Town of Christiansburg, Virginia

Sediment Impairment Action Plan

General Permit No. VAR040025

July 1, 2015

Updated 12/8/2015

Updated 4/10/2020

Updated 6/13/2025

Prepared by the Christiansburg Department of Engineering

MS4 TMDL ACTION PLAN UPDATES

CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

R. Wingfield 6-18-25

Randy Wingfield, Town Manager date

VAR040025 Town of Christiansburg

Executive Summary

The Town of Christiansburg was assigned Waste Load Allocations (WLA) for Sediment in both the Crab Creek and the Roanoke River watersheds. The Total Maximum Daily Load (TMDL) study for Crab Creek was approved by the State Water Control Board on December 2, 2004, and by the EPA on August 10, 2004. The State Water Control Board approved the TMDL study for the Upper Roanoke River watershed on September 7, 2006 and the EPA approval was on May 10, 2006. As a part of a 2020 census defined urban area, (previously called a census defined urbanized area), Christiansburg is required to maintain Municipal Separate Storm Sewer System (MS4) permit coverage in order to discharge stormwater from its storm drain system, and is defined as an MS4 operator under General Permit VAR04. In compliance with Section II, Part B, of General Permit VAR04, Christiansburg shall address sediment waste load allocations in accordance with Section II.B and this Local TMDL Action Plan.

This iteration of the Town of Christiansburg Sediment Action Plan addresses the special conditions of the MS4 General Permit through the following actions:

- Evaluation of existing street sweeping procedures and possible development of a street sweeping program that quantifies sweeper sediment removal targets.
- Maintenance of completed stream restorations and channel stabilization projects.
- Continued evaluation of stream restoration or channel stabilization projects as significant actions to address sediment loadings, and pursue additional grant funding through DEQ, VDOT and other potential sources to leverage capital spending.
- Maintaining the Town's lowered land disturbance threshold for post development stormwater management and more stringent requirements for post-development peak flow rates.
- Enhanced high-priority area SWPPP inspection frequencies.
- Public education and outreach efforts focused on the pollutant of concern

Due to the anticipated high cost to the Town of meeting the required reductions, the Town reserves the right to adjust this plan and to substitute any practices and projects that can achieve Pollutant of Concern (POC) reductions at less total cost.

Introduction

This document serves as a Town-specific Total Maximum Daily Load (TMDL) Action Plan to identify the best management practices and other interim milestone activities to be implemented to address the sediment waste load allocations (WLA) assigned to the Town's regulated MS4 area.

The TMDL project names and EPA approval dates are as follows:

Crab Creek Watershed

- *Fecal Bacteria and General Standard Total Maximum Daily Load Development for Crab Creek*
- State Water Control Board approval on December 2, 2004
- EPA approval on August 10, 2004

Roanoke River Watershed

- *Benthic TMDL Development for the Roanoke River, Virginia*
- State Water Control Board approval on September 7, 2006
- EPA approval on May 10, 2006

The referenced TMDL studies were developed in response to violations of the General Standard (benthic impairment) for aquatic life use. These violations resulted in the listing of Crab Creek and a portion of the Roanoke River watershed as impaired waters. "Benthic" refers to the aquatic organisms living in or on the bottom of a body of water and include crayfish, aquatic snails, clams, leeches, aquatic worms, certain insect larvae and nymphs, and adult aquatic insects. Changes in water quality generally result in changes in the types, numbers, or diversity of the benthic community. The TMDL studies identified sediment as a primary stressor to these organisms and established target levels of sediment to provide an environment that will lead to a healthy benthic community and delisting of the impaired water bodies.

The current town limits of Christiansburg incorporate approximately 14.75 square miles of land area. The Crab Creek watershed has a total area of 19.4 square miles and approximately 9.59 square miles, or 49% of the total area, lie within the Town limits. The Roanoke River impairment watershed is approximately 524.7 square miles and approximately 3.33 square miles, or 0.6% of the total area lie within Town limits. MS4 Permit requirements apply to both watersheds with equal weight and authority and the Action Plan will address the regulatory requirements in both watersheds.

Local TMDL Special Conditions

The VAR04 General Permit lists in Part II.B.4 specific criteria to be addressed when a permittee is assigned a WLA as listed below:

a) The TMDL project name;
b) The EPA approval date of the TMDL. (a) and (b) are listed above;
c) The wasteload allocated to the permittee (individually or in aggregate), and the corresponding percent reduction, if applicable;

Table 1: Wasteload Allocations for Sediment

Watershed	MS4 permittees assigned WLA	Existing load (tons/yr)	Percent reduction required	Tons/yr reduction required	TMDL WLA (tons/yr)
Roanoke River	Town of Christiansburg (VAR040025)	229.2*	69.5	159.2*	69.9
Crab Creek	Town of Christiansburg (VAR040025) VDOT (VAR040016)	55.14	50	27.57	27.57

**Existing load not given in TMDL report, calculated from the assigned WLA and the assigned percent reduction*

d) Identification of the significant sources of the pollutants of concern discharging to the permittee's MS4 and that are not covered under a separate VPDES permit. For the purposes of this requirement, a significant source of pollutants means a discharge where the expected pollutant loading is greater than the average pollutant loading for the land use identified in the TMDL;
   - POC is sediment
   - Under MCM6 in the 2013-2018 MS4 permit cycle, the Town performed a comprehensive review of owned or operated sites to identify sites with both high potential and high priority to discharge. The Town Public Works Station, known as "Operations Center", and the historic Town landfill site currently used for public works stockpiling and storage were identified as potential significant sources of sediment. High-priority area SWPPPs were developed for both sites in 2016.
     - Under this Action Plan, high priority SWPPP inspections are conducted more frequently than the required one time per year.
     - Part of the historic Town landfill site was determined to be land disturbance and is now covered under VPDES permit VAR10L731
   - Channel erosion
     - BMPs to address previously identified areas are listed below under "BMPs, other actions, and schedules to address sediment load reduction".

e) The BMPs designed to reduce the pollutants of concern in accordance with Parts II B5, B6, and B7;

f) Any calculations required in accordance with Part II B5, B6 or B7;

g) For action plans developed in accordance with Part II B5 and B6, an outreach strategy to enhance the public's education (including employees) on methods to eliminate and reduce discharges of the pollutants; and

h) A schedule of anticipated actions planned for implementation during this permit term.
   - Sections e through h are addressed below in "BMPs, other actions, outreach strategy, and schedules to address sediment load reduction."

Additionally, per Sections B.II.2.a.(1) and (2) of the permit, an evaluation of the results achieved by the previous action plan and any adaptive management strategies incorporated into the updated action plan based on action plan evaluation, are included in the section "BMPs, other actions, outreach strategy, and schedules to address sediment load reduction" as well.

BMPs, other actions, outreach strategy, and schedules to address sediment load reduction

Evaluation of results achieved by previous action plan:

BMPs and other actions

Part II.B.5 of the 2018 VAR04 General Permit lists specific categories from which the permittee may choose BMPs and other actions to address sediment load reductions. These include: (1) One or more of the BMPS from the Virginia Stormwater BMP Clearinghouse listed in 9VAC25-870-65 or other approved BMPs found on the Virginia Stormwater BMP Clearinghouse website; (2) One or more BMPs approved by the Chesapeake Bay Program; or (3) land disturbance thresholds lower than Virginia's regulatory requirements for erosion and sediment control and post development stormwater management. The 2023 VAR04 General Permit lists the same specific categories, adding a caveat to (2) that "Pollutant load reductions generated by annual practices, such as street and storm drain cleaning, shall only be applied to the compliance year I which the annual practice was implemented."

The Town of Christiansburg listed the following actions based on the requirements of the 2018 VAR04 General Permit sections Part II.B.3.e and f.

(1) and (2) Virginia Stormwater BMP Clearinghouse BMPs and/or Chesapeake Bay Program approved BMPs

BMP: Urban Stream Restoration

Crab Creek Watershed

- The Town has completed three stream restorations in the Crab Creek Watershed, Diamond Hills Park, Blue Leaf, and Towne Branch at Depot Park. The 2233 linear feet of stream restoration at Diamond Hills Park was credited to the Channel Erosion sediment source in the *Crab Creek Watershed Bacteria and Sediment TMDL Implementation Plan Technical Report* from December 30, 2014.
- The 5-year recertification of the BMP Blue Leaf stream restoration is scheduled for Fall 2021

Evaluation of Urban Stream Restoration in Crab Creek Watershed:

- The Diamond Hills Stream Restoration achieves a load reduction of 822 tons/year of sediment as of completion in late 2014. A 10-year monitoring plan was implemented for the restoration, and the Town is seeking the 10 year report.
- The Blue Leaf Stream Restoration achieves a load reduction of 52 tons/year of sediment as of completion in spring 2017. However, the Blue Leaf Stream Restoration requires maintenance according to the 5 yr recertification inspection conducted in May 2022 and will not be counted towards the Town's required sediment reduction until repairs are

complete.

- The Town Branch Stream Restoration achieves a load reduction of 163 tons/year as of completion in late 2018. The Towne Branch 5-year recertification inspection was conducted in May 2024 and the restoration is functioning as intended.
- Calculations for Diamond Hills, Blue Leaf, and Towne Branch can be found in Appendix B, in the Christiansburg Stream Restoration and Stormwater BMP Assessment Technical Memorandum dated 11-15-2013. Included text is the document summary, the entirety of the document including all appendices is available upon request from the Town.
- The Town met its required sediment reduction of 27.57 tons/year with the completion of the Diamond Hills Stream Restoration in 2014. The Town has continued to pursue stream restoration channel stabilization measures as both an amenity for Town residents and a backup to continue to meet the waste load allocation in case one restoration requires maintenance.

Roanoke River Watershed

- The Town has identified the Lomoor channel near Tower Rd. and the Christiansburg Industrial Park Detention Basin as two areas of concern due to channel erosion. Both areas have work planned and are currently in the design phase. Calculations for sediment load reduction and identification of the appropriate Chesapeake Bay Program BMP(s) and/or BMPs from the Virginia Stormwater BMP Clearinghouse will be provided in the MS4 Annual Report as they become available.

Evaluation of Channel Stabilization and Urban Stream Restoration Roanoke River Watershed:

- The Lomoor channel stabilization was completed in Fall 2022 with approximately 285 linear feet of channel stabilized and sanitary sewer relocated. The Town is investigating calculating sediment reduction based on pre and post repair channel cross sections.
- The Christiansburg Industrial Park Stream Restoration and Detention Pond retrofit project was completed in Spring 2025. The Christiansburg Industrial Park Stream Restoration achieves a sediment load reduction of 385 tons/year. Calculations are found in Appendix B in Christiansburg Industrial Park-Stream Benefits Analysis July 2021.
- The Town met its required sediment reduction of 159.2 tons/year with the completion of the Christiansburg Industrial Park Stream Restoration in spring 2025.

BMP: Street Cleaning (Street Sweeping) and/or Storm Drain cleaning

Crab Creek and Roanoke River Watersheds:

- The Town is currently re-evaluating its street sweeping program. Current (as of May 2019) guidance from the Chesapeake Bay Program BMP for street cleaning (street sweeping) and/or storm drain cleaning is being used to provide predicted sediment reductions.

Evaluation of Street Cleaning (Street Sweeping) and/or Storm Drain cleaning:

- The Town has determined that there was an error in the qualified lane miles approach used as a reporting mechanism and has recalculated the TSS load reduction as shown below using the mass loading approach from the 2011 Street

Sweeping BMP as found the 2016 CBP Expert Panel Report on Street and Storm Drain Cleaning. Please note that the Town is assuming that the caveat of "qualifying streets" only applies to calculating nutrient reductions and does not apply to calculating sediment reductions, as the BMP clearly defines "Qualifying Conditions for Street Sweeping Nutrient Reductions" and makes no such distinction for sediment loads. This methodology is found in Appendix C.

Table 2: Yearly TSS Load Reductions using 2011 Mass Loading Method

Watershed	Reporting year	Raw tonnage collected	TSS load reduction (tons)
Roanoke	2019-2020	36	7.56
Roanoke	2020-2021	30	6.3
Roanoke	2021-2022	25	5.25
Roanoke	2022-2023	84	17.64
Roanoke	2023-2024	12	2.52
Crab Creek	2019-2020	147	30.87
Crab Creek	2020-2021	139	29.19
Crab Creek	2021-2022	147	30.87
Crab Creek	2022-2023	148	31.08
Crab Creek	2023-2024	117	24.57

- In July 2021, the Town received the results of a study of possible ways to implement and quantify a targeted street sweeping/inlet cleaning program based on TMDL waste load allocations and the current Chesapeake Bay Program 2016 Street Sweeping Expert Panel Report. This information is under review.

(3) Land disturbance thresholds lower than Virginia's Regulatory Requirements

Crab Creek and Roanoke River Watersheds

- The Town has maintained the land disturbance threshold at 10,000 sq. ft. for Erosion and Sediment Control. The Town has lowered the land disturbance threshold for post development stormwater from the regulatory requirement of 1 acre down to 10,000 sq. ft. Additionally, the Town has added a section to the Town Code requiring that post-development peak flow rates for the two-year and ten-year 24 hour storm events be released at a rate that is less than the pre-development peak flow rate for the two-year and ten-year 24 hour storm events.
- The Center for Watershed Protection's spreadsheet based Watershed Treatment Model (WTM) will be employed to provide a methodology for assessing the effectiveness of this BMP, and to calculate load reductions from BMPs installed since the TMDL study.
- Given the availability of offsite nutrient credits to meet water quality requirements, and current guidance from DEQ regarding the application of Minimum Standard 19, the Town

is evaluating options for adjusting the Town code to more efficiently implement the more stringent requirements for channel protection.

Evaluation of Land Disturbance threshold reduction:

- The Town enforces the lowered land disturbance threshold for post-development stormwater management and the more stringent management of the 2 year and 10 year storm events.
- The Town has evaluated the CWP Watershed Treatment Model and determined that this methodology is not necessary given the sediment load reductions achieved by the stream restorations.
- The Town continues to evaluate how the availability of offsite nutrient credits to meet water quality requirements does little to ameliorate water quality issues in Town, as all nutrient credit banks are downstream of the Town. However, as the Town has not yet determined an actionable strategy that also reduces sediment loads, this proposed action is not yet relevant to the Sediment Action Plan and is being removed from the plan.
- Calculations are not required for these BMPs

Outreach Strategy

Under MCM 1, Public Education and Outreach, in the MS4 Program Plan, the Town has added a fourth water quality issue beyond the required three issues. The "Education on stream health" issue includes both education on stream health and education on lawn care and sediment, thus directly addressing the sediment pollutant of concern.

Additionally, the required staff good housekeeping/IDDE training currently contains information on local TMDLs including sediment.

Evaluation of Outreach Strategy:

- MS4 Annual Reports document consistent publication of educational material targeting public knowledge of benefits of stream restorations and lawn care as it pertains to sediment run off.
- The required staff good housekeeping/IDDE training currently contains information on local TMDLs including sediment. The Town meets its required biannual staff training requirement.

Review of Schedule of Anticipated Actions through the 2018 – 2023 Permit Cycle

- The Town is using the Center for Watershed Protection's spreadsheet based Watershed Treatment Model to assess the effectiveness of the structural and nonstructural best management practices employed under the Action Plan. Additionally, the spreadsheet will be used to evaluate public and private BMPs installed since the TMDL study to determine sediment reductions associated with those practices. Expected completion June 2021 for evaluation of BMPs already installed with an update at the end of the permit

cycle. **NOT COMPLETED, SEDIMENT REDUCTION ACHIEVED THROUGH OTHER METHODS, ACTION REMOVED FROM 2025 REVISION**

- Completion of sediment reduction calculations to be applied to the MS4 for completed stream restorations at Diamond Hills Park, Blue Leaf, and Towne Branch at Depot Park is expected by December 2020. **COMPLETED**
- Recertification of the sediment reduction credit/BMP at Blue Leaf Stream Restoration scheduled for Fall 2021. **COMPLETED INSPECTION. RESTORATION REQUIRES MAINTENANCE. TOWN WILL ADDRESS MAINTENANCE NEEDS**.
- Commencement of installation of BMPs at Lomoor channel and Christiansburg Industrial Park Detention Basin by October 2023. **PROJECTS COMPLETED**.
- Re-evaluation and re-structuring (if needed) of the street sweeping and/or storm drain cleaning program with supporting calculations for anticipated load reduction is expected by Fall 2020. **INCLUDED IN 2025 UPDATE**
- The Town will address the permit requirement to submit to the department the anticipated end date by which the permittee will meet the WLA for sediment by November 2021. **INCLUDED IN 2025 UPDATE**
- The Town is moving to a targeted approach to inspecting the privately owned stormwater management facilities instead of inspecting them all annually as proposed in the 2015 Sediment Action Plan. Inspections will still meet or exceed the General Permit minimum requirement that all facilities be inspected at least once every five years. **THE TOWN'S STORMWATER MANAGEMENT BMP MAINTENANCE AGREEMENT SPECIFIES ANNUAL INSPECTIONS BY THE TOWN, WHICH MAKES A TARGETED INSPECTION SCHEDULE DIFFICULT TO IMPLEMENT ON EXISTING FACILITIES WITH MAINTENANCE AGREEMENTS. THE TOWN IS AMENDING THIS ACTION IN THE 2025 REVISION.**

Schedule of Anticipated Actions through the 2023-2028 Permit Cycle

BMP: Urban Stream Restoration

- Complete design of Blue Leaf Extension stream restoration by Fall 2028.
- Start repairs at Blue Leaf Stream Restoration by Fall 2028.
- Calculate estimated sediment load reduction from Lomoor Channel stabilization
- Continue monitoring and maintenance of stream restorations per the monitoring and maintenance plans.
- Evaluate other channels for stabilization/restoration as need arises.

BMP: Street Cleaning (Street Sweeping) and/or Storm Drain cleaning

- Re-evaluation and re-structuring (if needed) of the street sweeping and/or storm drain cleaning program with supporting calculations for anticipated load reduction under the 2016 CBP Expert Panel Report on Street and Storm Drain Cleaning.

Land disturbance thresholds lower than Virginia's Regulatory Requirements

- The Town has maintained the land disturbance threshold at 10,000 sq. ft. for Erosion and Sediment Control. The Town has lowered the land disturbance threshold for post

development stormwater from the regulatory requirement of 1 acre down to 10,000 sq. ft. Additionally, the Town will maintain a section of the Town Code requiring that post-development peak flow rates for the two-year and ten-year 24 hour storm events be released at a rate that is less than the pre-development peak flow rate for the two-year and ten-year 24 hour storm events.

Other

- The Town continues to conduct high-priority area SWPPP inspections at a higher frequency then required by the permit. As there are sediment trapping measures currently in place at these facilities, the more frequent inspection schedule may enhance sediment retention.
- The Town continues to include public education and outreach efforts for the Pollutant of Concern in the MS4 Program Plan. As the MS4 Program Plan is iterative, the Town will be adjusting the audience and specific high priority issue for education and outreach on erosion and sedimentation issues as needed.
- Changes to the Town's post-construction stormwater management BMP inspection schedule will include a consideration of how likely the BMP is to discharge sediment if Town inspection frequency is decreased.

Public Comment

The Town held a Public Comment period from June 26, 2025, through July 13, 2025. The TMDL Action Plan was posted on the Town's website with contact information for comments submitted via email, in person, or via the US mail, posted on the same page. Links were provided via the Town's homepage and through the Town's Facebook and "X" accounts page.

The Town received one email with comments relevant to the Sediment Action Plan. Comments included asking for more frequent street sweeping, conserving more riparian buffers, and including education about landscape management on slopes to slow and absorb stormwater.

DEFINITIONS – For the purposes of this guidance document, the following definitions shall apply:

Best Management Practices ("BMPs") – Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices, including both structural and nonstructural practices to prevent or reduce the pollution of surface waters and groundwater systems.

Load Allocation ("LA") - The portion of the loading capacity attributed to (1) the existing nonpoint sources of pollution and (2) natural background sources.

Newly Designated MS4 permittees – MS4 permittees receiving initial permit coverage under the July 1, 2013 General Permit for Discharges of Stormwater from Small Municipal Separate Storm Sewer Systems.

Pollutant(s) of Concern ("POC") – The pollutant(s) impairing a water body for which one or more TMDL(s) has been developed.

TMDL Implementation Plan – A document guided by an approved TMDL(s) that at a minimum provides details of the corrective actions to address the load allocation of one or more TMDLs. The plan includes measureable goals needed to achieve pollutant(s) source load reductions; outlines a schedule to attain water quality standards along with costs, benefits, and environmental impacts to reduce pollutant(s) and remediate impaired waterbodies.

Total Maximum Daily Load ("TMDL") – The sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, natural background loading and a margin of safety.

Wasteload Allocation ("WLA") - The portion of a receiving waters' pollutant loading capacity that is allocated to existing or future point sources of pollution, such as an MS4.

***For terms not defined above, please refer to the 9VAC25-890-1, 9VAC25-875-20, or 9VAC25-31-10 of the Virginia Administrative Code*.**

Appendix A
BMP Schedules and Goals prior to 2018 permit cycle

The following BMP and schedules are from the 2015 Town of Christiansburg Sediment Action Plan. It is noted at the end of each BMP and schedule if it was completed, or if it is being modified or removed from the Action Plan. Detailed progress reports on these BMPs have already been submitted to DEQ through the MS4 Annual Reports.

Identify and Maintain a List of BMPs, Techniques, Design and Engineering methods beyond those required per the MCMs (per the 2013 VAR04 General Permit requirements)

- MCM 1 – Public Education:
    - Christiansburg will address sediment as a TMDL pollutant of concern in the spring 2016 survey intended to assess citizen knowledge and assist in the selection of high priority water quality issues. COMPLETED
    - Present TMDL information at a Town Council work session and a planned Open House that will also present the Stormwater Utility Program to the public. OPEN HOUSE HELD, NO INFORMATION ON TMDL COMMENTS
    - Include information about sediment as a POC in the annual mailer that also provides drinking water quality information. MAILER DISCONTINUED.
- MCM 2 – Public Involvement:
    - Christiansburg will address sediment as a TMDL pollutant of concern in the spring 2016 survey intended to assess citizen knowledge and assist in the selection of high priority water quality issues. COMPLETED
    - Solicit comments on the TMDL action plan at the proposed Stormwater Utility Open House. OPEN HOUSE HELD, NO INFORMATION ON TMDL COMMENTS
- MCM 3 – Illicit Discharge:
    - The Town website provides contact information to report IDDE comments and complaints. NOW REQUIRED UNDER VAR04 GENERAL PERMIT PART I.E.2. REMOVED FROM ACTION PLAN.
- MCM 4 – Construction Site Runoff:
    - Regulated land disturbance projects in the Town are required to be consistent with the Chapter 16 ESC and SWM Ordinances, which require approved plans that minimize sediment discharge from construction activity and post-construction. Inspections are required to be performed during construction activity. NOT APPLICABLE TO ACTION PLAN. REMOVED FROM ACTION PLAN.
    - The Town website provides contact information to report ESC comments and complaints. NOW REQUIRED UNDER VAR04 GENERAL PERMIT PART I.E.2. REMOVED **FROM ACTION PLAN.**

- MCM 5 – Post Construction Stormwater Management:
    - The Town SWM program requires regulated land disturbance projects to address post-construction water quality and requires a long-term inspection and maintenance program for stormwater management facilities to ensure functionality. As an additional practice, the SWM regulations and BMP maintenance requirements apply at a lower 10,000 square foot threshold as compared to the state 1-acre threshold. The facilities are designed to meet the technical criteria target phosphorus reductions; however, facilities that remove phosphorus inherently also remove sediment from passing downstream. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
    - The Town inspects all privately owned stormwater management facilities annually, exceeding the General Permit minimum requirement that all facilities be inspected at least once every five years. **THIS IS BEING REVISED TO A TARGETED APPROACH. ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
- MCM 6 – Good Housekeeping:
    - The Town performed a comprehensive review of owned or operated sites to identify sites with both high potential and high priority. The Town Public Works Station, known as "Station B", and the historic Town landfill site currently used for public works stockpiling and storage are identified as potential significant sources of sediment. The MS4 2015-2016 Program Plan will address the potential for significant POC through the plan to develop site specific Stormwater Pollution Prevention Plans (SWPPPs) for these two sites. **COMPLETED AND ADDRESSED ABOVE IN LOCAL TMDL SPECIAL CONDITIONS.**
    - Housekeeping SWPPPs to be developed for Town staff will include a TMDL educational component for sediment as a POC. **COMPLETED AND ONGOING.**
    - The Town SWPPP housekeeping training will occur at a more frequent training schedule than the biennial frequency required by the MS4 General Permit. **ADDRESSED ABOVE UNDER OUTREACH STRATEGIES.**
    - The Town has IDDE complaint contact information on the town website, as specified in the MS4 program plan, to enhance public IDDE reporting capabilities. **NOW REQUIRED BY MS4 PERMIT. REMOVED FROM ACTION PLAN.**
- Additional Management Practices
    - Street Sweeping - The Town Public Works Department employs a vacuum street sweeper and logs mileage swept. For the July 1, 2014- June 30, 2015 MS4 permit year the sweeper logged 4,411 miles. As an additional practice the Town proposes to develop a targeted street sweeping schedule to maximize POC collection and allow the Town to quantify reductions based on the DEQ Guidance Memo 15-2005, dated May 18, 2015; specifically the recommendations in Appendix V.G on urban street sweeping. Numeric measurable goals will be established as a part of the developed schedule. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
    - Stream Restoration:
        - The Town invested approximately $450,000.00 in the Diamond Hills Phase I project that included a stream restoration, an arch span culvert installation, and the construction of a detention pond and constructed wetlands as an overall plan to improve a section of a tributary of Crab Creek. The Diamond Hills Stream Restoration

Project is nearing completion and the scheduled monitoring will be used as a basis for reporting the estimated sediment load credit for this project. The project also proposed wetland best management practices within the stream floodplain and the "Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects" will be employed to estimate sediment reduction credit upon review of the final as-built BMP reporting. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**

- The Town has secured funding for two additional stream restoration projects, The Blue Leaf and Towne Branch Stream Restoration projects are in final design stage and construction is proposed in 2016. Upon completion the Action Plan will report sediment reduction credits based on the design calculations and as- built conditions. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
- The Town intends to leverage capital funding by pursuing grant funding through DEQ SLAF, VDOT Revenue Sharing, and other available funding sources in conjunction with a long-term funding plan. The capital plan is contingent on the establishment of a Stormwater Enterprise Fund and a specific funding level. Establishment of a stormwater utility is anticipated in 2016. **STORMWATER ENTERPRISE FUND ESTABLISHED JULY 2016.**

Measurable Goals through the 2013 – 2018 Permit Cycle

- Street Sweeping - Numeric measurable goals will be established as a part of the developed schedule, based on the May 2015 DEQ Chesapeake Bay Watershed Special Conditions Guidance. The target date for a revised street sweeping program is August, 2016. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
- Stream Restoration – Report estimated sediment credit upon final completion, review of as-built documentation, and any monitoring. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
    - Diamond Hills Stream restoration and wetland BMPs are expected to be completed by spring 2016.
    - Blue Leaf and Towne Branch Stream restorations are in final design stages and a 2016 construction start is projected.
- The Center for Watershed Protection's spreadsheet based Watershed Treatment Model (WTM) will be employed to provide a methodology for assessing the effectiveness of the TMDL Action Plan. The WTM will act as the primary methodology to assess the effectiveness of the structural and nonstructural best management practices employed under the Action Plan. The 2015-2016 MS4 Annual Report will include a Watershed Treatment Model spreadsheet populated with the Town's BMPs that will be used for pollutant credit reporting. **ADDRESSED IN ACTION PLAN UPDATE SPRING 2020.**
- Montgomery County, the Town of Blacksburg, and Virginia Tech met in December of 2014 to discuss the potential to coordinate MS4 program implementation. The Town will reach out to these MS4 permittees in 2016 to reconvene and reevaluate the potential for coordinated MS4 program efforts. The target date for the next meeting is May 1, 2016. **COMPLETED AND ONGOING. REMOVED FROM ACTION PLAN. ADDRESSED IN PUBLIC PARTICIPATION SECTION OF MS4 PROGRAM PLAN.**

- The Town participated in the development of both the Crab Creek Implementation Plan (IP) and the Roanoke River IP and believes that integral to ultimate achievement of the goal of delisting impaired waters is the participation of the Norfolk and Southern (N&S) Railroad Corporation in any Crab Creek Action Plan. As the primary landowner along the length of Crab Creek, N&S participation is important in coordinating any future structural buffers and stream restoration along the stream reach. The Town will reach out to N&S as a part of an anticipated FY16 DEQ SLAF application for limited Crab Creek urban stream restoration effort at the North Franklin Street Bridge. **COORDINATION WITH NORFOLK AND SOUTHERN RAILROAD CORPORATION WILL BE ATTEMPTED IF THE TOWN SEEKS TO INITIATE URBAN STREAM RESTORATION EFFORTS ALONG CRAB CREEK. CURRENTLY THE TOWN HAS NO URBAN STREAM RESTORATION EFFORTS PLANNED FOR CRAB CREEK.**

Appendix B
Load Reduction Calculations for Stream Restorations

EEE Consulting, Inc.
Environmental, Engineering and Educational Solutions

Technical Memorandum

To: Mr. Wayne Nelson, PE
Mr. Roy Nester, PE

From: EEE Consulting, Inc.

Date: November 15, 2013

Re: Christiansburg Stream Restoration and Stormwater BMP Assessment

Introduction

The Town of Christiansburg (the Town) is planning to implement several stream restoration and stormwater structural Best Management Practices (BMP) projects to address TMDL implementation requirements for Crab Creek, and to improve overall water quality of the New River and Roanoke River watersheds. Crab Creek is a 303d listed stream impaired by fecal coliform bacteria and sediment. The Town has contracted with EEE Consulting Inc. (EEE) to quantify stormwater pollutants removed by the implementation of these stream restoration and stormwater BMP projects. These projects are located in three separate drainage basins (Figure 1) and are in various phases of implementation.

This technical memorandum (TM) describes three project basins identified by the Town for initial water quality improvement projects. One of the rapid assessment tools used by the Town is drainage mapping and assessment of Bank Erosion Hazard Index (BEHI) conditions. These sites were selected as they are among the largest suspected sources of sediment from bank erosion in the Town. Diamond Hills and Town Branch (Depot Street Park) are two of the drainages assessed for BEHI conditions. Both of these tributaries flow in to Crab Creek and the proposed restoration plans identified within this TM can substantially reduce sediment to Crab Creek which is listed as a source of impairment for the TMDL. See Appendix A for supporting calculations of the BEHI analysis.

Projects located in the Diamond Hills Drainage Basin will be implemented in two phases. Phase I includes stream restoration with overbank stormwater wetlands and an extended detention basin. Construction documents have been completed and construction is scheduled to begin in 2014. Phase II includes another segment of stream restoration. Construction documents have been funded in the 2014 fiscal budget. Another stream restoration project and a constructed wetland retrofit have been planned, which includes the Depot Street Park Drainage Basin and Christiansburg Industrial Park, respectively. A schedule for the development of construction documents has not been completed at this time. See Appendix B for detailed planning and construction documents for the Diamond Hills and Depot Street projects.

Site Descriptions

The following stream restoration and stormwater BMP project sites are proposed on parcels owned by the Town, or with existing easements in place. See Appendix C for mapping of these parcels and easements. Pre-construction conditions have been documented with photos and are displayed in Appendix D.

Diamond Hills

The Diamond Hills Drainage Basin is located within the New River Watershed (HUC 05050001) and drains a total of 493 acres (Figure 2). The basin drains a large commercial area composed of 263 acres of impervious surfaces. It is estimated that this drainage contributes 891 tons/year of sediment to Crab Creek due to accelerated bank erosion along the 1.4 mile stream reach. Furthermore, over 98% (875 tons) of the annual sediment contribution for the drainage originates from 31% of the reach which are located in three areas of the basin. Subsequently the Town has identified these three areas as potential restoration projects in 2010 and now plans to address these areas in two phases.

Phase I includes the most aggressive water quality component for the drainage by constructing a 2,322 linear foot (LF) stream restoration project that target the reduction of 822 tons/year of sediment (92% of the basin annual sediment load). Phase I also includes overbank stormwater wetlands which will treat stormwater diverted from the restored stream in seven separate wetlands (Figure 3). Further upstream, an extended detention basin will be constructed to treat additional stormwater. The sub-basin (Basin A) draining to this BMP is 95 acres, with 71 acres of impervious surfaces. Basin B composes the remaining area of the Diamond Hills Drainage Basin and is 398 acres, with 192 acres of impervious surfaces. Phase II will include 500 LF of stream restoration near Blue Leaf Drive. Phase II will address the reduction of 52 tons/year of sediment (6% of the basin annual sediment load). Stream restoration for this basin will include in-stream rock structures, wood habitat structures, bioengineering techniques, riparian and stream bank planting. Once implemented, the restoration project will minimize bank erosion, increase oxygen concentration in the water column, promote more frequent overbank flows for increased nutrient and pollutant uptake, and decrease water temperature thereby improving aquatic habitat.

Depot Street (Town Branch)

The Depot Street Drainage Basin is located within the New River Watershed (HUC 05050001) and drains a total of 1,185 acres (Figure 4). The basin drains a majority of downtown Christiansburg and is composed of 594 acres of impervious surfaces. It is estimated that Town Branch contributes 169 tons/year of sediment to Crab Creek due to accelerated bank erosion along the 1.5 mile stream reach. Similar to Diamond Hills, 97% (163 tons) of the annual sediment contribution for the drainage originates from 15% of the reach. The proposed stream restoration project is located on Town Branch with Depot Street Park (Figure 5). The downstream extent of the project is located approximately 700 LF upstream of the Crab Creek/Town Branch confluence. Approximately 2,010 LF of stream restoration is proposed and will include constructed features such as in-stream rock structures, wood habitat structures, bioengineering techniques, riparian and stream bank planting. Once implemented, the restoration project will minimize bank erosion, increase oxygen concentration in the water column, promote more frequent overbank flows for increased nutrient and pollutant uptake, and decrease water temperature thereby improving

aquatic habitat. This project was identified in 2011 and will significantly reduce 163 tons/year of sediment to Crab Creek (97% of the basin's annual sediment load).

Christiansburg Industrial Park

The Christiansburg Industrial Park Basin is located within the Roanoke River Watershed (HUC 03010101) and drains a total of 174 acres (Figure 6). The basin drains a majority of the Industrial Park and is composed of 111 acres of impervious surfaces. An existing extended detention basin (Level 1) is located at the bottom of this drainage basin. In order to realize higher pollutant load removal, the Town has proposed to retrofit the detention basin into a constructed wetland meeting Level 2 requirements of The Virginia DCR Stormwater Design Specifications (Figure 7). See Appendix E for detailed constructed wetland calculations.

Methodology

Pollutant Load Calculations

Annual total phosphorous (TP) loads were calculated for each site's drainage basin using the *Virginia Runoff Reduction Methodology* (VRRM, April 2013). TP is the target pollutant for the VRRM methodology, and can be used as a surrogate for other pollutants such as bacteria and total suspended solids (TSS). The VRRM uses annual rainfall depth, drainage area, land cover and hydrologic soil type as input variables. VRRM specifies the use of 3 distinct land cover types for input; impervious surfaces, forest/open space, and managed turf. Delineating impervious surface area is a labor intensive process for large drainage basins. Therefore, percent impervious was calculated by delineating land cover types documented in *Technical Release 55, Urban Hydrology for Small Watersheds* (TR-55), published by the Natural Resources Conservation Service (NRCS). This document correlates land cover types to average percent impervious cover. See Appendix E for detailed impervious cover calculations. Table 1 documents these land cover types and the correlated average percent impervious cover.

Table 1. Land Cover Type and Average Percent Impervious, TR-55

Land Cover Type	Average Percent Impervious (%)
Roadway	100
Commercial	85
Industrial	72
School	50
Residential – 1/8 acre lots	65
Residential – 1/4 acre lots	38
Residential – 1/3 acre lots	30
Residential – 1/2 acre lots	25

Utilizing the previous table and land cover area calculations, impervious surface area was calculated for each site's drainage basin. The remaining area not impervious was assumed to be 25% Forest/Open Space and 75% Managed Turf. These assumptions were based on visual observations from aerial photography and observations during field visits.

Land cover area was then compared with hydrologic soil data. With the three land cover types and four standard hydrologic soil groups there are 12 unique combinations. Each unique combination correlates to a different Runoff Volume (Rv) Coefficient. Areas for each Rv Coefficient must be known to calculate the Treatment Volume (Tv). Rv Coeffients for the different land cover/soil combinations are displayed in Table 2.

Table 2. Virginia Runoff Reduction Methodology Rv Coefficients

Land Cover	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Using the appropriate Rv Coefficient, the Tv was calculated for each drainage basin. The annual precipitation depth was assumed to be 41 inches per year based on local precipitation data. The target precipitation depth recommended in VRRM is 1 inch. The event mean concentrations (EMC) for TP is 0.26 mg/L. Annual pollutant loads were then calculated within the VRRM, 2013 spreadsheet. See Appendix F for detailed spreadsheet calculations. The pollutant load calculations within the spreadsheet can be characterized by the following equation.

Annual Pollutant Load (lbs/year) =
Annual Rainfall Depth (in) * Tv (acre-feet) * Pollutant EMC (mg/L) * VRRM Adjustment Factor

Pollutant Removal Calculations

Pollutant load reduction calculations were performed for TP based on methodology documented in the following 3 documents.

- *The Virginia Stormwater BMP Clearinghouse, Table 4.1 BMP Pollutant Removal Efficiencies, March 2011*
- *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects, October 2012*
- *Attachment A - Stormwater Local Assistance Fund Program Guidelines, September 2013*

The Town has proposed to implement several BMPs which include stream restoration, constructed wetlands, floodplain/overbank wetlands, and extended dry detention. Table 3 documents the pollutant load reduction for the BMPs evaluated in this assessment.

Table 3. Total Phosphorous Reduction by BMP Type	
Best Management Practice	Total Phosphorous Mass Load Removal (TR, as %)
Constructed Wetland (Level 2[1])	75
Extended Dry Detention	15
Floodplain/Overbank Wetlands	18[2]
Stream Restoration	0.068 lbs/LF
[1]Level 2 design criteria based on the *Virginia DCR Stormwater Design Specifications* [2]Removal % calculated based on *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects, October 2012*	

Results

Annual TP Loads Removed

Annual TP loads removed where calculated for water quality project planned for implementation. TP removed for each project site is simply the product of the receiving load and the removal rate in percent form. If all projects are implemented, 612 lbs. of TP will be removed from the Town's surface waters each year. Table 4 further illustrates these results.

Table 4. Annual TP Load Removed By Project				
Project	Receiving TP Load (lbs/year)	Mass Load Removal Rate (%)	TP Removed (lbs/year)	Residual TP Load (lbs/year)
Diamond Hills Phase I Extended Detention Basin	156[1]	15	23	133
Diamond Hills Phase I Overbank Stormwater Wetlands	605[2]	18	109	496
Diamond Hills Phase I Stream Restoration	496[3]	0.068 lbs/LF * 2,322 LF	158	338
Diamond Hills Phase II Stream Restoration	338	0.068 lbs/LF * 500 LF	34	304
Depot Street Park Stream Restoration	1,450	0.068 lbs/LF * 2,010 LF	137	1,313
Christiansburg Industrial Park Constructed Wetland Retrofit	252	60[4]	151	101
		Annual TP Removed (lbs) =	612	
[1]TP load received from Diamond Hills Basin A [2]TP load received from Diamond Hills Basin B and the residual load from Basin A [3]TP load is the residual load from Basin A and B [4]TP Removal Rate for Level 2 constructed wetland reduced by 15% because of existing Level 1 detention basin				

Cost Analysis

Preliminary engineering (permitting and design) and construction cost was compiled for these projects, and is summarized in Table 5. Preliminary engineering cost for Diamond Hills has been paid by the Town at this time. Construction funds have not been paid, however they have been allocated in the 2014 fiscal budget. Construction is scheduled to begin in 2014. Preliminary engineering and construction funds for

Depot Street Park and Christiansburg Industrial Park have not been allocated in the 2014 budget. Implementation feasibility of these projects will likely rely on the success of securing grant funding.

The benefits of implanting these projects are also summarized in Table 5. Each project can be compared by a cost benefit ratio, or dollars spent per pound of TP removed, thus a lower number represents a more cost effective project. Cost benefit ratios range from $1,586 to $4,853 with an overall (all projects) ratio of $2,070. The most cost effective project is Diamond Hills Phase I. Diamond Hills Phase II has the highest ratio, however the benefits of the project are most likely realized when evaluating BEHI results and not annual TP load removal.

Table 5. Cost Benefit Summary

Project	Preliminary Engineering/ Design	Construction	Total	TP Removed (lbs/year)	Cost Benefit Ratio ($/lbs)
Diamond Hills Phase I	$55,000	$405,000	$460,000	290	$1,586.21
Diamond Hills Phase II	$19,000	$146,000	$165,000	34	$4,852.94
Depot Street Park Stream Restoration	$142,000	$250,000	$392,000	137	$2,861.31
Christiansburg Industrial Park Constructed Wetland Retrofit	$65,000	$185,000	$250,000	151	$1,655.63
Totals	$281,000	$986,000	$1,267,000	612	$2,070.26

Discussion

The Town has an established objective to implement water quality projects to remove stormwater pollutants from the New River and Roanoke River Basins, in addition to meeting waste load allocations for the Crab Creek TMDL. The projects evaluated in this assessment will help the Town meet this objective. Phase I and II of the Diamond Hills Project has been funded and will be implemented in 2014, which will result in 324 lbs of TP removed annually from Crab Creek and the New River Basin. In addition, this project will remove approximately 874 tons of sediment per year from Crab Creek. EEE recommends implementing projects in the future such as the Depot Street Park Stream Restoration Project and the Christiansburg Stormwater Wetland Retrofit Project. This assessment demonstrates that all of these projects are cost effective and will result in high levels of TP removed from the New River and Roanoke River Basins. EEE recommends pursuing grant funding to augment the Town's general fund budget in order to allow for a more aggressive implementation schedule.

List of Attachments

Stream Benefits Analysis
Christiansburg Industrial Park
Stream Restoration
WSSI #31036.01

Introduction

Approximately 700 linear feet of an unnamed stream are proposed to be restored, utilizing Natural Channel Design (NCD) techniques, at the Christiansburg Industrial Park Stream Restoration Project Site. At the request of the Town of Christiansburg, Virginia, Wetland Studies and Solutions, Inc. (WSSI) collected data that will allow the town staff to determine the pollutant removal benefit of the proposed stream restoration project. The pollutant removal benefit will be determined by applying the appropriate protocols from the 2014 guidance document titled "*Final Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects*". At this time WSSI believes that only Protocol 1 applies, and the necessary data for this protocol is presented herein.

Project Location/Site Description

The study area is located within the Town of Christiansburg Industrial Park, east of the intersection of Industrial Drive NE and Prospect Drive and west of Houchins Road. Figure 1 displays a vicinity map that depicts the approximate boundaries of the study area and its general location. The stream appears to be intermittent, with active flow present after runoff producing events. The main channel begins at the outflow of a 60-inch culvert passing under a driveway across from Prospect Drive and ends in an existing stormwater detention pond approximately 1200 feet after the culvert outflow. From approximately 700 to 800 feet downstream of the culvert the stream takes a sharp dive, increasing in slope from roughly 2% to 7.5%. This section is considered stable and not at risk of significant erosion because it is heavily armored with bedrock and placed boulders/ cement debris. This analysis will focus only on the portion of the site upstream of the armored section.

The portion of the stream in this study can be best described as severely eroding. Significant scour is present throughout the reach and is as deep as 4 feet at the culvert outfall (see Figure 2). Virtually all banks are vertical and actively eroding, ranging in height from 17 feet at the outfall to 2 feet near the hard point base level control at 700 feet downstream, banks progressively shorten as this point is approached. Left unaddressed, WSSI believes significant erosion will continue until a stable equilibrium channel slope is achieved. Further erosion will likely threaten adjacent infrastructure; this includes, but is not limited to, Industrial Drive NE and an 8-inch sanitary line running underneath, and the 60-inch culvert and associated driveway. Initial subsidence can already be seen in Industrial Drive NE via cracks in the asphalt (see Figure 3).

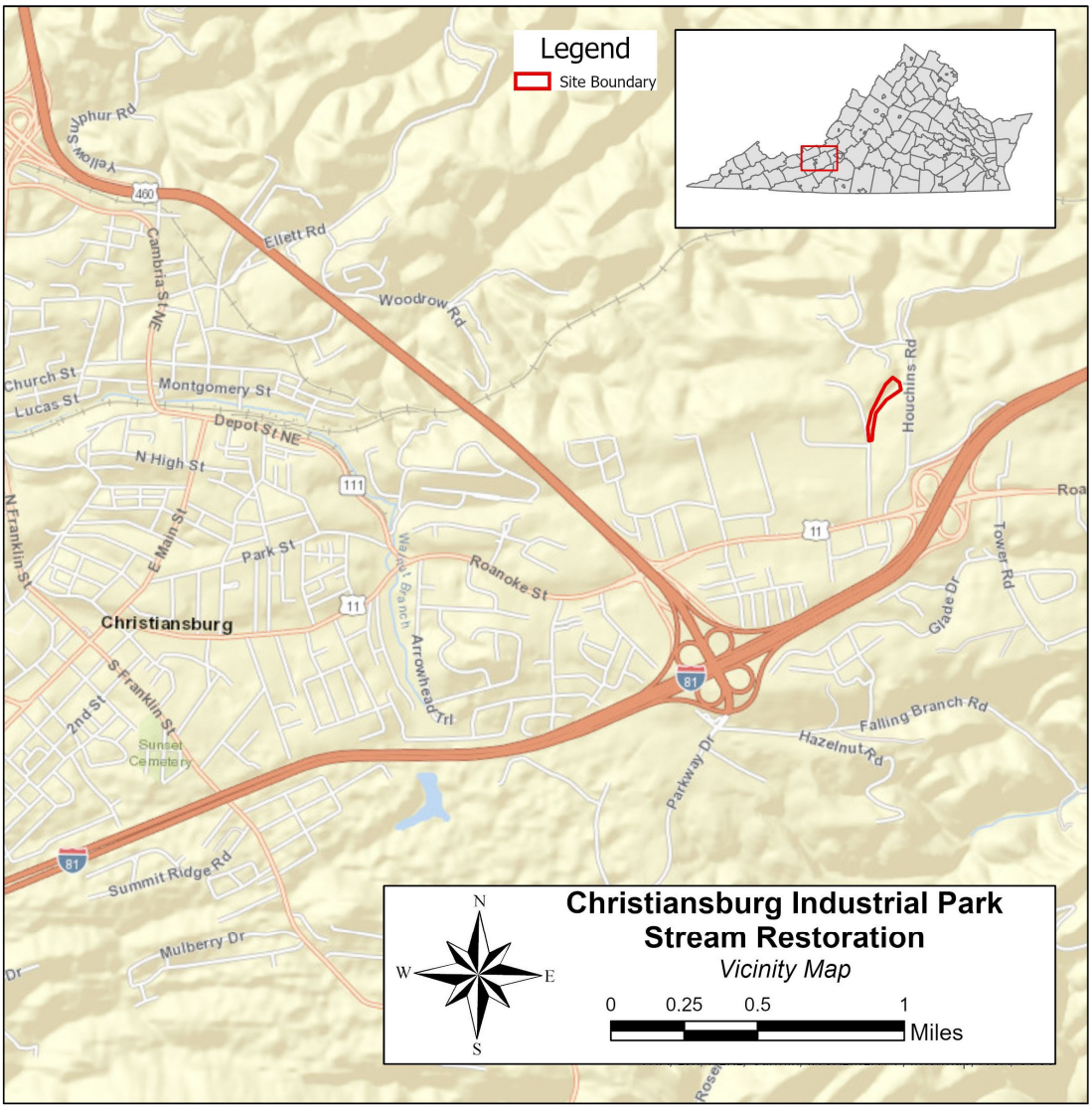

Figure 1. Site Vicinity Map

Figure 2. 60-inch culvert outfall, severe downcutting can be seen (approximately 4 feet), Industrial Drive NE is above the right bank.

Figure 3. Cracking in the asphalt making up Industrial Drive NE, the 60-inch outfall originates below the left shoulder and flows into the foreground, green striping marks the 8-inch sanitary.

Methodology

The above referenced guidance documents present four (4) protocols to estimate pollutant load reductions achieved by stream restoration projects. The protocols as summarized in the guidance document, and how WSSI believes they are applicable to this project, are as follows:

Protocol 1: Credit for Prevented Sediment during Storm Flow -- This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.
***(APPLICABLE*: The stream will be restored utilizing NCD techniques and will stabilize stream banks, reducing erosion and particle movement.)**

Protocol 2: Credit for Instream and Riparian Nutrient Processing during Base Flow -- This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow within the stream channel through hyporheic exchange within the riparian corridor.
***(NOT APPLICABLE*: The stream is intermittent and does not have consistent base flow.)**

Protocol 3: Credit for Floodplain Reconnection Volume -- This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events.
***(NOT APPLICABLE*: The proposed stream restoration will establish a bankfull channel that does not support more frequent storm events accessing the floodplain.)**

Protocol 4: Credit for Dry Channel Regenerative Stormwater Conveyance (RSC) as an Upland Stormwater Retrofit -- This protocol provides an annual nutrient and sediment reduction rate for the contributing drainage area to a qualifying dry channel RSC project. The rate is determined by the degree of stormwater treatment provided in the upland area using the retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel.
***(NOT APPLICABLE*: The proposed stream restoration does not involve RSC.)**

Data for Protocol 1 was determined as follows.

Protocol 1: Credit for Prevented Sediment during Storm Flow

Step 1: Bulk Density and Nutrient Concentration Sampling

WSSI collected stream bank soil samples along the length of the industrial park stream to determine soil bulk density, soil TP, and TN concentrations, which are required for Protocol 1. While the original Guidance Document allows the use of default nutrient concentrations, the revisions to Protocol 1 require on-site nutrient sampling. Sampling sites are selected based on mapped soil types, with one stream bank sample collected for every 200-500 linear feet of a soil type. Thus, 3 sampling sites were selected, as marked in the site map in Appendix A (Sta. 11+00', 14+10', and 16+60' along the existing stream centerline).

Soil bulk density testing was performed in compliance with USDA-NRCS Soil Quality Test Kit Guide, Section I, Chapter 4, pp. 9-13. Bulk density samples were collected using a 3" x 3" in-situ soil core sampling tube. Soil bulk density was calculated as the sample dry weight in pounds divided by the sample size in cubic feet.

The results from nutrient and bulk density sampling are pending laboratory analysis and will be utilized in final pollutant removal crediting. This initial assessment will use default values of 125 lb/ft^3 for bulk density, 1.05 lb/t phosphorous, and 2.28 lb/t Nitrogen. These values were obtained from the 2014 guidance and applicable for use in 2021 SLAF grant application submissions.

Step 2: Bank Condition Assessment

A stream bank condition assessment was conducted on September 16, 2020 by Nathan Staley, PE; and Thomas Schubert. Data was collected pursuant to the "Bank Assessment for Non-point Source Consequences of Sediment" (BANCS) method developed by Rosgen[1]. BANCS methodology utilizes two bank erosion estimation tools; the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) methods. Application of the BEHI and NBS methods require a field assessment of the pre-restored condition of the stream's banks to score the banks in sections of similar geometric and stability characteristics, referred to throughout this analysis as bank types.

Step 3: Estimation of Stream Sediment Erosion Rates

Segments of the same bank type were summed to obtain total bank lengths for each of the bank types. Each bank type is given a BEHI and NBS rating which is used to determine the Lateral Bank Erosion Rate (LBER) based on the North Carolina Stream Bank Erodibility Curve[2]. Defining characteristics of each bank type are listed in the BEHI and NBS summary tables provided in Appendix A - Table 3. Bank type locations are depicted in the Site Map provided in Appendix A. The sediment load per bank type is then calculated using the following formula:

$$S = (c*BH*BL*LBER)/2000$$

where:

	S	=	Sediment Load in tons per year
	c	=	Bulk Density of Soil[3]
	BH	=	Eroding Bank Height in feet
	BL	=	Bank Length in feet
	LBER	=	Lateral Bank Erosion Rate
	2000	=	Conversion rate from pounds to tons

[1] A Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25-29, 2001, Reno, NV. Available on the Wildland Hydrology website: http://www.wildlandhydrology.com/assets/Streambank_erosion_paper.pdf

[2] North Carolina Stream Bank Erodibility Curve is based on Doll et al. (2003).

[3] Soil bulk density based on default value of 125 lb/ft3

Step 4: Convert Stream Bank Erosion to Nutrient Loading

The sediment loading rates were converted to nutrient loading rates for Total Phosphorus (TP), Total Nitrogen (TN), and Total Suspended Sediments (TSS) in pounds per year using the following formula:

$$TP = S*TPC*RE$$
$$TN = S*TNC*RE$$
$$TSS = S*2000*RE$$

where:
- S = Sediment Load in tons per year
- TPC = TP Conversion, pounds TP per ton sediment[4]
- TNC = TN Conversion, pounds TN per ton sediment
- 2000 = Conversion rate from tons to pounds
- RE = Stream Restoration Removal Efficiency, 0.85

Step 5: Estimate Stream Restoration Efficiency

To account for potential uncertainty, an 85% efficiency rating for stream restoration was applied to sediment and nutrient loading to estimate reduction rates achieved by the project. Because this efficiency less conservative than the typical 50% efficiency, this project will be coupled with a post construction monitoring plan to ensure restoration is effective and persistent over time.

Results and Discussion

There are multiple bank types throughout the study reach. BEHI ratings varied from "Moderate" to "Extreme" and NBS ratings varied from "Low" to "High". More detailed information on each bank type, field measured variables, BEHI and NBS calculations and results are available in Appendix A - Table 3 and Table 4.

As discussed in the Methodology section above, sediment loads were determined using the Lateral Bank Erosion Rates based on the North Carolina Stream Bank Erodibility Curve. Protocol 1 sediment load calculations are detailed individually in Appendix A - Table 5. The following table summarizes the Protocol 1 results:

[4] TP and TN values based on default rates of 1.05 lbTP/ton and 2.28 lbTN/ton

Table 1. Total Annual Sediment Loads

	Existing Reach Length (ft)	Sediment Load (ton/yr)	Sediment Load (ton/lf/yr)
Main Channel - Reach 1	712	454	0.64
TOTALS	**712**	**454**	**0.64**

Also discussed in the Methodology section above, an 85% stream restoration removal efficiency was utilized for this analysis. Protocol 1 pollutant load reduction calculations are detailed individually in Table 5. The following table summarizes the Protocol 1 results:

Table 2. Total Pollutant Load Reductions via Stream Restoration Project (lbs/year)

	Total Phosphorus Load Reduction (lb TP/ yr)	Total Nitrogen Load Reduction (lb TN/ yr)	Total Suspended Solids Load Reduction (lb TSS/ yr)
	85% RE	85% RE	85% RE
Protocol 1	405	880	771,586
TOTALS	**405**	**880**	**771,586**

Limitations

This study is based on examination of the existing stream conditions, hydrology, and available reference documents. Field indicators can change with variations in hydrology, future erosion over time, and other factors. Therefore, our conclusions may vary from future observation by others. This report assesses the potential benefits for stream restoration at the site at the time of our review and does not address conditions at a given time in the future.

Our review and report have been prepared in accordance with generally accepted guidelines for the determination of potential stream restoration benefits. We make no other warranties, either expressed or implied.

Literature Cited

Doll, B. et al. 2003. *Stream Restoration – A Natural Channel Design Handbook*. North Carolina State University. Raleigh, NC.

McCandless, T.L. and Everett, R.A. 2002. Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region. U.S. Fish & Wildlife Services. CBFO-S02-01.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology Books. Pagosa Springs, CO.

Rosgen, D.L. 2001. A Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference: Vol. 2: 9-15.

Rosgen, D.L and Silvey, H.L. 2009. *Watershed Assessment of River Stability and Sediment Supply*, second edition. Wildland Hydrology. Fort Collins, CO.

Van Eps, M.J. et al. 2004. Using a Bank Erosion Hazard Index (BEHI) to Estimate Annual Sediment Loads from Streambank Erosion in the West Fork White River Watershed. American Society of Agricultural and Biological Engineers. St. Joseph, MI.

Water Quality Goal Implementation Team (WQGIT). 2014. Final Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Chesapeake Stormwater Network and Center for Watershed Protection.

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Appendix A – Protocol 1 Calculations and Results

Table 3. Summary of Collected BANCS Field Data

SEDIMENT EROSION CALCULATIONS
CHRISTIANSBURG STREAM BENEFITS ANALYSIS

WSSI Project Identifier	Locality	Investigators	Date of Site Investigation	Applicant
Christiansburg Industrial Park (WSSI# 31036.01)	Town of Christiansburg	JTS, NAS	September 1, 2020	N/A

Bank Erosion Hazard Index (BEHI)																											
		Measured Variables									Output Computations																
											Bank/Bankfull Height			Root Depth/Bank Height			Weighted Root Density			Bank Angle		Surface Protection		Materials	Stratification	Totals	
Reach	Bank Type	Bank Length[1]	Bank Height	Bankfull Height	Root Depth	Root Density	Bank Angle	Surface Protection	Bank Material	Bank Stratification	Value	Index	BEHI Rating	Value	Index	BEHI Rating	Value	Index	BEHI Rating	Index	BEHI Rating	Index	BEHI Rating	Index	Index	Index	BEHI Rating
			A	B	C	D					A/B			C/A			D*(C/A)										
		(ft)	(ft)	(ft)	(ft)	(%)	(deg.)	(%)																			
Christiansburg Industrial Park	A-R	149.7	14.0	1.1	5.0	20	55	20	Sand/Clay	5	12.7	10.0	Extreme	0.4	5.3	Moderate	7.1	8.8	Very High	3.7	Low	7.2	High	0.0	5.0	40.0	***Very High***
	B-L	153.8	17.0	1.1	10.0	20	50	25	Sand/Clay	5	15.5	10.0	Extreme	0.6	3.5	Low	11.8	8.2	Very High	3.4	Low	6.5	High	0.0	5.0	36.6	***High***
	C-R	96.9	7.5	1.1	1.0	15	50	25	Sand/Clay	5	6.8	10.0	Extreme	0.1	8.1	Very High	2.0	10.0	Extreme	3.4	Low	6.5	High	0.0	5.0	43.0	***Very High***
	D-L	156.9	5.5	1.1	1.5	20	90	15	Sand/Clay	5	5.0	10.0	Extreme	0.3	6.2	High	5.5	8.9	Very High	7.9	High	7.9	High	0.0	5.0	45.9	***Extreme***
	E-R	163.7	4.0	1.1	1.0	20	60	20	Sand/Clay	5	3.6	10.0	Extreme	0.3	6.5	High	5.0	9.0	Very High	3.9	Low	7.2	High	-5.0	5.0	36.6	***High***
	F-L	60.8	3.3	1.1	1.0	30	60	20	Sand/Clay	5	3.0	10.0	Extreme	0.3	5.8	Moderate	9.2	8.5	Very High	3.9	Low	7.2	High	0.0	5.0	40.4	***Very High***
	G-L	40.7	4.8	1.1	1.0	20	60	15	Sand/Clay	5	4.3	10.0	Extreme	0.2	7.1	High	4.2	10.0	Extreme	3.9	Low	7.9	High	0.0	5.0	43.9	***Very High***
	H-L	59.6	3.5	1.1	1.0	20	60	30	Sand/Clay	5	3.2	10.0	Extreme	0.3	6.1	High	5.7	8.9	Very High	3.9	Low	5.9	Moderate	0.0	5.0	39.8	***Very High***
	I-R	39.5	3.5	1.1	1.0	20	65	40	Sand/Clay	5	3.2	10.0	Extreme	0.3	6.1	High	5.7	8.9	Very High	4.4	Moderate	5.1	Moderate	0.0	5.0	39.5	***Very High***
	J-L	54.0	3.5	1.1	2.5	40	80	40	Sand/Clay	5	3.2	10.0	Extreme	0.7	2.9	Low	28.6	6.1	High	5.9	Moderate	5.1	Moderate	0.0	5.0	35.0	***High***
	K-R	95.9	3.5	1.1	1.5	20	50	30	Sand/Clay	5	3.2	10.0	Extreme	0.4	4.6	Moderate	8.6	8.6	Very High	3.4	Low	5.9	Moderate	0.0	5.0	37.5	***High***
	L-L	175.6	3.5	1.1	1.0	20	35	50	Sand/Clay	5	3.2	10.0	Extreme	0.3	6.1	High	5.7	8.9	Very High	2.7	Low	4.3	Moderate	0.0	5.0	37.0	***High***
	M-R	100.5	3.5	1.1	1.5	20	60	30	Sand/Clay	5	3.2	10.0	Extreme	0.4	4.6	Moderate	8.6	8.6	Very High	3.9	Low	5.9	Moderate	0.0	5.0	38.0	***High***
	N-R/L	47.8	2.0	1.1	1.0	30	45	70	Sand/Clay	0	1.8	7.0	High	0.5	3.9	Low	15.0	7.9	High	3.2	Low	2.7	Low	0.0	0.0	24.7	***Moderate***
	N-R/L	28.0	2.0	1.1	1.0	30	45	70	Sand/Clay	0	1.8	7.0	High	0.5	3.9	Low	15.0	7.9	High	3.2	Low	2.7	Low	0.0	0.0	24.7	***Moderate***

Table 4. Summary of Near Bank Stress

SEDIMENT EROSION CALCULATIONS
CHRISTIANSBURG INDUSTRIAL PARK STREAM BENEFITS ANALYSIS

Near Bank Stress (NBS)				
				Method 1[1]
Reach	Stream Bank Side	Bank Type	Bank Length	NBS Rating
	(L/R)		(ft)	
Christiansburg Industrial Park	R	A-R	149.7	***High***
	L	B-L	153.8	***High***
	R	C-R	96.9	***Moderate***
	L	D-L	156.9	***High***
	R	E-R	163.7	***Moderate***
	L	F-L	60.8	***Low***
	L	G-L	40.7	***High***
	L	H-L	59.6	***Low***
	R	I-R	39.5	***Moderate***
	L	J-L	54	***High***
	R	K-R	95.9	***Low***
	L	L-L	175.6	***Moderate***
	R	M-R	100.5	***Moderate***
	R	N-R/L	47.8	***Moderate***
	L	N-R/L	28	***Moderate***

Table 5. Sediment Load Calculations and Results

SEDIMENT LOAD CALCULATIONS
PROTOCOL 1 - PREVENTED SEDIMENT DURING STORM FLOW
CHRISTIANSBURG INDUSTRIAL PARK STREAM BENEFITS ANALYSIS

Sediment Load Estimate

Reach	Bank Type	NBS Adjective	BEHI Adjective	Bulk Density of Soil[1]	LBER[2]	Bank Length[3]	Eroding Bank Height	Eroding Bank Area	Sediment Load[4]
			620/2	c (lbs/ft^3)	R (ft/yr)	BL (ft)	BH (ft)	A = BH * BL (ft^2)	S = (cAR)/2000 (ton/yr)
Christiansburg Industrial Park	A-R	*High*	*Very High*	*125*	0.98	150	14.0	2,096	128.38
	B-L	*High*	*High*	*125*	0.20	154	17.0	2,615	32.69
	C-R	*Moderate*	*Very High*	*125*	0.73	97	7.5	727	33.17
	D-L	*High*	*Extreme*	*125*	3.80	157	5.5	863	204.96
	E-R	*Moderate*	*High*	*125*	0.16	164	4.0	655	6.55
	F-L	*Low*	*Very High*	*125*	0.60	61	3.3	198	7.43
	G-L	*High*	*Very High*	*125*	0.98	41	4.8	193	11.82
	H-L	*Low*	*Very High*	*125*	0.60	60	3.5	209	7.84
	I-R	*Moderate*	*Very High*	*125*	0.73	40	3.5	138	6.30
	J-L	*High*	*High*	*125*	0.20	54	3.5	189	2.36
	K-R	*Low*	*High*	*125*	0.10	96	3.5	336	2.14
	L-L	*Moderate*	*High*	*125*	0.16	176	3.5	615	6.15
	M-R	*Moderate*	*High*	*125*	0.16	101	3.5	352	3.52
	N-R/L	*Moderate*	*Moderate*	*125*	0.06	48	2.0	96	0.36
	N-R/L	*Moderate*	*Moderate*	*125*	0.06	28	2.0	56	0.21
							Existing Reach Length (lf)		712
							Total Sediment Load (ton/yr)		453.87
							Total Sediment Load (ton/lf/yr)		0.64

Total Reach Length (lf)	**712**
Total Sediment Load (ton/yr)	**454**
Total Sediment Load(ton/lf/yr)	**0.64**

[1] An average bulk density of banks (ρs) of 75.48 lb/ft3 was measured on site. See site map Appendix A.

[2] Lateral Bank Erosion Rates (LBER) were obtained from the North Carolina Stream Bank Erodibility Curve (Doll et. al. 2003)

[3] Measured from Existing Top of Bank.

[4] 1/2000 is the conversion rate from pounds (lbs) to tons.

Total Phosphorus (TP) Load Reduction

Parameter	Units		Value
Sediment Load to TP Conversion, TPC[5]	(lbs TP/ton Sed)		1.05
Stream Restoration Removal Efficiency, RE[6]			0.85
Lreach 1, TP Load Reduction, TP = S * TPC * RE	(lbs TP/yr)		405.1
Total TP Load Reduction, TP = S * TPC * RE	**(lbs TP/yr)**		**405**
Total TP Load Reductiion per LF of Restoration[7]	**(lbs TP/yr/LF)**		**0.58**

[5] Average value from three representative site samples.

[6] As specified in "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects".

[7] Based on proposed preliminary restoration length of 700 linear feet (not 712 LF of assessed bank).

Total Nitrogen (TN) Load Reduction

Parameter	Units		Value
Sediment Load to TN Conversion, TNC[5]	(lbs TN/ton Sed)		2.28
Stream Restoration Removal Efficiency, RE[6]			0.85
Reach 1, TN Load Reduction, TN = S * TNC * RE	(lbs TN/yr)		879.6
Total TN Load Reduction, TP = S * TPC * RE	**(lbs TN/yr)**		**880**
Total TN Load Reduction per LF of Restoration[7]	**(lbs TN/yr/LF)**		**1.26**

[5] Average value from three representative site samples.

[6] As specified in "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects".

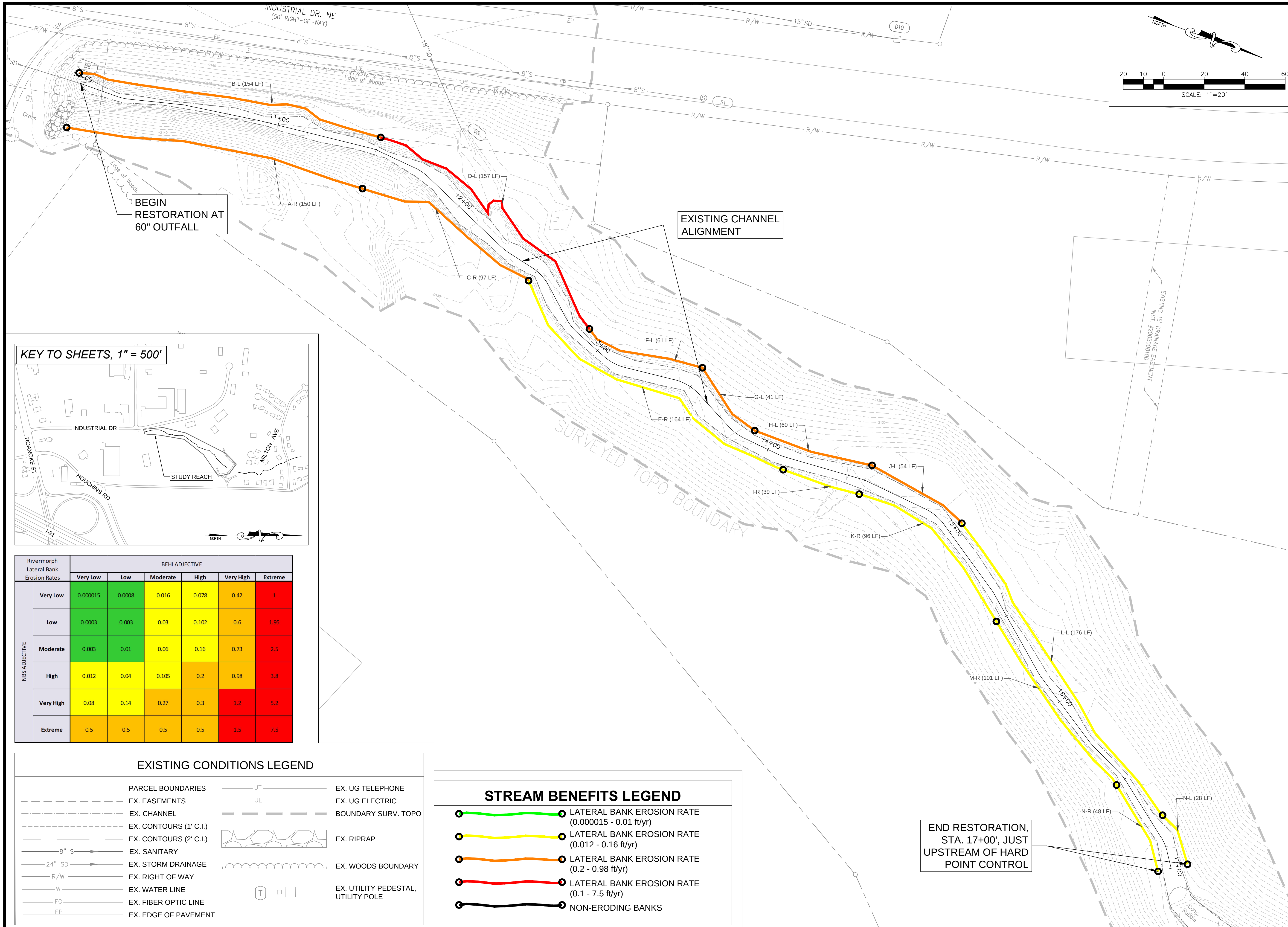
[7] Based on proposed preliminary restoration length of 700 linear feet (not 712 LF of assessed bank).

Total Suspended Sediment (TSS) Load Reduction

Parameter	Units		Value
Stream Restoration Removal Efficiency, RE[6]			0.85
Reach 1, TSS Load Reduction, TSS = S*CNV* RE	(lbs TSS/yr)		771,586
Total TSS Load Reduction, TSS = S*CNV* RE	**(lbs TSS/yr)**		**771,586**
Total TSS Load Reduction per LF of Restoration[7]	**(lbs TSS/yr/LF)**		**1,102**

[6] As specified in "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects".

[7] Based on proposed preliminary restoration length of 700 linear feet (not 712 LF of assessed bank).



Rivermorph Lateral Bank Erosion Rates		BEHI ADJECTIVE					
		Very Low	Low	Moderate	High	Very High	Extreme
NBS ADJECTIVE	Very Low	0.000015	0.0008	0.016	0.078	0.42	1
	Low	0.0003	0.003	0.03	0.102	0.6	1.95
	Moderate	0.003	0.01	0.06	0.16	0.73	2.5
	High	0.012	0.04	0.105	0.2	0.98	3.8
	Very High	0.08	0.14	0.27	0.3	1.2	5.2
	Extreme	0.5	0.5	0.5	0.5	1.5	7.5

EXISTING CONDITIONS LEGEND

- PARCEL BOUNDARIES
- EX. EASEMENTS
- EX. CHANNEL
- EX. CONTOURS (1' C.I.)
- EX. CONTOURS (2' C.I.)
- EX. SANITARY
- EX. STORM DRAINAGE
- EX. RIGHT OF WAY
- EX. WATER LINE
- EX. FIBER OPTIC LINE
- EX. EDGE OF PAVEMENT
- EX. UG TELEPHONE
- EX. UG ELECTRIC
- BOUNDARY SURV. TOPO
- EX. RIPRAP
- EX. WOODS BOUNDARY
- EX. UTILITY PEDESTAL, UTILITY POLE

STREAM BENEFITS LEGEND

- LATERAL BANK EROSION RATE (0.000015 - 0.01 ft/yr)
- LATERAL BANK EROSION RATE (0.012 - 0.16 ft/yr)
- LATERAL BANK EROSION RATE (0.2 - 0.98 ft/yr)
- LATERAL BANK EROSION RATE (0.1 - 7.5 ft/yr)
- NON-ERODING BANKS

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Christiansburg IP Stream Restoration
Stream Benefits Analysis
Christiansburg, Virginia

BEHI BANCS Assesment Site Map

COMMONWEALTH OF VIRGINIA
NATHAN A. STALEY
Lic. No. 047145
PROFESSIONAL ENGINEER

REVISIONS

No.	Date	Description	Rev. By	App. By

SCALE: 1" = 40'
DATE: April 2021

Horizontal Datum: VCS NAD 83
Vertical Datum: NGVD 29
Boundary and Topo Source: Mattern and Craig, Christiansburg GIS

Design	Draft	Approved
JTS	JTS	NAS

Sheet # 1 of 1

Computer File Name:

Appendix C
Load Reduction Calculations for Street Sweeping and Storm Drain Clean Out

Appendix A
Summary of 5.3.2 STREET SWEEPING Practice

Status: This credit was approved by a CBP BMP Expert Panel in March of 2011

Definition: Frequent street sweeping of the dirtiest roads and parking lots within a community can be an effective strategy to pick up nutrients and sediments from street surfaces before they can be washed off in stormwater runoff.

Technical Issues: The basic data for defining the credit were initially developed by Law et al (2008) based on a Baltimore monitoring study and a nationwide literature review of prior street sweeping studies.

Recommended Process: The first and most preferred option is the **mass loading approach**, whereby the mass of street dirt collected during street sweeping operations is measured (in tons) at the landfill or ultimate point of disposal.

Step 1*:* Determine the hopper capacity of your current sweeper technology

Step 2*:* Weigh the street solids collected to develop a simple relationship between street solid mass (in tons) to hopper capacity

Step 3*:* Keep records on the annual mass of street solids collected from qualifying streets

Step 4*:* Convert tons into pounds of street solids (multiply by 2000), and converted to dry weight using a factor of 0.7

Step 5*:* Derive your nutrient reduction credit by multiplying the dry weight of the solids by the following factors:

- Lbs of TN = 0.0025 pounds of dry weight sweeping solids
- Lbs of TP = 0.001 pounds of dry weight sweeping solids

These factors are based on sediment enrichment data reported by Law et al (2008), adjusted from original mg/kg values of 1200 (TP) and 2500 (TN)

Step 6*:* Compute the TSS reduction credit by multiplying the annual mass of dry weight sweeping solids by a factor of 0.3. This correction eliminates street solids that are greater than 250 microns in size, and therefore cannot be classified as total suspended solids. This factor was developed by the BMP panel and reflects particle size data from two recent street sweeping studies. SPU (2009) estimated TSS removal from street sweeping that was approximately 20% of the total dry sweeping solids load recovered. The particle size distribution for recovered street sweeping solids by Law et al. (2008) showed approximately 30% of the recovered solids in this TSS size range (i.e. ≤ 250 μm) by mass.

The second accepted method is **the qualifying street lanes method**.

Step 1*:* Each locality reports the number of qualifying lane miles they have swept during the course of the year.

Step 2*:* Qualifying lane miles are then converted into total impervious acres swept by multiplying the miles (5280 feet) by the lane width (10 feet) and dividing by 43,560. If both sides of the street are swept, use a lane width of 20.

Step 3*:* Multiply the impervious acres swept by the pre-sweeping annual nutrient load using the Simple Method unit loads (Schueler, 1987).

TP = 2.0 lbs/impervious acre/year
TN = 15.4 lbs/impervious acre/year

Step 4*:* Multiply the total pre-sweep baseline load by the pickup factors shown in Table A-1 to determine the nutrient and sediment load credit for street sweeping.

Table A-1 Multipliers to Reflect Effect of Street Sweeping on the Baseline Load [1]

Technology	TSS	TP	TN
Mechanical	.10	.04	.04
Regenerative/Vacuum	.25	.06	.05

[1] interpolated values from weekly and monthly street sweeping efficiencies as reported by Law et al (2008)

Qualifying Conditions for Street Sweeping Nutrient Reductions: The nutrient reductions only apply to an enhanced street sweeping program conducted by a community that has the following characteristics:

- An urban street with an high average daily traffic volume located in commercial, industrial, central business district, or high intensity residential setting.
- Streets are swept at a minimum frequency of 26 times per year (bi-weekly), although a municipality may want to bunch sweepings in the spring and fall to increase water quality impact.
- The reduction is based on the sweeping technology in use, with lower reductions for mechanical sweeping and higher reductions for vacuum assisted or regenerative air sweeping technologies.

Local Tracking, Reporting and Verification: Localities will need to maintain records on their street sweeping efforts using either method, and provide a certification each year as to either the annual dry solids mass collected or the number of qualifying street miles that were swept.