TOTAL MAXIMUM DAILY LOAD (TMDL)

For

pH and Metals

In the

Caney Fork River Watershed (HUC 05130108)

Bledsoe, Cumberland, Sequatchie, Van Buren & White Counties, Tennessee

FINAL

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DEPARTMENT OF ENVIRONMENT & CONSERVATION

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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
ITRC	Instream Total Recoverable Concentration
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
USGS	United States Geological Survey
WCS	Watershed Characterization SYstem
WLA	Waste Load Allocation

SUMMARY SHEET

Total Maximum Daily Load (TMDL) for pH and Metals in Caney Fork River Watershed (05130108)

Impaired Waterbody Information

State: Tennessee
Counties: Bledsoe, Cumberland, Sequatchie, Van Buren, White
Watershed: Caney Fork River (HUC 05130108)
Constituents of Concern: pH and metals (iron and manganese)

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN05130108024 – 4000	ROCKY RIVER	17.0
TN05130108027 – 0300	GARDNER CREEK	3.1
TN05130108027 – 0750	PINEY CREEK	12.28
TN05130108027 – 0850	DRY FORK	16.7
TN05130108036 – 0100	CLIFTY CREEK	21.4
TN05130108036 – 0900	PUNCHEONCAMP CREEK	12.8

Designated Uses:

The designated use classifications for waterbodies in the Caney Fork River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Rocky River (Mile 0.0 to headwaters) is also designated for domestic water supply.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2007 Version*:

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 or impair growth in fish or aquatic life or their offspring".

Derived from *Secondary maximum contaminant levels, 40 CFR Part 143.3,* for public water systems:

Iron 300 μg/L
Manganese 50 μg/L

For Gardner Creek, which is not designated for drinking water supply, there is not a specific numeric target for manganese. TDEC believes that meeting the water quality criteria for pH (and its surrogate net alkalinity) and iron will also ensure that Gardner Creek is no longer impaired for manganese.

TMDL Scope:

Waterbodies identified on the Final 2008 303(d) list as impaired due to pH and metals due to abandoned mining.

Monitoring data were unavailable for Clifty Creek, Gardner Creek, and Puncheoncamp Creek. Only limited data were available for Rocky River, Piney Creek, and Dry Fork. Additional monitoring is recommended to either confirm impairment or allow for delisting.

Analysis/Methodology:

Net alkalinity was used as a surrogate for pH. The net alkalinity TMDL for impaired waterbodies in the Caney Fork River Watershed was developed using a load duration curve methodology to assure compliance with the target net alkalinity of 10.8 mg/L (see 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 iron and manganese also were developed using load duration curves for analysis of impaired subwatersheds. The TMDLs, WLAs, and LAs for net alkalinity and each metal 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).

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Caney Fork River Watershed (HUC 05130108)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS	WLAs	LAs
			[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Rocky River	TN05130108024 – 4000	Net Alkalinity	58.1 x Q	NA[a]	58.1 x Q_2	(5.54 x 10^{-3} x Q) – (5.54 x 10^{-3} x Q_2)
		Iron	1.61 x Q	0.161 x Q	16.1 x Q_2	(1.38 x 10^{-4} x Q) – (1.54 x 10^{-3} x Q_2)
		Manganese	0.269 x Q	2.69 x 10^{-2}x Q	10.8 x Q_2	(2.31 x 10^{-5} x Q) – (1.03 x 10^{-3} x Q_2)
Gardner Creek	TN05130108027 – 0300	Net Alkalinity	58.1 x Q	NA[a]	NA	3.23 x 10^{-2} x Q
		Iron	5.38 x Q	0.538 x Q	NA	2.69 x 10^{-3} x Q
Piney Creek	TN05130108027 – 0750	Net Alkalinity	58.1 x Q	NA[a]	NA	3.93 x 10^{-3} x Q
		Iron	5.38 x Q	0.538 x Q	NA	3.27 x 10^{-4} x Q
Dry Fork	TN05130108027 – 0850	Net Alkalinity	58.1 x Q	NA[b]	NA	8.57 x 10^{-3} x Q
		Iron	5.38 x Q	0.538 x Q	NA	7.14 x 10^{-4} x Q
Clifty Creek	TN05130108036 – 0100	Net Alkalinity	58.1 x Q	NA[b]	NA	5.98 x 10^{-3} x Q
		Iron	5.38 x Q	0.538 x Q	NA	4.98 x 10^{-4} x Q
Puncheoncamp Creek	TN05130108036 – 0900	Net Alkalinity	58.1 x Q	NA[b]	NA	1.04 x 10^{-2} x Q

Notes: NA = Not Applicable.
NR = No Reduction Required
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Source

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

pH and METALS TOTAL MAXIMUM DAILY LOAD (TMDL)
CANEY FORK RIVER WATERSHED (HUC 05130108)

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 Caney Fork River Watershed (HUC 05130108) is located in middle and eastern Tennessee (Figure 1). The Caney Fork River Watershed falls within two Level III ecoregions (Southwestern 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.

- **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.

- **Outer Nashville Basin (71h)** is a heterogeneous region, with rolling and hilly topography and slightly higher elevations. The region encompasses most all of the outer areas of the generally no-cherty Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forest with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive, nutrient-rich waters, resulting in algae, rooted vegetation and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

The Caney Fork River Watershed, located in Bledsoe, Cannon, Cumberland, DeKalb, Putnam, Sequatchie, Smith, Van Buren, Warren, White, and Wilson Counties, Tennessee, has a drainage area of approximately 1,790 square miles (mi^2). 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 Caney Fork River Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Caney Fork River Watershed is summarized in Table 1 and Figure 3.

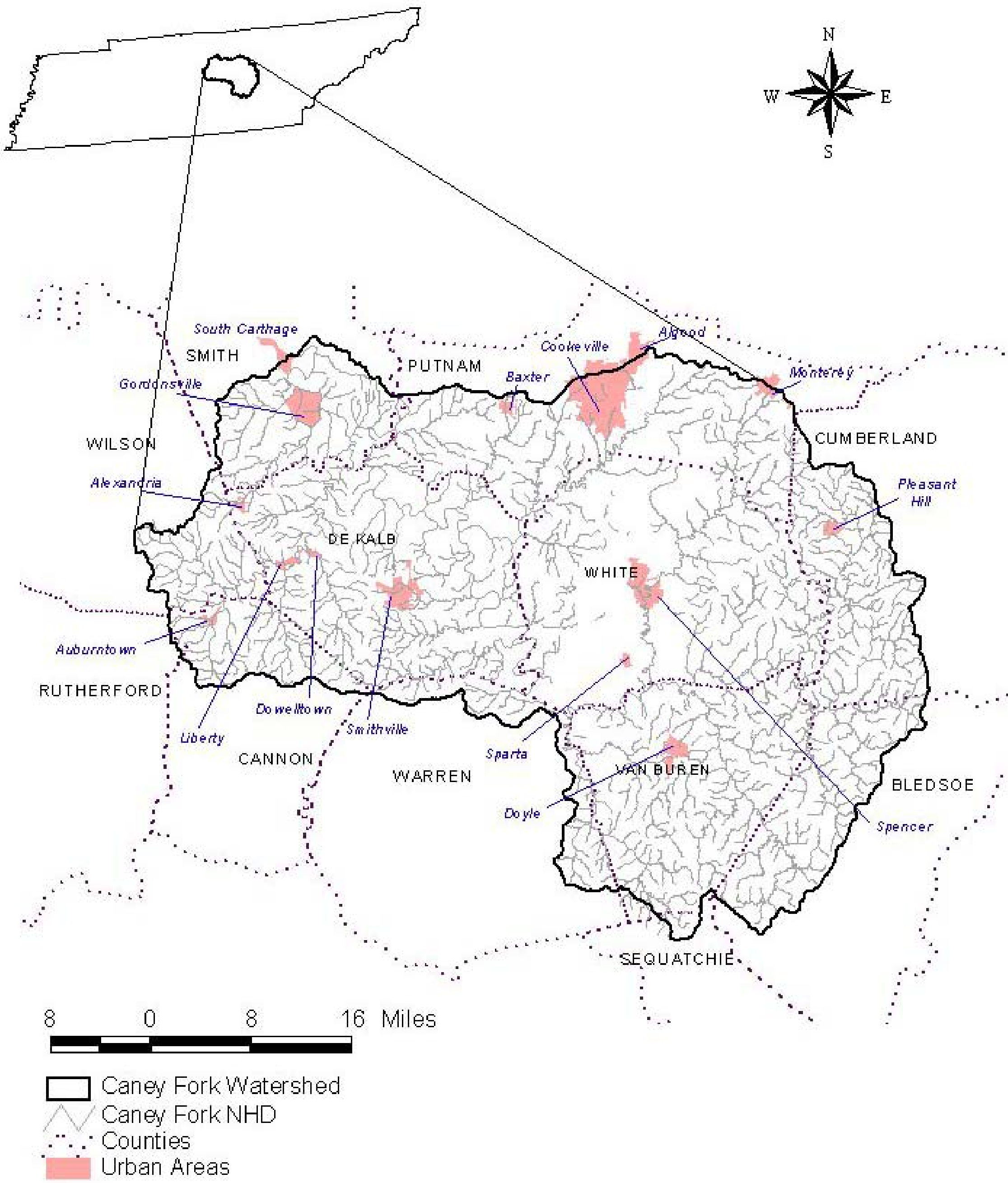

Figure 1 Location of Caney Fork River Watershed

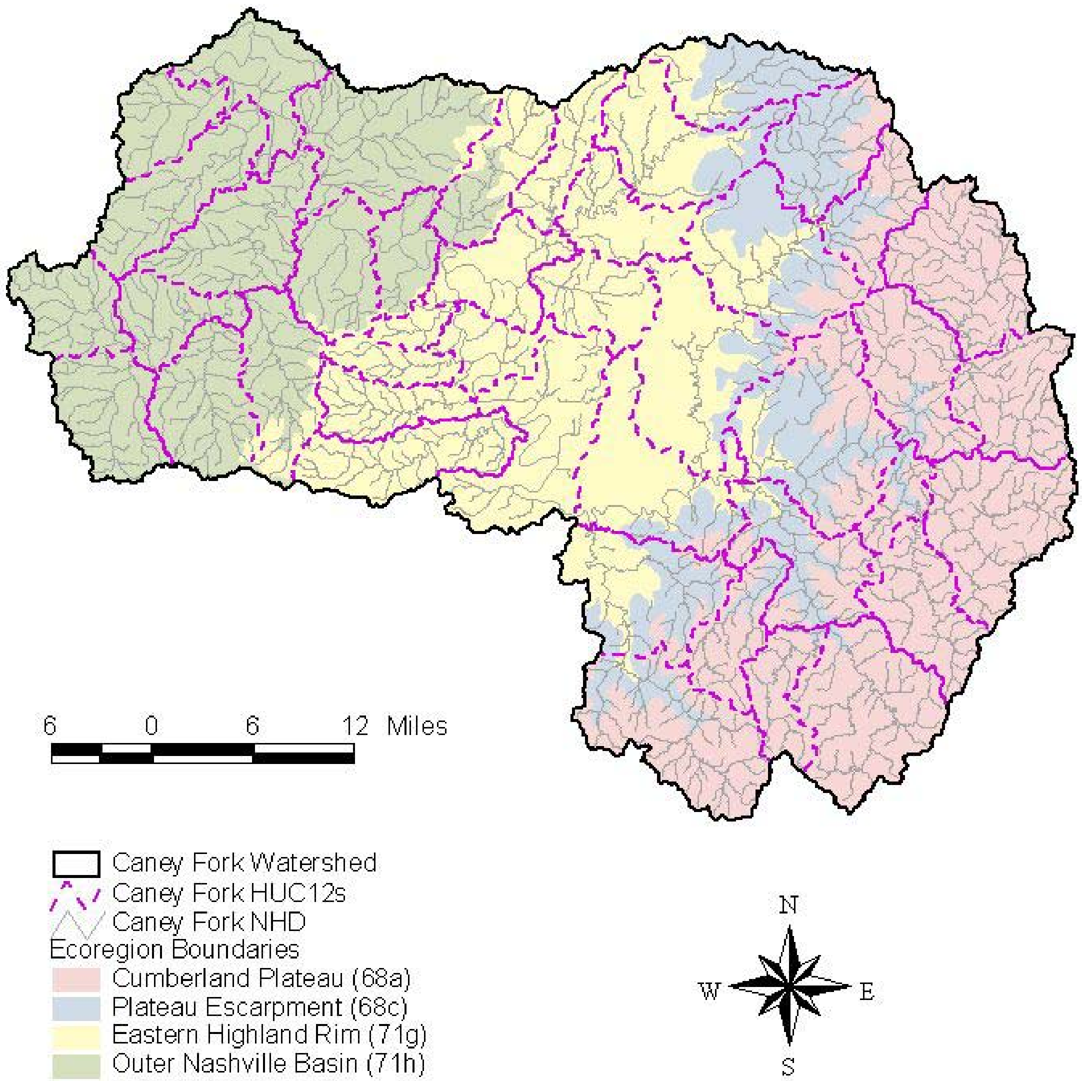

Figure 2 Caney Fork River Watershed Ecoregion Designation

Table 1. MRLC Land Use Distribution – Caney Fork Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	7	0.0
Deciduous Forest	619,711	53.9
Emergent Herbaceous Wetlands	42	0.0
Evergreen Forest	88,323	7.7
High Intensity Commercial/Industrial/ Transportation	5,210	0.5
High Intensity Residential	1,021	0.1
Low Intensity Residential	7,362	0.6
Mixed Forest	150,871	13.1
Open Water	18,663	1.6
Other Grasses (Urban/recreational)	7,775	0.7
Pasture/Hay	185,405	16.1
Quarries/Strip Mines/ Gravel Pits	532	0.1
Row Crops	57,498	5.0
Transitional	4,742	0.4
Woody Wetlands	2,806	0.2
Total	**1,149,968**	**100.0**

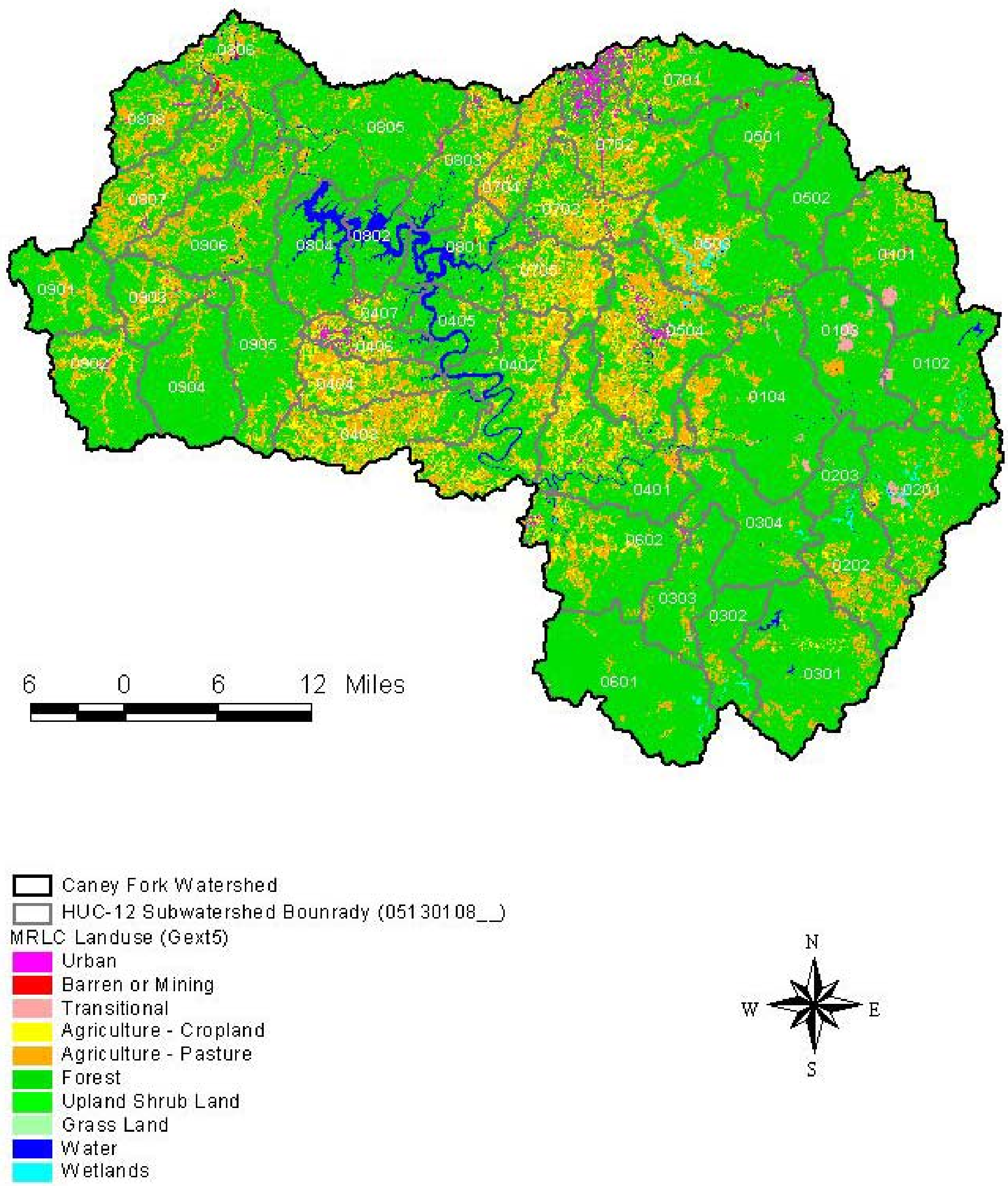

Figure 3 Caney Fork River Watershed Land Use Distribution

3.0 PROBLEM DEFINITION

The State of Tennessee's final 2008 303(d) list (TDEC, 2008) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in June of 2008. The list identified several waterbodies in the Caney Fork River Watershed as not supporting designated use classifications due, in part, to pH and metals associated with abandoned mines and resource extraction. Information regarding formation of acid mine drainage (AMD) is contained in Appendix A. An excerpt from the 2008 303(d) list is presented in Table 2. There are several permitted mines in the Caney Fork River Watershed. Impaired segments in the Caney Fork River Watershed are shown in Figure 4.

Table 2 2008 303(d) List – Caney Fork River Watershed

Waterbody ID	Impacted Waterbody	County	Miles/Acres Impaired	Cause	Pollutant Source
TN05130108 24 – 4000	Rocky River	Van Buren Warren	17.0	Manganese pH	Abandoned Mining
TN05130108 027 – 0300	Gardner Creek	Bledsoe	3.1	Manganese	Abandoned Mining
TN05130108 027 – 0750	Piney Creek	Van Buren	12.28	Iron pH	Abandoned Mining
TN05130108 027 – 0850	Dry Fork	Van Buren	16.7	Iron pH	Abandoned Mining
TN05130108 036 – 0100	Clifty Creek	White	21.4	pH Iron	Abandoned Mining
TN05130108 036 –0900	Puncheoncamp Creek	Cumberland	12.8	pH	Abandoned Mining

Assessment information for waterbodies impaired due to low pH in the Caney Fork River Watershed is available in the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody IDs in Table 2. ADB information may be accessed at: http://gwidc.memphis.edu/website/dwpc/ .

The designated use classifications for Caney Fork River and their tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Rocky River is also designated for domestic water supply.

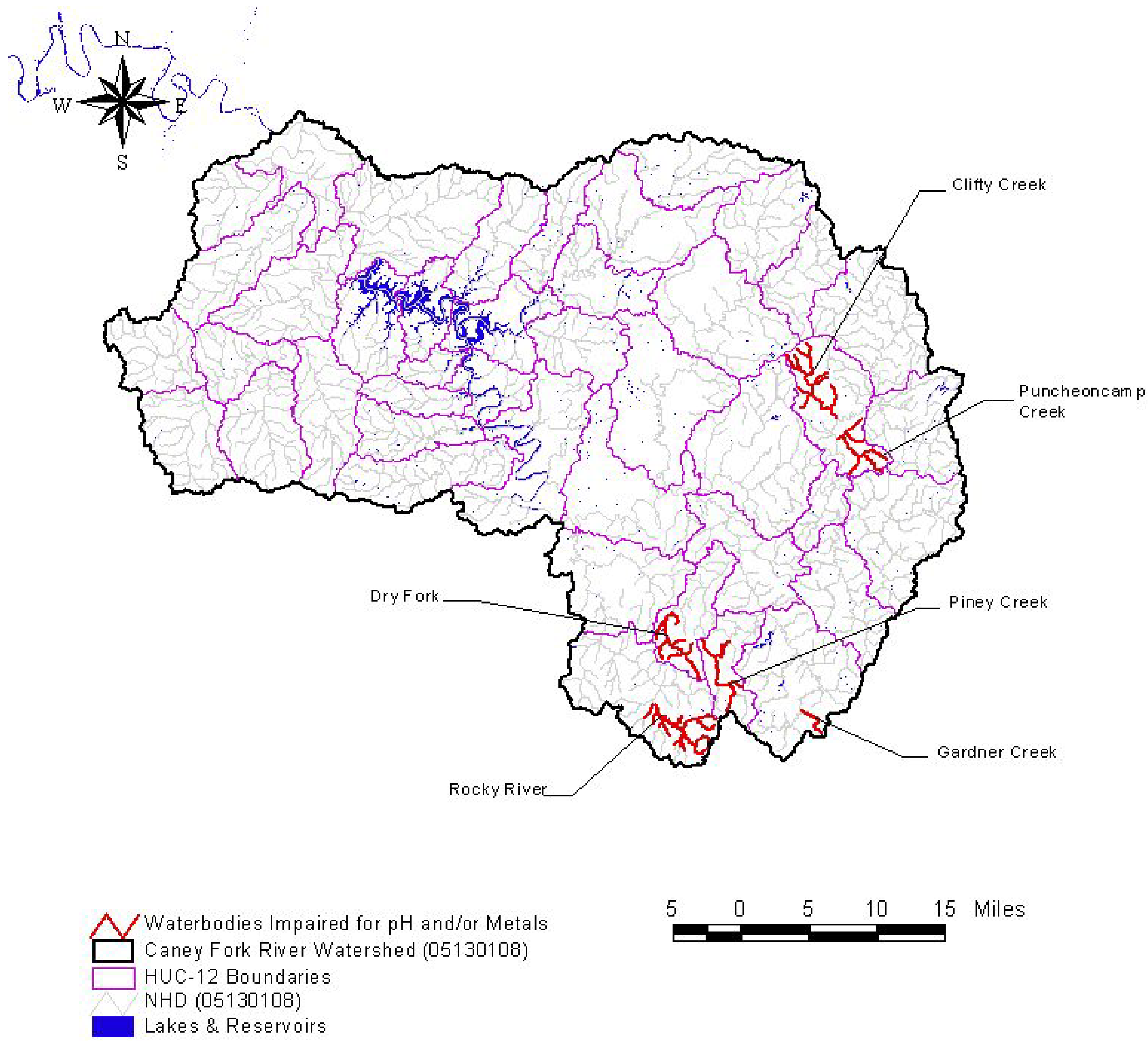

Figure 4 Caney Fork River Watershed pH- and Metal-Impaired Segments

4.0 TARGET IDENTIFICATION

The allowable instream range of pH for the Caney Fork River Watershed, is established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, 2007 Version* (TDEC, 2007) 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.

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 Caney Fork 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 watershed, 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 E, is shown 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 Caney Fork River Watershed 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, 2007 Version* (TDEC, 2007). 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 waterbodies not designated for drinking water supply in the Caney Fork River Watershed. 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 or impair growth in fish or aquatic life or their offspring". The water quality criteria of 300 μg/L (0.30 mg/L) established in the *Secondary maximum contaminant levels (40 CFR §143.3)* has been selected as the appropriate numeric target for waterbodies designated for drinking water supply in the Caney Fork River Watershed.

There is currently no numerical criterion for manganese established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, 2007 Version* (TDEC, 2007). The water quality criteria of 50 μg/L (0.05 mg/L) established in the *Secondary maximum contaminant levels (40 CFR §143.3)* has been selected as the appropriate numeric target for waterbodies designated for drinking water supply in the Caney Fork River Watershed. For Gardner Creek, which is not designated for drinking water supply, there is not a specific numeric target for manganese. According to the "Gold Book" (USEPA, 1986), manganese is not considered to be a problem in fresh waters. TDEC believes that meeting the water quality criteria for pH (and its surrogate net alkalinity) and iron will also ensure that Gardner Creek is no longer impaired for manganese.

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.

Table 3 Metals Criteria for Each Designated Use Classification

Metal (Total Recoverable)	Designated Use Classification	Criteria	Source of Criteria
		[μg/l]	
Iron	Drinking Water Supply	300	40 CFR §143.3
Iron	Fish & Aquatic Life (CCC)	1000	USEPA, 2006
Manganese	Drinking Water Supply	50	40 CFR §143.3

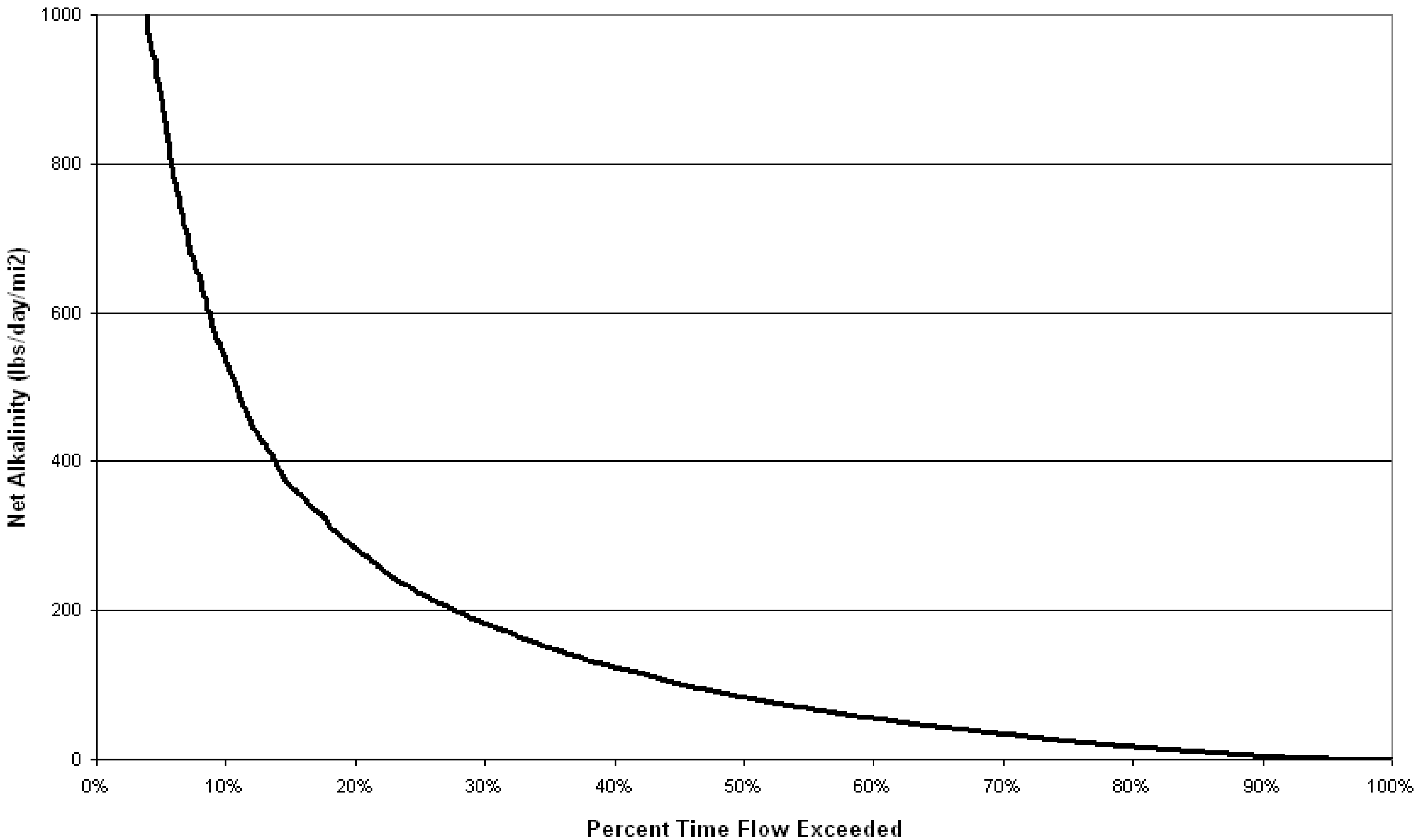

Figure 5 Target Net Alkalinity Load Duration Curve

5.0 WATER QUALITY ASSESSMENT AND DIFFERENCE FROM TARGET

Water quality monitoring of the Caney Fork River Watershed was conducted by Division of Water Pollution Control (DWPC) personnel from the Cookeville Environmental Field Office (EFO) during the period from 8/10/00 through 3/4/08. Several monitoring stations were located on or near impaired segments in the Caney Fork River watershed (see Figure 6).

- HUC-12 05130108_0103:
  - CLIFT001.0WH – Clifty Creek, at Eastland Rd.
- HUC-12 05130108_0302:
  - PINEY001.9VA – Piney Creek, at Falls Creek Falls State Park (below impaired segment)
- HUC-12 05130108_0303:
  - DRY007.2VA – Dry Fork, at the bridge at Pine Grove Rd. (below impaired segment)
- HUC-12 05130108_0601:
  - ROCKY030.0VA – Rocky River, near Chalybeate

The pH and metal data collected at each monitoring site (ref: Appendix B) in the Caney Fork River Watershed are tabulated and compared to the appropriate targets in Table 4.

No water quality monitoring data were available for Clifty Creek, Gardner Creek, and Puncheoncamp Creek at the time this TMDL was prepared. Clifty Creek was listed based on a 1998 biological survey that found zero EPT families and iron precipitate on substrate. Gardner Creek was listed based on a 1997 biological survey. Puncheoncamp Creek was listed based on OSM pH data from the 80s. Water quality monitoring data should be collected for these three waterbodies to confirm the status of each waterbody as impaired by pH and/or metals.

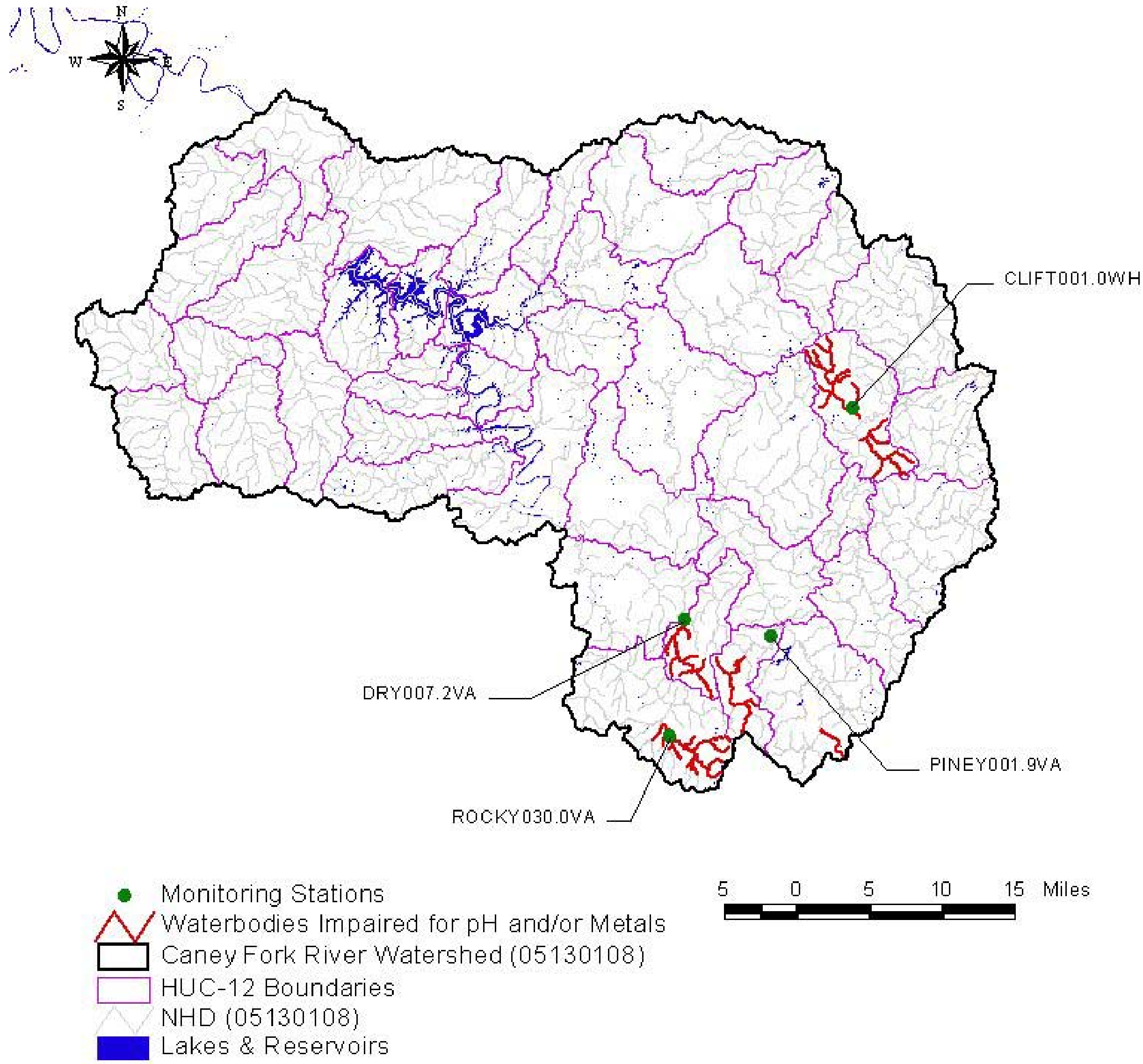

Figure 6 Caney Fork River Watershed Monitoring Stations

Table 4 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	Parameter	Data Pts.	Target (μg/L)	Min. (μg/L)	Avg. (μg/L)	Max. (μg/L)	No. Exceed. Target
DRY007.2VA	2002 – 2008	pH [a]	15	6.0-9.0	6.1	6.82	8.1	0
		Iron	12	1000	ND	716.5	7,100	1
		Manganese	12	NA	ND	100.8	640	0
PINEY001.9VA	2007 – 2008	pH [a]	7	6.0-9.0	6.72	7.39	10.52	1
		Iron	7	1000	ND	85.5	406	0
		Manganese	7	NA	21	183	438	0
ROCKY030.0VA	2000	pH [a]	2	6.0-9.0	4.01	4.14	4.25	2
		Iron	2	300[b]	102	1,271	2,440	1
		Manganese	2	50[b]	3,240	4,270	5,300	2

[a] pH is expressed in standard units (s.u.)
[b] Target for Rocky River is based on designation as domestic water supply.

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 19 facilities in the Caney Fork River Watershed that have NPDES permits authorizing the discharge of wastewater due to mine operations. Fifteen of the facilities are sand or gravel mining, which do not impact pH. The remaining four facilities are coal mining operations, although three of the permits are no longer active. Both of the Sequatchie Valley Coal Corp. facilities are located in an impaired subwatershed (see Table 5 & Figure 7). The permit limits for discharges from these facilities are in accordance with the effluent limitations specified in 40 CFR §434.35 and are given in Table 6.

Table 5 NPDES Permitted Coal Mines in Caney Fork River Watershed

NPDES Permit No.	Facility	Status	Size (acres)	Receiving Stream
TN0045951	Sequatchie Valley Coal Corp. - Mine 1	Active	138	Baltimore Branch & Rocky River
TN0042536	Sequatchie Valley Coal Corp. – Area #A-78	Inactive	36	Baltimore Branch
TN0045641	Eastern Minerals International Inc. – Deep Mine 1	Inactive	27	Cane Creek & unnamed trib to Cane Creek
TN0053376	Hitchcock Coal Co. – Area #4_R	Inactive	23	Mitchell Creek

Table 6 NPDES Permit Limits

Constituent	Monthly Average	Daily Max
Iron, total	3.0 mg/L	6.0 mg/L
Manganese, total	2.0 mg/L	4.0 mg/L
Total Suspended Solids	35.0 mg/L	70.0 mg/L
Settleable Solids	NA	0.5 mg/L
pH	6.5 to 9.0 Standard Units at all times	

6.2 Non-point Sources

There are a number of abandoned surface mining sites in the Caney Fork River Watershed that are susceptible to the formation of acid mine drainage as discussed in Appendix A. In the 2008 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.

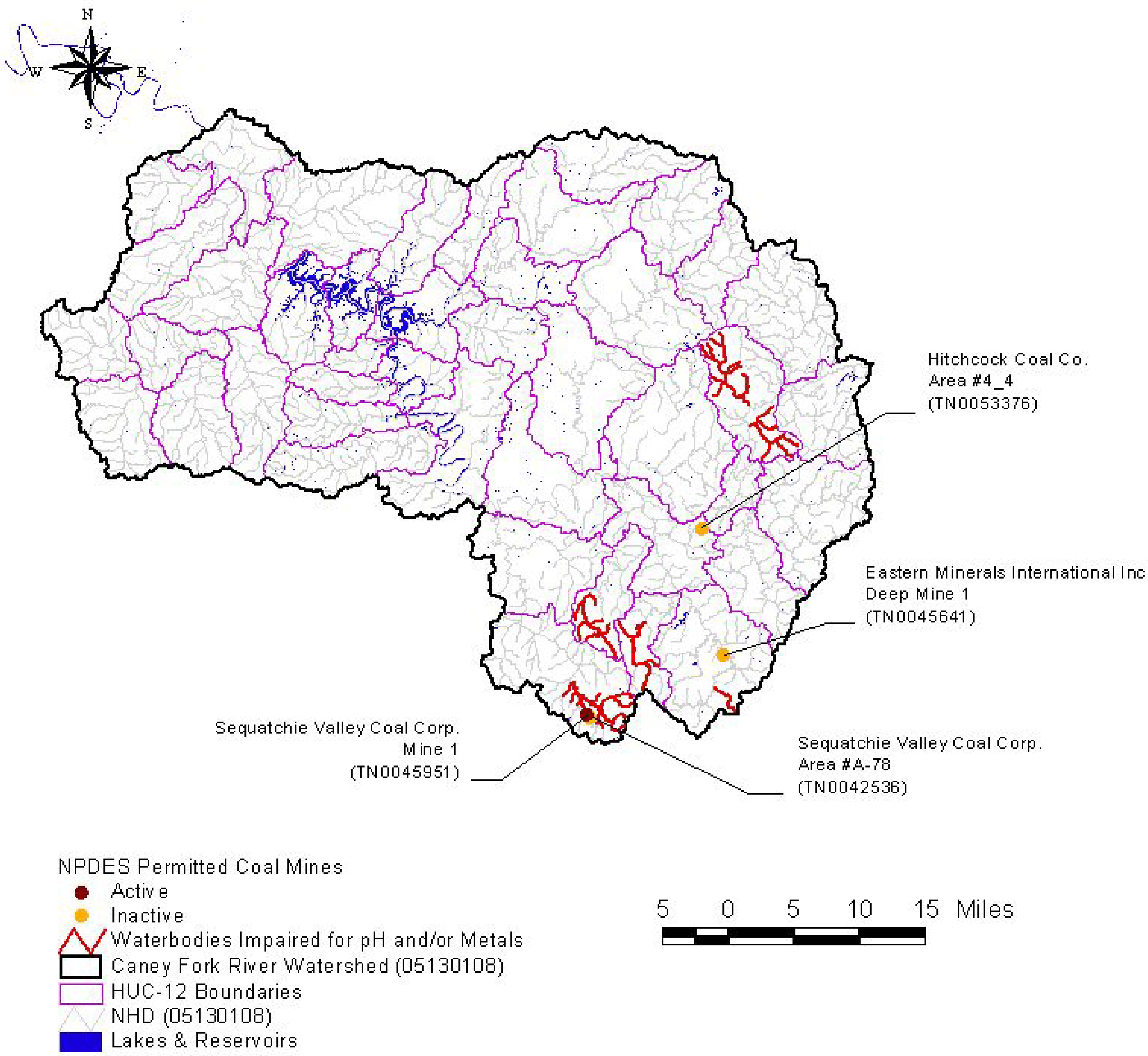

Figure 7 NPDES Permitted Mines in the Caney Fork River Watershed

7.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The 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) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

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 other appropriate measure.

7.1 Expression of TMDLs, WLAs, & LAs

In this document, the TMDL for each constituent is a daily load expressed as a function of mean daily flow (daily loading function). WLAs & LAs are also expressed as daily loading functions in lbs/day/acre. For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease constituent loads to TMDL target levels are also expressed.

7.2 TMDL Analysis Methodology

TMDLs for the Caney Fork River Watershed were developed using load duration curves for analysis of impaired waterbodies. 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 zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS.

7.3 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.

7.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source metals loading is an extended dry period followed by a rainfall runoff event. During the dry weather, metals build up on the land surface and are washed off by rainfall. The critical condition for point source loading occurs during period of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from October 1, 1997 to September 30, 2007 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions and seasonal variation are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies. In the Caney Fork River subwatersheds, water quality data have not been collected during all flow ranges.

7.5 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 and manganese 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 (Rocky River only)	MOS = 30 μg/L
Instantaneous Maximum for Iron (all other waterbodies)	MOS = 100 μg/L
Instantaneous Maximum for Manganese (Rocky River only)	MOS = 5 μg/L

7.6 Determination of Total Maximum Daily Loads

Daily loading functions were calculated for impaired segments in the Caney Fork River Watershed using LDCs to evaluate compliance with the maximum target concentrations according to the procedure in Appendix E. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 7. Note that for net alkalinity, the TMDL represents the minimum loading rather than the maximum loading.

7.7 Determination of WLAs, & LAs

WLAs and LAs were determined according to the procedures in Appendix D. These allocations represent the available loading after application of the explicit MOS. For waterbodies with no active mining operations, there is no WLA and the LA for pH is equal to the TMDL for pH. 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, WLAs, and LAs for net alkalinity, iron, and manganese in the Caney Fork River Watershed are summarized in Table 7.

Table 7. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Caney Fork River Watershed (HUC 05130108)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	TMDL	Explicit MOS	WLAs	LAs
			[%]	[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Rocky River	TN05130108024 – 4000	Net Alkalinity	NA	58.1 x Q	NA[a]	58.1 x Q_2	(5.54 x 10^{-3} x Q) – (5.54 x 10^{-3} x Q_2)
		Iron	76.4	1.61 x Q	0.161 x Q	16.1 x Q_2	(1.38 x 10^{-4} x Q) – (1.54 x 10^{-3} x Q_2)
		Manganese	93.0	0.269 x Q	2.69 x 10^{-2}x Q	10.8 x Q_2	(2.31 x 10^{-5} x Q) – (1.03 x 10^{-3} x Q_2)
Gardner Creek	TN05130108027 – 0300	Net Alkalinity	NA	58.1 x Q	NA[a]	NA	3.23 x 10^{-2} x Q
		Iron	NA	5.38 x Q	0.538 x Q	NA	2.69 x 10^{-3} x Q
Piney Creek	TN05130108027 – 0750	Net Alkalinity	NA	58.1 x Q	NA[a]	NA	3.93 x 10^{-3} x Q
		Iron	NR	5.38 x Q	0.538 x Q	NA	3.27 x 10^{-4} x Q
Dry Fork	TN05130108027 – 0850	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	8.57 x 10^{-3} x Q
		Iron	85.9	5.38 x Q	0.538 x Q	NA	7.14 x 10^{-4} x Q
Clifty Creek	TN05130108036 – 0100	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	5.98 x 10^{-3} x Q
		Iron	NA	5.38 x Q	0.538 x Q	NA	4.98 x 10^{-4} x Q
Puncheoncamp Creek	TN05130108036 – 0900	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	1.04 x 10^{-2} x Q

Notes: NA = Not Applicable.
NR = No Reduction Required
PLRG = Percent Load Reduction Goal
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Source

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

8.0 IMPLEMENTATION PLAN

Monitoring conducted in 2000 thru 2008 has identified a number of waterbodies in the Caney Fork River Watershed 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. It should be noted that the stream water quality documented during sampling conducted for this TMDL is not typical of the more severe acid mine drainage situations. Acid mine drainage has one or more of four major components: high acidity (low pH < 6 or alkalinity < 20 mg/L), high metal concentrations (> 500 μg/L), elevated sulfate levels (> 74 mg/L), and excessive suspended solids and/or siltation.

Individual metal load reduction goals were calculated for impaired segments using Load Duration Curves to evaluate compliance with the target concentrations according to the procedure in Appendix E. The load reductions were calculated at each monitoring site within the drainage area for which monitoring data was available. (No monitoring data was available for Clifty Creek, Gardner Creek, and Puncheoncamp Creek.) The load reductions for the Caney Fork River Watershed are also summarized in Table 7.

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 Caney Fork River Watershed meet, or exceed, the daily loading functions specified in Table 7.

Step 1: Conduct water quality testing for Clifty Creek, Gardner Creek, and Puncheoncamp Creek to confirm the status of each waterbody as impaired by pH and/or metals. No monitoring data was available for these waterbodies.

Step 2: Conduct additional water and minespoil testing to identify specific AMD sites and delineate actual areas of acid production at each site.

Step 3: 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 of the DWPC has expertise in the development of AMD remediation plans and has 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. One reclamation project was completed at the Three Sisters site in the North Chickamauga Creek subwatershed in 2000 at a cost of $95,000.

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, offering considerable technical advice in the remediation of problems similar to those found in the Caney Fork River Watershed.

Step 4: Conduct follow-up water quality testing of impaired waterbodies in the Caney Fork River Watershed to verify the effectiveness of remediation measures. Parameters should include flow, pH, acidity, total alkalinity, and metals (iron and manganese, as appropriate).

9.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pH TMDL for the Caney Fork 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 was posted on the Tennessee Department of Environment and Conservation website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDL (similar to the website announcement) was 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) Letters were sent to NPDES-permitted mines located in pH- or metal-impaired subwatersheds or drainage areas in the Caney Fork River Watershed, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the Final TMDL document would be provided on request. A letter was sent to the following entities:

   Sequatchie Valley Coal Corp., Mine #1 (TN0045951)

No comments were received during the public notice period.

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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REFERENCES

Electronic Code of Federal Regulations (e-CFR). "New Source Performance Standards (NSPS)", 40 CFR §434.35. current as of May 5, 2006.

Electronic Code of Federal Regulations (e-CFR). "Secondary Maximum Contaminant Levles", 40 CFR §143.3. current as of May 5, 2006.

Lumb, A.M., McCammon, R.B., and Kittle, J.L., Jr., 1994. Users Manual for an expert system, (HSPFEXP) for calibration of the Hydrologic Simulation Program –Fortran: U.S. Geological Survey Water-Resources Investigation Report 94-4168,102 p.

PDEP. 1998. *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*. Pennsylvania Department of Environmental Protection, Harrisburg, Pennsylvania. 5600-BK-DEP2256, August 1998.

Stiles, T., and B. Cleland, 2003. Using Duration Curves in TMDL Development and Implementation Planning. ASIWPCA "States Helping States" Conference Call, July 1, 2003. This document is available on the Indiana Office of Water Quality website: http://www.in.gov/idem/water/planbr/wqs/tmdl/durationcurveshscall.pdf .

TDEC. 2007. *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, 2007 Version.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2008. *Final 2008 303(d) List.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control, June 2008.

USEPA. 1975. *Development Document For Interim Final Effluent Limitations Guidelines for the Coal Mining Point Source Category.* U.S. Environmental Protection Agency, Washington, DC. Publication Number 440175057, October 1975.

USEPA. 1986. *Quality Criteria for Water.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/5-86-001, 1986.

USEPA. 1991a. *Guidance for Water Quality –based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

USEPA. 1991b. *Technical Support Document For Water Quality –based Toxics Control.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-505/2-90-001.

USEPA. 1996. *The Metals Translator: Guidance for Calculating a Total Recoverable Permit Limit from a Dissolved Criterion.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-823/B-96-007.

USEPA. 1997. *Ecoregions of Tennessee*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. EPA/600/R-97/022.

USEPA. 2001. *Abandoned Mine Site Characterization and Cleanup Handbook.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. EPA-530-R-01-002, March 2001.

USEPA. 2006. *National Recommended Water Quality Criteria.* U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology (4304T), Washington, DC. 2006.

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

<u>Chemistry of Pyrite Weathering</u>

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

Caney Fork River Watershed Monitoring Data

Table B-1 Rocky River Monitoring Data

Rocky River			**35 35' 10"N**
Mile 30.0			**85 31' 15"W**
Test	*Units*	*8/10/00*	*11/2/00*
pH	--	4.3	4.01
Conductivity	uMHO	463.0	642.0
Dissolved Oxygen	mg/L	9.4	9.8
Flow	cfs		3.3
Temperature	Celsius	22.4	12.6
Acidity	mg/L	12.00	12.00
Total Alkalinity	mg/L	1U	1U
Sulfate	mg/L	208.0	341.0
Total Hardness	mg/L	191	296
TSS	mg/L		
Turbidity	NTU		
Aluminum	ug/L	919.00	800.00
Cadmium	ug/L	1U	1U
Chromium	ug/L	1U	1U
Copper	ug/L	2	1U
Iron	ug/L	2440	102
Lead	ug/L	1U	1U
Manganese	ug/L	3240	5300
Nickel	ug/L	37.00	72.00
Zinc	ug/L	38	46

Table B-2 Piney Creek Monitoring Data

	Piney Creek						**35 40' 21"N**	
	Mile 1.9 (below impaired segment)						**85 23' 4"W**	
Test	*Units*	*7/23/07*	*8/13/07*	*9/11/07*	*11/29/07*	*12/11/07*	*1/9/08*	*2/6/08*
pH	--	8.1	7.3	7.5	8.1	8.9	6.7	10.52
Conductivity	uMHO	61.0	121.0	72.0	61.5	178.0	108.0	60.0
Dissolved Oxygen	mg/L	8.7	7.9	7.7	11.8	9.6	11.6	10.6
Flow	cfs	0.0	0.1	0.1	0.1	1.3	6.2	
Temperature	Celsius	21.0	22.3	21.1	6.8	9.7	7.1	8.2
Acidity	mg/L							
Total Alkalinity	mg/L							
Sulfate	mg/L	12.0	37.0	25.0	15.0	53.0	30.0	14.0
Total Hardness	mg/L	25	43	42	25	69	77	23
TSS	mg/L							
Turbidity	NTU	1.12	0.74	3.64	0.73	0.50	0.39	30.30
Aluminum	ug/L	100U	100U	100U	100U		100U	790.00
Cadmium	ug/L	1U	1U	1U	1U	1U	1U	1U
Chromium	ug/L	1U	1U	1U	1U	1U	1U	1U
Copper	ug/L	1U	1U	1U	1	1	1U	2
Iron	ug/L	68	25U	58	29	25U	25U	406
Lead	ug/L	1U	1U	1U	1U	1U	1U	1.90
Manganese	ug/L	168	125	438	94	25	21	410
Nickel	ug/L	10U	10U	10U	10U	10U	10U	10U
Zinc	ug/L	3	1U	9	1	2	3	13

Table B-3 Dry Fork Monitoring Data

	Dry Fork						35 41' 53"N		
	Mile 7.2 (below impaired segment)						85 29' 10"W		
Test	Units	11/7/02	12/17/02	1/7/03	2/12/03	3/12/03	4/14/03	7/29/03	8/14/03
pH	--	6.1	7.2	6.8	7.6	6.6	6.4	6.5	7.6
Conductivity	uMHO	48.0	46.3	53.7	67.7	61.3	109.0	41.0	53.7
Dissolved Oxygen	mg/L	10.5	9.7	10.3	10.1	11.3	10.7	8.1	8.3
Flow	cfs								
Temperature	Celsius	11.7	9.3	5.1	5.4	10.1	12.8	20.6	20.8
Acidity	mg/L	1U	1U	3.07	1U	1U	1U	1U	1U
Total Alkalinity	mg/L	3.73	4.41	32.00	2.50	2.66	2.83	8.15	9.49
Sulfate	mg/L	9.3	9.3	14.2	13.2	16.3	9.3	6.6	8.7
Total Hardness	mg/L								
TSS	mg/L								
Turbidity	NTU								
Aluminum	ug/L	100U	100U	100U	54	65	204	116	85
Cadmium	ug/L								
Chromium	ug/L								
Copper	ug/L								
Iron	ug/L	25U	25U	25U	46	33	97	492	156
Lead	ug/L								
Manganese	ug/L	5U	5U	5U	35	52	53	69	49
Nickel	ug/L								
Zinc	ug/L								
Test	Units	7/30/07	8/27/07	9/19/07	11/27/07	12/4/07	1/10/08	2/12/08	3/4/08
pH	--	7.74	7.51		7.62	7.23	7.43	8.10	7.26
Conductivity	uMHO	131.0	251.0	109.0	253.0	154.0	90.0	71.0	64.0
Dissolved Oxygen	mg/L	7.8	5.2	5.9	10.6	11.6	10.8	12.1	10.2
Flow	cfs	4.8	0.0	0.0	9.5	7.4	7.5	11.0	
Temperature	Celsius	20.7	23.4	18.6	8.8	5.3	9.1	7.4	11.0
Acidity	mg/L								
Total Alkalinity	mg/L								
Sulfate	mg/L	41.0	17.0	6.7	90.0	50.0	19.0	8.8	22.0
Total Hardness	mg/L	54	140	34	120	79	29	85	29
TSS	mg/L								
Turbidity	NTU		2.08	1.54	6.45	6.93	2.94	1.67	401
Aluminum	ug/L				471	381		128	11,000
Cadmium	ug/L								
Chromium	ug/L				1U	1U		1U	8
Copper	ug/L				1	1		1U	1
Iron	ug/L				286	285		66	7100
Lead	ug/L				1U	1U		1U	7.50
Manganese	ug/L				193	45		66	640
Nickel	ug/L				10U	10U		10U	10U
Zinc	ug/L				6	4		3	2

APPENDIX C

Development of Target Net Alkalinity

Since there is no numerical criterion for net alkalinity, all available monitoring data for the 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.

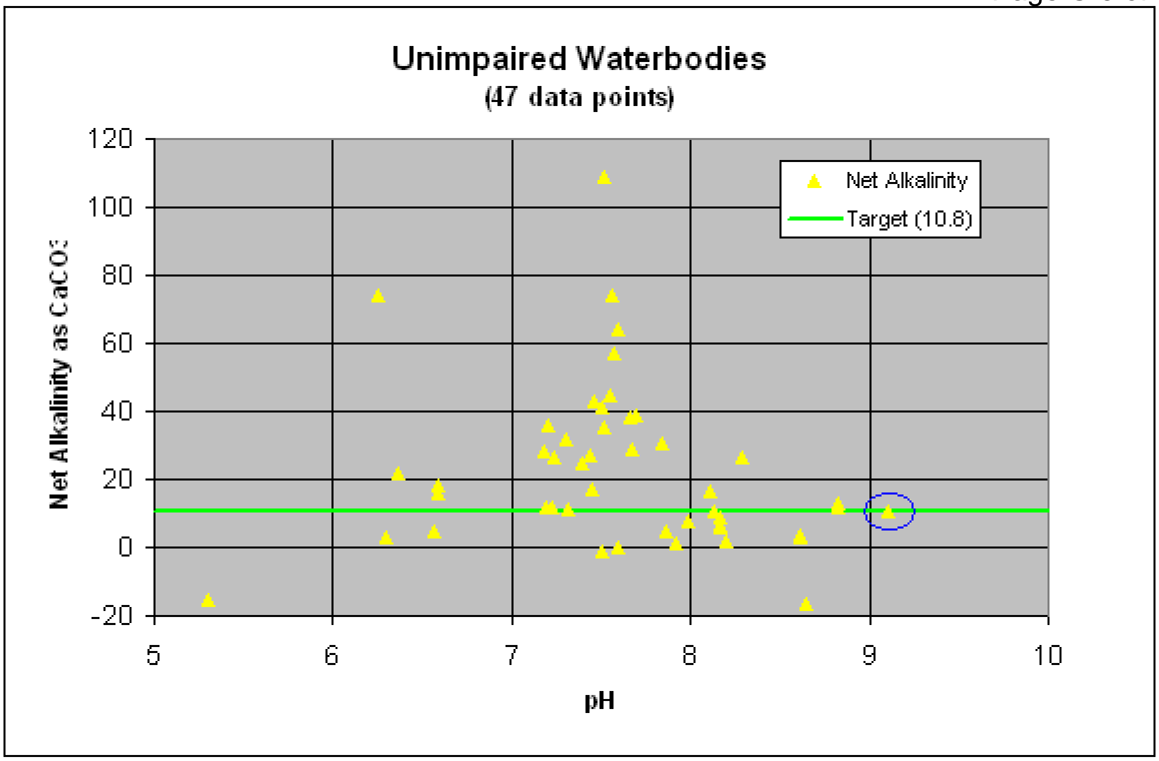

Figure C-1 pH and Net Alkalinity for Unimpaired Waterbodies in Tennessee
(no non-detects for either acidity or total alkalinity)

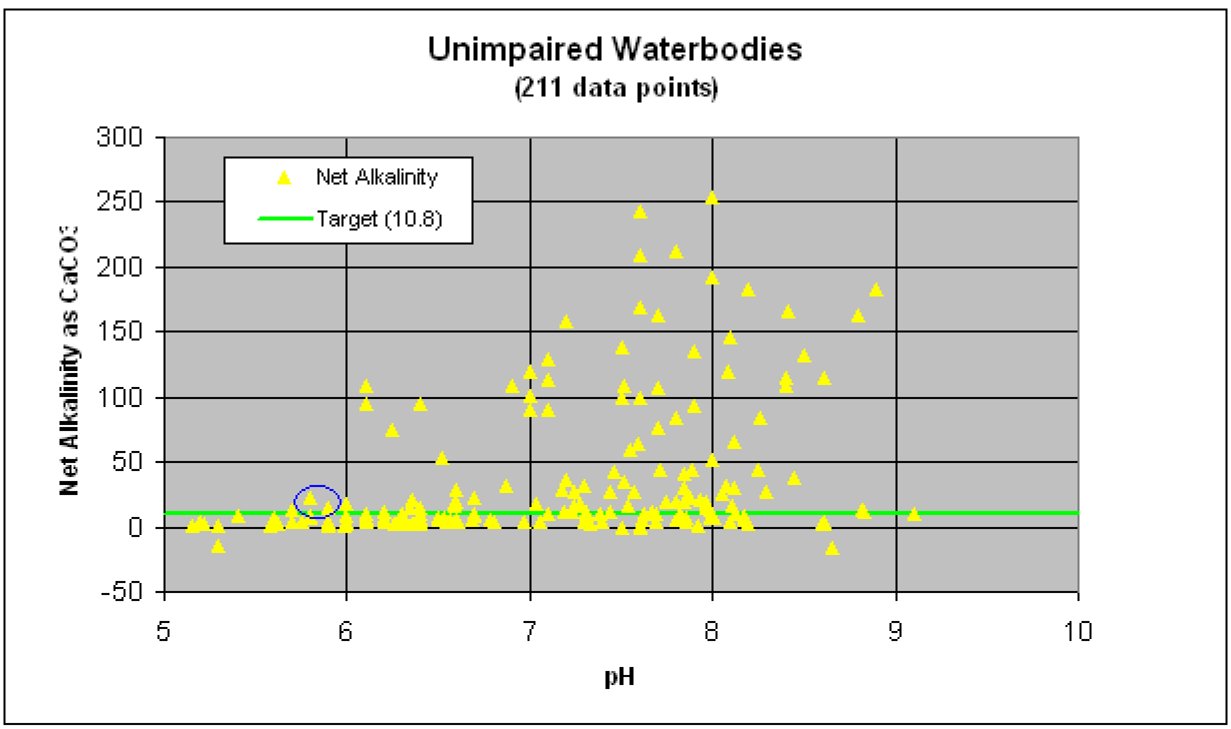

Figure C-2 pH and Net Alkalinity for Unimpaired Waterbodies in Tennessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

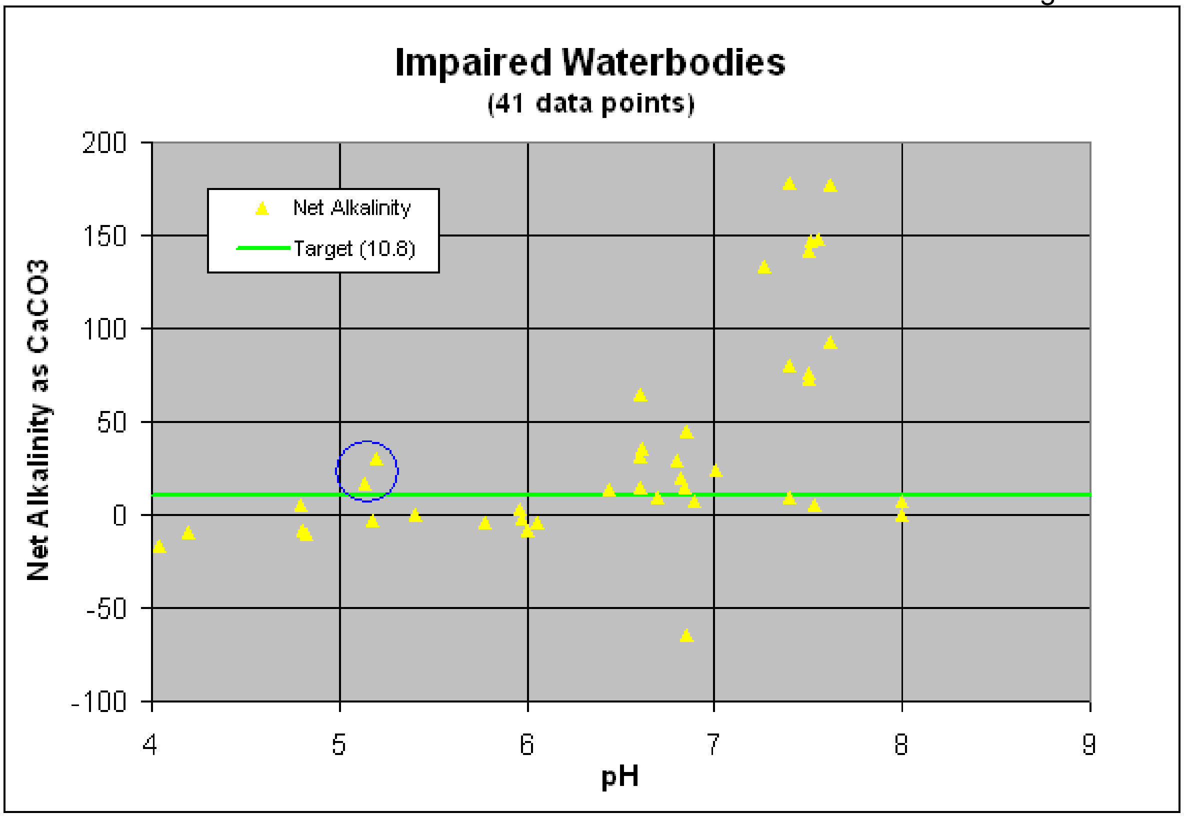

Figure C-3 pH and Net Alkalinity for Impaired Waterbodies in Tenneessee
(no non-detects for either acidity or total alkalinity)

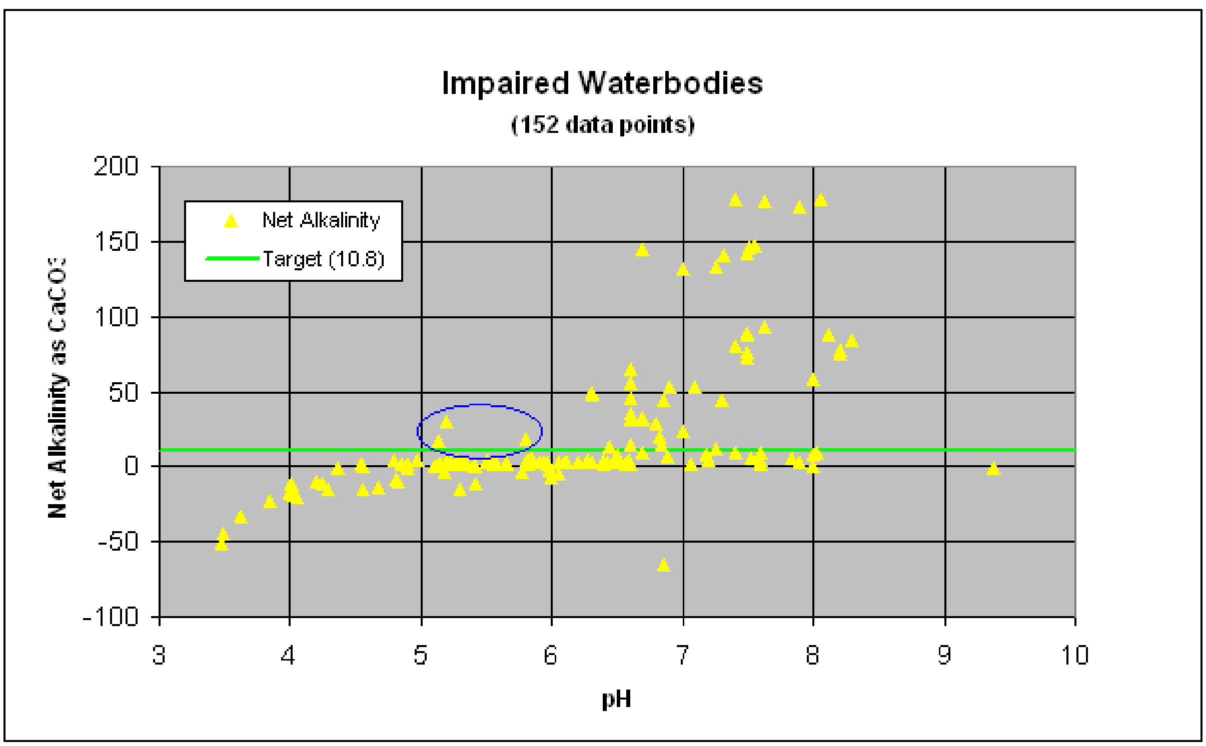

Figure C-4 pH and Net Alkalinity for Impaired Waterbodies in Tenneessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

APPENDIX D

Load Duration Curve Development
and
Determination of Daily Loading

The 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), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

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) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

Net alkalinity and individual metal TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Caney Fork River Watershed using Load Duration Curves (LDCs). Daily Loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function).

D.1 Development of Flow Duration Curves

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. 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 U.S. Geological Survey (USGS) continuous-record stations (http://waterdata.usgs.gov/tn/nwis/sw) 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 Caney Fork 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 E for details of calibration). For example, a flow-duration curve for Dry Fork at RM 7.2 was constructed using simulated daily mean flow for the period from 10/1/98 through 9/30/07 (RM 7.2 corresponds to the location of monitoring station DRY007.2VA). 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). The flow duration curve for other impaired waterbodies was derived using a similar procedure.

D.2 Development of Load Duration Curves

When a water quality target 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. The target net alkalinity load duration curve for the Caney Fork River Watershed was developed from the flow duration curve for Dry Fork developed in Section D.1. The target curve can be applied to all impaired waterbodies in the Caney Fork River Watershed because it was developed on a unit drainage area basis. 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:

Target Load = (10.8) x (Q/A) x (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 Caney Fork River Watershed 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.

The target load duration curve for each metal was developed similar to the target load duration curve for net alkalinity. The appropriate target concentration for each metal was applied to each of the ranked flows used to generate the flow duration curve and the results were plotted (Figures D-4 and D-5).

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 four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). 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).

Load duration curves for specific monitoring locations were developed using the following procedure (Dry Fork is used as an example):

1. Daily loads were calculated for each of the water quality samples collected at monitoring station DRY007.2VA (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor, and dividing by the subwatershed drainage area. DRY007.2VA was selected for LDC analysis because it was the monitoring station nearest to the impaired portion of Dry Fork with pH and metal concentration data available.

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 – 1/7/03 sampling event:
Modeled Flow = 8.90 cfs
Concentration = 13 μg/L
Area = 8,761.0 acres = 10.6 mi²
Daily Load = 5.66 x 10^{-2} lbs iron/day/mi²

2. 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 net alkalinity load duration curve is shown in Figure D-6.

Example – 1/7/03 sampling event:
Modeled Flow = 8.90 cfs
PDFE = 34.3%

LDCs for other metals and other impaired waterbodies were derived in a similar manner and are shown in Figures D-7 through D-11.

D.3 Development of WLAs, LAs, and MOS

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:

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

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 the percent load reductions necessary to achieve the WLAs and LAs:

Instantaneous Maximum for Iron (Rocky River only)
Target – MOS = (300 μg/L) – (30 μg/L) = 270 μg/L
Instantaneous Maximum for Iron (all other waterbodies)
Target – MOS = (1000 μg/L) – (100 μg/L) = 900 μg/L
Instantaneous Maximum for Manganese (Rocky River only)
Target – MOS = (50 μg/L) – (5 μg/L) = 45 μg/L

D.4 Daily Load Calculations

Each of the terms in the equation above can be derived sequentially:

TMDL = (Target Concentration) x (Q) x (UCF)

where: Target Concentration = water quality criterion
Q = daily mean flow
UCF = the required unit conversion factor

Using Dry Fork at Mile 7.2 as an example for iron:

$TMDL_{DryFork} = (1000\ \mu g/L) \times (Q) \times (UCF)$

$\mathbf{TMDL_{DryFork} = 5.38 \times Q\ (lbs/day)}$

$MOS_{DryFork} = TMDL \times 0.10$

$\mathbf{MOS_{DryFork} = 0.538 \times Q\ (lbs/day)}$

By rearranging the equation in section D.4 and expressing on a unit area basis:

Σ LAs = (TMDL – MOS – Σ WLAs) / DA

where: DA = waterbody drainage area (acres)

Since there are no permitted point sources contributing at Mile 7.2, WLA = 0. Therefore:

$LA_{DryFork} = \{(5.38 \times Q) - (0.538 \times Q)\} / (6{,}781.0)$

$\mathbf{LA_{DryFork} = (7.14 \times 10^{-4}) \times Q\ (lbs/day/ac)}$

For Rocky River, permitted point sources exist and the applicable WLA must be calculated:

$WLA = \{(Permit\ Limit) \times (Q_2) \times (UCF)\}$

where: Q_2 = daily mean flow for combined point sources
UCF = the required unit conversion factor

$WLA_{Rocky} = (3\ mg/L \times Q_2 \times UCF)$

$\mathbf{WLA_{Rocky} = 16.1 \times Q_2\ (lbs/day)}$

Since there are permitted point sources contributing to Rocky River:

$LA_{Rocky} = \{(1.61 \times Q) - (0.161 \times Q) - (16.1 \times Q_2)\} / (10{,}496.8)$

$\mathbf{LA_{Rocky} = \{(1.38 \times 10^{-4}) \times Q\} - \{(1.54 \times 10^{-3}) \times Q_2\}\ (lbs/day/ac)}$

TMDLs, WLAs, & LAs for impaired waterbodies in the Caney Fork River Watershed are summarized in Table D-7.

D.5 Calculation of Percent Load Reduction Goals (PLRGs)

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream loads to TMDL target levels (percent load reduction goals) were calculated. The following example is from Rocky River at Mile 30.0.

1. 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 – 8/10/00 sampling event:
   Target Concentration = 300 μg/L
   Measured Concentration = 2,440 μg/L
   Reduction to Target = 87.7%

2. The 90^{th} percentile value for all of the iron sampling data at the Rocky River monitoring station was determined. If the 90^{th} percentile value exceeded the target maximum iron concentration, the reduction required to reduce the 90^{th} percentile value to the target maximum concentration was calculated.

   Example: *Target Concentration = 300 μg/L*
   90^{th} Percentile Concentration = 2,206 μg/L
   Reduction to Target = 86.4%

Percent load reduction goals for iron and manganese for other impaired waterbodies were derived in a similar manner and are shown in Tables D-1 through D-6. TMDLs, WLAs, LAs, and PLRGs for impaired waterbodies in the Caney Fork River Watershed are summarized in Table D-7.

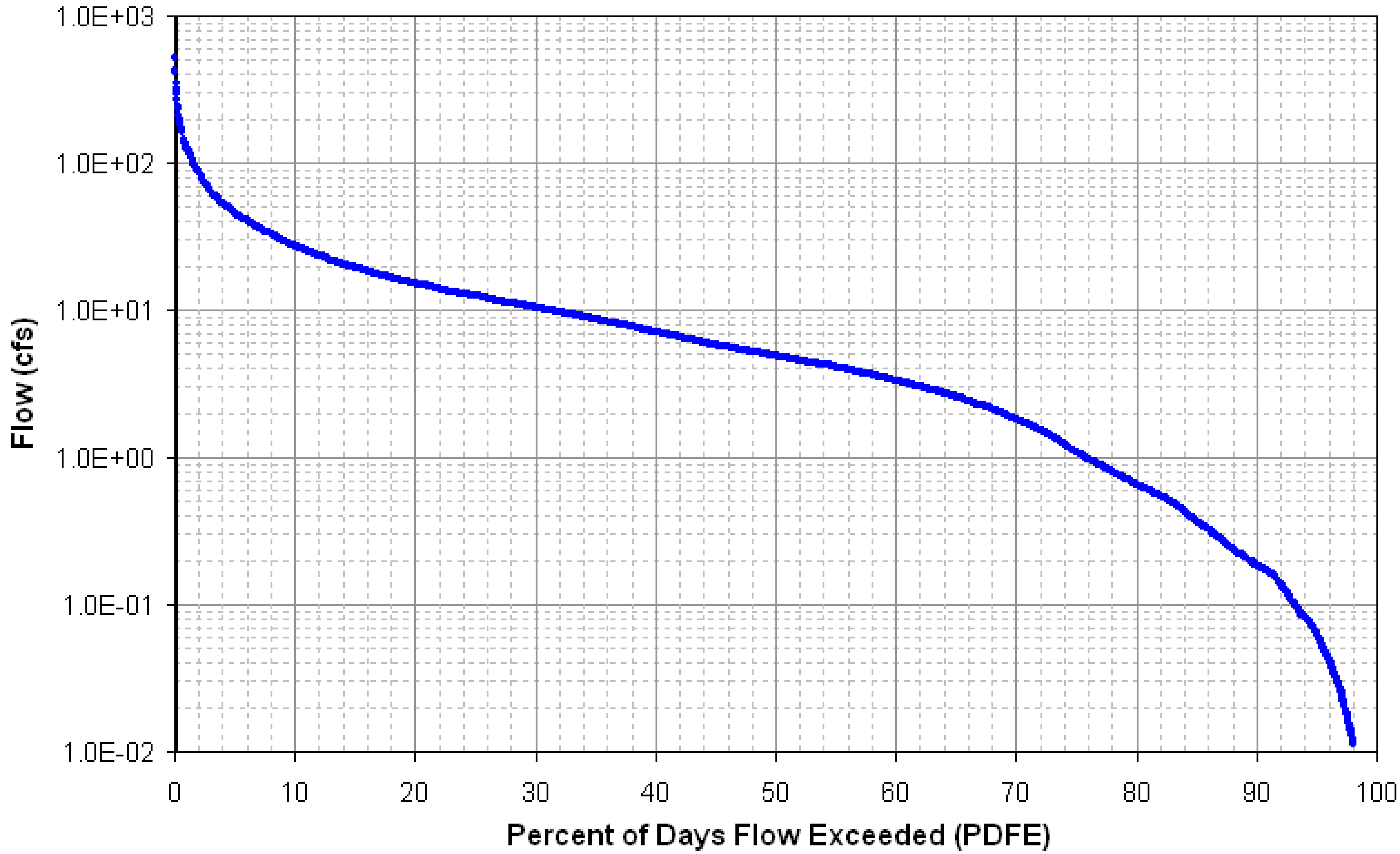

Figure D-1 Flow Duration Curve for Dry Fork at RM7.2

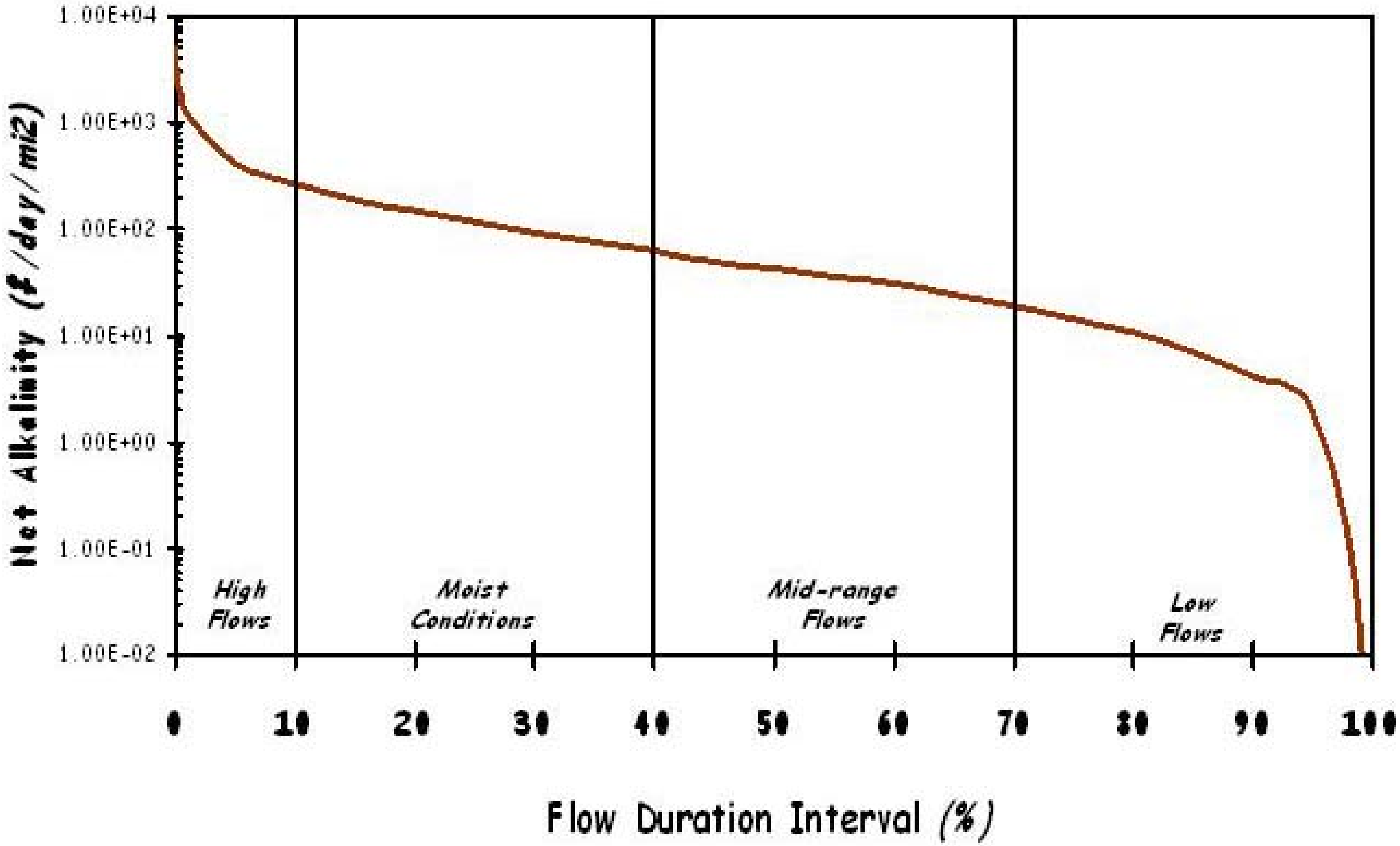

Figure D-2 Target Net Alkalinity Load Duration Curve (semi-log-scale)

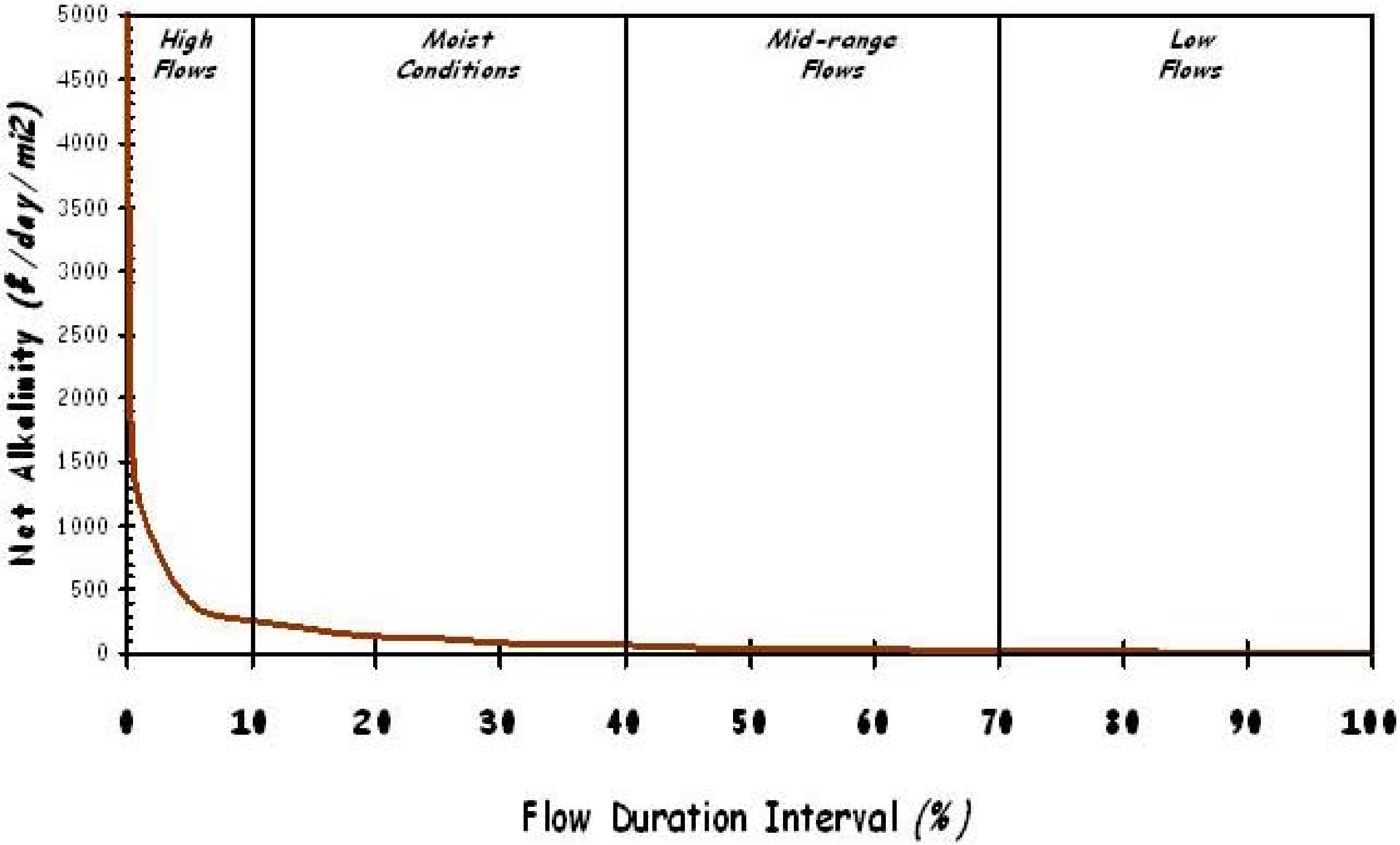

Figure D-3 Target Net Alkalinity Load Duration Curve (non-log scale)

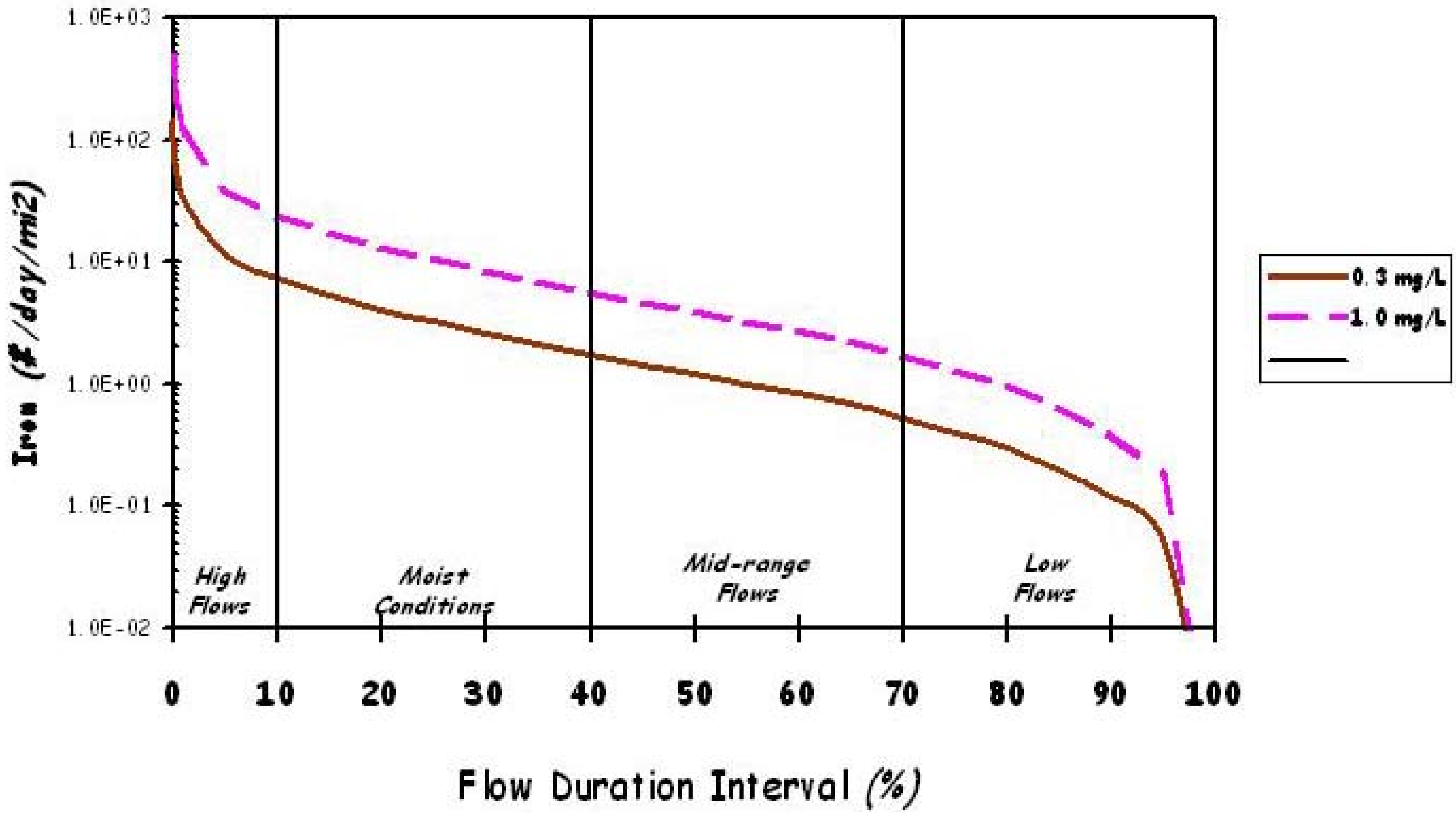

Figure D-4 Target Iron Load Duration Curve

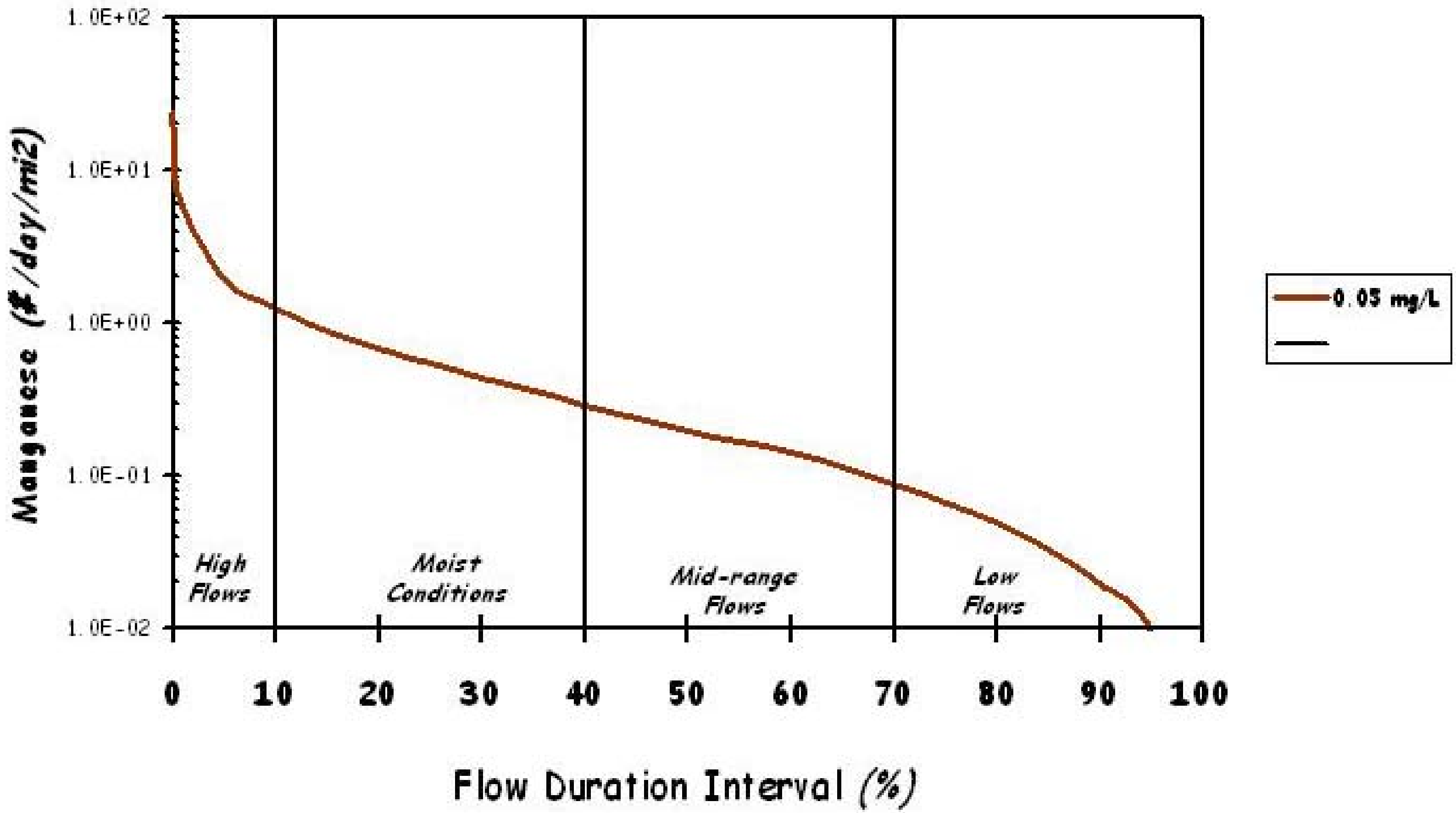

Figure D-5 Target Manganese Load Duration Curve

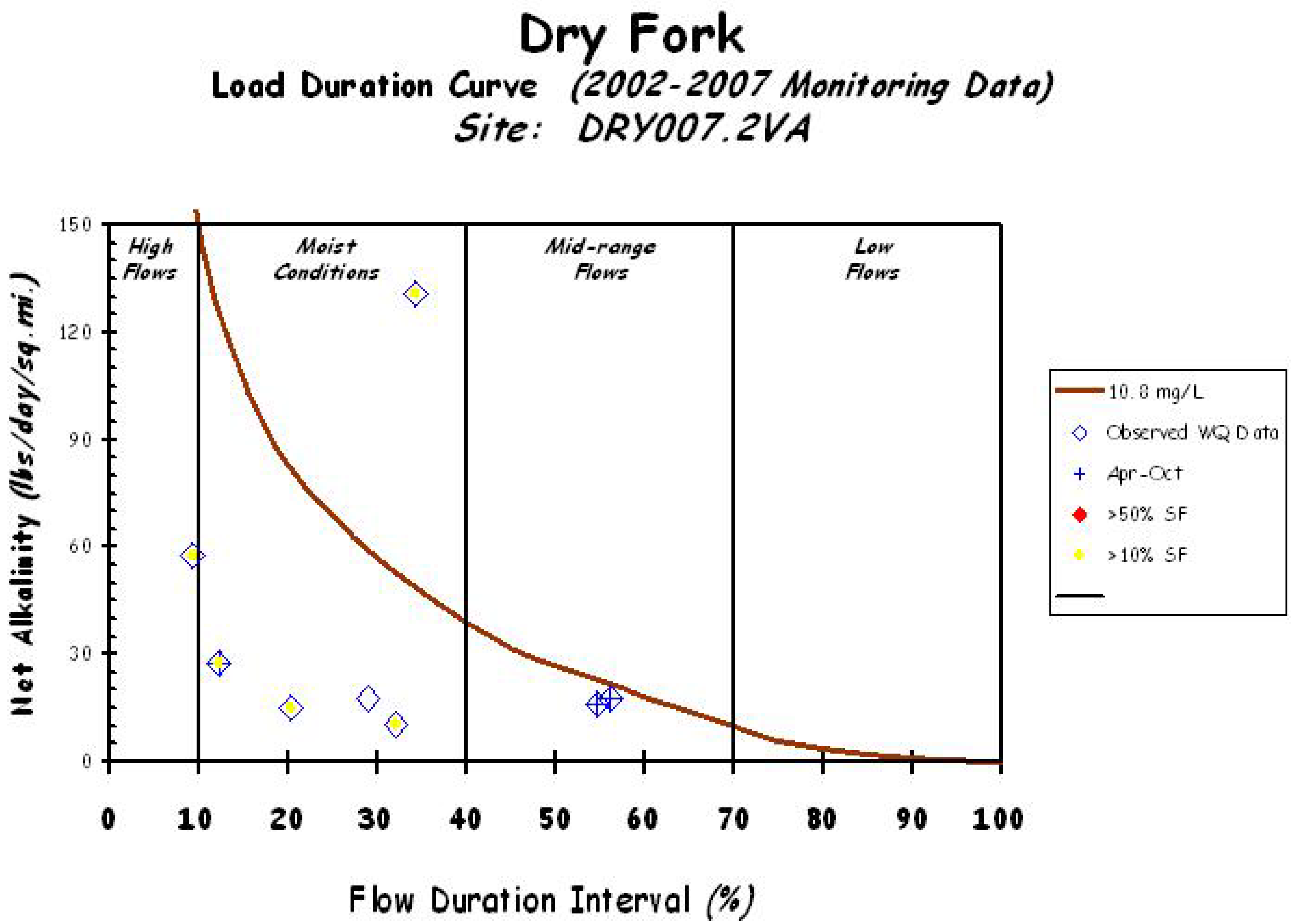

Figure D-6 Net Alkalinity Load Duration Curve for Dry Fork at Mile 7.2

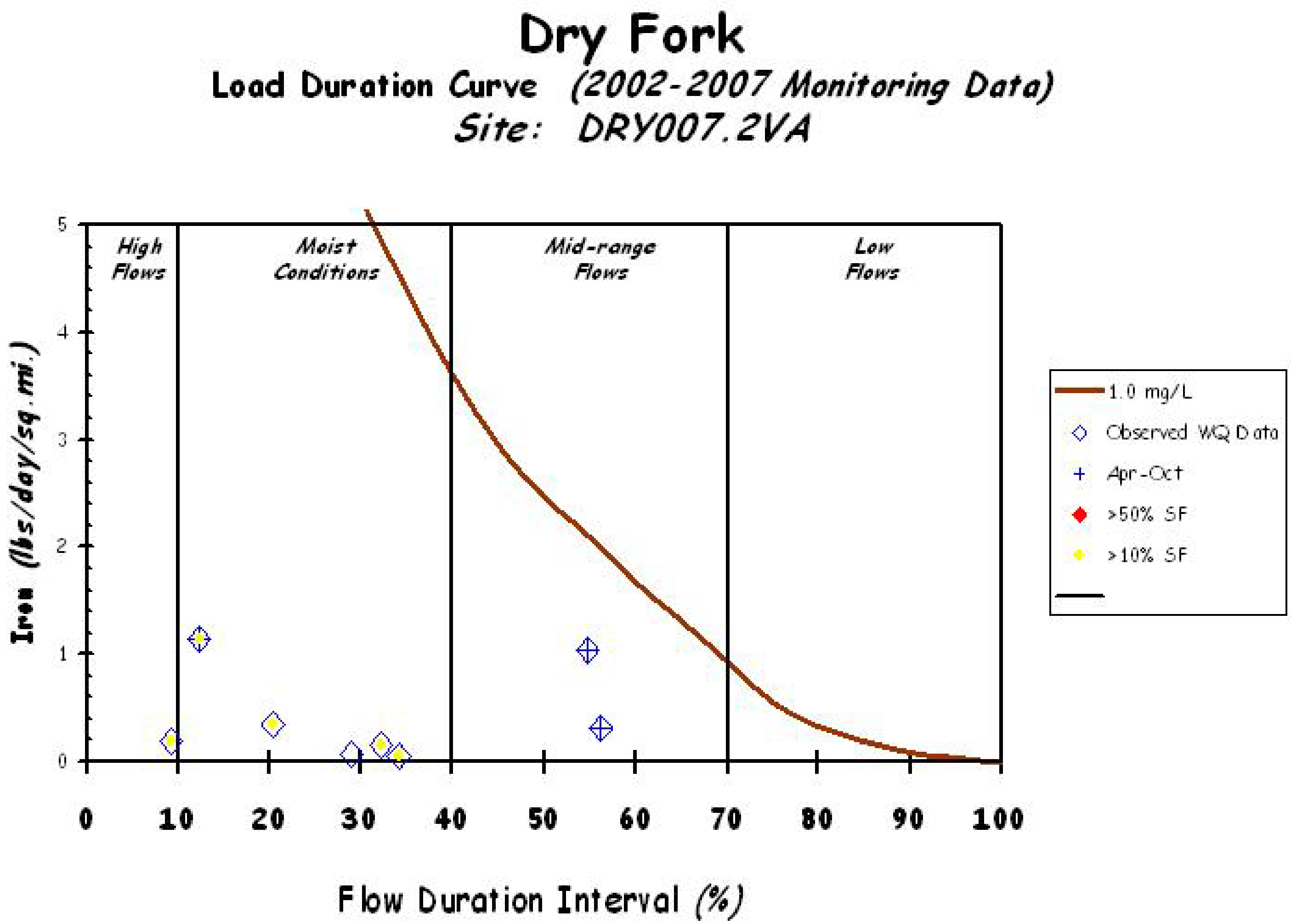

Figure D-7 Iron Load Duration Curve for Dry Fork at Mile 7.2

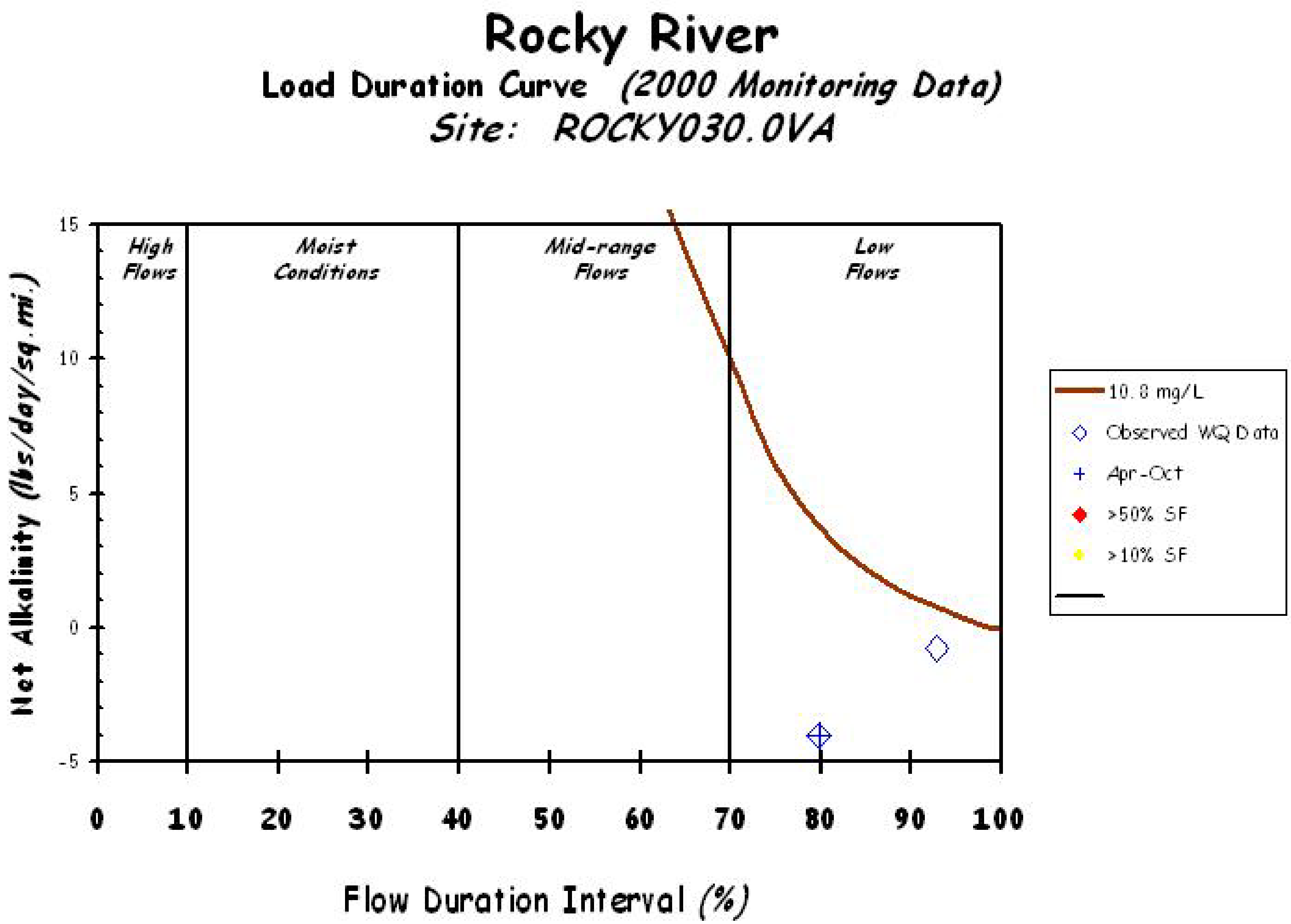

Figure D-8 Net Alkalinity Load Duration Curve for Rocky River at Mile 30.0

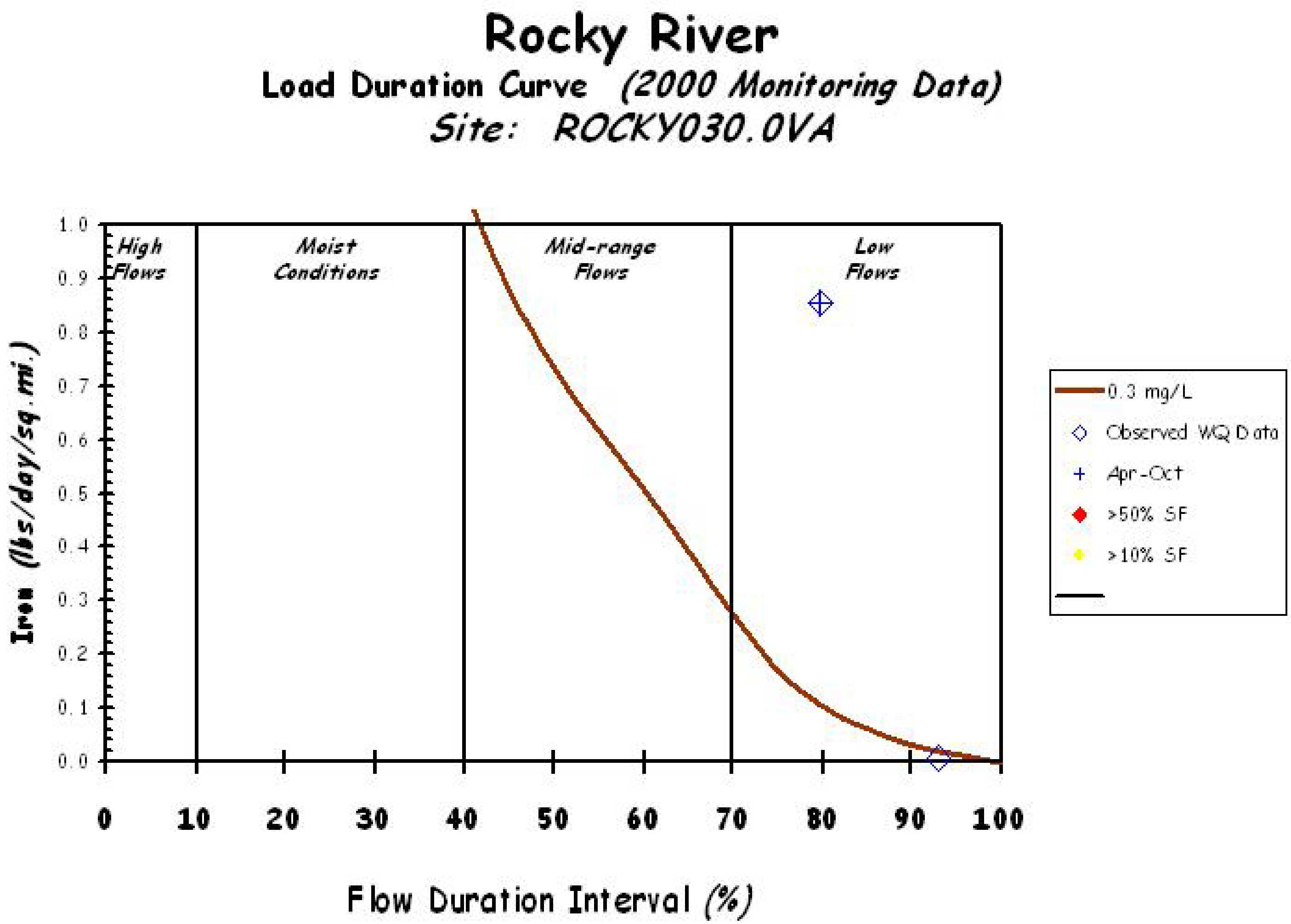

Figure D-9 Iron Load Duration Curve for Rocky River at Mile 30.0

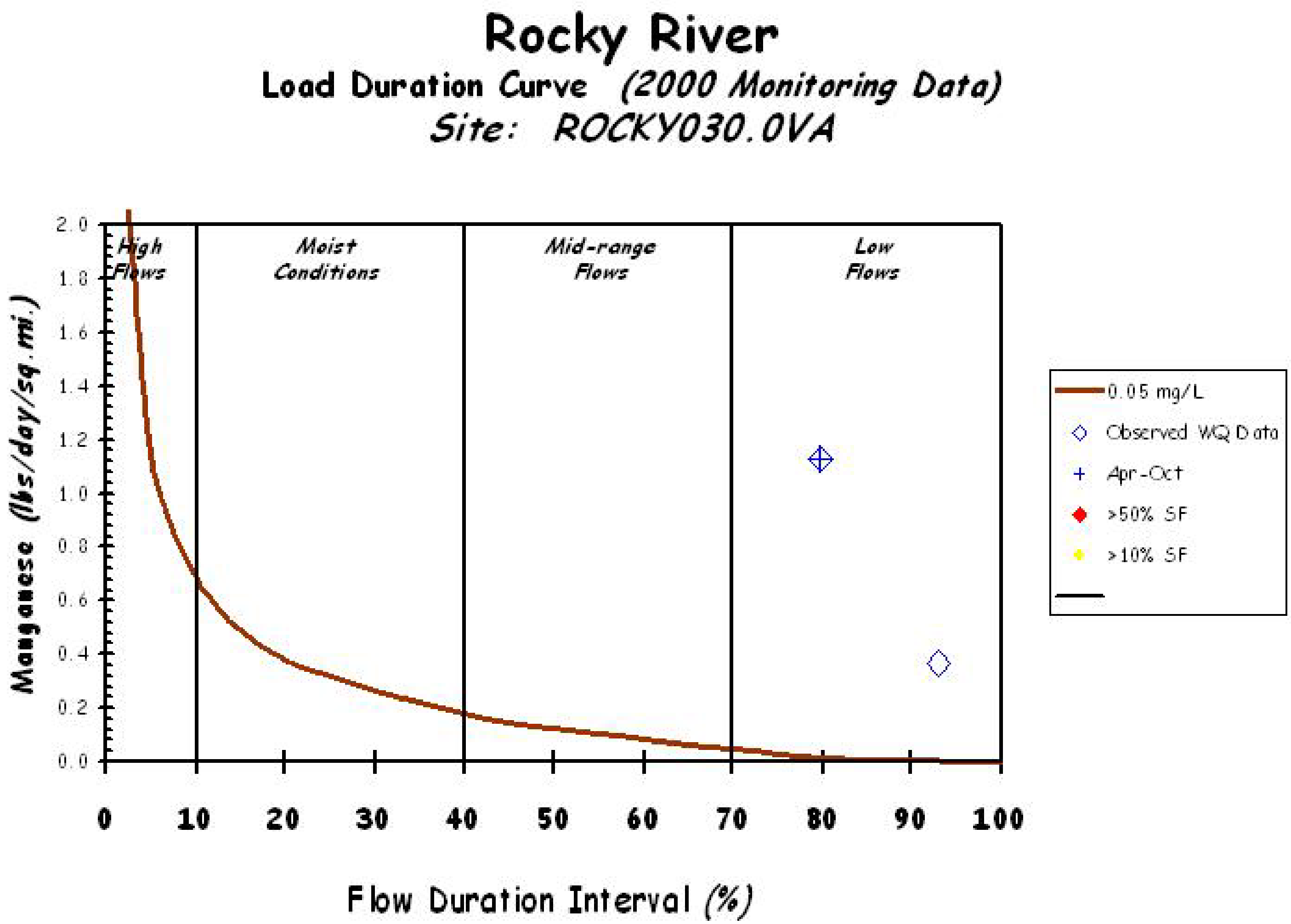

Figure D-10 Manganese Load Duration Curve for Rocky River at Mile 30.0

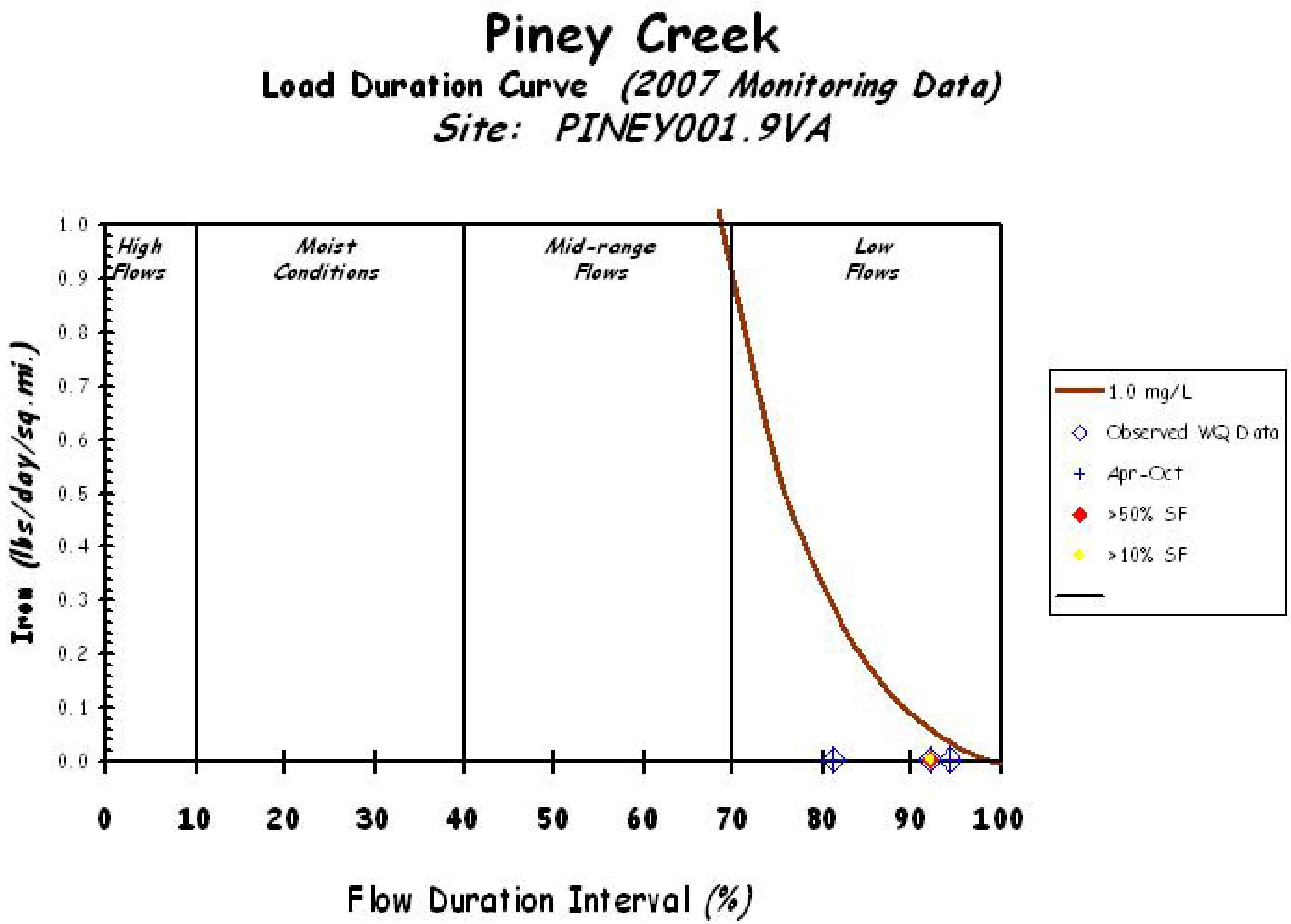

Figure D-11 Iron Load Duration Curve for Piney Creek at Mile 1.9

Table D-1. Net Alkalinity Load Calculations for Dry Fork – Mile 7.2

Sample	Flow		PDFE[a]	Net Alkalinity		Required Reduction	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(mg/L)	(lbs/day/mi^2)	(%)	(%)
11/7/02	10.75	1.014	29.1	3	1.77E+01	NA	NA
12/17/02	28.93	2.729	9.4	4	5.76E+01	NA	NA
1/7/03	8.90	0.839	34.3	29	1.31E+02	NA	NA
2/12/03	14.95	1.411	20.4	2	1.52E+01	NA	NA
3/12/03	9.64	0.910	32.2	2	1.06E+01	NA	NA
4/14/03	23.23	2.192	12.4	2	2.75E+01	NA	NA
7/29/03	4.14	0.390	54.8	8	1.61E+01	NA	NA
8/14/03	3.91	0.369	56.3	9	1.79E+01	NA	NA
7/30/07	2.56	0.242	65.3				
8/27/07	0.20	0.019	89.5				
9/19/07	0.20	0.018	89.7				
11/27/07							
12/4/07							
1/10/08							
2/12/08							
3/4/08							
90th Percentile Concentration				**15**		**NA**	**NA**
Note:	NA = Not Applicable						
a	Percent of Days Flow Is Exceeded						

Table D-2. Iron Load Calculations for Dry Fork – Mile 7.2

Sample	Flow		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(μg/L)	(lbs/day/mi^2)	(%)	(%)
11/7/02	10.75	1.014	29.1	13	6.84E-02	NR	NR
12/17/02	28.93	2.729	9.4	13	1.84E-01	NR	NR
1/7/03	8.90	0.839	34.3	13	5.66E-02	NR	NR
2/12/03	14.95	1.411	20.4	46	3.50E-01	NR	NR
3/12/03	9.64	0.910	32.2	33	1.62E-01	NR	NR
4/14/03	23.23	2.192	12.4	97	1.15E+00	NR	NR
7/29/03	4.14	0.390	54.8	492	1.04E+00	NR	NR
8/14/03	3.91	0.369	56.3	156	3.11E-01	NR	NR
7/30/07	2.56	0.242	65.3				
8/27/07	0.20	0.019	89.5				
9/19/07	0.20	0.018	89.7				
11/27/07				286		NR	NR
12/4/07				285		NR	NR
1/10/08							
2/12/08				66		NR	NR
3/4/08				7100		85.9	87.3
90th Percentile Concentration				**471**		**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-3. Net Alkalinity Load Calculations for Rocky River – Mile 30.0

Sample	Flow		PDFE[a]	Net Alkalinity Concentration		Required Reduction	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(mg/L)	(lbs/day/mi^2)	(%)	(%)
8/10/00	1.06	0.065	79.9	-11.5	-4.02E+00	NA	NA
11/2/00	0.21	0.013	93.0	-11.5	-8.01E-01	NA	NA
90th Percentile Concentration				-11.5		NA	NA
Note:	NA = Not Applicable						
a	Percent of Days Flow Is Exceeded						

Table D-4. Iron Load Calculations for Rocky River – Mile 30.0

Sample	Flow		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(μg/L)	(lbs/day/mi^2)	(%)	(%)
8/10/00	1.06	0.065	79.9	2440	0.85	87.7	88.9
11/2/00	0.21	0.013	93.0	102	0.01	NR	NR
90th Percentile Concentration				2206		86.4	87.8
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-5. Manganese Load Calculations for Rocky River – Mile 30.0

Sample	Flow		PDFE[a]	Manganese Concentration		Required Reduction[b]	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(μg/L)	(lbs/day/mi^2)	(%)	(%)
8/10/00	1.06	0.065	79.9	3240	1.13	98.5	98.6
11/2/00	0.21	0.013	93.0	5300	0.37	99.1	99.2
90th Percentile Concentration				5094		99.0	99.1
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-6. Iron Load Calculations for Piney Creek – Mile 1.9

Sample	Flow		PDFE[a]	Iron Concentration		Required Reduction[b]	
						to Target	to Target - MOS
Date	(cfs)	(cfs/mi^2)	(%)	(μg/L)	(lbs/day/mi^2)	(%)	(%)
7/23/07	0.29	0.013	21.7	68	4.60E-03	NR	NR
8/13/07	1.23	0.053	33.0	13	3.60E-03	NR	NR
9/11/07	0.15	0.006	33.8	58	2.03E-03	NR	NR
11/29/07				29		NR	NR
12/11/07				13		NR	NR
1/9/08				13		NR	NR
2/6/08				406		NR	NR
90th Percentile Concentration				203		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-7. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Caney Fork River Watershed (HUC 05130108)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	TMDL	Explicit MOS	WLAs	LAs
			[%]	[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Rocky River	TN05130108024 – 4000	Net Alkalinity	NA	58.1 x Q	NA[a]	58.1 x Q_2	(5.54 x 10^{-3} x Q) – (5.54 x 10^{-3} x Q_2)
		Iron	86.4	1.61 x Q	0.161 x Q	16.1 x Q_2	(1.38 x 10^{-4} x Q) – (1.54 x 10^{-3} x Q_2)
		Manganese	99.0	0.269 x Q	2.69 x 10^{-2}x Q	10.8 x Q_2	(2.31 x 10^{-5} x Q) – (1.03 x 10^{-3} x Q_2)
Gardner Creek	TN05130108027 – 0300	Net Alkalinity	NA	58.1 x Q	NA[a]	NA	3.23 x 10^{-2} x Q
		Iron	NA	5.38 x Q	0.538 x Q	NA	2.69 x 10^{-3} x Q
Piney Creek	TN05130108027 – 0750	Net Alkalinity	NA	58.1 x Q	NA[a]	NA	3.93 x 10^{-3} x Q
		Iron	NR	5.38 x Q	0.538 x Q	NA	3.27 x 10^{-4} x Q
Dry Fork	TN05130108027 – 0850	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	8.57 x 10^{-3} x Q
		Iron	NR	5.38 x Q	0.538 x Q	NA	7.14 x 10^{-4} x Q
Clifty Creek	TN05130108036 – 0100	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	5.98 x 10^{-3} x Q
		Iron	NA	5.38 x Q	0.538 x Q	NA	4.98 x 10^{-4} x Q
Puncheoncamp Creek	TN05130108036 – 0900	Net Alkalinity	NA	58.1 x Q	NA[b]	NA	1.04 x 10^{-2} x Q

Notes: NA = Not Applicable.
NR = No Reduction Required
PLRG = Percent Load Reduction Goal
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Sources (combined)

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

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 Caney Fork 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 Caney Fork 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 Caney Fork 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 2007. Meteorological data for a selected 10-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 9-year period (10/1/98 – 9/30/07) 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 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:	**10/01/98**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/07**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**192.66**	Total Observed In-stream Flow:	**209.15**
Total of highest 10% flows:	**97.74**	Total of Observed highest 10% flows:	**110.38**
Total of lowest 50% flows:	**15.63**	Total of Observed Lowest 50% flows:	**14.43**
Simulated Summer Flow Volume (months 7-9):	**25.22**	Observed Summer Flow Volume (7-9):	**20.99**
Simulated Fall Flow Volume (months 10-12):	**35.85**	Observed Fall Flow Volume (10-12):	**38.50**
Simulated Winter Flow Volume (months 1-3):	**78.15**	Observed Winter Flow Volume (1-3):	**90.69**
Simulated Spring Flow Volume (months 4-6):	**53.44**	Observed Spring Flow Volume (4-6):	**58.97**
Total Simulated Storm Volume:	**190.60**	Total Observed Storm Volume:	**207.78**
Simulated Summer Storm Volume (7-9):	**24.71**	Observed Summer Storm Volume (7-9):	**20.65**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-7.89**	10	
Error in 50% lowest flows:	**8.35**	10	
Error in 10% highest flows:	**-11.45**	15	
Seasonal volume error - Summer:	**20.13**	30	
Seasonal volume error - Fall:	**-6.89**	30	
Seasonal volume error - Winter:	**-13.82**	30	
Seasonal volume error - Spring:	**-9.38**	30	
Error in storm volumes:	**-8.27**	20	
Error in summer storm volumes:	**19.65**	50	

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

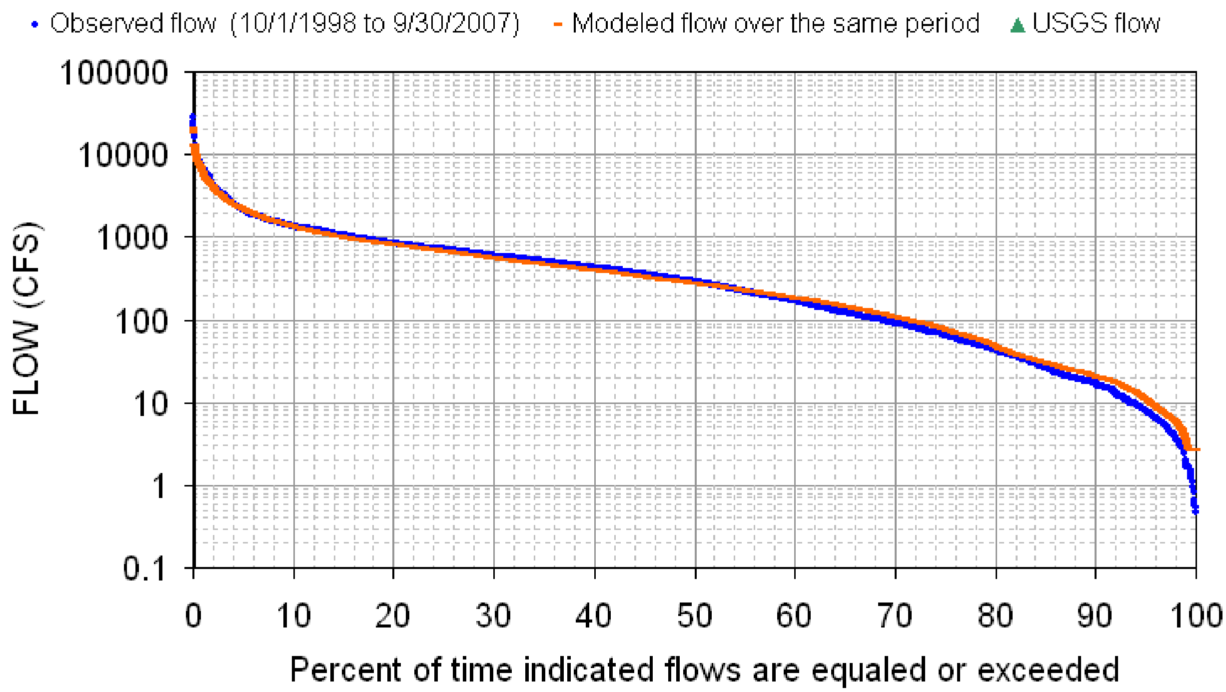

Figure E-1. Hydrologic Calibration: New River, USGS 03408500

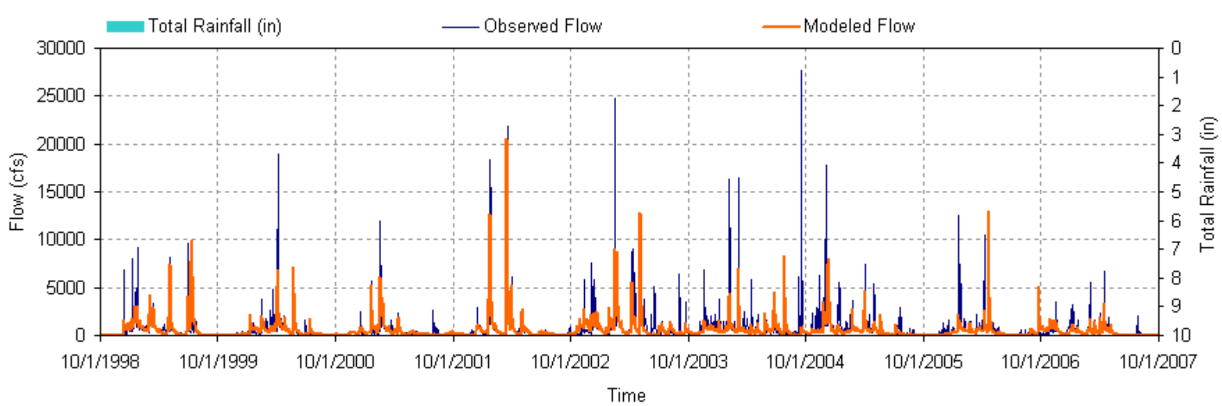

Figure E-2. 9-Year Hydrologic Comparison: New River, USGS 03408500

APPENDIX F

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 LOAD (TMDL) FOR pH and METALS IN THE CANEY FORK RIVER WATERSHED (HUC 05130108), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for pH and metals in the Caney Fork River watershed, 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.

Several waterbodies in the Caney Fork River watershed are listed on Tennessee's final 2008 303(d) list as not supporting designated use classifications due to low pH, iron, and manganese 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 Caney Fork River watershed pH and metals TMDLs may be downloaded from the Department of Environment and Conservation website:

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

Technical questions regarding this TMDL 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 May 26, 2009 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.