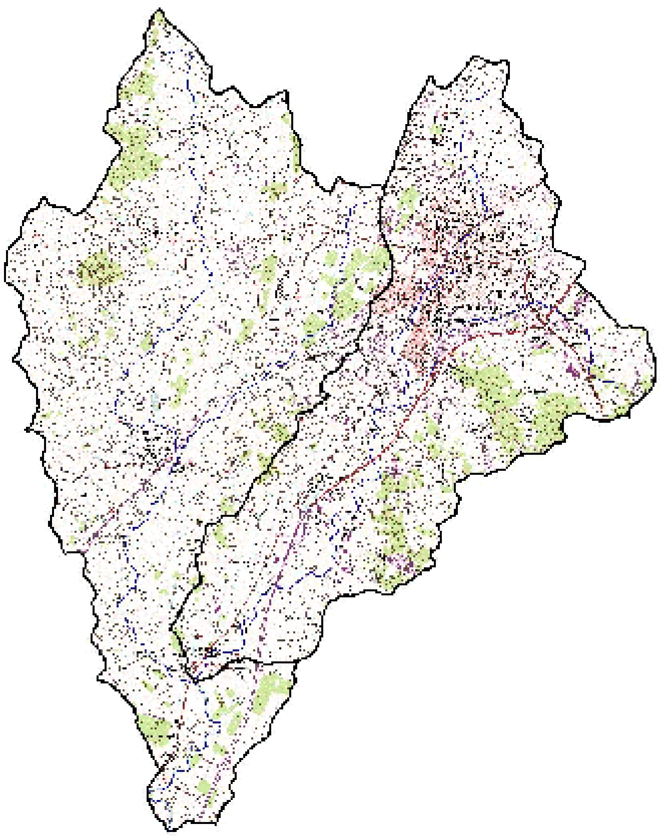
Total Maximum Daily Load (TMDL) Development for Blacks Run and Cooks Creek

Aquatic Life Use (Benthic) Impairment



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SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991a).

1.1.2 Impairment Listing

Blacks Run and Cooks Creek are listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's water quality standards for fecal coliform bacteria and violations of the General Standard (Benthics) (VADEQ 1998). The Cooks Creek segment begins at its headwaters and continues to its confluence with the North River (13.32 miles in length). The Blacks Run segment begins at its headwaters and ends at its confluence with Cooks Creek (10.74 miles in length). This report will address the benthic community impairments on Blacks Run and Cooks Creek. The Cooks Creek fecal coliform bacteria TMDL is presented in a companion report.

A TMDL for fecal coliform bacteria on Blacks Run is being developed concurrently by the United States Geological Survey (USGS) under a separate contract.

1.1.3 Watershed Location

Blacks Run and Cooks Creek are located in Rockingham County, Virginia in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005) (Figure 1.1). The waterbody identification codes (WBID, Virginia Hydrologic Unit) for the Blacks Run and Cooks Creek watersheds are VAV-B26R and VAV-B25R, respectively (VADEQ 1998). Blacks Run drains much of the City of Harrisonburg and is the major tributary to Cooks Creek.

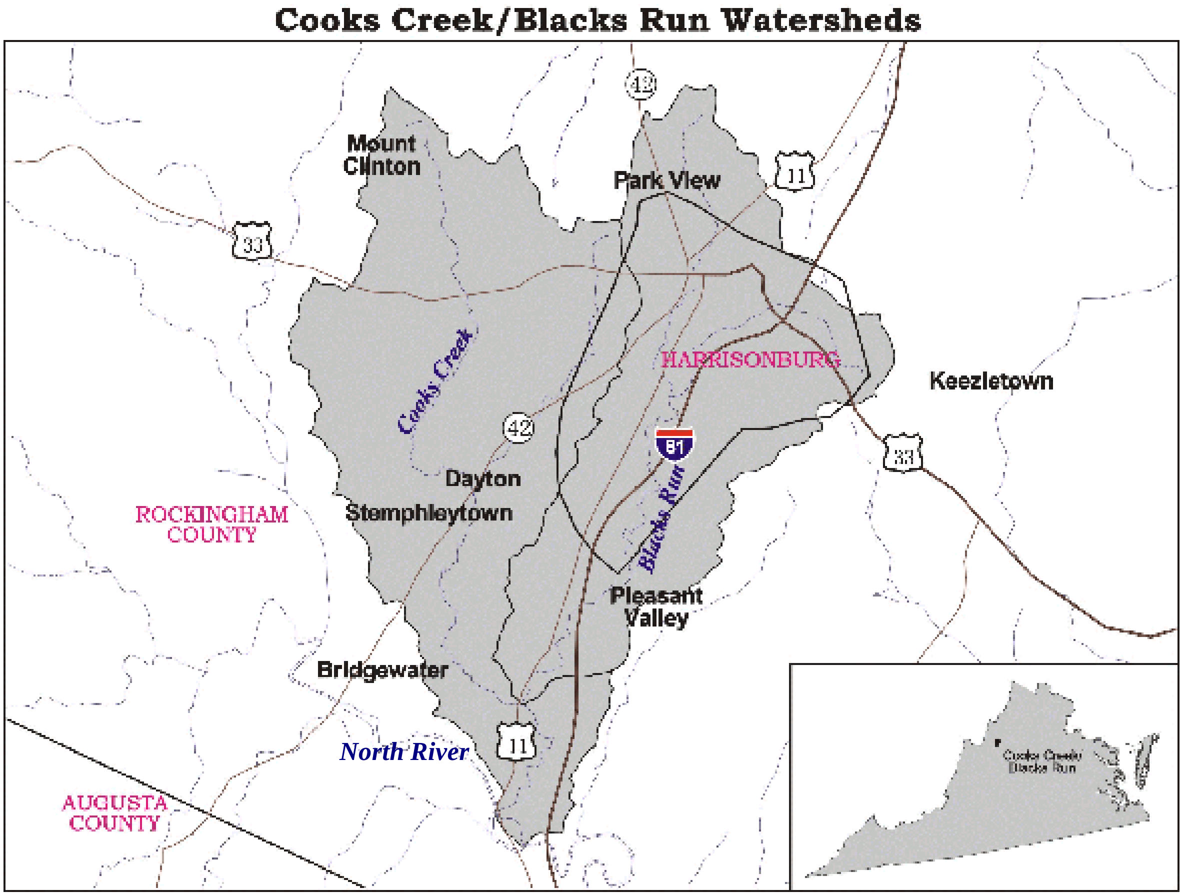

Figure 1.1 Location of the Cooks Creek and Blacks Run watersheds

1.2 Designated Uses and Applicable Water Quality Standards

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

1.2.1 Designation of Uses (9 VAC 25-260-10)

A. 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 reasonably be expected to inhabit them; wildlife; and the production of *edible and marketable natural resources (e.g., fish and shellfish).*

Blacks Run and Cooks Creek do not support the recreational (swimming) and aquatic life designated uses due to violations of the general (benthic) criteria and fecal coliform bacteria criteria (see below).

1.2.2 Water Quality Standards

General Criteria (9 VAC 25-260-20)

A. 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.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

Fecal Coliform Bacteria (9 VAC 25-260-170)

A. General Requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.

1.3 Biomonitoring and Assessment

Direct investigations of biological communities using rapid bioassessment protocols, or other biosurvey techniques, are best used for detecting aquatic life impairments and assessing their relative severity (Plafkin 1989). Biological communities reflect overall ecological integrity; therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

Many state water quality agencies use benthic macroinvertebrate community data to assess the biological condition of a waterbody. Virginia uses EPA's Rapid Bioassessment Protocol (RBP II) to determine the status of a stream's benthic macroinvertebrate community. This procedure relies on comparisons of the benthic macroinvertebrate community between a monitoring station and its designated reference site. Measurements of the benthic community, called metrics, are used to identify differences between monitored and reference stations. Metrics used in the RBP II protocol include taxa richness, percent contribution of dominant family, and other measurements which provide information on the abundance of pollution tolerant versus pollution intolerant organisms. The reference station for Blacks Run is located on Strait Creek in Highland County, Virginia and the reference station for Cooks Creek is located on the Jackson River in Bath County, Virginia. Biomonitoring stations are typically sampled in the spring and fall of each year. The biological condition scoring criteria and the bioassessment matrix are discussed in the technical document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (Plafkin 1989). The RBPII bioassessment scoring matrix is presented in Table 1.1.

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 1997). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the RBP ranking is either moderately or severely impaired. According to Virginia's 1998 303(d) list, the biological monitoring station on Blacks Run indicated moderate impairment and the biological monitoring station on Cooks Creek indicated severe impairment of the benthic community. As a result, these streams were listed as impaired due to violations of the general standard (aquatic life) on the 1998 303(d) list. These streams were assessed as moderately impaired in 2000. Recent biomonitoring data indicate that Cooks Creek remains moderately impaired and Blacks Run is now classified as severely impaired (2002 assessment).

Table 1.1 Bioassessment scoring matrix (Plafkin 1989)

% Compare to Reference Score (a)	Biological Condition Category	Attributes
>83%	Non-Impaired	Optimum community structure (composition and dominance).
54 - 79%	Slightly Impaired	Lower species richness due to loss of some intolerant forms.
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms.
<17%	Severely Impaired	Few species present. Dominant by one or two taxa. Only tolerant organisms present.
(a) Percentage values obtained that are intermediate to the above ranges require subjective judgement as to the correct placement.		

SECTION 2

BENTHIC TMDL ENDPOINT DETERMINATION

2.1 Reference Watershed Approach

Biological communities respond to any number of environmental stressors, including physical impacts and changes in water and sediment chemistry. According to Virginia's 1998 303(d) list, the cause of the benthic community impairment on Cooks Creek is believed to be organic enrichment and low dissolved oxygen. The cause of the impairment on Blacks Run was listed as unknown.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e. total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in both streams. A reference watershed approach was used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting non-impaired watersheds that share similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. A regionally-calibrated multimetric macroinvertebrate index is used to define differences in the benthic communities in impaired and reference streams. Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced. The reference watershed approach can also be used to examine physical impacts, such as hydromodification, and other controlling factors.

2.2 Watershed Characterization

2.2.1 General Information

Blacks Run and Cooks Creek are located in Rockingham County, Virginia in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005), which is part of the Chesapeake Bay watershed. The waterbody identification code (WBID, Virginia Hydrologic Unit) for the Blacks Run and Cooks Creek watersheds is VAV-B26R and VAV-B25R, respectively (VADEQ 1998). Blacks Run drains much of the City of Harrisonburg and is the major tributary to Cooks Creek. Blacks Run is 10.74 miles in length with a watershed of approximately 12,255 acres. Cooks Creek is located just west of Harrisonburg. This tributary to the North River is 13.32 miles in length and drains approximately 28,174 acres (including the Blacks Run subwatershed).

2.2.2 Geology

Blacks Run and Cooks Creek are located in the Shenandoah Valley of Virginia, which is part of the Valley and Ridge physiographic province. The Valley and Ridge physiographic province is a belt of folded and faulted clastic and carbonate sedimentary rocks situated west of the Blue Ridge crystalline rocks and east of the Appalachian Plateaus. The Shenandoah Valley makes up part of the Great Valley subprovince, which extends from New York southwest to Alabama. This area is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks. Limestone and dolomite (which are carbonate rocks) occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. The gently rolling lowland of the valley floor lies at an elevation of approximately 1000 feet above sea level. Sinkholes, caves, and caverns are common in the valley due to its karst (carbonate rock) geology.

2.2.3 Soils

Soils data were obtained from the Rockingham County Soil Survey (SCS 1981) and the State Soil Geographic (STATSGO) database for Virginia, as developed by the Natural Resources Conservation Service (NRCS 1994). The Rockingham County Soil Survey identifies three primary soil associations in the Blacks Run and Cooks Creek watersheds, as shown in Figure 2.1.

The Frederick-Lodi-Rock Outcrop and Chilhowie-Edom soil associations include valley soils that were formed in residual material weathered from limestone, dolomite, and calcareous shale. Frederick-Lodi-Rock Outcrop soils are located in the eastern and western sections of the Cooks Creek watershed (STATSGO map unit - VA003). Chilhowie-Edom soils are located in the central portion of the Cooks Creek watershed (STATSGO map unit - VA002). These soils associations are generally deep to moderately deep, gently sloping to steep, well drained soils that have a clayey subsoil and areas of rock outcrop, and are located on uplands underlain by limestome, dolomite, and interbedded shale. Infiltration is slow to moderate and runoff potential is moderate. Slopes typically range from 2 to 60 percent. The soils are fertile and cleared areas are commonly used for cropland and pasture. Corn and hay are the principal crops grown in these areas. Forested areas consist of northern red oak, yellow poplar, hickory, maple, black walnut, locust, eastern red cedar, and Virginia pine.

The third soil association, Monongahela-Unison-Cotaco, exists in the southern and southwestern portions of the Cooks Creek watershed and in the southern portion of the Blacks Run watershed (STATSGO map unit - VA004). This soil map unit follows the floodplain of the North River and other streams in the county, including downstream areas of Blacks Run and Cooks Creek. Monongahela-Unison-Cotaco soils are found on river terraces that formed in alluvial (unconsolidated sediments deposited by streams) or colluvial material (rock, soil, and other materials accumulated at the foot of a slope). These soils are generally level to moderately steep, well drained to moderately well drained, and have a loamy or clayey subsoil. Infiltration is slow in the fragipan and surface runoff is moderate. Slopes range from 0 to 25 percent. Most areas have been cleared of the original hardwood forest and used for pasture, cultivated crops, and industrial and residential sites. Corn and hay are the principal crops grown in these soils.

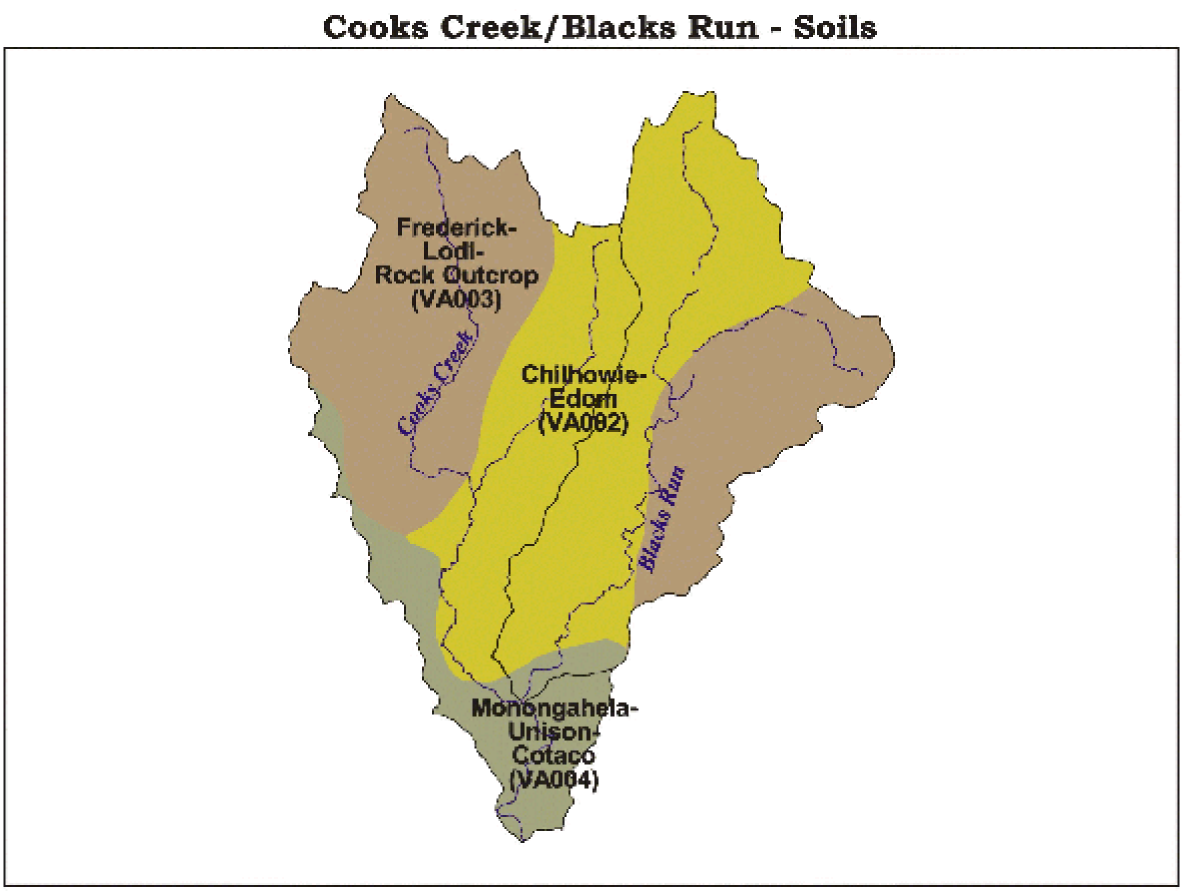

Figure 2.1 Soil associations and STATSGO map units in Cooks Creek and Blacks Run

2.2.4 Climate

The area's climate is typical of other regions in the Shenandoah Valley. The Blue Ridge Mountains to the east and the Alleghany Mountains to the west provide protection from the climate extremes experienced in other parts of Virginia. Weather data for these watersheds can be characterized using the Dale Enterprise meteorological station, which is located in the northwestern portion of the Cooks Creek watershed (period of record: 1961-1990). The growing season lasts from May 1 through October 11 in a typical year (SERCC 2000). Average annual precipitation is 33.6 inches with August having the highest average precipitation (3.58 inches). Average annual snowfall is 26.5 inches, most of which occurs in January and February. The average daily temperature for the year is 53.3°F. The average annual maximum and minimum daily temperature is 64.9°F and 41.7°F, respectively. The highest daily average temperatures are recorded in July (85.8°F) and the lowest temperatures are recorded in January (21.1°F).

2.2.5 Land Use

A GIS land use coverage was developed by the Virginia Department of Conservation and Recreation (VADCR) for the Blacks Run and Cooks Creek watersheds in the early 1990s using satellite imagery (Figure 2.2). Land use areas in these watersheds were ground-truthed by VADCR and Tetra Tech personnel in October 2000 and corrections to GIS coverages were made using this information and housing coverages provided by the planning offices of Rockingham County and the City of Harrisonburg. There are a total of 25 unique land use types in the GIS coverages, including various urban, agricultural, and forest categories (Table 2.1). Individual land use types were consolidated into ten broader categories that had similar attributes for modeling purposes.

Land use in the Blacks Run watershed is predominantly urban/suburban in the middle and upper portions of the watershed and agricultural in the lower portion. Overall, 66% of the Blacks Run watershed is urban/suburban, 16% is pasture/hayland, 9% is cropland, and 8% of the area is forest. Much of the City of Harrisonburg is located within the Blacks Run watershed, which accounts for the high percentage of urban area. Primary and secondary roads, including Interstate 81 and U.S. Highways 33 and 11, bisect the watershed and have helped support urban development in the area. The City of Harrisonburg has a population of approximately 40,468 people according to the 2000 Census. James Madison University is located within the City of Harrsionburg and is a major state university. The university and residential areas include large areas of green space, therefore, much of the classified urban area in the watershed consists of pervious lands. Agricultural land uses consist of cropland (primarily corn production), hayland, pasture, and livestock operations. Livestock in the watershed include dairy and beef cattle, hogs, sheep, chickens, and turkeys.

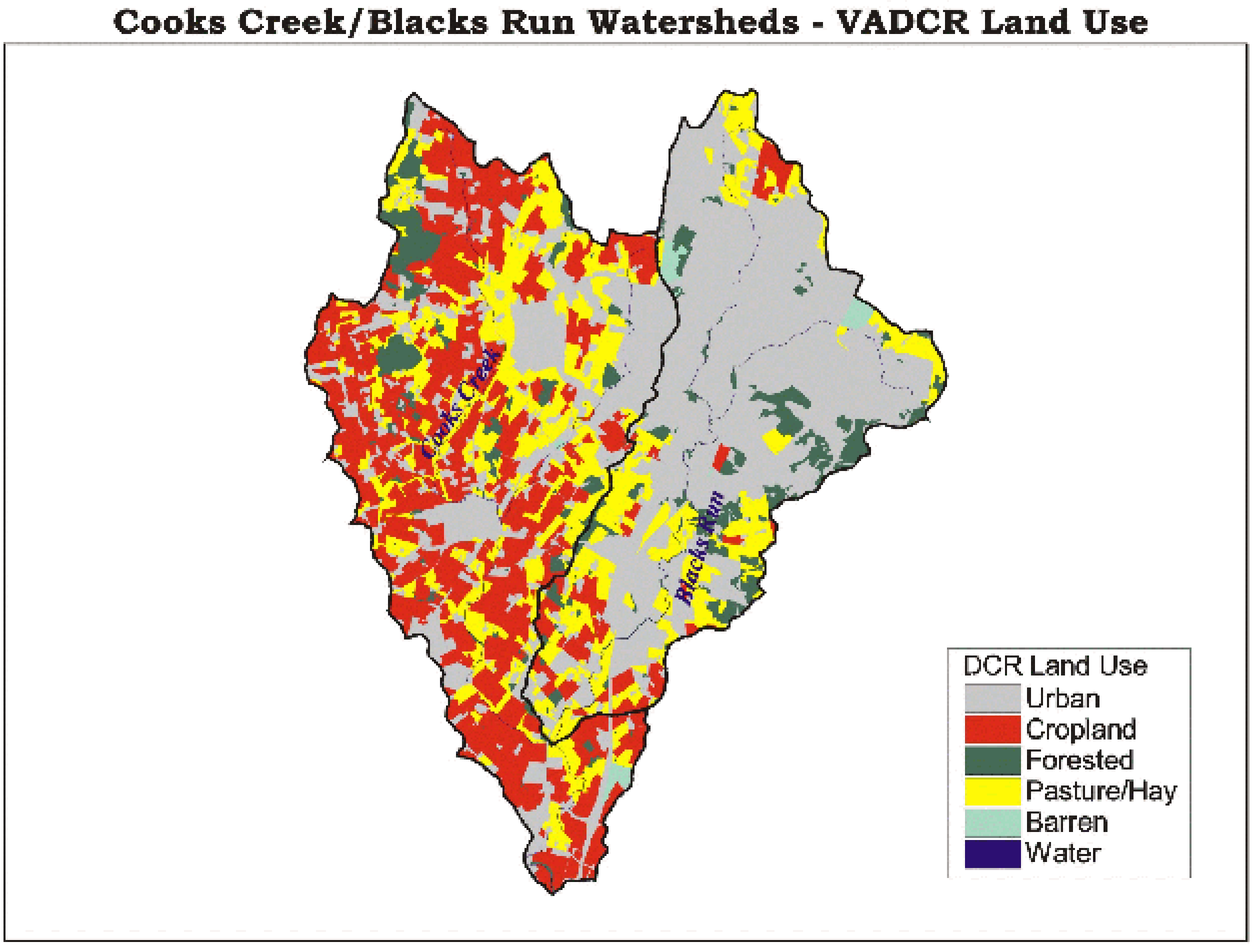

Figure 2.2 Land use in the Cooks Creek and Blacks Run watersheds (VADCR)

The Cooks Creek watershed is predominantly agricultural except for the Blacks Run portion. The entire Cooks Creek watershed, including Blacks Run, is 43% urban/suburban, 28% cropland, 21% pasture/hayland, and 8% forest. Excluding the Blacks Run subwatershed, the watershed is 26% urban, 41% cropland, 26% pasture/hayland, and 7% of the area is forest. Urban areas in the watershed include Mount Crawford, Park View, Dale Enterprise, the Town of Dayton, and the City of Harrisonburg (Blacks Run). The Town of Dayton is the second largest urban area in the watershed with a population of 1,344 people (Census 2000). Overall, the percentage of urban area is significantly less than in the Blacks Run watershed. Also, urban development is less concentrated and primarily consists of low intensity residential areas. Agricultural land uses, cultivated crops, and livestock grown in the watershed are the same as those listed above for Blacks Run. The livestock population in the Cooks Creek watershed is considerably higher than in the Blacks Run watershed.

Table 2.1 VADCR land use categories and consolidated land uses

VADCR land use Categories	Consolidated land use
Crop Land	Row Crops
Improved Pasture Unimproved Pasture Overgrazed Pasture Rotational Hay	Pasture/Hay
Barren Cattle Operations	Transitional
Open Urban Land	Urban / Recreational Grasses
Commercial and Services Industrial Transportation	High Intensity Commercial / Industrial / Transportation
High Density Residential Mixed Urban or Built-Up Mobile Home Park	High Intensity Residential
Medium Density Residential	Medium Intensity Residential
Low Density Residential Farmstead Large Dairy Waste Operations Poultry Operations	Low Intensity Residential
Forested Grazed Woodland Nurseries and Christmas Tree Farms Orchards Wooded Residential	Forest
Water	Water

2.2.6 Stream Characteristics

Blacks Run flows through downtown Harrisonburg and continues through a predominantly agricultural area in the lower reach. Views of Blacks Run and its watershed are shown in Figure 2.3. Several mainstem and tributary sections were placed in underground culverts years ago to allow for construction of city buildings and other structures. Other sections have been channelized and urban encroachment into riparian areas has occurred. Streams show evidence of de-stabilization including bank erosion, down-cutting (erosive deepening of the stream channel), and excessive sedimentation. This de-stabilization is likely caused by hydromodification of the stream channel due to increased runoff from impervious areas and stormwater outfalls during storm events. Stream banks have been armored with rip-rap or retaining walls in some sections to prevent bank erosion and slumping. Downstream areas of Blacks Run have also been negatively impacted by erosion from agricultural lands and riparian disturbances. Riparian vegetation is minimal throughout the watershed.

Cooks Creek has been primarily affected by agricultural practices, including the intensive use of riparian areas for cropland and pasture. Views of Cooks Creek and its watershed are shown in Figure 2.4. Erosion from cropland and overgrazed pasture land is primarily responsible for observed sedimentation problems. Livestock traffic has also resulted in bank erosion and other physical impacts to stream channels. Most riparian areas are in crop production or are utilized as pasture for grazing livestock. Urban development in the watershed, excluding Blacks Run, is less intense and is not generally concentrated within a close proximity to streams. As in Blacks Run, riparian vegetation is minimal throughout the watershed.

Figure 2.3 Views of Blacks Run (photos taken on 10/27/00)

Figure 2.4 Views of Cooks Creek (photos taken on 10/27/00)

2.2.7 Ecoregion

Blacks Run and Cooks Creek are located in the Valley and Ridge ecoregion - Level III classification 67 (Woods et al. 1999) (Figure 2.5). This ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia. It is characterized by alternating forested ridges and agricultural valleys that are elongated, folded and faulted. The region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, and sandstone. The valleys generally fall into two types, those underlain by limestone and those underlain by shale. The nutrient rich limestone valleys contain productive agricultural land and tend to have few streams. By contrast, the shale valleys are generally less productive, more irregular, and have greater densities of streams. Most of the streams in the limestone valleys are colder and flow all year, whereas those in the shale valleys tend to lack flow in dry periods. Limestone areas commonly have numerous springs and caves. Present-day forests cover about 50% of the region. A diversity of aquatic habitats and species of fish exist in this ecoregion due to the variation in its components.

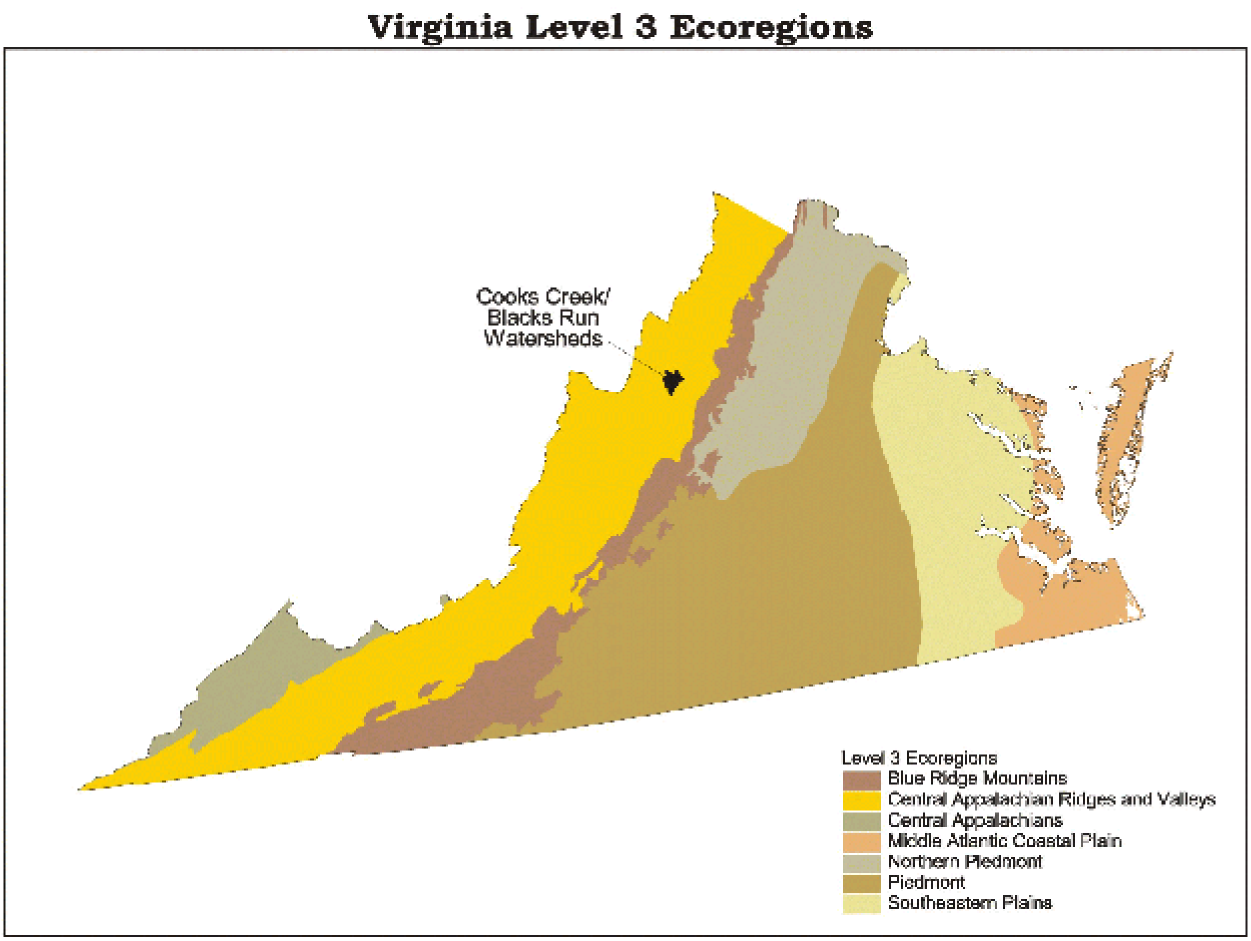

Figure 2.5 Virginia level 3 ecoregions

At a finer scale, Blacks Run and Cooks Creek are located in the Northern Limestone/Dolomite Valleys subecoregion - Level IV classification, 67a (Woods et al. 1999) (Figure 2.6). This subecoregion is characterized by broad, level to undulating, fertile valleys that are extensively farmed. Karst features including sinkholes and underground streams have developed in the underlying limestone/dolomite. Interbedded with these carbonate rocks are other rocks, including shale, which give the ecoregion topographic and soil diversity. Streams tend to have gentle gradients, a perennial flow regime, and distinctive fish assemblages. Local relief typically ranges from 50-500 feet (mean sea level). The climate varies significantly because of the ecoregion's elevational and latitudinal range. The growing season varies from 145 to 180 days. Farming predominates, with scattered woodlands occurring in steeper areas. Natural vegetation mostly consists of Appalachian Oak Forest (dominated by white and red oaks) in the north and Oak/Hickory/Pine forest in the south.

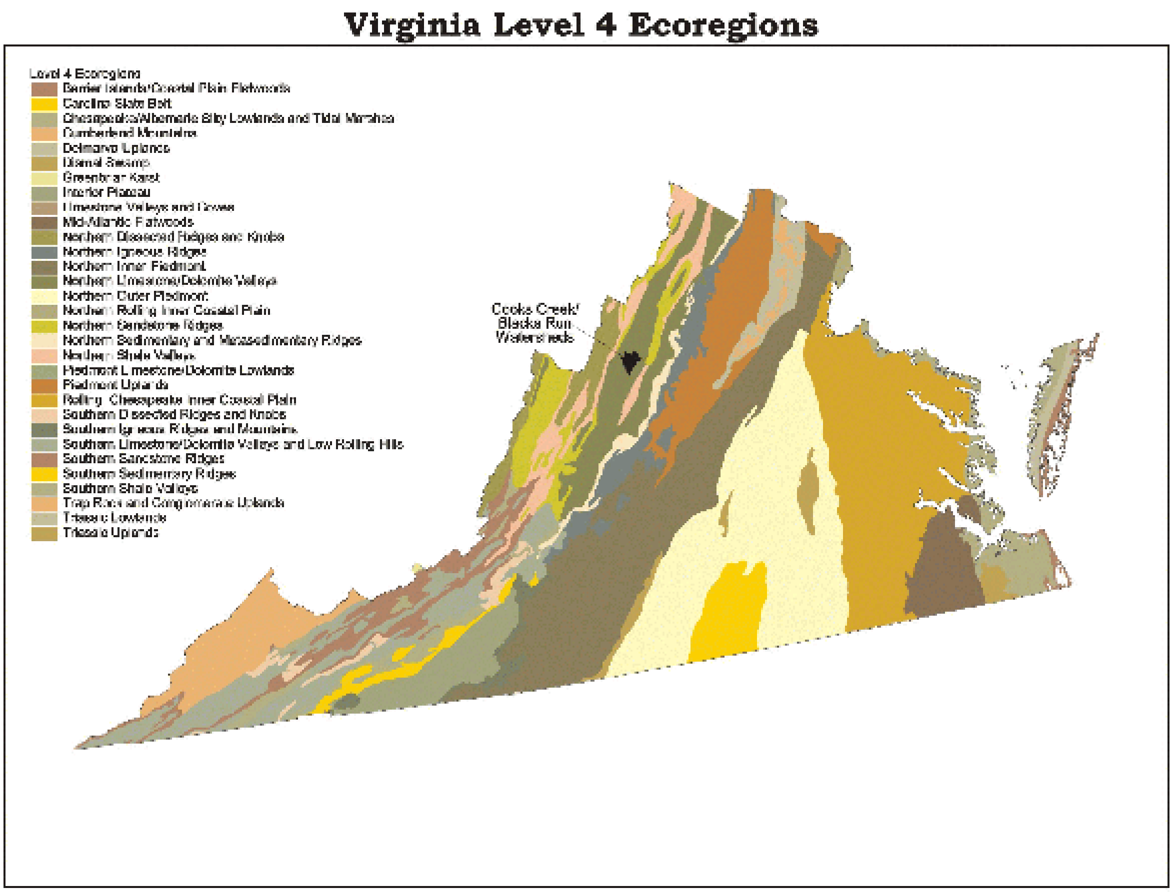

Figure 2.6 Virginia level 4 ecoregions

2.3 Reference Watershed Selection

The reference watershed selection process is based on a comparison of key watershed and stream characteristics. The goal of the process is to select similar, unimpaired reference watersheds that can be used to identify benthic community stressors and develop TMDL endpoints. Data used in the reference watershed selection process are shown in Table 2.2.

Table 2.2 Reference watershed selection data

Biomonitoring Data	Ecoregion Coverages
Topography	Land use Distribution
Soils	Watershed Size
Water Quality Data	Point Source Inventory

VADEQ biological monitoring stations located within the Valley and Ridge ecoregion were initially selected as potential reference sites. Ecoregions are defined as areas of relative homogeneity in ecological systems and their components. Therefore, in terms of a reference watershed approach to address biological impairments, the selection of a reference watershed within the same ecoregion is critical. Stations listed as impaired for aquatic life on Virginia’s 1998 303(d) list were eliminated from further consideration. As a result, the list of potential reference stations was reduced to include only those that were ranked as “Not Impaired” or “Slightly Impaired”. The watersheds of the remaining 141 biomonitoring stations were then delineated and GIS was used to characterize these watersheds. Of the 141 stations, 116 were excluded from further consideration for one or several of the following factors:

- The watershed is much larger or smaller
- Low percentage of agricultural land / primarily forested
- Narrow stream valleys
- Distinct differences in soils, subecoregion, or other watershed attributes
- Lack of water quality data

Virginia ecoregions (Level III) and the location of potential reference watersheds are shown in Figure 2.7.

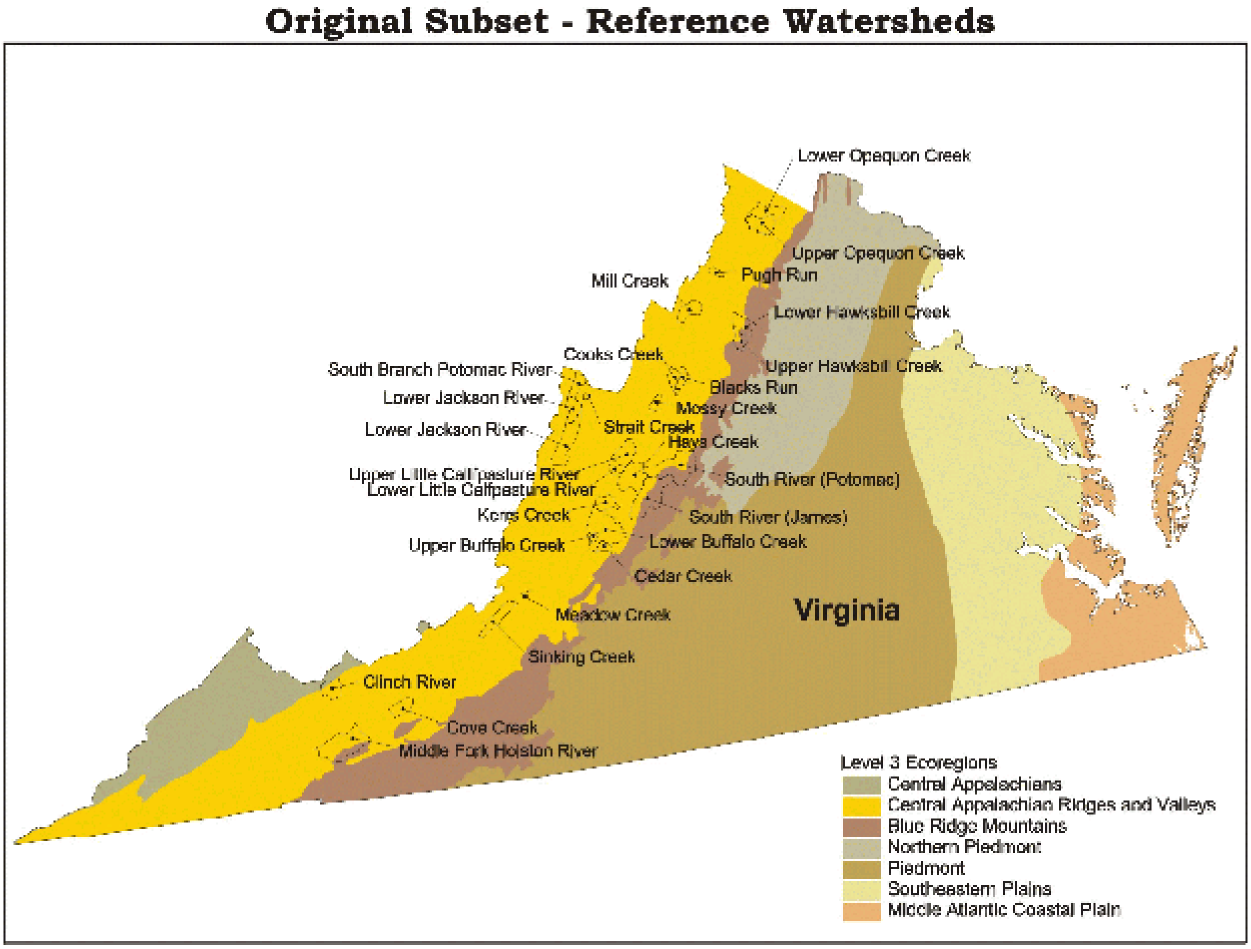

Figure 2.7 Potential reference watersheds—Virginia Ridge and Valley Ecoregion

2.4 Multimetric Bioassessment Index

A Virginia Ridge and Valley Multimetric Bioassessment Index (VRVMBI) was developed specifically for this TMDL study to provide a more detailed and reliable assessment of the benthic macroinvertebrate community in Blacks Run, Cooks Creek, and potential reference streams. The VRVMBI is a regionally-calibrated multimetric index which allows for the evaluation of biological condition as a factor in the reference watershed selection process and can be used to measure improvements in the benthic macroinvertebrate community in the future. As previously described, Virginia's current bioassessment procedure is patterned after EPA's Rapid Bioassessment Protocols for streams, published in 1989 (Plafkin et al. 1989). VADEQ uses benthic macroinvertebrate data from target and reference sites to calculate eight standard metrics, which are used state-wide. Multimetric scoring procedures comparing each monitored site to a designated reference site are used to derive a biological rating for the monitored site.

In the 10+ years since the publication of EPA's 1989 RBP guidance, biological assessment methods have been refined and improved with increased research and testing. VADEQ, with assistance from EPA Region 3, is currently undergoing a planning process to update its biomonitoring and bioassessment methods with currently recommended practices in the mid-Atlantic region. Planned improvements include moving from a paired reference site approach to a regional reference condition approach and developing one or more regionally-calibrated multimetric macroinvertebrate indexes for assessing biological condition in streams. Until such time that VADEQ completes and implements these planned improvements, the VRVMBI will serve as a valuable bioassessment tool (to support current VADEQ methods) and can be used to aid in the selection of reference watersheds in future TMDL studies.

The VRVMBI was developed according to the step-wise framework as described in several publications using historic biomonitoring data collected from Virginia Ridge and Valley ecoregion sites (Barbour et al. 1995, Gibson et al. 1996, and Barbour et al. 1996b). Biomonitoring data used in this analysis were collected from 1994 through 1998. Biological "metrics" are quantitative measures that characterize different categories of attributes of the benthic macroinvertebrate community. The individual metrics that make up the bioassessment index were selected based on previous studies and results from metric discrimination analyses (Smith and Voshell 1997, Smock and Garman 1997, Stribling et al. 1998, and Gerritsen et al. 2000). The ability of a particular metric to indicate differences (discriminate) between established reference and impacted sites determines its usefulness in assessing biological condition. The metrics selected represent various ecological characteristics of the benthic macroinvertebrate community, including taxonomic richness, taxonomic composition, population balance or diversity, tolerance to pollution or environmental stress, and functional feeding or trophic grouping. The decision rationale used in metric selection is presented in Table 2.3. The VRVMBI was calculated for each potential reference site and for the biomonitoring stations on Blacks Run and Cooks Creek.

Table 2.3 Metrics selected and tested—Virginia Ridge and Valley data

Candidate Metrics (by categories)	Expected Response to Disturbance	Discrimination Ability	Metric Selection Evaluation: Reason for including or excluding metric	Selected Metrics
Taxonomic Richness				
Total Taxa	Decrease	?	Good discrimination in this category, widely used and understood metric	?
EPT Taxa	Decrease	?	Highly correlated with EPT Taxa Less Hydropsychidae, with Total Taxa, and with Ephemeroptera Taxa	
EPT Taxa Less Hydropsychidae	Decrease	?	Good discrimination in this category	?
Ephemeroptera Taxa	Decrease	?	Closely correlated with EPT Taxa Less Hydropsychidae	
Diptera Taxa	Decrease		Inadequate discrimination ability	

Candidate Metrics (by categories)	Expected Response to Disturbance	Discrimination Ability	Metric Selection Evaluation: Reason for including or excluding metric	Selected Metrics
Taxonomic Composition				
% EPT	Decrease	?	Good discrimination in this category	?
% EPT Less Hydropsychidae	Decrease	?	High correlation with % Ephemeroptera in this category and with HBI	
% Ephemeroptera	Decrease	?	Good discrimination in this category	?
% Chironomidae	Increase		Inadequate discrimination ability	
Balance/Diversity				
% Dominant	Increase	?	Good discrimination in this category	?
% Top 5 Dominant	Increase	?	High negative correlation with Total Taxa	
Tolerance				
HBI (Family level)	Increase	?	Good discrimination in this category	?
# Intolerant Taxa	Decrease	?	High correlation with EPT Taxa and EPT Taxa Less Hydropsychidae	
% Tolerant	Increase	?	Good discrimination in this category	?
Trophic				
% Scrapers	Decrease	?	Good discrimination in this category	?
% Collectors	Increase or Decrease		Inadequate discrimination ability	
% Shredders	Decrease		Inadequate discrimination ability	

2.5 Selected Reference Watersheds

Potential reference watersheds were ranked based on quantitative and qualitative comparisons of watershed attributes (soils, subecoregion, stream order, etc.) and the results of the VRVMBI. Based on these comparison, two watersheds were identified as good reference candidates. The first watershed, Hays Creek, is located in Rockingham and Augusta counties (Figure 2.8). This stream flows into the Maury River north of the City of Lexington and drains a primarily rural watershed. The second watershed, Upper Opequon Creek, is located in Frederick and Clarke counties and includes the southern portion of the City of Winchester (Figure 2.9). This stream flows north into the Potomac River in West Virginia.

Hays Creek - Reference Watershed

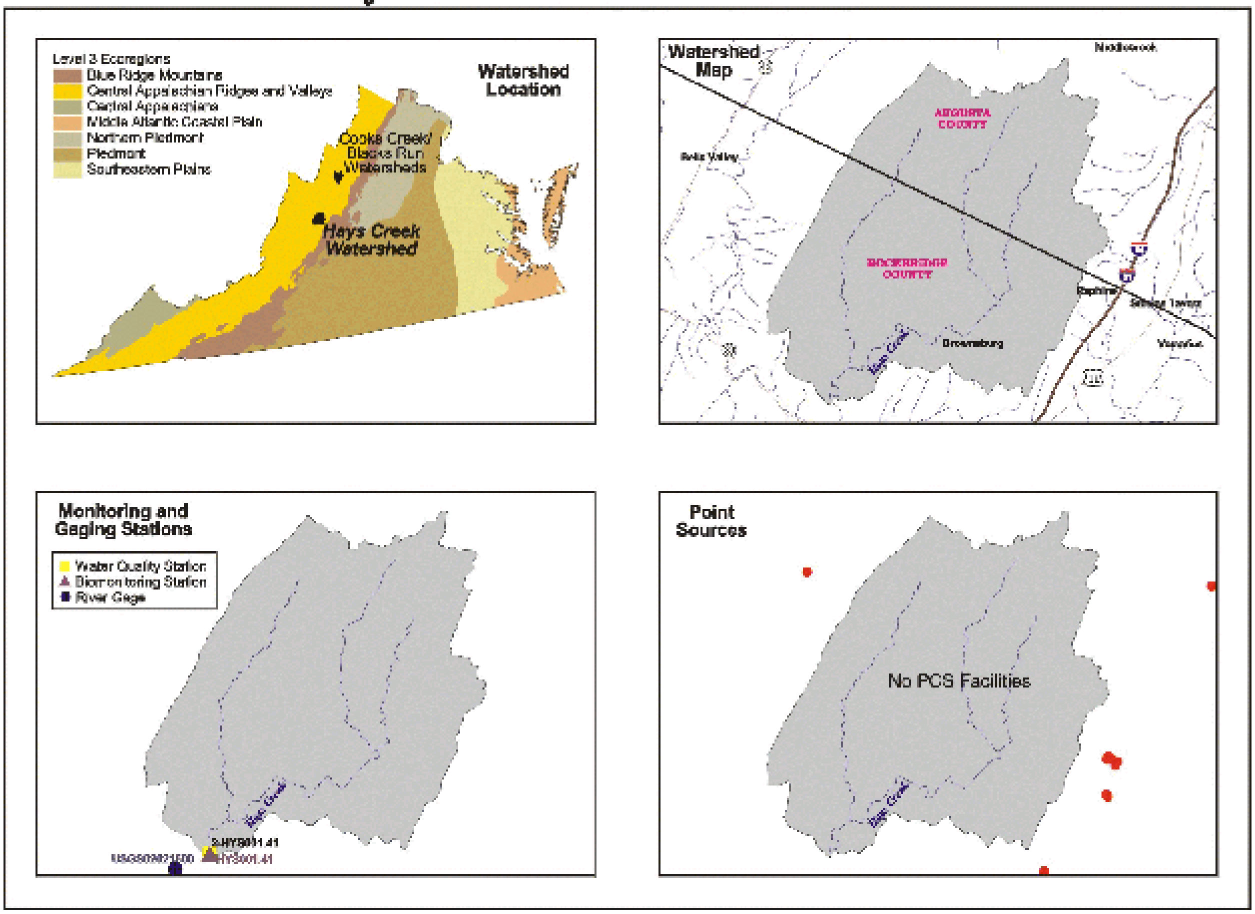

Figure 2.8 Hays Creek watershed location, monitoring stations, and VPDES facilities

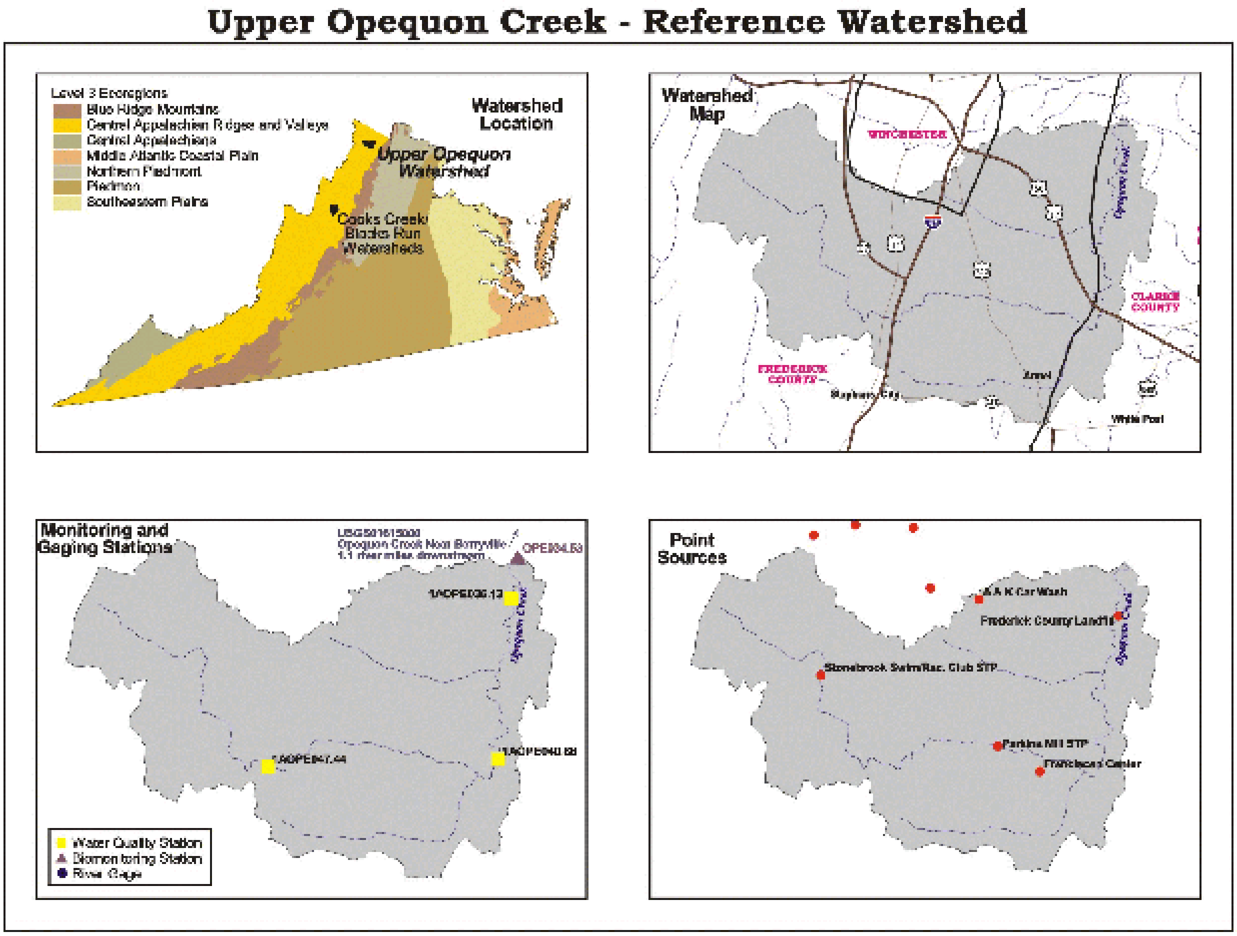

Figure 2.9 Upper Opequon Creek watershed location, monitoring stations, and VPDES facilities

2.6 Watershed Attributes

Impaired versus reference watershed comparisons of GIS data are presented in Figures 2.10 through 2.13. STATSGO data (NRCS) were used to compare the soil characteristics of impaired and reference watersheds (Figures 2.10 and 2.11). Subecoregion data were obtained from the EPA Region 3 coverage. VADCR land use data were not available for the Upper Opequon Creek and Hays Creek watersheds; therefore, land use comparisons were based on EPA's Multi-Resolution Land Characteristics (MRLC) data (USEPA 1992). The MRLC land use coverage for impaired and reference watersheds are presented in Figures 2.12 and 2.13. As with Blacks Run and Cooks Creek, land use areas in reference watersheds were ground-truthed and corrections were made to the land use distributions using this information. For comparative purposes, the percent distribution of MRLC land uses, STATSGO soil units, and Level IV subecoregions in target and reference watersheds is shown in Tables 2.4 through 2.6, respectively.

Table 2.4. MRLC land use distribution

Land Use (grouped)	Blacks Run	Cooks Creek (excluding Blacks Run watershed)	Upper Opequon Creek	Hays Creek
Urban	40%	11%	6%	0.2%
Forest	20	12	35	52
Pasture	33	64	55	46
Cropland	7	14	5	2

Table 2.5. STATSGO soil unit distribution

Map Unit (MUID)	Blacks Run	Cooks Creek (excluding Blacks Run watershed)	Upper Opequon Creek	Hays Creek
VA001	-	-	-	2%
VA002	59%	32%	18%	-
VA003	38	49	-	87
VA004	3	19	-	-
VA005	-	-	-	8
VA016	-	-	-	3
VA066	-	-	53	-
VA069	-	-	28	-

Table 2.6. Level IV subecoregion distribution

Subecoregion	Blacks Run	Cooks Creek (excluding Blacks Run watershed)	Upper Opequon Creek	Hays Creek
Northern Limestone/ Dolomite Valleys	100%	100%	49%	91%
Northern Shale Valleys	-	-	51	-
Norther Sandstone Ridges	-	-	-	9

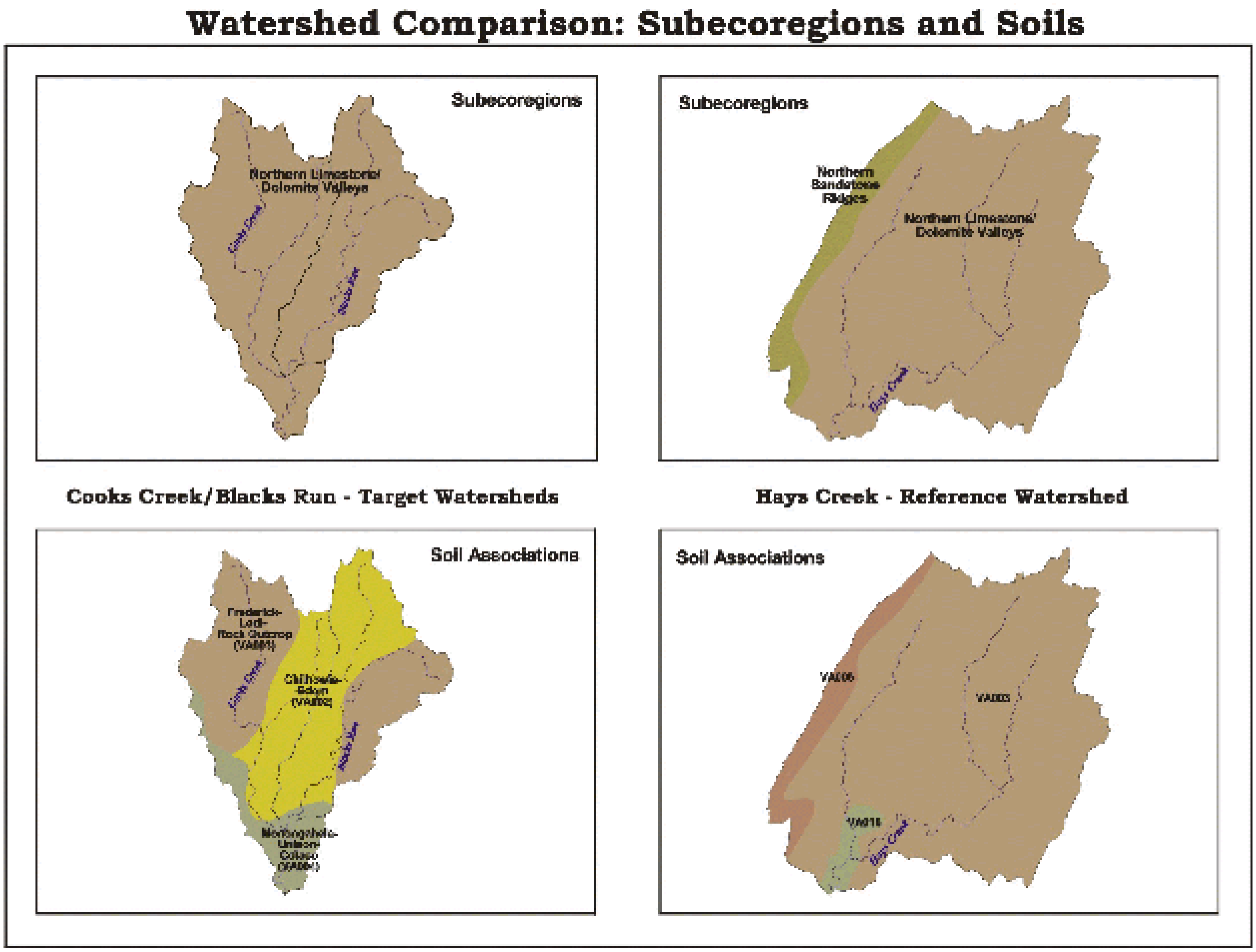

Figure 2.10 Hays Creek watershed comparison: subecoregion and soils

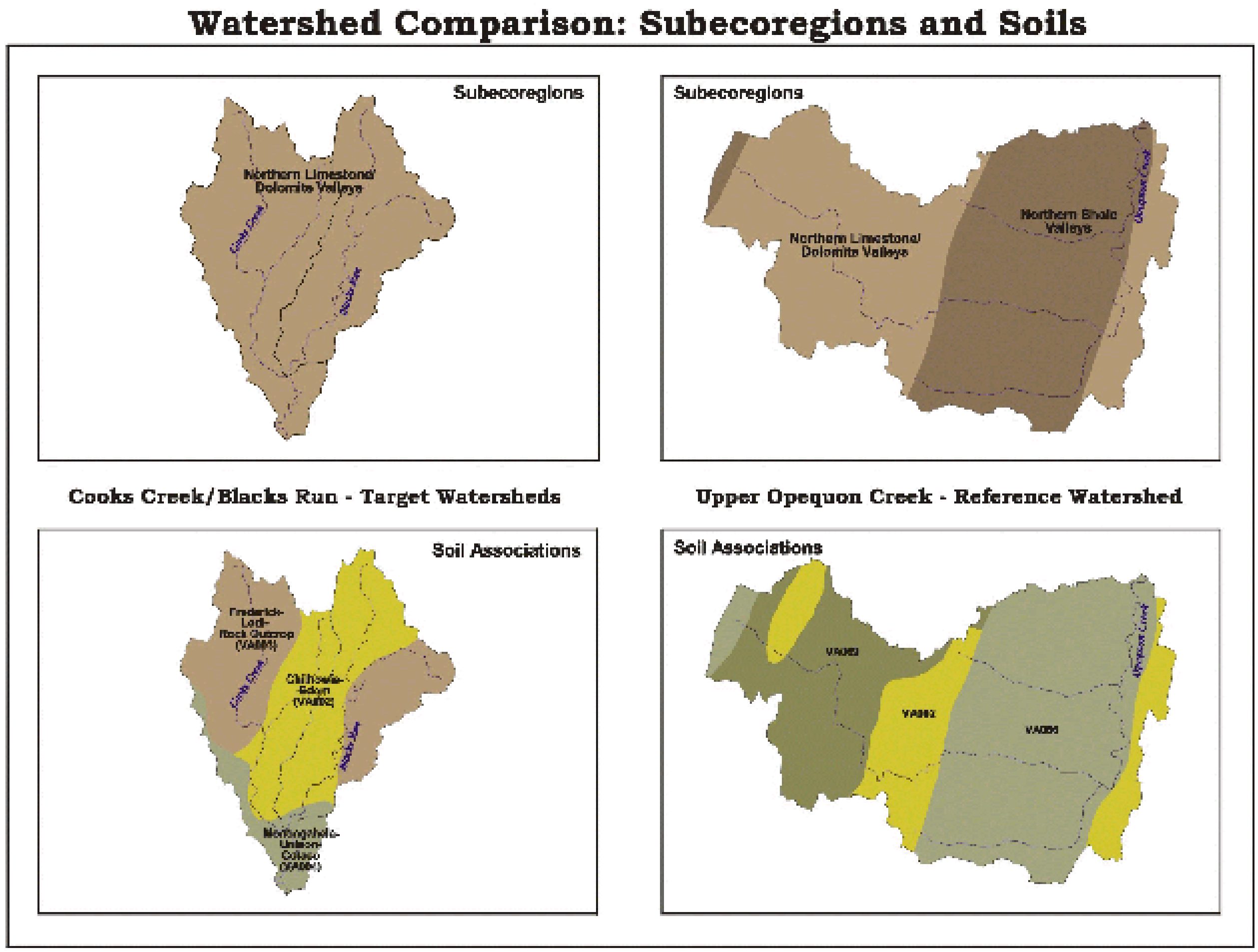

Figure 2.11 Upper Opequon Creek watershed comparisons: subecoregion and soils

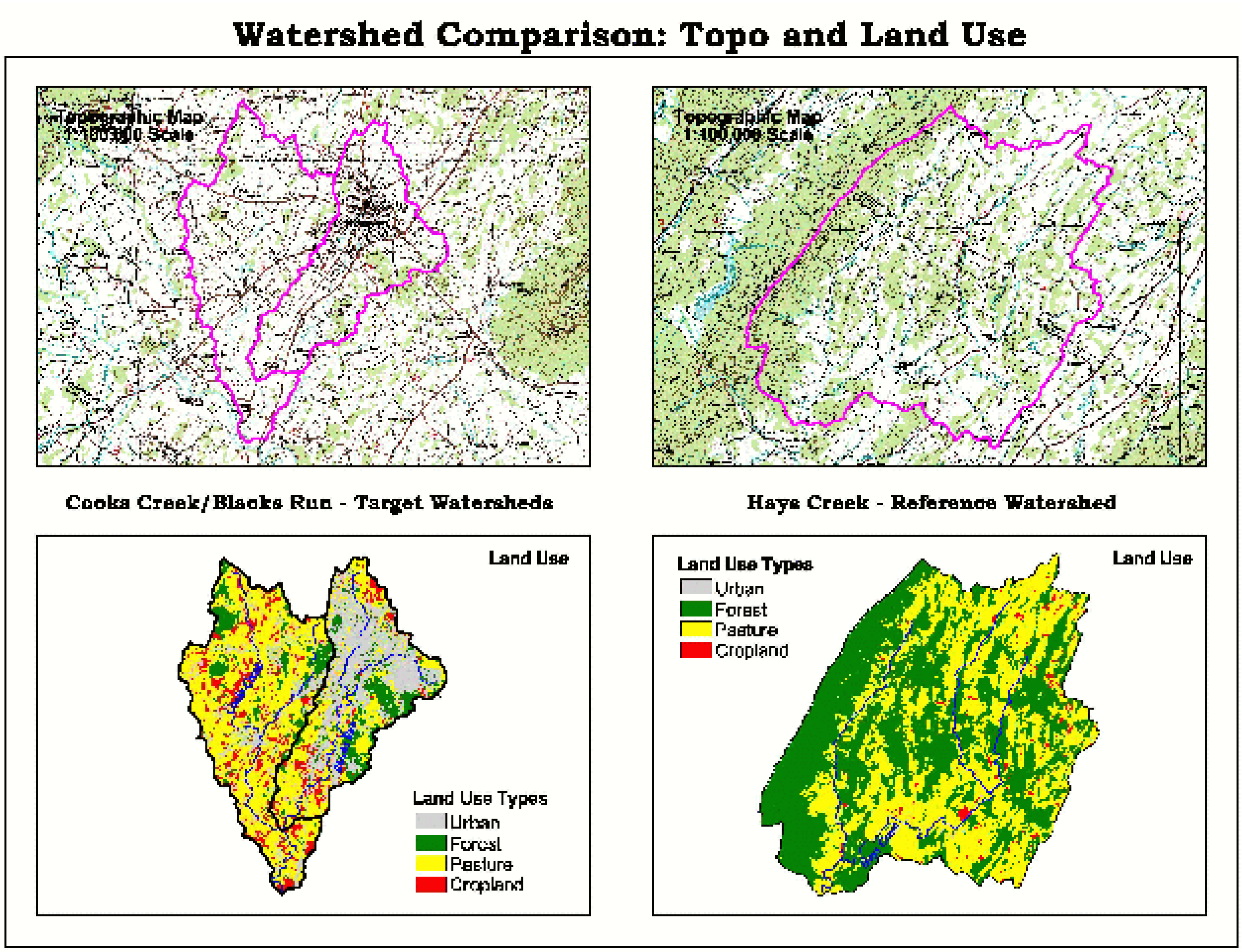

Figure 2.12 Hays Creek watershed comparison: topography and land use

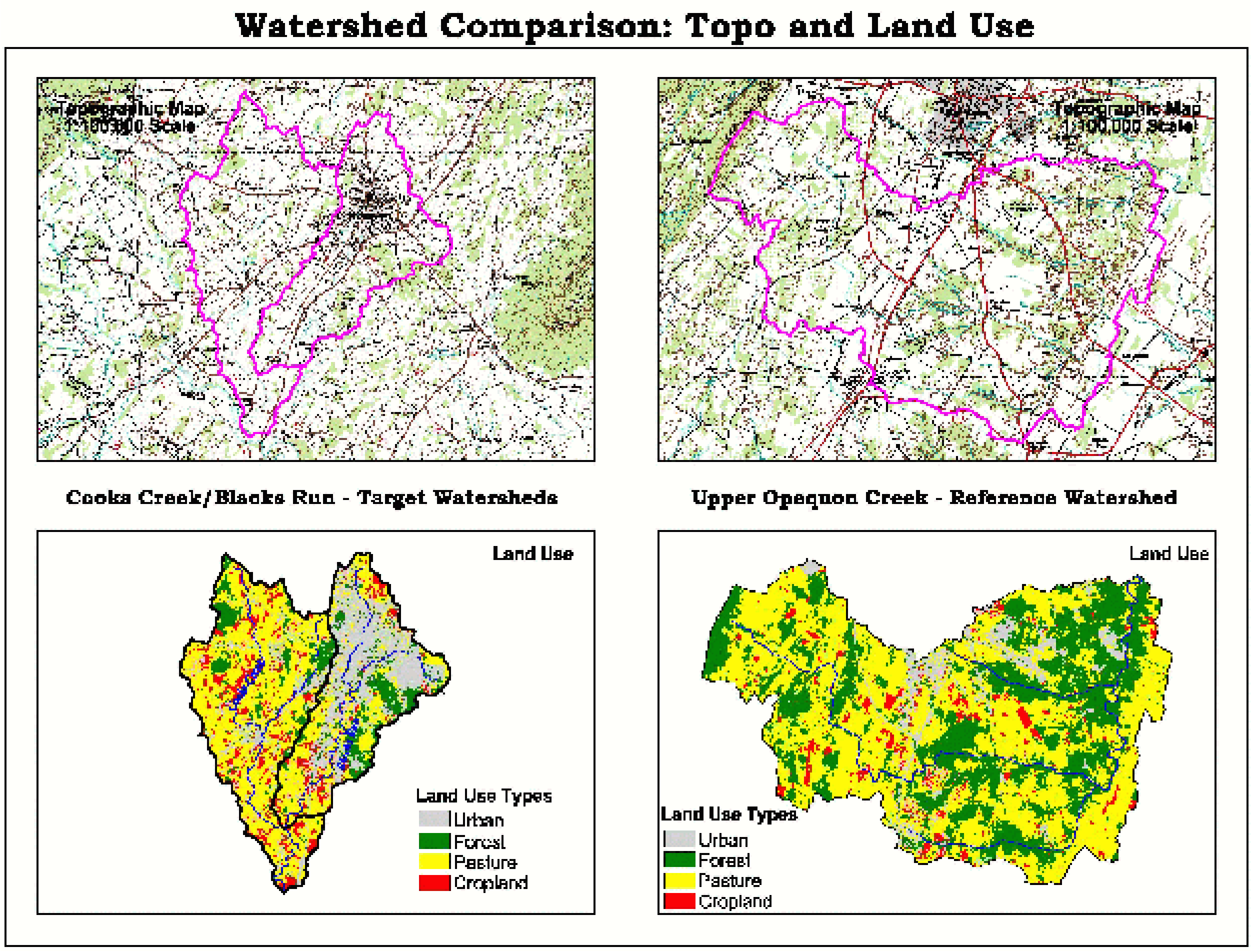

Figure 2.13 Upper Opequon Creek watershed comparisons: topography and soils

2.7 Selection Summary

Both reference streams recorded high VRVMBI bioassessment scores as compared to Blacks Run and Cooks Creek (Figure 2.14). Hays Creek was selected as the reference watershed for Cooks Creek based on similarities in soil composition, subecoregion, and other characteristics. Upper Opequon Creek had the highest percentage of urban land of all the candidate reference watersheds; therefore, this watershed was selected as the reference for Blacks Run. All watersheds with an urban land use percentage above 6% in the Virginia Valley and Ridge ecoregion were listed as impaired for aquatic life on Virginia's 1998 303(d) list and, therefore, could not be used as reference watersheds. Watershed attributes and other selection criteria are summarized in Table 2.7.

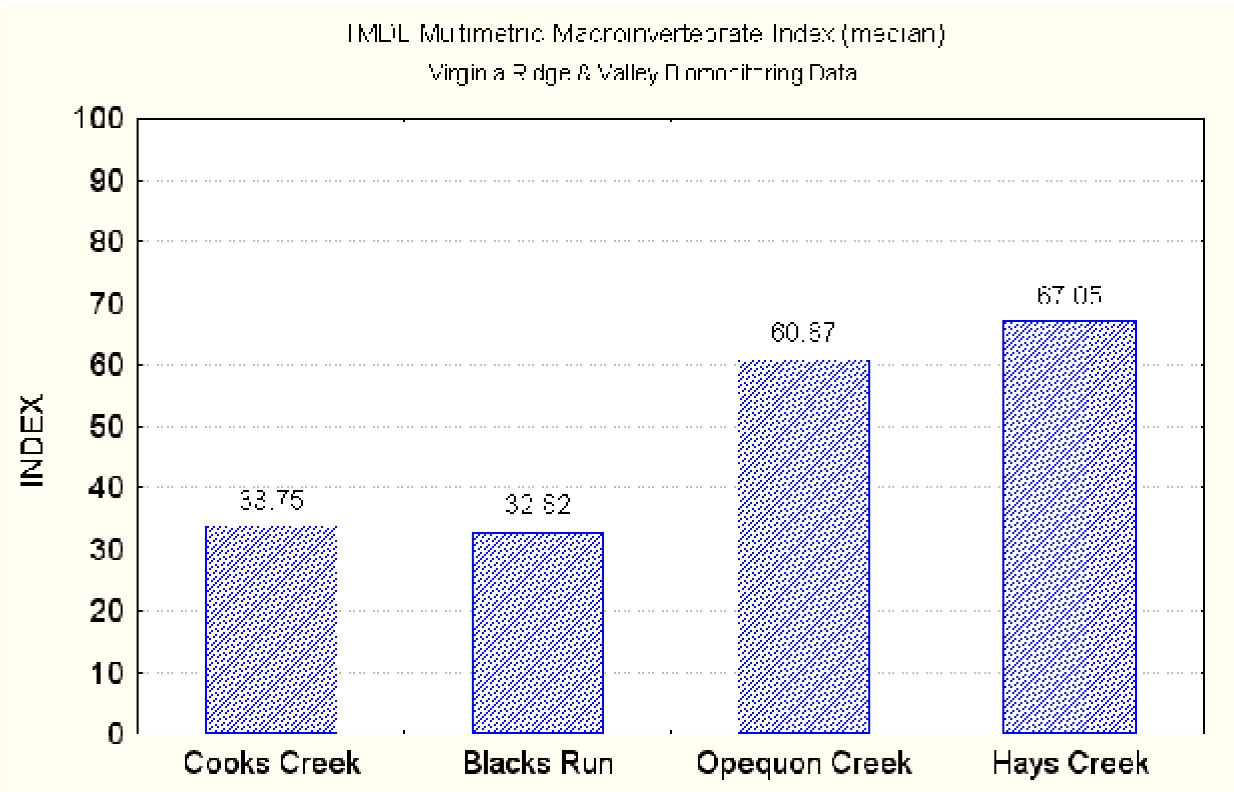

Figure 2.14 VRVMBI results for impaired and reference watersheds

Table 2.7 Selected reference watersheds

Upper Opequon Creek (reference for Blacks Run)	
Positives	
High bioassessment score (60.87)	Limestone/dolomite valleys (49% match)
Highest urban percentage (6%)	High agriculture percentage (60%)
Negatives	
Northern shale valleys (51% of total area)	Target soils (18% match)

Hays Creek (reference for Cooks Creek)	
Positives	
High bioassessment score (67.05)	Limestone/dolomite valleys (91% match)
High agriculture percentage (48%)	Target Soils (87% match)
Negatives	
Low urban percentage (0.2%)	

SECTION 3

STRESSOR IDENTIFICATION

3.1 Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. EPA developed the *Stressor Identification: Technical Guidance Document* to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment (Cormier et al. 2000). Elements of the stressor identification process were used to evaluate and identify the primary stressors of the benthic communities in Blacks Run and Cooks Creek. Watershed and water quality data from reference watersheds were used to help identify candidate causes.

3.2 Candidate Causes

Based on information provided by VADEQ and watershed data collected at the beginning of the TMDL study, it was hypothesized that sedimentation and excessive nutrient loads from non-point source inputs were responsible for the listed benthic impairments.

1) Low Dissolved Oxygen

Organic enrichment and low dissolved oxygen levels are specifically listed as likely causes on the 1998 303(d) fact sheet for Cooks Creek. In general, high nitrogen and phosphorus levels can lead to increased production of algae and macrophytes, which can result in the depletion of oxygen in the water column through metabolic respiration. In addition, at higher water temperatures the concentration of dissolved oxygen is lower because the solubility of oxygen (and other gases) decreases with increasing temperature. Higher water temperatures can be caused by the loss of shading, higher evaporation rates, reduced stream flow, and other factors.

Aquatic organisms, including benthic macroinvertebrates, are dependent upon an adequate concentration of dissolved oxygen. Less tolerant organisms generally cannot survive or are outcompeted by more tolerant organisms under low dissolved oxygen conditions. This process reduces diversity and alters community composition from a natural state. Aquatic insects and other benthic organisms serve as food items for fishes, therefore, alterations in the benthic community can impact fish feeding ecology (Hayward and Margraf 1987; Leach et al. 1977).

2) Sedimentation

Excessive sedimentation from anthropogenic sources is a common problem that can impact the stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling pools, critical riffle areas, and the interstitial spaces used by aquatic invertebrates. Substrate size is a particularly important factor that influences the abundance and distribution of aquatic insects. Sediment particles at high concentrations can directly affect aquatic invertebrates by clogging gill surfaces and lowering respiration capacity. Suspended sediment also increases turbidity in the water column which can affect the feeding efficiency of visual predators and filter feeders. In addition, pollutants, such as phosphorus, adsorb to sediment particles and are transported to streams through erosion processes.

3) Habitat Modification

Stormwater runoff and urban development in the Blacks Run watershed was considered to be a potential factor affecting the benthic community in Blacks Run. Blacks Run flows through the middle of the City of Harrisonburg and several sections flow through underground culverts below parking lots and buildings. An increase in the percent of impervious surface typically results in an altered flow regime which displays higher peak flows during storm events and lower baseflow due to the reduction in infiltration capacity (i.e. a reduction in groundwater discharge to the stream). Long-term flow alteration can lead to hydromodification of the stream channel. Effects can include bank erosion, down-cutting, and scouring of the bottom (from peak flows). Impacts to aquatic organisms depend on the type, severity, and frequency of the disturbance. Bottom scouring can result in physical disturbances to habitat and the displacement of aquatic organisms. Reduced baseflow can lead to higher water temperatures during low flow periods and other water quality problems.

Minimal riparian vegetation in both impaired watersheds was observed during TMDL development field visits. In the Cooks Creek watershed, riparian areas are used to grow crops and as pasture for livestock. Urban encroachment and agricultural uses are responsible for the lack of riparian vegetation in the Blacks Run watershed. Riparian areas perform many functions that are critical to the ecology of the streams that they border (Figure 3.1). Functional values include:

- Flood detention
- Plant roots stabilize banks and prevent erosion
- Nutrient cycling
- Wildlife habitat
- Canopy vegetation provides shading (decreases water temperature and increases baseflow through lower evaporation rates)

Figure 3.1 Riparian vegetation

4) Toxic Pollutants

Toxic pollutants in the water column and sediment can result in acute and chronic effects on aquatic organisms. Increased mortality rates, reduced growth and fecundity, respiratory problems, tumors, deformities, and other consequences have been documented in toxicity studies of aquatic organisms. Degraded water quality conditions and other environmental stressors can lead to higher rates of incidence of these ailments.

3.3 Monitoring Stations

VADEQ monitors water quality on Blacks Run and Cooks Creek on a monthly basis as part of the Ambient Water Quality Monitoring (AWQM) program. Benthic community data are collected at separate biomonitoring stations each spring and fall. The USGS and VADEQ also maintain a flow gaging station on Blacks Run that was in operation from February 1999 through January 2001. Station locations are listed in Table 3.1 and shown in Figure 3.2.

Table 3.1 Monitoring stations on Blacks Run and Cooks Creek

Station Type	Station Number	Stream and Location
AWQM	1BBLK000.38	Blacks Run - near the mouth, approximately 600 feet downstream of the Rt. 704 bridge
	1BCKS003.10	Cooks Creek - just upstream of the confluence with Blacks Run, at the Rt. 11 bridge
Biomonitoring	1BBLK005.62	Blacks Run - upstream, near a gravel parking lot off of Beery Road in Harrisonburg
	1BCKS003.04	Cooks Creek - just downstream of the AWQM station, between Rt. 11 and the confluence with Blacks Run
USGS Streamflow Gage	01621470	Blacks Run - at the Rt. 704 bridge

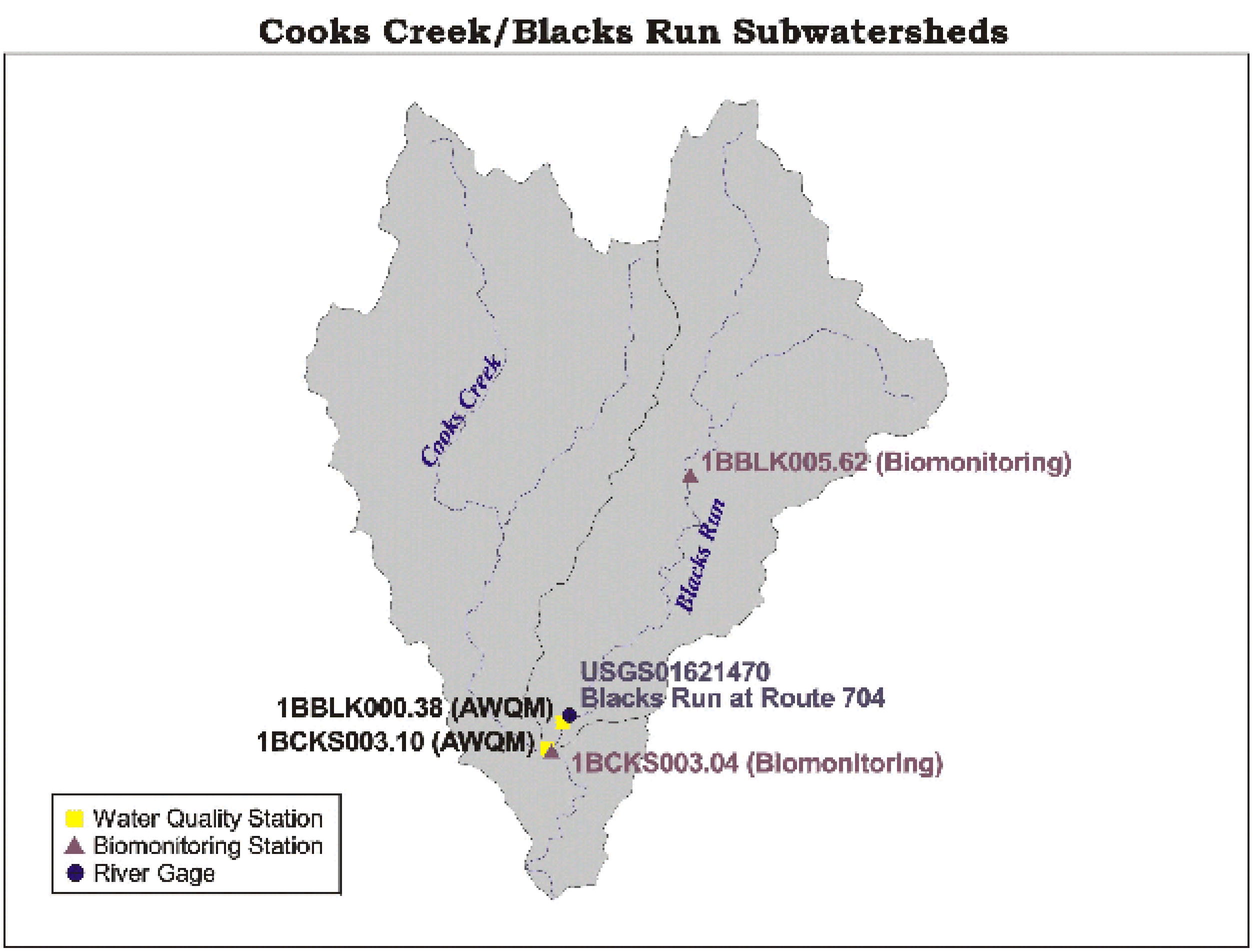

Figure 3.2 Monitoring stations on Cooks Creek and Blacks Run

The AWQM and biomonitoring stations on Cooks Creek are located upstream of its confluence with Blacks Run; therefore, data collected at these stations are not impacted by Blacks Run (and its watershed).

3.4 Water Quality Summary

3.4.1 Ambient Water Quality Monitoring (AWQM) Summary

Blacks Run and Cooks Creek are classified as Mountainous Zone Waters (Class IV) in Virginia Water Quality Standards (9 VAC 25-260-50). Numeric criteria for dissolved oxygen, pH, and maximum temperature for Class IV waters are shown in Table 3.2.

Table 3.2 Virginia numeric criteria for Class IV waters

Dissolved Oxygen (mg/L)			
Minimum	Daily Average	pH (standard units)	Maximum Temperature (ºC)
4.0	5.0	6.0 - 9.0	31

Water quality monitoring data were summarized to help determine general stream characteristics (Table 3.3). These data were collected by VADEQ from December 1991 through October 2000. VADEQ began analyzing for low-level concentrations of total phosphorus in Blacks Run and Cooks Creek in April 1994. Therefore, total phosphorus data presented in Table 3.3 were collected from April 1994 through October 2000.

Table 3.3 Water quality summary for Blacks Run and Cooks Creek

Parameter Name	Temp (ºC)	DO (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	NH3+NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	Fecal Coliform Bacteria (cfu/100 ml)
1BBLK000.38 (Blacks Run)									
Count	99	98	99	80	99	98	98	81	96
Mean	14.58	10.35	8.11	28.94	36.56	0.14	1.61	0.097	5292
Median	15.10	10.30	8.10	14.35	17.00	0.04	1.45	0.060	2300
Max	29.90	16.10	9.30	520.00	784.00	4.00	6.97	0.900	16000
Min	0.10	4.40	7.00	3.00	3.00	0.04	0.28	0.020	45

Parameter Name	Temp (ºC)	DO (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	NH3+NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	Fecal Coliform Bacteria (cfu/100 ml)
1BCKS003.10 (Cooks Creek)									
Count	99	98	99	80	99	98	98	81	97
Mean	14.71	9.91	8.11	60.10	68.90	0.20	4.85	0.258	7361
Median	14.50	10.05	8.10	29.70	40.00	0.12	4.12	0.170	6400
Max	30.00	15.30	9.50	390.00	506.00	1.69	9.45	1.410	16000
Min	0.20	3.30	7.00	6.45	4.00	0.04	0.39	0.040	100

By comparison, Cooks Creek had poorer water quality than Blacks Run for each parameter shown. The minimum dissolved oxygen criteria (4 mg/L) was exceeded on one occasion in Cooks Creek during this time period. Nutrients, total suspended solids, fecal coliform bacteria, and other water quality parameters were elevated above typical background concentrations in both streams indicating degraded water quality conditions.

3.4.2 Diel DO Analysis

To further investigate the potential for low DO concentrations in Blacks Run and Cooks Creek, VADEQ collected 24-hour diel DO data at stations on both streams. Diel DO data were used to calculate the day/night fluctuation in DO concentration. Primary producers (algae and macrophytes) produce oxygen during the day through photosynthesis and use oxygen during the night through respiration. This diel photosynthesis/respiration cycle results in higher DO concentrations during the day and lower DO concentrations at night. Nighttime DO values were estimated for both streams to determine “worst case” DO conditions.

VADEQ collected diel DO data on Blacks Run and Cooks Creek on October 3-6, 2000. Hydrolab datasondes were used to record DO concentration and water temperature at five-minute intervals over the 24-hour period each day. Blacks Run was sampled at the Early Road (Rt. 988) bridge crossing, which is located just upstream of the AWQM station. Cooks Creek was sampled at the Rt. 11 bridge crossing (AWQM station).

The diel pattern in DO concentrations for Blacks Run and Cooks Creek is shown in Figures 3.3 and 3.4. The highest DO levels at each station were recorded from 2-4 p.m. in the afternoon and the lowest DO levels were recorded from midnight until 7 a.m. The average DO concentration during maximum and minimum DO time periods was then calculated (Table 3.4). The range in DO fluctuation over the 24-hour period was used to estimate the nighttime DO value that corresponds with each monthly AWQM (daytime) measurement (AWQM data are discussed above and summarized in Table 3.3). Estimated nighttime values were calculated by subtracting the difference between the average diel DO values, recorded at the same hour as the AWQM measurement, and the average diel DO concentration recorded from midnight to 7 a.m.

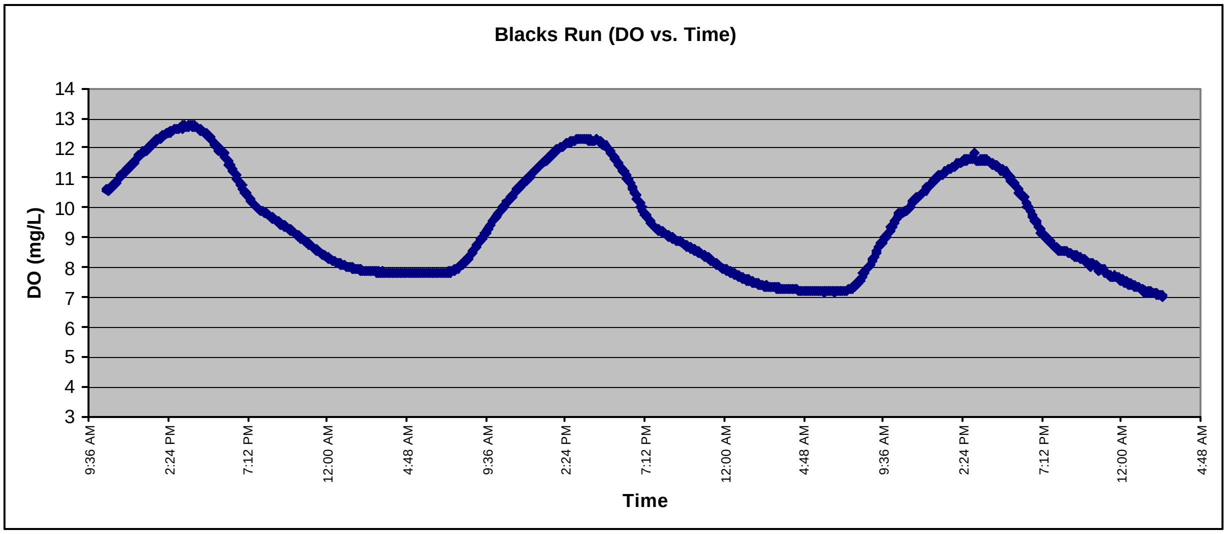

Figure 3.3 Diel dissolved oxygen pattern in Blacks Run

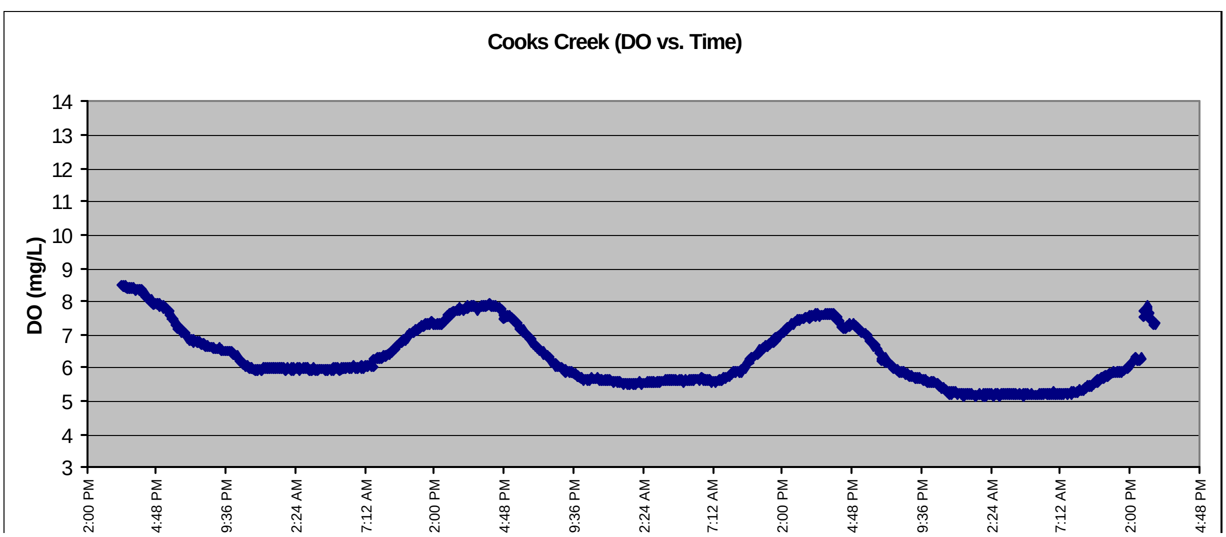

Figure 3.4 Diel dissolved oxygen pattern in Cooks Creek

Table 3.4 Diel dissolved oxygen fluctuation statistics

Stream	Avg. Daytime DO (mg/L)	Avg. Nighttime DO (mg/L)	Diel DO Fluctuation (mg/L)
Blacks Run	12.13	7.59	4.54
Cooks Creek	7.90	5.59	2.30

AWQM data and estimated nighttime DO values for Blacks Run and Cooks Creek are shown in Figure 3.5. These data were compared against the minimum and daily average DO criteria established in Virginia Water Quality Standards (9 VAC 25-260-50) to help determine whether low DO is a primary stressor of the benthic macroinvertebrate community in these streams. These data indicate that 8.2% of the values for Blacks Run and 3.1% of the values for Cooks Creek were less than the minimum DO criteria of 4 mg/L. As compared to the daily average DO criteria, 19.4% of the values for Blacks Run and 7.1% of the values for Cooks Creek were less than 5 mg/L.

* Note that the diel fluctuation in DO concentration may be more/less pronounced depending on time of year and other factors. This analysis is based on diel DO data collected in early October 2000, as described above.

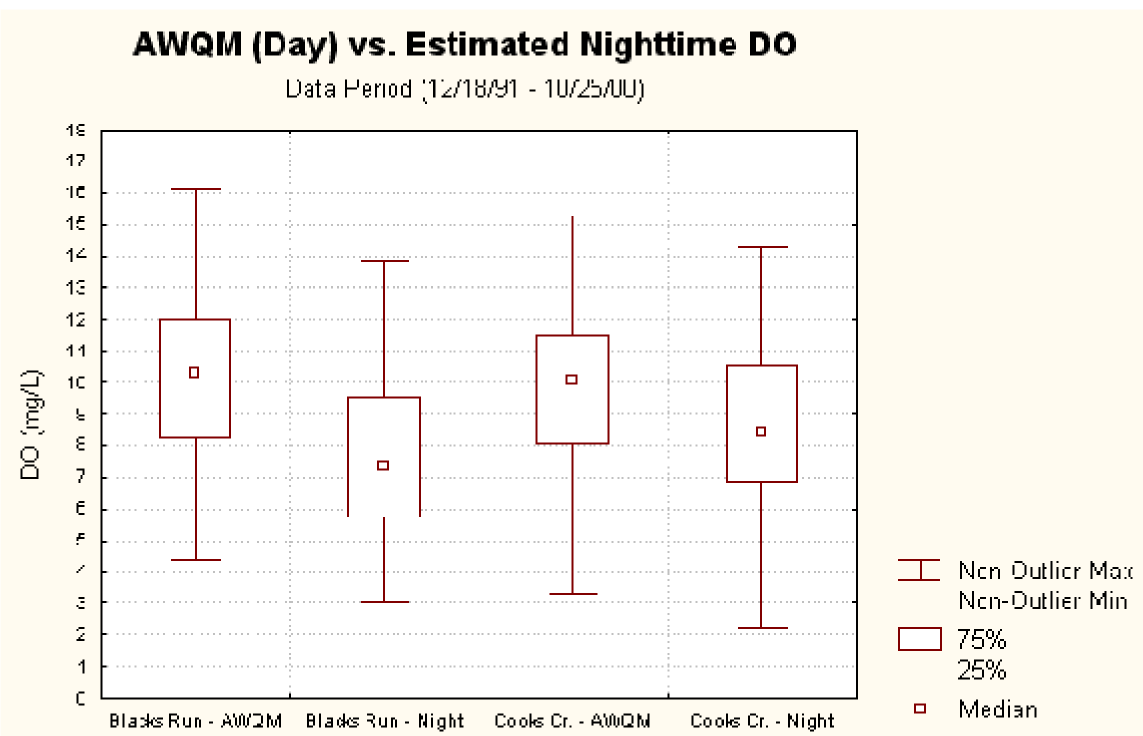

Figure 3.5 Estimated nighttime DO concentrations in impaired streams

3.5 Toxic Pollutants - Surface Water

Virginia Water Quality Standards list acute and chronic criteria for surface waters (9 VAC 25-260-140). These numeric criteria were developed for metals, pesticides, and other toxic chemicals which can cause acute and chronic toxicity effects on aquatic life and human health. Available water quality data were compared to these criteria to determine possible effects on aquatic life. Samples for water column metals were collected on June 1, 1998. Ammonia data were collected during monthly ambient monitoring runs (see Table 3.3 - summary table above). No exceedances of listed parameters were identified.

Water Quality Standards do not include specific criteria for un-ionized ammonia (NH_3), which has been shown to be toxic to aquatic life. Un-ionized ammonia data collected by VADEQ from 1991 through 1998 were compared to an accepted threshold value of 0.02 mg/L. The median values for Blacks Run and Cooks Creek were 0.005 mg/L and 0.002 mg/L, respectively. No exceedances were noted.

3.6 Toxic Pollutants - Sediment

Sediment criteria for toxic pollutants are not specifically listed in Virginia Water Quality Standards. Consistent with VADEQ 305(b)/303(d) guidance procedures, sediment data were assessed using NOAA Effects Range-Median (ER-M) screening values. Data on sediment metals and pesticides in Blacks Run and Cooks Creek were collected by VADEQ on three occasions since 1990. Sampling dates were July 20, 1992; June 18, 1996; and July 14, 1999. No exceedances were noted for sampled parameters.

3.7 EPA Toxicity Testing

Chronic toxicity tests were conducted by EPA Region 3 to determine possible toxic effects on benthic organisms in Blacks Run and Cooks Creek Water (grab) samples were collected on October 23, 25, and 27, 2000 by VADEQ at two stations on each stream and shipped to the EPA Region 3 lab in Wheeling, West Virginia. The survival and growth of fathead minnows (*Pimephales promelas*) and *Ceriodaphnia dubia* was measured using standard methods for chronic toxicity testing.

Results indicate no mortality difference with the control for both test organisms (USEPA 2001). Minnow growth was found to be statistically different from laboratory controls for both Blacks Run sites and one of the Cooks Creek sites. This slight difference in minnow growth was not considered to be biologically significant, due to the minimal variation in control samples.

3.8 Reference Watershed Comparisons

Selected reference watersheds were used to help identify the causes of biological impairment in Blacks Run and Cooks Creek. Stream conditions in reference watersheds are assumed to be representative of the conditions needed for the impaired stream to meet designated uses; therefore, comparative analyses of watershed and water quality data were used in stressor identification.

3.8.1 Flow Comparisons

As described in Section 2.2.6, the upper and middle portions of Blacks Run flow through downtown Harrisonburg with several mainstem and tributary segments located under buildings and parking lots. As compared to the reference streams, Blacks Run shows evidence of hydromodification caused by increased runoff from impervious areas and stormwater outfalls. An increase in the amount of impervious surface in a watershed typically results in higher peak flow during storm events (flashy conditions) and lower baseflow due to the reduction in infiltration capacity. This altered flow regime has resulted in stream bottom scouring, down-cutting, and other negative impacts to the stream channel and habitat conditions.

3.8.2 Water Quality Analyses

Box and Whisker plots were used to compare individual water quality parameters. This type of plot displays the median value, minimum value, maximum value, and 25th and 75th percentile values of a population of data (Figure 3.6). The box shows the range from the 25th percentile to the 75th percentile of the values (termed the interquartile range, or IQR). Within the box, the median, or 50th percentile value, is displayed as a point. Whiskers show the range from the non-outlier minimum value (often 0) to the non-outlier maximum value. The non-outlier minimum value is equal to the 25th percentile value minus 1.5 times the IQR, and the non-outlier maximum limit is equal to the 75th pecentile value plus 1.5 times IQR. The whiskers show the range of data values that are within these limits, not necessarily the actual 1.5x limits themselves. Extreme values are either greater than the 75th percentile value plus 3 times the IQR, or less than the 25th percentile value minus 3 times the IQR. Outliers are values that fall between 1.5 times IQR whisker thresholds and the 3 times IQR extreme thresholds. For graphical purposes, not all extreme and outlier values are displayed in the following box plots.

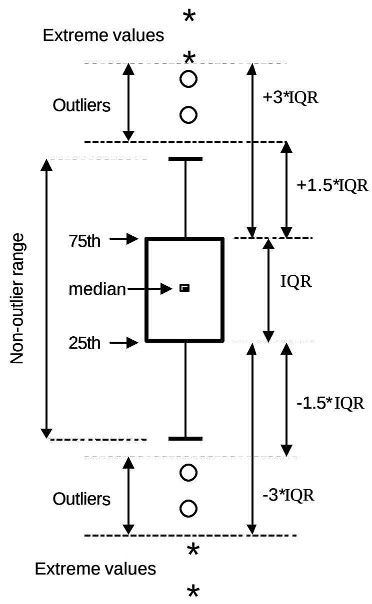

Figure 3.6 Box and whisker plot example

The data period for all parameters, except total phosphorus, is from December 1991 through October 2000. VADEQ began analyzing for low-level concentrations of Total Phosphorus (< 0.1 mg/L) in Opequon Creek and Hays Creek in the latter part of 1999. To properly account for low-level concentrations, Total Phosphorus analyses were performed using data from August 1999 through October 2000.

Dissolved oxygen (DO) levels in Blacks Run and Cooks Creek were measurably lower than in reference streams during this time period (Figure 3.7). Cooks Creek had the lowest median value (10.05 mg/L) and Hays Creek had the highest median value (11.0 mg/L). The 25^{th} percentile in DO concentrations was also lower for both impaired streams. The minimum DO concentration for Cooks Creek and Blacks Run was 3.3 mg/L and 4.4 mg/L, respectively.

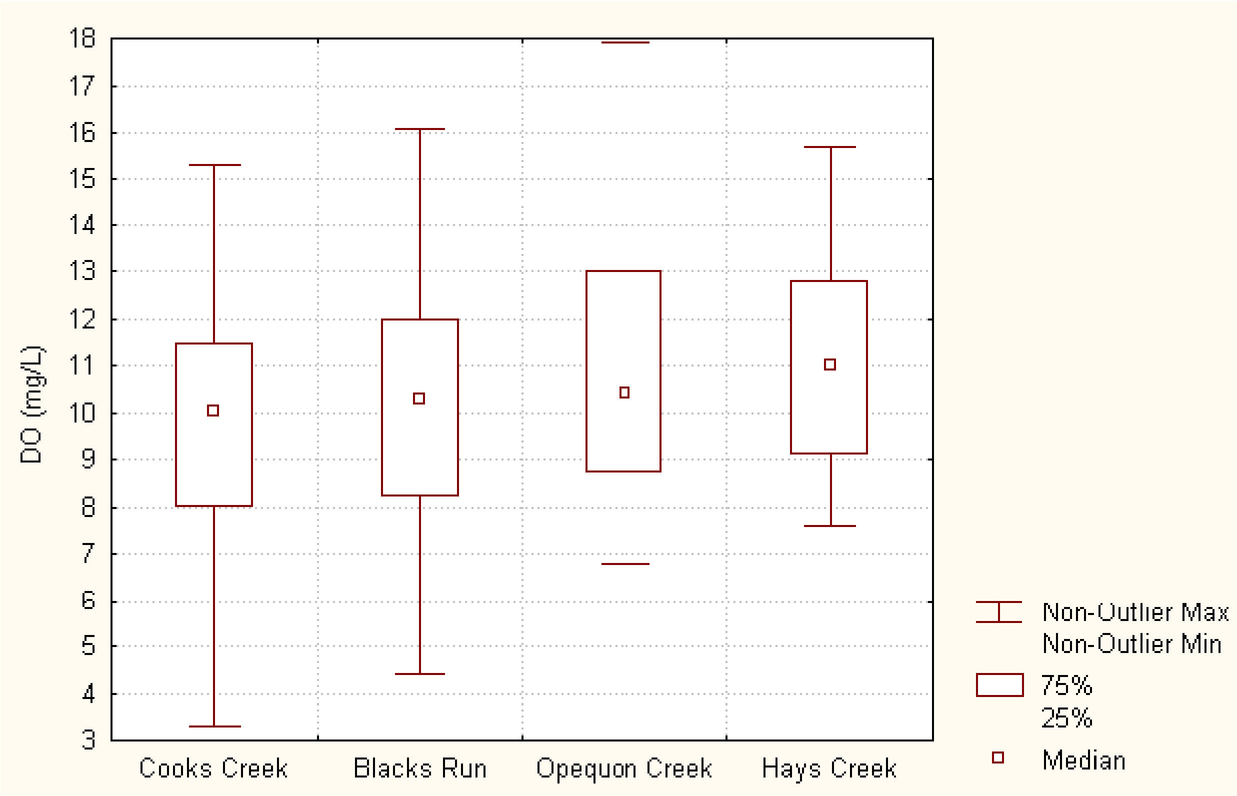

Figure 3.7 Dissolved oxygen concentrations in impaired and reference streams

Biochemical Oxygen Demand (BOD) results were consistent with the trend in DO concentrations between impaired and reference sites (Figure 3.8). Median BOD concentrations were higher for Cooks Creek and Blacks Run than for reference sites, indicating a higher concentration of oxygen-demanding pollutants in the impaired streams. The non-outlier values for Cooks Creek ranged from 1 mg/L to 7 mg/L. Non-outlier values for Blacks Run, Hays Creek, and Opequon Creek did not exceed 3 mg/L BOD. Hays Creek had the lowest median BOD concentration (1 mg/L).

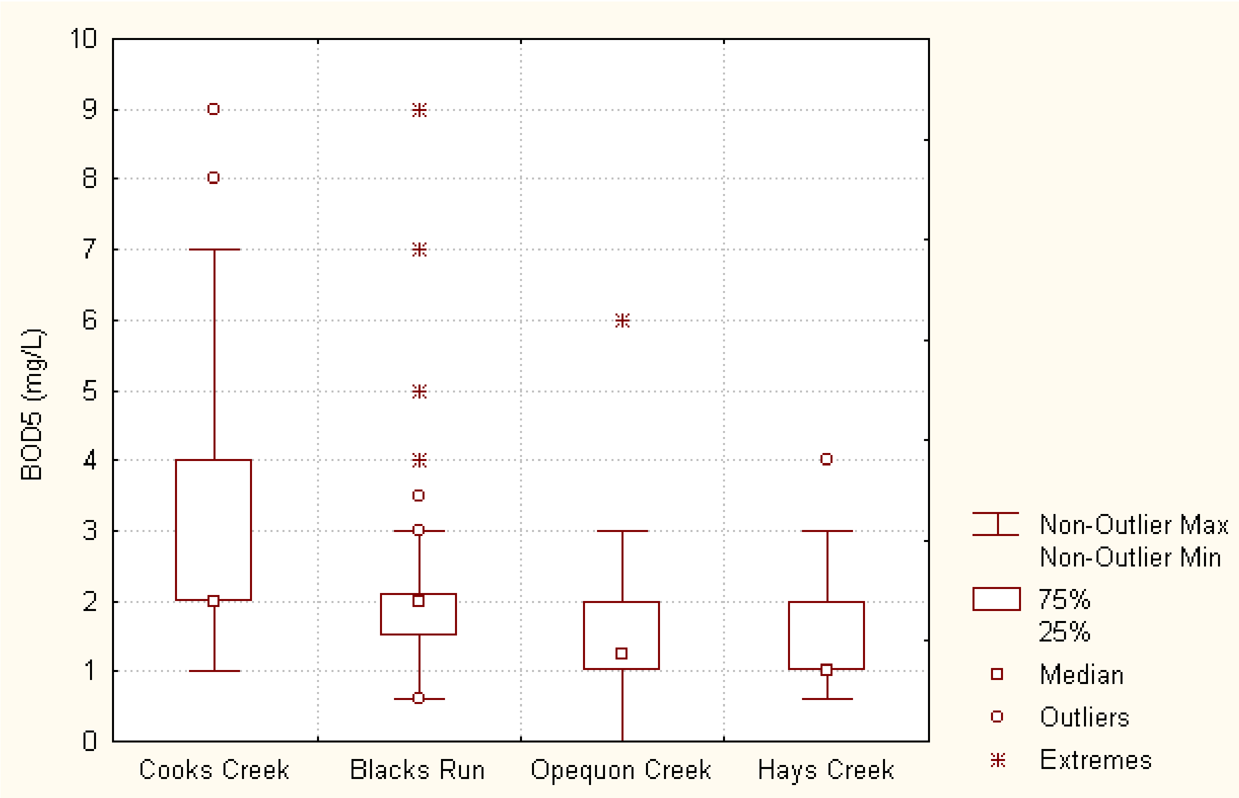

Figure 3.8 Biochemical oxygen demand levels in impaired and reference streams

Surface water temperatures were higher in Blacks Run and Cooks Creek as compared to reference streams (Figure 3.9). Blacks Run had the highest median value (15.1 ^{o}C) and Hays Creek had the lowest median value (12.2 ^{o}C). The relative lack of riparian vegetation in the impaired watersheds is likely responsible for elevated water temperatures. Lower baseflow in Blacks Run may also be contributing to this condition.

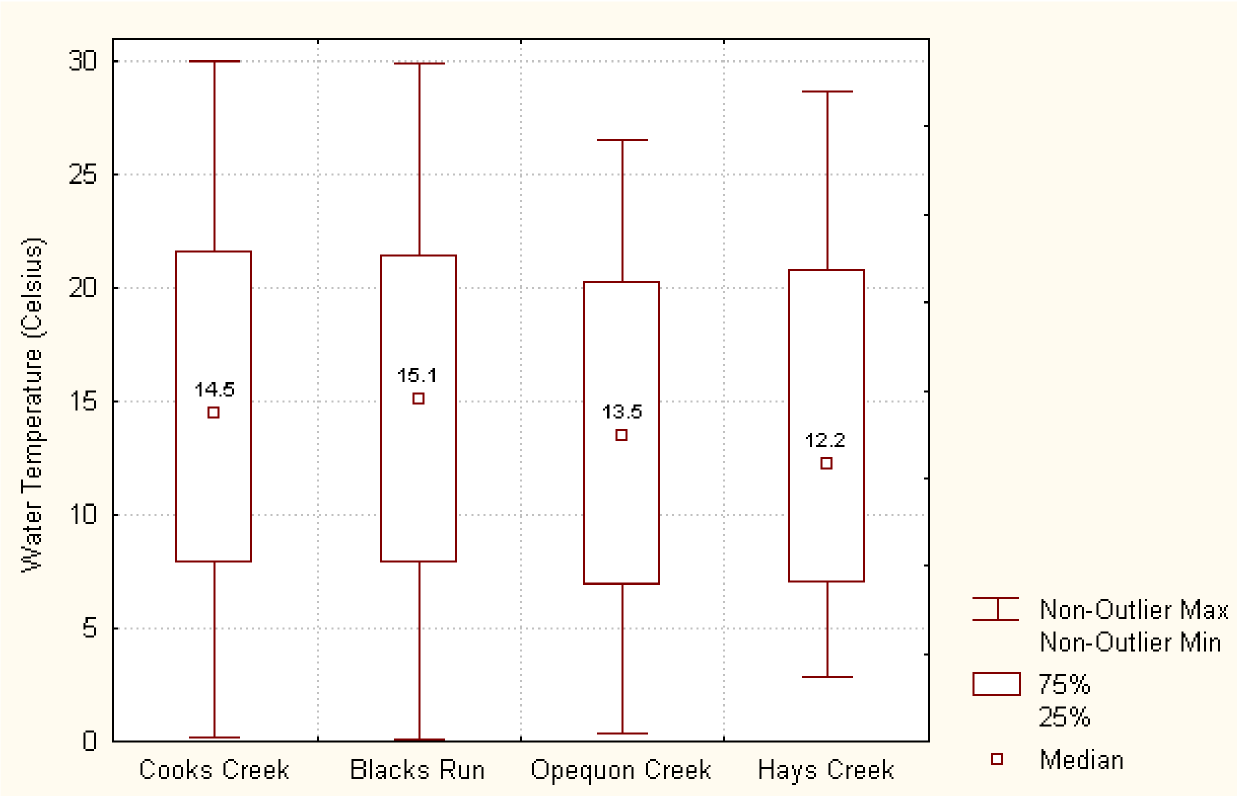

Figure 3.9 Surface temperature in impaired and reference streams

Nutrient data showed a similar trend between impaired and reference streams. Median nutrient concentrations were consistently higher in Cooks Creek than in Blacks Run, Opequon Creek, and Hays Creek. Ammonia concentrations (NH3+NH4) for Cooks Creek ranged from 0.05 mg/L to 0.5 mg/L (Figure 3.10, non-outlier range). Opequon Creek and Hays Creek had the lowest ammonia concentrations during this time period. Total kjeldahl nitrogen (TKN), nitrate, and nitrite concentrations showed similar results (TKN Figure 3.11, nitrate and nitrite not shown). Total phosphorus (TP) was also much higher in Cooks Creek than in reference streams (Figure 3.12). For example, the median TP concentration for Cooks Creek was 0.17 mg/L, whereas the median concentration for Hays Creek was 0.03 mg/L. TP concentrations for Cooks Creek ranged from 0.07 mg/L to an extremely high concentration of 1.25 mg/L. The median TP concentration in Opequon Creek (0.21 mg/L), however, was higher than that for Blacks Run and Cooks Creek. The cause of the elevated concentrations of total phosphorus in Opequon Creek is not clear, but may be related to the lack of long-term, low-level TP data, upstream point sources or other causes.

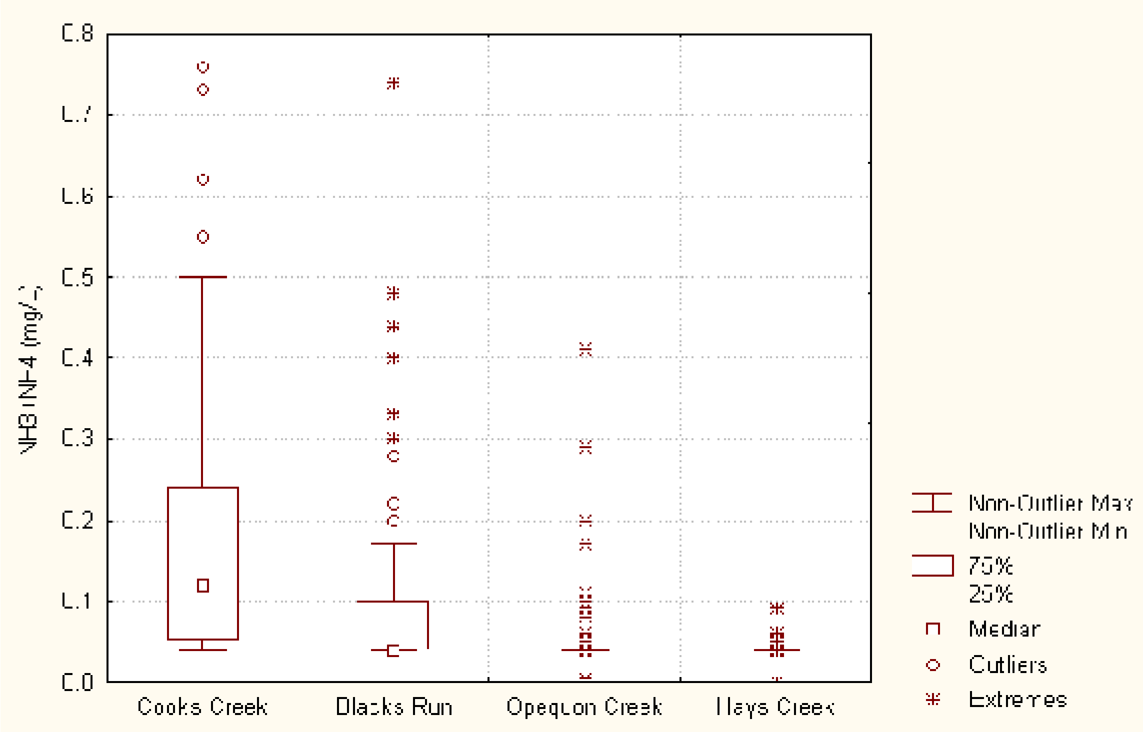

Figure 3.10 Ammonia concentrations in impaired and reference streams

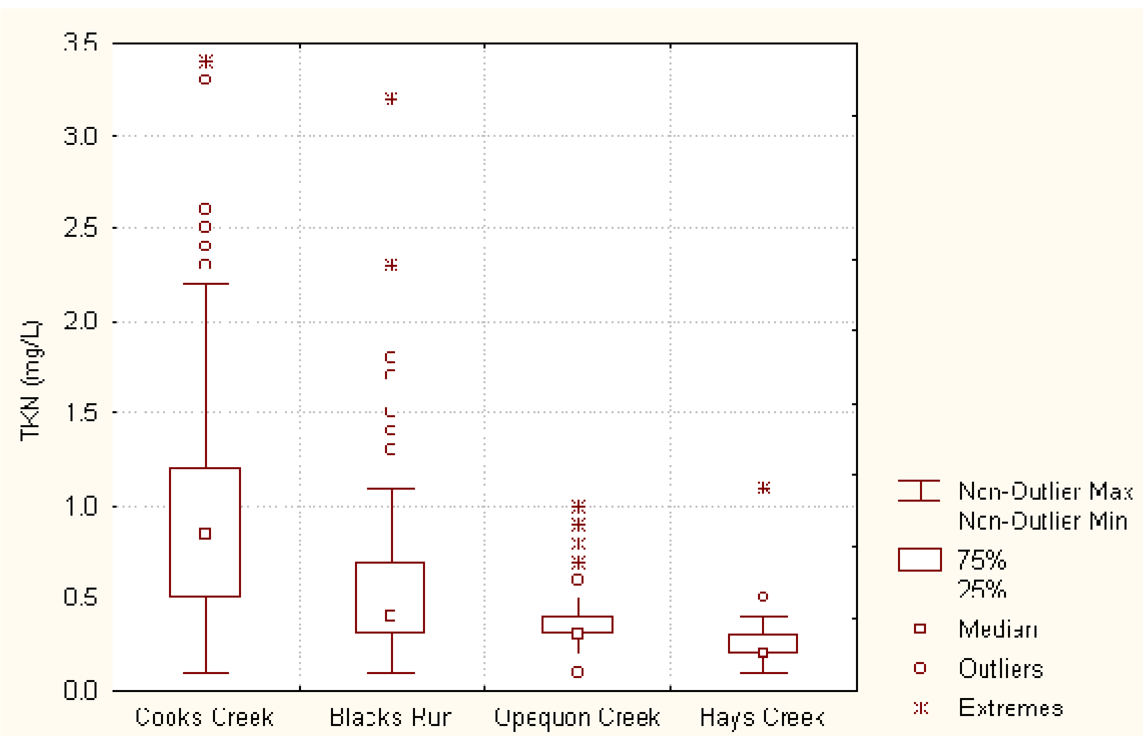

Figure 3.11 Total Kjeldahl nitrogen concentrations in impaired and reference streams

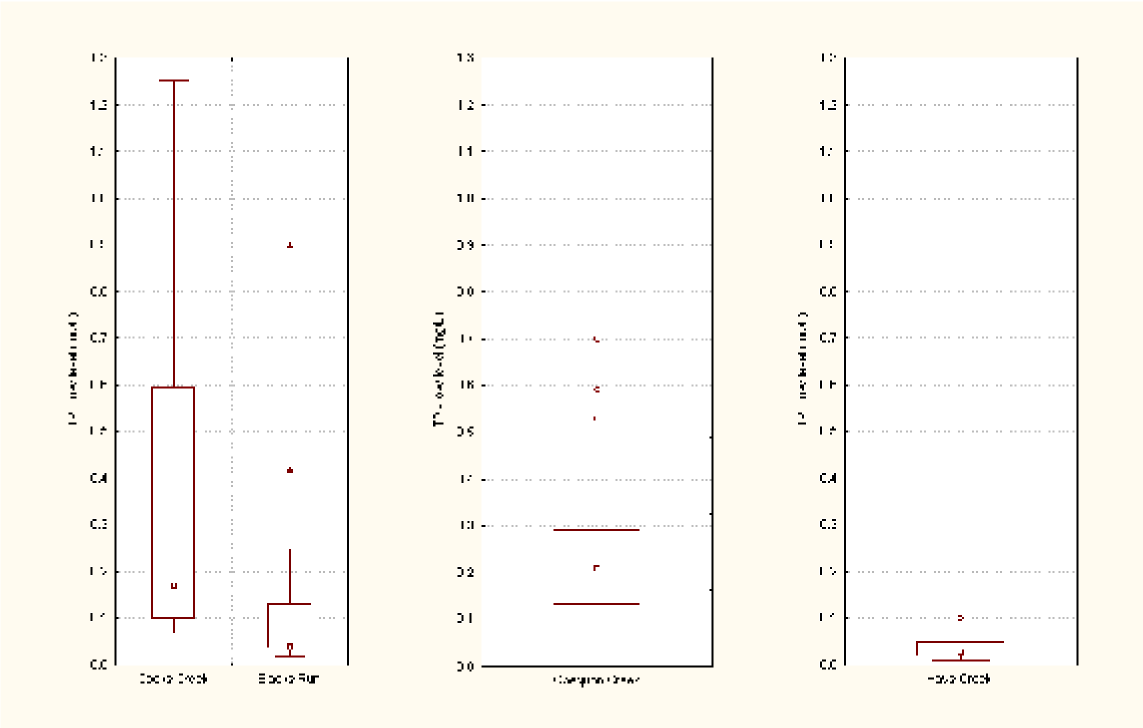

Figure 3.12 Total phosphorus (low-level) concentrations in impaired and reference streams

Total suspended solids (TSS) and turbidity data were used to examine the likelihood of sedimentation effects on the benthic community. TSS concentrations in the impaired streams were higher, as expected, with Cooks Creek having the highest concentrations overall (Figure 3.13). The non-outlier minimum and maximum TSS values for Cooks Creek were 4 mg/L and 176 mg/L, respectively. Blacks Run had the second highest median TSS concentration (17 mg/L), followed by Hays Creek (7 mg/L) and Opequon Creek (4 mg/L). Turbidity data showed a similar trend between impaired and reference sites (Figure 3.14).

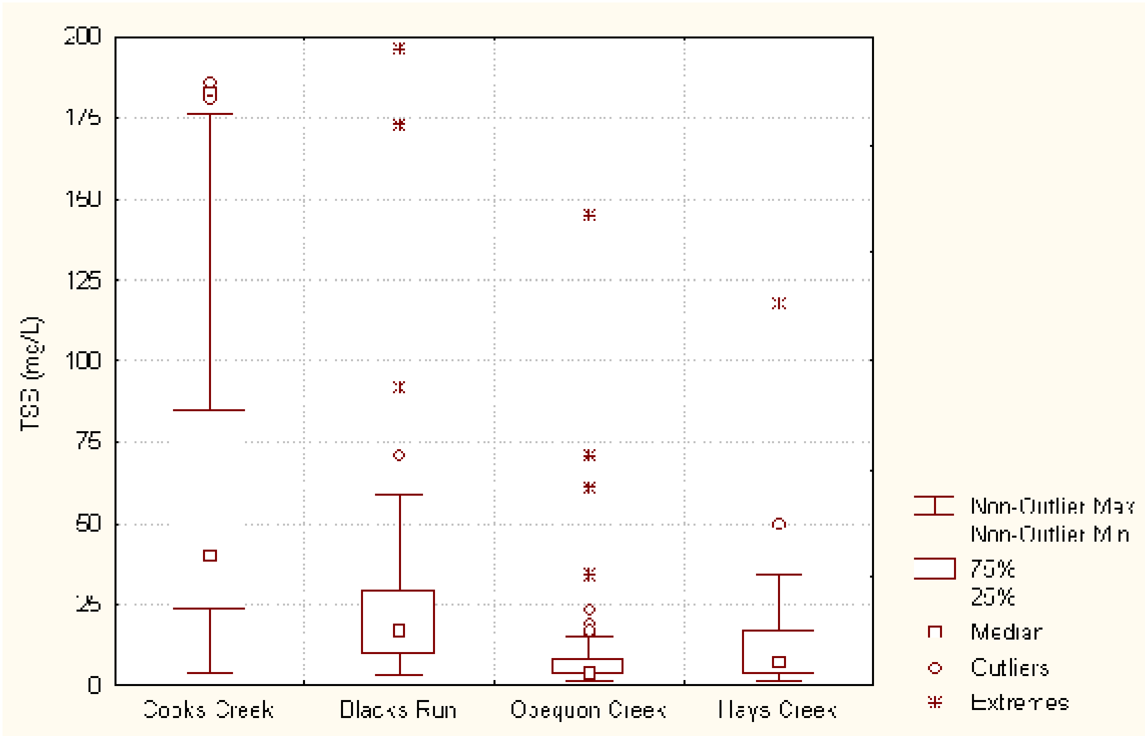

Figure 3.13 TSS concentrations in impaired and reference streams

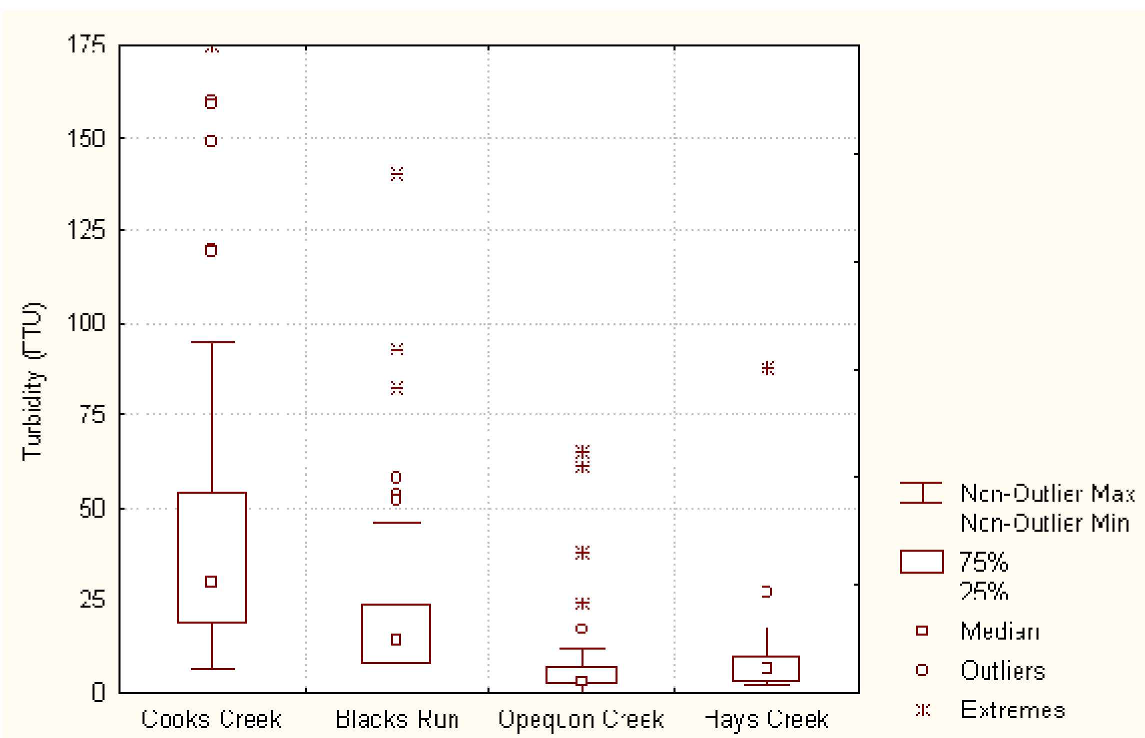

Figure 3.14 Turbidity levels in impaired and reference streams

3.9 Stressors and Selected Endpoints

1) Dissolved Oxygen

Low dissolved oxygen was listed as a likely cause of the benthic impairment on Cooks Creek, according to Virginia's 1998 303(d) list. Water quality comparisons with reference stream conditions and the results of the diel DO analysis support this conclusion. High nutrient concentrations in Cooks Creek increase algal growth and community respiration, especially during summer low flow periods, which leads to lower dissolved oxygen levels. A reduction in excess nutrient loading will subsequently decrease algal productivity in the water column resulting in an increase in dissolved oxygen concentration.

Typically in aquatic ecosystems the quantities of trace elements are plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the nutrient load to a waterbody can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem 1994). In most efforts to control eutrophication processes in waterbodies, emphasis is placed on the limiting nutrient.

Phosphorus is the limiting nutrient for aquatic growth in most freshwater bodies. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of nitrogen to the amount of phosphorus is often used to make this determination (Thomann and Mueller 1987). If the nitrogen/phosphorus ratio is less than 10, nitrogen is limiting; if this ratio is greater than 10, phosphorus is the limiting nutrient. For Cooks Creek, the nitrogen/phosphorus ratio was 25.8, which indicates phosphorus is the limiting nutrient. A phosphorus TMDL was, therefore, developed for Cooks Creek. Controlling the phosphorus loading to Cooks Creek will limit plant growth and reduce eutrophication. As described in Section 6, the numeric endpoint for phosphorus was based on the average annual load in tons/year of the Hays Creek reference watershed.

These data also indicate that low dissolved oxygen is a likely cause of the benthic impairment in Blacks Run; however, the mechanism involved may be more related to the loss of riparian buffers and alterations in the flow regime, than nutrient contributions. Nitrogen and phosphorus concentrations in Blacks Run were much lower than in Cooks Creek and the median values for all constituents (ammonia, nitrate, TP, etc.), although slightly higher in some cases, were more similar to reference stream concentrations. The concentration of dissolved oxygen is inversely proportional to temperature because the solubility of oxygen (and other gases) decreases with increasing temperature. Therefore, at higher temperatures the concentration of dissolved oxygen is lower. As discussed above, water temperature was higher in Blacks Run than in Cooks Creek and the reference streams (AWQM data). Higher water temperatures are likely due the loss of riparian vegetation which provides shading (canopy vegetation cools the stream and reduces evaporation) and the reduction in baseflow caused by impervious surfaces (reduced infiltration and groundwater discharge to the stream). Additional information is needed to determine the relative contribution of nutrient loading and water temperature to low dissolved oxygen conditions in Blacks Run. Although a TMDL for nutrients in Blacks Run is not proposed, phosphorus reductions required to meet the TMDL endpoint for Cooks Creek will require load reductions from contributing watersheds including the Blacks Run watershed. TMDL development will provide information on the annual phosphorus load that is delivered to Blacks Run.

2) Sedimentation

Excessive sedimentation is considered to be a primary cause of the listed benthic impairments in Blacks Run and Cooks Creek. This determination is based on ambient water quality monitoring data indicating high levels of TSS and turbidity in both streams. Agricultural and urban runoff, stream bank de-stabilization, the loss of riparian buffers, and other processes have resulted in sedimentation impacts to the benthic community in these streams. Sediment TMDLs and associated load reductions were, therefore, developed for both streams. As described in Section 6, the numeric endpoint for sediment loading in Blacks Run and Cooks Creek was based on the average annual load in tons/year of the reference watersheds: Upper Opequon Creek and Hays Creek, respectively. Reductions in sediment loading will result in corresponding reductions in phosphorus and other pollutants that adsorb to sediment particles.

3) Habitat Alteration

Habitat alterations combine a complex interaction of stressors. Urban development in the Blacks Run watershed, particularly the construction of buildings, parking lots and other impervious surfaces within the floodplain and riparian areas, has resulted in alterations to the physical structure of the stream channel and its flow regime, the loss of riparian vegetation functions, and associated water quality impacts. Habitat quality in Cooks Creek has been primarily affected by agricultural practices, especially the intensive use of riparian areas for agricultural production. Also, habitat alterations caused by urban and agricultural development in Blacks Run provide additional problems for Cooks Creek, below its confluence with Blacks Run.

The complex suite of stressors caused by habitat modification include: decreased detrital input which serves as an energy source; decreased woody debris which provides substrate; increased erosion; flow alterations which cause stream channel impacts and affect water quality; the loss of pools and riffles due to sedimentation and other causes; and other stressors (Tarplee et al. 1971, Karr and Schlosser 1977, Yount and Niemi 1990, Allan 1995). Field observations, analyses of water quality and biomonitoring data, and past studies of urban and agricultural watersheds provide evidence of these impacts.

Although these TMDLs do not directly address habitat modification, which is not a pollutant, reductions in sediment and nutrient loads are expected to benefit habitat conditions. Management practices expected to be used in reducing sediment and nutrient loads will include riparian zone management that benefits habitat conditions as well, through stream shading and stream bank protection.

4) Toxic Pollutants

Toxic pollutants in the water column and sediment were investigated as potential stressors of the benthic community. Analyses of water quality and sediment data do not indicate acute or chronic levels of metals, pesticides, or other toxins in these streams. In addition, EPA chronic toxicity tests, using water samples collected from Blacks Run and Cooks Creeks, did not indicate adverse impacts on test organisms. As a result, TMDLs for toxic pollutants were not required.

SECTION 4

SOURCE ASSESSMENT - SEDIMENT AND PHOSPHORUS

Point and nonpoint sources of sediment and phosphorus were assessed in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources in impaired and reference watersheds including: agricultural and land use information provided by VADCR and other sources, water quality monitoring and point source data provided by VADEQ, local housing and other spatial coverages provided by Rockingham County and the City of Harrisonburg, coordination with USGS (Blacks Run fecal coliform TMDL development), past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating sediment and phosphorus sources in the impaired watersheds are described in the following sections. Similar procedures were used to derive the required input data for reference watersheds, although the specific data products used varied for each watershed. Whenever possible, data development and source characterization was accomplished using locally-derived information.

4.1 Assessment of Nonpoint Sources

Virginia's 1998 303(d) list identifies urban runoff as the primary source of pollutants in the Blacks Run watershed. Cooks Creek was listed as impacted by agricultural nonpoint sources with the lower three miles also affected by urban runoff contributed by Blacks Run. Both watersheds were assessed by VADCR as having a high potential for nonpoint source pollution based on land use, soils, and other watershed characteristics (refer to Section 2).

Erosion of the land results in the transport of sediment to receiving waters through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are large contributors of sediment because the percentage of vegetative cover is typically lower. Urban areas can also contribute quantities of sediment to surface waters through the build-up and eventual washoff of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads. Timber operations represent another potential source of sedimentation. Although the sediment yield from undisturbed forests is generally low, clear-cut areas can contribute significant sediment loads.

Phosphorus, because of its tendency to adsorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Under normal conditions, phosphorus is scarce in the aquatic environment; however, land disturbance activities and fertilizer applications increase phosphorus loading in surface waters. Nonpoint sources of phosphorus include soil erosion, runoff from urban and agricultural lands, animal waste, residential septic systems, and groundwater.

4.1.1 Agricultural Land

Agricultural land was identified as a major source of nutrients and sediment in the Blacks Run and Cooks Creek watersheds. Agricultural runoff can contribute increased pollutant loads when farm management practices allow soils rich in nutrients from fertilizers or animal waste to be washed into the stream, increasing in-stream sediment and phosphorus levels. The erosion potential of cropland and over-grazed pasture land is particularly high due to the lack of year-round vegetative cover. The use of cover crops and other management practices have been shown to reduce the transport of pollutant loads from agricultural lands.

VADCR land use types in the Blacks Run and Cooks Creek watersheds are shown in Table 2.1. Consolidated land uses are also shown in this table and represent similar land use categories. Watershed land use percentages are presented in Section 2.2.5. The major crops grown in Rockingham County are corn hay, soybeans, barley, and wheat.

4.1.2 Livestock

Rockingham County ranks as the top agriculture producing county in Virginia, due in large part to livestock sales (NASS 1997). Rockingham County is the leading producer of poultry (broilers, pullets, layers, and turkeys) and dairy cattle, ranks third in beef cattle production, and is second in sheep and lamb production (VASS 2001). Horses, goats, and other livestock animals had very small populations as compared to the major livestock species listed above.

Grazing animals, such as beef and dairy cattle, deposit manure (and, therefore, nutrients) on the land surface, where it is available for washoff and delivery to receiving waterbodies. Spreading animal manure on agricultural lands also contributes to nutrient washoff. Livestock traffic, especially along stream banks, disturbs the land surface and reduces vegetative cover causing an increase in erosion from these areas.

4.1.3 Forest Land

Silviculture, especially clear-cut operations, can be an important nonpoint source of sediment and other pollutants. As discussed in Section 2.2.5, the percentage of forest land (evergreen, deciduous, and mixed forest) in both watersheds is very low. Urban and agricultural development in Rockingham County has resulted in the loss of mature forest areas. The remaining forest lands, generally, occupy higher elevations and agriculturally unproductive areas. The sediment and phosphorus yield from undisturbed forest lands, especially during the growing season, is low due to the amount of dense vegetative cover which stabilizes soils and reduces rainfall impact. Clear-cut areas have a high erosion potential and are represented in the VADCR land use type “Barren”.

4.1.4 Urban Areas

The City of Harrisonburg and other urban areas contribute to the high percentage of urban land in the Blacks Run and Cooks Creek watersheds. Urban land uses represented in the VADCR land use coverage include commercial, industrial, transportation, and residential areas. Watershed differences in urban land use distribution are discussed in Section 2.2.5.

Urban land uses consist of pervious and impervious areas. Stormwater runoff from impervious areas, such as paved roads and parking lots, contributes pollutants that accumulate on these surfaces directly to receiving waters without being filtered by soil or vegetation. Sediment and phosphorus deposits in impervious areas originate from vehicle exhaust, industrial and commercial activities, fertilizer spills, outdoor storage piles, wildlife and domestic pet waste, and other sources. Combined sewer overflows (CSOs) and leaking sewer lines may also be a source of nutrients in some urban areas. According to Novotny and Olem (1994), phosphorus concentrations in urban runoff range from 0.2 to 1.7 mg/L. In addition, stormwater runoff can cause streambank erosion and bottom scouring through high flow volumes, resulting in increased sedimentation and other habitat impacts.

The primary sources of sediment and phosphorus are construction sites and other pervious lands. Construction sites have high erosion rates due to the removal of vegetation and top soil. Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to 1 to 10 tons per acre per year for cropland. Residential lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. Fertilizer application on lawns can be a significant source of phosphorus and other pollutants. Wildlife and domestic pet waste is also deposited on pervious urban lands.

Urban land use areas were separated into pervious and impervious fractions based on the estimated percent impervious surface of each urban land use category. Field observations and literature values were used to determine the effective percent imperviousness of urban land uses (Table 4.1). Construction sites, quarries, and other bare soil areas are represented as “Barren” in the VADCR land use coverage.

Table 4.1 Percent imperviousness of urban land uses in Blacks Run and Cooks Creek

Urban land uses	Percent impervious
High Intensity Commercial / Industrial / Transportation	50%
High Intensity Residential	40%
Medium Intensity Residential	30%
Low Intensity Residential	20%

4.1.5 Septic Systems

On-site septic systems have the potential to deliver nutrients to surface waters due to system failure and malfunction. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems do not contribute phosphorus loads to surface waters. A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff. As a result, failing septic systems can contribute high phosphorus loads to surface waters. Short-circuited systems (those located close to streams) and direct discharges also contribute significant nutrient loads.

The population served by each type of septic system (normal, short-circuited, ponded, and direct discharge) was determined using the following methods (Table 4.2). Unsewered houses were identified and digitized using housing and sewer GIS coverages provided by Rockingham County and the City of Harrisonburg (E-911) data. Houses located within 300 feet of a sewer line were assumed to be connected to the regional sewer system. The location of unsewered houses was refined using the VADCR landuse coverage for the Cooks Creek watershed. Houses located within high density residential, medium density residential, commercial, industrial, transportation, mixed urban, and open urban landuse areas were also assumed to be connected to the sewer system. The population on septic was determined using the Rockingham County census multiplier of 2.69 persons/house.

The number of failing (ponded) septic systems in each watershed was estimated using a failure rate of 13.5%. This failure rate was based on information obtained by the USGS during the development of the Blacks Run fecal coliform TMDL. The number of short-circuited systems was estimated based on the proximity of unsewered houses to the closest perennial stream. Unsewered houses located within 50 feet (approximately 15 meters) of a perennial stream were assumed to have a short-circuited septic system. These systems are located close enough to surface waters, such that negligible adsorption of phosphorus takes place (Haith et al. 1992).

In some cases, human waste is directly deposited into surface waters from houses without septic systems.

These direct discharges are called "straight pipes" and are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located close to a waterbody. The number of straight pipes in each watershed was determined based on housing age and distance to a perennial stream. Older houses (pre-1967 and 1967-1985) located within 150 feet of a perennial stream were assumed to have a straight pipe according to the following percentages: pre-1967 (10% straight pipes), 1967-1985 (5% straight pipes).

Table 4.2 Septic population in each watershed

Watershed	Normal	Ponded (Failing)	Short-circuited	Direct discharge
Blacks Run	486	76	0	0
Cooks Creek	3,150	492	3	3

4.1.6 Groundwater

Agriculture and septic systems are two major sources that enrich the groundwater. Phosphorus concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992). The relative percentage of agriculture and forest land in each watershed and septic population data were used to estimate groundwater phosphorus concentrations from the study results.

4.2 Assessment of Point Sources

Point sources can contribute sediment and phosphorus loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ.

There are currently four minor point source facilities in the Cooks Creek and Blacks Run watersheds (Table 4.3 and Figure 4.1). The water treatment plants for the City of Harrisonburg and the Town of Dayton are located in the Cooks Creek watershed. Frazier Quarry and the U.S. Training and Development Center are located in the Blacks Run watershed. The permits for these facilities include a TSS limit of 30 mg/L, but do not contain nutrient limits. Nutrient limits were not required because filter backwash (from water treatment plants) and quarry water do not typically contain high nutrient concentrations. The annual sediment load contributed by each facility was calculated using the design flow and TSS permit limit (Table 4.3).

Table 4.3 VPDES point source facilities and TSS load

Stream	Facility Name	VPDES Permit No.	Discharge Type	TSS Load (pounds/year)
Blacks Run	Frazier Quarry	VAG841011	Quarry water	39,480
	U.S. Training and Development Center	VAG401217	Municipal	91
Cooks Creek	Dayton WTP	VA0090085	Filter backwash	8,220
	Harrisonburg WTP	VA0002674	Filter backwash	31,900

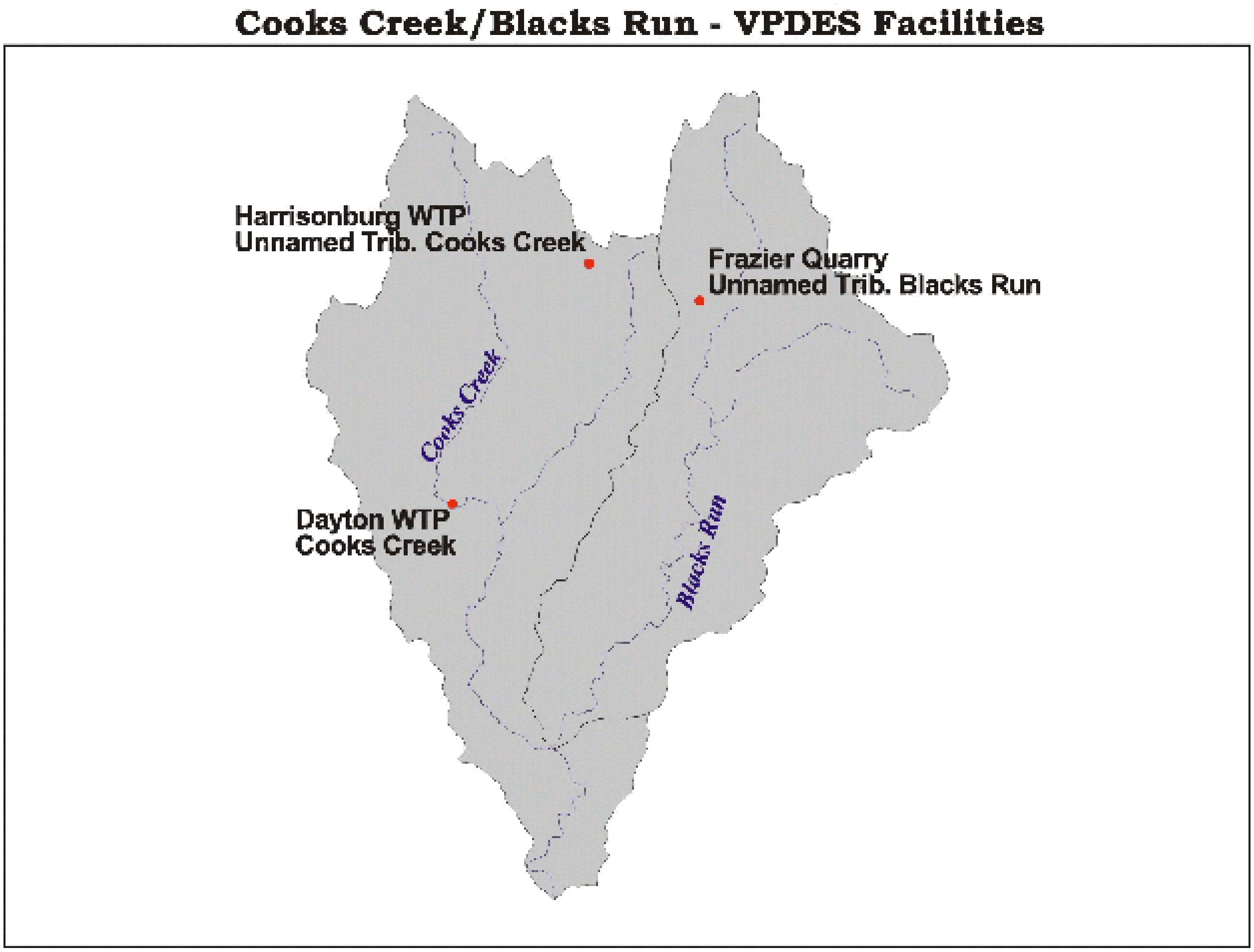

Figure 4.1 VPDES facilities (point sources) in the Cooks Creek and Blacks Run watersheds

* The U.S. Training and Development Center is not shown (permitted 9/01).

SECTION 5

WATERSHED MODELING

5.1 Overall Technical Approach

As discussed in Section 2.1, a reference watershed approach was used in this study to develop TMDLs for Blacks Run and Cooks Creek. A watershed model was used to simulate the sediment and phosphorus loads from potential sources in impaired and reference watersheds. The watershed model used in this study was the Generalized Watershed Loading Functions (GWLF) model (Haith and Shoemaker, 1987). GWLF modeling was accomplished using the BasinSim 1.0 watershed simulation program, which is a windows-based modeling system that facilitates the development of model input data and provides additional functionality (Dai et al. 2000). Numeric endpoints were based on the unit-area loading rates that were calculated for reference watersheds. TMDLs were then developed for each impaired stream segment based these endpoints and the results from load allocation scenarios.

5.2 Watershed Model

TMDLs were developed using BasinSim 1.0 and the GWLF model. The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker, 1987; Haith et al., 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges also can contribute to dissolved loads to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, also can be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel considers only a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker, 1987) and GWLF User's Manual (Haith et al. 1992).

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations). The weather file (WEATHER .DAT) contains daily average temperature and total precipitation values for each year simulated.

5.3 Model Setup

Watershed data needed to run the GWLF model in BasinSim 1.0 were generated using GIS spatial coverages, water quality monitoring and streamflow data, local weather data, literature values, and other information. Watershed boundaries for Blacks Run and Cooks Creek were delineated using the VADCR land use coverage for each watershed. For flow calibration purposes, the Blacks Run watershed was divided into two subwatersheds at the USGS gaging station on Blacks Run. The Cooks Creek watershed was sub-delineated at the confluence with Blacks Run to allow for comparisons of model output above and below this point. Reference watersheds were delineated using USGS 7.5 minute digital topographic maps (24K DRG - Digital Raster Graphics). Reference watershed outlets are located at the VADEQ biomonitoring stations on Hays Creek and Upper Opequon Creek. To equate target and reference watershed areas for TMDL development, the total area for each reference watershed was reduced to be equal to the area of its paired target watershed, after hydrology calibration. To accomplish this, land use areas (in each reference watershed) were proportionally reduced based on the percent land use distribution. As a result, the total watershed area for Upper Opequon Creek was reduced to be equal to the Blacks Run watershed area. Likewise, the total watershed area for Hays Creek was reduced to be equal to the Cooks Creek watershed area, excluding Blacks Run.

Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Hourly precipitation and daily temperature data were obtained from local National Climatic Data Center (NCDC) weather stations and other sources. Daily maximum and minimum temperature values were converted into daily averages for modeling purposes. Weather stations that correspond with each modeled watershed are shown in Table 5.1. The period of record selected for model runs (April 1, 1998 through March 31, 2001) was based on the availability of recent weather data and corresponding streamflow records. A combination of weather data collected at the USGS gage on Blacks Run and the NCDC station at Dale Enterprise was used to construct the weather file used in Blacks Run and Cooks Creek simulations. Hays Creek modeling was based on precipitation data collected at the NCDC station on Kerrs Creek and temperature data collected at the NCDC station in nearby Lexington. The calculated daily average temperatures for Lexington were reduced by 1^{o}C to adjust for the difference in elevation between Lexington and the Hays Creek watershed. Opequon Creek modeling was primarily based on weather data collected at the Winchester 7SE station (#449186). Data from Winchester Winc (#449181) and Dale Enterprise were used to fill in gaps in the Winchester 7SE data set.

Table 5.1 Weather stations used in GWLF models

Watershed	Weather Station	Data Type	Data Period
Blacks Run/ Cooks Creek	USGS gage on Blacks Run	Hourly Precip	9/15/98 - 1/23/01
	Dale Enterprise	Hourly Precip	4/1/98 - 9/14/98
		Daily Max/Min Temp	4/1/98 - 2/22/01
Opequon Creek	Winchester 7SE	Hourly Precip & Daily Max/Min Temp	4/1/90 - 3/31/97
	Winchester Winc (used to fill in gaps in 7SE dataset)	Hourly Precip & Daily Max/Min Temp	9/1/91 - 9/30/91 & 10/1/92 - 10/31/92
	Dale Enterprise (used to fill in gaps in 7SE dataset)	Hourly Precip & Daily Max/Min Temp	11/1/91 - 11/30/91, 11/1/92 - 11/30/92, & 2/1/93 - 2/28/93
Hays Creek	Kerrs Creek	Hourly Precip	4/1/90 - 3/31/97
	Lexington	Daily Max/Min Temp	4/1/90 - 3/31/97

Daily streamflow data, obtained from USGS gaging stations, were used to calibrate hydrologic parameters in the GWLF model for each watershed (Table 5.2). The USGS does not monitor flow on Cooks Creek and Hays Creek. Therefore, streamflow records from Blacks Run were used for Cooks Creek hydrology and Kerrs Creek flow data were used to estimate Hays Creek flows. Flow data were corrected based on differences in watershed size.

The USGS gage on Blacks Run went into operation on February 20, 1999 and ceased operation on January 23, 2001. As a result, flow data were not available from April 1, 1998 (beginning of the modeling period) through February 19, 1999 and from January 24, 2001 through March 31, 2001 (end of the modeling period). To create the USGS data file used in hydrology simulations for Blacks Run and Cooks Creek, a flow of zero was entered for the first ten months and the last two months of the modeling period

Table 5.2 USGS gaging stations used in modeling studies

Modeled Watershed	USGS station number	USGS gage location	Data Period
Blacks Run/ Cooks Creek	01621470	Blacks Run at Rt. 704 near Mount Crawford, VA	2/20/99 - 1/23/01
Opequon Creek	01615000	Opequon Creek near Berryville, VA	4/1/90 - 3/31/97
Hays Creek	02022500	Kerrs Creek near Lexington, VA	4/1/90 - 3/31/97

As described Section 5.2, the GWLF model provides the ability to simulate surface water runoff, as well as sediment and nutrient loads, from a watershed based on landscape conditions such as topography, land use/cover, and soil type. In essence, the model is used to estimate surface runoff and nonpoint source loads from different areas in the watershed. Transport loss estimates were applied to sediment loads from point sources in impaired and reference watersheds, as described in Section 6.1 (Hays Creek had no point sources)

5.4 Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized below:

Areal extent of different land use/cover categories: VADCR and MRLC land use coverages were used to calculate the area of each land use category in impaired and reference watersheds. Land use areas in these watersheds were ground-truthed by VADCR and Tetra Tech personnel in October 2000 (Blacks Run and Cooks Creek), March 2001 (Hays Creek and Opequon Creek), and May 2001 (Opequon Creek). Corrections to VADCR and MRLC land use coverages were made using this information and housing coverages provided by the planning offices of Rockingham County and the City of Harrisonburg.

Curve number: This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data were obtained from Virginia county soil surveys and the State Soil Geographic (STATSGO) database for Virginia, as developed by the Natural Resources Conservation Services (NRCS).

K factor: This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land.

* The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992). Average values for specific crops/land uses in each watershed county were used (Rockingham, Augusta, Rockbridge, Frederick, and Clarke counties). The predominant crop grown in these watersheds is corn; therefore, cropland values were based on data collected in corn crops.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

P factor: This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion..

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

Dissolved nitrogen in runoff: This parameter varies according to land use/cover type. Reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Dissolved phosphorus in runoff: Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Nutrient concentrations in runoff over manured areas: These concentrations are user-specified concentrations for nitrogen and phosphorus that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these concentrations are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations.

Nutrient buildup in nonurban areas: In GWLF, rates of buildup for both nitrogen and phosphorus have to be specified. These rates are estimated using published literature values and adjusted to local conditions.

Background nitrogen and phosphorus concentrations in groundwater: Subsurface concentrations of nutrients (primarily nitrogen and phosphorus) contribute to the nutrient loads in streams. Nutrient concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992).

Background nitrogen and phosphorus concentrations in soil: Because soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. This information was based on literature values that were adjusted locally depending on manure loading rates and farm animal populations.

Other less important factors that can affect sediment and nutrient loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al., 1992). Specific details in the manual that describe equations and typical parameter values used can be found on pages 15 through 41.

5.5 Flow Calibration

Using the input files created in the BasinSim 1.0, GWLF predicted overall water balances in impaired and reference watersheds. For Blacks Run and Cooks Creek, local weather data obtained from the USGS gage on Blacks Run and from the NCDC meteorological station located at Dale Enterprise were used to model the three year time period: April 1, 1998 through March 31, 2001. The GWLF model is based on the hydrologic year (Haith and Shoemaker, 1987); therefore, the modeling period always begins on April 1 and ends on March 31. As discussed in Section 5.3, the modeling period is determined based on the availability of weather and flow data that were collected during the same time period. The USGS gage on Blacks Run went into operation on February 20, 1999 and ceased operation on January 23, 2001. As a result, flow data were not available from April 1, 1998 (beginning of the modeling period) through February 19, 1999 and from January 24, 2001 through March 31, 2001 (end of the modeling period). To create the USGS data file used in hydrology simulations for Blacks Run and Cooks Creek, a flow of zero was entered for the first ten months and the last two months of the modeling period. Weather data were available for the entire modeling period. Monthly observed and simulated flow levels for Blacks Run (at the mouth) and Cooks Creek (not including the Blacks Run subwatershed) are shown in Figures 5.1 and 5.2, respectively. Calibration statistics are presented in Table 5.3. In general, an R^2 value greater than 0.7 indicates a strong, positive correlation between simulated and observed data. These results indicate a good correlation between simulated and observed results for these watersheds, especially given the lack of observed data in the beginning and end of the modeling period, as discussed above. A total flow volume error percentage of less than 10% was achieved. Flow calibration results and the modeled time period for reference watersheds are given in Figures 5.3 and 5.4 and Table 5.3. Reference watershed results also indicate a good correlation between simulated and observed flow volumes. As discussed above, streamflow data used for Cooks Creek and Hays Creek simulations were based on flow data collected at USGS gages located in similar watersheds. Recall that Blacks Run gaging data were used to calculate streamflow in Cooks Creek and Kerrs Creek gaging data were used to calculate flow in Hays Creek. Differences between observed and modeled flows in these watersheds are, therefore, likely due to inherent errors in flow estimation procedures based on watershed size.

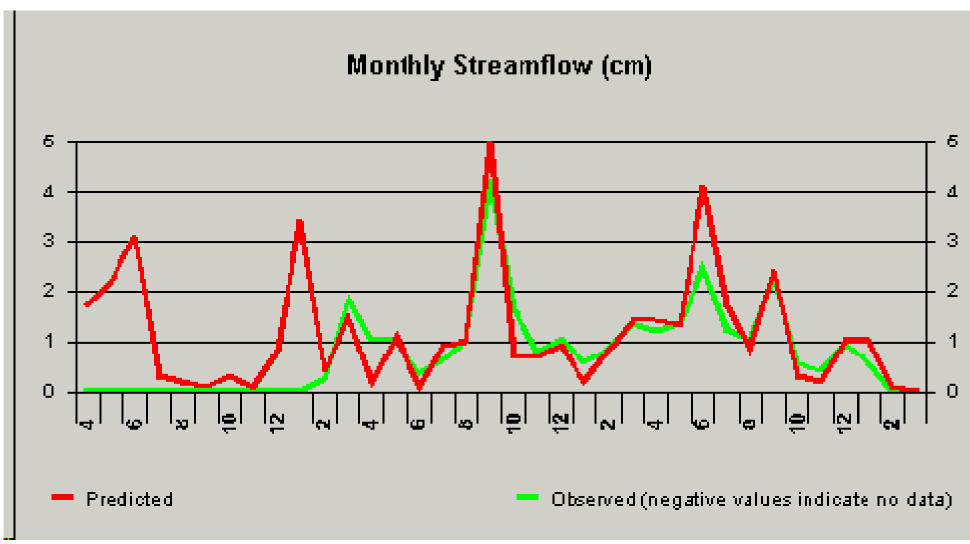

Figure 5.1 Flow calibration at the mouth of Blacks Run

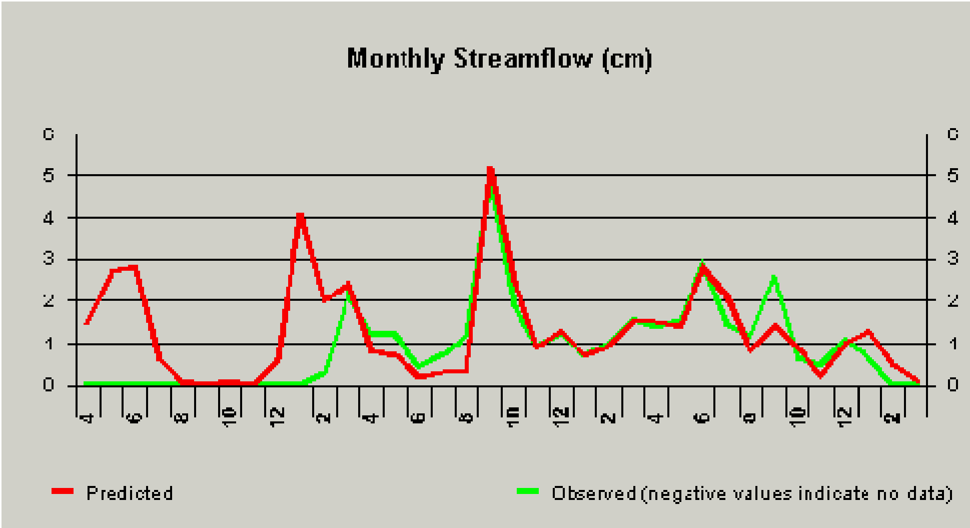

Figure 5.2 Flow calibration at Cooks Creek mouth (not incl. Blacks Run)

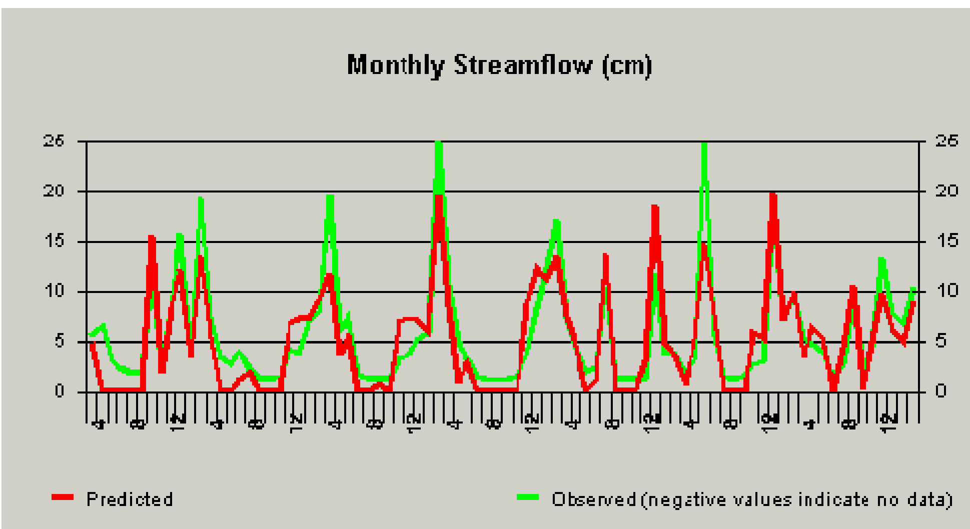

Figure 5.3 Flow calibration at Hays Creek VADEQ biomonitoring station

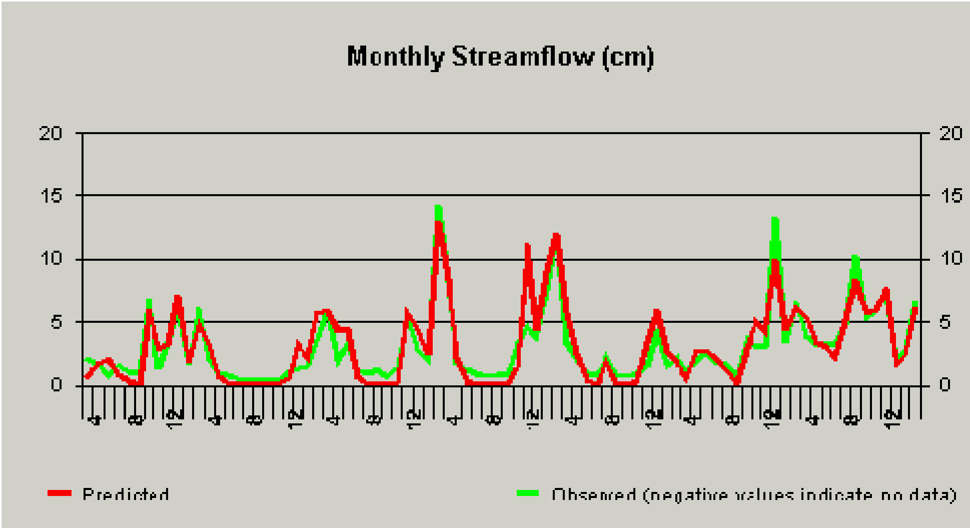

Figure 5.4 Flow calibration at Upper Opequon Creek VADEQ biomonitoring station

Table 5.3 GWLF flow calibration statistics

Modeled Watershed	Simulation Period	R2 (Correlation) Value	Total Volume % Error
Blacks Run (at the mouth)	4/1/98 - 3/31/01	0.85	2.5%
Cooks Creek (not including Blacks Run)	4/1/98 - 3/31/01	0.72	0.2%
Opequon Creek (at the VADEQ biostation)	4/1/90 - 3/31/97	0.83	2.6%
Hays Creek (at the VADEQ biostation)	4/1/90 - 3/31/97	0.77	9.2%

SECTION 6

TMDL METHODOLOGY

6.1 TMDL Calculation

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment and phosphorus, the GWLF models for Hays Creek and Upper Opequon Creek were run with the weather input file that was used for the impaired watershed simulations. This step was needed to standardize the modeling period (April 1, 1998 through March 31, 2001) and weather conditions (which affect pollutant loading rates) between impaired and reference watersheds for the calculation of TMDLs. In addition, the total area for each reference watershed was reduced to be equal to its paired target watershed, as discussed in Section 5.3. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 3-year means for pollutants of concern were determined for each land use/source category in each of the watersheds. Table 6.1 presents the existing average annual sediment load for Blacks Run. Sediment and phosphorus loading data for Cooks Creek are presented in Tables 6.2 (Cooks Creek above the confluence with Blacks Run) and 6.3 (Cooks Creek at the mouth). Pollutant loads from point sources in the Blacks Run watershed are included in the “Blacks Run Load” source category in Table 6.3.

Sediment and phosphorus loads contributed by Blacks Run, were added to the total load produced by point and nonpoint sources in the Cooks Creek watershed (at the mouth), after accounting for pollutant losses caused by in-stream processes (i.e. sediment burial, phosphorus uptake, etc.). Transport loss estimates were used to determine the total sediment and phosphorus load contributed by the Blacks Run watershed to the Cooks Creek mouth. These values were based on the model output from Blacks Run, the lower Cooks Creek subwatershed, and the combined watershed (Blacks Run + lower Cooks Creek). The percent difference between the combined watershed and the sum of its parts represents the transport loss for sediment (17.1%) and phosphorus (10.43%). In the same manner, transport loss estimates were applied to sediment loads from point sources in impaired and reference watersheds (Hays Creek had no point sources). The calculated sediment loss estimate for Cooks Creek point sources was 9.13%. The Upper Opequon Creek point source sediment load was reduced using the Blacks Run sediment transport loss estimate.

Table 6.1 Existing sediment loading in Blacks Run at the mouth

Source Category	Sediment Load (pounds per year)	Percent of Total Load
Row Crops	2,606,771	35.2%
Pasture/Hay	1,568,986	21.2
Barren	643,752	8.7
Forest	12,637	0.2
Water	0	0
Urban (grouped pervious & impervious areas)	2,546,159	34.4
Groundwater	0	0
Point Sources (permitted load minus transport loss)	32,844	0.4
Septic Systems	0	0
Total Existing Load	7,411,149	100%

Table 6.2. Existing sediment and phosphorus loading in Cooks Creek upstream of the confluence with Blacks Run

Source Category	Sediment Load (pounds per year)	Sediment % of Total	Phosphorus Load (pounds per year)	Phosphorus % of Total
Row Crops	20,670,624	83.3	14,620	75.8
Pasture/Hay	2,287,702	9.2	1,460	7.6
Barren	622,137	2.5	400	2.1
Forest	12,998	0.05	0	0
Water	0	0	0	0
Urban (grouped pervious & impervious areas)	1,182,372	4.77	2,040	10.6
Groundwater	0	0	360	1.9
Point Sources (permitted load minus transport loss)	36,457	0.15	0	0
Septic Systems	0	0	420	2.2
Total Existing Load	24,812,289	100%	19,300	100%

Table 6.3 Existing sediment and phosphorus loading in Cooks Creek at the mouth

Source Category	Sediment Load (pounds per year)	Sediment % of Total	Phosphorus Load (pounds per year)	Phosphorus % of Total
Row Crops	22,818,573	68.2%	16,300	56.3%
Pasture/Hay	2,414,872	7.2	1,540	5.3
Barren	786,107	2.4	500	1.7
Forest	13,096	0.04	0	0
Water	0	0	0	0
Urban (grouped pervious & impervious areas)	1,241,324	3.7	2,240	7.7
Groundwater	0	0	460	1.6
Point Sources, Cooks Creek only (permitted load minus transport loss)	36,457	0.11	0	0
Septic Systems	0	0	440	1.5
Blacks Run Load (incl. Blacks Run point sources)	6,143,842	18.4	7,494	25.9
Total Existing Load	33,454,271	100%	28,974	100%

The TMDLs established for Blacks Run and Cooks Creek consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment TMDL for Blacks Run was based on the total load calculated for the Upper Opequon Creek watershed (area adjusted to Blacks Run watershed size). Sediment and phosphorus TMDLs for Cooks Creek were based on the total loads calculated for these pollutants in the Hays Creek watershed (area adjusted to Cooks Creek watershed size, excluding Blacks Run). For the calculation of Cooks Creek TMDLs, post-allocation sediment and phosphorus loads contributed by Blacks Run were held fixed (no additional reduction).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of ten percent was used in TMDL calculations to provide an additional level of protection for designated uses.

TMDLs for Blacks Run and Cooks Creek were calculated by adding reference watershed loads for each pollutant of concern together with point source loads to give the TMDL value (Table 6.4). Sediment and phosphorus LAs for Cooks Creek include the Blacks Run (post-allocation) load contribution. Note that the sediment WLA values presented in the following tables represent the sum of all point source WLAs in each watershed, minus instream transport loss (as described on page 6-1).

Table 6.4 TMDLs for Blacks Run and Cooks Creek (at the mouth of each stream)

Watershed	Pollutant	TMDL (lbs/yr)	LA (lbs/yr)	WLA (lbs/yr)	MOS (lbs/yr)	Overall % Reduction
Blacks Run	Sediment	5,161,184	4,616,221	32,844	516,118	37%
Cooks Creek	Sediment	11,197,507	10,041,299	69,301 (incl. Blacks Run WLA)	1,119,751	68
	Phosphorus	9,367	8,430	0	937	68

6.2 Load Allocation

Load allocations were assigned to each source category in the watersheds. Several load allocation scenarios were developed for each watershed and pollutant to examine the outcome of various load reduction combinations. The recommended scenarios for Blacks Run (Table 6.5) and Cooks Creek (Table 6.6) are based on maintaining the existing percent load contribution from each source category. Two additional scenarios for each watershed and pollutant are presented for comparison purposes (Tables 6.7 and 6.8). Load reductions from agricultural sources are minimized in the first alternative and reductions from urban lands are minimized in the second alternative. The recommended scenarios balance the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. In each scenario, loadings from certain source categories were allocated according to their existing loads. For instance, sediment and nutrient loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced. Also, sediment loads from point sources were not reduced because these facilities are currently meeting their discharge limits for TSS (sediment) and because these loads were insignificant as compared with other sources.

TMDLs for Cooks Creek (at the mouth) were based on reducing sediment and phosphorus loads contributed by the Cooks Creek watershed only (excluding Blacks Run), assuming that pollutant reductions would be achieved in the Blacks Run watershed. Post-allocation sediment and phosphorus loads contributed by Blacks Run were, therefore, held fixed (no additional reduction). The Blacks Run TMDL load for sediment (minus MOS and transport loss) was used to calculate the Cooks Creek sediment TMDL and load reductions. Although a phosphorus TMDL was not required for Blacks Run, a reduction in phosphorus loading from Blacks Run, equal to the percent reduction required for sediment (37%), was used to calculate the Cooks Creek phosphorus TMDL. This assumption is based on the empirical relationship between phosphorus and sediment (as discussed in Section 4).

Table 6.5 Sediment allocations for Blacks Run

Source Category	Sediment Load Allocation (lbs/yr)	Sediment % Reduction
Row Crops	1,616,198	38%
Pasture/Hay	988,461	37
Barren	193,126	70
Forest	12,637	0
Water	0	0
Urban (grouped pervious & impervious areas)	1,801,799	29
Groundwater	0	0
Point Sources (WLA) Existing load minus transport loss (see footnote)	32,844 (total) *Frazier Quarry WLA = 32,768* *U.S. Training Center WLA = 76*	0
Septic Systems	0	0
TMDL Load (minus MOS)	4,645,065	

Table 6.6 Sediment and phosphorus allocations for Cooks Creek (at the mouth)

Source Category	Sediment Load Allocation (lbs/yr)	Sediment - % Reduction	Phosphorus Load Allocation (lbs/yr)	Phosphorus - % Reduction
Row Crops	4,791,900	79%	1,956	88%
Pasture/Hay	700,315	70	308	80
Barren	78,611	90	50	90
Forest	13,096	0	0	0
Water	0	0	0	0
Urban (grouped pervious & impervious areas)	606,620	51	681	70
Groundwater	0	0	460	0
Point Sources (WLA), Cooks Creek only. Existing load minus transport loss (see footnote)	36,457 (total) *Harrisonburg WTP = 28,983* *Dayton WTP = 7,474*	0	0	0
Septic Systems	0	0	264	40
Blacks Run Allocation Load (minus MOS and transport loss)	3,850,759 *Load includes Blacks Run WLA total (32,844)*	0	4,712	0
TMDL Load (minus MOS)	10,077,755		8,431	

**** Note: Point source WLAs represent the existing permitted load from each facility minus the estimated sediment transport loss, as described on pages 6-1 and 6-4. Therefore, the allocation load given for each point source facility is equal to the existing, permitted load (no reduction).***

Table 6.7 Alternative sediment allocations for Blacks Run

Source Category	Minimize Agricultural Load Reductions	Minimize Urban Load Reductions
Row Crops	15%	52%
Pasture/Hay	9	45
Barren	70	70
Forest	0	0
Water	0	0
Urban (grouped pervious & impervious areas)	70	10
Groundwater	0	0
Point Sources (WLA)	0	0
Septic Systems	0	0

Table 6.8 Alternative sediment and phosphorus allocations for Cooks Creek (at the mouth)

Source Category	Sediment		Phosphorus	
	Minimize Agricultural Reductions	Minimize Urban Reductions	Minimize Agricultural Reductions	Minimize Urban Reductions
Row Crops	77%	81%	85%	94%
Pasture/Hay	67	68	82	86
Barren	90	90	90	90
Forest	0	0	0	0
Water	0	0	0	0
Urban (grouped pervious & impervious areas)	90	20	85	25
Groundwater	0	0	0	0
Point Sources (WLA) Cooks Creek only	0	0	0	0
Septic Systems	0	0	85	25
Blacks Run Allocation Load (minus MOS and transport loss) *Load includes Blacks Run WLA*	0	0	0	0

6.3 Consideration of Critical Conditions

The GWLF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

6.4 Consideration of Seasonal Variations

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these model features accounts for seasonal variability.

SECTION 7

REASONABLE ASSURANCE AND IMPLEMENTATION

7.1 Reasonable Assurance

Sediment and phosphorus reductions in the TMDLs are allocated entirely to agricultural and urban sources in each watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of sediment reaching the streams can be made through the planting of riparian buffer zones, contour strips, and cover crops. These BMPs range in efficiency from 20% to 70% for sediment reduction. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus loading. Additional phosphorus reductions can be achieved through the installation of more effective animal waste management systems and stone ford cattle crossings. Other possibilities for attaining the desired reductions in phosphorus and sediment include stabilization of stream banks and stream fencing. Further “ground truthing” will be performed in order to assess existing BMPs, and to determine the most cost-effective and environmentally protective combination of future BMPs required for meeting the sediment and nutrient reductions outlined in this report.

7.2 Follow-Up Monitoring

The Department of Environmental Quality will maintain the existing monitoring stations in the Blacks Run and Cooks Creek watersheds in accordance with its ambient monitoring program. An additional biological monitoring station has been added at the same location as the ambient water quality station on Blacks Run to gather additional information from the lower part of Blacks Run. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate improvements in the benthic communities and the effectiveness of the TMDL in attaining and maintaining water quality standards.

7.3 Regulatory Framework

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be to develop a TMDL implementation plan, and the final step is to implement the TMDL until water quality standards are attained.

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include that date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact 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, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ 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.

7.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's CREP program, the state revolving loan program, and the VA Water Quality Improvement Fund.

7.5 TMDL Implementation

Implementation of best management practices (BMPs) in the watersheds will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the adequacy of the TMDL in achieving the water quality standard. Implementation of this TMDL will also contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. In 1987, the Commonwealth of Virginia joined its partners in the Chesapeake Bay Program in a commitment to reduce the flow of controllable nutrients to the Bay and its tributaries by 40 percent by the year 2000. To meet this commitment, the first Tributary Strategy, finalized in December of 1996, was developed for the Shenandoah and Potomac River Basins. That strategy has been implemented since passage of the Water Quality Improvement Act in 1997, leading to tens of millions of dollars worth of cost-share for the installation of point source and nonpoint source nutrient reduction projects across the basins. Since then, tributary-specific nutrient and sediment reduction goals and strategies – including implementation measures to achieve these goals by 2010 - were established. For the Shenandoah and Potomac River Basins, an Interim Nutrient Cap Strategy was published in March 2001. The Interim Nutrient Cap Strategy is intended to continue the coordinated effort, to maintain the level of nutrient reductions that have been achieved to date and to achieve the additional reductions needed to meet new environmental endpoints for the Chesapeake Bay. While the Interim Nutrient Cap Strategy contains both point and nonpoint source control mechanisms, the implementation of the Cooks Creek/Blacks Run sediment and phosphorus TMDLs will require only nonpoint source reductions. Therefore, Appendix A of this document includes Chapter V, Nonpoint Source Implementation Mechanisms, of the Strategy. The chapter contains reduction options in six major activity categories, which are 1) managing storm water runoff, 2) outreach and public education, 3) urban nutrient management, 4) on-site wastewater treatment, 5) agriculture, and 6) shoreline erosion and protection. For Cooks Creek and Blacks Run, all except the last category apply. The nutrient reduction options identified as part of the Interim Nutrient Cap Strategy can serve as useful guides in selecting and prioritizing measures to reduce sediment and phosphorus in Cooks Creek and Blacks Run.

7.6 Water Quality Standards

If implementation of reasonable BMPs has failed to improve or restore the benthic community and additional controls would have widespread social and economic impacts, VADEQ has the option of performing a Use Attainability Analysis (UAA) using the factors set forth in 40 CFR ' 131.10(g). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The primary factors to include are as follows: 1. the factor of widespread social and economic impacts 2. human caused conditions and sources of pollution prevent the attainment of the use and cannot be remedied. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

SECTION 8

PUBLIC PARTICIPATION

The first public meeting on the development of TMDLs for Blacks Run and Cooks Creek was held on April 12, 2001 from 7-10 p.m. at Pence Middle School in the Town of Dayton. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on March 26, 2001 (Volume 17, Issue 14). Copies of the presentation materials were made available for public distribution at the meeting. The public comment period ended on April 20, 2001. Eleven people attended the first public meeting. One comment letter was received and was responded to in writing.

The second public meeting on the development of TMDLs for Blacks Run and Cooks Creek was held on March 28, 2002 from 7-10 p.m. at the VADEQ Valley Regional Office in the City of Harrisonburg. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on March 11, 2002. Copies of the draft TMDL reports and presentation materials were made available for public distribution at the meeting. The public comment period ended on April 19, 2002. Fourteen people attended the second public meeting. No written comments were received.

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