TOTAL MAXIMUM DAILY LOAD (TMDL)
STAGE I

for

Low Dissolved Oxygen & Nutrients

in the

Nolichucky River Watershed (HUC 06010108)

Cocke, Greene, Hamblen, Hawkins, Jefferson, Unicoi, and Washington Counties, Tennessee

FINAL

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
DO	Dissolved Oxygen
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
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
MS4	Municipal Separate Storm Sewer System
NHD	National Hydrography Dataset
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PCS	Permit Compliance System
Rf3	Reach File v.3
RM	River Mile
STP	Sewerage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Stage I Total Maximum Daily Load for Low Dissolved Oxygen & Nutrients in Selected Waterbodies in the Nolichucky River Watershed (HUC 06010108)

Impaired Waterbody Information

State: Tennessee
Counties: Greene & Washington
Watershed: Nolichucky River (HUC 06010108)
Constituents of Concern: Low dissolved oxygen & nutrients

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	RM Not Fully Supporting
TN06010108030 - 0200	JOCKEY CREEK	8.0
TN06010108030 - 0220	CARSON CREEK	17.9
TN06010108035 – 0200	POTTER CREEK	15.3
TN06010108035 - 0900	PUNCHEON CAMP CREEK	11.5
TN06010108035 - 9000	LICK CREEK	7.7
TN06010108102 – 2000	RICHLAND CREEK	8.51
TN06010108510 – 0400	HOMINY CREEK	7.0

Designated Uses: The designated use classifications for the impaired waterbodies addressed in this document include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Scope of TMDLs: Stage I TMDLs focus on HUC-12 subwatersheds that contain impaired headwater and tributary streams (wadeable) and do not contain existing wastewater treatment facilities (WWTFs). In some cases, where impaired streams are located in the upstream portion of a subwatershed, TMDL are developed for the impaired drainage area only. In Stage II & III TMDLs, wasteload allocations (WLAs), and load allocations (LAs) for mainstem portions of larger waterbodies (non-wadeable) and waterbodies that receive wastewater treatment facility discharges will be developed. This document contains Stage I TMDLs, WLAs, and LAs for headwater and wadeable streams, as well as planning expectations for wastewater treatment facility dischargers to be covered in Stages II & III.

Water Quality Target:

Dissolved oxygen criteria (most stringent – fish & aquatic life) of 5 mg/l minimum.

Instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen, total phosphorus, and carbonaceous biochemical oxygen demand ($CBOD_5$). For the purposes of TMDL development, the water quality targets specified for these parameters were determined to comply with the water quality criteria specified for dissolved oxygen, nutrients, and biological integrity in support of the fish & aquatic life classification.

Nutrient targets are a numeric interpretation of narrative criteria for nutrients and biological integrity and are derived from the 75th percentile values of total nitrogen (TN) and total phosphorus (TP) data collected at Level IV ecoregion reference sites. Ecoregion reference sites are considered to be "least impacted" and supportive of designated use classifications.

Since $CBOD_5$ was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration equal to the value specified in the Tennessee/EPA Stream Model Agreement as the background concentration to be used for DO sag analysis when instream data is not available was considered to be appropriate (this value is lower than the limited number of data points at ecoregion reference sites (typically <2 mg/l)).

Level IV Ecoregion	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	$CBOD_5$ (mg/l)
67f	0.933	0.013	1.5
67g	0.988	0.054	1.5
67h	1.280	0.012	1.5
67i	No data	No data	1.5

TMDL Development

Nutrients

Analysis Methodology:

- Calibrated LSPC model used to simulate daily mean flow at Level IV ecoregion (67f, 67g, & 67h) reference sites for a 10-year period. Daily nutrient loads were calculated through application of target ecoregion nutrient concentrations for each reference site.

- TMDLs were developed for total nitrogen, total phosphorus, and $CBOD_5$ by calculating the geometric mean of average annual loads, on a unit area basis, for reference sites in the same Level IV ecoregion and applying these loads to subwatersheds or delineated drainage areas containing impaired waterbodies in the Nolichucky River Watershed. TMDLs are expressed as average annual loads (lbs/yr).

- WLAs for CAFOs are considered to be 0 lbs/yr.

- WLAs for MS4s and LAs are considered to be equal and are expressed as average annual loads per unit area (lbs/ac/yr).

- $CBOD_5$ TMDLs, WLAs, & LAs were developed for impaired subwatersheds only in cases where low dissolved oxygen was identified as a cause of waterbody impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that drop below 5 mg/l.

- Daily expressions of TMDLs, WLAs, & LAs were developed from statistical analysis of Level IV ecoregion reference site monitoring data. Daily values are expressed as a function of stream flow at the pour point of the impaired subwatershed or drainage area.

Seasonal Variation: Methodology addresses all seasons.

Margin of Safety (MOS): Explicit – 5% of the TMDL for each impaired subwatershed.
Implicit – Conservative modeling assumptions.

TMDL, WLAs, & LAs

Summary of Stage I Total Nitrogen, Total Phosphorus, & $CBOD_5$ TMDLs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL					
			Total Nitrogen		Total Phosphorus		$CBOD_5$	
			[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	32,713	$2.337 \times 10^1 * Q$	456	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Carson Ck DA	Carson Creek	TN06010108030-0220	18,029	$2.337 \times 10^1 * Q$	251	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Potter Ck DA	Potter Creek	TN06010108035-0200	10,527	$1.585 \times 10^1 * Q$	370	$1.802 \times 10^0 * Q$	14,415	$4.046 \times 10^1 * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	7,458	$1.788 \times 10^1 * Q$	408	$2.089 \times 10^0 * Q$	NA [b]	NA [b]
0801	Lick Creek (headwaters)	TN06010108035-9000	118,802	$2.143 \times 10^1 * Q$	2,541	$2.610 \times 10^0 * Q$	NA [b]	NA [b]
Richland Ck DA	Richland Creek	TN06010108102-2000	13,470	$2.337 \times 10^1 * Q$	186	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Hominy Ck DA	Hominy Creek	TN06010108501-0400	7,229	$2.337 \times 10^1 * Q$	101	$2.894 \times 10^0 * Q$	NA [b]	NA [b]

Notes: a. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
b. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).

Summary of Stage I Total Nitrogen WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA[b]		LA	
			MS4 [a]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day] [c]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	2.7927	$2.100 \times 10^{-3} * Q$	2.7927	$2.100 \times 10^{-3} * Q$
Carson Ck DA	Carson Creek	TN06010108030-0220	2.7927	$3.811 \times 10^{-3} * Q$	2.7927	$3.811 \times 10^{-3} * Q$
Potter Ck DA	Potter Creek	TN06010108035-0200	2.1138	$3.350 \times 10^{-3} * Q$	2.1138	$3.350 \times 10^{-3} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	1.5297	$3.860 \times 10^{-3} * Q$	1.5297	$3.860 \times 10^{-3} * Q$
0801	Lick Creek (headwaters)	TN06010108035-9000	2.4456	$4.643 \times 10^{-4} * Q$	2.4456	$4.643 \times 10^{-4} * Q$
Richland Ck DA	Richland Creek	TN06010108102-2000	2.7927	$5.101 \times 10^{-3} * Q$	2.7927	$5.101 \times 10^{-3} * Q$
Hominy Ck DA	Hominy Creek	TN06010108501-0400	2.7927	$9.504 \times 10^{-3} * Q$	2.7927	$9.504 \times 10^{-3} * Q$

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

Summary of Stage I Total Phosphorus WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA[b]		LA	
			MS4 [a]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day] [c]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	0.0390	$2.601 \times 10^{-4} * Q$	0.0390	$2.601 \times 10^{-4} * Q$
Carson Ck DA	Carson Creek	TN06010108030-0220	0.0390	$4.719 \times 10^{-4} * Q$	0.0390	$4.719 \times 10^{-4} * Q$
Potter Ck DA	Potter Creek	TN06010108035-0200	0.0744	$3.809 \times 10^{-4} * Q$	0.0744	$3.809 \times 10^{-4} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	0.0836	$4.510 \times 10^{-4} * Q$	0.0836	$4.510 \times 10^{-4} * Q$
0801	Lick Creek (headwaters)	TN06010108035-9000	0.0523	$5.655 \times 10^{-5} * Q$	0.0523	$5.655 \times 10^{-5} * Q$
Richland Ck DA	Richland Creek	TN06010108102-2000	0.0390	$6.316 \times 10^{-4} * Q$	0.0390	$6.316 \times 10^{-4} * Q$
Hominy Ck DA	Hominy Creek	TN06010108501-0400	0.0390	$1.177 \times 10^{-3} * Q$	0.0390	$1.177 \times 10^{-3} * Q$

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

Summary of Stage I $CBOD_5$ WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA[c]		LA	
			MS4 [b]			
			[lbs/ac/yr]	[lbs/ac/day] [d]	[lbs/ac/yr]	[lbs/ac/day] [d]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	NA [a]	NA [a]	NA [a]	NA [a]
Carson Ck DA	Carson Creek	TN06010108030-0220	NA [a]	NA [a]	NA [a]	NA [a]
Potter Ck DA	Potter Creek	TN06010108035-0200	2.8946	$8.552 \times 10^{-3} * Q$	2.8946	$8.552 \times 10^{-3} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	NA [a]	NA [a]	NA [a]	NA [a]
0801	Lick Creek (headwaters)	TN06010108035-9000	NA [a]	NA [a]	NA [a]	NA [a]
Richland Ck DA	Richland Creek	TN06010108102-2000	NA [a]	NA [a]	NA [a]	NA [a]
Hominy Ck DA	Hominy Creek	TN06010108501-0400	NA [a]	NA [a]	NA [a]	NA [a]

Notes:
a. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
b. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
c. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated to all existing and future permittees.
d. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

STAGE I LOW DISSOLVED OXYGEN & NUTRIENT TOTAL MAXIMUM DAILY LOAD (TMDL) NOLICHUCKY RIVER WATERSHED (HUC 06010108)

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 attaining water quality standards. State water quality standards consist of designated use(s) for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

Due to the complexity of processes associated with instream dissolved oxygen levels, TDEC has developed a three-stage strategy for nutrient TMDL development. The strategy considers impairment status, subwatershed type, limiting nutrients, and point source contribution to the total nutrient load to identify TMDL development methodologies, monitoring requirements, allocations, implementation measures, and other requirements appropriate for each impaired subwatershed.

Stage I TMDLs will focus on HUC-12 subwatersheds or delineated waterbody drainage areas that contain impaired headwater or tributary streams (wadeable) and do not contain existing wastewater treatment facilities (WWTFs). For impaired waterbodies receiving WWTF discharges, near-field dissolved oxygen (DO) sag analysis will continue to be conducted on stream segments immediately downstream of WWTFs to verify compliance with water quality standards as required (*Note: DO sag analyses for WWTFs are not included in this document, but may be found in the appropriate permit modeling file*). In cases where waterbody impairment is attributed solely to a source that is the result of a violation of NPDES permit conditions, no TMDL will be developed. Corrective measures to eliminate the source of pollution will be accomplished through appropriate enforcement action. This document presents details of Stage I TMDL development for waterbodies impaired by low dissolved oxygen or nutrients.

Stage II & III TMDLs will address larger waterbodies (non-wadeable) that are impaired due to Low DO or nutrients and the far-field effects of WWTF nutrient discharges. Stage II & III TMDL development will be conducted on a larger area scale (HUC-10 watershed or larger area) and will utilize a number of data resources and analysis tools, including the effluent and instream nutrient data collected by WWTFs. It is expected that implementation of Stage II & III TMDLs will include nutrient trading among point and nonpoint sources, if appropriate. Pollutant trading, including pollutant suitability analysis, financial attractiveness, identification of potential participants, and trading procedures, are presented in some detail in the *Water Quality Trading Assessment Handbook*, EPA 841-B-04-001 (USEPA, 2004).

3.0 GENERAL WATERSHED OVERVIEW

The Nolichucky River Watershed, Hydrologic Unit Code (HUC) 06010108, is located in North Carolina and East Tennessee (ref.: Figure 1). The information (including figures and tables) presented hereafter in this document is for the Tennessee portion of the watershed only. The watershed includes parts of Cocke, Greene, Hamblen, Hawkins, Jefferson, Unicoi, and Washington counties in Tennessee. The Nolichucky River Watershed lies within two Level III ecoregions (Blue Ridge Mountains and Ridge and Valley) and contains eight Level IV subecoregions as shown in Figure 2 (USEPA, 1997):

- **Southern Igneous Ridges and Mountains (66d)** occur in Tennessee's northeastern Blue Ridge near the North Carolina border, primarily on Precambrian-age igneous and high-grade metamorphic rocks. The typical crystalline rock types include granite, gneiss, schist, and metavolcanics, covered by well-drained, acidic brown loamy soils. Elevations of this rough, dissected region range from 2,000-6,200 feet, with Roan Mountain reaching 6,286 feet. Although there are a few small areas of pasture and apple orchards, the region is mostly forested; Appalachian oak and northern hardwood forests predominate.

- The **Southern Sedimentary Ridges (66e)** in Tennessee include some of the westernmost foothill areas of the Blue Ridges Mountains ecoregion, such as the Bean, Starr, Chilhowee, English, Stone, Bald, and Iron Mountain areas. Slopes are steep, and elevations are generally 1,000-4,500 feet. The rocks are primarily Cambrian-age sedimentary (shale, sandstone, siltstone, quartzite, conglomerate), although some lower stream reaches occur on limestone. Soils are predominantly friable loams and fine sandy loams with variable amounts of sandstone rock fragments, and support mostly mixed oak and oak-pine forests.

- **Limestone Valleys and Coves (66f)** are small but distinct lowland areas of the Blue Ridge, with elevations mostly between 1,500 and 2,500 feet. About 450 million years ago, older Blue Ridge rocks to the east were forced up and over younger rocks to the west. In places, the Precambrian rocks have eroded through to Cambrian or Ordovician-age limestones, as seen especially in isolated, deep cove areas that are surrounded by steep mountains. The main areas of limestone include the Mountain City lowland area and Shady Valley in the north; and Wear Cove, Tuckaleechee Cove, and Cades Cove of the Great Smoky Mountains in the south. Hay and pasture, with some tobacco patches on small farms, are typical land uses.

- The **Southern Metasedimentary Mountains (66g)** are steep, dissected, biologically-diverse mountains that include Clingmans Dome (6,643 feet), the highest point in Tennessee. The Precambrian-age metamorphic and sedimentary geologic materials are generally older and more metamorphosed than the Southern Sedimentary Ridges (66e) to the west and north. The Appalachian oak forests and, at higher elevations, the northern hardwoods forests include a variety of oaks and pines, as well as silverbell, hemlock, yellow poplar, basswood, buckeye, yellow birch, and beech. Spruce-fir forests, found generally above 5,500 feet, have been affected greatly over the past twenty-five years by the balsam woolly aphid. The Copper Basin, in the southeast corner of Tennessee, was the site of copper mining and smelting from the 1850s to 1987, and once left more than fifty square miles of eroded earth.

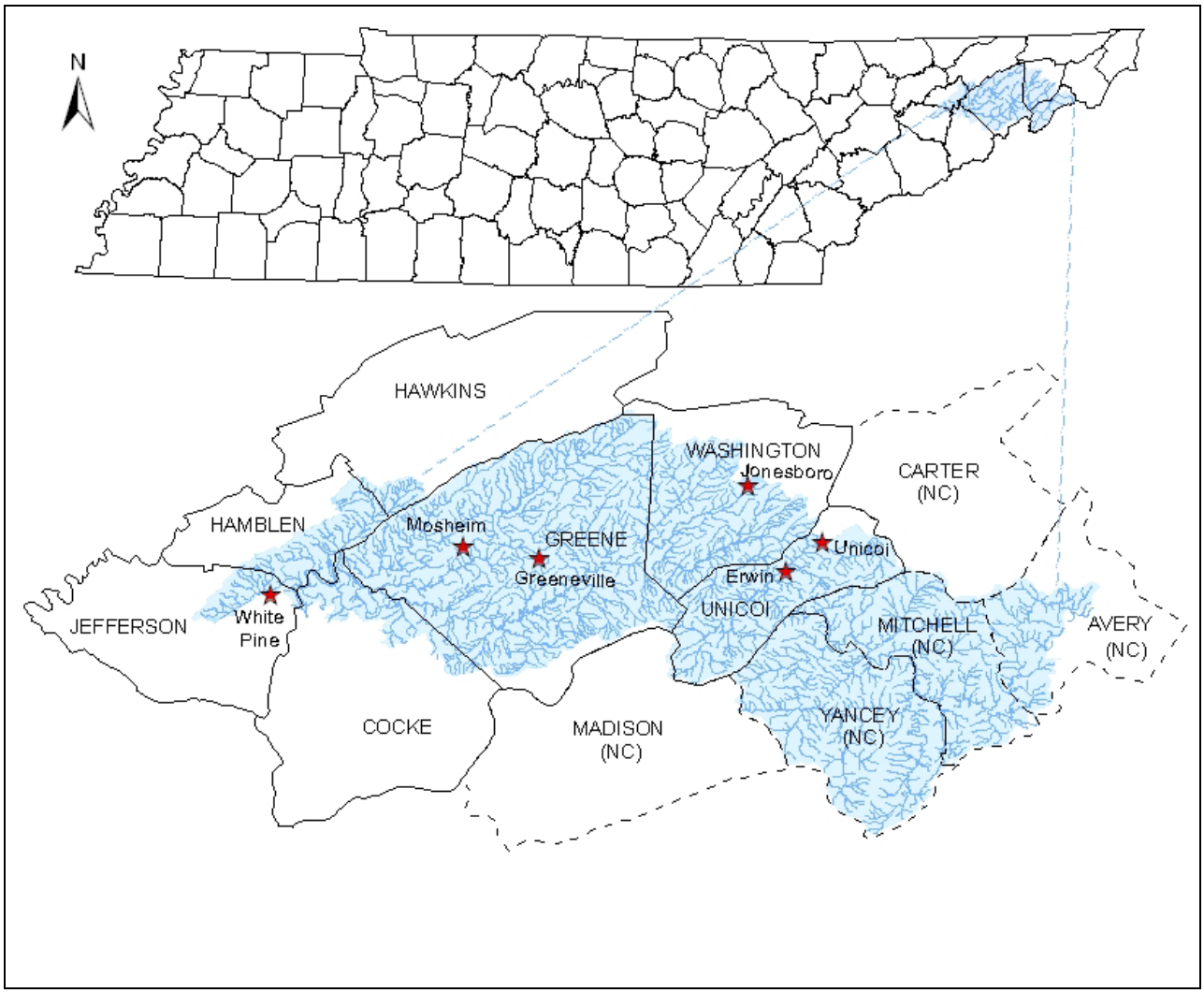
- The **Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the soils vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.

- The **Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn, tobacco, and garden crops are grown on the foot slopes and bottomland.

- The **Southern Sandstone Ridges (67h)** ecoregion encompasses the major sandstone ridges, but these ridges also have areas of shale and siltstone. The steep, forested ridges have narrow crests, and the soils are typically stony, sandy, and of low fertility. The chemistry of streams flowing down the ridges can vary greatly depending on the geologic material. The higher elevation ridges are in the north, including Wallen Ridge, Powell Mountain, Clinch Mountain, and Bays Mountain. White Oak Mountain in the south has some sandstone on the west side, but abundant shale and limestone as well. Grindstone Mountain, capped by the Gizzard Group sandstone, is the only remnant of Pennsylvanian-age strata in the Ridge and Valley of Tennessee.

- The **Southern Dissected Ridges and Knobs (67i)** contain more crenulated, broken, or hummocky ridges, compared to smoother, more sharply pointed sandstone ridges. Although shale is common, there is a mixture and interbedding of geologic materials. The ridges on the east side of Tennessee's Ridge and Valley tend to be associated with the Ordovician-age Sevier shale, Athens shale, and Holston and Lenoir limestones. These can include calcareous shale, limestone, siltstone, sandstone, and conglomerate. In the central and western part of the ecoregion, the shale ridges are associated with the Cambrian-age Rome Formation: shale and siltstone with beds of sandstone. Chestnut oak forests and pine forests are typical for the higher elevations of the ridges, with areas of white oak, mixed mesophytic forest, and tulip poplar on the lower slopes, knobs, and draws.

Figure 1 Location of the Nolichucky River Watershed



The Tennessee portion of the Nolichucky River Watershed (HUC 06010108) has approximately 1,920 miles of streams and 383 reservoir/lake acres (based on USEPA/TDEC Assessment Database (ADB)) and drains approximately 1,129 square miles to the Nolichucky River, which drains to the French Broad River as part of the Tennessee River Basin. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from around 2001. Although changes in the land use of the Nolichucky River watershed have occurred since 2001 as a result of rapid development, this is the most current land use data available. Land use for the Nolichucky River Watershed is summarized in Table 1 and shown in Figure 3.

Note: Stage I TMDLs will be developed primarily on a HUC-12 subwatershed or a waterbody drainage area basis. HUC-12 subwatershed boundaries and delineated waterbody drainage areas are shown in figures for reference.

Figure 2 Level IV Ecoregions in the Nolichucky River Watershed

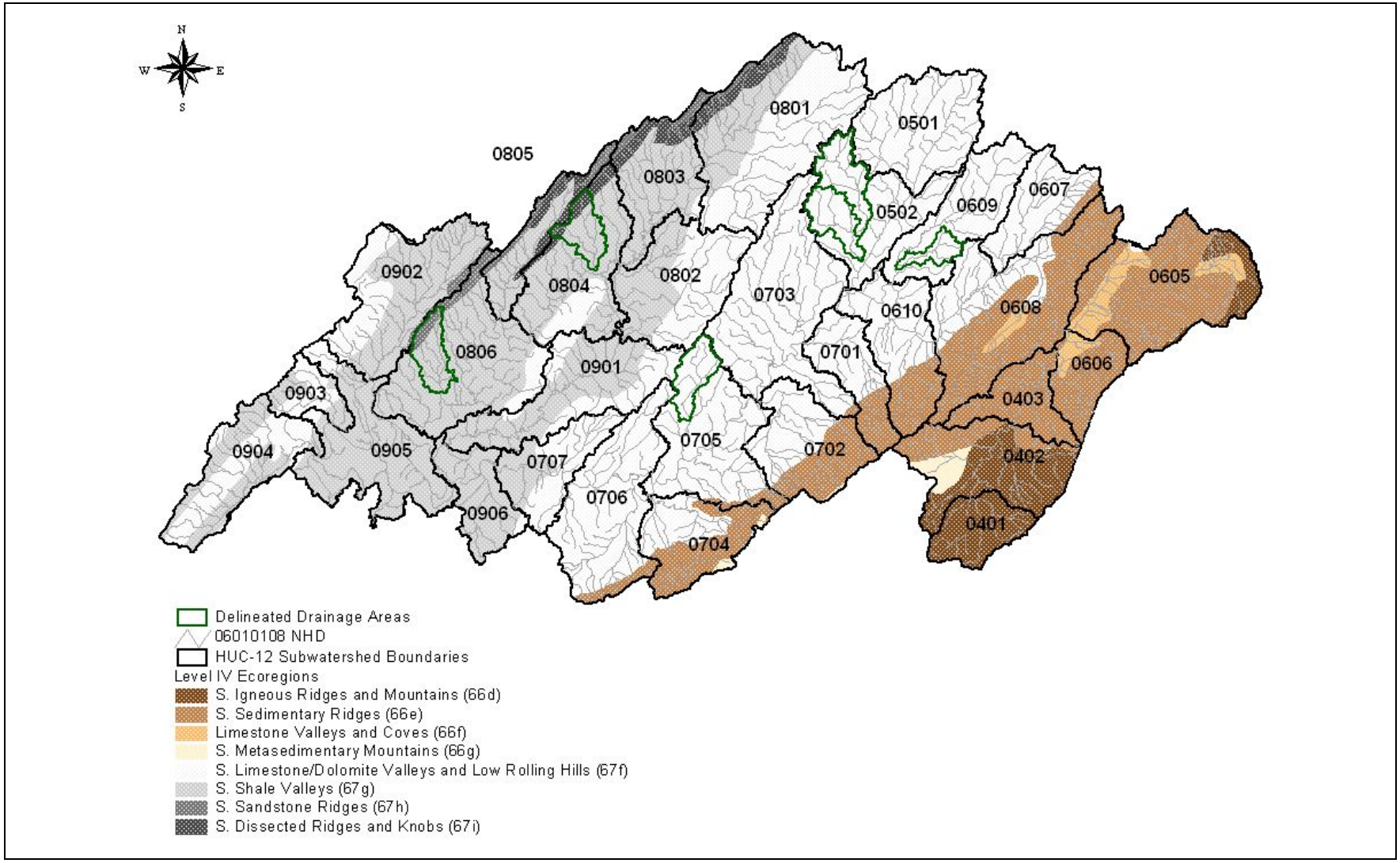


Figure 3 MRLC Land Use Distribution in the Nolichucky River Watershed

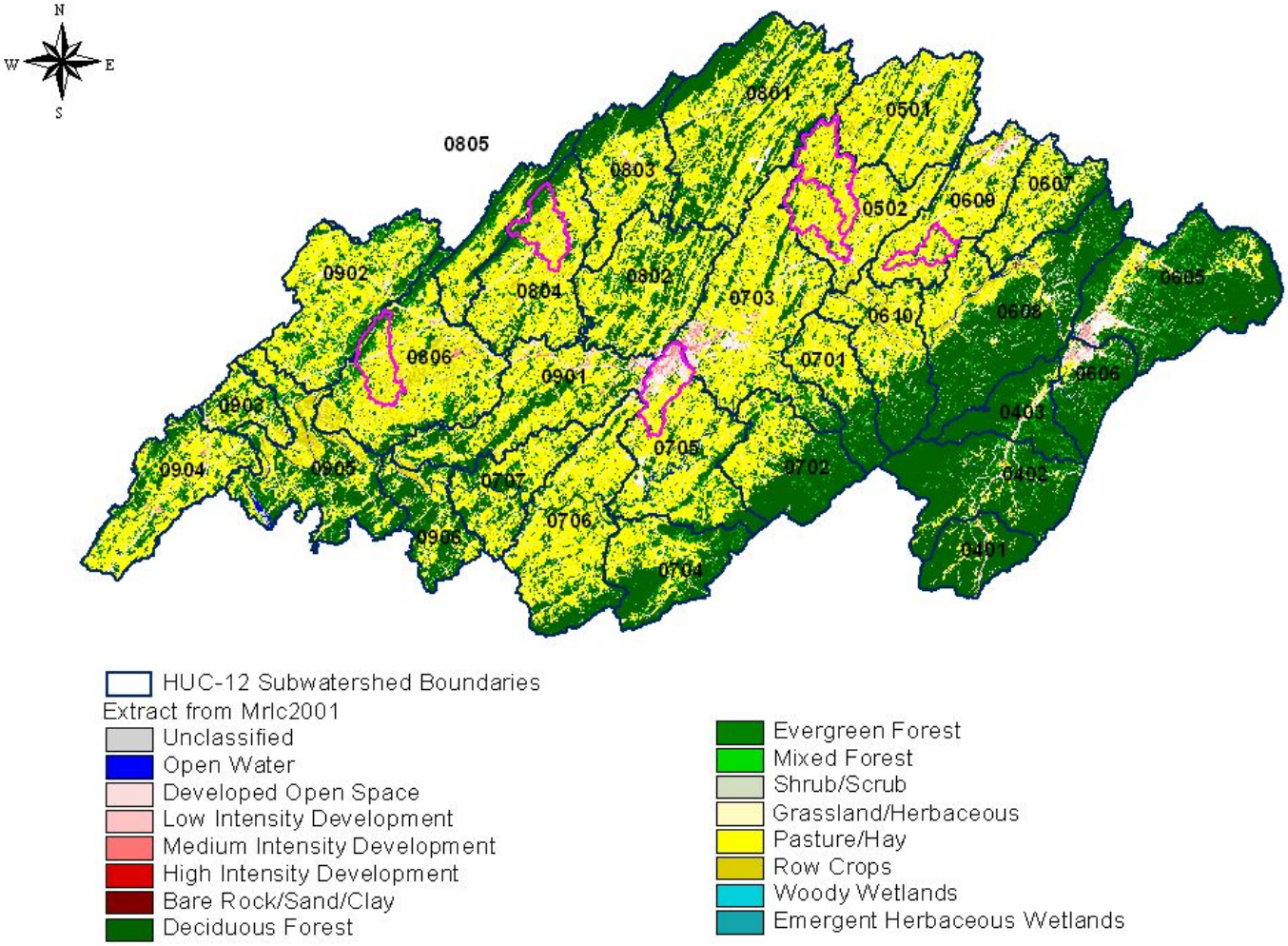


Table 1 2001 MRLC Land Use Distribution – Nolichucky River Watershed

Land Use	Area	
	[acres]	[%]
Unclassified	0	0.00
Open Water	2,068	0.29
Developed Open Spaces	37,660	5.21
Low Intensity Residential	11,259	1.56
Medium Intensity Residential	2,254	0.31
High Intensity Residential	899	0.12
Bare Rock/Sand/Clay	670	0.09
Deciduous Forest	284,089	39.33
Evergreen Forest	20,069	2.78
Mixed Forest	14,279	1.98
Shrub/Scrub	5,865	0.81
Grasslands/Herbaceous	10,133	1.40
Pasture/Hay	311,504	43.13
Row Crops	19,800	2.74
Woody Wetlands	1,767	0.24
Emergent Herbaceous Wetlands	0	0.00
Total	**722,316**	**100.00**

A comprehensive general resource for information regarding the Nolichucky River Watershed is the *Nolichucky River Watershed (06010108) of the Tennessee River Basin, Watershed Water Quality Management Plan* (TDEC, 2008a). This document includes chapters on watershed description, water quality assessment, point and nonpoint sources, water quality partnerships, and future direction. The plan is available on the TDEC website at:

http://www.state.tn.us/environment/wpc/watershed/wsmplans/.

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2008 303(d) list (TDEC, 2008) identified a number of waterbodies in the Nolichucky River Watershed as not fully supporting designated use classifications due to low dissolved oxygen or nutrients. The designated use classifications for the Nolichucky River and its tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Some waterbodies in the watershed are also classified for Domestic Water Supply, Industrial Water Supply, Naturally Reproducing Trout Stream, and/or Trout Stream (TDEC, 2007). Waterbodies in the Nolichucky River Watershed identified as impaired for low dissolved oxygen or nutrients on the 2008 303(d) list are summarized in Table 2 and shown in Figure 4.

Instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen, total phosphorus, and carbonaceous biochemical oxygen demand ($CBOD_5$).

Nutrient rich waters entering streams can cause abundant algae growth. The right combination of nutrients, algae, and sunlight may result in extreme dissolved oxygen fluctuations in the stream. Oxygen is produced during photosynthesis and consumed during respiration and decomposition. Because it requires light, photosynthesis occurs only during daylight hours. At night, photosynthesis cannot counterbalance the loss of oxygen through respiration and decomposition so dissolved oxygen concentrations decline (TDEC, 2003). $CBOD_5$ is a measure of the oxygen demand associated with the biochemical oxidation of carbonaceous organic matter. The interrelationship of major kinetic processes associated with instream dissolved oxygen are shown schematically in Figure 5. A more detailed discussion of the relationship between nutrients and water quality is presented in Appendix A.

A description of the stream assessment process in Tennessee can be found in *2008 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2008b). With respect to nutrients, this document states: "Waters are not assessed as impaired by nutrients unless biological or aesthetic impacts are also documented." Assessment information for waterbodies impaired due to low dissolved oxygen and/or nutrients in the Nolichucky watershed is summarized in Table 3. This information is excerpted from 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/ . A typical example of a stream assessment (Little Limestone Creek) is shown in Appendix B.

Table 2 2008 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Nolichucky River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	TMDL Development Stage
TN06010108030 - 0200	JOCKEY CREEK	8.0	Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing	I
TN06010108030 - 0220	CARSON CREEK	17.9	Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing Unrestricted Cattle Access	I
TN06010108030 - 2000	BIG LIMESTONE CREEK	8.8	Total Phosphorus Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing	II/III
TN06010108035 - 0200	POTTER CREEK	15.3	Low Dissolved Oxygen Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing	I
TN06010108035 - 0900	PUNCHEON CAMP CREEK	11.5	Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing	I
TN06010108035 - 1000	LICK CREEK	3.9	Nitrate+Nitrite Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing	II/III
TN06010108035 - 2000	LICK CREEK	2.3	Low dissolved oxygen Escherichia coli	Pasture Grazing	II/III
TN06010108035 - 3000	LICK CREEK	7.4	Nitrate+Nitrite Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing	II/III

Table 2 (Contd.) 2008 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Nolichucky River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	TMDL Development Stage
TN06010108035-5000, 6000 & 7000	LICK CREEK	36.1	Nitrate+Nitrite Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture grazing	II/III
TN06010108035 - 9000	LICK CREEK	7.7	Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Pasture grazing	I
TN06010108102 - 2000	RICHLAND CREEK	8.51	Nitrate+Nitrite Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture grazing Discharges from MS4 area	I
TN06010108510 - 0400	HOMINY CREEK	7.0	Nitrate+Nitrite Escherichia coli	Agriculture	I
TN06010108510-1000	LITTLE LIMESTONE CREEK	8.0	Nitrate+Nitrite Escherichia coli	Pasture grazing	II/III
TN06010108510-2000	LITTLE LIMESTONE CREEK	13.5	Nitrate+Nitrite Total Phosphorus Physical Substrate Habitat Alterations Ammonia Escherichia coli	Discharges from MS4 area Municipal Point Source Pasture Grazing	II/III

Figure 4 Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients (Documented on the 2008 303d List)

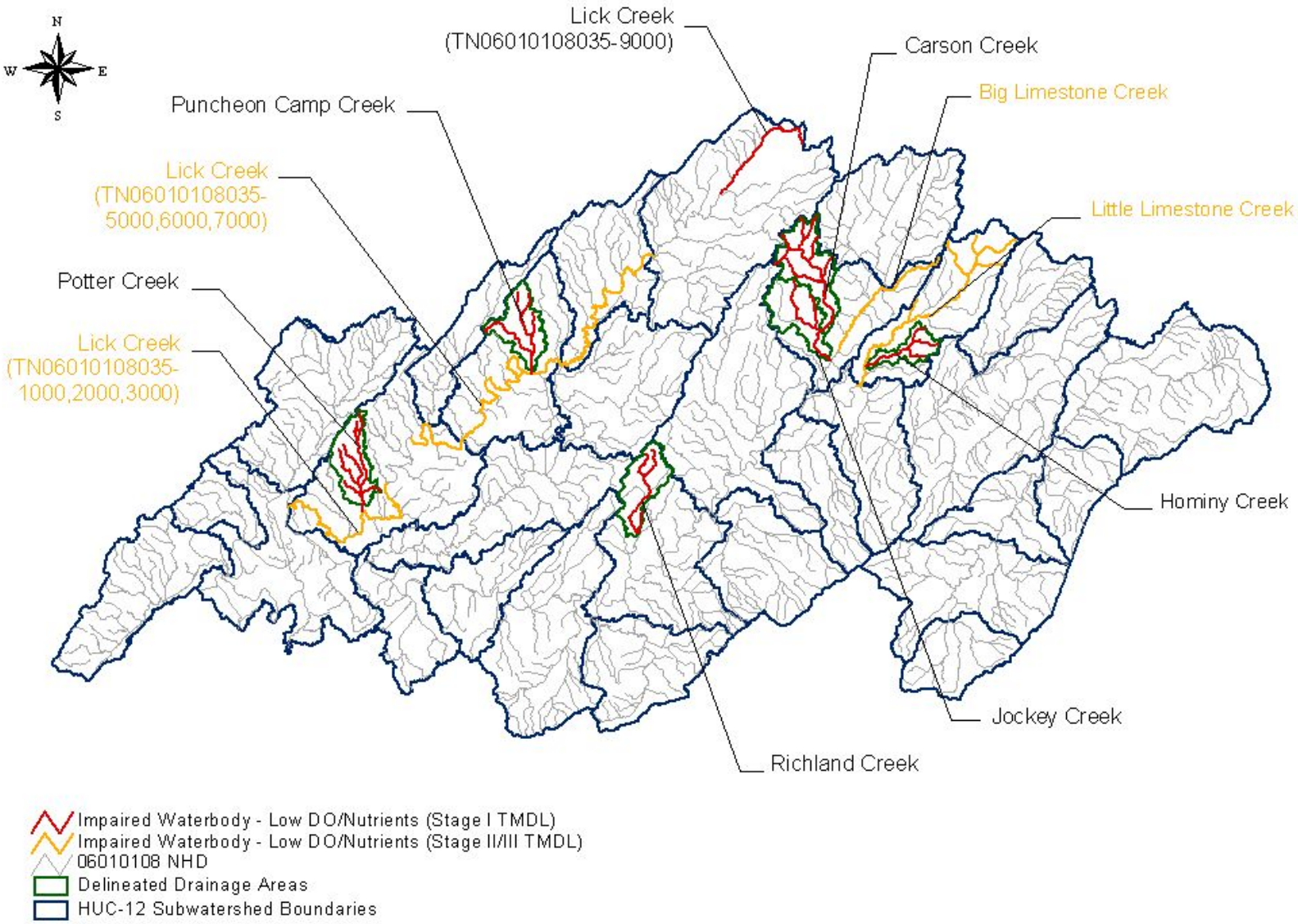


Figure 5 Interrelationship of Major Kinetic Processes Associated with Instream Dissolved Oxygen (USEPA, 1997a)

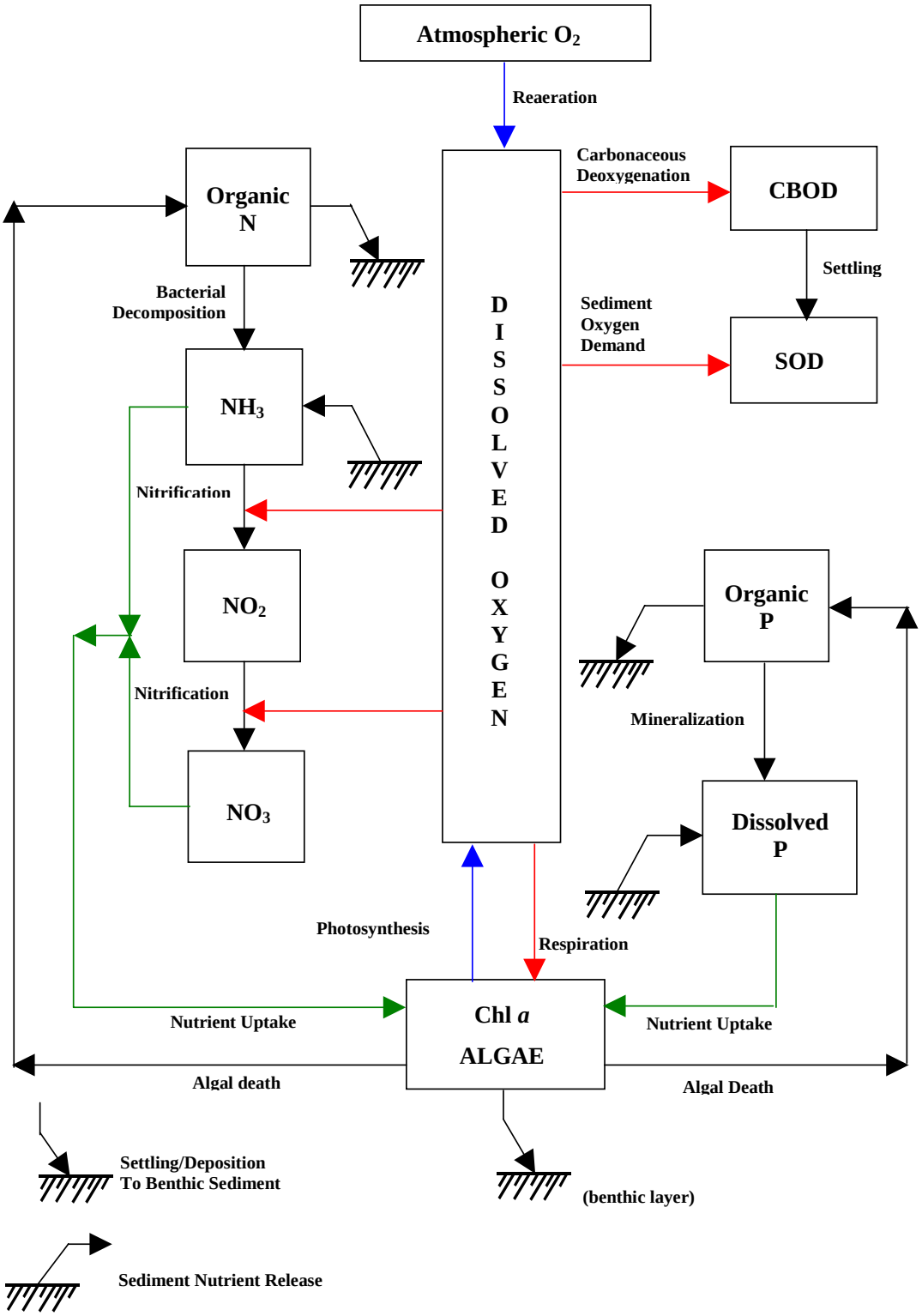


Table 3 Water Quality Assessment of Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients – Nolichucky River Watershed

Waterbody ID	Segment Name	Assessment Information
TN06010108030 - 0200	Jockey Creek	2003 TVA biorecon at mile 1.2 (Estepp Slaughter House). 10 EPT families, 6 intolerant, 26 total families. Index score = 15. 2001-02 TDEC chemical station at mile 0.1 (u/s Opre Arnold Road). Nutrients elevated. 2000 TDEC (LAB) SQSH at mile 0.1 (u/s Opre Arnold Road). 5 EPT genera, 21 total genera. Index score = 28. Habitat score = 140.
TN06010108030 – 0220	Carson Creek	2000 TDEC (LAB) SQSH at mile 0.1 (u/s Clear Springs Road). 5 EPT genera, 28 total genera. Index score = 24. Habitat score = 89. 319 project station at mile 1.5. NO2+NO3 levels elevated.
TN06010108030 - 2000	Big Limestone Creek (from unnamed trib near Limestone to headwaters)	2004-05 TDEC chemical station at mile 4.0 (u/s Hwy 11E). Nitrate-nitrite elevated. 2000 TDEC (LAB) SQSH at mile 4.0 (u/s Hwy 11E). 6 EPT genera, 32 total genera. Index score = 24. Habitat score = 110. 1995 LAB biological survey at Kykker Road. 9 EPT genera, 29 total genera.
TN06010108035-0200	Potter Creek	2005-06 TDEC pathogen station at mile 0.3 (Sapp Road). Five low DO observations. 2000 Lab biorecon at mile 0.3 (u/s Sapp Road). Zero EPT genera, zero intolerant, 28 total genera. Habitat score = 41. Failed biorecon criteria.
TN06010108035 - 0900	Puncheon Camp Creek	2000 Lab RBPIII at mile 0.5 (opff Route 70). 3 EPT genera, 30 total genera. Habitat score = 50. Pass biocriteria. A tributary, Pigeon Creek, also assessed at mile 1.0 (u/s Buffalo Road). 9 EPT genera, 33 total genera. Index score = 34. Habitat score = 134.
TN06010108035 - 1000	Lick Creek (Nolichucky River to Hwy 348)	2005-06 TDEC chemical station at mile 1.0 (Warrensburg Road). Two low DOs during 2005-06 monitoring. Suspended residue and phosphorus levels elevated. 2000 Lab RBPIII survey at mile 1.0 (u/s Warrensburg Road). 7 EPT genera, 27 total genera. Habitat score = 105. Site failed biocriteria.
TN06010108035 - 2000	Lick Creek (Hwy 348 to Black Creek)	2005-06 TDEC chemical station at mile 3.8 (u/s Glade Road & Brown Springs Road). Suspended residues and phosphorus elevated. 2003 TVA biorecon at mile 3.8 (u/s Glade Road & Brown Springs Road). 7 EPT families, 2 intolerant, 17 total families. Biorecon score = 7. 2000 Lab RBPIII survey at mile 3.8 (u/s Glad Road & Brown Springs Road). 10 EPT genera, 27 total genera. Habitat score = 133. Site passed biocriteria.
TN06010108035 - 3000	Lick Creek (Black Creek to Skipper Creek)	2000 Lab RBPIII survey at mile 6.5 (u/s Smelcer Road). 6 EPT genera, 23 total genera. Habitat score = 91. Site failed biocriteria.
TN06010108035 - 5000	Lick Creek (Mud Creek to Hwy 70)	2000 Lab RBPIII survey at mile 24.2 (u/s Old Highway 34). 3 EPT genera, 22 total genera. Habitat score = 108. Site failed biocriteria. TDEC chemical station at mile 20.5 (Pottertown Rd). Suspended residue and nitrate-nitrite elevated.

Table 3 (Contd.) Water Quality Assessment of Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients – Nolichucky River Watershed

Waterbody ID	Segment Name	Assessment Information
TN06010108035 - 6000	Lick Creek (Hwy 70 to Grassy Creek)	2003 TVA biorecon at mile 33.4 (Marvin Road). 10 EPT families, 3 intolerant, 23 total families. Biorecon score = 13. 2000 Lab RBPIII surveys at mile 33.6 (u/s Old Hwy 70) and at mile 40.8 (off John Graham Rd). 5 EPT genera, 24 total, habitat = 89 at mile 33.6. 4 EPT genera, 24 total, habitat = 90 at mile 40.8. Both sites failed biocriteria.
TN06010108035 - 7000	Lick Creek (Grassy Creek to Horse Fork)	2003 TVA biorecon at mile 49.8 (Lick Creek Mill). 10 EPT families, 3 intolerant, 28 total families. Biorecon score = 13. 2000 Lab RBPIII survey at mile 45.2 (u/s Wesley Chapel Road). 2 EPT genera, 28 total genera. Habitat score = 96. Site failed biocriteria. 2001 TDEC chemical station at mile 47.2 (Crumley Rd). Nitrate+nitrite levels elevated.
TN06010108035 - 9000	Lick Creek (I-81 to headwaters)	2000 Lab RBPIII survey at mile 61.0 (u/s Campbell Road). 7 EPT genera, 27 total genera. Habitat score = 117. Site failed biocriteria.
TN06010108102 - 2000	Richland Creek (from Right Fork Richland Creek to headwaters)	2005 TDEC SQSH at mile 6.0 (u/s Old Asheville Highway). 3 EPT genera, 26 total genera, Index score = 22, Habitat score = 123. Two tributaries also assessed: Middle Fork and Left Fork Richland. Both SQSHs failed. 2000 Lab RBPIII at mile 3.5 (u/s Old Asheville Highway) and 4.2 (East McKee Road). 3 EPT, 19 total at both. Both sites failed biocriteria. TDEC chemical station at mile 6.0 (McKee Street Bridge). Fecal coliform and nitrate-nitrite elevated.
TN06010108510 - 0400	Hominy Creek	2005-06 TDEC chemical station at mile 0.2 (Gravel Hill Road). Nitrate+nitrite levels elevated. 2000 Lab biorecon at mile 0.2 (Gravel Hill Road). 6 EPT genera, 1 intolerant, 20 total, habitat score = 82. Failed biorecon criteria. 319 project sampling station at mile 0.1. Pathogens and NO_2+NO_3 elevated.
TN06010108510 – 1000	Little Limestone Creek (Nolichucky River to Brown Creek at Telford)	2005-06 TDEC pathogen station at mile 0.1 (Water Plant Road). Nutrients elevated. 2003 TVA biorecon at mile 1.2 (near Broylesville). 10 EPT families, 2 intolerant, 25 total. Biorecon score = 11. 2000 Lab biorecon at mile 0.1 (J.B. Water Plant Rd). 6 EPT genera, 1 intolerant, 23 total. Habitat = 111. Failed biorecon criteria. 1997 TVA biological survey at mile 1.2 (near Broylesville). 12 EPT families, 25 total families.
TN06010108510 – 2000	Little Limestone Creek (Brown Creek to headwaters)	2006 TDEC SQSH surveys above and below Jonesboro STP at mile 12.3 (d/s Jonesboro STP), at mile 12.7 (Co-op ditch), at mile 13.0 (Ben Parish Farm), and at mile 13.8 (Spring Street). At mile 12.3: zero EPT genera, 8 total genera. Index score = 0. Habitat score = 96. At mile 12.7: 3 EPT genera, 23 total genera. Index score = 24. Habitat score = 127. At mile 13.0: 3 EPT genera, 29 total genera. Index score = 24. Habitat score = 122. At mile 13.8: 3 EPT genera, 17 total genera. Index score = 28. Habitat score = 128. 2002-07 TDEC chemical station at mile 7.0 (near Teleford). Nutrients elevated. 2005-06 TDEC chemical station at mile 7.7 (d/s SR 353). Nutrients elevated. 2000 Lab biorecon at mile 7.7 (Hwy 81). 1 EPT genera, 0 intolerant, 15 total genera. Habitat score = 91. Failed biorecon criteria. 2000 TDEC chemical station at mile 6.8 (near Teleford). NO_2 elevated.

5.0 WATER QUALITY GOAL

5.1 Water Quality Criteria

Several narrative criteria, applicable to nutrients, are established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, October 2007* (TDEC, 2007):

Applicable to all use classifications (except for fish & aquatic life):

> Dissolved Oxygen – There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

Applicable to the recreation use classification:

> Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that the public's recreational uses of the waterbody or other downstream waters are detrimentally affected. Unless demonstrated otherwise, the nutrient criteria found in 1200-4-3-.03(3)(k) will be considered adequately protective of this use.
>
> *Note: Section 1200–4-3-.03(3)(k) is the nutrient criteria applicable to the fish & aquatic life use classification cited below.*

Applicable to the fish & aquatic life use classification:

> Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and /or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected.
>
> Interpretation of this provision may be made using the document Development of Regionally based Interpretations of Tennessee's Narrative Nutrient Criterion and/or other scientifically defensible methods.
>
> Biological Integrity - The waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or adversely affected, except as allowed under 1200-4-3-.06.
>
> Interpretation of this provision for any stream which (a) has at least 80% of the upstream catchment area contained within a single bioregion and (b) is of the appropriate stream order specified for the bioregion and (c) contains the habitat (riffle or rooted bank) specified for the bioregion, may be made using the most current revision of the Department's Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys and/or other scientifically defensible methods.
>
> Interpretation of this provision for all other wadeable streams, lakes, and reservoirs may be made using Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA/841-B-99-002) or Lake and Reservoir Bioassessment and Biocriteria (EPA 841-B-98-007), and/or other scientifically defensible methods. Interpretation of this provision for wetlands or large rivers may be made using scientifically defensible methods. Effects to biological populations will be measured by comparisons to upstream

conditions or to appropriately selected reference sites in the same bioregion if upstream conditions are determined to be degraded.

In addition, numerical dissolved oxygen criteria are specified for the protection of fish & aquatic life:

Dissolved Oxygen - The dissolved oxygen shall not be less than 5.0 mg/l with the following exceptions.

1. In streams identified as trout streams, including tailwaters, dissolved oxygen shall not be less than 6.0 mg/L.

2. The dissolved oxygen concentration of trout waters designated as supporting a naturally reproducing population shall not be less than 8.0 mg/L. (Tributaries to trout streams or naturally reproducing trout streams should be considered to be trout streams or naturally reproducing trout streams, unless demonstrated otherwise. Additionally, all streams within the Great Smoky Mountains National Park should be considered naturally reproducing trout streams.)

3. In wadeable streams in subecoregion 73a, dissolved oxygen levels shall not be less than a daily average of 5.0 mg/L with a minimum dissolved oxygen level of 4.0 mg/L.

4. The dissolved oxygen level of streams in ecoregion 66 (Blue Ridge Mountains) not designated as naturally reproducing trout streams shall not be less than 7.0 mg/L.

Substantial and/or frequent variations in dissolved oxygen levels, including diurnal fluctuations, are undesirable if caused by man-induced conditions. Diurnal fluctuations shall not be substantially different than the fluctuations noted in reference streams in that region.

In lakes and reservoirs, the dissolved oxygen concentrations shall be measured at mid-depth in waters having a total depth of ten feet or less, and at a depth of five feet in waters having a total depth of greater than ten feet and shall not be less than 5.0 mg/L.

These TMDLs are being established to attain the fish and aquatic life designated use, which is the most stringent. A TMDL established to protect the fish and aquatic life use will protect all other uses for the identified waterbodies from adverse alteration due to low dissolved oxygen and excessive nutrient loading.

5.2 Water Quality Indicators & TMDL Targets

In order for a TMDL to be established, appropriate indicators and target values that are protective of the uses of the waterbody must be identified to serve as the basis for the TMDL. Where State regulation provides a numeric water quality criterion for the pollutant, the criterion forms the basis for the TMDL. Where state regulation does not provide a numeric water quality criterion at present, as in the case of nutrients and biological integrity, numeric interpretations of narrative water quality standards must be determined.

As discussed in Section 4.0 and Appendix A, instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen (TN), total phosphorus (TP), and carbonaceous biochemical oxygen demand ($CBOD_5$). These constituents have been selected as the appropriate indicators for TMDL development. It should be noted that total nitrogen and total phosphorus are not toxics. The primary importance of these nutrients with respect to water quality is in enabling the growth of algae and the ultimate effect on instream dissolved oxygen concentrations.

The nutrient and $CBOD_5$ targets established below are considered to support instream dissolved oxygen concentrations above the minimum specified by State water quality standards for the fish & aquatic life use classification.

Nutrients

One of the three methods mentioned in *Nutrient Criteria Technical Guidance Manual, Rivers and Streams* (USEPA, 2000) that can be used in developing nutrient criteria is the reference stream reach approach. Reference reaches are relatively undisturbed stream segments that can serve as examples of the natural biological integrity of a region. One of the ways to establish criteria (or goal) is the selection of a percentile from the distribution of primary variables of known reference systems. Primary variables include both causal variables, total nitrogen (TN) and total phosphorus (TP), and response variables, algal biomass as chlorophyll *a* and turbidity or transparency. EPA recommends the use of the 75th percentile value as the reference condition.

For the purposes of this TMDL, and in accordance with the standards for nutrients and biological integrity, the 75th percentile values of total nitrogen (TN) and total phosphorus (TP) data collected at Tennessee's Level IV ecoregion reference sites were determined to be the appropriate numeric interpretation of the narrative water quality standard (the location of these reference sites are shown in Figure E-1). The watersheds corresponding to these reference sites are considered the "least impacted" in the ecoregion and, as such, nutrient loading from these subwatersheds may serve as the appropriate basis for the TMDL water quality goal. Nutrient concentration targets were developed for those Level IV ecoregions that contained portions of the impaired subwatersheds covered in this Stage I TMDL. The nutrient concentration targets, corresponding to the 75th percentile data, for Level IV ecoregions 67f, 67g, & 67h are:

Level IV Ecoregion	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
67f	0.933	0.013
67g	0.988	0.054
67h	1.280	0.012

Note: Ecoregion reference sites are continuously sampled and evaluated, with sites added or deleted as circumstances warrant. The values shown were determined based on ecoregion reference sites as of April 30, 2005.

Small portions of the Puncheon Camp Creek drainage area and HUC-12 0801 lie in Level IV ecoregion 67i. However, no monitoring data were available to develop nutrient concentration targets for 67i. Therefore, the portion of the drainage areas lying in 67i was re-distributed between the other ecoregions for the drainage areas.

$CBOD_5$

Since $CBOD_5$ was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration of 1.5 mg/l was considered to be an appropriate water quality goal for Stage I TMDL development. This value is specified in the Tennessee/EPA Stream Model Agreement as the background concentration to be used for DO sag analysis when instream data is not available and is lower than the limited number of data points at ecoregion reference sites (typically <2 mg/l).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM WATER QUALITY TARGET

Chemical water quality data, relevant to Stage I TMDL development for waterbodies identified as impaired for low dissolved oxygen or nutrients in the Nolichucky River Watershed, are available from a number of sources and are summarized in the following sections.

6.1 STORET Data

There are a number of water quality monitoring stations that provide chemical data for waterbodies identified as impaired for low dissolved oxygen or nutrients in the Nolichucky River Watershed:

- CARSO000.1WN – Carson Creek, 100 yds u/s Clear Spring Rd.
- CARSO001.8WN – Carson Creek, at Bowmantown Rd.
- HOMIN000.2WN – Hominy Branch, 150 yds u/s Gravel Hill Rd.
- JOCKE000.1WN – Jockey Creek, 100 yds u/s Opie Arnold Rd.
- JOCKE003.2GE – Jockey Creek, at Old Stage Rd.
- LICK052.3GE – Lick Creek, 100 yds u/s Lost Mountain Pike
- LICK061.0GE – Lick Creek, 100 yds u/s Campbell Rd.
- PCAMP000.5GE – Puncheon Camp Creek, off route 70 thru field road, 50 yds u/s culvert
- POTTE000.3GE – Potter Creek, on Sapp Rd., off Concord Rd., west of Thula
- RICHL004.3GE – Richland Creek, south of Greeneville/Blue Jay Rd.
- RICHL006.0GE – Richland Creek, u/s Old Asheville Hwy at Devils Elbow
- RICHL007.1GE – Richland Creek, in Greeneville, at Jones Bridge Rd.

The location of these monitoring stations is shown in Figure 6. Water quality monitoring results for all stations are tabulated in Appendix D and summarized in Table 4. Examination of this data shows occasional violation of the instream dissolved oxygen standard and a number of instances where the target total nitrogen and total phosphorus concentrations are exceeded. Based on a review of available instream monitoring data and stream assessment data sheets, impairment causes of low dissolved oxygen and nutrients in these waterbodies are considered to be primarily due to high nutrient loading.

Figure 6 Selected Water Quality Monitoring Stations in the Nolichucky River Watershed

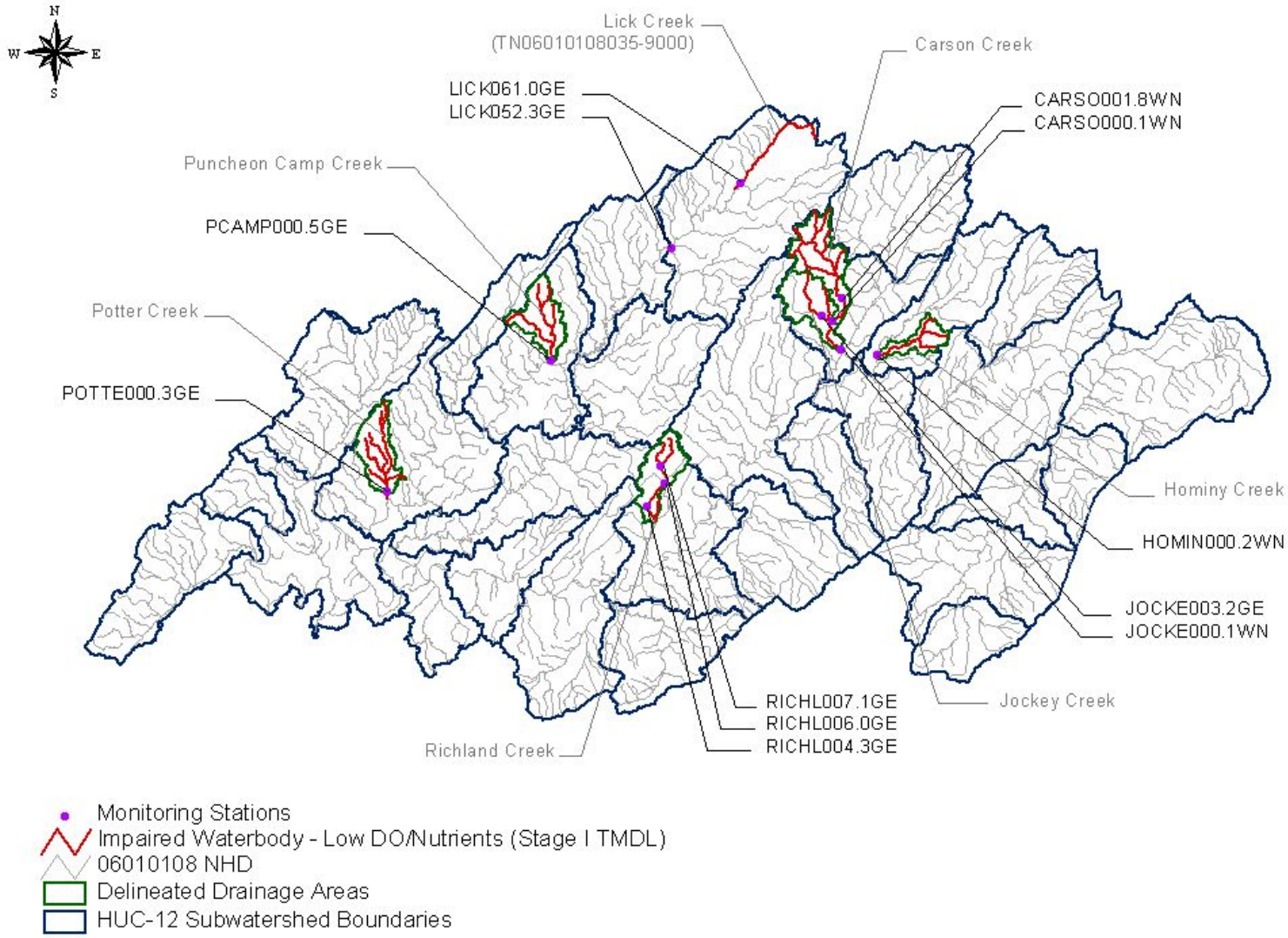


Table 4 Summary of Water Quality Monitoring Data [a]

Monitoring Station	Sample Dates	Dissolved Oxygen					Total Nitrogen [b]				Total Phosphorus			
		Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]	No. Viol. WQ Std.	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]
CARSO000.1WN	8/00 – 2/06	20	5.50	9.06	12.89	0	22	1.14	2.59	13.29	22	0.010	0.160	1.070
CARSO001.8WN	8/00 – 10/01	12	8.90	10.58	14.92	0	12	1.40	2.01	2.81	12	0.002	0.038	0.080
HOMIN000.2WN	7/05 – 6/06	13	7.94	9.74	11.81	0	13	0.90	1.56	2.34	13	0.005	0.028	0.150
JOCKE000.1WN	8/00 – 6/06	25	3.13	9.11	14.35	1	27	1.17	2.09	3.31	27	0.002	0.072	0.250
JOCKE003.2GE	8/00 – 10/01	12	9.33	10.85	13.45	0	13	1.41	1.91	2.30	12	0.002	0.044	0.100
LICK052.3GE	8/00 – 6/06	26	5.44	8.71	13.12	0	27	0.19	1.38	3.78	27	0.002	0.089	0.580
LICK061.0GE	8/00 – 6/06	27	6.07	9.01	12.18	0	27	0.65	1.23	3.12	27	0.002	0.026	0.150
PCAMP000.5GE	8/00 – 6/06	9	3.08	7.55	11.05	2	10	0.08	0.98	3.30	10	0.005	0.118	0.445
POTTE000.3GE	12/00 – 6/06	23	0.90	7.70	14.09	8	23	0.33	2.79	30.06	23	0.005	0.174	1.230
RICHL004.3GE	8/00 – 11/01	14	8.49	10.03	12.44	0	15	1.27	1.97	3.03	15	0.002	0.064	0.180
RICHL006.0GE	8/00 – 6/06	13	7.10	9.35	12.54	0	14	1.24	1.92	2.80	14	0.005	0.023	0.070
RICHL007.1GE	8/00 – 11/01	14	7.72	9.31	11.75	0	15	1.63	2.34	3.71	15	0.002	0.069	0.270

Notes: a. For cases where data were reported as less than an analytical detection level, ½ the detection level was used to determine average, maximum, and minimum values.
b. For all stations, total nitrogen data corresponds to sum of NO3+NO2 plus TKN for each sample date (see Table D-1).
Values shown are a summary of calculated total nitrogen data.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect instream dissolved oxygen levels and the amount of loading contributed by each of these sources. Pollutants of concern include $CBOD_5$, as well as excess amounts of total nitrogen (composed of organic nitrogen, ammonia, nitrate, & nitrite) and total phosphorus. $CBOD_5$ is an indicator of the oxygen consumed during the oxidation of organic matter, whereas nitrogen and phosphorus indirectly affect dissolved oxygen levels as nutrients that are essential to algae growth. Algal oxygen production, due to photosynthesis, and oxygen consumption, due to respiration, cause diurnal variations in stream dissolved oxygen levels.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain the primary nutrients nitrogen (organic nitrogen, ammonia, nitrate, & nitrite) and phosphorus (organic & inorganic). There are 15 NPDES permitted WWTFs in the Nolichucky River Watershed that discharge treated sanitary wastewater. In addition, there are two industrial facilities permitted to discharge non-process wastewater and storm water containing ammonia or nitrate/nitrite. Of these WWTFs, six discharge directly to an impaired waterbody (see Figure 7). As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTFs will be developed as part of Stages II & III and are not included in this document.

Figure 7 NPDES Permitted Wastewater Treatment Facilities with Discharges Containing BOD or Nutrients

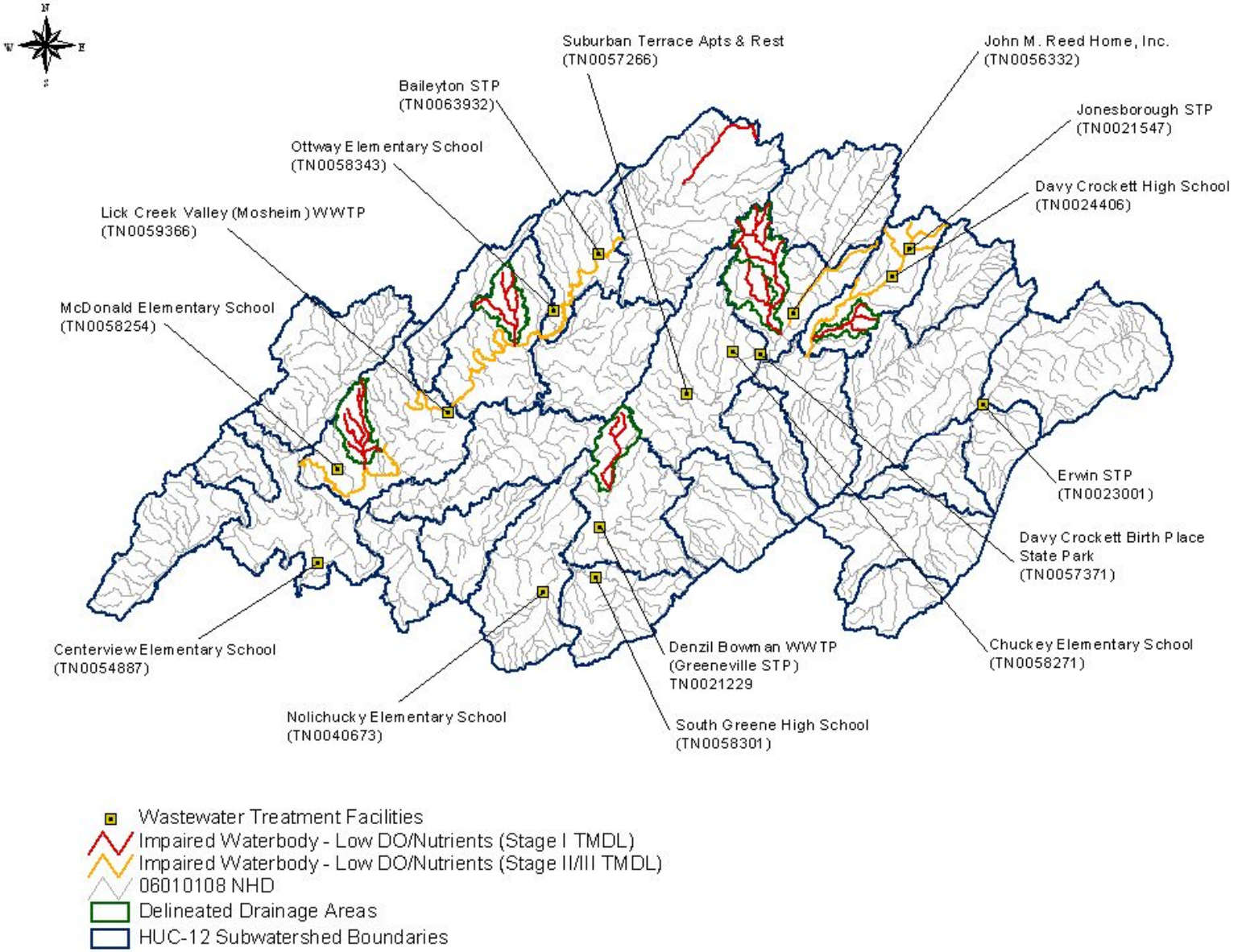
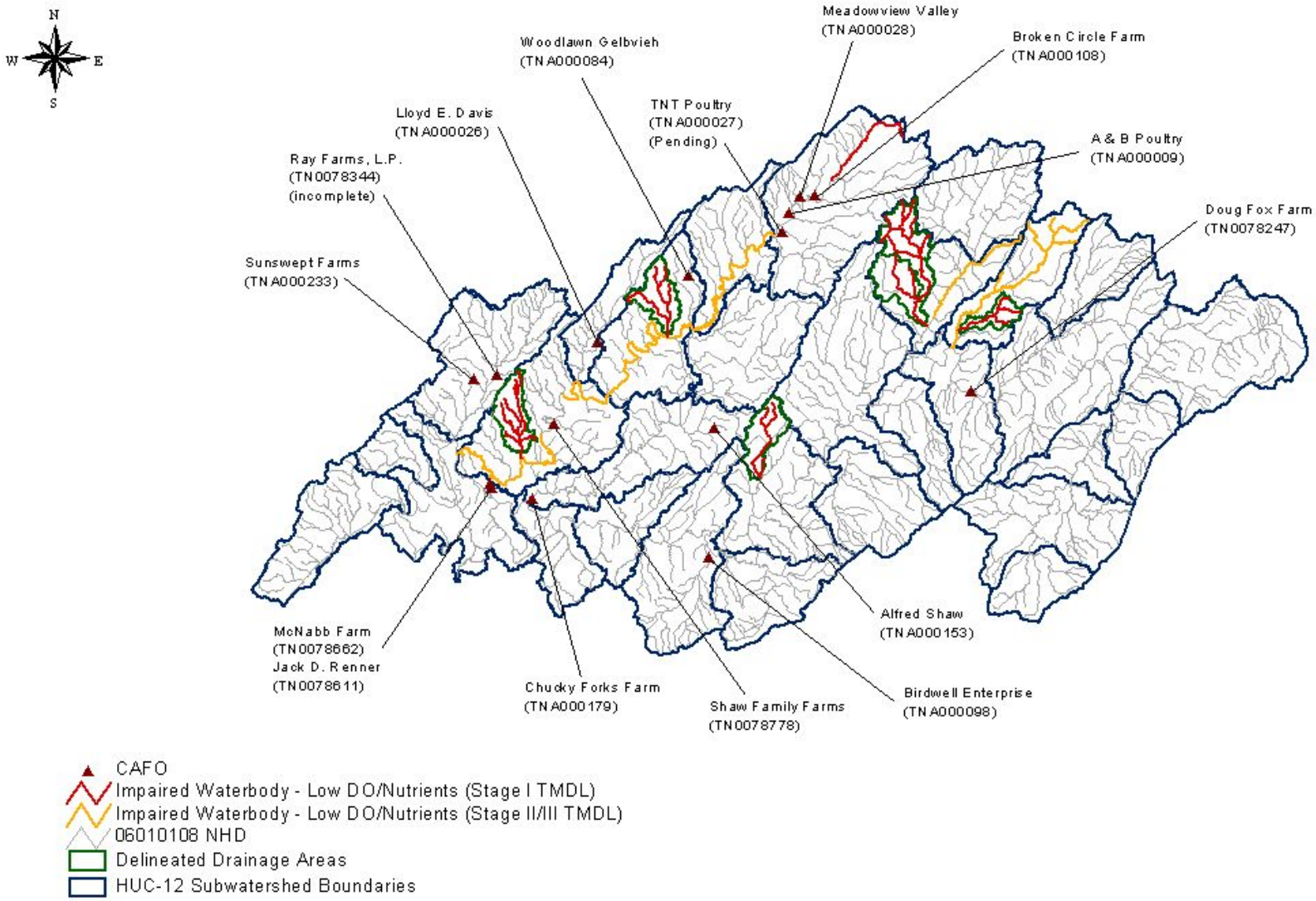


Figure 8 CAFOs Located in the Nolichucky River Watershed



7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of nutrients. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Large and medium MS4s serving populations greater than 100,000 people are required to obtain an NPDES storm water permit. At present, there are no MS4s of this size in the Nolichucky River Watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program. A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003a). Greenville, Jonesborough, and Washington County are covered under Phase II of the NPDES Storm Water Program.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway rights-of-way that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas.

Information regarding storm water permitting in Tennessee may be obtained from the TDEC website at http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of nutrient loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* (this permit may be obtained from the TDEC website at http://state.tn.us/environment/permits/cafo.shtml), while larger, Class I CAFOs are required to obtain an individual NPDES permit. Requirements of both the general and individual CAFO permits include:

- Development of a Nutrient Management Plan (NMP), and approval of the NMP by the Tennessee Department of Agriculture (TDA).
- Liquid waste handling systems, if utilized, be designed, constructed, and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event. A discharge from a liquid waste handling facility to waters of the

state during a chronic or catastrophic rainfall event, or as a result of an unpermitted discharge, upset, or bypass of the system, shall not cause or contribute to an exceedance of Tennessee water quality standards.

- Other Best Management Practices (BMPs).

As of October 24, 2008, there are nine active and one pending Class II CAFOs in the Nolichucky River Watershed with coverage under the general NPDES permit. There are also four active and one incomplete application for coverage under an individual CAFO permit. The location of these facilities is shown in Figure 8. It should be noted that most of these facilities are not located in HUC-12 subwatersheds containing waterbodies identified as impaired for low dissolved oxygen or nutrients. There are four facilities (three active and one pending) located in the HUC-12 containing the headwaters of Lick Creek. These facilities are all located downstream of the impaired segment.

7.2 Nonpoint Sources

Possible nonpoint sources of nutrients and organic materials include urban runoff (from areas not covered under an MS4 permit), atmospheric deposition, geology, failing septic systems, and agricultural runoff on land associated with fertilizer application and livestock waste. Typical nutrient loading ranges for various land uses is shown in Table 5. For the majority of the waterbodies undergoing Stage I TMDL development in the Nolichucky River Watershed, nonpoint sources are listed as the primary sources of pollution.

Table 5 Typical Nutrient Loading Ranges for Various Land Uses

Land Use	Total Phosphorus [kg/ha-y]			Total Nitrogen [kg/ha-y]		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Roadway	0.59	1.50	1.10	1.3	3.5	2.4
Commercial	0.69	0.91	0.80	1.6	8.8	5.2
Single Family – Low Density	0.46	0.64	0.55	3.3	4.7	4.0
Single Family – High Density	0.54	0.76	0.65	4.0	5.6	5.8
Multifamily Residential	0.59	0.81	0.70	4.7	6.6	5.6
Forest	0.10	0.13	0.11	1.1	2.8	2.0
Grass	0.01	0.25	0.13	1.2	7.1	4.2
Pasture	0.01	0.25	0.13	1.2	7.1	4.2

Source: Horner et al., 1994 in *Protocol for Developing Nutrient TMDLs* (USEPA 1999).

Watershed livestock, population on septic systems, and land use (MRLC) data for subwatersheds in the Nolichucky River Watershed were compiled utilizing the Watershed Characterization System (WCS). WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. Estimates of livestock and population on septic systems for impaired HUC-12 subwatersheds and drainage areas are presented in Tables 6 & 7, respectively. Land use for these subwatersheds and drainage areas is summarized in Figures 9 & 10 and tabulated in Appendix C.

Table 6 Livestock Distribution in the Nolichucky River Watershed

County	Livestock Population -2002 Census of Agriculture (USDA, 2004)						
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Horse
			Layers	Broilers			
Cocke	9,442	1,145	289	232,063	121	183	822
Greene	38,445	5,149	2,207	1,119,358	600	717	3,851
Hamblen	9,054	857	430	575,651	956	127	840
Hawkins	20,337	443	1,658	280,310	296	354	2,259
Jefferson	18,634	1,546	1,085	783,172	293	799	2,080
Unicoi	D	0	122	D	36	0	228
Washington	24,068	4,627	557	D	150	1,174	2,929

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 7 Estimated Population on Septic Systems in Impaired Subwatersheds & Drainage Areas

Impaired Subwatershed (06010108____) or Drainage Area	Population On Septic Systems
Jockey Ck DA	2,822
Carson Ck DA	1,863
Potter Ck DA	724
Puncheon Camp Ck DA	649
0801	7,756
Richland Ck DA	395
Hominy Ck DA	1,092

Figure 9 Land Use Area of Impaired Subwatersheds & Drainage Areas

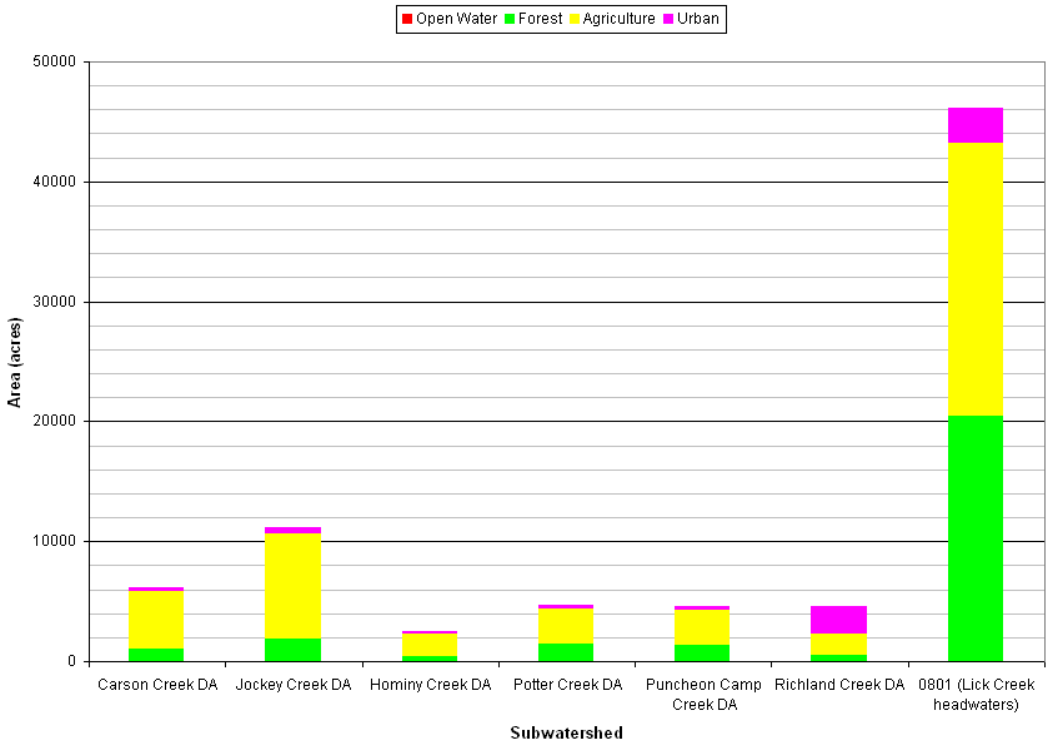
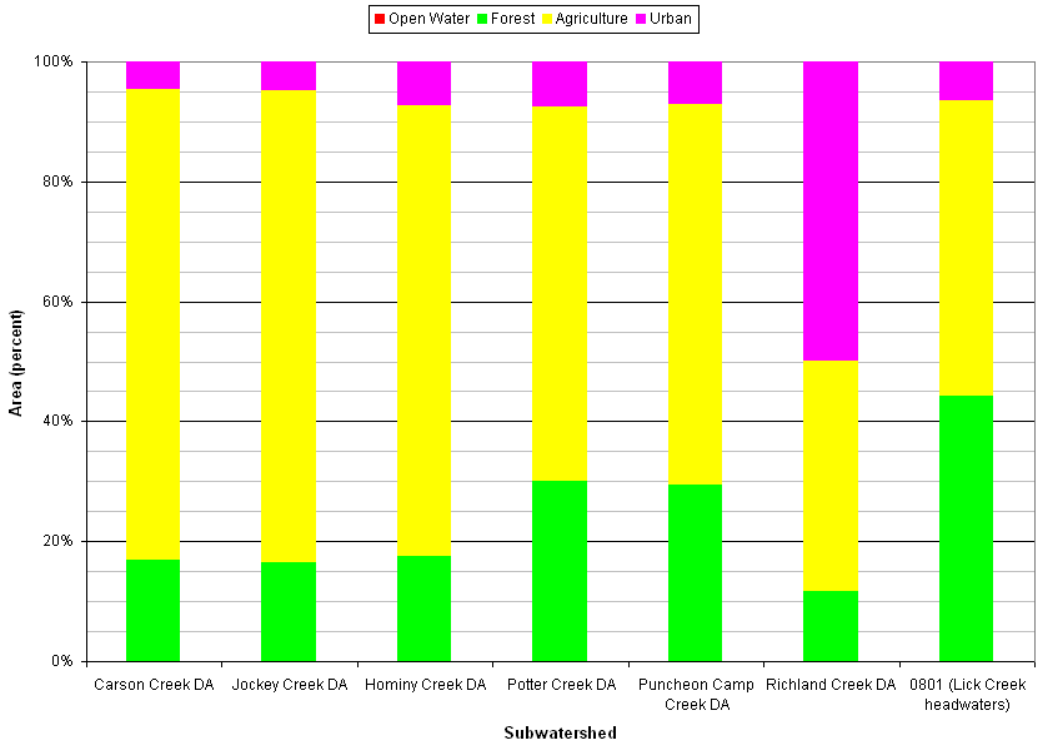


Figure 10 Land Use Percentage of Subwatersheds & Drainage Areas



From the data presented in Tables 5, 6, 7, & C-1 and Figures 9 & 10, it can be seen that approximately 50% of the land use in the Jockey Creek, Carson Creek, Hominy Creek, Potter Creek, Puncheon Camp Creek, and Lick Creek drainage areas is associated with agricultural activities. Agricultural sources are a significant source of nitrogen loading. This is reflected in the 2008 303(d) list (ref.: Table 2) where agriculture related sources are noted as the source of pollutants for impaired waterbodies in these subwatersheds. A significant portion of land use in the Richland Creek drainage areas is classified as urban. Urban land has the highest loading rates for both phosphorus and nitrogen.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

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 is equal to 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:

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

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, toxicity, or other appropriate measure.

8.1 Area Basis for TMDL Analysis

The basic area unit of analysis for Stage I TMDL development was the headwater HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to low dissolved oxygen or nutrients, as documented on the 2008 303(d) List. In some cases, for impaired tributaries in non-headwater subwatersheds, TMDLs were developed for the impaired waterbody drainage area only. HUC-12 subwatersheds and delineated drainage areas are shown in Figure 11. As stated in Section 2.0, TMDL development for impaired subwatersheds containing existing WWTFs are part of Stages II & III and are not included in this document.

8.2 TMDL Analysis Methodology

Since the acceleration of eutrophication is one of the significant effects of excess nutrient loading, an annual time scale for TMDL analysis was considered to be the most appropriate for representing the seasonal and long-term processes of algal growth in streams and the associated effects on instream dissolved oxygen and aquatic life (ref.: Appendix A). Accordingly, TMDLs, WLAs, and LAs were developed as annual average loads.

However, in response to a recent court decision, EPA issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et al., No.05-5015, (April 25, 2006) and Implications for NPDES Permits* (USEPA 2006) to clarify expectations regarding the appropriate time increment used to express TMDLS. In this document, EPA recommends that future TMDLs, WLAs, and LAs include a daily time increment in conjunction with other appropriate temporal expressions. In accordance with this guidance, daily expressions of allowable annual average loads were developed.

For each impaired subwatershed or waterbody drainage area, the TMDL (and associated WLAs & LAs) consists of: a) an allowable average annual load and b) a daily expression of that allowable average annual load.

8.2.1 Annual Loading Analysis

Stage I TMDLs were developed for impaired subwatersheds and drainage areas based on the target nutrient and $CBOD_5$ concentrations specified in Section 5.2. Utilizing these concentrations and simulated flow data for each ecoregion reference site, annual average loading targets were calculated for Level IV ecoregions 67f, 67g, & 67h. Total nitrogen, total phosphorus, and $CBOD_5$ TMDLs were determined by applying these ecoregion-based loading targets to each impaired subwatershed and drainage area. An explicit MOS was used and WLAS for MS4s and LAs for nonpoint sources were calculated on a unit area basis. $CBOD_5$ TMDLs were only developed for subwatersheds with low dissolved oxygen specifically identified as a cause of impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that fall below 5 mg/l. The annual loading analysis methodology is described in detail in Appendix E.

8.2.2 Daily Expression of Allowable Annual Loads

One of the options discussed in *Options for Expressing Daily Loads in TMDLs* (USEPA 2007) is the use of statistical analysis to identify a daily maximum load. The statistical approach selected to derive daily load expressions for Stage I TMDLs, WLAs, & LAs in the Nolichucky River Watershed was based on a procedure described in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991a). Using this methodology, allowable daily maximum concentrations for total nitrogen and total phosphorus were calculated from monitoring data collected at Level IV ecoregion reference sites (67f, 67g & 67h). Daily maximum nutrient loads were expressed as functions of stream flow for TMDLs, WLAs, & LAs. Derivation of daily expressions of annual average loads are detailed in Appendix F.

8.3 TMDLs for Impaired Subwatersheds and Drainage Areas

Stage I nutrient and $CBOD_5$ TMDLs are expressed as annual average loads (lbs/yr) for impaired subwatersheds and drainage areas and are summarized in Table 8.

8.4 Waste Load Allocations for Point Sources

8.4.1 NPDES Regulated Concentrate Animal Feeding Operations (CAFOs)

CAFOs are not authorized to discharge process wastewater from a liquid waste handling system except during a catastrophic or chronic rainfall event. Any discharges made under these circumstances, or as a result of a system upset or bypass, are not to cause an exceedance of Tennessee water quality standards. Therefore, a WLA of zero has been assigned to this class of facilities.

8.4.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

NPDES regulated Municipal Separate Storm Sewer Systems (MS4s) are considered point sources of nutrients. Since loading from these entities occurs primarily in response to storm events, WLAs are expressed as average annual loads on a unit area basis (lbs/ac/yr) and applied according to the subwatershed or drainage area into which the MS4 discharges. Stage I nutrient and $CBOD_5$ WLAs for MS4s are tabulated in Tables 9, 10, &11.

8.5 Load Allocations for Nonpoint Sources

Load allocations for nonpoint sources are numerically equal to the WLAs for MS4s (ref: Section 8.4.2) and are also expressed as average annual loads on a unit area basis (lbs/ac/yr). LAs apply to any nonpoint source loading in the impaired subwatershed or drainage area. Stage I nutrient and $CBOD_5$ LAs for nonpoint sources are tabulated in Tables 9, 10, &11.

8.6 Margin of Safety

There are two methods for incorporating a 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. In these TMDLs, both explicit and implicit MOS were utilized. An implicit MOS was incorporated through the use of conservative modeling assumptions. The primary conservative assumption was the selection of target concentrations based on the 75th percentile of nutrient data collected from Level IV ecoregion reference sites. These sites represent the least impacted streams in the ecoregions. In addition, 5% of each TMDL was reserved as explicit MOS.

8.7 Seasonal Variation

Nutrient loading is expected to fluctuate during the year according to season and the amount and distribution of rainfall. The determination of nutrient & $CBOD_5$ loads on an average annual basis accounts for seasonal variation of loading.

Figure 11 HUC-12 Subwatershed Boundaries & Delineated Drainage Areas in the Nolichucky River Watershed

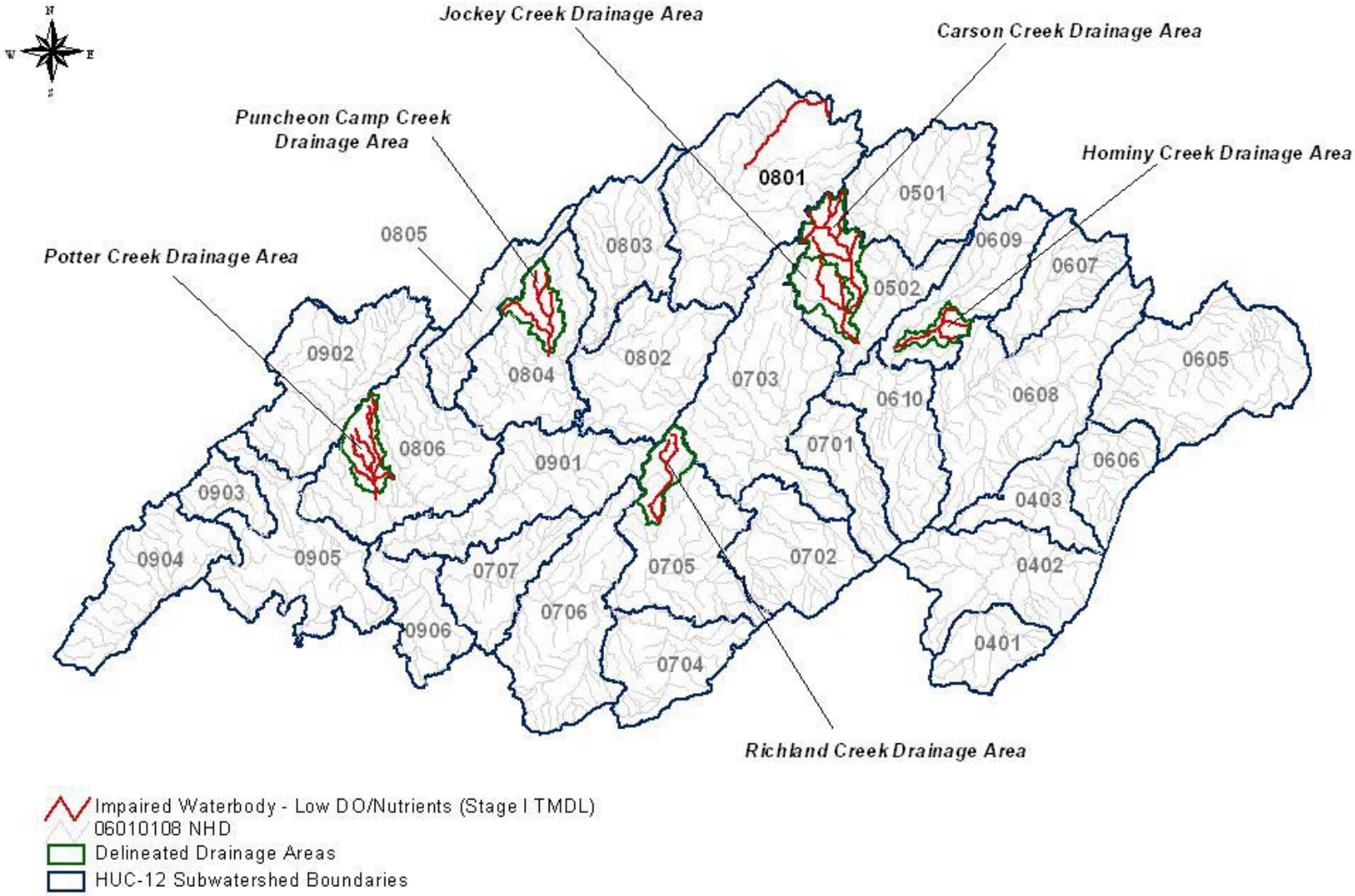


Table 8 Summary of Stage I Total Nitrogen, Total Phosphorus, & $CBOD_5$ TMDLs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL					
			Total Nitrogen		Total Phosphorus		$CBOD_5$	
			[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	32,713	$2.337 \times 10^1 * Q$	456	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Carson Ck DA	Carson Creek	TN06010108030-0220	18,029	$2.337 \times 10^1 * Q$	251	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Potter Ck DA	Potter Creek	TN06010108035-0200	10,527	$1.585 \times 10^1 * Q$	370	$1.802 \times 10^0 * Q$	14,415	$4.046 \times 10^1 * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	7,458	$1.788 \times 10^1 * Q$	408	$2.089 \times 10^0 * Q$	NA [b]	NA [b]
0801	Lick Creek (headwaters)	TN06010108035-9000	118,802	$2.143 \times 10^1 * Q$	2,541	$2.610 \times 10^0 * Q$	NA [b]	NA [b]
Richland Ck DA	Richland Creek	TN06010108102-2000	13,470	$2.337 \times 10^1 * Q$	186	$2.894 \times 10^0 * Q$	NA [b]	NA [b]
Hominy Ck DA	Hominy Creek	TN06010108501-0400	7,229	$2.337 \times 10^1 * Q$	101	$2.894 \times 10^0 * Q$	NA [b]	NA [b]

Notes: a. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
b. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).

Table 9 Summary of Stage I Total Nitrogen WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA [b] MS4 [a]		LA	
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day] [c]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	2.7927	$2.100 \times 10^{-3} * Q$	2.7927	$2.100 \times 10^{-3} * Q$
Carson Ck DA	Carson Creek	TN06010108030-0220	2.7927	$3.811 \times 10^{-3} * Q$	2.7927	$3.811 \times 10^{-3} * Q$
Potter Ck DA	Potter Creek	TN06010108035-0200	2.1138	$3.350 \times 10^{-3} * Q$	2.1138	$3.350 \times 10^{-3} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	1.5297	$3.860 \times 10^{-3} * Q$	1.5297	$3.860 \times 10^{-3} * Q$
0801	Lick Creek (headwaters)	TN06010108035-9000	2.4456	$4.643 \times 10^{-4} * Q$	2.4456	$4.643 \times 10^{-4} * Q$
Richland Ck DA	Richland Creek	TN06010108102-2000	2.7927	$5.101 \times 10^{-3} * Q$	2.7927	$5.101 \times 10^{-3} * Q$
Hominy Ck DA	Hominy Creek	TN06010108501-0400	2.7927	$9.504 \times 10^{-3} * Q$	2.7927	$9.504 \times 10^{-3} * Q$

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

Table 10 Summary of Stage I Total Phosphorus WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA [b] MS4 [a]		LA	
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day] [c]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	0.0390	$2.601 \times 10^{-4} * Q$	0.0390	$2.601 \times 10^{-4} * Q$
Carson Ck DA	Carson Creek	TN06010108030-0220	0.0390	$4.719 \times 10^{-4} * Q$	0.0390	$4.719 \times 10^{-4} * Q$
Potter Ck DA	Potter Creek	TN06010108035-0200	0.0744	$3.809 \times 10^{-4} * Q$	0.0744	$3.809 \times 10^{-4} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	0.0836	$4.510 \times 10^{-4} * Q$	0.0836	$4.510 \times 10^{-4} * Q$
0801	Lick Creek (headwaters)	TN06010108035-9000	0.0523	$5.655 \times 10^{-5} * Q$	0.0523	$5.655 \times 10^{-5} * Q$
Richland Ck DA	Richland Creek	TN06010108102-2000	0.0390	$6.316 \times 10^{-4} * Q$	0.0390	$6.316 \times 10^{-4} * Q$
Hominy Ck DA	Hominy Creek	TN06010108501-0400	0.0390	$1.177 \times 10^{-3} * Q$	0.0390	$1.177 \times 10^{-3} * Q$

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

Table 11 Summary of Stage I CBOD^5 WLAs & LAs

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA [c] MS4 [b]		LA	
			[lbs/ac/yr]	[lbs/ac/day] [d]	[lbs/ac/yr]	[lbs/ac/day] [d]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	NA [a]	NA [a]	NA [a]	NA [a]
Carson Ck DA	Carson Creek	TN06010108030-0220	NA [a]	NA [a]	NA [a]	NA [a]
Potter Ck DA	Potter Creek	TN06010108035-0200	2.8946	$8.552 \times 10^{-3} * Q$	2.8946	$8.552 \times 10^{-3} * Q$
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	NA [a]	NA [a]	NA [a]	NA [a]
0801	Lick Creek (headwaters)	TN06010108035-9000	NA [a]	NA [a]	NA [a]	NA [a]
Richland Ck DA	Richland Creek	TN06010108102-2000	NA [a]	NA [a]	NA [a]	NA [a]
Hominy Ck DA	Hominy Creek	TN06010108501-0400	NA [a]	NA [a]	NA [a]	NA [a]

Notes:
a. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
b. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
c. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
d. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first stage of a long-term effort to restore the biological health of impaired waters in the Nolichucky River Watershed through reduction of excessive $CBOD_5$ and nutrient loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals. Stage I TMDLs focus on HUC-12 subwatersheds and drainage areas that contain impaired headwater and tributary streams (wadeable) and do not contain wastewater treatment facilities (WWTFs).

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTF discharges will be developed as part of Stages II & III and are not included in this document. In order to make possible the future development of Stage II nutrient TMDLs, however, WWTFs will be expected to: 1) reduce nutrient discharges to the maximum extent feasible; 2) characterize facility nutrient loads through effluent nutrient monitoring; 3) determine the effect of facility nutrient discharges on impaired receiving waters by (but not necessarily limited to) monitoring instream nutrient levels upstream and downstream of the facility outfall; and 4) establish, improve, and increase canopy and provide a riparian buffer along stream banks downstream of facility outfalls to minimize diurnal dissolved oxygen fluctuations due to excessive algal growth. These expected actions may be implemented through appropriate NPDES permit provisions.

> *Note: Where suitable, trading may offer opportunities for overall reductions in watershed nutrient loading. Pollutant trading, including pollutant suitability analysis, financial attractiveness, identification of potential participants, and trading procedures, are presented in the Water Quality Trading Assessment Handbook (USEPA, 2004).*

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For existing and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs will be implemented through Phase I and II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003a) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include the following six minimum control measures:

1) Public education and outreach on storm water impacts;
2) Public involvement/participation;
3) Illicit discharge detection and elimination;
4) Construction site storm water runoff control;
5) Post-construction storm water management in new development and re-development;
6) Pollution prevention/good housekeeping for municipal (or TDOT) operations.

The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and description of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs. In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.

- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time.

- Instream biological monitoring at appropriate locations to demonstrate recovery of biological communities after implementation of storm water control measures.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of the monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

The WLAs provided to NPDES-regulated CAFOs will be implemented through the Nutrient Management Plan (NMP), liquid waste handling system, and Best Management Practices (BMP) provisions of NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*. All discharges, except during a catastrophic or chronic rainfall event, are not authorized by this permit. Any discharge shall not cause an exceedance of Tennessee water quality standards.

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of nutrient loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

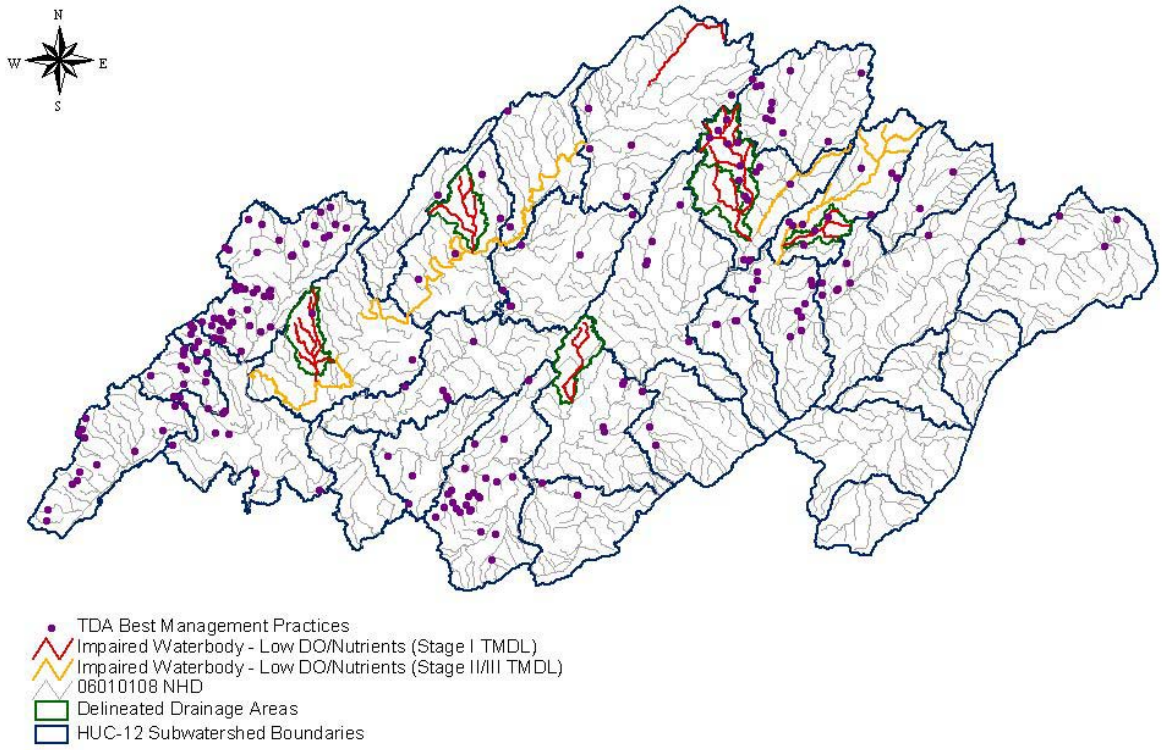
TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment,

TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and nongovernmental levels to be successful.

Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. One local stakeholder group, Middle Nolichucky Watershed Alliance (MNWA), is dedicated to improving the water quality of the Nolichucky River and its tributaries in Greene County, TN, through increasing public awareness about the sources of water pollution and the importance of each community member in protecting streams, rivers, and lakes. The MNWA is comprised of citizens interested in their community, local agency personnel, as well as state and federal representatives, which provide technical support for projects. Details regarding activities of the MNWA are available at their web site: (http://middlenolichuckywatershedalliance.org .

BMPs have been utilized in the Nolichucky River Watershed to reduce the amount of pollutants transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of nutrients and organic material in the Nolichucky River Watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Nolichucky River Watershed are shown in Figure 12.

Figure 12 Tennessee Department of Agriculture Best Management Practices in the Nolichucky River Watershed



9.3 Use of Load Duration Curve as a Guide to Implementation

The Load Duration Curve methodology (Appendix G) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. In discussing the use of load duration curves in TMDL development, Cleland states:

> A major advantage of the duration curve framework in TMDL development is the ability to meaningfully connect allocations to implementation efforts. Because the flow duration interval (FDI) provides a general indication of hydrologic condition (i.e. wet versus dry and to what degree), allocations and reduction targets can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g. high flow, moist, median flows, dry, and low flow) allows the development of allocation tables, which can be used to summarize potential implementation actions that most effectively address water quality concerns (Cleland, 2003).

Table 12 illustrates one example of an approach which could be used to assess management options for nutrient control in a way that considers the potential relative importance of hydrologic conditions using a duration curve framework (potential management practices may vary according to pollutant considered). A similar approach could be used based on the load duration curves developed in Appendix G for impaired waterbodies in the Nolichucky River Watershed (ref.: Figures G-1 through G-24).

Estimates of overall reductions in existing nutrient loading required to attain TMDLs were also calculated in Appendix G using the load duration curve methodology (Tables G-1 through G-12). These estimated reductions are summarized in Table 13 and are provided as a <u>guide for implementation only</u>. Estimated reductions in $CBOD_5$ loading were not developed due to lack of monitoring data.

Table 12 Example Use of Load Duration Curves to Evaluate Potential Control Measures (Based on Cleland, 2004)

Developing Solutions

Linking Load Duration Curves to Potential Control Measures

Control Measure		Duration Curve Zone				
		High	Moist	Mid-Range	Dry	Low
Agricultural Areas	Manure/Fertilizer Management		H	H	M	L
	Establish Riparian Buffer Zones		H	H	M	
	Erosion Control Measures		H	H	M	
	Limit Livestock Access to Streams		M	M	H	H
	Water Flow Management (Slow water flow, discharge runoff into filter areas, etc.)	M	H	H	M	
Urban Areas	Public Education/Outreach (Proper use of lawn fertilizers, water conservation, pet waste management, recycling, etc.)		M	H	M	L
	Laws & Ordinances (Pet waste disposal, low impact development, zoning, etc.)		M	H	M	L
	Elimination of Illicit Discharges			M	H	H
	SSO Repair/Abatement	H	H	M		
	Septic System Inspection/Repair	L	M	H	H	M
	Storm Drain Identification		M	H	H	M
	Establish Riparian Buffer Zones		H	H	M	
	Structural BMPs (Retention ponds, constructed wetlands, filtration systems, etc.)		M	H	H	
	Point Source Controls			M	H	H

Note: Potential relative importance of practice effectiveness under given hydrologic condition (H= High, M = Medium, L = Low)

Table 13 Estimates of Required Load Reductions for Impaired Subwatersheds & Drainage Areas

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Estimated Load Reduction	
		Total Nitrogen	Total Phosphorus
		[%]	[%]
Jockey Creek DA	Jockey Creek	51.5	83.4
Carson Creek DA	Carson Creek	53.2	88.0
Potter Creek DA	Potter Creek	39.9	69.1
Puncheon Camp Creek DA	Puncheon Camp Creek	41.4	46.0
0801	Lick Creek (Headwaters)	27.1	62.3
Richland Creek DA	Richland Creek	57.8	74.1
Hominy Creek DA	Hominy Creek	40.3	65.2

NR = No reduction required.

9.4 Evaluation of TMDL Effectiveness

The effectiveness of the TMDL will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of nutrient loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in $CBOD_5$ and nutrient loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed low dissolved oxygen & nutrient TMDLs for the Nolichucky River Watershed were placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

1) Notice of the proposed TMDLs 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 TMDLs (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) A letter was sent to the Water Quality Partners in the Nolichucky River Watershed. These partners include:

United States Environmental Protection Agency, Region IV
Natural Resources Conservation Service
Tennessee Department of Agriculture
The Nature Conservancy
Greene County Soil Conservation District
Upper Nolichucky Watershed Alliance
Middle Nolichucky Watershed Alliance
Smoky Mountain RC&D Council
The Appalachian Resource Conservation & Development Council

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in subwatersheds that contain waterbodies impaired due to low dissolved oxygen or nutrients. A draft copy was sent to the following entities:

City of Greeneville, Tennessee (TNS075710)
City of Jonesboro, Tennessee (TNS075728)
Washington County, Tennessee (TNS075787)
Tennessee Dept. of Transportation (TNS077585)

5) Letters were sent to WWTFs located in the Nolichucky River Watershed that would potentially be affected by Stage II or Stage III low dissolved oxygen/nutrient TMDLs, advising them of the proposed Stage I TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

Denzil Bowman WWTP (Greeneville STP) (TN0021229)
Jonesborough STP (TN0021547)
Davy Crockett High School (TN0024406)
John M. Reed Home, Inc. (TN0056332)
Ottway Elementary School (TN0058343)
Lick Creek Valley (Mosheim) WWTP (TN0059366)
Baileyton STP (TN0063932)

11.0 FURTHER INFORMATION

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

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

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

Nutrients & Water Quality

Nutrients and Water Quality

The following information was excerpted from *Protocol for Developing Nutrient TMDLs, First Edition* (USEPA, 1999). Minor formatting changes and the identification of the table have been made for inclusion in this TMDL document. References cited have been included on the last page of this Appendix.

Impact of Nutrients on Designated Uses

Excess nutrients in a waterbody can have many detrimental effects on designated or existing uses, including drinking water supply, recreational use, aquatic life use, and fishery use. For example, drinking water supplies can be impaired by nitrogen when nitrate concentrations exceed 10 mg/L and can cause methemoglobinemia (Blue Baby Syndrome) in infants. Water supplies containing more than 100 mg/L of nitrate can also taste bitter and can cause physiological distress (Straub, 1989).

Although these are examples of the direct impacts that can be associated with excessive nutrient loadings, waters more often are listed as impaired by nutrients because of their role in accelerating eutrophication. Eutrophication, or the nutrient enrichment of aquatic systems, is a natural aging process of a waterbody that transforms a lake into a swamp and ultimately into a field or forest. (The term *eutrophication* as used in this document refers to the nutrient enrichment of both lakes and rivers, although it is recognized that rivers do not have the same natural aging process.) This aging process can accelerate with excessive nutrient inputs because of the impact they have without other limiting factors, such as light.

A eutrophic system typically contains an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and macrophytes. Phytoplankton, photosynthetic microscopic organisms (algae), exist as individual cells or grouped together as clumps or filamentous mats. Periphyton is the assemblage of organisms that grow on underwater surfaces. It is commonly dominated by algae but also can include bacteria, yeasts, molds, protozoa, and other colony forming organisms. The term macrophyte refers to any larger than microscopic plant life in aquatic systems. Macrophytes may be vascular plants rooted in the sediment, such as pond weeds or cattails, or free-floating plant life, such as duckweed or coontail.

The eutrophication process can impair the designated uses of waterbodies as follows:

- *Aquatic life and fisheries.* A variety of impairments can result from the excessive plant growth associated with nutrient loadings. These impairments result primarily when dead plant matter settles to the bottom of a waterbody, stimulating microbial breakdown processes that require oxygen. Eventually, oxygen in the hypolimnion of lakes and reservoirs can be depleted, which can change the benthic community structure from aerobic to anaerobic organisms. Oxygen depletion also might occur nightly throughout the waterbody because of plant respiration. Extreme oxygen depletion can stress or eliminate desirable aquatic life and nutrients, and toxins also might be released from sediments when dissolved oxygen and pH are lowered (Brick and Moore, 1996).

Breakdown of dead organic matter in water also can produce un-ionized ammonia, which can adversely affect aquatic life. The fraction of ammonia present as un-ionized ammonia depends on temperature and pH. Fish may suffer a reduction in hatching success, reductions in growth rate and morphological development, and injury to gill tissue, liver, and kidneys. At certain ammonia levels fish also might suffer a loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and increased heart rate. At extreme ammonia levels, fish may experience convulsions, coma, and death (USEPA, 1986a; revised 1998b).

- *Drinking water supply.* Diatoms and filamentous algae can clog water treatment plant filters and reduce the time between backwashings (the process of reversing water flow through the water filter to remove debris). Disinfection of water supplies impaired by algal growth also might result in water that contains potentially carcinogenic disinfection byproducts, such as trihalomethanes. An increased rate of production and breakdown of plant matter also can adversely affect the taste and odor of the drinking water.

- *Recreational use.* The excessive plant growth in a eutrophic waterbody can affect recreational water use. Extensive growth of rooted macrophytes, periphyton, and mats of living and dead plant material can interfere with swimming, boating, and fishing activities, while the appearance of and odors emitted by decaying plant matter impair aesthetic uses of the waterbody.

Nutrient Sources and Transport

Both nitrogen and phosphorus reach surface waters at an elevated rate as a result of human activities. Phosphorus, because of its tendency to sorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Inorganic nitrogen, on the other hand, does not sorb as strongly and can be transported in both particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen also can be transported through the unsaturated zone (interflow) and ground water. Because nitrogen has a gaseous phase, it can be transported to surface water via atmospheric deposition. Phosphorus associated with fine-grained particulate matter also exists in the atmosphere. This sorbed phosphorus can enter natural waters by both dry fallout and rainfall. Finally, nutrients can be directly discharged to a waterbody via outfalls for wastewater treatment plants and combined sewer overflows. Table A-1 presents common point and nonpoint sources of nitrogen and phosphorus and the approximate associated concentrations.

Table A-1. Sources And Concentrations Of Nutrients from Common Point and Nonpoint Sources

Source	Nitrogen (mg/l)	Phosphorus (mg/l)
Urban Runoff	3-10	0.2 – 1.7
Livestock operations	6 – 800 [a]	4 – 5
Atmosphere (wet deposition)	0.9	0.015 [b]
Untreated wastewater	35	10
Treated wastewater (secondary treatment)	30	10

a As organic nitrogen; b Sorbed to airborne particulate
Source: Novotny and Olem, 1994

Once in the waterbody, nitrogen and phosphorus act differently. Because inorganic forms of nitrogen do not sorb strongly to particulate matter, they are more easily returned to the water. Phosphorus, on the other hand, can sorb to sediments in the water column and on the substrate and become unavailable. In lakes and reservoirs, continuous accumulation of sediment can leave some phosphorus too deep within the substrate to be reintroduced to the water column, if left undisturbed; however, a portion of the phosphorus in the substrate might be reintroduced to the water column. The activities of benthic invertebrates and changes in water chemistry (such as the reducing conditions of bottom waters and sediments often experienced during the summer months in a lake) also can cause phosphorus to desorb from sediment. A large, slow-moving river also might experience similar phosphorus releases. The sudden availability of phosphorus in the water column can stimulate algal growth. Because of this phenomenon, a reduction in phosphorus loading might not effectively reduce algal blooms for many years (Maki et al., 1983).

Nutrient Cycling

The transport of nutrients from their sources to the waterbody of concern is governed by several chemical, physical, and biological processes, which together compose the nitrogen or phosphorus cycle. Nutrient cycles are important to understand for developing a TMDL because of the information they provide about nutrient availability and the associated impact on plant growth.

Nitrogen

Nitrogen is plentiful in the environment. Almost 80 percent of the atmosphere by volume consists of nitrogen gas (N_2). Although largely available in the atmosphere, N_2 must be converted to other forms, such as nitrate (NO_3^-), before most plants and animals can use it. Conversion into usable forms, both in the terrestrial and aquatic environments, occurs through the four processes of the nitrogen cycle. Three of the processes—nitrogen fixation, ammonification, and nitrification—convert gaseous nitrogen into usable chemical forms. The fourth process, denitrification, converts fixed nitrogen back to the gaseous N_2 state.

- *Nitrogen fixation.* The conversion of gaseous nitrogen into ammonia ions (NH_3 and NH_4^+). Nitrogen-fixing organisms, such as blue-green algae (cyanobacteria) and the bacteria *Rhizobium* and *Azobacter*, split molecular nitrogen (N_2) into two free nitrogen molecules. The nitrogen molecules combine with hydrogen molecules to yield ammonia ions.

- *Ammonification.* A one-way reaction in which decomposer organisms break down wastes and nonliving organic tissues to amino acids, which are then oxidized to carbon dioxide, water, and ammonia ions. Ammonia is then available for absorption by plant matter.

- *Nitrification.* A two-step process by which ammonia ions are oxidized to nitrite and nitrate, yielding energy for decomposer organisms. Two groups of microorganisms are involved in the nitrification process. First, *Nitrosomonas* oxidizes ammonia ions to nitrite and water. Second, *Nitrobacter* oxidizes the nitrite ions to nitrate, which is then available for absorption by plant matter.

- *Denitrification.* The process by which nitrates are reduced to gaseous nitrogen by facultative anaerobes. Facultative anaerobes, such as fungi, can flourish in anoxic conditions because they break down oxygen containing compounds (e.g., NO_3^-) to obtain oxygen.

Once introduced into the aquatic environment, nitrogen can exist in several forms—dissolved nitrogen gas (N_2), ammonia (NH_4^+ and NH_3), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen as proteinaceous matter or in dissolved or particulate phases. The most important forms of nitrogen in terms of their immediate impact on water quality are the readily available ammonia ions, nitrites, and nitrates (dissolved nitrogen). (Note that plants cannot directly use nitrate but must first convert it to ammonium using the enzyme nitrate reductase. Because the ability to do this is ubiquitous, nitrate is considered to be bioavailable.) Particulate and organic nitrogen, because they must be converted to a usable form, are less important in the short term. Total nitrogen (TN) is a measurement of all forms of nitrogen.

Nitrogen continuously cycles in the aquatic environment, although the rate is temperature-controlled and thus very seasonal. Aquatic organisms incorporate available dissolved inorganic nitrogen into proteinaceous matter. Dead organisms decompose, and nitrogen is released as ammonia ions and then converted to nitrite and nitrate, where the process begins again. If a surface water lacks adequate nitrogen, nitrogen-fixing organisms can convert nitrogen from its gaseous phase to ammonia ions.

Phosphorus

Under normal conditions, phosphorus is scarce in the aquatic environment. Unlike nitrogen, phosphorus does not exist as a gas and therefore does not have gas-phase atmospheric inputs to aquatic systems. Rocks and natural phosphate deposits are the main reservoirs of natural phosphorus. Release of these deposits occurs through weathering, leaching, erosion, and mining. Terrestrial phosphorus cycling includes immobilizing inorganic phosphorus into calcium or iron phosphates, incorporating inorganic phosphorus into plants and microorganisms, and breaking down organic phosphorus to inorganic forms by bacteria. Some phosphorus is inevitably transported to aquatic systems by water or wind.

Nutrients and Water Quality

Phosphorus in freshwater and marine systems exists in either an organic or inorganic form.

- *Organic phosphorus.* Organic particulate phosphorus includes living and dead particulate matter, such as plankton and detritus. Organic nonparticulate phosphorus includes dissolved organic phosphorus excreted by organisms and colloidalphosphorus compounds.

- *Inorganic phosphorus.* The soluble inorganic phosphate forms $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}, known as soluble reactive phosphorus (SRP), are readily available to plants. Some condensed phosphate forms, such as those found in detergents, are inorganic but are not available for plant uptake. Inorganic particulate phosphorus includes phosphorus precipitates, phosphorus adsorbed to particulate, and amorphous phosphorus.

The measurement of all phosphorus forms in a water sample, including all the inorganic and organic particulate and soluble forms mentioned above, is known as total phosphorus (TP). TP does not distinguish between phosphorus currently unavailable to plants (organic and particulate) and that which is available (SRP). SRP is the most important form of phosphorus for supporting algal growth because it can be used directly. However, other fractions are transformed to more bioavailable forms at various rates dependent on microbial action or environmental conditions. In streams with relatively short residence times, it is less likely that the transformation from unavailable

to available forms will have time to occur and SRP is the most accurate estimate of biologically available nutrients. In lakes, however, where residence times are longer, TP generally is considered an adequate estimation of bioavailable phosphorus.

Phosphorus undergoes continuous transformations in a freshwater environment. Some phosphorus will sorb to sediments in the water column or substrate and be removed from circulation. Phytoplankton, periphyton, and bacteria assimilate the SRP (usually as orthophosphate) and change it into organic phosphorus. These organisms then may be ingested by detritivores or grazers, which in turn excrete some of the organic phosphorus as SRP. Some previously unavailable forms of phosphorus also convert to SRP. Continuing the cycle, the SRP is rapidly assimilated by plants and microbes.

Human activities have resulted in excessive loading of phosphorus into many freshwater systems. Overloads result in an imbalance of the natural cycling processes. Excess available phosphorus in freshwater systems can result in accelerated plant growth if other nutrients and other potentially limiting factors are available.

Other Limiting Factors

Many natural factors combine to determine rates of plant growth in a waterbody. First of these is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. In inland waters, typically phosphorus is the limiting nutrient of the two, because blue-green algae can “fix” elemental nitrogen from the water as a nutrient source. In marine waters, either phosphorus or nitrogen can be limiting. Although carbon and trace elements are usually abundant, occasionally they can serve as limiting nutrients. However, even if all necessary nutrients are available, plant production will not necessarily continue unchecked. Many natural factors, including light availability, temperature, flow levels, substrate, grazing, bedrock type and elevation, control the levels of macrophytes, periphyton, and phytoplankton in waters. Effective management of eutrophication in a waterbody may require a simultaneous evaluation of several limiting factors.

- *Light availability.* Shading of the water column inhibits plant growth. Numerous factors can shade waterbodies, including: (1) as plant production increases in the upper water layer, the organisms block the light and prevent it from traveling deeper into the water column; (2) riparian growth along waterbodies provides shade; and (3) particulates in the water column scatter light, decreasing the amount penetrating the water column and available for photosynthesis.

  With seasonally high particulate matter or shading (e.g., in deciduous forests), the high nutrients may cause excessive growth only during certain times of the year: for example, streams where snowmelt is common in the spring. Snowmelt could lead to high levels of suspended particulate matter and low algal biomass. During stable summer flows, however, there will be lower levels of suspended matter and hence higher algal biomass.

- *Temperature.* Temperature affects the rates of photosynthesis and algal growth, and composition of algal species. Depending on the plant, photosynthetic activity increases with temperature until a maximum photosynthetic output is reached, when photosynthesis declines (Smith, 1990). Moreover, algal community species composition in a waterbody often changes with temperature. For example, diatoms most often are the dominant algal species at water temperatures of 20 ° to 25 °C, green algae at 30 ° to 35 °C, and blue-green algae (cyanobacteria) above 35 °C (Dunne and Leopold, 1978; USEPA, 1986b).

- *Water Velocity.* Water movement in large lakes, rivers, and streams influences plant production. Stream velocity has a two-fold effect on periphyton productivity: increasing velocity to a certain level enhances biomass accrual but further increases can result in substantial scouring (Horner et al., 1990). Large lakes and estuaries can experience the scouring action of waves during strong storms (Quinn, 1991). In rivers and streams, frequent disturbance from floods (monthly or more frequently) and associated movement of bed materials can scour algae from the surface rapidly and often enough to prevent attainment of high biomass (Horner et al., 1990). Rapid flows can sweep planktonic algae from a river reach, while low flows may provide an opportunity for proliferation.

- *Substrate.* Macrophytes and periphyton are influenced by the type of substrate available. Macrophytes prefer areas of fine sediment in which to root (Wright and McDonnell, 1986, in Quinn, 1991). Thus, the addition and removal of sediment from a system can influence macrophyte growth. Periphyton, because of its need to attach to objects, grows best on large, rough substrates. A covering of sediment over a rocky substrate decreases periphyton biomass (Welch et al., 1992).

- *Grazing.* Dense populations of algae-consuming grazers can lead to negligible algal biomass, in spite of high levels of nutrients (Steinman, 1996). The existence of a “trophic cascade” (control of algal biomass by community composition of grazers and their predators) has been demonstrated for some streams (e.g., Power, 1990). Managers should realize the potential control of algal biomass by grazers, but they also should be aware that populations of grazers can fluctuate seasonally or unpredictably and fail to control biomass at times. Consideration of grazer populations might explain why some streams with high nutrients have low algal biomass.

- *Bedrock.* The natural effects of bedrock type also might help explain trophic state. Streams draining watersheds with phosphorus-rich rocks (such as rocks of sedimentary or volcanic origin) can be enriched naturally and, therefore, control of algal biomass by nutrient reduction in such systems might be difficult. Review of geologic maps and consultation with a local soil scientist might reveal such problems. Bedrock composition has been related to algal biomass in some systems (Biggs, 1995).

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APPENDIX B

Example of Stream Assessment
(Little Limestone Creek at Mile 12.7)

MACROINVERTEBRATE ASSESSMENT REPORT (Revised 10-06)

STATION NUMBER: LLIME012.7WN	LOG NUMBER: B0702007	
STREAM: Little Limestone Creek	ECOREGION(s): 67F	
LOCATION: D/S Co-op ditch	DATE: 11/22/06	
HUC/ADB SEGMENT: TN06010108	WATERSHED GROUP: 5	
STREAM ORDER: 3rd	DRAINAGE AREA:	
SAMPLED BY: BTB/TAR	ID BY: A.R.C.	SCORED BY: PDS 4/26/07

If new station send additional information requested on header of stream survey form to PAS

SAMPLE TYPE (circle one) **BIORECON** **SQBANK** **SQKICK**

BIORECON

METRIC	FAMILY LEVEL		GENUS LEVEL	
	Value	Score	Value	Score
Taxa Richness				
EPT Richness				
Intolerant Taxa				

BR INDEX SCORE:

COMMENTS :

SEMIQUANTITATIVE SAMPLE

Total number of individuals in subsample = 208

METRIC	VALUE	SCORE
Taxa Richness	23	4
EPT Richness	3	0
% EPT	37.0	4
% OC	41.8	4
NCBI	5.85	4
% Clingers	49.0	4
% Nutrient Tolerant	51.4	4

TMI SCORE: 24

COMMENTS :

HABITAT ASSESSMENT SCORE 127 RR/HIGH GRAD. (or) ___GP/LOW GRAD.

ABOVE BELOW HABITAT GUIDELINES FOR SUBREGION (Circle one)

METRICS - TENNESSEE CORE METRICS 4/26/2007

Stations.StationID	BenSamp.BenS	BenSamp.C	Ecoregion	IndexPe	CollMeth	M Tot	TotTa	EPT	%EPT	%OC	NCBI	%ClngI	%NutTol	%Chiro	%Oligo
LLIME012.7WN	B0702007	11/22/2006	67F	FALL	SQKICK	208	23	3	37.0	41.8	5.85	49.0	51.4	13.5	28.4

Sample taxa list 4/26/2007

BenSampID	Order	Family	FinalID	Individuals	Excluded Taxa	Comments
B0702007	Acarina	Acarina	Acarina	18	☐	
B0702007	Coleoptera	Elmidae	Optioservus	13	☐	
B0702007	Coleoptera	Elmidae	Stenelmis	4	☐	
B0702007	Diptera	Chironomidae	Chironomidae	5	☑	
B0702007	Diptera	Chironomidae	Cricotopus	13	☐	
B0702007	Diptera	Chironomidae	Eukiefferiella	1	☐	
B0702007	Diptera	Chironomidae	Micropsectra	1	☐	
B0702007	Diptera	Chironomidae	Parametriocne	1	☐	
B0702007	Diptera	Chironomidae	Rheocricotopus	1	☐	
B0702007	Diptera	Chironomidae	Rheotanytarsus	2	☐	
B0702007	Diptera	Chironomidae	Sublettea	1	☐	
B0702007	Diptera	Chironomidae	Tvetenia	3	☐	
B0702007	Diptera	Empididae	Chelifera	2	☐	
B0702007	Diptera	Tipulidae	Antocha	4	☐	
B0702007	Ephemeroptera	Baetidae	Baetidae	9	☐	
B0702007	Ephemeroptera	Baetidae	Baetis	2	☑	
B0702007	Haplonemertea	Tertastemmatid	Prostoma	1	☐	
B0702007	Isopoda	Asellidae	Caecidotea	2	☐	
B0702007	Trichoptera	Hydropsychida	Cheumatopsyc	27	☐	
B0702007	Trichoptera	Hydropsychida	Hydropsyche	27	☐	
B0702007	Trichoptera	Hydropsychida	Hydropsychida	12	☑	
B0702007	Tubificida	Naididae	Nais	53	☐	
B0702007	Tubificida	Naididae	Pristina	1	☐	
B0702007	Tubificida	Tubificidae	imm. w. cap. ch	1	☐	
B0702007	Tubificida	Tubificidae	imm. w/o cap. c	3	☐	
B0702007	Tubificida	Tubificidae	Limnodrilus	1	☐	

STREAM SURVEY FORM

H0611002

STREAM SURVEY INFORMATION (fill out all header information for new station and shaded fields for existing stations)

STORET NUMBER:	LLIME012.7WN	ASSESSORS:	KB LHR
STREAM NAME:	Little Limestone Creek	DATE:	11/22/06
STATION LOCATION:	d/s Co-op Ditch	TIME:	1130
COUNTY CODE:(FIPS)	179 (STATE CODE) 90	STREAM MILE:	12.7
WBID#/HUC:	06010108	STREAM ORDER:	3rd
HUC NAME:	Nolichucky	ADB SEGMENT	
LAT/LONG DEC:	36.28524 82.48261	3Q20:	
ECO'L SUBREGION:	67F	ELEVATION (ft):	
USGS QUAD:	198SW	GAZETTEER PAGE	
PROJECT/PURPOSE:			

SAMPLES COLLECTED

Aquatic Life Assessed: Macroinvertebrates Fish Algae Other:
Type of benthic sample: BIORECON RBP3/SQ KICK SQ BANK DENDY SURBER OTHER
CHEMICALS Yes No Previously

FIELD MEASUREMENTS

METERS USED:	Hydrolab	Insitu			Hydrolab	Insitu	
pH	7.79		SU	DISSOLVED OXYGEN	10.27		PPM
CONDUCTIVITY	462.4		UMHOS	TIME			
TEMPERATURE	11.11		°C	OTHERS			

Previous 48 hours Precip: UNKNOWN NONE LITTLE MODERATE HEAVY FLOODING
Ambient Weather: SUNNY CLOUDY BREEZY RAIN SNOW AIR TEMP:

WATERSHED CHARACTERISTICS App. % of watershed observed

UPSTREAM SURROUNDING LAND USE: (estimated %)

PASTURE		URBAN	50	RESID	40
CROPS		INDUSTRY		OTHER	10 ← Co-op
FOREST		MINING			

IMPACTS: rated S(light), M(oderate), H(igh) magnitude. Blank = not observed

CAUSES				SOURCES			
Pesticides (0200)	S	Flow Alter. (1500)		Pt. Source: Indust (0100)		Unknown (9000)	
Metals (0500)		Habitat Alt. (1600)	H	Logging (2000)		Municipal (2000)	
Ammonia (0600)		Thermal Alt. (1400)		Const;Land Devel (3200)	H	Mining (5000)	
Chlorine (0700)		Pathogens (1700)	H	U/S Dam (8800)		Road /bridge (3100)	
Nutrients (0900)	H	Oil & grease (1900)		Riparian loss (7600)	H	Urban Runoff (4000)	H
pH (1000)		Unknown (0000)		Agric: Row crop (1000)		Bank destabiliz (7700)	H
Organic Enrichment / Low D.O. (1200)		Siltation (1100)	H	Livestk grazing-ripar'n (1410)		Intensive Feedlot (1600)	
Other:				Other:		Dredging (7200)	

PHYSICAL STREAM CHARACTERISTICS LENGTH OF STREAM AREA ASSESSED (m): 350

SURROUNDING LAND USE (facing downstream):

ESTIMATE %	LDB	RDB		LDB	RDB		LDB	RDB
PASTURE			URBAN			RESID.		
CROPS			INDUSTRY	100 Coop		OTHER		100 RR Trail
FOREST			MINING					

% CANOPY COVER: Estimated: 15 Measured: Open(0-10) Partly Shaded(11-45) Mostly Shaded(46-80) Shaded(>80)
U/S_____ D/S_____ LB_____ RB_____

BANK HEIGHT (m): 3.6-6.0 HIGH WATER MARK (m): 1.2

SEDIMENT DEPOSITS: NONE SLIGHT MODERATE Heavy EXCESSIVE BLANKET
TYPE: SLUDGE MUD SAND SILT NONE OTHER_____ Contaminated Yes No
TURBIDITY CLEAR SLIGHT MODERATE HIGH OPAQUE

ALGAE PRESENT? NONE SLIGHT MODERATE CHOKING TYPE
AQUATIC VEGET. ROOTED FLOATING TYPE Moss
ADDITIONAL COMMENTS:(oil sheen, odor, colors) None

STREAM SURVEY FORM

PHYSICAL STREAM CHARACTERISTICS (cont.)

	RIFFLE	RUN	POOL
DEPTH (m)	0.05-0.065	0.08-0.15	0.3-0.5
WIDTH (m)	2.4	2.4	3.0
REACH LENGTH (m)	6.0	9.0	6.0

Staff Gauge/Bench Ht:
VELOCITY (FS)
FLOW (CFS)
HABITAT ASSESSMENT SCORE #: 127
RR # GP #

Gradient (sample reach): Flat Low Moderate High Cascade
Size (stream width) : V. Small (<1.5m) Small (1.5-3m) Med (3-10m) Large (10-25m) Very Lrg (>25m)

SUBSTRATE (Complete either particle count or estimate substate (%))

Particle Count - 100 measured particles (mm). **Circle one:** RIFFLE RUN

size (mm)	description	abbreviation
<0.062	silt/clay	cl
0.062-0.125	very fine sand	vfs
0.125-.250	fine sand	fs
0.25-0.50	med sand	ms
0.5-1.0	coarse sand	cs
1.0-2.0	very coarse san	(use actual size)
2.0-64.0	gravel	(use actual size)
64-256	cobble	(use actual size)
256-4096	boulder	(use actual size)
---	bedrock	bdrx
---	woody debris	wood

Record measured particle size. Use abbrev. below for smaller sizes.

1-10					
11-20					
21-30					
31-40					
41-50					
51-60					
61-70					
71-80					
81-90					
91-100					

SUBSTRATE (%) **(Visual estimates)**

	RIFFLE	RUN	POOL
BOULDER (> 10")	5 %	5 %	5 %
COBBLE (2.5-10")	20 %	20 %	10 %
GRAVEL (0.1-2.5")	40 %	40 %	30 %
BEDROCK	5 %	5 %	15 %
SAND (gritty)	10 %	10 %	%

	RIFFLE	RUN	POOL
CLAY (slick)	%	%	%
SILT	20 %	20 %	40 %
DETRITUS (CPOM)	%	%	%
MUCK-MUD (FPOM)	%	%	%
MARL (shell frags.)	%	%	%

STREAM USE SUPPORT: WATER WITHDRAWL NOTED Yes or No

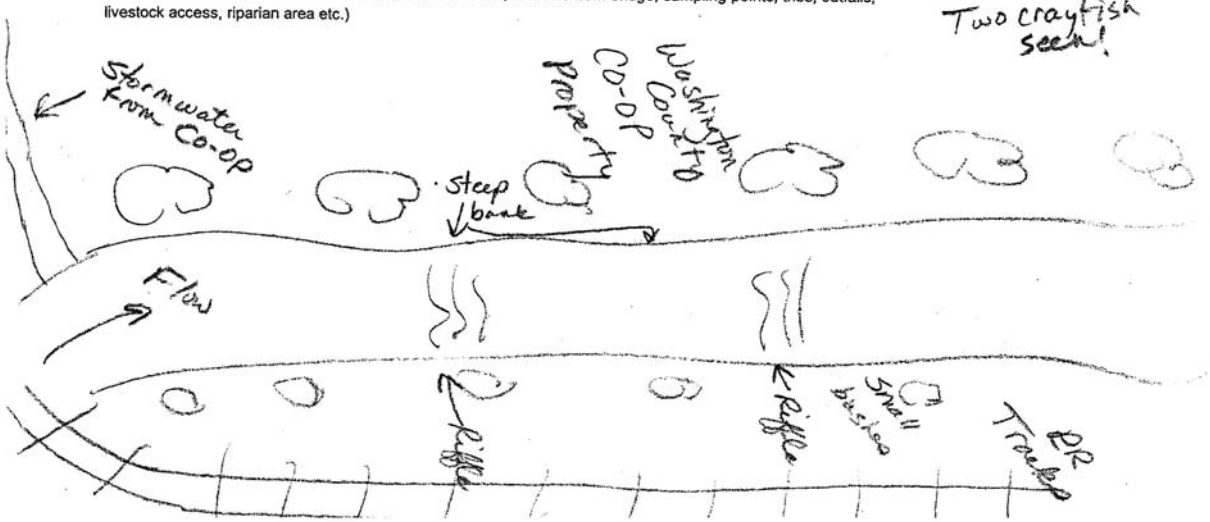
CLASSIFIED FOR:
Dom. H2O Supply — Ind. H2O Supply
TIER II/TIER III — Navigation
Trout >> — Nat. Repr?

POSTED FOR:
Bacteriological Advis.
Do Not Consume
Precautionary
Fish Tissue Advis.:

SUPPORT STATUS;
FULLY SUPPORTING (FS) PARTIALLY SUPPORTING (PS) SUPPORTING, BUT THREATENED (TH) NONSUPPORTING (NS)

Photos ?Y or N **Roll/Disc #** **Photo #ID** #/ID
#/ID #/ID

STREAM SKETCH (include flow direction, reach distance, distance from bridge, sampling points, tribs, outfalls, livestock access, riparian area etc.)



127

HABITAT ASSESSMENT DATA SHEET- HIGH GRADIENT STREAMS (FRONT)

Field No: H0611002

STREAM NAME LLIME Little Limestone	LOCATION 70 m D/S Coop Ditch
STATION # LLIME012.7WN RIVER MILE 12.7	ECOREGION 67F
LAT 36.28524 LONG 82.48261	RIVER BASIN Nolichucky
WBID/HUC 06010108	INVESTIGATORS TAR/BTB
FORM COMPLETED BY TAR	DATE 11/22/06 TIME 1130 (AM) PM

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 11	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 76% surrounded by fine sediment.
SCORE 12	20 19 18 17 16	15 14 13 (12) 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). Slow = <0.3m/s (12in); deep= >0.5m (20in).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE 16	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low –gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition in pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent, due to substantial sediment deposition.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 (7) 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25 % of channel substrate is exposed.	Waters fills 25-75 % of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel; mostly present as standing pools.
SCORE 20	(20) 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

HABITAT ASSESSMENT DATA SHEET- HIGH GRADIENT STREAMS (BACK)

STATION ID | DATE 11/22/00

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures, present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 15	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE 13	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60 % of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 7 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protective (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 6 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone) RB trace on RB	Width of riparian zone >18 meters; human activities (i.e. parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparia vegetation due to human activities.
SCORE 3 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE 127

TopoZone - Washington County, USGS Jonesborough (TN) Topo Map

Page 1 of 1

0 0.3 0.6 0.9 1.2 1.5 km

0 0.2 0.4 0.6 0.8 1 mi

RM 2.7

MPK

36.2852°N, 82.4826°W (NAD83/WGS84)

Washington County, USGS Jonesborough (TN) Quadrangle

Projection is UTM Zone 17 NAD83 Datum

M=-6.111
G=-0.878

Figure B-1 Little Limestone Creek at RM 12.7

Upstream and downstream views of Little Limestone Creek (LLIME012.7WN)
Downstream Washington County Co-op Ditch
11/22/06 B. Brown and T. Robinson

APPENDIX C

Land Use Distribution in Impaired Subwatersheds & Waterbody Drainage Areas

Table C-1 2001 MRLC Land Use Distribution of Impaired Subwatersheds & Drainage Areas

Land Use	Impaired Subwatershed (06010108____)							
	Carson Creek DA (part of Jockey Creek DA)		Jockey Creek DA		Hominy Creek DA		Potter Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Open Water	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Developed Open Space	258.2	4.21	473.3	4.25	168.8	6.87	191.7	4.05
Low Intensity Development	22.2	0.36	55.8	0.50	12.9	0.52	165.0	3.49
Medium Intensity Development	0.0	0.00	0.0	0.00	0.2	0.01	3.6	0.08
High Intensity Development	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Bare Rock	7.8	0.13	14.7	0.13	0.9	0.04	0.0	0.00
Deciduous Forest	888.5	14.49	1,556.1	13.98	379.4	15.43	980.8	20.73
Evergreen Forest	10.5	0.17	61.2	0.55	5.3	0.22	222.4	4.70
Mixed Forest	9.3	0.15	22.7	0.20	15.8	0.64	131.4	2.78
Shrub/Scrub	25.4	0.41	31.8	0.29	3.3	0.14	17.1	0.36
Grassland/Herbaceous	92.1	1.50	148.3	1.33	28.0	1.14	73.6	1.56
Pasture/Hay	4,228.9	68.95	7,804.1	70.13	1,803.4	73.35	2,646.3	55.93
Row Crops	588.2	9.59	955.4	8.59	40.5	1.65	298.2	6.30
Subtotal – Urban	280.4	4.57	529.1	4.75	181.9	7.40	360.3	7.62
Subtotal - Agriculture	4,817.1	78.54	8,759.5	78.72	1,843.9	75.00	2,944.5	62.24
Subtotal - Forest	1,035.7	16.89	1,839.0	16.53	432.8	17.60	1,426.2	30.15
Total	**6,133**	**100.00**	**11,128**	**100.00**	**2,459**	**100.00**	**4,731**	**100.0**

Table C-1 (Contd.) 2001 MRLC Land Use Distribution of Impaired Subwatersheds & Drainage Areas

Land Use	Impaired Subwatershed (06010108____)					
	Puncheon Camp Creek DA		Richland Creek DA		0801 (Lick Creek Headwaters)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.0	0.00
Open Water	0.0	0.00	0.0	0.00	10.0	0.02
Developed Open Space	218.4	4.72	790.2	17.24	2,468.1	5.35
Low Intensity Development	103.6	2.24	923.2	20.15	451.0	0.98
Medium Intensity Development	5.8	0.12	338.9	7.40	19.3	0.04
High Intensity Development	1.1	0.02	235.7	5.14	3.6	0.01
Bare Rock	7.1	0.15	0.0	0.00	43.4	0.09
Deciduous Forest	1,013.9	21.89	465.3	10.15	18,413.9	39.90
Evergreen Forest	150.3	3.25	12.7	0.28	563.6	1.22
Mixed Forest	77.8	1.68	11.8	0.26	385.4	0.84
Shrub/Scrub	30.7	0.66	2.4	0.05	135.0	0.29
Grassland/Herbaceous	79.8	1.72	35.6	0.78	850.7	1.84
Pasture/Hay	2,617.8	56.52	1,704.2	37.19	21,828.1	47.30
Row Crops	323.1	6.98	58.9	1.29	931.8	2.02
Woody Wetlands	2.0	0.04	3.3	0.07	44.7	0.10
Emergent Herbaceous Wetland	0.0	0.00	0.0	0.00	0.0	0.00
Subtotal – Urban	328.9	7.10	2,288.0	49.93	2,942.1	6.38
Subtotal - Agriculture	2,941.0	63.50	1,763.2	38.48	22,760.0	49.32
Subtotal - Forest	1,361.7	29.40	531.1	11.59	20,436.6	44.28
Total	**4,632**	**100.00**	**4,582**	**100.00**	**46,149**	**100.00**

APPENDIX D

Water Quality Monitoring Data in Impaired Waterbodies

Table D-1 Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
CARSON000.1WN	8/1/00	1027	8.24	0.04	0.48	2.38	2.86	0.13	21.71	5.89
	8/22/00	0950	8.9	<0.02	0.79	12.5	13.29	0.081	18.6	
	9/26/00	0945	8.61	0.13	0.89	1.60	2.49	1.07	16.05	
	10/17/00	1040	9.58	0.06	0.57	1.66	2.23	0.071	13.29	
	11/14/00	1000	10.41	0.6	0.22	1.52	1.74	0.107	9.1	
	12/12/00	1015	10.64	0.15	0.25	1.25	1.5	0.11	5.35	
	1/17/01	1015	m	0.02	0.21	1.30	1.51	0.04	7.64	
	2/13/01	0950	11.88	0.02	0.27	1.67	1.94	0.10	8.56	
	3/13/01	1005	10.78	0.09	0.40	2.40	2.8	0.24	11.71	
	4/17/01	0955	10.11	0.03	0.15	2.41	2.56	0.07	10.39	
	5/8/01	1025	9.18	0.07	0.21	1.91	2.12	0.16	16.18	
	6/5/01	0940	7.9	<0.02	1.19	1.24	2.43	0.16	22.77	
	7/11/01	1005	m	<0.02	0.45	2.50	2.95	0.17	m	
	10/24/01	1015	8.71	0.04	0.43	1.31	1.74	0.053	14.75	
	7/14/05	1010	6.01	0.19	0.77	0.94	1.71	0.15	21	
	8/10/05	0926	6.59	<0.03	1.35	1.21	2.56	0.23	21.99	
	9/14/05	1002	6.4	<0.03	1	0.55	1.55	0.12	19.08	
	10/18/05	0936	9.14	<0.03	<0.15	1.06	1.135	<0.02	11.64	
	11/3/05	0857	7.21	<0.03	0.64	1.1	1.74	<0.02	7.55	
	12/8/05	1057	12.5	<0.03	0.53	1.06	1.59	0.11	3.57	
	1/17/06	0931	5.5	0.62	<0.15	1.2	1.275	<0.02	7.28	
	2/6/06	1035	12.89	<0.03	0.9	2.3	3.2	0.32	2.64	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
CARSO001.8WN	8/22/00	0925	8.98	<0.02	0.33	2.48	2.81	0.035	17.7	
	9/26/00	0920	8.90	0.11	0.68	1.56	2.24	0.082	15.78	
	10/17/00	0915	9.97	0.05	0.35	1.10	1.45	<0.004	13.4	
	11/14/00	0930	10.95	0.04	0.20	1.63	1.83	0.061	9.16	
	12/12/00	0950	12.00	0.08	0.15	1.25	1.4	0.07	5.51	
	1/17/01	0920	14.92	0.03	0.28	1.44	1.72	0.03	2.45	
	2/13/01	0930	11.90	0.02	0.22	1.76	1.98	0.04	8.57	
	3/13/01	0935	10.71	<0.02	<0.10	2.50	2.55	0.03	11.26	
	4/17/01	0925	10.36	0.02	<0.10	2.39	2.44	0.04	10.07	
	5/8/01	1000	9.82	0.06	<0.10	2.03	2.08	0.08	15.51	
	6/5/01	0920	9.23	<0.02	0.49	1.26	1.75	0.04	22.52	
	10/24/01	0938	9.22	0.03	0.33	1.52	1.85	0.011	14.06	
HOMIN000.2WN	7/14/05	1005	8.45	<0.03	<0.15	1.2	1.275	0.02	18.32	
	8/10/05	0915	7.94	<0.03	<0.15	1.29	1.365	<0.02	18.97	
	9/14/05	0941	8.64	<0.03	0.51	1.1	1.61	0.04	16.68	
	10/20/05	0945	8.92	<0.03	<0.15	1.26	1.335	<0.02	14.15	
	11/3/05	0939	10.85	<0.03	0.5	1.3Z	1.8	<0.02	8	
	12/8/05	0911	11.63	<0.03	<0.15	1.15	1.225	<0.02	5.09	
	1/17/06	1027	9.40	<0.03	<0.15	1.3	1.375	<0.02	9.53	
	2/6/06	0935	11.81	<0.03	0.54	1.8	2.34	0.15	4.3	
	3/15/06	0939	11.69	<0.03	<0.15	1.6	1.675	<0.02	7.8	
	3/28/06	0951	9.71	<0.03	<0.15	1.7	1.775	0.05	9.7	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
HOMIN000.2WN (cont'd)	4/17/06	0947	9.79	<0.03	<0.15	0.82	0.895	<0.01	17.28	
	5/3/06	1001	9.43	<0.03	<0.15	1.9	1.975	<0.01	14.65	
	6/8/06	0943	8.38	<0.03	<0.15	1.6	1.675	0.05	16.36	
JOCKE000.1WN	8/1/00	1122	8.45	<0.02	0.55	2.38	2.93	0.150	21.47	12.63
	8/22/00	1000	8.71	0.08	0.23	2.81	3.04	0.053	17.79	
	9/26/00	1000	8.99	0.07	0.50	1.73	2.23	0.469	16.47	
	10/17/00	0955	9.95	<0.02	0.31	3.0	3.31	0.002	13.3	
	11/14/00	1010	10.87	<0.02	0.25	1.64	1.89	0.079	9.69	
	12/12/00	1030	11.61	0.07	0.13	1.26	1.39	0.040	6.05	
	1/17/01	1000	14.35	0.03	0.18	1.17	1.35	0.060	2.87	
	2/13/01	1000	11.89	0.04	0.24	1.69	1.93	0.090	8.69	
	3/13/01	1020	m	<0.02	0.15	2.40	2.55	0.060	m	
	4/17/01	1006	10.54	0.04	<0.10	2.39	2.44	0.060	10.54	
	5/8/01	1045	9.48	0.04	0.12	2.0	2.12	0.120	15.82	
	6/5/01	1005	8.23	<0.02	0.28	1.45	1.73	0.110	20.23	
	7/11/01	1020	m	<0.02	0.22	2.50	2.72	0.120	m	
	10/24/01	1030	8.6	<0.02	0.36	1.40	1.76	0.055	14.24	
	7/14/05	1030	5.31	<0.03	<0.15	1.2	1.275	0.080	20.37	
	8/10/05	0944	7.2	<0.03	0.8	1.74	2.54	0.010	21.6	
	9/14/05	1020	3.13	<0.03	0.54	0.88	1.42	0.100	18.3	
	10/18/05	0919	5.18	<0.03	<0.15	1.41	1.485	0.010	11.63	
	11/3/05	0909	9.65	<0.03	0.56Z	1.3Z	1.86	0.010	8.14	
	12/8/05	[b]	12.6	<0.03	<0.15	1.095	1.17	0.035	3.55	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
JOCKE000.1WN (cont'd)	1/17/06	0951	5.75	<0.03	0.79	1.3	2.09	0.140	7.51	
	2/6/06	1001	12.14	<0.03	0.8	2.2	3	0.250	2.74	
	3/15/06	1007	11.38	<0.03	<0.15	1.6	1.675	0.010	8.41	
	3/28/06	1053	10.21	<0.03	<0.15	1.9	1.975	0.077	9.38	
	4/17/06	1035	8.18	<0.03	<0.15	1.5	1.575	0.005	18.65	
	5/3/06	1051	8.46	<0.03	<0.15	2.5	2.575	0.005	15.51	
	6/8/06	1037	6.86	<0.03	<0.15	2.3	2.375	0.110	17.48	
JOCKE003.2GE	8/22/00	1038	11.1	<0.02	0.16	2.14	2.3	0.025	17.44	
	9/26/00	0935	9.62	0.02	0.33	1.77	2.1	0.039	14.43	
	10/17/00	1017	10.6	0.03	0.28	2.01	2.29	<0.004	12.89	
	11/14/00	0945	11	0.03	0.29	1.55	1.84	0.063	9.85	
	12/12/00	1000	12.15	0.03	0.11	1.40	1.51	0.04	6.56	
	1/17/01	0930	13.45	<0.02	<0.10	1.36	1.41	0.03	4.34	
	2/13/01	0940	11.76	<0.02	0.16	1.72	1.88	0.02	10.03	
	3/13/01	0950	10.67	0.04	<0.10	2.0	2.05	0.05	12.06	
	4/17/01	0940	10.62	<0.02	<0.10	2.22	2.27	0.04	10	
	5/8/01	1015	9.83	<0.02	<0.10	1.82	1.87	0.07	14.78	
	6/5/01	0930	10.04	<0.02	0.30	1.37	1.67	m	21.65	
	7/11/01	0955	m	<0.02	<0.10	1.69	1.74	0.10	m	
	10/24/01	1000	9.33	0.02	0.28	1.58	1.86	0.024	13.33	
LICK052.3WN	8/15/00	[b]	8.21	0.02	0.10	1.28	1.436	0.192	19.12	8.92
	9/14/00	1045	6.68	0.04	0.43	0.97	1.4	0.055	21.3	
	10/10/00	1005	9.86	<0.02	0.17	0.60	0.77	0.032	7.25	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
LICK052.3WN (cont'd)	11/7/00	1035	8.43	<0.02	0.10	0.09	0.19	0.012	12.3	
	12/5/00	1005	11.68	0.04	<0.10	0.91	0.96	0.022	2.57	
	1/4/01	1045	m	<0.02	<0.10	1.04	1.09	0.01	m	
	1/30/01	1030	10.6	0.03	0.19	2.04	2.23	0.04	6.46	
	2/28/01	1040	10.48	<0.02	<0.10	1.91	1.96	0.02	10.57	
	3/27/01	1025	13.12	<0.02	0.14	1.32	1.46	0.02	6.41	
	4/24/01	1017	7.88	<0.02	<0.10	0.98	1.03	<0.004	17.03	
	5/22/01	1040	6.82	0.04	<0.10	1.30	1.35	0.09	19.95	
	6/19/01	1035	7.38	0.02	0.10	1.42	1.52	0.11	20.75	
	7/24/01	1045	6.76	<0.02	0.21	1.46	1.67	0.09	21.79	
	9/12/01	1020	8.72	<0.02	<0.10	2.01	2.06	0.04	17.52	
	12/11/01	1001	9.59	0.07	0.34	1.0	1.34	0.103	8.65	
	7/20/05	0947	6.45	<0.03	<0.15	1.5	1.575	0.15	22.26	
	8/17/05	0937	5.44	<0.03	<0.15	0.99	1.065	<0.02	23.12	
	9/28/05	0945	6.33	<0.03	<0.15	0.54	0.615	<0.02	19.12	
	10/25/05	[b]	8.33	0.134	<0.15	0.06	0.315	<0.02	10.37	
	11/16/05	0935	5.6	<0.03	3.09	0.68	3.77	0.58	14.09	
	12/13/05	0935	10.57	<0.03	<0.15	0.68	0.755	0.1	2.4	
	1/18/06	0915	10.24	<0.03	1.4	1.32	2.72	0.5	6.57	
	2/21/06	0927	11.82	<0.03	<0.15	0.73	0.805	<0.02	4.9	
	3/20/06	1013	10.26	<0.03	<0.15	0.96	1.035	0.048	7.42	
	4/24/06	0905	8.27	<0.03	<0.15	1.7	1.775	<0.01	15.03	
	5/16/06	0925	9.18	<0.03	<0.15	0.13	0.205	0.06	12.48	
	6/20/06	0910	7.63	<0.03	<0.15	2.0	2.075	0.09	18.34	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
LICK061.0WN	8/15/00	[b]	8.97	<0.02	0.35	1.16	1.529	0.031	17.29	1.53
	9/14/00	0945	7.18	0.03	2.04	1.08	3.12	0.122	19.11	
	10/10/00	0920	10.05	<0.02	0.11	0.86	0.97	0.032	6.35	
	11/7/00	0940	8.09	<0.02	0.28	0.66	0.94	0.028	12.23	
	12/5/00	0910	11.6	0.06	0.52	1.47	1.99	0.146	4.65	
	1/4/01	0935	11.82	<0.02	<0.10	1.04	1.09	0.02	0.78	
	1/30/01	0940	10.4	0.03	0.22	1.07	1.29	0.03	6.95	
	2/28/01	0935	10.64	<0.02	<0.10	1.18	1.23	0.01	10.03	
	3/27/01	0930	12.18	<0.02	<0.10	0.92	0.97	0.02	5.47	
	4/24/01	0920	8.32	<0.02	<0.10	0.75	0.8	<0.004	15.53	
	5/22/01	0950	7.54	0.04	<0.10	1.05	1.1	0.09	18.43	
	6/19/01	0940	8.24	<0.02	0.13	1.19	1.32	0.07	19.29	
	7/24/01	0930	6.96	<0.02	<0.10	1.19	1.24	0.03	19.66	
	9/12/01	0940	8.97	<0.02	<0.10	1.39	1.44	0.01	16.58	
	12/11/01	0911	9.48	0.07	0.28	0.68	0.96	0.030	8.68	
	7/20/05	0915	7.18	<0.03	<0.15	1.2	1.275	<0.02	20.47	
	8/17/05	0907	6.07	<0.03	<0.15	0.86	0.935	<0.02	21.15	
	9/28/05	0915	6.41	<0.03	<0.15	0.61	0.685	<0.02	17.4	
	10/25/05	0920	8.36	<0.03	<0.15	0.76	0.835	<0.02	9.71	
	11/16/05	0930	6.31	0.23	0.71	0.78	1.49	<0.02	14.66	
	12/13/05	0926	10.95	<0.03	<0.15	0.57	0.645	<0.02	2.64	
	1/18/06	0920	9.44	<0.03	0.71	1.4	2.11	0.15	6.72	
	2/21/06	0918	11.57	<0.03	<0.15	0.59	0.665	<0.02	5.32	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
LICK061.0WN (cont'd)	3/20/06	0934	10.69	<0.03	<0.15	0.77	0.845	<0.008	7.02	
	4/24/06	0852	8.87	<0.03	<0.15	0.9	0.975	<0.01	13.7	
	5/16/06	0910	9.34	<0.03	<0.15	0.77	0.845	0.02	12.34	
	6/20/06	0900	7.71	<0.03	0.51	1.4	1.91	0.01	17.23	
PCAMP000.5GE	8/15/00	1217	3.55	0.05	0.69	0.08	0.77	0.105	19.33	
	7/20/05	1013	5.08	<0.03	0.67	0.9	1.57	0.2	22.94	
	8/17/05	1009	m	<0.03	0.79	0.11	0.9	0.16	m	
	12/13/05	[b]	8.00	<0.03	0.68	0.68	1.36	0.037	2.57	
	1/18/06	[b]	10.87	<0.03	1.30	2	3.30	0.445	5.16	
	2/21/06	0953	11.05	<0.03	<0.15	0.41	0.49	0.010	m	
	3/20/06	[b]	10.54	<0.03	<0.15	<0.006	0.08	0.040	6.17	
	4/24/06	[b]	7.67	<0.03	0.39	0.58	0.84	0.005	15.39	
	5/16/06	0935	8.11	<0.03	<0.15	0.21	0.285	0.06	12.12	
	6/20/06	0935	3.08	0.2	<0.15	0.18	0.255	0.1	19.76	
POTTE000.3GE	12/5/00	1015	12.21	0.4	1.29	1.77	3.06	0.214	2.26	
	1/4/01	1020	13.4	0.4	1.08	0.61	1.69	0.22	1.53	
	1/30/01	1017	11.5	0.19	0.49	1.23	1.72	0.18	6.21	
	2/28/01	1020	10.95	0.03	0.33	1.18	1.51	0.11	10.98	
	3/27/01	1020	11.61	0.08	0.53	0.82	1.35	0.09	6.54	
	4/24/01	1005	7.51	0.06	0.44	0.50	0.94	0.09	18.01	
	5/22/01	1030	5.07	0.59	0.85	0.23	1.08	0.23	20.14	
	6/19/01	1025	3.97	3.9	8.70	0.30	9	0.43	21.65	
	7/24/01	1035	0.9	11.6	30	0.06	30.06	1.23	23.24	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
POTTE000.3GE (cont'd)	9/12/01	1036	1.6	0.42	0.54	0.26	0.8	0.18	19.12	
	12/11/01	1005	9.65	0.17	0.86	1.03	1.89	0.32	9.38	
	7/20/05	1204	5.33	<0.03	<0.15	0.68	0.755	<0.02	24.31	
	8/17/05	1118	4.69	<0.03	<0.15	0.25	0.325	<0.02	24.65	
	9/28/05	1136	3.7	<0.03	0.51	<0.006	0.513	<0.02	18.92	
	10/25/05	1112	4.78	<0.03	0.67	<0.006	0.673	<0.02	9.47	
	11/16/05	1134	3.79	<0.03	0.67	0.67	1.34	<0.02	13.33	
	12/13/05	1125	12.19	<0.03	0.65	0.61	1.26	<0.02	2.34	
	1/18/06	1116	10.32	<0.03	1.2	0.91	2.11	0.39	5.82	
	2/21/06	1110	14.09	<0.03	<0.15	0.65	0.725	<0.02	4.93	
	3/20/06	1148	10.86	<0.03	<0.15	0.71	0.785	0.059	6.23	
	4/24/06	1042	3.48	<0.03	0.55	0.25	0.8	<0.01	18.25	
	5/16/06	1100	8.75	<0.03	<0.15	0.53	0.605	0.03	13.38	
	6/20/06	1140	6.84	<0.03	<0.15	1.0	1.075	0.07	22.12	
RICHL004.3GE	8/2/00	1215	8.97	0.07	0.28	1.87	2.15	0.033	18.66	
	8/29/00	1115	9.2	<0.02	<0.10	1.56	1.61	0.043	18.26	
	9/19/00	1100	9.61	0.03	0.22	1.65	1.87	0.140	16.18	
	10/24/00	1030	9.85	<0.02	0.26	1.19	1.45	0.010	15.51	
	11/29/00	1045	10.08	0.02	0.12	1.39	1.51	0.033	9.5	
	12/14/00	1100	11.28	0.63	1.59	1.32	2.91	0.18	9.16	
	1/9/01	1100	12.44	0.63	0.77	2.01	2.78	0.13	5.73	
	2/5/01	1035	10.79	<0.02	<0.10	1.50	1.55	0.02	8.46	
	3/7/01	1150	8.56	<0.02	<0.10	2.01	2.06	<0.004	8.7	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
RICHL004.3GE (cont'd)	4/4/01	1045	10.4	0.5	0.65	2.38	3.03	0.14	13.19	
	5/1/01	1102	9.56	<0.02	<0.10	1.61	1.66	0.03	15.76	
	5/29/01	1025	9.28	<0.02	<0.10	1.76	1.81	0.07	16.45	
	6/26/01	1220	m	<0.02	0.17	1.71	1.88	0.10	m	
	8/22/01	1100	8.49	<0.02	<0.10	1.89	1.94	<0.004	16.81	
	11/14/01	1020	11.86	<0.02	<0.10	1.22	1.27	<0.004	9.06	
RICHL006.0GE	8/21/00	1807	10.63	<0.02	0.17	2	2.17	0.027	19.22	2.26
	7/14/05	1120	8.21	<0.03	<0.15	1.3	1.38	0.04	18.51	
	8/10/05	1015	7.1	<0.03	<0.15	2.31	2.39	0.02	18.23	
	9/14/05	1113	8.49	<0.03	1.5	1.3	2.80	0.07	16.89	
	10/20/05	1101	8.03	<0.03	<0.15	1.43	1.51	<0.02	15.51	
	11/3/05	1047	9.21	<0.03	0.58	1.44	2.02	<0.02	10.55	
	12/8/05	1135	11.04	<0.03	<0.15	1.16	1.24	<0.02	8.44	
	1/17/06	1135	9.87	0.85	<0.15	1.8	1.88	<0.02	11.12	
	2/6/06	1121	12.54	<0.03	<0.15	2	2.08	<0.02	8.23	
	3/15/06	1112	9.2	<0.03	<0.15	1.8	1.88	0.081	10.78	
	3/28/06	1130	9.12	<0.03	<0.15	2	2.08	0.076	11.68	
	4/17/06	1130	9.57	<0.03	<0.15	1.9	1.98	<0.01	18.24	
	5/3/06	1108	8.55	<0.03	<0.15	2.0	2.08	0.01	15.29	
	6/8/06	1100	m	<0.03	<0.15	1.4	1.48	0.06	m	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Nolichucky River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen [a]	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
RICHL007.1GE	8/2/00	1200	7.72	0.17	0.37	3.34	3.71	0.051	17.79	
	8/29/00	1055	8.48	<0.02	<0.10	1.78	1.83	0.025	17.7	
	9/19/00	1050	8.75	<0.02	1.35	1.89	3.24	0.347	16.8	
	10/24/00	1015	9.21	<0.02	0.15	1.59	1.74	<0.004	m	
	11/29/00	1030	9.22	0.03	0.16	1.74	1.9	0.056	11.29	
	12/14/00	1045	9.94	0.76	1.77	1.75	3.52	0.27	9.7	
	1/9/01	1040	11.75	0.21	0.16	1.94	2.1	0.08	7.26	
	2/5/01	1020	10.13	<0.02	<0.10	1.79	1.84	0.02	9.78	
	3/7/01	1130	8.25	<0.02	<0.10	2.30	2.35	0.02	10.45	
	4/4/01	1030	9.84	0.92	0.90	2.49	3.39	0.20	13.82	
	5/1/01	1047	9.59	<0.02	<0.10	1.81	1.86	0.05	16.02	
	5/29/01	1010	8.77	<0.02	<0.10	1.92	1.97	0.02	16.35	
	6/26/01	1205	m	<0.02	0.45	1.96	2.41	0.11	m	
	8/22/01	1045	8.33	<0.02	<0.10	2.14	2.19	<0.004	16.8	
	11/14/01	1005	10.38	0.08	<0.10	1.58	1.63	<0.004	10.59	

Note: m = missing sample data.

[a] For all stations, total nitrogen data corresponds to sum of NO3+NO2 plus TKN for each sample data. If either NO3+NO2 or TKN is missing, the value for Total Nitrogen will be skewed.

[b] Value shown is geometric mean of multiple measures on sample date.

APPENDIX E

Development of Nutrients & $CBOD_5$ TMDLs, WLAs, & LAs – Annual Loading

DEVELOPMENT OF STAGE I NUTRIENTS & $CBOD_5$ TMDLS

Nutrient and $CBOD_5$ target concentrations for Level IV ecoregions 67f, 67g, & 67h were used to develop Stage I nutrients TMDLs for the Nolichucky River Watershed using the procedure outlined below.

E.1 Development of Target Nutrients Loads for Level IV Ecoregions

1. Reference sites for Level IV ecoregions 67f, 67g, & 67h were identified (see Figure E-1) and the watershed, corresponding to USGS 8-digit hydrologic unit codes (HUCs), in which each site was located noted. This information is summarized in Table E-1.

Table E-1 Location of Level IV Ecoregion Reference Sites

Level IV Ecoregion	Reference Site	Stream	Watershed	
			Name	HUC
67f	ECO67F06	Clear Creek	Lower Clinch	06010207
	ECO67F13	White Creek	Upper Clinch	06010205
	ECO67F14	Powell River	Powell	06010206
	ECO67F16	Hardy Creek	Powell	06010206
	ECO67F17	Big War Creek	Upper Clinch	06010205
	ECO67F23	Martin Creek	Powell	06010206
	ECO67F25	Powell River	Powell	06010206
67g	ECO67G01	Little Chucky Creek	Nolichucky	06010108
	ECO67G05	Bent Creek	Nolichucky	06010108
	ECO67G08	Brymer Creek	Hiwassee	06020002
	ECO67G09	Harris Creek	Hiwassee	06020002
	ECO67G10	Flat Creek	Lower French Broad	06010107
67h	ECO67H06	Laurel Creek	Little Tennessee	06010204

Note: Ecoregion reference sites are continuously reviewed, with sites added or deleted as circumstances warrant. The sites shown were the ecoregion reference sites as of April 30, 2005.

2. Using the Loading Simulation Program in C++ (LSPC), each 8-digit HUC containing a Level IV ecoregion reference site was calibrated for hydrology (LSPC is based on the Hydrological Simulation Program – Fortran [HSPF] and has been utilized extensively for pathogen TMDLs in EPA Region IV). The calibrations were performed over a 10-year period using an appropriate USGS continuous gaging station. Special attention was paid to total volume of water, both on a yearly basis as well as for the entire 10-year period.
3. The calibrated watershed models were then utilized to simulate the daily flow at each ecoregion reference site for a 10-year period.
4. The total nitrogen target concentration (ref. Section 5.2) was applied to each daily flow at each ecoregion reference site to generate daily total nitrogen loads.

5. The average annual total nitrogen loads for each ecoregion reference site were calculated by summing the daily loads for the 10-year period and dividing by 10.

6. The average annual total nitrogen loads, on a unit area basis, were calculated for each ecoregion reference site by dividing the average annual loads (Step 4) by the corresponding reference site drainage areas. Average annual total nitrogen loads per unit area are shown in Table E-2 for each ecoregion reference site.

7. The average annual total nitrogen load per unit area for Level IV ecoregion 67f was determined by calculating the geometric mean of annual total nitrogen loads per unit area (Step 5) of the seven ecoregion 67f reference sites. The target average annual total nitrogen loads per unit area for Level IV ecoregions 67f (5 sites) & 67h (1 site) were determined in a similar manner.

8. Steps 3 through 6 were repeated for total phosphorus and $CBOD_5$. Target nutrient and $CBOD_5$ loads, on a unit area basis, for Level IV ecoregions 67f, 67g & 67h are summarized in Table E-3.

Table E-2 Average Annual Nutrients & $CBOD_5$ Loads for Ecoregion Reference Sites

Ecoregion Reference Site	Total Nitrogen	Total Phosphorus	$CBOD_5$
	[lbs/ac/yr]	[lbs/ac/yr]	[lbs/ac/yr]
ECO67F06	3.2861	0.0458	5.2831
ECO67F13	3.2864	0.0458	5.2836
ECO67F14	1.5185	0.0212	2.4413
ECO67F16	3.0771	0.0429	4.9471
ECO67F17	3.4347	0.0479	5.5221
ECO67F23	3.4870	0.0486	5.6062
ECO67F25	3.1395	0.0437	5.0475
ECO67G01	0.2977	0.0163	0.4519
ECO67G05	0.2791	0.0153	0.4238
ECO67G08	4.0076	0.2190	6.0844
ECO67G09	3.9115	0.2138	5.9385
ECO67G10	8.3095	0.4542	12.6157
ECO67H06	4.5105	0.0423	5.2857

Table E-3 Target Nutrients & $CBOD_5$ Loads for Level IV Ecoregions 67f, 67g, & 67h

Level IV Ecoregion	Total Nitrogen	Total Phosphorus	$CBOD_5$
	[lbs/ac/yr]	[lbs/ac/yr]	[lbs/ac/yr]
67f	2.9397	0.0410	4.7263
67g	1.6102	0.0880	2.4446
67h	4.5105	0.0423	5.2857

E.2 Development of Nutrients TMDLs

Note: The following procedure describes development of the annual loading portion of nutrients and $CBOD_5$ TMDLs. Calculations for Subwatershed 060101080801 (Upper Lick Creek) are shown. The process for other subwatersheds and drainage areas is similar.

9. Since Subwatershed 060101080801 is approximately 68% in ecoregion 67f, 30% in ecoregion 67g, and 2% in ecoregion 67h, target nutrient loads for the subwatershed as a whole were based on an area-weighted combination of the ecoregion target loads:

$$TMDL_{0801} = (TL_{67f})\,(A_{67f}) + (TL_{67g})\,(A_{67g}) + (TL_{67h})\,(A_{67h})$$

where: $TMDL_{0801}$ = TMDL for Subwatershed 0801 [lbs/yr]
TL_{67f} = Target load for ecoregion 67f [lbs/acre/yr]
A_{67f} = Area of Subwatershed 0801 in ecoregion 67f [acres]
TL_{67g} = Target load for ecoregion 67g [lbs/acre/yr]
A_{67g} = Area of Subwatershed 0801 in ecoregion 67g [acres]
TL_{67h} = Target load for ecoregion 67h [lbs/acre/yr]
A_{67h} = Area of Subwatershed 0801 in ecoregion 67h [acres]

As an example, for total nitrogen:

$$TMDL_{0801} = (2.9397 \text{ lbs/ac/yr})\,(31{,}432 \text{ ac}) + (1.6102 \text{ lbs/ac/yr})\,(13{,}785 \text{ ac}) + (4.5105 \text{ lbs/ac/yr})\,(932 \text{ ac})$$

$$TMDL_{0801} = 118{,}802 \text{ lbs/yr}$$

For total phosphorus:

$$TMDL_{0801} = (0.0410 \text{ lbs/ac/yr})\,(31{,}432 \text{ ac}) + (0.0880 \text{ lbs/ac/yr})\,(13{,}785 \text{ ac}) + (0.0423 \text{ lbs/ac/yr})\,(932 \text{ ac})$$

$$TMDL_{0801} = 2{,}541 \text{ lbs/yr}$$

For $CBOD_5$:

$$TMDL_{0801} = (4.7263 \text{ lbs/ac/yr})\,(31{,}432 \text{ ac}) + (2.4446 \text{ lbs/ac/yr})\,(13{,}785 \text{ ac}) + (5.2857 \text{ lbs/ac/yr})\,(932 \text{ ac})$$

$$TMDL_{0801} = 187{,}183 \text{ lbs/yr}$$

Note: Calculations were performed using a spreadsheet program and may differ slightly from example values due to round off.

The annual loading portions of TMDLs for impaired HUC-12 subwatersheds and waterbody drainage areas are summarized in Table E-4. $CBOD_5$ TMDLs were only developed for subwatersheds with low dissolved oxygen specifically identified as a cause of impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that drop below 5 mg/l.

E.3 Development of Waste Load Allocations (WLAs) & Load Allocations (LAs)

Note: The following procedure describes development of the annual loading portion of nutrient and $CBOD_5$ WLAs & LAs

Determination of Waste Load Allocations for WWTFs

As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing WWTF discharges will be developed as part of Stages II & III and are not included in this document.

Determination of Waste Load Allocations for CAFOs

CAFOs are not authorized to discharge process wastewater from a liquid waste handling system except during a catastrophic or chronic rainfall event. Any discharges made under these circumstances, or as a result of a system upset or bypass, are not to cause an exceedance of Tennessee water quality standards. Therefore, a WLA of zero has been assigned to this class of facilities.

Determination of Waste Load Allocations for Municipal Separate Storm Sewer Systems & Load Allocations for Nonpoint Sources

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

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

where (ΣWLAs) includes the contributions from all WWTFs, CAFOs, and MS4s

Expanding the terms:

$$TMDL = (\Sigma\ WLA_{WWTF}) + [Load]_{MS4} + (\Sigma\ WLA_{CAFO}) + [Load]_{NPS} + MOS$$

where: TMDL = [lbs/yr]
$\Sigma\ WLA_{WWTF}$ = WLA for all WWTFs in the subwatershed [lbs/yr]
$\Sigma\ WLA_{CAFO}$ = WLA for all CAFOs in the subwatershed [lbs/yr]
$[Load]_{MS4}$ = Average annual nutrient load from all MS4 discharges [lbs/yr]
$[Load]_{NPS}$ = Average annual nutrient load from all nonpoint sources [lbs/yr]
MOS = Explicit Margin of Safety [lbs/yr]

Solving for $[Load]_{MS4} + [Load]_{NPS}$:

$$[Load]_{MS4} + [Load]_{NPS} = (TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS$$

If the $[Load]_{MS4}$ & $[Load]_{NPS}$ terms are expanded:

$$\Sigma[(WLA_{MS4})\ (A_{MS4})] + \Sigma[(LA_{NPS})\ (A_{NPS})] = (TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS$$

where: WLA_{MS4} = WLA for MS4s on a unit area basis [lbs/ac/yr]
LA_{NPS} = LA for nonpoint sources on a unit area basis [lbs/ac/yr]
A_{MS4} = Drainage area of MS4s [acres]
A_{NPS} = Drainage area of nonpoint sources [acres]

If $(WLA_{MS4}) = (LA_{NPS})$, and noting that $(\Sigma\ A_{MS4}) + (\Sigma\ A_{NPS}) \approx (A_{subw})$, then the left side of the above equation can be rewritten as:

$$\Sigma[(WLA_{MS4})\ (A_{MS4})] + \Sigma[(LA_{NPS})\ (A_{NPS})] = (LA_{NPS})\ [(\Sigma\ A_{MS4}) + (\Sigma\ A_{NPS})]$$
$$= (LA_{NPS})\ (A_{subw})$$

therefore:

$$(LA_{NPS})\ (A_{subw}) = (TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS$$

Solving for (LA_{NPS}):

$$(LA_{NPS}) = \frac{(TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS}{(A_{subw})}$$

The calculation for total nitrogen in HUC-12 Subwatershed 0801 is shown as an example. Calculations for total phosphorus & $CBOD_5$ are similar.

<u>Total Nitrogen in Subwatershed 0801</u>

$$LA_{NPS} = \frac{TMDL - (\Sigma WLA_{WWTF}) - (\Sigma WLA_{CAFO}) - MOS}{(A_{subw})}$$

Using an explicit MOS = equal to 5% of the TMDL and noting that for Stage I, $\Sigma WLA_{WWTF} = 0$:

$$LA_{NPS} = \frac{TMDL - (0) - (\Sigma WLA_{CAFO}) - \{(0.05)\ (TMDL)\}}{(A_{subw})}$$

$$LA_{NPS} = \frac{\{(0.95)\ (TMDL)\} - (\Sigma WLA_{CAFO})}{(A_{subw})}$$

Substituting the appropriate values from Tables E-4 & C-1 and noting that $WLA_{CAFO} = 0$:

$$LA_{NPS} = \frac{[(0.95)\ (118{,}802\ \text{lbs/yr})] - (0)}{(46{,}149\ \text{ac})}$$

therefore:

$$LA_{NPS} = WLA_{MS4} = 2.4456\ \text{lbs/ac/yr}$$

The annual loading portion of stage I nutrient WLAs for MS4s & CAFOs, and LAs for nonpoint sources are summarized in Table E-4 for total nitrogen, Table E-5 for total phosphorus, and Table E-6 for $CBOD_5$. WLAs for MS4s apply only to MS4 discharges into impaired subwatersheds and drainage areas. WLAs for CAFOs apply to existing and future entities.

Table E-4 Summary of Stage I Total Nitrogen TMDLs, WLAs, & LAs - Annual Loading Table

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA[b] MS4s [a]	LA
			[lbs/yr]	[lbs/ac/yr]	[lbs/ac/yr]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	32,713	2.7927	2.7927
Carson Ck DA	Carson Creek	TN06010108030-0220	18,029	2.7927	2.7927
Potter Ck DA	Potter Creek	TN06010108035-0200	10,527	2.1138	2.1138
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	7,458	1.5297	1.5297
0801	Lick Creek (headwaters)	TN06010108035-9000	118,802	2.4456	2.4456
Richland Ck DA	Richland Creek	TN06010108102-2000	13,470	2.7927	2.7927
Hominy Ck DA	Hominy Creek	TN06010108510-0400	7,229	2.7927	2.7927

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.

Table E-5 Summary of Stage I Total Phosphorus TMDLs, WLAs, & LAs - Annual Loading

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA[b] MS4s [a]	LA
			[lbs/yr]	[lbs/ac/yr]	[lbs/ac/yr]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	456	0.0390	0.0390
Carson Ck DA	Carson Creek	TN06010108030-0220	251	0.0390	0.0390
Potter Ck DA	Potter Creek	TN06010108035-0200	370	0.0744	0.0744
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	408	0.0836	0.0836
0801	Lick Creek (headwaters)	TN06010108035-9000	2,541	0.0523	0.0523
Richland Ck DA	Richland Creek	TN06010108102-2000	186	0.0390	0.0390
Hominy Ck DA	Hominy Creek	TN06010108510-0400	101	0.0390	0.0390

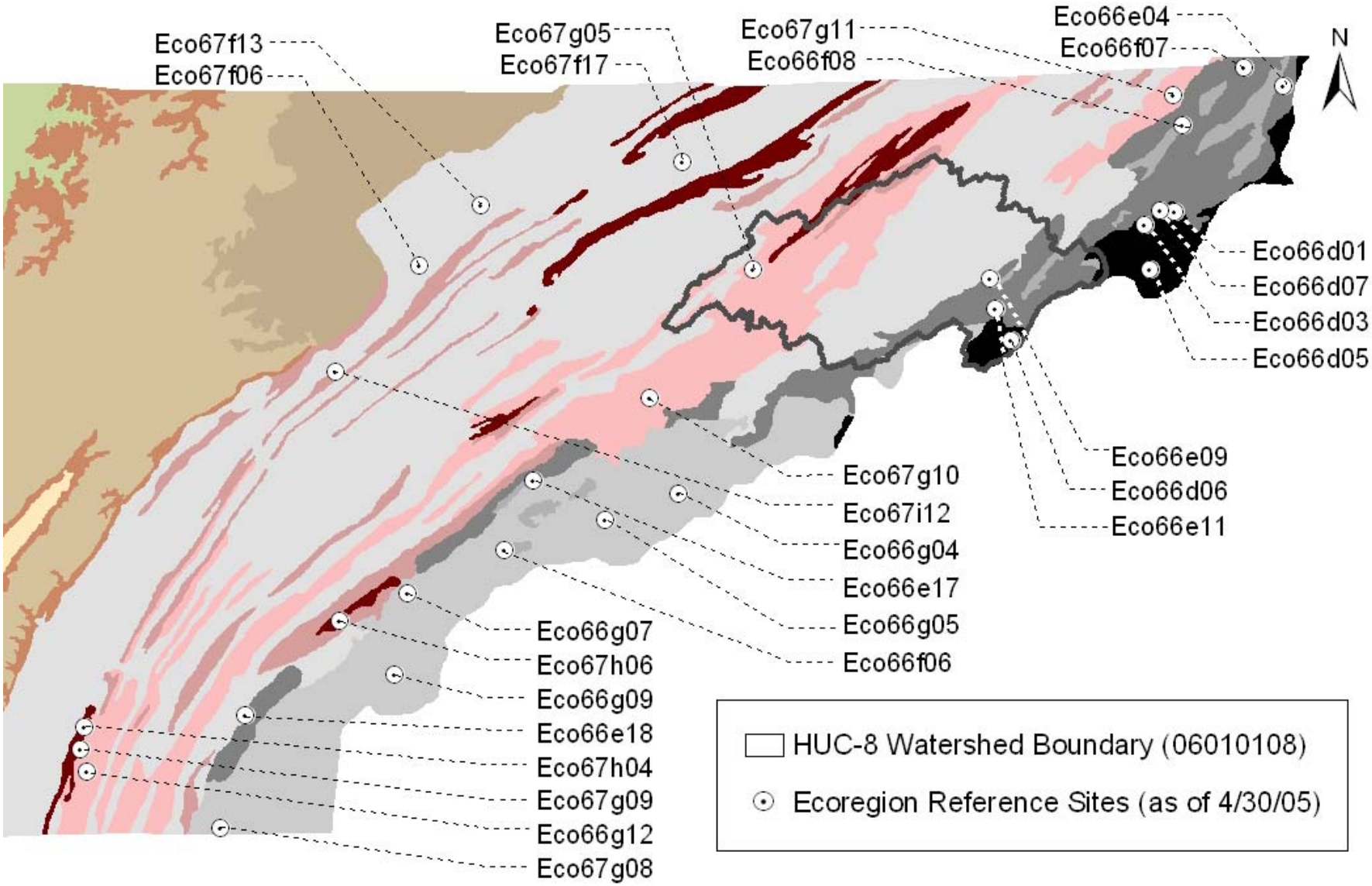
Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.

Table E-6 Summary of Stage I $CBOD_5$ TMDLs, WLAs, & LAs - Annual Loading

HUC-12 Subwatershed (06010108__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA[b] MS4s [a]	LA
			[lbs/yr]	[lbs/ac/yr]	[lbs/ac/yr]
Jockey Ck DA	Jockey Creek	TN06010108030-0200	NA [c]	NA [c]	NA [c]
Carson Ck DA	Carson Creek	TN06010108030-0220	NA [c]	NA [c]	NA [c]
Potter Ck DA	Potter Creek	TN06010108035-0200	14,415	2.8946	2.8946
Puncheon Camp Ck DA	Puncheon Camp Creek	TN06010108035-0900	NA [c]	NA [c]	NA [c]
0801	Lick Creek (headwaters)	TN06010108035-9000	NA [c]	NA [c]	NA [c]
Richland Ck DA	Richland Creek	TN06010108102-2000	NA [c]	NA [c]	NA [c]
Hominy Ck DA	Hominy Creek	TN06010108510-0400	NA [c]	NA [c]	NA [c]

Notes:
a. The WLA for MS4s applies to permitted discharges in the subwatershed or drainage area indicated.
b. Permitted CAFOs are not allowed to discharge except in the case of a 25-year, 24-hour rainfall event. Therefore, a WLA of zero is allocated for all existing and future permittees.
c. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).

Figure E-1 Reference Sites in Level IV Ecoregions 66d, 66e, 66f, 66g, 67f, 67g, 67h, and 67i



APPENDIX F

Development of Daily Expression of Annual Loads

One of the options discussed in *Options for Expressing Daily Loads in TMDLs* (USEPA 2007) is the use of statistical analysis to identify a daily maximum load. The statistical approach selected to derive daily load expressions for Stage I TMDLs, WLAs, & LAs in the Nolichucky River Watershed was based on a procedure described in the *Technical Support Document for Water Quality-based Toxics Control* (TSD)(USEPA 1991a). Using the methodologies described in Appendix E of the TSD document, allowable daily maximum concentrations for total nitrogen (TN) and total phosphorus (TP) were calculated from monitoring data collected at Level IV ecoregion reference sites (67f, 67g, & 67h). The 99.7th percentile daily maximum value was selected as the appropriate expression of the annual average loads developed in Appendix E of this (TMDL) document. The two referenced documents should be consulted for a more detailed description of these procedures.

F.1 Daily Maximum Concentrations for Total Nitrogen Based on the Lognormal Distribution

Analysis to determine daily maximum concentration for total nitrogen was based on the premise that ambient water quality data are often lognormally distributed. The logarithmic transformation of a random variable X, Y = ln(X) results in a random variable Y that is normally distributed. Since total nitrogen was not directly measured at ecoregion reference sites, TN concentrations were computed as the sum of nitrite+ nitrate (NO_2+NO_3) and total Kjeldahl nitrogen (TKN) concentrations. Only values based on <u>detected</u> NO_2+NO_3 and TKN measurements were used for daily maximum concentration calculations.

The following equations are excerpted from Table E-1 of the Technical Support Document (TSD) with all measurements greater than the detection limit (based on the lognormal distribution):

$X_{99.7}$ = 99.7th percentile daily maximum concentration
= $\exp[\mu_y + 2.778\ \sigma_y]$

where:

x_i	=	daily pollutant measurement i
y_i	=	$\ln(x_i)$
k	=	sample size of data set
μ_y	=	$\Sigma(y_i) / k \qquad 1 \le I \le k$
σ_y^2	=	$\Sigma[(y_i - \mu_y)^2] / (k - 1) \qquad 1 \le I \le k$
E(x)	=	$\exp(\mu_y + 0.5\sigma_y^2)$
V(x)	=	$\exp(2\mu_y + \sigma_y^2)\ [\exp(\sigma_y^2) - 1]$
cv(x)	=	$[\exp(\sigma_y^2) - 1]^{½}$

Total nitrogen data and calculated daily maximum concentrations for reference sites in Level IV ecoregions 67f, 67g, & 67h are shown in Tables F-1 through F-3.

F.2 Daily Maximum Concentrations for Total Phosphorus Based on the Delta-Lognormal Distribution

Since total phosphorus (TP) was measured directly at ecoregion reference sites, with a number of values reported as below a detection level, calculation of daily maximum concentrations based on the delta-lognormal distribution was considered appropriate. The Technical Support Document (TSD) describes the delta-lognormal distribution as follows:

> The delta-lognormal distribution is a generalization of the lognormal distribution. The delta-lognormal distribution may be used when the data contain a mixture of nondetect values and values above the detection limit and can be used to model nondetects in water quality-based limits. In delta-lognormal procedures, nondetect values are weighted in proportion to their occurrence in the data. The values above the detection limit are assumed to be lognormally distributed values.

The following equations are excerpted from Table E-1 of the TSD with some measurements less than the detection limit (based on the delta-lognormal distribution):

$X_{99.7}$ = 99.7th percentile daily maximum concentration

$= D \qquad \delta \geq 0.997$

$= \exp[\mu_y + 2.778\ \sigma_y] \qquad \delta < 0.997$

with $Z^* = \Phi^{-1}\ [(0.997 - \delta) / (1 - \delta)]$ (Φ^{-1} is the mathematical notation for Z scores)

where:

x_i	=	daily pollutant measurement i
k	=	sample size of data set
D	=	detection limit
r	=	number of nondetects
k - r	=	number of detects
y_i	=	$\ln(x_i)$
δ	=	r / k
μ_y	=	$\Sigma(y_i) / (k - r) \quad r+1 \leq i \leq k$ (excludes values $\leq$ D from sum)
σ_y^2	=	$\Sigma[(y_i - \mu_y)^2] / (k - r - 1) \quad r+1 \leq i \leq k$
E(x)	=	$\delta D + (1 - \delta) \exp(\mu_y + 0.5\sigma_y^2)$
V(x)	=	$(1 - \delta)\exp(2\mu_y + \sigma_y^2)\ [\exp(\sigma_y^2) - (1 - \delta)] + \delta\ (1 - \delta)\ D\ [D - 2\ \exp(2\mu_y + \sigma_y^2)]$

Total phosphorus data and calculated daily maximum concentrations for reference sites in Level IV ecoregions 67f, 67g, & 67h are shown in Tables F-4 through F-6.

F.3 Daily Maximum Concentrations for $CBOD_5$

Since $CBOD_5$ data was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration of 7.5 mg/l was selected as an appropriate daily maximum concentration. This value is based on five times the $CBOD_5$ target concentration specified in Section 5.2.

F.4 Determination of Daily Expression of Annual Average Loads

Daily expression of annual average loads for impaired subwatersheds and drainage areas were determined according to the following procedure:

1. Area-weighted daily maximum concentrations were calculated for each impaired subwatershed based on the amount of subwatershed area within each Level IV ecoregion.

$$DMC_{subw} = \frac{(DMC_{67F})\,(A_{67F}) + (DMC_{67G})\,(A_{67G}) + (DMC_{67H})\,(A_{67H})}{A_{subw}}$$

where:
DMC_{subw} = Daily maximum concentration for the subwatershed [mg/l]
DMC_{67F} = Daily maximum concentration for Level IV ecoregion 67F [mg/l]
DMC_{67G} = Daily maximum concentration for Level IV ecoregion 67G [mg/l]
DMC_{67H} = Daily maximum concentration for Level IV ecoregion 67H [mg/l]
A_{67F} = Subwatershed area in 67F [acres]
A_{67G} = Subwatershed area in 67G [acres]
A_{67H} = Subwatershed area in 67H [acres]
A_{subw} = Total subwatershed area [acres]

2. Daily maximum loads were calculated for the impaired subwatershed:

$$DML_{subw} = (DMC_{subw} \times UCF) \times Q$$

where:
DML_{subw} = Daily maximum load for the subwatershed [lbs/day]
UCF = Unit conversion factor
Q = Stream flow at the subwatershed pour point [cfs]

Daily maximum loads for subwatersheds and drainage areas are expressed as a function of stream flow (Q)

3. As noted in Appendix E, Section E.3, WLAs for MS4s are considered to be equal to LAs for nonpoint sources on a per unit area basis. Likewise, the daily expressions of the annual average loads on a per unit area for these allocations are also considered to be equal.

$$DML_{MS4} = DML_{NPS} = \frac{DML_{subw}}{A_{subw}} \times Q$$

Total nitrogen (TN) calculations for Subwatershed 060101080801 (Upper Lick Creek) are shown as an example. The procedure for TP and $CBOD_5$ in other impaired subwatersheds and drainage areas is similar.

Total Nitrogen in Subwatershed 0801

Step 1:

$$DMC_{subw} = \frac{(4.3325\ mg/l)\ (31{,}432\ ac) + (3.3145\ mg/l)\ (13{,}785\ ac) + (5.0365\ mg/l)\ (932\ ac)}{(46{,}149\ ac)}$$

$$DMC_{subw} = 3.9720\ mg/l$$

Step 2:

$$DML_{subw} = [(3.9720\ mg/l) \times (5.3944\ lb\text{-}L\text{-}sec/mg\text{-}cu.ft.\text{-}day) \times Q$$

$$DML_{subw} = (2.143 \times 10^{1}\ lb\text{-}sec/cu.ft.\text{-}day) \times Q \quad [lbs/day]$$

Step 3:

$$DML_{MS4} = DML_{NPS} = \frac{(2.143 \times 10^{1}\ lb\text{-}sec/cu.ft.\text{-}day)}{(46{,}149\ ac)} \times Q$$

$$DML_{MS4} = DML_{NPS} = (4.643 \times 10^{-4}) \times Q \quad [lbs/ac/day]$$

Daily expression of TN, TP, & $CBOD_5$ annual average loads for impaired subwatersheds and drainage areas are summarized in Table F-7.

Table F-1 Ecoregion 67F Total Nitrogen Monitoring Data & Statistics

Station ID	Date	TN [mg/l]	LN(TN)
ECO67F06	3/29/04	0.35	-1.0498
	9/8/04	0.81	-0.2107
ECO67F13	11/16/98	1.01	0.0100
	1/11/06	0.71	-0.3425
ECO67F14	4/8/96	0.89	-0.1165
	8/25/04	0.81	-0.2107
	10/28/04	0.66	-0.4155
	4/27/05	1.21	0.1906
	1/10/06	1.39	0.3293
ECO67F16	8/17/04	1.03	0.0296
	1/25/05	0.06	-2.8134
	4/27/05[a]	1.16	0.1512
ECO67F17	4/8/96	0.60	-0.5108
	6/8/00	0.69	-0.3711
	10/14/02	0.32	-1.1394
	7/21/03[a]	1.91	0.6491
	4/21/04	0.53	-0.6349
	8/18/04	0.50	-0.6931
	8/26/04	0.44	-0.8210
ECO67F23	8/17/04	0.67	-0.4005
	8/25/04	0.77	-0.2614
	4/27/05	1.09	0.0862
ECO67F25	12/9/96	1.29	0.2546
	5/6/97	0.94	-0.0619
	8/17/04	0.67	-0.4005
	8/25/04	0.75	-0.2877
k (number of data points)		26	
Minimum reported value [mg/l]		0.06	
Maximum reported value [mg/l]		1.91	
μ(y) (average of data set)			-0.6477
s(y) (std deviation of data set)			0.6491
t(y) (variance of data set)			0.1263
E(X*) (daily average)			0.8741
V(X*) (variance)			0.4062
Daily Maximum Limits (99.7th %tile)		**4.3325**	

Table F-2 Ecoregion 67G Total Nitrogen Monitoring Data & Statistics

Station ID	Date	TN [mg/l]	LN(TN)
ECO67G01	4/25/96	0.43	-0.8440
	11/14/96	0.59[b]	-0.5282
	3/10/97	1.10	0.0953
	5/12/97	0.80	-0.2231
	8/18/97	0.68[a]	-0.3858
	8/23/00	0.61	-0.4943
ECO67G05	4/25/96	0.75	-0.2877
	11/20/96	1.973[b]	0.6798
	2/19/97	0.655	-0.4228
	5/21/97	1.38	0.3221
	8/21/00	1.055[a]	0.0535
	1/9/06	1.42	0.3507
ECO67G08	7/30/02	0.31	-1.1712
	9/9/02	0.28	-1.2730
ECO67G09	7/30/02	0.57	-0.5621
	5/27/03	0.59	-0.5276
ECO67G10	4/24/03	1.31	0.2700
	11/20/03	1.09	0.0862
k (number of data points)		18	
Minimum reported value [mg/l]		0.2800	
Maximum reported value [mg/l]		1.97	
μ(y) (average of data set)			-0.2701
s(y) (std deviation of data set)			0.5286
t(y) (variance of data set)			0.2794
E(X*) (daily average)			0.8777
V(X*) (variance)			0.2483
Daily Maximum Limits (99.7th %tile)		**3.3145**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.

Table F-3 Ecoregion 67H Total Nitrogen Monitoring Data & Statistics

ECO67H06	3/31/04	0.04	-3.2189
	9/8/04	0.285[a]	-1.2567
k (number of data points)		2	
Minimum reported value [mg/l]		0.0400	
Maximum reported value [mg/l]		0.28	
μ(y) (average of data set)			-2.2378
s(y) (std deviation of data set)			1.3875
t(y) (variance of data set)			1.9252
E(X*) (daily average)			0.2794
V(X*) (variance)			0.4571
Daily Maximum Limits (99.7th %tile)		**5.0365**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.

Table F-4 Ecoregion 67F Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67F06	5/19/98	0.004U[a]	
	8/20/98	0.004U	
	11/16/98	0.004U	
	2/9/99	0.004U	
	5/17/99	0.004U	
	7/15/03	**0.004U[a]**	
	11/19/03	**0.004U**	
	1/6/04	**0.004**	-5.5215
	3/29/04	0.23	-3.7723
	8/23/04	0.004U[a]	
	8/30/04	**0.004U**	
	9/8/04	**0.004U**	
ECO67F13	4/8/96	**0.004U**	
	12/11/96	0.004[b]	-5.5215
	2/13/97	0.004	-5.5215
	5/1/97	0.03	-3.5066
	8/4/97	**0.004U**	
	12/2/97	**0.004U**	
	2/25/98	**0.004U**	
	5/20/98	**0.004U**	
	8/31/98	0.007	-4.9618
	11/16/98	3.03	1.1086
	2/9/99	0.004	-5.5215
	5/17/99	0.008	-4.8283
	5/9/00	0.02	-3.9120
	10/14/02	0.04	-3.2189
	8/11/04	**0.004U**	
	8/18/04	**0.004U**	
	8/24/04	**0.004U[a]**	
	4/14/05	**0.004U**	
	8/2/05	0.02	-3.9120
	10/4/05	0.02U	
	1/11/06	0.02U	
ECO67F14	4/8/96	0.02	-3.9120
	6/1/98	0.004U	
	8/27/98	0.004U	
	12/10/98	0.004U	
	3/11/99	0.010	-4.6052
	5/27/99	0.004U	
	9/28/00	0.230	-1.4697
	9/24/02	0.004	-5.5215
	10/21/02	0.004U	
	12/11/02	0.004U	
	4/7/04	0.011	-4.5099
	7/29/04	0.017	-4.0745
	8/12/04	0.004U	
	8/17/04	0.004U	
	8/25/04	0.005	-5.2983
	10/28/04	0.019	-3.9633
	1/26/05	0.15	-1.8971
	4/27/05	0.03	-3.5066
	8/23/05	0.02U	

Table F-4 (cont'd) Ecoregion 67F Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67F14 (cont'd)	10/5/05	0.02U	
	1/10/06	0.02U	
	4/4/06	0.077	-2.5639
	7/25/06	0.1	-2.3026
	10/24/06	0.02	-3.9120
	1/23/07	0.03	-3.5066
	4/17/07	0.06	-2.8134
	7/24/07	<0.01	
	10/30/07	0.01	-4.6052
	1/7/08	0.05	-2.9957
ECO67F16	6/1/98	0.004U[a]	
	8/27/98	0.004U	
	12/10/98	0.004U	
	3/11/99	0.01	-4.6052
	5/27/99	0.004U	
	6/21/00	0.004U	
	9/7/00	0.024	-3.7297
	12/6/00	0.004U	
	7/29/04	0.004	-5.5215
	8/9/04	0.027	-3.6119
	8/17/04	0.004U	
	8/25/04	0.004U	
	10/28/04	0.004U[a]	
	1/26/05	0.1119[c]	-2.1904
	4/27/05	0.0363[a]	-3.3148
ECO67F17	4/8/96	0.007	-4.9618
	12/5/96	0.0198[b]	-3.9232
	2/11/97	0.014	-4.2687
	4/22/97	0.004U	
	8/12/97	0.004U	
	10/21/97	0.004U	
	1/20/98	0.004U	
	6/2/98	0.178	-1.7260
	8/25/98	0.005	-5.2983
	12/17/98	0.0173[a]	-4.0559
	3/18/99	0.004U	
	6/3/99	00.01	-4.6052
	3/2/00	0.006	-5.1160
	6/8/00	0.004U	
	9/20/00	0.15	-1.1871
	12/13/00	0.004	-5.5215
	10/14/02	0.02	-3.9120
	7/21/03	0.04	-3.2189
	10/21/03	0.011	-4.5099
	1/21/04	0.004U	
	4/21/04	0.004U	
	8/9/04	0.034	-3.3814
	8/18/04	0.004U	
	8/26/04	0.004U	
ECO67F23	6/1/98	0.004U	
	8/27/98	0.004U	
	12/10/98	0.03	-3.5066

Table F-4 (Contd.) Ecoregion 67F Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67F23 (cont'd)	3/11/99	0.006	-5.1160
	5/27/99	0.004U	
	3/23/00	0.004U	
	6/21/00	**0.004U**	
	12/6/00	0.008	-4.8583
	10/21/02	0.004	-5.5215
	7/29/04	0.012	-4.4228
	8/12/04	**0.004U**	
	8/17/04	**0.004U**	
	8/25/04	**0.004U**	
	10/28/04	**0.004U**	
	1/26/05	0.16	-1.8326
	4/27/05	0.04	-3.2189
ECO67F25	12/11/96	0.0279[b]	-3.5775
	2/12/97	0.013	-4.3428
	5/6/97	**0.004U**	
	8/4/97	**0.004U**	
	12/2/97	0.006	-5.1160
	2/25/98	**0.004U**	
	1/19/00	0.006	-5.1160
	8/12/04	**0.004U**	
	8/17/04	**0.004U**	
	8/25/04	**0.004U**	
	8/2/05	0.02	-3.9120
	10/4/05	0.02U	
	1/11/06	0.02U	
	5/2/06	<0.01	
k (number of data points)		131	
Minimum reported value [mg/l]		0.002	
Maximum reported value [mg/l]		3.030	
D (detection limit) [mg/l]		0.004	
k - r (number of detects)		62	
r (number of nondetects)		69	
d (ratio of nondetects/total, delta)		0.5267	
μ(y) (average of detects)			-3.9781
s(y) (std deviation of detects)			1.3016
t(y) (variance of detects)			1.6941
E(X*) (daily average)			0.0228
V(X*) (variance)			0.0044
z*99.7 (adjusted Z-score, 99.7th %tile)			2.5247
Daily Maximum Limits (99.7th %tile)		**0.5006**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.
c. Value shown is geometric mean of measurements collected on two consecutive days.

Table F-5 Ecoregion 67G Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67G01	4/25/96	0.016	-4.1352
	11/14/96	0.029[b]	-3.5311
	3/10/97	0.29	-1.2379
	5/12/97	0.35	-1.0498
	8/18/97	0.075[a]	-2.5925
	3/12/98	0.007[a]	-4.8951
	6/9/98	0.02	-3.9120
	8/18/98	0.03	-3.5066
	12/3/98	0.004U	
	2/25/99	0.027	-3.6181
	5/25/99	0.04	-3.2189
	8/23/00	0.031	-3.4738
ECO67G05	4/25/96	0.014	-4.2687
	11/20/96	0.086[b]	-2.4506
	2/19/97	0.049[a]	-3.0058
	5/21/97	0.004U	
	8/6/97	0.004U	
	11/25/97	0.004U	
	2/18/98	0.06	-2.8134
	8/21/00	0.034[a]	-3.3884
	4/11/05	0.004U	
	8/1/05	0.02U	
	9/19/05	0.03	-3.5066
	1/9/06	0.02U	
ECO67G08	12/4/96	0.051[b]	-2.9794
	1/28/97	0.03	-3.5066
	5/21/97	0.004U[a]	
	7/30/02	0.059	-2.8302
	9/9/02	0.006	-5.1160
	3/18/03	0.007	-4.9618
	6/3/03	0.028[a]	-3.5654
	8/20/07	0.09	-2.4079
	1/22/08	0.05	-2.9957
ECO67G09	11/24/97	0.013[a]	-4.3578
	2/23/98	0.01	-4.6052
	7/30/02	0.052	-2.9565
	9/10/02	0.01	-4.6052
	3/18/03	0.004U	
	5/27/03	0.22	-3.8167
	8/20/07	0.04	-3.2189
	10/16/07	0.02[a]	-3.9120
	1/22/08	0.03	-3.5066

Table F-5 (Contd.) Ecoregion 67G Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67G10	4/24/03	0.16	-1.8326
	8/7/03	0.03	-3.5066
	11/20/03	0.054	-2.9188
	4/12/05	0.004U	
	8/3/05	0.02	-3.9120
	9/19/05	0.02[a]	-3.9120
	1/10/06	0.02U	
k (number of data points)		49	
Minimum reported value [mg/l]		0.002	
Maximum reported value [mg/l]		0.350	
D (detection limit) [mg/l]		0.004	
k - r (number of detects)		38	
r (number of nondetects)		11	
d (ratio of nondetects/total, delta)		0.2245	
μ(y) (average of detects)			-3.4218
s(y) (std deviation of detects)			0.9145
t(y) (variance of detects)			0.8364
E(X*) (daily average)			0.0394
V(X*) (variance)			0.0029
z*99.7 (adjusted Z-score, 99.7th %tile)			2.6937
Daily Maximum Limits (99.7th %tile)		**0.3835**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.

Table F-6 Ecoregion 67H Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO67H06	4/10/96	0.004	-5.5215
	7/22/03	0.004U[a]	
	11/18/03	0.004U	
	1/6/04	0.004U	
	3/31/04	0.005	-5.2983
	9/3/04	0.004U[a]	
	9/8/04	0.031	-3.4579
	9/13/04	0.004U	
k (number of data points)		8	
Minimum reported value [mg/l]		0.002	
Maximum reported value [mg/l]		0.031	
D (detection limit) [mg/l]		0.004	
k - r (number of detects)		3	
r (number of nondetects)		5	
d (ratio of nondetects/total, delta)		0.6250	
μ(y) (average of detects)			-4.7592
s(y) (std deviation of detects)			1.1325
t(y) (variance of detects)			1.2825
E(X*) (daily average)			0.0086
V(X*) (variance)			0.0003
z*99.7 (adjusted Z-score, 99.7th %tile)			2.4418
Daily Maximum Limits (99.7th %tile)		**0.1362**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.

Table F-7 Daily Expression of Annual Average Loads for Impaired Subwatersheds & Drainage Areas

HUC-12 Subwatershed (06010108__) or Drainage Area	Total Nitrogen			Total Phosphorus			$CBOD_5$		
	Daily Maximum Conc.	Daily Maximum Load		Daily Maximum Conc.	Daily Maximum Load		Daily Maximum Conc.	Daily Maximum Load	
	[mg/l]	[lbs/day]	[lbs/ac/day]	[mg/l]	[lbs/day]	[lbs/ac/day]	[mg/l]	[lbs/day]	[lbs/ac/day]
Jockey Ck DA	4.3325	$2.337 \times 10^{1} * Q$	$2.100 \times 10^{-3} * Q$	0.5365	$2.894 \times 10^{0} * Q$	$2.601 \times 10^{-4} * Q$	7.5	$4.046 \times 10^{1} * Q$	$3.636 \times 10^{-3} * Q$
Carson Ck DA	4.3325	$2.337 \times 10^{1} * Q$	$3.811 \times 10^{-3} * Q$	0.5365	$2.894 \times 10^{0} * Q$	$4.719 \times 10^{-4} * Q$	7.5	$4.046 \times 10^{1} * Q$	$6.597 \times 10^{-3} * Q$
Potter Ck DA	2.9379	$1.585 \times 10^{1} * Q$	$3.350 \times 10^{-3} * Q$	0.3341	$1.802 \times 10^{0} * Q$	$3.809 \times 10^{-4} * Q$	7.5	$4.046 \times 10^{1} * Q$	$8.552 \times 10^{-3} * Q$
Puncheon Camp Ck DA	3.3145	$1.788 \times 10^{1} * Q$	$3.860 \times 10^{-3} * Q$	0.3873	$2.089 \times 10^{0} * Q$	$4.510 \times 10^{-4} * Q$	7.5	$4.046 \times 10^{1} * Q$	$8.734 \times 10^{-3} * Q$
0801 (Upper Lick Ck)	3.9720	$2.143 \times 10^{1} * Q$	$4.643 \times 10^{-4} * Q$	0.4838	$2.610 \times 10^{0} * Q$	$5.655 \times 10^{-5} * Q$	7.5	$4.046 \times 10^{1} * Q$	$8.767 \times 10^{-4} * Q$
Richland Ck DA	4.3325	$2.337 \times 10^{1} * Q$	$5.101 \times 10^{-3} * Q$	0.5365	$2.894 \times 10^{0} * Q$	$6.316 \times 10^{-4} * Q$	7.5	$4.046 \times 10^{1} * Q$	$8.830 \times 10^{-3} * Q$
Hominy Ck DA	4.3325	$2.337 \times 10^{1} * Q$	$9.504 \times 10^{-3} * Q$	0.5365	$2.894 \times 10^{0} * Q$	$1.177 \times 10^{-3} * Q$	7.5	$4.046 \times 10^{1} * Q$	$1.645 \times 10^{-2} * Q$

APPENDIX G

Estimation of Required Reductions in Nutrients Loading

DEVELOPMENT OF LOAD DURATION CURVES & ESTIMATION OF REQUIRED REDUCTIONS IN NUTRIENTS & $CBOD_5$ LOADING

A flow duration curve (FDC) 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. 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).

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 to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: one representing high flows, another for moist conditions, one covering median or mid-range flows, another for dry conditions, and one representing low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect potential nonpoint source contributions (Cleland, 2003).

Flow duration curves were developed for impaired waterbodies in the Nolichucky River Watershed using simulated daily mean flow data from LSPC models constructed for each waterbody at an appropriate water quality monitoring station. Model setup and calibration are summarized in Appendix G. Load duration curves were developed from the FDCs using target nutrient concentrations, nutrient monitoring data, and flows measured at the time of sample collection. Estimated load reductions required to meet TMDL targets were then calculated from the LDCs according to the procedure described below (Jockey Creek is shown, other waterbodies are similar).

1. A flow-duration curve for Jockey Creek at water quality monitoring station JOCKE000.1WN (~RM 0.1) was constructed using simulated daily mean flow for the period from 10/1/97 through 9/30/07. A flow duration curve is a cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the largest daily mean flow during this period is exceeded 0% of the time and the smallest daily mean flow is exceeded ~100% of the time).

2. A target load-duration curve was generated for Jockey Creek at the water quality monitoring station by applying the target nitrogen concentration for Level IV ecoregion 67F (ref.: Section 5.2) to each of the 3,652 ranked flows:

   $(\text{Target Load})_{\text{Jockey Creek}} = (TN)_{67f} \times (Q_{Sim}) \times (UCF)$

   where: Q_{Sim} = Simulated daily mean flow
   UCF = the required unit conversion factor

   Note: For drainage areas that are located within more than one Level IV ecoregion, area-weighted target values were calculated.

3. Total nitrogen loads were calculated for each of the samples collected at the monitoring station (ref.: Table D-1) by multiplying the sample concentration by the measured flow and the required unit conversion factor.

4. Using the flow duration curve developed in Step 1, the "percent of days the flow was exceeded" (PDFE) was determined, based on the measured flow for each sampling event. Each sample load was then plotted on the load duration curve developed in Step 2 according to the PDFE. The resulting curve is shown in Figure G-1.

5. The percent load reduction corresponding to each sample load was determined through comparison with the target load corresponding to the PDFE. The overall reduction of existing nutrient load required to meet the TMDL target was <u>estimated</u> to be the geometric mean of the individual sample reductions. Negative reductions were not used in the estimation of the overall reduction.

   Note: The geometric mean was used in cases where the number of individual sample reductions was less than ten. The arithmetic mean (average) was used where the number of individual sample reductions was ten or greater.

6. Steps 2 through 5 were repeated for total phosphorus. The load duration curve for total phosphorus is shown in Figure G-2. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for Jockey Creek are summarized in Table G-1.

Load duration curves for other impaired waterbodies in the Nolichucky River Watershed are shown in Figures G-3 through G-24. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for these waterbodies are tabulated in Tables G-2 through G-12.

Figure G-1 Total Nitrogen Load Duration Curve – Jockey Creek at JOCKE000.1WN

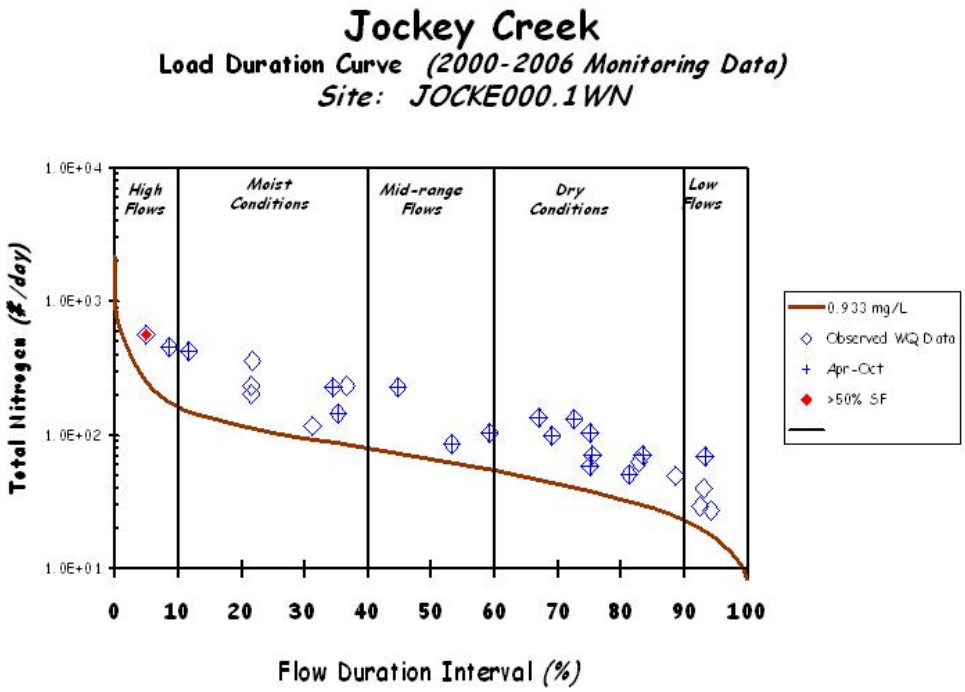


Figure G-2 Total Phosphorus Load Duration Curve – Jockey Creek at JOCKE000.1WN

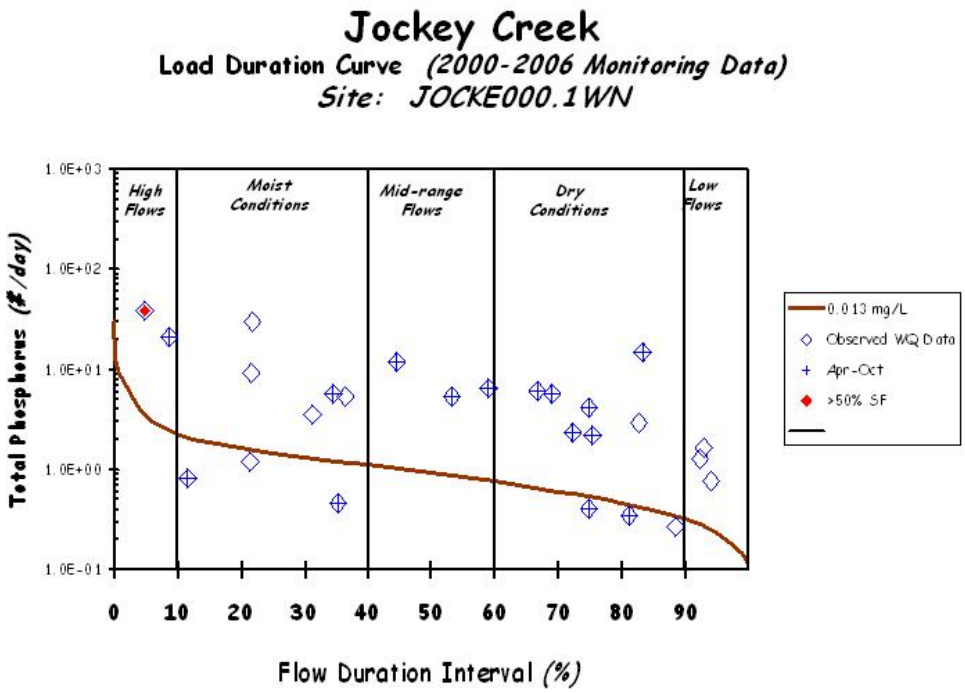


Figure G-3 Total Nitrogen Load Duration Curve – Jockey Creek at JOCKE003.2GE

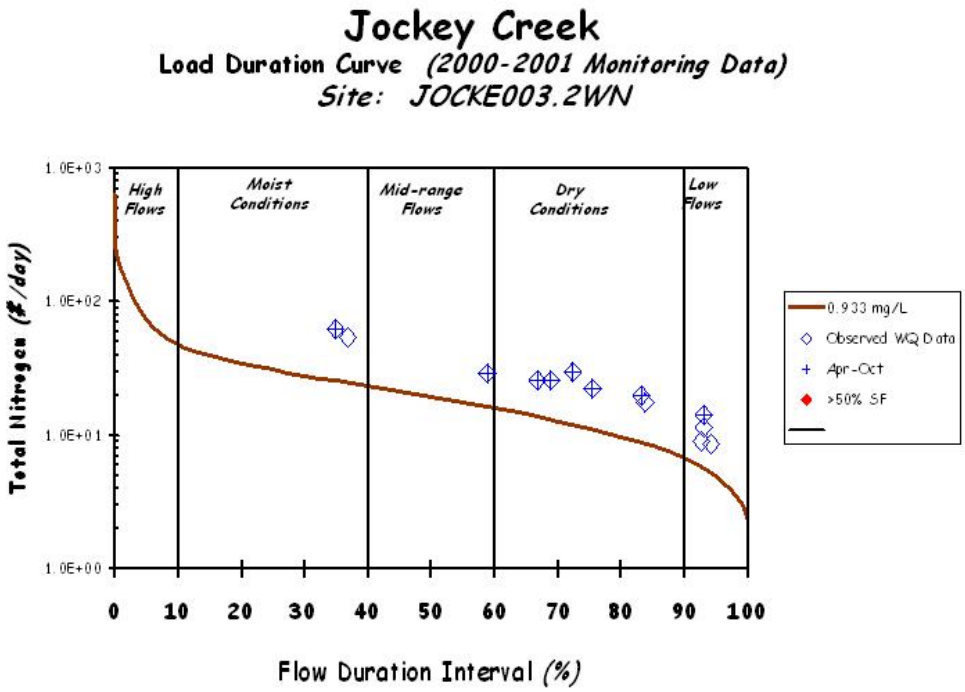


Figure G-4 Total Phosphorus Load Duration Curve – Jockey Creek at JOCKE003.2GE

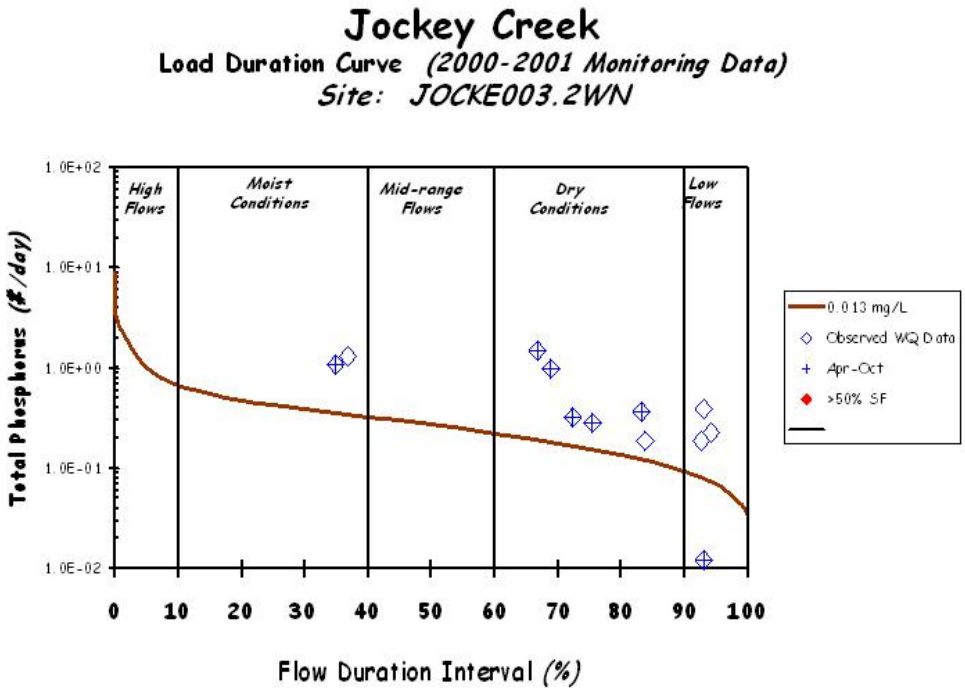


Figure G-5 Total Nitrogen Load Duration Curve – Carson Creek at CARSO000.1WN

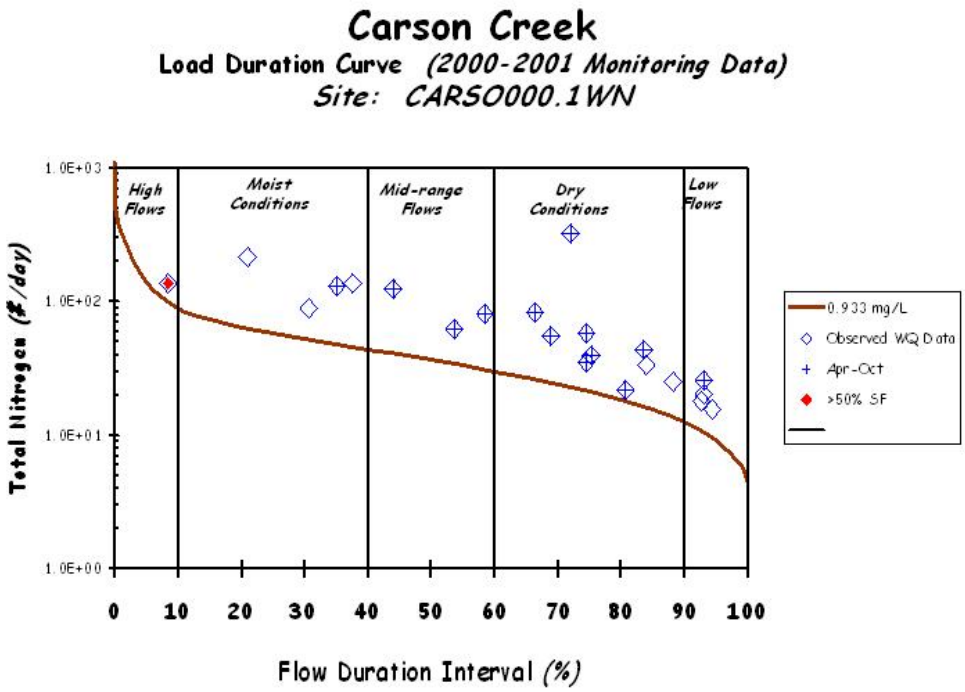


Figure G-6 Total Phosphorus Load Duration Curve – Carson Creek at CARSO000.1WN

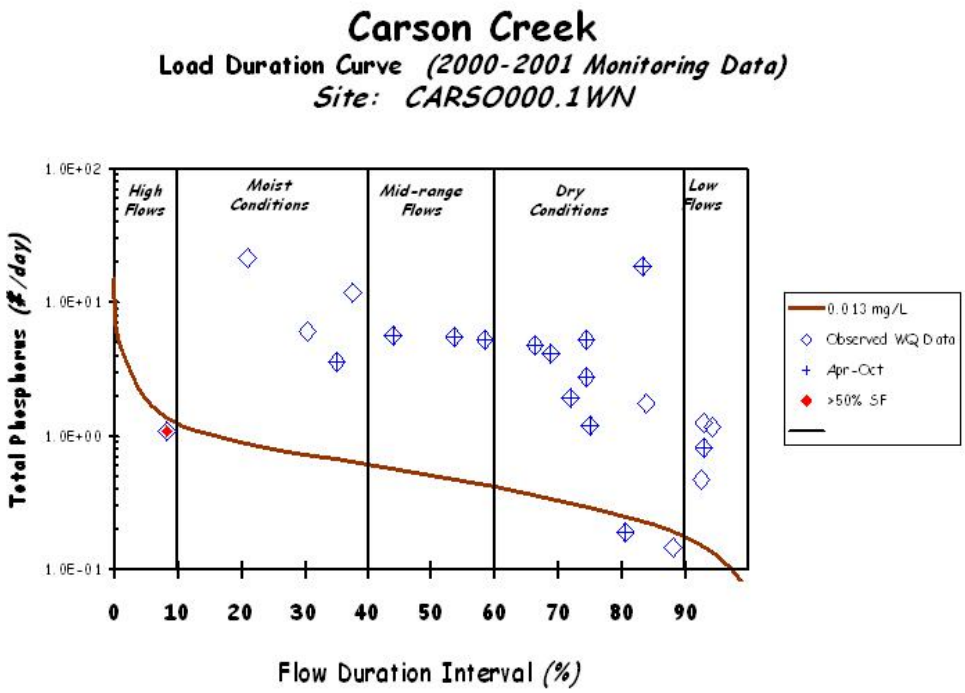


Figure G-7 Total Nitrogen Load Duration Curve – Carson Creek at CARSO001.8WN

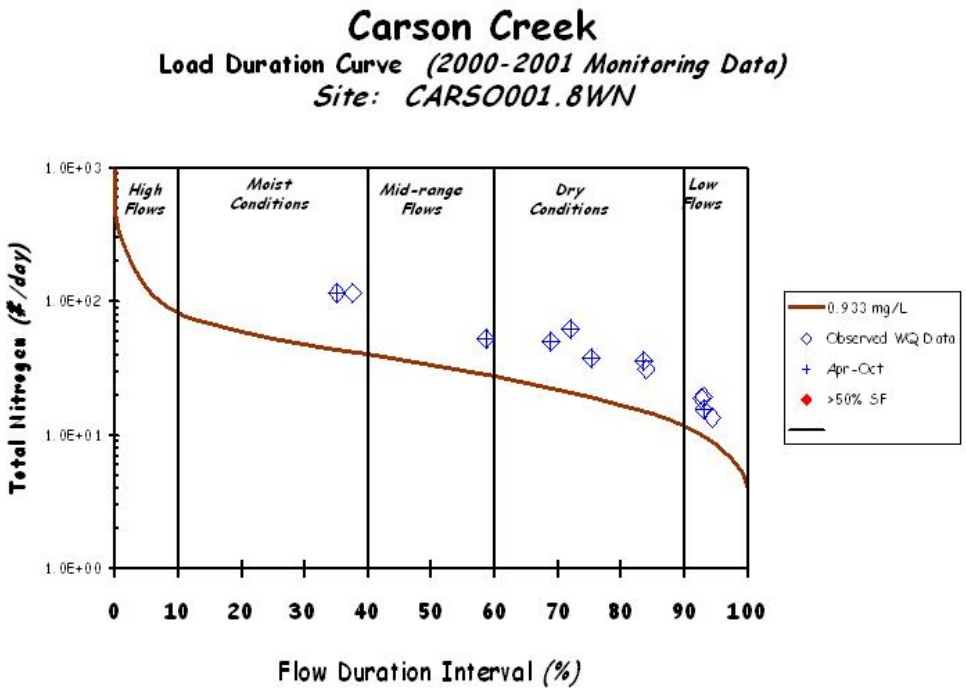


Figure G-8 Total Phosphorus Load Duration Curve – Carson Creek at CARSO001.8WN

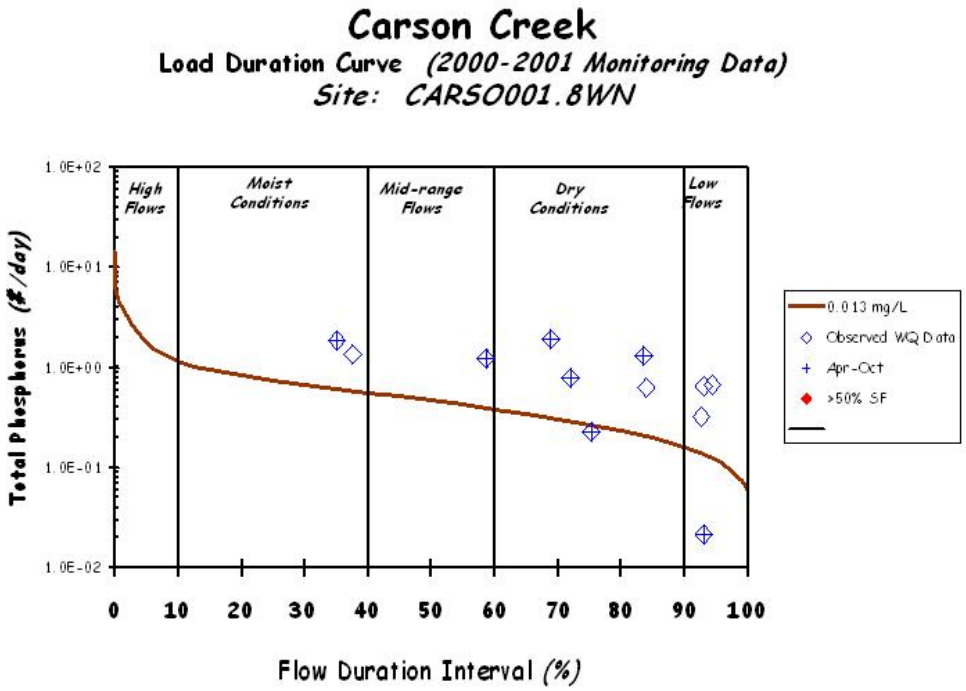


Figure G-9 Total Nitrogen Load Duration Curve – Potter Creek at POTTE000.3GE

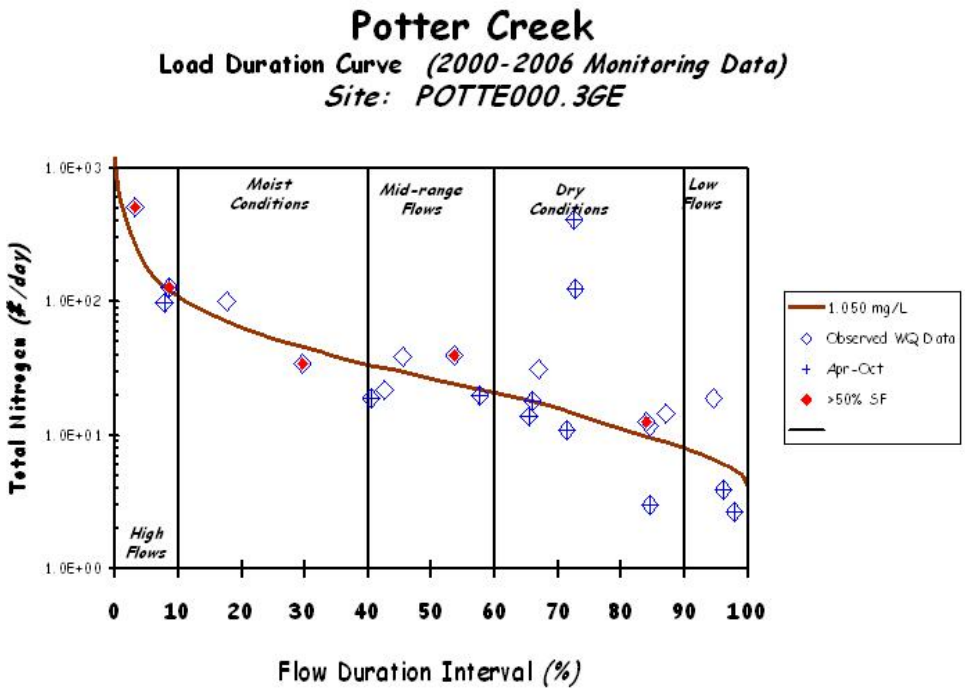


Figure G-10 Total Phosphorus Load Duration Curve – Potter Creek at POTTE000.3GE

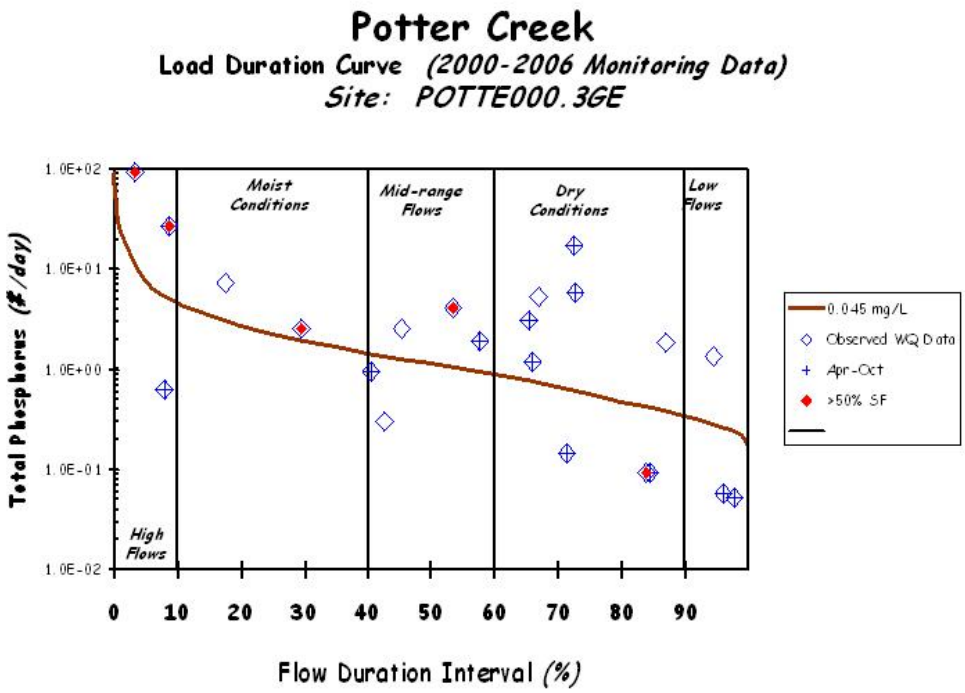


Figure G-11 Total Nitrogen Load Duration Curve – Puncheon Camp Creek at PCAMP000.5GE

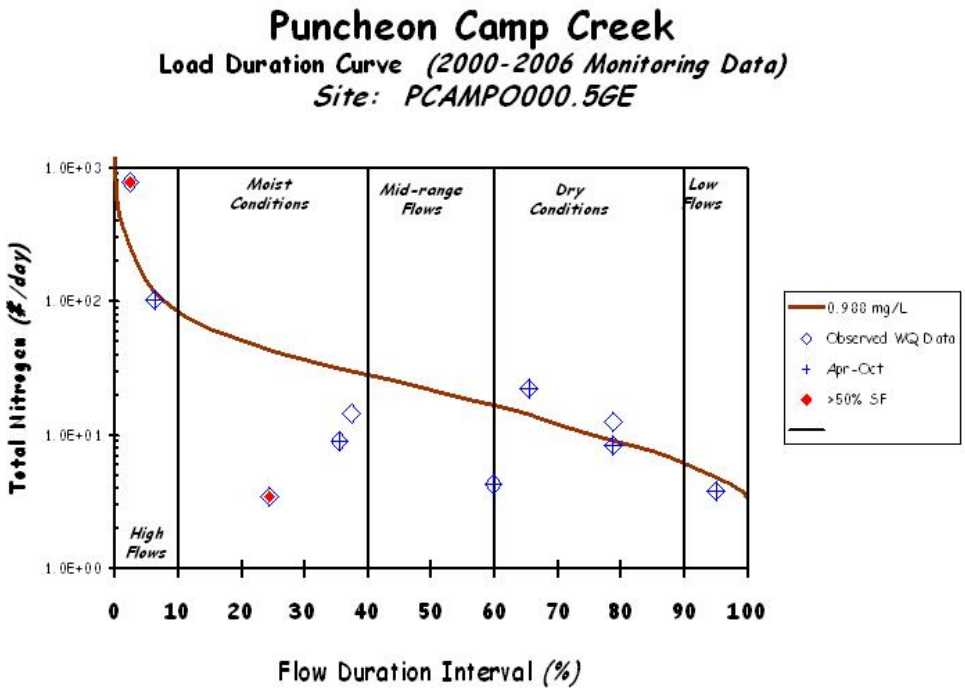


Figure G-12 Total Phosphorus Load Duration Curve – Puncheon Camp Creek at PCAMP000.5GE

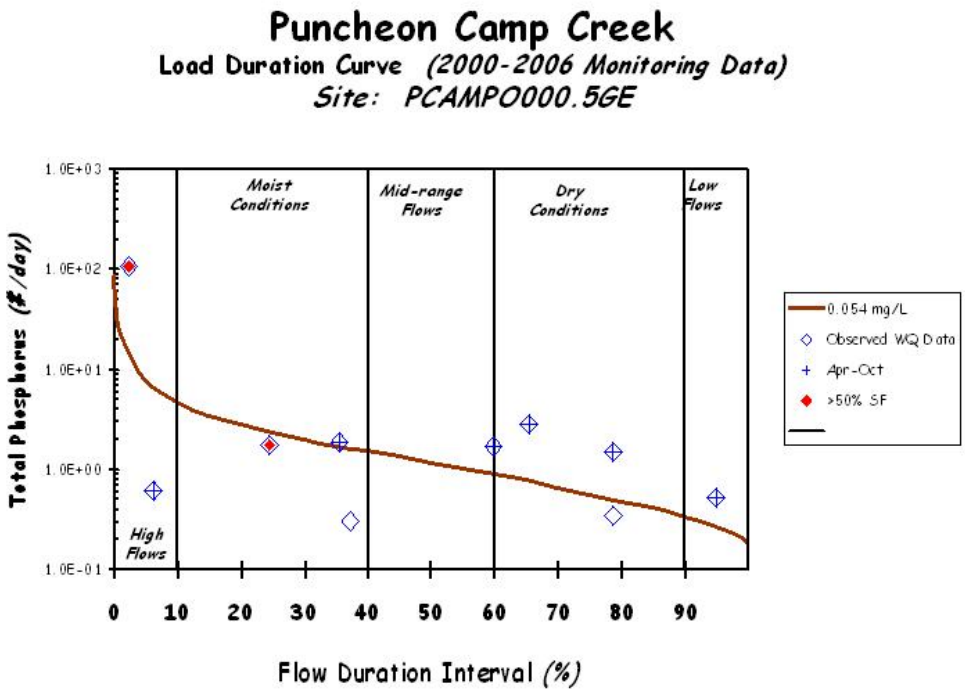


Figure G-13 Total Nitrogen Load Duration Curve – Lick Creek at LICK052.3GE

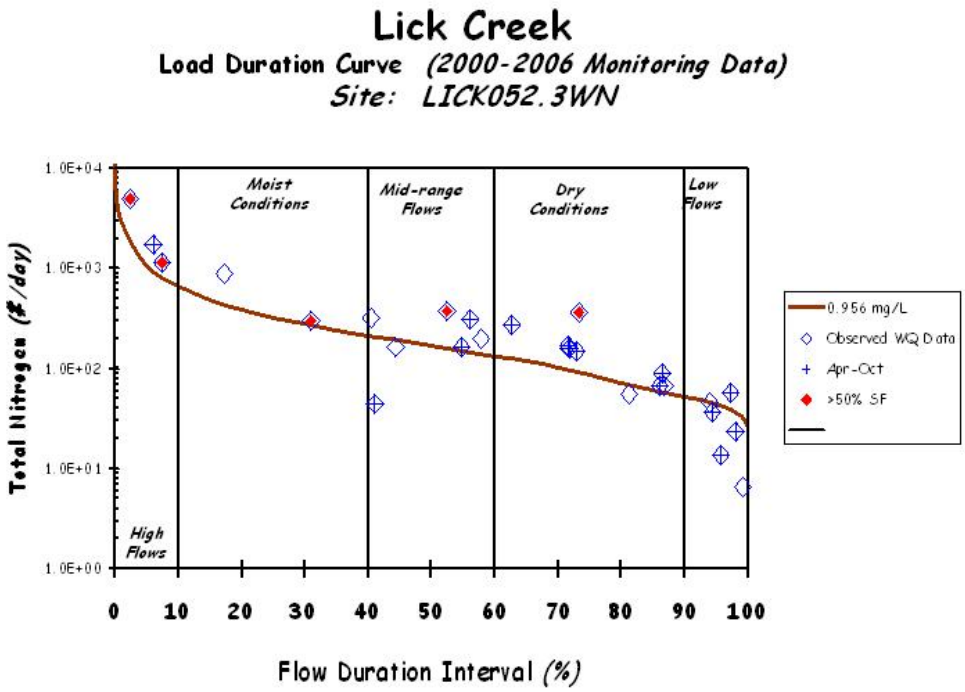


Figure G-14 Total Phosphorus Load Duration Curve – Lick Creek at LICK052.3GE

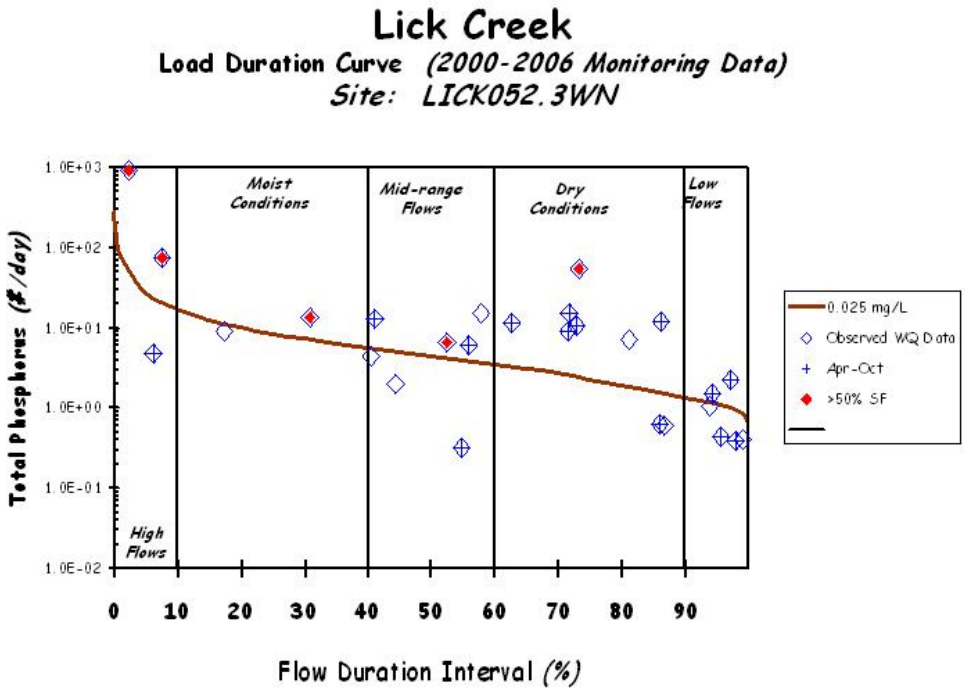


Figure G-15 Total Nitrogen Load Duration Curve – Lick Creek at LICK061.0GE

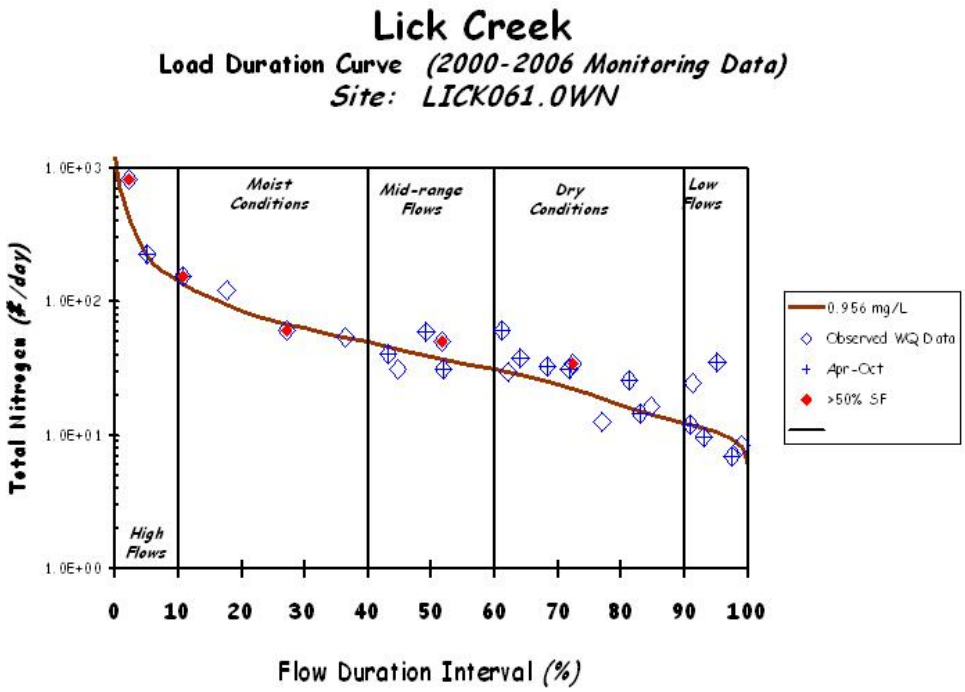


Figure G-16 Total Phosphorus Load Duration Curve – Lick Creek at LICK061.0GE

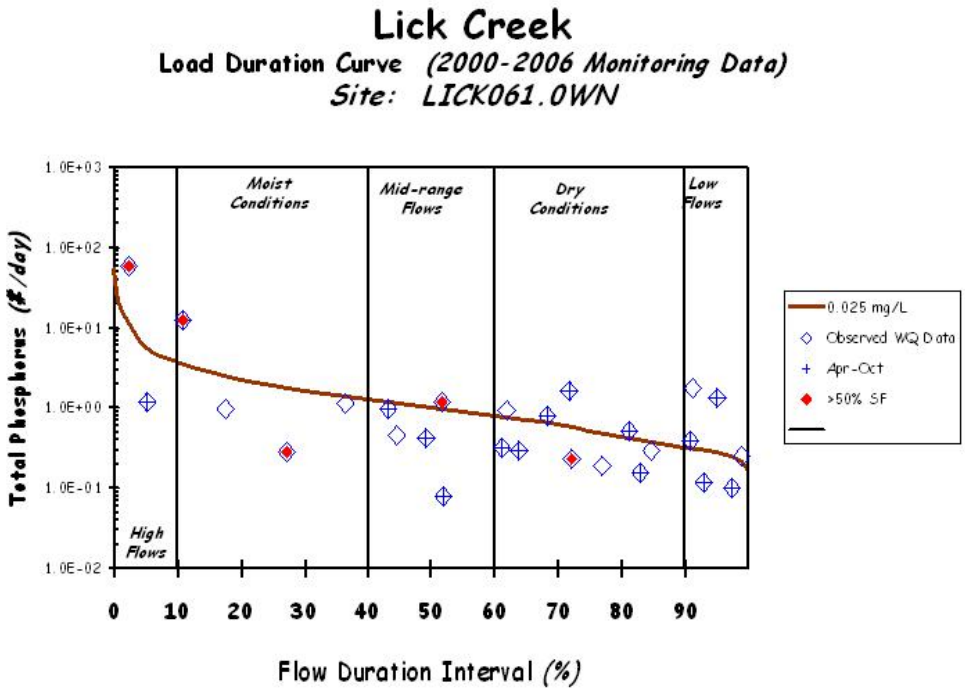


Figure G-17 Total Nitrogen Load Duration Curve – Richland Creek at RICHL004.3GE

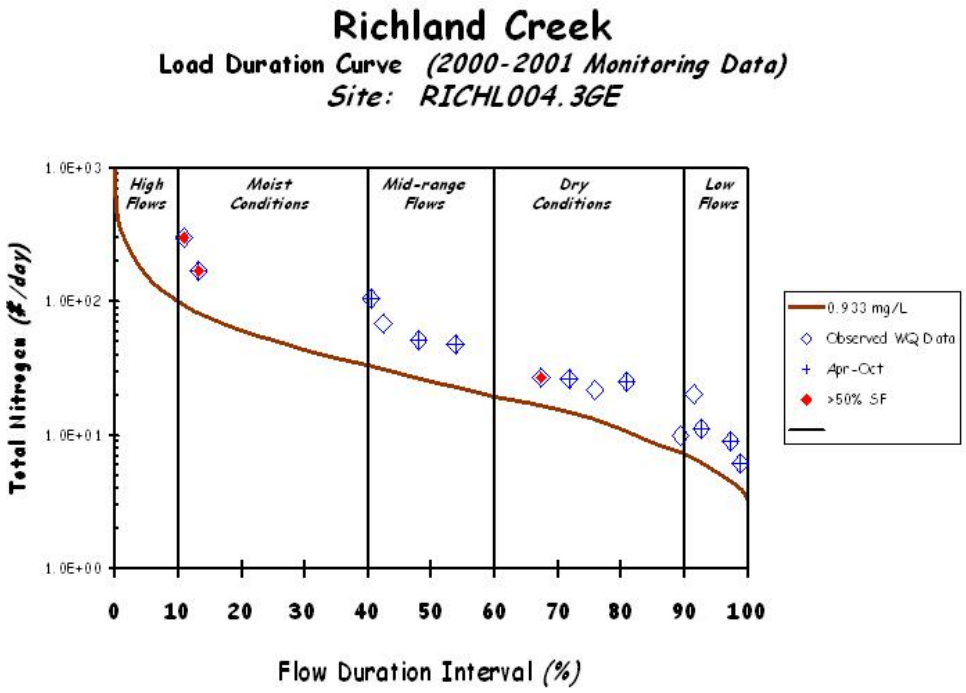


Figure G-18 Total Phosphorus Load Duration Curve – Richland Creek at RICHL004.3GE

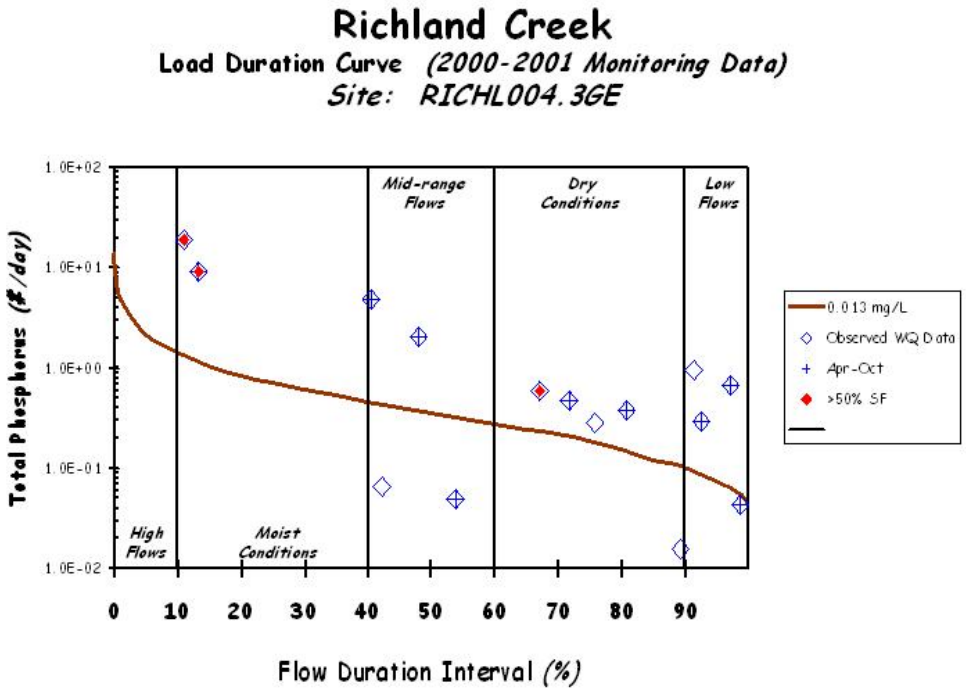


Figure G-19 Total Nitrogen Load Duration Curve – Richland Creek at RICHL006.0GE

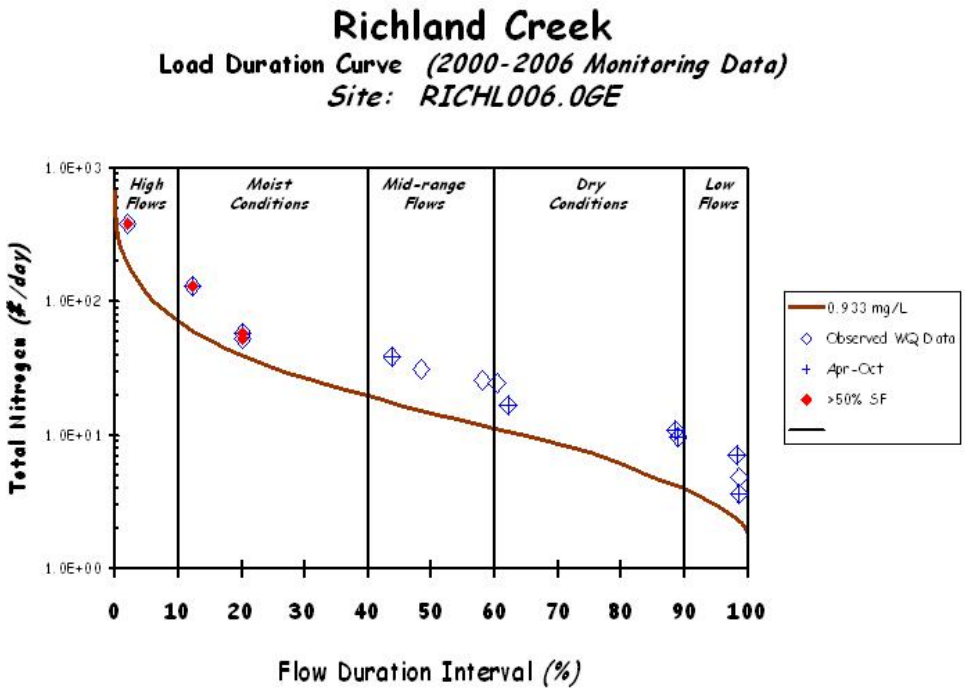


Figure G-20 Total Phosphorus Load Duration Curve – Richland Creek at RICHL006.0GE

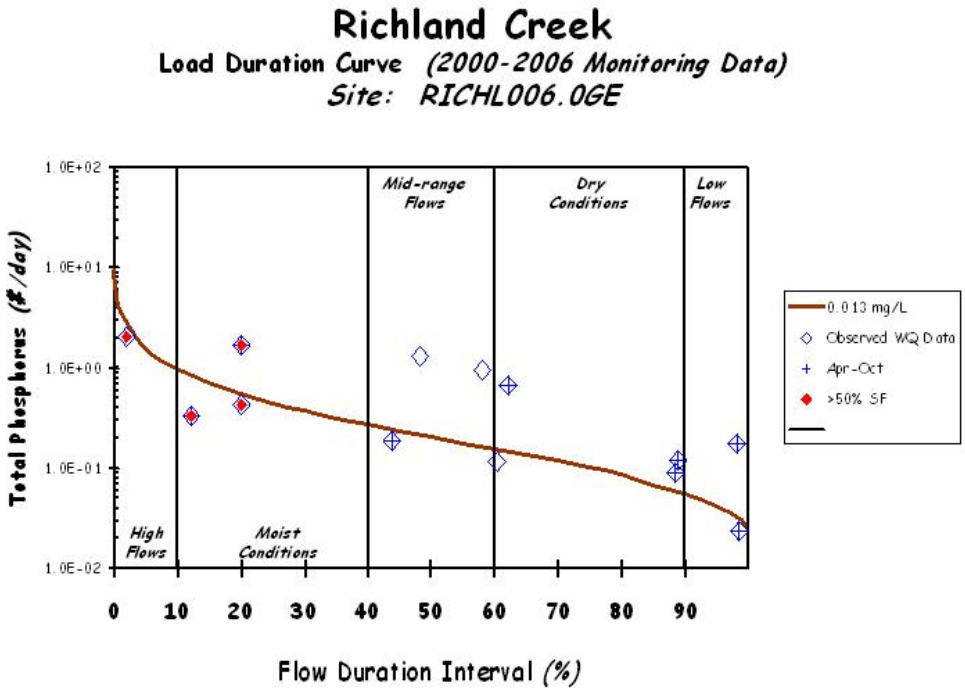


Figure G-21 Total Nitrogen Load Duration Curve – Richland Creek at RICHL007.1GE

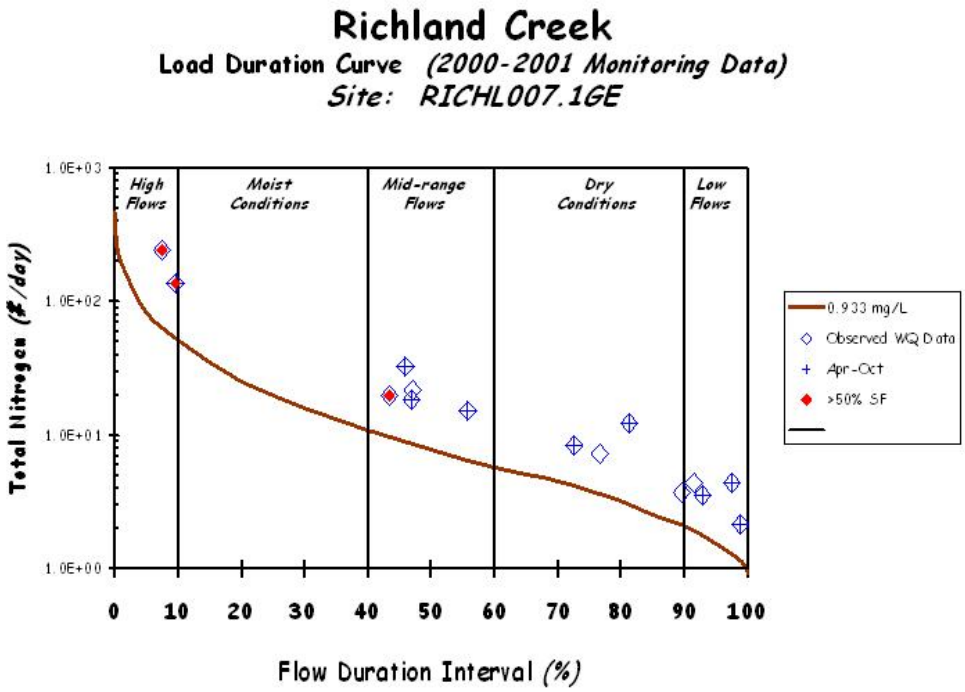


Figure G-22 Total Phosphorus Load Duration Curve – Richland Creek at RICHL007.1GE

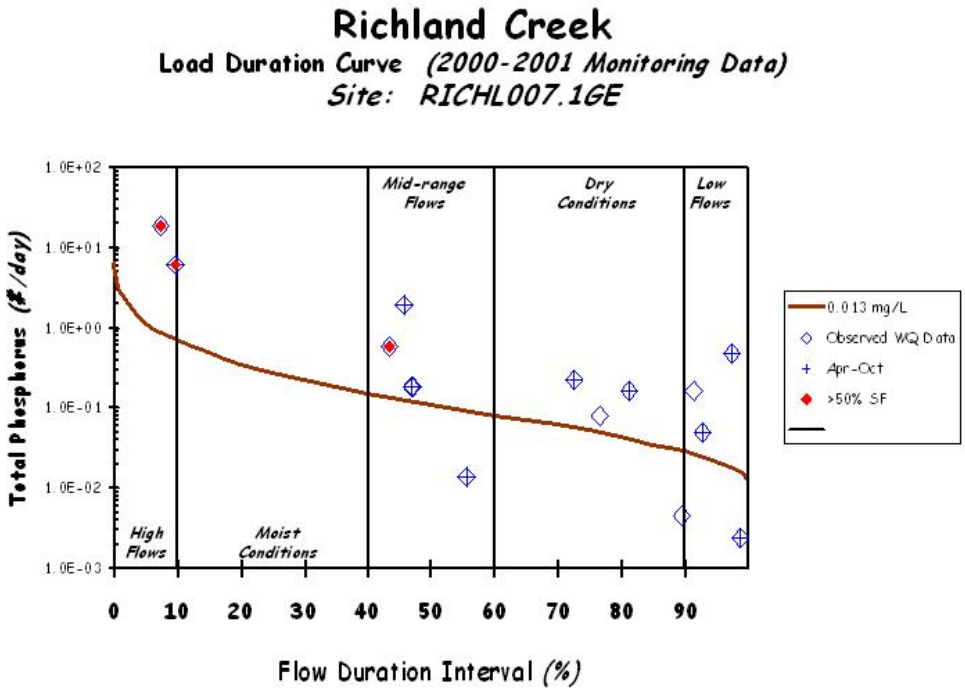


Figure G-23 Total Nitrogen Load Duration Curve – Hominy Creek at HOMIN000.2WN

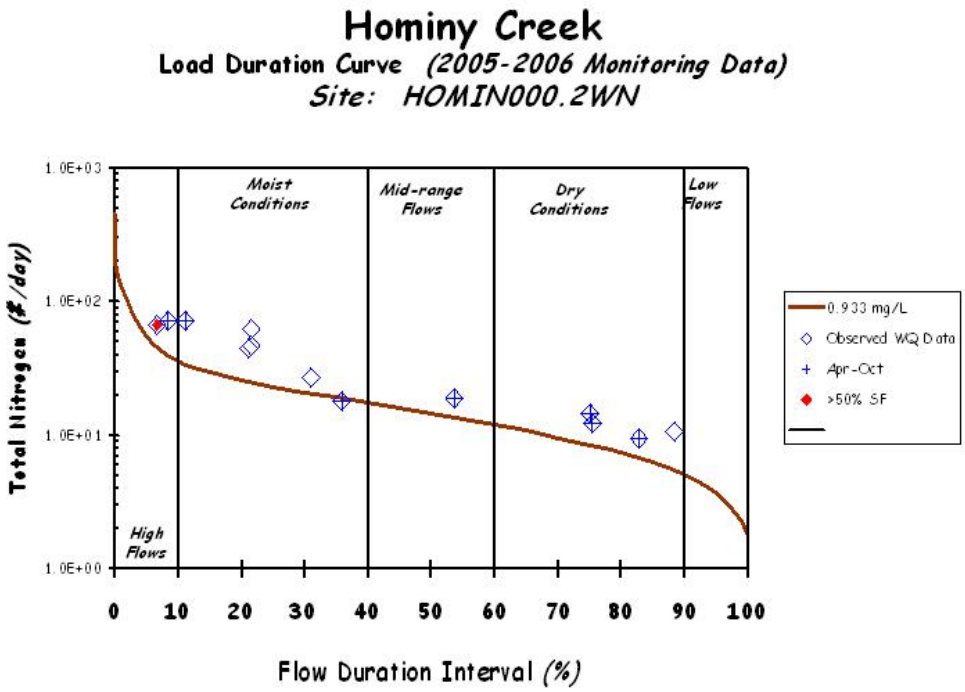


Figure G-24 Total Phosphorus Load Duration Curve – Hominy Creek at HOMIN000.2WN

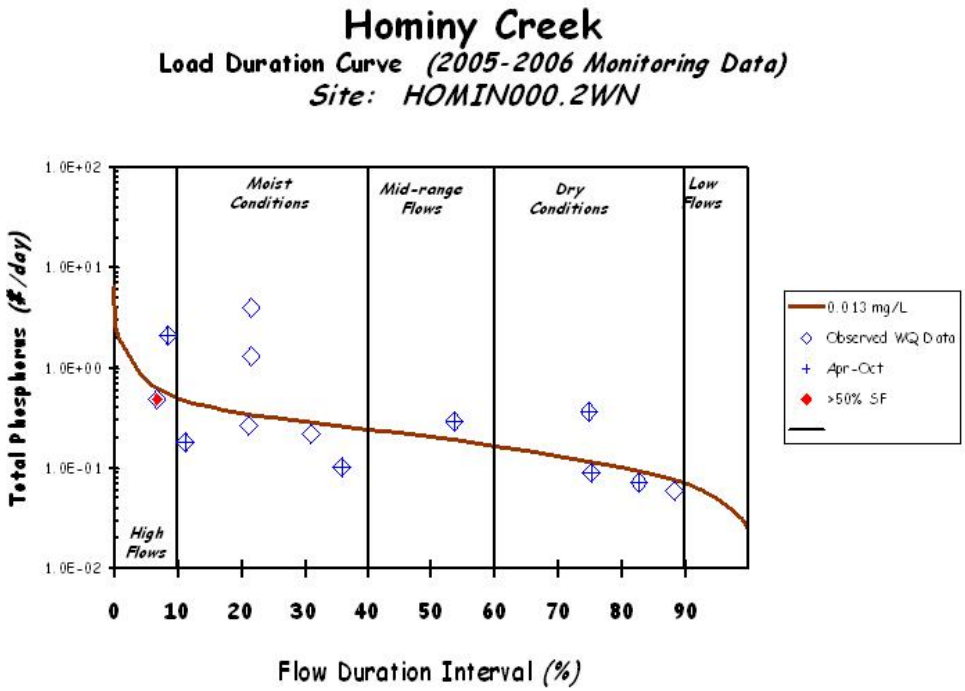


Table G-1 Determination of Overall Required Nutrient Load Reduction for Jockey Creek at RM0.1

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/1/00	14.59	44.7	2.93	230.67	73.45	68.2	0.150	11.81	1.02	91.3
8/22/00	8.10	72.5	3.04	132.76	40.75	69.3	0.053	2.31	0.57	75.5
9/26/00	5.95	83.4	2.23	71.56	29.94	58.2	0.469	15.05	0.42	97.2
10/17/00	3.88	93.2	3.31	69.25	19.52	71.8	0.002	0.04	0.27	NR
11/14/00	3.92	93.1	1.89	39.94	19.72	50.6	0.079	1.67	0.27	83.5
12/12/00	3.60	94.2	1.39	27.00	18.12	32.9	0.040	0.78	0.25	67.5
1/17/01	4.03	92.5	1.35	29.33	20.27	30.9	0.060	1.30	0.28	78.3
2/13/01	6.04	82.9	1.93	62.85	30.38	51.7	0.090	2.93	0.42	85.6
3/13/01	16.83	36.6	2.55	231.52	84.71	63.4	0.060	5.45	1.18	78.3
4/17/01	17.48	34.6	2.44	230.07	87.97	61.8	0.060	5.66	1.23	78.3
5/8/01	8.77	69.2	2.12	100.35	44.16	56.0	0.120	5.68	0.62	89.2
6/5/01	11.06	59.2	1.73	103.23	55.67	46.1	0.110	6.56	0.78	88.2
7/11/01	9.28	66.9	2.72	136.24	46.73	65.7	0.120	6.01	0.65	89.2
10/24/01	7.53	75.5	1.76	71.49	37.90	47.0	0.055	2.23	0.53	76.4
7/14/05	12.50	53.3	1.28	85.95	62.90	26.8	0.080	5.39	0.88	83.8
8/10/05	7.64	75.0	2.54	104.73	38.47	63.3	0.010	0.41	0.54	NR
9/14/05	7.65	75.0	1.42	58.57	38.48	34.3	0.100	4.12	0.54	87.0
10/18/05	6.40	81.2	1.49	51.24	32.19	37.2	0.010	0.35	0.45	NR
11/3/05	4.92	88.6	1.86	49.32	24.74	49.8	0.010	0.27	0.34	NR
12/8/05	18.54	31.3	1.17	117.00	93.30	20.3	0.035	3.50	1.30	62.9

Table G-1 (cont'd) Determination of Overall Required Nutrient Load Reduction for Jockey Creek at RM0.1

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/17/06	50.79	5.0	2.09	572.65	255.64	55.4	0.140	38.36	3.56	90.7
2/6/06	22.21	21.8	3.00	359.35	111.76	68.9	0.250	29.95	1.56	94.8
3/15/06	22.32	21.6	1.68	201.71	112.36	44.3	0.010	1.20	1.57	NR
3/28/06	22.28	21.7	1.98	237.37	112.14	52.8	0.077	9.25	1.56	83.1
4/17/06	17.26	35.4	1.58	146.69	86.89	40.8	0.005	0.47	1.21	NR
5/3/06	30.39	11.7	2.58	422.11	152.94	63.8	0.005	0.82	2.13	NR
6/8/06	35.50	8.7	2.38	454.85	178.68	60.7	0.110	21.07	2.49	88.2
					Average →	**51.5**			**Average →**	**83.4**

Notes: NR = Sample load is lower than target load; no reduction required.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-2 Determination of Overall Required Nutrient Load Reduction for Jockey Creek at RM3.2

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/22/00	2.38	72.4	2.30	29.54	11.98	59.4	0.025	0.32	0.17	48.0
9/26/00	1.75	83.2	2.10	19.81	8.80	55.6	0.039	0.37	0.12	66.7
10/17/00	1.14	93.1	2.29	14.11	5.75	59.3	ND			
11/14/00	1.15	93.0	1.84	11.45	5.80	49.3	0.063	0.39	0.08	79.4
12/12/00	1.05	94.2	1.51	8.54	5.28	38.2	0.040	0.23	0.07	67.5
1/17/01	1.18	92.6	1.41	8.95	5.92	33.8	0.030	0.19	0.08	56.7
2/13/01	1.73	83.7	1.88	17.55	8.71	50.4	0.020	0.19	0.12	35.0
3/13/01	4.91	36.9	2.05	54.29	24.71	54.5	0.050	1.32	0.34	74.0
4/17/01	5.11	34.9	2.27	62.63	25.74	58.9	0.040	1.10	0.36	67.5
5/8/01	2.58	69.0	1.87	26.06	13.00	50.1	0.070	0.98	0.18	81.4
6/5/01	3.26	58.9	1.67	29.38	16.41	44.1				
7/11/01	2.73	66.7	1.74	25.67	13.76	46.4	0.100	1.48	0.19	87.0
10/24/01	2.22	75.4	1.86	22.25	11.16	49.8	0.024	0.29	0.16	45.8
					Average →	**50.0**			**Average →**	**64.5**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-3 Determination of Overall Required Nutrient Load Reduction for Carson Creek at RM0.1

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/1/00	8.11	44.1	2.86	125.07	40.80	67.4	0.13	5.69	0.57	90.0
8/22/00	4.49	72.1	13.29	322.02	22.61	93.0	0.081	1.96	0.31	84.0
9/26/00	3.25	83.5	2.49	43.71	16.38	62.5	1.07	18.79	0.23	98.8
10/17/00	2.16	93.1	2.23	25.95	10.86	58.2	0.071	0.83	0.15	81.7
11/14/00	2.16	93.0	1.74	20.30	10.89	46.4	0.107	1.25	0.15	87.9
12/12/00	1.95	94.4	1.50	15.80	9.83	37.8	0.11	1.16	0.14	88.2
1/17/01	2.21	92.6	1.51	17.99	11.11	38.2	0.04	0.48	0.15	67.5
2/13/01	3.22	84.0	1.94	33.72	16.22	51.9	0.10	1.74	0.23	87.0
3/13/01	9.13	37.7	2.80	137.85	45.93	66.7	0.24	11.82	0.64	94.6
4/17/01	9.56	35.2	2.56	131.99	48.10	63.6	0.07	3.61	0.67	81.4
5/8/01	4.86	68.9	2.12	55.57	24.45	56.0	0.16	4.19	0.34	91.9
6/5/01	6.16	58.5	2.43	80.71	30.99	61.6	0.16	5.31	0.43	91.9
7/11/01	5.17	66.4	2.95	82.35	26.04	68.4	0.17	4.75	0.36	92.4
10/24/01	4.18	75.2	1.74	39.26	21.05	46.4	0.053	1.20	0.29	75.5
7/14/05	6.83	53.7	1.71	62.99	34.37	45.4	0.15	5.53	0.48	91.3
8/10/05	4.25	74.6	2.56	58.65	21.38	63.6	0.23	5.27	0.30	94.3
9/14/05	4.25	74.6	1.55	35.50	21.37	39.8	0.120	2.75	0.30	89.2
10/18/05	3.55	80.7	1.14	21.75	17.88	17.8	ND			
11/3/05	2.72	88.3	1.74	25.54	13.69	46.4	ND			
12/8/05	10.37	30.6	1.59	88.98	52.21	41.3	0.11	6.16	0.73	88.2

Table G-3 (cont'd) Determination of Overall Required Nutrient Load Reduction for Carson Creek at RM0.1

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/17/06	20.14	8.4	1.28	138.50	101.35	26.8	ND			
2/6/06	12.46	21.1	3.20	215.05	62.70	70.8	0.32	21.51	0.87	95.9
					Average →	**53.2**			**Average →**	**88.0**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-4 Determination of Overall Required Nutrient Load Reduction for Carson Creek at RM1.8

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/22/00	4.12	72.1	2.81	62.38	20.71	66.8	0.035	0.78	0.29	62.9
9/26/00	2.98	83.5	2.24	36.05	15.02	58.3	0.082	1.32	0.21	84.1
10/17/00	1.98	93.1	1.45	15.45	9.94	35.7	ND			
11/14/00	1.98	93.0	1.83	19.56	9.97	49.0	0.061	0.65	0.14	78.7
12/12/00	1.79	94.4	1.40	13.51	9.01	33.4	0.070	0.68	0.13	81.4
1/17/01	2.02	92.6	1.72	18.77	10.18	45.8	0.030	0.33	0.14	56.7
2/13/01	2.95	84.0	1.98	31.56	14.87	52.9	0.040	0.64	0.21	67.5
3/13/01	8.37	37.6	2.55	115.11	42.12	63.4	0.030	1.35	0.59	56.7
4/17/01	8.76	35.1	2.44	115.31	44.09	61.8	0.040	1.89	0.61	67.5
5/8/01	4.45	68.9	2.08	49.95	22.40	55.1	0.080	1.92	0.31	83.8
6/5/01	5.64	58.6	1.75	53.24	28.38	46.7	0.040	1.22	0.40	67.5
10/24/01	3.83	75.2	1.85	38.24	19.28	49.6	0.011	0.23	0.27	NR
					Average →	**51.5**			**Average →**	**70.7**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-5 Determination of Overall Required Nutrient Load Reduction for Potter Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
12/5/00	1.16	94.6	3.06	19.13	6.56	65.7	0.214	1.34	0.28	79.0
1/4/01	1.58	87.1	1.69	14.44	8.97	37.9	0.220	1.88	0.38	79.5
1/30/01	4.31	53.6	1.72	39.98	24.41	39.0	0.180	4.18	1.05	75.0
2/28/01	12.40	17.7	1.51	100.99	70.22	30.5	0.110	7.36	3.01	59.1
3/27/01	5.28	45.5	1.35	38.45	29.90	22.2	0.090	2.56	1.28	50.0
4/24/01	3.92	57.7	0.94	19.85	22.18	NR	0.090	1.90	0.95	50.0
5/22/01	21.72	8.7	1.08	126.55	123.04	2.8	0.230	26.95	5.27	80.4
6/19/01	2.57	72.8	9.00	124.55	14.53	88.3	0.430	5.95	0.62	89.5
7/24/01	2.57	72.6	30.06	417.37	14.58	96.5	1.230	17.08	0.62	96.3
9/12/01	3.20	65.4	0.80	13.82	18.13	NR	0.180	3.11	0.78	75.0
12/11/01	3.07	67.0	1.89	31.27	17.37	44.4	0.320	5.29	0.74	85.9
7/20/05	2.67	71.5	0.76	10.88	15.14	NR	ND		0.65	
8/17/05	1.71	84.6	0.33	3.00	9.71	NR	ND		0.42	
9/28/05	0.96	97.9	0.51	2.66	5.44	NR	ND		0.23	
10/25/05	1.07	96.1	0.67	3.88	6.05	NR	ND		0.26	
11/16/05	1.74	84.0	1.34	12.54	9.83	21.6	ND		0.42	
12/13/05	1.72	84.5	1.26	11.67	9.73	16.7	ND		0.42	
1/18/06	44.56	3.3	2.11	507.24	252.42	50.2	0.390	93.76	10.82	88.5
2/21/06	5.59	42.7	0.73	21.88	31.68	NR	ND		1.36	
3/20/06	8.14	29.7	0.79	34.47	46.11	NR	0.059	2.59	1.98	23.7

Table G-5 (cont'd) Determination of Overall Required Nutrient Load Reduction for Potter Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
4/24/06	23.04	8.0	0.80	99.41	130.48	NR	ND			
5/16/06	5.86	40.6	0.61	19.12	33.19	NR	0.030	0.95	1.42	NR
6/20/06	3.14	66.1	1.08	18.21	17.78	2.3	0.070	1.19	0.76	35.7
					Average →	**39.9**			**Average →**	**69.1**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-6 Determination of Overall Required Nutrient Load Reduction for Puncheon Camp Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/15/00	0.92	95.0	0.77	3.81	4.89	NR	0.105	0.52	0.27	48.6
7/20/05	2.67	65.4	1.57	22.63	14.24	37.1	0.200	2.88	0.78	73.0
8/17/05	1.71	78.7	0.90	8.32	9.13	NR	0.160	1.48	0.50	66.3
12/13/05	1.72	78.7	1.36	12.59	9.15	27.3	0.037	0.35	0.50	NR
1/18/06	44.56	2.5	3.30	792.95	237.51	70.0	0.445	106.97	12.98	87.9
2/21/06	5.59	37.4	0.49	14.64	29.81	NR	0.010	0.30	1.63	NR
3/20/06	8.14	24.5	ND				0.040	1.77	2.37	NR
4/24/06	23.04	6.3	0.84	104.20	122.78	NR	0.005	0.62	6.71	NR
5/16/06	5.86	35.5	0.29	9.01	31.23	NR	0.060	1.90	1.71	10.0
6/20/06	3.14	59.9	0.26	4.32	16.73	NR	0.100	1.69	0.91	46.0
					Geometric Mean →	**41.4**			**Geometric Mean →**	**46.0**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-7 Determination of Overall Required Nutrient Load Reduction for Lick Creek at RM52.3

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/15/00	11.48	86.4	1.44	88.94	59.21	33.4	0.192	11.89	1.55	87.0
9/14/00	7.54	97.3	1.40	56.95	38.89	31.7	0.055	2.24	1.02	54.5
10/10/00	8.75	94.4	0.77	36.36	45.14	NR	0.032	1.51	1.18	21.9
11/7/00	6.35	99.3	0.19	6.51	32.74	NR	0.012	0.41	0.86	NR
12/5/00	8.85	94.1	0.96	45.84	45.65	0.4	0.022	1.05	1.19	NR
1/4/01	11.36	86.8	1.09	66.77	58.56	12.3	0.010	0.61	1.53	NR
1/30/01	30.82	52.6	2.23	370.72	158.93	57.1	0.040	6.65	4.16	37.5
2/28/01	84.04	17.4	1.96	888.56	433.40	51.2	0.020	9.07	11.33	NR
3/27/01	40.97	40.6	1.46	322.65	211.27	34.5	0.020	4.42	5.52	NR
4/24/01	29.22	54.8	1.03	162.35	150.69	7.2	ND			
5/22/01	154.76	7.6	1.35	1127.1	798.13	29.2	0.090	75.14	20.87	72.2
6/19/01	17.99	73.0	1.52	147.53	92.79	37.1	0.110	10.68	2.43	77.3
7/24/01	18.97	71.7	1.67	170.92	97.84	42.8	0.090	9.21	2.56	72.2
9/12/01	28.28	56.1	2.06	314.31	145.86	53.6	0.040	6.10	3.81	37.5
12/11/01	27.06	57.9	1.34	195.58	139.53	28.7	0.103	15.03	3.65	75.7
7/20/05	18.79	71.9	1.58	159.65	96.91	39.3	0.150	15.20	2.53	83.3
8/17/05	11.60	86.1	1.07	66.66	59.83	10.2	ND			
9/28/05	7.10	98.1	0.62	23.57	36.63	NR	ND			
10/25/05	8.12	95.8	0.32	13.80	41.89	NR	ND			
11/16/05	17.76	73.3	3.77	361.13	91.58	74.6	0.580	55.56	2.39	95.7
12/13/05	13.41	81.3	0.76	54.63	69.18	NR	0.100	7.24	1.81	75.0

Table G-7 (cont'd) Determination of Overall Required Nutrient Load Reduction for Lick Creek at RM52.3

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/18/06	338.45	2.5	2.72	4966.0	1745.41	64.9	0.500	912.87	45.64	95.0
2/21/06	37.45	44.4	0.81	162.64	193.15	NR	ND			
3/20/06	53.00	31.0	1.04	295.90	273.31	7.6	0.048	13.72	7.15	47.9
4/24/06	181.20	6.2	1.78	1735.0	934.47	46.1	ND			
5/16/06	40.43	41.1	0.21	44.71	208.50	NR	0.060	13.09	5.45	58.3
6/20/06	24.19	62.7	2.08	270.73	124.73	53.9	0.090	11.74	3.26	72.2
					Average →	**25.2**			**Average →**	**62.3**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-8 Determination of Overall Required Nutrient Load Reduction for Lick Creek at RM61.0

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/15/00	3.10	81.2	1.53	25.59	16.00	37.5	0.031	0.52	0.42	19.4
9/14/00	2.07	95.1	3.12	34.86	10.68	69.4	0.122	1.36	0.28	79.5
10/10/00	2.30	91.0	0.97	12.05	11.88	1.4	0.032	0.40	0.31	21.9
11/7/00	1.66	99.0	0.94	8.44	8.59	NR	0.028	0.25	0.22	10.7
12/5/00	2.29	91.3	1.99	24.55	11.79	52.0	0.146	1.80	0.31	82.9
1/4/01	2.78	84.7	1.09	16.35	14.34	12.3	0.020	0.30	0.37	NR
1/30/01	7.27	51.7	1.29	50.57	37.47	25.9	0.030	1.18	0.98	16.7
2/28/01	18.17	17.7	1.23	120.56	93.70	22.3	0.010	0.98	2.45	NR
3/27/01	10.43	36.5	0.97	54.57	53.78	1.4	0.020	1.13	1.41	NR
4/24/01	7.24	51.9	0.80	31.23	37.32	NR	ND			
5/22/01	26.24	10.9	1.10	155.69	135.31	13.1	0.090	12.74	3.54	72.2
6/19/01	4.38	71.9	1.32	31.22	22.61	27.6	0.070	1.66	0.59	64.3
7/24/01	4.91	68.4	1.24	32.82	25.30	22.9	0.030	0.79	0.66	16.7
9/12/01	7.70	49.3	1.44	59.83	39.72	33.6	0.010	0.42	1.04	
12/11/01	5.72	62.1	0.96	29.60	29.48	0.4	0.030	0.93	0.77	16.7
7/20/05	5.48	64.0	1.28	37.69	28.26	25.0	ND			
8/17/05	2.90	83.1	0.94	14.65	14.98	NR	ND			
9/28/05	1.87	97.4	0.69	6.91	9.64	NR	ND			
10/25/05	2.17	93.0	0.84	9.76	11.18	NR	ND			
11/16/05	4.31	72.3	1.49	34.63	22.22	35.8	ND			
12/13/05	3.58	77.1	0.65	12.46	18.47	NR	ND			

Table G-8 (cont'd) Determination of Overall Required Nutrient Load Reduction for Lick Creek at RM61.0

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/18/06	73.02	2.4	2.11	831.10	376.56	54.7	0.150	59.08	9.85	83.3
2/21/06	8.61	44.7	0.67	30.87	44.38	NR	ND			
3/20/06	13.25	27.2	0.85	60.40	68.34	NR	ND			
4/24/06	43.28	5.3	0.98	227.65	223.21	1.9	ND			
5/16/06	8.93	43.3	0.85	40.71	46.06	NR	0.020	0.96	1.20	NR
6/20/06	5.85	61.2	1.91	60.30	30.18	49.9	0.010	0.32	0.79	NR
					Average →	**27.1**			**Average →**	**44.0**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-9 Determination of Overall Required Nutrient Load Reduction for Richland Creek at RM4.3

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/2/00	2.15	80.9	2.15	24.95	10.83	56.6	0.033	0.38	0.15	60.6
8/29/00	1.28	92.6	1.61	11.12	6.45	42.0	0.043	0.30	0.09	69.8
9/19/00	0.90	97.3	1.87	9.10	4.54	50.1	0.140	0.68	0.06	90.7
10/24/00	0.79	98.9	1.45	6.19	3.98	35.7	0.010	0.04	0.06	NR
11/29/00	3.33	67.3	1.51	27.09	16.74	38.2	0.033	0.59	0.23	60.6
12/14/00	19.39	11.0	2.91	304.44	97.61	67.9	0.180	18.83	1.36	92.8
1/9/01	1.36	91.5	2.78	20.36	6.83	66.4	0.130	0.95	0.10	90.0
2/5/01	2.61	75.8	1.55	21.80	13.12	39.8	0.020	0.28	0.18	35.0
3/7/01	6.14	42.4	2.06	68.27	30.92	54.7	ND			
4/4/01	6.48	40.6	3.03	105.98	32.63	69.2	0.140	4.90	0.45	90.7
5/1/01	2.95	71.8	1.66	26.42	14.85	43.8	0.030	0.48	0.21	56.7
5/29/01	5.35	48.1	1.81	52.23	26.92	48.5	0.070	2.02	0.38	81.4
6/26/01	16.83	13.4	1.88	170.66	84.70	50.4	0.100	9.08	1.18	87.0
8/22/01	4.56	53.9	1.94	47.76	22.97	51.9	ND			
11/14/01	1.47	89.4	1.27	10.04	7.38	26.5	ND			
					Average →	**49.5**			**Average →**	**74.1**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-10 Determination of Overall Required Nutrient Load Reduction for Richland Creek at RM6.0

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/21/00	0.83	89.0	2.17	9.76	4.19	57.0	0.027	0.12	0.06	51.9
7/14/05	7.90	20.2	1.38	58.61	39.77	32.1	0.040	1.70	0.55	67.5
8/10/05	0.84	88.7	2.39	10.81	4.23	60.9	0.020	0.09	0.06	35.0
9/14/05	0.47	98.2	2.80	7.09	2.36	66.7	0.070	0.18	0.03	81.4
10/20/05	0.44	98.7	1.51	3.60	2.23	38.0	ND			
11/3/05	0.45	98.7	2.02	4.86	2.24	53.8	ND			
12/8/05	7.86	20.2	1.24	52.37	39.56	24.5	ND			
1/17/06	38.10	2.1	1.88	385.37	191.76	50.2	ND			
2/6/06	2.18	60.4	2.08	24.39	10.96	55.0	ND			
3/15/06	3.05	48.4	1.88	30.87	15.36	50.2	0.081	1.33	0.21	84.0
3/28/06	2.31	58.1	2.08	25.82	11.61	55.0	0.076	0.95	0.16	82.9
4/17/06	12.41	12.3	1.98	132.18	62.44	52.8	ND			
5/3/06	3.48	43.9	2.08	38.95	17.52	55.0	0.010	0.19	0.24	NR
6/8/06	2.09	62.2	1.48	16.61	10.50	36.7	0.060	0.68	0.15	78.3
					Average →	**49.1**			**Geometric Mean →**	**66.0**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-11 Determination of Overall Required Nutrient Load Reduction for Richland Creek at RM7.1

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/2/00	0.61	81.2	3.71	12.16	3.06	74.9	0.051	0.17	0.04	74.5
8/29/00	0.36	92.8	1.83	3.57	1.82	49.0	0.025	0.05	0.03	48.0
9/19/00	0.25	97.5	3.24	4.44	1.28	71.2	0.347	0.48	0.02	96.3
10/24/00	0.23	98.8	1.74	2.13	1.14	46.4	ND			
11/29/00	1.96	43.5	1.90	20.05	9.84	50.9	0.056	0.59	0.14	76.8
12/14/00	12.85	7.5	3.52	244.01	64.68	73.5	0.270	18.72	0.90	95.2
1/9/01	0.39	91.5	2.10	4.37	1.94	55.6	0.080	0.17	0.03	83.8
2/5/01	0.73	76.7	1.84	7.23	3.67	49.3	0.020	0.08	0.05	35.0
3/7/01	1.72	47.1	2.35	21.85	8.68	60.3	0.020	0.19	0.12	35.0
4/4/01	1.79	45.9	3.39	32.82	9.03	72.5	0.200	1.94	0.13	93.5
5/1/01	0.83	72.6	1.86	8.35	4.19	49.8	0.050	0.22	0.06	74.0
5/29/01	1.73	46.9	1.97	18.41	8.72	52.6	0.020	0.19	0.12	35.0
6/26/01	10.48	9.7	2.41	136.25	52.75	61.3	0.110	6.22	0.73	88.2
8/22/01	1.30	55.7	2.19	15.32	6.53	57.4	ND			
11/14/01	0.42	89.6	1.63	3.69	2.11	42.8	ND			
					Average →	**57.8**			**Average →**	**69.6**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table G-12 Determination of Overall Required Nutrient Load Reduction for Hominy Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
7/14/05	2.73	53.7	1.28	18.75	13.72	26.8	0.020	0.29	0.19	35.0
8/10/05	1.66	75.4	1.37	12.22	8.35	31.6	ND			
9/14/05	1.68	75.0	1.61	14.62	8.47	42.0	0.040	0.36	0.12	67.5
10/20/05	1.33	82.8	1.34	9.57	6.69	30.1	ND			
11/3/05	1.09	88.5	1.80	10.58	5.49	48.2	ND			
12/8/05	4.08	31.1	1.23	26.99	20.55	23.8	ND			
1/17/06	9.00	6.8	1.38	66.77	45.30	32.1	ND			
2/6/06	4.91	21.7	2.34	62.01	24.73	60.1	0.150	3.98	0.34	91.3
3/15/06	4.96	21.3	1.68	44.77	24.94	44.3	ND			
3/28/06	4.91	21.7	1.78	47.02	24.71	47.4	0.050	1.32	0.34	74.0
4/17/06	3.76	35.9	0.90	18.18	18.95	NR	ND			
5/3/06	6.78	11.2	1.98	72.25	34.13	52.8	ND			
6/8/06	7.93	8.5	1.68	71.66	39.92	44.3	0.050	2.14	0.56	74.0
					Average →	**40.3**			**Geometric Mean →**	**65.2**

Notes: NR = Sample load is lower than target load; no reduction required.
ND = Sample concentration below detection limit.
a. Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

APPENDIX H

Development and Calibration of LSPC Model

H.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected to simulate flow for load duration curve (LDC) development for dissolved oxygen and nutrient impaired waterbodies in the Nolichucky River watershed. LSPC is a dynamic watershed model, based on the Hydrologic Simulation Program – Fortran (HSPF), capable of simulating nonpoint source runoff and associated pollutant loadings and performing flow routing through stream reaches.

H.2 Model Calibration

In order to simulate flow as accurately as possible, a model must be calibrated. This involves comparison of simulated stream flow to historic stream flow data from USGS stream gaging stations for the same period of time. The USGS continuous record station located at Afton, Tennessee (USGS 03466228) was selected as the basis of the hydrology calibration. This station is located in the Nolichucky River Watershed within Level IV ecoregion 67f and with a drainage area of 13.7 square miles.

The drainage area upstream of the selected USGS station was delineated and an LSPC model constructed. The delineation was performed using the Watershed Characterization System (WCS) and based on National Hydrology Dataset (NHD) stream coverage and Digital Elevation Model (DEM) data. WCS is a geographic information system (GIS) tool used to display, analyze, and compile available information to support hydrology model simulations. In addition to NHD and DEM data, this information includes land use categories, point source dischargers, soil types and characteristics, and stream characteristics. WCS has the capability to export GIS and watershed data to the LSPC model.

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 stream flow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. An important factor influencing model results is the precipitation data used for the simulation. Meteorological data from a station at the Bristol Tri-Cities Regional Airport, Tennessee was used for hydrologic calibration. The results of the hydrologic calibration are shown in Table H-1 and Figure H-1.

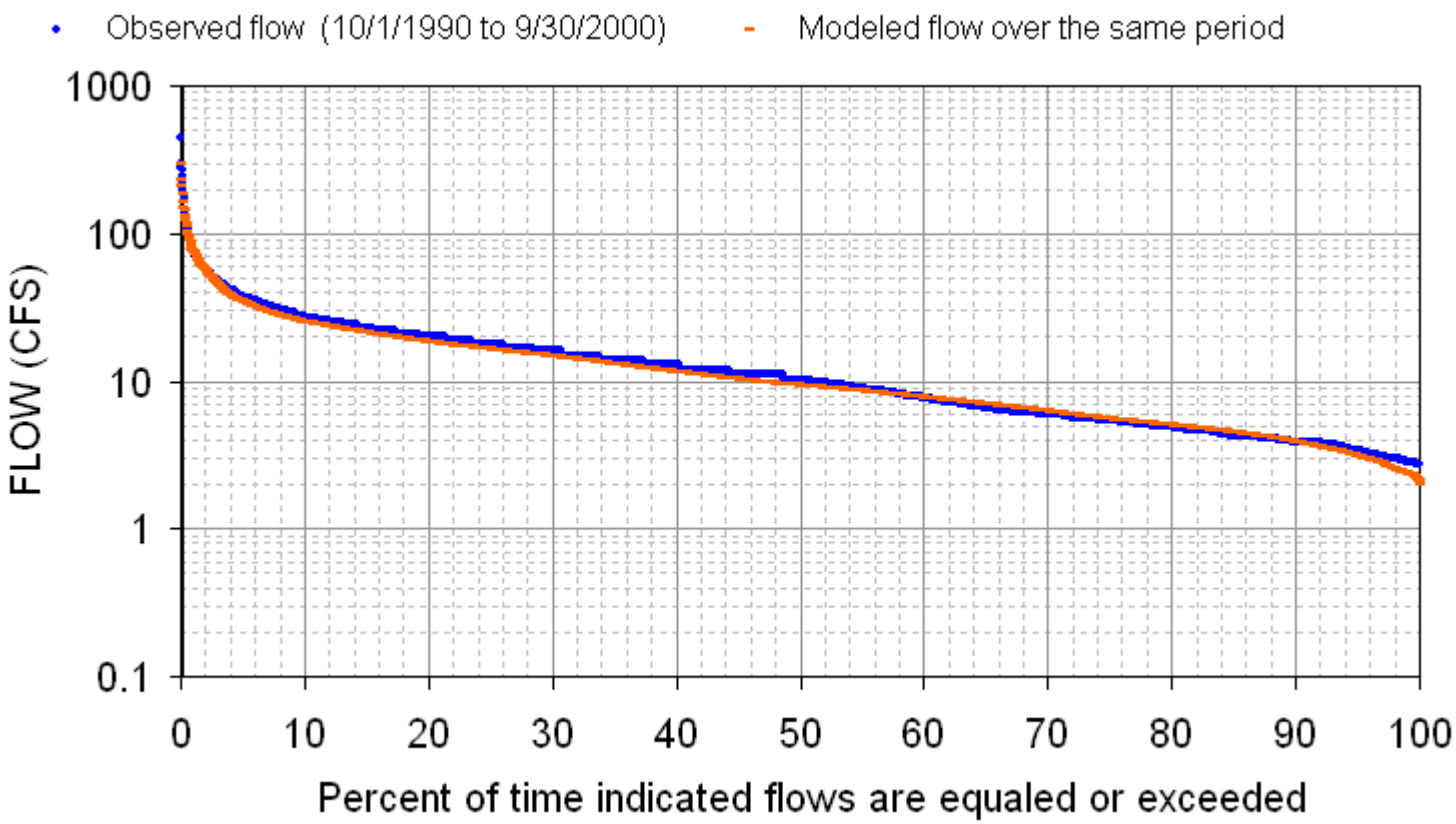
H.3 Flow Simulation for Impaired Waterbodies

The drainage areas upstream of the relevant water quality monitoring stations on Carson Creek, Jockey Creek, Potter Creek, Puncheon Camp Creek, Richland Creek, and the headwater portion of Lick Creek were delineated and LSPC models constructed. Using the hydrologic parameter values determined during calibration (Section H.2), each impaired waterbody model was run for the period 10/1/97 through 9/30/07. Data from the Erwin, TN weather station was used for the Carson, Jockey, and Hominy Creek simulations, while data from the Rogersville, TN station was used for the Potter and Puncheon Camp Creek simulations. Data from both Erwin and Rogersville weather stations were used for the Richland Creek simulations, while data from the Rogersville and Bristol Tri-Cities Regional Airport weather stations were used for the Lick Creek simulations.

Table H-1 Hydrologic Calibration Summary of Sinking Creek at USGS Station 03466228

Simulation Name:	USGS03466228	**Simulation Period:**	
		Watershed Area (ac):	9715.10
Period for Flow Analysis			
Begin Date:	**10/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/00**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**122.33**	Total Observed In-stream Flow:	**130.90**
Total of highest 10% flows:	**41.48**	Total of Observed highest 10% flows:	**45.73**
Total of lowest 50% flows:	**25.77**	Total of Observed Lowest 50% flows:	**27.02**
Simulated Summer Flow Volume (months 7-9):	**16.07**	Observed Summer Flow Volume (7-9):	**17.40**
Simulated Fall Flow Volume (months 10-12):	**16.69**	Observed Fall Flow Volume (10-12):	**17.49**
Simulated Winter Flow Volume (months 1-3):	**51.48**	Observed Winter Flow Volume (1-3):	**57.25**
Simulated Spring Flow Volume (months 4-6):	**38.09**	Observed Spring Flow Volume (4-6):	**38.77**
Total Simulated Storm Volume:	**98.72**	Total Observed Storm Volume:	**104.08**
Simulated Summer Storm Volume (7-9):	**10.14**	Observed Summer Storm Volume (7-9):	**10.64**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-6.55**	10	
Error in 50% lowest flows:	**-4.62**	10	
Error in 10% highest flows:	**-9.29**	15	
Seasonal volume error - Summer:	**-7.60**	30	
Seasonal volume error - Fall:	**-4.58**	30	
Seasonal volume error - Winter:	**-10.08**	30	
Seasonal volume error - Spring:	**-1.75**	30	
Error in storm volumes:	**-5.15**	20	
Error in summer storm volumes:	**-4.65**	50	

Figure H-1 Comparison of Simulated Flow vs. Observed Flow at USGS 03466228



APPENDIX I

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 (TMDLS) FOR LOW DISSOLVED OXYGEN & NUTRIENTS FOR WATERBODIES IN THE NOLICHUCKY RIVER WATERSHED (HUC 06010108), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Loads (TMDLs) for low dissolved oxygen and nutrients for several waterbodies in the Nolichucky River Watershed, located in 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.

A number of waterbodies located in the Nolichucky River watershed are identified on Tennessee's Final 2008 303(d) list as not supporting designated use classifications due, in part, to low dissolved oxygen or nutrients associated with urban storm water runoff, point source discharges, collection system failure, agriculture, and land development. Using a staged approach, the TMDLs utilize Tennessee's general water quality criteria, data from ecoregion reference sites, in-stream water quality monitoring data, load duration curves, and an appropriate Margin of Safety (MOS) to establish nutrient loading levels which will result in lower in-stream concentrations and the attainment of water quality standards. The TMDLs require reductions in nutrient loading of approximately 27% to 88% in subject waterbodies.

The proposed low dissolved oxygen and nutrient 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

Bruce R. Evans, P.E., Watershed Management Section
Telephone: 615-532-0668

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

Persons wishing to comment on the proposed TMDL are invited to submit their comments in writing no later than April 27, 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.

APPENDIX J

Public Comments Received

Tel: (865) 522-7007
Fax: (865) 525-4988
info@tcwn.org
www.tcwn.org

TCWN
TENNESSEE CLEAN WATER NETWORK

P.O. Box 1521
Knoxville, Tennessee 37901
123A South Gay Street
Knoxville, TN 37902

April 2, 2009

Ms. Sherry H. Wang
Tennessee Department of Environment and Conservation
Division of Water Pollution Control
Watershed Management Section
7th Floor, L&C Annex
401 Church Street
Nashville, TN 37243-1534

BY EMAIL

Re: Proposed Total Maximum Daily Load (TMDL) Stage I for Low Dissolved Oxygen and Nutrients in the Nolichucky River Watershed (HUC 06010108)

Dear Ms Wang:

These comments are submitted on behalf of the Tennessee Clean Water Network regarding the proposed Total Maximum Daily Load (TMDL) Stage I for Low Dissolved Oxygen and Nutrients in the Nolichucky River Watershed, dated March 23, 2009. We appreciate the opportunity to participate in the TMDL Stage I development and review process.

There are some positive elements in the proposed TMDL for the Nolichucky River Watershed for which we support your efforts. However, we do not believe the proposed TMDL satisfies federal regulations, in particular the requirement waste load allocations be calculated for point source discharges of relevant pollutants.

1. The proposed TMDL does not appropriately include individual Waste Load Allocations (WLAs).

A TMDL is defined in 40 C.F.R. § 130.2(i):

> *(i) Total maximum daily load (TMDL). The sum of the individual WLAs for point sources and LAs for nonpoint sources and natural background. If a receiving water has only one point source discharger, the TMDL is the sum of that point source WLA plus the LAs for any nonpoint sources of pollution and natural background sources, tributaries, or adjacent segments. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs.* (emphasis added)

The definition of TMDL clearly notes individual WLAs are to be used as the summation for point source contributions in the TMDL. A WLA is defined in 40 C.F.R. § 130.2(h):

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> *(h) Wasteload allocation (WLA). The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.* (emphasis added)

In Tables 9, 10, and 11 on pages 33 and 34 and in Appendix E (Tables E-4, E-5, and E-6) of the proposed TMDL Stage I, WLAs are provided as categories of point source types. Specifically MS4s, of which there are three Phase II permit holders in the watershed, are grouped together rather than allocated individual WLAs constituting a effluent limitation as defined in 40 C.F.R. § 130.2(h).

It is recognized a memo from the US EPA entitled *"Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs"* dated November 22, 2002 notes:

> *It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs. See 40 C.F.R. § 130.2(i). In cases where wasteload allocations are developed for categories of discharges, these categories should be defined as narrowly as available information allows.* (Emphasis added)

However, with the monitoring data provided in Appendix D (Water Quality Monitoring Data in Impaired Watersheds), Figure 6 (Selected Water Quality Monitoring Stations in the Nolichucky River Watershed), Table 4 (Summary of Water Quality Monitoring Data), and Tables F-1 through F-6 (Eco-region Monitoring Data and Statistics) it would appear the Division has sufficient data and information to assign each MS4 and TDOT an individual WLA. There is not a lack of adequate data which would justify grouping multiple point source discharges into a single categorical WLA.

This use of categorical allocations also has no practical application in implementation of the TMDL in accordance with the geographic layout of the MS4s in relation to the impaired waterbodies. Tables 9, 10, and 11 provide MS4 WLAs for Puncheon Camp Creek and Potter Creek; however currently there are no designated MS4 dischargers in these sub-watersheds. If these allocations serve to address future point sources of pollution or are applicable to the Tennessee Department of Transportation this is not clear in the TMDL.

Each individual MS4 (Greeneville, Jonesborough, Washington County, and TDOT) must receive individual WLAs in the TMDL relevant to the waterbodies to which they discharge for two reasons: (1) This requirement is obvious in the definitions of TMDL (40 C.F.R. § 130.2(i)) and Wasteload Allocation (40 C.F.R. § 130.2(h)). The use of categorical point sources as referenced in the November 22, 2002 memo from the US EPA is not applicable here as there is sufficient data to incorporate individual allocations. (2) WLAs for MS4 permit holders in sub-watersheds with no apparent permitted discharge are unnecessary and illogical. In order to appropriately implement and understand the WLAs in this TMDL, individual allocations for point sources must be employed.

2. The proposed TMDL does not contain adequate waste load allocations (WLAs) for point sources subject to general NPDES permits.

The proposed TMDL does not even address the active NPDES general permits within the watershed. Construction General Permits and Multi-sector General Permits fall under the category of Industrial NPDES permits in accordance with 40 C.F.R. § 122.26 and must be included in the TMDL as required by 40 C.F.R. § 130.2(i). This is acknowledged in the TMDL under *7.0 Source Assessment*:

> *The National Pollutant Discharges Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources.* (emphasis added)

In *8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS* of the proposed TMDL it is reiterated that "A TMDL is equal to the sum of all point source loads (Waste Load Allocations)..." Both the regulations and the TMDL itself make it evident all regulated point sources must be included in the TMDL; however, this proposed TMDL fails to address any NPDES general permits for storm water discharges.

According to the Division's 2008 data these seven waterbodies contain 14 Construction General Permits and eight Multi-sector General Permits with over half of these NPDES general permits located within the Richland Creek sub-watershed. The potential contribution of these general permits to the nutrient and dissolved oxygen impairments of this watershed is completely neglected in the proposed TMDL. The negative impact of land disturbing activities to nutrient loading into adjacent waters has been well reviewed. Site stabilization is a requirement of Storm Water Pollution Prevention Plans, and stabilization is most often achieved through the use of vegetative cover which incorporates the application of fertilizer. Research has shown nitrogen and phosphorus runoff from hydro-seeding can be a significant contributor to nutrient loading.

All NPDES regulated point sources must be allocated waste loads. The WLAs for existing NPDES general permits should not be categorical, as the TMDL provides an extensive amount of monitoring data which is enough information to develop individual allocations.

We appreciate the opportunity to submit these comments and request the Division revise the proposed TMDL in accordance with the requirements of 40 C.F.R. § 130.2(i). Thank you again for the opportunity to submit these comments.

Sincerely,

Dana L. Wright

Dana L. Wright
Director of Policy and Legislative Affairs

Cc: Paul Davis, Water Pollution Control, TN Department of Environment & Conservation
Katherine Sciera, Region 4, USEPA
Shawneille Campbell, Region 4, USEPA

APPENDIX K

Response to Public Comments

1. The proposed TMDL does not appropriately include individual Waste Load Allocations (WLAs).

TMDLs are developed for each combination of waterbody and pollutant. Waste Load Allocations (WLAs) are a component of each TMDL. The WLAs are expressed as a load per unit area. This allows for a dynamic WLA because the actual numeric value of the WLA varies depending on the flow in the waterbody and the area being addressed. It is possible for the area being addressed to change if the boundaries of an MS4 change. By using a dynamic WLA, the WLA will automatically be adjusted as the boundaries of the MS4 vary.

The WLA for each MS4 is the sum of the WLAs for each of the waterbodies lying within the jurisdiction of that MS4. The Richland Creek drainage area appears to lie within the jurisdiction of the City of Greenville MS4, while the Jockey Creek, Carson Creek, and Hominy Creek drainage areas appear to lie within the jurisdiction of the Washington County MS4. The remaining impaired waterbodies do not appear to lie within the jurisdiction of any specific MS4, but may be covered by the TDOT MS4 permit. To allow for this possibility, the WLAs for these waterbodies have been calculated and included in the appropriate tables.

2. The proposed TMDL does not contain adequate waste load allocations (WLAs) for point sources subject to general NPDES permits.

Construction General Permits (CGP) and Multi-Sector General Permits (TMSP) cover stormwater discharges from industrial facilities and/or activities. This TMDL does not specifically address active permits within the watershed that fall into these two categories. TDEC has determined that these permits do not contribute a significant load relative to loading from the entire watershed.

According to the most recent data available to the Division, there are 13 sites with coverage under the CGP located within the seven impaired drainage areas addressed in this TMDL. These 13 sites cover a total of 48.9 acres, while the impaired drainage areas cover a total of 71,563 acres. Since the construction sites comprise less than 0.1% of the impaired drainage areas, these construction sites are considered to be a minor source of loading. The comments from TCWN specifically mentioned stabilization, fertilizing, and hydro-seeding. While these activities are potential sources of nutrient loading, they are temporary and transient in nature. Therefore, the sites located in the impaired drainage areas and covered by the CGP have not been assigned a WLA in this TMDL.

According to the most recent data available to the Division, there are 4 sites with coverage under the TMSP located within the seven impaired drainage areas addressed in this TMDL. Facilities with coverage under theTMSP are grouped into sectors based on the Standard Industrial Classification (SIC) code associated with the facility. Each sector has specific monitoring requirements based on their potential to discharge certain pollutants. The 4 sites located within the drainage areas addressed in this TMDL belong to sectors that do not require monitoring for parameters that contribute to the impairment due to low dissolved oxygen or nutrients. Facilities within these sectors are not considered to have the potential to discharge significant amounts of the pollutants for which the receiving waters are impaired. Therefore, the sites located in the impaired drainage areas and covered by the TMSP have not been assigned a WLA in this TMDL.