MS4 Pollutant Reduction Plan
for
New Britain Borough
Bucks County, Pennsylvania

July 2023

Prepared For:

New Britain Borough
45 Keeley Avenue
New Britain, PA 18901
(215) 348-4586

Prepared By:

Gilmore & Associates, Inc.
Engineers ♦ Land Surveyors ♦ Planners ♦ GIS Consultants
65 E. Butler Avenue, Suite 100
New Britain, PA 18901
215 345-4330

Table of Contents

Table of Figures

Appendices

A. INTRODUCTION

New Britain Borough, Bucks County is submitting this Municipal Separate Storm Sewer System (MS4) Pollutant Reduction Plan in accordance with the requirements of the *National Pollutant Discharge Elimination System (NPDES) Individual Permit to Discharge Stormwater from Small Municipal Separate Storm Sewer Systems (MS4s);* specifically, in accordance with the *MS4 Requirements Table (Municipal) Anticipated Obligations for Subsequent NPDES Permit Term (Revised 11/18/2019)*. New Britain Borough must create a Pollution Reduction Plan (PRP) and Total Maximum Daily Load (TMDL) Plan due to stormwater discharges from their MS4 to the Neshaminy Creek watershed, including the Pine Run and Cooks Run sub watersheds, which have been listed as impaired for sediment and nutrients as shown in the Municipal Requirements Table. As permitted by the *NPDES Individual Permit to Discharge Stormwater from Small Municipal Separate Storm Sewer Systems TMDL Plan Instructions* included as part of the NPDES individual permit application for MS4s, New Britain Borough has chosen to combine the TMDL Plan with the PRP; this combined document is referred to as the MS4 Pollutant Reduction Plan.

The intent of this MS4 Pollutant Reduction Plan is to establish the Planning Areas that drain to the MS4 from within the jurisdiction of New Britain Borough, determine existing pollutant loads discharged from the MS4 to each of these Planning Areas, and to present a plan to reduce the pollutant loads. This MS4 Pollutant Reduction Plan is organized to follow the “Required TMDL Plan Elements” presented in the TMDL Plan Instructions and also addresses the PRP requirements established in the *NPDES Stormwater Discharges from Small Municipal Separate Storm Sewer Systems Pollutant Reduction Plan (PRP) Instructions*. This MS4 Pollutant Reduction Plan will be evaluated and updated by New Britain Borough on an as-needed basis, based on its effectiveness in reducing pollutant loads in discharges from the MS4. If New Britain Borough determines that updates are needed, the Borough will work with the Department of Environmental Protection (DEP) for review and approval of any revisions or updates.

Per the *TMDL Plan* and *PRP Instructions*, this Plan includes all elements listed in the Table of Contents.

B. PUBLIC PARTICIPATION

As part of this MS4 Pollutant Reduction Plan, New Britain Borough was required to address the following components related to public participation:

- Make a complete copy of the MS4 Pollutant Reduction Plan available for public review.
- Publish, in a newspaper of general circulation in the area, a public notice containing a statement describing the Plan, where it may be reviewed by the public, and the length of time the Borough will provide for the receipt of comments. The public notice must be published at least 45 days prior to the deadline for submission of the MS4 Pollutant Reduction Plan to DEP. **A copy of the Public Notice and Proof of Advertisement will be included within Appendix B upon approval of the plan.**
- Accept written comments for a minimum of 30 days from the date of public notice. **Any comments received during the 30-day comment period will be included within Appendix B.**
- Accept comments from any interested member of the public at a public meeting or hearing, which may include a regularly scheduled meeting of the governing body of the municipality that is the permittee. **A copy of Council's public meeting agenda and meeting minutes from when the MS4 Pollutant Reduction Plan will be included within Appendix B.**
- Consider and make a record of the consideration of each timely comment received from the public during the public comment period concerning the Plan, identifying any changes made to the Plan in response to the comment. **A copy of the Borough's record of consideration of all timely comments received in the public comment period will be included within Appendix B.**

The following dates are important to understanding how New Britain Borough met the public participation requirements **(To be determined upon approval of the plan)**:

- Date the MS4 Pollutant Reduction Plan was made available for public review/comment: ___________
- Date the MS4 Pollutant Reduction Plan public notice was published in newspaper: ___________
- End date for the receipt of written comments (30 days from the date of public notice): ___________
- Date the MS4 Pollutant Reduction Plan listed on the public meeting agenda: ___________
- Date the MS4 Pollutant Reduction Plan comments were accepted at a public meeting: ___________

C. MAPS

Mapping was an integral part of the MS4 Pollutant Reduction Plan and required a level of detail suitable to determine the topography, MS4 drainage areas and loading for the listed impairments.

The MS4 Planning Area Map was developed to identify the PRP and TMDL Planning Areas, including all storm sewershed boundaries, and the proposed locations of structural Best Management Practices (BMPs) to be implemented to achieve the required pollutant load reductions. Parsed areas, which are the areas within the storm sewershed excluded from the Planning Areas and related calculations for land area and existing pollutant loads, were also identified. Examples of land area that were parsed include:

- Land area associated with non-municipal stormwater NPDES permit coverage that exist within the Borough;
- Land area associated with PennDOT roadways (roads and rights-of-way);
- Land area in which stormwater runoff does not enter the MS4. Examples include homeowner's associations and schools which do not contain municipal roads or other municipal infrastructure.

All BMPs located within these parsed areas have been excluded from calculations for achieving pollutant load reduction objectives.

The Planning Area was calculated to be a total of 298 acres for the Neshaminy Creek, consisting of 126 acres in the Pine Run sub-watershed and 172 acres in the Cooks Run sub-watershed. The MS4 Planning Area Map identifies the boundary between these two sub-watersheds of the Neshaminy Creek watershed, along with contours and locations of outfalls, storm sewer inlets, manholes, and other related appurtenances.

The MS4 Land Use Map identifies the municipal boundary and existing land uses. Both the MS4 Planning Area and MS4 Land Use Maps are included in Appendix C.

D. POLLUTANTS OF CONCERN

The pollutants addressed by this MS4 Pollutant Reduction Plan are based on the Requirement(s) column of the *MS4 Requirements Table (Municipal) Anticipated Obligations for Subsequent NPDES Permit Term*, included in Appendix A. The impaired downstream waters and pollutants in New Britain Borough consist of the following: Cooks Run, impaired for nutrients; Neshaminy Creek main branch, impaired for nutrients; Pine Run, impaired for excessive algal growth; and the Neshaminy Creek with a TMDL for siltation (hereinafter referred to as “sediment”). Per the DEP, the most limiting nutrient is total phosphorus (TP) and therefore this is the only nutrient that this MS4 Pollutant Reduction Plan considers.

Please note that for the purposes of the PRP, the Cooks Run main branch and Pine Run were considered an aggregate watershed in the calculations and are collectively referred to as “Neshaminy Creek.”

For the purposes of the TMDL, per Table E.2 of the *Total Maximum Daily Load (TMDL) Assessment for the Neshaminy Creek Watershed in Southeast Pennsylvania, last revised December 2003,* New Britain Borough only has a sediment waste load allocation (WLA) for Pine Run and therefore this is the only WLA considered in the TMDL Plan section.

Per the PRP Instructions, if the impairment is due to both siltation and nutrients, a 10 percent sediment load and 5 percent TP reduction must be addressed. However, per the PRP and TMDL Instructions, the MS4 may use a presumptive approach in which it is assumed that a 10 percent sediment reduction will also accomplish the required 5 percent TP reduction.

Furthermore, the TMDL Instructions indicate that MS4s may combine TMDL Plans with PRPs and, if the Plan demonstrates that the sediment and/or TP will be reduced by 10 percent and/or 5 percent during the permit term within the TMDL Planning Area, this satisfies all PRP requirements for any impaired waters within the watershed of the TMDL waters for the subsequent NPDES permit term.

This MS4 Pollutant Reduction Plan combines the TMDL Plans with the PRPs and uses the presumptive approach for the Neshaminy Creek, demonstrating how the Borough will achieve the 10 percent sediment load reduction; therefore, TP load reductions are not addressed or calculated separately.

E. DETERMINATION OF EXISTING LOADS FOR POLLUTANTS OF CONCERN

The existing sediment loading was calculated for New Britain Borough in April 2022 as follows:

As the first step in determining the existing pollutant loads, New Britain Borough determined its PRP and TMDL Planning Areas within the Neshaminy Creek. The PRP and TMDL Planning Areas are the land areas that drain to the municipal separate storm sewer system from within the jurisdiction of the MS4 permittee, also known as the "storm sewershed." Lands owned by the Commonwealth, County, homeowner's associations, schools, etc. as well as land areas that drain directly to non-Borough roads, streams, or permitted BMPs were parsed since they are outside the Borough's jurisdiction. The drainage areas within each Planning Area were delineated using PAMAP data known as Light Detection and Ranging (LiDAR) contours and were then modified as necessary based on field conditions, such as curbing and localized high points. New Britain Borough did not claim "credit" for any existing BMPs. The Table below summarizes the division of the total area of New Britain Borough.

TABLE E- 1: SUMMARY OF BOROUGH AREA

Land Area Location	Area
Borough Area within Neshaminy Creek Watershed (acres)	774
Area Parsed (acres)	476
Area Parsed (%)	62%
Borough Planning Area within Neshaminy Creek Watershed (acres, total)	298
Borough Planning Area within Pine Run Sub-watershed (acres)	126
Borough Planning Area within Cooks Run Sub-watershed (acres)	172

Next, New Britain Borough utilized the MapShed software program to model the total sediment load from the existing land uses. MapShed is a customized GIS interface used to create input data for an enhanced version of the Generalized Watershed Loading Functions – Enhanced (GWLF-E) watershed model originally developed at Cornell University. MapShed was improved by Dr. Barry Evans and his group at the Penn State Institute of Energy and the Environment using AVGWLF, which is a GIS-based watershed modeling tool that uses hydrology, land cover, soils, topography, weather, pollutant discharges, and other critical environmental data to model sediment and nutrient transport within a watershed. MapShed was run for each sub watershed to properly quantify the existing load associated with the Pine Run TMDL, as explained in Section F, in addition to the entire Neshaminy

Creek watershed to properly account for downstream channel impacts and included impaired waters identified in the MS4 Requirements Table. The MapShed outputs for the Planning Areas are available in Appendix D. New Britain Borough has a total existing loading of 221,976 lbs/year in its Neshaminy Creek Planning Area (see Appendices D-2 and D-4).

The existing sediment Planning Area load was multiplied by 10 percent to determine the required sediment load reduction. Table E-2 shows a summary of the Pine Run and Cooks Run watershed loadings, Planning Area loadings, and the required Neshaminy Creek reduction.

TABLE E- 2: SUMMARY OF PLANNING AREA LOADING

Land Area Location	Sediment Load (lbs/year)	Area (acres)
Pine Run Watershed	3,557,417	7,460
Cooks Run Watershed	16,527,165	18,775
New Britain Borough Planning Area		
Pine Run – Area 0	6,344	11
Pine Run – Area 1	60,304	115
Cooks Run – Area 0	51,025	43
Cooks Run – Area 1	51,111	68
Cooks Run – Area 2	26,667	31
Cooks Run – Area *3	160	0.32
Cooks Run – Area 4	15,289	19
Cooks Run – Area 5	1,039	2
Cooks Run – Area *6	760	1.52
Cooks Run – Area 7	1,039	2
Cooks Run – Area 8	8,238	5
Borough Planning Area Total Loading	**221,976**	**298**
Required Borough Sediment Reduction (10%)	**22,198**	

*MapShed Program does not recognize Planning Areas <2ac. Assumed 500lbs/ac.

For the Neshaminy Creek, existing sediment loads were calculated using the information provided in the *Total Maximum Daily Load (TMDL) Assessment for the Neshaminy Creek Watershed in Southeast Pennsylvania,* approved by the United States Environmental Protection Agency (USEPA) on December 8, 2003. The TMDL Assessment also established a nutrient TMDL, but this was withdrawn on January 31, 2008; therefore, the "simplified method" discussed above was used to calculate the existing TP loads for the Neshaminy Creek sewershed.

F. WASTELOAD ALLOCATIONS (WLAS)

Per Table E.2 of the Total Maximum Daily Load (TMDL) Assessment for the Neshaminy Creek Watershed in Southeast Pennsylvania, last revised December 2003, Pine Run is the only sub-area within New Britain Borough with a sediment wasteload allocation (WLAs).

Table E.3 of the TMDL Assessment indicates the total WLA for the Pine Run sub-area is 1,944,239 lbs/year. Section 4.0 of the TMDL Assessment, including Table C4.5 “Sediment Load Allocation by Each Land Use/Source”, provides detail on how the required 52 percent reduction in sediment loads and 1,944,239 lbs/year Pine Run WLA was calculated. No WLA was provided in the TMDL Assessment specific to New Britain Borough.

As indicated in prior sections, the TMDL Planning Area for Pine Run is 115 acres and the existing sediment load within New Britain Borough’s Pine Run Planning Area was calculated to be 66,648 lbs/year; therefore, a 52 percent reduction would result in WLA of 34,657 lbs/year.

In summary, the wasteload allocation for the Pine Run Planning Area is as follows:

TABLE F- 1: SUMMARY OF PINE RUN WLA

Pine Run Sediment WLA	
Borough Planning Area within Pine Run Sub-watershed (acres)	126
Borough Pine Run Planning Area Sediment Load (lbs/year)	66,648
TMDL Required Sediment Load Reduction (%)	52%
TMDL Allocated Sediment Wasteload – 25 Years (lbs/year)	34,657
TMDL Minimum Required Sediment Load Reduction – 25 Years (lbs/year)	34,657
TMDL Minimum Required Sediment Load Reduction – 5 Years (lbs/year)	6,931

G. ANALYSIS OF TMDL OBJECTIVES

In the short-term, which is defined as this 5-year permit term beginning upon the DEP's issuance of an individual permit, New Britain Borough has decided to pursue reducing the existing sediment load by 10 percent and, presumptively, the TP load by 5 percent as permitted by the TMDL Plan Instructions. This MS4 Pollutant Reduction Plan is intended to supersede and replace all MS4 TMDL Strategies previously submitted by New Britain Borough. The Table below summarizes the existing pollutant loads and short-term TMDL reductions for each Planning Area.

TABLE G- 1: SUMMARY OF SEDIMENT LOADING & SHORT-TERM REDUCTIONS

Pine Run Sediment WLA	
Borough Pine Run Planning Area Sediment Load (lbs/year)	66,648
TMDL Minimum Required Sediment Load Reduction – 5 Years (lbs/year)	6,931
Proposed Sediment Load Reduction – 5 Years (lbs/year)	**Up to 16,818**

In the long-term, New Britain Borough is required to reduce the sediment load in the Pine Run sub-watershed by 52 percent. The Borough plans to systematically achieve the required long-term wasteload allocations through the use of structural and non-structural BMPs intended to remove sediment and TP pollutants from stormwater runoff generated within the TMDL Planning Areas. The Borough believes it can achieve the sediment WLAs within 25 years, if not sooner, due to future DEP permit requirements.

This next table summarizes the required long-term TMDL reductions for each Planning Area:

TABLE G- 2: SUMMARY OF LONG-TERM TMDL REDUCTIONS

Pine Run Sediment WLA	
Borough Pine Run Planning Area Sediment Load (lbs/year)	66,648
TMDL Required Sediment Load Reduction (%)	52%
TMDL Minimum Required Sediment Load Reduction – 25 Years (lbs/year)	34,657

This MS4 Pollutant Reduction Plan will be evaluated and updated by New Britain Borough on an as-needed basis, based on its effectiveness in reducing pollutant loads in discharges from the Planning Areas. If New Britain Borough determines that updates are needed, the Borough will work with the DEP for review and approval of any revisions or updates.

H. BMP SELECTION TO ACHIEVE MINIMUM REQUIRED POLLUTANT REDUCTIONS

As part of this MS4 Pollutant Reduction Plan, New Britain Borough is required to implement Best Management Practices (BMPs) within the five-year term of the individual permit coverage that will reduce sediment pollutant loads by 10 percent, and presumptively also reduce TP pollutant loads by 5 percent, within the Planning Areas, in addition to addressing the Neshaminy Creek TMDL. As previously stated, the DEP has determined that a 10 percent sediment load reduction will also result in at least a 5 percent TP load reduction; therefore, TP load reductions were not separately examined and calculated as part of this MS4 Pollutant Reduction Plan.

As discussed above, the existing pollutant loads and required reductions are as follows:

TABLE H- 1: SUMMARY OF EXISTING LOADS & REDUCTION REQUIREMENTS

Land Area Location	Sediment Load (lbs/year)
Pine Run	66,648
Cooks Run	155,328
Borough Planning Area Total Loading	**221,976**
Required Borough Sediment Reduction (10%)	**22,198**

New Britain Borough plans to achieve the sediment reduction by designing, constructing, operating, and maintaining structural BMPs. The drainage area to each structural BMP was delineated using PAMAP data known as Light Detection and Ranging (LiDAR) contours and were then modified as necessary based on field conditions, such as curbing and localized high points. All BMP effectiveness values were obtained from the PADEP's *BMP Effectiveness Values document (3800-PM-BCW0100m)*.

As indicated in Table H-1, the minimum required sediment load reduction in New Britain Borough's Planning Areas is 22,198 lbs/year. New Britain Borough will be using the permitted approach of addressing the sediment load reduction in total, versus reductions in each Planning Area. As demonstrated in Table H-2 below, New Britain Borough may select to implement any combination of the potential BMPs to meet the minimum sediment load reduction requirements. Table H-2 notes the sediment removal values as "up to" since the load reduction cannot be verified until the time of BMP design. Once the minimum required sediment load reduction has been met, New Britain Borough may choose to continue implementing additional BMPs to reduce the sediment load by up to 51,509 lbs/year; however, the Borough does not commit to these additional sediment load reductions within the 5-year term of the individual permit coverage.

Table H-2 is a summary of the potential BMPs under consideration, including location, type, area treated, sediment removed, and the sub-watershed in which the BMP would be located:

TABLE H- 2: SUMMARY OF BMPS

	BMP Location	BMP Type	Area Treated by BMP (Acres)	Sediment Load Removed by BMP (lbs/year)	Planning Area
1	Aarons Avenue	Bioswale	3.9	Up to 3,507	Cooks Run
2	North Tamenend Avenue	Bioswale	15.2	Up to 5,318	Pine Run
3	South Landis Mill Road	Rain Garden	2.0	Up to 2,008	Cooks Run
4	South Sand Road	Bioswale	13.9	Up to 11,305	Cooks Run
5	Fluehr Funeral Home	Basin Retrofit	20.5	Up to 15,448	Cooks Run
6	Barrie Circle	Rain Garden	3.3	Up to 2,423	Cooks Run
7	Pine Run Creek, Covered Bridge/Orchard Parks	Stream Restoration	100 ft	Up to 11,500	Pine Run

The proposed reduction in sediment for each BMP is calculated by taking the proposed TSS loading with the BMP and deducting it from the base total watershed loading. With the exception of the proposed streambank restoration, the proposed TSS loading for each BMP can be found in Appendix E - Urban Area Viewer window related to each BMP. The proposed TSS loading for streambank restoration is based on the MapShed loading rate of 115 lbs/ft/year multiplied by the proposed length of stream restoration. The base total watershed loading for the Pine Run, 3,557,417 lbs., can be found in Appendix D-1. The base total watershed loading for Cooks Run, 16,527,165 lbs., can be found in Appendix D-3. The difference between the pre- and post-BMP loadings is the net TSS reduction for each BMP. The summation of all proposed BMP load reductions for the associated watersheds yields a total sediment reduction that exceeds both the TMDL and PRP requirements for this permit term.

The following table summarizes the existing sediment load and required sediment load reduction for each of New Britain Borough's Planning Areas and the Borough in total; however, as stated above, New Britain Borough will be using the permitted approach of addressing the sediment load reduction in total, versus individual sewersheds.

TABLE H- 3: SUMMARY OF MS4 POLLUTANT REDUCTION PLAN

Planning Area	Area (acres)	Existing Sediment Load (lbs/year)	Potential Proposed Sediment Load Reduction (lbs/year)
Pine Run	126	66,648	16,818
Cooks Run	172	155,329	34,691
Total	**298**	**221,976**	**51,509**
Minimum PRP Reduction	**22,198 (required 10% of total)**		

The Borough plans to systematically achieve the required long-term wasteload allocations through the use of structural and non-structural BMPs intended to remove the sediment and TP pollutant loads from stormwater runoff generated within the TMDL Planning Areas. The Borough believes it can achieve the sediment WLAs within 25 years, if not sooner due to requirements of future permits.

BMPs that would be considered to achieve the long-term wasteload allocations include those included in the Pennsylvania Stormwater Best Management Practices Manual, BMPs recognized by the EPA Chesapeake Bay Program, or other BMPs where the pollutant reduction efficiency is known or may be determined. These BMPs may be in the form of additional stream restoration, dry extended detention basin or infiltration practices with sand, vegetation, bioswales, etc.

I. IDENTIFICATION OF FUNDING MECHANISMS

New Britain Borough will be working during the five-year term of the individual permit coverage to determine the best funding source for each proposed BMP, as each project is undertaken. Funding sources for the proposed structural BMPs outlined in this MS4 Pollutant Reduction Plan could include the following:

- General Fund
- MS4 Dedicated Fund
- MS4 Stormwater Fee
- Developer Cooperation
- Grant Funding
- PennVest Low-Interest Loan
- Bond

For example, New Britain Borough intends to apply for related grants, such as Growing Greener, to implement these BMPs but will utilize general fund monies to cover the design and construction costs for the proposed BMPs should grant money not be awarded.

J. IDENTIFICATION OF BMP OPERATION AND MAINTENANCE (O&M) RESPONSIBILITIES

Once implemented, the BMPs must be maintained in order to continue producing the expected pollutant load reductions. Actual Operations and Maintenance (O&M) activities will be identified by New Britain Borough in their Annual MS4 Status Reports, submitted under the individual permit. At this time, it is anticipated that all BMPs will be owned by the Borough and maintained by the Borough's Public Works Department, with the exception of the basin retrofit on the Fluehr Funeral Home property which would continue to be maintained by the property owner. O&M activities and frequency are anticipated to be completed in accordance with the latest version of the PA BMP Manual.

TABLE J- 1: OPERATION & MAINTENANCE OF BMPS

BMP Location	BMP Type	Responsible Party	Activity & Frequency
Aarons Avenue	Bioswale	New Britain Borough	Per PA BMP Manual
North Tamenend Avenue	Bioswale	New Britain Borough	Per PA BMP Manual
South Landis Mill Road	Rain Garden	New Britain Borough	Per PA BMP Manual
South Sand Road	Bioswale	New Britain Borough	Per PA BMP Manual
Fluehr Funeral Home	Basin Retrofit	Fluehr Funeral Home	Per PA BMP Manual
Barrie Circle	Rain Garden	New Britain Borough	Per PA BMP Manual
Pine Run Creek, Covered Bridge/Orchard Parks	Stream Restoration	New Britain Borough	Per PA BMP Manual

- See Appendix F for general BMP descriptions and operations and maintenance (O&M) requirements.
- Specific O&M notes and frequencies for each BMP will be provided on the plans for each BMP.

K. GENERAL INFORMATION

Terms: The term "nutrients" refers to "Total Phosphorus" (TP) unless specifically stated otherwise in DEP's latest Integrated Report. The terms "sediment," "siltation," and "suspended solids" all refer to inorganic solids and are hereinafter referred to as "sediment."

The term, "storm sewershed" is defined in the PAG-13 General Permit as the land area that drains to the municipal separate storm sewer from within the jurisdiction of the MS4 permittee. This term is used as well as the term "TMDL Planning Area," "PRP Planning Area," as appropriate, or more generally as "Planning Area" which refers to all the storm sewersheds that an MS4 must calculate existing loads and plan load reductions for.

The term "baseline load" is used to refer to the pollutant load discharged by an MS4 as reported in a TMDL. A baseline load can be revised by 1) conducting a new modeling effort that utilizes the land use/land cover information from the original TMDL and 2) by considering the reductions achieved through structural BMPs installed prior to approval of a TMDL that were not considered during development of the TMDL.

The term "existing load" refers to the pollutant load that the MS4 estimates is draining to impaired waters from the Planning Area at the time of TMDL Plan submission. The existing load will be the same as the baseline load (regardless of whether or not the baseline load is revised) unless the MS4 accounts for reductions from structural BMPs installed between the date of TMDL approval and TMDL Plan submission.

Pollutants of Concern and Required Reductions: For all PRPs, MS4s shall calculate existing loading of the pollutant(s) of concern, in lbs/year; calculate the minimum reduction in loading, in lbs/year; select BMP(s) to reduce loading; and demonstrate that the selected BMP(s) will achieve the minimum reductions.

For PRPs developed for impaired waters, the pollutant(s) are based on the impairment listing, as provided in the MS4 Requirements Table. If the impairment is based on siltation only, a minimum 10% sediment reduction is required. If the impairment is based on nutrients only or other surrogates for nutrients (e.g., "Excessive Algal Growth" and "Organic Enrichment/Low D.O."), a minimum 5% TP reduction is required. If the impairment is due to both siltation and nutrients, both sediment (10% reduction) and TP (5% reduction) must be addressed. PRPs may use a presumptive approach in which it is assumed that a 10% sediment reduction will also accomplish a 5% TP reduction. However, MS4s may not presume that a reduction in nutrients will accomplish a commensurate reduction in sediment.

The pollutants of concern for TMDL Plans will be based on the following:

If a WLA has been established in a TMDL for sediment, the MS4 is expected to develop the TMDL Plan based on the reduction of sediment.

If WLAs have been established in a TMDL for sediment and nutrients, the MS4 is expected to develop the TMDL Plan based on the reduction of sediment and TP, unless the MS4 chooses to utilize a presumptive approach for TP. DEP will allow MS4s to calculate loads and pollutant reductions based on sediment, under the assumption that the achievement of TMDL Plan objectives for sediment will also achieve the objectives for TP. MS4s must identify use of the presumptive approach in its TMDL Plan if chose.

TMDL Plan Objectives: There are two objectives for a TMDL Plan:

1. **Long-Term Reduction** – plan for the reduction of pollutant load(s) to achieve the WLA(s) in the TMDL.
    - The TMDL Plan must describe a general plan as to how WLA(s) will ultimately be achieved.
2. **Short-Term Reduction** – plan for the short-term reduction of pollutant load(s) that will be achieved within the subsequent NPDES permit term (i.e., the 5-year permit term resulting from DEP's issuance of a permit in response to the receipt of the MS4's next submission of an individual permit application).
    - MS4s must achieve at least one of the following objectives within the 5-year permit term: 1) the WLA(s) in the TMDL, or 2) if the WLA(s) cannot be achieved, a load reduction of at least 10% for sediment and/or 5% for TP, compared to the existing load for these pollutants at the time of TMDL Plan submission. A load reduction of at least 10% for sediment may be used as the objective in lieu of a 5% reduction in TP under the presumptive approach.

Existing Pollutant Loads: The estimation or determination of existing loads for TMDL Plans is different than the estimation of existing loads for PRPs. MS4s have two options in establishing the existing pollutant loads for pollutants of concern for TMDL Plans:

- MS4s may report the existing loads specified in the TMDL (i.e., the TMDL "baseline load"). The baseline loads may be represented in the TMDL as either:
- Loads that are specific to the MS4
- Loads that are not specific to the MS4, in which the MS4 will need to delineate its individual loads

MS4s may choose to calculate its existing loads for a TMDL Plan through a new modeling effort using the MapShed model developed by the Pennsylvania State University (www.mapshed.psu.edu) or a comparable, or more robust, continuous simulation model. Any new modeling effort must focus on the TMDL Planning Area and account for overland flow as well as downstream channel and bank erosion; therefore, modeling must be done at a scale that allows for the quantification of both impacts. **New modeling must utilize the same land use/land cover information that was used to develop the TMDL or other quality assured land use/land cover data from the time of TMDL approval.**

If a combined PRP and TMDL Plan is developed, in which the PRP and TMDL Planning Areas are combined into one Planning Area, the existing loads for the Planning Area may only be derived using a new modeling effort.

Existing loading for PRP Planning Areas must be calculated and reported for the portion of the Planning Area which drains to impaired waters as of the date of the development of the PRP. MS4s may not claim credit for street sweeping and other non-structural BMPs implemented in the past. If structural BMPs were implemented prior to development of the PRP and continue to be operated and maintained, the MS4 may claim pollutant reduction credit in the form of reduced existing loading.

Each impairment identified on the MS4 Requirements Table (“Table”) must be addressed in a PRP document. The Table listings for each MS4 are different because they reflect local conditions, which is why an MS4 must carefully interpret the information on the Table.

NOTE – An MS4 may not reduce its obligations for achieving permit term pollutant load reductions through previously installed BMPs. An MS4 may use all BMPs installed prior to the date of the load calculation to reduce its estimate of existing pollutant loading. For example, if a rain garden was installed ten years ago and is expected to remove 100 lbs of sediment annually, and the overall annual loading of sediment in the storm sewershed is estimated to be 1,000 lbs without specifically addressing the rain garden, an MS4 may not claim that the rain garden satisfies its obligations to reduce sediment loading by 10%. The MS4 may, however, use the rain garden to demonstrate that the existing load is 900 lbs instead of 1,000 lbs, and that 90 lbs rather than 100 lbs needs to be reduced during the term of permit coverage.

BMP Effectiveness: All MS4s must use the BMP effectiveness values contained within DEP’s BMP Effectiveness Values document (3800-PM-BCW0100m) or Chesapeake Bay Program expert panel reports for BMPs listed in those resources when determining pollutant load reductions in TMDL Plans and PRPs, except as otherwise approved by DEP. For BMPs not listed in 3800-PM-BCW0100m or expert panel reports, MS4s may use effectiveness values from other technical resources; such resources must be documented in the TMDL plan and PRP and must reflect both overland flow and stream erosion components. For example, PRPs/TMDL Plans may also apply thoroughly vetted mechanistic models with self-contained BMP modules (e.g., Storm Water

Management Model (SWMM), WinSLAMM) to demonstrate achievement of reduction targets. Application of these data intensive models could allow for a streamlining of the planning and design phases of the stormwater control process that may provide future cost savings as municipalities move toward implementation of the plan. Such resources must be documented in the Plan and must reflect both overland flow and in-stream erosion components.

Combining Planning Obligations: MS4s with multiple TMDL Plan development obligations may develop one TMDL Plan for submission to DEP, if desired. If this is done, MS4s may elect to address each TMDL water separately or in combination. If done in combination, unless specifically restricted in the TMDL, the MS4 has flexibility when locating BMPs between the TMDL Planning Areas. If the MS4 elects to meet the percent reduction requirements (10% sediment or 5% TP) in lieu of meeting the WLA(s) within the first permit term, it may elect to reduce pollutants by a greater percentage in one TMDL Planning Area over another, as long as the overall reduction for the planning effort achieves the percent reduction requirements.

MS4s may also combine TMDL Plans with PRPs, and the same flexibility is provided as discussed above. In addition, where TMDL Plans demonstrate: 1) WLA(s) have been achieved, or 2) WLA(s) will be achieved during the permit term, or 3) sediment and/or TP will be reduced by 10% and/or 5% during the permit term within the TMDL Planning Area, this satisfies all PRP requirements for any impaired waters within the watershed of the TMDL waters for the subsequent NPDES permit term. Where TMDL and PRP Planning Areas are combined, existing loads must be determined based on a new modeling effort.

BMP Selection: MS4s may select BMPs from the Pennsylvania Stormwater Best Management Practices

Manual (363-0300-002), BMPs recognized by the EPA Chesapeake Bay Program, or other BMPs where the pollutant reduction efficiency is known or may be determined. Land use changes are not BMPs but may be used to demonstrate pollutant load reductions. For land use changes and BMPs implemented within a Planning Area as part of an NPDES permit requirement (e.g., post-construction stormwater management BMPs for Chapter 102 NPDES permits), pollutant load reduction credit may be claimed based on an analysis of pre- and post-construction or land use conditions, where the credit is a demonstrated net decrease in pollutant load.

MS4s may propose and take credit for only those BMPs that are not required to meet regulatory requirements or otherwise go above and beyond regulatory requirements. For example, a BMP that was installed to meet Chapter 102 NPDES permit requirements for stormwater associated with construction activities may not be used to meet permit term minimum pollutant reductions unless the MS4 can demonstrate that the BMP exceeded regulatory requirements; if this is done, the MS4 may take credit for only those reductions that will occur as a result of exceeding regulatory requirements.

NOTE – Street sweeping may be proposed as a BMP for pollutant loading reductions if 1) street sweeping is not the only method identified for reducing pollutant loading, and 2) the BMP effectiveness values contained in 3800-PM-BCW0100m or Chesapeake Bay Program expert panel reports are utilized.

Combining PRPs: If the MS4 discharges into multiple local surface waters impaired for nutrients and/or sediment, one PRP may be submitted to satisfy Appendix E but calculations and BMP selections must be completed independently for the storm sewershed of each impaired water. If, for example, an MS4 permittee must complete three PRPs according to the MS4 Requirements Table for three separate surface waters, storm sewershed maps must be developed, existing loads must be calculated, and BMPs must be implemented for pollutant reductions independently within those storm sewersheds. In other words, BMPs cannot be implemented in one storm sewershed to count toward pollutant reductions in an entirely separate storm sewershed for a different impaired water.

Where local surface waters are impaired for nutrients and/or sediment, and those waters are tributary to a larger body of water that is also impaired, MS4s can propose BMPs within the upstream impaired waters to meet the pollutant reduction requirements of both the upstream and downstream waters. For example, if Stream A flows through a municipality that is tributary to Stream B, both are impaired and the MS4 has discharges to both streams, the MS4 can implement BMPs in the storm sewershed of Stream A to satisfy pollutant reduction requirements for both Streams A and B. In general, the MS4 permittee would not be able to satisfy pollutant reduction requirements for both streams if BMPs were only implemented in the storm sewershed of Stream B; however, on a case-by-case basis DEP will consider such proposals where it can be demonstrated that implementing BMPs in the upstream storm sewershed is infeasible.

If, however, Stream A does not flow into Stream B, both are impaired and the MS4 has discharges to both streams, in general DEP would expect that BMPs be implemented in the storm sewershed of both streams to meet pollutant reduction requirements.

MS4s participating in collaborative efforts are encouraged to contact DEP's Bureau of Clean Water during the PRP development phase for feedback on proposed approaches.

PRP and TMDL Plan Implementation and Final Report: Under the individual permit, the permittee must achieve the required pollutant load reductions within 5 years following DEP's issuance of the permit and must submit a report demonstrating compliance with the minimum pollutant load reductions as an attachment to the first Annual MS4 Status Report that is due following expiration of the permit.

For example, if DEP issues a permit to a permittee on June 1, 2018, the required pollutant load reductions must be implemented by June 30, 2023, and the final report documenting the BMPs that were implemented (with appropriate calculations) must be attached to the annual report that is due September 30, 2023.

Appendix A: MS4 Requirements Table

Applicable portion of the MS4 Requirements Table (Municipal) Anticipated Obligations for Subsequent NPDES Permit Term (Revised 11/18/2019)

MS4 Name	NPDES ID	Individual Permit Required?	Reason	Impaired Downstream Waters or Applicable TMDL Name	Requirement(s)	Other Cause(s) of Impairment
Bucks County						
MIDDLETOWN TWP	PAG130028	Yes	TMDL Plan	Neshaminy Creek	Appendix B-Pathogens (5), Appendix C-PCB (5), Appendix E-Nutrients, Organic Enrichment/Low D.O. (5)	
				Delaware River	Appendix C-PCB (4a)	
				Lake Luxembourg	Appendix E-Nutrients, Suspended Solids (4a)	
				Magnolia Lake	Appendix E-Excessive Algal Growth, Nutrients, Organic Enrichment/Low D.O., Suspended Solids (5)	
				Mill Creek	Appendix C-PCB (4a), Appendix E-Siltation (5)	Other Habitat Alterations, Water/Flow Variability (4c)
				Neshaminy Creek TMDL	TMDL Plan-Siltation, Suspended Solids (4a)	
				Queen Anne Creek	Appendix E-Siltation (5)	Other Habitat Alterations, Water/Flow Variability (4c)
				Silver Lake	Appendix E-Excessive Algal Growth, Nutrients, Suspended Solids (5)	Other Habitat Alterations (5)
				Unnamed Tributaries to Neshaminy Creek		Water/Flow Variability (4c)
MILFORD TWP	PAI130022	Yes	SP, IP	Beaver Run	Appendix E-Siltation (5)	Water/Flow Variability (4c)
				Unnamed Tributaries to Beaver Run		Other Habitat Alterations (4c)
				Morgan Creek	Appendix E-Nutrients, Siltation (5)	
				Delmont Lake		Exotic Species (5)
				Tohickon Creek	Appendix E-Nutrients, Siltation (5)	
				Unnamed Tributaries to Unami Creek	Appendix E-Siltation (5)	Water/Flow Variability (4c)
MORRISVILLE BORO	PAG130104	No		Martins Creek	Appendix C-PCB (4a), Appendix E-Siltation (5)	Flow Alterations (4c)
				Delaware River	Appendix C-PCB (4a)	
				Rock Run	Appendix E-Siltation (5)	Flow Alterations (4c)
NEW BRITAIN BORO	PAG130154	Yes	TMDL Plan	Cooks Run	Appendix E-Nutrients (5)	
				Neshaminy Creek	Appendix B-Pathogens (5), Appendix E-Nutrients, Organic Enrichment/Low D.O. (5)	
				Neshaminy Creek TMDL	TMDL Plan-Siltation, Suspended Solids (4a)	
				North Branch Neshaminy Creek		Water/Flow Variability (4c)
				Pine Run	Appendix E-Excessive Algal Growth (5)	

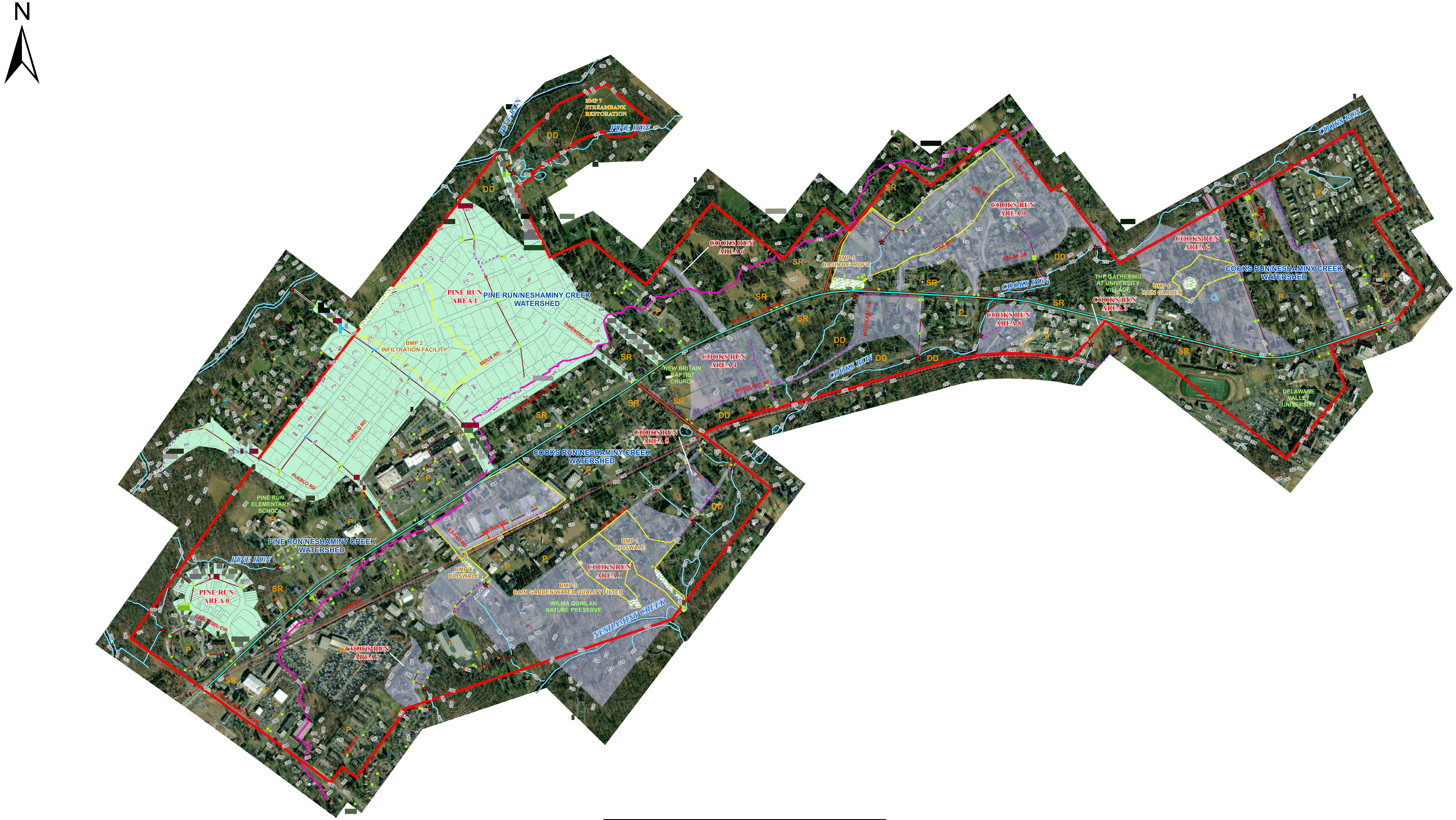
Appendix B: Public Participation

To be forthcoming upon plan approval.

Appendix C: Maps

Appendix C-1: New Britain Borough MS4 Planning Area Map

See attached at the end of the Report



NOTE: THE ENTIRETY OF NEW BRITAIN BOROUGH IS LOCATED WITHIN THE PENNSYLVANIA URBANIZED AREA.

PARSING CLASSIFICATION LEGEND

DD = DIRECT DISCHARGE; AREA FLOWS DIRECTLY TO STREAM AND DOES NOT ENTER OR MIX WITH THE MUNICIPALITY'S MS4

P = PRIVATELY OWNED/MAINTAINED; AREA IS NOT MAINTAINED BY MUNICIPALITY AND IS A SEPARTE PRIVATE ENTITY. NO DRAINAGE ENTERS OR MIXES WITH THE MUNICIPALITY'S MS4

SR = STATE ROAD; AREA IS MAINTAINED BY PENNDOT & ALL DRAINAGE TO ROAD IS MAINTAINED BY PENNDOT

Legend

Municipal Boundary	Inlet
Watershed Boundary	Manhole
Surface Water	Endwall
Planning Area - Cooks Run	Storm Pipe
BMP Locations	Swale
BMP Drainage Area	Contours
Outfall	Parcel
	State Road
	Railroad

MS4 PLANNING AREA MAP

NEW BRITAIN BOROUGH, BUCKS COUNTY, PA

GILMORE & ASSOCIATES, INC.
ENGINEERING & CONSULTING SERVICES
65 E. BUTLER AVENUE, SUITE 100, NEW BRITAIN, PA 18901 - (215) 345-4330
www.gilmore-assoc.com

JOB NO: 20-04007 | DATE: APRIL 2022 | 0 0.05 0.1 Miles

Appendix C-2: New Britain Borough Land Use Map

See attached at the end of the Report

MS4 LAND USE MAP

NEW BRITAIN BOROUGH, BUCKS COUNTY, PA

GILMORE & ASSOCIATES, INC.
ENGINEERING & CONSULTING SERVICES
65 E. BUTLER AVENUE, SUITE 100, NEW BRITAIN, PA 18901 - (215) 345-4330
www.gilmore-assoc.com

JOB NO: 20-04007 | DATE: SEPTEMBER 2021 | 0 0.05 0.1 Miles

Appendix D: Existing Loads for Pollutants of Concern

Appendix D- 1: Pine Run Total Watershed Loading

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_pine\Output\nbb_pine-8697_ua.csv

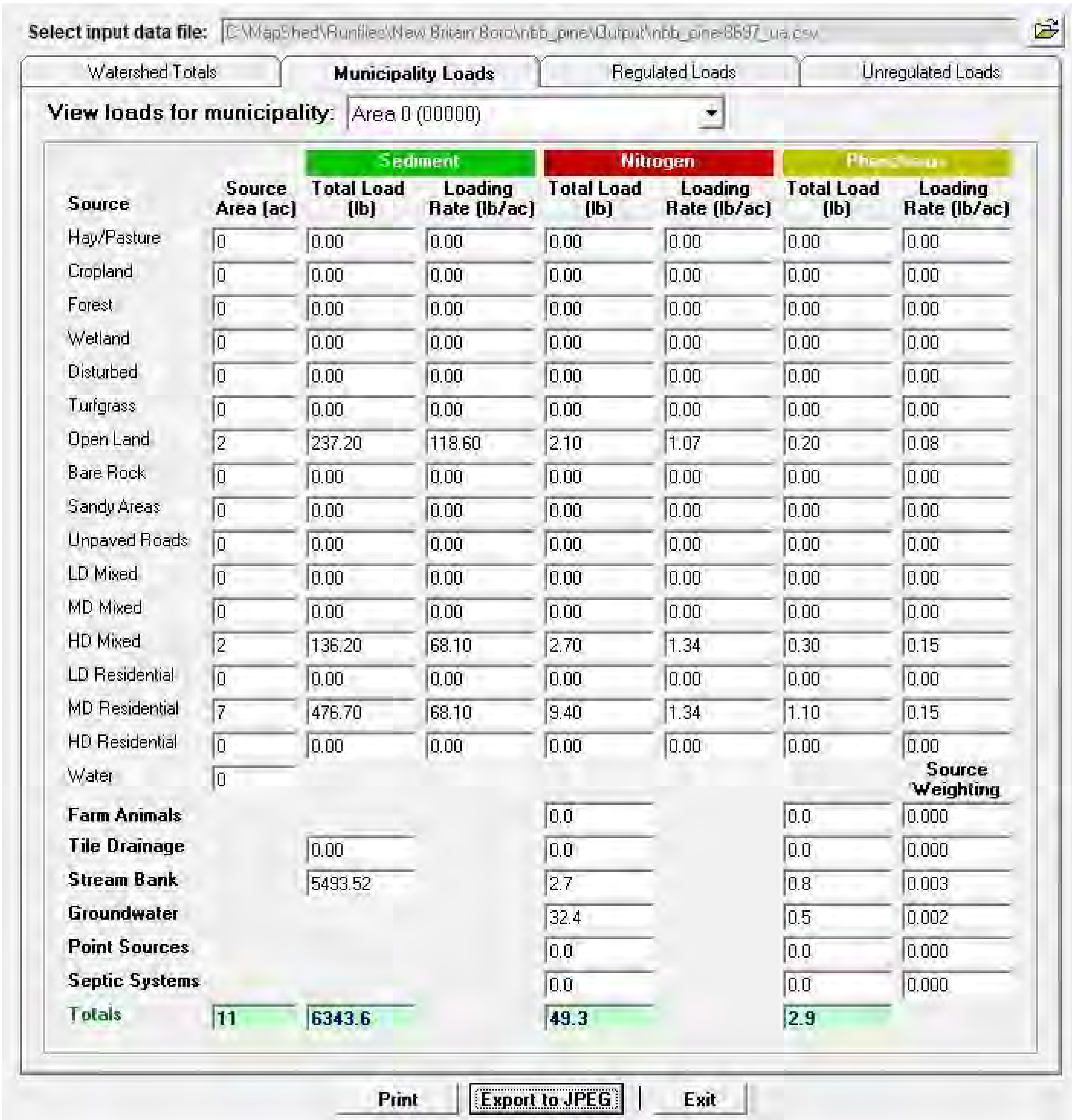
Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 8697

Source	Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	853	85914.14	100.70	583.50	0.68	152.10	0.18
Cropland	514	613921.26	1194.40	2870.51	5.58	458.45	0.89
Forest	1176	7098.88	6.00	137.63	0.12	10.56	0.01
Wetland	264	462.97	1.80	84.30	0.32	4.65	0.02
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	689	81703.31	118.60	735.53	1.07	58.33	0.08
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	247	3836.04	15.50	93.87	0.38	10.23	0.04
MD Mixed	435	29608.08	68.10	581.49	1.34	66.73	0.15
HD Mixed	529	36001.49	68.10	707.02	1.34	81.15	0.15
LD Residential	420	6525.68	15.50	159.59	0.38	17.39	0.04
MD Residential	2234	152074.87	68.10	2986.71	1.34	342.82	0.15
HD Residential	44	3020.33	68.60	59.48	1.35	6.83	0.16
Water	55						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		2537249.5		1267.7		363.8	
Groundwater				16209.8		251.0	
Point Sources				0.0		0.0	
Septic Systems				3439.0		0.0	
Totals	**7460**	**3557417**		**29916**		**1824**	

Print | Export to JPEG | Exit

Appendix D- 2: Pine Run Planning Area Loading



Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_pine\Output\nbb_pine-8697_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 0 (00000)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	2	237.20	118.60	2.10	1.07	0.20	0.08
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Mixed	2	136.20	68.10	2.70	1.34	0.30	0.15
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	7	476.70	68.10	9.40	1.34	1.10	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		5493.52		2.7		0.8	0.003
Groundwater				32.4		0.5	0.002
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	**11**	**6343.6**		**49.3**		**2.9**	

Print | Export to JPEG | Exit

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_pine\Output\nbb_pine-8697_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 1 (00001)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	2	136.20	68.10	2.70	1.34	0.30	0.15
HD Mixed	5	340.50	68.10	6.70	1.34	0.80	0.15
LD Residential	12	186.00	15.50	4.60	0.38	0.50	0.04
MD Residential	96	6537.60	68.10	128.60	1.34	14.40	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		53104.02		26.5		7.6	0.029
Groundwater				356.6		5.5	0.022
Point Sources				0.0		0.0	0.000
Septic Systems				99.7		0.0	0.029
Totals	**115**	**60304.3**		**625.4**		**29.1**	

Print | Export to JPEG | Exit

Appendix D- 3: Cooks Run Total Watershed Loading

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cook~0_ua.csv

Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 0

		Sediment		Nitrogen		Phosphorus	
Source	**Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	1707	198790.82	116.50	1222.15	0.72	315.08	0.18
Cropland	1033	1378748.94	1334.70	6058.61	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.38	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.33	0.38	26.17	0.04
MD Mixed	1310	89838.37	68.60	1774.15	1.35	201.90	0.15
HD Mixed	1278	87633.75	68.60	1730.63	1.35	196.94	0.15
LD Residential	1324	20745.50	15.70	503.18	0.38	54.78	0.04
MD Residential	4888	335279.01	68.60	6621.28	1.35	753.50	0.15
HD Residential	7	507.06	72.40	10.05	1.44	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14103006.2		7052.6		1982.0	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	**18775**	**16527165**		**76435**		**5394**	

Print | Export to JPEG | Exit

Appendix D- 4: Cooks Run Planning Area Loadings

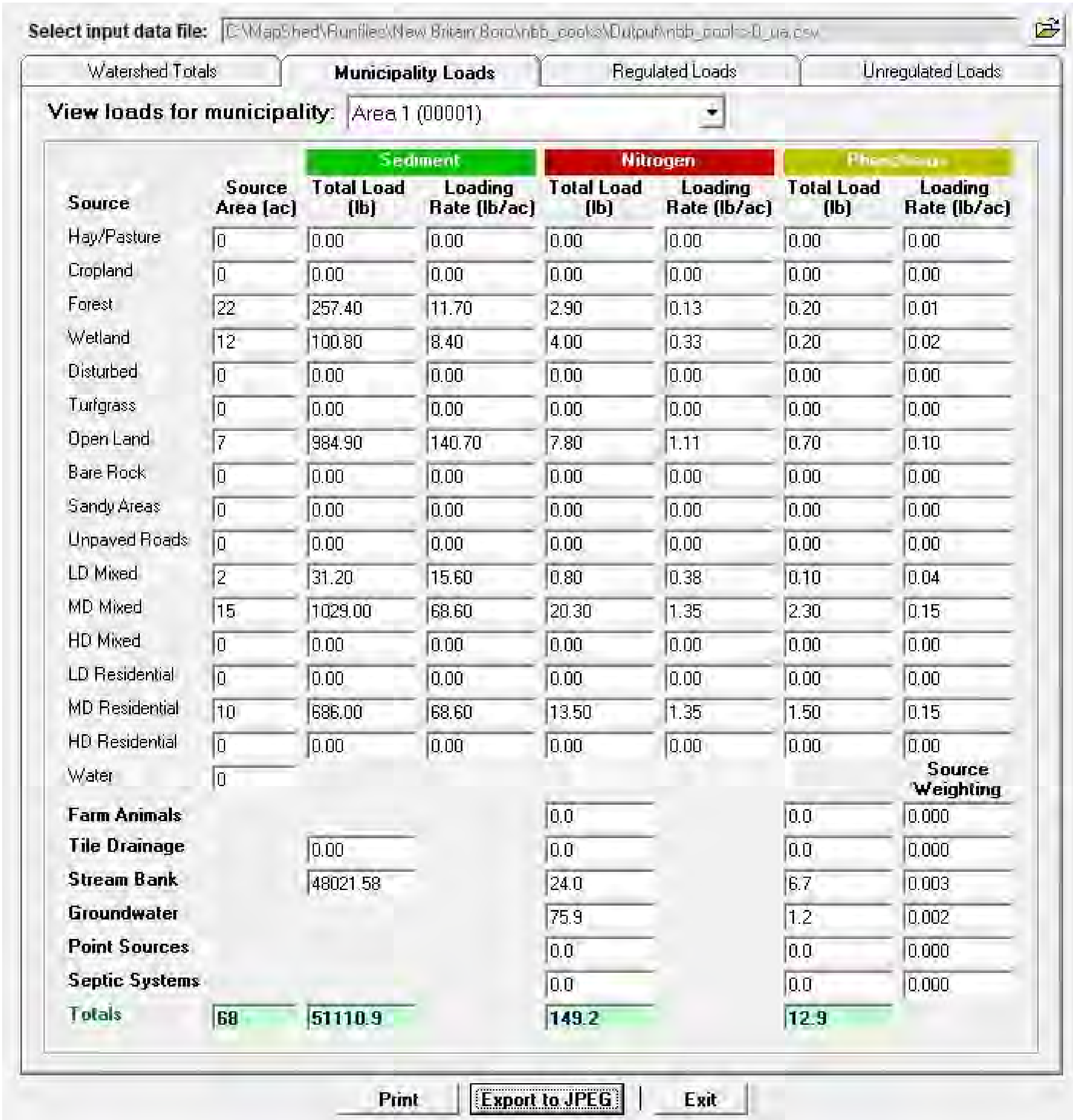
Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 0 (00000)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	2	281.40	140.70	2.20	1.11	0.20	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	2	137.20	68.60	2.70	1.35	0.30	0.15
HD Mixed	2	137.20	68.60	2.70	1.35	0.30	0.15
LD Residential	2	31.40	15.70	0.80	0.38	0.10	0.04
MD Residential	35	2401.00	68.60	47.30	1.35	5.30	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		48036.60		24.0		6.8	0.005
Groundwater				113.8		1.9	0.003
Point Sources				0.0		0.0	0.000
Septic Systems				20.8		0.0	0.002
Totals	43	51024.8		214.3		14.9	

Print | Export to JPEG | Exit



Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 1 (00001)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	22	257.40	11.70	2.90	0.13	0.20	0.01
Wetland	12	100.80	8.40	4.00	0.33	0.20	0.02
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	7	984.90	140.70	7.80	1.11	0.70	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	2	31.20	15.60	0.80	0.38	0.10	0.04
MD Mixed	15	1029.00	68.60	20.30	1.35	2.30	0.15
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	10	686.00	68.60	13.50	1.35	1.50	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		48021.58		24.0		6.7	0.003
Groundwater				75.9		1.2	0.002
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	**68**	**51110.9**		**149.2**		**12.9**	

Print | Export to JPEG | Exit

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

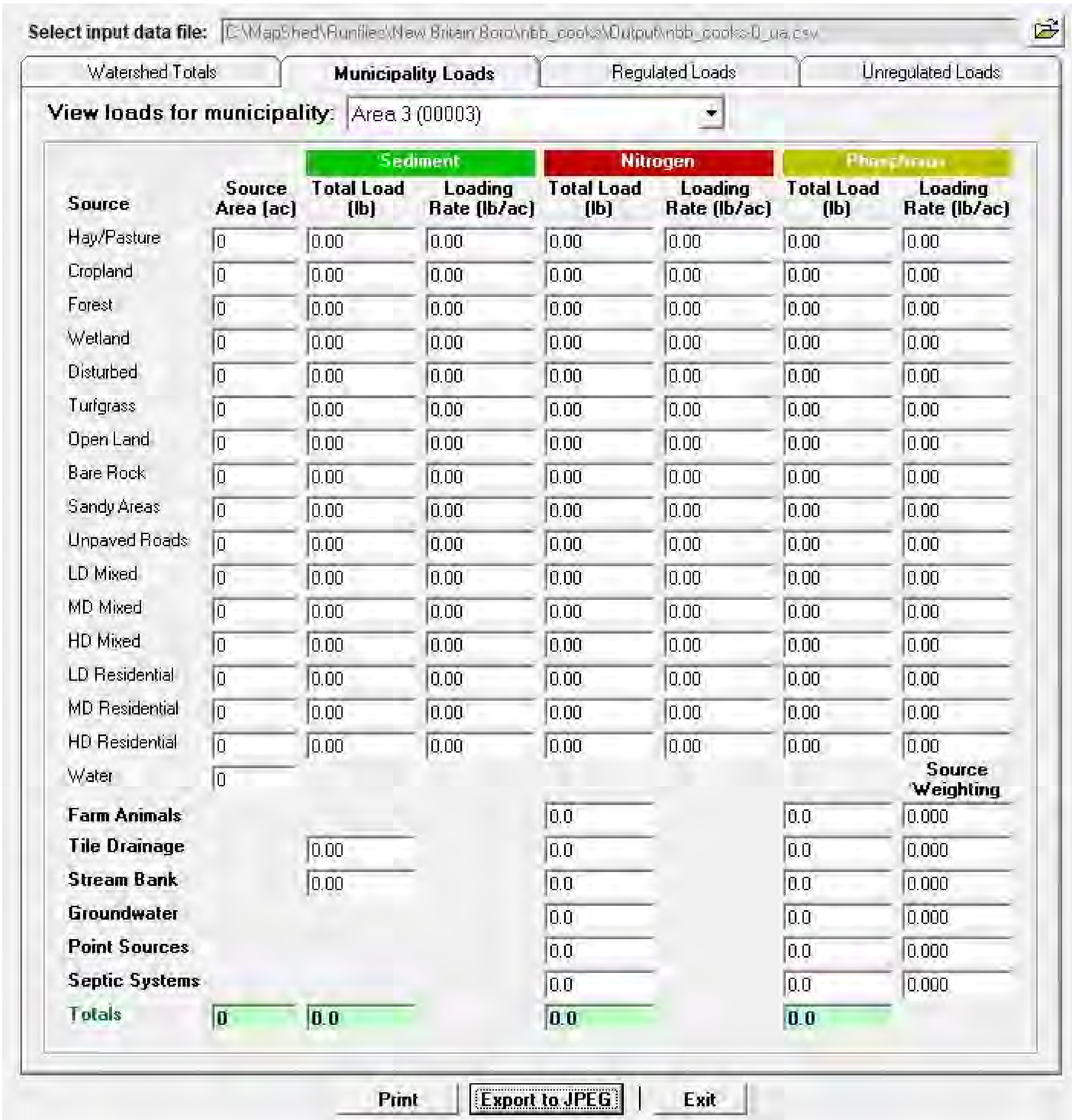
Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 2 (00002)

Source	Source Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	2	137.20	68.60	2.70	1.35	0.30	0.15
HD Mixed	2	137.20	68.60	2.70	1.35	0.30	0.15
LD Residential	22	345.40	15.70	8.40	0.38	0.90	0.04
MD Residential	5	343.00	68.60	6.80	1.35	0.80	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						

Source	Source Area (ac)	Sediment Total Load (lb)	Nitrogen Total Load (lb)	Phosphorus Total Load (lb)	Source Weighting
Farm Animals			0.0	0.0	0.000
Tile Drainage		0.00	0.0	0.0	0.000
Stream Bank		25704.65	12.9	3.6	0.002
Groundwater			113.8	1.9	0.003
Point Sources			0.0	0.0	0.000
Septic Systems			176.5	0.0	0.017
Totals	31	26667.5	323.8	7.8	

Print | Export to JPEG | Exit



Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks-0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 3 (00003)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		0.00		0.0		0.0	0.000
Groundwater				0.0		0.0	0.000
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	0	0.0		0.0		0.0	

Print | Export to JPEG | Exit

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 4 (00004)

Source	Source Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	5	58.50	11.70	0.70	0.13	0.10	0.01
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	2	281.40	140.70	2.20	1.11	0.20	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	2	137.20	68.60	2.70	1.35	0.30	0.15
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	10	157.00	15.70	3.80	0.38	0.40	0.04
MD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		14655.11		7.3		2.1	0.001
Groundwater				37.9		0.6	0.001
Point Sources				0.0		0.0	0.000
Septic Systems				72.7		0.0	0.007
Totals	**19**	**15289.2**		**127.3**		**3.7**	

Print | Export to JPEG | Exit

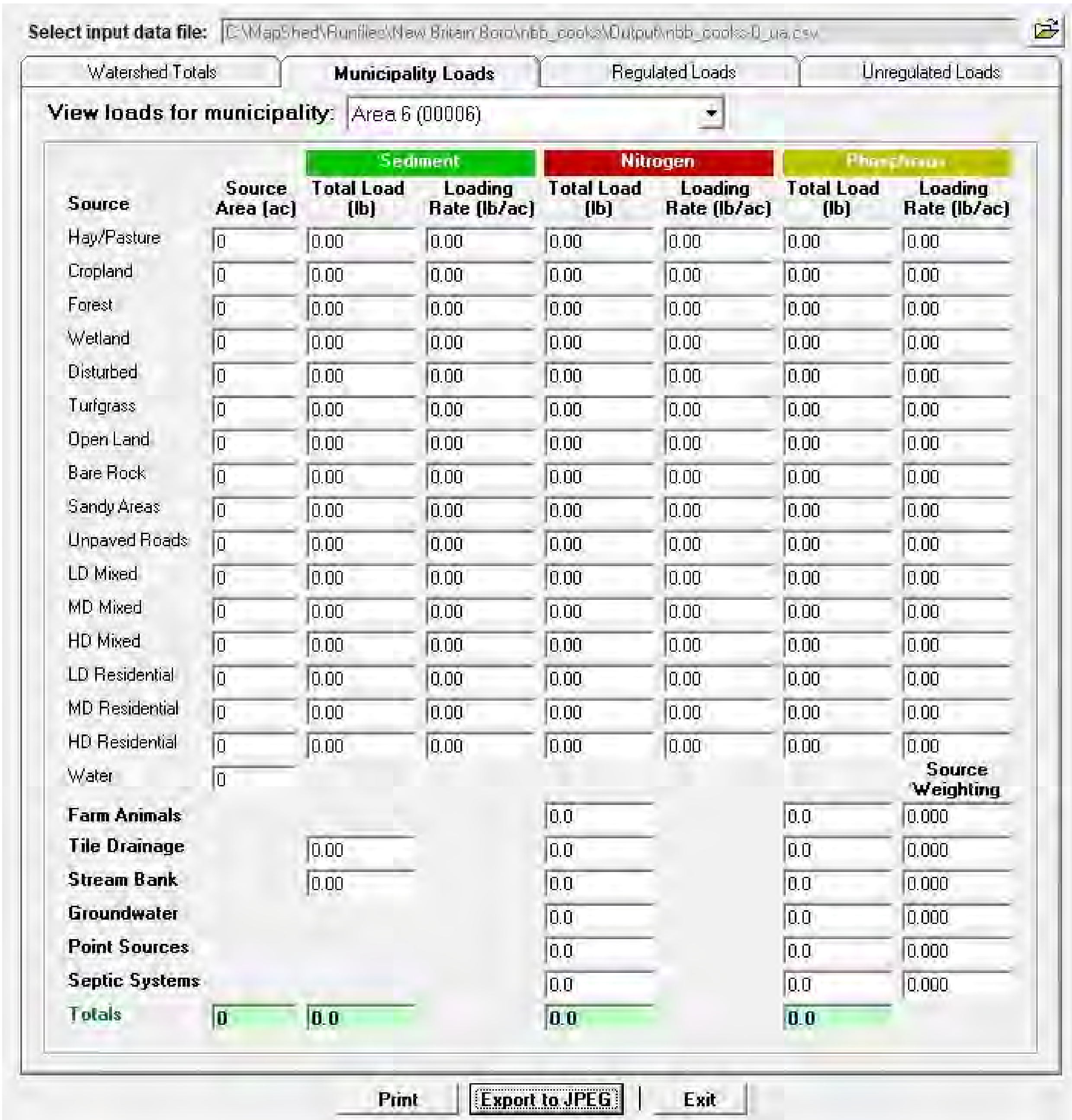
Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 5 (00005)

Source	Source Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	2	137.20	68.60	2.70	1.35	0.30	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		901.39		0.5		0.1	0.000
Groundwater				0.0		0.0	0.000
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	2	1038.6		3.2		0.4	

Print | Export to JPEG | Exit


Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks-0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 6 (00006)

Source	Source Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						Source Weighting
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		0.00		0.0		0.0	0.000
Groundwater				0.0		0.0	0.000
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	0	0.0		0.0		0.0	

Print | Export to JPEG | Exit

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

View loads for municipality: Area 7 (00007)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	2	137.20	68.60	2.70	1.35	0.30	0.15
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		901.39		0.5		0.1	0.000
Groundwater				0.0		0.0	0.000
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	2	1038.6		3.2		0.4	

Print | Export to JPEG | Exit

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks-0_ua.csv

Watershed Totals | **Municipality Loads** | Regulated Loads | Unregulated Loads

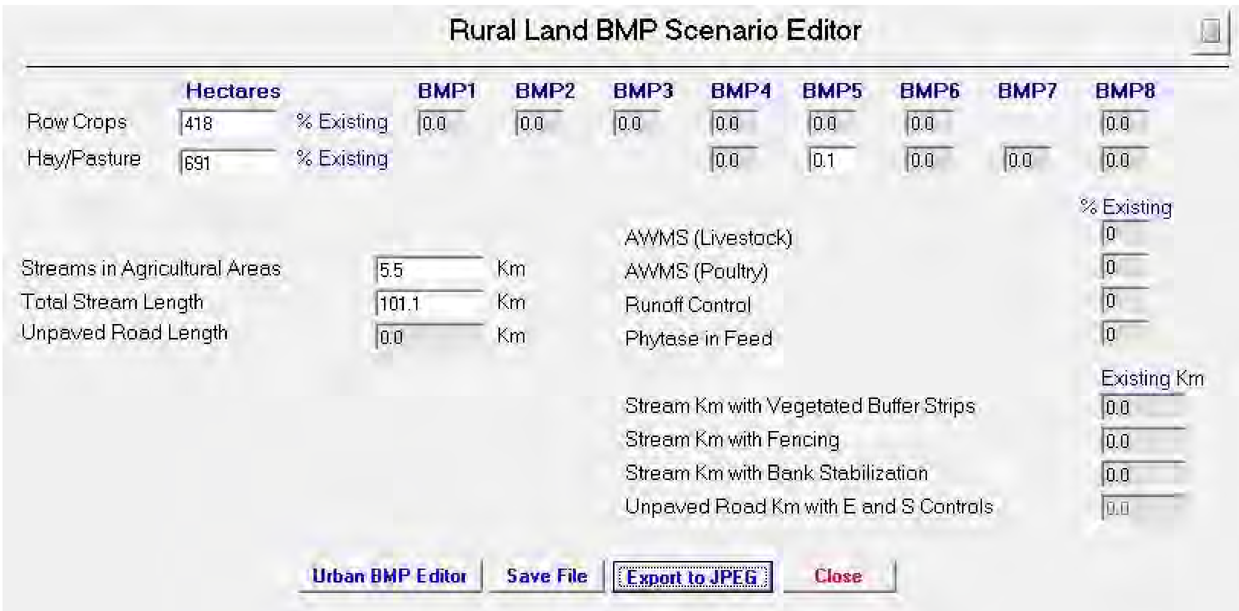
View loads for municipality: Area 8 (00008)

		Sediment		Nitrogen		Phosphorus	
Source	**Source Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	0	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	0	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0	0.00	0.00	0.00	0.00	0.00	0.00
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	0	0.00	0.00	0.00	0.00	0.00	0.00
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Mixed	5	343.00	68.60	6.80	1.35	0.80	0.15
HD Mixed	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
MD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
HD Residential	0	0.00	0.00	0.00	0.00	0.00	0.00
Water	0						**Source Weighting**
Farm Animals				0.0		0.0	0.000
Tile Drainage		0.00		0.0		0.0	0.000
Stream Bank		7894.68		3.9		1.1	0.001
Groundwater				0.0		0.0	0.000
Point Sources				0.0		0.0	0.000
Septic Systems				0.0		0.0	0.000
Totals	5	8237.7		10.7		1.9	

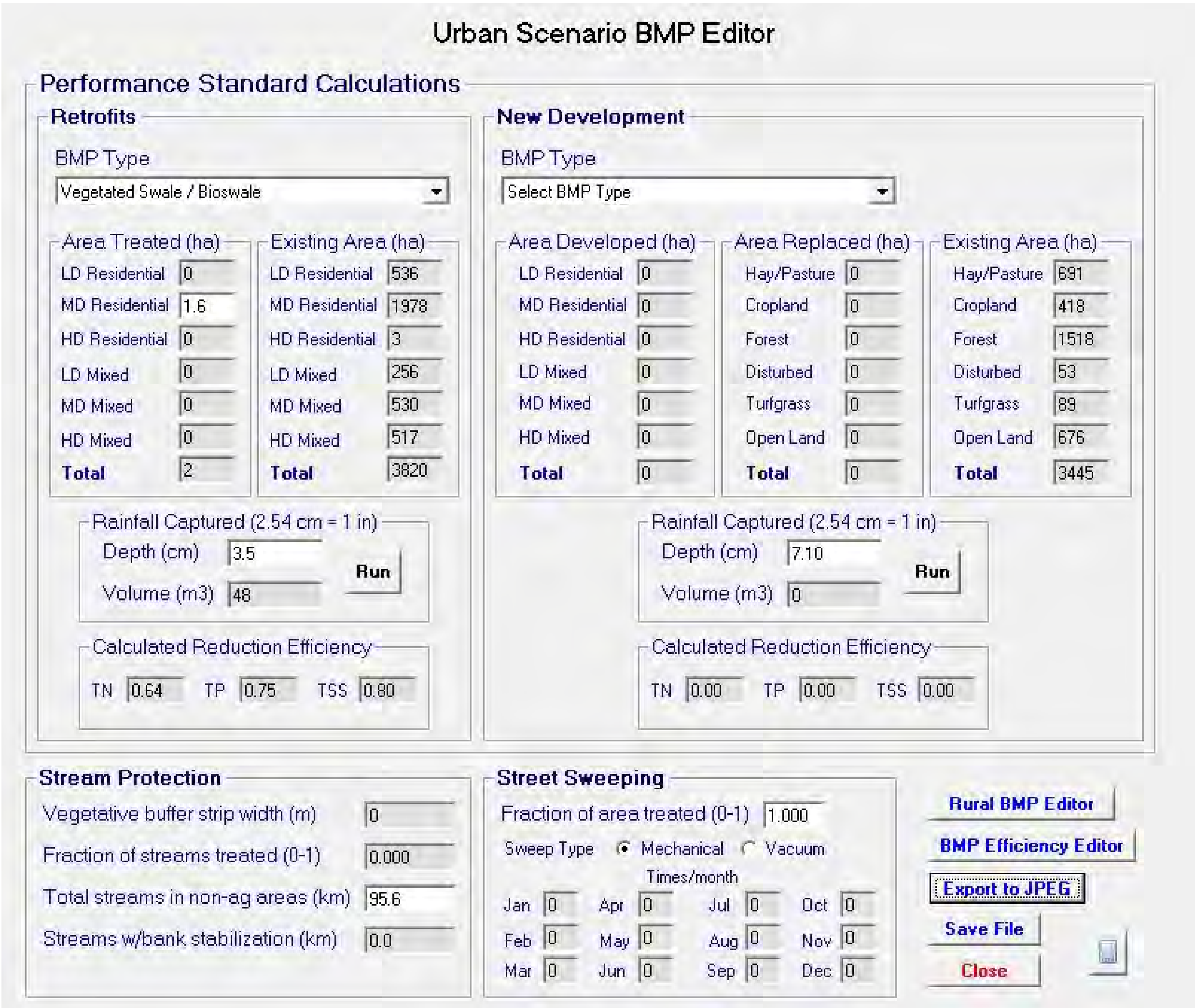
Print | Export to JPEG | Exit

Appendix E: Proposed Pollutant Load Reductions

Appendix E-1.1: BMP 1 – Aarons Ave., Drainage Area Parameters



Appendix E-1.2: BMP 1 – Aarons Ave., BMP Type & Efficiency



Appendix E-1.3: BMP 1 – Aarons Ave., Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks_bmp1_aaron-0_na.csv

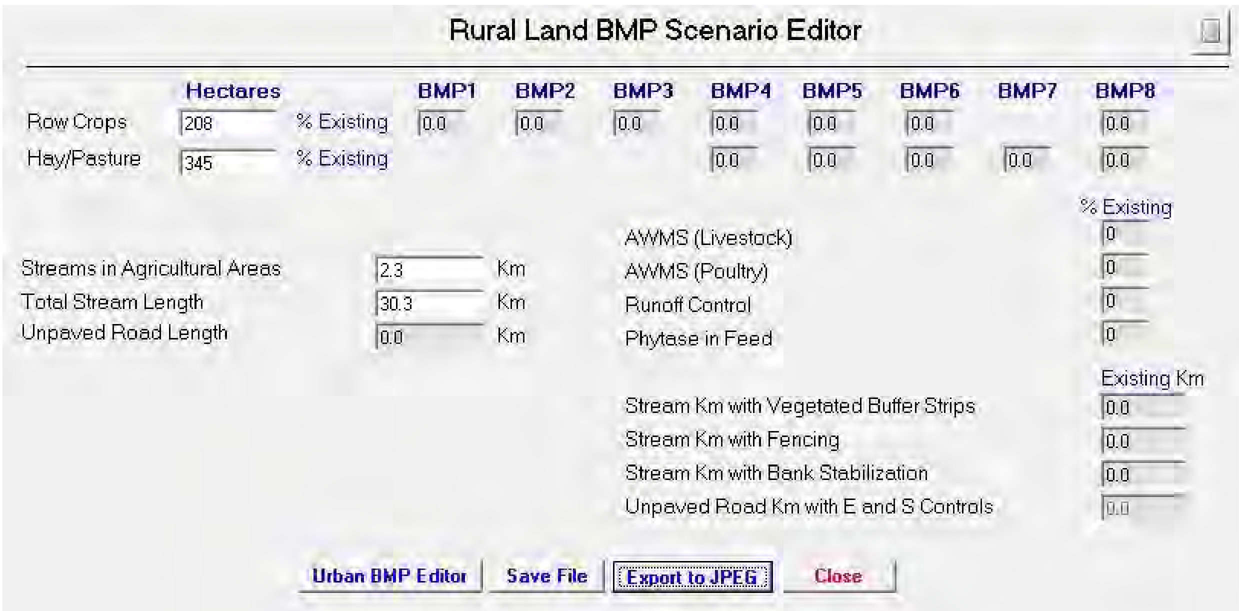
Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 0

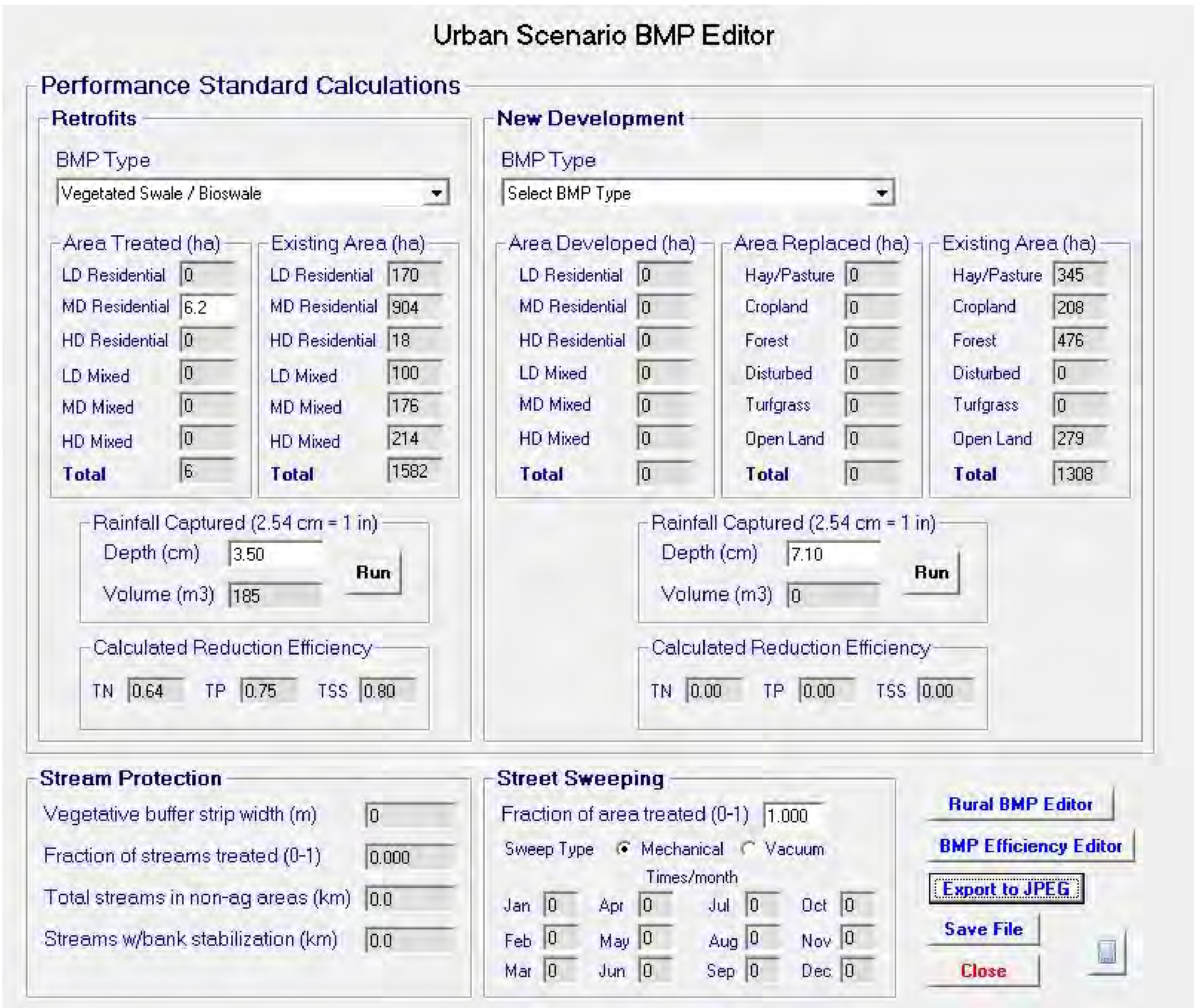
		Sediment		Nitrogen		Phosphorus	
Source	**Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	1707	198614.45	116.40	1221.36	0.72	314.84	0.18
Cropland	1033	1378748.94	1334.70	6058.63	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.38	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.26	0.38	26.15	0.04
MD Mixed	1310	89816.33	68.60	1773.64	1.35	201.83	0.15
HD Mixed	1278	87611.70	68.60	1730.14	1.35	196.87	0.15
LD Residential	1324	20745.50	15.70	503.05	0.38	54.76	0.04
MD Residential	4888	335168.78	68.60	6619.40	1.35	753.25	0.15
HD Residential	7	507.06	72.40	10.03	1.43	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14099829.3		7050.4		1982.0	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	18775	16523658		76429		5394	

Print | Export to JPEG | Exit

Appendix E-2.1: BMP 2 – N. Tamanend Ave., Drainage Area Parameters



Appendix E-2.2: BMP 2 – N. Tamanend Ave., BMP Type & Efficiency



Appendix E-2.3: BMP 2 – N. Tamanend Ave., Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_pine\Output\nbb_pine_bmp2_Tamanend-8697_ua.csv

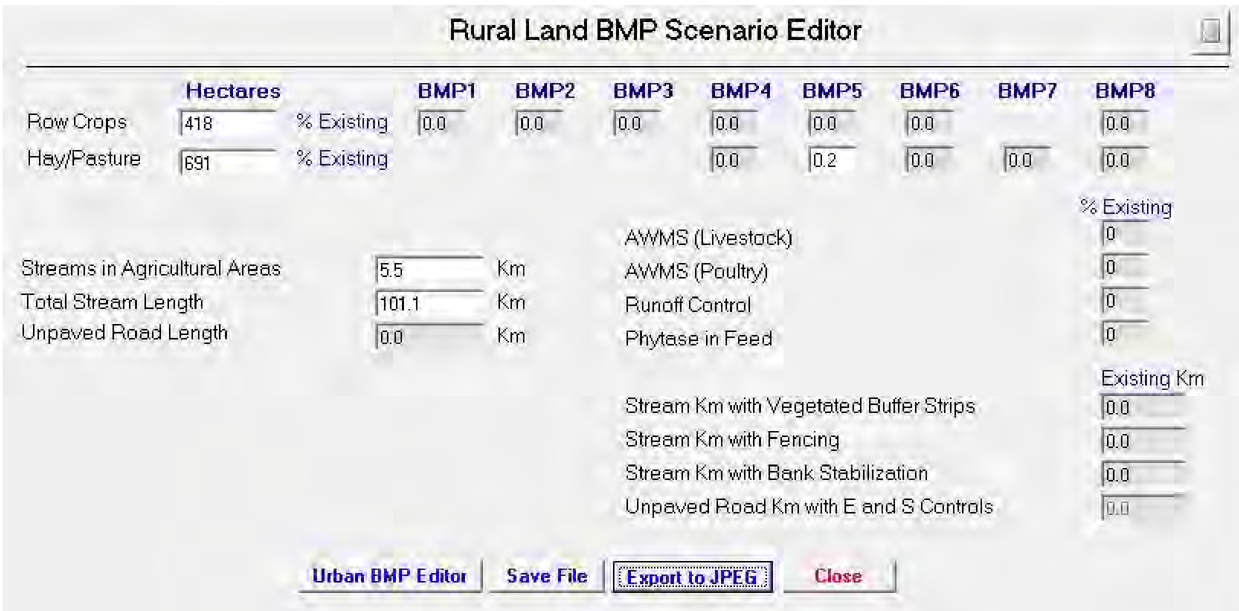
Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 8697

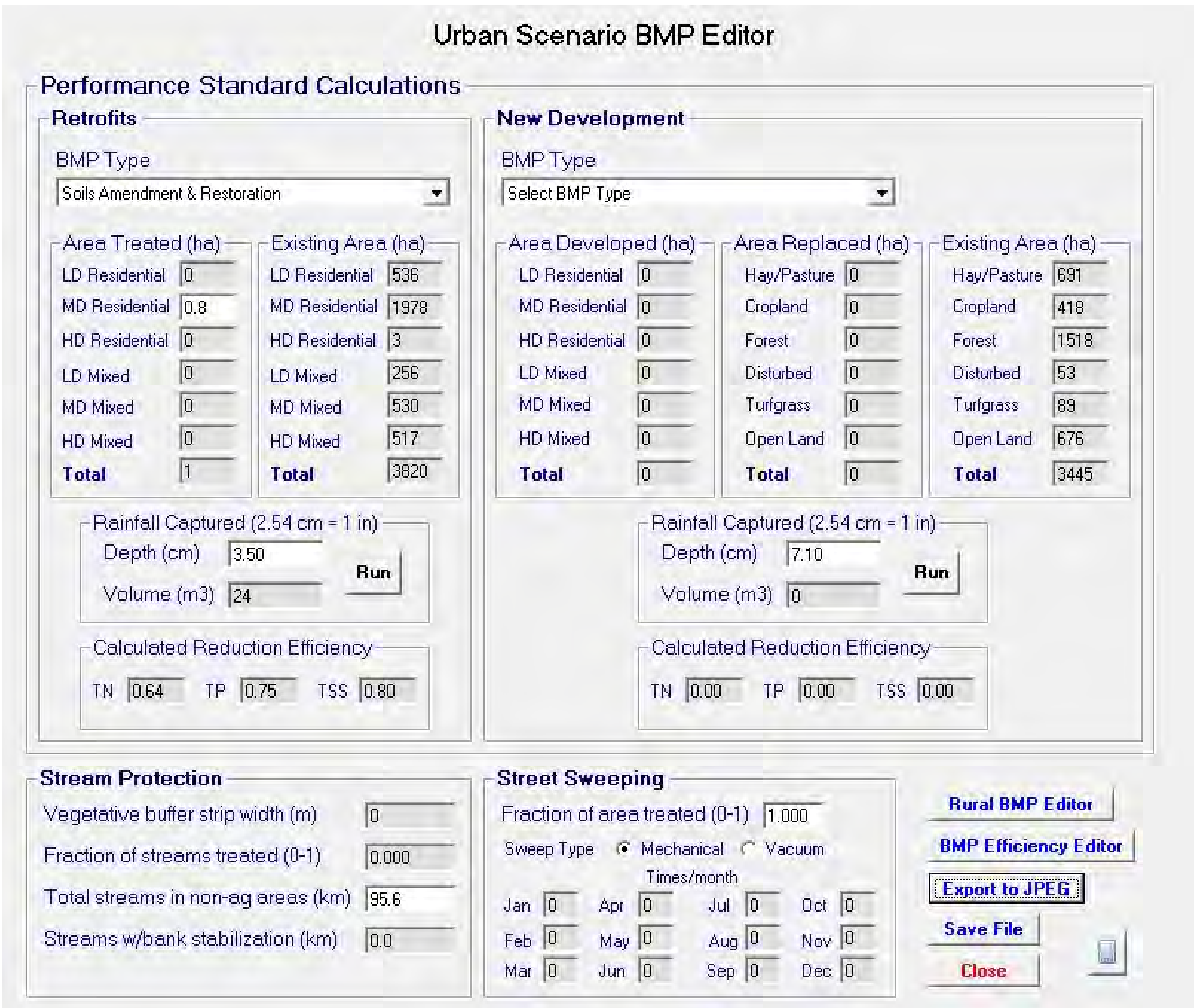
		Sediment		Nitrogen		Phosphorus	
Source	**Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	853	85914.14	100.70	583.50	0.68	152.10	0.18
Cropland	514	613921.26	1194.40	2870.51	5.58	458.45	0.89
Forest	1176	7098.88	6.00	137.63	0.12	10.56	0.01
Wetland	264	462.97	1.80	84.30	0.32	4.65	0.02
Disturbed	0	0.00	0.00	0.00	0.00	0.00	0.00
Turfgrass	0	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	689	81703.31	118.60	735.53	1.07	58.33	0.08
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	247	3836.04	15.50	93.87	0.38	10.23	0.04
MD Mixed	435	29608.08	68.10	581.49	1.34	66.73	0.15
HD Mixed	529	36001.49	68.10	707.02	1.34	81.15	0.15
LD Residential	420	6525.68	15.50	159.59	0.38	17.39	0.04
MD Residential	2234	152074.87	68.10	2986.71	1.34	342.82	0.15
HD Residential	44	3020.33	68.60	59.48	1.35	6.83	0.16
Water	55						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		2531931.9		1265.5		363.8	
Groundwater				16209.8		251.0	
Point Sources				0.0		0.0	
Septic Systems				3439.0		0.0	
Totals	7460	3552099		29914		1824	

Print | Export to JPEG | Exit

Appendix E-3.1: BMP 3 – S. Landis Mill Rd., Drainage Area Parameters



Appendix E-3.2: BMP 3 – S. Landis Mill Rd., BMP Type & Efficiency



Appendix E-3.3: BMP 3 – S. Landis Mill Rd., Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks_bmp3_LandisMill-0_ue.c

Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

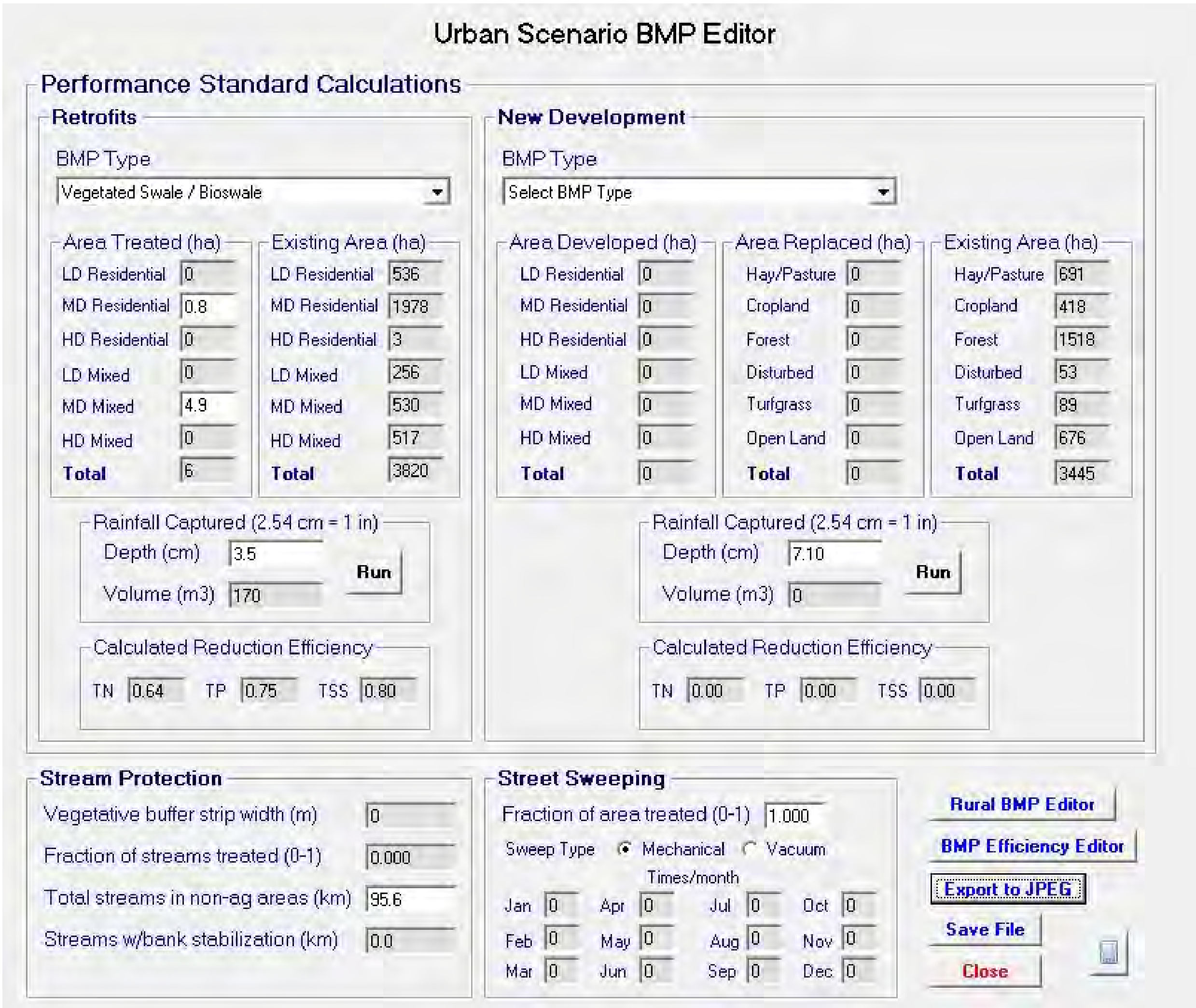
GWLF-E Average Loads by Source for Watershed 0

Source	Area (ac)	Sediment Total Load (lb)	Sediment Loading Rate (lb/ac)	Nitrogen Total Load (lb)	Nitrogen Loading Rate (lb/ac)	Phosphorus Total Load (lb)	Phosphorus Loading Rate (lb/ac)
Hay/Pasture	1707	198460.13	116.30	1220.59	0.72	314.62	0.18
Cropland	1033	1378748.94	1334.70	6058.63	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.38	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.30	0.38	26.17	0.04
MD Mixed	1310	89816.33	68.60	1773.91	1.35	201.86	0.15
HD Mixed	1278	87611.70	68.60	1730.39	1.35	196.92	0.15
LD Residential	1324	20745.50	15.70	503.12	0.38	54.76	0.04
MD Residential	4888	335234.92	68.60	6620.35	1.35	753.39	0.15
HD Residential	7	507.06	72.40	10.03	1.43	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14101416.6		7050.4		1982.0	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	**18775**	**16525157**		**76430**		**5394**	

Print | Export to JPEG | Exit

Appendix E-4.1: BMP 4 – S. Sand Rd., Drainage Area Parameters

Appendix E-4.2: BMP 4 – S. Sand Rd., BMP Type & Efficiency



Appendix E-4.3: BMP 4 – S. Sand Rd., Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks_bmp4_Sands-0_ue.cs

Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 0

		Sediment		Nitrogen		Phosphorus	
Source	**Area (ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**	**Total Load (lb)**	**Loading Rate (lb/ac)**
Hay/Pasture	1707	198790.82	116.50	1222.15	0.72	315.08	0.18
Cropland	1033	1378748.94	1334.70	6058.63	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.39	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.33	0.38	26.17	0.04
MD Mixed	1310	89838.37	68.60	1774.15	1.35	201.90	0.15
HD Mixed	1278	87633.75	68.60	1730.63	1.35	196.94	0.15
LD Residential	1324	20745.50	15.70	503.21	0.38	54.78	0.04
MD Residential	4888	335279.01	68.60	6621.28	1.35	753.50	0.15
HD Residential	7	507.06	72.40	10.05	1.44	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14091700.9		7046.0		1979.8	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	**18775**	**16515860**		**76428**		**5392**	

Print | Export to JPEG | Exit

Appendix E-5.1: BMP 5 – Fluehr Funeral Home, Drainage Area Parameters

Appendix E-5.2: BMP 5 – Fluehr Funeral Home, BMP Type & Efficiency

Appendix E-5.3: BMP 5 – Fluehr Funeral Home, Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks_bmp5_Fluehr-0_ua.csv

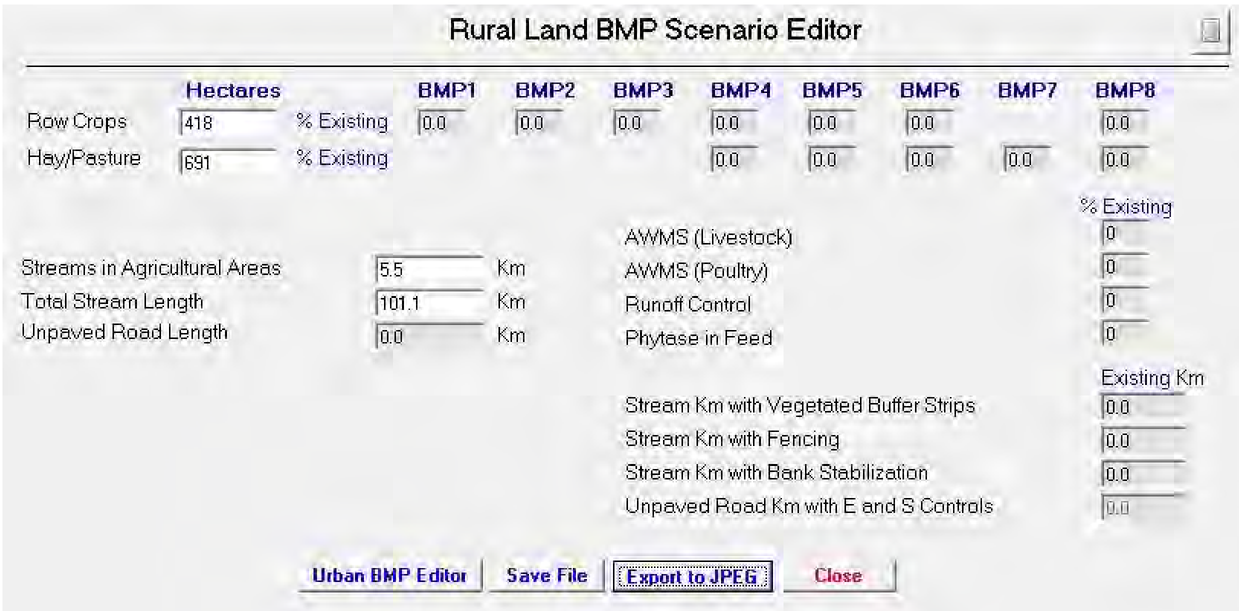
Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 0

		Sediment		Nitrogen		Phosphorus	
Source	Area (ac)	Total Load (lb)	Loading Rate (lb/ac)	Total Load (lb)	Loading Rate (lb/ac)	Total Load (lb)	Loading Rate (lb/ac)
Hay/Pasture	1707	198614.45	116.40	1221.36	0.72	314.84	0.18
Cropland	1033	1378748.94	1334.70	6058.63	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.38	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.33	0.38	26.17	0.04
MD Mixed	1310	89838.37	68.60	1774.15	1.35	201.90	0.15
HD Mixed	1278	87633.75	68.60	1730.63	1.35	196.94	0.15
LD Residential	1324	20745.50	15.70	503.21	0.38	54.78	0.04
MD Residential	4888	335279.01	68.60	6621.28	1.35	753.50	0.15
HD Residential	7	507.06	72.40	10.05	1.44	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14087734.8		7043.8		1979.8	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	**18775**	**16511717**		**76425**		**5392**	

Print | Export to JPEG | Exit

Appendix E-6.1: BMP 6 – Barrie Cir., Drainage Area Parameters



Appendix E-6.2: BMP 6 – Barrie Cir., BMP Type & Efficiency

Appendix E-6.3: BMP 6 – Barrie Cir., Watershed Loading w/ BMP

Select input data file: C:\MapShed\Runfiles\New Britain Boro\nbb_cooks\Output\nbb_cooks_bmp6_Barrie-0_na.cs

Watershed Totals | Municipality Loads | Regulated Loads | Unregulated Loads

GWLF-E Average Loads by Source for Watershed 0

		Sediment		Nitrogen		Phosphorus	
Source	Area (ac)	Total Load (lb)	Loading Rate (lb/ac)	Total Load (lb)	Loading Rate (lb/ac)	Total Load (lb)	Loading Rate (lb/ac)
Hay/Pasture	1707	198790.82	116.50	1222.15	0.72	315.08	0.18
Cropland	1033	1378748.94	1334.70	6058.63	5.87	985.42	0.95
Forest	3751	43849.94	11.70	481.38	0.13	45.37	0.01
Wetland	823	6922.52	8.40	273.35	0.33	17.55	0.02
Disturbed	131	8135.06	62.10	21.47	0.16	7.17	0.05
Turfgrass	220	8884.63	40.40	277.85	1.26	24.32	0.11
Open Land	1670	234924.59	140.70	1856.12	1.11	159.75	0.10
Bare Rock	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandy Areas	0	0.00	0.00	0.00	0.00	0.00	0.00
Unpaved Roads	0	0.00	0.00	0.00	0.00	0.00	0.00
LD Mixed	633	9898.76	15.60	240.33	0.38	26.17	0.04
MD Mixed	1310	89838.37	68.60	1774.15	1.35	201.90	0.15
HD Mixed	1278	87633.75	68.60	1730.63	1.35	196.94	0.15
LD Residential	1324	20745.50	15.70	503.21	0.38	54.78	0.04
MD Residential	4888	335279.01	68.60	6621.28	1.35	753.50	0.15
HD Residential	7	507.06	72.40	10.05	1.44	1.15	0.16
Water	7.6210909						
Farm Animals				0.0		0.0	
Tile Drainage		0.0		0.0		0.0	
Stream Bank		14100583.3		7050.4		1982.0	
Groundwater				37930.9		623.1	
Point Sources				0.0		0.0	
Septic Systems				10380.9		0.0	
Totals	18775	16524742		76433		5394	

Print | Export to JPEG | Exit

Appendix E-7: BMP 7 – Pine Run Creek, Covered Bridge/Orchard Parks, Streambank Restoration BMP Calculation

BMP 7 - Pine Run Creek, Covered Bridge/Orchard Parks		
BMP Type	Streambank Restoration	
Reduction Requirement (per MapShed loading rate)		
TN	TP	TSS
		115 lbs/ft/year

Streambank Length to be Restored (ft)	100
Sediment Load Removed by BMP (lbs/year)	11,500

Appendix F: BMP Descriptions, Operations, Maintenance and Inspections

Appendix F-1: Bioswale Description, Operation, Maintenance and Inspections

BMP 6.4.8: Vegetated Swale

Hawthorne Ridge Subdivision (SE 162nd, South of Foster)

A Vegetated Swale is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. In steeper slope situations, check dams may be used to further enhance attenuation and infiltration opportunities.

- Plant dense, low-growing native vegetation that is water-resistant, drought and salt tolerant, providing substantial pollutant removal capabilities
- Longitudinal slopes range from 1 to 6%
- Side slopes range from 3:1 to 5:1
- Bottom width of 2 to 8 feet
- Check-dams can provide limited detention storage, as well as enhanced volume control through infiltration. Care must be taken to prevent erosion around the dam
- Convey the 10-year storm event with a minimum of 6 inches of freeboard
- Designed for non-erosive velocities up to the 10-year storm event
- Design to aesthetically fit into the landscape, where possible
- Significantly slow the rate of runoff conveyance compared to pipes

Potential Applications

Residential:
Commercial: Yes Yes
Ultra Urban: Limited
Industrial: Yes Yes
Retrofit: Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Med./High
Water Quality: Med./High

Water Quality Functions

TSS: 50%
TP: 50%
NO3: 20%

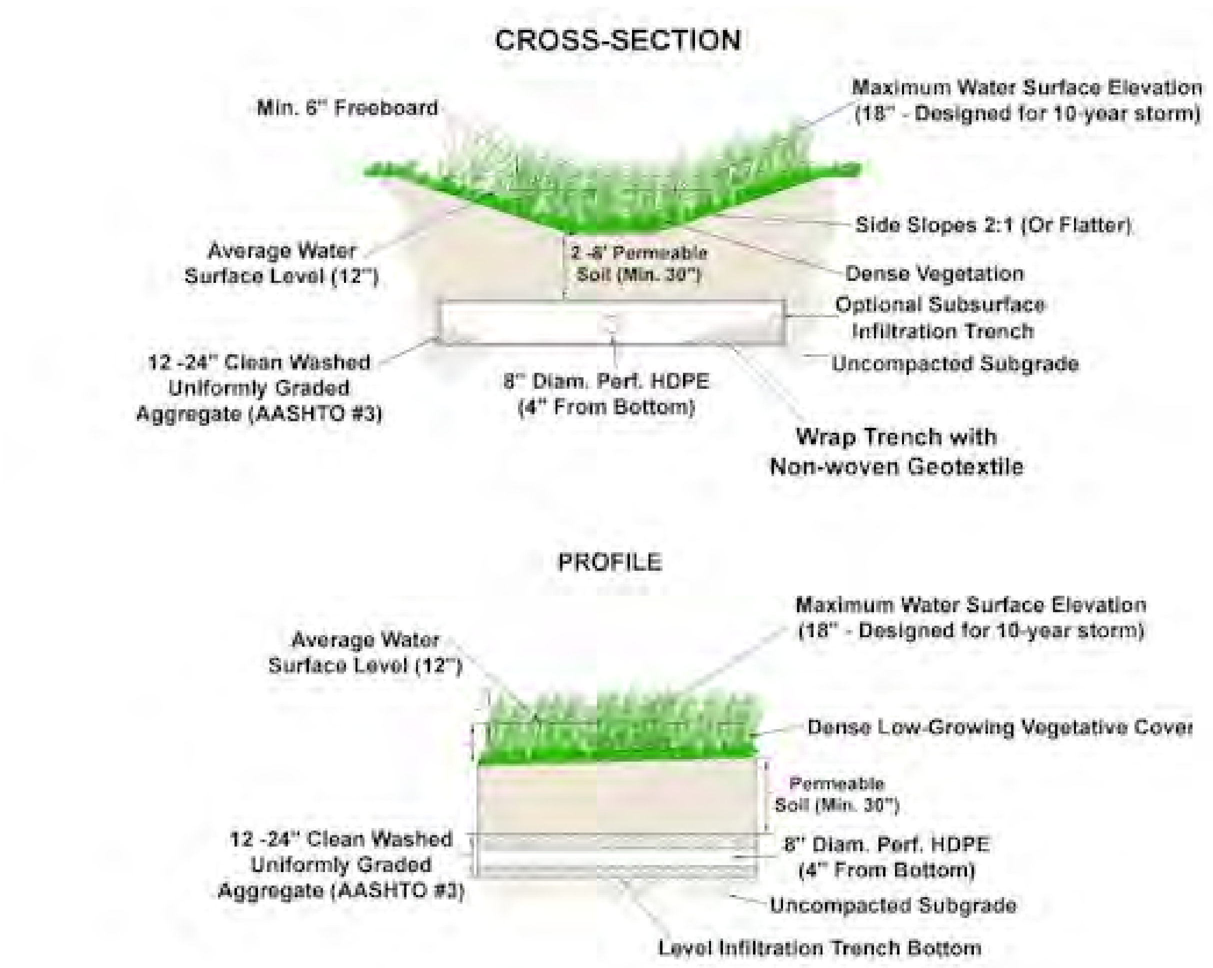
Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed whenever infiltration of runoff is desired, see Appendix C

Description

Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated Swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems, while providing partially treated (pretreatment) and partially distributed stormwater flows to subsequent BMPs. Swales are often heavily vegetated with a dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential. The various pollutant removal mechanisms of a swale include: sedimentary filtering by the swale vegetation (both on side slopes and on bottom), filtering through a subsoil matrix, and/or infiltration into the underlying soils with the full array of infiltration-oriented pollutant removal mechanisms.

A Vegetated Swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (See BMP 6.4.4 Infiltration Trench for further design guidelines).



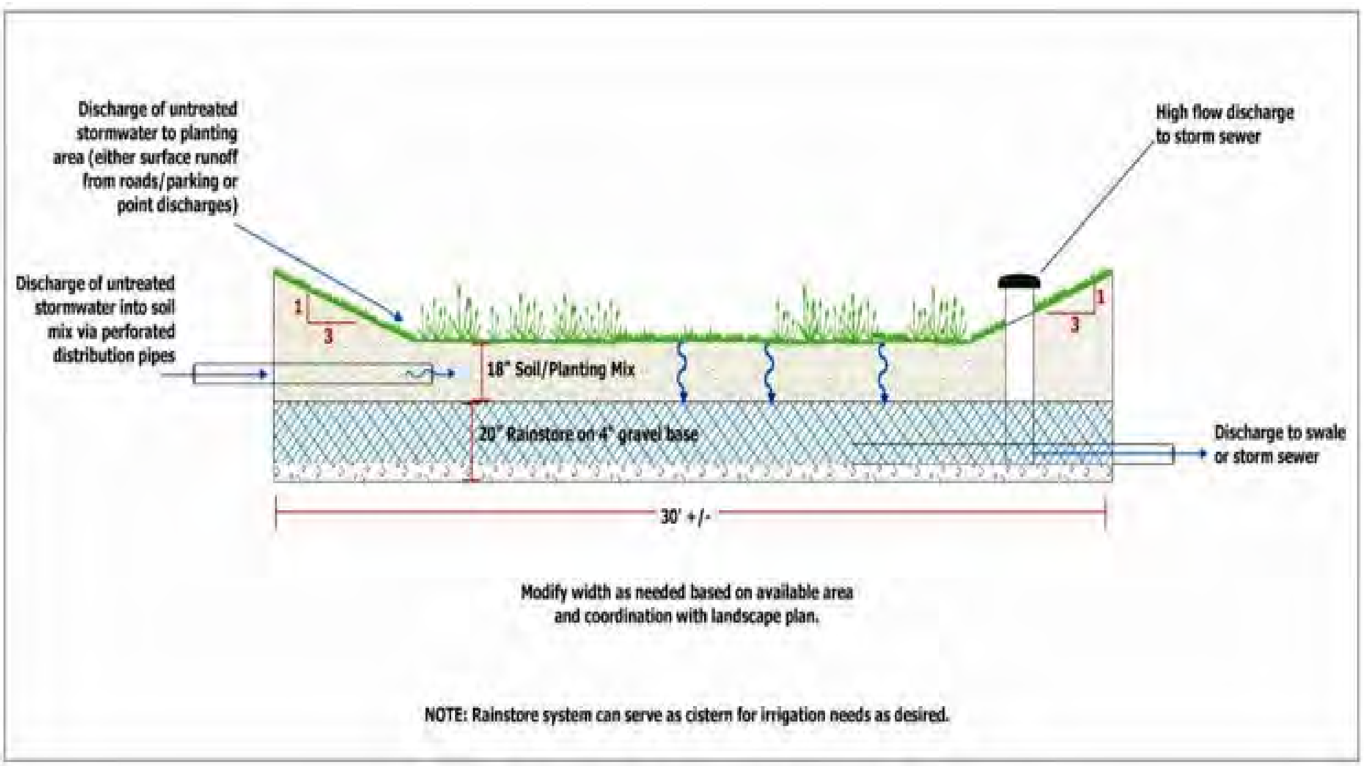
A major concern when designing Vegetated Swales is to make certain that excessive stormwater flows, slope, and other factors do not combine to produce erosive flows, which exceed the Vegetated Swale capabilities. Use of check dams or turf reinforcement matting (TRM) can enhance swale performance in some situations.

A key feature of vegetated swale design is that swales can be well integrated into the landscape character of the surrounding area. A vegetated swale can often enhance the aesthetic value of a site through the selection of appropriate native vegetation. Swales may also discreetly blend in with landscaping features, especially when adjacent to roads.

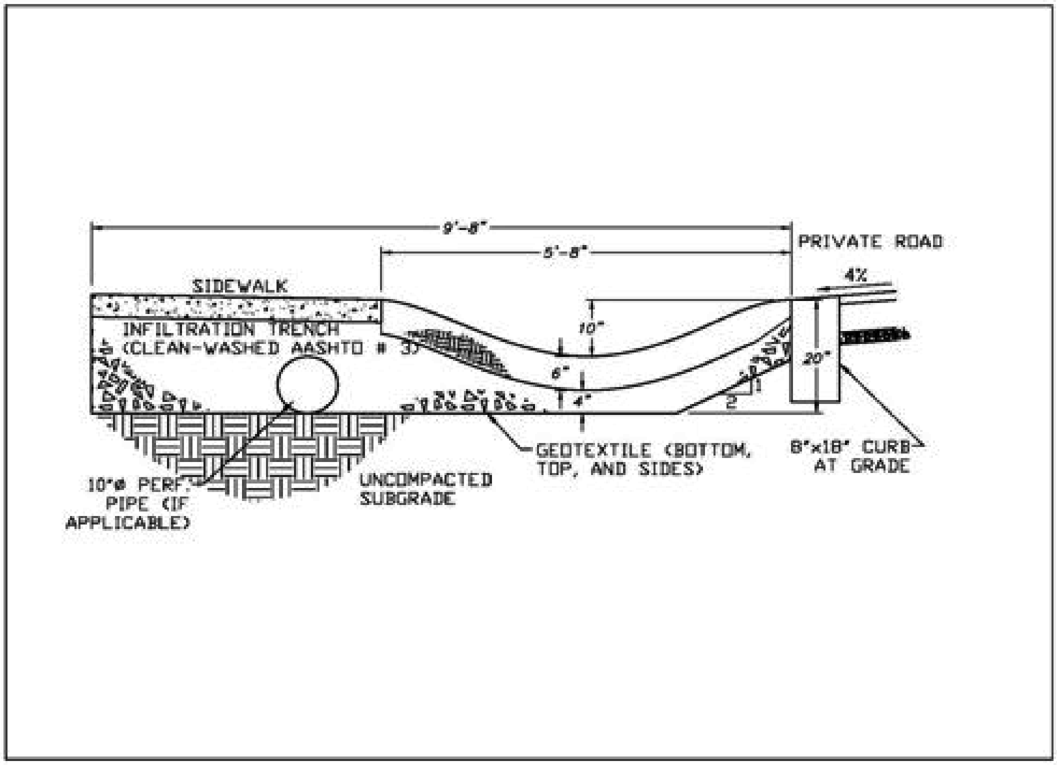
Variations

Vegetated Swale with Infiltration Trench

This option includes a 12 to 24 inch aggregate bed or trench, wrapped in a nonwoven geotextile (See BMP 6.4.4 Infiltration Trench for further design guidelines). This addition of an aggregate bed or trench substantially increases volume control and water quality performance although costs also are increased. Soil Testing and Infiltration Protocols in Appendix C should be followed.



Vegetated Swales with Infiltration Trenches are best fitted for milder sloped swales where the addition of the aggregate bed system is recommended to make sure that the maximum allowable ponding time of 72 hours is not exceeded. This aggregate bed system should consist of at least 12 inches of uniformly graded aggregate. Ideally, the underdrain system shall be designed like an infiltration trench. The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the required storage of the 1-inch storm event.



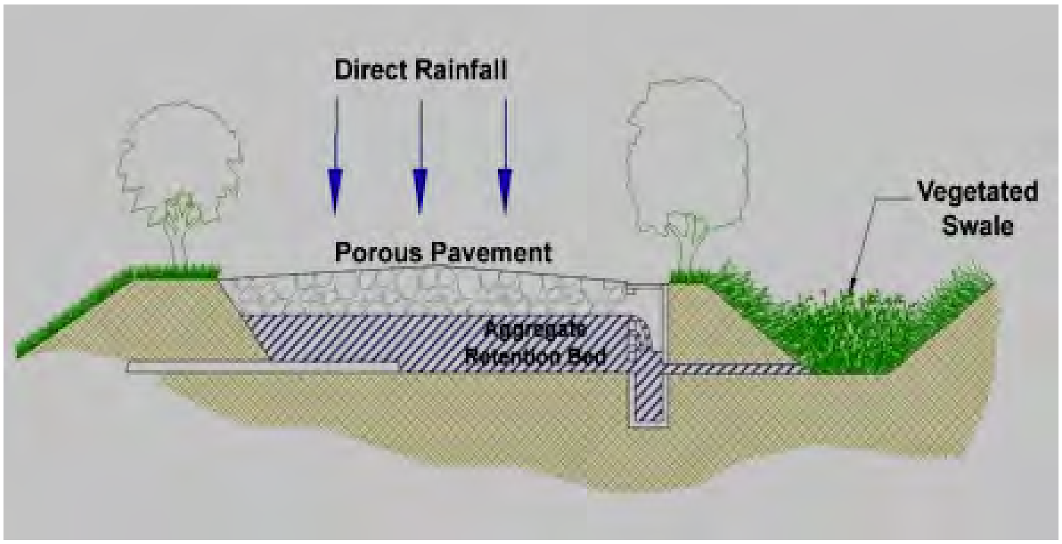
Grass Swale

Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than swales with longer and denser vegetation. However, they provide far less infiltration and pollutant removal opportunities. Grass swales are to be used only as pretreatment for other structural BMPs. Design of grass swales is often rate-based. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to reduce the rate of flow across a site.

Wet Swales

Wet swales are essentially linear wetland cells. Their design often incorporates shallow, permanent pools or marshy conditions that can sustain wetland vegetation, which in turn provides potentially high pollutant removal. A high water table or poorly drained soils are a prerequisite for wet swales. The drawback with wet swales, at least in residential or commercial settings, is that they may promote mosquito breeding in the shallow standing water (follow additional guidance under Constructed Wetland for reducing mosquito population). Infiltration is minimal if water remains for extended periods.

Applications



- **Parking**
- **Commercial and light industrial facilities**
- **Roads and highways**
- **Residential developments**
- **Pretreatment for volume-based BMPs**
- **Alternative to curb/gutter and storm sewer**

Design Considerations

1. Vegetated Swales are sized to temporarily store and infiltrate the 1-inch storm event, while providing conveyance for up to the 10-year storm with freeboard; flows for up to the 10-year storm are to be accommodated without causing erosion. Swales should maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout. Six inches of freeboard is recommended for the 10-year storm. Residence times between 5 and 9 minutes are acceptable for swales without check-dams. The maximum ponding time is 48 hours, though 24 hours is more desirable (minimum of 30 minutes). Studies have shown that the maximum amount of swale filtering occurs for water depths below 6 inches. It is critical that swale vegetation not be submerged, as it could cause the vegetation to bend over with the flow. This would naturally lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

2. Longitudinal slopes between 1% and 3% are generally recommended for swales. If the topography necessitates steeper slopes, check dams or TRM's are options to reduce the energy gradient and erosion potential.

3. Check dams are recommended for vegetated swales with longitudinal slopes greater than 3%. They are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity, and promote additional filtering and settling of nutrients and other pollutants. In effect, check-dams create a series of small, temporary pools along the length of the swale, which shall drain down within a maximum of 72 hours. Swales with check-dams are much more effective at mitigating runoff quantity and quality than those without. The frequency and design of check-dams in a swale will depend on the swale length and slope, as well as the desired amount of storage/treatment volume. Care must be taken to avoid erosion around the ends of the check dams.

   Check-dams shall be constructed to a height of 6 to 12 in and be regularly spaced. The following materials have been employed for check-dams: natural wood, concrete, stone, and earth. Earthen check-dams however, are typically not recommended due to their potential to erode. A weep hole(s) may be added to a check-dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep hole(s) is not subject to clogging. In the case of a stone check-dam, a better approach might be to allow low flows (2-year storm) to drain through the stone, while allowing higher flows (10-year storm) drain through a weir in the center of the dam. Flows through a stone check-dam are a function of stone size, flow depth, flow width, and flow path length through the dam. The following equation can be used to estimate the flow through a stone check dam up to 6 feet long:

$$q = h^{1.5} / (L/D + 2.5 + L^2)^{0.5}$$

   where:

   q = flow rate exiting check dam (cfs/ft)
   h = flow depth (ft)
   L = length of flow (ft)
   D = average stone diameter (ft) (more uniform gradations are preferred)

   For low flows, check-dam geometry and swale width are actually more influential on flow than stone size. The average flow length through a check-dam as a function of flow depth can be determined by the following equation:

$$L = (ss) \times (2d - h)$$

where:
ss = check dam side slope (maximum 2:1)
d = height of dam (ft)
h = flow depth (ft)

When swale flows overwhelm the flow-through capacity of a stone check-dam, the top of the dam shall act as a standard weir (use standard weir equation). (Though a principal spillway, 6 inches below the height of the dam, may also be required depending on flow conditions.) If the check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

4. The effectiveness of a vegetated swale is directly related to the contributing land use, the size of the drainage area, the soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. Use of natural low points in the topography may be suited for swale location, as are natural drainage courses although infiltration capability may also be reduced in these situations. The topography of a site should allow for the design of a swale with sufficiently mild slope and flow capacity. Swales are impractical in areas of extreme (very flat or steep) slopes. Of course, adequate space is needed for vegetated swales. Swales are ideal as an alternative to curbs and gutters along parking lots and along small roads in gently sloping terrain.

   Siting of vegetated swales should take into account the location and function of other site features (buffers, undisturbed natural areas, etc.). Siting should also attempt to aesthetically fit the swale into the landscape as much as possible. Sharp bends in swales should be avoided.

   Implementing vegetated swales is challenging when development density exceeds four dwelling units per acre, in which case the number of driveway culverts often increases to the point where swales essentially become broken-pipe systems.

   Where possible, construct swales in areas of uncompacted cut. Avoid constructing side slopes in fill material. Fill slopes can be prone to erosion and/or structural damage by burrowing animals.

5. Soil Testing is required when infiltration is planned (see Appendix C).

6. Guidelines for Infiltration Systems should be met as necessary (see Appendix C).

7. Swales are typically most effective, when treating an area of 1 to 2 acres although vegetated swales can be used to treat and convey runoff from an area of 5 to 10 acres in size. Swales serving greater than 10-acre drainage areas will provide a lesser degree water quality treatment, unless special provisions are made to manage the increased flows.

8. Runoff can be directed into Vegetated Swales either as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is

included (see #6). If flow is to be directed into a swale via curb cuts, provide a 2 to 3 inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately.

9. Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially roadway runoff. However, when swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the heavier sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Pretreatment options include a vegetated filter strip, a sediment forebay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a 6-inch drop where parking lot sheet flow is directed into a swale.

10. The soil base for a vegetated swale must provide stability and adequate support for proposed vegetation. When the existing site soil is deemed unsuitable (clayey, rocky, coarse sands, etc.) to support dense vegetation, replacing with approximately 12 inches of loamy or sandy soils is recommended. In general, alkaline soils should be used to further reduce and retain metals. Swale soils should also be well-drained. If the infiltration capacity is compromised during construction, the first several feet should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth.

11. Swales are most efficient when their cross-sections are parabolic or trapezoidal in nature. Swale side slopes are best within a range of 3:1 to 5:1 and should not be greater than 2:1 for ease of maintenance and side inflow from sheet flow.

12. To ensure the filtration capacity and proper performance of swales, the bottom widths typically range from 2 to 8 feet. Wider channels are feasible only when obstructions such as berms or walls are employed to prohibit braiding or uncontrolled sub-channel formation. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.

13. Ideal swale vegetation should consist of a dense and diverse selection of close-growing, water-resistant plants whose growing season preferably corresponds to the wet season. For swales that are not part of a regularly irrigated landscaped area, drought tolerant vegetation should be considered as well. Vegetation should be selected at an early stage in the design process, with well-defined pollution control goals in mind. Selected vegetation must be able to thrive at the specific site and therefore should be chosen carefully (See Appendix B). Use of native plant species is strongly advised, as is avoidance of invasive plant species. Swale vegetation must also be salt tolerant, if winter road maintenance activities are expected to contribute salt/chlorides.

Table 6.8.1

Commonly used vegetation in swale (New Jersey BMP Manual, 2004)		
Common Name	Scientific Name	Notes
Alkai Saltgrass	Puccinellia distans	Cool, good for wet, saline swales
Fowl Bluegrass	Poa palustris	Cool, good for wet swales
Canada Bluejoint	Calamagrostis canadensis	Cool, good for wet swales
Creeping Bentgrass	Agrostis palustris	Cool, good for wet swales, salt tolerant
Red Fescue	Festuca rubra	Cool, not for wet swales
Redtop	Agrostis gigantea	Cool, good for wet swales
Rough Bluegrass	Poa trivialis	Cool, good for wet, shady swales
Switchgrass	Panicum virgatum	Warm, good for wet swales, somwe salt tolerance
Wildrye	Elymus virginicus/rigarius	Cool, good for wet, shady swales

Notes: These grasses are sod forming and can withstand frequent inundation, and are idela for the swale or grass channel environment. A few are also salt tolerant. Cool refers to cool season grasses that grow during the colder temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot , mid summer months.

By landscaping with trees along side slopes, swales can be easily and aesthetically integrated into the overall site design without unnecessary loss of usable space. An important consideration however, is that tree plantings allow enough light to pass and sustain a dense ground cover. When the trees have reached maturity, they should provide enough shade to markedly reduce high temperatures in swale runoff.

14. Check the temporary and permanent stability of the swale using the standards outlined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual. Swales should convey either 2.75 cfs/acre or the calculated peak discharge from a 10-year storm event. The permissible velocity design method may be used for design of channel linings for bed slopes <0.10 ft/ft; use of the maximum permissible shear stress is acceptable for all bed slopes. Flow capacity, velocity, and design depth in swales are generally calculated by Manning's equation.

    Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, compost blankets, or curled wood blankets. Most vendors will provide information about the Manning's 'n' value and will specify the maximum permissible velocity or allowable shear stress for the lining material.

    The post-vegetation establishment capacity of the swale should also be confirmed. Permanent turf reinforcement may supersede temporary reinforcement on sites where not exceeding the maximum permissible velocity is problematic. If driveways or roads cross a swale, culvert capacity may supersede Manning's equation for determination of design flow depth. In these cases, the culvert should be checked to establish that the backwater elevation would not exceed the banks of the swale. If the culverts are to discharge to a minimum tailwater condition, the exit velocity for the culvert should be evaluated for design conditions. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures should be implemented. The following tables list the maximum permissible shear stresses (for various channel liners) and velocities (for channels lined with vegetation) from the Pennsylvania Erosion and Sediment Pollution Control Program Manual.

Maximum Permissible Shear Stresses for Various Channel Liners

Lining Category	Lining Type	lb/ft2
Unlined - Erodible Soils*	Silts, Fine - Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Erosion Resistant Soils**	Clay loam	0.25
	Silty Clay loam	0.18
	Sandy Clay Loam	0.10
	Loam	0.07
	Silt Loam	0.12
	Sandy Loam	0.02
	Gravely, Stony, Channery Loam	0.05
	Stony or Channery Silt Loam	0.07
Temporary Liners	Jute	0.45
	Straw with Net	1.45
	Coir - Double Net	2.25
	Coconut Fiber - Double Net	2.25
	Curled Wood Mat	1.55
	Curled Wood - Double Net	1.75
	Curled Wood - Hi Velocity	2.00
	Synthetic Mat	2.00
Vegetative Liners	Class B	2.10
	Class C	1.00
	Class D	0.60
Riprap***	R-1	0.25
	R-2	0.50
	R-3	1.00
	R-4	2.00
	R-5	3.00
	R-6	4.00
	R-7	5.00
	R-8	8.00

* Soils having an erodibility "K" factor greater than 0.37
** Soils having an erodibility "K" factor less than or equal to 0.37
*** Permissible shear stresses based on rock at 165 lb/cuft. Adjust velocities for other rock weights used. See Table 12.

Manufacturer's shear stress values based on independent tests may be used.

xture Reed Canarygrass	<5 5-10	5 4	4 3
Serecea Lespedeza Weeping Lovegrass Redtop Red Fescue	<5	3.5	2.5
Annuals Temporary cover only Sudangrass	<5	3.5	2.5

[1]Cohesive (clayey) fine grain soils and coarse grain soils with a plasticity index OF 10 TO 40 (CL, CH, SC and GC). Soils with K values less than 0.37.
[2]Soils with K values greater than 0.37.
[3]Use velocities exceeding 5 ft/sec only where good cover and proper maintenance can be obtained.

15. Manning's roughness coefficient, or 'n' value, varies with type of vegetative cover and design flow depth. Two common methods are based on design depth (see adjacent graph) and based on vegetative cover (as defined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual). Either of these can be used in design.

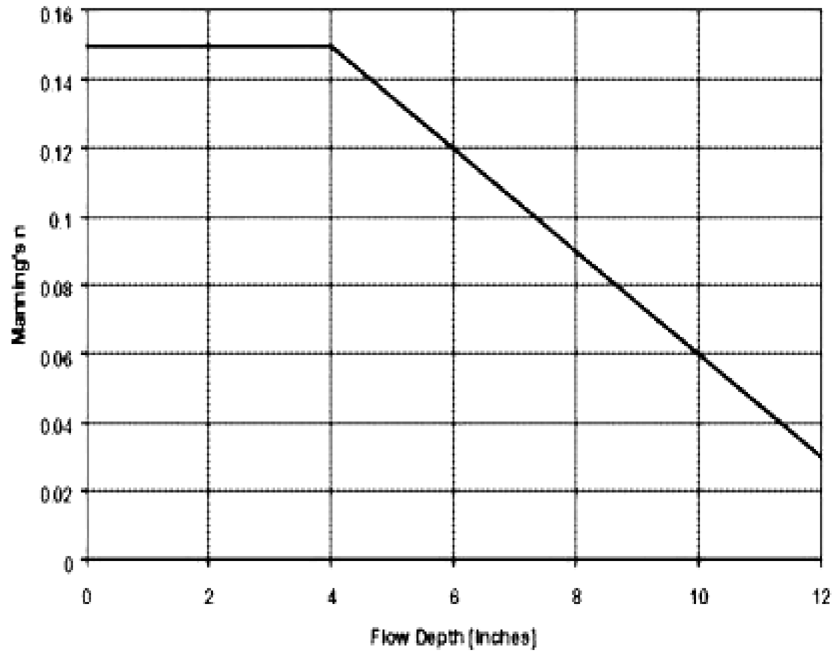


Figure D9.1 Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

16. If swales are designed according to the guidelines discussed in this section, significant levels of pollutant reduction can be expected through filtration and infiltration. In a particular swale reach, runoff should be well filtered by the time it flows over a check-dam. Thus, the stabilizing stone apron on the downhill side of the check-dam may be designed as an extension of an infiltration trench. In this way, only filtered runoff will enter a subsurface infiltration trench, thereby reducing the threat of groundwater contamination by metals.

17. Culverts are typically used in a vegetated swale at driveway or road crossings. By oversizing culverts and their flow capacity, cold weather concerns (e.g. clogging with snow) are lessened.

18. Where grades limit swale slope and culvert size, trench drains may be used to cross driveways.

19. Swales should discharge to another structural BMP (bioretention, infiltration basin, constructed wetlands, etc.), existing stormwater infrastructure, or a stable outfall.

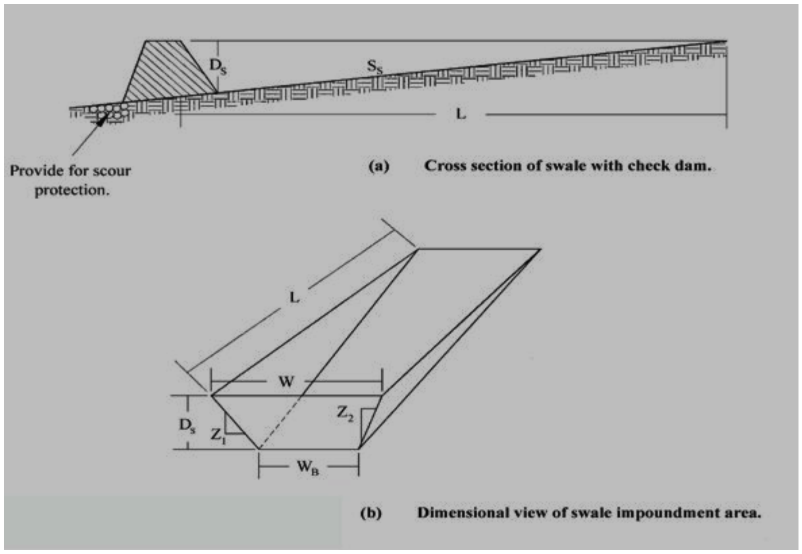
Detailed Stormwater Functions

Infiltration Area (if needed)

Volume Reduction Calculations

The volume retained behind each check-dam can be approximated from the following equation:

Storage Volume = 0.5 x Length of Swale Impoundment Area Per Check Dam x Depth of Check Dam x (Top Width of Check Dam + Bottom Width of Check Dam) / 2



Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin vegetated swale construction only when the upgradient temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's *Erosion and Sediment Pollution Control Program Manual,* March 2000 or latest edition.)

2. Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

3. Construct check dams, if required.

4. Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

5. Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

6. Once all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving upland stormwater flow.

7. Follow maintenance guidelines, as discussed below.

   Note: If a vegetated swale is used for runoff conveyance during construction, it should be regraded and reseeded immediately after construction and stabilization has occurred. Any damaged areas should be fully restored to ensure future functionality of the swale.

Maintenance Issues

Compared to other stormwater management measures, the required upkeep of vegetated swales is relatively low. In general, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a dense vegetative cover. Experience has proven that proper maintenance activities ensure the functionality of vegetated swales for many years. The following schedule of inspection and maintenance activities is recommended:

Maintenance activities to be done annually and within 48 hours after every major storm event (> 1 inch rainfall depth):

- Inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when > 3 inches at any spot or covering vegetation)
- Inspect vegetation on side slopes for erosion and formation of rills or gullies, correct as needed
- Inspect for pools of standing water; dewater and discharge to an approved location and restore to design grade
- Mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation; dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting
- Inspect for litter; remove prior to mowing
- Inspect for uniformity in cross-section and longitudinal slope, correct as needed
- Inspect swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage, correct as needed

Maintenance activities to be done as needed:

- Plant alternative grass species in the event of unsuccessful establishment

- Reseed bare areas; install appropriate erosion control measures when native soil is exposed or erosion channels are forming

- Rototill and replant swale if draw down time is more than 48 hours

- Inspect and correct check dams when signs of altered water flow (channelization, obstructions, erosion, etc.) are identified

- Water during dry periods, fertilize, and apply pesticide **only when absolutely necessary**

Most of the above maintenance activities are reasonably within the ability of individual homeowners. More intensive swales (i.e. more substantial vegetation, check dams, etc.) may warrant more intensive maintenance duties and should be vested with a responsible agency. A legally binding and enforceable maintenance agreement between the facility owner and the local review authority might be warranted to ensure sustained maintenance execution. Winter conditions also necessitate additional maintenance concerns, which include the following:

- Inspect swale immediately after the spring melt, remove residuals (e.g. sand) and replace damaged vegetation without disturbing remaining vegetation.

- If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of deicing agents.

- Use nontoxic, organic deicing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.

- Use salt-tolerant vegetation in swales.

Cost Issues

As with all other BMPs, the cost of installing and maintaining Vegetated Swales varies widely with design variability, local labor/material rates, real estate value, and contingencies. In general, Vegetated Swales are considered relatively low cost control measures. Moreover, experience has shown that Vegetated Swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers. The following table compares the cost of a typical vegetated swale (15 ft top width) with the cost of traditional conveyance elements.

ot)			
Total Annual Cost (per linear foot)	$1 (from seed) $2 (from sod)	No data	No data
Lifetime (years	50		20

It is important to note that the costs listed above are strictly estimates and shall be used for design purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding (if required). The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) reported that actual costs, which do include these activities, may range from $8.50 to $50.00 per linear foot depending on swale depth and bottom width. When all pertinent construction activities are considered, it is still likely that the cost of vegetated swale installation is less than that of traditional conveyance elements. When annual operation and maintenance costs are considered however, swales may prove the more expensive option, though they typically have a much longer lifespan.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Swale Soil** shall be USCS class ML (Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity), SM (Silty sands, poorly graded sand-silt mixtures), SW (Well-graded sands, gravelly sands, little or no fines) or SC (Clayey sands, poorly graded sand-clay mixtures). The first three of these designations are preferred for swales in cold climates. In general, soil with a higher percent organic content is preferred.

2. **Swale Sand** shall be ASTM C-33 fine aggregate concrete sand (0.02 in to 0.04 in).

3. **Check dams** constructed of natural wood shall be 6 in to 12 in diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable, as they can rot over time: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen **check dam** shall be constructed of sand, gravel, and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone **check dam** shall be constructed of R-4 rip rap, or equivalent.

4. Develop a native **planting mix**. (see Appendix B)

5. If infiltration trench is proposed, see BMP 6.4.4 Infiltration Trench for specifications.

References

Alameda Countywide Clean Water Program (ACCWP). “Grassy Swales.” *Catalog of Control Measures*. <http://www.oaklandpw.com/creeks/pdf/Grassy_Swales.pdf>

AMEC Earth and Environmental Center for Watershed Protection et al. *Georgia Stormwater Management Manual*. 2001.

California Stormwater Quality Association. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. 2003.

Caraco and Claytor. *Stormwater BMP Design Supplement for Cold Climates*. 1997.

City of Portland Environmental Services. *City of Portland Stormwater Management Manual: Revision #2*. 2002.

Center for Watershed Protection and Maryland Department of the Environment. *2000 Maryland Stormwater Design Manual*. Baltimore, MD: 2000.

Claytor, R.A. and T.R. Schuler. *Design of Stormwater Filtering Systems. Center for Watershed Protection*. Silver Spring, MD: 1996.

Colwell, S. R. et al. *Characterization of Performance Predictors and Evaluation of Mowing Practices in Biofiltration Swales*. 2000.

Fletcher, T., Wong, T., and Breen, P. "Chapter 8 – Buffer Strips, Vegetated Swales and Bioretention Systems." *Australian Runoff Quality (Draft)*. University of New Castle – Australia.

Lichten, K. "Grassy Swales." BMP Fact Sheets. Bay Area Stormwater Management Agencies Association (BASMAA). 1997.

Maine Department of Transportation. *Maine Department of Transportation BMP Manual for Erosion and Sedimentation Control*. 1992.

North Central Texas Council of Governments. *Stormwater Best Management Practices: A Menu of Management Plan Options for Small MS4s in North Central Texas*. 2002.

Schueler, T. et al. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone*. 1992.

United States Environmental Protection Agency (USEPA). "Post-Construction Storm Water Management in New Development & Redevelopment." *National Pollutant Discharge Elimination System (NPDES).* <http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/post_8.cfm>

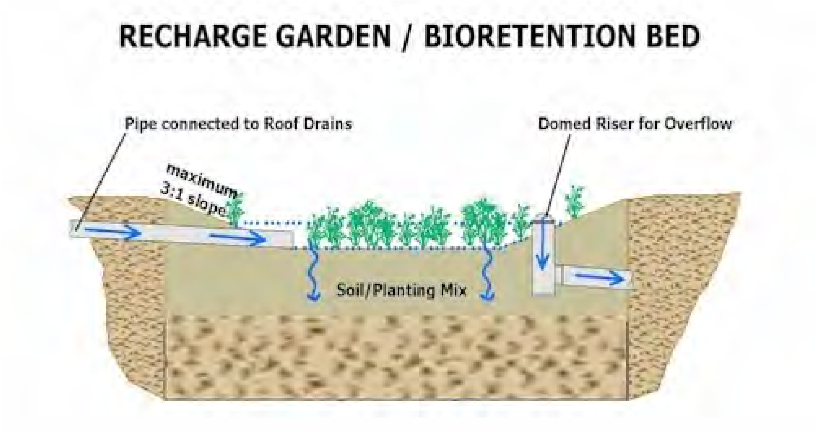
United States Environmental Protection Agency (USEPA). *Storm Water Technology Fact Sheet: Vegetated Swales* (EPA 832-F-99-006). 1999.

Vermont Agency of Natural Resources. *The Vermont Stormwater Management Manual*. 2002.

Virginia Stormwater Management Handbook, Volumes 1 and 2, First Edition, 1999

Appendix F-2: Rain Garden Description, Operation, Maintenance and Inspections

BMP 6.4.5: Rain Garden/Bioretention



A Rain Garden (also called Bioretention) is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff.

Key Design Elements

- Flexible in terms of size and infiltration
- Ponding depths generally limited to 12 inches or less for aesthetics, safety, and rapid draw down. Certain situations may allow deeper ponding depths.
- Deep rooted perennials and trees encouraged
- Native vegetation that is tolerant of hydrologic variability, salts and environmental stress
- Modify soil with compost.
- Stable inflow/outflow conditions
- Provide positive overflow
- Maintenance to ensure long-term functionality

Potential Applications

Residential: Commercial: Ultra Urban: Industrial: Retrofit: Highway/Road:
Yes Yes Yes Yes Yes Yes

Stormwater Functions

Volume Reduction: Medium
Recharge: Med./High
Peak Rate Control: Low/Med.
Water Quality: Med./High

Water Quality Functions

TSS: TP: 85% 85%
NO3: 30%

Other Considerations

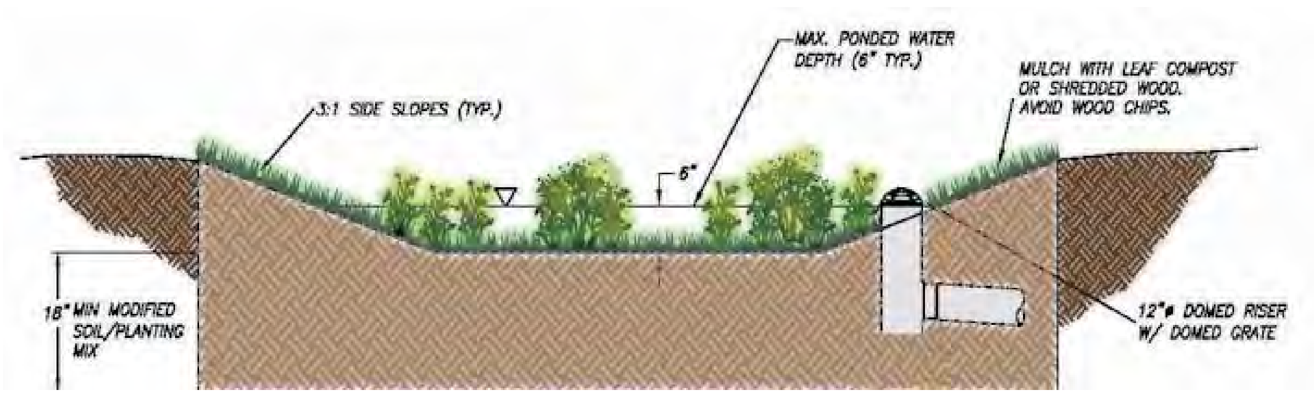
- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

Description

Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Bioretention techniques are used to accomplish water quality improvement and water quantity reduction. Prince George's County, Maryland, and Alexandria, Virginia have used this BMP since 1992 with success in many urban and suburban settings.

Bioretention can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMPs described in Chapter 5.

The vegetation serves to filter (water quality) and transpire (water quantity) runoff, and the root systems can enhance infiltration. The plants take up pollutants; the soil medium filters out pollutants and allows storage and infiltration of stormwater runoff; and the bed provides additional volume control. Properly designed bioretention techniques mimic natural ecosystems through species diversity, density and distribution of vegetation, and the use of native species, resulting in a system that is resistant to insects, disease, pollution, and climatic stresses.



Rain Gardens / Bioretention function to:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Recharge groundwater by infiltration
- Reduce stormwater temperature impacts
- Enhance evapotranspiration
- Enhance aesthetics
- Provide habitat

Primary Components of a Rain Garden/Bioretention System

The primary components (and subcomponents) of a rain garden/bioretention system are:

Pretreatment (optional)

- Sheet flow through a vegetated buffer strip, cleanout, water quality inlet, etc. prior to entry into the Rain Garden

Flow entrance

- Varies with site use (e.g., parking island versus residential lot applications)
- Water may enter via an inlet (e.g., flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection
- Trench drain
- Entering velocities should be non-erosive.

Ponding area

- Provides temporary surface storage of runoff
- Provides evaporation for a portion of runoff
- Design depths allow sediment to settle
- Limited in depth for aesthetics and safety

Plant material

- Evapotranspiration of stormwater
- Root development and rhizome community create pathways for infiltration
- Bacteria community resides within the root system creating healthy soil structure with water quality benefits
- Improves aesthetics for site
- Provides habitat for animals and insects
- Reinforces long-term performance of subsurface infiltration
- Should be tolerant of salts if in a location that would receive snow melt chemicals

Organic layer or mulch

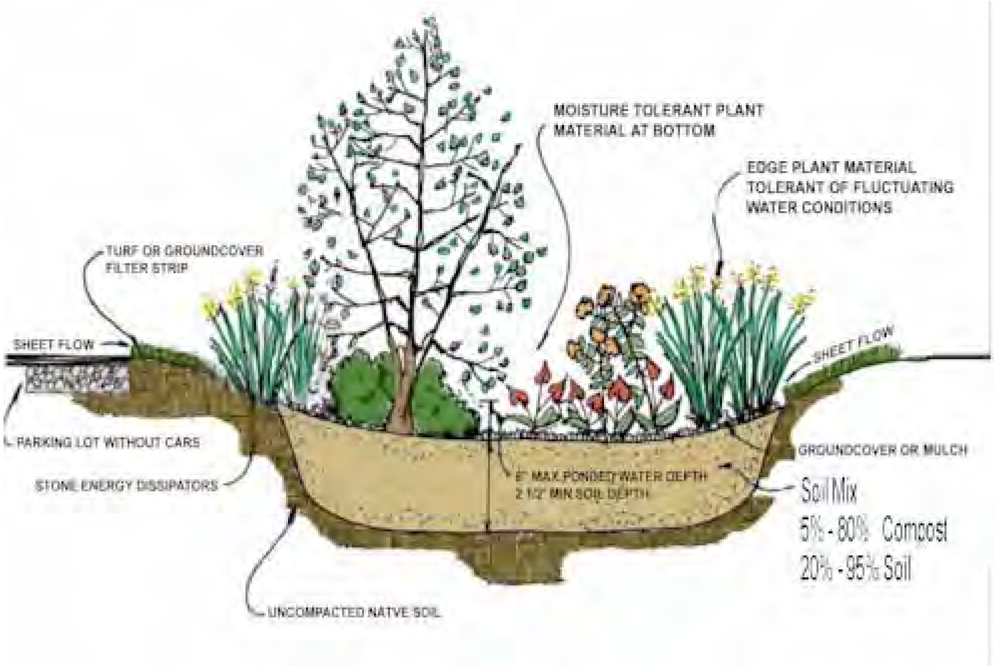
- Acts as a filter for pollutants in runoff
- Protects underlying soil from drying and eroding
- Simulates leaf litter by providing environment for microorganisms to degrade organic material
- Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals
- Wood mulch should be shredded - compost or leaf mulch is preferred.

Planting soil/volume storage bed

- Provides water/nutrients to plants
- Enhances biological activity and encourages root growth
- Provides storage of stormwater by the voids within the soil particles

Positive overflow

- Will discharge runoff during large storm events when the storage capacity is exceeded. Examples include domed riser, inlet, weir structure, etc.
- An underdrain can be included in areas where infiltration is not possible or appropriate.



Variations

Generally, a Rain Garden/Bioretention system is a vegetated surface depression that provides for the infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis (versus the total development site). If greater volumes of runoff need to be managed or stored, the system can be designed with an expanded subsurface infiltration bed or the Bioretention area can be increased in size.

The design of a Rain Garden can vary in complexity depending on the quantity of runoff volume to be managed, as well as the pollutant reduction objectives for the entire site. Variations exist both in the components of the systems, which are a function of the land use surrounding the Bioretention system.

The most common variation includes a gravel or sand bed underneath the planting bed. The original intent of this design, however, was to perform as a filter BMP utilizing an under drain and subsequent discharge. When a designer decides to use a gravel or sand bed for volume storage under the planting bed, then additional design elements and changes in the vegetation plantings should be provided.

Flow Entrance: Curbs and Curb Cuts

Flow Entrance: Trench Drain

Positive Overflow: Domed Riser

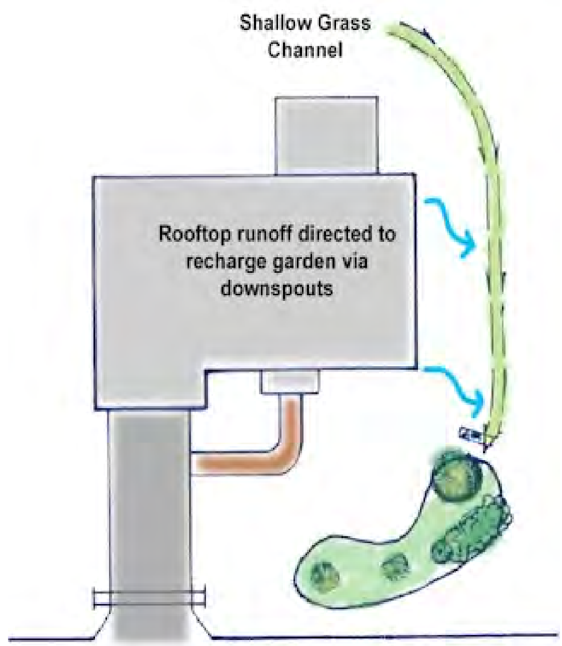
Positive Overflow: Inlet

Applications

Bioretention areas can be used in a variety of applications: from small areas in residential lawns to extensive systems in large parking lots (incorporated into parking islands and/or perimeter areas).

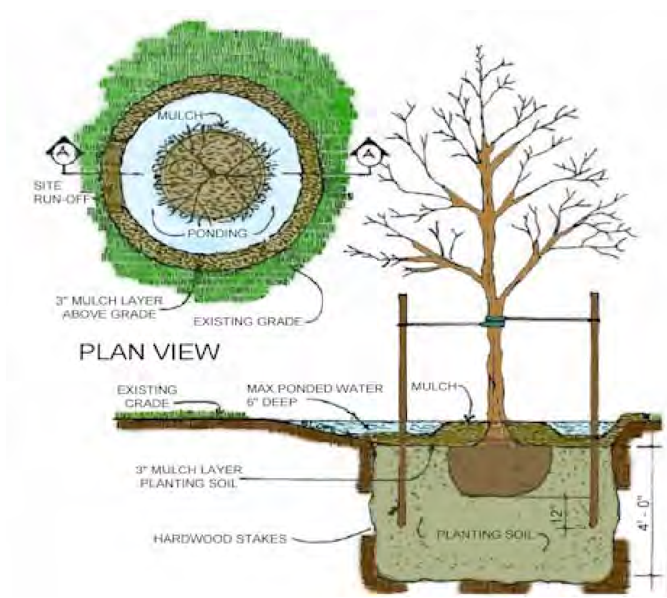
- **Residential On-lot**

  Rain Garden (Prince George's County)
  Simple design that incorporates a planting bed in the low portion of the site

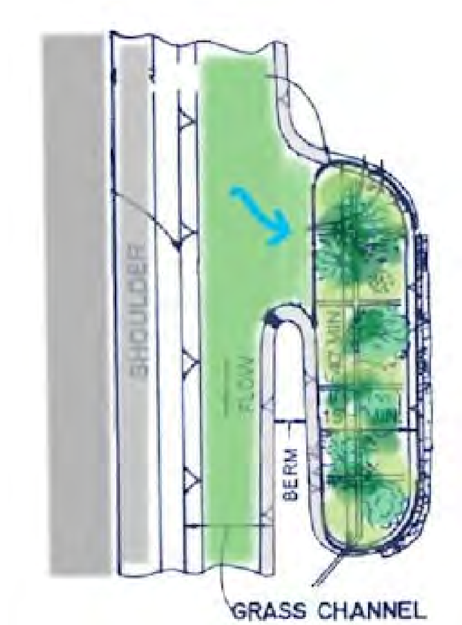


- **Tree and Shrub Pits**
  Stormwater management technique that intercepts runoff and provides shallow ponding in a dished mulched area around the tree or shrub.

  Extend the mulched area to the tree dripline



- **Roads and highways**



- **Parking Lots**
- **Parking Lot Island Bioretention**

- **Commercial/Industrial/Institutional**

In commercial, industrial, and institutional situations, stormwater management and greenspace areas are limited, and in these situations, Rain Gardens for stormwater management and landscaping provide multifunctional options.

- **Curbless (Curb cuts) Parking Lot Perimeter Bioretention**
  The Rain Garden is located adjacent to a parking area with no curb or curb cuts , allowing stormwater to sheet flow over the parking lot directly into the Rain Garden. Shallow grades should direct runoff at reasonable velocities; this design can be used in conjunction with depression storage for stormwater quantity control.

- **Curbed Parking Lot Perimeter Bioretention**

- **Roof leader connection from adjacent building**

Design Considerations

Rain Gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. Though Rain Gardens are a structural BMP, the initial siting of bioretention areas should respect the Integrating Site Design Procedures described in Chapter 4 and integrated with the preventive non-structural BMPs.

It is important to note that bioretention areas are not to be confused with constructed wetlands or wet ponds which permanently pond water. Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.1 inches per hour). In extreme situations where permeability is less than 0.1 inches per hour, special variants may apply, including under drains, or even constructed wetlands.

Rain Gardens are often very useful in retrofit projects and can be integrated into already developed lots and sites. An important concern for all Rain Garden applications is their long-term protection and maintenance, especially if undertaken in multiple residential lots where individual homeowners provide maintenance. In such situations, it is important to provide some sort of management that insures their long-term functioning (deed restrictions, covenants, and so forth).

1. **Sizing criteria**

   a. **Surface area** is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 5:1 (impervious drainage area to infiltration area; see Protocol 2. Infiltration Systems Guidelines (Appendix C) for additional guidance on loading rates.)

   b. **Surface Side slopes** should be gradual. For most areas, maximum 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.

   c. **Surface Ponding depth** should not exceed 6 inches in most cases and should empty within 72 hours.

   d. **Ponding area** should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where feasible.

   e. **Planting soil depth** should generally be at least 18" where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased, depending on plant species.

2. **Planting Soil** should be a loam soil capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A typical organic amended soil is combined with 20-30% organic material (compost), and 70-80% soil base (preferably topsoil). Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.

3. **Volume Storage Soils** should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10% (a small amount of clay is beneficial to adsorb pollutants and retain water), be free of toxic substances and unwanted plant material and have a 5 –10% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine volume storage capacity of amended soils).

4. Proper **plant selection** is essential for bioretention areas to be effective. Typically, native floodplain plant species are best suited to the variable environmental conditions encountered. If shrubs and trees are included in a bioretention area (which is recommended), at least three species of shrub and tree should be planted at a rate of approximately 700 shrubs and 300 trees per acre (shrub to tree ratio should be 2:1 to 3:1). An experienced landscape architect is recommended to design native planting layout.

5. **Planting periods** will vary, but in general trees and shrubs should be planted from mid-March through the end of June, or mid-September through mid-November

6. A maximum of 2 to 3 inches of shredded **mulch** or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. Mulch / compost layer should not exceed 3" in depth so as not to restrict oxygen flow to roots.

7. Must be designed carefully in areas with **steeper slopes** and should be aligned parallel to contours to minimize earthwork.

8. Under drains should not be used except where in-situ soils fail to drain surface water to meet the criteria in Chapter 3.

Detailed Stormwater Functions

Infiltration Area

Volume Reduction Calculations

The storage volume of a Bioretention area is defined as the sum total of 1. and the smaller of 2a or 2b below. The surface storage volume should account for at least 50% of the total storage. Inter-media void volumes may vary considerably based on design variations.

1. Surface Storage Volume (CF) = Bed Area (ft^2) x Average Design Water Depth

2a. Infiltration Volume = Bed Bottom area (sq ft) x infiltration design rate (in/hr) x infiltration period (hr) x 1/12.
2b. Volume = Bed Bottom area (sq ft) x soil mix bed depth x void space.

Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence; however, alterations might be necessary depending on design variations.

1. Install temporary sediment control BMPs as shown on the plans.

2. Complete site grading. If applicable, construct curb cuts or other inflow entrance but provide protection so that drainage is prohibited from entering construction area.

3. Stabilize grading within the limit of disturbance except within the Rain Garden area. Rain garden bed areas may be used as temporary sediment traps provided that the proposed finish elevation of the bed is 12 inches lower than the bottom elevation of the sediment trap.

4. Excavate Rain Garden to proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.

5. Backfill Rain Garden with amended soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light hand tamping is acceptable if necessary.

6. Presoak the planting soil prior to planting vegetation to aid in settlement.

7. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans.

8. Plant vegetation according to planting plan.

9. Mulch and install erosion protection at surface flow entrances where necessary.

Maintenance Issues

Properly designed and installed Bioretention areas require some regular maintenance.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may also need to be removed every year. Perennial plantings may be cut down at the end of the growing season.
- Mulch should be re-spread when erosion is evident and be replenished as needed. Once every 2 to 3 years the entire area may require mulch replacement.
- Bioretention areas should be inspected at least two times per year for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, Bioretention areas may require watering.
-
- Trees and shrubs should be inspected twice per year to evaluate health.

Cost Issues

Rain Gardens often replace areas that would have been landscaped and are maintenance-intensive so that the net cost can be considerably less than the actual construction cost. In addition, the use of Rain Gardens can decrease the cost for stormwater conveyance systems at a site. Rain Gardens cost approximately $5 to $7 (2005) per cubic foot of storage to construct.

Specifications

The following specifications are provided for informational purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1Vegetation - See Appendix B

2 Execution

a. Subgrade preparation

1. Existing sub-grade in Bioretention areas shall NOT be compacted or subject to excessive construction equipment traffic.
2. Initial excavation can be performed during rough site grading but shall not be carried to within one feet of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
3. Where erosion of sub-grade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material shall be removed with light

equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent by light tractor.

4. Bring sub-grade of bioretention area to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
5. Halt excavation and notify engineer immediately if evidence of sinkhole activity or pinnacles of carbonate bedrock are encountered in the bioretention area.

b. Rain Garden Installation

1. Upon completion of sub-grade work, the Engineer shall be notified and shall inspect at his/her discretion before proceeding with bioretention installation.
2. For the subsurface storage/infiltration bed installation, amended soils should be placed on the bottom to the specified depth.
3. Planting soil shall be placed immediately after approval of sub-grade preparation/bed installation. Any accumulation of debris or sediment that takes place after approval of sub-grade shall be removed prior to installation of planting soil at no extra cost to the Owner.
4. Install planting soil (exceeding all criteria) in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket or by hand). Keep equipment movement over planting soil to a minimum – **do not over compact**. Install planting soil to grades indicated on the drawings.
5. Plant trees and shrubs according to supplier’s recommendations and only from mid-March through the end of June or from mid-September through mid-November.
6. Install 2-3” shredded hardwood mulch (minimum age 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
7. Protect Rain Gardens from sediment at all times during construction. Hay bales, diversion berms and/or other appropriate measures shall be used at the toe of slopes that are adjacent to Rain Gardens to prevent sediment from washing into these areas during site development.
8. When the site is <u>fully vegetated</u> and the soil mantle stabilized the plan designer shall be notified and shall inspect the Rain Garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.
9. Water vegetation at the end of each day for two weeks after planting is completed.

Contractor should provide a one-year 80% care and replacement warranty for all planting beginning after installation and inspection of all plants.

Appendix F-3: Basin Retrofit Description, Operation, Maintenance and Inspections

BMP 6.7.3: Soil Amendment & Restoration

Soil amendment and restoration is the process of improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long-term capacity for infiltration and pollution removal.

Key Design Elements

- Existing soil conditions should be evaluated before forming a restoration strategy.
- Physical loosening of the soil, often called subsoiling, or tilling, can treat compaction.
- The combination of subsoiling and soil amendment is often the more effective strategy.
- Compost amendments increase water retention.

Potential Applications

Residential:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway/Road:	Yes

Stormwater Functions

Volume Reduction:	Low/Med.
Recharge:	Low/Med.
Peak Rate Control:	Medium
Water Quality:	Medium

Water Quality Functions

TSS:	85%
TP:	85%
NO3:	50%

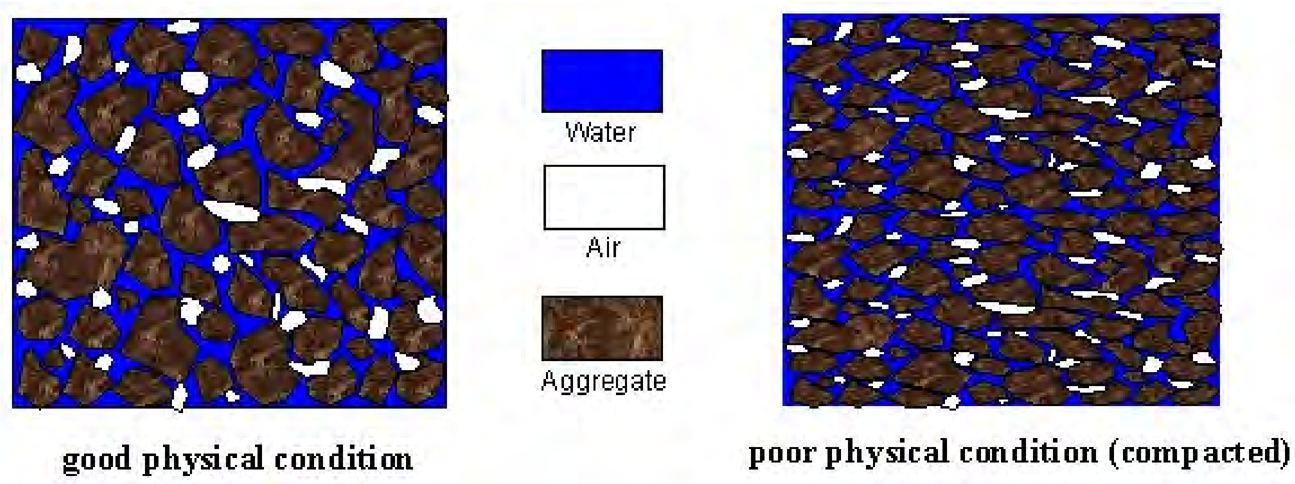
Problem Description

Animals, farm equipment, trucks, construction equipment, cars, and people cause compaction. Wet soil compacts easier than dry soil. Natural compaction occurs due to special chemical or physical properties, and these occurrences are called “hard pans”. A typical soil after compaction has strength of about 6,000 kPa, while studies have shown that root growth is not possible beyond 3,000 kPa.

Different Types of Compaction

1) Minor Compaction – surface compaction within 8-12” due to contact pressure, axle load > 10 tons can compact through root zone, up to 1’ deep

2) Major Compaction – deep compaction, contact pressure and total load, axle load > 20 tons can compact up to 2’ deep (usually large areas compacted to increase strength for paving and foundation with overlap to “lawn” areas)



In general, compaction problems occur when airspace drops to 10-15% of total soil volume. Compaction affects the infiltrating and water quality capacity of soils. When soils are compacted, the soil particles are pressed together, reducing the pore space necessary to move air and water throughout the soil. This decrease in porosity causes an increase in bulk density (weight of solids per unit volume of soil). The greater the bulk density, the lower the infiltration and therefore the larger volume of runoff.

Different types of soils have bulk density levels at which compaction starts to limit root growth. When root growth is limited, the uptake of water and nutrients by vegetation is reduced.

Soil organisms are also affected by compaction; biological activity is greatly reduced, decreasing their ability to intake and release nutrients.

The best soil restoration is the complete revegetation of woodlands, as “A mature forest can absorb as much as 14 times more water than an equivalent area of grass.” (DNREC and Brandywine Conservancy, 1997) (See Structural BMP 6.7.2 Landscape Restoration and use in combination with this BMP)

Soil Restoration Methodology

Soil restoration is a technique that can be used to restore and enhance compacted soils or soils low in organic content by physical treatment and/or mixture with additives such as compost. Soil restoration has been shown to alter soil properties known to affect water relations of soils, including water holding capacity, porosity, bulk density and structure. Two methods have been shown to restore some of the characteristics of soils that are damaged by compaction; tilling and addition of amendments such as compost or other materials.

One of the options for soil amendment is compost, which has many benefits. It improves the soil structure, creating and enhancing passageways in the soil for air and water that have been lost due to compaction. This recreates a better environment for plant growth. Compost also supplies a slow release of nutrients to plants, specifically nitrogen, phosphorous, potassium, and sulfur. Using compost reuses natural resources, reducing waste and cost.

Soil amendment with compost has been shown to increase nutrients in the soil, such as phosphorus and nitrogen, which provides plants with needed nutrients, reducing or eliminating the need for fertilization. This increase in nutrients results in an aesthetic benefit as turf grass and other plantings establish and proliferate more quickly, with less maintenance requirements. Soil amendment with compost increases water holding and retention capacity, improves infiltration, reduces surface runoff, increases soil fertility, and enhances vegetative growth. Compost also increases pollutant-binding properties of the soil properties, which improves the quality of the water passing through the soil mantle and into the groundwater.

The second method is tilling, which involves the digging, scraping, mixing, and ripping of soil with the intent of circulating air into the soil mantle in various layers. Compaction down to 20 inches often requires ripping for soil restoration. Tilling exposes compacted soil devoid of oxygen to air and recreates temporary air space.

Bulk density field tests may be used to determine the compaction level of soils.

Soil Texture	Ideal Bulk densities	Bulk densities that may afffect root growth	Bulk densities that restrict root growth
	g/cm3	g/cm3	g/cm3
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Slilt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47

Source: Protecting Urban Soil Quality, USDA-NRCS

Variations

- Soil amendment media can include compost, sand, and manufactured microbial solutions.
- Seed can be included in the soil amendment to save application time.

Applications

- **New Development (Residential, Commercial, Industrial)** – new lawns can be amended with compost and not heavily compacted before planting, to increase the porosity of the soils.

- **Urban Retrofits** - Tilling of soils that have been compacted before it is converted into meadow, lawn, or a stormwater facility is recommended.

- **Detention Basin Retrofits** – The inside face of detention basins is usually heavily compacted, and tilling the soil mantle on surfaces beyond the constructed embankment will encourage infiltration to take place. Tilling may be necessary to establish better vegetative cover.

- **Landscape Maintenance** – compost can substitute for dwindling supplies of native topsoil in urban areas.

- **Golf Courses** – Using compost as part of the landscaping upkeep on the greens has been shown to alleviate soil compaction, erosion, and turf disease problems.

Design Considerations

1. Treating Compaction by **Soil Restoration**
   a) Soil amendment media usually consists of compost, but can include mulch, manures, sand, and manufactured microbial solutions.
   b) Compost should be added at a rate of 2:1 (soil:compost). If a proprietary product is used, the manufacturer's instructions should be followed in terms of mixing and application rate.
   c) Soil restoration should not be used on slopes greater than 30%. In these areas, deep-rooted vegetation can be used to increase stability.
   d) Soil restoration should not take place within the drip line of a tree to avoid damaging the root system.
   e) On-site soils with an organic content of at least 5 percent can be properly stockpiled (to maintain organic content) and reused.
   f) Procedure: rototill, or rip the subgrade, remove rocks, distribute the compost, spread the nutrients, rototill again.
   g) Add 6 inches compost / amendment and till up to 8 inches for minor compaction.
   h) Add 10 inches compost / amendment and till up to 20 inches for major compaction.

2. Treating Compaction by **Ripping / Subsoiling / Tilling / Scarification**
   a) Subsoiling is only effective when performed on dry soils.
   b) Ripping, subsoiling, or scarification of the subsoil should be performed where subsoil has become compacted by equipment operation, dried out and crusted, or where necessary to obliterate erosion rills.
   c) Ripping (Subsoiling) should be performed using a solid-shank ripper and to a depth of 20 inches, (8 inches for minor compaction).

d) Should be performed before compost is placed and after any excavation is completed.
e) Subsoiling should not be performed within the drip line of any existing trees, over underground utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design.

Subsoiling should not be performed with common tillage tools such as a disk or chisel plow because they are too shallow and can compact the soil just beneath the tillage depth.

3. Other methodologies:
a) Irrigation Management – low rates of water should be applied, as over-irrigation wastes water and may lead to environmental pollution from lawn chemicals, nutrients, and sediment.
b) Limited mowing – higher grass corresponds to greater evapotranspiration.
c) Compost can be amended with bulking agents, such as aged crumb rubber from used tires or weed chips. This can be a cost-effective alternative that reuses waste materials.
d) In areas where compaction is less severe (not as a result of heavy construction equipment), planting with deep-rooted perennials can treat compaction, however restoration takes several years.

Table 2. Mean runoff from unvegetated test plots during a 30 minute high-intensity (~ 4 in/hr) rain storm

	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Geometric mean runoff (mm) during 30-minute rainfall	0.13[a]	<0.01[a]	0.08[a]	26.22[b]	15.54[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

Table 3. Mean time to initiate runoff from unvegetated test plots

	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Mean time (min)	31.08[c]	56.92[d]	32.17[c,d]	4.67[a]	7.83[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

Detailed Stormwater Functions

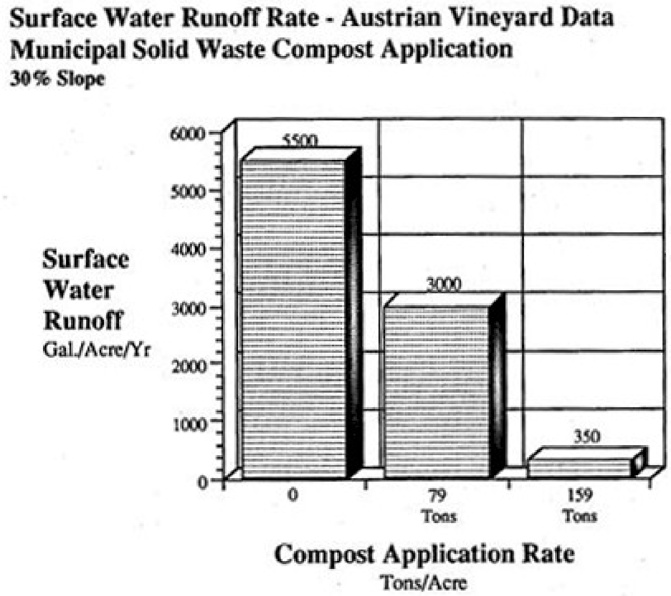
Infiltration Area (If needed)

The infiltration area will be the entire area restored, depending on the existing soil conditions, and the restoration effectiveness.

Volume Reduction Calculations

Soil Amendments can reduce the need for irrigation by retaining water and slowly releasing moisture, which encourages deeper rooting. Infiltration is increased; therefore the volume of runoff is decreased.

Compost amended soils can significantly reduce the volume of stormwater runoff. For soils that have either been compost amended according to the recommendations of their BMP, or subject to restoration such that the field measured bulk densities meet the Ideal Bulk Densities of Table 1, the following volume reduction may be applied:



Amended Area (ft^2) x 0.50in x 1/12 = Volume (cf)

Peak Rate Mitigation

See Section 8 for peak rate mitigation.

Water Quality Improvement

See Section 8 for water quality improvement.

Table 4. Adsorbed Mass of Nutrients and Metals in Unvegetated Plot Runoff From 30-Minute, High-Intensity (100-mm/hr.) Rainstorm

	Compost Treatments			Conventional Treatments	
	Biosolids	Yardwaste	Bioindustrial Compost	Compacted Subsoil	Topsoil
Element	Geometric Mean (mg)				
Chromium	0.01^{b}	$<0.01^{a}$	$<0.01^{b}$	0.92^{c}	0.76^{d}
Copper	0.02^{b}	$<0.01^{a}$	0.01^{b}	1.03^{c}	0.66^{c}
Nickel	$<0.01^{b}$	$<0.01^{a}$	$<0.01^{b}$	0.86^{c}	0.67^{c}
Lead	0.01^{b}	$<0.01^{a}$	$<0.01^{b}$	1.82^{c}	0.95^{c}
Zinc	0.10^{b}	$<0.01^{a}$	0.03^{b}	6.55^{d}	3.99^{d}
Nitrogen	0.47^{b}	$<0.01^{a}$	$0.09^{a,b}$	266.65^{c}	211.87^{c}
Phosphorus	0.45^{b}	$<0.01^{a}$	$0.09^{a,b}$	36.47^{c}	29.07^{c}
Potassium	0.17^{b}	$<0.01^{a}$	$0.09^{a,b}$	103.94^{c}	71.57^{d}

Means within the same row with different letter designations are significantly different ($p<0.05$).

Highest | Medium | Lowest

Construction Sequence

1. All construction should be completed and stabilized before beginning soil restoration.

Maintenance Issues

The soil restoration process may need to be repeated over time, due to compaction by use and/or settling. (For example, playfields or park areas will be compacted by foot traffic.)

Cost Issues

Tilling costs, including scarifying sub-soils, range from $800/ac to $1000/ac.

Compost amending of soil ranges in cost from $860/ac to $1000/ac.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. SCOPE

    a. This specification covers the use of compost for soil amendment and the mechanical restoration of compacted, eroded and non-vegetated soils. Soil amendment and restoration is necessary where existing soil has been deemed unhealthy in order to restore soil structure and function, increase infiltration potential and support healthy vegetative communities.

    b. Soil amendment prevents and controls erosion by enhancing the soil surface to prevent the initial detachment and transport of soil particles.

2. COMPOST MATERIALS

    a. Compost products specified for use in this application are described in Table 1. The product's parameters will vary based on whether vegetation will be established on the treated slope.

    b. Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used in this application. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limit standards pertaining to the feedstocks (source materials) in which it is derived.

    c. Very coarse compost should be avoided for soil amendment as it will make planting and crop establishment more difficult.

d. **Note 1** - Specifying the use of compost products that are certified by the U.S. Composting Council's Seal of Testing (STA) Program (www.compostingcouncil.org) will allow for the acquisition of products that are analyzed on a routine basis, using the specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products.

3. SUB-SOILING TO RELIEVE COMPACTION

a. Before the time the compost is placed and preferably when excavation is completed, the subsoil shall be in a loose, friable condition to a depth of 20 inches below final topsoil grade and there shall be no erosion rills or washouts in the subsoil surface exceeding 3 inches in depth.

b. To achieve this condition, subsoiling, ripping, or scarification of the subsoil will be required as directed by the owners s representative, wherever the subsoil has been compacted by equipment operation or has become dried out and crusted, and where necessary to obliterate erosion rills. Sub-soiling shall be required to reduce soil compaction in all areas where plant establishment is planned. Sub-soiling shall be performed by the prime or excavating contractor and shall occur before compost placement.

c. Subsoiled areas shall be loosened to less than 1400 kPa (200 psi) to a depth of 20 inches below final topsoil grade. When directed by the owner's representative, the Contractor shall verify that the sub-soiling work conforms to the specified depth.

d. Sub-soiling shall form a two-directional grid. Channels shall be created by a commercially available, multi-shanked, parallelogram implement (solid-shank ripper). The equipment shall be capable of exerting a penetration force necessary for the site. No disc cultivators chisel plows, or spring-loaded equipment will be allowed. The grid channels shall be spaced a minimum of 12 inches to a maximum of 36 inches apart, depending on equipment, site conditions, and the soil management plan. The channel depth shall be a minimum of 20 inches or as specified in the soil management plan. If soils are saturated, the Contractor shall delay operations until the soil will not hold a ball when squeezed. Only one pass shall be performed on erodible slopes greater than 1 vertical to 3 horizontal. When only one pass is used, work should be at right angles to the direction of surface drainage, whenever practical.

e. Exceptions to sub-soiling include areas within the drip line of any existing trees, over utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design (abutments, footings, or in slopes), and on inaccessible slopes, as approved by the owner's representative. In cases where exceptions occur, the Contractor shall observe a minimum setback of 20 feet or as directed by the owner's representative. Archeological clearances may be required in some instances.

4. COMPOST SOIL AMENDMENT QUALITY

a. The final, resulting compost soil amendment must meet all of the mandatory criteria in Table 4.

5. COMPOST SOIL AMENDMENT INSTALLATION

   a. Spread 2-3 inches of approved compost on existing soil. Till added soil into existing soil with a rotary tiller that is set to a depth of 6 inches. Add an additional 4 inches of approved compost to bring the area up to grade.

   b. After permanent planting/seeding, 2-3 inches of compost blanket will be applied to all areas not protected by grass or other plants

References

"The Compaction of Urban Soils", Technical Note #107 from Watershed Protection Techniques, Article 36, 3(2): 661-665.

Dallas, H. and A. Lewandowski, 2003. Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications. USDA Natural Resources Conservation Services.

OCSCD, 2001. *Impact of Soil Disturbance During Construction on Bulk Density and Infiltration in Ocean County, New Jersey*. Ocean County Soil Conservation District, Schnabel Engineering Assoicates, Inc., USDA Natural Resources Conservation Services. www.ocscd.org.

Pitt, R. et al., 2002. "Compacted Urban Soils Effects on Infiltration and Bioretention Stormwater Control Designs."

Pitt, R. et al., 2002. "Infiltration Through Disturbed Urban Soils and compost-Amended Soil Effects on Runoff Quality and Quantity."

"The Relationship Between Soil and Water", Soils for Salmon, The Urban Environment, 1999

"Soil Quality Resource Concerns: Compaction", USDA Natural Resources Conservation Service, 1996

"Soil Quality Resource Concerns: Available Water Capacity", USDA Natural Resources Conservation Service, 1998

"Specifications for Soil Amendments", Low Impact Development Center, Inc., www.lid-stormwater.net/soilamend/soilamend_specs.htm

"Urban Soil Compaction", Soil Quality – Urban Technical Note, No. 2, USDA Natural Resources Conservation Services, 2000.

Department of Natural Resources and Environmental Control Division of Soil and Water. *Delaware Erosion and Sediment Control Handbook for Development*. Newark, DE

Appendix F-4: Stream Restoration Description, Operation, Maintenance and Inspections

*Area of stream restoration to be marked out by the Borough and photographs available upon request

BMP 6.7.1: Riparian Buffer Restoration

A riparian buffer is a permanent area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands. Riparian forests are the most beneficial type of buffer for they provide ecological and water quality benefits. Restoration of this ecologically sensitive habitat is a responsive action to past activities that may have eliminated any vegetation.

Key Design Elements

- Reestablish buffer areas along perennial, intermittent, and ephemeral streams
- Plant native, diverse tree and shrub vegetation
- Buffer width is dependant on project preferred function (water quality, habitat creation, etc.)
- Minimum recommended buffer width is 35’ from top of stream bank, with 100’ preferred.
- Create a short-term maintenance and long-term maintenance plan
- Mature forest as a vegetative target
- Clear, well-marked boundary

Potential Applications

Residential:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway/Road:	Limited

Stormwater Functions

Volume Reduction:	Medium
Recharge:	Medium
Peak Rate Control:	Low/Med.
Water Quality:	Med./High

Water Quality Functions

TSS:	65%
TP:	50%
NO3:	50%

Description

The USDA Forest Service estimates that over one-third of the rivers and streams in Pennsylvania have had their riparian areas degraded or altered. This fact is sobering when one considers the important stormwater functions that riparian buffers provide. The non-structural BMP, Riparian Forest Buffer Protection, addresses the importance of protecting the three-zone system of existing riparian buffers.

The values of riparian buffers – economic, environmental, recreational, aesthetic, etc. – are well documented in scientific literature and numerous reports and thus will not be restated here in this BMP sheet. Rather, this BMP serves to provide a starting point for the designer that seeks to restore the riparian buffer. Important reports are cited consistently throughout this section and should be mentioned upfront as sources for additional information to a designer seeking to restore a riparian buffer. The first, the *Chesapeake Bay Riparian Handbook: a Guide for Establishing and Maintaining Riparian Forest Buffers* was prepared by the US Department of Agriculture (USDA) Forest Service for the Chesapeake Bay Program in 1997. The second, the *Pennsylvania Stream ReLeaf Forest Buffer Toolkit* was developed by the Alliance for the Chesapeake Bay specifically for the Pennsylvania streams in 1998. A third and often-referenced report, is the *Riparian Forest Buffers* series written by Robert Tjaden for the Maryland Cooperative Extension Service in 1998.

Riparian buffers are scientifically proven to provide a number of economic and environmental values. Buffers are characterized by high species density, high species diversity, and high bio-productivity as a transition between aquatic and upland environments. Project designers should take into account the benefits or services provided by the buffer and apply these to their project goals. Priorities for riparian buffer use should be established early on in the planning stages. Some important considerations when establishing priorities are:

- **Habitat** – Restoring a buffer for habitat enhancement will require a different restoration strategy than for restoring a buffer for increased water quality.
- **Stream Size** – A majority of Pennsylvania's stream miles is comprised of small streams (first, second, and third order), which may be priority areas to reduce nutrients. Establishing riparian buffers along these headwater streams will reduce the high nutrient loads relative to flow volumes typical of small streams.
- **Continuous Buffers** - Establishing continuous riparian forest buffers in the landscape should be given a higher priority than establishing larger but fragmented buffers. Continuous buffers provide better stream shading and water quality protection, as well as corridors for the movement of wildlife.
- **Degree of Degradation** – Urban streams are usually buried or piped. Streams in areas without forests, such as pastures, may benefit the most from buffer restoration, as sources of headwater streams. Highly urbanized/altered streams may not be able to provide high levels of pollution control.
- **Loading Rates** - The removal of pollutants may be highest where nutrient and sediment loading are the highest.
- **Land Use** – Adjacent land uses will influence Buffer Width and Vegetation types used to establish a riparian buffer. While the three-zone riparian-forested buffers described earlier are the ideal, they may not always be feasible to establish, especially in urban situations.

Preparation of a *Riparian Buffer Restoration Plan* is critical to ensuring long-term success of the project and should be completed before any planting is to occur. It is essential that site conditions are well understood, objectives of the landowner are considered, and the appropriate plants chosen for the site, tasks that are completed in the planning stages. Below is a summary of the nine steps that are recommended for the planning stages of a buffer restoration project.

1. Obtain Landowner Permission and Support
Landowner commitment is essential for the success of the project. Landowners must be aware of all maintenance activities that will occur once buffer is planted.

2. Make Sure Site is Suitable for Restoration
If streambanks are extensively eroded, consider an alternative location. Rapidly eroding streambanks may undermine seedlings. Streambank restoration may need to occur prior to riparian buffer restoration. Obtain professional help in evaluating the need for streambank restoration.

3. Analyze Site's Physical Conditions
The most important physical influence of the site is the soil, which will control plant selection. Evaluate the soil using the County soil survey book to determine important soil characteristics such as flooding potential, seasonal high water table, topography, soil pH, soil moisture, etc. Also, a simple field test can suffice, with direct observation of soil conditions.

4. Analyze Site's Vegetative Features
Existing vegetation present at the restoration site should be examined to determine the strategy for buffer establishment. Strategies will differ for various pre-restoration conditions such as pasture, overgrown abandoned field, mid-succession forest, etc.

- *Identify Desirable Species*: Native tree and shrub species that thrive in riparian habitats in Pennsylvania should be used. These species should be identified in the restoration site and protected for their seed bank potential. Several native vines and shrubs (blackberry, Virginia creeper, and spicebush) can provide an effective ground cover during establishment of the buffer, though they should be selectively controlled to minimize herbaceous competition.
- *Identify Undesirable Species:* Consider utilizing undesirable species such as the black locust for their shade function during buffer establishment. Consider controlling invasive plants prior to buffer planting.
- *Identify Sensitive Species*: Since riparian zones are rich in wildlife habitat and wetland plant species to be aware of any rare, threatened or endangered plant (or animal) species.

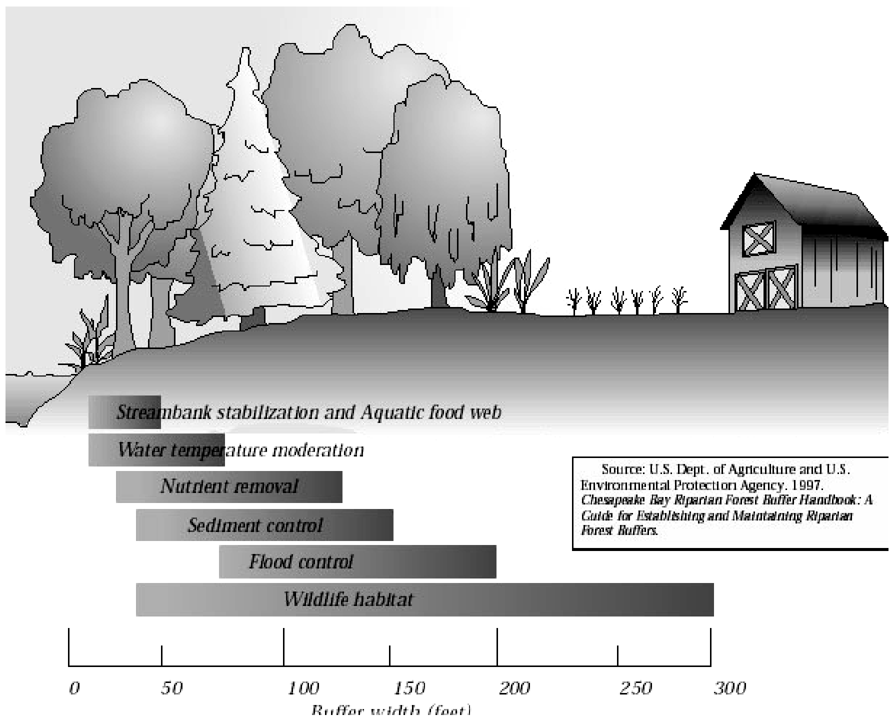
5. Draw a Map of the Site (Data collection)
Prepare a sketch of the site that denotes important existing features, including stream width, length, streambank condition, adjacent land uses and stream activities, desired width of buffer, discharge pipes, obstructions, etc.

6. Create a Design that Meets Multiple Objectives
Ideally, the three-zone system should be incorporated into the design, in a flexible manner to obtain water quality and landowner objectives.

- *Consider landowner objectives*: Consider the current use of the buffer by the landowner, especially if the buffer will be protected in perpetuity. Consider linking the buffer to an existing (or planned trail system).
- *Buffer width*: Riparian buffer areas do not have a fixed linear boundary, but vary in shape, width, and vegetative type and character. The function of the buffer (habitat, water quality, etc) is the overriding criterion in determining buffer width (Figure 1). Many factors including slope, soil type, adjacent land uses, floodplain, vegetative type, and

water shed condition influence what can be planted. The most commonly approved minimum buffer widths for water quality and habitat maintenance are 35 –100 feet. Buffers less than 35 feet do not protect aquatic resources long term.

Figure 1



- *Consider costs:* The planting design (density, type, mix, etc.) will ultimately be based on the financial constraints of the project. See discussion below for estimating direct costs for planting and maintenance.
- *Choose the appropriate plants:* This manual encourages the use of native plants in stormwater management facilities. Since they are best suited to our local climate, native species have distinct genetic advantages over non-native species. Ultimately using native plants translates into greater survivorship with less replacement and maintenance which is a cost benefit to the landowner. Please refer to the plant list in Appendix B for a comprehensive list of native trees and shrubs available for stormwater management facility planting.

Plant Size: Choice of planting stock (seeds, container seedling, bare-root seedlings, plugs, etc.) is ultimately determined by funding resources. Larger material will generally cost more, although it will usually establish more rapidly.

7. Draw a Planting Plan

Planting Density: Trees should be planted at a density sufficient to provide 320 trees per acre at maturity. To achieve this density, approximately 436 (10 x 10 feet spacing) to 681 (8 x 8 feet spacing) trees per acre should be planted initially. Some rules of thumb for tree spacing and density based on plant size at installation:

Seedlings	6-10 feet spacing (~700 seedlings / acre)
Bare Root Stock	14-16 feet spacing (~200 plants / acre)
Larger & Container	16 – 18 feet spacing (~150 plants/acre)

Formula for Estimating Number of Trees and Shrubs:
Plants = length x width of corridor (ft) / 50 square feet

This formula assumes each tree will occupy an average of 50 sq. ft., random placement of plants approximately 10 feet apart, and mortality rate of up to 40% that can be absorbed by the growing forest system.

Alternatively, the adjacent table can be utilized to estimate the number of trees per acre needed for various methods of spacing.

Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)
2x2	10,890	7x9	691	12x15	242
3x3	4,840	7x10	622	12x18	202
4x4	2,722	7x12	519	12x20	182
4x5	2,178	7x15	415	12x25	145
4x6	1,815	8x8	681	13x13	258
4x7	1,556	8x9	605	13x15	223
4x8	1,361	8x10	544	13x20	168
4x9	1,210	8x12	454	13x25	134
4x10	1,089	8x15	363	14x14	222
5x5	1,742	8x25	218	14x15	207
5x6	1,452	9x9	538	14x20	156
5x7	1,245	9x10	484	14x25	124
5x8	1,089	9x12	403	15x15	194
5x9	968	9x15	323	15x20	145
5x10	871	10x10	436	15x25	116
6x6	1,210	10x12	363	16x16	170
6x7	1,037	10x15	290	16x20	136
6x8	908	10x18	242	16x25	109
6x9	807	11x11	360	18x18	134
6x10	726	11x12	330	18x20	121
6x12	605	11x15	264	18x25	97
6x15	484	11x20	198	20x20	109
7x7	889	11x25	158	20x25	87
7x8	778	12x12	302	25x25	70

Planting Layout: Given planting density and mix, drawing the planting plan is fairly straightforward. The plan can vary from a highly technical drawn to scale plan, or a simple line drawing of the site. Any plan must show the site with areas denoted for trees and shrub species with notes for plant spacing and buffer width.

8. Prepare Site Ahead of Time

Existing site conditions will determine the degree of preparation needed prior to planting. Invasive infestation and vegetative competition are extremely variable, and therefore must be considered in the planning stages. Site preparation should begin in the fall prior to planting. Enlist professional to determine whether use of chemical controls are necessary to prepare site for planting. Eliminate undesired species with either herbicide application (consult a professional) or physical removal. If utilizing a highly designed planting layout, mark site ahead of time with flags, spray paint, or other markers so that the appropriate plant is put in the right place.

9. Determine Maintenance Needs

An effective buffer restoration project should include management and maintenance guidelines, including a description of the allowable uses in the various zones of the buffer. Buffer boundaries should be well defined with clear signs or markers. Weed control is essential for the survival and rapid growth of trees and shrubs, and can include any of the following:

- Organic mulch
- Weed control fabrics
- Shallow cultivation
- Pre-emergent herbicides
- Mowing

Non-chemical weed control methods are preferred since chemicals can easily enter the water system. If possible, avoid working in the riparian area between April 15 and August 15, the mating and newborn period for local wildlife.

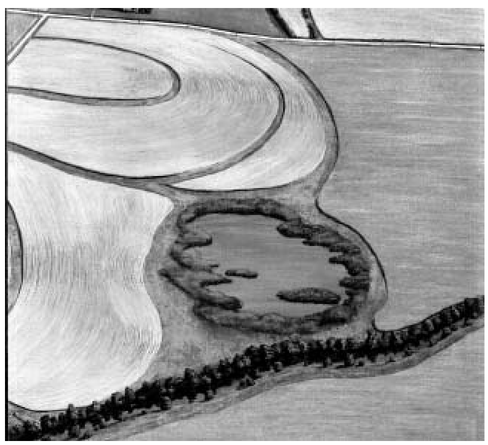
Variations

See Applications

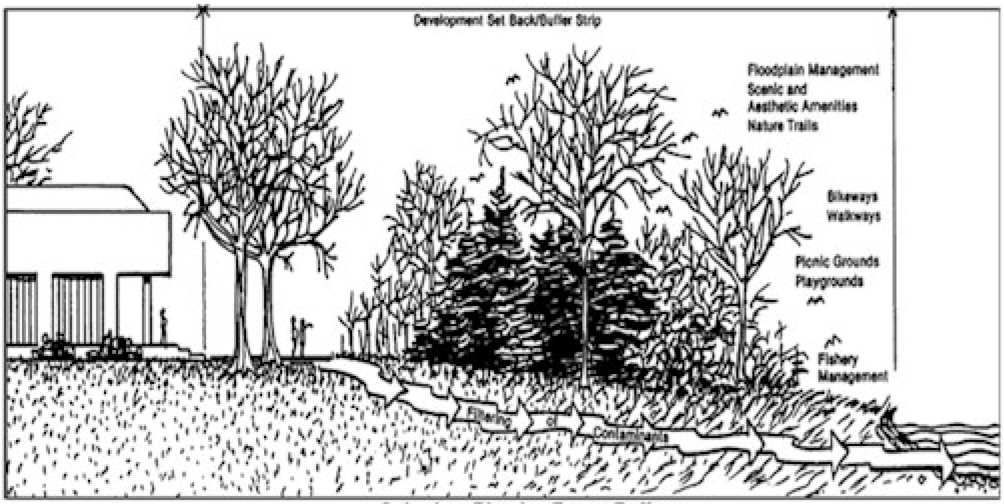
Applications

- **Forested Landscape**

- **Agricultural Landscape**

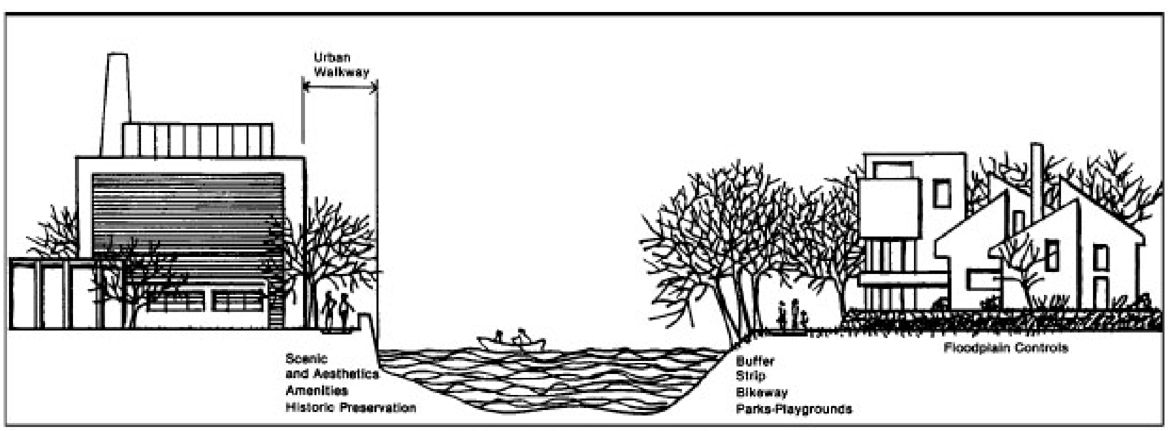


- **Suburban / Developing Landscape**



Suburban Riparian Forest Buffer

- **Urban Landscape**



Urban Riparian Forest Buffer

Design Considerations

The considerations listed below should all be taken into account during the planning stage. There are many potential threats to the long-term viability of riparian plant establishment and with proper foresight, these problems can be eliminated or addressed.

1. Deer Control

    a. Look for signs of high deer densities, including an overgrazed understory with a browse line 5-6 feet above the ground.

2. Tree Shelters

    a. Recommended for riparian plantings where deer predation or human intrusion may be a problem.
    b. Plastic tubes that fit over newly planted trees that are extremely successful in protecting seedlings.
    c. Protect trees from accidental strikes from mowing or trimming
    d. Create favorable microclimate for seedlings
    e. Secure with wooden stake and place netting over top of tree tube
    f. Remove tree shelters 2 to 3 years after plants emerge

3. Stream Buffer Fencing

    a. Deer can jump fences up to 10 feet high, preferring to go under barriers.
    b. Farm animals cause greatest damage to stream banks – consider permanent fencing like high-tensile smooth wire fencing or barbed fencing.
    c. The least expensive is 8 foot plastic fencing, which are effective against deer and easily repaired.

4. Vegetation

    a. Consider using plants that are able to survive frequent or prolonged flooding conditions. Plant trees that can withstand high water table conditions. Figure 5 shows tree species that fit into the moisture conditions of a streamside area.
    b. Soil disturbance can result in unanticipated infestation by invasive plants.

Figure 5. Sample Planting Recommendations According to Moisture Conditions

TREES

- Silver Maple
- Box Elder
- Persimmon →
- Black Ash
- Red Ash
- Pawpaw →
- Sweet-bay Magnolia
- Sycamore →
- Cottonwood
- Swamp White Oak
- Oak, Willow →
- Willow, Sandbar & Black

SMALL TREES/SHRUBS

- River Birch
- Smooth Alder
- Chokeberry, Red
- Chokeberry, Black →
- Groundselbush
- Dogwood, Red Osier & Silky
- Summersweet →
- Winterberry →
- Inkberry →
- Swamp Rose
- Swamp Azalea
- Meadowsweet →
- Highbush Blueberry →
- Witherod →
- N. Arrowwood

TREES

- ← Maple, Red →
- Bitternut Hickory →
- ← Redbud →
- Hackberry →
- American Beech →
- ← Ash, White →
- ← Honey Locust →
- Kentucky Coffee Tree →
- ← Sweet-gum
- Tuliptree →
- Black-gum →
- ← Large-toothed Aspen →
- ← Oak, Pin →

SMALL TREES/SHRUBS

- ← Black/Sweet Birch →
- Mountain Laurel →
- ← Hornbeam →
- Yellow Birch →
- ← Shadbush (A.arborea & canadensis) →
- ← Dogwood, Gray & Flowering →
- Fringe Tree →
- American Hazelnut →
- ← Black Huckleberry
- ← Common Spicebush →
- ← Rosebay Rhododendron
- ← Southern Arrowwood
- ← Ninebark
- ← American Elder →
- Bayberry →
- ← Highbush Cranberry →
- Red Elm

TREES

- White Pine
- Black Cherry
- Sassafras
- Canada Hemlock
- Oak, White
- ← Oak, Red
- Oak, Chestnut
- Hickory, Shagbark
- Maple, Sugar
- Black Walnut

SMALL TREES/ SHRUBS

- Hop-hornbeam
- Witchhazel
- Staghorn Sumac
- Nannyberry
- Blackhaw

Arrows denote that certain species can tolerate either a wetter or drier environment.

Construction Sequence

The PA Stream ReLeaf project provides a checklist that can substitute for a construction sequence for riparian buffer restoration. A slightly modified version follows:

1. SELECT SITE

    - Confirm site is suitable for restoration
    - Obtain landowner permission

2. ANALYSE SITE

    - Evaluate site's physical conditions (soil attributes, geology, terrain)
    - Evaluate site's vegetative features (desirable and undesirable species, native species, sensitive habitats)
    - Sketch or map site feature

3. DESIGN BUFFER

    - Consider landowner objectives in creating buffer design
    - Determine desired functions of buffer in determining buffer width
    - Match plant species to site conditions (hardiness zone, moisture, soil pH)
    - Match plant Species to objectives of buffer functions (water quality, wildlife, recreation, etc.)
    - Match plant sizes to meet budget limitations
    - Develop sketch of planting plan

4. PREPARE SITE

    - Eliminate undesirable species ahead of planting date
    - Mark planting layout at the site
    - Purchase plants and planting materials (mulch, tree shelters)

5. SITE PLAN SHOULD INCLUDE:

    - Site map with marked planting zones
    - Plant species list
    - Planting directions (spacing, pattern of planting)
    - Equipment/tool list
    - Site preparation directions
    - Maintenance schedule

6. PLANTING DAY

    - Keep plants moist and shaded
    - Provide adequate number of tools
    - Document with photos of site during planting

7. SITE MAINTENANCE (additional information below)

- Assign responsibilities watering, weeding, mowing, and maintenance
- Monitor site regularly for growth and potential problems

Maintenance Issues

The riparian buffer is subject to many threats, including:

- Browsing
- Invasion by exotic species
- Competition for nutrients by adjacent herbaceous vegetation
- Human disturbance

Proper awareness of these issues is critical to ensure the long-term effectiveness of a restored riparian buffer.

The most critical period during buffer establishment is maintenance of the newly planted trees during canopy closure, typically the first 3 to 5 years. Ongoing maintenance practices are necessary for both small seedlings and larger plant materials. Maintenance and monitoring plans should be prepared for the specific site and caretakers need to be advised of required duties during the regular maintenance period.

Maintenance measures that should be performed regularly:

Watering

- Plantings need deep regular watering during the first growing season, either natural watering via rainfall, or planned watering, via caretaker.
- Planting in the fall increases the likelihood of sufficient rain during planting establishment.

Mulching

- Mulch will assist in moisture retention in the root zone of plantings, moderate soil temperature, provide some weed suppression, and retard evaporation
- Use coarse, organic mulch that is slow to decompose in order minimize repeat application
- Apply 2-4 inch layer, leaving air space around tree trunk to prevent fungus growth.
- Use combination of woodchips, leaves, and twigs that are stockpiled for six months to a year.

Weed control

- Weed competition limits buffer growth and survival, therefore weeds should be controlled by either herbicides, mowing, or weed mats:

  Herbicides

  This is a short-term maintenance technique (2-3 years) that is generally considered less expensive and more flexible than mowing, and will result in a quicker establishment of the buffer. Herbicide use is regulated by the PA Department of Agriculture. Proper care should be taken to ensure that proximity to water features is considered.

Mowing

Mowing controls the height of the existing grasses, yet increases nutrient uptake, therefore competition for nutrients will persist until the canopy closure shades out lower layers. A planting layout similar to a grid format will facilitate ease of mowing yet yield an unnaturally spaced community. Mowing may result in strikes on the trunk unless protective measures are utilized. Mowing should occur twice each growing season. Mower height should be set between 8 –12 inches.

Weed Mats

Weed mats are geo-textile fabrics that are used to suppress weed growth around newly planted vegetation by providing shade and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds.

Deer damage

- Deer will browse all vegetation within reach, generally between 5-6 feet above the ground
- Approaches to minimize damage include: 1) selecting plants that deer do not prefer (ex. Paper Birch, Beech, Ash, Common Elderberry) 2) homemade deer repellants 3) tree shelters

Tree shelters

- Repair broken stakes
- Tighten stake lines
- Straighten leaning tubes
- Clean debris from tube
- Remove netting as tree grows
- Remove when tree is approximately 2 inches wide

Invasive Plants

- Monitor restoration sight regularly for any signs of invasive plants.
- Appendix B contains common invasive plants found in Pennsylvania.
- Choice of control method is based on a variety of considerations, but falls into three general categories:
    - Mechanical
    - Mechanical with application of herbicide
    - Herbicide

Special Maintenance Considerations

Riparian buffer restoration sites should be monitored to maximize wildlife habitat and water quality benefits, and to discover emerging threats to the project. During the first four years, the new buffer should be monitored four times annually (February, May, August, and November are recommended) and inspected after any severe storm. Repairs should be made as soon as possible.
Depending on restoration site size, the buffer area should be sampled to approximate survival rate. Data derived should consider survival of the planted material and natural regeneration to determine if in-fill planting should occur to supplement plant density.

Survival rates of at least 70% are deemed to be successful. Calculate percent survival by the following equation:

(# of live plants / # of installed plants) 100 = % survival

Cost Issues
Establishment and maintenance costs should be considered up front in the riparian buffer plan design. Installing a forest riparian buffer involves site preparation, tree planting, second year reinforcement planting, and additional maintenance. Both the USDA Riparian Handbook and the PADEP/PADCNR Stream ReLeaf Forest Buffer Toolkit utilize a basic outline for estimating costs for establishment and maintenance:

Costs may fluctuate based on numerous variables including whether or not volunteer labor is utilized, whether plantings and other supplies are donated or provided at a reduced cost.

Specifications

The USDA Forest Service developed a riparian forest buffer specification, which outlines three distinct zones and establishes the minimally acceptable requirements for reforestation by landowners.

Definition
An area of trees and other vegetation located in areas adjoining and upgradient from surface water bodies and designed to intercept surface runoff, wastewater, subsurface flow, and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and ground water recharge areas.

Scope
This specification establishes the minimally acceptable requirements for the reforestation of open lands, and renovation of existing forest to be managed as Riparian Forest Buffers for the purposes stated.

Purpose
To remove nutrients, sediment, animal-derived organic matter, and some pesticides from surface runoff, subsurface flow, and near root zone groundwater by deposition, absorption, adsorption, plant uptake, denitrification, and other processes, thereby reducing pollution and protecting surface water and groundwater quality.

Conditions Where Practice Applies
Subsurface nutrient buffering processes, such as denitrification, can take place in the soil wherever carbon energy, bacteria, oxygen, temperature, and soil moisture is adequate. Nutrient uptake by plants occurs where the water table is within the root zone. Surficial filtration occurs anywhere surface vegetation and forest litter are adequate.

The riparian forest buffer will be most effective when used as a component of a sound land management system including nutrient management and runoff, and sediment and erosion control practices. Use of this practice without other nutrient and runoff, sediment and erosion control practices can result in adverse impacts on buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting, and the carrying of excess nutrients and sediment through the buffer by concentrated flows.

This practice applies on lands:

1. adjacent to permanent or intermittent streams which occur at the lower edge of upslope cropland, grassland or pasture;

2. at the margins of lakes or ponds which occur at the lower edge of upslope cropland, grassland or pasture;

3. at the margin of any intermittent or permanently flooded, environmentally sensitive, open water wetlands which occur at the lower edge of upslope cropland, grassland or pasture;

4. on karst formations at the margin of sinkholes and other small groundwater recharge areas occurring on cropland, grassland, or pasture.

Note: In high sediment production areas (8-20 in./100 yrs.), severe sheet, rill, and gully erosion must be brought under control on upslope areas for this practice to function correctly.

Riparian Buffer Installation Costs - Estimation per Acre

				Cost, ea.	Number	Cost, Total
Phase 1: Establishment						
	Preparation					
		Light site preparation (mow, disking)		-	-	$ 12.00
	Planting					
		Tree Seedlings (12" - 18" Hardwoods)		$ 1.15	430	$ 494.50
		Tree Shelters	(optional)	$ 5.00	430	$ 2,150.00
		Fencing (1 ac = 282 ft)	(optional)			$ 564.00
			Subtotal			**$ 3,220.50**
Phase 2: Maintenance						
	Reinforcement Planting					
		Tree Seedlings in Year 2		$ 1.15	50	$ 57.50
		Herbicide Treatment	(optional)			$ 54.00
		Mowing	(optional)			$ 12.00
			Subtotal			**$ 123.50**
Total Costs, no options						**$ 564.00**
Total Costs, with options						**$ 3,344.00**

Design Criteria

Riparian Forest Buffers

Riparian forest buffers will consist of three distinct zones and be designed to filter surface runoff as sheet flow and downslope subsurface flow, which occurs as shallow groundwater. For the purposes of these buffer strips, shallow groundwater is defined as: saturated conditions which occur near or within the root zone of trees, and other woody vegetation and at relatively shallow depths where bacteria, oxygen, and soil temperature contribute to denitrification. Streamside Forest Buffers will be designed to encourage sheet flow and infiltration and impede concentrated flow.

Zone 1

<u>Location</u>
Zone 1 will begin at the top of the streambank and occupy a strip of land with a fixed width of fifteen feet measured horizontally on a line perpendicular to the streambank.

<u>Purpose</u>
The purpose of Zone 1 is to create a stable ecosystem adjacent to the water's edge, provide soil/water contact area to facilitate nutrient buffering processes, provide shade to moderate and stabilize water temperature encouraging the production of beneficial algal forms, and to contribute necessary detritus and large woody debris to the stream ecosystem.

<u>Requirements</u>
Runoff and wastewater to be buffered or filtered by Zone 1 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 1. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipes or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Dominant vegetation will be composed of a variety of native riparian tree and shrub species and such plantings as necessary for streambank stabilization during the establishment period. A mix of species will provide the prolonged stable leaf fall and variety of leaves necessary to meet the energy and pupation needs of aquatic insects.

Large overmature trees are valued for their detritus and large woody debris. Zone 1 will be limited to bank stabilization and removal of potential problem vegetation. Occasional removal of extreme high value trees may be permitted where water quality values are not compromised. Logging and other overland equipment shall be excluded except for stream crossings and stabilization work.

Livestock will be excluded from Zone 1 except for designed stream crossings.

Zone 2

Location
Zone 2 will begin at the edge of Zone 1 and occupy an additional strip of land with a minimum width of 60 feet measured horizontally on a line perpendicular to the streambank. Total minimum width of Zones 1 & 2 is therefore 75 feet. Note that this is the minimum width of Zone 2 and that the width of Zone 2 may have to be increased as described in the section "Determining the Total Width of Buffer" to create a greater combined width for Zones 1 & 2.

Purpose
The purpose of Zone 2 is to provide necessary contact time and carbon energy source for buffering processes to take place, and to provide for long term sequestering of nutrients in the form of forest trees. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipe or tile, thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer, or treated elsewhere in the system prior to entering the surface water.

Requirements
Runoff and wastewater to be buffered or filtered by Zone 2 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 2.

Predominant vegetation will be composed of riparian trees and shrubs suitable to the site, with emphasis on native species, and such plantings as necessary to stabilize soil during the establishment period. Nitrogen-fixing species should be discouraged where nitrogen removal or buffering is desired. Species suitability information should be developed in consultation with state and federal forestry agencies, Natural Resources Conservation Service, and USDI Fish and Wildlife Service.

Specifications should include periodic harvesting and timber stand improvement (TSI) to maintain vigorous growth and leaf litter replacement, and to remove nutrients and pollutants sequestered in the form of wood in tree boles and large branches. Management for wildlife habitat, aesthetics, and timber are not incompatible with riparian forest buffer objectives as long as shade levels and production of leaf litter, detritus, and large woody debris are maintained. Appropriate logging equipment recommendations shall be determined in consultation with the state and federal forestry agencies.

Livestock shall be excluded from Zone 2 except for necessary designed stream crossings.

Zone 3

Location
Zone 3 will begin at the outer edge of Zone 2 and have a minimum width of 20 feet. Additional width may be desirable to accommodate land-shaping and mowing machinery. Grazed or ungrazed grassland meeting the purpose and requirements stated below may serve as Zone 3.

Purpose

The purpose of Zone 3 is to provide sediment filtering, nutrient uptake, and the space necessary to convert concentrated flow to uniform, shallow, sheet flow through the use of techniques such as grading and shaping, and devices such as diversions, basins, and level lip spreaders.

Requirements

Vegetation will be composed of dense grasses and forbs for structure stabilization, sediment control, and nutrient uptake. Mowing and removal of clippings are necessary to recycle sequestered nutrients, promote vigorous sod, and control weed growth.

Vegetation must be maintained in a vigorous condition. The vegetative growth must be hayed, grazed, or otherwise removed from Zone 3. Maintaining vigorous growth of Zone 3 vegetation must take precedence and may not be consistent with wildlife needs.

Zone 3 may be used for controlled intensive grazing when conditions are such that earthen water control structures will not be damaged.

Zone 3 may require periodic reshaping of earth structures, removal or grading of accumulated sediment, and reestablishment of vegetation to maintain effectiveness of the riparian buffer.

Determining Need For Protection

Buffers should be used to protect any body of water which will not be:

- treated by routing through a natural or artificial wetland determined to be adequate treatment;

- treated by converting the flow to sheet flow and routing it through a forest buffer at a point lower in the watershed.

Determining Total Width of the Buffer

Note that while not specifically addressed, slope and soil permeability are components of the following buffer width criteria.

Each of the following criteria is based on methods developed, or used by persons conducting research on riparian forests.

Streamside Buffers

The minimum width of streamside buffer areas can be determined by any number of methods suitable to the geographic area.

1. Based on soil hydrologic groups as shown in the county soil survey report, the width of Zone 2 will be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C which are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 & 2 may be limited to the 75 foot minimum.

2. Based on area, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 equal to one third of the slope distance from the streambank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream which occupies approximately one third of the source area.

3. Based on the Land Capability Class of the buffer site as shown in the county soil survey, the width of Zone 2 should be increased to provide a combined width of Zones 1 & 2 as shown below.

Capability Class	Buffer Width
Cap. I, II e/s, V	75'
Cap. III e/s, IV e/s	100'
Cap. VI e/s, VII e/s	150'

Pond and Lake-Side Buffer Strips

The area of pond or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic Group and Capability Class methods of determining width remain the same as for streamside buffers. Minimum widths apply in all cases.

Environmentally Sensitive Wetlands

Some wetlands function as nutrient sinks. When they occur in fields or at field margins, they can be used for renovation of agricultural surface runoff and/or drainage. However, most wetlands adjoining open water are subject to periodic flushing of nutrient-laden sediments and, therefore, require riparian buffers to protect water quality.

Where open water wetlands are roughly ellipsoid in shape, they should receive the same protection as ponds.

Where open water wetlands exist in fields as seeps along hillslopes, buffers should consist of Zones 1, 2 & 3 on sides receiving runoff and Zones 1 & 3 on the remaining sides. Livestock must be excluded from Zones 1 & 2 at all times and controlled in Zone 3. Where Zones 1 & 3 only are used, livestock must be excluded from both zones at all times, but hay removal is desirable in Zone 3.

Vegetation Selection

Zone 1 & 2 vegetation will consist of native streamside tree species on soils of Hydrologic Groups D and C and native upland tree species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter which drives bacterial processes that remove nitrogen, as well as, the sequestering of nutrients in the growth processes. In warmer climates, evergreens are also important due to the potential for nutrient uptake during the winter months. In both cases, a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs.

Species recommendations for vegetated buffer areas depend on the geographic location of the buffer. Suggested species lists should be developed in collaboration with appropriate state and federal forestry agencies, the Natural Resources Conservation Service, and the USDI Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, forbs, as well as site preparation techniques. Fertilizer and lime, helpful in establishing buffer vegetation, must be used with caution and are not recommended in Zone 1.

Maintenance Guidelines

General
Buffers must be inspected annually and immediately following severe storms for evidence of sediment deposit, and erosion, or concentrated flow channels. Prompt corrective action must be taken to stop erosion and restore sheet flow.

The following should be avoided within the buffer areas: excess use of fertilizers, pesticides, or other chemicals; vehicular traffic or excessive pedestrian traffic; and removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives.

Zone 1 vegetation should remain undisturbed except for removal of individual trees of extremely high value or trees presenting unusual hazards such as potentially blocking culverts.

Zone 2 vegetation, undergrowth, forest floor, duff layer, and leaf litter shall remain undisturbed except for periodic cutting of trees to remove sequestered nutrients; to maintain an efficient filter by fostering vigorous growth; and for spot site preparation for regeneration purposes. Controlled burning for site preparation, consistent with good forest management practices, could also be used in Zone 2.

Zone 3 vegetation should be mowed and the clippings removed as necessary to remove sequestered nutrients and promote dense growth for optimum soil stabilization. Hay or pasture uses can be made compatible with the objectives of Zone 3.

Zone 3 vegetation should be inspected twice annually, and remedial measures taken as necessary to maintain vegetation density and remove problem sediment accumulations.

Stable Debris
As Zone 1 reaches 60 years of age, it will begin to produce large stable debris. Large debris, such as logs, create small dams which trap and hold detritus for processing by aquatic insects, thus adding energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Wherever possible, stable debris should be conserved.

Where debris dams must be removed, try to retain useful, stable portions which provide detritus storage.

Deposit removed material a sufficient distance from the stream so that it will not be refloated by high water.

Planning Considerations

1. Evaluate the type and quantity of potential pollutants that will be derived from the drainage area.

2. Select species adapted to the zones based on soil, site factors, and possible commercial goals such as timber and forage.

3. Plan to establish trees early in the dormant season for maximum viability.

4. Be aware of visual aspects and plan for wildlife habitat improvement if desired.

5. Consider provisions for mowing and removing vegetation from Zone 3. Controlled grazing may be satisfactory in Zone 3 when the filter area is dry and firm.

References

Natural Resources Conservation Service. 1997. USDA Natural Resources Conservation Practice Standard Riparian Forest Buffer. USDA Natural Resources Conservation Service.

Palone, R.S. and A.H. Todd (editors.) 1997. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. USDA Forest Service. NA-TP-02-97. Radnor, PA. http://www.chesapeakebay.net/pubs/subcommittee/nsc/forest or *order from: U.S. EPA Chesapeake Bay Program. 410 Severn Ave. Suite 109. Annapolis, MD. 1-800-968-7229*.

PA Department of Environmental Protection. 1998. *Pennsylvania Stream ReLeaf – Forest Buffer Toolkit*, http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/StreamReLeaf/default.htm

Tjaden, R.L. and G.M. Weber. 1997. An Introduction to the Riparian Forest Buffer. Maryland Cooperative Extension Fact Sheet 724. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS724.pdf.

Tjaden, R.L. and G.M. Weber. 1997. Riparian Buffer Systems. Maryland Cooperative Extension Fact Sheet 733. College Park, MD. 2 pages. http://www.riparianbuffers.umd.edu/PDFs/FS733.pdf.