Benthic TMDL Development for the Rivanna River Watershed

Submitted by

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Executive Summary

Introduction

As required by Section 303(d) of the Clean Water Act and current EPA regulations, states are required to develop Total Maximum Daily Loads (TMDLs) for waterbodies that exceed water quality standards. One segment of the Rivanna River mainstem was first included on Virginia's 1996 Section 303(d) List of Impaired Waters, and was subsequently included on Virginia's 303(d) Lists of Impaired Waters and Water Quality Assessment 305(b)/303(d) Integrated Reports because of violations of the General Standard (benthic impairment). During the 2006 303(d) assessment, DEQ concluded that a second segment was also biologically impaired (DEQ, 2006). This report addresses both benthic impairments. The Rivanna River is located in central Virginia, and is a tributary to the James River. The watershed encompasses the City of Charlottesville, and covers portions of four counties: Albemarle, Greene, Nelson, and Orange counties. Of these four counties, Albemarle and Greene County cover the majority of the watershed.

Impairment Listing

The Virginia Department of Environmental Quality (DEQ) uses biological monitoring of benthic macroinvertebrates as one method to assess support of the aquatic life use for a waterbody. There are currently two benthic impairments on the mainstem Rivanna River. The upstream impairment of the Rivanna River (VAV-H28R-01) begins at the confluence with the North and South Fork Rivanna Rivers, and ends downstream at the confluence with Moores Creek. This segment was first included on Virginia's 1996 Section 303(d) List, and was subsequently included on Virginia's 303(d) Lists of Impaired Waters and Water Quality Assessment 305(b)/303(d) Integrated Reports based on biomonitoring results obtained between 1996 and 2005. According to the 2004 303(d) fact sheets, the cause for the benthic macroinvertebrate impairment is believed to be related to non-point source urban runoff. During the 2006 303(d) assessment, DEQ concluded that the segment directly downstream of VAV-H28R-01 was also biologically impaired (DEQ, 2006). This segment (VAV-H29R-01) begins at the confluence with Moores Creek and ends downstream at an unnamed tributary just after the RWSA-

Glenmore STP. Based on the 2006 303(d) list (DEQ, 2006), the source of the benthic macroinvertebrate impairment is unknown.

Watershed Characterization and Environmental Monitoring

The Rivanna River benthic impaired watershed covers approximately 332,530 acres. Dominant land uses in the watershed are forest (65%) and agriculture (22%), which account for a combined 87% of the total land area in the watershed. The Occoquan-Meadowville-Buckhall soils comprise 48.2% of the watershed.

Environmental monitoring efforts in the Rivanna River watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, and toxicity testing. These monitoring efforts were critical in the development of the Rivanna River TMDL, and have been conducted by agencies at both the state and local levels, including the Virginia Department of Environmental Quality (VADEQ) and United States Geological Survey (USGS). In addition to these agencies a citizen monitoring group, StreamWatch, has conducted monitoring efforts. Biological monitoring and habitat condition assessment data were collected by the VA DEQ at monitoring stations 2-RVN035.67 and 2-RVN033.65, located in the benthic impaired segment VAV-H29R-01. Stream watch conducted biological monitoring at 3 additional locations in the watershed. Water quality data were collected from two stations on the Rivanna River, 2-RVN037.54 and 2-RVN033.65, in addition to four stations located on tributaries that affect the upstream Rivanna River; 2-RRS003.12, 2-RRN002.19, 2-MWC000.60, and 2-MSC000.60. The Rivanna River Roundtable conducted water quality monitoring at 14 stations in the Rivanna River watershed. A relative bed stability analysis was also conducted by VA DEQ at station 2-RVN033.65.

Stressor Identification

Assessment of the primary stressor contributing to biological impairment in the Rivanna River was based on evaluations of candidate stressors that can potentially impact the river. The identification of the most probable cause of biological impairment in the Rivanna River was based on evaluations of these candidate stressors. The evaluation

includes candidate stressors such as dissolved oxygen, temperature, pH, metals, organic chemicals, nutrient, toxic compounds, and sediments. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed.

Furthermore, potential stressors were classified as:

Non-stressors: The stressors with data indicating normal conditions and without water quality standard violations, or without any apparent impact

Possible stressors: The stressors with data indicating possible links, however, with inconclusive data to show direct impact on the benthic community

Most probable stressors: The stressors with the conclusive data linking them to the poorer benthic community.

The data and analysis presented in this report indicate that temperature, pH, and dissolved oxygen in the biologically impaired segment of the Rivanna River are adequate to support a healthy invertebrate community, and are not stressors contributing to the benthic impairment. Concentrations of metals and organic chemicals were generally low or below analytical detection limits and are also classified as non-stressors.

Phosphorous, potentially from the Moores Creek STP may be causing eutrophication in the stream. This was reflected by a majority of samples composed of macroinvertebrates typically tolerant to pollution from organic wastes or nutrients. Phosphorous is therefore identified as a possible stressor. Toxicity tests found biological effects on fathead minnow survival and biomass, making toxicity another potential stressor.

Based on the Stressor Identification Analysis, sedimentation caused by higher runoff flows has been identified as a primary stressor impacting benthic invertebrates in the biologically impaired segments of the Rivanna River. Embeddedness and sediment deposition were found to be suboptimal. Potential causes of sediment loading in the watershed include land use, poor riparian zone conditions, erosion, and runoff. Although the majority of the watershed is forested and agricultural land, the area upstream and

surrounding the portion of the Rivanna River benthic impairment is within the City of Charlottesville. The impervious surfaces of urban areas will increase the speed of runoff, which can erode banks, scour stream beds, and deliver toxic chemicals. Also, in the upper portion of the watershed, studies have shown that there is a high level of sedimentation related to stream bank instability.

The interrelation between sedimentation, higher runoff flows, and habitat alteration, allows a TMDL for sediments to address habitat degradation as well as increased urban runoff. Improvement of the benthic community in the biologically impaired segment of the Rivanna River watershed is dependent upon reducing sediment loadings through stormwater control, as well as restoring instream and riparian habitat to alleviate the impacts of urbanization on the river.

To address these issues, a sediment TMDL will be developed for the biologically impaired segments of the Rivanna River watershed.

Modified Reference Approach

In the case of the modified reference watershed approach, conditions in several non-impaired watersheds are used to establish the TMDL endpoint. Selection of an appropriate reference watershed is based on similarities in ecoregion and stream order. Similar watersheds help to ensure similarities in the benthic communities that potentially may inhabit the streams. Similar watersheds also provide for similar watershed hydrology which influences pollutant loading rates to the stream. Several DEQ stations, located in non-impaired watersheds, were used as references for the impaired Rivanna River watershed. The non-impaired reference stations included stations from: the Rapidan (3-RAP030.21), Piney (2-PNY005.30), Robinson (3-ROB005.42 and 3-ROB004.98), Rockfish (2-RKF0216.13), and South Mayo River (4-ASMR017.72) as well as a station in Goose Creek (4-AGSE015.07).

Sediment Rating Curves

The sediment rating curve is used to compare correlations of flow vs. sediment for the non-impaired reference stations and the impaired segment of the Rivanna River. The sediment rating curve is the result of attributing each TSS sample collected at an impaired or non-impaired DEQ station with flow data collected at a nearby USGS station. The result of this comparison is a regression equation, or sediment rating curve, which is then used to generate a load duration curve (described in the following section). The non-impaired sediment rating curve is the basis for the TMDL.

Load Duration Curves

A Sediment Load Duration Curve characterizes sediment loads at different flow regimes and displays the relationship between stream flow and loading capacity (US EPA, 2007). Using the sediment rating curve equations, predicted non-impaired and impaired sediment loads are calculated for all flow conditions in the impaired watershed. The sediment load duration curves are used to assign numerical values to the flow regime in the unimpaired reference stations and the impaired Rivanna River segment for comparison. The non-impaired load duration curve represents the TMDL endpoint. Additionally, the curve allows for each TSS target to be categorized into high flows, mid-range flows, dry conditions and low flows.

Generalized Watershed Loading Functions (GWLF) Model

The load duration curve does not distinguish between sources, however using the GWLF model, the percent sediment loading from land erosion from each landuse type is determined. GWLF is a time variable simulation model that simulates hydrology and sediment loadings on a watershed basis. The GWLF model is used to generate annual sediment loads by source, thereby determining the percentage of the total sediment load contributed from each land use type.

TMDL Allocation

Sediment TMDL allocations for the benthic impaired Rivanna River were based on the following equation.

$$TMDL = WLA + LA + MOS$$

Where:

TMDL= Total Maximum Daily Load (Based on the Sediment Load of the Adjusted Reference Watershed)

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The wasteload allocation represents the total sediment loading allocated to point sources. The load allocation represents the total sediment loading allocated to non-point sources. A margin of safety is applied to account for uncertainty in methodologies and determination of sediment loadings. A margin of safety of 10% was used for the Rivanna River benthic TMDL.

For the purpose of TMDL development, daily point source loadings for the 13 individually permitted facilities currently active or under application in the benthic impaired watershed were computed based on the average flow and the average total suspended solids concentration for each facility **(Table E-1).**

Table E-1: Point Source Daily Loads in the Benthic Impaired Rivanna River Watershed

Permit #	Facility Name	Existing Load (lbs/day)
VA0025488	Camelot STP	15.9
VA0025518	Moores Creek Regional STP	470.5
VA0027065	Cooper Industries	4.4
VA0028398	Avionics Specialties Inc	0.03
VA0029556	Blue Ridge School STP	.5
VA0055000	Crozet WTP	2.4
VA0075981	Ramada Inn Monticello STP	0.6
VA0076244	Stone Robinson Elementary School	0.3
VA0080781	Ehart Subdivision STP	8.8
VA0085979	Keswick STP	1.2

Table E-1: Point Source Daily Loads in the Benthic Impaired Rivanna River Watershed

Permit #	Facility Name	Existing Load (lbs/day)
VA0086584	Glenmore STP	3.8
VA0087351	Virginia Oil - Charlottesville	Discharges to MS4 VAR040051
VA0091120	North Rivanna WTP	16.3
	Total	**524.5**

Five areas within the Rivanna River watershed have Municipal Separate Storm Sewer (MS4) permits. The MS4 permits state that the City of Charlottesville, the Virginia Department of Transportation (VDOT), University of Virginia, Albemarle County, and Piedmont Virginia Community College are permitted to discharge into the Rivanna River impaired watershed. The Charlottesville MS4 area was calculated by subtracting the VDOT major road areas (interstates and primary roads) within the City of Charlottesville from the US Census Urban Areas. VDOT road areas were estimated using the roads length within the urban areas and assuming a 25 foot-road-width. The Albemarle County MS4 was calculated using the urban areas identified in the Albemarle County Comprehensive Plan GIS data layer and subtracting major and minor VDOT road areas (interstates, primary roads, secondary roads, and other roads). Stormwater permits typically do not have numeric limits for sediment.

To separate sediment loading attributed to the MS4s from other land-based sediment loading, an area weighted sediment load was determined for the MS4s, in which the percentage of sediment loading from each source area attributed to the MS4s was proportional to the percentage of that source area in the Rivanna River impaired watershed covered by the various MS4 permits. The MS4 acres and land based sediment loads currently in the watershed are shown in **Table E-2**. The wasteload allocations were based on each municipality's share of the contributing urbanized area of the impairment. To separate sediment loading attributed to the MS4s from other land-based sediment loading, an area weighted sediment load approach was used to determine the MS4 sediment loads. Additionally, stormwater runoff from MS4s results in increased stream

bank erosion. Bank erosion resulting from MS4 stormwater runoff, and bank erosion resulting from overland runoff, were separated using a runoff weighted approach. Using this approach, the MS4 flow was calculated as a percentage of the total watershed flow, and used to calculate the bank erosion load for the MS4 areas. Sediment from other land sources in the watershed and the remainder of the bank erosion sediment load were attributed to the non-point sources.

Table E-2: Land Based Non-Point Sediment Load in the Benthic Impaired Rivanna River Watershed by MS4 Area

Permit Number	MS4 Permit Holder	Existing Land Based Load (lbs/day)
VAR040051	City of Charlottesville	477
VAR040033	VDOT Charlottesville Major Roads	5
VAR040073	University of Virginia (Charlottesville)	17
	University of Virginia (Albemarle)	70
VAR040074	Albemarle County	1,606
VAR040033	VDOT Albemarle Roads	41
Application	Piedmont Community College	7
Instream Erosion		6,545
Total		**8,768**

The total load, wasteload allocations, and margin of safety for Rivanna River are summarized in **Table E-3** and **Table E-4**. Recommended allocations for each source in the watershed are provided in **Table E-5**. Overall, the sediment load in the Rivanna River watershed must be reduced by 45.1% to meet the established TMDL endpoint.

Table E-3: Sediment TMDL for Rivanna River (lbs/day)

TMDL	Load Allocation	Wasteload Allocation (Point Source + MS4s)	Margin of Safety (10%)
35,896	22,007	10,229	3,590

Table E-4: Sediment TMDL for Rivanna River (lbs/year)

TMDL	Load Allocation	Wasteload Allocation	Margin of Safety (10%)
1.31E+07	8.06E+06	3.73E+06	1.31E+06

Table E-5: Summary of Existing and Allocated Sediment Loads for the Rivanna River Watershed

Source	Land Use Type	Existing Load (lbs/day)	Allocated Load (lbs/day)	Percent Reduction (%)
Non-Point Source	Forest	164	164	-
	Row Crop	14,654	5,958	59.3
	Pasture/Hay	15,829	6,435	59.3
	High Intensity Residential	2,292	932	59.3
	Low Intensity Residential	225	91	59.3
	Instream Erosion	20,900	8,497	59.3
MS4	Land-based	2,223	904	59.3
	Instream Erosion	6,545	2,661	59.3
General Permits Outside MS4 Area	Land-based	1,146	1,146	-
	Instream Erosion	882	882	-
Point Source	Individual VPDES Permits	524	4,636	-
MOS			3,590	
	Total	**65,384**	**35,896**	**45.1**

Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Public Participation

The development of the Rivanna River benthic TMDLs would not have been possible without public participation. Public meetings were held on March 15, 2007 and on February 11, 2008 at the Albemarle County Office Building in Charlottesville, Virginia. Copies of the presentation were available for public distribution at each meeting. Also, each meeting was public noticed in *The Virginia Register of Regulations.*

1.0 Introduction

Total Maximum Daily Load (TMDL) development for biological impairment requires a methodology to identify impairment causes and to determine pollutant reductions that will allow streams to attain their designated uses. The identification of the pollutant(s), or *stressor(s)*, responsible for the impaired biological communities is an important first step in developing a TMDL that accurately specifies the pollutant load reductions necessary for the stream to comply with Virginia's water quality standards. This report details the steps used to identify and characterize the stressor(s) responsible for biological impairments in the Rivanna River, Virginia. The first section of this report presents the regulatory guidance and defines the applicable water quality criteria for biological impairment. In the subsequent sections, watershed and environmental monitoring data collected on Rivanna River are presented and discussed. Stressors that may be affecting the creek are then analyzed in the stressor identification section. Based on this analysis, candidate stressors impacting benthic invertebrate communities in the creek are identified. A Total Maximum Daily Load (TMDL) will be developed for the stressor identified as the primary source of biological impairment in the Rivanna River.

1.1 Regulatory Framework

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) both require states to develop TMDLs for waterbodies that 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 instream 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 in order to restore and maintain the quality of their water resources (EPA, 2001).

The lead regulatory agency for environmental matters in Virginia is the Department of Environmental Quality (VA DEQ). VA DEQ works in coordination with the Virginia Department of Conservation and Recreation (VA DCR), the Department of Mines, Minerals, and Energy (VDMME), and the Virginia Department of Health (VDH) to develop and implement a more effective TMDL process. VA DEQ is the lead agency for the development of TMDLs statewide, and focuses its efforts on all aspects of reduction and prevention of pollution in state waters. VA DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA, passed by the Virginia General Assembly in 1997), and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. VDMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state, which details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the Section 303(d) List of Impaired Waters. In addition to Section 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001). DEQ also solicits participation and comments from watershed stakeholders and the public throughout the TMDL process. Once TMDLs have been developed and the public comment period has been completed, the TMDLs are submitted to EPA for approval.

1.2 Impairment Listing

The Rivanna River is located in central Virginia, and is a tributary to the James River. The Rivanna River benthic impaired watershed covers approximately 332,530 acres in central Virginia, and is located within the James River Basin. The watershed

encompasses the City of Charlottesville, and covers portions of four counties: Albemarle, Greene, Nelson, and Orange counties. The majority of the watershed lies within Albemarle County (approximately 79%), and within Greene County (approximately 18%).

There are currently two benthic impairments on the mainstem Rivanna River (**Figure 1-1**). The upstream impairment of the Rivanna River (VAV-H28R-01) begins at the confluence with the North and South Fork Rivanna Rivers, and ends downstream at the confluence with Moores Creek. This segment was first included on Virginia's 1996 Section 303(d) List, and was subsequently included on Virginia's 303(d) Lists of Impaired Waters and Water Quality Assessment 305(b)/303(d) Integrated Reports based on biomonitoring results obtained between 1996 and 2005. According to the 2004 303(d) fact sheets, the cause for the benthic macroinvertebrate impairment is believed to be related to non-point source urban runoff. During the 2006 303(d) assessment, DEQ concluded that the segment directly downstream of VAV-H28R-01 was also biologically impaired (DEQ, 2006). This segment (VAV-H29R-01) begins at the confluence with Moores Creek and ends downstream at an unnamed tributary just after the RWSA-Glenmore STP. Based on the 2006 303(d) list (DEQ, 2006), the source of the benthic macroinvertebrate impairment is unknown.

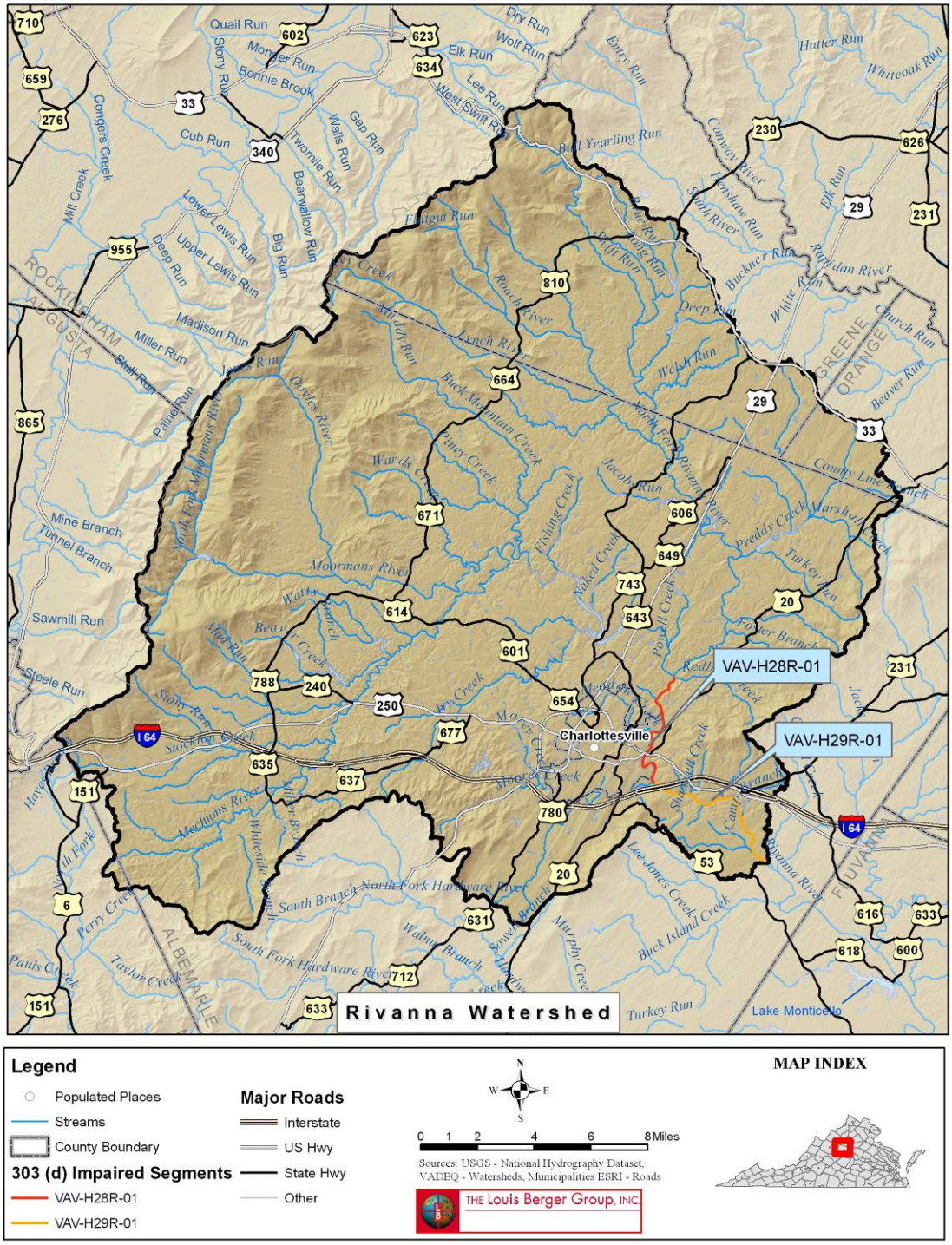


Figure 1-1: Rivanna River Benthic Impaired Segments and Delineated Watershed

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a waterbody, and the water quality criteria necessary to support those designated uses. 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 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.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"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)."*

Based on the biological assessment surveys conducted on the stream, the listed segment defined in Section 1.2 does not fully support the propagation and growth of aquatic life in the Rivanna River.

1.3.2 Water Quality Criteria

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or*

> *interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

The biological assessments conducted on the Rivanna River indicate that some pollutant(s) are interfering with attainment of the General Standard, as impaired invertebrate communities have been observed in the listed segment of the creek. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

2.0 Watershed Characterization

The physical conditions of the Rivanna River were characterized using a geographic information system (GIS) developed for the watershed. The purpose of the characterization was to provide an overview of the conditions in the watershed related to the benthic impairment present in the listed segment of the stream. Information contained in the watershed GIS was used in the stressor identification analysis, as well as for subsequent TMDL development. Physical watershed features such as topography, soils types, and land use conditions were characterized. In addition, the number and location of permitted discharge facilities and DEQ monitoring stations in the watershed were summarized.

2.1 Physical Characteristics

Important physical characteristics of the Rivanna River watershed that may be contributing to the benthic impairment were analyzed using GIS layers developed for the area. GIS layers for the watershed boundary, stream network, topography, soils, land use, and ecoregions of the watershed were compiled and analyzed.

2.1.1 Watershed Location and Boundary

The Rivanna River is located in central Virginia, and is a tributary to the James River. The Rivanna River benthic impaired watershed covers approximately 332,530 acres in central Virginia, and is located within the James River Basin. The watershed encompasses the City of Charlottesville, and covers portions of four counties: Albemarle, Greene, Nelson, and Orange counties. Of these four counties, Albemarle and Greene County cover the majority of the watershed.

2.1.2 Stream Network

The stream network for the Rivanna River watershed was obtained from the USGS National Hydrography Dataset (NHD). The stream network and benthic impairment segment are presented in **Figure 2-1**.

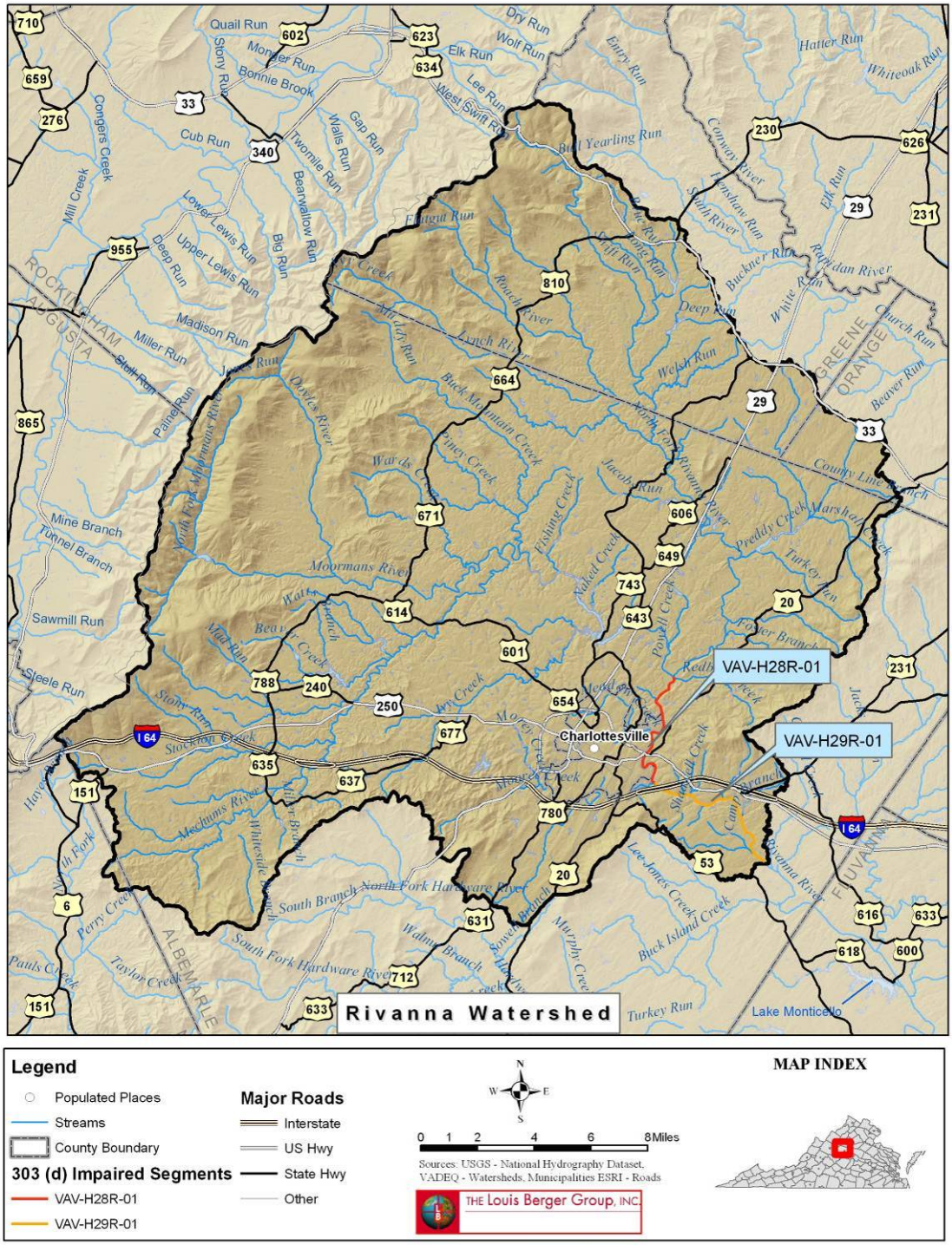


Figure 2-1: Stream Network for the Benthic Impaired Rivanna River Watershed

2.1.3 Topography

A digital elevation model (DEM) was used to characterize topography in the watershed. DEM data obtained from the USGS show that elevation in the watershed ranges from approximately 242 ft to 3,584 ft (74 to 1,093 meters).

2.1.4 Soils

The Rivanna River watershed soil characterization was based on data obtained from the STATSGO database, archived and distributed by the NRCS. There are eight general soil associations located in the watershed (see **Table 2-1)**. The Occoquan-Meadowville-Buckhall soils, which comprise 48.2% of the watershed, are deep to very deep, well-drained, moderately permeable loamy soils occurring predominantly in forested areas.

Table 2-1: Major Soil Associations within the Rivanna River Watershed

Soil Name	Acres	Percentage of Watershed
Myersville-Catoctin	62,533	18.8%
Hayesville	41,248	12.4%
Kinkora-Hatboro-Codorus	4,086	1.2%
Braddock	52,415	15.8%
Occoquan-Meadowville-Buckhall	160,135	48.2%
Nason-Manteo	3,490	1.0%
Penn-Croton	1,320	0.4%
Rabun	7,303	2.2%
Total	**332,530**	**100%**

The hydrologic soil group linked with each soil association is also presented in **Table 2-2**. The hydrologic soil groups represent the different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A," soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-3**.

Table 2-2: Soil Hydrogroups within the Rivanna River Watershed

Hydrogroup	Acres	Percentage of Watershed
A	0	0%
B	323,608	97%
C	4,842	2%
D	4,080	1%
Total	**332,530**	**100%**

Table 2-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover
C/D	Combination of Hydrologic Soil Groups C and D

2.1.5 Land Use

The land use characterization for the Rivanna River watershed was based on land cover data from NLCD using 2001 reference data. The distribution of land uses in the watershed, by land area and percentage, is presented in **Table 2-4**. Dominant land uses in the watershed are forest (65%) and agriculture (22%), which account for a combined 87% of the total land area in the watershed. Brief descriptions of land use classifications are presented in **Table 2-5**. **Figure 2-2** depicts the land use distribution within the Rivanna River watershed.

Table 2-4: Land Use Categories within the Rivanna River Watershed

General Land Use Category	Specific Land Use Types	Acres		Percent of Watershed's Land Use Area	
Water/ Wetlands	Open Water	2,618	1%	<1%	1
	Woody Wetlands	249		<1%	
	Emergent Herbaceous Wetlands	9		<1%	
Developed	Developed, Open Space	27,578	12%	8%	12
	Developed, Low Intensity	10,097		3%	
	Developed, Medium Intensity	2,737		<1%	
	Developed, High Intensity	1,081		<1%	
Agriculture	Pasture/Hay	70,068	22%	21%	22
	Cultivated Crops	1,687		1%	
Forest	Deciduous Forest	164,974	65%	49%	65
	Evergreen Forest	25,415		8%	
	Mixed Forest	25,891		8%	
Barren	Barren Land	126	<1	<1%	<1
	Total	**332,530**		**100%**	**100%**

Table 2-5: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent cover on water.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover, and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover, and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/ Industrial/ Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities). Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: Multi-Resolution Land Characteristics Consortium NLCD (2001)

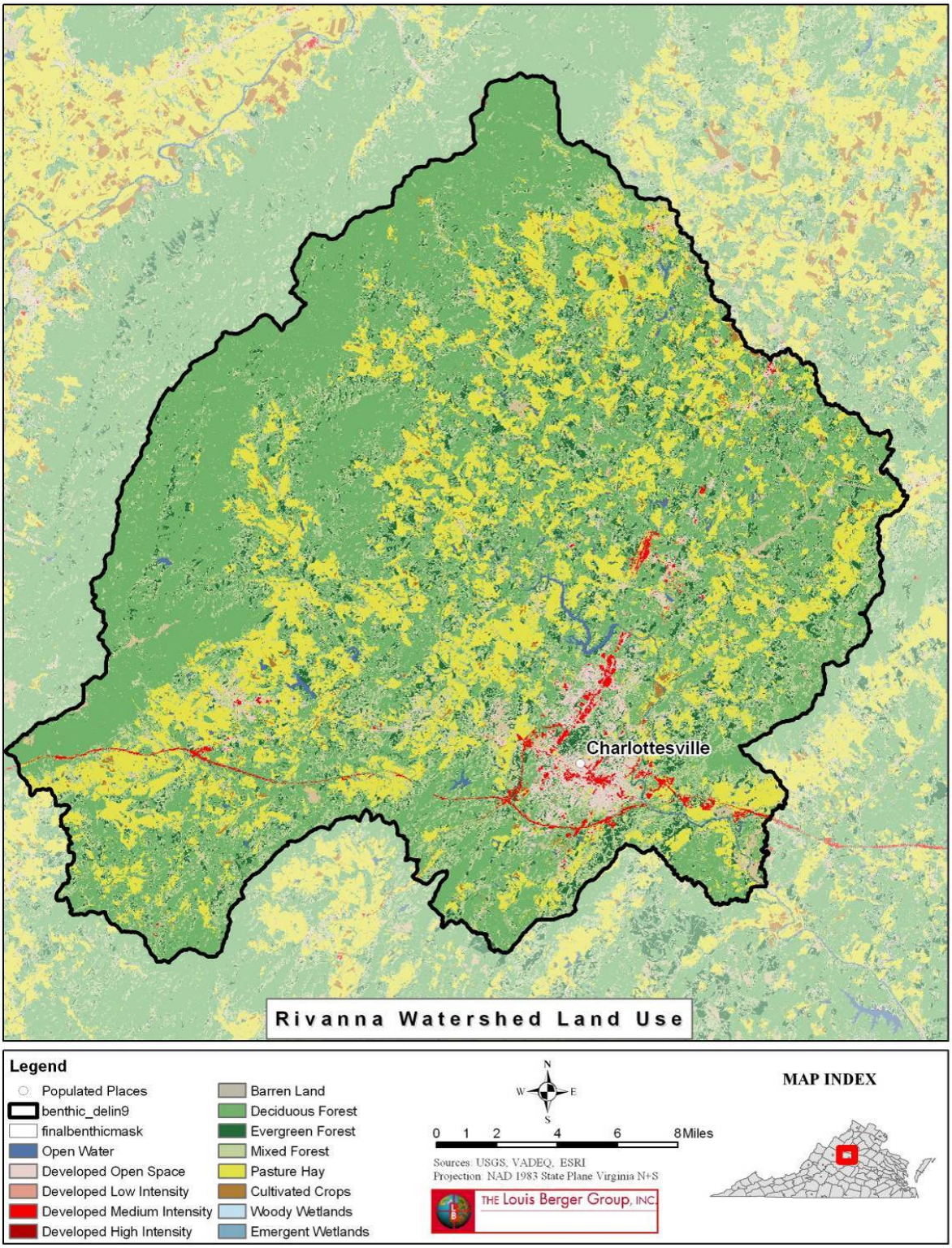


Figure 2-2: Land Use in the Benthic Impaired Rivanna River Watershed

2.1.6 Land Use Update

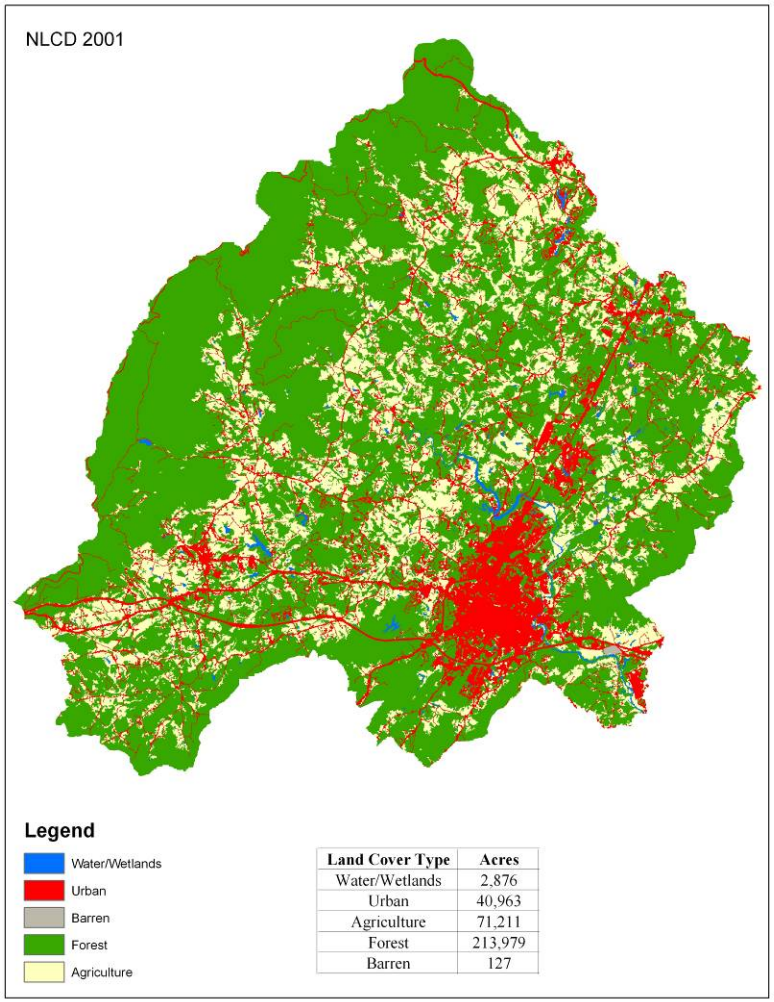
Because of the urban growth since 2001, it was necessary to update the NLCD land use data to better reflect changes in the watershed, as increases in urban and impervious surface areas have large impacts on the watershed hydrology. In order to update the NLCD data, land use data from 2005, developed by the Virginia Department of Forestry (DOF) for the Commonwealth of Virginia, was used. DOF's land use data was developed through segment-based classification of Landsat satellite imagery acquired from 03/10/2002 to 05/08/2005, and provides an up-to-date land use distribution for the commonwealth. The satellite imagery used for the Rivanna River watershed was all from 2005.

The land cover classifications in the DOF land cover data set and the NLCD have different formats and land use classifications. The DOF land classifications have different break-downs of the urban land covers (pavement, rooftop, and residential/industrial as opposed to the low/medium/high intensity development in the NLCD classifications), have additional classifications not specifically included in the NLCD (mine/quarry, forest harvest, and salt marsh), and are lacking some of the NLCD classifications (freshwater wetland classifications and shrub/scrub). As such, only the urban classifications from the DOF data were incorporated into the NLCD 2001 data to produce a hybrid land use dataset that provides an update of the urban land use distribution in the Rivanna River watershed.

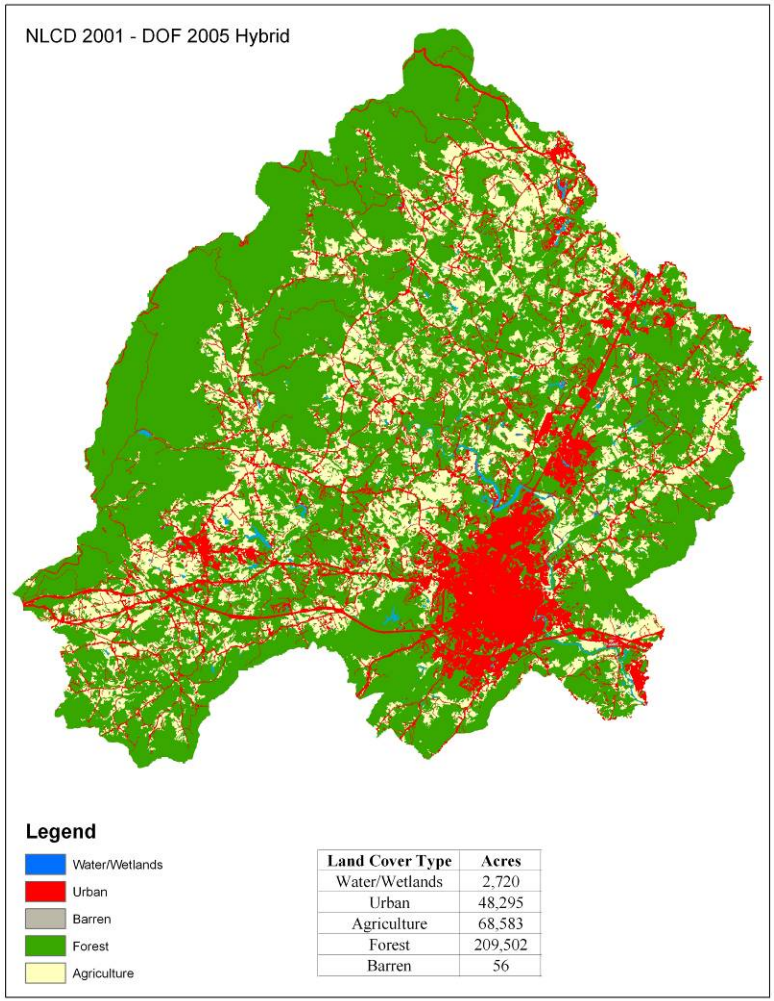
The result of incorporating the DOF's 2005 urban land use into the NLCD 2001 is shown in **Table 2-6**. **Figure 2-3** provides a visual comparison of the NLCD and hybrid datasets.

Table 2-6: NLCD 2001 and Hybrid Land Covers

Land Cover Type	NLCD 2001	Hybrid	Change in Acreage
Water/Wetlands	2,876	2,720	-157
Urban	40,963	48,295	7,332
Agriculture	71,211	68,583	-2,628
Forest	213,979	209,502	-4,477
Barren	217	56	-71



Land Cover Type	Acres
Water/Wetlands	2,876
Urban	40,963
Agriculture	71,211
Forest	213,979
Barren	127



Land Cover Type	Acres
Water/Wetlands	2,720
Urban	48,295
Agriculture	68,583
Forest	209,502
Barren	56

Figure 2-3: NLCD 2001 and Hybrid Land Use Layers for the Benthic Impaired Rivanna River Watershed

2.1.7 Ecoregion Classification

The Rivanna River watershed is located within the Northern Piedmont, Piedmont, and Blue Ridge ecoregions, USEPA Level III classification numbers 64, 45, and 66, respectively (Woods et al., 1999). The watershed is primarily composed of the Northern Piedmont ecoregion (75%), followed by the Blue Ridge (23%), and Piedmont (2%) ecoregions. The location of the Rivanna River watershed within these ecoregions is presented in **Figure 2-4**.

The Northern Piedmont ecoregion is a region of low rounded hills, irregular plains, and open valleys that serves as a transitional area between the low mountains to the north and west and the flat coastal plains to the east. Natural vegetation in the Northern Piedmont ecoregion is predominantly Appalachian oak forest, in contrast to the mostly oak-hickory-pine forests of the Piedmont ecoregion to the southwest.

The Blue Ridge ecoregion extends from southern Pennsylvania to northern Georgia, varying from narrow ridges to hilly plateaus to more massive mountainous areas, with high peaks reaching over 2000 meters. The mostly forested slopes, high-gradient, cool, clear streams, and rugged terrain occur primarily on metamorphic rocks, with minor areas of igneous and sedimentary geology. Annual precipitation of over 200 centimeters can occur in the wettest areas.

The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia, and comprises a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

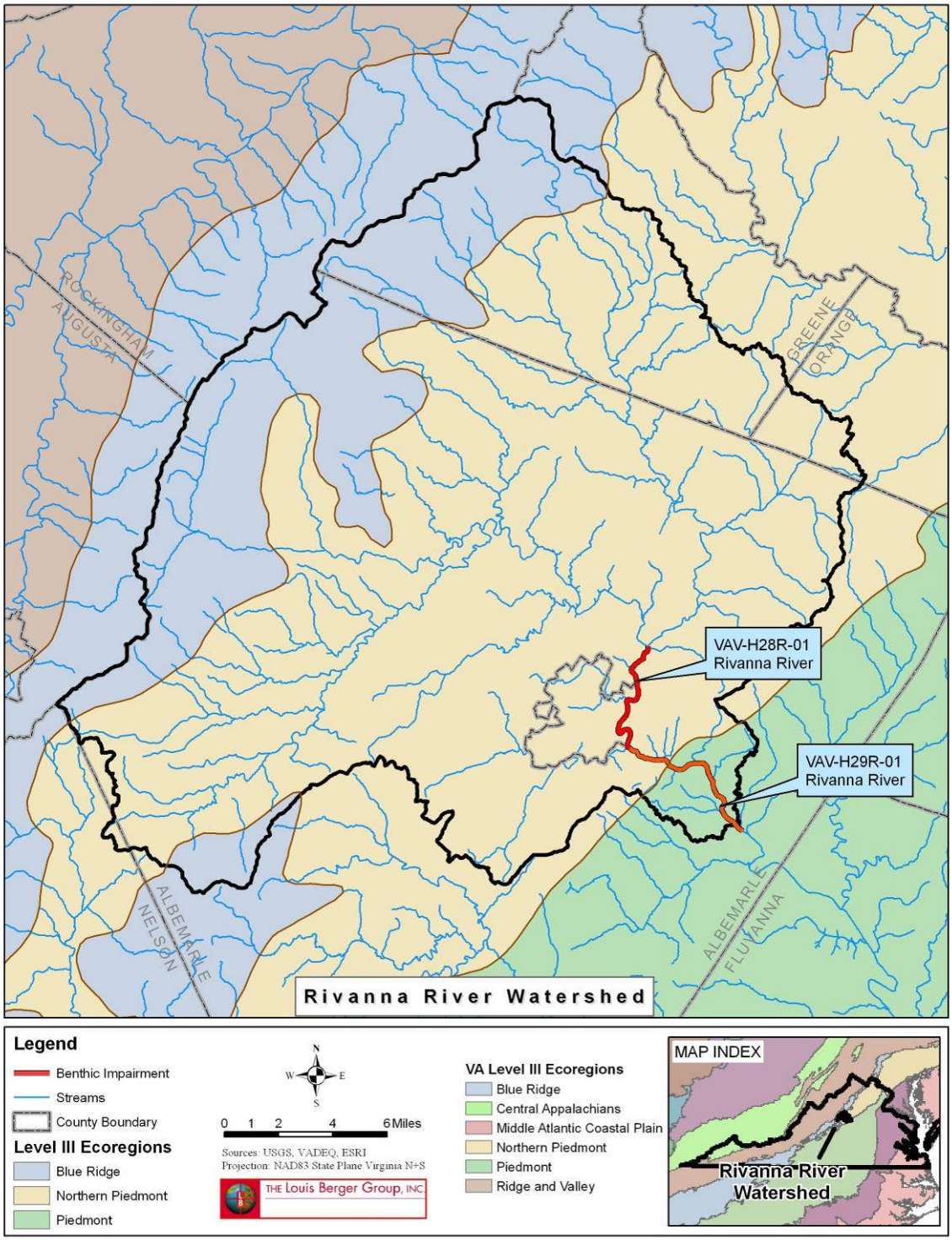


Figure 2-4: Virginia Level III Ecoregions in the Benthic Impaired Rivanna River Watershed

2.2 Permitted Discharge Facilities

Data obtained from the DEQ's Valley Regional Office indicate that there are 13 individually permitted facilities currently active or under application within in the Rivanna River Watershed. The permit number, design flow, and status for each permit are presented in **Table 2-7** and shown in **Figure 2-5**.

Table 2-7: Individual Permitted Facilities within the Rivanna River Watershed

Permit #	Facility Name	Receiving Stream	River Mile	Status	Size	Category	Design Flow (MDG)
VA0025488	Camelot STP	NF Rivanna River	9.72	Active	Minor	Municipal	0.365
VA0025518	Moores Creek Regional STP	Moores Creek	0.19	Active	Major	Municipal	15
VA0027065	Cooper Industries	S. F. Rivanna River, U.	1.25	Active	Minor	Industrial	0.033
VA0028398	Avionics Specialties Inc	Naked Creek, U.T.	0.68	Active	Minor	Municipal	0.005
VA0029556	Blue Ridge School STP	Chesley Creek	0.6	Active	Minor	Municipal	0.035
VA0055000	Crozet WTP	Beaver Creek Reservoir,	0.2	Active	Minor	Industrial	0.186
VA0075981	Ramada Inn Monticello STP	Shadwell Creek	0.66	Active	Minor	Municipal	0.04
VA0076244	Stone Robinson Elementary School	Rivanna River	34.05	Active	Minor	Municipal	0.007
VA0080781	Ehart Subdivision STP	Peddy Creek, UT	1.3	Active	Minor	Municipal	0.07
VA0085979	Keswick STP	Carroll Creek UT	2.68	Active	Minor	Municipal	0.099
VA0086584	Glenmore STP	Rivanna River	31.35	Active	Minor	Municipal	0.381
VA0087351	Virginia Oil - Charlottesville	Schenks Branch, U.T.	0.12	Active	Minor	Industrial	Discharges to MS4 VAR040051
VA0091120	North Rivanna WTP	North Fork Rivanna River	10.28	Active	Minor	Industrial	0.065

There are also 64 general permits issued within the watershed. The active and application general permits are shown in **Table 2-8**.

Table 2-8: General Permitted Facilities within the Rivanna River Watershed

Permit	Facility Name	Receiving Stream	Type
VAR051387	Moores Creek Regional STP	Moores Creek	Industrial Facility
VAR050793	J Bruce Barnes Inc	Lickinghole Creek	Industrial Facility
VAR050932	USPS - Charlottesville Vehicle Maintenance Facility	Meadow Creek, UT	Industrial Facility
VAR050965	Harry A Wright's Inc	Rivanna River	Industrial Facility
VAR051372	University of VA - Parking and Transportation Department	Meadow Creek	Industrial Facility
VAR051402	LexisNexis	Rivanna River	Industrial Facility
VAR051403	Charlottesville Transit Service	Schenks Branch	Industrial Facility
VAR050974	BFI Waste Services - Charlottesville	Moores Creek, UT	Industrial Facility
VAR050876	Sperry Marine	Meadows Creek, UT	Industrial Facility
VAR050785	Badger Fire Protection	NF Rivanna River	Industrial Facility
VAR050503	Charlottesville-Albemarle Airport	Flat Branch, UT	Industrial Facility
VAR050933	S. L. Williamson - Shadwell Asphalt Plant	Barn Branch, UT	Industrial Facility
VAR050780	United Parcel Service - Charlottesville	Barn Branch	Industrial Facility
VAR051507	Faulconer Const Co Office/Maintenance Facility	Little Ivy Creek, UT	Industrial Facility
VAR051618	Greene County Materials Recovery Facility	Quarter Creek UT	Industrial Facility
VAR050948	R A Yancey Lumber Corporation	Stockton Creek, UT	Industrial Facility
VAR050960	M & M Service & Salvage Yard Inc	Welsh Run	Industrial Facility
VAR050973	Ivy Materials Utilization Center	Broad Axe Creek	Industrial Facility
VAR051730	CARR Service Center	Preddy Creek	Industrial Facility
VAR050931	Mountain Lumber Company Inc	Preddy Creek, UT	Industrial Facility
VAG110064	Allied Concrete Company - Charlottesville	Schenks Branch, UT	Concrete Facility
VAG111032	HT Ferron Company	Moores Creek	Concrete Facility
VAG110184	Colonial Concrete-Charlottesville	Flat Branch UT	Concrete Facility
VAG840037	Luck Stone - Charlottesville Plant	Rivanna River, UT	Quarries/Mines
DCR-06-102123	C. W. Hurt Contractors, LLC	-	Construction Site
DCR-07-100002	W. C. English, Inc.	-	Construction Site
DCR-07-100223	Ontour Construction	-	Construction Site

Table 2-8: General Permitted Facilities within the Rivanna River Watershed			
DCR-07-100143	Choco Cruz, LLC	-	Construction Site
DCR-06-102237	Habitat for Humanity of Greater Charlottesville	-	Construction Site
DCR-06-101976	Fritz Ballard	-	Construction Site
DCR-05-100037	Martin/Horn, Inc.	-	Construction Site
DCR-05-100352	Carolina Green Corporation	-	Construction Site
DCR-05-100376	Branch Highways, Inc.	-	Construction Site
DCR-06-101551	C.W. Hurt Contractors, LLC	-	Construction Site
DCR-07-100228	General Excavation, Inc.	-	Construction Site
DCR-07-100239	General Services Project Mgr./County of Albemarle	-	Construction Site
DCR-06-102352	C.W. Hurt Contractors, LLC	-	Construction Site
DCR-06-102410	Church Hill Development, LLC	-	Construction Site
DCR-06-102426	W.M. Jordan	-	Construction Site
DCR-06-101252	C.W. Hurt Contractors, LLC	-	Construction Site
DCR-06-101925	R.E. & Son, Inc.	-	Construction Site
DCR-06-101302	Worrell Land and Development Company, LLC	-	Construction Site
DCR-06-101300	Chick-fil-A, Inc.	-	Construction Site
DCR-06-101463	R.E. Lee and Sons, Inc.	-	Construction Site
DCR-06-102147	Shiflett Farm, LLC/Stonehaus Development	-	Construction Site
DCR-07-100486	Weather Hill Development, LLC	-	Construction Site
DCR-06-101747	Marcia Joseph	-	Construction Site
DCR-06-101771	General Excavation, Inc.	-	Construction Site
DCR-07-100374	Huntley of Charlottesville Ltd.	-	Construction Site
DCR-07-100514	Kjellstrom & Lee Construction	-	Construction Site
DCR-06-102219	Tom Garrison	-	Construction Site
DCR-06-101225	Terra Engineering and Land Solutions, PC	-	Construction Site
DCR-06-101226	Terra Engineering and Land Solutions, PC	-	Construction Site
DCR-06-102251	KG Associates	-	Construction Site
DCR-06-102229	NVR, Inc. dba Ryan Homes	-	Construction Site
DCR-06-102228	NVR, Inc. dba Ryan Homes	-	Construction Site
DCR-06-100348	Shiflett Farm, LLC c/o Stonehaus Development	-	Construction Site
DCR-06-101918	NVR, Inc. dba Ryan Homes	-	Construction Site

Table 2-8: General Permitted Facilities within the Rivanna River Watershed			
DCR-06-100504	Basheer/Edgemoore-Whitehall, L.L.C.	-	Construction Site
DCR-06-100373	Gaylon Beights	-	Construction Site
DCR-06-101858	Gaylon Beights	-	Construction Site
VAG750045	Vehicle Maintenance Facility	Ivy Creek, UT	Car Wash Facility
VAG401839	Twin Lakes Subdivision Residence - Lot	Lake Skyline	Single Family Domestic Sewage
VAG401840	Twin Lakes Subdivision Residence - Lot	Lake Shenandoah, UT	Single Family Domestic Sewage

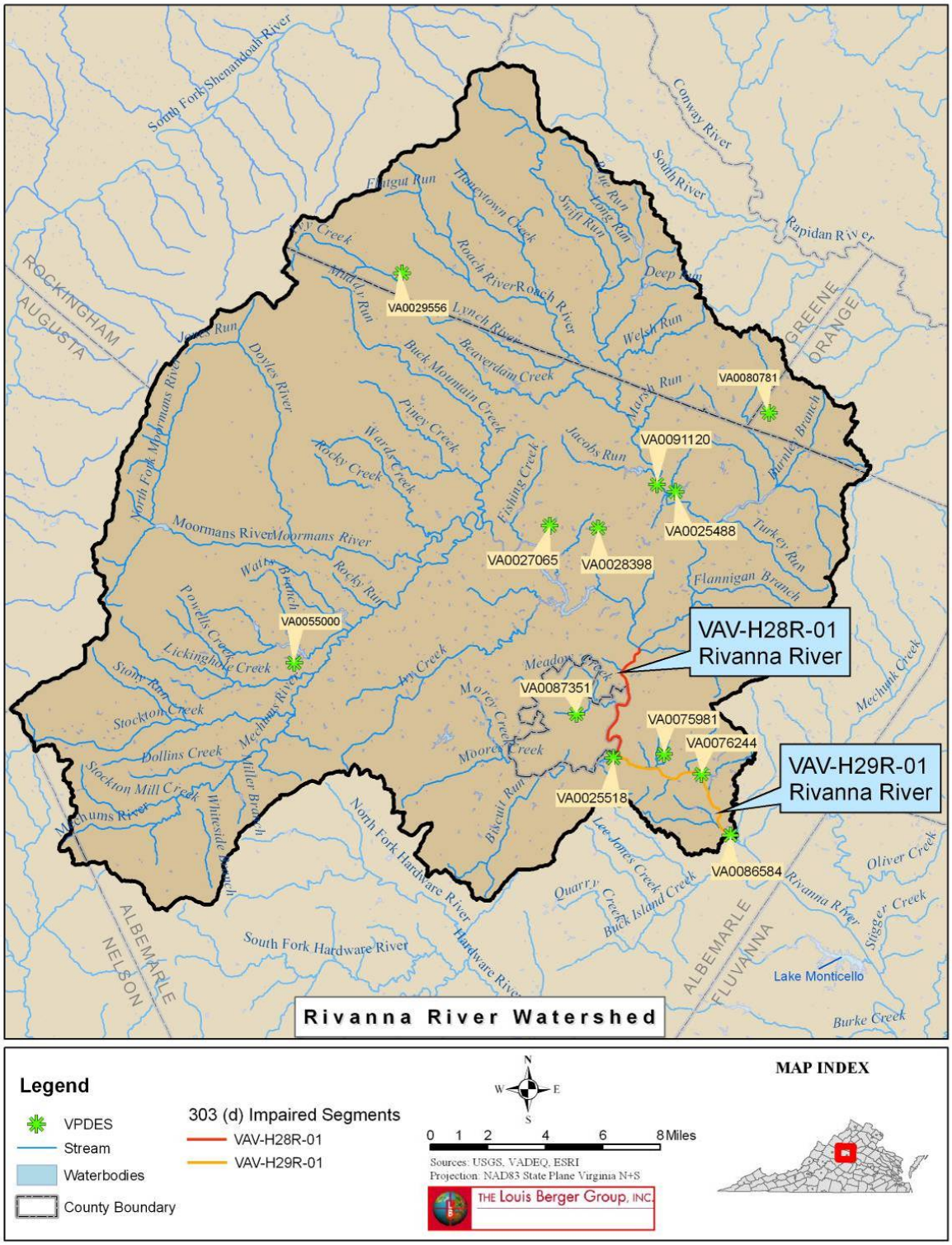


Figure 2-5: Permitted Facilities in the Benthic Impaired Rivanna River Watershed

In addition to the individual and general permits presented above, Municipal Separate Storm Sewer (MS4) permits have been issued to cities, counties, and other facilities within the benthic impaired Rivanna River watershed. **Table 2-9** lists all the MS4 permit holders with the area covered by each MS4 locality. The Charlottesville MS4 area was calculated by subtracting the VDOT major road areas (interstates and primary roads) within the City of Charlottesville from the US Census Urban Areas. VDOT road areas were estimated using the roads length within the urban areas and assuming a 25 foot-road-width. The Albemarle County MS4 was calculated using the urban areas identified in the Albemarle County Comprehensive Plan GIS data layer and subtracting major and minor VDOT road areas (interstates, primary roads, secondary roads, and other roads). The Comprehensive Plan is Albemarle County's document outlining local growth and development. Combined, these MS4 permits cover approximately 9% of the Rivanna River benthic impaired watershed. **Figure 2-6** presents the major MS4 areas located within the Rivanna River bacteria impaired Watershed.

Table 2-9: MS4 Permits within the Rivanna River Watershed

Permit Number	MS4 Permit Holder	Permit Acreage	MS4 Locality	Locality Acreage
VAR040051	City of Charlottesville	6,237	City of Charlottesville	6,513
VAR040033	VDOT Charlottesville Major Roads	60		
VAR040073	University of Virginia (Charlottesville)	216		
	University of Virginia (Albemarle)	916	Albemarle County	22,530
VAR040074	Albemarle County	20,984		
VAR040033	VDOT Albemarle Roads	535		
Application	Piedmont Community College	95		
Total				**29,043**

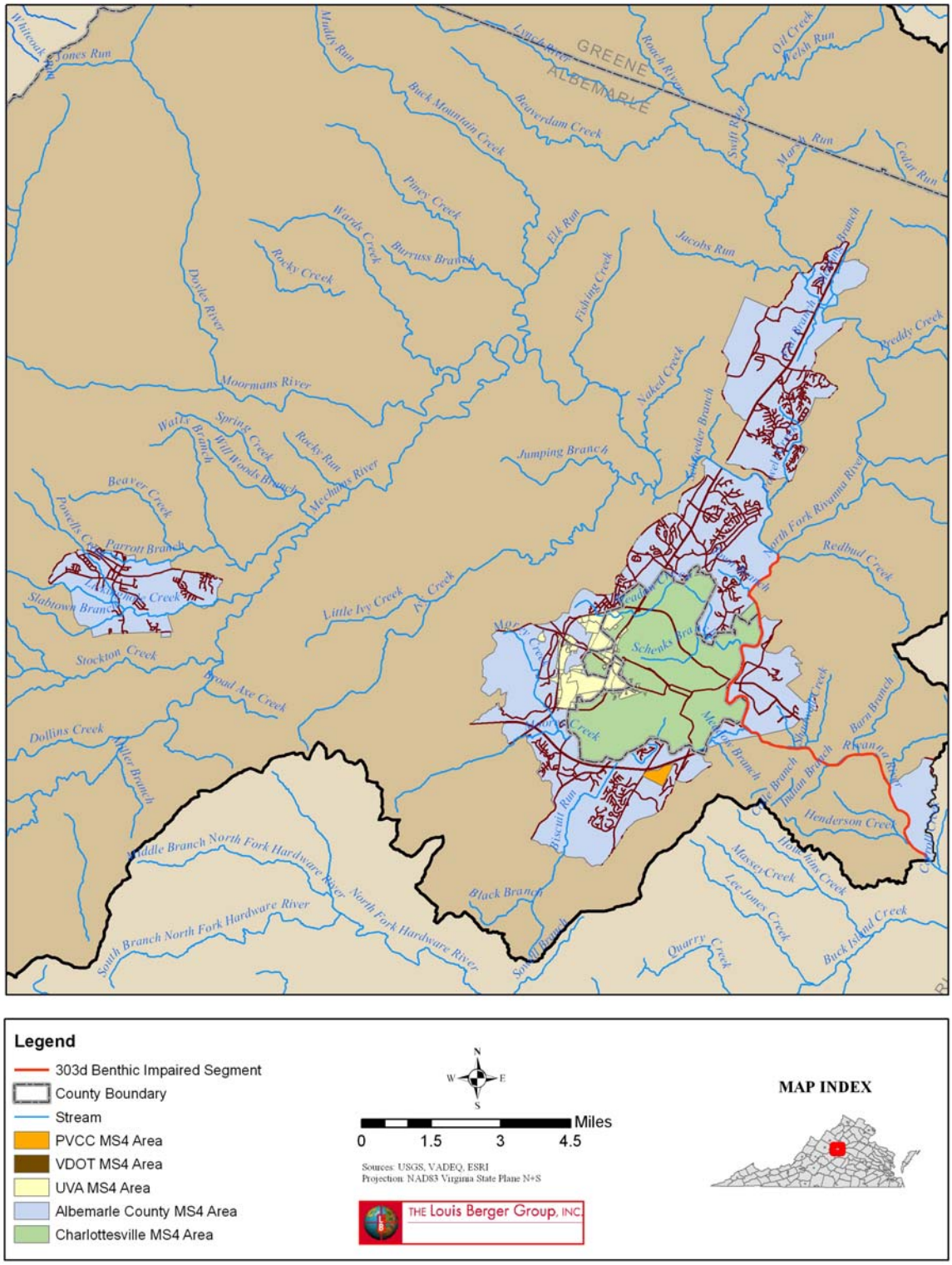


Figure 2-6: Rivanna River Benthic Impaired Watershed MS4s

2.3 DEQ Monitoring Stations

DEQ has monitored ambient water quality and/or sediment chemistry at eight locations on the Rivanna River mainstem and major tributaries to the impaired segment. Monitoring of the benthic macroinvertebrate community has been conducted by DEQ at stations 2-RVN035.67 and 2-RVN033.65 on the biologically impaired segment of the Rivanna River. A list of these DEQ monitoring stations and the water quality stations in the Rivanna River benthic watershed is provided in **Table 2-10** and the locations of these stations are presented in **Figure 2-7**. Station identification numbers include the abbreviated creek name and the river mile on that creek where the station is located. The river mile number represents the distance from the mouth of the creek. Monitoring data from all stations in the watershed were evaluated as part of the benthic stressor analysis.

A detailed discussion of the available environmental monitoring data is presented in *Section 3.0*.

Table 2-10: Water Quality Monitoring Stations Used for the Benthic TMDL

Station ID[1]	Station Description	Stream Name	First Sampled	Last Sampled	Number of Samples
2-RVN037.54	Near I-64	Impaired Segment	08/18/1993	05/02/2005	51
2-RVN035.67	0.4 miles upstream of Barn Branch		05/23/2002	05/23/2002	1
2-RVN033.65	Old Rt. 729 bridge site		01/29/1996	07/06/2006	149
2-RVN032.46	Near Milton Field (old airport)		05/23/2002	05/23/2002	1
2-RRS003.12	South Fork @ Polo Grounds	South Fork Rivanna River	01/03/1990	05/02/2005	113
2-RRN002.19	North Fork @ 649 - B	North Fork Rivanna River	01/03/1990	07/12/2006	154
2-MWC000.60	Holmes Avenue Bridge	Meadow Creek	08/05/1991	05/02/2005	59
2-MSC000.60	RWSA STP bridge	Moores Creek	08/05/1991	09/20/2006	75

[1]Note: The last 5 digits of the DEQ station number corresponds to stream mile.

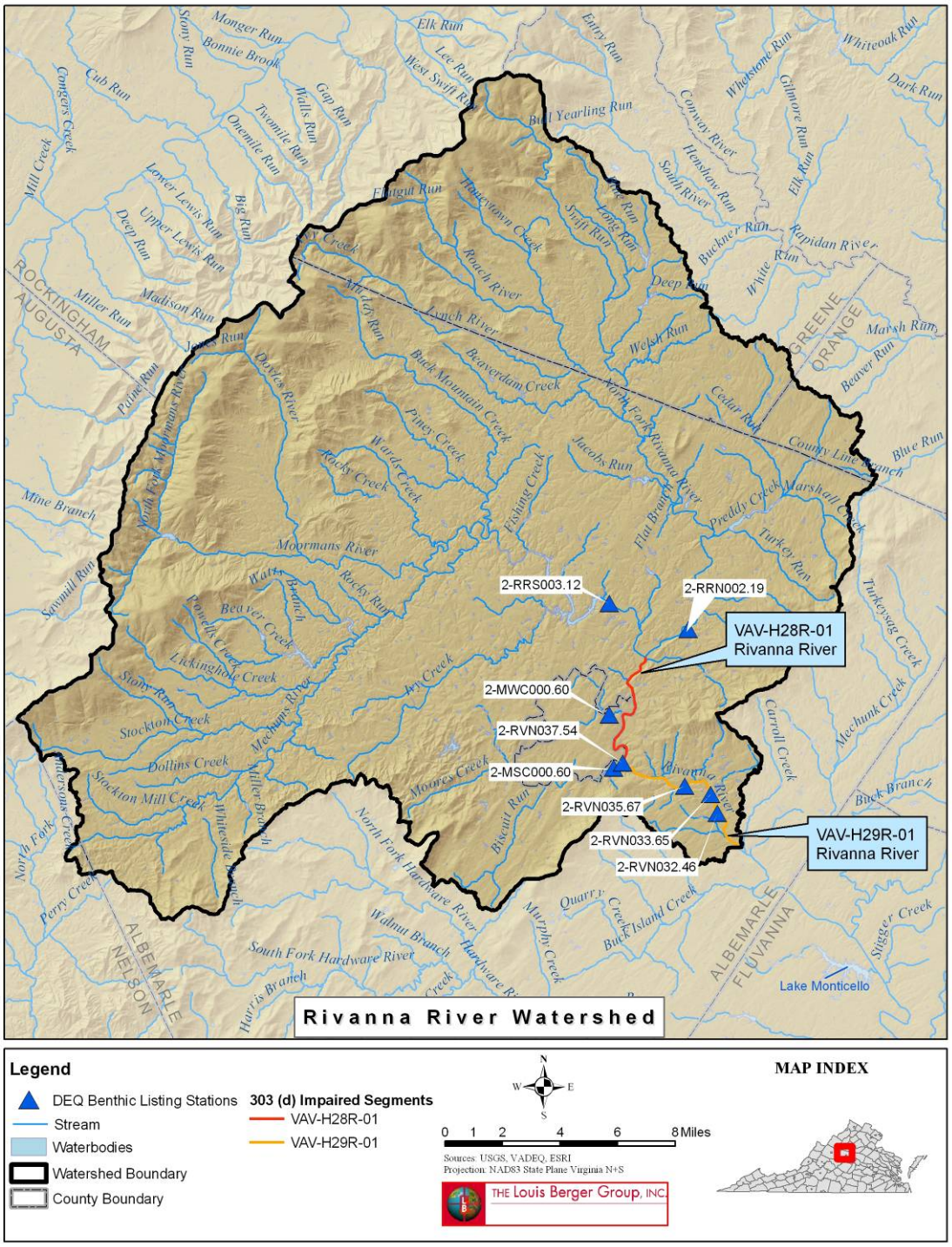


Figure 2-7: Water Quality Monitoring Stations in the Benthic Impaired Rivanna River Watershed

2.4 Overview of the Rivanna River Watershed

Forested lands (64%), developed lands (14%), and agricultural lands (21%) represent the dominant land uses in the Rivanna River watershed, based on the updated land use classification. There are 13 facilities holding individual discharge permits that are active or under application in the watershed, and 64 facilities holding active general permits. Monitoring of the benthic macroinvertebrate community has been conducted by DEQ at stations 2-RVN035.67 and 2-RVN033.65 on the biologically impaired segment of the Rivanna River. Water quality monitoring conducted at stations located along the benthic-impaired segments and stations (boundary stations) along the tributaries to the benthic-impaired segments was used in the development of this TMDL.

3.0 Environmental Monitoring

Environmental monitoring efforts in the Rivanna River watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, and toxicity testing. Monitoring efforts have been conducted by agencies at both the state and local levels, including the Virginia Department of Environmental Quality (VADEQ) and United States Geological Survey (USGS). In addition, a citizen monitoring group, StreamWatch, has conducted monitoring efforts. **Figure 3-1** plots the location of the monitoring stations that were used for the analysis of the benthic impairment of the Rivanna River.

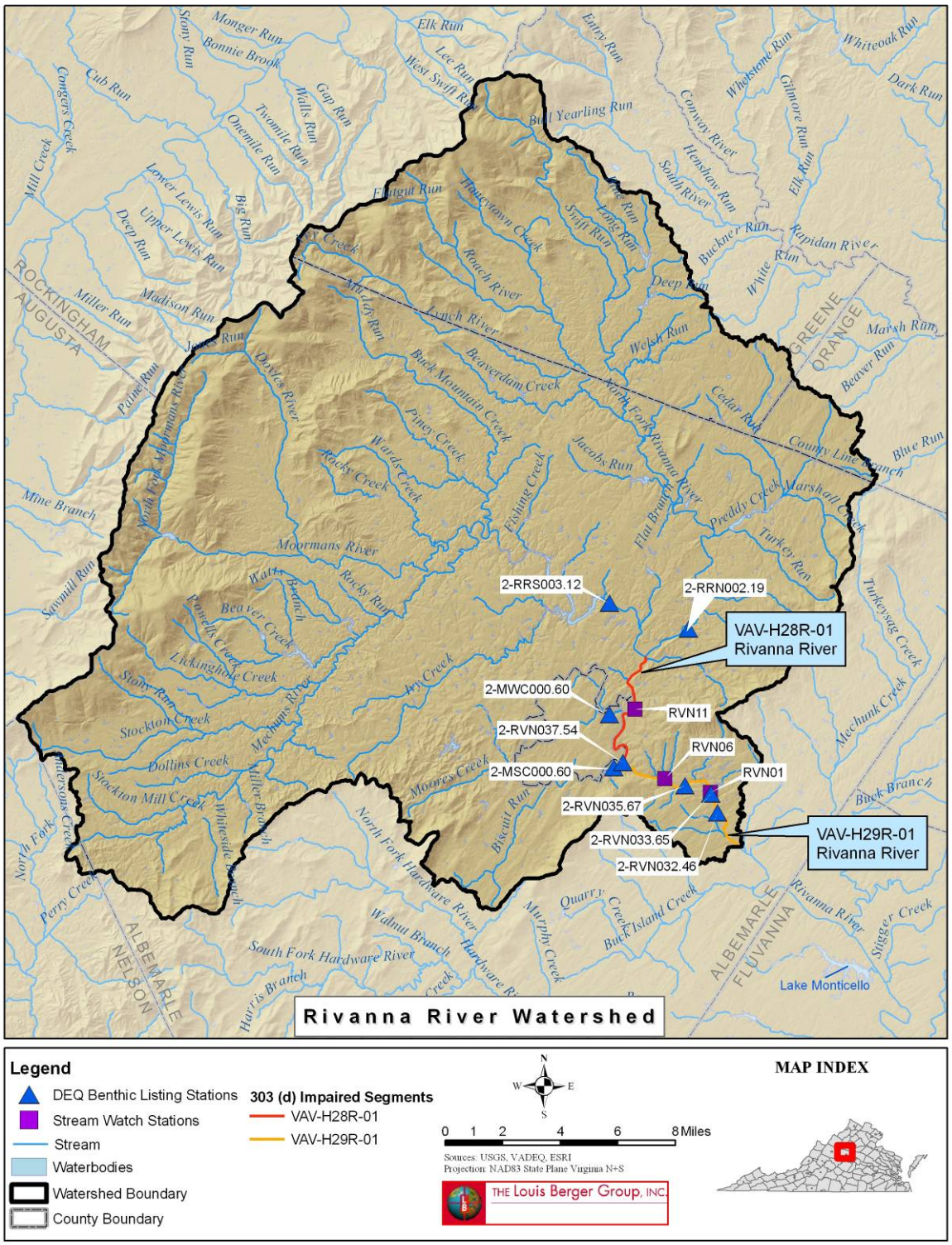


Figure 3-1: Monitoring Locations in the Rivanna River Watershed

3.1 Virginia DEQ Environmental Monitoring Data

The first step in benthic TMDL development is the identification of the pollutant stressor(s) that is impacting the benthic community. Environmental monitoring data are vital to this initial step. The following sections summarize and present the available monitoring data used to determine the primary stressor impacting the biologically impaired segment of the Rivanna River. Data analyzed include available biological and water quality monitoring data, Discharge Monitoring Reports (DMR) from permitted facilities within the watershed (*See Section 3.3*), and results from recent DEQ instream toxicity studies conducted on the Rivanna River. The collection period, content, and monitoring stations for these data are summarized in **Table 3-1**. The locations of permitted discharge facilities and monitoring stations are presented in **Figure 3-1**.

Table 3-1: Inventory of VDEQ Environmental Monitoring Data for the Rivanna River

Data Type	Collection Period	Monitoring Stations				
		RVN037.54	RVN035.67	RVN033.65	2-RVN032.46	Permitted Facilities
Biological Monitoring	2002,2005	X		X		
Ambient Water Quality Monitoring	1968-2006	X	X	X	X	
Sediment	Varied	X	X	X	X	
Toxicity Study	2005, 2006			X		
Discharge Monitoring Reports (DMR)	2000- 2007					X

3.1.1 Biological Monitoring Data

Biological monitoring data in the Rivanna River watershed was available from both VA DEQ and StreamWatch. StreamWatch is a partnership composed of the Albemarle and Fluvanna counties, the Nature Conservancy, the Thomas Jefferson Soil and Water Conservation District, Rivanna Conservation Society, and the Rivanna Water and Sewer Authority.

Biological monitoring data was collected by the VA DEQ at monitoring stations 2-RVN035.67 and 2-RVN033.65, located in the benthic impaired segment VAV-H29R-01 in

the spring and fall of 2002 and 2005. An additional sample was taken in May of 2006 at station 2-RVN033.65. The biological monitoring data were evaluated using three indicator scores; the EPA's Rapid Bioassessment Protocol II (RBPII), the Virginia Stream Condition Index (VSCI) as developed for the VA DEQ by Tetra Tech, and the Macroinvertebrate Aggregated Index for Streams (MAIS) as developed by Voshell et. al (1997).

3.1.1.1. Modified Rapid Bioassessment Protocol (RBPII) Index

Calculation of the RBP II score incorporates eight standard metrics (Barbour et al., 1999, presented in **Table 3-2**) based on the numbers and types of macroinvertebrates present at each station. Points are awarded for indicators of health such as high diversity, and the presence of taxa that are known to be intolerant to stressful conditions. These metrics are taken from stations located in the impaired segment as well from one paired reference station in a non-impaired upstream that is located within the watershed. The final score is based on a comparison of the impaired segment with the reference site. Stations that are very similar to the reference site receive a high score and are generally un-impaired, while stations that score low are very dissimilar to a healthy condition.

The benthic community in the Rivanna River was assessed by the RBP II in 2002 and 2005, but not in 2006.

Table 3-2: Candidate RBPII Metrics Specified in Barbour et al. (2002)

Category	Metric	Definition	Response to Disturbance
Richness Measures	Total No. Taxa	Measures overall variety of invertebrate assemblage	Decrease
	No. EPT Taxa	Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa	Decrease
	No. Ephemeroptera Taxa	Number of mayfly taxa	Decrease
	No. Plecoptera Taxa	Number of stonefly taxa	Decrease
	No. Trichoptera Taxa	Number of caddisfly taxa	Decrease
Composition Measures	% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae	Decrease
	% Ephemeroptera	Percent of mayfly nymphs	Decrease
Tolerance/ Intolerance	No. Intolerant Taxa	Taxa richness of organisms considered to be sensitive to perturbation	Decrease

Table 3-2: Candidate RBPII Metrics Specified in Barbour et al. (2002)

Category	Metric	Definition	Response to Disturbance
Measures	% Tolerant Organisms	Percent of the macrobenthos considered to be tolerant of various types of perturbation	Increase
	% Dominant Taxon	Measures dominance of the most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa	Increase
Feeding Measures	% Filterers	Percent of the macrobenthos that filter FPOM from water column or sediment	Variable
	% Grazers and Scrapers	Percent of macrobenthos that scrape or graze upon periphyton	Decrease
Other Measures	Hilsenhoff Biotic Index (HBI)	Uses tolerance values to weight abundance in an estimate of overall pollution	Increase

a) Richness Measures

Taxa richness measures the overall variety of the invertebrate assemblage. High taxa richness is an indicator of a healthy benthic community whereas a community that is highly dominated by a few taxa indicates that stream conditions are not suitable for more sensitive species. Certain macroinvertebrates inhabit the crevices of rocks. A lack of these species indicates that sediment may be filling in their habitat and impacting the macroinvertebrate community. All samples taken at the two stations scored low for total number of taxa.

b) Feeding Measures and Tolerant Organisms

Certain macroinvertebrates are adapted to feed by scraping the thin layer of algae off the surface of stream substrate. The abundance of 'scrapers' tends to increase with increased diatom abundance, and decrease with increasing filamentous algae and mosses because of the reduction in growing area for their food source (Voshell, 2002). Other macroinvertebrate species, called 'filterers,' strain water to capture and feed on suspended detritus and particulate organic matter. Filterers tend to have the opposite responses from scrapers, as more abundant algae and mosses increases the amount of detritus in the stream. Black flies (*Simuliidae*) and net-spinning caddisflies (*Hydropsychidae*) are examples of filterer species. *Hydrosychidae*, commonly called netspinners, are frequently used as an indicator species because they are tolerant to pollution and can become abundant in streams that are subjected to moderate levels of organic wastes or nutrients (Voshell, 2002).

At both stations in the impaired segment of Rivanna River, the ratio of scraper to filterer macroinvertebrates was greater in the fall than in the spring. In the majority of samples, *Hydrosychidae* were the dominant order.

c) Final RBP II Scoring

The data discussed in the sections above were included by VA DEQ in calculating RPB II scores for the biomonitoring stations 2-RVN033.65 and 2-RVN035.67, located in the benthic impaired segment of Rivanna River. VA DEQ calculated RBP II scores for these stations in the spring and fall of 2002 and 2005. Based on these assessments, the benthic community was listed as 'moderately impaired' at each station during the spring, and 'slightly impaired' during the fall (**Table 3-3**).

Table 3-3: RBPII Assessment Ratings for Rivanna River Biomonitoring Surveys

Station ID	**2-RVN033.65**		**2-RVN035.67**	
Location	Old Rt. 729 bridge site		0.4 miles upstream of Barn Branch	
Collection Date	5/23/2005	11/1/2005	5/23/2002	10/16/2002
Total Number of Taxa	11	15	12	16
HBI Score	5	5	6	6
SC/FC Ratio	0	1	0	1
EPT/Chir Abundance	2	9	2	3
%1Dominant	32	44	57	29
EPT Taxa	4	7	4	5
% Shredders	1	8	1	2
RBPII Score	46	71	35	54
Impairment Level	**Moderately Impaired**	**Slightly Impaired**	**Moderately Impaired**	**Slightly Impaired**

3.1.1.2. Virginia Stream Condition Index (VSCI)

Virginia Stream Condition Index (VSCI) scoring is described in the VSCI Validation Report (VA DEQ, 2006). Like RBP II scoring, the calculation of VSCI scores incorporates eight standard metrics, similar to those used in RBP II. These metrics evaluated together produce a unit-less score that provides an overall indication of ecological integrity. VSCI scores are compared to the biological condition of a reference condition that is based on an aggregate of

unimpaired streams of a region rather than a single paired reference site. Therefore, VSCI scores provide a measure of stream biological integrity on a regional basis. The VSCI metrics and their expected response to declining stream conditions are presented in **Table 3-4**.

An impairment cutoff score of 60 has been established for assessing results obtained with the VSCI. Streams that score greater than 60 are considered to be non-impaired and streams that score less than 60 are considered impaired.

Table 3-4: Metrics Used to Calculate the Virginia Stream Condition Index (SCI)

Candidate Metrics (by categories)	Expected Response to Disturbance	Definition of Metric
Taxonomic Richness		
Total Taxa	Decrease	Total number of taxa observed
EPT Taxa	Decrease	Total number of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa observed
Taxonomic Composition		
% EPT Less Hydropsychidae	Decrease	% EPT taxa in samples, subtracting pollution-tolerant Hydropsychidae
% Ephemeroptera	Decrease	% Ephemeroptera taxa present in sample
% Chironomidae	Increase	% pollution-tolerant Chironomidae present
Balance/Diversity		
% Top 2 Dominant	Increase	% dominance of the 2 most abundant taxa
Tolerance		
HBI (Family level)	Increase	Hilsenhoff Biotic Index (HBI)
Trophic		
% Scrapers	Decrease	% of scraper functional feeding group

In the Rivanna River watershed, VSCI scores were calculated at two stations, both located on the impaired segment, in the spring and fall of 2002 and 2005, and the spring of 2006 (**Figure 3-1**). As shown in **Table 3-5,** the results of these biological assessments show that all scores were below the impairment cut-off. Therefore, all samples collected at these two stations were considered impaired. The metrics and the macroinvertebrate community structure indicated that nutrient and organic pollution, as well as riffle embeddedness, may be impacting the macroinvertebrate community.

Table 3-5: SCI Assessment Ratings for Rivanna River Biomonitoring Surveys		
Season	**2-RVN033.65**	**2-RVN035.67**
Spring 2002	-	33.03
Fall 2002	-	53.94
Spring 2005	44.66	-
Fall 2005	56.92	-
Spring 2006	21.88	-
Average	**41.15**	**43.48**

3.1.1.3. Macroinvertebrate Aggregated Index for Streams (MAIS)

The MAIS index was developed by Voshell et al. (1997) and uses similar rankings to the RBPII and VSCI methods. However, MAIS incorporates benthic macroinvertebrate data from hundreds of streams, including the Mid-Atlantic Highlands of Maryland (51 sites), Pennsylvania (53 sites), Virginia (126 sites), and West Virginia (200 sites). Furthermore, MAIS incorporates 10 metrics instead of 8. Values for the individual metrics are given a score of 0, 1, or 2 and then combined into the highest possible score of 20. These metrics (described in **Tables 3-2** and **3-4)** are listed in **Table 3-6**.

Table 3-6: Metrics Used to Calculate the Macroinvertebrate Aggregated Index for Streams (MAIS)
Ephemeroptera Richness
EPT Richness
Intolerant Taxa Richness
% Ephemeroptera
% EPT
% 5 Dominant Taxa
Simpson Diversity
Hilsenhoff Biotic Index (HBI)
% Scrapers
% Haptobenthos

MAIS scores calculated at the two benthic-impaired stations indicated that there is a moderate benthic impairment at both stations (**Table 3-7).**

Table 3-7: MAIS Scores at Rivanna River Stations

Station ID	Season Sampled	MAIS Score	Assessment
2-RVN033.65	Spring 2002	10	Moderate Impairment
	Fall 2002	12	Moderate Impairment
2-RVN035.67	Spring 2005	7	Moderate Impairment
	Fall 2005	11	Moderate Impairment
	Spring 2006	6	Severe Impairment

3.1.1.4. Supplementary Benthic Macroinvertebrate Sampling

StreamWatch has been monitoring the benthic community of the Rivanna River watershed since 2002. This community monitoring group used both the VSCI method and the Save our Streams (SOS) method to assess the biological condition of the stream's benthic invertebrate communities. StreamWatch has conducted sampling at numerous stations within the watershed, including three stations located within the benthic-impaired segment VAV-H29R-01. The following summary only includes data collected along the benthic-impaired segments at stations (RVN01, RVN06, RNV11, **Figure 3-1**).

As shown in **Table 3-8**, the ecological conditions for the majority of the samples (12 out of 18) were below standards. The percentages of tolerant insects in these samples were consistently high (average: 40%) with netspinners comprising 0.1 to 59%. At the upstream station RVN11, 4 of 11 scores were above the VSCI cutoff of 60.0, the remaining 7 were unacceptable. The single sample collected at station RVN06 indicated that the benthic community was in an unacceptable condition. A calculated VSCI score for this station is not available. The percent of netspinners collected at station RVN06 was higher than samples collected downstream at station RVN01. All but 2 samples collected at station RVN01 had VSCI scores indicating impairment.

Table 3-8: StreamWatch Results at the Stations along the Benthic Impaired Segments

Station	Season	SCI Scores*
RVN01-Rivanna @ Milton	Winter2002	NA
	Spring 2003	NA
	Fall 2003	NA
	Winter 2004	47.0
	Spring 2004	38.1
	Summer 2004	NA
	Fall 2004	44.6
	Winter 2005	52.7
	Spring 2005	61.9
	Summer 2005	56.8
	Fall 2005	60.0
	Winter 2006	51.1
	Spring 2006	41.4
	Summer 2006	52.8
	Fall 2006	50.0
RVN06-Rivanna @ Milton	Fall 2003	NA
RVN11- Rivanna # Darden Towne	Winter 2002	NA
	Spring 2003	NA
	Fall 2003	NA
	Winter 2004	38.4
	Spring 2004	49.6
	Fall 2004	55.3
	Winter 2005	53.3
	Spring 2005	55.9
	Summer 2005	62.8
RVN11- Rivanna # Darden Towne	Fall 2005	63.9
	Winter 2006	38.5
	Spring 2006	72.5
	Summer 2006	57.8
	Fall 2006	69.9

* NA: Indicates that a SCI score was not able to be calculated

3.2 Habitat Assessment Scores

Habitat condition assessments of the benthic impaired segment were conducted by VA DEQ and StreamWatch. However, the instream habitat condition assessment by StreamWatch was not available for stations along the impaired segments. Therefore, only the habitat condition assessment by VA DEQ is presented for this analysis.

As part of the biological assessments conducted on the Rivanna River, a suite of habitat variables were visually inspected at monitoring stations 2-RVN035.67 and 2-RVN033.65 in the spring and fall of 2002 and 2005, as well as the spring of 2006 at station 2-RVN033.65. The parameters examined include channel alteration, sediment deposition, substrate embeddedness, riffle frequency, channel flow and velocity, stream bank stability and vegetation, and riparian zone vegetation. Each parameter was assigned a score from 0 to 20, with 20 indicating optimal conditions, and 0 indicating very poor conditions. Habitat assessment scores for the Rivanna River biomonitoring and relevant reference stations are presented in **Table 3-9**.

Overall, habitat assessment scores were generally low for several parameters at these stations. Specifically, scores for embeddedness and sediment deposition were found to be suboptimal. Embeddedness is a measure of how much sediment is occupying the spaces between the cobbles and rocks in the streambed, which serves as important habitat for various macroinvertebrate species. Sediment deposition corresponds with embeddedness, and can be visible in a stream in the form of sand bars. This buildup of sediment in the stream bed can drastically change the composition and availability of macroinvertebrate habitats and therefore can be a stressor for the benthic community.

Table 3-9: DEQ Habitat Condition Assessments

Station ID	**2-RVN033.65**			**2-RVN035.67**	
Collection Date	5/23/2005	11/1/2005	2/25/2006	5/23/2002	10/16/2002
Total Habitat Score	159	139	145	155	163
Channel Alteration	18	18	14	20	19
Bank Stability	16	12	12	18	18
Bank Vegetation	18	18	18	18	20
Embeddedness*	**12**	**6**	**7**	**-**	**13**
Channel Flow	14	15	15	17	19
Riffles	18	18	16	16	14
Riparian Zone	18	14	18	20	20
Sediment Deposition*	**12**	**10**	**17**	**12**	**11**
Substrate	15	12	11	17	12
Velocity Regime	18	16	17	17	17

*These habitat parameters were considered to be suboptimal for all samples.

3.1.3 Ambient Water Quality Monitoring

There are 51 active VA DEQ water quality monitoring stations in the Rivanna River watershed. For the purpose of this study, only water quality monitoring stations located along the benthic impaired segments and tributaries to the impaired segments were used in the development of this TMDL. **Table 3-10** shows the water quality monitoring stations used in the TMDL development.

VA DEQ collected instream water quality measurements for field parameters such as temperature, DO, pH, and specific conductance, and lab parameters such as nutrients, solids, heavy metals, and organic contaminants. The river sediment was analyzed for heavy metals and organics. Data collected from 1996 to 2006 was included in the analysis and compared to VA DEQ water quality standards to correspond with the impairment listing date (DEQ, 2006).

Table 3-10: Water Quality Monitoring Stations Used for the Benthic TMDL

Station ID[1]	Station Description	Stream Name	First Sample Date	Last Sample Date	Number of Samples
2-RVN037.54	0.4 miles upstream of Barn Branch	Impaired Segment	08/18/1993	05/02/2005	51
2-RVN035.67	0.4 miles upstream of Barn Branch		05/23/2002	05/23/2002	1
2-RVN033.65	Old Rt. 729 bridge site		01/29/1996	07/06/2006	149
2-RVN032.46	Near Milton Field (old airport)		05/23/2002	05/23/2002	1
2-RRS003.12	South Fork @ Polo Grounds	South Fork Rivanna River	01/03/1990	05/02/2005	113
2-RRN002.19	North Fork @ 649 - B	North Fork Rivanna River	01/03/1990	07/12/2006	154
2-MWC000.60	Holmes Avenue Bridge	Meadow Creek	08/05/1991	05/02/2005	59
2-MSC000.60	RWSA STP bridge	Moores Creek	08/05/1991	09/20/2006	75

[1]Note: The last 5 digits of the DEQ station number corresponds to stream mile.

3.2.1 Water Quality Analysis within the Impaired Segments

Of the four monitoring stations located on the impaired segments only two stations, 2-RVN037.54 and 2-RVN033.65, were used for the analysis of the instream water quality data, since the remaining two water quality stations (2-RVN032.46, and 2-RVN035.67) were only sampled once. **Table 3-11** shows a summary of selected instream data collected at stations 2-RVN037.54 and 2-RVN033.65.

Table 3-11: Summary of Instream Water Quality Data Collected at 2-RVN037.54 and 2-RVN033.65 between 1996 and 2006

Station ID		2-RVN037.54				2-RVN033.65			
Parameter	**Units**	**No of Samples**	**Min**	**Max**	**Avg**	**No of Samples**	**Min**	**Max**	**Avg**
Temperature	°C	48	0.20	27.90	15.37	80	1.20	29.50	15.13
DO	mg/L	48	6.20	15.00	10.04	80	5.50	17.40	10.67
Field pH		48	5.90	8.20	7.27	80	6.30	8.90	7.51
Spec. Conductance	µmhos/cm	10	56.40	89.30	69.33	5	58.30	190.00	117.92
Chloride	mg/L	18	3.90	10.25	5.91	65	4.50	41.80	9.21
Turbidity	FTU	21	1.80	28.00	10.06	75	1.20	77.00	10.23
TSS[1]	mg/L	22	3.00	19.00	7.77	86	3.00	90.00	9.56
VSS[2]	mg/L	18	3.00	4.00	3.06	32	10.00	52.00	26.00
BOD_5	mg/L	18	1.00	2.00	1.61	65	1.00	3.00	1.78
Total NH_3-N	mg/L	29	0.04	0.10	0.05	85	0.04	0.80	0.07
NO_2-N + NO_3-N	mg/L	29	0.11	0.86	0.33	87	0.00	6.27	1.11
TN[3]	mg/L	29	0.25	1.10	0.57	87	0.00	7.57	1.49
PO_4-P	mg/L	17	0.01	0.04	0.02	85	0.02	1.48	0.20
TP	mg/L	29	0.01	0.10	0.06	76	0.01	1.60	0.24
Chl*a*[4]	ug/L	-	-	-	-	10	0.50	4.17	1.58

[1] TSS = total suspended solids (total non-filterable residue)
[2] VSS = volatile suspended solids (total volatile residue)
[3] Combination of measured and computed (TN = TKN + NO3-N + NO2-N) values
[4] Phytoplankton

A summary of instream field data for the monitoring stations along Rivanna River is provided below:

- Field dissolved oxygen (DO) data presented in **Figure 3-2** indicates that adequate DO levels are found in the benthic impaired segments of the Rivanna River (range: 5.5 - 17.4 mg/L). The VA DEQ daily average criterion of 5mg/L was not exceeded.

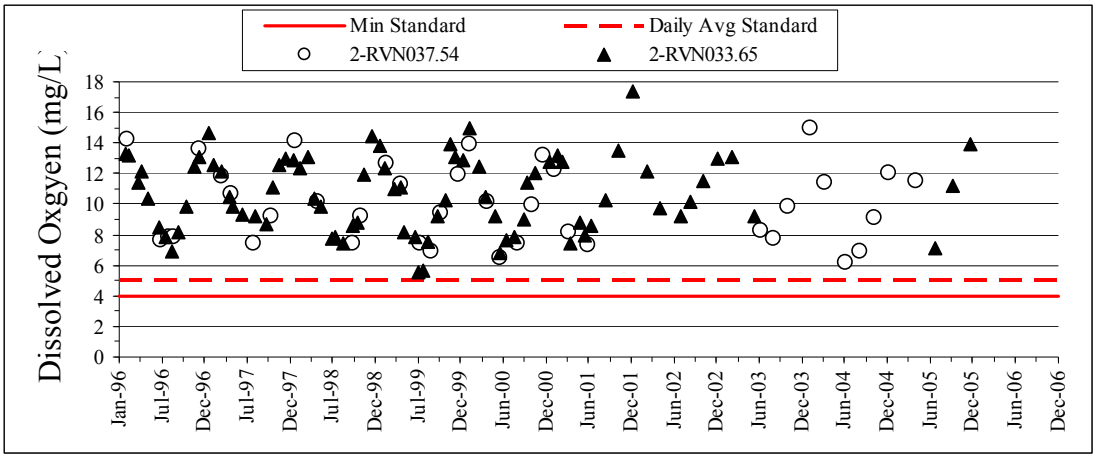


Figure 3-2: Ambient Dissolved Oxygen Measurements in the Benthic Impaired Segment of the Rivanna River

- A DO diurnal study conducted between August 7 and August 9, 2006 (**Figure 3-3**) shows DO levels above the minimum standard, with normal diurnal swings of approximately 3.3 mg/L.

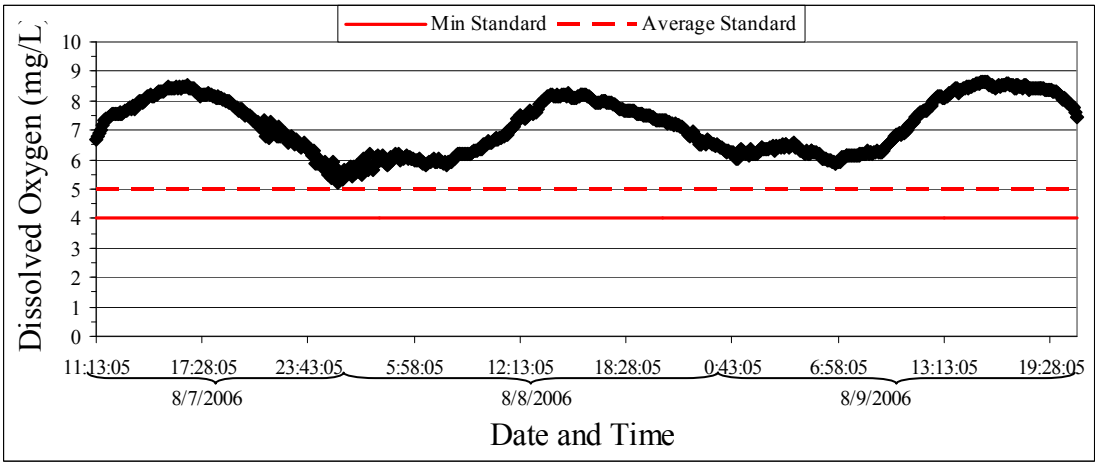


Figure 3-3: Ambient Continuous Dissolved Oxygen Measurements in the Benthic Impaired Segment of the Rivanna River

- Temperature values (range: 0.2-29.5 °C) were in compliance with VA DEQ criterion of a max of 32 °Celsius (**Figures 3-4**).

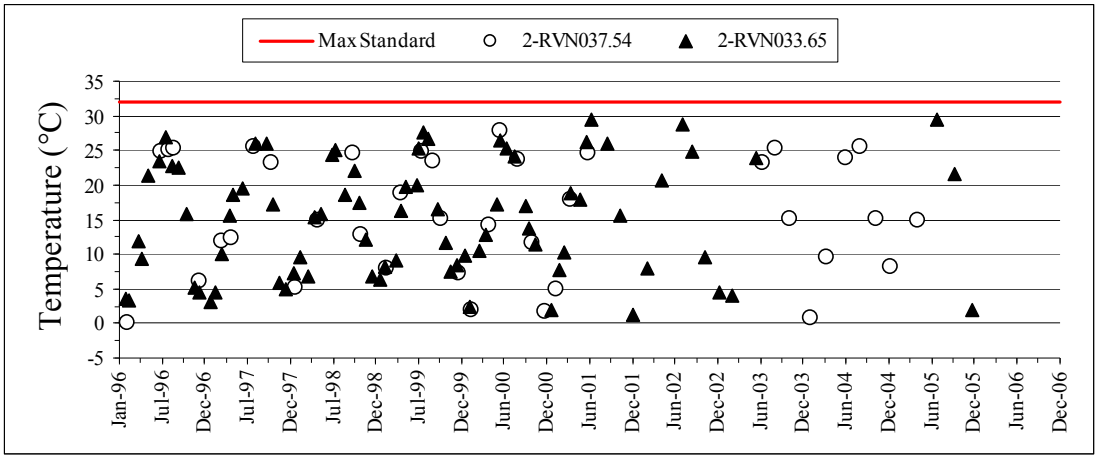


Figure 3-4: Ambient Temperature Measurements in the Benthic Impaired Segment of the Rivanna River

- Except for one occasion in September of 1998, field pH values (range: 5.9-8.9) were in compliance with VA DEQ criteria range of 6 to 9 (**Figures 3-5**).

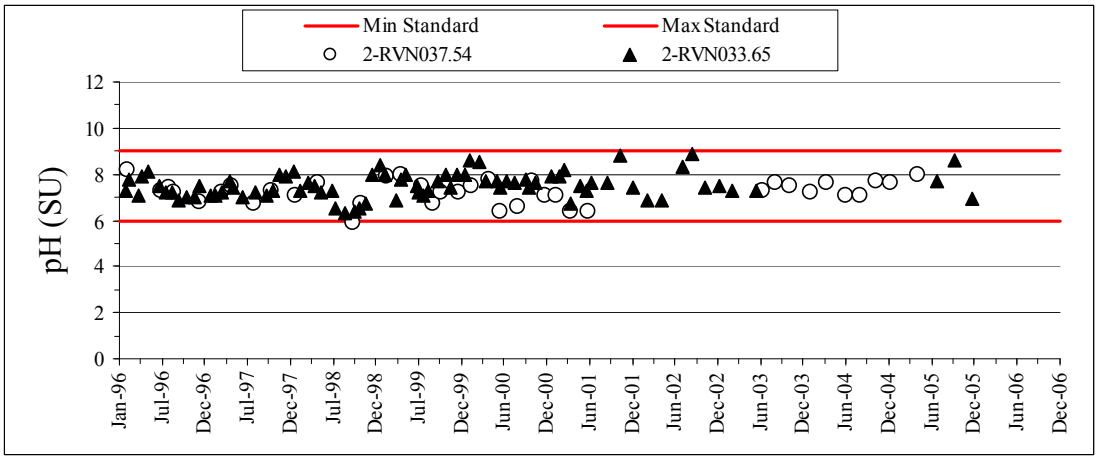


Figure 3-5: Ambient pH Measurements in the Benthic Impaired Segment of the Rivanna River

- The DEQ reference-filter criterion for Specific Conductance in the Piedmont ecoregion is established at < 250 µmhos/cm (DEQ 2006c). Conductivity levels in the Rivanna River were relatively low at both stations, ranging between 56 and 190 µmhos/cm (**Figure 3-6**).

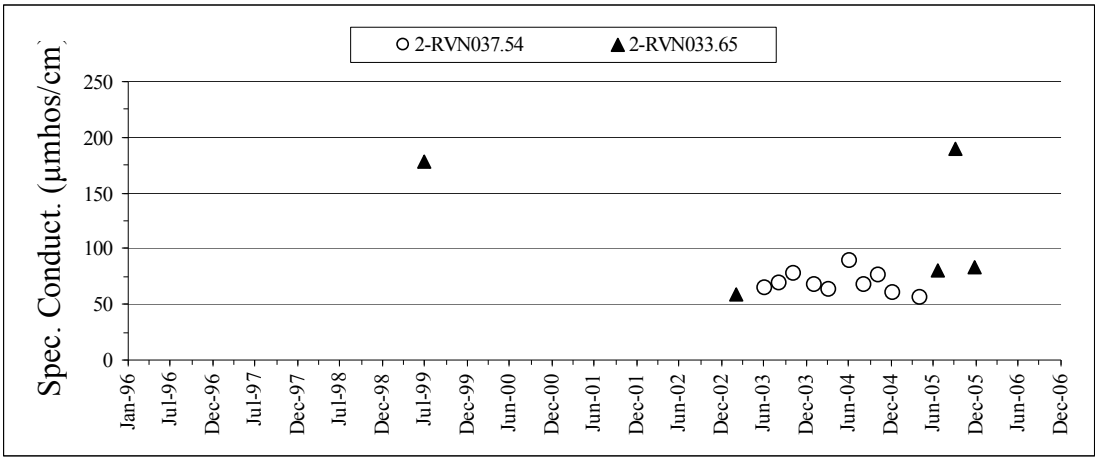


Figure 3-6: Ambient Specific Conductivity Measurements in the Benthic Impaired Segment of the Rivanna River

- Biochemical oxygen demand (BOD5) concentrations were generally low with averages between 1.6 and 1.8 at both stations (**Figure 3-7**). There are no screening values for BOD established by the VA DEQ.

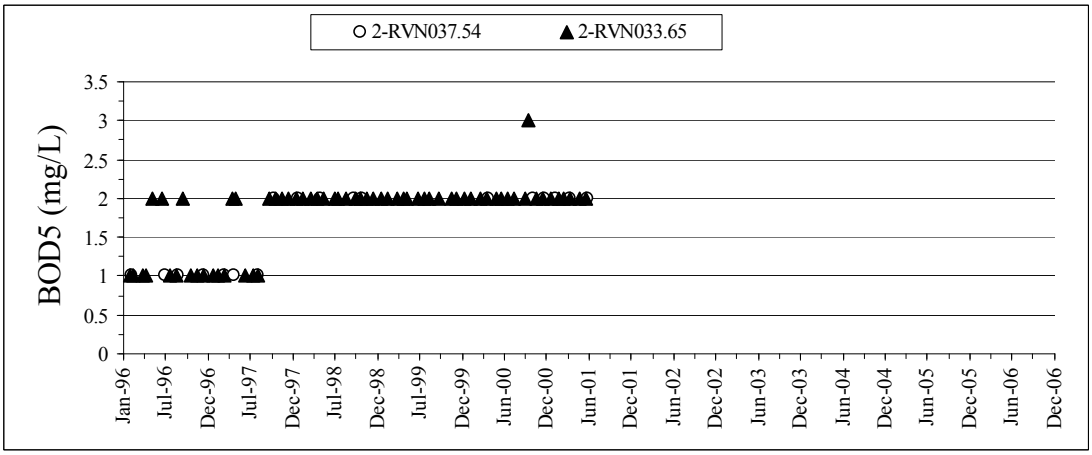


Figure 3-7: Ambient BOD5 Measurements in the Benthic Impaired Segment of the Rivanna River

- Total suspended solids concentrations (TSS, total non-filterable residue) were generally low at both stations with averages of 7.8 and 9.6 mg/L (**Figure 3-8**). There are no VA DEQ screening values for TSS levels. During high flow events, measured TSS levels increased to as high as 90 mg/L.

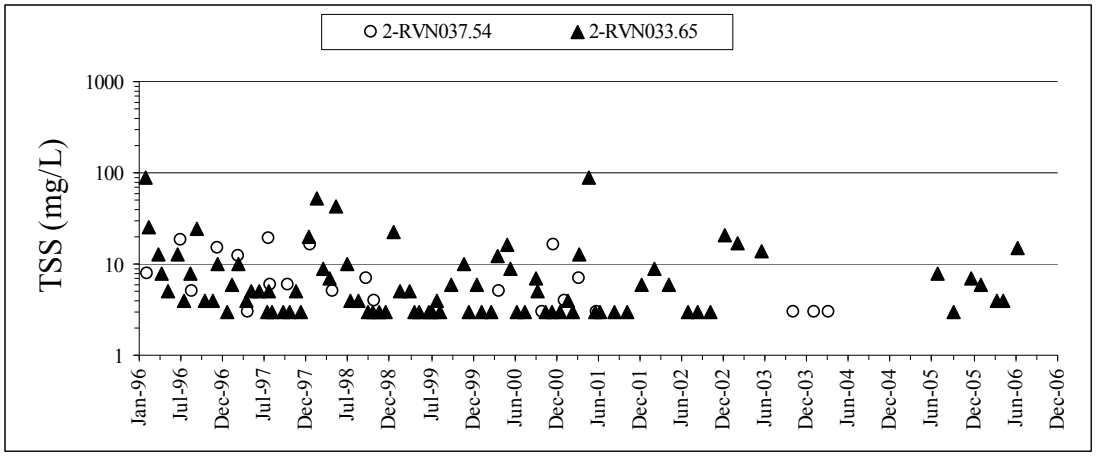


Figure 3-8: Ambient TSS Measurements in the Benthic Impaired Segment of the Rivanna River

- Turbidity levels were on average approximately 10 Formazin Turbidity Units (FTU) at both stations. The relatively low levels support the low values of observed TSS levels. (**Figure 3-9**). There are no VA DEQ screening values for Turbidity in FTU.

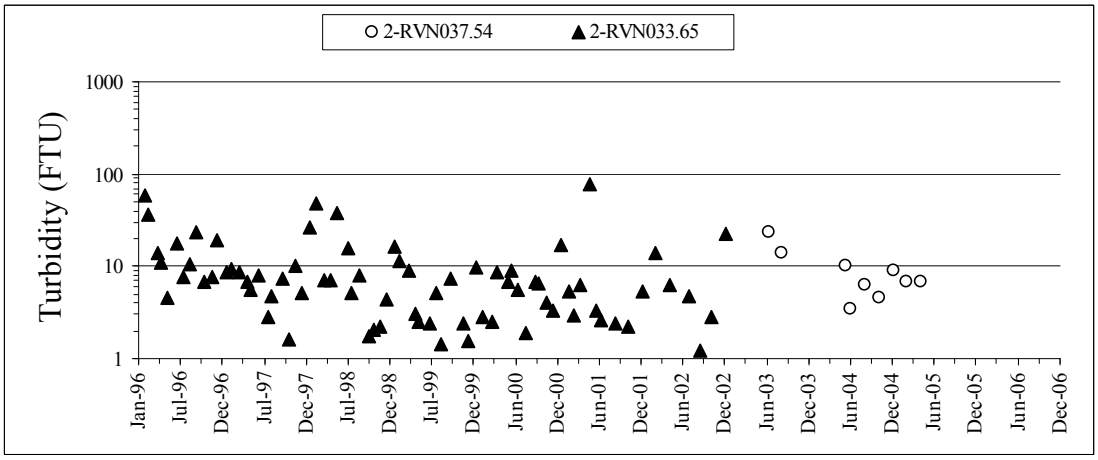


Figure 3-9: Ambient Turbidity Measurements in the Benthic Impaired Segment of the Rivanna River

- All total ammonia concentrations were in compliance with VA DEQ criterion, averaging between 0.05 and 0.07 mg/L (**Figures 3-10**). VA DEQ ammonia criteria vary with pH and the presence of sensitive fish (trout). At a low pH (6.5) when trout are present, ammonia shall not exceed 32.6 mg/L. At a high pH (9) when trout are present, ammonia shall not exceed 0.885 mg/L. These limits are higher in the absence of trout.

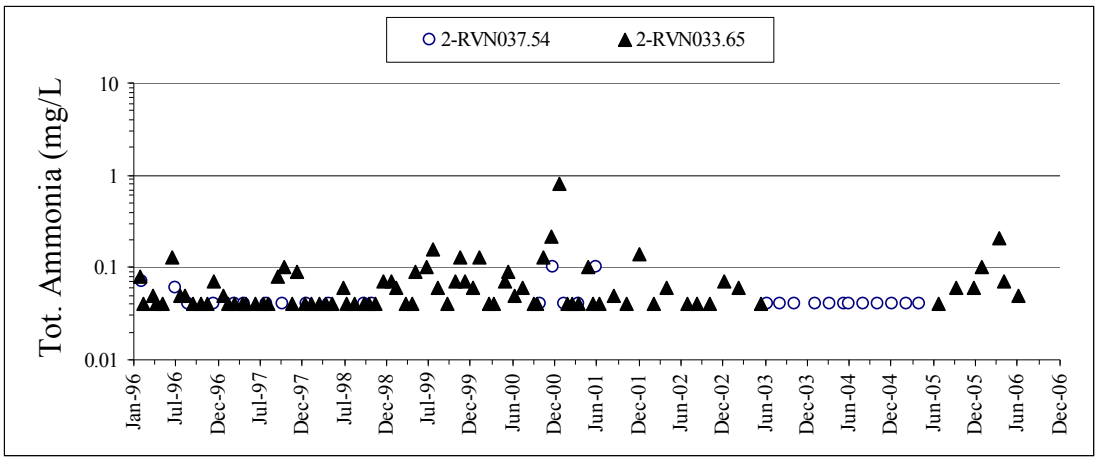


Figure 3-10: Ambient Total Ammonia Measurements in the Benthic Impaired Segment of the Rivanna River

- NOx-N (Nitrite and Nitrate) and total nitrogen (TN) concentrations were generally low at both stations, with averages at 0.33 and 1.11 mg/L for NOx-N, and 0.57 and 1.49 mg/L for TN. The VA DEQ reference value for TN is 1.5 mg/L (DEQ 2006c). It should be noted that nitrate and TN levels at station 2-RVN033.65 are higher than at station 2-RVN037.54, and fluctuate largely with several peaks (**Figure 3-11**). The higher levels and seasonal fluctuations of nitrogen are most likely attributable to the Moores Creek STP, which discharges into the Moores Creek at the confluence with the Rivanna River (downstream of station 2-RVN037.54).

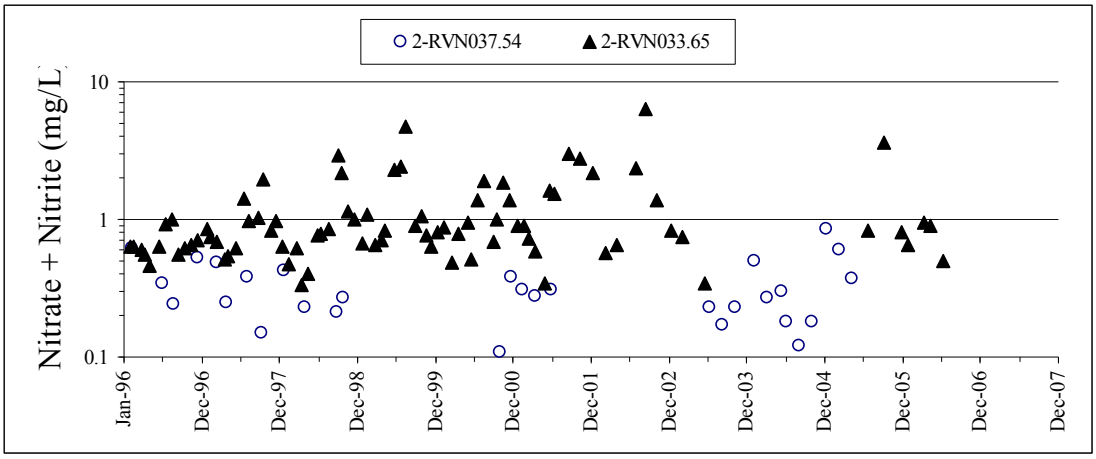


Figure 3-11: Ambient Nitrate and Nitrite Measurements in the Benthic Impaired Segment of the Rivanna River

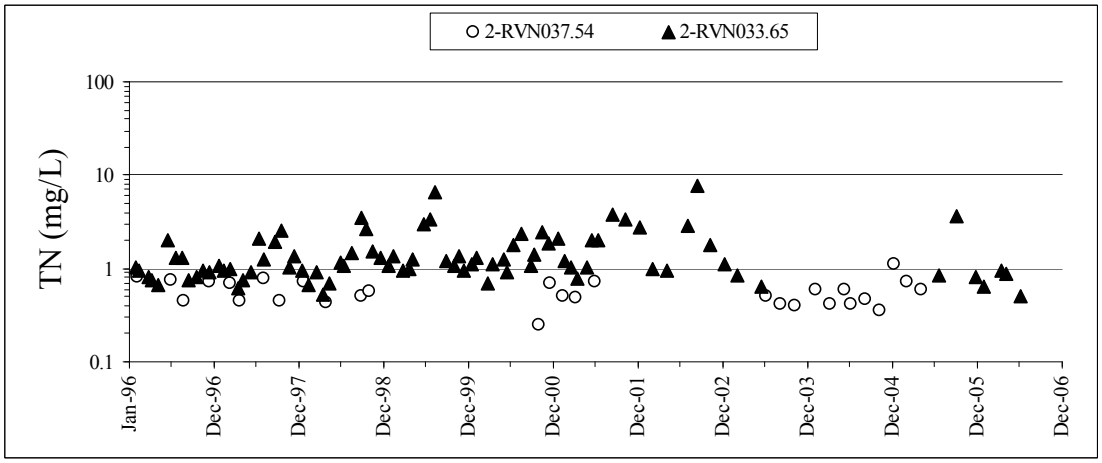


Figure 3-12: Ambient TN Measurements in the Benthic Impaired Segment of the Rivanna River

- PO_4-P and total phosphorus (TP) concentrations followed a trend similar to that of NO_x-N and TN. The VA DEQ criterion for Total Phosphorous is established at a maximum of 0.05 mg/L. The phosphorus concentrations increased significantly at station 2-RVN033.65 compared to station 2-RVN037.54. In fact, the ortho-phosphorus concentration at the downstream station (2-RVN033.65) was ten times higher than the PO_4-P concentration at the upstream station (2-RVN037.54). Also, PO_4-P and TP concentrations fluctuated with several peaks (**Figure 3-13** and **Figure 3-14**). The higher levels and seasonal fluctuations of phosphorus at station 2-RVN033.65 are most likely attributable to the Moores Creek STP. There are no DEQ screening values for ortho-phosphorous.

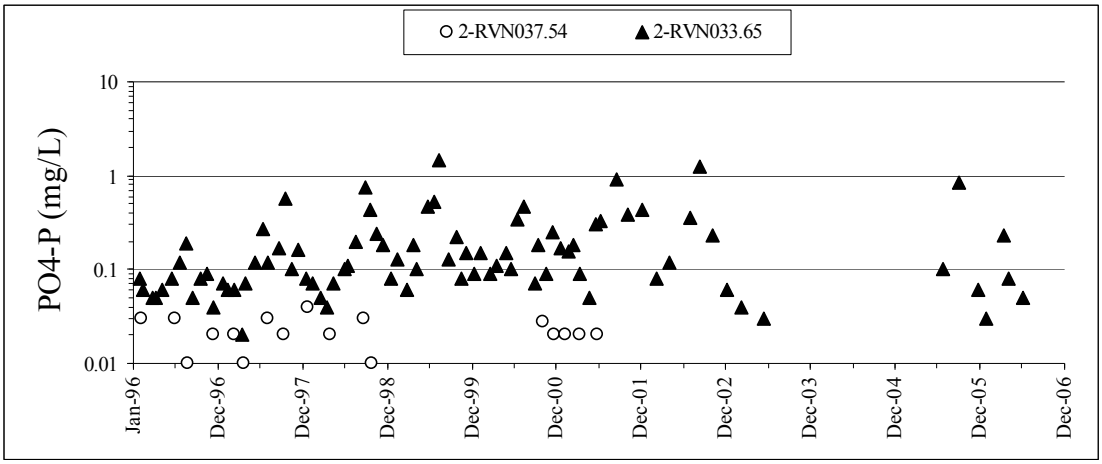


Figure 3-13: Ambient PO_4-P Measurements in the Benthic Impaired Segment of the Rivanna River

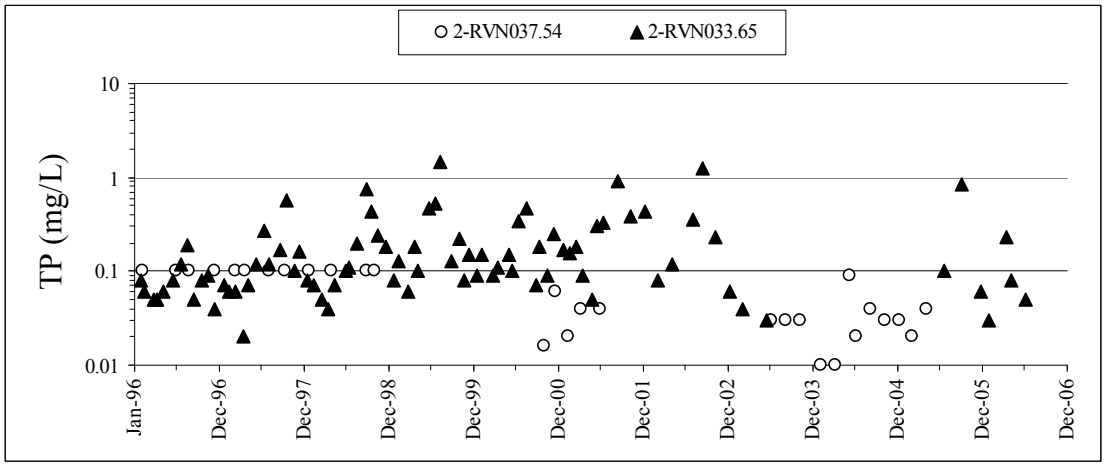


Figure 3-14: Ambient TP Measurements in the Benthic Impaired Segment of the Rivanna River

- Phytoplankton chlorophyll *a* was only measured at station 2-RVN033.65, and ranged between 0.5 and 4.17 µg/L (average: 1.51 µg/L) (**Figure 3-15**). The EPA reference standard for chlorophyll a is established at 1.61 µg/L.

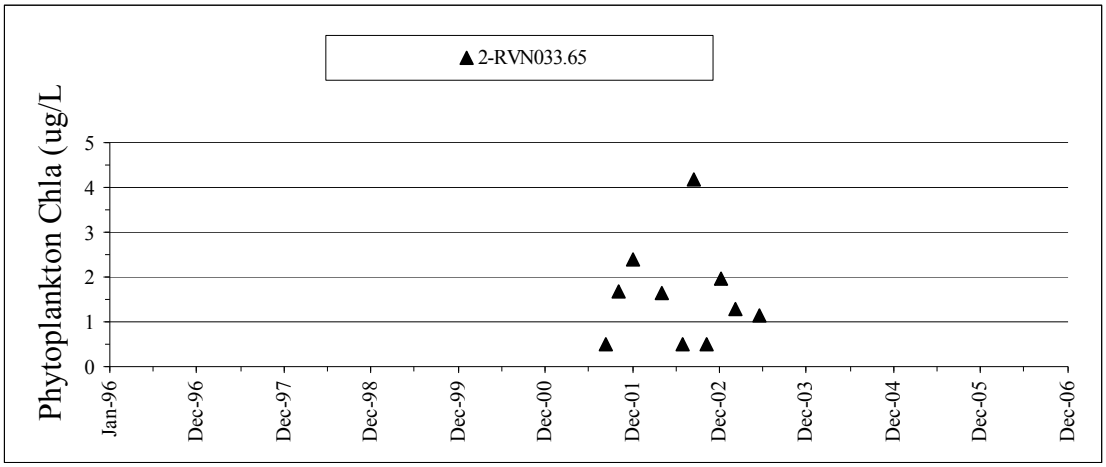


Figure 3-15: Ambient Phytoplankton Chl *a* Measurements in the Benthic Impaired Segment of the Rivanna River

Ambient water quality monitoring was conducted for the four stations located on tributaries that affect the upstream Rivanna River, as well as for stations within the impaired segments. The water quality analysis from the upstream stations (South Fork and North Fork Rivanna River), and the tributary stations is depicted in **Table 3-12** and **Table 3-13**, respectively. In general, all ambient water quality parameters showed relatively low levels (average TN: 0.45 – 1.26 mg/L, TP: 0.06-0.09 mg/L, and TSS: 7.02-14.9 mg/L). Therefore, under representative conditions, none of the boundaries provide significant pollutants.

Table 3-12: Summary of Instream Water Quality Data Collected at 2-RRS003.12 and 2-RRN002.19 between 1996 and 2005

Station ID		2-RRS003.12				2-RRN002.19			
Parameter	**Units**	**No of Samples**	**Min**	**Max**	**Avg**	**No of Samples**	**Min**	**Max**	**Avg**
Temperature	°C	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-
Field pH		-	-	-	-	-	-	-	-
Spec. Conductance	µmhos/cm	20	56.50	85.00	68.56	-	-	-	-
Chloride	mg/L	46	3.40	7.60	5.26	29	3.00	5.00	4.79
Turbidity	FTU	59	2.00	76.00	11.00	32	2.60	92.00	14.90
TSS[1]	mg/L	61	3.00	49.00	7.02	32	3.00	81.00	15.09
VSS[2]	mg/L	36	3.00	6.00	3.33	29	3.00	18.00	4.07
BOD_5	mg/L	44	1.00	5.00	1.82	29	1.00	3.00	1.34
Total NH_3-N	mg/L	70	0.04	0.68	0.09	48	0.04	0.09	0.04
NO_3-N	mg/L	67	0.04	0.59	0.23	36	0.04	0.49	0.25

Table 3-12: Summary of Instream Water Quality Data Collected at 2-RRS003.12 and 2-RRN002.19 between 1996 and 2005

TN[3]	mg/L	69	0.15	1.17	0.58	41	0.21	0.92	0.45
PO_4-P	mg/L	58	0.01	0.08	0.02	36	0.01	0.10	0.03
TP	mg/L	70	0.01	0.20	0.07	41	0.02	0.20	0.09
Chl*a*[4]	ug/L	12	1.30	12.39	4.98	-	-	-	-

[1] TSS = total non-filterable residue
[2] VSS = total volatile residue
[3] combination of measured and computed (TN = TKN + NO3-N + NO2-N) values
[4] Phytoplankton

Table 3-13: Summary of Instream Water Quality Data Collected at 2-MWC000.6 and 2-MSC000.6 between 1996 and 2006

Station ID		**2-MWC000.60**				**2-MSC000.60**			
Parameter	**Units**	**No of Samples**	**Min**	**Max**	**Avg**	**No of Samples**	**Min**	**Max**	**Avg**
Temperature	°C	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-
Field pH	-	-	-	-	-	-	-	-	-
Spec. Conductance	µmhos/cm	6	68.30	1445.00	386.05	-	-	-	-
Chloride	mg/L	18	7.00	426.00	49.89	18	7.40	57.00	16.28
Turbidity	FTU	21	1.60	63.40	7.12	28	1.60	24.50	6.09
TSS[1]	mg/L	21	3.00	90.00	7.62	32	3.00	37.00	5.13
VSS[2]	mg/L	18	3.00	16.00	3.83	32	3.00	7.00	3.13
BOD_5	mg/L	18	1.00	4.00	1.89	18	1.00	3.00	1.67
Total NH_3-N	mg/L	29	0.04	0.21	0.05	28	0.04	0.11	0.05
NO_3-N	mg/L	17	0.04	1.41	0.95	28	0.20	1.29	0.54
TN[3]	mg/L	29	0.65	1.79	1.26	-	-	-	-
PO_4-P	mg/L	17	0.01	0.03	0.02	28	0.01	0.18	0.03
TP	mg/L	29	0.01	0.11	0.06	29	0.02	0.22	0.07
Chl*a*[4]	ug/L	-	-	-	-	-	-	-	-

[1] TSS = total non-filterable residue
[2] VSS = total volatile residue
[3] combination of measured and computed (TN = TKN + NO3-N + NO2-N) values
[4] Phytoplankton

3.2.2 Heavy Metals Data

Dissolved instream and sediment metals were examined at stations 2-RVN037.54, 2-RVN035.67, and 2-RVN032.46 within the benthic-impaired segments of the Rivanna River. Parameter measurements included aluminum, antimony, arsenic, cadmium, chromium,

copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. All available dissolved metals data were analyzed to determine whether the parameters complied with Virginia's established water quality criteria. No metals parameters exceeded the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards for dissolved metals. The majority of the metals parameters analyzed were below analytical detection limits.

3.2.3 Organics Data

Instream organic contaminants parameters (aldrin, chlordane, DDT, DDE, DDD, dicofol, dieldrin, endrin, heptachlor epoxide, n-propylbenzene, PCP, toxaphene, and n-propylbenzen) were examined at stations 2-RVN037.54, 2-RVN035.67, and 2-RVN032.46 within the benthic impaired segments of the Rivanna River, and were analyzed to determine whether the examined parameters complied with Virginia's established water quality criterion. Based on the available data, no violations of the acute or chronic criteria were observed, and the majority of dissolved organic parameters measured fell below detection limits.

3.2.4 Toxicity Testing

Toxicity testing was performed on water samples collected on the Rivanna River by DEQ at stations 2-RRN002.19, located on the North Fork Rivanna River, and 2-RVN033.65, located on the mainstem of the benthic impaired segment VAV-H29R-01 on October 24, 26, and 28 2005. The EPA Region Three laboratory in Wheeling, West Virginia performed chronic toxicity testing on samples using fathead minnows and *Ceriodaphnia dubia*, also known as water fleas. Results indicated that *Ceriodaphnia* mortality and reproduction in the Rivanna River water samples were not statistically different than mortality and reproduction in the control samples, thus indicating that there were no toxic water column effects.

Toxic effects were noted on fathead minnows in the Rivanna River water samples. Fathead minnow survival rates in samples collected at station 2-RRN002.19 and at station 2-RVN033.65 were statistically different from the laboratory control. The EPA Region 3 laboratory in Wheeling indicated that this result "was probably biologically significant", and

that it was necessary to compare the observed toxicity testing results with other water quality data collected at this site to determine the presence of toxicity.

Additional samples were collected for toxicity testing by DEQ at station 2-RVN033.65 on May 15, 17, and 19, 2006. These samples did not have any effects on *Ceriodaphnia* mortality and reproduction. However, results from these samples did indicate that there was an adverse effect on both the fathead minnow survival and biomass. It should also be noted that during both sampling periods of the toxicity tests, there were major storm events based on readings at USGS gage at Palmyra. These storm events would have temporarily provided more runoff from the land area, which could potentially temporarily increase the toxic effects in the river. Therefore, based on these tests, there is a possible toxic effect in the Rivanna River.

3.2.5 Relative Bed Stability Analysis

A Relative Bed Stability (RBS) analysis was conducted by VA DEQ at station 2-RVN033.65 on July 12, 2007. The results of this analysis indicate that the Rivanna River shows signs of widening and incision. According to VA DEQ RBS experts, this means that the channel is adjusting to increases in flow frequency. In addition, high percentages of fines (24%) and sand (21%) were observed (**Table 3-14**). This indicates that the stream bed substrate is "fining" slightly, or becoming increasingly more composed of fines. Small particles, like sand and fines, fill in the interstitial spaces between larger particles in the stream bed causing embeddedness. This reduces water circulation and habitat space in the substrate, which decreases benthic macroinvertebrate diversity. EPT species for example, require coarse substrate with sufficient water flow for feeding, breathing, and protection. A high percentage of sand and fines in the substrate fills in these habitat spaces, which forces out these sensitive taxonomic groups.

Table 3-14: Relative Bed Stability 2007 Streambed Composition at Station 2-RVN033.65	
Substrate Type	**% Composition**
BedRock	10.5
Boulder	3.8
Cobble	9.5
Gravel Course	24.8
Gravel Fine	6.7
Sand	21.0
Fines	23.8

3.3 Supplemental Water Quality Monitoring Data

3.3.1 The Rivanna River Basin Roundtable

The Rivanna River Roundtable (RRR) was established by the Thomas Jefferson Planning District Commission (TJPDC) in order to characterize historic and present conditions in the Rivanna River watershed, and to propose suggestions for improving the watershed. The RRR incorporates twenty-four stakeholders from the Rivanna River watershed in developing the *Rivanna River Basin Project* (Rivanna River Roundtable, 1998), which collects information used to improve water quality, and which informs citizens in the Rivanna River watershed. The *Rivanna River Basin Project* (Rivanna River Roundtable, 1998) included the following parameters:

- stream morphology measurements
- water balance calculations
- water quality measurements for field parameters (dissolved oxygen, pH, and temperature)
- water quality measurements for chemical parameters (total suspended solids (TSS), fecal coliform, total nitrogen (TN), total phosphorus (TP), and ammonia)
- benthic invertebrates measurements
- fish species collection

The data for the project was to some extent obtained from VA DEQ and U.S. Geological Survey (USGS). Additional data such as stream morphology, water quality parameters, and

benthic macroinvertebrates was measured by the Rivanna River Basin Project at 14 stations in the Rivanna River watershed between 1996 and 1997. **Figure 3-16** shows the location of the monitoring stations. The water quality data collected during this time period included samples taken under low and high flow conditions. The results of the measurements are summarized in the following paragraph. **Table 3-15** shows the stations within the impaired segment and their descriptions used for stream morphology, water quality analysis, and benthic invertebrate sampling.

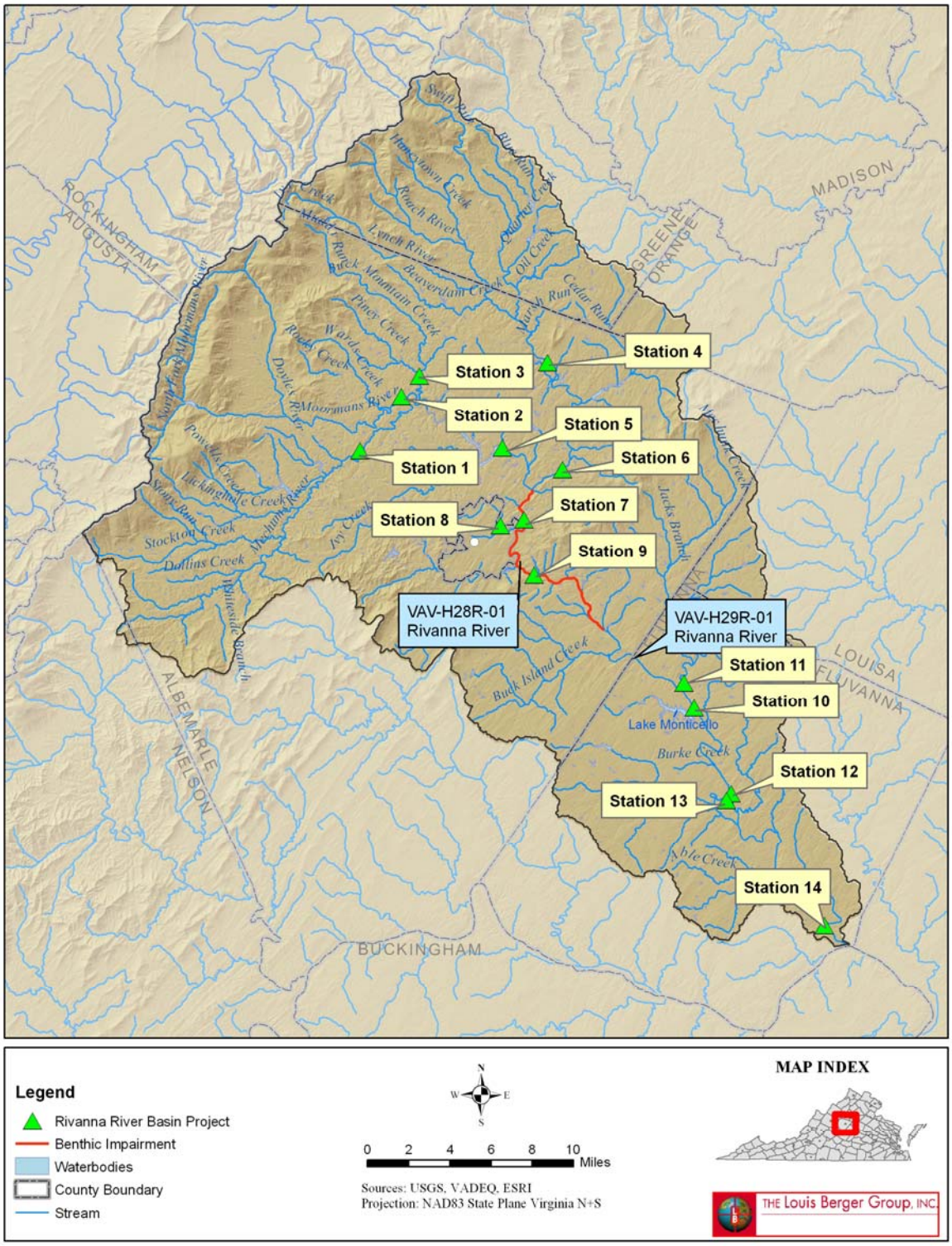


Figure 3-16: Monitoring Locations of the Rivanna River Roundtable in the Rivanna River Watershed

Table 3-15: Stream Morphology, Water Quality, and Biological Stations by the Rivanna River Basin Project

Stream	Station location	Stream Morphology	Water Quality	Benthic Invertebrates
Mechums River	Route 614, tributary of South Fork River	X	X	X
Moormans River	Route 601, tributary of South Fork River	X	X	X
Buck Mountain Creek	Route 667, tributary of South Fork River	X	X	X
South Fork Rivanna	Downstream of South Fork Dam, Route 29		X	X
North Fork Rivanna	Route 606	X	X	X
North Fork Rivanna	Proffit, upstream of confluence with South Fork River	X	X	X
Meadow Creek	Holmes Ave.	X	X	X
Rivanna River	Darden Towe Park by Route 20		X	X
Rivanna River	Downstream of Charlottesville, Monticello		X	X
Rivanna River	Leslie Site		X	X
Mechunk Creek	Route 616	X	X	X
Rivanna River	Route 15, Palmyra		X	X
Cunningham Creek	Route 15	X	X	X
Rivanna River	Mouth of Rivanna River, Route 6, Columbia		X	X
X indicate that station was used for data collection				

Instream water quality in the Rivanna River watershed generally showed elevated levels of all collected chemical water quality parameters only under high flow conditions. In particular, TSS and TP concentrations increased significantly when compared to measurements under dry weather conditions:

1) Total Suspended Sediment

Under high flow conditions, tributaries of the South Fork Rivanna River (Mechums River, Moormans River, and Buck Mountain Creek) had average TSS concentrations between 78 and 282 mg/L. However, it should be noted that the TSS load originating from these tributaries is mostly captured in the South Fork Dam. This is confirmed by the South Fork Rivanna station located downstream of the South Fork Dam, which showed relatively low TSS levels under high flow (25 mg/L). In contrast, the North Fork Rivanna River showed the highest levels of average TSS under high flow, ranging between 160

and 654 mg/L. Therefore, the majority of the TSS load at the confluence of North and South Fork Rivanna River (which forms the Rivanna River) is contributed from the North Fork Rivanna River watershed. Additional TSS loads entering the Rivanna River under high flow were contributed by Meadow, Mechunk, and Cunningham Creeks with average TSS levels between 43 and 82 mg/L. As a result of these TSS loads, the Rivanna River showed elevated average TSS levels under high flow conditions along the entire river ranging between 151 and 229 mg/L at the middle section of the Rivanna River and up to 253 mg/L at the mouth of the Rivanna River. The elevated loads of TSS during high flow were the most probable cause for the significant sedimentation of the riverbed as stream morphology measurements indicated at several sites in the Rivanna River watershed. Moreover, the sedimentation may have adversely affected the benthic community. However, benthic macroinvertebrate measurements observed during this study showed that the majority of the monitoring sites in the Rivanna River watershed achieved excellent SOS (Save Our Streams) index scores overall.

2) Total Phosphorus

TP levels under high flow conditions ranged between 0.23 and 0.4 mg/L in the Rivanna River and between 0.07 and 0.4 mg/L in the North and South Fork Rivanna River. TP levels at other tributaries showed lower levels ranging between and 0.1 and 0.2 mg/L.

3) Dissolved Oxygen

DO levels in the Rivanna River watershed never exceeded the VA DEQ minimum standard of 4 mg/L. However, dissolved oxygen levels at 4 mg/L were frequently measured at South Fork Rivanna station located downstream of the South Fork Dam. The low DO levels were probably caused by the release of water with low dissolved oxygen from the South Fork Dam.

3.3.2 Discharge Monitoring Reports

Discharge Monitoring Reports (DMR) for each of the individual permitted facilities discharging into the Rivanna River watershed were obtained and analyzed. DMR data are graphically presented in Appendix C. There were no recorded exceedances of permit limits

for the provided parameters: TSS, chlorine, E. coli, or Fecal Coliform at any of the facilities within the watershed.

4.0 Stressor Identification Analysis

TMDL development for a benthic impairment requires identification of pollutant stressor(s) affecting the benthic macroinvertebrate community. Stressor identification for the biologically impaired segment of the Rivanna River was performed using the available environmental monitoring and watershed characterization data discussed in previous sections. The stressor identification follows guidelines outlined in the EPA Stressor Identification Guidance (EPA, 2000).

The identification of the most probable cause of biological impairment in the Rivanna River was based on evaluations of candidate stressors potentially impacting the river. The evaluation includes possible stressors such as dissolved oxygen, temperature, pH, metals, organic chemicals, nutrients, toxic compounds, and sediments. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Each stressor was then classified as one of the following:

Non-stressor: Stressor with data indicating normal conditions, without water quality standard exceedances, or without any apparent impact.

Possible stressor: Stressor with data indicating possible links to the benthic impairment, but without conclusive data to show a direct impact on the benthic community.

Most probable stressor: Stressor with conclusive data linking it to the poor health of the benthic community.

Table 4-1 summarizes the results of the stressor analysis for the Rivanna River.

Table 4-1: Summary of Stressor Identification in the Rivanna River
Non-Stressors
Temperature and pH
Dissolved oxygen
Instream metals
Organic and metal contaminants in river sediments
South Fork Rivanna Reservoir Discharge
Possible Stressors
Phosphorus
Toxicity
Most Probable Stressors
Sediment/ Urban Runoff

4.1 Non-Stressors

4.1.1. Temperature and pH

Benthic invertebrates require a suitable range of temperature and pH conditions. High instream temperature values, and either very high or very low pH values, may result in a poor quality invertebrate assemblage comprised predominantly of tolerant organisms. Field measurements indicated that adequate temperature values were recorded on the biologically impaired segments. All recent pH measurements showed a suitable range for benthic invertebrates, except for one occasion in September of 1998 when pH was one-tenth of a pH unit lower than the minimum pH standard (see **Section 3.2.1**). However, since it was so slight and occurred on one occasion, this exceedance is deemed unrepresentative. Therefore, temperature and pH do not appear to be adversely impacting benthic communities in the Rivanna River and are classified as non-stressors.

4.1.2. Dissolved Oxygen

Adequate dissolved oxygen (DO) levels are necessary for invertebrates and other aquatic organisms to survive in the benthic sediments of rivers or streams (see **Section 3.2.1**). Decreases in instream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. The field DO samples and the diurnal monitoring samples both complied with the DO criteria. Therefore, dissolved oxygen is not considered to be impacting the benthic community.

4.1.3. Heavy Metals and Organic Contaminants in the Water Column and River Sediments

All available dissolved heavy metals data (aluminum, antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc) and organic contaminants in the water column and river sediment were below the detection limits (see **Sections 3.2.3** and **3.2.4**). Consequently, heavy metals and organic contaminants do not appear to be stressors affecting benthic macroinvertebrates in the Rivanna River.

4.1.4. South Fork Rivanna Reservoir Discharge

The South Fork Rivanna Reservoir is located approximately 3.4 miles upstream of the benthic-impaired segment. Stakeholders at the local steering committee meeting mentioned the possibility of water with low dissolved oxygen released from the bottom

of the reservoir impacting the benthic health. Discharge from reservoirs can have a localized effect on the benthic community downstream of the impoundment due to reduced oxygen and limited upstream recruitment of macroinvertebrates.

The South Fork Rivanna Reservoir is considered to be a non-stressor on the Rivanna mainstem. The distance between the reservoir and the impaired reach is considered adequate for reaeration. The North Fork Rivanna River, which is unimpaired, would provide additional flow, oxygen, and macroinvertebrate recruitment before the Rivanna River mainstem impairment. In addition, the upstream end of the Rivanna River mainstem impaired reach typically had better benthic scores than the downstream portion (based on StreamWatch scores from Darden Towe and Milton stations). These scores would be expected to be lower if the South Fork Reservoir was a primary stressor on the mainstem Rivanna benthic community.

4.2 Possible Stressors

4.2.1 Phosphorus

An abundance of instream phosphorus is considered to play a major role in the eutrophication of stream systems. Based on VA DEQ benthic macroinvertebrate sampling conducted in the impaired segment VAV-H29R-01 at VA DEQ stations 2-RVN035.67, 2-RVN033.65, and 2-RVN032.46 (see **Section 3.1.1**), the majority of samples were composed of macroinvertebrates typically tolerant to pollution from organic wastes or nutrients. The diurnal dissolved oxygen fluctuation is indicative of a healthy system with no dissolved oxygen standard violations, and the instream total phosphorus loads in the downstream impaired segment may be a possible stressor affecting benthic macroinvertebrates. The Moores Creek STP is considered to be the primary cause of the increase of phosphorus between the two ambient monitoring stations. By 2010, this plant will be upgraded to remove nutrients in order to comply with the new state regulations on nitrogen and phosphorus loadings to the Chesapeake Bay.

These nutrient levels and the dissolved oxygen levels show that the stream may be prone to eutrophic conditions in the future. Nutrient enrichment could impact benthic health

through changing species composition and community structure prior to observing decreased dissolved oxygen levels. For this reason, phosphorous is considered a possible stressor.

4.2.2 Toxicity

Acute and chronic toxicity testing was conducted along the impaired segment. These tests showed that there was not a toxic effect on the *Ceriodaphnia dubia*, also known as water fleas, for either surveys (see **Section 3.2.4**). However, based on results from both toxicity tests, there was a biological effect on fathead minnow survival and biomass. It should be noted that these toxicity tests do not provide information on the source of the toxics that may be affecting the fish community. It should also be noted that during both sampling periods of the toxicity tests, there were major storm events. These storm events could have provided more runoff from the land area and potentially increased the toxic effects in the river that may not be present normally. Therefore, based on these tests, toxic effects may be affecting the biological community of the Rivanna River.

4.3 Most Probable Stressors

4.3.1 Sedimentation and Urban Runoff

Sedimentation and urban runoff have been identified as most probable stressors in the Rivanna River benthic impaired segments, based on the composition of the benthic community and benthic habitat data from the stations along the impaired segment. In particular, embeddedness and sediment deposition habitat scores at these stations were suboptimal (see **Section 3.2**). Although riparian and bank stability scores were considered to be within an acceptable range in the impaired segments, land use and riparian zone data in the upper portion of the watershed is considered suboptimal. Erosion and runoff contributions from the upstream areas would add to the embeddedness and sediment deposition observed at these stations.

Although the majority of the watershed is forested and agricultural land, the area upstream and surrounding the portion of the Rivanna River benthic impairment is within

the City of Charlottesville (see **Section 2.1.5**). The impervious surfaces within the urban areas will increase the speed of runoff, which can erode banks, scour stream beds, and deliver toxic chemicals. Also, in the upper portion of the watershed, studies have shown that there is a high level of sedimentation related to stream bank instability. StreamWatch, The Nature Conservancy, The Thomas Jefferson Soil and Water Conservation District, Rivanna Conservation Society, and the Rivanna Water and Sewer Authority have conducted stream surveys in the area. One survey conducted in 2002, which covered 20 miles in Albemarle County, estimated that 15% of banks are eroded. A 2006 survey found that 24%-30% of banks near monitoring stations were actively eroding (StreamWatch, 2006).

The Relative Bed Stability (RBS) analysis conducted by VA DEQ in 2007 found that the Rivanna River was adjusting to flow increase by widening and incision. Also, the river substrate was becoming increasingly composed of fines and sand, which cause embeddedness (see **Section 3.2.5**).

The Nature Conservancy's Rivanna Watershed Conservation Area Plan (2004) listed historical land clearing and conversion of forests to agriculture as the largest threat to the system. Although sedimentation is regarded as the primary stressor, it is unclear if the primary source of sediment loading is from stream banks or runoff. According to Bowler (2003), sediment loads have varied over the decades, although not measurably between 1980 and 1990. This may indicate that human influence has not increased or decreased the rate of sedimentation. Also, sediment loads may have varied due to large storm events such as hurricanes.

Urban runoff may contribute toxic chemicals to the water column, and nutrients from land areas, to the stream. The toxicity studies indicated that there was a toxic effect on fathead minnows. However, the source of the toxicity has not been identified. These observations indicate that urban runoff may be affecting the benthic community.

4.4 Conceptual Model and Causal Analysis

A conceptual model, when used in formulating problems, is defined as a written description and visual representation of predicted relationships between the environment and its stressors. The model is described by causal pathways that link the sources to the most probable stressor and eventually to the impairment. The main benefit of developing a conceptual model is that it provides a powerful communication tool highlighting known understanding of a system for future implementation. In addition, conceptual models are a learning tool which can be adapted as the study proceeds (EPA, 1998).

A conceptual model was developed for the benthic-impaired segments of the Rivanna River to show the known sources and their causal pathways, leading to the most probable stressor (sedimentation) and finally to the benthic impairment. **Figure 4-1** shows the developed conceptual model, which identified impervious surfaces, agriculture, and silviculture as potential sources causing the benthic impairments in the Rivanna River. Impervious surfaces restrict ground water absorption, which increases the amount of storm water runoff that reaches the river. Increased runoff also concentrates water flows, increases wave action in the river, and may contribute urban erosion from construction sites and street dust. Also, urban runoff often causes litter to accumulate in the river. The result of increased runoff from impervious surfaces is an increase in instream erosion, sediment transport, and sedimentation in the downstream sections of the Rivanna River.

There are two main components to agricultural runoff within the watershed. First, overgrazing and soil compaction have lead to a decrease in land vegetation, and a subsequent decrease in water absorption. This results in sheet erosion across large areas of land. Second, cattle seeking water in local streams and rivers causes stream bed and bank erosion, thus putting extra sediment into the waterways. Both of these cause increases in sedimentation.

Silviculture is also impacting sedimentation in the Rivanna River, but probably to a lesser extent than impervious surfaces and agriculture. According to the DOF 2005,

there is 12,389 acres of Forest Harvest in the Rivanna Benthic Watershed, which accounts for 10 percent of the entire watershed area. Silviculture is the harvest of forests, and often requires the establishment of roads for timber transport. There are three main practices of silviculture leading to an increase in erosion. First, clear cutting practices decrease ground vegetation causing an increase in sheet erosion. Second, road building increases sheet erosion due to construction based runoff, as well as the clearing of vegetation. Third, timber transportation increases sheet erosion due to the establishment of roads through clearing and the use of large machinery to transport the timber harvest. Sheet erosion caused by silviculture has lead to an increase in sedimentation in the Rivanna River region.

As the conceptual model shows, increased sedimentation from various sources causes embeddedness, which is defined as the degree to which rocks are covered with silt, sand or mud. When sediment fills the interstitial spaces in stream substrate, available habitat for many macroinvertebrates is decreased, causing the benthic community to become impaired.

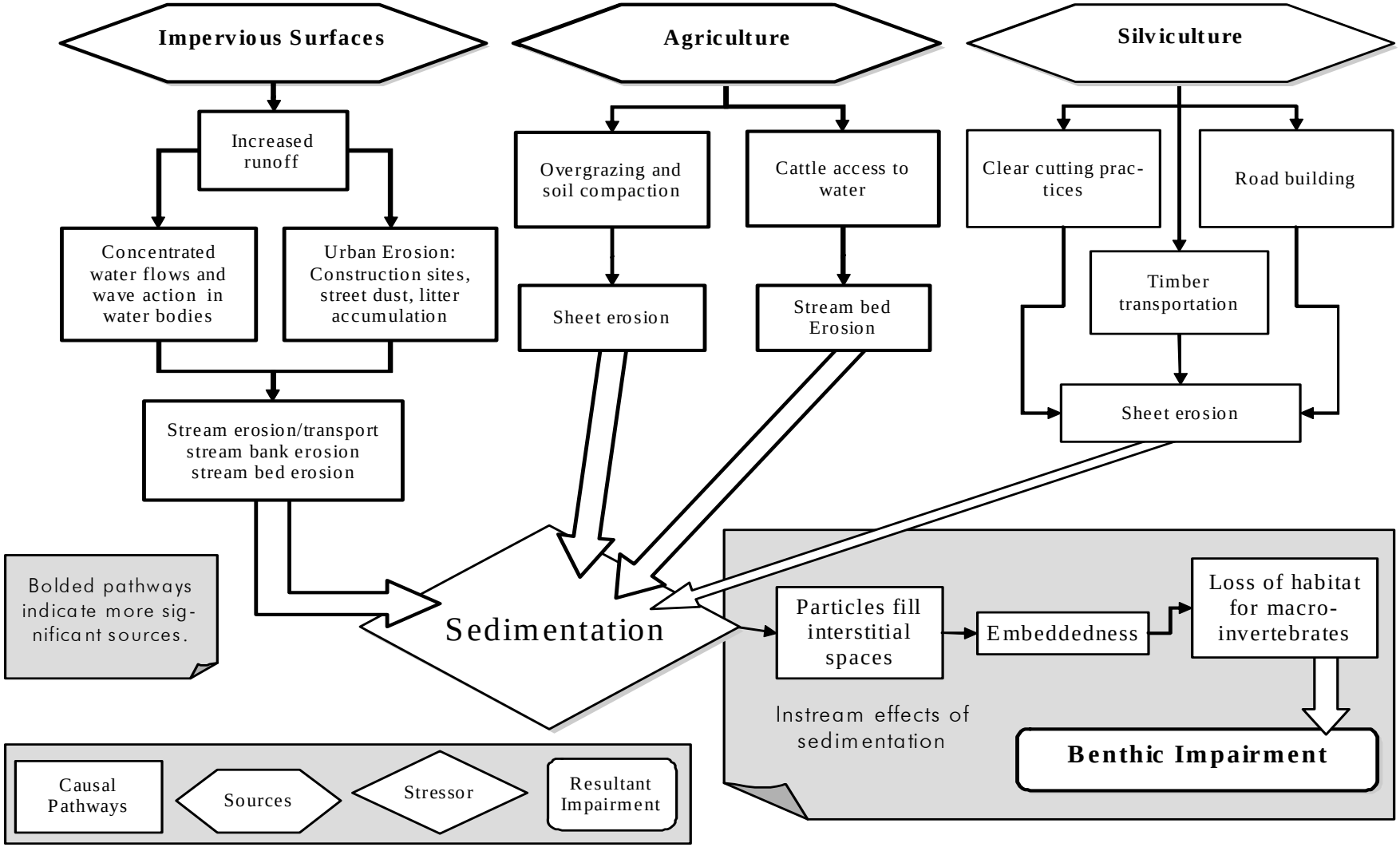


Figure 4-1: Conceptual Model for the Causes of the Benthic Impairment in the Rivanna River

4.5 Stressor Identification Summary

The data and analysis presented in this section indicate that temperature, pH, dissolved oxygen, instream metals, organic and inorganic contaminants in the sediments, and impacts from the South Fork Rivanna Reservoir are not affecting the invertebrate community in the benthic-impaired segment, and therefore are not stressors contributing to the benthic impairment. The data analysis also shows that phosphorus, as well as toxicity, may contribute to the benthic impairment in Rivanna River. Consequently, these parameters are classified as possible stressors. The most probable stressors for the Rivanna River watershed are considered to be sedimentation and urban runoff. In fact, several of the probable stressors identified, such as nutrients and toxicity, may be the result of urban runoff.

5.0 TMDL Endpoint Identification

TMDL development requires the determination of endpoints, or water quality goals/targets, for the impaired waterbody. TMDL endpoints represent stream conditions that meet water quality standards. Endpoints are normally expressed as the numeric water quality criteria for the pollutant causing the impairment. Compliance with numeric water quality criteria, such as a maximum allowable pollutant concentration, is expected to achieve full use support for the waterbody. However, not all pollutants have established numeric water quality criteria. In these cases, a modified reference watershed approach, in which data from several unimpaired watersheds may be used to define the TMDL endpoint, may be used.

As discussed in Chapter 1, the upstream impairment of the Rivanna River (VAV-H28R-01) was first included on Virginia's 1996 Section 303(d) List, and was subsequently included on Virginia's 303(d) Lists of Impaired Waters and Water Quality Assessment 305(b)/303(d) Integrated Reports based on biomonitoring results obtained between 1996 and 2005. According to the 2004 303(d) fact sheets, the cause for the benthic macroinvertebrate impairment is believed to be related to non-point source urban runoff. During the 2006 303(d) assessment, DEQ concluded that the segment directly downstream of VAV-H28R-01 was also biologically impaired (VAV-H29R-01) (DEQ, 2006). Based on the 2006 303(d) list (DEQ, 2006), the source of the benthic macroinvertebrate impairment is unknown. As detailed in Section 4.0, sedimentation and urban runoff were identified as the most probable stressor for the benthic impairment in the stream. Currently, Virginia does not have numeric criteria for sediment. Therefore, a modified reference watershed approach was used to establish the numeric sediment TMDL endpoint for the Rivanna River.

5.1 Modified Reference Watershed Approach

Under the reference watershed approach, the TMDL endpoint for an impaired watershed is established based on conditions in a similar, but non-impaired, reference watershed. In the case of the modified reference watershed approach, conditions in several non-impaired watersheds are used to establish the TMDL endpoint. In terms of benthic

impairment caused by excessive sediment, the TMDL endpoint is determined by establishing a load duration curve, which illustrates the sediment loading in each of the unimpaired watersheds at different flow frequencies. The TMDL endpoint is expressed as the sediment loading rate at High, Moist, Mid-Range, Dry and Low flow conditions in the non-impaired reference watersheds. Reduction of the sediment loading rates at different flow levels in the impaired watershed to levels comparable to the unimpaired watersheds is assumed to be sufficient for recovery of the benthic community in the impaired watershed.

Reference watersheds are selected based on their similarities in ecoregion and stream order. Selecting a similar reference watershed helps to ensure similarities in the benthic communities that may potentially inhabit the streams. Similar watersheds also provide for similar watershed hydrology, which influences pollutant loading rates in the stream.

5.1.1 Selected Reference Watersheds

Several DEQ stations, located in non-impaired watersheds, were used as references for the impaired Rivanna River watershed. The non-impaired reference stations included stations from: the Rapidan (3-RAP030.21), Piney (2-PNY005.30), Robinson (3-ROB005.42 and 3-ROB004.98), Rockfish (2-RKF0216.13), and South Mayo River (4-ASMR017.72), as well as from a station in Goose Creek (4-AGSE015.07). Each of these stations is located on a fourth order stream within close proximity to a USGS flow monitoring station (**Figure 5-1**). The Rapidan, Robinson, and Piney stations are part of the Rappahannock River watershed located northeast of the Rivanna watershed, near Fredericksburg, VA. The Rockfish River is part of the James River watershed and is located in Nelson County, VA. The South Mayo River is South of Rivanna River in Patrick County, VA. The Upper Goose Creek watershed is about 20 miles northwest of the Rivanna River watershed. The Rivanna River and the non-impaired watersheds are located primarily in the Northern Piedmont, Piedmont and Blue Ridge ecoregions. The Northern Piedmont region consists of low rounded hills that serve as a transitional area between the low mountains to the north and west and the flat coastal plains to the east. The Piedmont region extends from Southwest PA, and consists of mostly shallow valleys,

irregular plains, and low hills. The Blue Ridge ecoregion extends from southern PA to northern Georgia, and has a more mountainous topography.

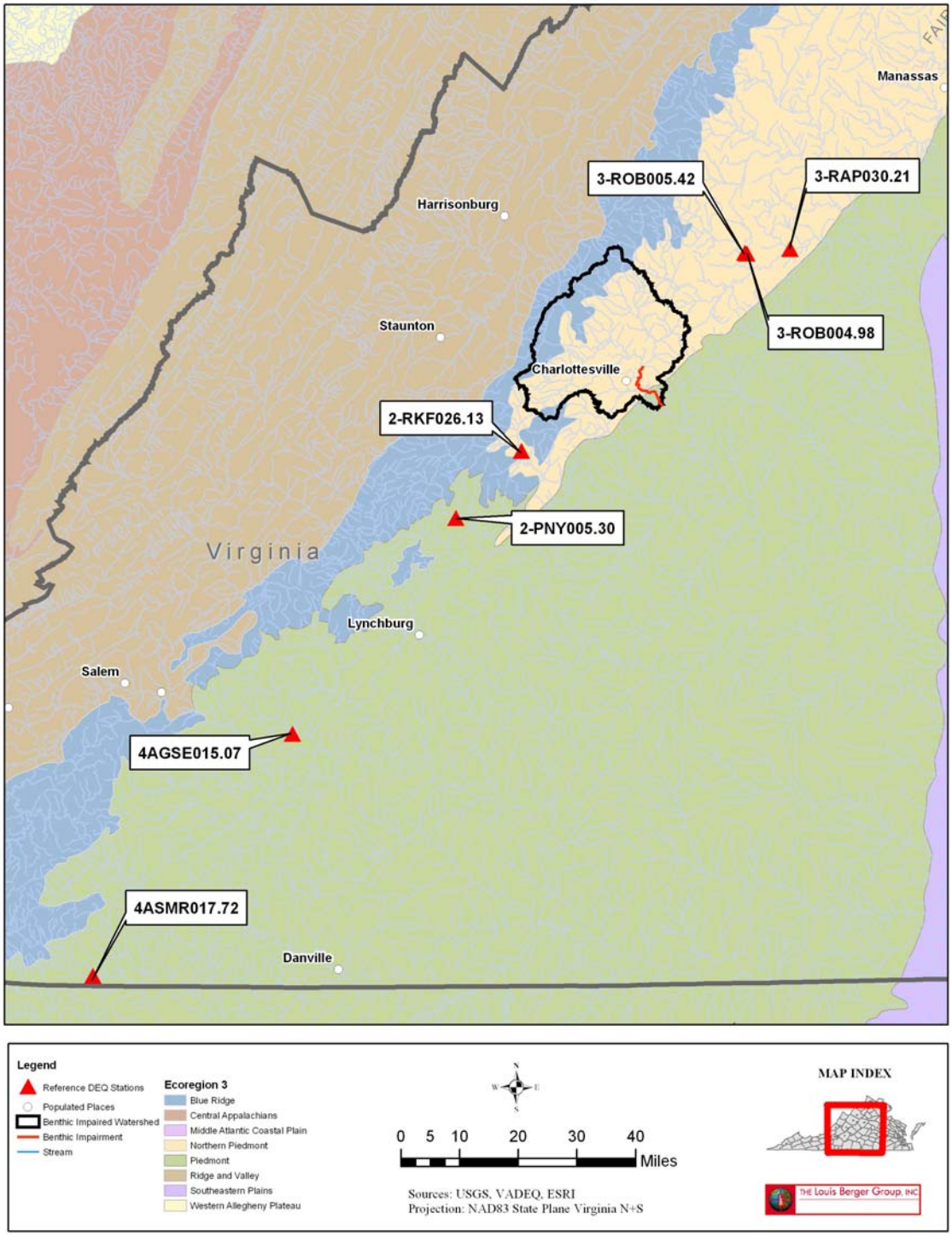


Figure 5-1: Location of Reference Stations for the Benthic Impaired Rivanna River

5.2 Sediment Rating Curves

The sediment rating curve is used to compare correlations of flow vs. sediment for the non-impaired reference stations and for the impaired segment of the Rivanna River. The sediment rating curve is the result of attributing each TSS sample collected at an impaired or non-impaired DEQ station with flow data collected at a nearby USGS station. The result of this comparison is a regression equation, or sediment rating curve, which is then used to generate a load duration curve (described in the following section). The non-impaired sediment rating curve is the basis for the TMDL. The sediment rating curves for the impaired and non-impaired stations are shown in **Figures 5-2** and **5-3**.

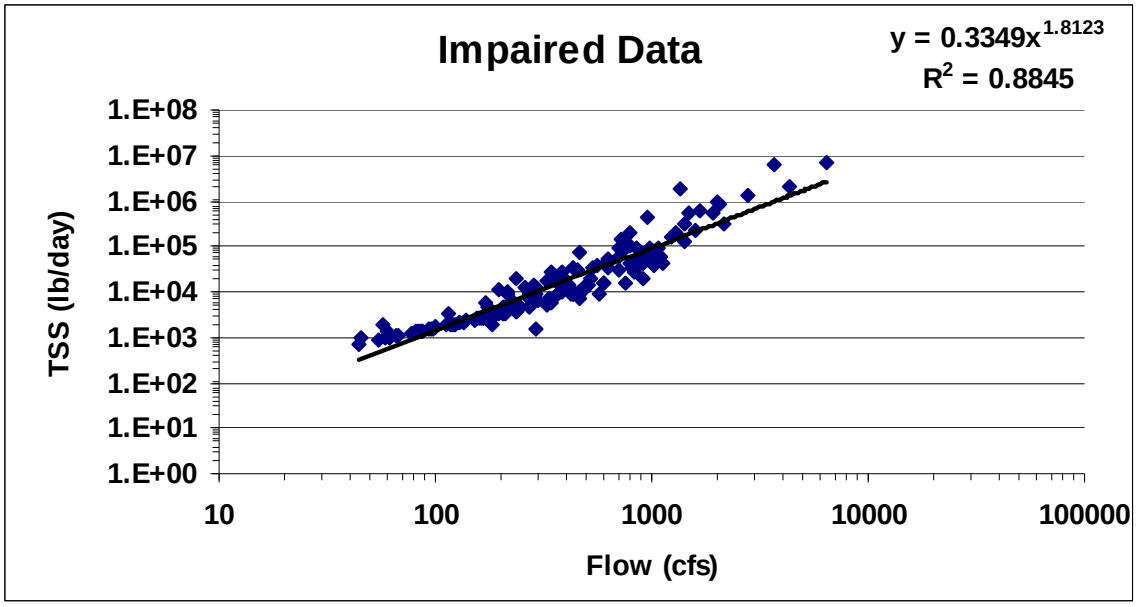


Figure 5-2: Sediment Rating Curves for Impaired Segments

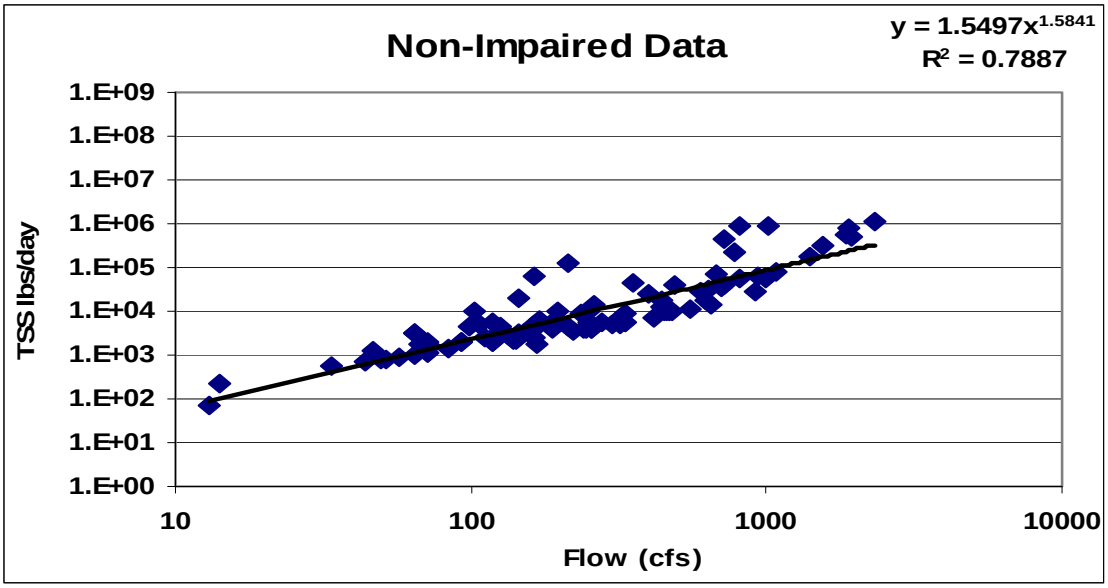


Figure 5-3: Sediment Rating Curves for Non-Impaired Segments

5.3 Sediment Load Duration Curves

A Sediment Load Duration Curve characterizes sediment loads at different flow regimes and displays the relationship between stream flow and loading capacity (US EPA, 2007). Sediment load duration curves for the impaired and non-impaired stations are developed from the sediment rating curves (**Figures 5-2** and **5-3**). Using the sediment rating curve equations, predicted non-impaired and impaired sediment loads are calculated for all flow conditions in the impaired watershed. The sediment load duration curves are used to assign sediment loads to the flow regime in the unimpaired reference stations and in the impaired Rivanna River segment for comparison. The non-impaired load duration curve represents the TMDL endpoint. Additionally, the curve allows for each TSS target to be categorized into high flows, mid-range flows, dry conditions, and low flows. **Figure 5-4** and **Table 5-1** both show that the impaired segments of the river have a higher sediment load (lbs/day) than the unimpaired segments in all flow regime conditions, except under low flow conditions. **Table 5-1** includes all flow regime conditions and the percent reduction needed for the impaired segments to be considered non-impaired. The

calculated reduction percentage shows a need for sediment reduction in flow regimes, under high, moist, mid-range, and dry conditions

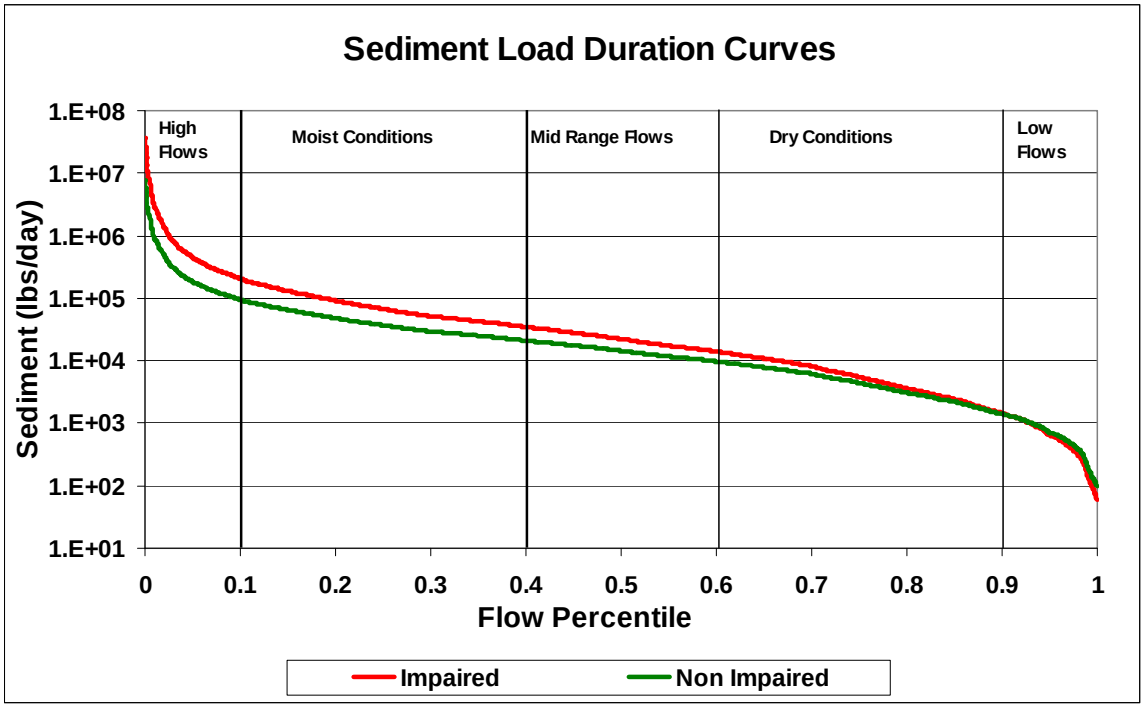


Figure 5-4: Sediment Load Duration Curves for Non-Impaired and Impaired Watersheds

Table 5-1: Sediment Loads by Flow Regime for the Non-Impaired and Impaired Stations

Load (lbs/day)	Flow Regime				
	High	Moist	Mid-Range	Dry	Low
Impaired Load Duration Curve (Existing Conditions)	455,542	67,343	22,342	5,538	643
Non-Impaired Load Duration Curve (TMDL)	187,400	36,942	14,470	4,438	643
Reduction (%)	58.9	45.1	35.2	20.1	0

6.0 Sediment Load Determination

As discussed in the previous section, a modified reference watershed approach was used to develop the sediment TMDL for the Rivanna River watershed. Data from several non-impaired river stations were identified and combined for use as a reference in the benthic impaired segment of the Rivanna River. Sediment load duration curves were developed for both the reference and impaired watersheds in order to quantify the sediment loading reductions that would be necessary to achieve the designated aquatic life use for the Rivanna River watershed. The sediment load duration curve developed for the reference watershed was used to define the numeric TMDL endpoint for the impaired watershed. See Section 5.3 for an in-depth discussion of sediment load duration curves.

While it does provide overall load estimates, the load duration curve does not distinguish between sources. The GWLF model is therefore used to generate annual sediment loads by source to determine the percentage of the total sediment load contributed from each land use type.

6.1 Sediment Source Assessment

Excessive sedimentation can adversely affect benthic invertebrate communities through a loss of habitat and degradation of water quality. Sediment can be delivered to the stream from point sources located within the watershed and it can be carried in the form of non-point source runoff from non-vegetated or protected land areas. In addition, sediment can be generated in the stream through the processes of scour and deposition, which are primarily a function of stream flow. During periods of high flow, increased erosion of the stream channel occurs. The eroded materials are deposited downstream as stream flow decreases.

Potential sediment sources within the Rivanna River watershed are discussed in the next section followed by a presentation of the methodology used to quantify these sources for TMDL development.

6.1.1 Non-Point Sources

The erosion of land is dependent upon many factors, including land use type and cover, soil type, and topography. The land use types in the Rivanna River watershed were characterized from NLCD 2001 reference data and DOF 2005 reference data. Dominant land uses in the watershed are forest (64%) and agriculture (21%), which account for a combined 85% of the total land area in the watershed. The land use distribution for the Rivanna River watershed was previously shown in **Tables 2-4** and **2-6.** Brief descriptions of land use classifications are presented in **Table 2-5**, and land use distribution is presented in **Figure 2-2**. Sediment loadings from generalized land use types present in the Rivanna River watershed are discussed below.

Forested Lands

Sediment loads from forested lands are typically low, due to the extensive root systems and vegetative cover that serve to stabilize soils. In addition, forest canopies intercept and dampen the impact of rainfall.

Agricultural Lands

Sediment loads from agricultural lands tend to be elevated, due to the exposure of soil that occurs in agricultural practices. Cropland and pastureland are two sources of elevated sediment loads.

Developed Lands

Developed lands consist of both pervious and impervious surfaces. Impervious surfaces are not subject to soil erosion, but sediment loads may result from the washoff of solids deposited on impervious surfaces. Sediment loads from developed lands tend to be high. In addition, elevated levels of uncontrolled stormwater runoff from developed lands contributes to streambank erosion, as discussed below.

Water/Wetlands

The amount of sediment loading from water and wetland areas typically is not significant.

Barren Lands

Transitional lands represent areas of sparse vegetative cover, often due to land use types such as forest clear-cuts and construction lands. Due to increased levels of soil exposure, sediment loads from transitional lands typically are high.

6.1.2 Point Sources

Sediment loadings from point sources are attributable to the suspended solids present in discharge effluent. There are 13 individually permitted facilities currently active or under application within the Rivanna River Watershed. In addition, general permitted facilities which include municipal separate storm sewer systems (MS4s), industrial facilities, concrete facilities, quarries/mines, construction sites, car wash facilities, and single family domestic sewage permits are located within the benthic impaired watershed. MS4s transport stormwater runoff that is ultimately discharged into local rivers and streams without treatment. The City of Charlottesville, and portions of Albemarle County, are covered by MS4 permits which regulate their stormwater discharges. In addition, VDOT (Charlottesville and Albemarle), University of Virginia (Charlottesville), University of Virginia (Albemarle) and Piedmont Community College each have separate MS4 permits. Common pollutants from MS4s include trash, sediments, oil and grease from roadways, and pesticides from lawns. Combined, these MS4 permits cover approximately 9% of the Rivanna River benthic impaired watershed. There are an additional 64 facilities located in the watershed that have general permits issued to them, 46 of which are located within an MS4 area, 18 of which are located outside the MS4 area but within the watershed.

6.1.3 Instream Bank Erosion

Sediment loading derived from instream bank erosion is dependent upon numerous watershed characteristics. These include soils, physiographic information, and land use. Land use types found in the watershed may affect hydrology. In particular, large agricultural areas may lead to increased stream flows that erode the stream channel and banks. Likewise, watersheds defined by steep topography may experience high levels of runoff that cause instream erosion. The level of instream erosion is dependent on the erodibility of the soil, normally defined as the soil K factor. Since the Rivanna River

benthic impairment watershed contains a significant percentage of agricultural and forested lands, the overall amount of sediment generated by instream erosion would be expected to be high.

6.2 Estimating Sediment Loads

6.2.1 Non-Point Source Sediment

Using the Generalized Watershed Loading Functions (GWLF) model, the percent annual sediment loading from land erosion from each land use type is determined. GWLF is a time variable simulation model that simulates hydrology and sediment loadings on a watershed basis. Observed daily precipitation data is required in GWLF as the basis for water budget calculations. Surface runoff, evapotranspiration, and groundwater flows are calculated based on user-specified parameters. Stream flow is the sum of surface runoff and groundwater discharge. Surface runoff is computed using the Soil Conservation Service Curve Number Equation. Curve numbers are a function of soils and land use type. Evapotranspiration is computed based on the method described by Hamon (1961), and is dependent upon temperature, daylight hours, saturated water vapor pressure, and a cover coefficient. Groundwater discharge to the stream is described by a lumped-parameter watershed water balance for unsaturated and shallow saturated water zones. Infiltration to the unsaturated zone occurs when precipitation exceeds surface runoff and evapotranspiration. Percolation to the shallow saturated zone occurs when the unsaturated zone capacity is exceeded. The shallow saturated zone is modeled as a linear reservoir in order to calculate groundwater discharge. In addition, the model allows for seepage to a deep saturated zone. Erosion and sediment loading is a function of the land source areas present in the watershed. Multiple source areas may be defined based on land use type, the underlying soils type, and the management practices applied to the lands. Sediment loadings from each source area are summed to obtain a watershed total. The Universal Soil Loss Equation (USLE) is used to compute erosion for each source area. A sediment delivery ratio is applied to determine the sediment loadings to the stream (USLE, Wischmeier and Smith, 1978), and the USLE is expressed as:

$$A = R\ K\ LS\ C\ P$$

Where:

A =Average annual soil loss in tons per acre per year

R =Rainfall/runoff erosivity

K =Soil erodibility

LS = Field slope length and steepness

C =Cover/management factor

P =Conservation practice factor

The R factor is an expression of the erosivity of rainfall and runoff in the area of interest; the R factor increases as the amount and intensity of rainfall increases. The K factor represents the inherent erodibility of the soils in the area of interest under standard experimental conditions. The K factor is expressed as a function of the particle-size distribution, organic-matter content, structure, and permeability of the soils. The LS factor represents the effect of topography, specifically field slope length and steepness, on rates of soil loss at a particular site. The LS factor increases as field slope length and steepness increase due to the accumulation and acceleration of surface runoff as it flows in a down-slope direction. The C factor represents the effects of surface cover and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at the area of interest. The C factor decreases as surface cover and soil biomass increase. The P factor represents the effects of supporting conservation practices, such as contouring, buffer strips, and terracing, on soil loss at the area of interest.

6.2.2 Point Source Loadings

For the purpose of TMDL development, daily point source loadings for the 13 individually permitted facilities currently active or under application in the benthic impaired watershed were computed based on the average flow and the average total suspended solids concentration for each facility **(Table 6-1).** In instances where such data was not available for each facility, permitted or DEQ-approved values were used.

Table 6-1: Point Source Daily Loads in the Benthic Impaired Rivanna River Watershed

Permit #	Facility Name	Existing Load (lb/day)
VA0025488	Camelot STP	15.9
VA0025518	Moores Creek Regional STP	470.5
VA0027065	Cooper Industries	4.4
VA0028398	Avionics Specialties Inc	0.03
VA0029556	Blue Ridge School STP	0.5
VA0055000	Crozet WTP	2.4
VA0075981	Ramada Inn Monticello STP	0.6
VA0076244	Stone Robinson Elementary School	0.3
VA0080781	Ehart Subdivision STP	8.8
VA0085979	Keswick STP	1.2
VA0086584	Glenmore STP	3.8
VA0087351	Virginia Oil - Charlottesville	Discharges to MS4 VAR040051
VA0091120	North Rivanna WTP	16.3
	Total	**524.5**

Five areas within the Rivanna River watershed have Municipal Separate Storm Sewer (MS4) permits (**Previously shown in Table 2-3**). The MS4 permits state that the City of Charlottesville, VDOT, University of Virginia, Albemarle County, and Piedmont Virginia Community College are permitted to discharge into the Rivanna River impaired watershed. MS4 acreages were estimated using the Census Bureau data for urban areas and existing MS4 data for each jurisdiction. An in-depth description of MS4 load calculations is presented in **Section 6.4.2**.

There are an additional 64 facilities located in the watershed that have general permits issued, 46 of which are located within an MS4 area, 18 of which are located outside an MS4 area. The existing MS4 sediment loads shown in **Table 6-1** cover the entire MS4 urban areas. Therefore, implicit in the loads shown in **Table 6-1** are the loads from general stormwater permits issued to industrial facilities, domestic sewage facilities,

mines/quarries, concrete facilities, car wash facilities, and construction sites within the MS4 area. **Table 6-2** displays the 18 general permitted facilities located outside the MS4 areas and their existing loads. For a complete list of General Permitted Facilities in the watershed, see **Appendix A**.

Table 6-2: General Permitted Facilities Daily Loads in the Benthic Impaired Rivanna River Watershed

Category	Number of Permits	Land-Based Allocated Load (lbs/day)
Industrial Facilities	9	79.8
Concrete Facilities	0	0.0
Quarries/Mines	1	1.7
Construction Sites	5	1058.7
Car Wash Facilities	1	5.3
Single Family Domestic Sewage	2	0.5
Total	**18**	**1146.0**

6.2.3 Instream Erosion

Instream erosion in the Rivanna River was calculated using a spatial technique developed by Evans et al. (2003) that estimates streambank erosion based on watershed characteristics. Using this method, a watershed-specific lateral erosion rate is calculated as follows:

$$LER = aQ^{0.6}$$

Where:
LER = an estimated lateral erosion rate, expressed as meters per month
a = an empirically-derived "erosion potential factor"
Q = monthly stream flow, expressed as cubic meters per second.

The *'a'* factor is computed based on a wide variety of watershed parameters, including the fraction of developed area of the watershed, average field slope, mean soil erodibility (K factor), average curve number value, and the mean livestock density for the watershed.

$$a = (0.00147*PD) + (0.000143*AD) + (0.000001*CN)$$

$$+ (0.000425*KF) + (0.000001*MS) – 0.00016$$

Where:
PD = fraction developed land
AD = animal density measured in animal equivalent units/acre
CN = area-weighted runoff curve number value
KF = area-weighted K factor
MS = mean field slope

The fraction of developed land in the Rivanna River watershed was obtained from NLCD and DOF data. The average watershed curve number was developed based on curve numbers applied in the GWLF model. Livestock densities for the watershed were based on county livestock inventories.

LER values were calculated using predicted stream flow from the GWLF model. Monthly sediment loads from streambank erosion (kg/month) were then calculated as the product of the LER (meters/month), total stream length (meters), average streambank height (meters), and average soil bulk density (kg/m^3). The total stream length for the Rivanna River was obtained from the National Hydrography Dataset (NHD). Bank height and mean soil bulk density are based on values that were used to calculate instream erosion for a similar watershed. Annual sediment loads from streambank erosion were computed as the summation of monthly loads.

The computed instream bank erosion for the Rivanna River impaired watershed was found to be 28,327 lbs/day.

6.3 GWLF Model Setup and Calibration

6.3.1 GWLF Model Development

GWLF model simulations were performed for 1990 to 2006 in order to reflect the period of biomonitoring assessments that resulted in the impairment listing for the Rivanna River watershed. In addition, the 16 year simulation period accounts for both seasonal and annual variations in hydrology and sediment loading. The GWLF model also uses precipitation data from weather station Charlottesville 2w between 1990 and 2006, as

well as site-specific model parameters (i.e. land use, evapotranspiration, curve numbers, and erosion factors) for the benthic impaired watershed. The simulated flow from GWLF was calibrated based on USGS station 0203400. Model simulations were performed using BasinSim 1.0, which is a windows interface program for GWLF that facilitates the creation of model input files and processing of model results.

6.3.2 Weather Data

Daily precipitation and temperature data for the period of 1990-2006 were obtained from weather station Charlottesville 2w, and were used for model simulations. This weather station is located within the Rivanna River watershed, near the reference watersheds, and thus provided the most accurate precipitation and temperature coverage.

6.3.3 Model Input Parameters

In addition to weather data, GWLF requires specification of input parameters relating to hydrology, erosion, and sediment yield. In general, Appendix B of the GWLF manual (Haith et al., 1992) served as the primary source of guidance in developing input parameters.

Runoff curve numbers and USLE erosion factors are specified as an average value for a given source area. The land use types present in the watershed (shown previously in **Table 2-4**) were used to define model source areas. Therefore, a total of 14 source areas were defined in the model. Runoff curve numbers were developed for each model source area in the watershed based on values published in the NRCS Technical Release 55 (NRCS, 1986). STATSGO soils GIS coverages were analyzed to determine the dominant soil hydrologic groups for each model source area. Evapotranspiration cover coefficients were developed based on values provided in the GWLF manual (Haith et al., 1992) for each model source area. Average watershed monthly evapotranspiration cover coefficients were computed based on an area weighted method. Initialization and groundwater hydrology parameters were set to the default values recommended in the GWLF manual.

USLE factors for soil erodibility (K), length-slope (LS), cover and management (C), and supporting practice (P) were derived from multiple sources based on data availability.

Average KLSCP values for model source areas were determined based on GIS analysis of soils and topographic coverages, and on a literature review. The rainfall erosivity coefficient was determined based on values given in the GWLF manual. The sediment delivery ratio was computed internally by BasinSim 1.0.

Annual sediment loads generated from GWLF were calibrated based on annual sediment loads developed from the impaired watershed. The KLSCP and evapotranspiration cover coefficients were adjusted to obtain a best fit with observed data.

6.3.4 Hydrology Simulation

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings on a watershed basis. Designers of the model intended for it to be implemented without calibration. Nonetheless, comparisons were made between predicted and observed stream flows for the Rivanna River impaired and reference watersheds, in order to ensure the general validity of the model.

USGS station 2034000, located on the Rivanna River downstream from the impaired watershed, was selected for hydrology calibration based on the period of available monitoring data, its location in the watershed, and the proximity of the gage to the weather station used to develop the model precipitation inputs. Flow data from USGS gauging station 2034000 was modified to represent flow in the impaired watershed, using a multiplier based on the ratio between the USGS station watershed size and the impaired watershed size. **Figure 6-1** provides the location of the flow gage and weather station in relation to the Benthic Impaired Rivanna River Watershed.

GWLF parameters relating to hydrology were calibrated based on the modified Rivanna River flow data collected at USGS Station 2034000. The groundwater seepage coefficient and the unsaturated zone available water capacity were adjusted to obtain a best fit with observed data.

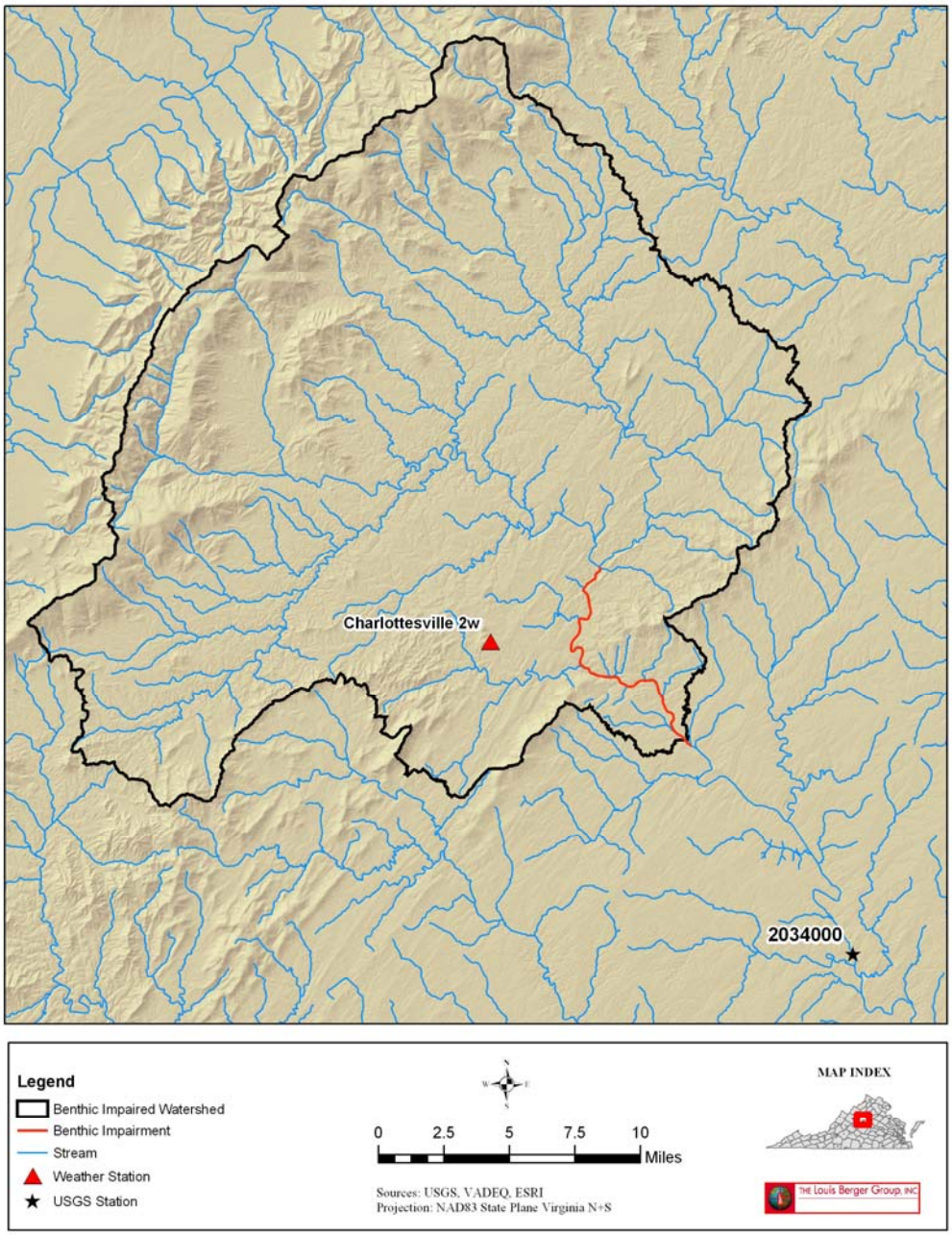


Figure 6-1: Location of Weather and Flow Gages Used in Model Development

6.4 Sediment Load Estimates

6.4.1 Sediment Loads from Non-Point Sources

The model was used to estimate the percentage of sediment loading contributed by each land use type in the benthic impaired Rivanna River Watershed. The existing land-based

daily sediment loads for each land use type were computed by applying these percentages to the total load developed using the sediment load duration curves. These non-point source loads are presented below in **Table 6-3.**

Table 6-3: Land Based Non-Point Sediment Load in the Benthic Impaired Rivanna River Watershed by Land Use Type

Source	Land Use Type	Existing Load (lbs/day)
Non-Point Source	Forest	164
	Row Crop	14,654
	Pasture	15,829
	High Intensity Residential	2,292
	Low Intensity Residential	225
	Instream Erosion	20,900
	Total	**54,063**

The existing conditions loads of 58,884 lbs/day falls into a moist-conditions flow regime using the load duration curves developed in Section 5-3. Therefore for the purposes of this TMDL, the impaired and non-impaired daily loads for the moist-conditions flow regime are used to determine the endpoint and necessary reductions. Consequently, the daily sediment load in the benthic impaired segment of Rivanna River needs to be reduced by 45.1% to be considered non-impaired (**Table 5-1**).

6.4.2 Sediment Loads from Point Sources

Existing sediment loads from individually permitted facilities within the watershed are described in **Section 6.2.2**.

To separate sediment loading attributed to the MS4s from other land-based sediment loading, an area weighted sediment load was determined for the MS4s, in which the percentage of sediment loading from each source area attributed to the MS4s was proportional to the percentage of that source area in the Rivanna River impaired watershed covered by the various MS4 permits. The MS4 acres and land-based sediment

loads currently in the watershed are shown in **Table 6-4**. Stormwater runoff from MS4s resulted in increased streambank erosion. Bank erosion resulting from MS4 stormwater runoff, and bank erosion resulting from overland runoff, were separated using a runoff weighted approach. Using this approach, the MS4 flow was calculated as a percentage of the total watershed flow, and used to calculate the bank erosion load for the MS4 areas.

Table 6-4: Land Based Non-Point Sediment Load in the Benthic Impaired Rivanna River Watershed by MS4 Area

Permit Number	MS4 Permit Holder	Existing Land Based Load (lbs/day)
VAR040051	City of Charlottesville	477
VAR040033	VDOT Charlottesville Major Roads	5
VAR040073	University of Virginia (Charlottesville)	17
	University of Virginia (Albemarle)	70
VAR040074	Albemarle County	1,606
VAR040033	VDOT Albemarle Roads	41
Application	Piedmont Community College	7
Instream Erosion		6,545
Total		**8,768**

6.4.3 Sediment Loads from Instream Erosion

Instream erosion was estimated based on the streambank lateral erosion rate equation introduced by Evans et al. (2003), as described in Section 6.2.3. The daily sediment loads for instream erosion are presented in **Table 6-5**.

Table 6-5: Existing Land Based and Instream Erosion Sediment Load in the Benthic Impaired Rivanna River Watershed

Source	Land Based Load (lbs/day)	Instream Erosion Load (lbs/day)	Existing Total Load (lbs/day)
Land-Based (NPS)	33,164	20,900	54,063
MS4	2,223	6,545	8,768
General Permitted	1,146	882	2,028
Total	**36,533**	**28,327**	**64,860**

7.0 TMDL Allocation

The purpose of TMDL allocation is to quantify the pollutant load reductions necessary for each source to achieve water quality standards. Sediment was identified as the primary stressor to the benthic community in the Rivanna River impaired watershed and a modified reference watershed approach was used for TMDL development. The load duration curve based on the non-impaired stations (**Figure 5-3** and **Table 5-1**) represents the TMDL endpoint for the Rivanna River impaired watershed at various flow regimes. Reduction of sediment loading in the impaired watershed to the level computed for the non-impaired sediment loading curve is expected to restore support of the aquatic life use for Rivanna River.

7.1 Basis for TMDL Allocations

Sediment TMDL allocations for the Rivanna River impaired watershed were based on the following equation.

$$TMDL = WLA + LA + MOS$$

Where:

TMDL= Total Maximum Daily Load (Based on the Sediment Load of the Area-Adjusted Reference Watershed)

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The wasteload allocation represents the total sediment loading allocated to point sources. The load allocation represents the total sediment loading allocated to non-point sources. The margin of safety is a required TMDL element to account for uncertainties in TMDL development.

7.1.1 Margin of Safety

An explicit margin of safety of 10% was used for the Rivanna River to account for uncertainties in the methodologies used to determine sediment loadings.

7.1.2 Wasteload Allocation

The daily wasteload allocated to point sources in the watershed was based on the design flow and the maximum permitted concentration of total suspended solids for each facility, as shown in **Table 7-1**. The yearly wasteload allocated to point sources in the watershed was based on the design flow and the permitted average TSS concentration for each facility (**Table 7-1**). In cases were a facility did not have a TSS limit or design flow, a DEQ approved value was used.

Table 7-1: Point Source Wasteload Allocations for the Benthic Impaired Rivanna River Watershed

Permit #	Facility Name	Existing Daily Load (lbs/day)	Allocated Daily Load (lbs/day)	Allocated Yearly Load (lbs/year)
VA0025488	Camelot STP	15.9	137.1	3.34E+04
VA0025518	Moores Creek Regional STP	470.5	4,131.7	1.01E+06
VA0027065	Cooper Industries	4.4	16.5	3.02E+03
VA0028398	Avionics Specialties Inc	.03	0.8	1.83E+02
VA0029556	Blue Ridge School STP	0.5	13.1	3.20E+03
VA0055000	Crozet WTP	2.4	93.2	1.70E+04
VA0075981	Ramada Inn Monticello STP	0.6	15.0	3.66E+03
VA0076244	Stone Robinson Elementary School	0.3	2.6	6.40E+02
VA0080781	Ehart Subdivision STP	8.8	13.1	3.20E+03
VA0085979	Keswick STP	1.2	37.3	9.05E+03
VA0086584	Glenmore STP	3.8	143.1	3.48E+04
VA0087351	Virginia Oil - Charlottesville	-	-	Discharges to MS4 VAR040051
VA0091120	North Rivanna WTP	16.3	32.6	5.94E+03
	Total	**524.5**	**4636.0**	**1.12E+06**

The City of Charlottesville, as well as portions of Albemarle County, VDOT Charlottesville road areas, the University of Virginia, and Piedmont Virginia Community College are covered by MS4 permits, which are included in the wasteload allocations. As discussed in Section 6.0, land-based loads were allocated to the MS4 based on an area weighted method. **Table 7-2** presents the contribution of sediment from stormwater sources regulated under the municipal separate storm sewer system (MS4) program. As presented in **Table 7-2**, a 59.3 percent reduction in land-based sources and instream erosion allocated to the MS4s is required to achieve the TMDL endpoint. Wasteload

allocations were based on an equal percent reduction from controllable sources. Loads from forested lands within the MS4 areas are not subject to reduction.

Table 7-2: Wasteload Allocation by MS4 Location[#] Within the Rivanna River Benthic Impaired Watershed

Permit Number	MS4 Permit Holder	Land-Based Loads (lbs/day)	Instream Erosion (lbs/day)	Existing Total Load (lbs/day)	Allocated Load (lbs/day)	Percent Reduction*
VAR040051	City of Charlottesville	477	1,406	1,883	776	59.3
VAR040033	VDOT Charlottesville Major Roads	5	14	18	7	59.3
VAR040073	University of Virginia (Charlottesville)	17	49	65	27	59.3
	University of Virginia (Albemarle)	70	206	277	112	59.3
VAR040074	Albemarle County	1,606	4,729	6,335	2,576	59.3
VAR040033	VDOT Albemarle Roads	41	121	162	66	59.3
Application	Piedmont Virginia Community College	7	21	29	12	59.3
Total		2,223	6,545	8,768	3,565	59.3

(*) The percent load reduction for the MS4s accounts for loads from all land sources including forested areas.

(#) MS4 loads include loads from general stormwater permits issued to industrial facilities, domestic sewage facilities, mines/quarries, concrete facilities, and construction sites.

The MS4 sediment allocations shown in **Table 7-2** cover the entire MS4 urban area. Therefore, implicit in the loads shown in **Table 7-2** are the loads from general stormwater permits issued to industrial facilities, domestic sewage facilities, mines/quarries, concrete facilities, car wash facilities, and construction sites within the MS4 area. For a list of general permits located within each MS4, please see **Appendix A**.

Table 7-3 presents the sediment wasteload allocation for the sources regulated under general permits which are located within the watershed, but outside the MS4 areas. The wasteload allocation for each general stormwater permit is presented in **Appendix A**.

Construction sites are based on those sites whose general locations and areas were provided by VA DEQ. There are no concrete facilities currently existing outside the MS4 areas, in the benthic impaired watershed.

Table 7-3: Wasteload Allocation Outside MS4 Areas in the Rivanna River Benthic Impaired Watershed

Category	Number of Permits	Land-Based Allocated Load (lbs/day)	Instream Erosion (lbs/day)	Total Allocated Load (lbs/day)
Industrial Facilities	9	80	61	141
Concrete Facilities	0	0	0	0
Quarries/Mines	1	2	1	3
Construction Sites	5	1,059	815	1,874
Car Wash Facilities	1	5	4	9
Single Family Domestic Sewage	2	1	0	1
Total	**18**	**1,146**	**882**	**2,028**

The total wasteload allocation includes loading from individually permitted point sources and general stormwater permit sources. All the general stormwater permit sources are aggregated by category based on the type of permit (e.g. MS4s, industrial facilities, concrete facilities, quarries/mines, construction sites, car wash facilities, and single family domestic sewage permits) in **Table 7-4**. The wasteload allocation computed for each general stormwater permit category shall be allocated to the individual permit holders at the discretion of the permitting regulatory agency through the issuance of VPDES stormwater permits.

Table 7-4: Wasteload Allocation Summary

WLA Category	Existing Load (lbs/day)	Allocated Load (lbs/day)
Point Source	524	4,636
MS4	8,768	3,565
Industrial Facilities	141	141
Concrete Facilities	0	0
Quarries/Mines	3	3
Construction Sites	1,874	1,874
Car Wash Facilities	9	9
Single Family Domestic Sewage	1	1
Total	**11,321**	**10,229**

7.1.3 Load Allocation

Load allocations for non-point sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Loads from forested lands are considered to be representative of the natural condition and therefore were not subject to reductions. The existing and allocated sediment loads for each non-point source in the Rivanna River impaired watershed are presented in **Table 7-5**. In addition, the necessary percent reduction is shown for each source.

Table 7-5: Load Allocations Summary for Rivanna River

Source	Land Use Type	Existing Load (lbs/day)	Allocated Load (lbs/day)
Non-point Source	Forest	164	164
	Row Crop	14,654	5,958
	Pasture/Hay	15,829	6,435
	High Intensity Residential	2,292	932
	Low Intensity Residential	225	91
	Instream Erosion	20,900	8,497
	TOTAL	**54,063**	**22,077**

7.2 Overall Recommended TMDL Allocations

The total load, wasteload allocations, and margin of safety for Rivanna River are summarized in **Table 7-6** and **Table 7-7**. Recommended allocations for each source in the watershed are provided in **Table 7-8**. Overall, the sediment load in the Rivanna River watershed must be reduced by 45.1% in order to meet the established TMDL endpoint.

Table 7-6: Sediment TMDL for Rivanna River (lbs/day)

TMDL	Load Allocation	Wasteload Allocation	Margin of Safety (10%)
35,896	22,007	10,229	3,590

Table 7-7: Sediment TMDL for Rivanna River (lbs/year)

TMDL	Load Allocation	Wasteload Allocation	Margin of Safety (10%)
1.31E+07	8.06+06	3.73E+06	1.31E+06

Table 7-8: Summary of Existing and Allocated Sediment Loads for the Rivanna River Watershed

Source	Land Use Type	Existing Load (lbs/day)	Allocated Load (lbs/day)	Percent Reduction (%)
Non-Point Source	Forest	164	164	-
	Row Crop	14,654	5,958	59.3
	Pasture/Hay	15,829	6,435	59.3
	High Intensity Residential	2,292	932	59.3
	Low Intensity Residential	225	91	59.3
	Instream Erosion	20,900	8,497	59.3
MS4	Land-based	2,223	904	59.3
	Instream Erosion	6,545	2,661	59.3
General Permits Outside MS4 Area	Land-based	1,146	1,146	-
	Instream Erosion	882	882	-
Point Source	Individual VPDES Permits	524	4,636	-
MOS			3,590	
	Total	**65,384**	**35,896**	**45.1**

7.3 Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that designated uses are protected throughout the year, including vulnerable periods.

In the case of the Rivanna River, the primary stressor resulting in the benthic impairment in the river is excessive sediment loading, which has led to siltation and the loss of benthic habitat. On an average daily basis, land-based sources and in-stream erosion account for 99.2% of the total sediment load to the stream; this includes non-point source loading, and loading attributed to the general permits (MS4s, industrial facilities, concrete facilities, quarries/mines, construction sites, car wash facilities, and single family domestic sewage permits) in the watershed. Point source facilities contribute only .8% of the sediment load, based on the average TSS concentrations and design flows for

permitted facilities. Therefore, most of the sediment load is delivered under high flow conditions associated with stormwater runoff.

7.4 Consideration of Seasonal Variability

Seasonal variations involve changes in stream flow and sediment loading as a result of hydrologic and climatological patterns. Seasonal variations were explicitly incorporated in the modeling approach for this TMDL. GWLF is a continuous simulation model that incorporates seasonal variations in hydrology and sediment loading by using a daily time-step for water balance calculations. Therefore, the 10 year simulation performed with GWLF adequately captures seasonal variations.

8.0 TMDL Implementation

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

8.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

8.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

8.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

8.3.1 Treatment Plants

This TMDL does not require reductions from municipal or industrial treatment plants.

8.3.2 Stormwater

DEQ and DCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. DEQ regulates stormwater

discharges associated with industrial activities through its VPDES program, while DCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

Municipal Separate Storm Sewer Systems – MS4s

For MS4/VSMP permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the iterative implementation of programmatic BMPs. BMP effectiveness would be determined through permittee implementation of an individual control strategy that includes a monitoring program that is sufficient to determine its BMP effectiveness. As stated in EPA's Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002, "The NPDES permits must require the monitoring necessary to assure compliance under the permit limits". Ambient in-stream monitoring would not be an appropriate means of determining permit compliance. Ambient monitoring would be appropriate to determine if the entire TMDL is being met by ALL attributed sources. This is in accordance with recent EPA guidance. If future monitoring indicates no improvement in the quality of the regulated discharge, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. Any changes to the TMDL resulting from water quality standards changes on the Rivanna River would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed as a condition of the MS4 permit. An implementation plan will identify types of corrective actions and strategies to obtain the load allocation for the pollutant causing the water quality impairment. Permittees will be required to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL. For example, MS4 permittees regulate erosion and sediment control programs that affect discharges that are not regulated by the MS4 permit.

Additional information on Virginia's Stormwater program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm.

Active Coal Mining Operations

In November 2005, the Department of Mines, Minerals and Energy, Division of Mined Land Reclamation issued Guidance Memorandum No. 14-05 to address the implementation of coal mining-related TMDL wasteload allocations. The memorandum can be accessed on DEQ's TMDL web page, http://www.deq.virginia.gov/tmdl. As of December 1, 2005 the Division of Mined Land Reclamation (Division) has been implementing the steps outlined in the memorandum regarding permit applications in watersheds with adopted benthic Total Maximum Daily Loads (TMDLs). A brief summary is provided below.

Generally, a BMP approach will be used in Virginia to meet WLAs in lieu of altered effluent limitations for permitted coal mine point source discharges. DMME's TMDL coordinator will track assigned and available WLAs. Prior to approval of new NPDES points within a TMDL watershed, the Division Water Quality staff will confer with the TMDL coordinator and/or consult the WLA information folder to determine that a WLA is available. Applications that involve NPDES discharge points within TMDL watersheds with total dissolved solids (TDS) WLAs shall include a plan to monitor TDS and conductivity at designated outfalls. The monitoring should be designed to assess TDS loading, but shall not include the assignment of effluent limits. The TMDL

coordinator and Water Quality staff will use the monitoring to track loadings and evaluate conformity with the adopted TMDL. Loadings for other WLAs will be tracked using results of routine NPDES monitoring. When tracking indicates that WLAs are being exceeded, the Division will request the permittee to revise the BMPs to reduce wasteloads.

8.3.3 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, DEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on DEQ's web site at http://www.deq.virginia.gov/waterguidance/.

8.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

8.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters".

The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

8.4.2 Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in section 8.6, Attainability of Designated Uses.

8.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed. Currently, there are various organizations dedicated to protection and restoration of the Rivanna River. Among these are Stream Watch, the Rivanna Conservation Society, the Thomas Jefferson Planning District Commission, and the Nature Conservancy.

Stream Watch's main goal is to maintain, protect and ultimately improve the water quality of rivers and the Rivanna River Basin. The Stream Watch program was designed to provide the community with scientific data and information on current conditions of the watershed. This is to be accomplished through monitoring, data consolidation, and information development and distribution. The Rivanna Conservation Society, the Thomas Jefferson Planning District Commission, and the Nature Conservancy are all partners of the Stream Watch organization.

The Rivanna Conservation Society is a non-profit organization located in Charlottesville, VA and is devoted to the restoration and preservation of the Rivanna River. Their main goal is to protect the aesthetic, biological and recreational values of the Rivanna River

and watershed. Conservation efforts are carried out through members, volunteers, donations, and corporate and government grants.

The Thomas Jefferson Planning District Commission strives to promote sustainable solutions to regional issues. This commission is devoted to district 10, which encompasses the city of Charlottesville, VA and includes the Rivanna River. Their main effort is the Rivanna River Basin Project whose overall goal is to gather biological information regarding the past and current conditions of the river in order to develop strategies to improve water quality and community enjoyment.

The Nature Conservancy in Virginia is committed to protecting the biological integrity of the local nature and wildlife areas. The Nature Conservancy recently banded together with local communities to establish the Rivanna River Basin Commission. Authorized in 2004, the Commission's role, once funding is secured, will be to develop and publicize comprehensive scientific information to the community and local governments.

8.4.4 Implementation Funding Sources

The implementation on pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia

Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at http://www.dcr.virginia.gov/sw/wqia.htm.

8.5 Follow-Up Monitoring

Following the development of the TMDL, DEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan

prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year. See **Table 8-1** for the location of active water quality monitoring stations in the Benthic Impaired Rivanna River Watershed.

Table 8-1: Active Water Quality Monitoring Stations in the Benthic Impaired Rivanna River Watershed

Station ID[1]	Station Description	Stream Name
2-RVN037.54	0.4 miles upstream of Barn Branch	Impaired Segment
2-RVN033.65	Old Rt. 729 bridge site	
2-RRS003.12	South Fork @ Polo Grounds	South Fork Rivanna River
2-RRN002.19	North Fork @ 649 - B	North Fork Rivanna River
2-MWC000.60	Holmes Avenue Bridge	Meadow Creek
2-MSC000.60	RWSA STP bridge	Moores Creek

[1]Note: The last 5 digits of the DEQ station number corresponds to stream mile.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring

managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

8.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment during this process. Additional information can be obtained athttp://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation would be for the reductions of all controllable sources to the maximum extent practicable using the implementation approaches described above. DEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and

no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed".

9.0 Public Participation

The development of the Rivanna River benthic TMDL would not have been possible without public participation. Four technical advisory committee (TAC) meetings and two public meetings were held within the watershed. The following is a summary of the meetings.

TAC Meeting No. 1: The first TAC meeting was held on November 8, 2006 at the Scottsville Town Council Chambers in Scottsville, Virginia to present and review the steps and the data used in the development of the benthic TMDL for the Rivanna River listed segments.

TAC Meeting No. 2: The second TAC meeting was held on June 6, 2007 at the Albemarle County Office Building in Charlottesville, Virginia to discuss the stressor identification for the benthic impaired Rivanna River.

TAC Meeting No. 3: The third TAC meeting was held on October 4, 2007 at the Education Building at the Ivy Creek Natural Area in Charlottesville, Virginia to review the stressor identification and discuss technical approaches for developing a numerical TMDL endpoint for the Rivanna River benthic TMDL.

TAC Meeting No. 4: The fourth TAC meeting was held on December 13, 2007 at the Albemarle County Office Building in Charlottesville, Virginia to present the Sediment Rating Curves, Sediment Load Duration Curves, and GWLF Model Results, and the Numerical Sediment Endpoint/Target for the benthic impaired Rivanna River.

Public Meeting No. 1: The first public meeting was held in on March 15, 2007 at the Albemarle County Office Building in Charlottesville, Virginia to present the process for TMDL development of the benthic impaired Rivanna River forty-five people attended the meeting. Copies of the presentation were available for public distribution. This meeting was publicly noticed in the *Virginia Register*. Written comments were received from the Rivanna Conservation Society during the 30-day comment period, and DEQ responded to these comments.

Public Meeting No. 2: The second public meeting was held on February 11, 2008 at the Albemarle County Office Building in Charlottesville, Virginia to present the results of the TMDL study. This meeting was publicly noticed in the Virginia Register and advertised by the Thomas Jefferson Planning District Commission. Twenty-nine people attended the meeting. Copies of the presentation and the Rivanna TMDL Executive Summary were made available at the meeting. The full TMDL report was made available on the DEQ website. Three sets of written comments were received during the 30-day comment period, which were responded to by VADEQ.

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APPENDIX A: General Permit Stormwater TMDL Allocations

The land-based allocated load for each permitted facility was calculated using a DEQ assigned TSS concentration and the corresponding runoff amount generated on the site based on the facility area or the facility discharge. The land-based allocated load for each permit type was calculated as follows:

- For individual permitted facilities and general stormwater permits issued to industrial facilities the allocated load was calculated based on a TSS concentration of 100 mg/L, and 72.54 cm of runoff per year. The annual average runoff of 72.54 cm corresponds to an annual average rainfall of 40.8 inches (103.63 cm) and an industrial land cover with 70 percent imperviousness. The facility area was assumed to be 5 acres of impervious surface for each permittee.

$$Q_{sed}(lbs/day) = 5(acres)\frac{4{,}046.87m^2}{acre} x \frac{0.7254\,m\,runoff}{yr} x \frac{1000\,liter}{m^3} x \frac{100\,mg}{liter} x \frac{kg}{10^6\,mg} x \frac{2.204\,lbs}{kg} x \frac{yr}{365 days}$$

- For general permits issued to concrete facilities and quarries/mines, the allocated load was calculated based on a TSS concentration of 30 mg/L, and 45.9 cm of runoff per year. The facility area was assumed to be 5 acres for each facility.

$$Q_{sed}(lbs/day) = 5(acres)\frac{4{,}046.87m^2}{acre} x \frac{0.459\,m\,runoff}{yr} x \frac{1000\,liter}{m^3} x \frac{30\,mg}{liter} x \frac{kg}{10^6\,mg} x \frac{2.204\,lbs}{kg} x \frac{yr}{365\,days}$$

- For general permits issued to construction sites, the allocated load was calculated based on a TSS concentration of 685 mg/L[1] and 45.9 cm of runoff per year. The area for each facility is based on the permitted disturbed area of the construction site.

$$Q_{sed}(lbs/day) = permitted(acres)\frac{4{,}046.87m^2}{acre} x \frac{0.459\,m\,runoff}{yr} x \frac{1000\,liter}{m^3} x \frac{685\,mg}{liter} x \frac{kg}{10^6\,mg} x \frac{2.204\,lbs}{kg} x \frac{yr}{365\,days}$$

- For general permits issued to car washes the allocated load was calculated based on a TSS concentration of 60 mg/L, and 72.54 cm of runoff per year. The annual average runoff of 72.54 cm corresponds to an annual average rainfall of 40.8 inches (103.63 cm) and an industrial land cover with 70 percent imperviousness. The facility area was assumed to be 5 acres of impervious surface for each permittee.

[1] Based on estimates found in *Environmental Assessment for Proposed Effluent Guidelines and Standards for the Construction and Development Category*, EPA, 2002.

$$Q_{sed}(lbs/day) = 5(acres)\frac{4{,}046.87m^2}{acre} x \frac{0.7254\,m\,runoff}{yr} x \frac{1000\,liter}{m^3} x \frac{60\,mg}{liter} x \frac{kg}{10^6\,mg} x \frac{2.204\,lbs}{kg} x \frac{yr}{365days}$$

- For general permits issued to domestic sewage facilities, the allocated load was calculated based on a TSS concentration of 30 mg/L and a discharge flow value of 1,000 gpd.

$$Q_{sed}(lbs/day) = 1000\frac{gallons}{day} x \frac{3.785\,liter}{gallon} x \frac{30\,mg}{liter} x \frac{kg}{10^6\,mg} x \frac{2.204\,lbs}{kg}$$

Table D-1: TMDL Allocations for General Permits Issued to Industrial Facilities

Permit	Facility Name	Receiving Stream	Land-Based Allocated Load (lbs/day)
VAR051387	Moores Creek Regional STP	Moores Creek	Discharges to MS4 VAR040074
VAR050793	J Bruce Barnes Inc	Lickinghole Creek	Discharges to MS4 VAR040074
VAR050932	USPS - Charlottesville Vehicle Maintenance Facility	Meadow Creek, UT	Discharges to MS4 VAR040051
VAR050965	Harry A Wright's Inc	Rivanna River	Discharges to MS4 VAR040051
VAR051372	University of VA - Parking and Transportation Department	Meadow Creek	Discharges to MS4 VAR040051
VAR051402	LexisNexis	Rivanna River	Discharges to MS4 VAR040051
VAR051403	Charlottesville Transit Service	Schenks Branch	Discharges to MS4 VAR040051
VAR050974	BFI Waste Services - Charlottesville	Moores Creek, UT	Discharges to MS4 VAR040074
VAR050876	Sperry Marine	Meadows Creek, UT	Discharges to MS4 VAR040074
VAR050785	Badger Fire Protection	NF Rivanna River	Discharges to MS4 VAR040074
VAR050503	Charlottesville-Albemarle Airport	Flat Branch, UT	Discharges to MS4 VAR040074
VAR050933	S. L. Williamson - Shadwell Asphalt Plant	Barn Branch, UT	8.9
VAR050780	United Parcel Service - Charlottesville	Barn Branch	8.9
VAR051507	Faulconer Const Co Office/Maintenance Facil	Little Ivy Creek, UT	8.9
VAR051618	Greene County Materials Recovery Facility	Quarter Creek UT	8.9
VAR050948	R A Yancey Lumber Corporation	Stockton Creek, UT	8.9
VAR050960	M & M Service & Salvage Yard Inc	Welsh Run	8.9
VAR050973	Ivy Materials Utilization Center	Broad Axe Creek	8.9
VAR051730	CARR Service Center	Preddy Creek	8.9
VAR050931	Mountain Lumber Company Inc	Preddy Creek, UT	8.9
		Total	**79.8**

Table D-2: TMDL Allocations for General Permits Issued to Concrete Facilities			
Permit	**Facility Name**	**Receiving Stream**	**Land-Based Allocated Load (lbs/day)**
VAG110064	Allied Concrete Company - Charlottesville	Schenks Branch, UT	Discharges to MS4 VAR040051
VAG111032	HT Ferron Company	Moores Creek	Discharges to MS4 VAR040051
VAG110184	Colonial Concrete-Charlottesville	Flat Branch UT	Discharges to MS4 VAR040074

Table D-3: TMDL Allocations for General Permits Issued to Quarries/Mines			
Permit	**Facility Name**	**Receiving Stream**	**Land-Based Allocated Load (lbs/day)**
VAG840037	Luck Stone - Charlottesville Plant	Rivanna River, UT	1.7

Table D-4: TMDL Allocations for General Permits Issued to Construction Sites		
Permit	**Facility**	**Land-Based Allocated Load (lbs/day)**
DCR-06-102123	C. W. Hurt Contractors, LLC	Discharges to MS4 VAR040073
DCR-07-100002	W. C. English, Inc.	Discharges to MS4 VAR040051
DCR-07-100223	Ontour Construction	Discharges to MS4 VAR040074
DCR-07-100143	Choco Cruz, LLC	Discharges to MS4 VAR040051
DCR-06-102237	Habitat for Humanity of Greater Charlottesville	Discharges to MS4 VAR040051
DCR-06-101976	Fritz Ballard	Discharges to MS4 VAR040073
DCR-05-100037	Martin/Horn, Inc.	Discharges to MS4 VAR040051
DCR-05-100352	Carolina Green Corporation	Discharges to MS4 VAR040051
DCR-05-100376	Branch Highways, Inc.	Discharges to MS4 VAR040073
DCR-06-101551	C.W. Hurt Contractors, LLC	Discharges to MS4 VAR040074
DCR-07-100228	General Excavation, Inc.	Discharges to MS4 VAR040074
DCR-07-100239	General Services Project Mgr./County of Albemarle	Discharges to MS4 VAR040074
DCR-06-102352	C.W. Hurt Contractors, LLC	Discharges to MS4 VAR040074
DCR-06-102410	Church Hill Development, LLC	Discharges to MS4 VAR040074
DCR-06-102426	W.M. Jordan	Discharges to MS4 VAR040074
DCR-06-101252	C.W. Hurt Contractors, LLC	Discharges to MS4 VAR040074
DCR-06-101925	R.E. & Son, Inc.	Discharges to MS4 VAR040074
DCR-06-101302	Worrell Land and Development Company, LLC	Discharges to MS4 VAR040074
DCR-06-101300	Chick-fil-A, Inc.	Discharges to MS4 VAR040074
DCR-06-101463	R.E. Lee and Sons, Inc.	Discharges to MS4 VAR040074
DCR-06-102147	Shiflett Farm, LLC/Stonehaus Development	Discharges to MS4 VAR040074
DCR-07-100486	Weather Hill Development, LLC	Discharges to MS4 VAR040074
DCR-06-101747	Marcia Joseph	Discharges to MS4 VAR040051
DCR-06-101771	General Excavation, Inc.	Discharges to MS4 VAR040074
DCR-07-100374	Huntley of Charlottesville Ltd.	Discharges to MS4 VAR040051
DCR-06-101225	Terra Engineering and Land Solutions, PC	Discharges to MS4 VAR040051
DCR-06-101226	Terra Engineering and Land Solutions, PC	Discharges to MS4 VAR040051
DCR-06-102251	KG Associates	Discharges to MS4 VAR040051

Table D-4: TMDL Allocations for General Permits Issued to Construction Sites		
DCR-06-102229	NVR, Inc. dba Ryan Homes	Discharges to MS4 VAR040051
DCR-06-102228	NVR, Inc. dba Ryan Homes	Discharges to MS4 VAR040074
DCR-06-100348	Shiflett Farm, LLC c/o Stonehaus Development	Discharges to MS4 VAR040074
DCR-06-101918	NVR, Inc. dba Ryan Homes	Discharges to MS4 VAR040074
DCR-07-100514	Kjellstrom & Lee Construction	36.9
DCR-06-102219	Tom Garrison	33.0
DCR-06-100504	Basheer/Edgemoore-Whitehall, L.L.C.	475.6
DCR-06-100373	Gaylon Beights	225.9
DCR-06-101858	Gaylon Beights	287.4
	Total	**1058.7**

Table D-5: TMDL Allocations for General Permits Issued to Car Washes			
Permit	**Facility**	**Receiving Stream**	**Land-Based Allocated Load (lbs/day)**
VAG750045	Vehicle Maintenance Facility	Ivy Creek, UT	5.3

Table D-6: TMDL Allocations for General Permits Issued to Single Family Domestic Sewage			
Permit	**Facility**	**Receiving Stream**	**Land-Based Allocated Load (lbs/day)**
VAG401839	Twin Lakes Subdivision Residence - Lot	Lake Skyline	0.3
VAG401840	Twin Lakes Subdivision Residence - Lot	Lake Shenandoah, UT	0.3
		Total	**0.5**

Table D-7: Land-Based Existing Load by MS4 Area		
Permit Number	**MS4 Permit Holder**	**Land-Based Existing Load (lbs/day)**
VAR040051	City of Charlottesville	477
VAR040033	VDOT Charlottesville Major Roads	5
VAR040073	University of Virginia (Charlottesville)	17
	University of Virginia (Albemarle)	70
VAR040074	Albemarle County	1,606
VAR040033	VDOT Albemarle Roads	41
Application	Piedmont Community College	7
Total		**2,223**