DRAFT
Crab Creek
Bacteria and Sediment
TMDL Implementation Plan

Prepared by the
Crab Creek IP Steering Committee

In Cooperation with the
Virginia Tech Department of Biological Systems Engineering *and the*
Virginia Department of Environmental Quality

October 8, 2014

Acknowledgments

Many thanks to those who dedicated their time and efforts to the development of this plan:

Farm Service Agency
Local residents and landowners
Montgomery County
Natural Resources Conservation Service
New River Conservancy
New River Valley Planning District Commission
Skyline Soil and Water Conservation District
Town of Christiansburg
Virginia Department of Conservation and Recreation
Virginia Department of Health
Virginia Department of Transportation
Virginia Save Our Streams

Crab Creek near the Christiansburg Aquatic Center

A special thanks to the following organizations for the use of their facilities for meetings:

Montgomery County
Town of Christiansburg

For additional information, please contact:

Virginia Department of Environmental Quality
Chris Burcher, TMDL Nonpoint Source Coordinator
Southwest Regional Office
355-A Deadmore Street
Abingdon, Virginia 24210
276-676-4803
chris.burcher@deq.virginia.gov

Table of Contents

Executive Summary

Crab Creek, which is located entirely in Montgomery County, is part of the New River basin. All 12 miles of Crab Creek, from its headwaters to its confluence with the New River, are impaired for violations of the fecal coliform bacteria water quality standard and the General Standard (benthic). VADEQ first listed Crab Creek on the 1996 303(d) list for these impairments and completed the corresponding TMDL studies in 2004. The purpose of this Implementation Plan (IP) is to describe the actions needed to achieve water quality goals in the Crab Creek watershed and achieve fully supporting status for Crab Creek.

Review of TMDL Development

The Crab Creek watershed is located in Montgomery County and the Town of Christiansburg. It flows generally west to its confluence with the New River. The Crab Creek watershed comprises approximately 12,400 acres of land area with 42% characterized as developed, 33% agriculture and 24% forested according to 2012 National Agricultural Statistics Service (NASS) and 2006 National Land Cover Database (NLCD) geospatial data. Over 40 % of the Crab Creek watershed is located within the town limits of Christiansburg. The 2004 TMDL estimated a population of 15,711 in the watershed using US Census data. All 12 miles of Crab Creek, from its headwaters to its confluence with the New River, are impaired for violations of the (fecal coliform) bacteria water quality standard and the General Standard (benthic). VADEQ first listed Crab Creek on the 1996 303(d) list for these impairments and completed the corresponding TMDL studies in 2004.

The 2004 TMDL identified the primary sources of bacteria in Crab Creek as nonpoint source pollution, specifically agricultural runoff from pasture and croplands, straight pipes and sewer overflows, and direct deposition of livestock manure in streams. Other nonpoint sources of bacteria include failing septic systems, pet waste, forests, commercial and barren lands, and wildlife. A stressor analysis identified sediment as the Most Probable Stressor for aquatic life in Crab Creek. The 2004 TMDL identified the primary sources of sediment in Crab Creek as channel erosion, pastureland, and cropland. Additional nonpoint sources of sediment include forest and disturbed forest, MS4, transitional, residential, and commercial land uses.

The TMDL study included evaluations of several allocation scenarios for meeting both the bacteria and sediment TMDLs. The final allocation scenarios for meeting the bacteria and sediment TMDLs in Crab Creek were chosen by watershed stakeholders and updated during Implementation Plan development based on BMP implementation, land use changes, and corrections to the channel erosion load. These allocation scenarios are located in Table ES-1 (bacteria) and Table ES-2 (sediment).

Table ES-1. Allocation scenario used in the Crab Creek Implementation Plan for meeting the Crab Creek bacteria TMDL

	Percent Reduction in Bacteria Loading					Percent Violations	
Stage	Cattle Direct Deposition	Residential/ Urban	Pasture	Cropland	Straight Pipes/ SSOs	GM >126 cfu/ 100ml	Single Sample Exceeds 235 cfu/100ml
1	100	76	60	31	100	0	12.80
2	100	80	88	31	100	0	10.35

Table ES-2. Sediment allocation scenario for meeting the Crab Creek sediment goals

Sediment Source	Existing Condition		Allocations Stage 1		Stage 2
Categories	**(T/yr)**	**(%)**	**(T/yr)**	**(%)**	**(T/yr)**
LDR-PER	29.830	0	29.830	5	28.339
HDR-PER	0.083	0	0.083	0	0.083
COM-PER	7.074	0	7.074	0	7.074
Transitional	63.624	0	63.624	0	63.624
Forest	25.463	0	25.463	0	25.463
Disturbed Forest	84.852	0	84.852	0	84.852
Pastureland	1,276.101	32	867.749	37	803.944
Cropland	505.871	17	419.873	17	419.873
LDR-IMP	16.858	0	16.858	5	16.015
HDR-IMP	1.141	0	1.141	0	1.141
COM-IMP	0.005	0	0.005	0	0.005
Water	0.000	0	0.000	0	0.000
MS4-Existing (minus WLA of 55.14)	43.348	3	42.047	15	36.846
MS4-Future	20.652	3	20.032	15	17.554
Active Ag BMPs[1]	*-281.96*		*-281.96*		*-281.960*
Active Ag BMPs[2]	*-84.60*		*-84.6*		*-84.600*
Active Urban BMPs[3]	*-22.28*		*-22.28*		*-22.280*
NPS Load	**1,686.06**		**1,189.79**		**1,115.97**
Channel Erosion	2,944.37	71	853.868	71	853.868
Total	**4,630.44**		**2,043.66**		**1,969.84**
Target Allocation Load (TMDL - MOS - WLA)					**1,971.26**
Target In-stream Load (All Sources-MOS)					**2,047.63**

[1]Credited during TMDL development

[2]Credited since TMDL development

[3]Credited 2,233 linear ft of stream restoration- Diamond Hills project

The allocation scenario for Stage 1 bacteria includes load reductions of 100% from direct deposition by livestock – Livestock (DD), 60% from pasture, 31% from cropland, 76% reduction from residential and urban sources (Res./Urban), and 100% from straight pipes and Sanitary

Sewer Overflow (SSO) loads. The allocation scenario for Stage 2 requires increasing overall reductions of the residential and urban load to 80% and pasture load reductions to 88%. This final allocation scenario will result in no violations of the *E.coli* geometric mean criterion and less than 10.5% violations of the *E.coli* single sample maximum criterion. On attainment of these water quality milestones, Crab Creek would be delisted for *E.coli*.

The sediment allocation scenario for meeting the Crab Creek TMDL requires total load reductions of 5% from low-density residential pervious, 5% from low-density residential impervious, 37% from pastureland, 17% from cropland, 15% from the existing MS4 load (not including the MS4 load attributed to the WLA), 15% from the future MS4 load, and 71% from channel erosion (Table ES-2). These source reductions will result in a 57% overall reduction in sediment load which will meet both the Implementation Plan Target Modeling Load and the original TMDL.

Goals and Milestones

The ultimate goal of the Implementation Plan is to improve water quality in order to protect the use of Crab Creek for recreational activities such as swimming and for aquatic life. The proposed timeline for achieving restored water quality in Crab Creek is ten years with implementation actions divided into two stages. The first stage (Stage 1) will take six years and the second stage (Stage 2) will take an additional four years. This staged approach concentrates early efforts on the most cost-efficient control measures and targets sources with the most interest from stakeholders.

Two types of milestones have been created for evaluating progress during each stage. Water quality milestones establish the goals for observing improvements in water quality while the implementation milestones outline the extent of BMPs to be installed. For the Crab Creek watershed, the Stage 1 water quality milestone for bacteria is based on recommendations from both the TMDL and watershed stakeholders. The modified Stage 1 reductions to bacteria reduce violations of the single sample standard to equal or less than 12.80% and result in zero violations of the geometric mean standard (Table ES-3). For Stage 2, the bacteria milestone is to reduce violations of the single sample standard to equal or less than 10.5% and to reduce violations of the geometric mean standard to 0%. This condition will meet Virginia's water quality standards for bacteria and allow for the delisting of Crab Creek from Virginia's 303(d) List of Impaired Waters.

Table ES-3. Implementation goals for reducing bacteria in the Crab Creek watershed and the corresponding sediment reductions

Objective	Stage 1	Stage 2
Bacteria (*E.coli*)		
% Violations of the Geomean Standard	0.00%	0.00%
% Violations of the Instantaneous Standard	12.80%	10.35%
Average Annual Load (cfu/yr)	$1.40x10^{15}$	$9.44x10^{14}$
Sediment		
% Reduction	55%	57%
Average Annual Load (T/yr)	2,120.03	2,046.21

The agricultural BMPs installed for Stage 1 bacteria reductions will also help meet the sediment reductions needed from pasture. Additional stormwater BMPs and streambank stabilization practices implemented during Stage 1 will help meet the Stage 1 goal of reducing the sediment load in Crab Creek by 55%. During Stage 2, additional stormwater and pasture BMPs will be implemented to meet both the TMDL and the IP Target Allocation Load for sediment (Table ES-4).

Table ES-4. Implementation goals for reducing sediment in the Crab Creek watershed

Load Summary	Crab Creek Sediment (T/yr)	Reduction Required (T/yr)	Reduction Required (% of existing load)
TMDL Existing Load	6,307	4,088	64.8
TMDL Projected Future Load	7,197	4,978	69.2
TMDL	2,551		
IP Projected Future Load	4,814	2,766	57.0
IP Target In-stream Load[1]	2,047		
IP Target Allocation Load[2]	1,971		

[1] Corrected TMDL minus MOS
[2] Corrected TMDL minus the WLA and the MOS

Progress towards these goals can be assessed during the implementation process by tracking the development and execution of programs, policies, and practices (implementation actions) and through continued water quality monitoring. Improvements in water quality will be measured through monitoring of bacteria concentrations and the aquatic community throughout the watershed.

Implementation Actions

Potential control measures, their costs, and pollutant removal effectiveness estimates were identified through a review of the TMDL report, through input from the TMDL IP Work Groups, from a literature review, and from modeling. Because the TMDL watersheds contains a combination of residential and agricultural land uses, implementation actions to address the required pollutant reductions include a variety of control measures which target each pollutant source.

The quantity of corrective measures, or implementation actions, needed to meet the source load reductions was determined through spatial analysis and the model used in the TMDL study. The recommended residential management practices needed to attain the necessary reductions in both sediment and bacteria include

- pumping out 565 septic tanks,
- identifying and replacing 4 straight pipes,
- repairing or replacing 316 failing septic systems,
- replacing 36 failing septic systems with alternative on-site waste treatment systems,
- connecting 7 failing septic systems to public sewer,
- placing 15 pet waste stations in the watershed,
- distributing 50 pet waste digesters and/or composters,
- implementing a pet waste education program,
- treating 78 acres with rain gardens,
- treating 3.5 acres with bioretention filters,
- treating 7 acres with bioswales,
- treating 61 acres with forested riparian buffers,
- treating 100 acres with grass/shrub riparian buffers,
- treating 92 acres with detention and 100 acres with extended detention,
- treating 3 acres with manufactured BMPs,
- treating 10.5 acres with a combination of detention and manufactured BMPs,
- treating 0.5 acres with constructed wetlands and/or wet ponds,
- treating 1.5 acres with infiltration practices, and
- treating 1 acre with vegetated open channels.

The recommended agricultural management practices include

- installing 45 livestock exclusion systems,
- treating 3,265 acres of pasture with grazing land management systems,
- reforesting 28 acres of erodible pasture,
- planting 29 acres of critical areas with permanent vegetative cover,
- installing 20 heavy use area protection systems,
- applying continuous no-till to 5 acres, and
- implementing 20 acres of small grain cover crop.

In addition to these residential and agricultural practices, streambank stabilization practices should be installed on 11,254 linear feet of streams within the watershed to reduce the sediment load from channel erosion.

Associated costs for each implementation action were estimated from the Virginia Department of Conservation and Recreation (VADCR) agricultural BMP database, from previous TMDL IPs,

and from discussions with local stakeholders. The total estimated cost for implementation is $10,388,725.

Stakeholders and their Roles

Stakeholders are individuals who live or have land management responsibilities in the watershed, including private individuals, residential and agricultural landowners, government agencies, businesses, and special interest groups. Stakeholder participation and support is essential for achieving the goals of this TMDL effort (i.e., improving water quality and removing streams from the impaired waters list).

The Virginia Department of Environmental Quality (VADEQ) is the lead state agency in the TMDL process. VADEQ will continue monitoring in the watershed to evaluate water quality throughout the implementation period. Additional monitoring support will be provided through the Virginia Save Our Streams program, Radford University, Christiansburg High School, and the New River Conservancy (formerly the National Committee for the New River).

The Skyline Soil and Water Conservation District (SWCD) will provide cost-share funds, lead education and technical efforts, and track the agricultural and residential implementation practices. The USDA Natural Resources Conservation Service (NRCS) will also assist private landowners by providing funding through federal programs and offering technical assistance with installation of implementation practices. Administrative support for the residential and urban practice needs may also be provided by the New River Valley Planning District Commission. Additional targeting and prioritization efforts could be led by the New River Land Trust.

The Town of Christiansburg has taken great strides to improve the quality of water entering Crab Creek from land within the Town and they should continue their efforts to address stormwater, erosion and sediment, and sanitary sewer overflows. As Montgomery County transitions to a Phase II MS4, they will have similar responsibilities in the watershed. The Virginia Department of Transportation should also continue implementing their MS4 program requirements as they relate to the Crab Creek watershed.

Integration with Other Watershed Plans

Like most watersheds in Virginia, water quality improvements in the Crab Creek watershed are a component of many different organizations, programs and activities. Such efforts include, but are not limited to, watershed implementation plans, TMDLs, Roundtables, Water Quality Management Plans, Erosion and Sediment Control Regulations, Stormwater Management Programs, Source Water Assessment Programs, local comprehensive and strategic plans, and local environmentally-focused organizations. These efforts should be evaluated to determine their potential impacts on the implementation goals outlined in this clean-up plan. Often, these efforts are related or collaborative, but this is not always the case. Coordination of local

programs can increase participation and prevent redundancy. Initiatives coinciding with TMDL implementation efforts in this watershed include the New River Livability Initiative Study and the Town of Christiansburg's Comprehensive Plan and Vision 2020.

Potential Funding Sources

A list of potential funding sources available for implementation efforts has been developed as part of this plan. Detailed descriptions can be obtained from VADEQ, VADCR, the Soil and Water Conservation Districts, NRCS, and the Virginia Cooperative Extension. Some of the most commonly used funding sources include: the Virginia Agricultural Best Management Practices Cost-Share and Tax Credit Programs, Virginia Agricultural Best Management Practices Loan Program, Conservation Reserve Enhancement Program (CRP/CREP), Virginia Water Quality Improvement Fund, Environmental Quality Incentives Program (EQIP), Southeast Rural Community Assistance Project (SERCAP), and the Clean Water State Revolving Fund.

Introduction

The **Clean Water Act (CWA)** requires that all of our streams, rivers, and lakes meet state water quality standards. The CWA also requires that states conduct monitoring to identify polluted waters that do not meet their standards. Through monitoring, the state of Virginia has found that many streams do not meet state water quality standards for protection of the five beneficial **designated uses**: recreation, the production of edible and marketable natural resources, aquatic life, wildlife, and drinking. When streams fail to meet standards they are placed on the state's impaired waters list, and the state must then develop a **Total Maximum Daily Load (TMDL)** for each pollutant. A TMDL is a "pollution budget" for a stream, meaning that it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and non-point source loadings are considered. Non-point source pollution occurs when rain transports pollutants from multiple sources across the land to a body of water. Point source pollution discharges directly into streams. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

The Virginia Department of Environmental Quality (VADEQ) developed a TMDL for Crab Creek in 2004 after water quality monitoring showed:

1) Levels of bacteria observed in Crab Creek violate the water quality standard protecting primary contact recreation activities like swimming. Until 2003, the water quality criteria for bacteria were based on the concentration of **fecal coliform** in the water. Specifically, the fecal coliform bacteria count should not exceed a geometric mean of 200 cfu per 100 mL of water for two or more samples taken over a 30-day period, and it should not exceed 400 cfu per 100 mL in any one sample. In 2003, Virginia switched to an ***Escherichia coli (E. coli)*** based water quality standard after it was found that there was a more positive correlation between contact with *E. coli* and gastrointestinal illness or infection. Consequently, the TMDL for Crab Creek was developed for *E. coli*. The *E. coli* standard, effective January 15, 2003, states that the *E. coli* bacteria count should not exceed a geometric mean of 126 cfu per 100 mL for two or more samples taken over a 30-day period, and it should not exceed 235 cfu per 100 mL in any one sample.
2) Crab Creek violated the **general standard** for aquatic life use. This standard states that all state waters should support "the propagation and growth of a balanced indigenous population of aquatic life…" (State Water Control Board 2006). Based on biological monitoring of the benthic macroinvertebrate community conducted by VADEQ, it was concluded that Crab Creek did not meet this designation. After an in-depth review and analysis of available data by a Technical Advisory Committee, sediment was identified as the primary stressor on the benthic community in Crab Creek.

Once a TMDL is developed and approved by the **Environmental Protection Agency (EPA)**, measures must be taken to reduce pollution levels in the waterbody. These measures, which can

include the use of better treatment technology and the installation of **best management practices (BMPs)**, are implemented in a staged process described in an Implementation Plan (IP). This IP characterizes implementation actions that will achieve water quality goals in the Crab Creek watershed.

One goal of an IP is to identify funding needs and options. A common resource for funding TMDL projects is CWA Section 319 nonpoint source (NPS) grants awarded to states by the EPA. The EPA develops guidelines to describe the process and criteria used to award these CWA Section 319 nonpoint source (NPS) grants. An Implementation Plan must include nine components to be eligible for this funding.

Implementation Plan Requirements for 319 Funding

1. Identify the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in the watershed-based plan;
2. Estimate the load reductions expected to achieve water quality standards;
3. Describe the nonpoint source (NPS) management measures that will need to be implemented to achieve the identified load reductions;
4. Estimate the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement the watershed-based plan;
5. Provide an information/education component that will be used to enhance public understanding of the project and encourage the public's participation in selecting, designing, and implementing NPS management measures;
6. Provide a schedule for implementing the NPS management measures identified in the watershed-based plan;
7. Describe interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented;
8. Identify a set of criteria for determining if loading reductions are being achieved and if progress is being made towards attaining water quality standards; if not, identify the criteria for determining if the watershed-based plan needs to be revised; and
9. Establish a monitoring component to evaluate the effectiveness of the implementation efforts.

Review of TMDL Development

Description of Watershed and Impairments

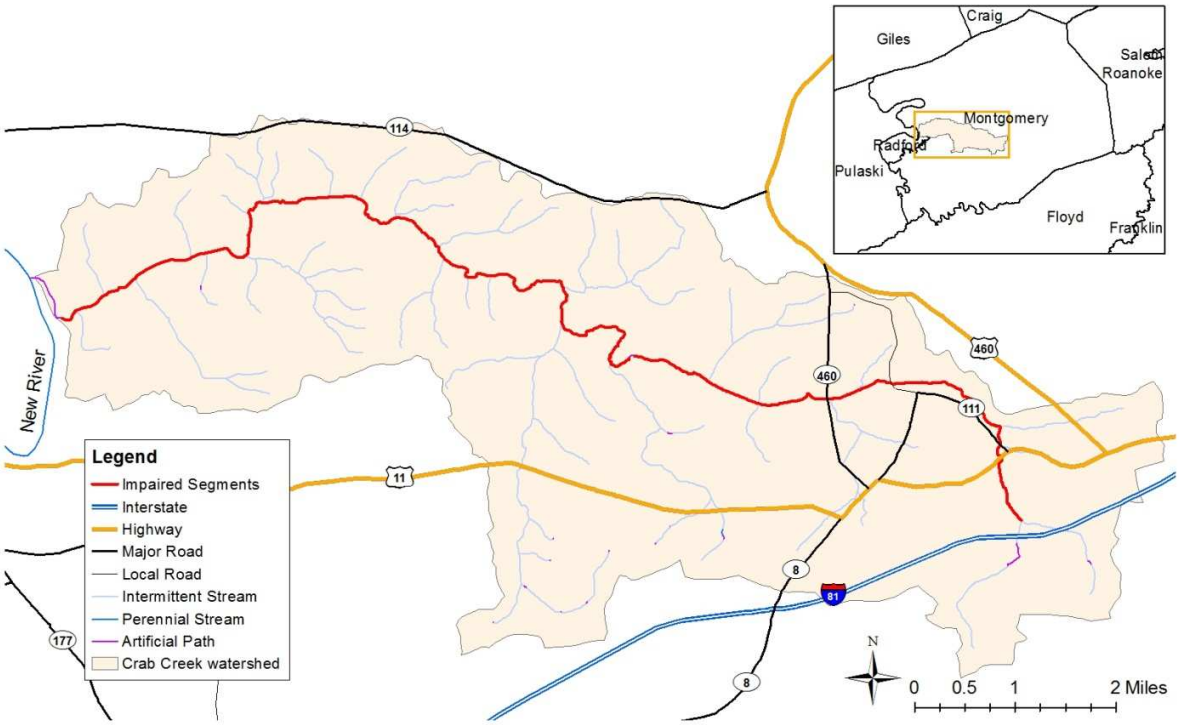

Figure 1. Location of the Crab Creek watershed and its stream impairments

The Crab Creek watershed is located in Montgomery County and the Town of Christiansburg. It flows generally west to its confluence with the New River. The Crab Creek **watershed** comprises approximately 12,400 acres of land area with 42% characterized as developed, 33% agriculture and 24% forested according to 2012 National Agricultural Statistics Service (NASS) and 2006 National Land Cover Database (NLCD) geospatial data. Over 40 % of the Crab Creek watershed is located within the town limits of Christiansburg. The 2004 TMDL estimated a population of 15,711 in the watershed using US Census data. The entire 12 miles of Crab Creek, from its headwaters to its confluence with the New River, is impaired for violations of the (fecal coliform) bacteria water quality standard and the General Standard (benthic) (

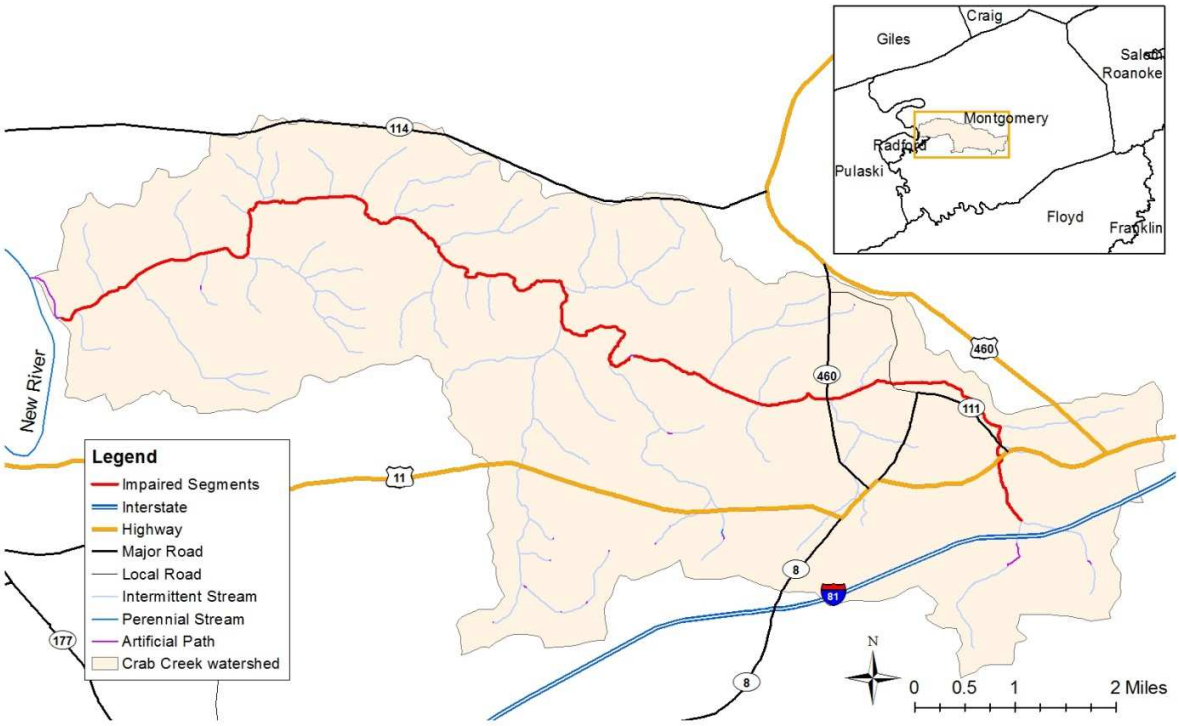

Figure 1). VADEQ first listed Crab Creek on the 1996 303(d) list for these impairments and completed the corresponding TMDL studies in 2004.

Water Quality Monitoring Results

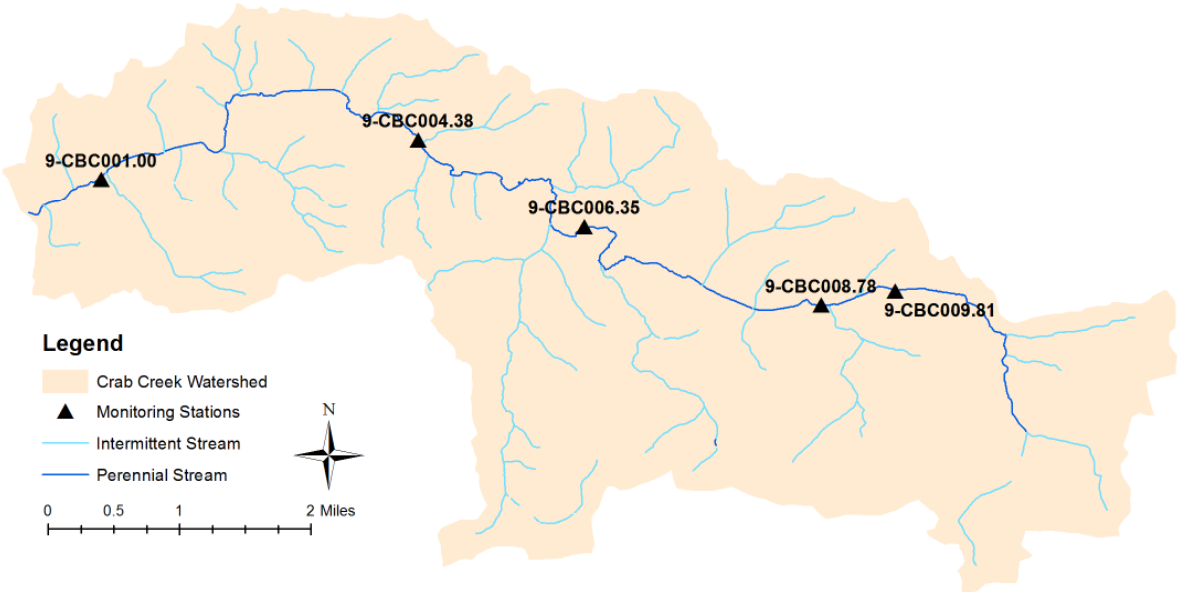

Figure 2. Locations of Crab Creek VADEQ monitoring stations

The bacteria TMDL was based on monitoring at five VADEQ in-stream water quality monitoring stations: 9-CBC001.00 (upstream), 9-CBC004.38, 9-CBC006.35, 9-CBC008.78, 9-CBC009.81 (downstream) (Figure 2). A wide range of fecal coliform concentrations had been recorded in the watershed. Exceedances of the single sample maximum were reported throughout the monitoring period and in all flow regimes.

The benthic TMDL was based on monitoring conducted by VADEQ at three benthic monitoring stations: 9CBC001.00, 9CBC004.38, 9CBC006.35. Crab Creek was first listed in 1996 as being moderately impaired based on the RBPII assessment method. Results from all three stations consistently indicated impaired conditions. Habitat assessments of Crab Creek considered in the 2004 TMDL also indicated sub-optimal conditions with the primary problem being the lack of riparian vegetation (VADEQ 2004).

Water Quality Modeling

The US Geological Survey (USGS) Hydrologic Simulation Program – Fortran (HSPF) model simulated existing conditions in the watershed and was used to create the bacteria TMDL load allocations. Due to a lack of continuous stream flow data for Crab Creek, the paired-watershed approach along with instantaneous flow measurements were used to calibrate the HSPF model. The HSPF model calculated fecal coliform loads from land-based nonpoint sources by considering wildlife populations and ranges, biosolids application rates and practices, septic system failure rates and locations, domestic pet populations, livestock populations, and livestock and manure management practices.
A reference watershed approach defined allowable TMDL loading rates for sediment by comparing Crab Creek to a watershed supportive of the aquatic life use. The **Generalized Watershed Loading Function (GWLF)** model (Haith et al. 1992) was used for the comparative modeling. The model calculated sediment loads for each land use in the watershed while accounting for expected increases in developed land within the Crab Creek watershed.

Bacteria Nonpoint Pollution Sources

The 2004 TMDL identified the primary sources of bacteria in Crab Creek as nonpoint source pollution, specifically agricultural runoff from pasture and croplands, straight pipes and sewer overflows, and direct deposition of livestock manure in streams. Other nonpoint sources of bacteria include failing septic systems, pet waste, forests, commercial and barren lands, and wildlife. There are currently two **Municipal Separate Storm Sewer System (MS4)** permits in the watershed, one held by the Town of Christiansburg and one held by the Virginia Department of Transportation (VDOT).

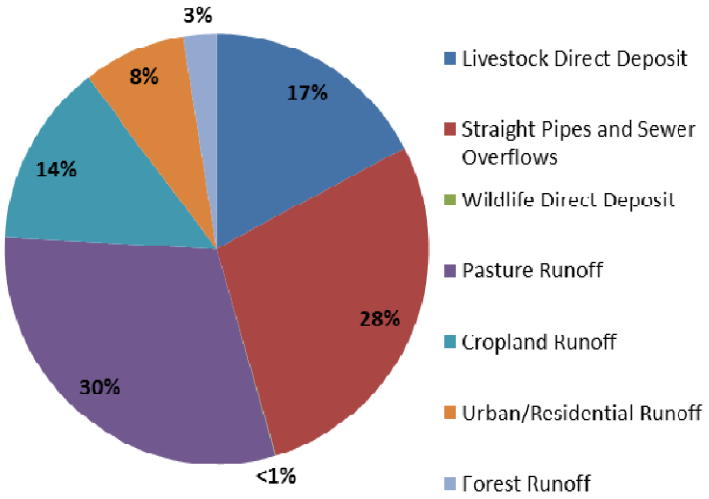

Figure 3. Nonpoint sources of bacteria in the Crab Creek watershed. 'Livestock Direct Deposit' includes waste deposited directly in the stream and on adjacent land by cattle with stream access.

Sediment Nonpoint Pollution Sources

A stressor analysis identified sediment as the Most Probable Stressor for aquatic life in Crab Creek. The 2004 TMDL identified the primary nonpoint sources of sediment in Crab Creek as channel erosion, pastureland, and cropland. Other nonpoint sources of sediment include forest and disturbed forest, MS4, transitional, residential, and commercial land uses (Figure 4). This estimate does not consider potential sediment reductions from the agricultural BMPs in place at the time of TMDL development.

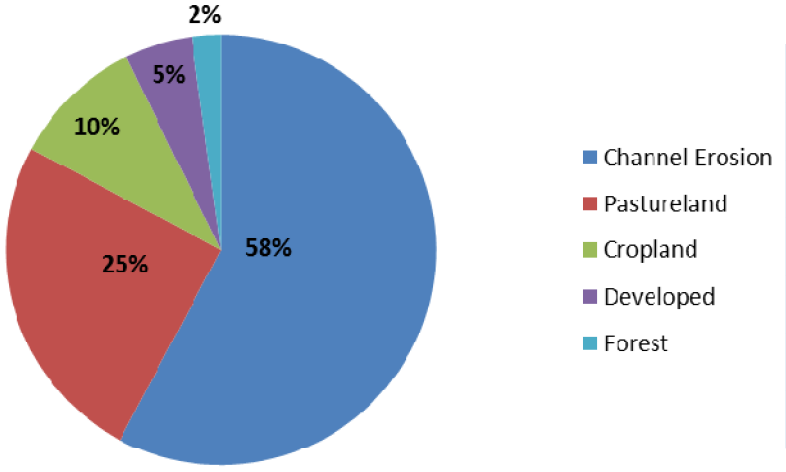

Figure 4. Nonpoint sources of sediment in the Crab Creek watershed

TMDL Allocation and Load Reductions

Bacteria

Various pollutant reduction scenarios were evaluated to meet the state water quality standards for *E. coli*, with zero violations (a requirement of the TMDL). An implicit margin of safety (MOS) was used in the bacteria TMDL by using conservative estimations of factors that would affect bacteria loadings in the watershed (e.g., animal numbers, production rates, contributions to the stream). These factors were estimated in such a way as to represent the greatest amount of bacteria from each source in the watershed. The portion of *E. coli* that may come from permitted discharge sources, including NPS sources under an MS4 permit, was included in the Waste Load Allocation (WLA) and not given a load reduction during TMDL development. The WLA will be addressed through the Virginia Pollutant Discharge Elimination System (VPDES) Program administered by the Virginia Department of Environmental Quality.

Normally, the Stage 1 implementation goal is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample criterion (235 cfu/100 mL) are less than 10.5 percent. However, in this case, meeting that goal would require a 99% reduction in land-based bacteria loads so Scenario 4 was selected as the Stage 1 bacteria goal during TMDL development. Also in the TMDL study, violations of the instantaneous standard could not be eliminated without reductions to the land-based wildlife load. Reductions to wildlife fecal bacteria are not addressed in this implementation plan.

Table 1. TMDL allocation scenarios for bacteria with 2004 loading estimates in the Crab Creek watershed

Scenario Number	Percent Reduction in Loading from 2004 Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture/ Livestock	Res./ Urban	Straight Pipe/ Sewer Overflow	GM >126 cfu/ 100ml	Single Sample Exceeds 235 cfu/100ml
1	0	0	0	0	0	0	76.7	27.8
2	0	0	0	0	0	100	73.3	27.8
3	0	0	90	50	50	100	11.7	17.6
4	0	0	100	60	60	100	3.33	16.1
5	0	0	100	99	99	100	0	1.92
6	0	99	100	99	99	100	0	1.53
7	99	99	100	99	99	100	0	1.53
8	0	99	100	99.95	99.95	100	0	0

Sediment

The Crab Creek benthic TMDL was developed for sediment, with Toms Creek as the reference watershed. The margin of safety (MOS) for the sediment TMDL was explicitly set to 10% to account for uncertainty in developing benthic TMDLs. The TMDL anticipated that active development, including commercial and housing, would continue near Christiansburg over the next 20 to 25 years. Therefore, changes in land use were estimated by modeling future loads as

part of the allocation process. The broad based land use change that was modeled resulted in the percentage developed land increasing from 8% to 11.3%. The reductions required to meet the TMDL considering future growth are shown in Table 2.

Table 2. Required sediment reductions for the Crab Creek watershed as calculated in the 2004 TMDL

Load Summary	Crab Creek (T/yr)	Reductions Required	
		T/yr	% of existing load
Existing Load	6,307	4,088	64.8
Projected Future Load	7,197	4,978	69.2
TMDL	2,551		
Target Modeling Load	2,219		

Two sediment reduction alternatives were presented in the TMDL and are listed in Table 3.

Table 3. Source reductions needed to meet the sediment TMDL for Crab Creek

Sediment Source Categories	Existing Condition (T/yr)	Allocations			
		Alternative 1		Alternative 2	
		(%)	(T/yr)	(%)	(T/yr)
LDR-PER	14.66	0	14.66	0	14.66
HDR-PER	0.04	0	0.04	0	0.04
COM-PER	3.48	0	3.48	0	3.48
Transitional	31.27	0	31.27	0	31.27
Forest	34.37	0	34.37	0	34.37
Disturbed Forest	114.55	0	114.55	0	114.55
Pastureland	1,996.80	72	547.80	51	978.43
Cropland	761.81	0	761.81	41	449.47
LDR-IMP	2.69	0	2.69	0	2.69
HDR-IMP	0.02	0	0.02	0	0.02
COM-IMP	3.72	0	3.72	0	3.72
Water	0.00	0	0.00	0	0.00
MS4-Existing	55.14	50	27.57	50	27.57
MS4-Future	22.35	50	11.18	50	11.18
NPS Load	**3,040.90**		**1,553.15**		**1,671.44**
Active Ag BMPs	-281.96		-281.96		-281.960
Channel Erosion	4,416.56	79.1	923.06	82	794.98
Point Source Loads	21.23		21.23		21.23
Total	**7,196.73**		**2,215.48**		**2,205.69**
Target Allocation Load (TMDL-MOS-MS4s-Point Sources)			**2,219**		**2,219**

Alternative 1 requires sediment reductions from pastureland (72%), channel erosion (79.1%), and MS4 permitted areas. The reductions could be achieved through riparian buffers, livestock exclusion from streams, stormwater management and improved pasture management. Alternative 2 requires a 41% reduction from cropland, a 51% reduction from pastureland, an 82% reduction

of channel erosion, and reductions from MS4 permitted areas. During Implementation Plan development, stakeholders identified Alternative 2 as the preferred allocation scenario to build upon in the plan, primarily because it addresses sediment from cropland sources.

Changes and Progress since the TMDL Study

BMP Implementation

Since the 2004 TMDL, progress has been made in the Crab Creek watershed to reduce both bacteria and sediment pollution through the implementation of new BMPs (Table 4). Information on agricultural BMPs installed since 2004 was gathered from the Virginia Agricultural Cost Share Tracking Program and represents BMPs implemented since 2004 that have also received cost-share funding. It does not represent additional agricultural BMPs that landowners have decided to implement voluntarily without participation in a state and/or federally sponsored cost-share program. In addition to agricultural BMPs, the Town of Christiansburg reported new stormwater BMPs within Town boundaries and the Virginia Department of Transportation (VDOT) reported BMPs in its MS4 Year 5 Progress Report (VDOT 2013).

Table 4. BMPs installed in the Crab Creek watershed since the 2004 TMDL

Land Use Category	BMP Name	Extent Installed (practices or systems, unless otherwise noted)	Acres Benefitted
Agriculture	Stream Exclusion With Grazing	10,664 feet	320.0
	Land Management		
	Legume Cover Crop	2	247.1
	Animal Waste Storage Facility	1	(115 animals)
Urban	Bio-retention	3	9.60
	Bioretention Basin	1	4.25
	Bioretention Filter	3	10.33
	Detention	37	1,159.29
	Detention	21	TBD
	Detention & Manufactured BMP	1	0.29
	Extended Detention	6	170.91
	Infiltration	3	1.29
	Infiltration Basin	1	TBD
	Manufactured BMP	3	3.84
	Underground Detention	5	22.40
	Street Sweeping[1]	2	176.89

[1] Estimated 164.89 acres (approximately 70 lane miles) treated by the Town of Christiansburg and 12 acres (approximately 5 lane miles) treated by VDOT

Land Use Changes

During plan development, stakeholders agreed that land use conversion from agriculture and forest to development most likely proceeded quicker since completion of the TMDL than the study anticipated. Available data from the 2012 National Agricultural Statistics Service (NASS) and 2006 National Land Cover Database (NLCD) geospatial databases confirmed this issue and

thus, the allocation scenarios for sediment were modified. Table 5 lists the land use change estimates for the watershed used in the TMDL and in this IP.

Table 5. Land use changes in the Crab Creek watershed

Land Use	Crab Creek TMDL – Existing Conditions (2003-2004)		Crab Creek TMDL – 25 yr Projected Growth		2012 NASS-NLCD Land Use Layer	
	Acres	*%*	*Acres*	*%*	*Acres*	*%*
Agriculture	6,158.55	49	5,572.33	45	3,961.004	32
Developed	2,248.52	18	2,942.09	24	5,592.657	45
Forest	4,042.27	32	3,909.38	31	2,895.897	23

Sediment TMDL Modifications

Since TMDL development, a GWLF modeling software error was uncovered that overestimated channel erosion load. In the TMDL study, sediment load from channel erosion sediment was simulated as 4,417 tons/year in Crab Creek and 823 tons/year in the reference watershed Toms Creek. The corrected channel erosion loads are 2,944 tons/year in Crab Creek and 549 tons/year in Toms Creek. The original TMDL for Crab Creek was 2,551 tons/year with a target modeling load of 2,219 tons/year. Re-calculating the TMDL with the corrected channel erosion loads results in a target in-stream load (TMDL minus the MOS) of 2,047.63 and a target allocation load (TMDL minus the WLA and the MOS) of 1,971.26.

The corrected channel erosion load and the updated land use categorization resulted in changes in the overall sediment load, the TMDL, the target load (TMDL – MOS), and the required percent reductions. The WLA of 77 tons/year calculated during the 2004 TMDL study remains the same. The implementation plan preserves the unit-area sediment loads (UALs) for each land use category simulated in the TMDL study. A summary of the categorized areas, associated sediment loads, load reductions from BMP implementation since TMDL development, and target sediment loads used for implementation planning are shown in Table 6.

For implementation planning, therefore, our beginning sediment load is 4,706.81 tons/year and our target sediment load for the load allocation is 1,971.26 tons/year, which requires an overall reduction of 57%. Implementation planning will proceed with the revised estimate of percent reduction for three main reasons: 1) The IP is being developed in a staged approach using sediment load reduction as a surrogate measure for benthic health improvement, 2) the reference watershed approach sets a “relative” target load based on the reference watershed, and 3) the revised TMDL load more accurately represents current conditions in the watershed.

During implementation planning, the recommended percent reductions from each sediment source in the allocation scenario changed significantly from the TMDL study. The changes in land use, BMPs installed since the TMDL study, and the reductions needed to meet the bacteria

water quality goal were considered when selecting the final allocation scenario for the sediment TMDL. The BMPs installed since the TMDL study resulted in an estimated reduction of sediment load of 6% from agricultural land uses and 19% from MS4 areas in the watershed. The Diamond Hills stream restoration currently in development will result in an estimated 2,233 linear feet of stream restoration which was credited toward the streambank stabilization goal. The agricultural BMPs prescribed to meet the Stage 2 bacteria goals result in a 37% reduction of sediment from pasture and a 17% reduction from cropland. The level of effort that the Town of Christiansburg has already put forth in the installation of BMPs, the potential for additional BMPs, and costs were weighed when selecting the percent reductions from MS4 areas and channel erosion.

Table 6. Changes in area, sediment loads, and targeted % reductions for Crab Creek

Sediment Source	Existing Condition	Allocations			
		Stage 1		Stage 2	
Categories	**(T/yr)**	**(%)**	**(T/yr)**	**(%)**	**(T/yr)**
LDR-PER	29.830	0	29.830	5	28.339
HDR-PER	0.083	0	0.083	0	0.083
COM-PER	7.074	0	7.074	0	7.074
Transitional	63.624	0	63.624	0	63.624
Forest	25.463	0	25.463	0	25.463
Disturbed Forest	84.852	0	84.852	0	84.852
Pastureland	1,276.101	32	867.749	37	803.944
Cropland	505.871	17	419.873	17	419.873
LDR-IMP	16.858	0	16.858	5	16.015
HDR-IMP	1.141	0	1.141	0	1.141
COM-IMP	0.005	0	0.005	0	0.005
Water	0.000	0	0.000	0	0.000
MS4-Existing (minus WLA of 55.14)	43.348	3	42.047	15	36.846
MS4-Future	20.652	3	20.032	15	17.554
Active Ag BMPs[1]	*-281.96*		*-281.96*		*-281.960*
Active Ag BMPs[2]	*-84.60*		*-84.6*		*-84.600*
Active Urban BMPs[2]	*-22.28*		*-22.28*		*-22.280*
NPS Load	**1,686.06**		**1,189.79**		**1,115.97**
Channel Erosion[3]	2,944.37	71	853.868	71	853.868
Total	**4,630.44**		**2,043.66**		**1,969.84**
Target Allocation Load (TMDL - MOS - WLA)					**1,971.26**
Target In-stream Load (All Sources-MOS)					**2,047.63**

[1]Credited during TMDL development

[2]Credited since TMDL development

[3]Credited 2,233 linear ft of stream restoration- Diamond Hills project

Community Participation

The development of this clean-up plan relied heavily on input collected from the local community. Knowledge contributed by local citizens and stakeholder organizations guided the identification of conservation and outreach strategies included in this plan. This collaborative process also helped build understanding and trust among participants who need to maintain close working relationships in order to meet the plan's water quality goals. Public participation occurred via a series of public meetings, Table 7.

Table 7. Crab Creek Implementation Plan meetings and public participation

Meeting Date	Meeting Type	# of Attendees
November 12, 2013	Watershed Field Tour	5
November 12, 2013	IP Kick-off Meeting	17
November 12, 2013	Agricultural Working Group	12
November 12, 2013	Residential Working Group	5
January 10, 2014	Government Working Group	14
March 13, 2014	Agricultural & Residential Working Groups	13
August 27, 2014	Steering Committee	19
October 7, 2014	Final Public Meeting	9

VADEQ held a public kick-off meeting for the plan on November 12, 2013 at the Montgomery County Government Building in Christiansburg. The meeting was publicized through a press release published in local papers, email announcements, and flyers posted throughout the watersheds. Approximately 17 people attended the meeting. The meeting served as an opportunity for local residents to learn about water quality in Crab Creek, become familiar with the TMDL and clean-up process, and provide feedback on local watershed concerns and opportunities. A presentation by VADEQ staff preceded meetings of the Agricultural and Residential Working Groups.

Agricultural, residential, and government working groups were formed to discuss implementation and outreach strategies suitable for different land uses in the watershed. Each working group consisted of stakeholders who were familiar with land use management issues specific to their particular working group focus area. The agricultural and residential working groups met twice during the development of the clean-up plan while the government working group met just once.

The Agricultural Working Group reviewed conservation practices and outreach strategies from an agricultural perspective. During the first agricultural working group meeting, held as a break out session during the first public meeting in November, the group discussed how land change within the watershed may have proceeded quicker than accounted for in the TMDL (see 5). Much of the conversation focused on livestock exclusion practices, including how to best contact

potential participants. Additional BMPs considered for the Crab Creek watershed included conversion of erodible pasture to forest, critical area treatment, and cover crops. Streambank stabilization practices were also discussed with reservation due to the recent revocation of NRCS engineering support for Soil and Water Conservation District (SWCD) projects. The stakeholders also noted that no dairies are located in the watershed and that the fields receiving biosolids are required to have a nutrient management plan that should prevent runoff to nearby waterbodies.

The Residential Working Group identified strategies to reduce bacteria from human sources and pet waste as well as to reduce sediment from residential and urban settings. At their first meeting in November, the residential working talked about known stormwater and wastewater issues within the Town of Christiansburg and work being done by the Town to address these issues. The group emphasized rain gardens as a way to address stormwater and educate the public about water quality improvement efforts given previous low turnouts for these types of meetings. Further outreach could be conducted to improve citizen turnout by advertising on the Town's Facebook and directly to Homeowner Associations. Lastly, the group discussed ongoing monitoring efforts in the watershed by citizen groups and monitoring resource needs after the IP is completed.

The Government Working Group facilitated a conversation about water quality in the Crab Creek watershed between local governments, regional organizations and representatives of state and federal agencies. Approximately 13 people attended the Government Working Group meeting on January 10, 2014 at the Christiansburg Town Hall. The group reviewed conservation practices and outreach strategies as well as identified technical and financial resources needed to carry out implementation. They discussed septic systems and straight pipes at length, specifically barriers to reaching potential participants and strategies for fine-tuning the estimates for both numbers and practices needed to address the problem. Representatives of the Town discussed their responsibilities as an MS4 permittee which includes educational efforts, street sweeping, and a current stream restoration project. Stakeholders, specifically the Skyline Soil and Water Conservation District (SWCD), already conduct pet waste education programs, but saw potential in expanding efforts, adding more waste stations, and perhaps even creating a dog park within the Town. Discussion of agricultural sources and practices emphasized strategies eligible for state cost-share funds and the potential difficulties with reaching the smaller farms within the watershed. Other issues of note included well water quality, wetland restoration, what VDOT is doing to address their erosion issues in the watershed, potential funding sources, and stakeholder roles in implementation.

Implementation Measures

Selection of Practices

While management actions such as livestock exclusion and correction of failing septic systems were directly prescribed by the TMDL, additional measures will be needed to control bacteria and sediment coming from land-based sources and channel erosion. Various scenarios were developed and presented to the working groups, who reviewed both the economic costs and the water quality benefits. The majority of agricultural BMPs in this plan are included in state and federal agricultural cost share programs that promote conservation. In addition, innovative management practices suggested by local producers and technical conservation staff were considered. The final set of practices identified and the efficiencies used in this study are listed in Appendix A.

It should be noted that an adaptive management strategy will be utilized in the implementation of this plan. BMPs that are easiest to implement, provide the greatest water quality benefits, and offer the greatest economic return to landowners will be implemented first. The effectiveness of these practices will be continually evaluated, and adjustments of actions will be made as appropriate. As new technologies and innovative BMPs to address bacteria and sediment become available, these practices should also be evaluated for implementation in the watersheds.

Straight Pipes and Failing Septic Systems

Figure 5. Failing septic system

Septic systems can be a safe and effective method for treating domestic wastewater as long as they are sized, sited and properly maintained. A number of factors can cause septic systems to fail, including unsuitable soil conditions, improper design and installation, and inadequate maintenance (EPA 2014). In some cases, wastewater illegally discharges from homes directly to streams or the land surface through what is known as a "straight pipe". Release and runoff of human waste from straight pipes and failing septic systems into streams can have a variety of negative effects including the spread of diseases which make waterways unsafe for recreation. State laws require both failing septic systems and straight pipes be corrected once identified which translates to a 100% reduction in bacteria from these sources.

Table 8 shows the estimated number of households in the Crab Creek watershed with failing septic systems and straight pipes as identified in the 2004 TMDL. The failing septic system estimate factored in the age of homes in the watershed, and in the case of straight pipes, the proximity of homes to streams. The TMDL projected the number of households in the watershed to 2003 based on the Montgomery County growth rates which resulted in 1,713 septic systems.

The TMDL also projected an increase in the number of septic systems to 1,882 by 2008. Practices for treating these two issues were chosen based on input from the local Virginia Health Department staff and stakeholders as well as research from previous IPs. Based on existing conditions in the watershed, it was estimated that 66% of failing septic systems would require repairs, 22% replacements with a conventional system, 10% replacement with an **alternative waste treatment system** and 2% replacement with a connection to public sewer.

Table 8. Estimated failing septic systems, straight pipes and residential practices needed in the Crab Creek watershed

Failing Septic Systems	Straight Pipes	Pump-outs	Connection to Sewer	Repairs	Septic System Replacements	Alternative Waste Treatment Systems
359	4	565	7	237	81	38

Stakeholders identified septic system pump-outs as a practice to offer residents as an educational tool and as a way to further identify failing systems. This program could receive cost-share funding as an incentive for homeowner participation; it could also target homeowners closest to identified streams or those with financial burdens. The number of pump outs listed in Table 8 was calculated as 30% of the 2008 estimate of households in the watershed with septic systems. Stakeholders also identified the cost of connecting to sewer as a practice that could be bolstered by the availability of cost-share funding. In the Town of Christiansburg, once a homeowner's septic system fails they are required to connect to the public sewer system. This is not a requirement for Montgomery County homeowners, but the sewer system does extend in places (generally along Crab Creek) into the County. Based on this feedback, it was estimated that 2% of failing septic systems could be replaced by connections to public sewer.

Sanitary System Overflows (SSOs)

Sanitary sewer systems collect and transport sewage from homes and commercial buildings to publicly owned treatment works (POTW). Unintentional discharges of raw sewage occur in almost every system of this type due to a variety of causes including blockages, line breaks, sewer defects that allow stormwater and groundwater infiltration, improper operation and maintenance, power failures, inadequate design and vandalism. Known as sanitary sewer overflows (SSOs), these discharges release untreated sewage which can impact local water quality.

Christiansburg's sanitary sewer system consists of approximately 155 miles of sewer main and 4,207 manhole structures (Town of Christiansburg 2014). As a requirement of the Town of Christiansburg's Wastewater Treatment Facility VPDES permit (#VA0061751), they are required to report any SSOs within five days to VADEQ. The 2004 Crab Creek TMDL calls for a 100% reduction of these releases.

Since the development of the Crab Creek TMDL in 2004, the Town of Christiansburg has implemented a number of collection system improvements designed to reduce the potential for sanitary sewer overflows (SSOs). These improvements included the development of a GIS-based collection system mapping program to store specific collection system component information; the implementation of a grease trap maintenance monitoring program to reduce the potential for grease-related back-ups and overflows; active SSO identification and reporting to support problem area identification; sewer shed-specific evaluation and rehabilitation; and general system repairs and maintenance.

In conjunction with a 2011 Letter of Agreement with DEQ, the Town conducted an evaluation of Inflow and Infiltration (I/I) sources in the College Street area, a section of the collection system that experienced SSOs during heavy precipitation events. The investigation included flow monitoring, wet weather observations, manhole inspections, smoke testing, and closed circuit television (CCTV) inspections. The College Street system was monitored as a whole, and additionally was subdivided into sub-basins to more effectively locate sources of I/I. The Town performed 296 dry weather manhole inspections and 303 wet weather inspections out of the 318 manholes in the College Street area. During the course of this work, thirteen manholes were rehabilitated by Town staff in order to eliminate obvious inflow contributors. The Town also performed smoke testing on almost 46,000 feet of line (or 70% of the College Street sewer lines) and performed CCTV inspections on 16,790 feet of sewer. Based upon this work, the Town contracted with a sewer rehabilitation contractor to rehabilitate 1,850 linear feet of sanitary sewer utilizing cured-in-place pipe technology and rehabilitated 43 manholes. This work was completed in 2013.

The ongoing and completed work performed in the College Street area and in other areas of the Town's collection system since 2004 represents the replacement of more than 10,000 feet of sewer line, the rehabilitation of another 6,000 feet of existing line, and the rehabilitation or replacement of more than 100 manholes. Collectively these improvements have significantly reduced sanitary sewer overflow potential.

The Town continues to perform preventive maintenance work within its collection system. The Public Works Department routinely maintains approximately 28,000 linear feet of collection lines every year. This maintenance includes point repair, routine cleaning/jetting, and CCTV inspection. In addition, the Town recently contracted with two firms to provide root control and grease treatment within selected sections of the collection system. In 2013, approximately 12,000 feet of sewer pipe was treated in several different drainage areas, and a pilot project with a grease control treatment was conducted on more than 3,000 feet of sewer line located in the Roanoke Street area. These routine maintenance procedures have proven to reduce the number of SSO and the Town plans to continue and improve its preventive maintenance program.

The Town is also currently revising the Sewer Use and Building Code sections of the Town Code to add Fats, Oil and Grease (FOG) permitting requirement as well as revising and expanding the current FOG monitoring and enforcement policies. The Town envisions that this policy revision will reduce the probability of SSO events. A GIS component to the FOG program will identify the location of residential, commercial, and industrial land use and specific restaurants for parcels served within each pump station or other sanitary sewer system monitoring location.

In addition to its ongoing collection system maintenance program, the Town has future plans to develop a system-wide sewer model of its major pipe network to include known SSO locations. Once developed and calibrated, the Town will utilize the model as a tool to aid in developing a long-term sanitary sewer capital improvements plan (CIP). The CIP will prioritize work that will further reduce the frequency of SSOs.

Pet Waste

Studies show that approximately 60-70% of pet owners claim to clean up after their dogs most or all of the time while the remaining 30-40% rarely or never pick up their dog's waste (Hardwick 1997). Left on the ground, pet waste can easily be washed by runoff into storm drains or nearby waterbodies. Pet waste not only harbors bacteria, viruses, and parasites that can threaten the health of humans and wildlife, but it can also contain excess nutrients that promote extreme algal growth. Studies show that up to 95% of fecal matter could potentially be eliminated from an urban watershed if all dog owners simply picked up after their pets (Alderserio et al. 1996; Trail et al. 1993).

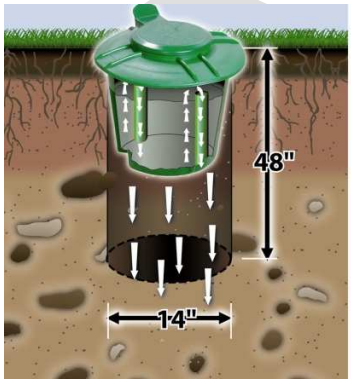

Figure 6. Diagram of a Doggie Dooley system
(Photo: doggiedooley.com)

A pet waste education program increases public awareness about these water quality issues and encourages pet owners to properly dispose of their pet's waste at home and in public dog walking areas. The Skyline SWCD already provides some pet waste education to children as part of their school-based outreach. A fully implemented pet waste education program will include the development and distribution of educational materials, installation of pet waste stations in key locations (local parks, Huckleberry Trail, etc.), and the promotion of other pet waste BMPs such as pet waste digesters or composters. Pet waste digesters and composters allow pet owners to safely collect and treat pet waste outside. There are several types available with varying degrees of required maintenance. For example, the Doggie Dooley system pictured in Figure 6 is a septic tank digester inserted in the ground and covered with a lid.

A "pooper-scooper" ordinance is another effective solution that may be considered in the Crab Creek watershed. Many communities have pooper-scooper laws that mandate pet waste cleanup. Some of these laws specifically require anyone who takes an animal off their property to carry a bag, shovel, or scoop. Any waste left by the animal must be collected immediately. Some of these laws incorporate fines that can offset some of the program costs. In addition to ordinances, many communities have also established dog parks. At dog parks, the use of vegetated buffers, pet waste stations, and thoughtful siting away from drainageways, streams, and steep slopes could help control the community-wide impacts of dog waste on receiving waters (NVPDC 2005). Self-governance principles predict that owners are more likely to properly dispose of pet waste in these designated areas (Mattisof and Noonan 2012). Dog parks can also be convenient locations for concentrating education efforts for maximum pet owner exposure.

Urban Stormwater

Impervious surfaces (roads, parking lots, sidewalks, etc.) are made from materials that unlike soil prevent water from percolating down into the ground. During storms, these surfaces carry the water, along with any materials (bacteria, sediment, trash, fertilizers, etc.) it picks up along the way, to storm drains and nearby waterbodies. Measure known as BMPs or stormwater treatment practices (STPs), mitigate these impacts by storing and filtering runoff before it can affect downstream water bodies. The Crab Creek watershed needs BMPs that address both stormwater quality and quantity in order to reduce urban bacteria and sediment loads. In Virginia, local jurisdictions, like the Town of Christiansburg, are the primary provider of stormwater services, but these practices can and should be applied to any developed area in the watershed needing stormwater control.

Urban stormwater BMPs are diverse and continuing to grow. Ultimately, BMP selection for a specific site will depend upon its physical and financial feasibility as well as other factors such as pollutant removal efficiency, maintenance needs, aesthetics, and wildlife habitat function. This IP includes a selection of potential BMPs based on their common usage, high cost-effectiveness, and stakeholder feedback. However, the various Working Groups recognized that other BMPs, some of which are already listed in the **Virginia Stormwater BMP Clearinghouse**, may be better suited for specific projects in the Crab Creek watershed. These BMPs should be evaluated for their bacteria and sediment pollutant reduction capacity and considered among the many options available.

Here are examples of specific stormwater BMPs referenced in this IP:

Figure 7. Extended detention basin (Photo: USEPA)

Figure 8. Manufactured BMP

Figure 9. Constructed wetland (Photo: Chesapeake Bay Foundation)

Figure 10. Riparian buffer

Figure 11. Infiltration trench

Figure 12. Rain garden

Extended detention basins, also known as dry detention ponds, detain stormwater runoff for 12 to 24 hours post-rain event, reducing peak flow and allowing particles and pollutants to settle out of the water (Figure 7). These do not typically have a large, permanent pool of water. Extended detention basins are widely used as they are applicable to most types of development, including redevelopment and retrofit situations.

The category of manufactured BMPs includes a variety of proprietary technologies that vary in form and function (Figure 8). Also known as manufactured treatment devices (MTDs), these measures may be designed to capture sediments, nutrients, metals, hydrocarbons, and/or floatables before runoff is conveyed to a storm sewer system. These devices are generally compact and suitable where space is limited. Effective performance of a manufactured treatment device usually requires regular maintenance. VADEQ is currently working on issuing guidance describing the process for approving MTDs and assigning pollutant removal credits. MTDs meeting those criteria will be listed in the Virginia Stormwater BMP Clearinghouse.

Wetlands act like the kidneys of the landscape, filtering and storing pollutants before they can reach flowing waterbodies. Although natural wetlands can sometimes be used to treat stormwater runoff, most should be protected from development because of potential adverse effects associated with alterations in hydrology. Instead, constructed wetlands (which are similar to wet ponds) should be designed and constructed to meet the stormwater treatment needs associated with human development (Figure 9). High pollutant removal efficiencies and limited maintenance needs make constructed wetlands a popular practice.

Riparian buffers contain vegetation that physically separates a waterbody from surrounding development (Figure 10). Buffers can provide economic, environmental, recreational, and aesthetic value to a community. They preserve the floodplain, encourage infiltration, filter pollutants, capture sediment, provide wildlife habitat, and regulate water temperature.

Low Impact Development (LID) BMPs

Low impact development (LID) is about managing rainfall at the source using smaller-scale controls rather than the traditional method of channeling stormwater through pipes to large-scale holding areas. LID mimics natural hydrology by allowing rainwater to infiltrate, filter, evaporate, and accumulate at the source. These types of control measures should be considered because they are flexible and can easily be integrated into urban sites. LID techniques also tend to cost less to construct because they require less grey infrastructure than traditional, conventional stormwater controls.

Infiltration practices include dry wells, infiltration trenches (Figure 11), and infiltration basins (VA DEQ 2011). Dry wells are small, stone-filled pits that store and infiltrate pre-filtered runoff from small (less than one acre) areas like the roof of a single-family home. Trenches temporarily

store runoff so it can infiltrate into the ground in stone-filled surface or underground trenches. They are suitable for drainage areas less than ten acres whereas basins may be suitable for drainage areas of 5 to 50 acres. Infiltration basins are impoundment structures constructed over permeable soil, but unlike detention basins, they are not designed to release any stormwater as surface flow.

Bioretention practices use a landscaped, conditioned soil bed to capture and eventually filter rainwater to an underdrain that connects to the larger storm drain system. They range in size depending on the area of impervious surface they are designed to treat, but generally they are used on sites of five acres or less. Small-scale bioretention filters designed for individual lots are generally referred to as rain gardens (Figure 12). Bioswales are similar to rain gardens by design, but are typically linear and located along roadways or walkways. By maximizing rainwater infiltration, bioretention areas reduce runoff and provide high pollutant removal efficiencies. They can also provide secondary benefits, including enhanced aesthetics, noise control, wind protection, and wildlife habitat (EPA 1999). Stakeholders suggested schools as good sites for rain gardens because of the additional teaching and learning opportunities.

Other examples of LID include vegetated roofs, permeable pavement and pavers, rain barrels, and rain gutter disconnects.

Pollution Prevention/Good Housekeeping

In addition to structural BMPs, local municipalities can implement or enhance certain activities to address the impacts of stormwater on bacteria and sediment loads in Crab Creek. Over time, streets and parking lots accumulate pollutants including sediment, debris, trash, road salt, and even waste that can be carried by runoff to nearby surface waters. Street sweeping can minimize these loads while also improving roadway aesthetics. The effectiveness of a street sweeping program will depend upon the equipment, its operation and maintenance, sweeping schedule, waste storage and disposal. Bacteria and sediment loads may be reduced further by the regular cleaning of storm drain systems

All localities are required by law to develop a program to reduce pollutants in stormwater runoff from construction sites disturbing one or more acres. These programs generally begin with an ordinance that requires the implementation of erosion and sediment BMPs as well as procedures for reviewing site plans, responding to public concerns, site inspections, and enforcement. Programs must meet the minimum standards set forth in the Virginia Erosion and Sediment Control Law, Regulations, and Certification Regulations (effective July 1, 2013), but Enhanced Erosion and Sediment Controls may be an option for permittees in watersheds with known sediment issues to reduce their loads. Municipalities can “enhance” their program several ways such as designating a smaller threshold for construction sites requiring E&S plans, mandating faster site stabilization, adding staff to ensure proper enforcement of existing program

components, and increasing the frequency of inspections in watersheds with sediment impaired streams. (Clark et al. 2014).

Green Infrastructure

In addition to small-scale structural BMPs, urban stormwater could potentially be addressed through the development of green infrastructure. **Green infrastructure** is both the interconnected green space network managed for its natural resource values and the process of promoting systematic and strategic land conservation for the good of nature and people. The scale of green infrastructure ranges from small urban rain gardens to greenways to large tracts of undeveloped land. Green infrastructure can address several different water issues including stormwater management, flood mitigation, and water quality. For example, Milwaukee, Wisconsin developed a conservation plan for important floodplain areas to complement traditional stormwater management techniques and improve water quality (Benedict and McMahon 2006). Local efforts to create walking paths, trails, and greenways could also expand to include conservation corridors and the protection of water resources.

Streambank Stabilization and Restoration

Figure 13. An eroding streambank

Streambank erosion is a natural process, but alterations to the stream system can greatly accelerate the process resulting in erosion rates far greater than those typically seen (Figure 13). Channel erosion is estimated to contribute about 61% of the sediment reaching Crab Creek from nonpoint sources, making streambank stabilization efforts critical. Significant reductions could be made through the implementation of improved stormwater management in urban areas, installation of riparian buffers throughout the watershed, and livestock exclusion from streams. However, additional stream mitigation will be needed to meet the in-stream channel erosion reductions identified in the Crab Creek TMDL.

Due to the variability in streambank form and needs, streambank stabilization and restoration techniques must be selected on a site-by-site basis. Resource needs will depend on the specific technique(s), ranging from low tech, landowner friendly projects (live plantings) to relatively high-cost designs requiring professional design services (channel re-shaping). The 2004 Virginia Stream Restoration and Stabilization Best Management Practices Guide provides an in-depth review of the permitting issues, planning and design principles, costs, and best management practices associated with stream restoration projects (VADCR 2004).

In 2009, the Town of Christiansburg initiated a stream preservation and restoration program to improve the function and water quality of degraded streams throughout the Town. The first site chosen for restoration was the Diamond Hills Park creek site near Independence Boulevard in the northeast portion of the Crab Creek watershed (Figure 14). Construction on the project began in late 2013 and at its completion will restore 2,233 linear feet of impaired stream channel that drains directly into Crab Creek. This project is estimated to remove approximately 874 tons of sediment per year from Crab Creek (Town of Christiansburg 2013). When completed, the Diamond Hills Park will be protected in perpetuity by the Town as green space and future plans include a trail network.

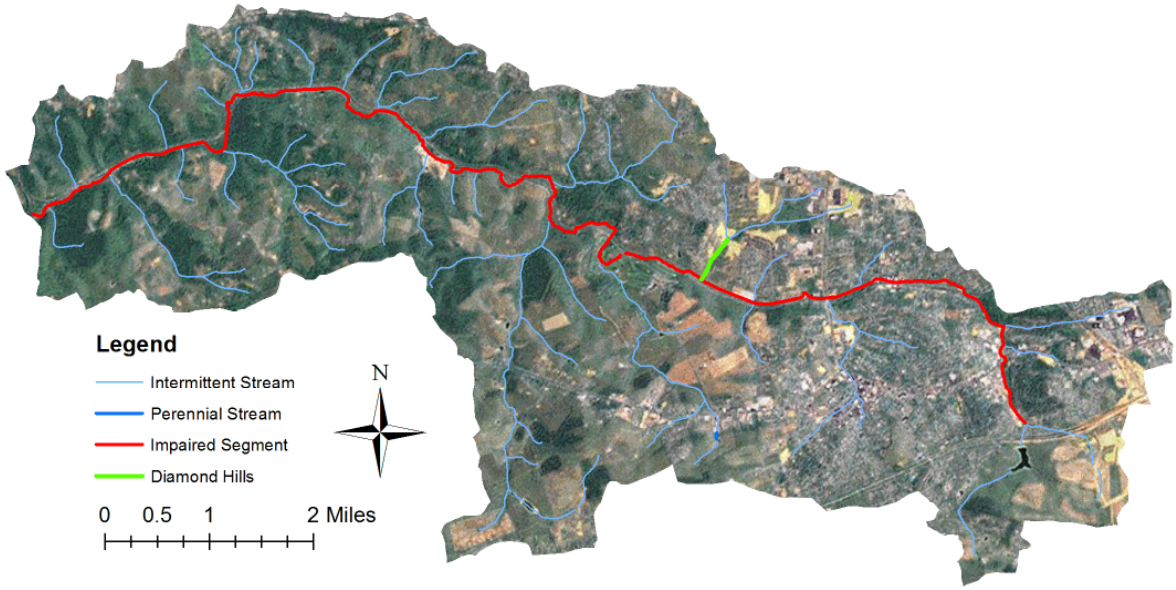

Figure 14. Diamond Hills stream restoration location

Direct Deposition

Figure 15. Exclusion fencing system with stream crossing (Photo: NRCS)

When livestock, especially cattle, have uncontrolled access to streams, they often deposit their feces nearby or directly into the stream. Their waste contains fecal bacteria, an indicator of other disease-causing bacteria that can harm human health. Additionally, the livestock tend to congregate around the water source, trampling the stream banks and overgrazing the riparian vegetation which further contributes to stream sedimentation issues. The 2004 TMDL study specified a 100% reduction in the direct deposition of waste into the stream by livestock. This will be accomplished by limiting livestock access to streams with fencing and providing alternative water sources (Figure 15).

A GIS analysis of hydrologic and land use data was conducted to assess potential fencing needs. Perennial and intermittent stream segments flowing through pastureland were identified and evaluated against aerial imagery to detect land uses categorized as pasture but serving an alternative purpose (i.e. golf course). Fencing lengths were calculated for both sides of a stream segment if it flowed through identified pastureland and only for one side if it flowed adjacent to pasture and another land use. While not every pasture has grazing livestock at every single point in time, it was assumed that all pasture areas have the potential for livestock access. Stream feet within pasture, current fencing extent, and estimated stream exclusion fencing needs are listed in Table 9.

Table 9. Stream exclusion fencing needs (feet)

Total Stream Length	Fencing installed after TMDL[1]	Fencing Needed
29,553	10,664	18,889

[1] Four systems have been installed and recorded in the VADCR BMP Cost-share database since the 2004 TMDL study

Landowners have a growing number of cost-share options for livestock exclusion fencing systems. The most common resources for fencing systems in Virginia are the state Agricultural BMP Cost-share program administered by local Soil and Water Conservation Districts (SWCDs) and the National Resource Conservation Service (NRCS) Cost-share program. Technical specifications and cost-share rates vary by practice as shown in Table 10. Local District, NRCS, and Farm Service Agency (FSA) personnel provided feedback on the typical distribution of systems among the available cost-share practices as well as the average cost of systems associated with the different practices. Data was also pulled from the VADCR BMP Cost-share database for comparison to these estimates and to help account for the fencing systems put into place in the watershed since the 2004 TMDL.

Table 10. Comparison of Virginia cost-share program livestock exclusion practices

Practice Code	Required Buffer Distance (feet)	Cost-share Rate	Components Eligible for Cost-share Payment				
			Permanent Stream Crossing	Cross Fencing	Alternate Water Supply	Restricted Crossing	Hardened Access or Crossing
SL-6T	35	100%	X	X	X	X	
LE-1T	35	85%	X	X	X	X	
LE-2T	10	50%	X	X	X	X	
WP-2T	35	75%	X				X

Based on stakeholder feedback, this plan estimates that 85% of needed exclusion systems will be installed as a Stream Exclusion with Grazing Land Management (SL-6T) practice or Livestock Exclusion with Riparian Buffer practice (LE-1T). VADCR is currently marketing the SL-6T

practice at 100% cost-share for two years (fiscal years 2014 and 2015) after which time the cost-share percentage will be reduced. All participant enrollments received during the two-year period will be honored as cost-share becomes available even if enrollment outpaces available funding. The LE-1T practice has consistently been marketed at 85% which could make it the preferable choice when the SL-6T cost-share is reduced. The remaining systems will likely be a mixture of Livestock Exclusion with Reduced Setback (LE-2T) and Stream Protection (WP-2T) practices.

This IP quantifies fencing along both perennial and intermittent streams. The highest priority should be given to livestock exclusion systems on perennial streams to achieve the most impact on reducing bacteria loads; therefore, all perennial stream fencing is included in Stage 1. Stage 2 includes the estimates for livestock exclusion on the intermittent streams within the Crab Creek watershed.

Pastureland

Pasture lands provide forage for grazing by domestic livestock, commodities which contribute largely to Virginia's economic prosperity (VDACS 2014). Improper pastureland management can lead to soil compaction and overgrazing which encourage erosion and runoff. Grazing animals deposit manure on any available pastureland, but waste tends to be most concentrated near feeding and watering areas. Poorly located or managed areas can quickly become barren, increasing the possibility of contaminated runoff (Alderfer and Robinson 1947). Pasture runoff carries both bacteria from the livestock waste and sediment from the eroding soils to nearby streams. Pastureland BMPs can greatly reduce these pollutant loads as well as improve overall pastureland production.

Grazing Land Management encompasses several cost-share practices (EQIP 528 or SL-10T) and generally refers to the controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective. Grazing management may address stocking rates, rest periods, intensity, frequency, duration and season of grazing to promote ecologically and economically stable plant communities. In addition to reducing bacterial and sediment pollution, these practices can help improve soil and animal health as well as potentially increase profitability. The Reforestation of Erodible Crop and Pastureland practice (FR-1) offers an incentive to change land use on eroded pasture to one that will better control soil and nutrient loss from surface runoff. Permanent Vegetative Cover on Critical Areas (SL-11) provides cost-sharing and tax credits for land shaping and planting of permanent vegetative cover that will significantly reduce erosion and improve water quality. In areas frequently and intensively used by people, animals, or vehicles, the Heavy Use Area Protection (NRCS 561) practice may be used to establish vegetative cover, surface with suitable materials, and/or install structures like roofs.

Cropland

When exposed to rainfall, manure fertilized cropland may contribute additional bacteria and sediment to runoff. Filtering practices such as riparian buffers can help trap those pollutants before they reach local streams. Reducing soil tillage, increasing soil organic content, and improving soil cover can also help reduce the amount of runoff and soil loss during rain events. Certain practices may also help reduce the levels of bacteria in the manure prior to application such as increasing storage times and during application by reducing manure use.

Farmers in Montgomery County already employ some of these BMPs as confirmed by the Skyline SWCD. While a few of these cropland and other agricultural practices are documented in the VADCR Cost-share database, other practices are not included because they are undertaken voluntarily by the producers. Thus, Working Group members helped establish some baseline estimates for the watershed. In preparing this plan, it was estimated that 70% of cropland currently employs cover crops and that only 6% of cropland is currently in high tillage.

Farmers till their land to aerate, warm, and shape soil as well as to bury crop residue and remove weeds. Beyond these benefits though, tilling results in many other negative effects like soil compaction, loss of organic matter, disruption of soil organisms, and increased soil erosion and runoff. No-till farming, in contrast, minimizes soil disruption, but requires different management techniques to maintain crop yields. The **Continuous No-Till** System practice (SL-15A) provides a per-acre payment for farmers who stop tilling their soil (Figure 16).

Figure 16. Continuous no-till system

Figure 17. Field with cover crop

Although **cover crops** have been used by farmers for centuries, the practice had recently been replaced by the widespread increase in fertilizer and herbicide use. Farmers are generally moving back toward the use of cover crops because of the benefits associated with improved soil quality, enhanced fertility, decreased field maintenance, and erosion control. Two types of cover cropping practices were considered in this plan, harvestable and small grain (Figure 17). The

small grain cover crop practice (SL-8B) was selected because it provides cost-share and tax credits to participating farmers for establishing vegetative cover, specifically grains like winter rye and winter wheat, on cropland for protection from erosion and the reduction of nutrient losses to groundwater (VACS Manual 2014). In this practice, the cover crop is killed or grazed, but not harvested.

Technical Assistance

The implementation plan will require the involvement of many landowners throughout the watershed, many of which will have no prior knowledge of water quality issues and BMPs. A survey of producers by the National Institute of Food and Agriculture found the most effective educational programs required dedicated personnel, a resource currently in decline (Luloff et al. 2012). Individuals are needed to help identify, educate and involve landowners as well as help design and install the actual BMPs. Therefore, technical assistance resources are a key component of this clean-up plan.

Technical Assistance Tasks

- Assist in and approve design of BMPs for residential and/or agricultural land uses
- Inspect completed cost-share practices and document site visits
- Verify landowner match requirement
- Complete paperwork for cost-share payments
- Track and report practice implementation
- Educate and provide outreach to the general public about the implementation plan and other ways to improve local water quality

The plan estimates technical assistance needs based on the scope of BMPs identified in this plan, discussions with local stakeholders, and levels included in similar implementation projects. The plan calls for two technical assistance positions: one for agricultural practices and one for residential/urban practices. The Skyline SWCD showed interest in managing the agricultural position. The residential/urban position would potentially work on septic system, pet waste, and stormwater implementation practices. While they could also be employed through the District, a better fit may be the New River Valley Planning District Commission (NRVPDC) or the New River Conservancy (formerly the National Committee for the New River).

Education and Outreach

Staff members of the Skyline SWCD and NRCS already provide outreach, technical and financial assistance to farmers in the Crab Creek watershed to encourage the installation of agricultural BMPs. Additional information on agricultural implementation practices could be distributed through the Virginia Cooperative Extension, local businesses (Southern States), and community events. Bulk mailings to target properties where specific practices are needed would also be an inexpensive and effective way to reach the farming community.

Additionally, Skyline SWCD already provides educational programming to school children about water quality and water quality practices, such as cleaning up after pets. The Town of Christiansburg's wastewater treatment plant also conducts tours and offered the property as a potential location for additional outreach activities. The school system was identified as a willing partner for outreach activities and as a way to reach many citizens throughout the watershed. Christiansburg High School students currently have an opportunity to participate in a class which conducts biological, chemical, and physical monitoring throughout the Crab Creek watershed. These monitoring efforts both teach students about the watershed and provide additional data collection opportunities for understanding water quality throughout the watershed.

Stakeholders recommended creating educational campaigns for promoting both residential septic and pet waste efforts. VDH was suggested as a partner in locating failing septic systems and straight pipes, and SERCAP was mentioned as a potential source for additional funding. Other septic system maintenance education programs have utilized websites, displays, handouts, educational videos, utility bill inserts, public service announcements and workshops (often referred to as "septic socials"). In addition to improving water quality, a pet waste outreach campaign can empower community members to take action and build further support for water quality improvement efforts. A pet waste campaign could include brochures distributed with County dog licenses and at local veterinarian offices, messages delivered through local media (TV, radio, newspapers, etc.), flyers, informational meetings, a website, educational materials, and participation incentives such as dog waste kits.

Implementation Costs

Residential BMP Costs

The total cost for residential septic system, straight pipe, and pet waste practices totals $2,240,000 as shown in Table 11. The costs for residential practices were estimated using input from local Virginia Department of Health (VDH) staff and the Skyline SWCD as well as information from other recent TMDL Implementation Plans in Virginia. All of the following residential practices will be prioritized for implementation during Stage 1, which encompasses the first six years of implementation efforts.

Table 11. Estimated residential BMPs and costs

Control Measure	BMP Code	Units	Unit Cost	Stage 1 Units	Stage 2 Units	Total	Total Cost
Failing Septic Systems							
Septic Tank Pump-out	RB-1	system	$300	565		565	$169,500
Connection to Public Sewer	RB-2	system	$5,000	7		7	$35,000
Septic Tank System Repair	RB-3	system	$3,500	237		237	$829,500
Septic Tank System Installation/Replacement	RB-4	system	$7,500	79		79	$592,500
Alternative On-site Waste Treatment System	RB-5	system	$15,000	36		36	$540,000
Straight Pipes							
Septic Tank System Installation/Replacement	RB-4	system	$7,500	2		2	$15,000
Alternative On-site Waste Treatment System	RB-5	system	$15,000	2		2	$30,000
Pet Waste Management							
Pet Waste Stations[1]		system	$1,300	15		15	$19,500
Pet Waste Digesters/ Composters		system	$100	50		50	$5,000
Pet Waste Education Program		program	$4,000	1		1	$4,000
						Total	$2,240,000

[1] Unit cost based on purchasing system as well as the estimated cost of trash can liners, waste bags, and maintenance for 10 years

The number of pet waste stations needed was estimated by analyzing the number of parks and miles of trails within the watershed. It was estimated that a total of 15 pet waste stations are needed in the watershed (Table 12). Over a lifespan of 5 years, each pet waste station will cost about $1,300 considering the cost of the station hardware, waste can liners, waste bag refills, and maintenance. Pet waste digesters/composters could be placed in the watershed at veterinary clinics, kennels, or private residences. These systems are most applicable to residences in urban areas with small lots that allow for easy retrieval of pet waste. This plan estimates that at least 50 units could be placed in the watershed at an average cost of $100 per system.

Table 12. Locations identified for future placement of pet waste stations.

Location	# Stations	Details[1]
Circle Park	1	Neighborhood park on Ellett Drive
Depot Park	1	On Depot St. with walking/jogging path
Downtown Park	1	Paved walking trail to library
Harkrader Sports Complex	1	Encircled by a 0.4 mile paved walking track
Kiwanis Park	1	Located off Roanoke Street, behind Southern States
Town and Country Park	1	Neighborhood park on Summit Ridge Road
Wall Street Park	1	Neighborhood park located on Wall Street, off Radford Street
Huckleberry Trail	3	Total = 10, 737 ft; Existing = 1,483 ft; Design = 9,254 ft
Trail near George Edward Via NW	1	Proposed walkway = 5,455 ft
Holmes St. NE to Mill Ln. NE	1	Proposed walkway = 2,491 ft
Aspen St. SE to Falling Branch	2	Proposed walkway = 6,578 ft
Dog Park	1	Proposed, no location
Total	15	

[1] Details derived from the Town of Christiansburg Parks and Recreation website and trail maps. Trail lengths are estimated.

A Pet Waste Education program for the watershed would cost approximately $4,000. This would cover the cost of outreach efforts to educate landowners about this particular water quality issue. Lack of knowledge of the connection between pet waste and water quality issues has been recognized as one of the main barriers in getting pet owners to clean up their dog's waste. (Syferd 1995). Outreach efforts may include creating and distributing flyers, posters, waste bag samples, cost-share for the purchase of digesters/composters, advertisements, and display materials.

Stormwater BMP Costs

Stormwater BMP cost estimates were developed using stakeholder input, information from other recent Implementation Plans and other available literature. The estimated total cost for stormwater BMPs is $1,604,250. Table 13 lists the various urban and residential stormwater BMPs and their associated costs. Stormwater BMPs installed during Stage 1 will meet the sediment reduction goal from MS4 permitted areas, and combined with the Residential BMPs will meet the Stage 1 bacteria goals from residential and urban sources. While there is no specific bacteria reduction goal for MS4-related loads, many of these stormwater BMPs will be placed within the MS4 area, resulting in potential reductions to the MS4 bacteria load.

Table 13. Urban and residential stormwater BMP costs (units in acres treated)

BMP	Units	Avg. Cost	# of BMPs			Costs		
			Stage 1	Stage 2	Total	Stage 1	Stage 2	Total
Rain Gardens (MS4)	acres treated	$5,000	2	57	59	$10,000	$285,000	$295,000
Rain Gardens (non-MS4)	acres treated	$5,000		10	10	$0	$50,000	$50,000
Bioretention Filters	acres treated	$20,000	1.5	2	3.5	$30,000	$40,000	$70,000
Bioswales	acres treated	$15,000	1	6	7	$15,000	$90,000	$105,000
Riparian Buffers - Forested	acres treated	$3,500	0.5	55.5	55.5	$1,750	$192,500	$194,250
Riparian Buffers - Grass/Shrubs (MS4)	acres treated	$500		75	75		$37,500	$37,500
Riparian Buffers - Grass/Shrubs (non-MS4)	acres treated	$500		20	20		$10,000	$10,000
Detention	acres treated	$2,000	25	57	82	$50,000	$114,000	$164,000
Extended Detention	acres treated	$2,000	40	60	100	$80,000	$120,000	$200,000
Manufactured BMPs	acres treated	$15,000	2.5	10	12.5	$37,500	$150,000	$187,500
Detention and Manufactured BMPs	acres treated	$16,000	0.5	15	15.5	$8,000	$240,000	$248,000
Constructed Wetlands/Wet Ponds	acres treated	$8,000	0.5		0.5	$4,000		$4,000
Infiltration	acres treated	$20,000	0.5	1	1.5	$10,000	$20,000	$30,000
Vegetated Open Channels	acres treated	$9,000	0.5	0.5	1	$4,500	$4,500	$9,000
							Total Cost	$1,604,250

Streambank Stabilization BMP Costs

Streambank stabilization estimates shown in Table 14 were based on similar watershed clean-up plans and input from the Crab Creek working groups. The estimated total cost for streambank stabilization efforts is $1,688,100. All streambank stabilization practices have been prioritized for implementation during the first stage of work based on stakeholder feedback. Streambank stabilization practices are applicable to all land uses in the watershed. More complex stream restoration projects would be applicable in the watershed to support sediment reduction efforts and stakeholders estimated the cost of full stream channel restoration at $200-$300 per linear foot. However, the increased unit cost may result in a greater sediment removal rate than just

basic stabilization efforts, making restoration projects a potentially cost-effective option. The Diamond Hills project being undertaken by the Town of Christiansburg was credited for 2,233 linear feet of streambank stabilization during plan development.

Table 14. Streambank stabilization estimates for the Crab Creek watershed

Control Measure	Unit	Unit Cost	Units Needed		Total Cost	
			Stage 1	Stage 2	Stage 1	Stage 2
Streambank Stabilization	linear ft.	$300	11,254		$3,376,200	$0

Agricultural BMP Costs

The total cost of agricultural BMPs needed in the Crab Creek watershed is $2,088,275 (Table 15). This includes $1,356,400 for practices to address direct deposition through livestock exclusion systems, $671,245 for pastureland practices, and $600 for cropland practices. Costs associated with each of the agricultural BMPs needed in the watershed were estimated using data from the Virginia Agricultural BMP Tracking Program and feedback from Skyline SWCD and NRCS staff. The majority of recommended practices are eligible for state and federal cost share programs. These programs offer landowners financial assistance for implementing practices and may include with some practices incentive payments to further encourage participation. The per system costs shown for each practice in Table 15 include the total practice cost which is comprised of both the expected cost share payment and the landowner's cost responsibility. The Stage 1 1ivestock exclusion goal is based on fencing needs estimated for perennial streams while the Stage 2 estimate covers additional intermittent stream miles that may need exclusion systems.

Table 15. Estimated agricultural BMPs and costs

Control Measure	BMP Code	Units	Average Unit Cost	Stage 1		Stage 2		Total Units	Costs		
				Units	% LU Treated	Units	% LU Treated		Stage 1	Stage 2	Total
Livestock Exclusion											
Livestock Exclusion with Riparian Buffers	SL-6T, LE-1T	system	$32,800	16	85%	22	21%	38	$524,800	$721,600	$1,246,400
Livestock Exclusion with Reduced Setback	LE-2T	system	$20,000	2	10%	2	3%	4	$40,000	$40,000	$80,000
Stream Protection System	WP-2	system	$10,000	1	5%	2	1%	3	$10,000	$20,000	$30,000
Pasture											
Grazing Land Management System	EQIP 528, SL-10T	acres	$75	3,265	95%			3,265	$244,875		$244,875
Reforestation of Erodible Pasture	FR-1	acres	$1,000			28	0.5%	28		$28,000	$28,000
Permanent Vegetative Cover on Critical Areas	SL-11	acres	$2,000			29	0.5%	29		$58,000	$58,000
Heavy Use Area Protection	EQIP 561	system	$20,000			20	4%	20		$400,000	$400,000
Cropland											
Continuous No-till	SL-15A	acres	$20	5	2%			5	$100		$100
Small Grain Cover Crop	SL-8B	acres	$45	20	6%			20	$900		$900
									Total Cost		**$2,088,275**

Technical Assistance Costs

Technical Assistance costs were based on the types and extent of practices included in the Implementation Plan. It was estimated that one full-time (FTE) position would be needed during Stage 1 and ½ FTE would be needed during Stage 2 for the residential/urban practices and that one full-time (FTE) position would be needed during both Stage 1 and Stage 2 for the agricultural practices (Table 16). Stage 1 includes the first six years of implementation and Stage 2 covers the next four years. A cost estimate of $60,000 per year per full-time position was used based on existing staffing costs for TMDL Implementation projects across the Commonwealth.

Table 16. Technical assistance costs for implementation projects

BMP Category	Stage 1	Stage 2	Total
Agricultural	$360,000	$240,000	$600,000
Residential/Urban	$360,000	$120,000	$480,000
Total	$720,000	$360,000	$1,080,000

Total Implementation Cost

In total, it is estimated that meeting the TMDLs and achieving water quality standards in the Crab Creek watershed will cost $10,388,725 as shown in Table 17. These costs are broken down into the two stages of implementation as well as into four basic categories: residential, stormwater, agricultural, and technical assistance.

Table 17. Total estimated cost for the Crab Creek Implementation Plan

	Residential BMPs	Stormwater BMPs	Stream Stabilization BMPs	Agricultural BMPs	Technical Assistance	Total
Stage 1	$2,240,000	$250,750	$3,376,200	$820,675	$720,000	$7,407,625
Stage 2	$0	$1,353,500	$0	$1,267,600	$360,000	$2,981,100
Total	**$2,240,000**	**$1,604,250**	**$3,376,200**	**$2,088,275**	**$1,080,000**	**$10,388,725**

Implementation Benefits

The ultimate goal of this clean-up plan is to meet water quality standards in Crab Creek that support human recreational use and the propagation of aquatic life. Reducing bacteria and sediment loads in Crab Creek will protect human health and safety, promote healthy aquatic communities, improve agricultural production, and add to the economic vitality of the community.

Human Health and Safety

Human, livestock, and wildlife waste can carry viruses and bacteria that are harmful to human health. Throughout the United States, the Centers for Disease Control (CDC) estimates that at least 73,000 cases of illnesses and 61 deaths per year are caused by *E. coli* 0157:H7 bacteria (CDC, 2001). Other fecal pathogens (*e.g., E. coli* 0111) are responsible for similar illnesses. Reducing the presence of bacteria in the watershed should considerably reduce the chances of infection from *E. coli* sources through contact with Crab Creek's surface waters. In addition to preventing infection and disease, strategies in this plan addressing stormwater could help mitigate and prevent future flooding.

Healthy Aquatic Communities

Excessive sediment can smother a stream by killing aquatic flora and clogging the spaces in between river bed substrate that usually provide habitat for **benthic macroinvertebrates** (Harrison et al. 2007). Accumulation of sediment may also lead to changes in the composition of the benthic macroinvertebrate community, favoring tolerant taxa over intolerant types (examples shown in Figure 18). These "bugs" are often a major food source for many species of freshwater fish and a decrease in their availability can ripple up the food chain. Thus, the health of the whole aquatic ecosystem is dependent in part upon its physical habitat.

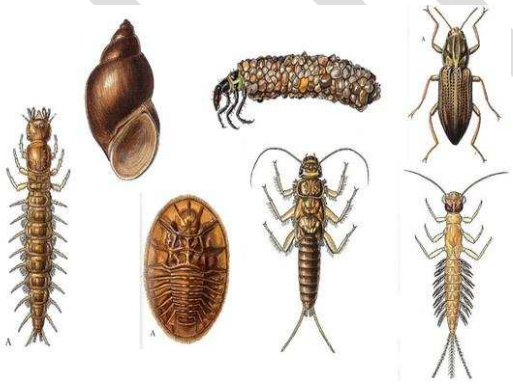

Figure 18. Examples of intolerant benthic macroinvertebrates

Reducing sediment in the Crab Creek watershed will help restore the health of aquatic communities for the benefit of the flora, fauna and human residents. For example, streamside buffers will help reduce erosion and provide shade for fisheries which will in turn provide more stock for local anglers. In 2011 alone, approximately $3.5 billion was spent on wildlife recreation in Virginia (USDOI et al. 2011). Buffers can also improve habitat for wildlife that also benefit from having access to a healthy, thriving aquatic community.

Agricultural Production

This plan recognizes that each and every farmer faces their own unique management challenges. Thus, some of the BMPs in this plan may be more suitable and more cost-effective for one landowner than for another in the watershed. Similarly, the benefits of implementing these practices will vary, but can be estimated based on general research.

Restricting cattle access to streams and providing them with a clean water source can improve weight gain and milk production (Zeckoski et al. 2007; Landefeld et al. 2002). Increasing weight as well as milk and butterfat production can translate into economic gains for producers as shown in Table 18 (Zeckoski et al. 2007). Additionally, keeping cattle in clean, dry areas has been shown to reduce the occurrence of **mastitis** and foot rot. The Virginia Cooperative Extension estimates mastitis costs producers $150 per cow in reduced milk production quantity and quality (Jones and Balley 2009).

Table 18. Production gains associated with provision of clean water for beef cattle

Typical calf sale weight	Additional weight gain with access to clean water	Price	Increased revenue
500 lb/calf	5% (25lb)	$2.00/lb	$50/calf

Community Economic Vitality

Healthy watersheds provide many **ecosystem services** necessary for a community's well-being. These services include, but are not limited to, water filtration and storage, air filtration, carbon storage, energy, nutrient cycling, removal of pollutants, soil formation, recreation, food and timber. Many of these services are hard to quantify in terms of dollars and are often under-valued (Bockstael et al. 2000). However, it is understood that many of these services are difficult to replace and often expensive to artificially engineer. Efforts to restore the Crab Creek watershed to a healthier state will reduce the financial burden on residents, businesses, and municipalities who currently bear the cost of damages caused by a degraded aquatic system such as flooding. Stormwater infrastructure that keeps stormwater runoff onsite can reduce losses from flood damage by $6,700-$9,700 per acre (Medina et al. 2011.) Urban stormwater BMPs can also help increase stormwater retention and lower peak discharges, thereby reducing the pressure on and need for stormwater infrastructure. This will in turn lower engineering, land acquisition, and material costs for municipalities and private enterprises.

Once the IP is complete, organizations in the watershed will be eligible to apply for competitive funding to help cover some of the costs associated with installing the BMPs. These potential funds along with matching funds from other sources will benefit many local contractors involved in the repair and installation of septic systems, building of fencing systems, and installation of stormwater structures. In a 2009 study, researchers estimated that every $1 million invested in

environmental efforts such as reforestation, land and watershed restoration, and sustainable forest management, would create approximately 39 jobs (Heintz et al. 2009).

Individual homeowners and residents could also see financial benefits from these efforts. Implementation activities in the plan will help give homeowners the knowledge and tools needed for extending the life of their septic systems. The overall cost of ownership could also be reduced by advocating regular pump outs which cost about $300 compared to the $6,000-$25,000 cost of a repair or replacement system. The additional services provided by new stormwater BMPs could raise the market value of nearby homes 0-5% (Braden and Johnston, 2004). Another study in the Chesapeake Bay area found that lower fecal coliform concentrations correlates with increased property values (Leggett and Bockstael 2000).

Measurable Goals and Milestones

The ultimate goals of this Implementation Plan are to restore the water quality in Crab Creek so it meets water quality standards and to de-list Crab Creek from the Commonwealth of Virginia's 303(d) List of Impaired Waters. The proposed timeline for achieving restored water quality in Crab Creek is 10 years with actions divided into two stages. **Stage 1 will take six years and Stage 2 will take four years for a total of ten years of implementation**. This staged approach will concentrate early efforts on the most cost-efficient control measures with the most interest from stakeholders. For example, the TMDL study indicated that 17% of the total bacteria load in Crab Creek is the result of direct deposition of manure into streams by livestock. Concentrating resources on livestock exclusion fencing systems may provide the highest return on water quality improvement with the least cost to landowners because of the very beneficial cost-share options currently available for this practice. The benefits of staged implementation are 1) as stream monitoring continues, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties which exist in any implementation plan; 3) it provides a mechanism for developing public support; 4) it helps to ensure that the most cost-effective practices are implemented initially; and 5) it allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard.

Two types of milestones have been created for evaluating progress during each stage. Water quality milestones establish the goals for observing improvements in water quality while the implementation milestones outline the extent of BMPs to be installed. For the Crab Creek watershed, the Stage 1 bacteria reductions recommended in the 2004 TMDL include a 100% reduction in direct deposition by livestock – Livestock (DD), 60% reduction in pastureland nonpoint source pollution – Pasture (NPS), 60% reduction in residential and urban sources, and 100% reduction in straight pipe and sewer overflow loads water. During implementation planning, these Stage 1 goals were modified by the agricultural and residential working groups. The agricultural working group decided to add cropland practices during Stage 1. The residential working group chose to implement the streambank stabilization practices during Stage 1.

Reductions in bacteria from wildlife would be necessary to meet the TMDL for *E. coli* (i.e. 0% violations of the single sample and geometric mean standards). Since reductions to wildlife fecal bacteria are not addressed in this implementation plan, the Stage 2 bacteria milestone is to reduce violations of the single sample standard to equal or less than 10.5% and to reduce violations of the geometric mean standard to 0%. In addition, the Stage 2 sediment milestone is to reduce the sediment load to meet the sediment TMDL (Table 19). This condition will meet Virginia's water quality standards for bacteria and sediment and allow for the delisting of Crab Creek from Virginia's 303(d) List of Impaired Waters.

Table 19. Crab Creek sediment loads and required reductions

Load Summary	Crab Creek Sediment (T/yr)	Reduction Required (T/yr)	Reduction Required (% of existing load)
TMDL Existing Load	6,307	4,088	64.8
TMDL Projected Future Load	7,197	4,978	69.2
TMDL	2,551		
IP Projected Future Load	4,814	2,766	57.0
IP Target In-stream Load[1]	2,047		
IP Target Allocation Load[2]	1,971		

The implementation milestones outline the extent of BMPs to be installed during each stage of implementation. Stage 1 covers the first six years of implementation and Stage 2 covers the final four years of implementation. Table 20 lists the control measures needed to meet the Stage 1 implementation milestones and water quality milestones for the Crab Creek watershed. Table 21 lists the additional control measures needed to meet the Stage 2 implementation and water quality milestones.

Tracking

Tracking of agricultural practices will be done by the Skyline SWCD through the existing VADCR BMP Tracking Program. Tracking information will include the locations and numbers of practices installed in the watershed. Additional tracking of residential practices implemented using cost-share funding could also be tracked by Skyline SWCD. Progress made by the Town of Christiansburg to reduce Sanitary Sewer Overflows (SSOs) will be tracked as an annual reporting requirement of their VPDES permit (starting after reissuance of their permit in 2015). Any other grant funded projects, including educational program and outreach activities, will be tracked as a component of the grant application or contract. The Steering Committee will provide oversight and direction as needed during implementation.

Table 20. Practices needed to meet bacteria and sediment TMDL milestones in Stage 1

Control Measure	Units	# Units Needed	Cost
Residential			
Septic Pump-out	system	565	$169,500
Connection to Public Sewer	system	7	$35,000
Septic Tank System Repair	system	237	$829,500
Septic Tank System Installation/Replacement	system	81	$607,500
Alternative On-site Waste Treatment System	system	38	$570,000
Pet Waste Stations	system	15	$19,500
Pet Waste Digester/Composter	system	50	$5,000
Pet Waste Education Program	program	1	$4,000
Rain Gardens	acres treated	2	$10,000
Bioretention Filters	acres treated	1.5	$30,000
Bioswales	acres treated	1	$15,000
Riparian Buffers (Forested)	acres treated	0.5	$1,750
Detention	acres treated	25	$50,000
Extended Detention	acres treated	40	$80,000
Manufactured BMPs	acres treated	2.5	$37,500
Detention and Manufactured BMPs	acres treated	0.5	$8,000
Constructed Wetlands/Wet Ponds	acres treated	0.5	$4,000
Infiltration	acres treated	0.5	$10,000
Vegetated Open Channels	acres treated	0.5	$4,500
Streambank Stabilization	linear feet	11,254	$3,376,200
Agricultural			
Livestock Exclusion with Riparian Buffers	system	16	$524,800
Livestock Exclusion with Reduced Setback	system	2	$40,000
Stream Protection System	system	1	$10,000
Grazing Land Management System	acres	3,265	$244,875
Continuous No-till	acres	5	$100
Small Grain Cover Crop	acres	20	$900
Stage 1 Water Quality Milestones			
Bacteria (*E.coli*)			
% Violations of the Geomean Standard		0.00%	
% Violations of the Single Sample Standard		12.80%	
Average Annual Load (cfu/yr)		$1.40x10^{15}$	
Sediment			
% Reduction		55%	
Average Annual Load (T/yr)		2,120.03	

Table 21. Practices needed to meet bacteria and sediment TMDL milestones in Stage 2

Control Measure	Units	# Units Needed	Cost
Residential			
Rain Gardens	acres treated	76	$380,000
Bioretention Filters	acres treated	2	$40,000
Bioswales	acres treated	6	$90,000
Riparian Buffers (Forested)	acres treated	60.5	$211,750
Riparian Buffers (Grass/Shrub)	acres treated	100	$50,000
Detention	acres treated	67	$134,000
Extended Detention	acres treated	60	$120,000
Manufactured BMPs	acres treated	0.5	$7,500
Detention and Manufactured BMPs	acres treated	10	$160,000
Infiltration	acres treated	1	$20,000
Vegetated Open Channels	acres treated	0.5	$4,500
Agricultural			
Livestock Exclusion with Riparian Buffers	system	22	$721,600
Livestock Exclusion with Reduced Setback	system	2	$40,000
Stream Protection System	system	2	$20,000
Reforestation of Erodible Pasture	acres	28	$28,000
Permanent Vegetative Cover on Critical Areas	acres	29	$58,000
Heavy Use Area Protection	system	20	$400,000
Stage 2 Water Quality Milestones			
Bacteria (*E.coli*)			
% Violations of the Geomean Standard		0.00%	
% Violations of the Single Sample Standard		10.35%	
Average Annual Load (cfu/yr)		$9.44x10^{14}$	
Sediment			
% Reduction		57%	
Average Annual Load (T/yr)		2,047.63	

Monitoring

Implementation monitoring will help evaluate the effectiveness of implemented BMPs and progress toward the water quality milestones listed in this plan. Commonly, there is a lag between the completion of the Implementation Plan and any measurable changes in water quality. This can be due to the time needed for watershed stakeholders to organize, secure funding, and establish BMPs. VADEQ implementation monitoring should begin no sooner than two years following the initiation of documented TMDL implementation. Beginning implementation monitoring after two or more years of implementation will help ensure that sufficient time has passed for remedial measures to have stabilized and BMPs to have become functional.

Since, the main goal of implementation monitoring is to de-list the stream segments for all impairments; VADEQ will focus its monitoring resources on the original listing stations (Table 22). De-listing occurs when the original listing stations meet water quality criteria for the listed impairment(s). Thus, when significant implementation progress towards reducing bacteria and

sediment loads in Crab Creek has been made, VADEQ will begin monitoring the initial listing stations for bacteria bimonthly for a period of four years. For the benthic impairment, VADEQ biologists will monitor the original listing stations in the spring and fall for approximately two years. If VADEQ is unable to de-list Crab Creek for bacteria and/or sediment in these timeframes, additional monitoring may be scheduled for the express purpose of trying to de-list the stream.

Table 22. VADEQ monitoring stations in the Crab Creek watershed

VADEQ Station ID	Station Type	Location
9-CBC001.00	Ambient, Biological	Route 663 Bridge, near Walton, Montgomery County
9-CBC004.38	Ambient, Biological	Route 660 bridge below Christiansburg STP
9-CBC006.35	Ambient, Biological	Old Route 661 Ford – Montgomery County
9-CBC008.78	Ambient, Biological	Route 460 bridge below Christiansburg
9-CBC009.81	Ambient	Route 111 in Downtown Christiansburg

Additional monitoring beyond what VADEQ can provide with its limited resources may be conducted in Crab Creek. Groups from organizations such as New River Valley Save Our Streams, Radford University, and Christiansburg High School have already begun citizen monitoring efforts in the Crab Creek watershed. Specifically, Save Our Streams is now monitoring at two locations (Figure 19). These efforts are encouraged and stakeholders (also including the New River Conservancy) should work together to distribute monitoring resources throughout the watershed to best capture implementation needs and progress. The Town of Christiansburg has expressed interest in supporting additional citizen monitoring efforts to both capture data about their efforts to improve water quality and to provide the data necessary to prove water quality progress in Crab Creek.

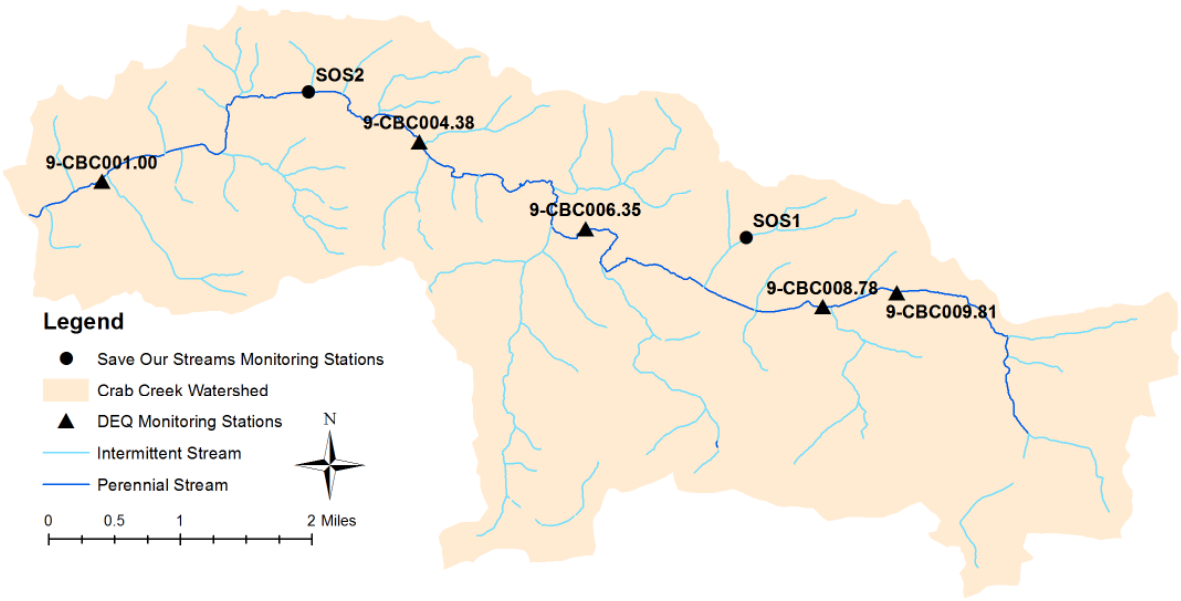

Figure 19. VADEQ and Save Our Streams monitoring locations in the Crab Creek watershed.

Targeting

Staged implementation implies the process of targeting BMPs to get the "most bang for the buck" in the watershed (Table 23). Targeting different BMPs across the stages optimizes the use of limited resources by focusing on the most cost-efficient practices and those that present the least obstacles (acceptance by landowners, available cost-share, etc.). For example, stream exclusion practices (SL-6T, LE-1T, LE-2T, and WP-2T) are considered 100% effective at removing bacteria entering the stream through direct deposition by livestock. Moreover, the SL-6T practice is currently available at 100% cost-share for eligible landowners who enroll by July 2015. Thus, the stream exclusion systems needed to protect perennial streams have been prioritized in Stage 1. Similarly, practices that reduce bacteria from residential septic systems and straight pipes are also considered 100% efficient. The cost of these practices can often be offset by the procurement of grant funding, making them even more popular with local residents who directly benefit from maintaining or fixing their systems.

Additional targeting for education and outreach efforts could be refined through GIS analysis as proposed by the New River Land Trust (NRLT). Using ESRI's ArcGIS ModelBuilder, NRLT could identify key properties within the watershed based on characteristics such as location, presence of active agricultural production, size, erodibility of soils, slope, etc. Their model is based on a similar study done in South Carolina's Catawba River Basin which used GIS analysis to target education and outreach efforts to specific types of properties. NRLT estimates the cost of such an effort, including staff time and actual outreach materials, to be around $9,300. This cost estimate is not included in the overall IP cost.

Table 23. Implementation priorities for implementation efforts in the Crab Creek watershed

Stage 1 Priorities	Stage 2 Priorities
• Straight pipes • Failing septic systems • Pet waste • Urban stormwater • Livestock exclusion systems on perennial streams • Grazing land management • Cropland practices including continuous no-till and small grain cover crops • Streambank stabilization • Outreach and education • Agricultural and residential technical assistance	• Residential stormwater • Livestock exclusion systems on intermittent streams • Grazing land management systems • Heavy use area protection • Permanent vegetative cover on critical areas • Reforestation of erodible pasture • Agricultural technical assistance

Stakeholders and their Roles

Landowners

In addition to local farms, participation from homeowners and developers is also critical to the success of this plan. The plan calls for the extensive reduction of bacteria and sediment through the use of residential and urban BMPs. In order to meet the required reductions, private individuals will need to make significant changes in their behaviors including disposal of pet waste and proper septic system maintenance.

Meadows Swim & Golf Club

As a neighbor of Crab Creek, the Meadows Swim & Golf Club, which encompasses a stretch of Crab Creek, could be a candidate for streambank stabilization efforts and a nutrient management plan. The Virginia Golf Course Superintendents Association (VGCSA) published an Environmental Best Management Practices for Virginia's Golf Courses manual that details how courses can implement BMPs specific to Virginia's environment while still preserving the quality experience for golfers. Potential incentives for golf courses implementing these practices include reduced environmental impact, improved turf quality, improved golf outing experiences, improved worker safety, efficient allocation of resources, and reduced maintenance expenditures. (VGCSA 2012).

Montgomery County

While not currently an MS4, it is anticipated that Montgomery County will become a Phase II MS4 in the near future. At that time, any part of the MS4 discharging to the Crab Creek watershed will be subject to the bacteria and sediment TMDLs. The County will need to develop an action plan that when implemented, will guide County stormwater programs.

New River Conservancy (formerly the National Committee for the New River)

The New River Conservancy works with landowners and citizens to conserve critical lands, restore riparian areas, and advocate for the protection of the New River throughout its multi-state watershed.

New River Valley Planning District Commission

The New River Valley Planning District serves the local governments in the counties of Floyd, Giles, Montgomery, and Pulaski, and the City of Radford and their citizenry by providing a number of different services ranging from economic development to regional recycling. The purpose of the planning district commission is to promote regional cooperation, to coordinate the activities and policies of member local governments, and to provide planning assistance to local governments. The commission is financed by a combination of local, state, and federal funds. The commission provides natural resource planning assistance to local governments in the region. With funding from the Virginia Department of Forestry, the PDC began Green

Infrastructure Planning in 2006, a natural resource planning method to map and prioritize water, forests, farmland, wildlife habitats, views, and recreation opportunities. The commission could serve as a grant project partner and/or manager during implementation.

Skyline SWCD, NRCS, and FSA

During project implementation, the Skyline Soil and Water Conservation District and the local National Resources Conservation Service (NRCS) office should continue and if possible expand outreach efforts in Crab Creek to both agricultural producers and community members. These organizations will be the primary technical and financial resource for implementing the agricultural practices in this plan. Their responsibilities include promoting BMP funding and benefits and assisting with BMP development on individual properties. Outreach activities should specifically encourage participation of Crab Creek farmers in the BMPs outlined in this plan to reduce bacteria and sediment loads. Outreach activities may include mailing newsletters, planning field days, and giving presentations. The Skyline SWCD works throughout Floyd, Giles, Montgomery, and Pulaski counties. It is recommended that a technician be hired and devoted at least part-time to water quality efforts in the Crab Creek watershed. The local Farm Service Agency (FSA) office may also play a role in addressing agricultural sources by advertising and administering their conservation programs which include the Conservation Reserve Program (CRP) and the Conservation Reserve Enhancement Program (CREP).

Save Our Streams

Virginia Save Our Streams (SOS) organizes citizens to monitor water quality of streams throughout the Commonwealth and also educates the public about importance of clean water. Currently, SOS has two monitoring sites within the Crab Creek watershed. Find more information about SOS at www.vasos.org.

Town of Christiansburg

The Town of Christiansburg has taken great strides to improve the quality of water entering Crab Creek from land within the Town. As an MS4 permittee, they have created a comprehensive stormwater management program to meet each of the six minimum control measures. In addition to current education and outreach efforts, they are also planning to develop and execute a Public Education and Outreach Plan (PEOP) that should address some of the outreach needs outlined within this plan regarding urban and residential practices. The Town's street sweeping program collected approximately 448 tons of debris in 2012. The recent purchase of a new street sweeper will most likely improve the program's efficiency as will any increases in sweeping frequency. Their Storm Sewer Cleaning Program will also support water quality improvement efforts by ensuring proper operation and maintenance of stormwater infrastructure. As the Town continues to create and expand their stormwater management program, they may want to consider options for procuring additional resources (EFC University of Maryland 2014). Mechanisms for financing stormwater services include general fund allocations, fees for permit review and

inspections, property taxes and special assessments, grants, loans, and utility fees. Whatever mechanism or mechanisms are pursued will depend upon future resource needs as well as stakeholder support.

In addition to its ongoing collection system maintenance program (outlined in Section 6.3), the Town has future plans to develop a system-wide sewer model of its major pipe network to include known SSO locations. Once developed and calibrated, the Town will utilize the model as a tool to aid in developing a long-term sanitary sewer capital improvements plan (CIP). The CIP will prioritize work that will further reduce the frequency of SSOs within the Crab Creek watershed.

Virginia Department of Agriculture and Consumer Services

Through Virginia's Agricultural Stewardship Act, the VDACS Commissioner of Agriculture has the authority to investigate claims that an agricultural producer is causing a water quality problem on a case-by-case basis. If deemed a problem, the Commissioner can order the producer to submit an agricultural stewardship plan to the local soil and water conservation district. If a producer fails to implement the plan, corrective action can be taken which can include a civil penalty up to $5,000 per day. The Commissioner of Agriculture can issue an emergency corrective action if runoff is likely to endanger public health, animals, fish and aquatic life, public water supply, etc. An emergency order can shut down all or part of an agricultural activity and require specific stewardship measures. The enforcement of the Agricultural Stewardship Act is entirely complaint-driven. This Act is considered as a state regulatory tool that can support implementing conservation practices to address pollutant sources in TMDL impaired watersheds.

Virginia Department of Conservation and Recreation

The Department of Conservation and Recreation (DCR) will work closely with project partners including the Skyline Soil and Water Conservation District to track implementation progress and provide cost share for agricultural best management practices through the Virginia Agricultural Cost Share Program. In addition, DCR will provide support to improve the implementation process through utilization of existing authorities and resources.

Virginia Department of Environmental Quality

Improvements in water quality and implementation progress will be determined through monitoring conducted by the VA Department of Environmental Quality's ambient and biological monitoring programs. The Code of Virginia directs VADEQ to maintain a list of impaired waters and to develop TMDLs to address impairments. When monitoring shows a stream no longer violates water quality standards, VADEQ is responsible from removing the stream from the list. Every two years, VADEQ completes the Virginia Water Quality Assessment 305(b)/303(d) Integrated Report. This report covers a six year period of water quality monitoring an includes the state's 303(d) report on impaired waters and de-listings which is submitted to the Environmental Protection Agency for approval. VADEQ TMDL program staff will work with

interested partners on grant proposals to generate funds for projects included in the implementation plan that are not funded through state and federal cost share programs. When needed, VADEQ staff can facilitate additional meetings of the steering committee to discuss implementation progress and make necessary adjustments to the implementation plan. VADEQ staff can also provide support with education and outreach related to water quality.

Virginia Department of Health

VDH is responsible for maintaining safe drinking water measured by standards set by EPA. Their duties also include septic system regulation and, in the past, regulation of biosolids land application. Like VDACS, VDH's program is complaint-driven. Complaints can range from a vent pipe odor that is not an actual sewage violation and takes very little time to investigate, to a large discharge violation that may take many weeks or longer to effect compliance. In the scheme of this TMDL IP, VDH has the responsibility of enforcing actions to correct or eliminate failed septic systems and straight pipes, respectively. VDH staff also issue permits for the repair and installation of septic systems and the installation of alternative waste treatment systems.

Virginia Department of Transportation (VDOT)

The Virginia Department of Transportation's (VDOT's) Municipal Storm Sewer System Program (MS4) follows the six minimum control measures required by the Virginia MS-4 General Permit. The VDOT MS4 program strives to improve environmental compliance, quality and stewardship on VDOT land-disturbing activities through effective management, implementation, and enforcement of sound technical guidelines, criteria, and practices for stormwater management and erosion and sediment control.

There are numerous additional opportunities for future partnerships in the implementation of this plan and the partnership noted above. Additional potential partners in implementation include:

- Montgomery County schools
- Montgomery County Master Gardeners
- Montgomery County Master Naturalists
- New River Land Trust
- Radford University
- Trout Unlimited
- Virginia Cooperative Extension
- Virginia Department of Forestry
- Virginia Department of Game and Inland Fisheries
- Virginia Farm Bureau
- Virginia Outdoors Foundation

Integration with Other Watershed Plans

Like most watersheds in Virginia, water quality in the Crab Creek watershed is a component of many different organizations, programs and activities. Such efforts include, but are not limited to, watershed implementation plans, TMDLs, Roundtables, Water Quality Management Plans, Erosion and Sediment Control Regulations, Stormwater Management Programs, Source Water Assessment Programs, local comprehensive and strategic plans, and local environmentally-focused organizations. These efforts should be evaluated to determine their potential impacts on the implementation goals outlined in this clean-up plan. Often, these efforts are related or collaborative, but this is not always the case. Coordination of local programs can increase participation and prevent redundancy. Initiatives coinciding with TMDL Implementation efforts in this watershed include the:

New River Livability Initiative Study

The New River Livability Initiative was a three year regional planning process which provided an opportunity for the New River Valley's residents to develop a vision for the future and develop strategies that businesses, community organizations, local governments, and individuals can use to make this future vision a reality. The study considered all major factors influencing quality of life in the larger New River Valley including housing, transportation, energy, economic development, community health, arts and cultural heritage, and natural resources. One of the plan's listed goals is to improve and protect water resources. Strategies to meet this goal include: increase public understanding of activities that impact water quality by coordinating services and outreach efforts, develop comprehensive watershed management and regional stream restoration plans that pave the way for funding requests, expand outreach efforts with farmers and landowners to increase adoption of agricultural and forestry BMPs, incorporate stormwater BMPs into land use policies and development requirements, and where there are community health concerns, expand water quality monitoring of point-source polluters where there are specific community health concerns. Find the full draft report at http://nrvlivability.org/news/draft-plan-ready-review.

Town of Christiansburg Comprehensive Plan and Vision 2020

Approximately 63% of the Town of Christiansburg is drained by Crab Creek. The Town of Christiansburg's primary environment goal is to preserve and enhance the natural resources of the Town through education, regulation, and service provision. In addition to their TMDL requirements as an MS4 permittee, the Town's strategies for improving water quality that align with this plan include:

- closely regulate drainage and erosion on sites with steep slopes during and after the construction process,
- encourage environmental education courses in rain barrel building, rain garden planting, stormwater runoff reduction, and composting methods,
- expand the use of green infrastructure BMPs in the land development process.

- encourage the use of rain gardens, permeable pavement, green roofs, and urban tree canopy to reduce stormwater runoff,
- encourage on-site water infiltration systems using natural vegetation and natural filtration systems for new developments,
- encourage natural plantings on critical slopes to reduce erosion and runoff,
- encourage stream restoration projects,
- consider establishing stricter standards for buffers between water bodies and impervious surfaces and structures,
- create comprehensive watershed-based stormwater models to assess infrastructure needs and utilize the watershed models to identify system weaknesses and analyze proposed modifications to and improvements of system infrastructure,
- develop a stormwater taskforce with staff and citizens to address stormwater issues.
- create a permanent funding mechanism for stormwater management,
- consider adoption of more stringent stormwater regulations and the creation of a stormwater utility,
- continue to actively oversee and inspect construction of new stormwater management infrastructure,
- reduce stormwater runoff and prevent flooding at existing sites by requiring upgrades with redevelopment or rezoning,
- encourage improvements to stormwater facilities for existing neighborhoods through BMPs such as bioretention, rain gardens, and rain barrels,
- continue to enforce Town Code regarding illicit discharges in the stormwater system in an effort to keep storm drains free of debris and operating at maximum capacity.
- identify new strategies and resources to maintain maximum stormwater system capacity and operations,
- encourage the retention of existing trees and wooded lots and the planting of additional trees during development,
- implement riparian buffers to assist in water infiltration, soil stabilization, and bank restoration along rivers and creeks, and
- cooperate with state and federal agencies in the preservation of wetland areas.

Potential Funding Sources

This list of potential funding resources is a compilation of sources from other Virginia Implementation Plans as well as ideas from local stakeholders. Detailed descriptions of the agricultural cost-share programs can be obtained from the Skyline SWCD, VA Department of Conservation and Recreation, Natural Resources Conservation Service and the Virginia Cooperative Extension.

Federal

Federal Clean Water Act Section 319 Incremental Funds

Through Section 319 of the Federal Clean Water Act, Virginia is awarded grant funds to implement the nonpoint source programs. VADEQ reports annually to the EPA on the progress made in nonpoint source pollution prevention and control. Stakeholder organizations can apply annually, on a competitive basis, for 319 grants to implement BMPs and educational components included in a TMDL IP.

USDA – FSA

Conservation Reserve Program (CRP)

Through this program, cost-share assistance is available to establish cover of trees or herbaceous vegetation on cropland. Offers for the program are ranked, accepted and processed during fixed signup periods that are announced by FSA. If accepted, contracts are developed for a minimum of 10 and not more than 15 years. Payments are based on a per-acre soil rental rate. To be eligible for consideration, the following criteria must be met: 1) cropland was planted or considered planted in an agricultural commodity for two of the five most recent crop years and 2) cropland is classified as "highly-erodible" by NRCS. Application evaluation points can be increased if certain tree species, spacing, and seeding mixtures that maximize wildlife habitats are selected. Land must have been owned or operated by the applicant for at least 12 months prior to the close of the signup period. The payment to the participant is up to 50% of the cost for establishing ground cover. Incentive payments for wetlands hydrology restoration equal 25% of the cost of restoration.

Conservation Reserve Enhancement Program (CREP)

This program is an "enhancement" of the existing USDA CRP Continuous Sign-up. It has been "enhanced" by increasing the cost-share rates from 50% to 75% and 100%, increasing the rental rates, and offering a flat rate incentive payment to place a permanent "riparian easement" on the enrolled area. Pasture and cropland (as defined by USDA) adjacent to streams, intermittent streams, seeps, springs, ponds and sinkholes are eligible to be enrolled. Cost-sharing (75% - 100%) is available to help pay for fencing to exclude livestock from the riparian buffer, watering facilities, hardwood tree planting, filter strip establishment, and wetland restoration. In addition, a 40% incentive payment upon completion is offered and an average rental rate of $70/acre on

stream buffer area for 10-15 years. The State of Virginia will make an additional incentive payment to place a perpetual conservation easement on the enrolled area. Landowners can obtain and complete CREP application forms at their local FSA center.

USDA - NRCS

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) is a voluntary program that encourages agricultural and forestry producers to address resource concerns by (1) undertaking additional conservation activities and (2) improving and maintaining existing conservation systems. CSP provides financial and technical assistance to help land stewards conserve and enhance soil, water, air, and related natural resources on their land. CSP is available to all producers, regardless of operation size or crops produced. Eligible lands include cropland, grassland, prairie land, improved pastureland, rangeland, nonindustrial private forest land, and agricultural land. NRCS makes CSP available on a nationwide basis through continuous sign-up, with announced cut-off dates for ranking and funding applications. CSP pays participants for conservation performance—the higher the performance, the higher the payment. It provides two possible types of payments. An annual payment is available for installing new conservation activities and maintaining existing practices. A supplemental payment is available to participants who also adopt a resource conserving crop rotation.

Environmental Quality Incentives Program (EQIP)

This program was established in the 1996 Farm Bill to provide a single voluntary conservation program for farmers and landowners to address significant natural resource needs and objectives. Approximately 65% of the EQIP funding for the state of Virginia is directed toward "Priority Areas." These areas are selected from proposals submitted by a locally led conservation work group. Proposals describe serious and critical environmental needs and concerns of an area or watershed, and the corrective actions they desire to take to address these needs and concerns. The remaining 35% of the funds are directed toward statewide priority concerns of environmental needs. EQIP offers 5 to 10-year contracts to landowners and farmers to provide 75% cost-share assistance, 25% tax credit, and/or incentive payments to implement conservation practices and address the priority concerns statewide or in the priority area. Eligibility is limited to persons who are engaged in livestock or agricultural production. Eligible land includes cropland, pasture, and other agricultural land in priority areas, or land that has an environmental need that matches one of the statewide concerns.

Agricultural Lands Easement Program

The 2014 Farm Bill authorized $1 billion in funding for the new Agricultural Lands Easement program, which consolidates the former Farm and Ranch Lands Protection Program (FRPP), Grassland Reserve Program (GRP) and Wetlands Reserve Program (WRP) into a single program. This program will provide grants to purchase conservation easements that permanently

restrict development on important farmland and reward landowners who participate in the program with permanent tax breaks.

United States Fish and Wildlife Service

The US Fish and Wildlife Service (USFWS) administers a variety of natural resource assistance grants to governmental, public and private organizations, groups and individuals. Natural resource assistance grants are available to state agencies, local governments, conservation organizations, and private individuals.

State

Virginia Agricultural Best Management Practices (BMPs) Cost-Share Program

The cost-share program is funded with state and federal monies through local Soil and Water Conservation Districts (SWCDs). SWCDs administer the program to encourage farmers and landowners to use BMPs on their land to better control transportation of pollutants into our waters due to excessive surface flow, erosion, leaching, and inadequate animal waste management. Program participants are recruited by SWCDs based upon those factors, which have a great impact on water quality. Cost-share is typically 75% of the actual cost, not to exceed the local maximum.

Virginia Agricultural Best Management Practices Loan Program

The purpose of the Virginia Land Conservation Loan Program is to provide a long term source of low interest financing for the conservation of land in Virginia in order to improve and/or protect the water resources of the Commonwealth. Additional benefits of the program include the protection of open space or natural values of the properties and/or the assurance of the availability of the land for agricultural, forestal, recreation, or open space use. Although these other benefits are of value, the principle focus and utilization of the Fund is on beneficial impact to water quality.

Loan requests are accepted through VADEQ. The interest rate is 3% per year and the term of the loan coincides with the life span of the practice. To be eligible for the loan, the BMP must be included in a conservation plan approved by the local SWCD Board. The minimum loan amount is $5,000; there is no maximum limit. Eligible BMPs include 23 structural practices such as animal waste control facilities, loafing lot management systems, and grazing land protection systems. The loans are administered through participating lending institutions.

Virginia Agricultural Best Management Practices Tax Credit Program

For all taxable years, any individual or corporation engaged in agricultural production for market, who has in place a soil conservation plan approved by the local SWCD, is allowed a credit against the tax imposed by Section 58.1-320 of an amount equaling 25% of the first $70,000 expended for agricultural best management practices by the individual. Any practice

approved by the local SWCD Board must be completed within the taxable year in which the credit is claimed. The credit is only allowed for expenditures made by the taxpayer from funds of his/her own sources. The amount of the credit cannot exceed $17,500 or the total amount of the tax imposed by this program (whichever is less) in the year the project was completed. If the amount of the credit exceeds the taxpayer's liability for such taxable year, the excess may be carried over for credit against income taxes in the next five taxable years until the total amount of the tax credit has been taken. This program can be used independently or in conjunction with other cost-share programs on the stakeholder's portion of BMP costs. It is also approved for use in supplementing the cost of repairs to streamside fencing.

Virginia Clean Water Revolving Loan Fund

EPA awards grants to states to capitalize their Clean Water State Revolving Funds (CWSRFs). The states, through the CWSRF, make loans for high-priority water quality activities. As loan recipients make payments back into the fund, money is available for new loans to be issued to other recipients. Eligible projects include point source, nonpoint source and estuary protection projects. Point source projects typically include building wastewater treatment facilities, combined sewer overflow and sanitary sewer overflow correction, urban stormwater control, and water quality aspects of landfill projects. Nonpoint source projects include agricultural, silvicultural, rural, and some urban runoff control; on-site wastewater disposal systems (septic tanks); land conservation and riparian buffers; leaking underground storage tank remediation, etc.

Virginia Department of Environmental Quality Citizen Water Monitoring Grant Program

The primary purpose of the Virginia Department of Environmental Quality Citizen Water Monitoring Grant Program is to provide funding for water quality monitoring groups and individuals to monitor the quality of Virginia's waters. The grant can be used in a variety of ways, including purchasing water quality monitoring equipment, training citizen volunteers, lab analysis costs, and promoting stream monitoring efforts in locations where DEQ is not currently collecting water quality samples. To be eligible for funding under the regular Citizen Monitoring Grant, a grantee must follow certain guidelines, including developing a quality assurance project plan (QAPP).

Virginia Forest Stewardship Program

The purpose of the Forest Stewardship Program is to encourage the long-term stewardship of nonindustrial private forest lands, by assisting the owners of such lands to more actively manage their forest and related resources. The Forest Stewardship Program provides assistance to owners of forest land and other lands where good stewardship, including agroforestry applications, will enhance and sustain the long term productivity of multiple forest resources. Special attention is given to landowners in important forest resource areas and those new to, or in the early stages of

managing their land in a way that embodies multi-resource stewardship principles. The program provides landowners with the professional planning and technical assistance they need to keep their land in a productive and healthy condition. The planning assistance offered through the Forest Stewardship Program may also provide landowners with enhanced access to other USDA conservation programs and/or forest certification programs.

Private nonindustrial forest lands that are managed under existing Federal, State, or private sector financial and technical assistance programs are eligible for assistance under the Forest Stewardship Program. Forest resource management activities on such forest lands must meet, or be expanded or enhanced to meet the requirements of the Forest Stewardship Program. Participation in the Forest Stewardship Program is voluntary. To enter the program, landowners agree to manage their property according to an approved Forest Stewardship Management Plan. Landowners also understand that they may be asked to participate in future management outcome monitoring activities.

Virginia Outdoors Foundation

Conservation easements are voluntary agreements that allow individuals or groups to limit the type or amount of development on their property. Easements typically describe the resource they are designed to protect (e.g., agricultural, forest, historic, or open space). Conservation easements may indirectly contribute to water quality protection due to the restrictions on future development. The Virginia Outdoors Foundation is the state's largest holder of conservation easements. While their easements do not require riparian buffers, they do strongly encourage them along all streams, rivers, or other significant water resources on a conserved property. A gift of a permanent open-space easement may qualify as a charitable gift and be eligible for certain state and federal tax benefits. In addition, there may be local property tax reductions and federal estate tax exemptions.VOF also administers the *Open Space Lands Preservation Trust Fund*, which assists landowners with the costs of conveying open-space easements and purchases all or part of the value of easements. Priority for funding is given to applications on family farms and for those with demonstrated financial need.

Virginia Small Business Environmental Assistance Fund Loan Program

The Fund, administered through VADEQ, is used to make loans or to guarantee loans to small businesses for the purchase and installation of environmental pollution control equipment, equipment to implement voluntary pollution prevention measures, or equipment and structures to implement agricultural BMPs. The equipment must be needed by the small business to comply with the federal Clean Air Act, or it will allow the small business to implement voluntary pollution prevention measures. The loans are available in amounts up to $50,000 and will carry an interest rate of 3%, with favorable repayment terms based on the borrower's ability to repay and the useful life of the equipment being purchased or the life of the BMP being implemented. There is a $30 non-refundable application processing fee. The Fund will not be used to make

loans to small businesses for the purchase and installation of equipment needed to comply with an enforcement action. To be eligible for assistance, a business must employ 100 or fewer people and be classified as a small business under the federal Small Business Act.

Virginia Stormwater Assistance Fund (SLAF)

SLAF funds stormwater projects including: 1) new stormwater best management practices, 2) stormwater best management practices retrofits, 3) stream restoration, 4) low impact development projects, 5) buffer restorations, 6) pond retrofits, and 7) wetlands restoration. Eligible recipients are local governments, meaning any county, city, town, municipal corporation, authority, district, commission, or political subdivision created by the General assembly or pursuant to the Constitution or laws of the Commonwealth. The fund is administered by VADEQ.

Virginia Water Quality Improvement Fund

This is a permanent, non-reverting fund established by the Commonwealth of Virginia in order to assist local stakeholders in reducing point and nonpoint nutrient loads to surface waters. Eligible recipients include local governments, SWCDs, and individuals. Grants for point sources are nonpoint sources are administered through VADEQ. Most WQIF grants provide matching funds on a 50/50 cost-share basis.

Regional and Private Sources

Community Development Block Grants (CDBG)

The Community Development Block Grant (CDBG) program is a flexible program that provides communities with resources to address a wide range of unique community development needs. Over a 1, 2, or 3-year period, as selected by the grantee, not less than 70 percent of CDBG funds must be used for activities that benefit low- and moderate-income persons. In addition, each activity must meet one of the following national objectives for the program: benefit low- and moderate-income persons, prevention or elimination of slums or blight, or address community development needs having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available.

Community Foundation of the New River Valley

The Community Foundation of the New River Valley awards grants twice a year. A typical grant amount is $500 to $2,000. Their fields of interest include the conservation and preservation of natural, historical and cultural resources. Additionally, their Community Impact Grant Program funds efforts that help to either launch a new program or substantially expand successful existing programs that strengthen community by addressing current or future needs and are sustainable and feature collaboration with other community organizations.

National Fish and Wildlife Foundation

Grant proposals for this funding are accepted throughout the year and processed during fixed sign up periods. There are two decision cycles per year. Each cycle consists of a pre-proposal evaluation, a full proposal evaluation, and a Board of Directors' decision. Grants generally range between $10,000 and $150,000. Grants are awarded for the purpose of conserving fish, wildlife, plants, and their habitats. Special grant programs are listed and described on the NFWF website (www.nfwf.org). If the project does not fall into the criteria of any special grant programs, a proposal may be submitted as a general grant if it falls under the following guidelines: 1) it promotes fish, wildlife and habitat conservation, 2) it involves other conservation and community interests, 3) it leverages available funding, and 4) project outcomes are evaluated.

Five Star and Urban Waters Restoration Grant Program

The Five Star and Urban Waters Restoration Program seeks to develop nation-wide-community stewardship of local natural resources, preserving these resources for future generations and enhancing habitat for local wildlife. Projects seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. The program requires the establishment and/or enhancement of diverse partnerships and an education/outreach component that will help shape and sustain behavior to achieve conservation goals. The Five Star program provides $20,000 to $50,000 grants with an average award size of $25,000. Grants that are in the $30,000-$50,000 range are typically two years and are in urban areas.

Funding priorities for this program include:

- On-the-ground wetland, riparian, in-stream and/or coastal habitat restoration
- Meaningful education and training activities, either through community outreach, participation and/or integration with K-12 environmental curriculum
- Measurable ecological, educational and community benefits
- Partnerships: Five Star projects should engage a diverse group of community partners to achieve ecological and educational outcomes

Norcross Wildlife Foundation

The Norcross Wildlife Sanctuary in Monson, Massachusetts was founded in 1939 by Arthur Norcross and the Norcross Wildlife Foundation was founded in 1964 after his passing. The Foundation provides grants to environmental conservation NGOs primarily for the purchase of office and field equipment as well as publications and other educational materials that have a practical, immediate use. Grant requests may be up to $10,000, but awards generally average less than $5,000. Examples of funded projects include computers, cameras, GPS units, GIS software, data loggers, and water quality testing materials.

Southeast Rural Community Assistance Project (SERCAP)

The mission of this project is to promote, cultivate, and encourage the development of water and wastewater facilities to serve low-income residents at affordable costs and to support other development activities that will improve the quality of life in rural areas. Staff members of other community organizations complement the SE/R-CAP staff across the region. They can provide (at no cost): on-site technical assistance and consultation, operation and maintenance/management assistance, training, education, facilitation, volunteers, and financial assistance. Financial assistance includes $1,500 toward repair/replacement/ installation of a septic system and $2,000 toward repair/replacement/installation of an alternative waste treatment system. Funding is only available for families making less than 125% of the federal poverty level.

Virginia Environmental Endowment

The Virginia Environmental Endowment is a nonprofit, independent grant-making foundation whose mission is to improve the quality of the environment by using its capital to encourage all sectors to work together to prevent pollution, conserve natural resources, and promote environmental literacy. Current grant-making priorities in Virginia include improving local rivers and protecting water quality throughout Virginia, Chesapeake Bay restoration, enhancing land conservation and sustainable land use, advancing environmental literacy and public awareness, and supporting emerging issues in environmental protection. Applications are accepted biannually with deadlines of June 15th and December 1st.

Wetland and Stream Mitigation Banking

Mitigation banks are sites where aquatic resources such as wetlands, streams and streamside buffers are restored, created, enhanced, or in exceptional circumstances, preserved expressly for the purpose of providing compensatory mitigation in advance of authorized impacts to similar resources. Mitigation banking is a commercial venture that provides compensation for aquatic resources in financially and environmentally preferable ways. Not every site or property is suitable for mitigation banking. Mitigation banks are required to be protected in perpetuity, to provide financial assurances and long term stewardship. The mitigation banking process is overseen by an Inter-Agency Review Team made up of state and federal agencies and chaired by VADEQ and Army Corps of Engineers.

References

Alderfer RB and Robinson RR. 1947. Runoff from pastures in relation to grazing intensity and soil compaction. Journal of American Society of Agronomy. 39: 948-958.

Alderserio K, Wait D and Sobsey M. 1996. Detection and characterization of male-specific RNA Coliphages in a New York City reservoir to distinguish between human and non-human sources of contamination. Proceedings of a Symposium on New York City Water Supply Studies, ed. McDonnell et al. TPS-96-2. American Water Resources Association. Herndon, VA.

Benedict MA and McMahon ET. 2006. Green infrastructure. Island Press: Washington. 300pp.

Bockstael NE, Freeman III AM, Kopp RJ, Portney PR, and Smith VK. 2000. On measuring economic values for nature. Environmental Science & Technology 34: 1384-1389.

Clark S, Grose M, Greer R, Jarrett A, Kunkel S, Lake D, Law N, McCutcheon J, McLaughlin R, Mumaw K, Young B. 2014. Recommendations of the expert panel to define removal rates for erosion and sediment control practices. Prepared by Hanson J, Chesapeake Research Consortium and Schueler T and Lane C, Chesapeake Stormwater Network. 110p.

EFC University of Maryland. 2014. Local government stormwater financing manual: A process for program reform. <http://efc.umd.edu/assets/publications/2efc_stormwater_financing_manual_final_(1).pdf>.

EPA. 1999. Storm water technology fact sheet: Bioretention. EPA 832-F-99-012. <http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_biortn.pdf>.

EPA National Menu of Best Management Practices for Storm Water Phase II. < http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/pdf/small_files/Main.pdf>.

EPA. 2014. Preventing septic system failure. < http://water.epa.gov/polwaste/npdes/swbmp/Preventing-Septic-System-Failure.cfm>.

Local government stormwater financing manual: A process for program reform (2014). Environmental Finance Center, University of Maryland <http://efc.umd.edu/assets/publications/2efc_stormwater_financing_manual_final_(1).pdf>.

Luloff AE, Hoag DLK, Osmond DL, Woods BR, Gordon JS, Gruver J, Roka K, Raboanarielina CM, Longmire C, Ward M, and Weigle JL. 2012. Chapter 2: Key informant survey to understand what farmers, agency personnel, and stakeholders think: National institute of food and agriculture – conservation effects assessment project. Osmond DL, Meals DW, Hoag DLK, and Arabi M, eds. 2012. How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture–Conservation Effects Assessment Project Experience. Ankeny, IA: Soil and Water Conservation Society.

Hardwick N. 1997. Lake Sammamish watershed water quality survey. King County Water and Land Resources Division, Seattle, WA. 122 pp.

Harrison ET, Norris RH, and Wilkinson SN. 2007. The impact of fine sediment accumulation on bethic macroinvertebrates: implications for river management. Proceedings of the 5th Australian Stream Management Conference. Australian rivers: making a difference. Charles Sturt University, Thurgoona, New South Wales.

Heintz J, Pollin R, and Garrett-Peltier H. 2009. How infrastructure investments support the U.S. economy: employment, productivity and growth. Political Economy Research Institute, Amherst, MA. <http://americanmanufacturing.org/files/peri_aam_finaljan16_new.pdf>.

Jones GM and Balley, Jr. TL. 2009. Understanding the basics of mastitis. Virginia Cooperative Extension 404-233.

Leggett CG and Bockstael NE. 2000. Evidence of the effects of water quality on residential land prices. Journal of Environmental Economic and Management 39: 121-144.

Matisoff D and Noonan D. 2012. Managing contested greenspace: neighborhood commons and the rise of dog parks. International Journal of the Commons.

Medina DE, Monfils J, and Baccata Z. 2011. Green infrastructure benefits for floodplain management: a case study. Stormwater: The Journal for Surface Water Quality Professionals.

NVPDC. 2005. NVPDC's dog park BMP pilot project: Making the connection between dog waste and bacteria contamination in streams. <http://www.myxyz.org/phmurphy/dog/NorthVirginia%20Dog%20Park%20BMP%20Pilot%20Project.pdf>.

Syferd E. 1995. Water quality consortium research summary report. Seattle, WA; cited in Center for Watershed Protection.

Town of Christiansburg. 2013. Stream restoration and stormwater BMP assessment.

Town of Christiansburg. 2014. <http://www.christiansburg.org/>. Accessed May 21, 2014.

Trial, Jr. W, Slaughterbeck C, Goldberg J, Ma G, and Samadpour M. 1993. Bacterial source tracking: Studies in an urban Seattle watershed. *Puget Sound Notes*. 30:1-3.

U.S. Department of the Interior (USDOI), U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2011 National survey of fishing, hunting, and wildlife-associated recreation. Virginia, revised 2014. < http://www.census.gov/prod/2013pubs/fhw11-va.pdf>.

VADCR. 2004. The Virginia stream restoration and stabilization best management practices guide. Virginia Department of Conservation and Recreation Division of Soil and Water

Conservation.
< http://www.aces.edu/waterquality/streams/Fact%20Sheets/vastreamguide.pdf>.

VADEQ. 2011. Virginia DEQ stormwater design specification no. 8: Infiltration practices. Version 1.9. <http://vwrrc.vt.edu/swc/documents/2013/DEQ%20BMP%20Spec%20No%208_INFILTRATION_Final%20Draft_v1-9_03012011.pdf>.

VADEQ. 2014. Virginia water quality assessment 305(b)/303(d) integrated report. <http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityAssessments/IntegratedReport/2012/ir12_Integrated_Report_All_Final.pdf>.

VDACS. 2014. Virginia agriculture – facts and figures. <http://www.vdacs.virginia.gov/agfacts/>.

VDOT. 2013. MS4 year 5 progress report. Virginia Department of Transportation Virginia Stormwater Management Program (VSMP) Permit General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems Serving the Urbanized Areas of Virginia.

VGCSA. 2012. Environmental best management practices for Virginia's golf courses. Virginia Golf Superintendents Association. <http://www2.cybergolf.com/sites/images/373/Virginia-BMP-Full-Report-final.pdf>.

Glossary

Alternative Waste Treatment Systems - on-site technologies for treating domestic sewage where conventional means (public sewer or septic tank with drainfield) are not available; generally, the alternative systems will be more expensive than conventional septic systems and the operation of alternative systems in Virginia requires an annual inspection and maintenance contract

Benthic macroinvertebrates "benthos"– small animals without backbones that live on the rocks, logs, sediment and aquatic plants at the bottom of a waterbody during a period in their life

Best Management Practices (BMPs) - those methods or techniques determined to be the most efficient, practical, and cost-effective measures identified to guide a particular activity or to address a particular problem, as in this case, the reduction or control of water pollutant(s)

Bioretention practices – landscaped areas, including rain gardens, created to provide on-site temporary storage and treatment of stormwater runoff; generally, they are applied to small sites in urbanized setting

Clean Water Act – passed in 1972, this is the primary federal law in the United States regulating water pollution. The CWA established the goals of eliminating releases of high amounts of toxic substances into water, eliminating additional water pollution by 1985, and ensuring that surface waters would meet standards necessary for human recreation by 1983.

Continuous No-Till – a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated; in most cases, large amounts of crop residue are left on the surface to protect the soil from storm events.

Cover Crop - a crop such as grasses, legumes, or small grains planted primarily to manage soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife on agricultural fields

Designated uses – a function of, or activity in, a water that is supported by a level of water quality and specified in state or tribal water quality standards regulations for each water body or segment (whether or not they are currently being attained

Ecosystem services – the benefits humans obtain from functioning ecosystems

EPA - The United States Environmental Protection Agency (EPA or sometimes USEPA) is an agency of the U.S. federal government which was created for the purpose of protecting human health and the environment by writing and enforcing regulations based on laws passed by Congress.

***E. coli* (*Escherichia coli*)** – a bacterium commonly found in the intestines of warm-blooded organisms of which some strains can cause serious gastrointestinal stress in humans

Fecal coliform – bacterium that live in the digestive tracks of warm-blooded animals, including humans, and are excreted in the feces; in water, can help indicate the potential presence of other harmful pathogens

General Standard – the general standard, as defined by Virginia state law 9 VAC 25-260-20, states: all state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."

Generalized Watershed Loading Function (GWLF) - a continuous simulation watershed loading model developed to assess non-point source flow and sediment and nutrient loading from urban and rural watersheds; provides the ability to simulate runoff, sediment, and nutrient loadings (N and P) from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land)

Green Infrastructure – the use of vegetation, soils, and natural processes to manage water and create healthier urban environments; at the municipality scale, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water and at the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water

Infiltration practices - Structures used to infiltrate runoff and to facilitate filtering through the soil; the infiltrated water is then partitioned into groundwater recharge, discharge through an underdrain (if applicable), and transpiration

Low Impact Development (LID) - an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible; LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product

Mastitis – inflammation of the mammary gland and udder tissue in dairy cows usually occurring as an immune response to bacterial invasion

Municipal Separate Storm Sewer System (MS4) - a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) designed or used for collecting or conveying stormwater that discharges into waters of the United States. They can be owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created to or pursuant to state law) including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act

Total Maximum Daily Load (TMDL) - a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that load

among the various sources of that pollutant. For more information, visit: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm.

Virginia Stormwater BMP Clearinghouse - a web site administered by VADEQ and the Virginia Water Resources Research Center to serve several key purposes: disseminate the design standards and specifications of all stormwater best management practices (BMPs) approved for use in Virginia to control the quality and/or quantity of stormwater runoff, disseminate the results of Virginia's process to evaluate and certify the performance claims of manufactured/ proprietary BMPs approved for use in Virginia; and provide information and links to related websites to those who must comply with the Virginia Stormwater Management Law and Regulations.

Watershed – the area of land where all of the water that is under it or drains off of it goes into the same place

Appendix A. Best Management Practice Efficiency Information

Management Practice	Extent Units	% Effectiveness		Effectiveness Source		Cost/ Unit
		Bacteria	Sediment	Bacteria	Sediment	
Agricultural						
Stream exclusion with grazing land management	system	100	NA	1	NA	$32,000
Livestock exclusion with reduced setback	system	100	NA	1	NA	$20,000
Stream protection	system	100	NA	1	NA	$10,000
Animal waste control facility - beef	system	40	40	2	5	$150,000
Animal waste control facility - dairy	system	40	40	2	5	$150,000
Continuous no-till system	acres	70	70	2	5	$20
Cover crops	acres	20	20	2	5	$45
Grazing land management	acres	50	30	3	5	$75
Heavy use area protection	system	40	40	2	5	$20,000
Loafing lot management system	system	40	40	2	5	$20,000
Permanent vegetative cover on critical areas	acres	75	75	4	4	$2,000
Reforestation of erodible crop and pastureland	acres	land use conversion		4	4	$1,000
Sediment retention, erosion or water control structures	acres treated	50	50	2	5	$138
Residential						
Septic system pump outs	#	5	NA	3	NA	$300
New sewer hookups	#	100	NA	1	NA	$5,000
Septic system repairs	#	100	NA	1	NA	$3,500
New septic systems	#	100	NA	1	NA	$7,500
Alternative septic systems	#	100	NA	1	NA	$15,000
Pet waste stations	#	100	NA	9	NA	$1,300
Pet waste composters	#	100	NA	1	NA	$75
Pet waste program	program	25	NA	6	NA	$4,000
Urban Stormwater						
Bioretention	acres treated	90	90	2	5	$20,000
Bioswales						$15,000
Constructed wetlands/wet ponds		60	60	2	5	$8,000
Detention		10	10	2	5	$2,000
Detention and Manufactured BMPs		82	82	2	7	$16,000
Extended Detention		60	60	2	5	$2,000
Infiltration		95	95	2	5	$20,000
Manufactured BMPs		80	80	2	5	$15,000
Rain gardens		90	90	2	5	$5,000
Riparian Buffers (Forested)		57	57	2	3	$3,500
Riparian Buffers (Grass/Shrub)		50	50	2	3	$500
Vegetated Open Channels		70	70	2	5	$9,000
Street sweeping		9	9	2	5	
Streambank						
Streambank stabilization	linear foot	NA	310 lbs/ft/yr	NA	8	$150

1 - Removal efficiency is defined by the practice

2 - Bacteria efficiency assumed equal to sediment efficiency

3 - VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans

4 - Based on differential loading rates to different land uses

5 - Chesapeake Assessment Scenario Tool - BMP effectiveness values by land use and HGMR and pollutant

6 - Swann, C. 1999. A survey of residential nutrient behaviors in the Chesapeake Bay. Widener Burrows, Inc. Chesapeake Bay Research Consortium. Center for Watershed Protection. Ellicott City, MD. 112pp.

7- Overlapping BMPs

8 - Chesapeake Bay Program. 2013. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects

9 – Removal efficiency is defined by the practice, estimates 10 pets/day