Natural Conditions Assessment for Low Dissolved Oxygen, Tuckahoe Creek Henrico County, Virginia

Submitted by

Virginia Department of Environmental Quality

July, 2004

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive Summary

This report presents the assessment of whether low dissolved oxygen (DO) in the Tuckahoe Creek watershed is due to natural conditions or whether a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. The Tuckahoe Creek watershed is located in Henrico County in the James River Basin (USGS Hydrologic Unit Code 02080205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Tuckahoe Creek is VAP-H39R in the Coastal Plain region of Virginia.

The drainage area of the Tuckahoe Creek watershed is approximately 64.3 square miles. The average annual rainfall as recorded in Ashland, VA, within 13 miles of the study area is 42.2 inches. The approximately 41,200 acre watershed is predominately forested (52.3 percent). Agriculture encompasses 22.0 percent of the watershed, with 5.4 percent cropland and 16.5 percent pasture/hayland. Residential and high use industrial areas compose approximately 19.7 percent of the land base. Transitional use composes 1.5 percent of the watershed. The remaining 4.7 percent of the watershed is comprised of wetlands and open water.

There were four separate impaired segment listings in the 2002 303(d) list for the Tuckahoe Creek watershed: Major Tuckahoe Creek tributaries (Anderson, Broad, Georges and Readers Branches, 11.76 mi.), Tuckahoe Creek (8.7 mi.), Little Tuckahoe Creek (5.25 mi and Deep Run (4.49 mi.). Thus approximately 30.2 miles of Tuckahoe Creek and tributaries were listed as impaired due to a violation of Virginia's water quality standard for DO and fecal coliform bacteria. A bacterial TMDL performed on the Tuckahoe Creek watershed was reported in a separate document.

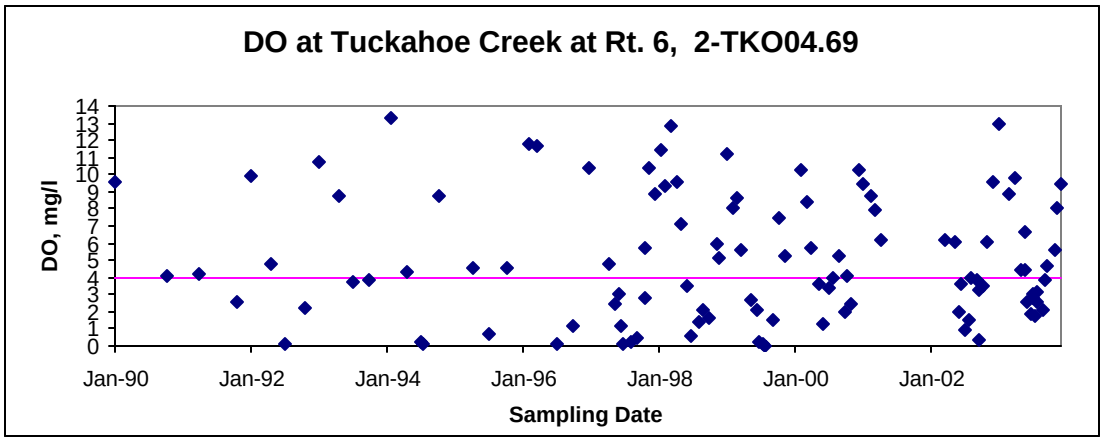
The major Tuckahoe Creek tributaries Anderson, Broad, Georges and Readers Branches (2002 303(d) Segment ID# VAP-H39R-01) were listed as threatened on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for DO at the mainstem Tuckahoe Creek station 2-TKO004.69.

Tuckahoe Creek (2002 303(d) Segment ID# VAP-H39R-02) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for DO. A total of 109 DO data points, with 52 water quality standard violations (47.7%), were taken by DEQ at station 2-TKO004.69 (Figure E1) from January 1990 through December 2003.

Little Tuckahoe Creek (2002 303(d) Segment ID# VAP-H39R-03) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard DO. A total of 58 DO data points, with 7 water quality standard violations (12.1%), were taken by DEQ at station 2-LIY001.73 from July 8, 1997 1990 through December 11, 2003.

Deep Run (2002 303(d) Segment ID# VAP-H39R-04) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for DO. A total of 63 DO data points, with 10 water quality standard violations (15.9%), were taken by DEQ at station 2-DPR002.46 from July 8, 1997 through December 11, 2003.

Figure E1. Time series of DO concentrations (station 2-TKO004.69), Jan. 1990 and Dec. 2003.



According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Tuckahoe Creek must support all designated uses and meet all applicable criteria. The Tuckahoe Creek does not appear to support aquatic life use because of DO water quality standard violations.

VADEQ proposes a methodology for determining whether low DO originates from natural or anthropogenic sources, adapted from "Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia." (MapTech 2003)

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen-restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen- depleting processes. Conditions in a free-flowing stream that would typically be associated with naturally low DO include slow-moving, ripple-less waters where the bacterial decay of organic matter depletes DO at a faster rate than it can be replenished. Indicators of these conditions include low slope, the presence of wetlands, and often low pH due to organic acids (tannins, humic and fulvic substances) produced in the decay process.

These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in free-flowing streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Before implementing this procedure for low DO, all DO data should be screened for flows less than the 7Q10. DO data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly.

Step 1. Determine slope and appearance (presence of wetlands).
Step 2. Determine nutrient levels and compare with USGS background concentrations.
Step 3. Determine degree of seasonal fluctuation (for DO only).
Step 4. Determine anthropogenic impacts from permitted dischargers and land use.

. The preliminary 7Q10 screening revealed that a significant percentage of the Deep Run and Little Tuckahoe Creek low DO data were collected at flows less than the 7Q10. Therefore, **DEQ recommends de-listing the Deep Run (2-DPR002.46) and Little Tuckahoe Creek (2-LIY001.73) DO impairment segments because the percent violations minus low DO data sampled at flows less than the 7Q10 were less than the 10.5 percent listing threshold.**

The smaller tributaries including Anderson, Readers, Cabin Branches, East Branch Tuckahoe Creek and several unnamed tributaries where 7Q10 = 0 cfs experienced long term DO levels below the water quality standard of 4.0 mg/l during the 2002 summer drought because they were pooled rather than flowing. These low D0 values qualify as standard violations because the DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow (9 VAC 25-260-50 ***). These DO violations all occurred during drought zero flow conditions, and thus are due to the natural absence of rainfall. **DEQ recommends de-listing the major Tuckahoe Creek tributaries Anderson, Broad, Georges and Readers Branches (2002 303(d) Segment ID# VAP-H39R-01), due to natural drought conditions, not requiring a TMDL.** Drought monitoring of several tributaries for this TMDL effort revealed DO violations that will not be assessed until the next integrated report assessment. These streams were East Branch Tuckahoe Creek and those unnamed tributaries whose DO violations all occurred during drought zero flow conditions due to the natural absence of rainfall. They will be assessed as Category 4C, Impaired due to natural conditions with no TMDL needed, in future water quality integrated assessment reports.

Tuckahoe Creek exhibits low slope (0.07%) with significant wetlands. A large wetland named Big Swamp exists for 4 miles above Rt. 6. There are wetlands noted on the land use map along Tuckahoe Creek and Little Tuckahoe Creek from just below Rt. 250 downstream approximately 8 miles to below Rt. 650. Wetlands promote input of decaying vegetation throughout this 8-mile segment, which causes low DO from bacterial decomposition.

Tuckahoe Creek exhibits low nutrient concentrations below national background levels in streams from undeveloped areas, which is not indicative of human impact.

Tuckahoe Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high.

High Intensity Residential, and Commercial / Industrial land use comprised 6.15 % of the watershed, located primarily in the eastern tributaries. The watershed is predominately forested (52.3 percent), with 4.69 percent wetlands and open water. This land use was considered not indicative of human impact, because the nutrient concentrations did not point to anthropogenic contributions.

A change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for mainstem Tuckahoe Creek from its confluence with Little Tuckahoe Creek to the confluence with the James River.

The development of the Tuckahoe Creek low DO natural condition assessment was not possible without public participation. A Technical Advisory Committee meeting was held at the Piedmont Regional Office training room in Glen Allen, VA at 2 pm on January 13, 2004. A public meeting was held at the Fairfield Area Library, 1001 North Laburnum Avenue, Richmond, VA. at 7 pm on January 29, 2004. The purpose of these meeting was to discuss both the process for low DO natural condition assessment and the bacterial TMDL. Twelve persons attended the public meeting. Copies of the presentation materials were available for public distribution. The public meeting was public noticed in the Virginia Register. There was a 30-day public comment period after the public meeting. Three written comments were mailed to DEQ. These comments and responses dealt with the bacterial impairment and were submitted to EPA separately from this document.

1. Introduction

This report presents the assessment of whether low dissolved oxygen in the Tuckahoe Creek watershed is due to natural conditions or a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. Section 303(d) of the Clean Water Act and US Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 1991).

The Commonwealth of Virginia's (Virginia's) 1997 Water Quality Monitoring, Information, and Restoration Act (WQMIRA) codifies the requirement for the development of TMDLs for impaired waters. Specifically section § 62.1-44.19:7 C states:

"The plan required by subsection A shall, upon identification by the Board of impaired waters, establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters. The Board shall develop and implement pursuant to a schedule total maximum daily loads of pollutants that may enter the water for each impaired water body as required by the Clean Water Act. "

The EPA specifies that in order for a TMDL to be considered complete and approvable, it must include the following eight elements:

1. It must be designed to meet applicable water quality standards,
2. It must include a total allowable load as well as individual waste load allocations and load allocations,
3. It must consider the impacts of background pollution,
4. It must consider critical environmental conditions or those conditions (stream flow, precipitation, temperature, etc.) which together can contribute to a worst-case exceedance of the water quality standard,
5. It must consider seasonal variations which together with the environmental variations can lead to a worst-case exceedance,
6. It must include an implicit or explicit margin of safety to account for uncertainties inherent in the TMDL development process,
7. It must allow adequate opportunity for public participation in the TMDL development process,
8. It must provide reasonable assurance that the TMDL can be met.

The following document details the assessment of whether low DO in the Tuckahoe Creek watershed is due to natural conditions or a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts to the DO. There were four separate impaired segment listings in the 2002 303(d) list for the Tuckahoe Creek watershed: Tuckahoe Creek (8.7 mi.), Little Tuckahoe Creek (5.25 mi.), Major Tuckahoe Creek tributaries (Anderson, Broad, Georges and Readers Branches, 11.76 mi.), and Deep Run (4.49 mi.). Thus approximately 30.2 miles of Tuckahoe Creek and tributaries were listed as impaired due to a violation of Virginia's water quality standard for DO and fecal coliform bacteria. The fecal coliform bacteria TMDL is addressed in a separate document.

A glossary of terms used throughout this report is presented as Appendix A.

2. Physical Setting

2.1. Listed Water Bodies

Tuckahoe Creek is located in Henrico County in the James River Basin (USGS Hydrologic Unit Code 02080205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Tuckahoe Creek is VAP-H39R. There are 89.51 total stream miles in the Tuckahoe watershed (National Hydrography Dataset (NHD). The impaired segment is 30.2 miles long. It contains the entire Tuckahoe Creek watershed, from its headwaters in Hanover and Goochland Counties downstream to its confluence with the James River at Tuckahoe Island above Boshers Dam (Figure 1).

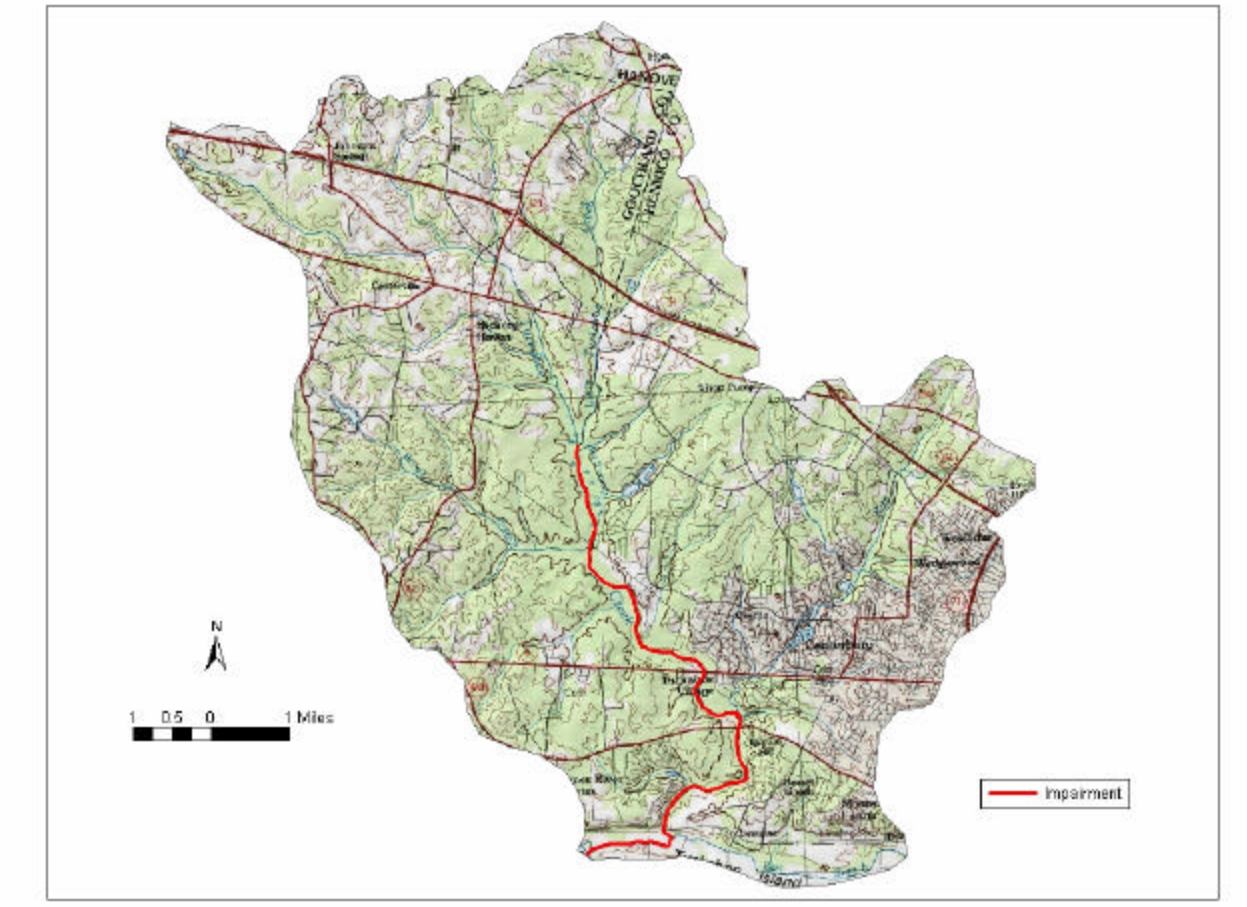
This bacterial TMDL encompasses **four** 303(d) listed impaired segments in the Tuckahoe Creek watershed. The Tuckahoe Creek watershed is located in Henrico and Goochland Counties in the James River Basin (USGS Hydrologic Unit Code 02080205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Tuckahoe Creek is VAP-H39R. There are 89.51 total stream miles in the Tuckahoe Creek watershed (National Hydrography Dataset (NHD). The four DO impaired segments total 30.2 miles long. They contain Tuckahoe Creek from its confluence with Little Tuckahoe Creek downstream to the James River at Tuckahoe Island, the major tributaries of Tuckahoe Creek including Little Tuckahoe Creek, Anderson, Broad, Georges and Readers Branches, but excluding mainstem Tuckahoe Creek above Little Tuckahoe Creek, and Deep Run upstream of the impoundment at rivermile 1.47 at Pump Road (Table 1 and Figure 1). Figure 1 highlights only mainstem Tuckahoe Creek below Little Tuckahoe Creek as impaired, omitting the major tributaries. A fecal coliform impairment in the same segments will be addressed separately from this document.

Table 1. Impaired segment description (Tuckahoe Creek)

Segment (segment ID)	Impairment (source of impairment)	Upstream Limit Description	Downstream Limit Description	Miles Affected
Major Tuckahoe Creek Tributaries: Anderson, Broad, Georges and Readers Branches (Seg ID# VAP-H39R-01)	Fecal Coliform bacteria Dissolved Oxygen (Unknown)	Tributary headwaters; (excludes mainstem Tuckahoe Creek above Little Tuckahoe Creek)	Tributary mouths	11.76
Tuckahoe Creek (Seg ID# VAP-H39R-02)	Fecal Coliform bacteria Dissolved Oxygen (Unknown)	Confluence with Little Tuckahoe Creek	James River at Tuckahoe Island	8.7
Little Tuckahoe Creek (Seg ID# VAP-H39R-03)	Fecal Coliform bacteria Dissolved Oxygen (Unknown)	Headwaters	Confluence with Tuckahoe creek	5.25

Deep Run (Seg ID# VAP-H39R-04)	Fecal Coliform bacteria Dissolved Oxygen (Unknown)	Headwaters	Pond at rivermile 1.47 at Pump Road	4.49

Figure 1. Map of the Tuckahoe Creek study area



2.2. Watershed

2.2.1. General Description

Tuckahoe Creek, located within Henrico, Goochland and Hanover Counties, is a minor tributary to the James River. It is about 17 miles long and flows southeastward from its headwater 2 miles east of Oilville to its confluence with the James River. The watershed itself is approximately 13 miles long and 5 miles wide, having an area of 64.3 square miles. The major tributaries to Tuckahoe Creek are Little Tuckahoe Creek and Anderson Branch entering from the north, Broad and Readers Branches entering from the west, and Deep Run and Georges Branch entering from the east.

2.2.2. Geology, Climate, Land Use

Geology and Soils

Tuckahoe Creek is in the Piedmont physiographic region. The Piedmont of Virginia extends eastward from the Blue Ridge to the Fall Line, where Paleozoic-age and older igneous and metamorphic rocks are covered by unconsolidated sediments of the Atlantic Coastal Plain. The Virginia Piedmont is part of the greater southeastern Piedmont, which extends from northeastern Alabama through Georgia, South Carolina, North Carolina, Virginia, Maryland, and southeastern Pennsylvania. The Piedmont is characterized by deeply weathered, poorly exposed bedrock and a high degree of geological complexity, making it one of the last frontiers of North American regional geology. (http://www.geology.state.va.us/DOCS/Geol/pied.html).

Soils for the Tuckahoe Creek watershed were documented utilizing the VA State Soil Geographic Database (STATSGO). Two general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdname.cgi). Figure 2 shows the location of these general soil types in the watershed.

The Cecil-Madison-Enon-Wilkes-Chewacla series (VA019) are very deep to shallow soils which have been formed from residuum weathered from igneous and high-grade metamorphic rocks, or alluvium deposits of these same parent materials. Located in the Piedmont uplands, these soils are located on ridges and side slopes of the Piedmont uplands and floodplains. This series are moderately drained in the uplands and somewhat poorly drained in floodplains. Soils are moderate to slowly permeable.

Soils of the Appling-Wedowee-Ashlar-Louisburg-Vance-Worsham series (VA030) moderate to very deep that formed in residuum from weathered crystalline rock of the Piedmont Plateau. Soils range from excessively to poorly drained, with moderately rapid to slow permeability.

The Altavista-Congaree-Chewacla-Wehadkee-Wickham-Turbeville-Hiwassee series (VA032) are very deep to deep soils. Soils are located on stream terraces in the Piedmont and Upper Atlantic Coastal Plain. This series is formed from recent fluvial sediments. The drainage class is moderately well to very poorly drained, with moderate to poor permeability.

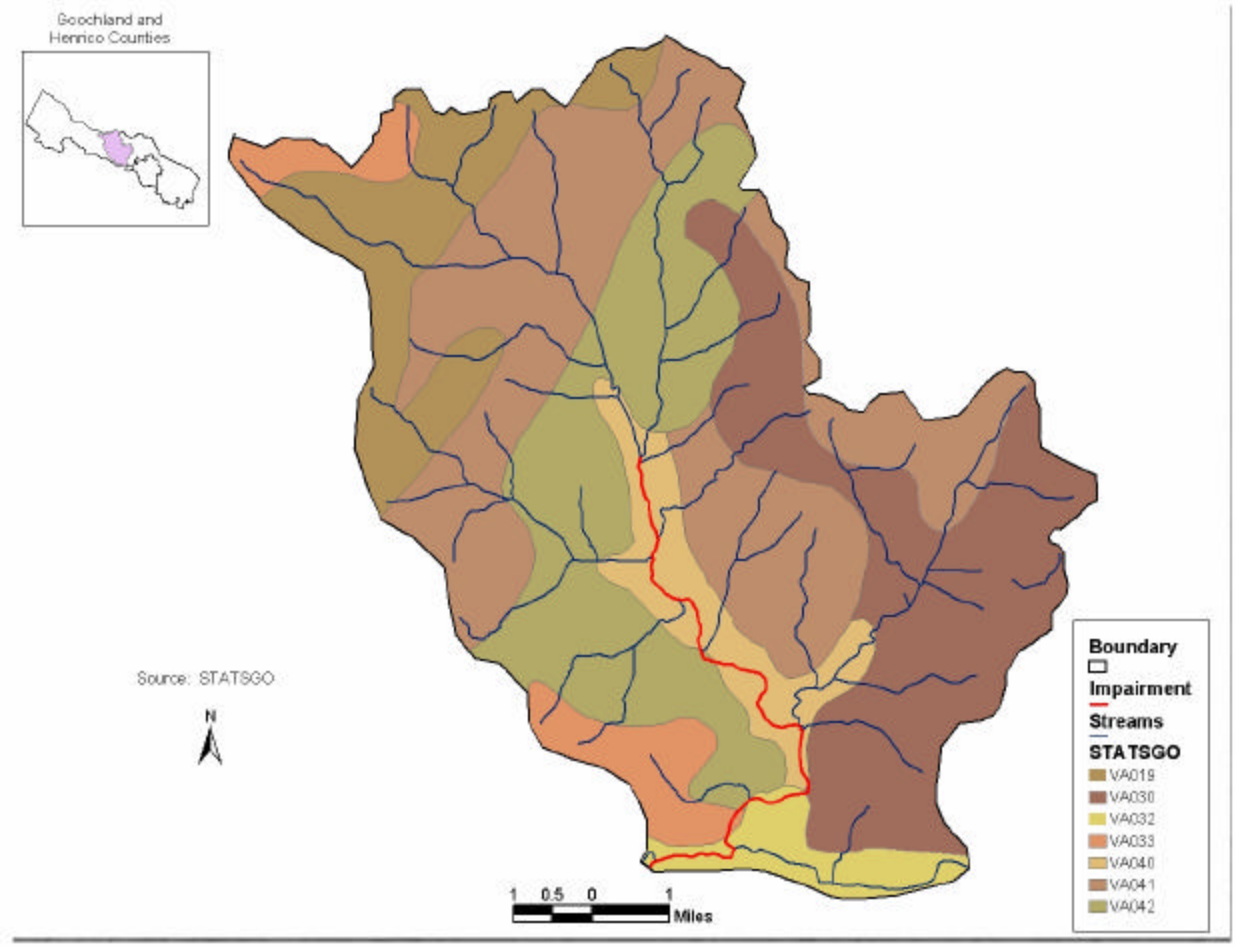
Soils of the State-Turbeville-Hiwassee-Dogue-Augusta-Congaree-Chewacla-Wehadkee-Edgehill series (VA033) are very deep to deep soils. Soils are located on stream terraces in the Piedmont and Upper Atlantic Coastal Plain. This series is formed from recent fluvial sediments. The drainage class is moderately well to very poorly drained, with moderate to poor permeability.

Soils of the Bojac-Pamunkey-Munden-Angie-Augusta-Molena-Argent (VA040) series are found mainly in floodplains and terraces. These soils are very deep and range from well drained to poorly or very poorly drained. Permeability for this series ranges from moderately rapid in the uplands to slowly permeable soils formed in clayey marine sediments.

Soils of the Colfax-Bourne-Helena-Vance-Orange series (VA041) consists are well drained to somewhat poorly drained. Permeability is moderate to slow. These soils formed from residuum weathered from acid and basic rocks in the Piedmont.

The Creedmoor-Partlow-Mayodan-Pinkston soils (VA042) are very deep, well drained to poorly drained soils. Permeability for this series ranges from moderately rapid to slow. These soils have formed either from Triassic material or in local colluvial and alluvial materials.

Figure 2. Soil Characteristics of the Tuckahoe Creek Watershed



Climate

The climate summary for the Tuckahoe Creek watershed comes from a weather station located in Ashland, VA, within 13 miles of the study area, with a period of record from 8/02/1948 to 12/31/2002. The average annual maximum and minimum temperature (°F) at the weather station is 68.1 and 45.2 and the annual rainfall is 42.2 inches (Table 2) (Southeast Regional Climate Center, http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?va0327).

Table 2. Climate summary for Ashland, Virginia (440327)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	46.4	50.6	58.9	69.7	76.6	83.6	87.1	85.7	79.7	69.2	59.7	49.4	68.1
Average Min. Temperature (F)	25.4	28.2	34.3	43.5	52.8	61.1	65.7	64.5	57.6	45.4	35.8	28.4	45.2
Average Total Precipitation (in.)	3.34	3.03	3.86	3.06	3.83	3.37	4.23	4.07	3.67	3.37	3.09	3.28	42.20

Land Use

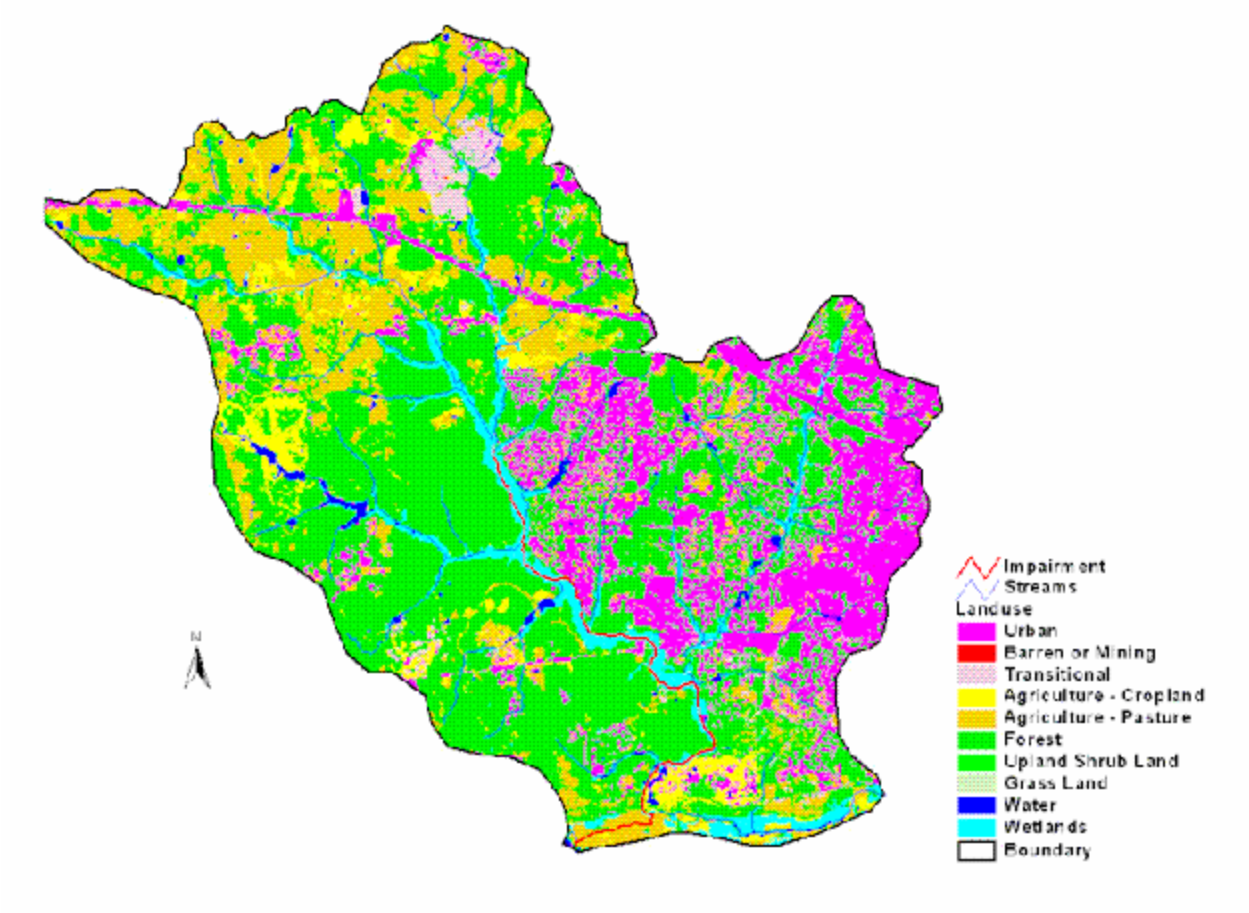
The Tuckahoe Creek watershed extends approximately 13 miles upstream from the stream's confluence with the James River and is approximately 5 miles wide. The approximately 41,200 acre watershed is predominately forested (52.3 percent). Agriculture encompasses 22.0 percent of the watershed, with 5.4 percent cropland and 16.5 percent pasture/hayland. Residential and high use industrial areas compose approximately 19.7 percent of the land base. Transitional use composes 1.5 percent of the watershed. The remaining 4.7 percent of the watershed is comprised of wetlands and open water.

A map of the distribution of land use in the watershed (Figure 3) shows that urban land is found in the eastern portions of the watershed. Forest land is found primarily in the southern and western portions of the watershed. Agriculture is scattered in the northern part of the watershed.

Table 3. Land Use in the Tuckahoe Creek Watershed

Landuse Category	**Area (acres)**	**Area (%)**
Open Water	51.8	0.13
Low Intensity Residential	5555.0	13.50
High Intensity Residential	1.1	0.00
High Intensity Commercial/Industrial	2531.1	6.15
Quarries/Strip Mines/Gravel Pits	3.3	0.01
Transitional	611.4	1.48
Deciduous Forest	13173.8	31.99
Evergreen Forest	1946.6	4.73
Mixed Forest	6418.5	15.59
Pasture/Hay	6777.7	16.46
Row Crops	2225.5	5.40
Woody Wetlands	1203.4	2.92
Emergent Herbaceous Wetlands	677.2	1.64
Total Acres	41176.4	100.00
Total Square Miles	64.3 sq. mi.	

Figure 3. Land Use in the Tuckahoe Creek Watershed



3. Description of Water Quality Problem/Impairment

The major Tuckahoe Creek tributaries Anderson, Broad, Georges and Readers Branches (2002 303(d) Segment ID# VAP-H39R-01) were listed as threatened on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for fecal coliform bacteria and DO at the mainstem Tuckahoe Creek station 2-TKO004.69.

Tuckahoe Creek (2002 303(d) Segment ID# VAP-H39R-02) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for fecal coliform bacteria and DO. A total of 109 DO data points, with 52 water quality standard violations (47.7%), have been taken by DEQ at station 2-TKO004.69 (Figure 4) from January 1990 through December 2003 (Table 4a).

Little Tuckahoe Creek (2002 303(d) Segment ID# VAP-H39R-03) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for fecal coliform bacteria and DO. A total of 58 DO data points, with 7 water quality standard violations (12.1%), have been taken by DEQ at station 2-LIY001.73 (Figure 4) from July 8, 1997 1990 through December 11, 2003 (Table 4b).

Deep Run (2002 303(d) Segment ID# VAP-H39R-04) was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report and 2002 303(d) Report on Impaired Waters (VADEQ, 1998 & 2002) due to violations of the State's water quality standard for fecal coliform bacteria and DO. A

total of 63 DO data points, with 10 water quality standard violations (15.9%), have been taken by DEQ at station 2-DPR002.46 (Figure 4) from July 8, 1997 through December 11, 2003 (Table 4c).

Finally, an upstream station on Tuckahoe Creek at Rt. 250, 2-TKO010.64, was sampled from May 1997 to December 2003. A total of 57 DO data points, with 3 water quality standard violations (5.3%), have been taken by DEQ at station 2-TKO010.64 (Figure 4) from May 27, 1997 through December 11, 2003 (Table 4d). From these results at less than a 10 percent violation rate, the upper portion of mainstem Tuckahoe Creek above Little Tuckahoe Creek was removed from the 303(d) segment in the 2002 assessment.

Table 4a. DO data collected by DEQ on Lower Tuckahoe Creek at Rt. 6

				mg/l			
Station	**Date of First Sample**	**Date of Last Sample**	**Number of Samples**	**Average**	**Minimum**	**Maximum**	**Number of Violations**
2-TKO004.69	01/16/1990	12/11/2003	109	5.11	0.09	14.41	52

Table 4b. DO data collected by DEQ on Little Tuckahoe Creek

				mg/l			
Station	**Date of First Sample**	**Date of Last Sample**	**Number of Samples**	**Average**	**Minimum**	**Maximum**	**Number of Violations**
2-LIY001.73	07/8/1997	12/11/2003	58	7.80	2.34	12.78	7

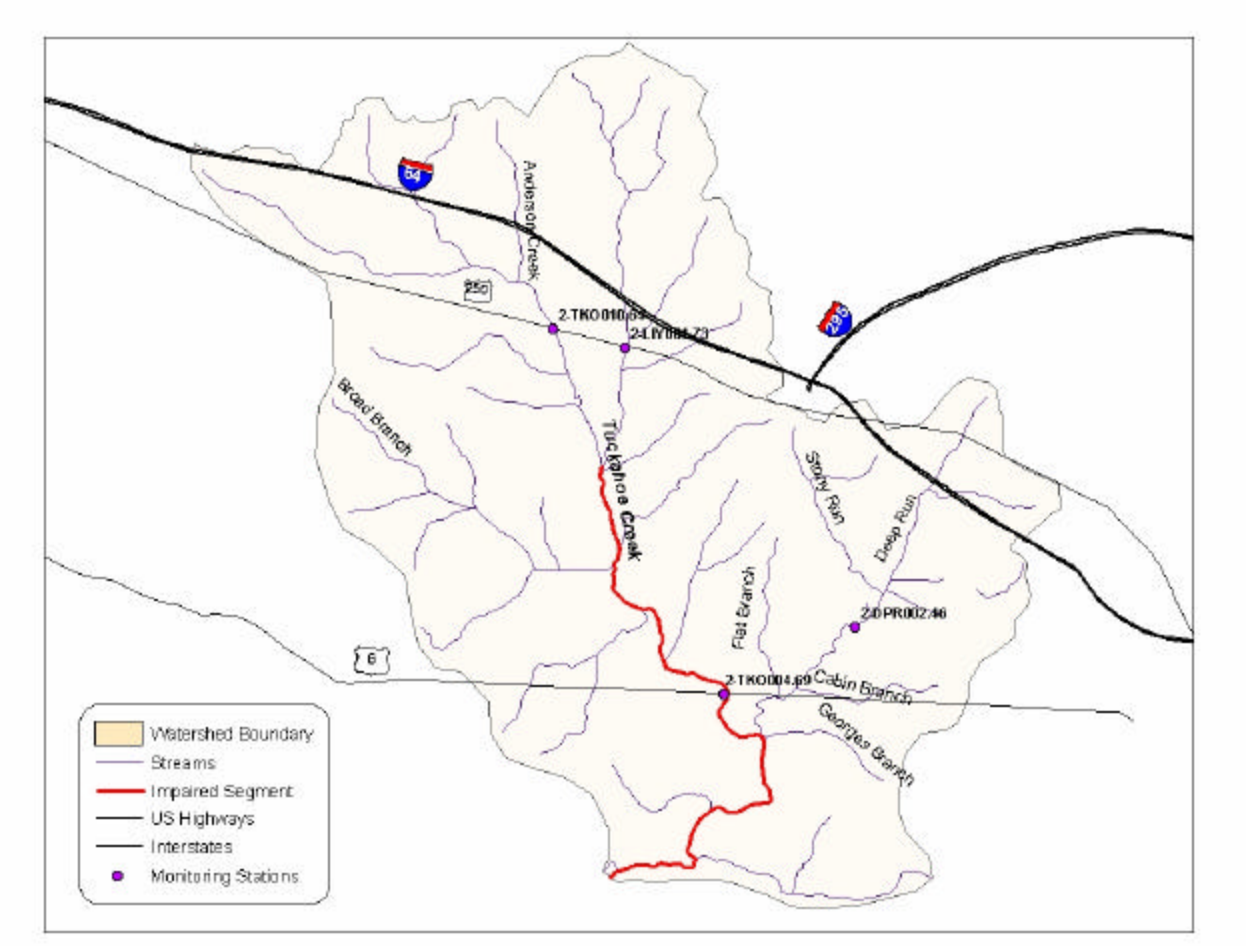
Table 4c. DO data collected by DEQ on Deep Run

				(Cfu/100 ml)			
Station	**Date of First Sample**	**Date of Last Sample**	**Number of Samples**	**Average**	**Minimum**	**Maximum**	**Number of Violations**
2-DPR002.46	07/8/1997	12/11/2003	63	6.91	1.42	11.18	10

Table 4d. DO data collected by DEQ on Upper Tuckahoe Creek at Rt. 250

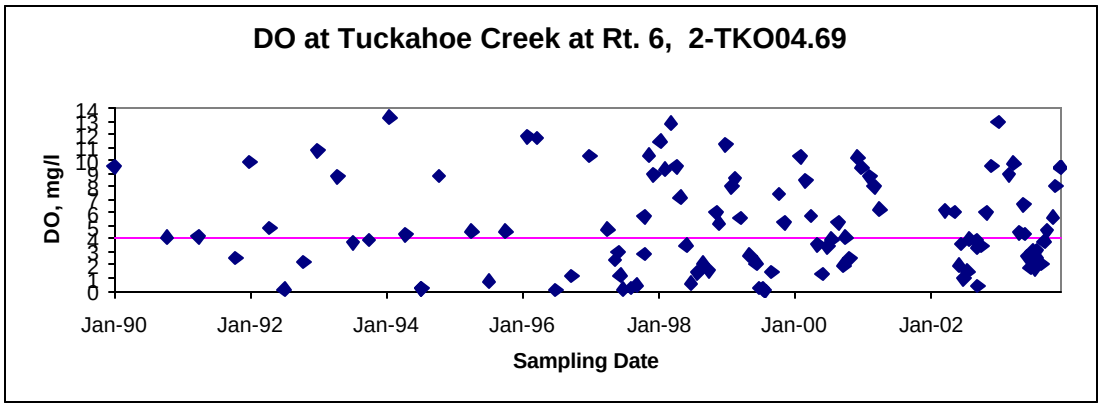
				(Cfu/100 ml)			
Station	**Date of First Sample**	**Date of Last Sample**	**Number of Samples**	**Average**	**Minimum**	**Maximum**	**Number of Violations**
2-TKO010.64	05/27/1997	12/11/2003	57	8.50	0.53	13.12	3

Figure 4. Map of Tuckahoe Creek watershed with stations 2-TKO004.69, 2-LIY001.73, 2-TKO010.64, and 2-DPR002.46



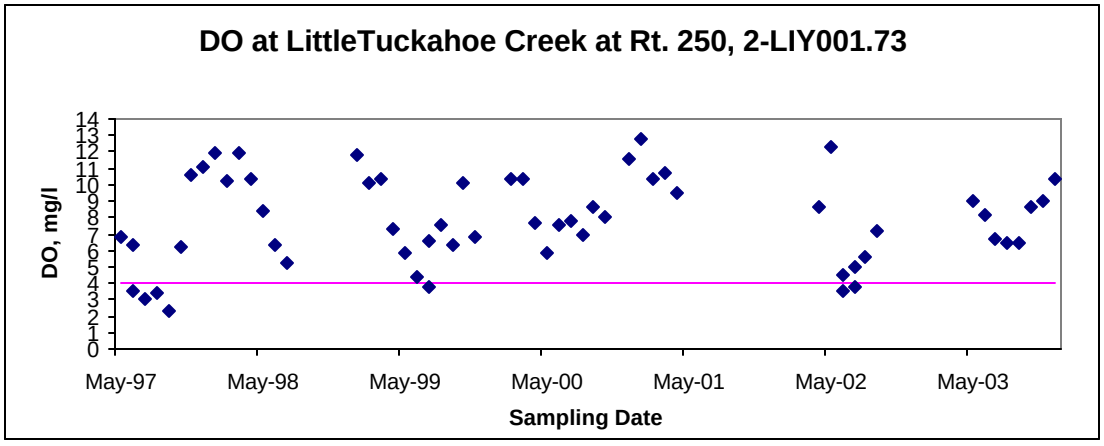
A time series graph of all data collected at station 2-TKO004.69 shows the DO concentrations ranging from 0.09 mg/l to 14.41 mg/l (Figure 5a). The horizontal line at the DO = 4.0 mg/l mark represents the minimum water quality standard. The data points below the DO = 4.0 mg/l line illustrate violations of the water quality standard.

Figure 5a. Time series of DO concentrations (station 2-TKO004.69)



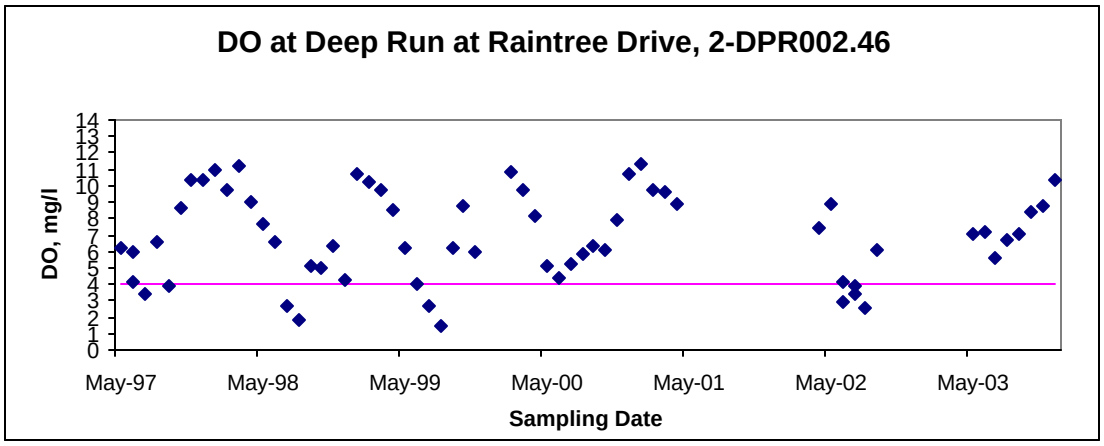
A time series graph of all data collected at station 2-LIY001.73 shows the DO concentrations ranging from 2.34 mg/l to 12.78 mg/l (Figure 5b). The horizontal line at the DO = 4.0 mg/l mark represents the minimum water quality standard. The data points below the DO = 4.0 mg/l line illustrate violations of the water quality standard.

Figure 5b. Time series of DO concentrations (station 2-LIY001.73)



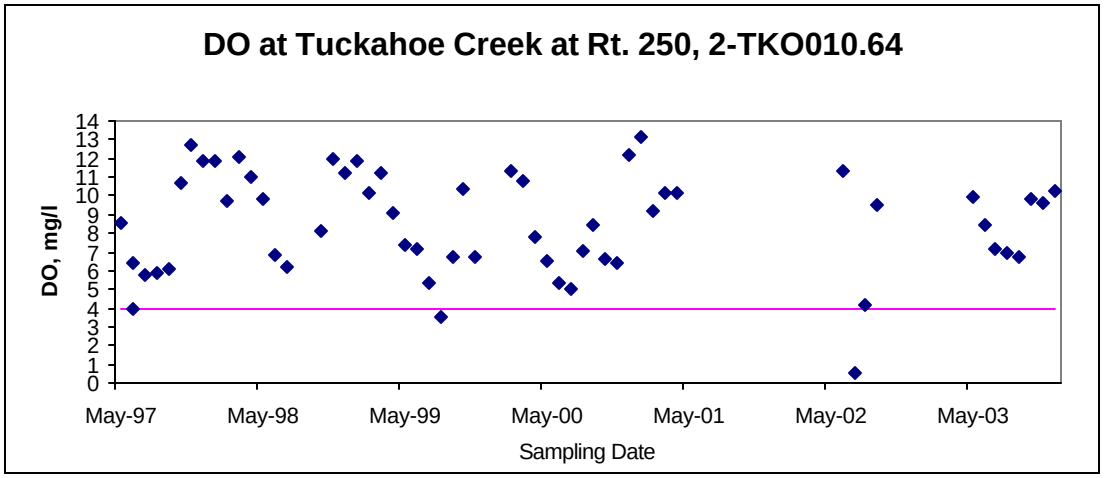
A time series graph of all data collected at station 2-DPR002.46 shows the DO concentrations ranging from 1.42 mg/l to 11.18 mg/l (Figure 5c). The horizontal line at the DO = 4.0 mg/l mark represents the minimum water quality standard. The data points below the DO = 4.0 mg/l line illustrate violations of the water quality standard.

Figure 5c. Time series of DO concentrations (station 2-DPR002.46)



A time series graph of all data collected at station 2-TKO010.64 shows the DO concentrations ranging from 0.53 mg/l to 13.12 mg/l (Figure 5d). The horizontal line at the DO = 4.0 mg/l mark represents the minimum water quality standard. The data points below the DO = 4.0 mg/l line illustrate violations of the water quality standard.

Figure 5d. Time series of DO concentrations (station 2-TKO010.64)



4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

As stated above, Virginia water quality standards consist of a designated use or uses and a water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

As stated above, Tuckahoe Creek must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for pH in the Tuckahoe Creek watershed is an instantaneous minimum DO of 4.0 mg/l.

Table 5. Applicable water quality standards

Parameter	Minimum, mg/l	Maximum, mg/l
DO	4.0	na

If the waterbody exceeds the criterion listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

5. Assessment of Natural Conditions Affecting low DO - Process for determining if DO and pH impairments in free-flowing streams are due to natural conditions.

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen-restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen- depleting processes. The level of pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity. Conditions in a stream that would typically be associated with naturally low DO and pH include slow-moving, ripple-less waters or wetlands where the decay of organic matter produces organic acids. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below.

Step 1. Determine slope and appearance.
Step 2. Determine nutrient levels.

Step 3. Determine degree of seasonal fluctuation (for DO only).
Step 4. Determine anthropogenic impacts.

The results from this methodology (or process or approach) will be used to determine if the stream should be re-classified as Class VII Swamp Waters. Each step is described in detail below.

Procedure for Natural Condition Assessment of low pH and low DO in Virginia Streams

Prepared by Virginia Department of Environmental Quality
October 2004

I. INTRODUCTION

Virginia's list of impaired waters currently shows many waters as not supporting the aquatic life use due to exceedances of pH and/or DO criteria that are designed to protect aquatic life in Class III waters. However, there is reason to believe that most of these streams or stream segments have been mis-classified and should more appropriately be classified as Class VII, Swamp Waters. This document presents a procedure for assessing if natural conditions are the cause of the low pH and/or low DO levels in a given stream or stream segment.

The level of dissolved oxygen (DO) in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen-restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of acidity as registered by pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity.

Conditions in a stream that would typically be associated with naturally low DO and/or naturally low pH include slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids (tannins, humic and fulvic substances). These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Waters that are shown to have naturally low DO and pH levels will be re-classified as Class VII, Swamp Waters, with the associated pH criterion of 4.3 to 9.0 SU. An associated DO criterion is currently being developed from swamp water data. A TMDL is not needed for these waters. An assessment category of 4C will be assigned until the waterbody has been re-classified.

II. NATURAL CONDITION ASSESSMENT

Following a description of the watershed (including geology, soils, climate, and land use), a description of the DO and/or pH water quality problem (including a data summary, time series and monthly data distributions), and a description of the water quality criteria that were the basis for the impairment determination, the available information should be evaluated in four steps.

Step 1. Determine appearance and flow/slope.

Streams or stream segments that have naturally low DO (< 4 mg/L) and low pH (< 6 SU) are characterized by very low slopes and low velocity flows (flat water with low reaeration rates). Decaying vegetation in such swampy waters provides large inputs of plant material that consumes oxygen as it decays. The decaying vegetation in a swamp water also produces acids and decreases pH. Plant materials contain polyphenols such as tannin and lignin. Polyphenols and partially degraded polyphenols build up in the form of tannic acids, humic acids, and fulvic acids that are highly colored. The trees of swamps have higher polyphenolic content than the soft-stemmed vegetation of marshes. Swamp streams (blackwater) are therefore more highly colored and more acidic than marsh streams.

Appearance and flow velocity (or slope if flow velocity is not available) must be identified for each stream or stream segment to be assessed for natural conditions and potential re-classification as a Class VII swamp water. This can be done through maps, photos, field measurements or other appropriate means.

Step 2. Determine nutrient levels.

Excessive nutrients can cause a decrease in DO in relatively slow moving systems, where aeration is low. High nutrient levels are an indication of anthropogenic inputs of nitrogen, phosphorus, and possibly organic matter. Nutrient input can stimulate plant

growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels.

USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L.

Nutrient levels must be documented for each stream or stream segment to be assessed for natural conditions and potential re-classification as a Class VII swamp water. Streams with average concentrations of nutrients greater than the national background concentrations should be further evaluated for potential impacts from anthropogenic sources.

Step 3. Determine degree of seasonal fluctuation (for DO only).

Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. Seasonal analyses should be conducted for each potential Class VII stream or stream segment to verify that DO is depressed in the summer months and recovers during the winter, as would be expected in natural systems. A weak seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

Step 4. Determine anthropogenic impacts.

Every effort should be made to identify human impacts that could exacerbate the naturally low DO and/or pH. For example, point sources should be identified and DMR data analyzed to determine if there is any impact on the stream DO or pH concentrations. Land use analysis can also be a valuable tool for identifying potential human impacts.

Lastly, a discussion of acid rain impacts should be included for low pH waters. The format of this discussion can be based either on the process used for the recent Class VII classification of several streams in the Blackwater watershed of the Chowan Basin (letter from DEQ to EPA, 14 October 2003). An alternative is a prototype regional stream comparison developed for Fourmile Creek, White Oak Swamp, Matadequin Creek and Mechumps Creek (all east of the fall line). The example analysis under IV in this document, or the example report prepared for Fourmile Creek, illustrate this approach. For streams west of the fall line, a regional stream comparison for 2004 analyses encompasses Winticomack, Winterpock, and Skinquarter Creeks.

7Q10 Data Screen

If the data warrant it, a data screen should be performed to ensure that the impairment was identified based on valid data. All DO or pH data that violate water quality standards should be screened for flows less than the 7Q10. Data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate

recalculated accordingly. Only those waters with violation rates determined days with flows > or = 7Q10 flows should be classified as impaired.

In some cases, data were collected when flow was 0 cfs. If the 7Q10 is identified as 0 cfs as well, all data collected under 0 cfs flow would need to be considered in the water quality assessment. In those cases, the impairment should be classified as 4C, Impaired due to natural conditions, no TMDL needed. However, a reclassification to Class VII may not always be appropriate.

III. NATURAL CONDITION CONCLUSION MATRIX

The following decision process should be applied for determining whether low pH and/or low DO values are due to natural conditions and justify a reclassification of a stream or stream segment as Class VII, Swamp Water.

If velocity is low or if slope is low (<0.50%) AND
If wetlands are present along stream reach AND
If no point sources or only point sources with minimal impact on DO and pH AND
If nutrients are < typical background

- ❖ average (= assessment period mean) nitrate less than 0.6 mg/L
- ❖ average total nitrogen (TN) less than 1.0 mg/L, and
- ❖ average total phosphorus (TP) are less than 0.1 mg/L AND

For DO: If seasonal fluctuation is normal AND
For pH: If nearby streams without wetlands meet pH criteria OR if no correlation between in-stream pH and rain pH,

THEN determine as impaired due to natural condition
→ assess as category 4C in next assessment
→ initiate WQS reclassification to Class VII Swamp Water
→ get credit under consent decree

The analysis must state the extent of the natural condition based on the criteria outlined above. A map showing land use, point sources, water quality stations and, if necessary, the delineated segment to be classified as swamp water should be included.

In cases where not all of these criteria apply, a case by case argument must be made based on the specific conditions in the watershed.

5.1 Preliminary Data Screen for Low Flow 7Q10

The 7Q10 flow of a stream is the lowest streamflow for seven consecutive days that occurs on average once every ten years. The first step for low flow 7Q10 screening is to determine the most accurate 7Q10 available. There is no long-term flow gaging station in the Tuckahoe Creek basin. In the "Bacteria TMDL for Tuckahoe Creek, Little Tuckahoe Creek, Anderson, Broad, Georges and Readers Branches, and Deep Run, Henrico, Goochland and Hanover Counties, Virginia" (DEQ 2004), DEQ used the Deep Creek near Mannboro, VA gage as a the most accurate reference gage for flow. The Deep Creek gage had a Pearson's coefficient (R = 0.9205) compared to Tuckahoe Creek flow measurements. A Pearson's coefficient of 0.8-1.0 is considered very strong in this application. Then the regression equation ($y=0.2204x^{1.1343)}$ may be created to estimate flows at Tuckahoe Creek at Rt. 6 (y) from mean daily flows at the Deep Creek gage (x).

Similarly, the 7Q10 flow for Tuckahoe Creek DO stations may be estimated by a drainage area ratio from the Deep Creek near Mannboro, VA. Gage. The drainage area of the Deep Creek gage = 158 mi^2; of Tuckahoe Creek at Rt. 6 = 64.3 mi^2; of Deep Run at Raintree Drive gage = 13.8 mi^2; of Little Tuckahoe Creek at Rt. 250 = 9.76 mi^2; and of Anderson, Readers, Cabin Branches, East Branch of Tuckahoe Creek and several unnamed tributaries to Tuckahoe Creek monitored for this low DO assessment < 2mi^2.

From these the 7Q10 flow of TKO Creek at Rt. 6 = 0.2 cfs, of Deep Run at Raintree Drive = 0.04 cfs, of Little Tuckahoe Creek at Rt. 250 = 0.03 cfs, and of the smaller tributaries including Anderson, Readers, Cabin Branches, East Branch Tuckahoe Creek and several unnamed tributaries = 0 cfs.

The DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow, but **NOT** below 7Q10 flow (9 VAC 25-260-50 ***). Therefore in streams where the 7Q10 > 0 cfs, DO less than 4 mg/l taken at flows below 7Q10 are not water quality standard violations. However, in streams where the 7Q10 = 0 cfs, **ALL** DO data < 4.0 mg/l are standard violations, even if the flow = 0 cfs when the DO was taken.

Performing the preliminary 7Q10 screening on the Tuckahoe, Little Tuckahoe and Deep Run DO datasets, the results are in Tables 6a, 6b, and 6c. The 7Q10 preliminary screening impacts are as follows:

- **Tuckahoe Creek at Rt. 6 -**

Total DO Violations = 47.7% (52 of 109)
7Q10 Corrected DO Viol. = 43.1% (47 of 109)

- **Deep Run at Raintree Dr. -**

Total DO Violations = 15.9% (10 of 63)
7Q10 Corrected DO Violations = 9.5% (6 of 109).
Recommend to delist 2-DPR002.46.

- **Little Tuckahoe Creek at Rt. 250 -**

Total DO Violations = 12.1% (7 of 58)
7Q10 Corrected DO Violations = 8.6% (5 of 58).
Recommend to delist 2-LIY001.73.

Table 6a. Preliminary 7Q10 Screening for Tuckahoe Creek at Rt. 6.

			TKO Q from Deep Q	7Q10 = 0.20cfs
01/16/90	9.55	4		
10/24/90	4.1	4		RED = DO Violations
04/11/91	4.15	4		Green = NO DO Violation
10/29/91	2.54	4	16.1	
01/13/92	9.89	4		Total DO < 4 md\g/l = 52 / 109 = 47.7%Violations
04/27/92	4.84	4		
07/14/92	0.14	4	5.85	7Q10-corrected DO violations = 47 / 109 = 43.1%Violations
10/27/92	2.22	4	8.11	
01/12/93	10.76	4		
04/28/93	8.77	4		
07/20/93	3.71	4	6.97	
10/13/93	3.88	4	2.6	
01/31/94	13.31	4		
04/27/94	4.33	4		
07/20/94	0.2	4	7.72	
07/22/94	0.17	4	8.49	
10/24/94	8.8	4		
04/19/95	4.56	4		
07/20/95	0.73	4	22	
10/18/95	4.58	4		
02/13/96	11.79	4		
04/02/96	11.72	4		
07/10/96	0.09	4	4.76	
10/07/96	1.14	4	17.4	
01/08/97	10.36	4		
04/16/97	4.73	4		
05/27/97	2.4	4	25.1	
06/12/97	2.98	4	20.3	
06/26/97	1.21	4	7.72	
07/08/97	0.15	4	8.88	
08/20/97	0.24	4	2.4	
09/18/97	0.47	4	2.73	
10/30/97	5.68	4		
10/30/97	2.83	4	17	
11/25/97	10.37	4		
12/22/97	8.92	4		
01/27/98	11.48	4		
02/18/98	9.31	4		
03/24/98	12.85	4		
04/23/98	9.54	4		
05/14/98	7.14	4		
06/15/98	3.53	4	24.7	
07/07/98	0.62	4	6.22	
08/12/98	1.4	4	1.34	
09/10/98	2.11	4	1.12	
10/14/98	1.59	4	1.62	
11/23/98	5.99	4		
12/07/98	5.19	4		
01/12/99	11.18	4		
02/10/99	8.01	4		
03/03/99	8.61	4		

04/01/99	5.57	4	
05/20/99	2.74	4	19.1
06/24/99	2.11	4	5.12
07/08/99	0.25	4	2.2
07/28/99	0.17	4	1.4
08/10/99	0.05	4	0.82
09/15/99	1.46	4	5.85
10/25/99	7.42	4	
11/22/99	5.25	4	
02/15/00	10.3	4	
03/14/00	8.45	4	
04/11/00	5.75	4	
05/18/00	3.56	4	11.2
06/13/00	1.3	4	10.4
07/12/00	3.37	4	8.11
08/01/00	3.94	4	64.8
09/07/00	5.22	4	
10/05/00	1.98	4	12
10/16/00	4.1	4	
11/08/00	2.47	4	11.6
12/20/00	10.24	4	
01/10/01	9.48	4	
02/21/01	8.75	4	
03/19/01	7.98	4	
04/18/01	6.23	4	
04/03/02	6.14	4	
05/22/02	6.04	4	
06/17/02	1.96	4	0.57
06/26/02	3.61	4	0.08
07/10/02	0.98	4	0.11
07/31/02	1.51	4	0.13
08/12/02	3.95	4	0.01
09/18/02	3.85	4	0.91
09/23/02	3.32	4	0.25
09/25/02	0.39	4	0.19
10/16/02	3.45	4	23.4
11/12/02	6.03	4	
12/09/02	9.56	4	
01/13/03	12.95	4	
02/11/03	14.41	4	
03/11/03	8.92	4	
04/07/03	9.77	4	
05/07/03	4.48	4	
05/28/03	6.6	4	
06/04/03	4.38	4	
06/17/03	2.62	4	75.2
07/07/03	1.84	4	49.4
07/16/03	2.85	4	24.7
07/17/03	3.07	4	23.4
07/28/03	1.73	4	27.7
08/05/03	3.11	4	468
08/06/03	2.6	4	280
09/03/03	2.09	4	14.9
09/17/03	3.8	4	27.3

10/02/03	4.64	4
11/04/03	5.62	4
11/17/03	8.04	4
12/11/03	9.45	4

Table 6b. Preliminary 7Q10 Screening for Little Tuckahoe Creek at Rt. 250 and Deep Run at Raintree Drive.

Little TKO and Deep Run DO Violations and Flow Comparison

LIY DO Violations Date	DO, mg/l	TKO Flow estimate,* cfs	L. TKO Flow estimate,* cfs	7Q10 0.03 cfs	
06/26/97	3.57	8.11	1.23		Total DO < 4 mg/l = 7 / 58 = 12.1%Violations
07/08/97	3.01	10.05	1.53		
08/20/97	3.46	2.73	0.41		7Q10 corrected DO < 4mg/l = 5 / 58 = 8.6 %Violations
09/18/97	2.34	2.73	0.41		
07/08/99	3.72	2.2	0.33		
06/26/02	3.58	0.08	0.01		
07/10/02	3.77	0.11	0.02		

Deep Run DO violations			Deep Run Flow estimate,* cfs	7Q10 0.04 cfs	
07/08/97	3.37	10.05	2.2		Total DO < 4 mg/l = 10 / 63 = 15.9%Violations
09/18/97	3.92	2.73	0.59		
07/07/98	2.66	6.22	1.3		7Q10 corrected DO < 4mg/l = 6 / 63 = 9.5 %Violations
08/12/98	1.88	1.34	0.29		
07/08/99	2.62	2.2	0.47		
08/10/99	1.42	0.82	0.18		
06/26/02	2.96	0.08	0.02		
07/10/02	3.44	0.11	0.02		
07/31/02	3.95	0.13	0.03		
08/12/02	2.58	0.01	0.002		

* Flow estimated by a flow regression between Tuckahoe Creek flow measurements and Deep Creek near Mannboro gaging station mean daily flows. Then drainage area (DA) ratios between Tuckahoe Creek and Deep Run (0.215 DA coeff.), and Tuckahoe Creek and Little Tuckahoe Creek (0.152 DA coeff.) estimated Deep Run and Little Tuckahoe Cr. flows from Tuckahoe Creek.

5.2 Low slope, Wetlands or Large Forested Areas

The hydrologic slope from the 150 ft. topographic contour at rivermile 10.55 below Rt. 250 downstream to the 120 ft. contour at rivermile 2.59 above the old railroad grade below Rt. 650 is estimated at 0.07%, which is considered very low slope. The low slope contributes no human impact.

Visual inspection at bridges on Rt. 6 (Figure 6) and Rt.650 (Figure 7) revealed very swampy conditions. A large wetland named Big Swamp exists for 4 miles above Rt. 6. There are wetlands noted on the land use map along Tuckahoe Creek and Little Tuckahoe Creek from just below Rt. 250 downstream approximately 8 miles to below Rt. 650. Wetlands promote input of decaying vegetation throughout this 8 mile segment, which causes low DO from bacterial decomposition. The wetlands impacts are not indicative of human impact.

Figure 6. Tuckahoe Creek upstream of Rt. 6.

Figure 7. Tuckahoe Creek downstream of Rt. 650.

5.3 Instream Nutrients

The VADEQ collected nutrient data from station 2-TKO004.69 from January 1990 to December 2003. The average nutrient concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas levels of nitrate < 0.6 mg/l; total nitrogen (TKN + NO_3 + NO_2) < 1.0 mg/l; and total phosphorus < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

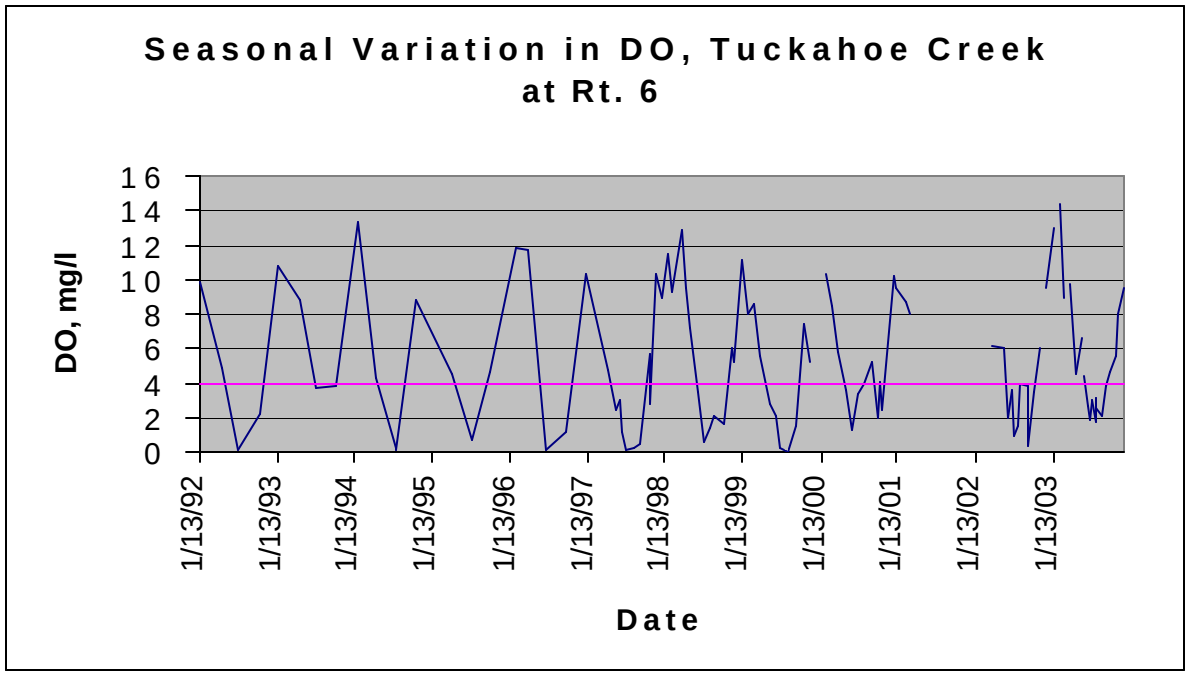
Parameter	Average Conc.	Number
Total Phosphorus	**0.069 mg/l**	(n=91)
Orthophosphorus	0.036 mg/l	(n=80)
Total Kjeldahl Nitrogen	0.665 mg/l	(n=85)
Ammonia as N	0.04 mg/l	(n=91)
Nitrite + Nitrate as N	0.075 mg/l	(n=86)
Total Nitrogen	**0.74 mg/l**	(n-85)
Nitrate as N	**0.053 mg/l**	(n=71)

These levels of nitrate, total nitrogen and total phosphorus are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas levels of nitrate < 0.6 mg/l; TN (TKN + NO_3 + NO_2) < 1.0 mg/l; and TP < 0.1 mg/l.

5.4 Natural Seasonal DO Fluctuation

Tuckahoe Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high. This is depicted in Figure 8.

Figure 8. Seasonal Variation in DO at Tuckahoe Creek at Rt. 6, 1992 – 2003.



5.5 Impact from Point Source Dischargers and Land Use

Four permitted point sources discharge in the Tuckahoe Creek watershed. Henrico Water Treatment Plant (VA0091197) is not discharging at this time, and is not required to report DO or CBOD. Henrico County MS4 (VA0088617) is not required to report DO or CBOD. Two general stormwater permittees Henrico WTP and Short Pump Town Center, are not required to report DO or CBOD. None of these facilities discharges an effluent high in oxygen demand. These are shown in Table 7.

Table 7. VPDES, and Industrial Stormwater Permittees in the Tuckahoe Creek Watershed.

Facility Name	VPDES Permit Number	Discharge Type[1]	Design Flow (MGD)	Permitted *DO, BOD5 or CBOD* Limit
Henrico County Multiple Stormwater Sewer System (MS4)	VA0088617	Municipal Minor	NL	NA
Henrico County Water Treatment Plant	VA0091197	Municipal Minor	0.70	NA
Henrico County Water Treatment Plant	VAR440575	General Stormwater	NL	NA
Short Pump Town Center	VAR440710	General Stormwater	NL	NA

NL = No limit, NA = Not applicable, not required to report DO or BOD5 or CBOD.

High Intensity Residential, and Commercial / Industrial land use comprised 6.15 % of the watershed (2532.2 ac), located primarily in the eastern tributaries. The watershed is predominately forested (52.3 percent), with 4.69 percent wetlands and open water. This land use was considered not indicative of human impact, because the nutrient concentrations did not point to anthropogenic contributions. However, human E. coli impairment was identified at 12% of the annual bacterial load in the bacterial TMDL study, therefore it is possible that some human activities impact the watershed.

5.6 Low DO at the smaller tributaries including Anderson, Readers, Cabin Branch, East Branch Tuckahoe Creek and several unnamed tributaries where 7Q10 = 0 cfs.

The smaller tributaries including Anderson, Readers, Cabin Branch, East Branch Tuckahoe Creek and several unnamed tributaries where 7Q10 = 0 cfs experienced long term DO levels below the water quality standard of 4.0 mg/l during the 2002 summer drought because they were pooled rather than flowing. See Figure 9 for pooled flow conditions at east Branch Tuckahoe Creek on July 10, 2002. These low D0 values qualify as standard violations because the DO Instantaneous Water Quality Standard applies **AT**

7Q10 flow …(9 VAC 25-260-50 ***). A list of tributaries and DO violations during the 2002 drought are presented in Table 8.

Figure 9. Pooled flow conditions during drought at East Branch Tuckahoe Creek on July 10, 2002.

Table 8. Tuckahoe Tributaries with zero 7Q10 DO standard violations during zero flow Summer 2002

Tuckahoe & Tributaries with 7Q10 = 0 cfs, Low DO Violations June - Sept. 2002
With Drought Flow = Zero cfs

Station ID	Date	DO, mg/l
Broad Br, Rt. 288	07/10/02	3.17
	09/25/02	1.7
Broad Br, Rt. 676	06/17/02	1.75
	07/10/02	1.82
	08/12/02	1.99
	09/25/02	3.31
Georges Br Foxmere Dr	07/10/02	3.19
Readers Br, Rt. 623	06/17/02	3.67
	07/10/02	1.11

Stony Run, Falcon Br Rd	**08/12/02**	**1.63**
East Branch Tuckahoe Creek	**07/10/02**	**2.05**
	08/12/02	**1.79**
	09/25/02	**2.13**
UT Tuckahoe Cr, Rt. 6	**06/17/02**	**2.51**
UT Tuckahoe, Lauderdale Rd	**07/10/02**	**1.96**
	09/25/02	**2.4**
UT Little TKO, Rt. 250	**08/12/02**	**3.05**
UT Tuckahoe, Lower TKO Rd	**06/17/02**	**3.42**
	09/25/02	**1.54**

These DO violations all occurred during drought zero flow conditions, and thus are due to the natural absence of rainfall. **Therefore DEQ recommends de-listing the major Tuckahoe Creek tributaries Anderson, Broad, Georges and Readers Branches (2002 303(d) Segment ID# VAP-H39R-01), due to natural drought conditions, not requiring a TMDL. Drought monitoring of several tributaries for this TMDL effort revealed DO violations that will not be assessed until the next integrated report assessment. These streams were East Branch Tuckahoe Creek and those unnamed tributaries whose** DO violations all occurred during drought zero flow conditions due to the natural absence of rainfall. They will be assessed as Category 4C, Impaired due to natural conditions with no TMDL needed, in future water quality integrated assessment reports.
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6.0. Public Participation

The development of the Tuckahoe Creek TMDL was not possible without public participation. A Technical Advisory Committee meeting was held at the Piedmont Regional Office training room in Glen Allen, VA at 2 pm on January 14, 2004. A public meeting was held at the Piedmont Regional Office of DEQ, 4949-A Cox Road, Glen Allen, VA. at 7 pm on January 20, 2004 to discuss the process for the bacterial TMDL development and the DO natural assessment for Tuckahoe Creek. Twelve people attended the public meeting. Copies of the presentation materials were available for public distribution. The public meeting was public noticed in the Virginia Register. There was a 30 day-public comment period after the public meeting. Two written comments addressing the bacterial TMDL were mailed to DEQ. These questions, comments and responses were submitted to EPA separately from this document.

7.0 CONCLUSION

Performing the preliminary 7Q10 screening on the Tuckahoe, Little Tuckahoe and Deep Run DO datasets caused the removal of five DO values less than 4 mg/l with flows below the 7Q10 at Tuckahoe Creek at Rt. 6, lowering the percent violations to 43.1 percent. At Deep Run, four DO values below 4 mg/l were taken at flows below the 7Q10, lowering the percent violations to 9.5 percent, below the listing threshold of 10.5 percent. At Little Tuckahoe Creek, two DO values below 4 mg/l were taken at flows below the 7Q10, lowering the percent violations to 8.6 percent. **DEQ recommends de-listing the Deep Run (2-DPR002.46) and Little Tuckahoe Creek (2-LIY001.73) DO impairment segments because the percent violations minus low DO data sampled at flows less than the 7Q10 were less than the 10.5 percent listing threshold.**

The smaller tributaries including Anderson, Readers, Cabin Branches, East Branch Tuckahoe Creek and several unnamed tributaries where 7Q10 = 0 cfs experienced long term DO levels below the water quality standard of 4.0 mg/l during the 2002 summer drought because they were pooled rather than flowing. These low D0 values qualify as standard violations because the DO Instantaneous Water Quality

Standard applies **AT** 7Q10 flow (9 VAC 25-260-50 ***). These DO violations all occurred during drought zero flow conditions, and thus are due to the natural absence of rainfall. **DEQ recommends de-listing the major Tuckahoe Creek tributaries Anderson, Broad, Georges and Readers Branches (2002 303(d) Segment ID# VAP-H39R-01), due to natural drought conditions, not requiring a TMDL. Drought monitoring of several tributaries for this TMDL effort revealed DO violations that will not be assessed until the next integrated report assessment. These streams were East Branch Tuckahoe Creek and those unnamed tributaries whose** DO violations all occurred during drought zero flow conditions due to the natural absence of rainfall. They will be assessed as Category 4C, Impaired due to natural conditions with no TMDL needed, in future water quality integrated assessment reports.

Tuckahoe Creek exhibits very low slope with significant wetlands. These contribute large inputs of decaying vegetation, which reduce DO as they decay. These are not considered anthropogenic impacts.

Tuckahoe Creek exhibits low nutrient concentrations below national background levels in streams from undeveloped areas, which not indicative of human impact.

Tuckahoe Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high.

Four permittees discharging to the Tuckahoe Creek watershed have insignificant low DO impact. Residential / Commercial land use (6.15%) has only a minor low DO effect on the eastern tributaries. There is no significant DO impact attributed to human activity.

A change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for mainstem Tuckahoe Creek from its confluence with Little Tuckahoe Creek to the confluence with the James River.

8. References

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http://www.dnr.state.sc.us/climate/sercc/products/historical/historical_va.html (Accessed 12/18/02)

USGS (United States Geological Survey), National Background Nutrient Concentrations in Streams from Undeveloped Areas. 1999.

VADEQ (Virginia Department of Environmental Quality), Virginia Water Quality Assessment 1998. Virginia. 1998.

VADEQ (Virginia Department of Environmental Quality), Virginia Water Quality Assessment 2002. Virginia. 2002.

Appendix A

Glossary

GLOSSARY

Note: All entries in italics are taken from USEPA (1998). All non-italicized entries are taken from MapTech (2002).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

7Q10. The lowest streamflow for seven consecutive days that occurs on average once every ten years.

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Background levels. *Levels representing the chemical, physical, and Bacterial conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or Bacterial impurities.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge permits (under VPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the*

receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Mean. The sum of the values in a data set divided by the number of values in the data set.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Non-point source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, Bacterial materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, Bacterial, chemical, and radiological integrity of water.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Stakeholder. Any person with a vested interest in assessment of natural condition or TMDL development.

Standard. In reference to water quality (e.g. pH 6 – 9 SU limit).

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

DCR. Department of Conservation and Recreation.

DEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, Bacterial, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The Bacterial, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*