Tennessee in FY 1990, 1991, and 1992. The AML Program has supplied from $75,000 to $140,000 each year for BMP funding. The NPS Program has also used section 319 funds, totaling $130,000, for pre- and post-BMP monitoring. Tennessee has also received an additional $375,000 in section 319 funds to complete the project and install the final demonstration BMPs. The state AML Program will match these funds. A special $15,000 U.S. Fish and Wildlife Service grant will support water quality monitoring near an endangered mussel habitat. Additional information regarding the Bear Creek watershed project is available at: http://www.epa.gov/owow/NPS/Section319I/TN.html

One of the prominent examples of reclamation is occurring on a 160 acre abandoned mine site, where 65 acres are being reclaimed as a recreational park with soccer, baseball and softball fields. A public day care center is also being located on the reclaimed site. An industrial park will occupy the remaining acreage. NRCS is treating the water quality on the site while the Town of Oneida is providing the funding for the recreation and other infrastructure.

The Mining Section issues NPDES permits for discharges of wastewater from coal and non-coal mines and, where applicable, Mining Law permits to non-coal facilities in Tennessee. This section of the DWPC has worked with a number of permitted mine sites across the state, offering considerable technical advice in the remediation of problems similar to those found in the Bear Creek subwatershed.

Step 2: Conduct follow-on water quality testing of impaired waterbodies in the Bear Creek subwatershed to verify the effectiveness of remediation measures. Parameters should include flow, pH, acidity, total alkalinity, and iron.

Additional monitoring is recommended at 6-12 month intervals at each of the sites discussed in Section 5.0 and Appendix D:

Bear Creek at USGS gage
Bear Creek d/s confluence of East Branch & West Branch
East Branch Bear Creek at sites 1, 13, and 15
West Branch Bear Creek at sites 5, 8, 10, 11, and 12

Monitoring at inlets and seeps, while informative, is not necessary for the purpose of this TMDL and may be discontinued at the discretion of the sampling authority.

Step 3: When monitoring confirms that pH and net alkalinity are meeting the targets established in Section 4.0, monitoring data for iron should be re-examined to determine whether additional treatment will be required in order to meet water quality standards for iron.

Table 6 Required Load Reductions for the Bear Creek Subwatershed

Monitoring Site	Waterbody Name & ID	Iron	
		% Reduction for TMDL	% Reduction for LA
@ gage		NR	NR
d/s of East Branch & West Branch		NR	NR
	Bear Creek (mainstem) TN05130104050 – 1000	NR	NR
Previt Branch (Site 13)		51.8	56.6
Chick House Out (Site 1)		**80.2**	**82.2**
East Phase 5 Out (Site 15)		66.9	70.2
	East Branch Bear Creek TN05130104050 – 0100	80.2	82.2
Atomic School Rd. (Site 5)		73.6	76.3
West 4 Out (Site 8)		93.4	94.1
Phillips 10 (Site 10)		83.4	95.1
Phillips 11 (Site 11)		**97.7**	**97.9**
Phi 12/West 3 (Site 12)		62.8	66.5
	West Branch Bear Creek TN05130104050 – 0200	97.7	97.9

* There are currently no point sources in the Bear Creek Subwatershed; therefore, there is no required load reduction for point sources (WLA). Any future point sources must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

9.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed TMDL for the South Fork Cumberland River Watershed will be placed on Public Notice for a 35-day period and comments solicited. Steps that will be taken in this regard include:

1) Notice of the proposed TMDL will be posted on the Tennessee Department of Environment and Conservation website. The announcement will invite public and stakeholder comment and will provide a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDL (similar to the website announcement) will be included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) A letter will be sent to water quality partners in the Bear Creek Watershed advising them of the proposed TMDLs and their availability on the TDEC website. The letter also will state that a written copy of the draft TMDL document will be provided upon request. A letter will be sent to the following partners:

    City of Oneida, TN
    Scott County Commission
    Kentucky Dept. of Environmental Protection, Division of Water –
        Nonpoint Source Program
    Scott County Soil Conservation District
    US DOI – Fish & Wildlife Service
    US DOI – National Park Service – Big South Fork (BISO)
    US DOI – Office of Surface Mining
    Tennessee Valley Authority
    Tennessee Department of Agriculture – NRCS
    Tennessee Wildlife Resources Agency
    Tennessee Citizens for Wilderness Planning
    Upper Cumberland Water Watch (Kentucky)
    Bear Creek Watershed Alliance
    Cumberland River Compact
    Cumberland Coalition
    The Nature Conservancy

10.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

Acid Mine Drainage

Acid Mine Drainage Formation

The following information regarding acid mine drainage formation was taken from the U.S. Department of Interior, Office of Surface Mining (OSM) website at www.osmre.gov/amdform.htm. The first section on the Chemistry of Pyrite Weathering is reproduced below. Discussion of subsequent sections can be found on the OSM website.

The formation of acid drainage is a complex geochemical and microbially mediated process. The acid load ultimately generated from a minesite is primarily a function of the following factors:

- Chemistry
- Microbiological Controls
- Depositional environment
- Acid/base balance of the overburden
- Lithology
- Mineralogy
- Minesite hydrologic conditions

Chemistry of Pyrite Weathering

A complex series of chemical weathering reactions are spontaneously initiated when surface mining activities expose spoil materials to an oxidizing environment. The mineral assemblages contained in the spoil are not in equilibrium with the oxidizing environment and almost immediately begin weathering and mineral transformations. The reactions are analogous to "geologic weathering" which takes place over extended periods of time (i.e., hundreds to thousands of years) but the rates of reaction are orders of magnitude greater than in "natural" weathering systems. The accelerated reaction rates can release damaging quantities of acidity, metals, and other soluble components into the environment. The pyrite oxidation process has been extensively studied and has been reviewed by Nordstrom (1979). For purposes of this description, the term "pyrite" is used to collectively refer to all iron disulfide minerals.

The following equations show the generally accepted sequence of pyrite reactions:

$2\ FeS_2 + 7\ 0_2 + 2\ H_2O \rightarrow\rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$ (Equation 1)

$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O$ (Equation 2)

$4\ Fe^{3+} + 12\ H_2O \rightarrow 4\ Fe(OH)_3 + 12\ H^+$ (Equation 3)

$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$ (Equation 4)

In the initial step, pyrite reacts with oxygen and water to produce ferrous iron, sulfate and acidity. The second step involves the conversion of ferrous iron to ferric iron. This second reaction has been termed the "rate determining" step for the overall sequence.

The third step involves the hydrolysis of ferric iron with water to form the solid ferric hydroxide (ferrihydrite) and the release of additional acidity. This third reaction is pH dependent. Under very acid conditions of less than about pH 3.5, the solid mineral does not form and ferric iron remains in solution. At higher pH values, a precipitate forms, commonly referred to as “yellowboy.”

The fourth step involves the oxidation of additional pyrite by ferric iron. The ferric iron is generated by the initial oxidation reactions in steps one and two. This cyclic propagation of acid generation by iron takes place very rapidly and continues until the supply of ferric iron or pyrite is exhausted. Oxygen is not required for the fourth reaction to occur.

The overall pyrite reaction series is among the most acid-producing of all weathering processes in nature.

APPENDIX B

Bear Creek Subwatershed Monitoring Data

Table B-1 Bear Creek Monitoring Data (TVA)

	BISO_NPS_BR-1						**36 37' 32"N**						
	Mouth of Bear Creek (in Kentucky)						**84 32' 01"W**						

Test	*Units*	*10/27/82*	*12/7/82*	*1/8/83*	*1/30/83*	*3/2/83*	*4/19/83*	*5/17/83*	*6/14/83*	*7/6/83*	*8/16/83*	*9/9/83*	*10/3/83*
pH	--	5.6	5.3	5.1	4.7	4.8	4.7	5.4	4.7	4.5	5.2	5.6	6.4
Conductivity	uMHO	280.0	123.0		140.0	140.0	138.0	76.0		180.0	190.0	220.0	210.0
Dissolved Oxygen	mg/L	11.3	11.6	13.0	12.0	12.7	12.2	10.6	9.6	8.7		7.0	8.3
Flow	cfs												
Temperature	Celsius	8.5	11.0	7.0	7.5	8.0	6.3	12.1	21.0	20.4	21.0	19.7	15.3
Acidity	mg/L	21.00	9.90	16.90	12.80	13.90	10.40	9.80	19.30	18.00	11.40	9.70	18.40
Total Alkalinity	mg/L	2.50	2.30	2.50	2.00	2.30	2.90	2.60	1.50	2.20	2.60	4.00	5.90
Sulfate	mg/L		52.0	80.0	60.8	67.0	66.0	33.0	80.0	75.0	80.0	51.0	15.0
Total Hardness	mg/L	118	45	71	53	51	48	29	74	68	79	72	62
TSS	mg/L												
Turbidity	NTU	0.9	3.9	1.5	4.3	1.5	3.5	9.7	1.7	8.6	1.5	1.7	1.6
Aluminum	ug/L												
Iron	ug/L	420	100	250	200	100	100	200	100	100	100	100	100
Lead	ug/L												
Manganese	ug/L					2700	1900	600	1400	3400	3300	2500	250

Test	*Units*	*11/1/83*	*12/5/83*	*1/9/84*	*2/14/84*	*3/6/84*	*4/2/84*	*5/15/84*	*6/4/84*	*7/12/84*	*9/5/84*	*10/9/84*	***MEAN***
pH	--	4.5	5.1	5.3	6.5	4.8	4.8	4.5	4.3	5.5	4.5		4.8
Conductivity	uMHO	430.0	121.0	165.0	91.0	132.0	126.0	479.0	260.0	210.0	325.0	255.0	190.0
Dissolved Oxygen	mg/L	10.0	11.1	13.7	12.0	12.1	12.2	9.8	9.5	7.9	8.7	9.3	10.6
Flow	cfs												
Temperature	Celsius	10.6	8.9	2.3	7.9	5.6	6.6	14.4	18.8	23.1	17.7	15.4	12.6
Acidity	mg/L	29.30	9.40	14.20	13.00	13.10	11.90	17.80	22.90	18.10	18.10	14.60	15.40
Total Alkalinity	mg/L	2.30	3.70	2.20	1.50	1.50	2.80	1.50	0.00	0.00	1.70	2.00	2.30
Sulfate	mg/L	80.0	41.0	61.0	32.0	51.0	47.0	66.0	80.0	80.0	80.0	80.0	61.7
Total Hardness	mg/L	205	38	65	34	47	43	65	93	101	120	100	73
TSS	mg/L												
Turbidity	NTU	0.4	6.3	1.0	12.0	3.1	1.8		0.9	2.1	1.0	6.3	3.4
Aluminum	ug/L												
Iron	ug/L	100	100	100	100	100	200	100	100	100	100	250	140
Lead	ug/L												
Manganese	ug/L	8000	1500	3100	2600	2100	1700	3000	4000	250	3300	2500	2532

Table B-1 (cont'd) Bear Creek Monitoring Data (TVA)

	BISO_NPS_BR-3						36 35' 35"N			
	Bear Creek 300 ft. above Slaven Branch						84 31' 09"W			
Test	*Units*	*11/1/82*	*1/13/83*	*2/22/83*	*3/23/83*	*4/22/83*	*5/12/83*	*6/13/83*	*7/22/83*	*8/8/83*
pH	--	4.5	4.4	4.1	4.5	4.2	4.5	4.1	3.9	4.4
Conductivity	uMHO	355.0	210.0	260.0	180.0	175.0	165.0	285.0	320.0	310.0
Dissolved Oxygen	mg/L	9.1	13.7	11.8	13.1	11.7	10.5	9.3	7.3	7.4
Flow	cfs									
Temperature	Celsius	11.6	1.0	7.5		8.8	13.0	18.2	26.4	23.8
Acidity	mg/L		19.40	27.30	19.30	15.40	15.80	28.10	30.00	19.90
Total Alkalinity	mg/L		0.00	0.00	1.50	1.00	0.00	0.00	0.00	1.00
Sulfate	mg/L		80.0	80.0	80.0	77.0	72.0	80.0	80.0	80.0
Total Hardness	mg/L		80	102	75	62	80	103	136	123
TSS	mg/L									
Turbidity	NTU		4.0	1.1	3.6	2.1	2.2	1.4	1.0	0.9
Aluminum	ug/L									
Iron	ug/L		250	400	450	100	100	250	100	100
Lead	ug/L									
Manganese	ug/L				3700	1800	1900	2600	7000	6400
Test	*Units*	*10/24/83*	*1/26/84*	*3/13/84*	*5/16/84*	*6/27/84*	*7/23/84*	*8/21/84*	*10/11/84*	***MEAN***
pH	--	3.9	5.5	4.2	4.3	4.2	4.3	4.2	4.1	4.2
Conductivity	uMHO	490.0	171.0	271.0	300.0	450.0	415.0		420.0	299.0
Dissolved Oxygen	mg/L	9.3	12.6	11.8	10.4	8.4	8.1	8.5	8.5	10.1
Flow	cfs									
Temperature	Celsius	14.0	0.1	5.2	12.6	20.4	21.1	19.6	15.1	13.7
Acidity	mg/L		16.20	30.90	28.20	38.60	33.00	33.40	45.30	28.60
Total Alkalinity	mg/L		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Sulfate	mg/L		54.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Total Hardness	mg/L	201	56	98	104	150	157	145	168	115
TSS	mg/L									
Turbidity	NTU	1.3	5.8	87.0		0.7	0.8	0.7	1.0	7.6
Aluminum	ug/L									
Iron	ug/L	850	200	1600	250	350	200	200	500	369
Lead	ug/L									
Manganese	ug/L	9900	2600	10000	4700	7500	6000	5100	5000	5300

Table B-2 Bear Creek Monitoring Data (USFWS)

	Bear Creek Baseline Data (1995)									
Site	*Units*	*CH6*	*CH3G*	*WB1*	*WB3*	*WB4*	*WB6*	*WB8*	*Previt-Br1*	*Previt-Br2*
Latitude		*36-32-55*	*36-32-51*	*36-32-26*	*36-32-28*	*36-32-35*	*36-32-47*	*36-33-08*	*36-33-34*	*36-33-31*
Longitude		*84-29-51*	*84-29-50*	*84-31-40*	*84-31-05*	*84-31-11*	*84-31-20*	*84-31-21*	*84-31-09*	*84-30-58*
pH	--	3.6	4.6	3.8	4.3	3.6	4.1	3.5	3.9	4.3
Conductivity	uMHO	715.0	593.0	428.0	239.0	1660.0	177.0	714.0	455.0	337.0
Dissolved Oxygen	mg/L									
Flow	cfs									
Temperature	Celsius									
Acidity	mg/L	79.6	26.8	37.2	24.2	313.0	25.8	69.2	52.8	19.5
Total Alkalinity	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sulfate	mg/L	392.0	393.0	179.0	101.0		75.8	350.0	185.0	176.0
Total Hardness	mg/L									
TSS	mg/L	2.0	1.0	nd	nd	2.0	nd	nd	2.0	nd
Turbidity	NTU									
Aluminum	ug/L	10700	3160	3980	3040	55900	2960	7620	6750	2520
Iron	ug/L	1600	1090	1530	365	1990	1040	3700	3080	409
Manganese	ug/L	15700	8020	8240	3990	45400	4460	13800	12100	6100

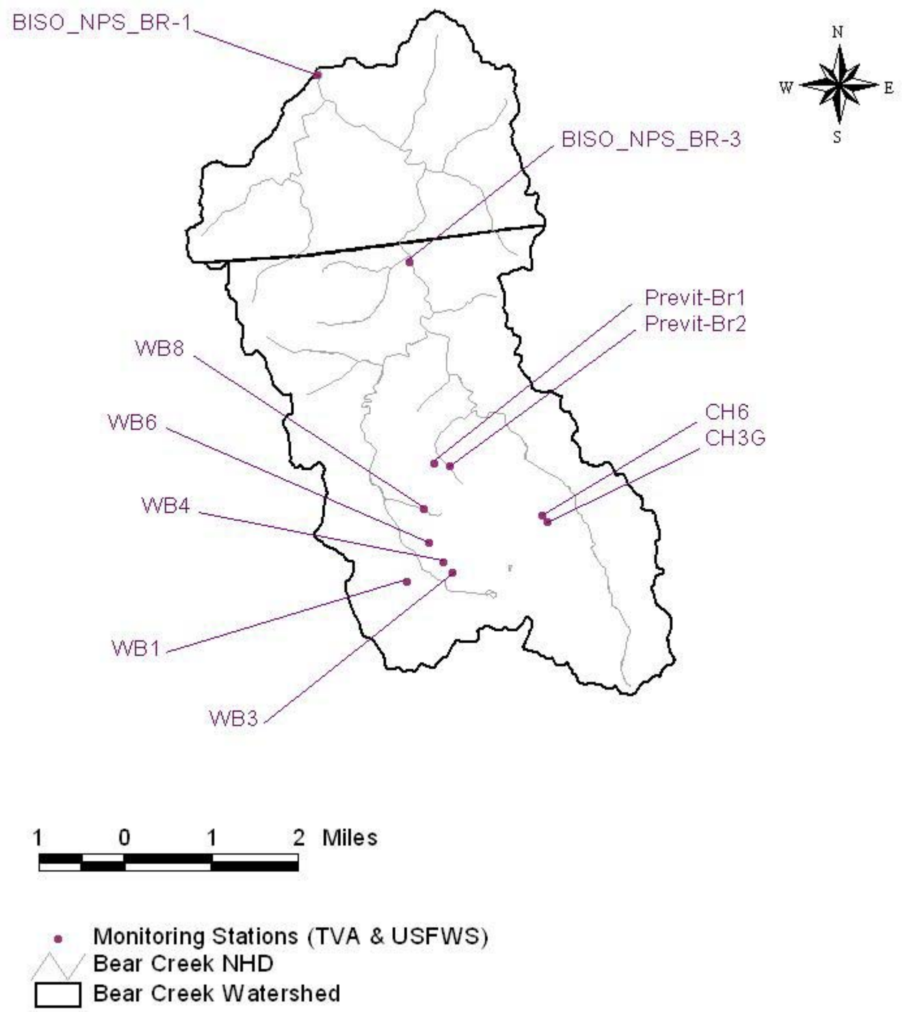

Figure B-1 Bear Creek Monitoring Stations (TVA & USFWS)

Table B-3 Bear Creek Monitoring Data (OSM)

	1 - Chick House Out									36 32' 51"N					
										84 29' 49"W					
Test	*Units*	*3/21/00*	*9/13/00*	*2/12/01*	*5/7/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/15/06*
pH	--	3.80	5.28	4.40	4.96	4.45	6.07	5.96	4.61	4.34	6.45	6.20	5.71	6.09	5.54
Conductivity	uMHO	100.0	721.0	397.0	370.6	557.0	667.0	823.3	457.5	410.0	856.0	486.0	546.0	553.0	624.0
Dissolved Oxygen	mg/L	10.2	3.5	0.6	0.6	10.9	8.5		11.9	5.9		5.7		4.7	8.0
Flow	gpm		0.5			395.0									
Temperature	Celsius	9.90	22.32	7.20	17.61	7.24	30.00	10.14	6.50	22.29	23.70	9.90	26.80	13.96	13.10
Acidity	mg/L	40.00	76.00	55.00	23.00	64.00	20.00	5.00	70.00	20.00	0.00	0.00	0.00	8.00	0.00
Total Alkalinity	mg/L	0.00	10.00	0.00	4.00	0.00	16.00	26.00	0.00	0.00	190.00	20.00	25.00	19.00	18.00
Sulfate	mg/L	187.5	262.5	230.0	275.0	250.0	250.0	340.0	85.0	84.8	304.0	220.0	92.0	233.0	250.0
Total Hardness	mg/L														
TSS	mg/L														
Turbidity	NTU														
Aluminum	ug/L	260	3560	1680	1420	250	380	1100	140	120	310	100	110	100	170
Iron	ug/L	600	2410	350	1210	400	1380	6200	400	1500	12000	190	330	720	320
Lead	ug/L														
Manganese	ug/L	7700	15600	9200	11200	5200	5600	8400	3100	7600	5600	5000	4770	7700	3830

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	5 - Atomic School Road								**36 32' 26"N**						
									84 31' 39"W						
Test	*Units*	*3/21/00*	*9/13/00*	*2/12/01*	*5/7/01*	*1/28/02*	*6/12/02*	*11/5/02*	*2/25/03*	*6/17/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/16/06*
pH	--	3.80	3.81	3.98	4.16	3.59	4.66	4.52	5.18	6.99	4.60	4.66	4.96	5.99	4.35
Conductivity	uMHO	55.8	596.0	271.0	245.5	377.0	286.0	569.8	319.8	188.5	485.0	337.0	383.0	296.0	425.0
Dissolved Oxygen	mg/L	14.0	5.2	2.4	2.4	11.4	6.8		11.4	5.9		6.7		9.8	9.5
Flow	gpm		5.0	101.3			48.2			1962.0	1.5				
Temperature	Celsius	10.80	22.60	6.20	15.89	10.37	19.90	10.01	4.17	19.05	25.50	6.40	21.10	17.05	11.65
Acidity	mg/L	36.00	68.00	60.00	70.00	15.00	50.00	39.00	32.00	7.00	40.00	37.00	15.00	22.00	25.00
Total Alkalinity	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	2.00	3.00	0.00
Sulfate	mg/L	137.5	207.5	84.8	187.5	82.5	182.5	207.5	82.5	52.0	184.5	92.0	106.0	68.0	33.2
Total Hardness	mg/L														
TSS	mg/L														
Turbidity	NTU														
Aluminum	ug/L	90	2190	260	1330	330	380	360	700	150	560	250	240	100	2380
Iron	ug/L	900	680	440	280	930	1600	2850	2260	4200	9800	2500	2500	1260	780
Lead	ug/L														
Manganese	ug/L	4600	13400	8200	11900	5600	10000	5900	4680	3200	7700	5400	4700	4600	7900

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	8 - West 4 - Out									36 33' 17"N					
										84 31' 23"W					
Test	*Units*	*3/21/00*	*9/13/00*	*2/12/01*	*5/8/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/27/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/15/06*
pH	--	3.40	3.80	3.32	3.06	3.27	3.76	3.10	3.93	3.76	3.75	3.96	4.96	3.37	2.69
Conductivity	uMHO	31.8	1696.0	441.0	536.4	525.0	830.0	1228.0	651.6	300.2	1258.0	367.0	484.0	673.0	578.0
Dissolved Oxygen	mg/L	15.6	1.0	0.3	0.0	11.0	6.3		11.9	7.0		6.6		7.5	7.3
Flow	gpm					351.0				216.0	2.0				
Temperature	Celsius	11.70	22.90	7.12	18.50	8.60	25.20	10.19	5.63	19.58	26.40	7.10	24.80	18.55	16.30
Acidity	mg/L		115.00	130.00	140.00	76.00	28.00	340.00	100.00	51.00	130.00	67.00	12.00	84.00	56.00
Total Alkalinity	mg/L		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00
Sulfate	mg/L		800.0	260.0	397.5	212.5	387.5	550.0	250.0	80.0	669.0	100.0	164.0	223.0	197.5
Total Hardness	mg/L														
TSS	mg/L														
Turbidity	NTU														
Aluminum	ug/L		2170	3050	4280	500	1000	4000	360	170	1240	380	820	100	2520
Iron	ug/L		4900	15700	13200	5500	1770	26000	3600	2600	11000	6700	10600	7600	1360
Lead	ug/L														
Manganese	ug/L		17000	14500	17400	5700	8000	13900	4580	2460	12000	4560	3580	9100	4300

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	9A - West 4 - In Pit									36 33' 18"N			
										84 31' 21"W			
Test	*Units*	*2/12/01*	*5/8/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/15/06*
pH	--	3.35	3.27	3.35	3.23	4.45	4.31	4.91	3.04	4.98	4.86	4.76	2.90
Conductivity	uMHO	223.2	328.4	355.0	418.0	770.4	187.3	130.2	1320.0	157.0	326.0	303.0	696.0
Dissolved Oxygen	mg/L	3.2	0.9	11.2	7.2		12.3	8.5		6.3		6.6	5.6
Flow	gpm	22.1						1440.0	2.0	80.1	4.0		
Temperature	Celsius	7.06	15.60	11.05	24.50	10.85	6.70	17.50	21.60	10.40	27.40	15.51	12.50
Acidity	mg/L	79.00	136.00	72.00	462.00	240.00	52.00	9.00	416.00	32.00	61.00	57.00	70.00
Total Alkalinity	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	4.00	1.00	0.00	0.00
Sulfate	mg/L	81.0	212.5	84.8	275.0	387.5	60.0	41.0	584.0	60.8	156.5	79.5	119.0
Total Hardness	mg/L												
TSS	mg/L												
Turbidity	NTU												
Aluminum	ug/L	530	3580	310	1560	1750	150	150	5200	350	350	100	14400
Iron	ug/L	2420	10000	4020	7600	29900	2000	2500	68000	4400	6800	11800	16400
Lead	ug/L												
Manganese	ug/L	4100	9000	3950	5900	11800	600	900	17200	1700	4880	3660	4300

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	10 - Phillips 10									**36 32' 46"N**	
										84 31' 20"W	
Test	*Units*	*2/12/01*	*5/7/01*	*1/28/02*	*6/12/02*	*11/5/02*	*2/24/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/16/06*
pH	--	3.84	4.80	3.51	3.64	6.82	7.04	7.06	6.57	6.73	6.93
Conductivity	uMHO	109.0	134.8	142.0	289.0	365.2	232.1	194.0	287.0	334.0	376.0
Dissolved Oxygen	mg/L	7.4	4.4	11.4	4.9		11.8	7.6	8.2	11.2	8.9
Flow	gpm	36.0		76.5	4.5						
Temperature	Celsius	6.25	15.10	10.27	18.20	14.78	8.26	7.20	23.40	18.99	13.60
Acidity	mg/L	50.00	65.00	50.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Alkalinity	mg/L	0.00	2.00	0.00	0.00	70.00	56.00	40.00	71.00	75.00	80.00
Sulfate	mg/L	55.0	81.0	46.0	81.0	82.5	39.8	44.4	44.8	53.2	82.0
Total Hardness	mg/L										
TSS	mg/L										
Turbidity	NTU										
Aluminum	ug/L	230	2900	260	2000	700	50	100	100	100	230
Iron	ug/L	1410	5370	1650	2370	12000	2010	1380	2750	3140	2600
Lead	ug/L										
Manganese	ug/L	5900	12200	4050	7200	2870	190	1500	1150	1280	1110

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	11 - Phillips 11									36 32' 34"N	
										84 31' 11"W	
Test	*Units*	*2/12/01*	*5/7/01*	*1/28/02*	*6/12/02*	*11/5/02*	*2/24/03*	*6/17/03*	*1/26/04*	*5/24/05*	*5/16/06*
pH	--	3.60	6.20	5.40	6.47	6.27	6.30	5.79	5.99	6.49	6.50
Conductivity	uMHO	703.0	481.9	1515.0	109.0	892.5	1134.0	765.0	872.0	1263.0	1249.0
Dissolved Oxygen	mg/L	0.0	0.1	8.3	8.4		9.3	6.1	5.5	10.5	7.8
Flow	gpm	24.8		25.7				81.0			
Temperature	Celsius	8.23	16.49	12.80	20.90	11.11	10.21	18.70	9.10	22.80	12.85
Acidity	mg/L	350.00	0.00	90.00	40.00	45.00	45.00	70.00	0.00	26.00	0.00
Total Alkalinity	mg/L	0.00	50.00	7.00	74.00	52.00	110.00	36.00	30.00	53.00	75.00
Sulfate	mg/L	810.0	387.5	423.8	600.0	295.0	405.0	300.0	478.0	637.5	598.0
Total Hardness	mg/L										
TSS	mg/L										
Turbidity	NTU										
Aluminum	ug/L	1350	2550	3800	2140	1450	3170	770	350	1260	4720
Iron	ug/L	10000	9800	69750	3100	14000	40000	12900	7500	24400	33500
Lead	ug/L										
Manganese	ug/L	23900	8700	14400	9600	5600	8000	11100	7700	18300	10100

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	12 - Phi 12/West 3									36 32' 28"N			
										84 31' 04"W			
Test	*Units*	*2/12/01*	*5/7/01*	*1/28/02*	*6/12/02*	*11/5/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/16/06*
pH	--	0.05	6.44	3.51	6.79	5.92	5.02	4.26	6.75	4.03	5.25	6.67	6.85
Conductivity	uMHO	127.7	121.5	169.0	243.0	479.2	141.8	159.1	368.0	176.0	181.0	211.0	243.0
Dissolved Oxygen	mg/L	6.4	4.9	10.9	7.7		11.7	8.6		6.5	8.5	10.3	8.4
Flow	gpm	35.1		203.4	23.8		199.8	1035.0	3.0				
Temperature	Celsius	6.48	15.20	12.10	20.10	10.96	8.16	19.38	23.90	7.30	20.80	17.08	12.12
Acidity	mg/L	32.00	0.00	27.00	0.00	0.00	10.00	20.00	0.00	20.00	18.00	15.00	0.00
Total Alkalinity	mg/L	3.00	15.00	0.00	34.00	20.00	6.00	0.00	106.00	0.00	7.00	6.00	12.00
Sulfate	mg/L	75.0	80.0	46.5	77.5	197.5	41.5	43.0	59.2	66.6	58.6	61.4	74.5
Total Hardness	mg/L												
TSS	mg/L												
Turbidity	NTU												
Aluminum	ug/L	190	390	180	110	250	1	100	100	160		100	1930
Iron	ug/L	270	3900	760	120	270	520	670	50	900	2850	1240	680
Lead	ug/L												
Manganese	ug/L	3440	1600	2150	720	4900	120	1700	310	2870	3120	3260	3050

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	13 - Chick House Road (Previt Branch)									36 33' 22"N			
										84 30' 49"W			
Test	*Units*	*2/12/01*	*5/8/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/15/06*
pH	--	4.99	4.12	3.54	4.95	5.54	4.48	4.28	5.70	5.10	4.32	3.87	3.64
Conductivity	uMHO	195.1	303.4	367.0	429.0	406.5	283.7	110.0	300.0	287.0	328.0	423.0	571.0
Dissolved Oxygen	mg/L	4.1	1.5	10.8	8.9		12.1	7.9		7.3		10.1	8.4
Flow	gpm			0.9	30.0		239.9	94.5	1.0	90.0			
Temperature	Celsius	6.5	15.6	8.8	21.7	10.7	6.6	18.8	21.2	8.2	25.4	16.6	12.3
Acidity	mg/L	50.00	40.00	30.00	89.00	30.00	25.00	20.00	72.00	40.00	42.00	36.00	35.00
Total Alkalinity	mg/L	0.00	0.00	0.00	2.00	8.00	0.00	0.00	26.00	7.00	0.00	0.00	0.00
Sulfate	mg/L	81.0	212.5	82.5	182.5	84.8	80.0	55.5	70.0	85.0	86.5	95.0	231.0
Total Hardness	mg/L												
TSS	mg/L												
Turbidity	NTU												
Aluminum	ug/L	1220	440	270	640	220	220	100	1360	190	270	100	1590
Iron	ug/L	540	800	460	940	1660	390	960	12900	880	2110	1770	980
Lead	ug/L												
Manganese	ug/L	4840	9900	3440	4900	4000	1900	2000	5600	3160	4310	7300	4900

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	14 - East Phase 5 - In									36 32' 54"N 84 29' 52"W		
Test	*Units*	*2/12/01*	*5/7/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*
pH	--	3.29	3.55	3.28	3.37	3.11	3.70	3.37	3.14	5.21	3.69	3.54
Conductivity	uMHO	433.8	424.1	476.0	810.0	1008.0	444.0	526.0	960.0	567.0	701.0	746.0
Dissolved Oxygen	mg/L	0.3	0.3	11.0	8.6		11.5	4.6		6.0		3.7
Flow	gpm	32.9		122.0				157.5	1.0	472.5	10.0	
Temperature	Celsius	7.40	15.81	7.24	24.60	11.20	6.33	19.90	25.50	7.90	22.00	14.61
Acidity	mg/L	130.00	140.00	72.00	140.00	180.00	60.00	132.00	170.00	49.00	110.00	86.00
Total Alkalinity	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
Sulfate	mg/L	250.0	300.0	182.5	300.0	400.0	84.8	182.5	434.0	249.0	262.0	265.0
Total Hardness	mg/L											
TSS	mg/L											
Turbidity	NTU											
Aluminum	ug/L	2550	2810	420	3100	1450	290	220	2150	380	370	1660
Iron	ug/L	1840	2100	1290	1090	7000	570	2850	4400	3250	4980	5280
Lead	ug/L											
Manganese	ug/L	15300	16000	5000	13400	11700	3280	7500	11400	4400	7500	17100

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	15 - East Phase 5 - Out								**36 32' 55"N**				
									84 29' 50"W				
Test	*Units*	*2/12/01*	*5/7/01*	*1/28/02*	*6/11/02*	*11/4/02*	*2/24/03*	*6/16/03*	*8/28/03*	*1/26/04*	*7/12/04*	*5/24/05*	*5/15/06*
pH	--	4.30	5.82	3.62	5.37	4.42	4.06	3.72	6.69	3.58	4.59	4.82	4.96
Conductivity	uMHO	379.0	410.6	437.0	670.0	860.0	412.3	483.2	945.0	417.0	535.0	602.0	669.0
Dissolved Oxygen	mg/L	0.6	0.3	11.2	6.0		12.2	6.1		5.6		2.7	7.2
Flow	gpm								1.0				
Temperature	Celsius	7.40	19.56	6.59	25.60	10.45	6.22	21.37	26.40	7.80	23.50	16.61	13.30
Acidity	mg/L	110.00	0.00	70.00	35.00	80.00	64.00	70.00	0.00	72.00	50.00	27.00	0.00
Total Alkalinity	mg/L	0.00	19.00	0.00	10.00	0.00	0.00	0.00	40.00	0.00	0.00	6.00	24.00
Sulfate	mg/L	132.5	297.5	170.0	275.0	387.5	84.8	84.8	351.0	224.0	241.0	236.0	275.0
Total Hardness	mg/L												
TSS	mg/L												
Turbidity	NTU												
Aluminum	ug/L	930	220	290	2140	390	180	340	200	280	260	100	2840
Iron	ug/L	1920	160	860	180	2020	680	3100	460	2300	1200	1190	4040
Lead	ug/L												
Manganese	ug/L	11600	6600	4500	10600	7500	3700	7800	4350	4000	5900	11000	5100

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

Bear Creek d/s of Confluence East & West Branches — 36 34' 57"N, 84 31' 04"W

Test	*Units*	*5/9/01*	*1/29/02*	*2/20/03*	*8/27/03*
pH	--	5.65	6.15		5.59
Conductivity	uMHO	149.8	152.0	160.0	258.0
Dissolved Oxygen	mg/L	5.2	10.8		
Flow	gpm				
Temperature	Celsius	14.90	10.40		22.40
Acidity	mg/L	24.00	0.00	0.00	21.00
Total Alkalinity	mg/L	8.00	21.00	17.00	11.00
Sulfate	mg/L	80.0	49.0	46.0	78.5
Total Hardness	mg/L				
TSS	mg/L				
Turbidity	NTU				
Aluminum	ug/L	230	70	90	100
Iron	ug/L	150	160	390	80
Lead	ug/L				
Manganese	ug/L	1770	1140	1220	1420

Table B-3 (cont'd) Bear Creek Monitoring Data (OSM)

	Bear Creek at USGS Gage (03410500)									36 37' 37"N
										84 32' 00"W
Test	*Units*	*5/9/01*	*1/29/02*	*11/5/02*	*2/25/03*	*6/17/03*	*8/27/03*	*1/27/04*	*5/25/05*	*5/16/06*
pH	--	5.47	5.95	6.30	6.15	7.09	6.58	6.10	6.02	6.58
Conductivity	uMHO	98.3	94.0	199.3	158.8	66.5	196.0	98.4	90.0	116.0
Dissolved Oxygen	mg/L	7.2	11.1		14.5	9.0		6.6		9.9
Flow	gpm									
Temperature	Celsius	16.25	8.17	9.62	4.53	17.97	25.70	6.10	14.90	12.63
Acidity	mg/L	20.00	0.00	55.00	11.00	35.00	5.00	16.00	9.00	0.00
Total Alkalinity	mg/L	7.00	13.00	20.00	10.00	24.00	12.00	0.00	5.00	7.00
Sulfate	mg/L	54.0	31.0	55.0	26.5	20.0	53.4	28.3	31.8	33.6
Total Hardness	mg/L									
TSS	mg/L									
Turbidity	NTU									
Aluminum	ug/L	120	40	1	1	100	100	100	100	
Iron	ug/L	160	170	280	390	1370	90	100	220	220
Lead	ug/L									
Manganese	ug/L	700	500	140	140	420	110	520	11	10

ACSP Sampling Points - Bear Creek, Tennessee
Knoxville Field Office

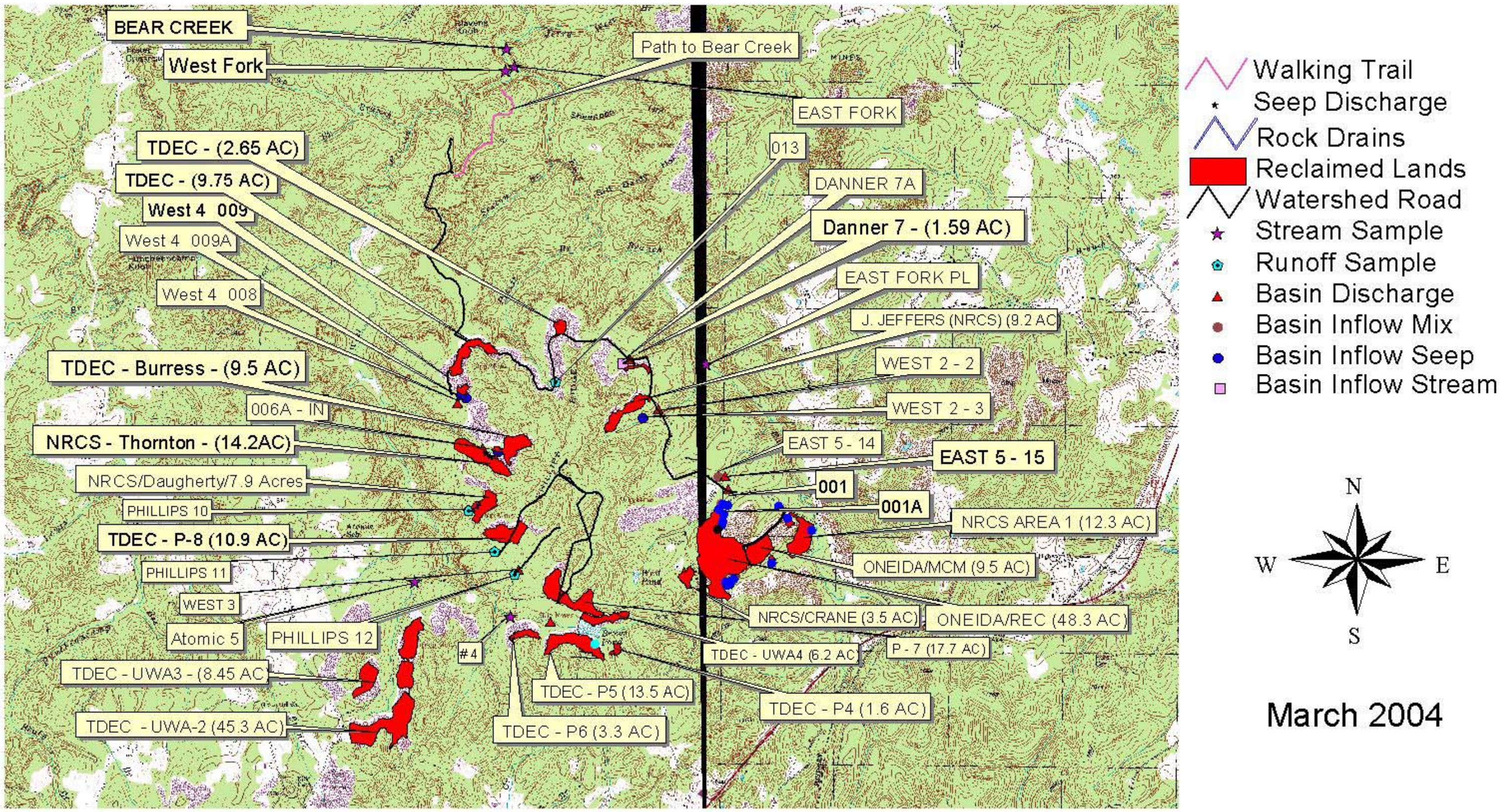

Figure B-2 Bear Creek Monitoring Stations (OSM)

APPENDIX C

Development of Target Net Alkalinity

Since there is no numerical criterion for net alkalinity, monitoring data for the entire State of Tennessee was examined in an effort to develop a target net alkalinity.

Of the available monitoring data for waterbodies that are not impaired for pH, 47 data points existed for which numerical values for both acidity and total alkalinity were available. (See Figure C-1.) The highest calculated net alkalinity that fell outside of the desired pH range of 6.0 to 9.0 was 10.78 mg/L as $CaCO_3$ at a pH of 9.1. Therefore, a net alkalinity of 10.8 was selected as the target net alkalinity.

Analysis was then expanded to include monitoring data for waterbodies that are not impaired for pH and for which both total alkalinity and acidity were analyzed, but for which either acidity or total alkalinity, but not both, was not detected. (See Figure C-2.) For the purpose of calculating net alkalinity, the analyte concentrations were estimated to be one half of the appropriate detection limit (10 mg/L for total alkalinity and 1 mg/L for acidity). Of the 211 data points, only 3 points (or 1.4%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but were not within the required pH range.

Available monitoring data for waterbodies that are included on the 303(d) List as impaired for pH were also compared to the target net alkalinity. Of 41 data points for which numerical values for both acidity and total alkalinity were available, only 2 points (or 4.9%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but was not within the required pH range. These data points were for North Suck Creek on 5/21/2005 (pH 5.14, net alkalinity 16.9) and South Suck Creek on 9/9/2004 (pH 5.2, net alkalinity 29.96). When analysis was expanded to include data points for which both acidity and total alkalinity were analyzed, but for which either acidity or total alkalinity, but not both, was not detected, only 3 points (or 2.0%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but were not within the required pH range. These data points were the previously mentioned points for North and South Suck Creek and a data point for North Suck Creek on 3/22/2005 (pH 5.8, net alkalinity 18.5).

Therefore, based on analysis of all available monitoring data for the State of Tennessee, selection of a target net alkalinity of 10.8 mg/L as $CaCO_3$ should provide a pH within the criteria of 6.0 to 9.0 standard pH units for waterbodies with a designated use of Fish & Aquatic Life.

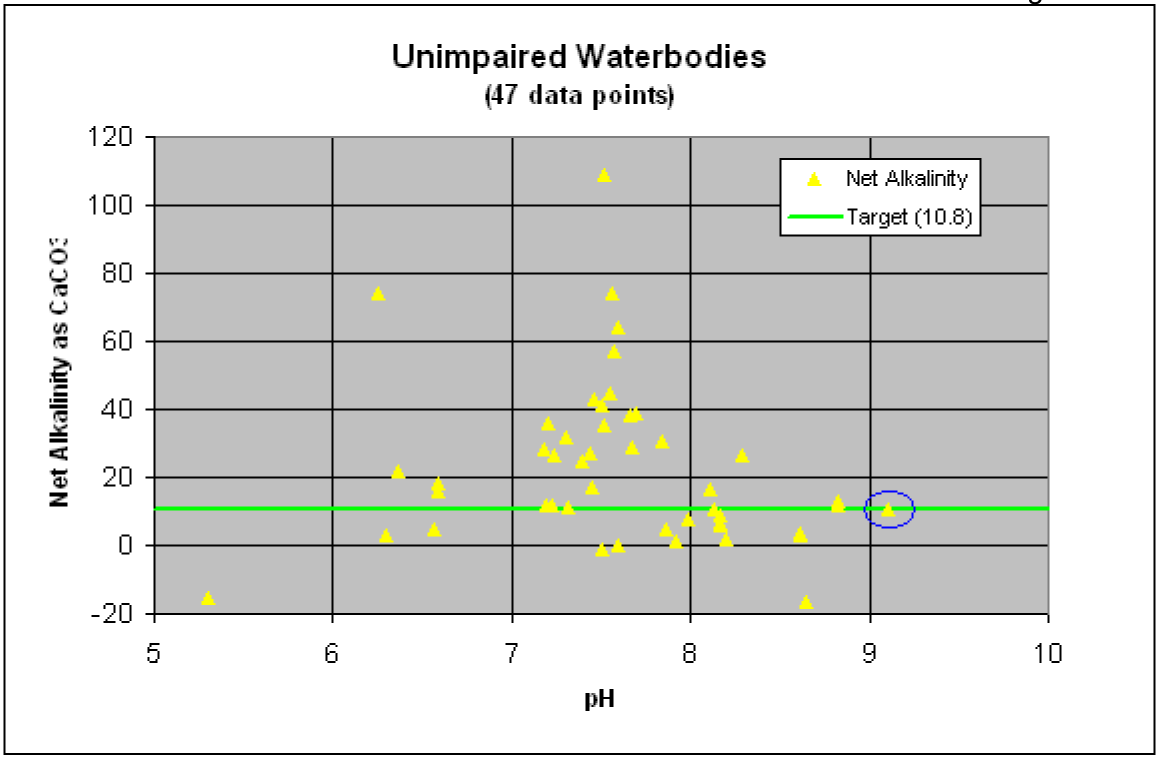

Figure C-1 pH and Net Alkalinity for Unimpaired Waterbodies in Tennessee
(no non-detects for either acidity or total alkalinity)

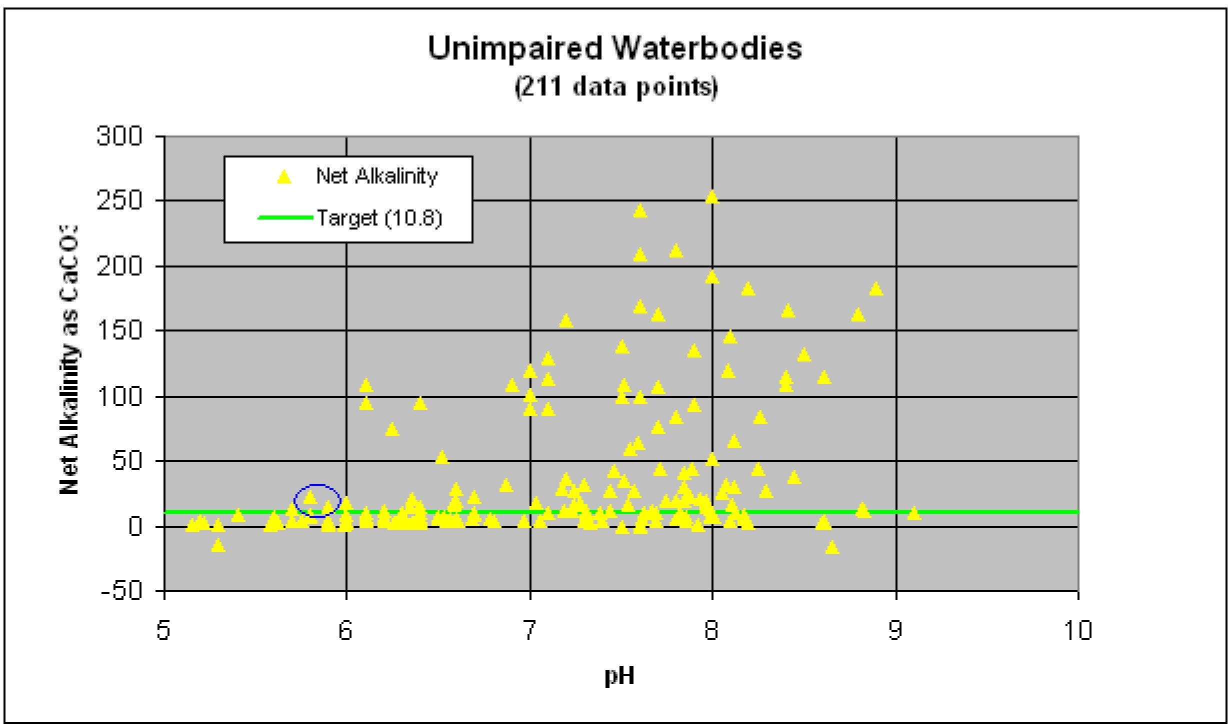

Figure C-2 pH and Net Alkalinity for Unimpaired Waterbodies in Tennessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

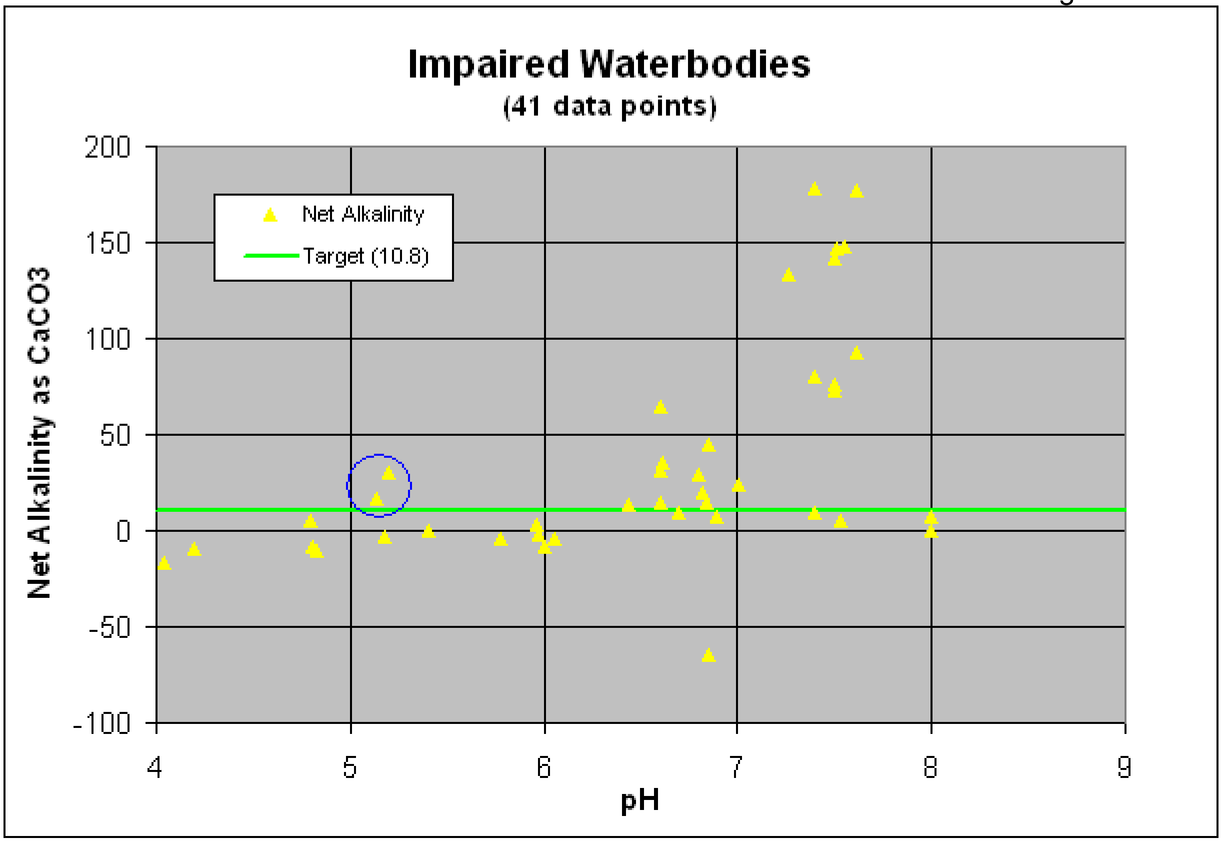

Figure C-3 pH and Net Alkalinity for Impaired Waterbodies in Tenneessee
(no non-detects for either acidity or total alkalinity)

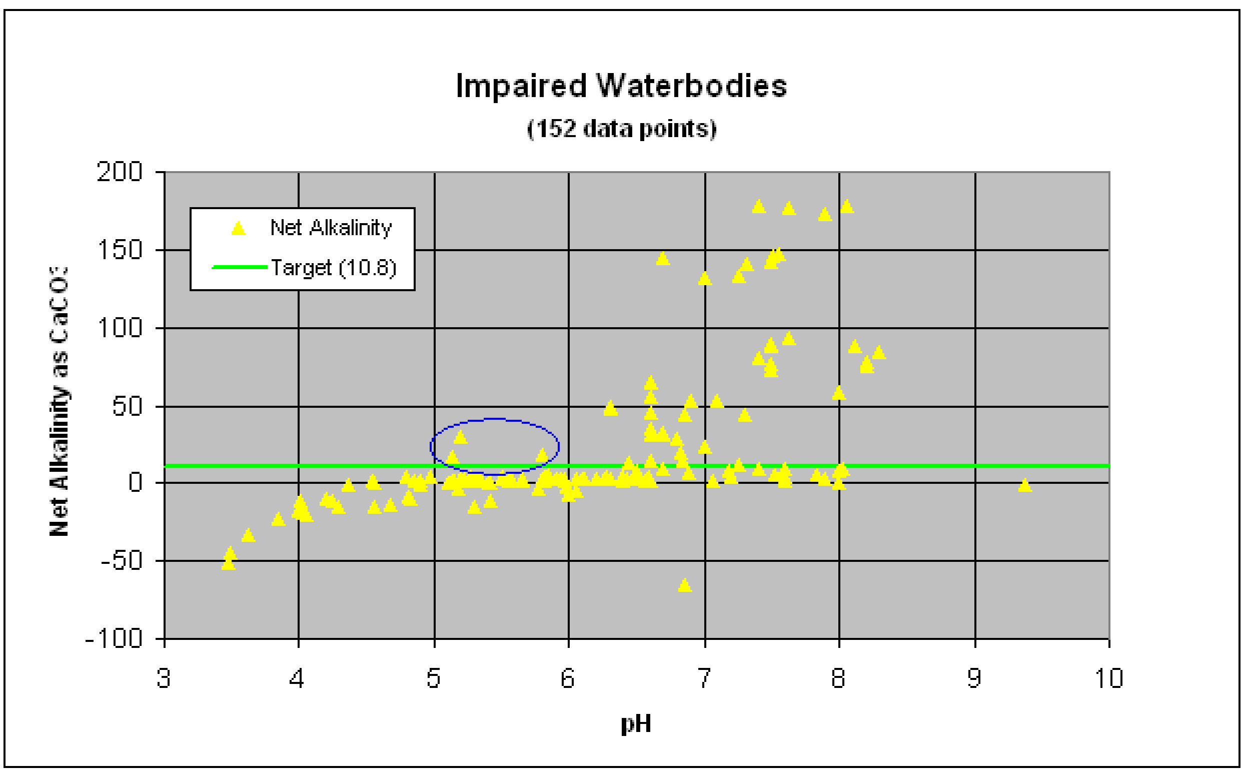

Figure C-4 pH and Net Alkalinity for Impaired Waterbodies in Tenneessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

APPENDIX D

Development of Load Duration Curves for Bear Creek Subwatershed

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. When a water quality target (or criteria) concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

D.1 Development of Flow Duration Curves

Flow duration curves are developed for a waterbody from daily discharges of flow over a period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from USGS continuous-record stations located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for pH-impaired waterbodies in the South Fork Cumberland River watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at USGS Station No. 03408500, located on New River at New River, Tennessee, in the South Fork Cumberland River watershed (see Appendix F for details of calibration). For example, a flow-duration curve for the Bear Creek subwatershed was constructed using simulated daily mean flow for Bear Creek downstream of the confluence of East Branch and West Branch Bear Creek for the period from 1/1/00 through 12/31/05 and dividing by the drainage area. This flow duration curve is shown in Figure D-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). This flow duration curve could be applied to all impaired waterbodies because it was developed on a “per area” basis.

D.2 Development of Target Load Duration Curve for Net Alkalinity

The target net alkalinity load duration curve for the Bear Creek subwatershed was developed from the flow duration curve for the Bear Creek subwatershed developed in Section D.1. The net alkalinity target concentration of 10.8 mg/L was applied to each of the ranked flows used to generate the flow duration curve and the results were plotted. The net alkalinity target load corresponding to each ranked daily mean flow is:

$$\text{Target Load}_{\text{Bear Creek}} = (\text{Target Net Alkalinity})_{\text{Bear Creek}} \times (Q/A) \times (UCF)$$

where: Q = daily mean flow
A = drainage area
UCF = the required unit conversion factor

The target net alkalinity load duration curve, on a unit drainage area basis, is presented in Figures D-2 and D-3. Figure D-2 is presented in semi-log scale format while Figure D-3 is presented in non-log scale format. Because the calculated net alkalinity of the Bear Creek subwatershed can be negative and negative values cannot be plotted on a log or semi-log scale format, the non-log scale format will be used for net alkalinity load duration curves in this TMDL.

D.3 Development of Load Duration Curves for Net Alkalinity

Sampling was conducted at several sites in the Bear Creek subwatershed by OSM. Net alkalinity load duration curves were developed from the target load duration curves developed in Section D.2 and water quality monitoring data collected by OSM. Load duration curves were developed using the following procedure (Previt Branch at Chick House Road is used as an example):

1. Daily net alkalinity loads were calculated for each of the water quality samples collected at the Previt Branch monitoring station by multiplying the calculated net alkalinity by the daily mean flow (on an area basis) for the sampling date and the required unit conversion factor. Net Alkalinity Calculations for the Bear Creek subwatersheds are summarized in Tables D-1 thru D-10.

   Note: *In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data was available for some sampling dates.*

   Example – 1/28/02 sampling event:
   Modeled Flow = 6.28 cfs/mi^2
   Calculated Net Alkalinity = -30 mg/L $CaCO_3$
   Net Alkalinity Load = -1,016.4 lbs $CaCO_3$/day/mi^2

2. Using the flow duration curve developed in Figure D-1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event.

Example – 1/28/02 sampling event:
Modeled Flow = 6.28 cfs/mi²
PDFE from flow duration curve for Bear Creek subwatershed corresponding to 6.28 cfs/mi² = 4.5%

3. Each sample load was then plotted on the target load duration curve developed in Section D.2 according to the PDFE. The resulting curve is presented in Figure D-7.

   Load duration curves for net alkalinity for other impaired waterbodies were derived in a similar manner and are shown in Figures D-5 through D-14 and Tables D-1 thru D-10.

4. The magnitude of the difference between the target net alkalinity load and each calculated net alkalinity load is calculated by:

$$\text{Net Alkalinity}_{\text{Difference}} = (\text{Net Alkalinity}_{\text{Previt Branch}}) - (\text{Net Alkalinity}_{\text{Target}})$$

where:
Net Alkalinity is in lbs $CaCO_3$/day/mi^2

Example – 1/28/02 sampling event:
Calculated net alkalinity load = -1016.4 lbs $CaCO_3$*/day/mi*^{2}
Target net alkalinity load = 365.9 lbs $CaCO_3$*/day/mi*^{2}
$\textit{Net alkalinity}_{Difference} = (-1016.4 \text{ lbs } CaCO_3/\text{day/mi}^2) – (365.9 \text{ lbs } CaCO_3/\text{day/mi}^2)$
$\textit{Net alkalinity}_{Difference} = -1382.3 \text{ lbs } CaCO_3/\text{day/mi}^2$

The difference between the target net alkalinity load and the calculated net alkalinity load for the Bear Creek subwatersheds are summarized in Tables D-11 thru D-20.

A negative sign indicates that the net alkalinity load must be <u>increased</u> to meet the target.

D.4 Development of Load Duration Curves for Iron

The target load duration curve for iron was developed similar to the load duration curve for net alkalinity developed in Section D.2. The appropriate target concentration for iron was applied to each of the ranked flows used to generate the flow duration curve and the results were plotted in Figure D-4. Load duration curves for specific monitoring locations were developed using the following procedure (Previt Branch at Chick House Road is used as an example):

1. A target load-duration curve (LDC) was generated for Previt Branch at Chick House Road by applying the iron target concentration of 1.0 mg/L to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The iron target maximum load corresponding to each ranked daily mean flow is:

Target $Load_{Bear\ Creek}$ = (1.0 mg/L) x (Q/A) x (UCF)

where: Q = daily mean flow
A = drainage area
UCF = the required unit conversion factor

2. Daily loads were calculated for each of the water quality samples collected at the Previt Branch monitoring station (ref.: Table B-3) by multiplying the sample concentration by the daily mean flow (on an area basis) for the sampling date and the required unit conversion factor.

   Note: In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data was available for some sampling dates.

   Example – 11/4/02 sampling event:
   Modeled Flow = 0.76 cfs/mi^2
   Concentration = 1,660 μg/L
   Daily Load = 6.77 lbs iron/day/mi^2

3. Using the flow duration curves developed in D.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting iron load duration curve is shown in Figure D-17.

   Example – 11/4/02 sampling event:
   Modeled Flow = 0.76 cfs/mi^2
   PDFE = 42.2%

4. For cases where the existing load exceeded the target maximum load at a particular PDFE, the reduction required to reduce the sample load to the target load was calculated.

   Example – 11/4/02 sampling event:
   Target Concentration = 1000 μg/L
   Measured Concentration = 1,660 μg/L
   Reduction to Target = 39.8%

5. The 90th percentile value for all of the iron sampling data at the Previt Branch monitoring station was determined. If the 90th percentile value exceeded the target maximum iron concentration, the reduction required to reduce the 90th percentile value to the target maximum concentration was calculated.

   Example: *Target Concentration = 1000 μg/L*
   90th Percentile Concentration = 2,076 μg/L
   Reduction to Target = 51.8%

6. The load reductions at each monitoring site within the drainage area (East Branch, West Branch, mainstem Bear Creek) were compared and the load reduction of the greatest magnitude selected as the load reduction for the drainage area.

Load duration curves for iron for other impaired waterbodies were derived in a similar manner and are shown in Figures D-15 through D-24 and Tables D-21 thru D-30.

D.4.1 Development of WLAs & LAs

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

For waterbodies with active mining operations, the WLAs for existing mining operations are equal to their existing NPDES permit limits. For waterbodies with no active mining operations, there is no WLA.

For waterbodies with active mining operations, the LA for each metal is equal to the difference between the TMDL and the WLA. For waterbodies with no active mining operations, LAs for precipitation-based nonpoint sources are expressed as the percent reduction in loading required to decrease instream metal concentrations to TMDL target values minus MOS. As stated in Section 7.2, an explicit MOS, equal to 10% of the water quality targets (ref.: Section 4.0), was utilized for determination of LAs:

Instantaneous Maximum for Iron

Target – MOS = (1000 μg/L) – (100 μg/L) = 900 μg/L

D.4.2 Determination of LAs for Precipitation-Based Nonpoint Sources

LAs for precipitation-based nonpoint sources were developed using methods similar to those described in D.4 (again, using Previt Branch at Chick House Road as an example):

7. For cases where the existing load exceeded the "target maximum load – MOS" at a particular PDFE, the reduction required to reduce the sample load to the "target – MOS" load was calculated.

Example – 11/4/02 sampling event:

Target Concentration -- MOS = 900 μg/L
Measured Concentration = 1,660 μg/L
Reduction to Target -- MOS = 45.8%

8. If the 90th percentile value (calculated in Step 5) exceeded the "target maximum – MOS" iron concentration, the reduction required to reduce the 90th percentile value to the "target maximum – MOS" concentration was calculated (Table D-23).

   Example: *Target Concentration -- MOS = 900 μg/L*
   90th Percentile Concentration = 2,076 μg/L
   Reduction to Target -- MOS = 56.6%

9. The load reductions at each monitoring site within the drainage area (East Branch, West Branch, mainstem Bear Creek) were compared and the load reduction of the greatest magnitude selected as the load reduction for the drainage area.

Load duration curves and required load reductions for iron for other impaired waterbodies were derived in a similar manner and are shown in Figures D-15 through D-24 and Tables D-21 through D-30. Required load reductions for impaired waterbodies in the Bear Creek Subwatershed are summarized in Table D-31. TMDLs, WLAs, & LAs for impaired waterbodies in the Bear Creek subwatershed are summarized in Table D-32.

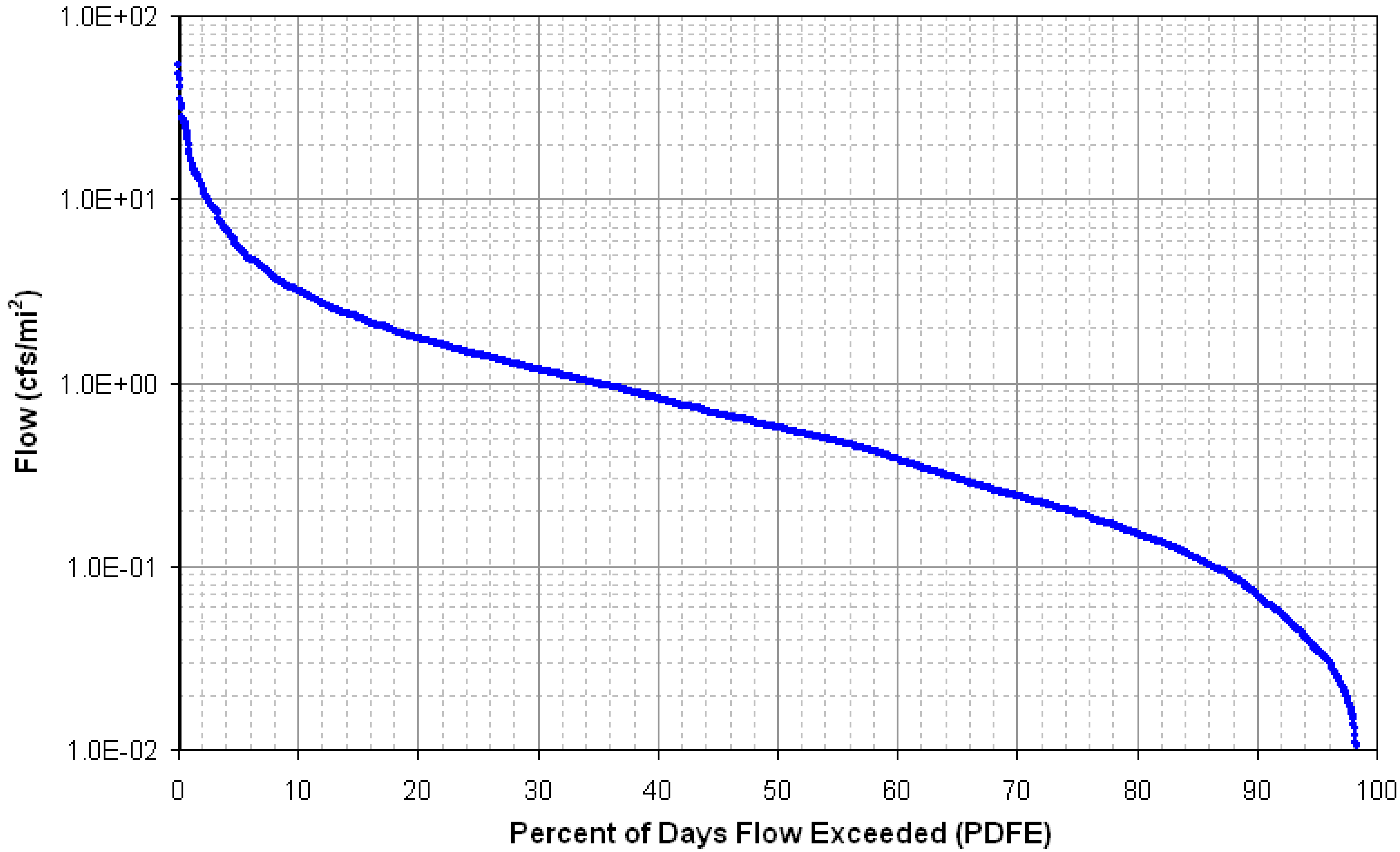

Figure D-1 Flow Duration Curve for Bear Creek Subwatershed

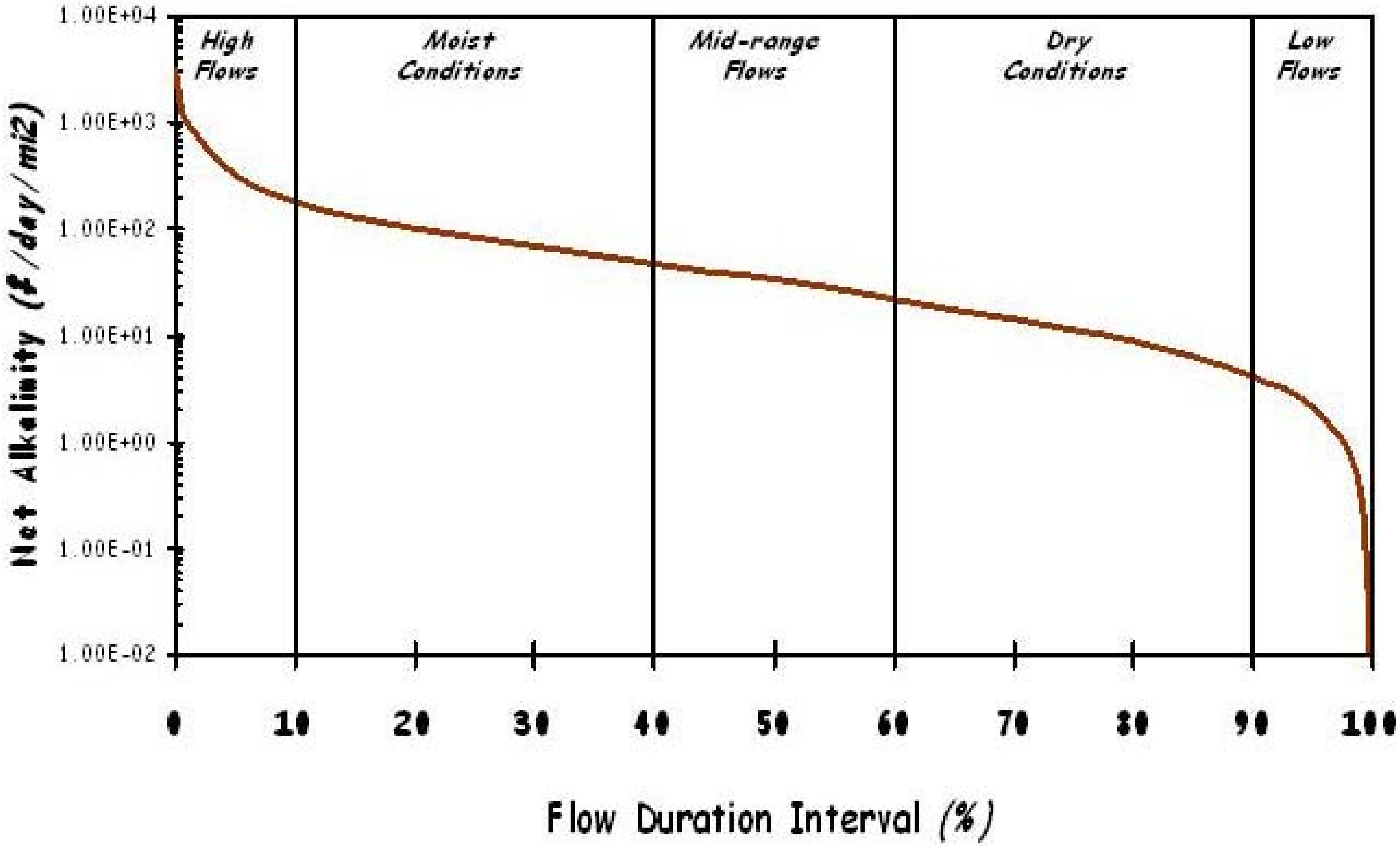

Figure D-2 Target Net Alkalinity Load Duration Curve (semi-log-scale)

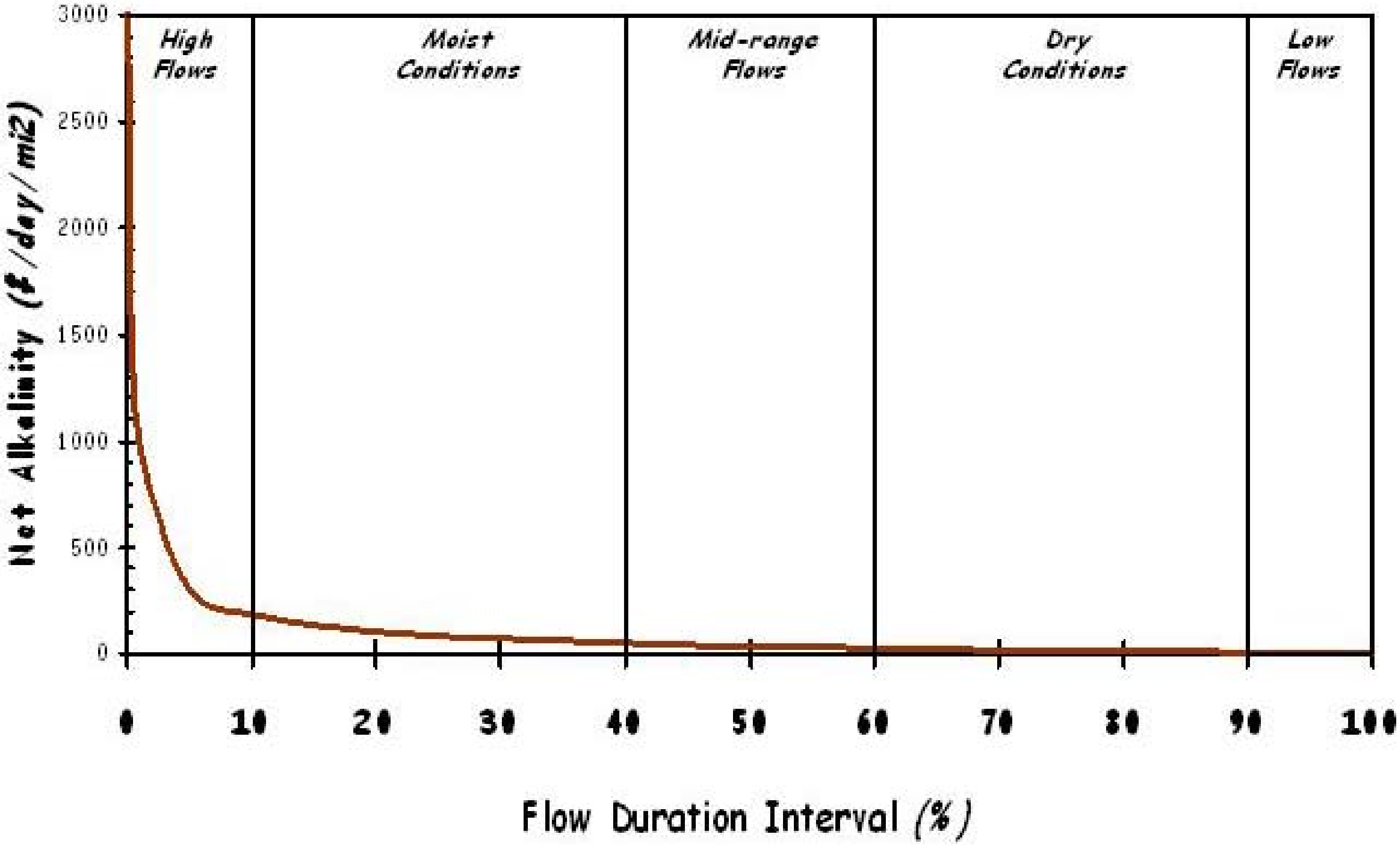

Figure D-3 Target Net Alkalinity Load Duration Curve (non-log scale)

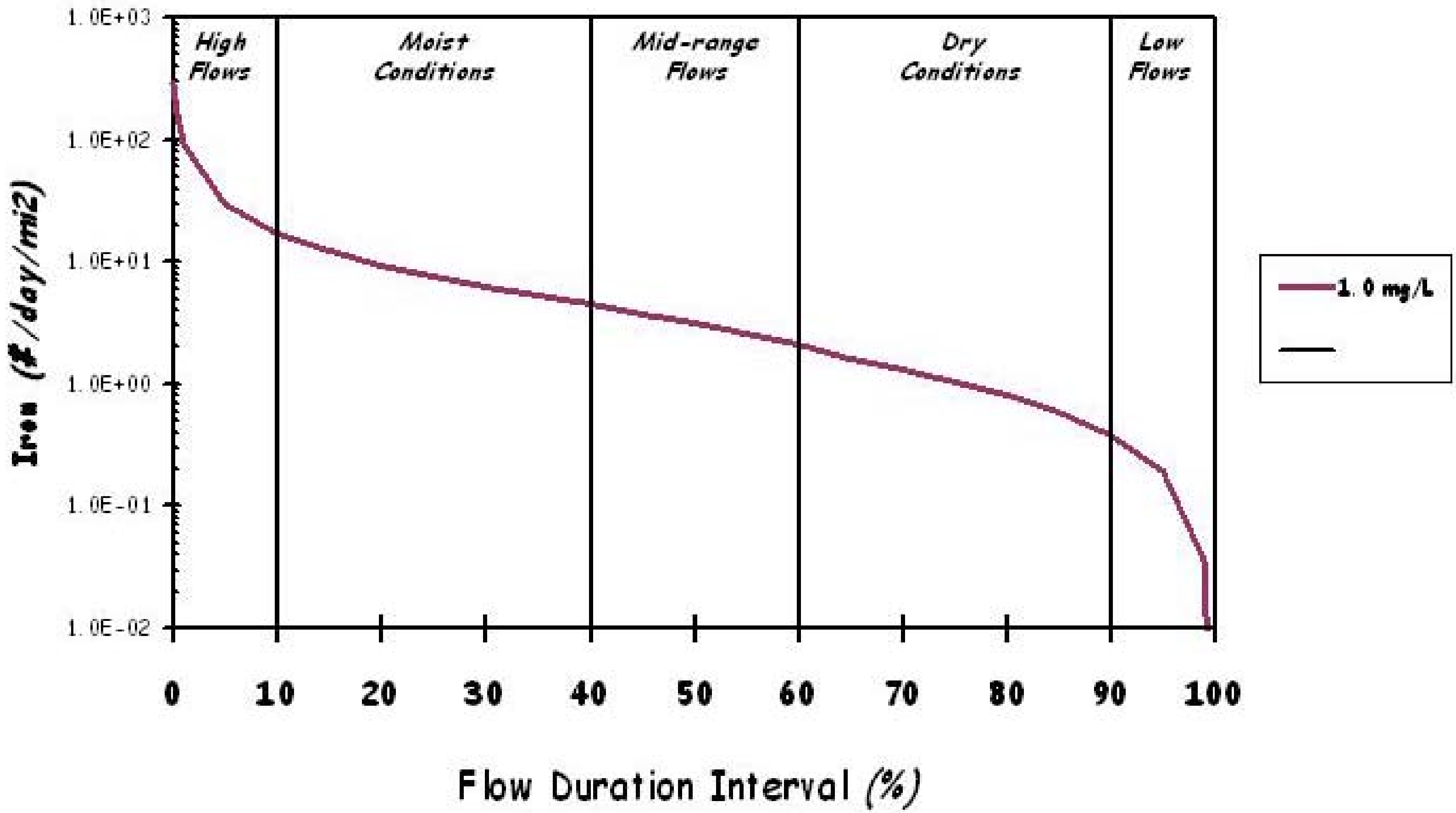

Figure D-4 Target Iron Load Duration Curve

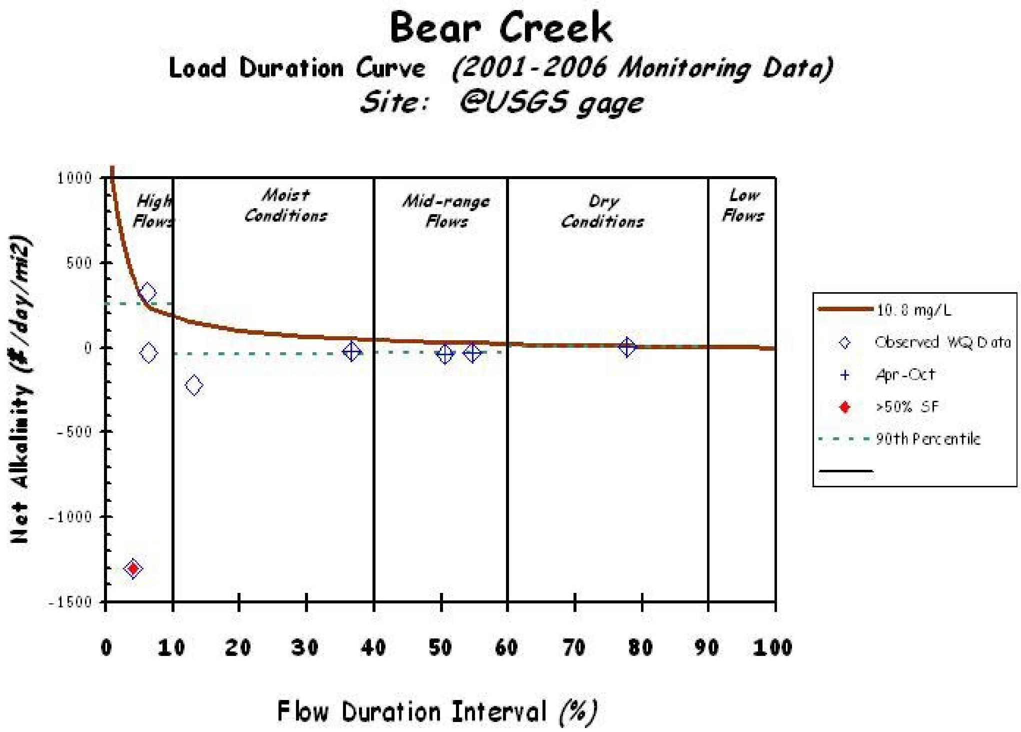

Figure D-5 Net Alkalinity Load Duration Curve for Bear Creek at Gaging Station

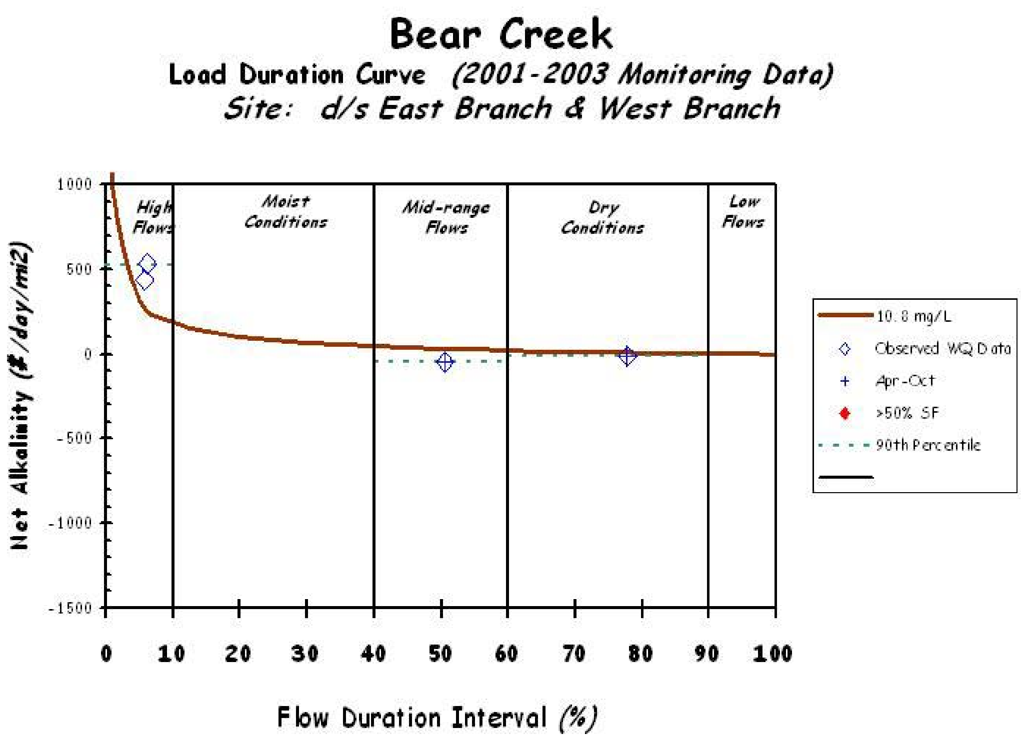

Figure D-6 Net Alkalinity Load Duration Curve for Bear Creek d/s East Branch & West Branch

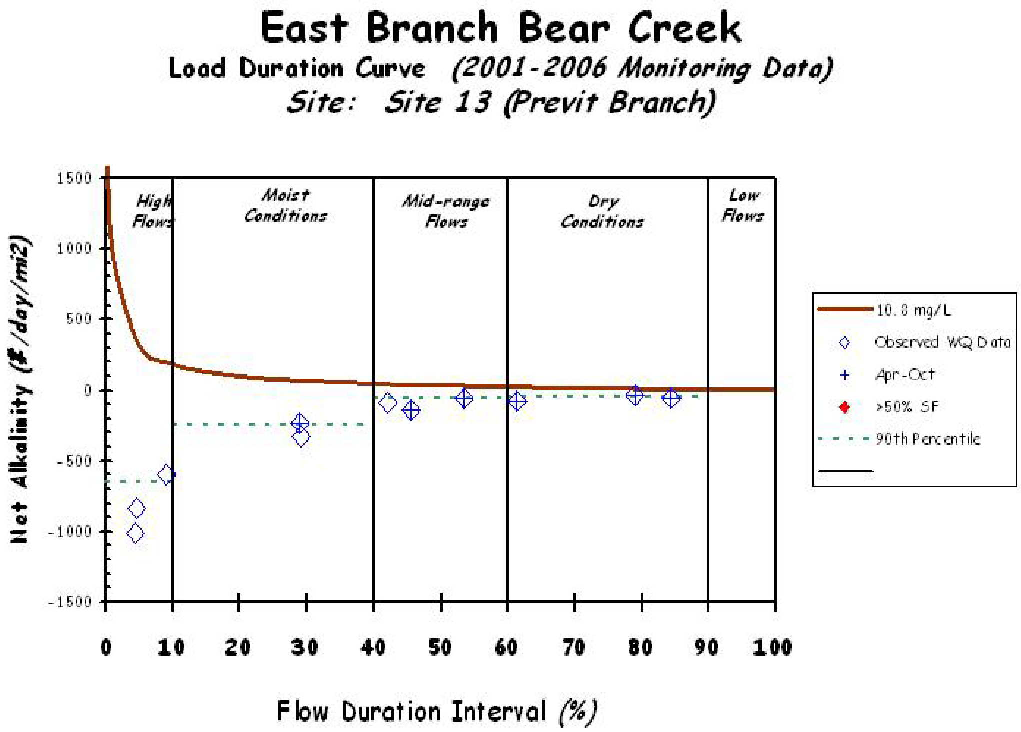

Figure D-7 Net Alkalinity Load Duration Curve for Previt Branch

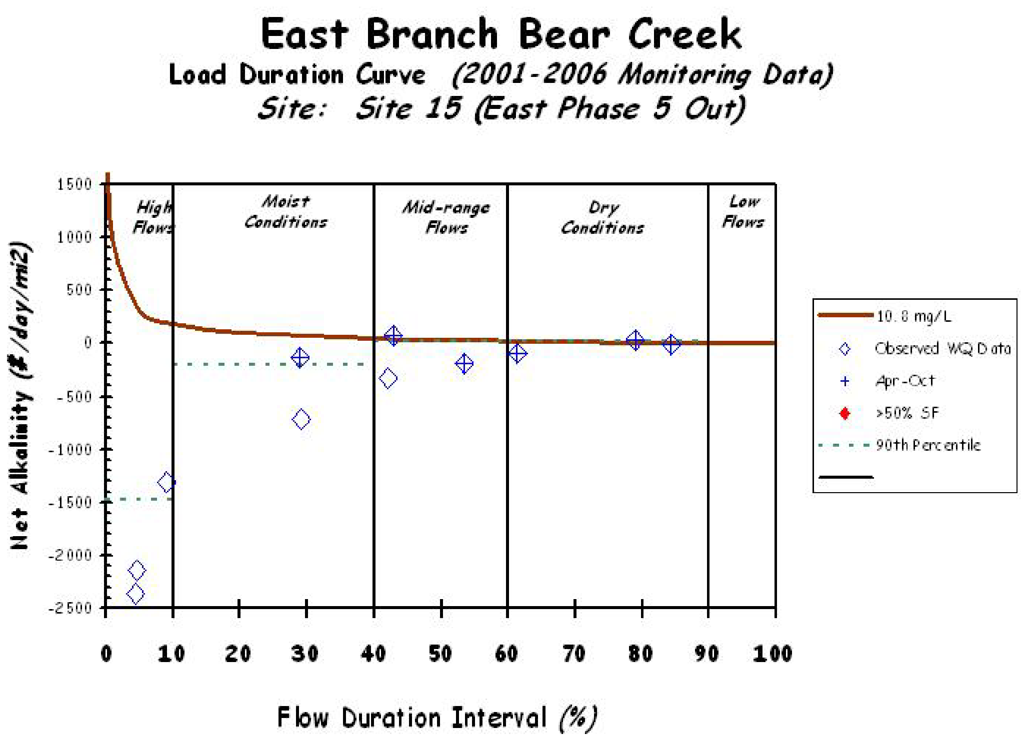

Figure D-8 Net Alkalinity Load Duration Curve for East Phase 5 Out

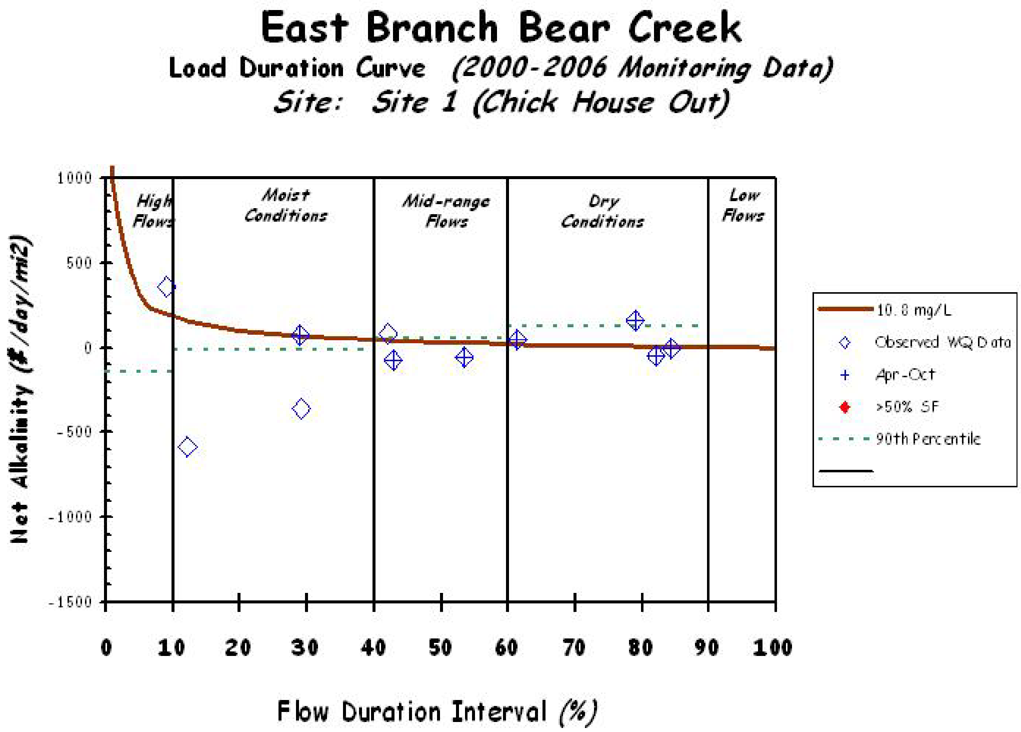

Figure D-9 Net Alkalinity Load Duration Curve for Chick House Out (Site 1)

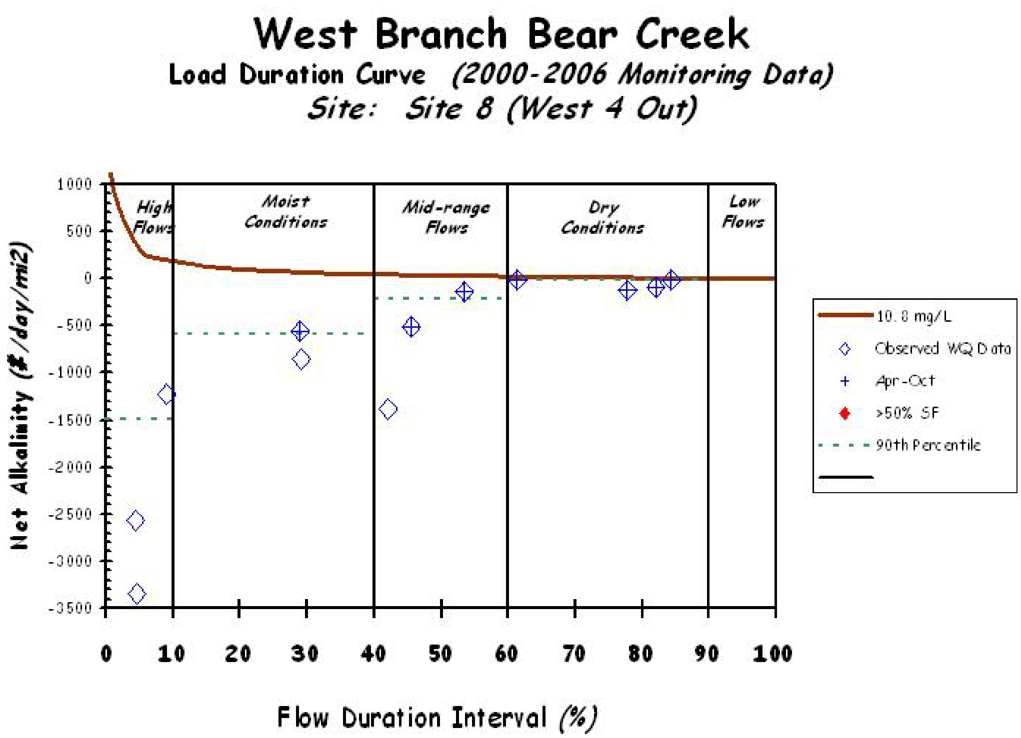

Figure D-10 Net Alkalinity Load Duration Curve for West 4 Out (Site 8)

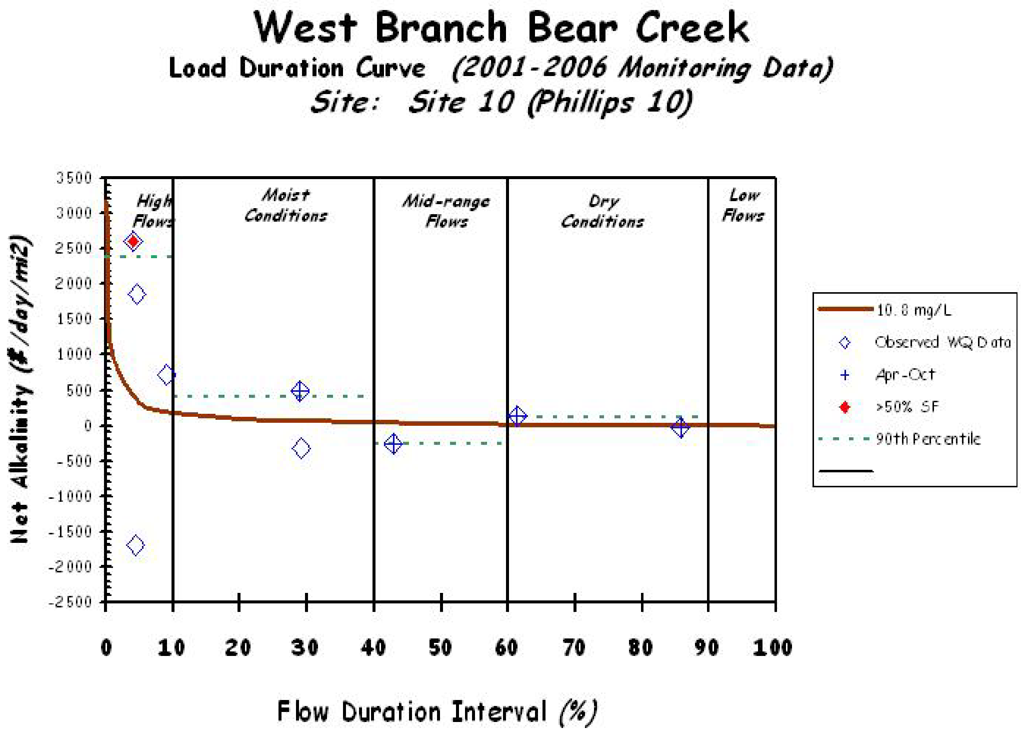

Figure D-11 Net Alkalinity Load Duration Curve for Phillips 10

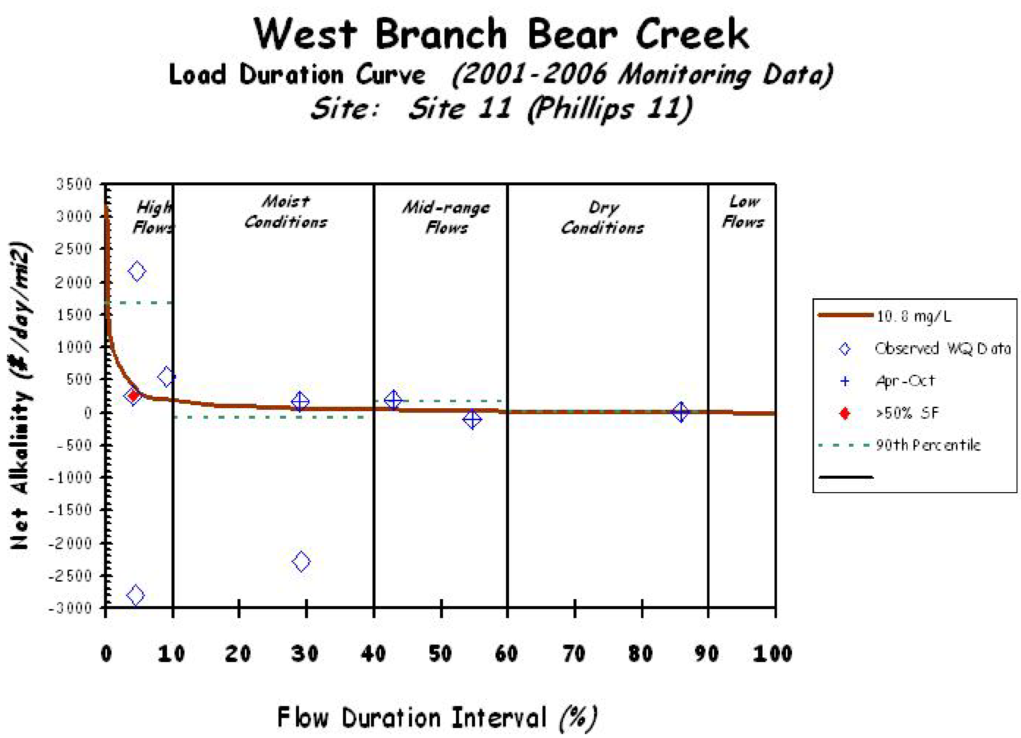

Figure D-12 Net Alkalinity Load Duration Curve for Phillips 11

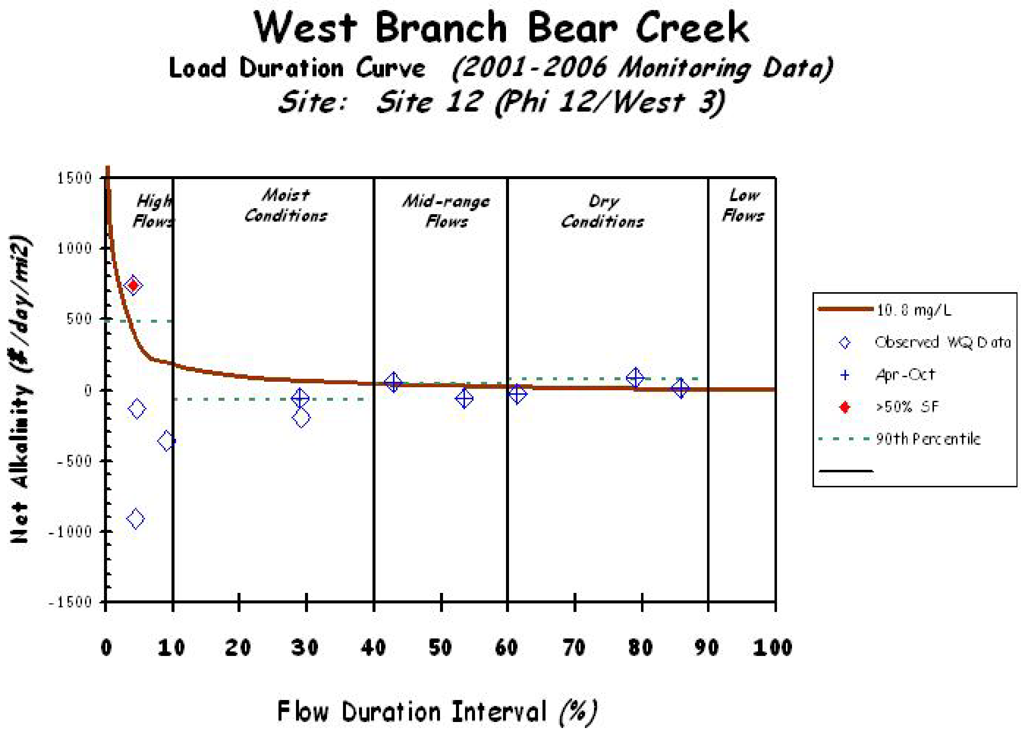

Figure D-13 Net Alkalinity Load Duration Curve for Phi 12/West 3

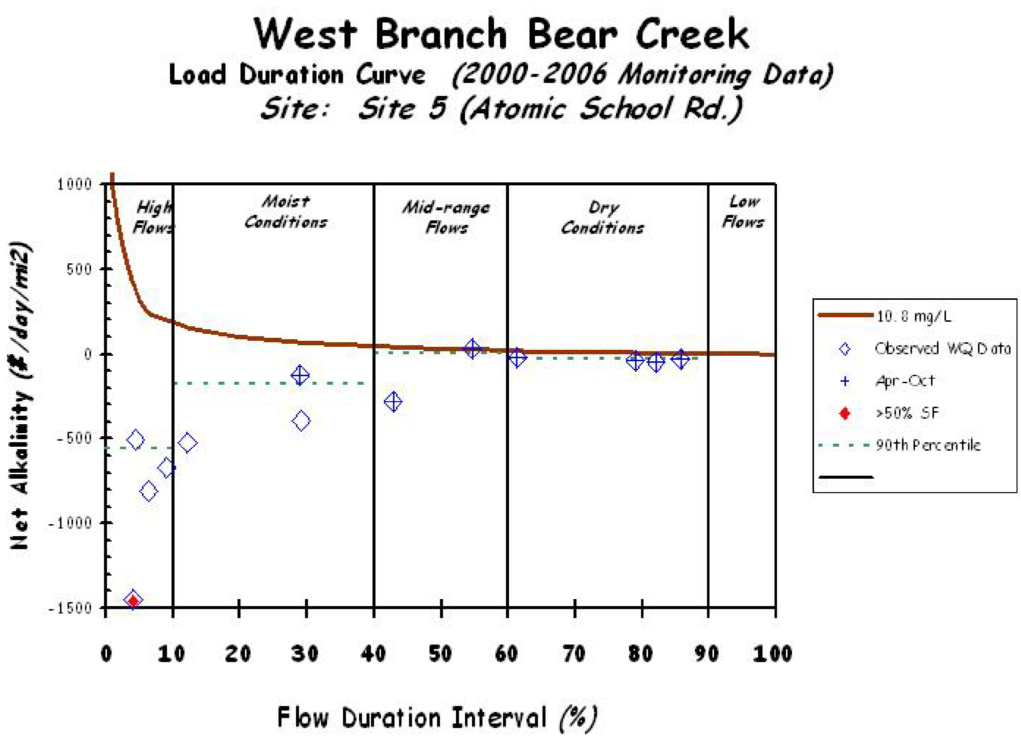

Figure D-14 Net Alkalinity Load Duration Curve for Atomic School Rd.

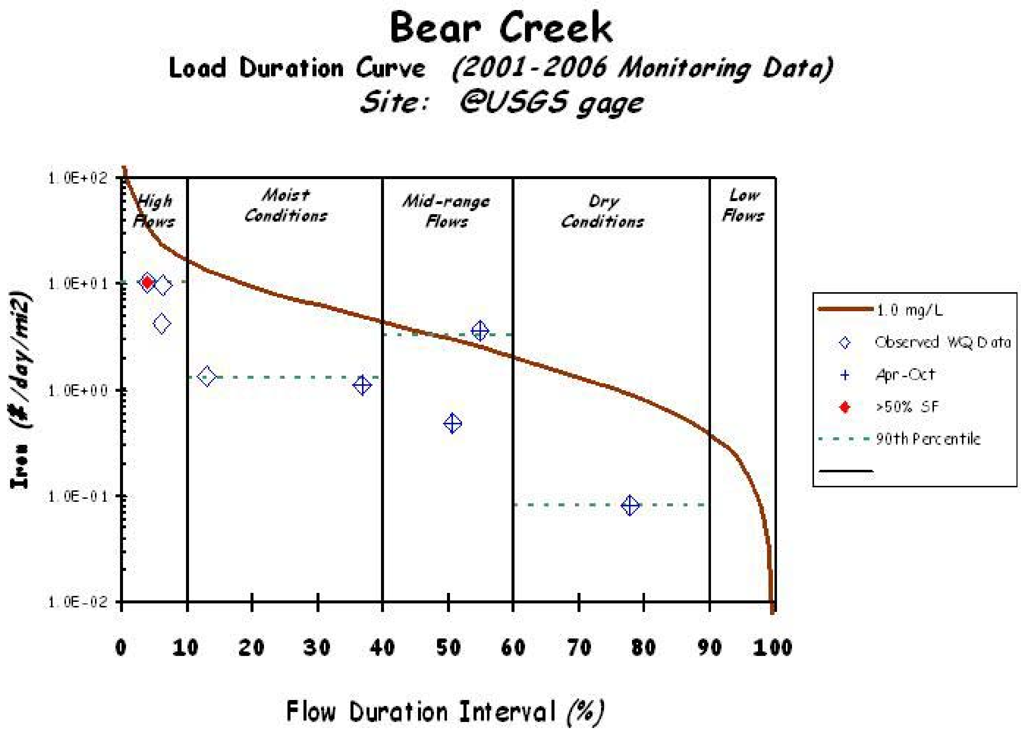

Figure D-15 Iron Load Duration Curve for Bear Creek at Gaging Station

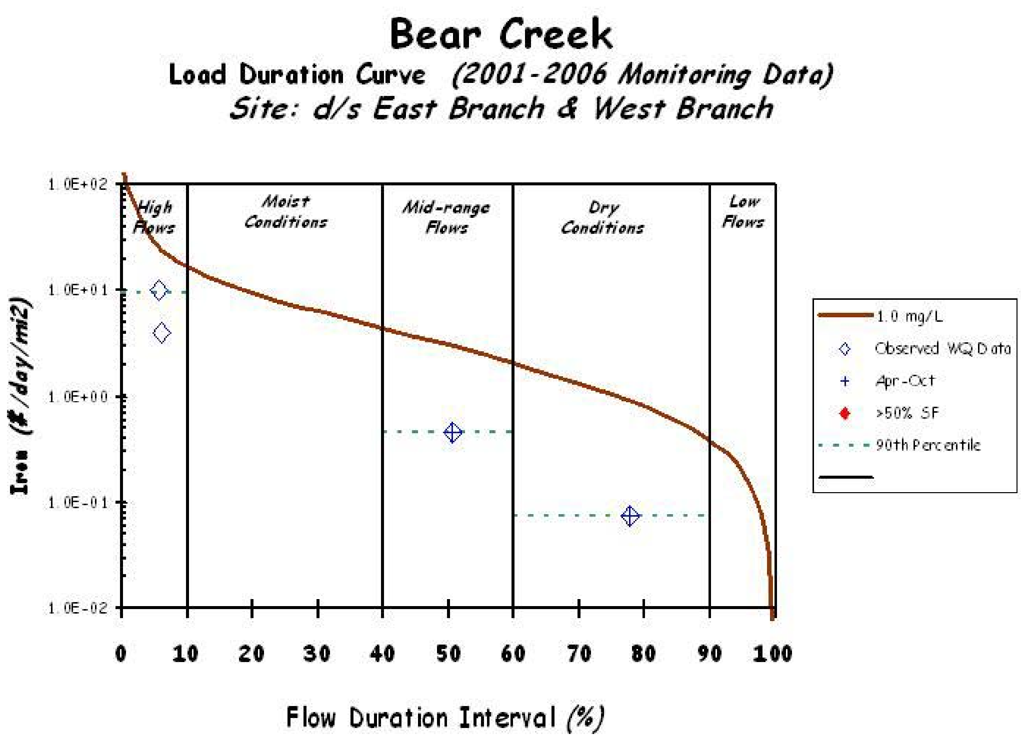

Figure D-16 Iron Load Duration Curve for Bear Creek d/s East Branch & West Branch

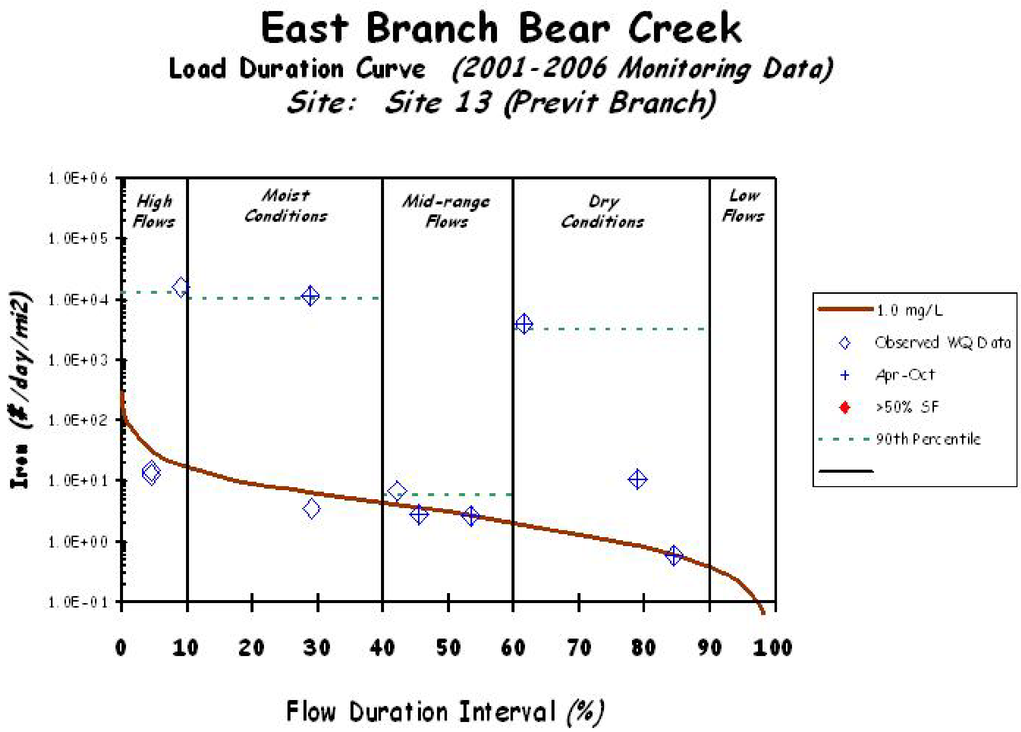

Figure D-17 Iron Load Duration Curve for Previt Branch

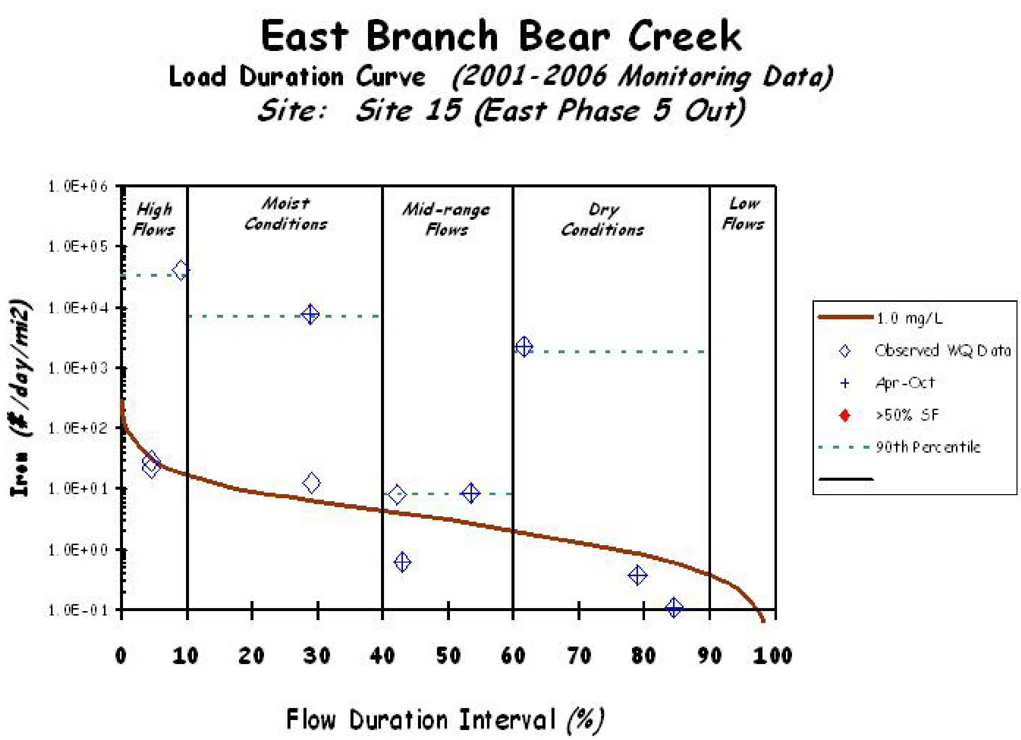

Figure D-18 Iron Load Duration Curve for East Phase 5 Out

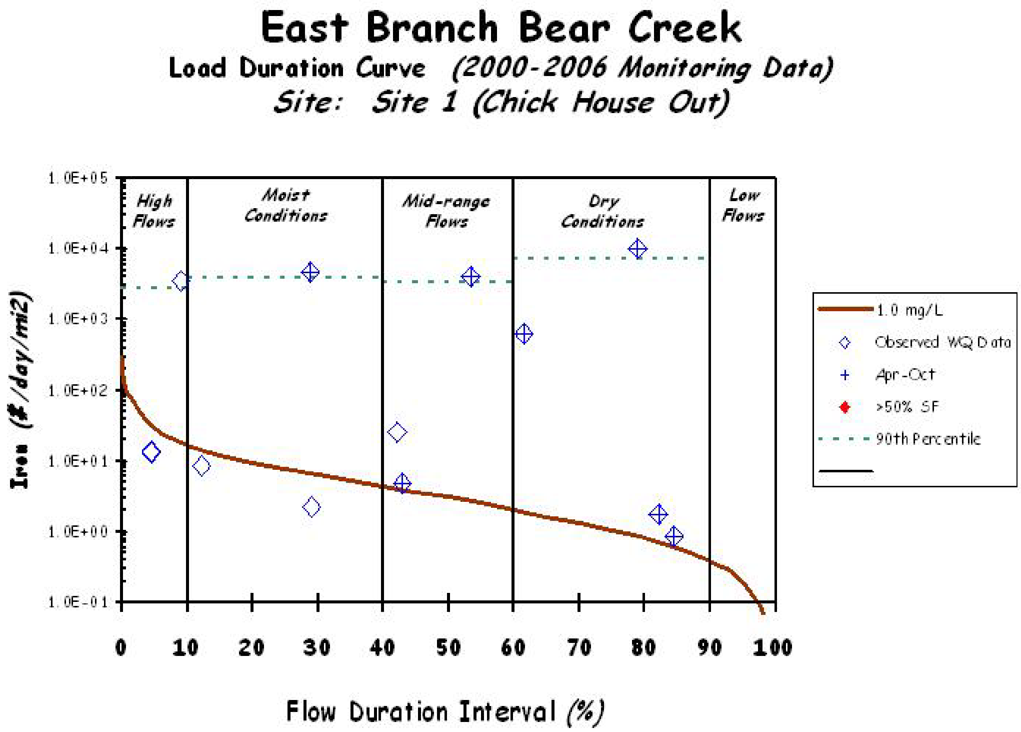

Figure D-19 Iron Load Duration Curve for Chick House Out (Site 1)

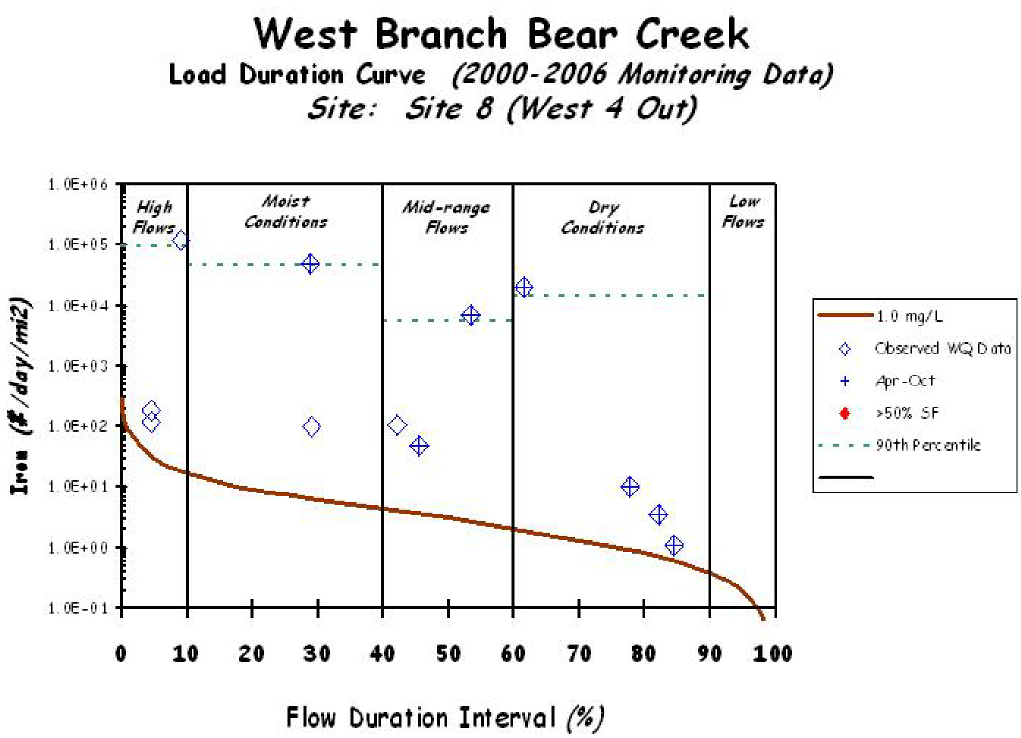

Figure D-20 Iron Load Duration Curve for West 4 Out (Site 8)

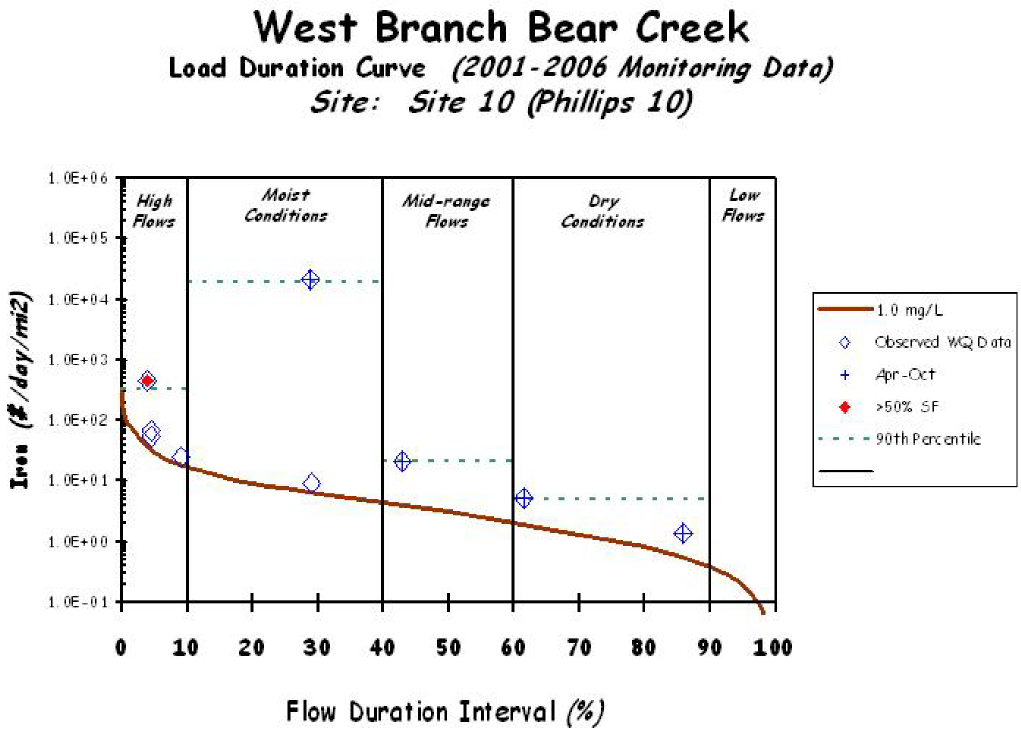

Figure D-21 Iron Load Duration Curve for Phillips 10

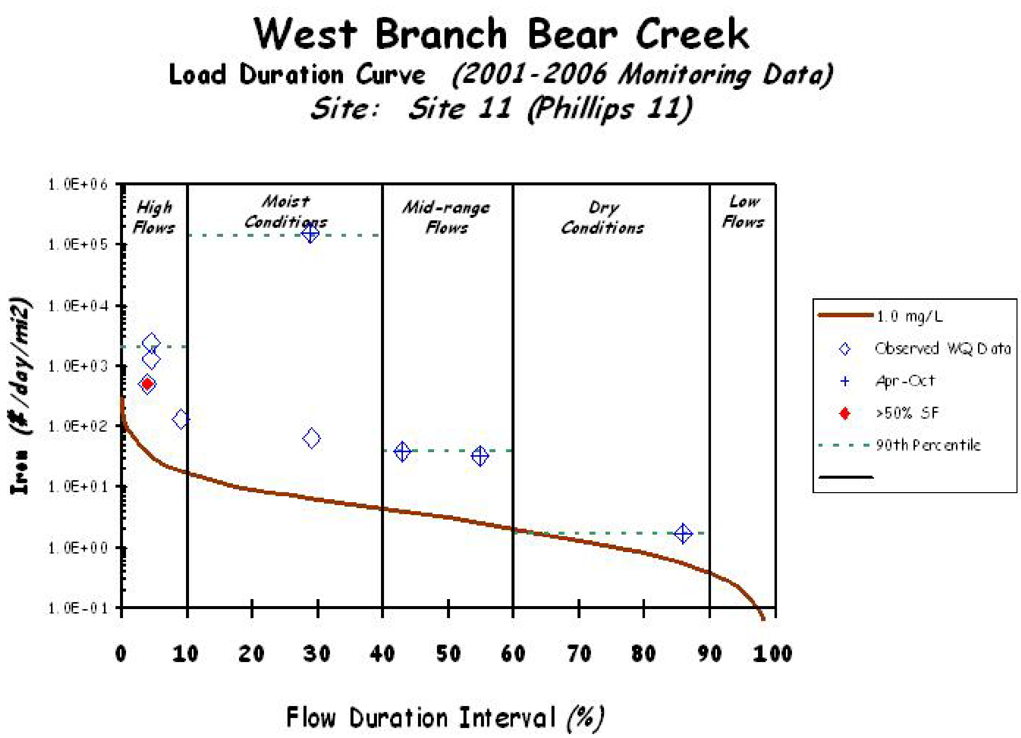

Figure D-22 Iron Load Duration Curve for Phillips 11

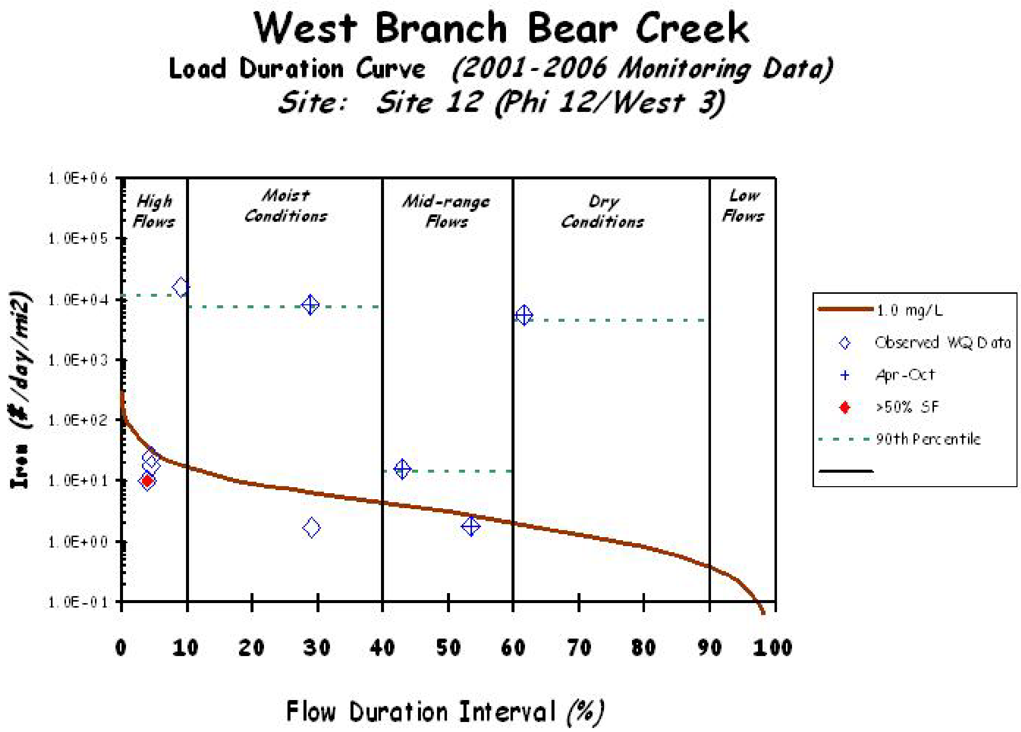

Figure D-23 Iron Load Duration Curve for Phi 12/West 3

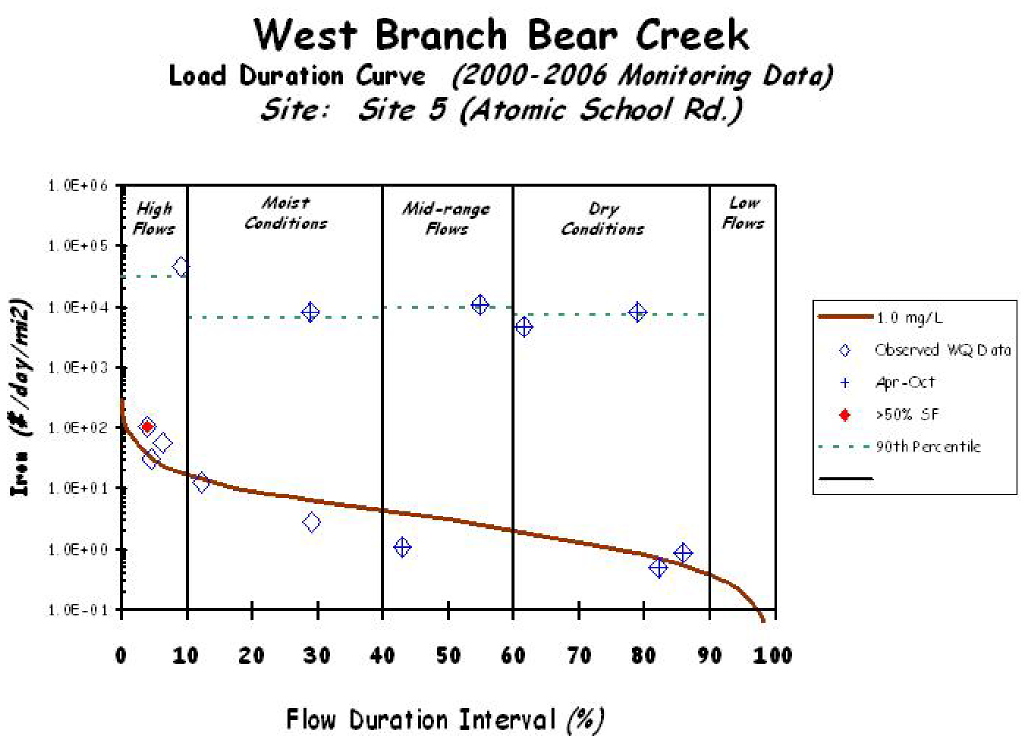

Figure D-24 Iron Load Duration Curve for Atomic School Rd.

Table D-1. Net Alkalinity Load Calculations for Bear Creek at Gaging Station

Sample	Bear Creek Flow (@ gage)		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
5/9/01	12.9	0.56	20.00	7.00	-13.00	-39.2
1/29/02	107.6	4.68	0.00	13.00	13.00	328.0
11/5/02	159.3	6.93	55.00	20.00	-35.00	-1307.5
2/25/03	107.5	4.68	11.00	10.00	-1.00	-25.2
6/17/03	11.2	0.49	35.00	24.00	-11.00	-28.9
8/27/03	3.9	0.17	5.00	12.00	7.00	6.4
1/27/04	57.7	2.51	16.00	0.00	-16.00	-216.4
5/25/05	21.6	0.94	9.00	5.00	-4.00	-20.2
5/16/06			0.00	7.00	7.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-2. Net Alkalinity Load Calculations for Bear Creek d/s East Branch & West Branch

Sample	Bear Creek Flow (@ confluence)		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
5/9/01	7.2	0.56	24.00	8.00	-16.00	-48.3
1/29/02	60.0	4.69	0.00	21.00	21.00	530.9
2/20/03	61.6	4.81	0.00	17.00	17.00	441.1
8/27/03	2.2	0.17	21.00	11.00	-10.00	-9.2
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-3. Net Alkalinity Load Calculations for Previt Branch at Chick House Rd.

Sample	Site 13		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
2/12/01	0.16	1.21	50.00	0.00	-50.00	-327.7
5/8/01	0.09	0.67	40.00	0.00	-40.00	-144.3
1/28/02	0.84	6.28	30.00	0.00	-30.00	-1016.4
6/11/02	0.02	0.11	89.00	2.00	-87.00	-53.9
11/4/02	0.10	0.76	30.00	8.00	-22.00	-89.7
2/24/03	0.83	6.22	25.00	0.00	-25.00	-838.6
6/16/03	0.07	0.51	20.00	0.00	-20.00	-54.8
8/28/03	0.02	0.16	72.00	26.00	-46.00	-39.3
1/26/04	0.45	3.38	40.00	7.00	-33.00	-600.9
7/12/04	0.05	0.36	42.00	0.00	-42.00	-80.8
5/24/05	0.16	1.23	36.00	0.00	-36.00	-239.0
5/15/06			35.00	0.00	-35.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-4. Net Alkalinity Load Calculations for East Phase 5 Out

Sample	Site 15		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
2/12/01	0.16	1.21	110.00	0.00	-110.00	-720.9
5/7/01	0.10	0.74	0.00	19.00	19.00	76.2
1/28/02	0.81	6.28	70.00	0.00	-70.00	-2371.7
6/11/02	0.01	0.11	35.00	10.00	-25.00	-15.5
11/4/02	0.10	0.76	80.00	0.00	-80.00	-326.3
2/24/03	0.80	6.22	64.00	0.00	-64.00	-2146.9
6/16/03	0.07	0.51	70.00	0.00	-70.00	-191.8
8/28/03	0.02	0.16	0.00	40.00	40.00	34.1
1/26/04	0.43	3.38	72.00	0.00	-72.00	-1311.0
7/12/04	0.05	0.36	50.00	0.00	-50.00	-96.2
5/24/05	0.16	1.23	27.00	6.00	-21.00	-139.4
5/15/06			0.00	24.00	24.00	
[a]	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-5. Net Alkalinity Load Calculations for Chick House Out (Site 1)

Sample	Site 1		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
3/21/00	1.02	2.69	40.00	0.00	-40.00	-580.7
9/13/00	0.05	0.13	76.00	10.00	-66.00	-48.0
2/12/01	0.46	1.21	55.00	0.00	-55.00	-360.4
5/7/01	0.28	0.74	23.00	4.00	-19.00	-76.2
1/28/02	2.37	6.28	64.00	0.00	-64.00	-2168.4
6/11/02	0.04	0.11	20.00	16.00	-4.00	-2.5
11/4/02	0.29	0.76	5.00	26.00	21.00	85.7
2/24/03	2.35	6.22	70.00	0.00	-70.00	-2348.2
6/16/03	0.19	0.51	20.00	0.00	-20.00	-54.8
8/28/03	0.06	0.16	0.00	190.00	190.00	162.2
1/26/04	1.28	3.38	0.00	20.00	20.00	364.2
7/12/04	0.13	0.36	0.00	25.00	25.00	48.1
5/24/05	0.46	1.23	8.00	19.00	11.00	73.0
5/15/06			0.00	18.00	18.00	
[a]	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-6. Net Alkalinity Load Calculations for West 4 Out (Site 8)

Sample	Site 8		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
3/21/00	0.76	2.69				
9/13/00	0.04	0.13	115.00	0.00	-115.00	-83.6
2/12/01	0.34	1.21	130.00	0.00	-130.00	-851.9
5/8/01	0.19	0.67	140.00	0.00	-140.00	-505.2
1/28/02	1.78	6.28	76.00	0.00	-76.00	-2574.9
6/11/02	0.03	0.11	28.00	0.00	-28.00	-17.3
11/4/02	0.21	0.76	340.00	0.00	-340.00	-1387.0
2/24/03	1.76	6.22	100.00	0.00	-100.00	-3354.6
6/16/03	0.14	0.51	51.00	0.00	-51.00	-139.7
8/27/03	0.05	0.17	130.00	0.00	-130.00	-119.6
1/26/04	0.95	3.38	67.00	0.00	-67.00	-1220.0
7/12/04	0.10	0.36	12.00	2.00	-10.00	-19.2
5/24/05	0.35	1.23	84.00	0.00	-84.00	-557.6
5/15/06			56.00	0.00	-56.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-7. Net Alkalinity Load Calculations for Phillips 10

Sample	Site 10		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
2/12/01	0.08	1.21	50.00	0.00	-50.00	-327.7
5/7/01	0.05	0.74	65.00	2.00	-63.00	-252.8
1/28/02	0.40	6.28	50.00	0.00	-50.00	-1694.0
6/12/02	0.01	0.10	70.00	0.00	-70.00	-39.5
11/5/02	0.45	6.93	0.00	70.00	70.00	2614.9
2/24/03	0.40	6.22	0.00	56.00	56.00	1878.6
1/26/04	0.22	3.38	0.00	40.00	40.00	728.4
7/12/04	0.02	0.36	0.00	71.00	71.00	136.7
5/24/05	0.08	1.23	0.00	75.00	75.00	497.9
5/16/06			0.00	80.00	80.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-8. Net Alkalinity Load Calculations for Phillips 11

Sample	Site 11		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
2/12/01	0.03	1.21	350.00	0.00	-350.00	-2293.6
5/7/01	0.02	0.74	0.00	50.00	50.00	200.6
1/28/02	0.15	6.28	90.00	7.00	-83.00	-2812.1
6/12/02	0.00	0.10	40.00	74.00	34.00	19.2
11/5/02	0.16	6.93	45.00	52.00	7.00	261.5
2/24/03	0.15	6.22	45.00	110.00	65.00	2180.5
6/17/03	0.01	0.49	70.00	36.00	-34.00	-89.3
1/26/04	0.08	3.38	0.00	30.00	30.00	546.3
5/24/05	0.03	1.23	26.00	53.00	27.00	179.2
5/16/06			0.00	75.00	75.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-9. Net Alkalinity Load Calculations for Phi 12/West 3

Sample	Site 12		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
2/12/01	0.29	1.21	32.00	3.00	-29.00	-190.0
5/7/01	0.18	0.74	0.00	15.00	15.00	60.2
1/28/02	1.48	6.28	27.00	0.00	-27.00	-914.8
6/12/02	0.02	0.10	0.00	34.00	34.00	19.2
11/5/02	1.63	6.93	0.00	20.00	20.00	747.1
2/24/03	1.47	6.22	10.00	6.00	-4.00	-134.2
6/16/03	0.12	0.51	20.00	0.00	-20.00	-54.8
8/28/03	0.04	0.16	0.00	106.00	106.00	90.5
1/26/04	0.80	3.38	20.00	0.00	-20.00	-364.2
7/12/04	0.08	0.36	18.00	7.00	-11.00	-21.2
5/24/05	0.29	1.23	15.00	6.00	-9.00	-59.7
5/16/06			0.00	12.00	12.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-10. Net Alkalinity Load Calculations for Atomic School Road

Sample	Site 5		Acidity	Total Alkalinity	Net Alkalinity	
Date	(cfs)	(cfs/mi^2)	(mg/L)[a]	(mg/L)[a]	(mg/L)[a]	(lbs/day/mi^2)[a]
3/21/00	1.05	2.69	36.00	0.00	-36.00	-522.6
9/13/00	0.05	0.13	68.00	0.00	-68.00	-49.5
2/12/01	0.47	1.21	60.00	0.00	-60.00	-393.2
5/7/01	0.29	0.74	70.00	0.00	-70.00	-280.9
1/28/02	2.46	6.28	15.00	0.00	-15.00	-508.2
6/12/02	0.04	0.10	50.00	0.00	-50.00	-28.2
11/5/02	2.71	6.93	39.00	0.00	-39.00	-1456.9
2/25/03	1.83	4.68	32.00	0.00	-32.00	-807.1
6/17/03	0.19	0.49	7.00	20.00	13.00	34.2
8/28/03	0.06	0.16	40.00	0.00	-40.00	-34.1
1/26/04	1.32	3.38	37.00	0.00	-37.00	-673.7
7/12/04	0.14	0.36	15.00	2.00	-13.00	-25.0
5/24/05	0.48	1.23	22.00	3.00	-19.00	-126.1
5/16/06			25.00	0.00	-25.00	
a	Acidity, total alkalinity, & net alkalinity are reported as mg/L $CaCO_3$ or lbs $CaCO_3$/day/mi^2.					

Table D-11. Net Alkalinity Difference Relative to Target Bear Creek at Gaging Station

Sample	Bear Ck Flow (@gage)	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
5/9/01	0.56	-39.2	50.7%	32.6	-71.8
1/29/02	4.68	328.0	6.2%	272.5	55.5
11/5/02	6.93	-1307.5	4.0%	403.4	-1710.9
2/25/03	4.68	-25.2	6.3%	272.4	-297.6
6/17/03	0.49	-28.9	54.8%	28.4	-57.3
8/27/03	0.17	6.4	77.9%	9.9	-3.5
1/27/04	2.51	-216.4	13.1%	146.1	-362.5
5/25/05	0.94	-20.2	36.8%	54.6	-74.8
5/16/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-12. Net Alkalinity Difference Relative to Target Bear Creek d/s East Branch & West Branch

Sample	Bear Ck Flow (@confluence)	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
5/9/01	0.56	-48.3	50.7%	32.6	-80.9
1/29/02	4.68	530.9	6.2%	272.5	258.4
2/20/03	6.93	441.1	5.8%	403.4	37.7
8/27/03	4.68	-9.2	77.9%	272.4	-281.6
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-13. Net Alkalinity Difference Relative to Target Previt Branch at Chick House Rd.

Sample	Site 13	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
2/12/01	1.21	-327.7	29.2%	70.8	-398.4
5/8/01	0.67	-144.3	45.6%	39.0	-183.3
1/28/02	6.28	-1016.4	4.5%	365.9	-1382.3
6/11/02	0.11	-53.9	84.5%	6.7	-60.6
11/4/02	0.76	-89.7	42.2%	44.1	-133.8
2/24/03	6.22	-838.6	4.6%	362.3	-1200.9
6/16/03	0.51	-54.8	53.5%	29.6	-84.4
8/28/03	0.16	-838.6	79.1%	9.2	-847.9
1/26/04	3.38	-54.8	9.1%	196.7	-251.5
7/12/04	0.36	-80.8	61.6%	20.8	-101.6
5/24/05	1.23	-239.0	29.0%	71.7	-310.7
5/15/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-14. Net Alkalinity Difference Relative to Target East Phase 5 Out

Sample	Site 15	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
2/12/01	1.21	-720.9	29.2%	70.8	-791.6
5/8/01	0.74	76.2	42.9%	43.3	32.9
1/28/02	6.28	-2371.7	4.5%	365.9	-2737.6
6/11/02	0.11	-15.5	84.5%	6.7	-22.2
11/4/02	0.76	-326.3	42.2%	44.1	-370.4
2/24/03	6.22	-2146.9	4.6%	362.3	-2509.2
6/16/03	0.51	-191.8	53.5%	29.6	-221.4
8/28/03	0.16	-2146.9	79.1%	9.2	-2156.1
1/26/04	3.38	-191.8	9.1%	196.7	-388.5
7/12/04	0.36	-96.2	61.6%	20.8	-117.0
5/24/05	1.23	-139.4	29.0%	71.7	-211.1
5/15/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-15. Net Alkalinity Difference Relative to Target Chick House Out (Site 1)

Sample	Site 1	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
3/21/00	2.69	-580.7	12.2%	156.8	-737.5
9/13/00	0.13	-48.0	82.2%	7.9	-55.9
2/12/01	1.21	-360.4	29.2%	70.8	-431.2
5/7/01	0.74	-76.2	42.9%	43.3	-119.6
1/28/02	6.28	-2168.4	4.5%	365.9	-2534.3
6/11/02	0.11	-2.5	84.5%	6.7	-9.2
11/4/02	0.76	85.7	42.2%	44.1	41.6
2/24/03	6.22	-2348.2	4.6%	362.3	-2710.5
6/16/03	0.51	-54.8	53.5%	29.6	-84.4
8/28/03	0.16	162.2	79.1%	9.2	153.0
1/26/04	3.38	364.2	9.1%	196.7	167.5
7/12/04	0.36	48.1	61.6%	20.8	27.3
5/24/05	1.23	73.0	29.0%	71.7	1.3
5/15/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-16. Net Alkalinity Difference Relative to Target West 4 Out (Site 8)

Sample	Site 8	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
3/21/00	2.69		12.2%		
9/13/00	0.13	-83.6	82.2%	7.9	-91.5
2/12/01	1.21	-851.9	29.2%	70.8	-922.7
5/8/01	0.67	-505.2	45.6%	39.0	-544.2
1/28/02	6.28	-2574.9	4.5%	365.9	-2940.9
6/11/02	0.11	-17.3	84.5%	6.7	-24.0
11/4/02	0.76	-1387.0	42.2%	44.1	-1431.0
2/24/03	6.22	-3354.6	4.6%	362.3	-3716.9
6/16/03	0.51	-139.7	53.5%	29.6	-169.3
8/27/03	0.17	-119.6	77.9%	9.9	-129.6
1/26/04	3.38	-1220.0	9.1%	196.7	-1416.7
7/12/04	0.36	-19.2	61.6%	20.8	-40.0
5/24/05	1.23	-557.6	29.0%	71.7	-629.3
5/15/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-17. Net Alkalinity Difference Relative to Target Phillips 10

Sample	Site 10	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
2/12/01	1.21	-327.7	29.2%	70.8	-398.4
5/7/01	0.74	-252.8	42.9%	43.3	-296.1
1/28/02	6.28	-1694.0	4.5%	365.9	-2060.0
6/12/02	0.10	-39.5	85.9%	6.1	-45.6
11/5/02	6.93	2614.9	4.0%	403.4	2211.5
2/24/03	6.22	1878.6	4.6%	362.3	1516.3
1/26/04	3.38	728.4	9.1%	196.7	531.7
7/12/04	0.36	136.7	61.6%	20.8	115.9
5/24/05	1.23	497.9	29.0%	71.7	426.2
5/16/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-18. Net Alkalinity Difference Relative to Target Phillips 11

Sample	Site 11	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	(lbs/day/mi^2)[b]	(%)	(lbs/day/mi^2)[b]	(lbs/day/mi^2)[b]
2/12/01	1.21	-2293.6	29.2%	70.8	-2364.4
5/7/01	0.74	200.6	42.9%	43.3	157.3
1/28/02	6.28	-2812.1	4.5%	365.9	-3178.0
6/12/02	0.10	19.2	85.9%	6.1	13.1
11/5/02	6.93	261.5	4.0%	403.4	-142.0
2/24/03	6.22	2180.5	4.6%	362.3	1818.2
6/17/03	0.49	-89.3	54.8%	28.4	-117.7
1/26/04	0.36	546.3	9.1%	20.8	525.5
5/24/05	1.23	179.2	29.0%	71.7	107.5
5/16/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.				

Table D-19. Net Alkalinity Difference Relative to Target Phi 12/West 3

Sample	Site 12	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	($lbs/day/mi^2$)[b]	(%)	($lbs/day/mi^2$)[b]	($lbs/day/mi^2$)[b]
2/12/01	1.21	-190.0	29.2%	70.8	-260.8
5/7/01	0.74	60.2	42.9%	43.3	16.9
1/28/02	6.28	-914.8	4.5%	365.9	-1280.7
6/12/02	0.10	19.2	85.9%	6.1	13.1
11/5/02	6.93	747.1	4.0%	403.4	343.7
2/24/03	6.22	-134.2	4.6%	362.3	-496.5
6/16/03	0.51	-54.8	53.5%	29.6	-84.4
8/28/03	0.16	-134.2	79.1%	9.2	-143.4
1/26/04	3.38	-54.8	9.1%	196.7	-251.5
7/12/04	0.36	-21.2	61.6%	20.8	-42.0
5/24/05	1.23	-59.7	29.0%	71.7	-131.4
5/16/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3/day/mi^2$.				

Table D-20. Net Alkalinity Difference Relative to Target Atomic School Road

Sample	Site 5	Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
Date	(cfs/mi^2)	($lbs/day/mi^2$)[b]	(%)	($lbs/day/mi^2$)[b]	($lbs/day/mi^2$)[b]
3/21/00	2.69	-522.6	12.2%	156.8	-679.4
9/13/00	0.13	-49.5	82.2%	7.9	-57.3
2/12/01	1.21	-393.2	29.2%	70.8	-464.0
5/7/01	0.74	-280.9	42.9%	43.3	-324.2
1/28/02	6.28	-508.2	4.5%	365.9	-874.1
6/12/02	0.10	-28.2	85.9%	6.1	-34.3
11/5/02	6.93	-1456.9	4.0%	403.4	-1860.3
2/25/03	4.68	-807.1	6.3%	272.4	-1079.5
6/17/03	0.49	34.2	54.8%	28.4	5.8
8/28/03	0.16	-34.1	79.1%	9.2	-43.4
1/26/04	3.38	-673.7	9.1%	196.7	-870.4
7/12/04	0.36	-25.0	61.6%	20.8	-45.8
5/24/05	1.23	-126.1	29.0%	71.7	-197.8
5/16/06					
a	Percent of Days Flow Is Exceeded				
b	Net alkalinity is reported as lbs $CaCO_3/day/mi^2$.				

Table D-21. Iron Load Calculations for Bear Creek at Gaging Station

Sample Date	Bear Creek Flow (@ gage)		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi^2)	(%)	(µg/L)	(lbs/day/mi^2)	[%]	[%]
5/9/01	12.9	0.56	50.7%	160	0.48	NR	NR
1/29/02	107.6	4.68	6.2%	170	4.29	NR	NR
11/5/02	159.3	6.93	4.0%	280	10.46	NR	NR
2/25/03	107.5	4.68	6.3%	390	9.84	NR	NR
6/17/03	11.2	0.49	54.8%	1,370	3.60	27.0%	34.3%
8/27/03	3.9	0.17	77.9%	90	0.08	NR	NR
1/27/04	57.7	2.51	13.1%	100	1.35	NR	NR
5/25/05	21.6	0.94	36.8%	220	1.11	NR	NR
5/16/06				220		NR	NR
90th Percentile Concentration				**586**		**NR**	**NR**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-22. Iron Load Calculations for Bear Creek d/s East Branch & West Branch

Sample Date	Bear Creek Flow (@ confluence)		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi^2)	(%)	(µg/L)	(lbs/day/mi^2)	[%]	[%]
5/9/01	7.2	0.56	50.7%	150	0.45	NR	NR
1/29/02	60.0	4.69	6.2%	160	4.05	NR	NR
2/20/03	61.6	4.81	5.8%	390	10.12	NR	NR
8/27/03	2.2	0.17	77.9%	80	0.07	NR	NR
90th Percentile Concentration				**321**		**NR**	**NR**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-23. Iron Load Calculations for Previt Branch at Chick House Rd.

Sample Date	Site 13		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
2/12/01	0.16	1.21	29.2%	540	3.54	NR	NR
5/8/01	0.09	0.67	45.6%	800	2.89	NR	NR
1/28/02	0.84	6.28	4.5%	460	15.59	NR	NR
6/11/02	0.02	0.11	84.5%	940	0.58	NR	4.3%
11/4/02	0.10	0.76	42.2%	1,660	6.77	39.8%	45.8%
2/24/03	0.83	6.22	4.6%	390	13.08	NR	NR
6/16/03	0.07	0.51	53.5%	960	2.63	NR	6.3%
8/28/03	0.02	0.16	79.1%	12,900	11.01	92.2%	93.0%
1/26/04	0.45	3.38	9.1%	880	16.02	NR	NR
7/12/04	0.05	0.36	61.6%	2,110	4.06	52.6%	57.3%
5/24/05	0.16	1.23	29.0%	1,770	11.75	43.5%	49.2%
5/15/06				980		NR	8.2%
90th Percentile Concentration				**2,076**		**51.8%**	**56.6%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-24. Iron Load Calculations for East Phase 5 Out

Sample Date	Site 15		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
2/12/01	0.16	1.21	29.2%	1,920	12.58	47.9%	53.1%
5/7/01	0.10	0.74	42.9%	160	0.64	NR	NR
1/28/02	0.81	6.28	4.5%	860	29.14	NR	NR
6/11/02	0.01	0.11	84.5%	180	0.11	NR	NR
11/4/02	0.10	0.76	42.2%	2,020	8.24	50.5%	55.4%
2/24/03	0.80	6.22	4.6%	680	22.81	NR	NR
6/16/03	0.07	0.51	53.5%	3,100	8.49	67.7%	71.0%
8/28/03	0.02	0.16	79.1%	460	0.39	NR	NR
1/26/04	0.43	3.38	9.1%	2,300	41.88	56.5%	60.9%
7/12/04	0.05	0.36	61.6%	1,200	2.31	16.7%	25.0%
5/24/05	0.16	1.23	29.0%	1,190	7.90	16.0%	24.4%
5/15/06				4,040		75.2%	77.7%
90th Percentile Concentration				**3,020**		**66.9%**	**70.2%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-25. Iron Load Calculations for Chick House Out (Site 1)

Sample Date	Site 1		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
3/21/00	1.02	2.69	12.2%	600	8.71	NR	NR
9/13/00	0.05	0.13	82.2%	2,410	1.75	58.5%	62.7%
2/12/01	0.46	1.21	29.2%	350	2.29	NR	NR
5/7/01	0.28	0.74	42.9%	1,210	4.86	17.4%	25.6%
1/28/02	2.37	6.28	4.5%	400	13.55	NR	NR
6/11/02	0.04	0.11	84.5%	1,380	0.85	27.5%	34.8%
11/4/02	0.29	0.76	42.2%	6,200	25.29	83.9%	85.5%
2/24/03	2.35	6.22	4.6%	400	13.42	NR	NR
6/16/03	0.19	0.51	53.5%	1,500	4.11	33.3%	40.0%
8/28/03	0.06	0.16	79.1%	12,000	10.24	91.7%	92.5%
1/26/04	1.28	3.38	9.1%	190	3.46	NR	NR
7/12/04	0.13	0.36	61.6%	330	0.64	NR	NR
5/24/05	0.46	1.23	29.0%	720	4.78	NR	NR
5/15/06				320		NR	NR
90th Percentile Concentration				**5,063**		**80.2%**	**82.2%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-26. Iron Load Calculations for West 4 Out (Site 8)

Sample Date	Site 8		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
3/21/00	0.76	2.69	12.2%				
9/13/00	0.04	0.13	82.2%	4,900	3.56	79.6%	81.6%
2/12/01	0.34	1.21	29.2%	15,700	102.89	93.6%	94.3%
5/8/01	0.19	0.67	45.6%	13,200	47.63	92.4%	93.2%
1/28/02	1.78	6.28	4.5%	5,500	186.34	81.8%	83.6%
6/11/02	0.03	0.11	84.5%	1,770	1.10	43.5%	49.2%
11/4/02	0.21	0.76	42.2%	26,000	106.06	96.2%	96.5%
2/24/03	1.76	6.22	4.6%	3,600	120.76	72.2%	75.0%
6/16/03	0.14	0.51	53.5%	2,600	7.12	61.5%	65.4%
8/27/03	0.05	0.17	77.9%	11,000	10.12	90.9%	91.8%
1/26/04	0.95	3.38	9.1%	6,700	122.00	85.1%	86.6%
7/12/04	0.10	0.36	61.6%	10,600	20.40	90.6%	91.5%
5/24/05	0.35	1.23	29.0%	7,600	50.45	86.8%	88.2%
5/15/06				1,360		26.5%	33.8%
90th Percentile Concentration				**15,200**		**93.4%**	**94.1%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-27. Iron Load Calculations for Phillips 10

Sample Date	Site 10		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
2/12/01	0.08	1.21	29.2%	1,410	9.24	29.1%	36.2%
5/7/01	0.05	0.74	42.9%	5,370	21.55	81.4%	83.2%
1/28/02	0.40	6.28	4.5%	1,650	55.90	39.4%	45.5%
6/12/02	0.01	0.10	85.9%	2,370	1.34	57.8%	62.0%
11/5/02	0.45	6.93	4.0%	12,000	448.27	91.7%	92.5%
2/24/03	0.40	6.22	4.6%	2,010	67.43	50.2%	55.2%
1/26/04	0.22	3.38	9.1%	1,380	25.13	27.5%	34.8%
7/12/04	0.02	0.36	61.6%	2,750	5.29	63.6%	67.3%
5/24/05	0.08	1.23	29.0%	3,140	20.84	68.2%	71.3%
5/16/06				2,600		61.5%	65.4%
90th Percentile Concentration				**6,033**		**83.4%**	**85.1%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-28. Iron Load Calculations for Phillips 11

Sample Date	Site 11		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi²)	(%)	(µg/L)	(lbs/day/mi²)	[%]	[%]
2/12/01	0.03	1.21	29.2%	10,000	65.53	90.0%	91.0%
5/7/01	0.02	0.74	42.9%	9,800	39.32	89.8%	90.8%
1/28/02	0.15	6.28	4.5%	69,750	2363.19	98.6%	98.7%
6/12/02	0.00	0.10	85.9%	3,100	1.75	67.7%	71.0%
11/5/02	0.16	6.93	4.0%	14,000	522.98	92.9%	93.6%
2/24/03	0.15	6.22	4.6%	40,000	1341.83	97.5%	97.8%
6/17/03	0.01	0.49	54.8%	12,900	33.90	92.2%	93.0%
1/26/04	0.08	3.38	9.1%	7,500	136.57	86.7%	88.0%
5/24/05	0.03	1.23	29.0%	24,400	161.97	95.9%	96.3%
5/16/06				33,500		97.0%	97.3%
90th Percentile Concentration				**42,975**		**97.7%**	**97.9%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-29. Iron Load Calculations for Phi 12/West 3

Sample Date	Site 12		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi^2)	(%)	(µg/L)	(lbs/day/mi^2)	[%]	[%]
2/12/01	0.29	1.21	29.2%	270	1.77	NR	NR
5/7/01	0.18	0.74	42.9%	3,900	15.65	74.4%	76.9%
1/28/02	1.48	6.28	4.5%	760	25.75	NR	NR
6/12/02	0.02	0.10	85.9%	120	0.07	NR	NR
11/5/02	1.63	6.93	4.0%	270	10.09	NR	NR
2/24/03	1.47	6.22	4.6%	520	17.44	NR	NR
6/16/03	0.12	0.51	53.5%	670	1.84	NR	NR
8/28/03	0.04	0.16	79.1%	50	0.04	NR	NR
1/26/04	0.80	3.38	9.1%	900	16.39	NR	NR
7/12/04	0.08	0.36	61.6%	2,850	5.49	64.9%	68.4%
5/24/05	0.29	1.23	29.0%	1,240	8.23	19.4%	27.4%
5/16/06				680		NR	NR
90th Percentile Concentration				**2,689**		**62.8%**	**66.5%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-30. Iron Load Calculations for Atomic School Road

Sample Date	Site 5		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
	(cfs)	(cfs/mi^2)	(%)	(µg/L)	(lbs/day/mi^2)	[%]	[%]
3/21/00	1.05	2.69	12.2%	900	13.07	NR	NR
9/13/00	0.05	0.13	82.2%	680	0.49	NR	NR
2/12/01	0.47	1.21	29.2%	440	2.88	NR	NR
5/7/01	0.29	0.74	42.9%	280	1.12	NR	NR
1/28/02	2.46	6.28	4.5%	930	31.51	NR	3.2%
6/12/02	0.04	0.10	85.9%	1,600	0.90	37.5%	43.8%
11/5/02	2.71	6.93	4.0%	2,850	106.46	64.9%	68.4%
2/25/03	1.83	4.68	6.3%	2,260	57.00	55.8%	60.2%
6/17/03	0.19	0.49	54.8%	4,200	11.04	76.2%	78.6%
8/28/03	0.06	0.16	79.1%	9,800	8.37	89.8%	90.8%
1/26/04	1.32	3.38	9.1%	2,500	45.52	60.0%	64.0%
7/12/04	0.14	0.36	61.6%	2,500	4.81	60.0%	64.0%
5/24/05	0.48	1.23	29.0%	1,260	8.36	20.6%	28.6%
5/16/06				780		NR	NR
90th Percentile Concentration				**3,795**		**73.6%**	**76.3%**
Note:	NR = No reduction required						
a	Percent of Days Flow Is Exceeded						
b	Reductions for individual samples (shaded area) are included for reference only.						

Table D-31. Required Load Reductions for the Bear Creek Subwatershed

Monitoring Site	Waterbody Name & ID	Iron	
		% Reduction for TMDL	% Reduction for LA
@ gage		NR	NR
d/s of East Branch & West Branch		NR	NR
	Bear Creek (mainstem) TN05130104050 – 1000	NR	NR
Previt Branch (Site 13)		51.8	56.6
Chick House Out (Site 1)		80.2	82.2
East Phase 5 Out (Site 15)		66.9	70.2
	East Branch Bear Creek TN05130104050 – 0100	80.2	82.2
Atomic School Rd. (Site 5)		73.6	76.3
West 4 Out (Site 8)		93.4	94.1
Phillips 10 (Site 10)		83.4	95.1
Phillips 11 (Site 11)		97.7	97.9
Phi 12/West 3 (Site 12)		62.8	66.5
	West Branch Bear Creek TN05130104050 – 0200	97.7	97.9

* There are currently no point sources in the Bear Creek Subwatershed; therefore, there is no required load reduction for point sources (WLA).
Any future point sources must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

Table D-32. TMDLs, WLAs[a], & LAs expressed as daily loads for Impaired Waterbodies in the Bear Creek Subwatershed (part of HUC 05130104)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS	LAs
			[lbs/day]	[lbs/day]	[lbs/day]
Bear Creek (mainstem)	TN05130104050 – 1000	Net Alkalinity	5.81×10^{1} * Q	NA[b]	5.81×10^{1} * Q
		Iron	5.38 * Q	5.38×10^{-1} * Q	4.842 * Q
East Branch Bear Creek	TN05130104050 – 0100	Net Alkalinity	5.81×10^{1} * Q	NA[b]	5.81×10^{1} * Q
		Iron	5.38 * Q	5.38×10^{-1} * Q	4.842 * Q
West Branch Bear Creek	TN05130104050 – 0200	Net Alkalinity	5.81×10^{1} * Q	NA[b]	5.81×10^{1} * Q
		Iron	5.38 * Q	5.38×10^{-1} * Q	4.842 * Q

Notes: NA = Not Applicable.
Q = Mean Daily Flow (cfs).

a. There are currently no point sources in the Bear Creek Subwatershed; therefore, there is no required load reduction for point sources (WLA). Any future point sources must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

b. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.2).

APPENDIX E

Hydrodynamic Modeling Methodology

E.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for TMDL analyses of pH- and metal-impaired waters in the South Fork Cumberland River watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program – Fortran (HSPF).

E.2 Model Set Up

The South Fork Cumberland River watershed was delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed “pour points” coincided with HUC-12 delineations, impaired waterbodies, and water quality monitoring stations. Watershed delineation was based on the NHD stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support hydrology model simulations for the South Fork Cumberland River subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data contained in the meteorological data file used in the simulation. Weather data from the Knoxville meteorological station were available for the time period from January 1980 through December 2005. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/95 – 9/30/05) used for TMDL analysis.

E.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U.S. Geological Survey (USGS) stream gaging stations for the same period of time. A USGS continuous record station located in the South Fork Cumberland River Watershed with a sufficiently long and recent historical record was selected as a basis of the hydrology calibration. The USGS station was selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibration for New River at New River, Tennessee, USGS Station 03408500, are shown in Table E-1 and Figures E-1 and E-2.

Table E-1 Hydrologic Calibration Summary: New River, USGS 03408500

				381.96	sq. m
	Simulation Name:	3408500	**Simulation Period:**		
		New River @ New River	**Watershed Area (ac):**	244456.93	
	Period for Flow Analysis				
	Begin Date:	**07/01/98**	**Baseflow PERCENTILE:**	2.5	
	End Date:	**06/30/04**	*Usually 1%-5%*		
	Total Simulated In-stream Flow:	**130.26**	Total Observed In-stream Flow:	**137.03**	
	Total of highest 10% flows:	**71.67**	Total of Observed highest 10% flows:	**74.48**	
	Total of lowest 50% flows:	**8.23**	Total of Observed Lowest 50% flows:	**7.91**	
	Simulated Summer Flow Volume (months 7-9):	**15.86**	Observed Summer Flow Volume (7-9):	**10.63**	
	Simulated Fall Flow Volume (months 10-12):	**18.27**	Observed Fall Flow Volume (10-12):	**19.77**	
	Simulated Winter Flow Volume (months 1-3):	**60.40**	Observed Winter Flow Volume (1-3):	**65.07**	
	Simulated Spring Flow Volume (months 4-6):	**35.73**	Observed Spring Flow Volume (4-6):	**41.55**	
	Total Simulated Storm Volume:	**128.87**	Total Observed Storm Volume:	**136.42**	
	Simulated Summer Storm Volume (7-9):	**15.52**	Observed Summer Storm Volume (7-9):	**10.48**	
	Errors (Simulated-Observed)		*Recommended Criteria*	Last run	
	Error in total volume:	**-4.94**	10		
	Error in 50% lowest flows:	**4.04**	10		
	Error in 10% highest flows:	**-3.78**	15		
***	Seasonal volume error - Summer:	**49.15**	30		
	Seasonal volume error - Fall:	**-7.63**	30		
	Seasonal volume error - Winter:	**-7.18**	30		
	Seasonal volume error - Spring:	**-14.00**	30		
	Error in storm volumes:	**-5.54**	20		
	Error in summer storm volumes:	**48.04**	50		

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

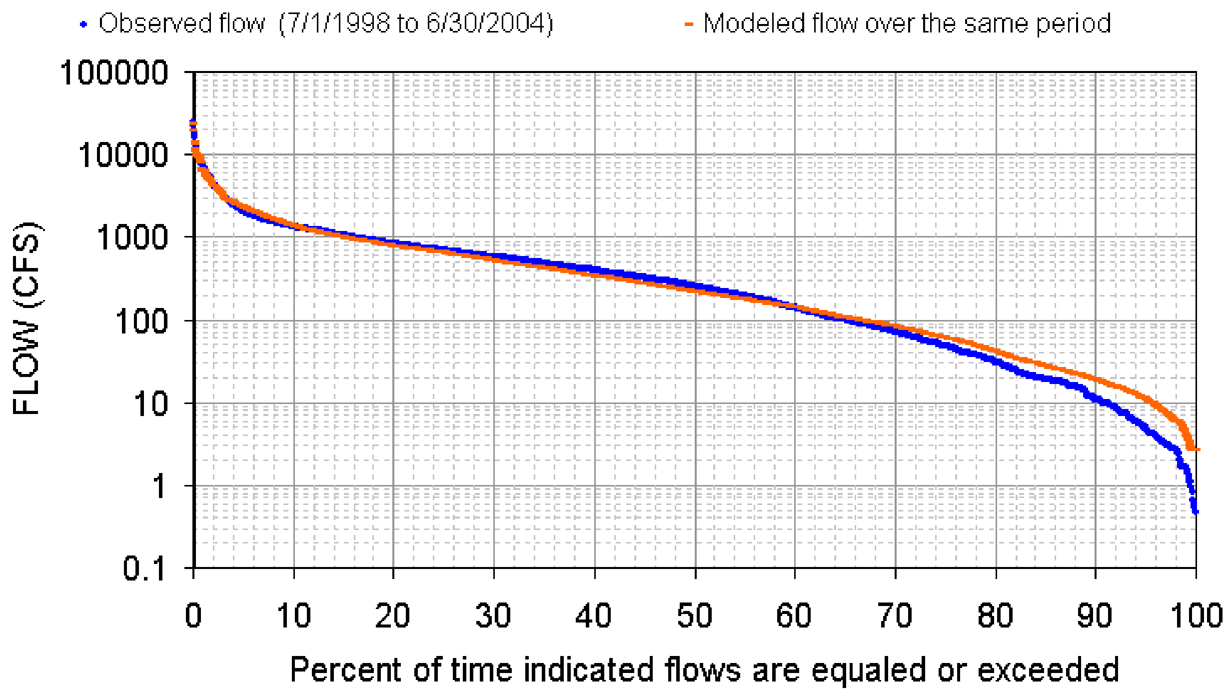

Figure E-1. Hydrologic Calibration: New River, USGS 03408500

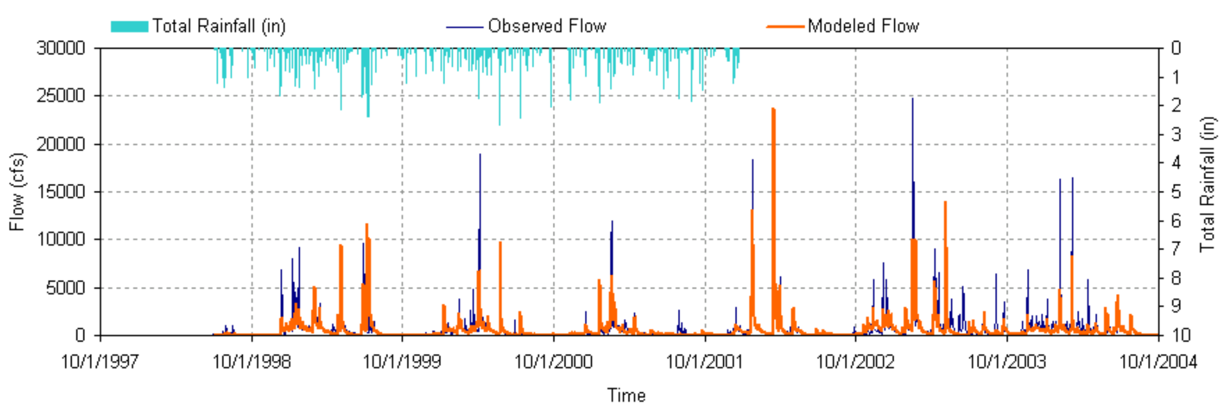

Figure E-2. 7-Year Hydrologic Comparison: New River, USGS 03408500

APPENDIX F

Comparison of Recent Monitoring Data to Historical Data

Figures F-1 thru F-10 display pH for the time period 2000 thru 2006 compared to the baseline pH. The baseline pH for the mainstem Bear Creek stations is the mean pH reported by TVA for the time period 1982 thru 1984 (see Table B-1). The baseline pH for East Branch and West Branch Bear Creek and their tributaries is the observed pH reported by USFWS in 1995 (see Table B-2).

In all cases, the majority of pH values at each station for the time period 2000 thru 2006 were higher than the baseline pH value at each station. This suggests that improvement has occurred as the result of reclamation efforts in the Bear Creek watershed.

Figures F-11 thru F-20 display calculated net alkalinity concentrations for the time period 2000 thru 2006 compared to the baseline net alkalinity. The baseline net alkalinity for the Bear Creek stations is calculated from the mean acidity and mean total alkalinity reported by TVA for the time period 1982 thru 1984 (see Table B-1). The baseline net alkalinity for East Branch and West Branch Bear Creek and their tributaries is calculated from the observed acidity and total alkalinity reported by USFWS in 1995 (see Table B-2).

In most cases, the majority of net alkalinity values at each station for the time period 2000 thru 2006 were higher than the baseline net alkalinity value at each station. This suggests that improvement has occurred as the result of reclamation efforts in the Bear Creek watershed. However, net alkalinity values at West 4 Out (Site 8) and Atomic School Road do not appear to have improved.

Figure F-21 thru F-30 display total iron concentrations for the time period 2000 thru 2006 compared to the baseline total iron concentration. The baseline total iron concentration for the Bear Creek stations is the mean total iron concentration reported by TVA for the time period 1982 thru 1984 (see Table B-1). The baseline total iron concentration for East Branch and West Branch Bear Creek and their tributaries is the observed total iron concentration reported by USFWS in 1995 (see Table B-2).

The total iron concentrations at each station for the time period 2000 thru 2006 compared to the baseline iron concentration at each station do not appear to follow a single trend. Total iron concentrations for both mainstem Bear Creek sites, Previt Branch, and Chick House Out (Site 1) appear to have decreased compared to baseline concentrations except for occasional high values. The high values do not appear to be the results of rainfall events. For Chick House Out (Site 1), the concentrations appear to increase as pH increases. Total iron concentrations for East Phase 5 Out appear to be relatively unchanged with no extremely high values. This suggests that improvement has occurred as the result of reclamation efforts in the East Branch Bear Creek subwatershed. However, total iron concentrations for all West Branch tributary sites appear to have increased rather than decreased. The reason for this trend is not known. For Phillips 11, the concentrations appear to increase as pH increases.

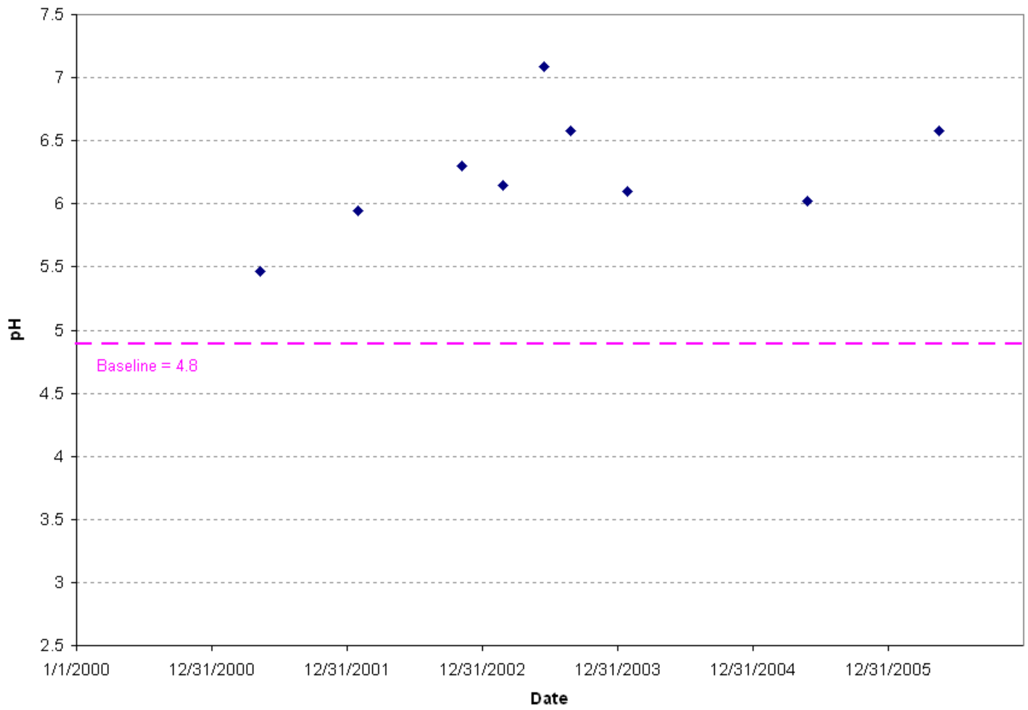

Figure F-1 pH Values for Bear Creek at Gaging Station (2000-2006)

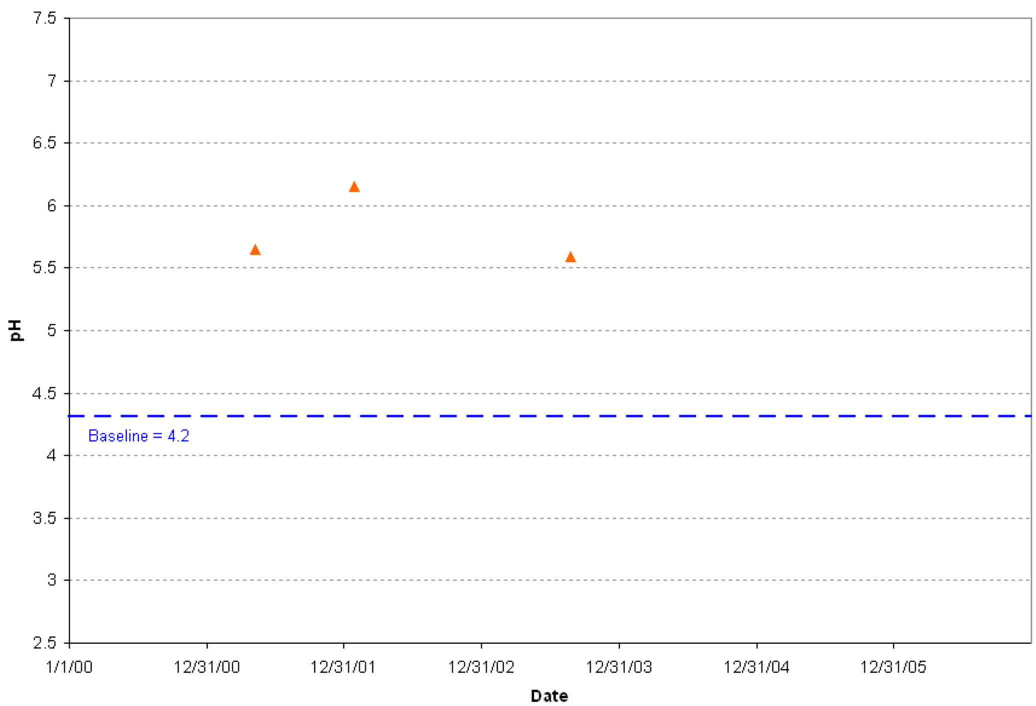

Figure F-2 pH Values for Bear Creek d/s East Branch & West Branch (2000-2006)

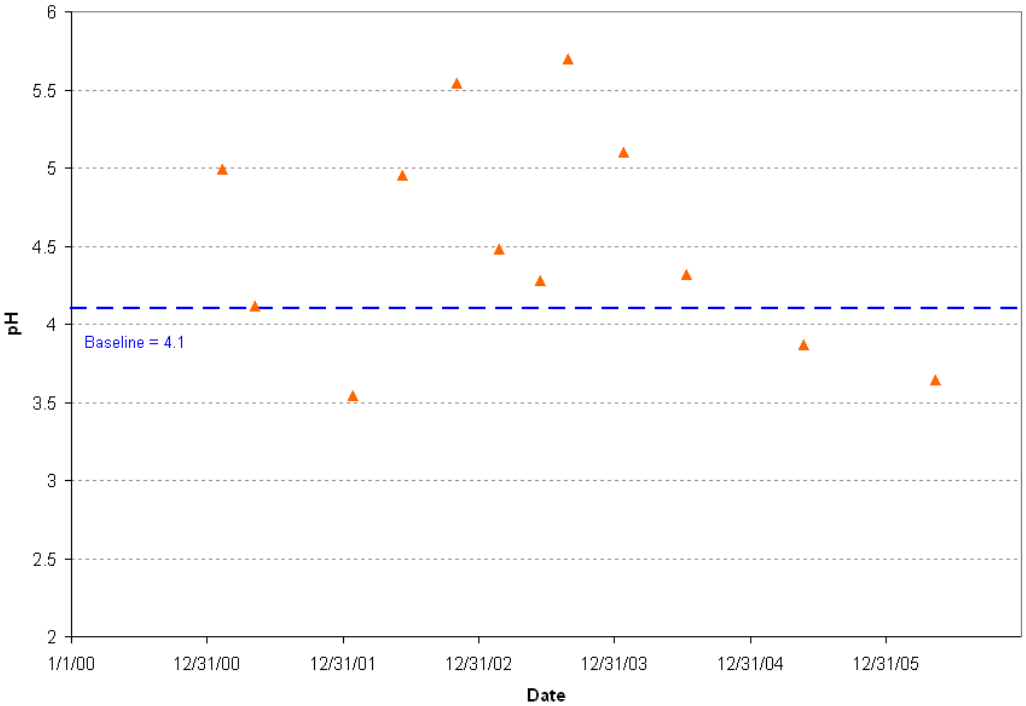

Figure F-3 pH Values for Previt Branch at Chick House Rd. (2000-2006)

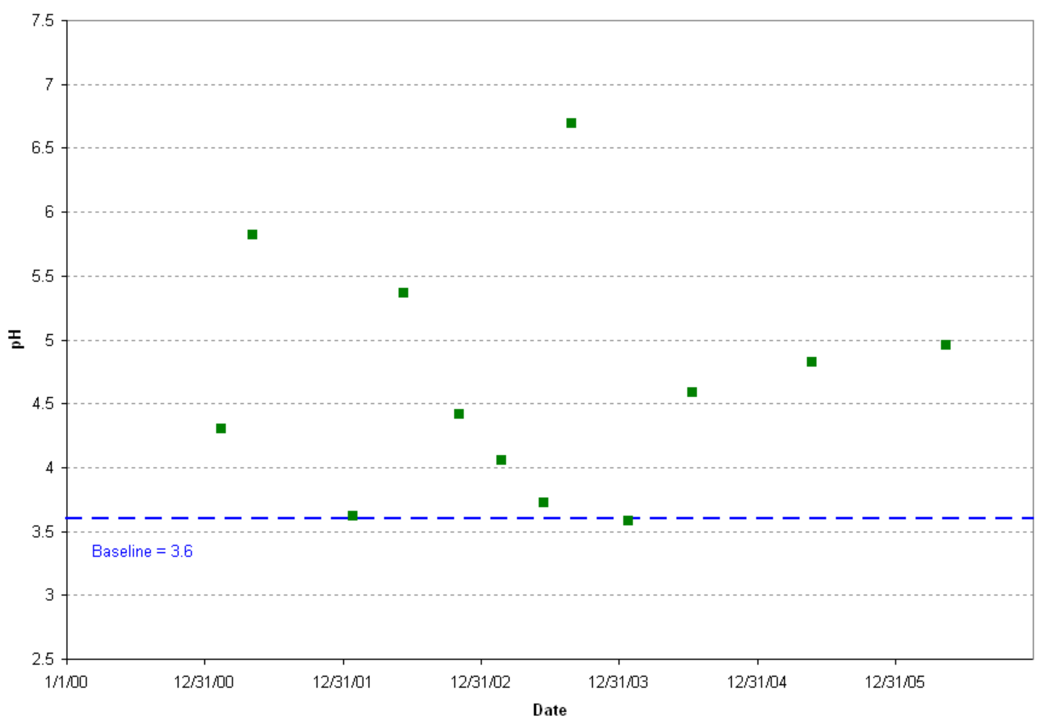

Figure F-4 pH Values for East Phase 5 Out (2000-2006)

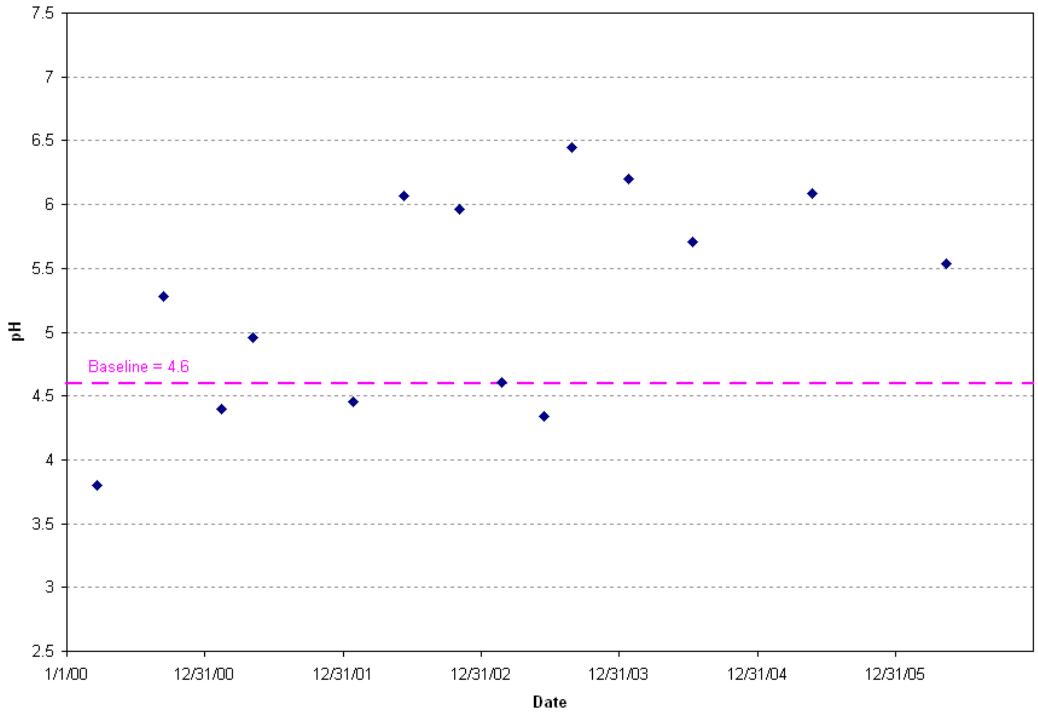

Figure F-5 pH Values for Chick House Out (Site 1) (2000-2006)

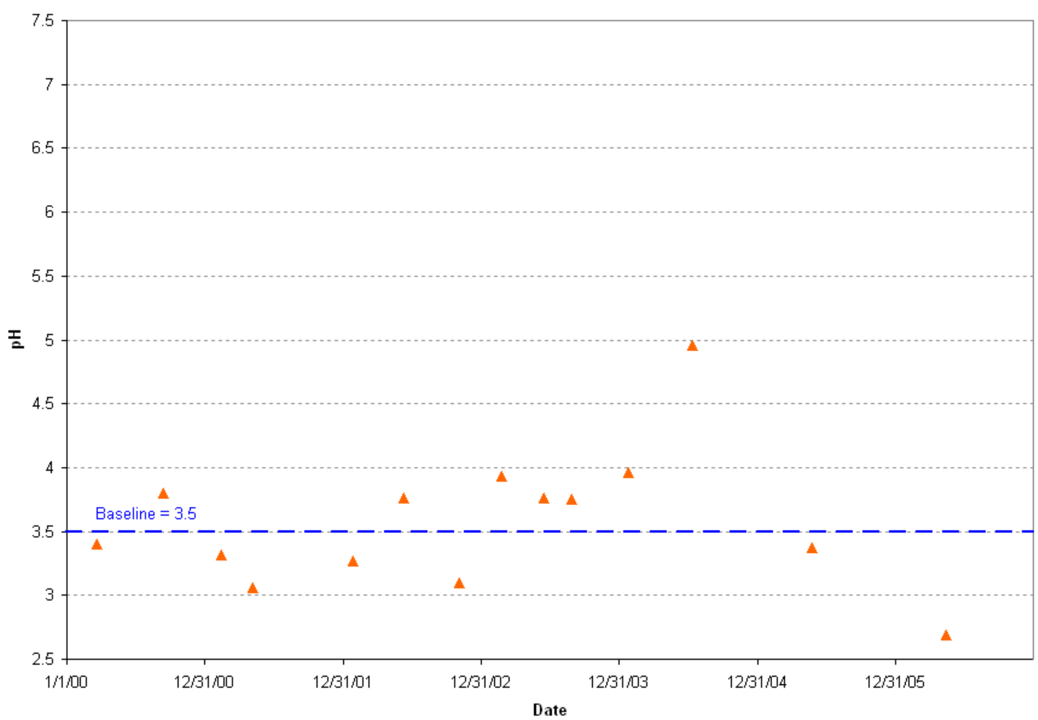

Figure F-6 pH Values for West 4 Out (Site 8) (2000-2006)

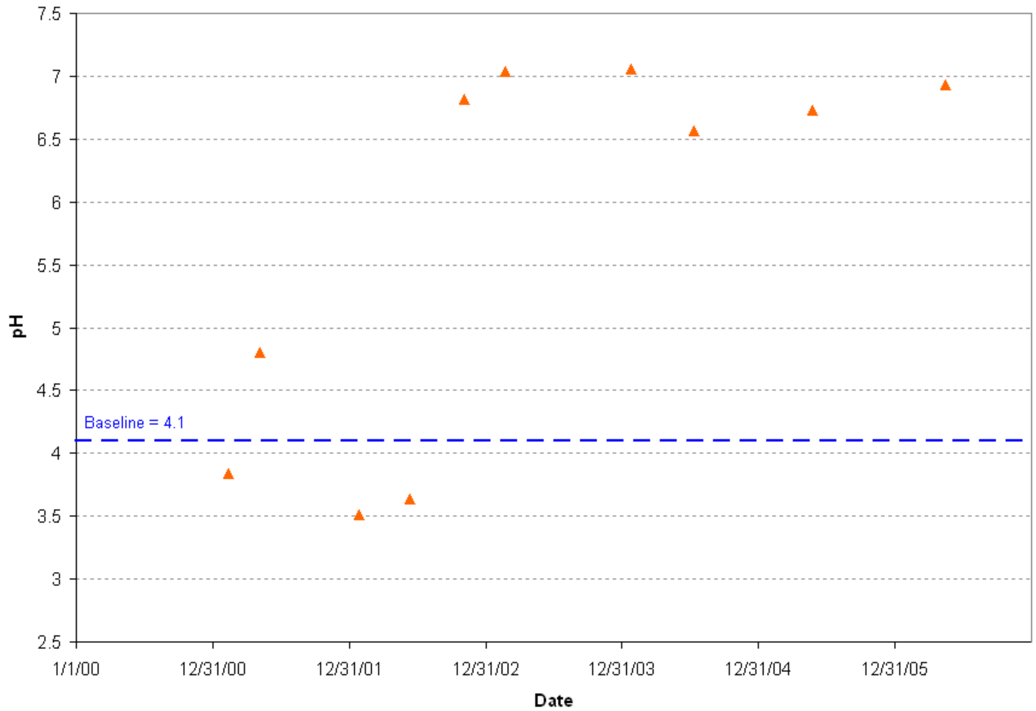

Figure F-7 pH Values for Phillips 10 (2000-2006)

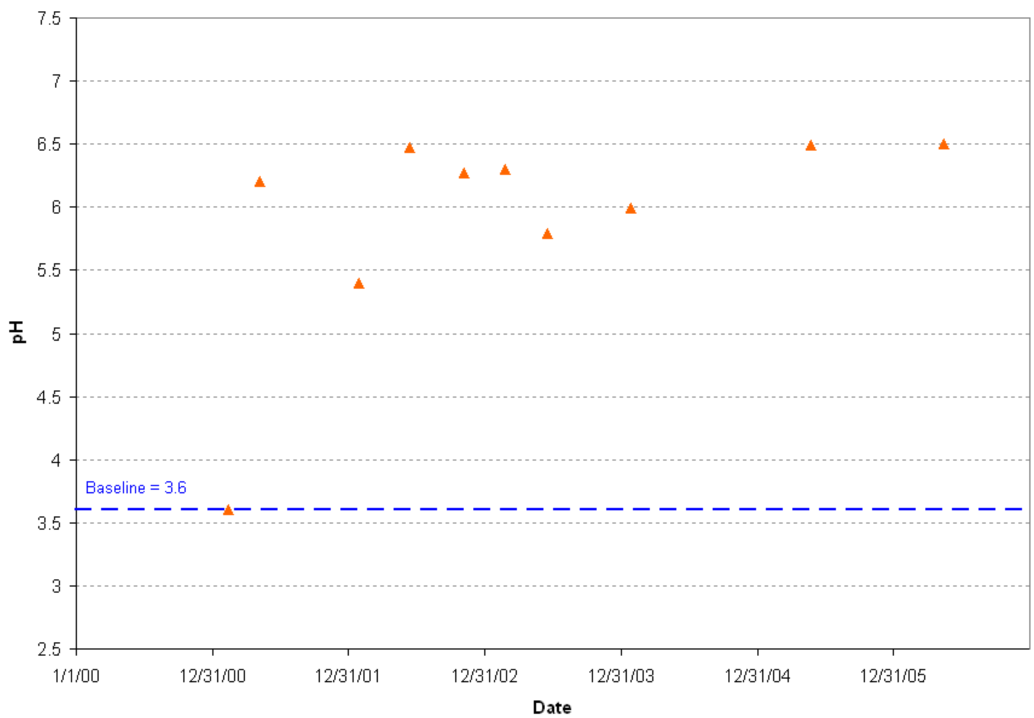

Figure F-8 pH Values for Phillips 11 (2000-2006)

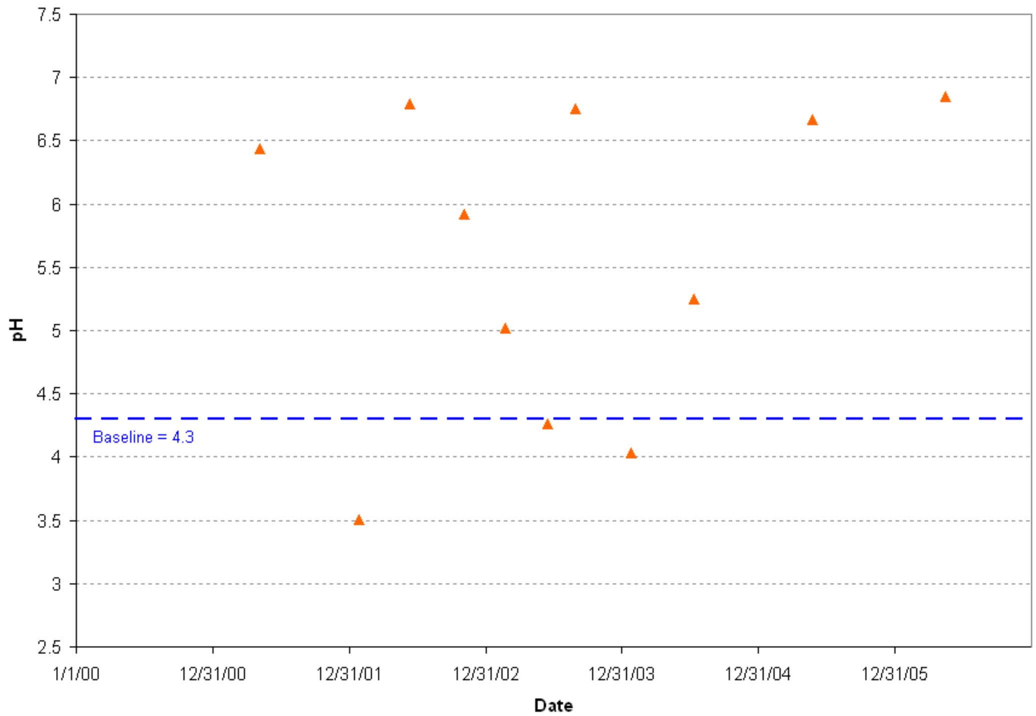

Figure F-9 pH Values for Phi 12/West 3 (2000-2006)

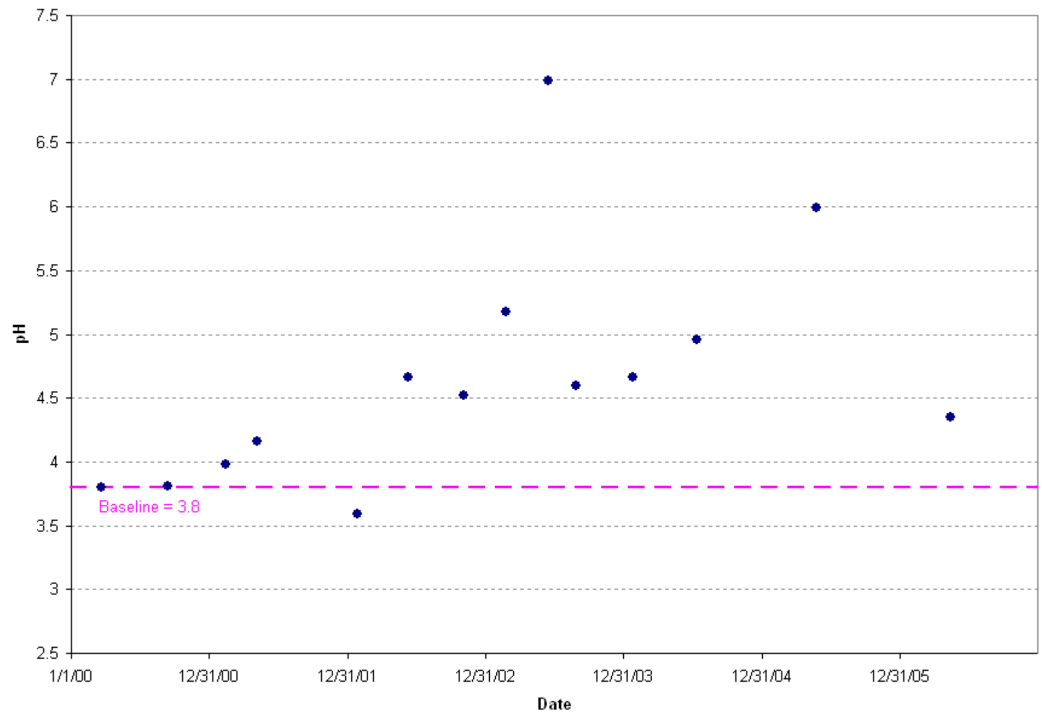

Figure F-10 pH Values for Atomic School Road (2000-2006)

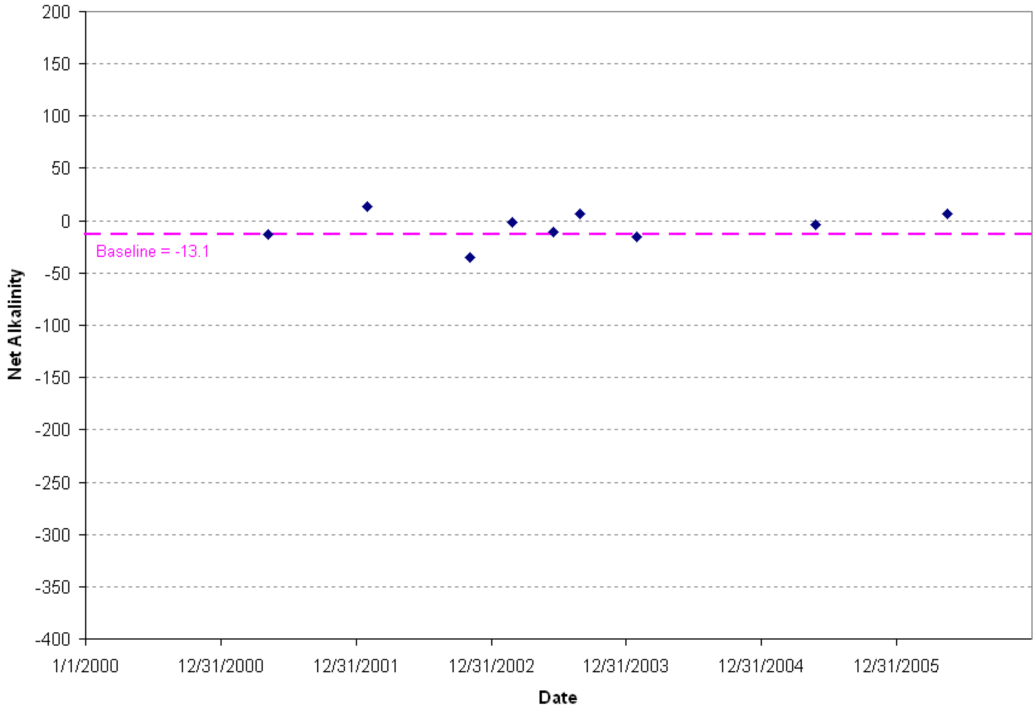

Figure F-11 Net Alkalinity Concentrations for Bear Creek at Gaging Station (2000-2006)

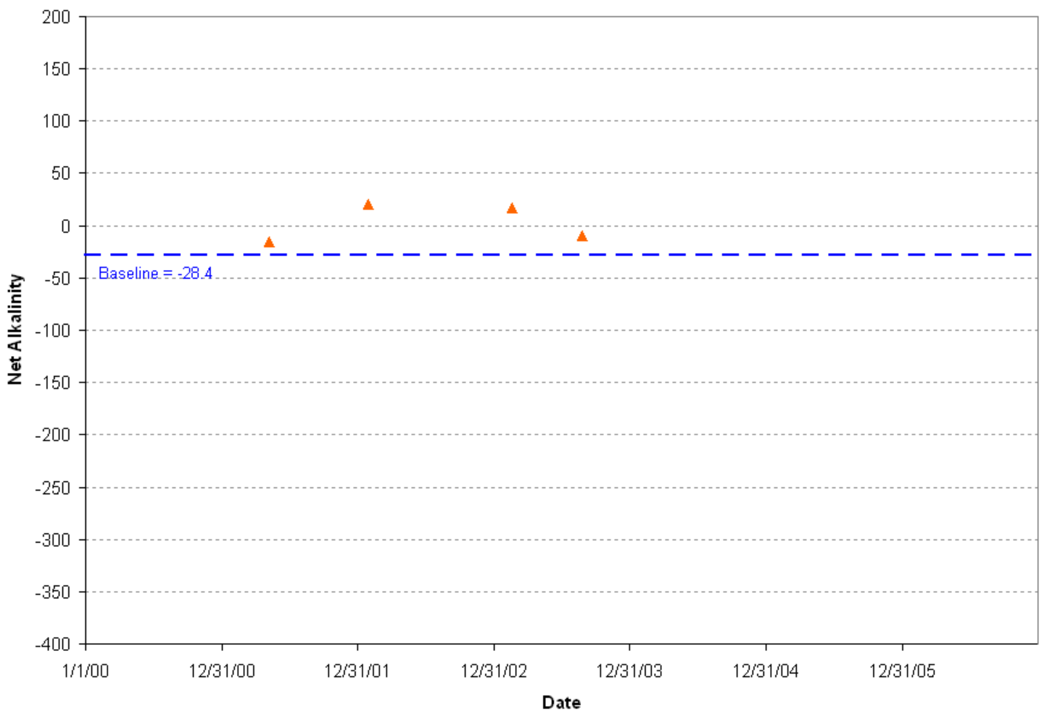

Figure F-12 Net Alkalinity Concentrations for Bear Creek d/s East Branch & West Branch (2000-2006)

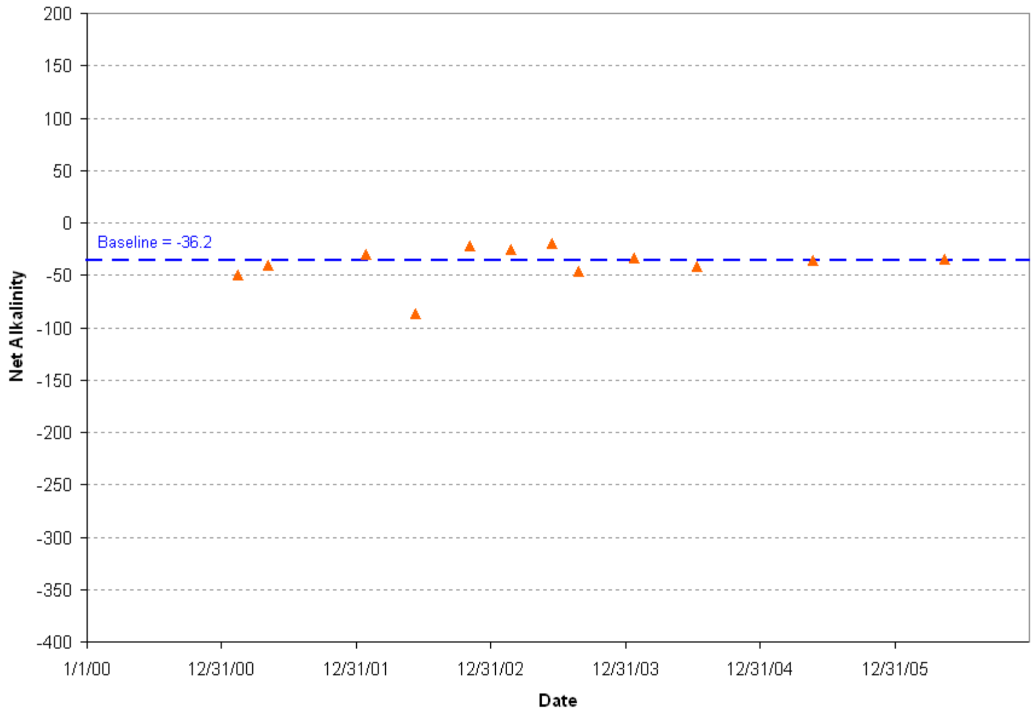

Figure F-13 Net Alkalinity Concentrations for Previt Branch at Chick House Rd. (2000-2006)

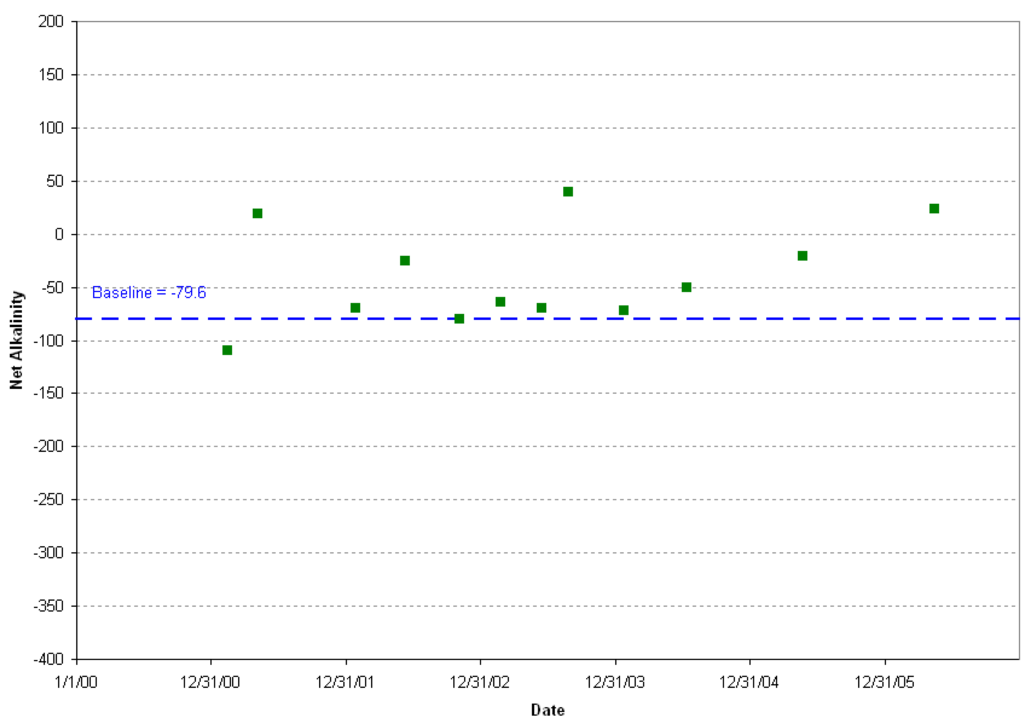

Figure F-14 Net Alkalinity Concentrations for East Phase 5 Out (2000-2006)

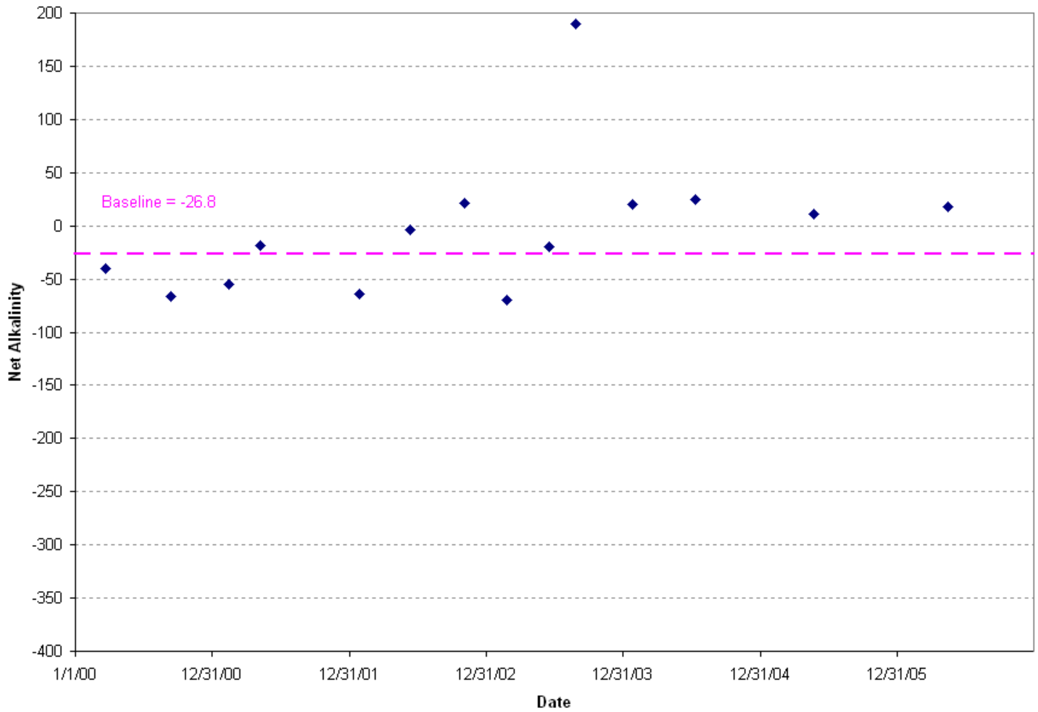

Figure F-15 Net Alkalinity Concentrations for Chick House Out (Site 1) (2000-2006)

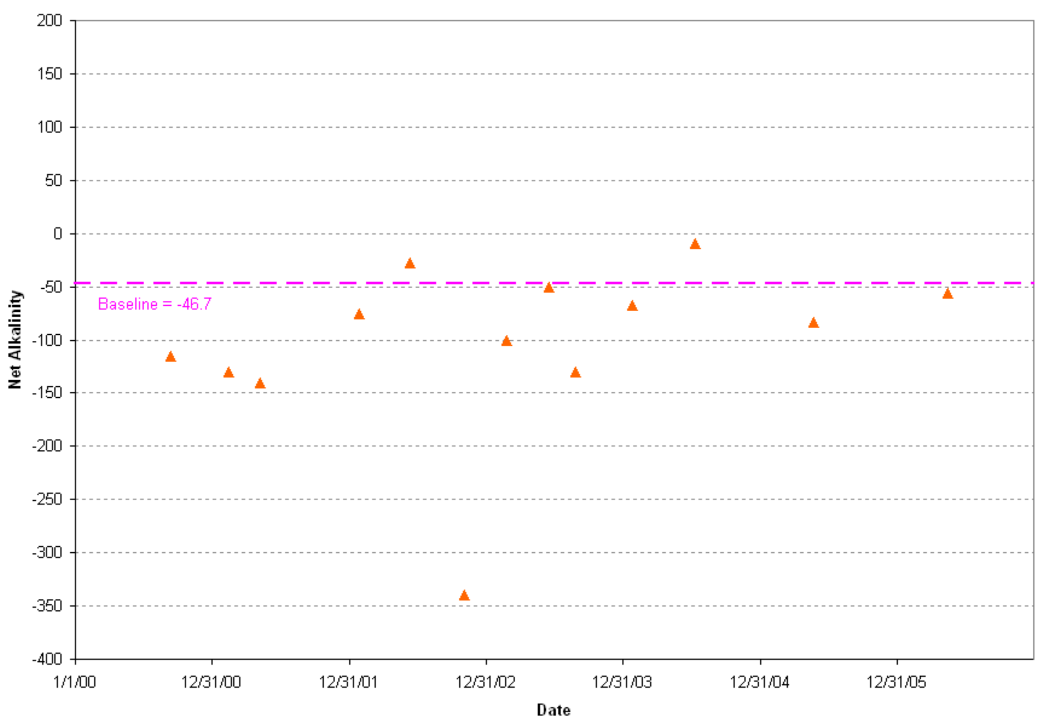

Figure F-16 Net Alkalinity Concentrations for West 4 Out (Site 8) (2000-2006)

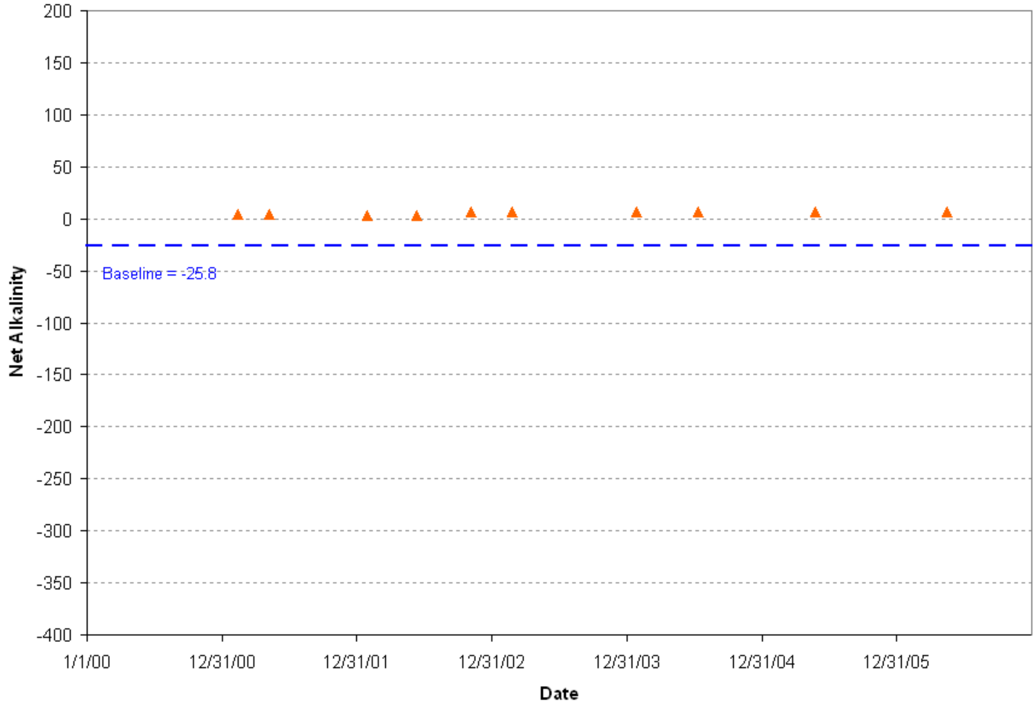

Figure F-17 Net Alkalinity Concentrations for Phillips 10 (2000-2006)

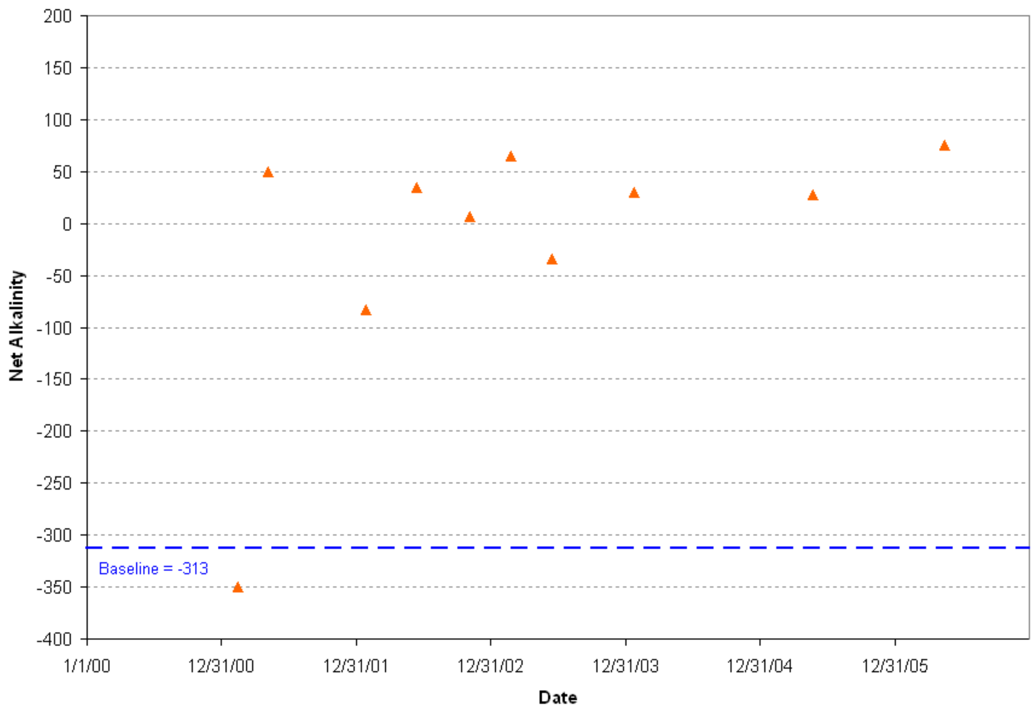

Figure F-18 Net Alkalinity Concentrations for Phillips 11 (2000-2006)

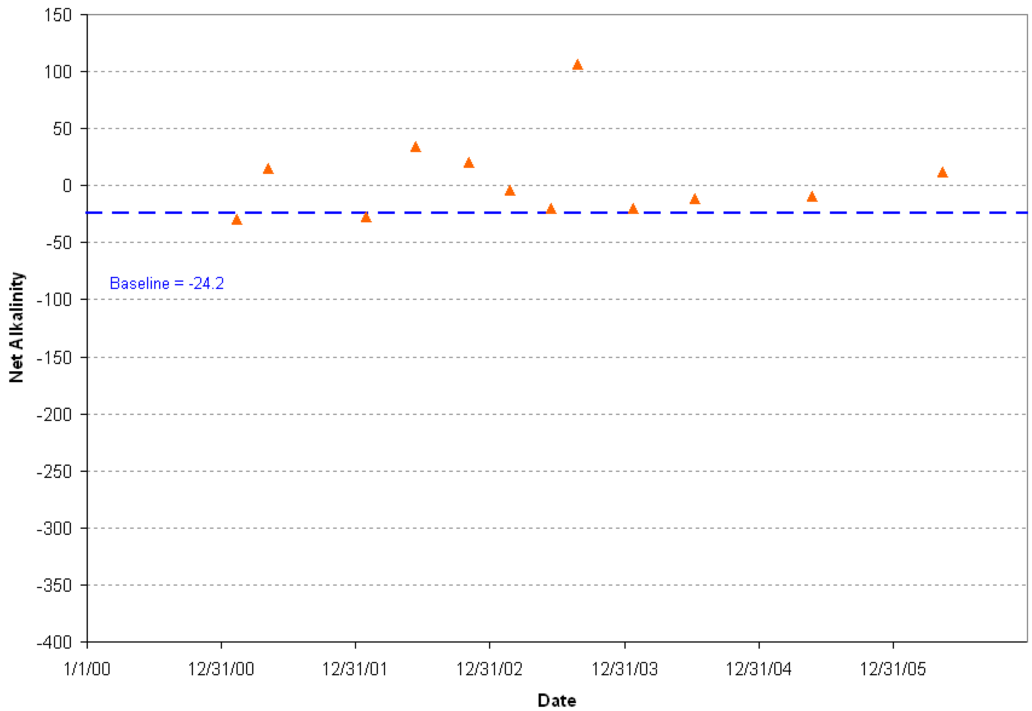

Figure F-19 Net Alkalinity Concentrations for Phi 12/West 3 (2000-2006)

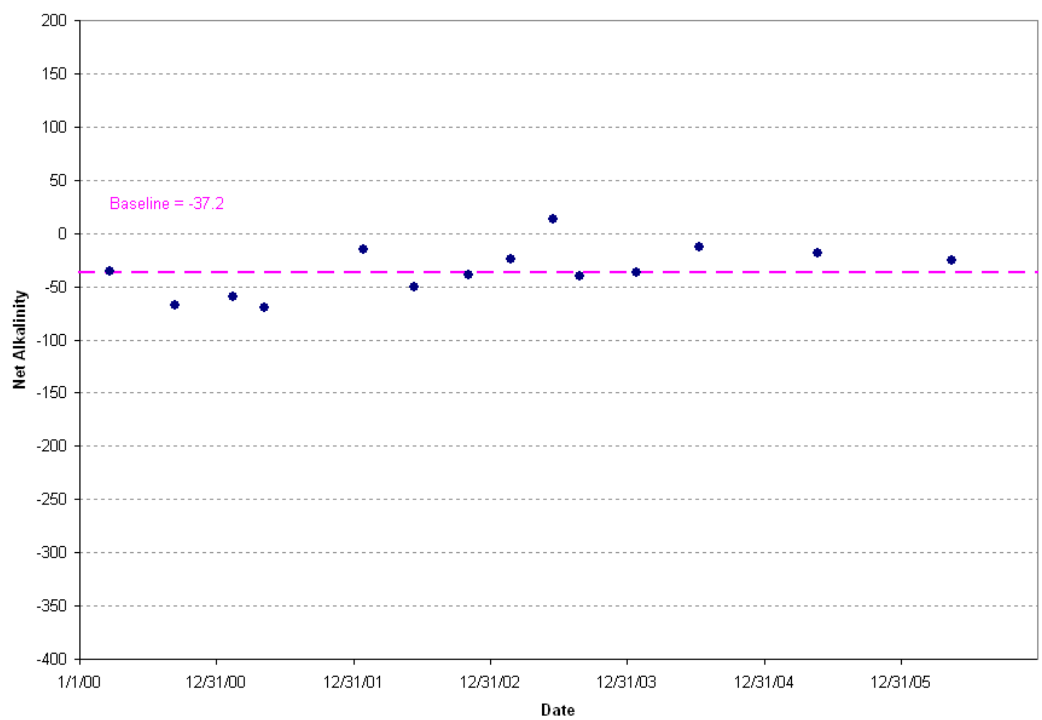

Figure F-20 Net Alkalinity Concentrations for Atomic School Road (2000-2006)

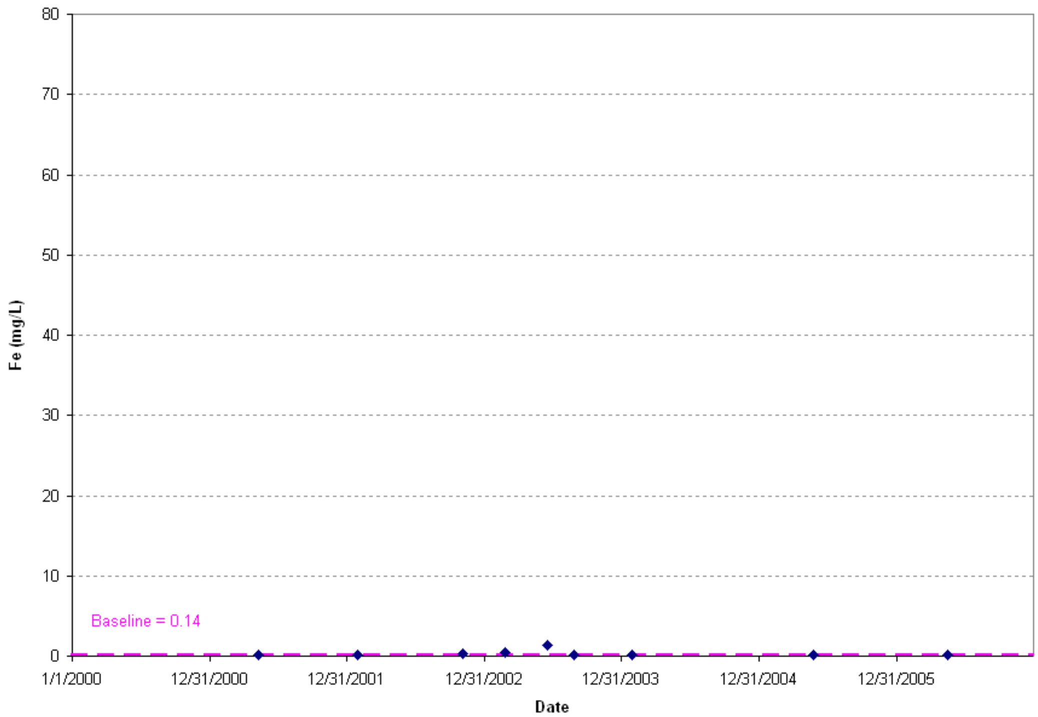

Figure F-21 Iron Concentrations for Bear Creek at Gaging Station (2000-2006)

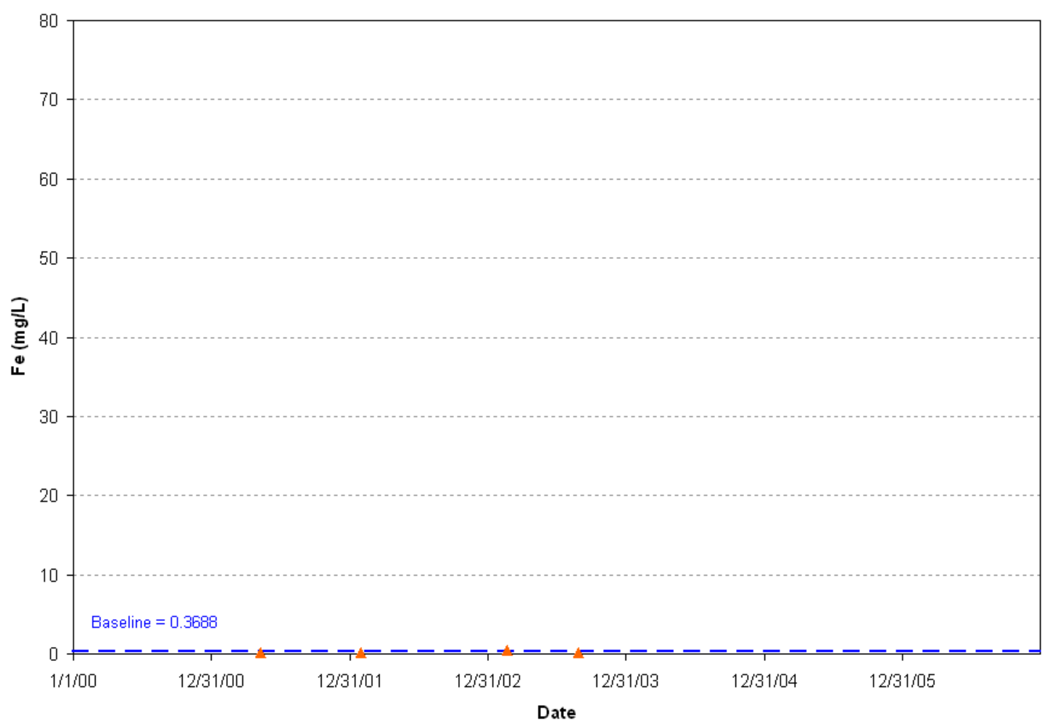

Figure F-22 Iron Concentrations for Bear Creek d/s East Branch & West Branch (2000-2006)

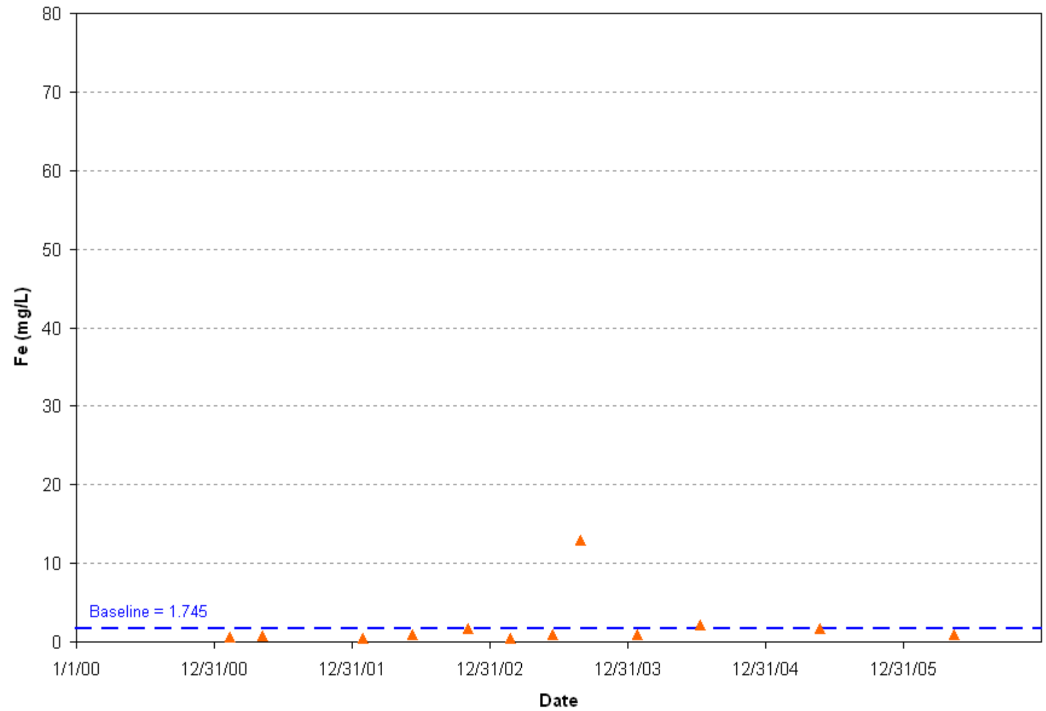

Figure F-23 Iron Concentrations for Previt Branch at Chick House Rd. (2000-2006)

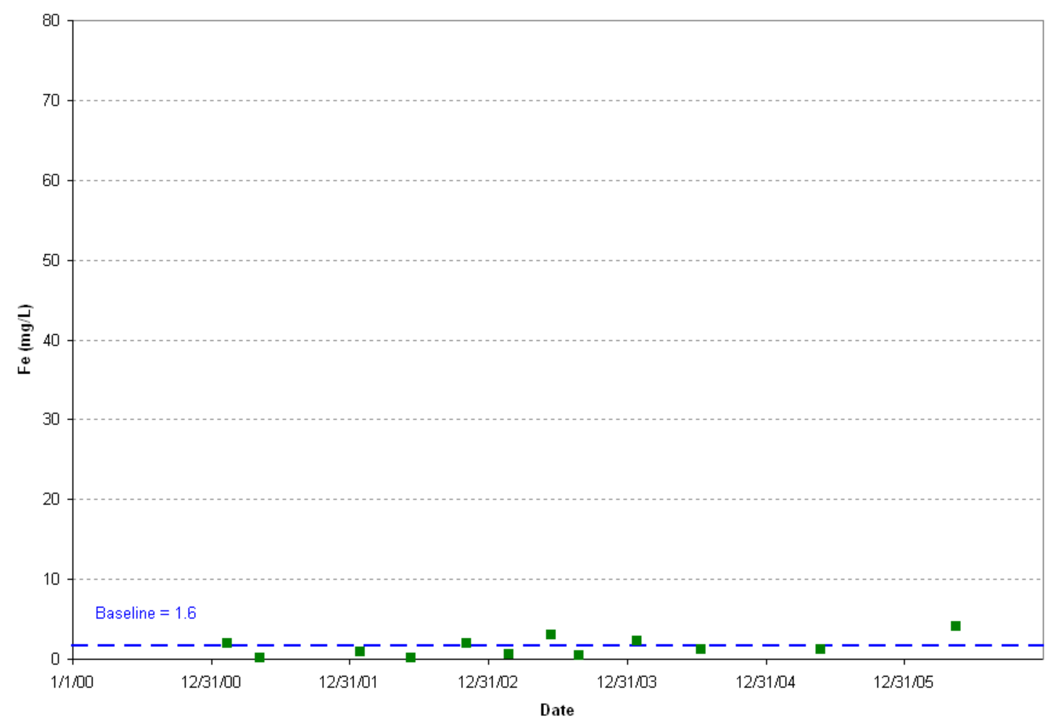

Figure F-24 Iron Concentrations for East Phase 5 Out (2000-2006)

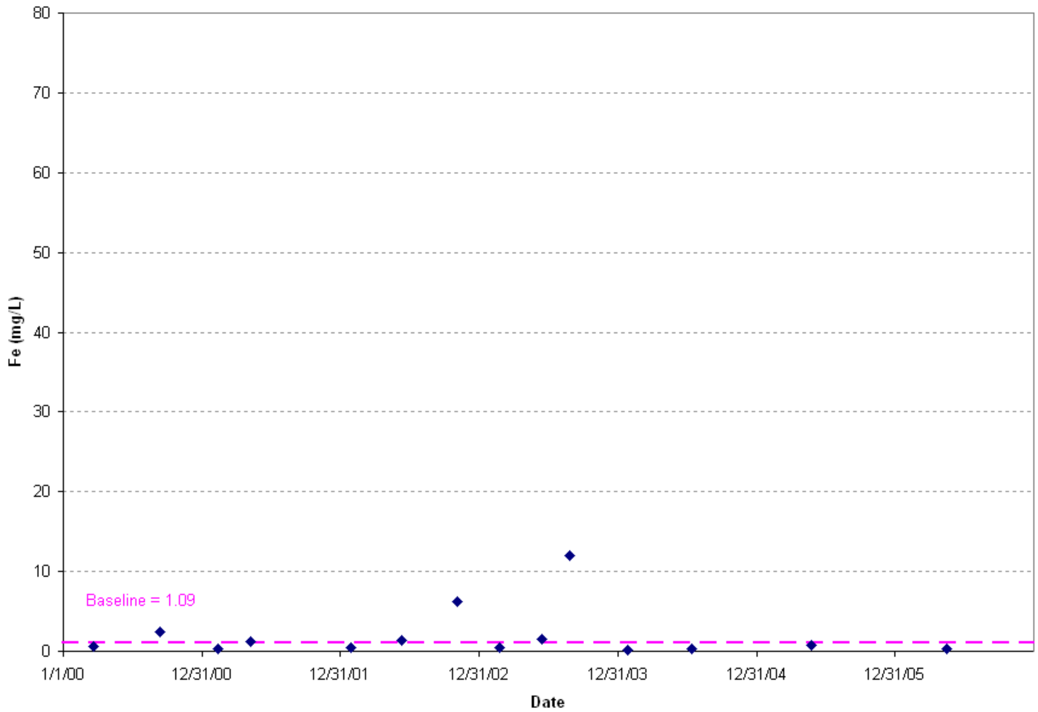

Figure F-25 Iron Concentrations for Chick House Out (Site 1) (2000-2006)

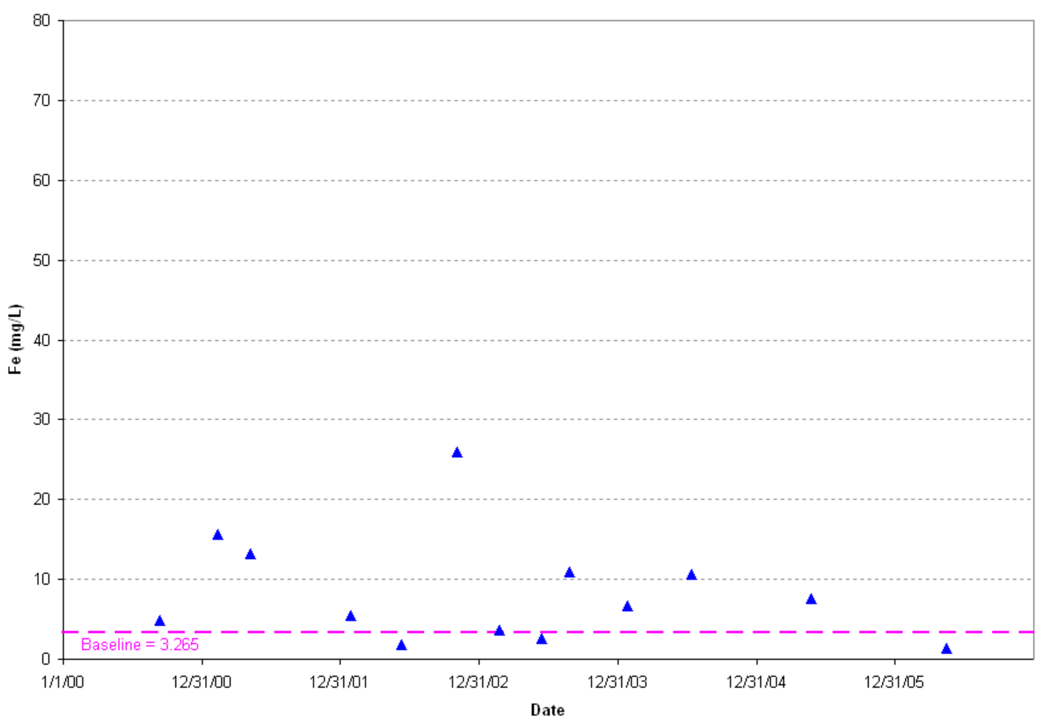

Figure F-26 Iron Concentrations for West 4 Out (Site 8) (2000-2006)

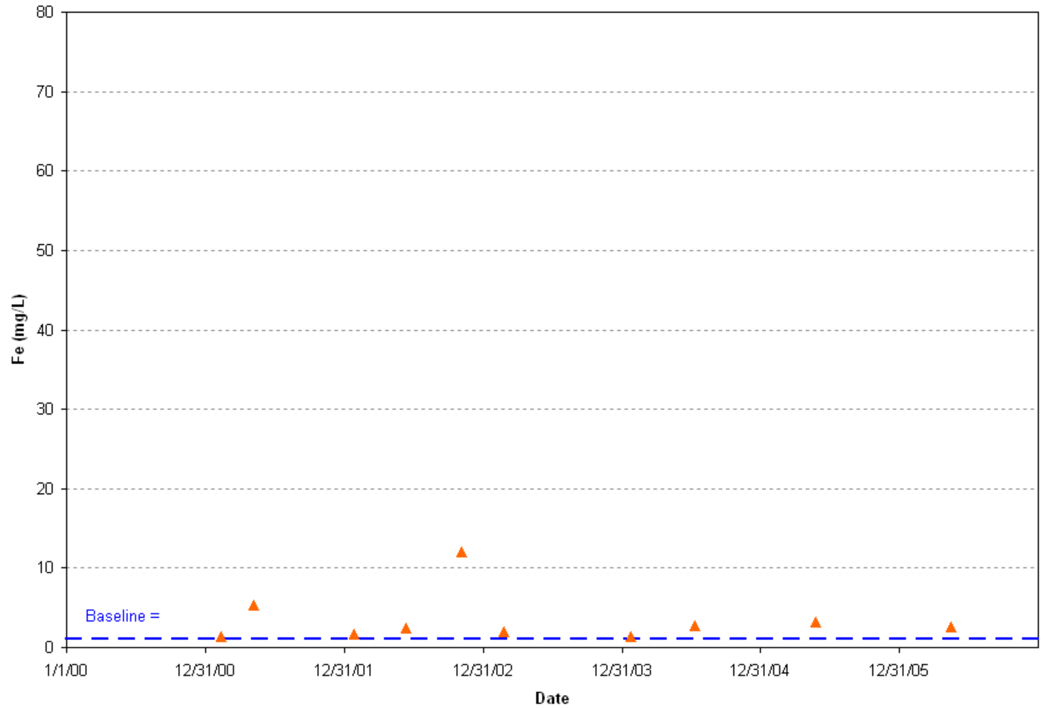

Figure F-27 Iron Concentrations for Phillips 10 (2000-2006)

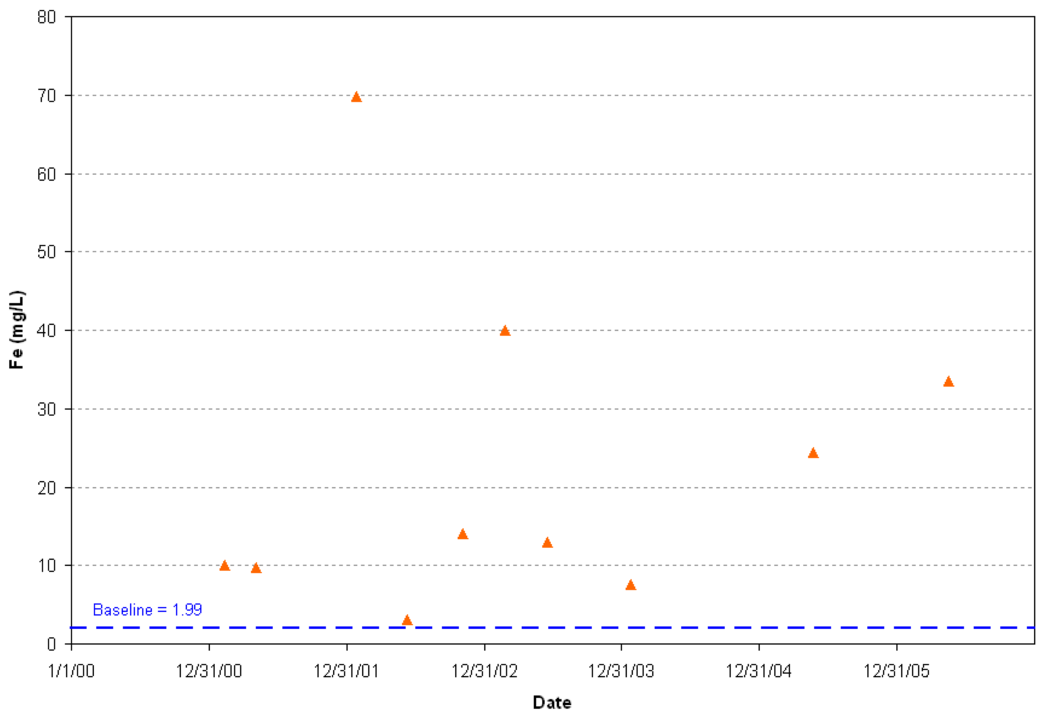

Figure F-28 Iron Concentrations for Phillips 11 (2000-2006)

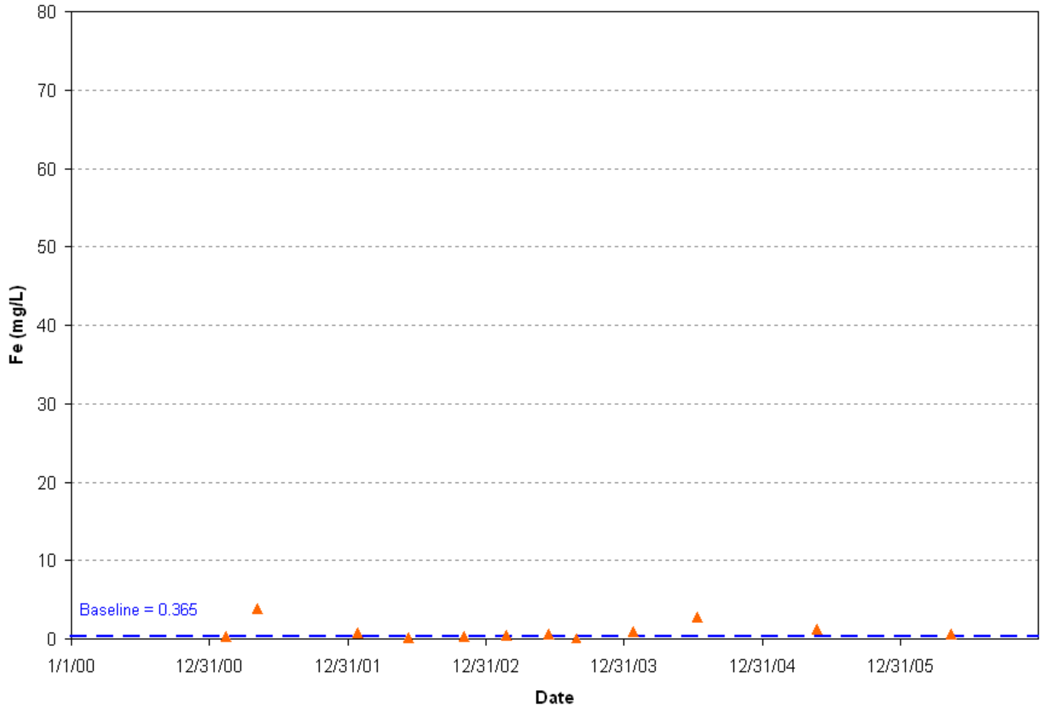

Figure F-29 Iron Concentrations for Phi 12/West 3 (2000-2006)

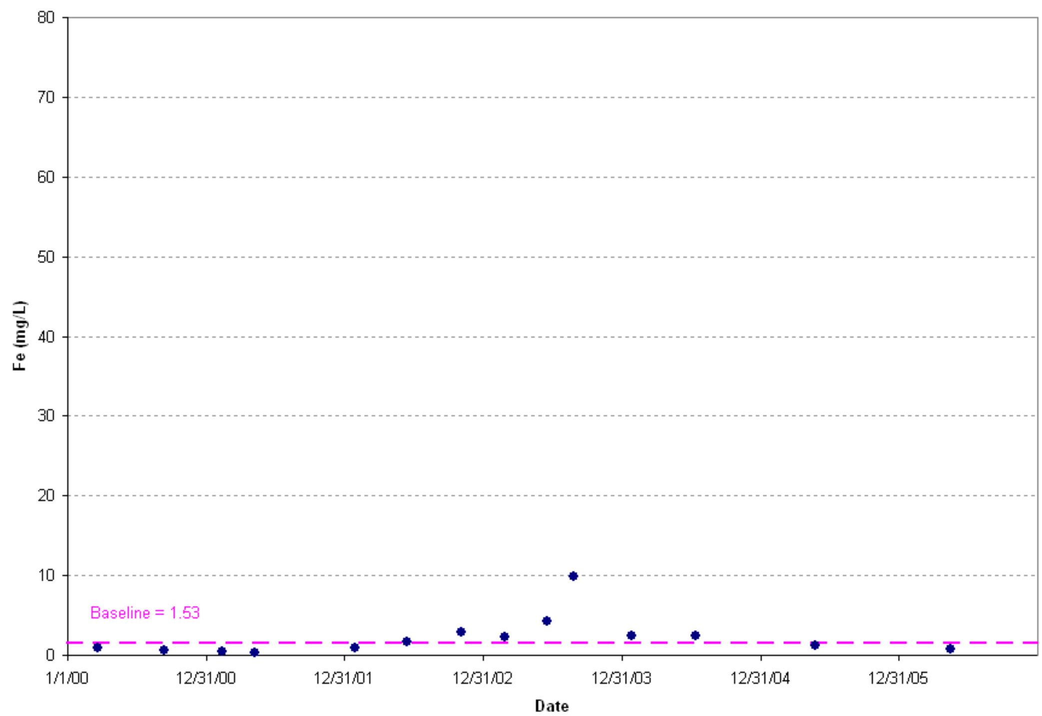

Figure F-30 Iron Concentrations for Atomic School Road (2000-2006)

APPENDIX G

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR pH, Iron, Manganese, and Aluminum IN THE BEAR CREEK SUBWATERSHED SOUTH FORK CUMBERLAND RIVER WATERSHED (HUC 05130104), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Loads (TMDLs) for pH, iron, manganese, and aluminum in the Bear Creek subwatershed, located in middle and eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

Bear Creek and East Branch Bear Creek are listed on Tennessee's Final 2006 303(d) list as not supporting designated use classifications due, in part, to low pH and iron associated with abandoned mines. The TMDL utilizes Tennessee's general water quality criteria, net alkalinity (as $CaCO_3$) as a surrogate for pH, USGS continuous record station flow data, in-stream water quality monitoring data, a calibrated dynamic water quality model, load duration curves, and an appropriate Margin of Safety (MOS) to establish loadings of net alkalinity (as $CaCO_3$) which will result in the attainment of water quality standards for pH.

The proposed Bear Creek pH, Iron, Manganese, and Aluminum TMDLs may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding these TMDLs should be directed to the following members of the Division of Water Pollution Control staff:

Vicki S. Steed, P.E., Watershed Management Section
Telephone: 615-532-0707

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than July 16, 2007 to:

Division of Water Pollution Control
Watershed Management Section
7th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.