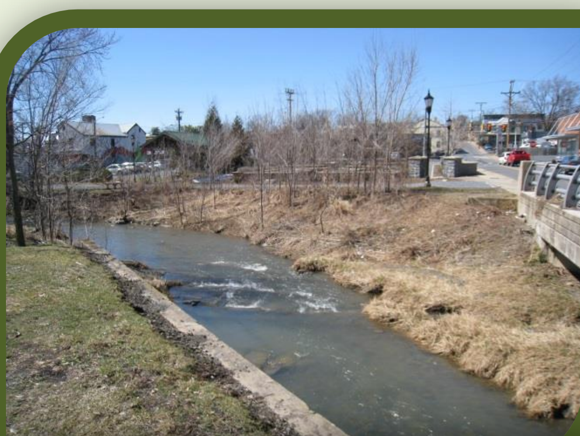


Stormwater Retrofit Opportunities on Public Land in Harrisonburg

September 2013
FINAL

PREPARED FOR:

City of Harrisonburg, VA

PREPARED BY:

CENTER FOR WATERSHED PROTECTION

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
www.cwp.org

ACKNOWLEDGEMENTS

The project team from the Center for Watershed Protection (CWP) would like to acknowledge the significant contributions from Thanh Dang (Harrisonburg), Abe Kaufman and Dale Chestnut (JMU), David Nichols (Bridgewater), and Erin Yancey (Central Shenandoah Planning District Commission). Each provided coordination, guidance, and insight that allowed this project to be successful.

This study received additional support from the following:

Rick Altizer (Harrisonburg)
Ray Bailey (Harrisonburg)
Danny DeLong (Harrisonburg)
Tanya Denckla-Cobb (UVA Institute for Environmental Negotiation)
Jeremy Harold (Harrisonburg)
Tom Hartman (Harrisonburg)
CJ Mitchem (CSPDC)
Megan O'Gorek (Shenandoah SWCD)
Jerry Prey (Harrisonburg)
Natalie Raffol (UVA Institute for Environmental Negotiation)
Dan Rublee (Harrisonburg)
Wes Runion (Harrisonburg)
Tara Sieber (VADEQ)
John Ware (Bridgewater)
Tara Willging (VADEQ)

The CWP project team consisted of the following individuals:

Joe Battiata
David Hirschman
Lisa Fraley-McNeal
Chris Swann
Laurel Woodworth

We are grateful to the Central Shenandoah Planning District Commission for securing a Local Government Technical Assistance grant from the National Fish and Wildlife Foundation (NFWF) to fund this project, Grant # 0600.12.038466.

NFWF Disclaimer: The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government or the National Fish and Wildlife Foundation. Mention of trade names of commercial products does not constitute their endorsement by the U.S. Government or the National Fish and Wildlife Foundation.

Table of Contents

List of Figures

List of Tables

SECTION 1. PROJECT BACKGROUND

1.1 Purpose

The intent of this project was to conduct a stormwater retrofit inventory for three neighboring communities in Virginia's Shenandoah Valley: the City of Harrisonburg, James Madison University, and the Town of Bridgewater. This study will help each of these communities determine the level to which stormwater retrofits on public properties can reduce urban nutrients and sediment. This report is tailored specifically to the study findings for Harrisonburg. In addition to serving as an inventory of potential retrofits, the report also quantifies costs of retrofit construction and pollutant removal, and suggests several scenarios for incorporating retrofits into the Small Municipal Separate Storm Sewer System (MS4) program and TMDL Action Plans.

"Stormwater retrofitting" refers to the practice of installing stormwater management features in places where development has already occurred. In some cases, existing developed land has no stormwater treatment to begin with. In others, older facilities, such as detention ponds, can be upgraded to enhance pollutant removal. A stormwater retrofit study provides an opportunity to look at the developed landscape, analyze how it changed as properties were developed, and imagine how it can be modified to better manage the flow of water that runs off it and to local streams.

This is not just an academic exercise. Runoff from existing developed properties is a major source of pollutants and increased storm flow that leads to the erosion of stream banks and degradation of waterways. Beyond these purposes, stormwater retrofits also foster innovation and create excitement in a community and are often used for educational purposes. People become excited about taking simple actions to promote clean water and to "green up" school campuses, parks, and other public buildings. Often, a few stormwater retrofits on public land can shift the way that stormwater is managed across the entire community, with developers and even homeowners adapting ideas to their own uses.

Controlling urban runoff is also the goal of evolving regulatory programs, such as the EPA-driven Chesapeake Bay Total Maximum Daily Load (TMDL) effort to reduce non-point sources of pollution to the Bay. In an effort to achieve the goals of the Bay TMDL, Virginia's Small MS4General Permit calls for regulated jurisdictions to achieve 5% of the total phosphorous, nitrogen, and sediment load reductions outlined as part of Virginia's Watershed Implementation Plans (WIP) within the current MS4 permit cycle (2013 – 2018). The remaining pollutant reductions must be achieved in subsequent permit cycles.

In March 2013, field teams consisting of CWP staff and Harrisonburg/JMU/Bridgewater staff fanned out across nearly 100 publically-owned sites (51 in Harrisonburg, 35 at JMU, and 13 in Bridgewater,). The teams investigated how to use the landscape to reduce, capture, and filter runoff that otherwise flows directly to nearby streams. This report describes the field investigation process and the analysis that followed and presents a prioritized list of stormwater retrofit concepts for Harrisonburg to consider constructing in the near term and as part of long-range planning.

This retrofit assessment was made possible through a grant from the National Fish and Wildlife Foundation's Chesapeake Bay Local Government Assistance Program. The grant proposal was secured by the Central Shenandoah Planning District Commission on behalf of the City of Harrisonburg, Town of Bridgewater, and James Madison University. This grant secured technical assistance from the Center for Watershed Protection to work on retrofit investigations with each of these jurisdictions. As MS4s, Harrisonburg, JMU, and Bridgewater have benefitted from working together through this project as they have been able to communicate more frequently about stormwater program issues and retrofitting strategies.

SECTION 2. RETROFIT INVENTORY PROTOCOLS

2.1 Site Selection

Each partner first developed a list of potential public property retrofit sites in their jurisdiction to assess in the field. Based on available mapping layers and stormwater BMP data, CWP staff then identified additional retrofit sites. This screening was based on public ownership and/or presence of existing detention or extended detention basins that may benefit from retrofitting.

In Harrisonburg, additional sites identified by CWP included all schools, a majority of city-owned land, and detention basins identified as public from the City's BMP data. City-owned land with limited opportunities for retrofitting (i.e., parking garages and sites with limited space) were excluded. Each list of field sites was finalized in consultation with each partner and a unique ID was assigned to each site. A total of 48 sites in Harrisonburg were pre-identified for field inspection. At James Madison University, additional sites identified by CWP included detention and extended detention basins that may benefit from retrofitting. A total of 35 sites at JMU were pre-selected to visit during field work. Finally, the retrofit sites suggested by Bridgewater staff included all town and public properties and no additional sites were identified by CWP. A total of 13 sites were selected for field inspection in Bridgewater.

2.2 Field Methodology

Using geographic information systems (GIS) data provided by each partner, CWP staff created field maps with recent aerial images, roads, topography, stormwater infrastructure, utilities, and streams. (Note: Maps for Bridgewater only contained aerial imagery and road locations.) These maps were used to identify the specific drainage areas of each potential retrofit and to make note of details, such as the direction of flow and discharge points for runoff.

Fieldwork was conducted from March 19-21, 2013. Many people were involved in conducting the retrofit field assessments. The following is a list of participants:

- *Bridgewater:* David Nichols and John Ware
- *James Madison University:* Dale Chestnut and Abe Kaufman
- *Harrisonburg:* Rick Altizer, Ray Bailey, Thanh Dang, Danny DeLong, Jeremy Harold, Tom Hartman, Jerry Prey, Wes Runion
- *Central Shenandoah Planning District Commission:* CJ Mitchem
- *Virginia Department of Environmental Quality:* Tara Sieber and Tara Willging
- *Shenandoah Soil and Water Conservation District:* Megan O'Gorek
- *Institute for Environmental Negotiation (UVA):* Tanya Denckla-Cobb, Natalie Raffol
- *Center for Watershed Protection:* Joe Battiata, Lisa Fraley-McNeal, David Hirschman, Chris Swann, Laurel Woodworth

Each of five field teams was led by a CWP staff person experienced with retrofitting. The latest Retrofit Reconnaissance Investigation (RRI) form was used (see **Appendix A**), and methods outlined in CWP's *Urban Stormwater Retrofit Practices* were used as guidance (CWP, 2007). Using the RRI form, the teams evaluated the stormwater retrofit potential of each candidate site by analyzing existing drainage patterns, drainage areas, impervious cover, available space, and site constraints (e.g., conflicts with existing utilities and land uses, site access, and potential impacts to natural areas). Unless there were obvious site constraints and/or evidence that a particular stormwater retrofit would offer few or no watershed benefits, a stormwater retrofit concept was developed for each candidate project site, including a sketch plan when appropriate. Occasionally, other issues such as stream bank erosion, stormwater outfall pipe erosion, pollution hotspots, and impacted buffers were found in the field. The field crews noted these problems and potential solutions on different types of forms, also found in **Appendix A**.

Figure 1. *Field crews searching for potential stormwater retrofits.*

More detail on conducting the Retrofit Reconnaissance Inventory can be obtained directly from the guidance manual, Urban Stormwater Retrofit Practices (CWP, 2007). This publication contains extensive information on identifying and evaluating potential retrofit locations within a subwatershed as well as profile sheets on individual retrofit designs and guidance on construction, maintenance, and costs.

After field work was completed, CWP staff reviewed all field forms for completeness and compiled the data for each retrofit concept into a combined spreadsheet. This allowed evaluation of each retrofit to determine the nutrient and runoff reduction capabilities, planning-level cost, and cost efficiency. This spreadsheet also served as a platform for scoring and ranking each retrofit concept. See **Section 3** for more information about this evaluation process. Completed field forms for each site can be found in **Appendix D**, along with photos and maps of the project locations.

2.3 Retrofit Types

A wide variety of stormwater management retrofit options were considered while inventorying these public properties. This project followed the conventions in *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects* (Schueler and Lane, 2012) by assigning retrofits to one of three categories:

New Retrofits: Retrofit projects that create storage to reduce nutrients from existing developed land that is not currently receiving any stormwater treatment.

BMP Conversions: Retrofits of older, existing stormwater ponds to employ more effective treatment mechanism(s), such as converting a dry pond to a constructed wetland.

BMP Enhancements: Retrofits that utilize the existing treatment mechanism in an existing BMP, but improve removal by increasing storage volume or hydraulic residence time.

The report includes a fourth category, BMP Restoration, which includes major maintenance upgrades to existing BMPs that have failed or lost their original treatment capacity. This category was not included in the study, since all projects involving an existing BMP aimed to maximize pollutant removal by including a conversion or enhancement of the existing practice. Some of the projects do include restoring treatment capacity, but that was factored into the conversion or enhancement concept design.

The project also had a category for Other Practices. These include practices such as pollution prevention, landscape maintenance, tree planting and reforestation, and outfall stabilization. **Table 1** shows examples and descriptions of the types of stormwater practices that were considered as options for retrofitting the subject properties.

Table 1. Examples of Stormwater Retrofit Practices			
New Retrofits	**Bioretention or Bioswale**		Landscaped practice that uses plants, mulch, and soil to treat runoff. Most have underdrain pipes to ensure water only ponds temporarily. Common in parking lot islands and edges and as part of commercial site plans.
	Rain Garden		Similar to bioretention/bioswale, but generally smaller and less expensive. Designed to treat runoff from rooftops, driveways, and yard areas. To keep design and construction simple, underdrains and gravel are not generally used.
	Wet Swale		Linear wetland cells that intercept shallow groundwater to maintain a wetland plant community. Saturated soils support wetland vegetation, which provides an ideal environment for gravitational settling, biological uptake, and microbial activity.
	Dry Swale		Also similar to bioretention/bioswale. Main difference is that the dry swale has a longitudinal slope to fit site conditions and may be narrower than typical bioretention. Sometimes check dams are used to slow water down and create temporary ponding cells.
	Filter Strip		Vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils.
	Filtering Practice		Stormwater filters capture, temporarily store, and treat stormwater runoff by passing it through an engineered filter media, collecting it in an underdrain and then returning it back to the storm drain system. The filter consists of two chambers; the first is devoted to settling, and the second serves as a filter bed (with sand or an organic filtering media).

Table 1. Examples of Stormwater Retrofit Practices

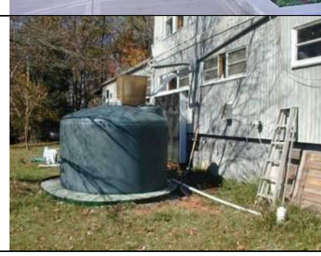
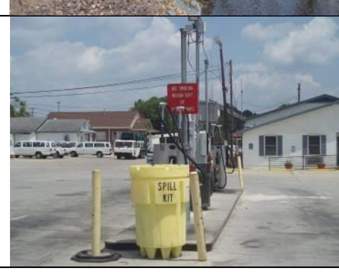
	Infiltration		Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to infiltrate into underlying soils. These practices are suitable for use in areas where *measured* soil permeability rates exceed 1/2 inch per hour.
	Constructed Wetland		Constructed wetlands are shallow depressions that receive stormwater inputs for treatment. Wetlands are typically less than one foot deep (although they have deeper pools at the forebay and micropool) and possess variable microtopography to promote dense and diverse wetland cover.
	***Regenerative Stormwater Conveyance** **See App. C for longer description* **(Photo by: Keith Underwood)**		Linear open channel systems used at stormwater outfalls that convey and treat stormwater runoff in a stable manner. A series of shallow pools, an underlying sand bed, and native vegetation provide stability, even during large storm events. These designs are currently being used for wooded ravine outfalls in Anne Arundel County, MD.
	Impervious Disconnection		Disconnecting rooftop or other impervious surfaces so that runoff goes through vegetated areas instead of directly to storm sewer, driveway, parking lot, etc. Can be “simple” disconnection to grass (as shown in photo), or disconnection to rain garden, rain barrel, or soil-amended area.
	Stormwater Planter		Stormwater planters (also known as vegetative box filters or foundation planters) take advantage of limited space available for stormwater treatment by placing a soil filter in a container, often along buildings at the bottom of roof downspouts.
	Rainwater Harvesting		Collection of rooftop water in tank or cistern for later use for outdoor or indoor applications, including irrigation, washing, cooling systems, toilet flushing, laundry, etc. Cisterns can be above-ground or underground.

Table 1. Examples of Stormwater Retrofit Practices

	Permeable Pavement		Pavement made from permeable materials, such as interlocking paver blocks, permeable concrete, and permeable asphalt. Storage for runoff is provided below pavement surface in a stone or gravel layer, and water either infiltrates into the ground or drains out slowly through underdrain pipes.
BMP Conversion/Enhancement			Existing stormwater ponds are either converted into a different BMP that employs more effective treatment mechanisms, or enhanced by increasing treatment volume and/or increasing hydraulic retention time. Most pond retrofits involve the conversion of older ponds into a constructed wetland or wet pond.
Other Practices	**Re-Vegetation / Tree-planting**		Vegetating turf areas with trees and shrubs to restore water retention capacity and provide other services, such as shade and habitat. In some cases, soil amendments are needed prior to re-vegetation. Deep tilling, or “sub-soiling,” of soil prior to planting can also greatly improve infiltration.
	Outfall Protection		Adding stone, rip-rap, plunge pools, check dams, or vegetated conveyance channels to pipe outfalls that are eroding and causing damage to receiving streams.
	Stream Restoration		Repairing stream bank erosion and/or reconnecting stream flow to the floodplain.
	Pollution Prevention		Variety of management practices for spill response, materials storage, landscape maintenance, dumpster management, disposal of wash water and wastewater, vehicle maintenance, and employee training to keep pollutants out of stormwater runoff and waterways.

SECTION 3. EVALUATION & RANKING

3.1 Evaluation Method

Evaluation of the candidate retrofit projects involved:

1. Selecting "Screening Factors" that provide objective and subjective assessment of the relative value of candidate retrofit practices.
2. Scoring each candidate practice based on the Screening Factors.
3. Ranking the practices based on their respective scores.

This section will summarize the methodologies and computations involved in the scoring and ranking process. First, however, it is important to note several key objectives and caveats for this process:

- Since the overall intent of the project was to identify and evaluate retrofits in the context of numerical targets in the MS4 permits and Watershed Implementation Plans (WIPs), the scoring process, to the extent possible, used methods developed by the Chesapeake Bay Program to assign pollutant removal efficiencies to various BMPs. Of particular importance are the methods in *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects* (Schueler and Lane, 2012). A potential significant caveat is that the state of Virginia (DEQ) has yet to define exactly the methods that MS4s are to use to report BMP pollutant removals (aside from inputting BMP implementation data into the VAST tool) and what role the Expert Panel methods will play in the Virginia system. As of the writing of this report, DEQ has assembled a Stakeholder Advisory Group to address this and other issues associated with the TMDL Action Plans. As such, the Expert Panel methods, as interpreted by the CWP project team, are the most up-to-date process for assigning retrofit pollutant removal rates.
- As noted, the Expert Panel report required some interpretation by the project team in order to apply the methods to specific projects. It was beyond the scope of the Expert Panel to envision every retrofit scenario, so the project team had to "fill in the blanks" in some cases. This section of the report documents the methods and computation procedures used to do this.

3.2 Ranking Process

The following sections provide detailed descriptions of each of the 3 steps outlined above.

Step 1: Selecting Screening Factors

Screening factors are metrics that define the overall value of a retrofit project. Since "overall value" is relative, the selection of screening factors involves careful vetting and analysis of the outcomes that are most important to a particular local program. Screening factors can fall into two general categories:

1. Calculated/Objective: Some screening factors are based on calculations derived from retrofit concepts. Calculation inputs can include drainage area and associated land cover to the retrofit site, potential storage volume provided by the retrofit (as measured in the field), and pollutant removal rates assigned to particular BMPs.
2. Subjective: Some screening factors are subjective and qualitative, but reflect important values for the program. Examples can include: value for education and outreach, public visibility, level of maintenance required, community acceptance, etc.

Generally, four to eight screening factors are selected. Often, the various factors are assigned "weights" so that each project can be scored on a 100-point scale.

In order to select screening factors for this project, a joint meeting was held with project representatives from Bridgewater, Harrisonburg, and JMU on April 25, 2013. At this meeting, potential screening factors were presented and discussed. There was a good deal of agreement among project participants, with only slight differences in the weighting of the various factors.

Table 2 portrays the screening factors selected for Harrisonburg and how each factor is assigned a maximum score to produce a maximum possible overall score of 100 points. The first two factors – Cost Effectiveness and Total Phosphorus removal – are calculated and reflect the importance of pollutant removal and cost for the management of MS4 programs. As such, these two factors are weighted the heaviest ("primary" factors), with each having a maximum score of 35. The remaining three factors – Maintenance Burden, Utility and Site Constraints, and Aesthetics/Safety – are subjective, and can be considered "secondary" factors with maximum scores in the 5 to 15 point range.

Table 2. Screening Factors Used for Retrofit Scoring

Screening Factor	Description	Scoring
Pounds of Total Phosphorus (TP) Removed – TP used as indicator for other pollutants	Screening factor that combines influence of total drainage area treated and pollutant removal efficiency of proposed retrofit.	Each retrofit scored as % of best TP removal x 35 Maximum Score = **35**
Cost Effectiveness ($ per pound of TP removed)	Cost of construction per pound of total phosphorus removed by the retrofit	Each retrofit scored as % of best cost effectiveness x 35 Maximum Score = **35**
Maintenance Burden (Long-term)	Low maintenance retrofits rely on vegetation and passive treatment mechanisms (e.g., most stream restoration projects). It should be understood that ALL practices may have initial "high level" maintenance period to get plants established, control invasives, etc. As such, this metric measures long-term maintenance requirements. Retrofits with High maintenance burden may require removing debris after most storm events or have risk of heavy sediment loading, for example.	Low maintenance burden = **15**
		Medium maintenance burden = **7.5**
		High maintenance burden = **0**
Potential Utility or Site Constraints	Presence and significance of utility conflicts or other site constraints, such as limited space, required grading, or property issues	No apparent constraints = **10**
		Access somewhat constrained or utilities present but relatively easy to move (e.g., electric or phone lines) = **5**
		Poor access, major grading required, or major utilities must be moved (e.g., sewer) = **0**
Aesthetics and Safety	Since these projects are on public land, this factor considers issues such as standing water in close proximity to foot traffic, steep drop-offs or slopes, etc. The factor also considers projects that can enhance aesthetics by adding landscaping.	Practice adds landscaping and/or would enhance aesthetics at the site = **5**
		Practice neither detracts from aesthetic/safety nor adds much in the way of value = **2.5**
		Practice would pose an aesthetic or safety issue based on the practice type and location= **0**
		Total Maximum Score = 100

Step 2: Scoring Each Candidate Practice Based on the Screening Factors

Scoring each individual retrofit concept was accomplished by using a unique spreadsheet for each jurisdiction. The spreadsheet includes input cells populated by measurements taken in the field (e.g., potential practice surface area) and/or derived from GIS (e.g., drainage area, impervious cover). The spreadsheet uses these data to perform certain computations that relate to the screening factors discussed above. **Appendix B** contains a table of the significant fields from the completed spreadsheets.

The three tables that follow provide documentation for the calculations and scoring method:

- **Table 3** lists and describes the inputs to the spreadsheet. The table details inputs for all retrofit projects, plus additional inputs for BMP conversion and enhancement projects.
- **Table 4** documents the calculations performed by the spreadsheet and how these are used to assign scores for the selected screening factors.
- **Table 5** shows unit cost data used to score the cost-effectiveness screening factor, as well as whether the practice is categorized in the Expert Panel report as Runoff Reduction (RR) or Stormwater Treatment (ST).

Table 3. Description of Retrofit Spreadsheet Inputs	
ALL PRACTICES – GENERAL INPUT DATA	
CWP Lead Staff Person	Chris Swann (CPS), David Hirschman (DJH), Joe Battiata (JGB), Laurel Woodworth (LW), Lisa Fraley-McNeal (LFM).
Unique Site ID	Site identifier that starts with B (Bridgewater), H (Harrisonburg), J (JMU). For example, H8. Multiple retrofit projects on a single site are labeled H8-A, H8-B, etc.
Site Description	Site name and/or location within a larger site.
Drainage Area	Drainage area to the retrofit, in acres.
Impervious Cover	Impervious cover within the drainage area, in acres.
Proposed Practice	Generally practices from Table 2 in Expert Panel report (Schueler and Lane, 2012). Based on the report, practices are categorized as either "Runoff Reduction" (RR) or "Stormwater Treatment" (ST). JMU also had a stream restoration project, so this practice was added to the list of practice types.
Retrofit Practice Dimensions	Available surface footprint and depth to install the retrofit practice. Depending on the practice and site, this may include length, width, ponding depth, filter media depth (e.g., for bioretention), gravel depth (e.g., for underdrains). Depth can be constrained by the elevation of existing storm sewer inlets, topography, etc.
CONVERSIONS & ENHANCEMENTS – ADDITIONAL INPUT DATA	
Existing Practice	Choices include Dry Detention Pond (originally designed only for peak rate control) or Extended Detention (ED) Pond (designed for both peak rate control and water quality treatment).
Pre-Retrofit Performance Discount & Issue	Based on existing conditions, some ponds exhibit performance issues, such as short-circuiting or by-passing of the treatment area, storage filled with sediment, clogging, or the practice being undersized. Depending on the severity of the problem, a performance discount of 0, 0.25, 0.5, 0.75, or 1.0 can be assigned to existing ponds, with 0 being no performance issue and 1 being total practice failure. A column is also assigned to document the particular performance issue. Enhancement projects can also assign a Post-Retrofit Performance Discount (for example, even after the retrofit, the practice is undersized). The reason this Post-Retrofit discounts apply only to enhancements is that enhancement projects do not use the performance curves in the Expert Panel report, and thus treatment volume is not used to scale pollutant removal performance.

Table 4. Documentation of Calculations in the Spreadsheet
*NOTE: Items in bold are CALCULATED SCREENING FACTORS used in the scoring and ranking process (see **Table 2**)*

<table>
<tr><td>Target Water Quality Volume (WQ_V)</td><td>This represents the "target" storage volume for a retrofit, based on treating runoff from 1" of rainfall (standard for new development and redevelopment in Virginia stormwater regulations). While retrofits do not have the same regulatory obligation as new and redevelopment, establishing a target based on the regulatory standard can be an important screening factor.

Target WQV = 1" x Rv x DA x 3630

Where:
Target WQV = Target water quality volume (cubic feet)
Rv = Composite runoff coefficient in the drainage area = (% Impervious x 0.95) x (% Turf x 0.22)
DA = Drainage area (acres)
3630 = Conversion factor</td></tr>
<tr><td>Total Volume Provided By Retrofit Practice</td><td>Often retrofits cannot meet the full target water quality volume storage due to site constraints. This metric measures the actual storage volume potentially provided by the practice based on practice dimensions and storage layers, as measured in the field.

Total Volume = Surface Ponding + Soil Media Storage + Underdrain Gravel Storage

Assumptions:
Soil media porosity = 0.25
Gravel porosity = 0.40, as per VA Bioretention specification (No. 9)
Side slopes = 3:1

NOTE: The spreadsheet also calculates the "% of the Target WQ_V" stored in the practice, using the first two calculations</td></tr>
<tr><td>Drainage Area Pollutant Loads for TP, TN, TSS</td><td>These are the pollutant loads generated by the land covers in the drainage area <u>without any retrofit or existing practice.</u> Loading rates for TP, TN, and TSS were derived from 2009 Edge-Of-Stream rates from Phase 5.3.2 of the Chesapeake Bay Model for the Potomac River Basin.

Pollutant Load = (Urban Impervious x LR) + (Urban Pervious x LR)

LR = Loading Rate (lbs/acre per yr) from table below

<table><tr><td></td><td>TP</td><td>TN</td><td>TSS</td></tr><tr><td>Regulated Urban Impervious</td><td>1.62</td><td>16.86</td><td>1,171.32</td></tr><tr><td>Regulated Urban Pervious</td><td>0.41</td><td>10.07</td><td>175.8</td></tr></table></td></tr>
<tr><td>Runoff Depth Captured Per Impervious Acre</td><td>This value is the "X-axis" input to the Performance Curves in the Expert Panel report (see Appendix B of the Expert Panel report).

Retrofit Storage in acre-inches/Impervious acres in drainage area</td></tr>
<tr><td>Pollutant Removal for New Retrofits (lbs per year)</td><td>This computation replicates the performance curves in the Expert Panel report. The curves generate a % removal for TP, TN, and TSS and then applies the % removal to the pollutant load generated by the drainage area. There are curves for Runoff Reduction (RR) and Stormwater Treatment (ST) practices. RR practices treat stormwater through some treatment mechanism, such as filtering or settling, but also reduce the overall volume of runoff exiting the practice. ST practices accomplish just the former. Table 5 includes which practices are categorized as RR or ST, respectively.</td></tr>
</table>

<table>
<tr><td></td><td>
An example of a performance curve equation is shown below for RR practice TP removal:
$TP\ Removal\ \% = 0.0304x^5+0.2619x^4+0.9161x^3-1.6837x^2+1.7072x-0.0091$
There was one stream restoration project at JMU (Arboretum, J35). Pollutant removals for this project were based on the interim rates in the Stream Restoration Expert Panel report (Schueler and Stack, 2013) and a restoration length of 700 linear feet. [1] The provisional rates in lbs/ft/year are: TP = 0.068; TN = 0.20; TSS = 310 (NOTE: for TSS, the actual rate is closer to 55 lbs/ft/year since a delivery factor of around 0.175 is applied). It is important to note that actual rates for the project will be based on one of the three protocols in the Expert Panel report, so may vary considerably from the interim projections.
</td></tr>
<tr><td>Pollutant Removal for Conversions & Enhancements (lbs per year)</td><td>
For Conversions & Enhancements, there is an extra step to calculate the “Credited Pollutant Removal.” This is the removal accomplished by the retrofit minus the removal assigned to the existing practice (with relevant performance discounts). Existing practice removal rates are derived from Table A-5 in the Retrofits Expert Panel report (approved CBP rates). It is important to note that, based on the Expert Panel report, post-retrofit rates for Conversions (e.g., converting a dry pond to a constructed wetland) DO use the performance curves, but post-retrofit rates for Enhancements still use Table A-5 rates.[2]
<u>Conversion</u> Credited Pollutant Removal =
Conversion Removal from Performance Curves – Existing Practice Removal from Table A-5
<u>Enhancement</u> Credited Pollutant Removal = Enhancement Removal from Table A-5 – Existing practice removal x Difference between pre- and post-retrofit performance discounts.
Table A-5 (undiscounted) rates are listed in the table below (lbs/acre per yr):
<table>
<tr><th></th><th>TP</th><th>TN</th><th>TSS</th></tr>
<tr><td>Dry Detention Pond</td><td>10</td><td>5</td><td>10</td></tr>
<tr><td>Dry ED Pond</td><td>20</td><td>20</td><td>60</td></tr>
</table>
</td></tr>
<tr><td>Retrofit Cost</td><td>
These are planning-level cost for the retrofit type, using unit construction costs ($/per cubic foot treated) from available studies. With the caveat that cost data are notoriously variable, the project team used the most up-to-date cost data from the Bay Watershed and elsewhere. The unit costs were derived from a variety sources, including JRA (2013), King & Hagan (2011), CWP (2007), and, where available, actual construction bids for retrofit projects (see, for example, CWP, 2011). These represent reasonable planning-level costs, but these data can be modified using local cost data. Also, it is important to note that these costs are construction costs and NOT BMP life-cycle costs. This is because construction costs are easier to ascertain and have less “scatter,” so represent a more reliable metric to compare projects. Life-cycle costs include project planning and permitting, administration, long-term inspection and maintenance, and other costs. Information on life-cycle BMP costs is available from WVDEP (2012), King & Hagan (2011), and WERF (2009), among other sources.
Cost = Cubic Foot Treated x Unit Construction Cost from Table 5
</td></tr>
<tr><td>Cost-Effectiveness ($/lb of TP removed per year)</td><td>
TP was used for this calculation since it is the keystone pollutant for the Virginia regulations.
Cost Effectiveness in $ = Retrofit Cost/lbs of TP Removed by Retrofit
</td></tr>
</table>

[1] A proposal by Ecosystem Services, LLC (May 1, 2013) notes that there is approximately 1,400 linear feet of stream channel in this reach. A conservative estimate was made that the stream restoration protocols would apply to half of this reach length.
[2] This is because Enhancements, in theory, do not change the type of the existing practice, and so they are still considered an ED pond (even though the enhancement may add wetland cells, increase the flow path, etc.). Based on the Expert Panel report, dry and ED ponds should not use the performance curves. As such, with the method used in this project, the only net removal for Enhancements is assigning a performance discount to the existing practice and removing the discount, in part or in full, for the Enhancement retrofit.

Table 5. Unit Construction Costs and RR/ST Designation for Various Retrofit Practices

Retrofit Practice	RR or ST	Construction Cost/CF treated
Bioretention	RR	$24.46
Constructed Wetlands	ST	$12.37
Dry Swale	RR	$20.00
Filtering Practice	ST	$11.60
Green Roof	RR	$170.00
Infiltration	RR	$12.68
Permeable Pavers	RR	$63.15
Wet Ponds	ST	$12.37
Wet Swale	ST	$12.37
Rain Tank	RR	$15.00
Stormwater Planter	RR	$38.05
Regenerative Stormwater Conveyance*	RR	$45.00
Filter Strip	RR	$6.00
Stream Restoration	--	$12.47
Conversion & Enhancements	--	$3.59

**See Appendix C for detailed description of this practice.*

Step 3: Ranking the Projects

As a final step, the spreadsheet ranks the candidate retrofit projects within each jurisdiction from highest to lowest score, with the top-scoring project ranked #1. This ranking should not be taken at face value with regard to the final prioritizations of projects, as professional judgment is still required to identify which projects are most important for Harrisonburg to implement. For instance, projects that score high may have hidden "project killers" that reduce their feasibility. These may include overall cost, willingness of the landowner or manager, conflicts with other capital projects, community acceptance, loss of parking spaces, and other factors. Alternately, relatively low-ranking projects can be elevated by local stormwater managers because they can be implemented quickly, linked with other capital projects, and/or be implemented by an eager property manager or department director.

In order to vet the rankings produced by the spreadsheets, another meeting was held with the MS4 project representatives on July 3, 2013. At this meeting, the project team reviewed the mechanics of the scoring and ranking spreadsheets, presented the high-ranking projects, and requested that the MS4 representatives review and potentially amend the rankings. Practices with No Score or Rank: It is important to note that some concepts developed during the field inventory were not given a score due to the nature of the practice. These include the following concept types:

- Bank Erosion Repair
- Impacted Buffer Repair
- Landscape Maintenance / Re-forestation
- Outfall Stabilization
- Pollution Prevention
- Filter Strip

These cannot be scored alongside the other practices because they do not create a storage volume and/or they represent changes in maintenance procedures or operations. However, these practices are listed in the overall retrofit inventory and should be equally considered for implementation.

As part of the broader MS4 program planning, some of these practices (e.g., buffer restoration, re-forestation) can be programmed in the VAST tool to compare pollutant removal benefits (see suggested scenarios in Section 5).

SECTION 4. STUDY RESULTS

4.1 Summary of Projects

Table 6 lists all of the 44 projects identified in Harrisonburg, with the rank of each practice, as applicable. To see detailed parameters and values for each project, see **Appendix B**. For summaries and photos of each site, see **Appendix D**. One should be aware that the scores are provided for comparative purposes. For instance, a project with a score in the 40s or 30s may seem like a "throw-away," but can actually be a sensible and achievable project.

Table 6. All Projects Identified in Harrisonburg

Site ID	Site Description	Proposed Practice	Rank
H200 alternate	Heritage Oaks Golf Course	Regenerative Stormwater Conveyance*	outlier[1]
H42	Median on Route 33 Market Street	Regenerative Stormwater Conveyance*	1
H11	Ralph Sampson Park	Enhancement	2
H47	Linda Lane Extended	Enhancement	3
H10-D	Ralph Sampson Park @ b'ball courts	Bioretention	4
H29-A	Keister Elementary School	Bioretention	5
H22-A	Westover Park Entrance	Bioretention	7
H-10A	Lucy Simms Basin	Enhancement	6
H4	Harrisonburg Electric Commission operations	Bioretention	8
H10-C	Lucy Simms Building	Rain Tank	9
H27	Harrisonburg High School	Bioretention	10
H37	Harrisonburg Public works yard	Wet Swale	11
H31	Purcell Park	Bioretention	13
H29-B	Keister Elementary School	Bioretention	12
H38-C	Harrisonburg Recycling Center	Bioretention	15
H201	Fire Station #3	Bioretention	14
H38-A	Harrisonburg Water & Sewer dept	Bioretention	16
H50	Old South High St	Bioretention	17
H45-A	Spotswood Elementary School	Bioretention	20
H19-B	Department of Community Development	Bioretention	19
H21	W. Market Street Basin No. 1	Enhancement	18
H200	Heritage Oaks Golf Course	Bioretention	21
H8-A	Waterman Elementary School	Bioretention	24
H10-B	Lucy Simms Parking Lot	Bioretention	23
H8-C	Waterman Elementary School	Dry Swale	22
H30	Unused Parcel between Rt 11 and Railroad	Bioretention	25
H38-B	Harrisonburg Public Works storage yard	Bioretention	26
H28 - Option 3	Maryland Ave Fire Station (truck washing activities)	Bioretention	27
H22-B	Westover Park Parking Lot	Bioretention	28

H9	Rockingham County Admin Bldg.	Bioretention	29
H8-B	Waterman Elementary School	Bioretention	30
H19-A	Department of Community Development	Bioretention	31
H16	Massanutten Regional Library	Stormwater Planter	32
H28 - Option 1	Maryland Ave Fire Station Driveway (truck washing activities)	Bioretention	33
H13-PP	City of Harrisonburg Hose Company #4	Pollution Prevention	N/A
H14-ER	Harrison Plaza	Bank Erosion	N/A
H14-IB	Harrison Plaza	Impacted Buffer	N/A
H15-A	County Court House	Landscape Maintenance	N/A
H15-B	County Court House	Landscape Maintenance	N/A
H28 - Option 2	Maryland Ave Fire Station (truck washing activities)	Filter Strip	N/A
H37-PP	Harrisonburg Public Works	Pollution Prevention	N/A
H40	Stone Spring Elementary School	Landscape Maintenance	N/A
H41-OT	A Dream Come True Playground	Outfall Stabilization	N/A
H45-B	Spotswood Elementary School	Landscape Maintenance	N/A
**See Appendix C for more detailed description of this type of practice.*			

Based on a natural break in the retrofit scores, the 10 highest-scoring practices were considered as the "Top-Ranked" category. **Table 7** summarizes the top-ranked projects for Harrisonburg**.**

Table 7. Summary of 10 Top-Ranked Retrofit Sites for Harrisonburg

Site	DA (ac.)	%WQ$_V$[1]	TP (lbs/yr)	TN (lbs/yr)	TSS (lbs/yr)	Construction Cost	$/lb TP reduced per yr
H200-Alt: Heritage Oaks G.C. RSC	100.00	5%	16.26	308.44	2,493	$220,320	$13,552
H42: Market St. Median	88.50	7%	12.22	123.44	9,574	$740,070	$60,545
H11: Ralph Sampson Park BMP	0.64	11%	0.18	2.02	436	$775	$4,234
H47: Linda Lane Extended	10.25	99%	0.86	12.81	1,483	$63,503	$73,472
H10-D: Ralph Sampson Park Courts	4.09	33%	1.50	25.57	439	$35,701	$23,776
H29: Keister E.S.	0.60	38%	0.38	3.58	331	$17,330	$45,174
H10-A: Lucy Simms Basin	20.16	19%	0.76	12.1	1,158	$21,540	$28,344
H22-A: Westover Park Entrance	3.00	56%	1.30	20.88	467	$48,478	$37,392
H4: H'burg Electric Commission	2.60	21%	0.94	9.63	743	$34,259	$36,493
H10-C: Lucy Simms Bldg.	1.39	100%	1.48	13.47	1,289	$67,920	$46,035
TOTALS	**231.23**		**35.88**	**531.94**	**18,415**	**$1,249,896**	**$34,835**[2]

[1] *This refers to the percent of the Target Water Quality Volume (WQ$_V$) captured by the practice, as described in* ***Table 4****. Since these are retrofit projects, they do not have a regulatory obligation to meet 100% of the WQ$_V$, but it is a good metric by which to compare projects.*
[2] *This value is not a Total, per se, but the total cost for the 10 projects divided by the total TP removal.*

4.2 Trends in the Three Communities

The following observations are general trends noted for all three jurisdictions.

What Are The Most Cost-Effective Practices?

Based on the scoring metric of cost per pound of Total Phosphorus reduced (cost-effectiveness), BMP conversions and enhancements are generally more cost-effective. **Table 8** shows the values for this metric for all three jurisdictions included in the project. Within each jurisdiction, conversions/enhancements are more cost-effective than new retrofits. For all three jurisdictions, the average cost-effectiveness for new retrofits is $56,279, compared to $23,647 for conversions/enhancements. As **Table 8** also illustrates, there is a wide range of cost-effectiveness values for both new and conversion/enhancement projects, and project-specific factors (e.g., drainage area, type of project) will dictate this.

Of equal importance, conversions/enhancements, while more cost-effective on average, are limited in number because they rely on a pre-existing practice, while new retrofits can be located across the broader landscape. The three jurisdictions had a total of 64 candidate new retrofit projects on public land, but only 9 conversions/enhancements.

What this means in practical terms is that an MS4 should seek first to convert and/or enhance existing BMPs, but will likely need to blend this with the most cost-effective new retrofits in order to meet load reduction targets. These data also suggest that MS4s would be well-served to seek conversion/enhancement projects for existing practices on private land. While the administrative issues would be more difficult for private land projects (e.g., securing easements, working with landowners), the overall cost-effectiveness may be worth the effort.

What Are "Heroic" Retrofit Projects?

For each jurisdiction, there appears to be one or two "heroic" retrofit projects that have large drainage areas, are cost-effectiveness, and achieve disproportionately high load reductions. The influence of these heroic projects can be quite pronounced, as illustrated in **Table 9**. Compared to the load reductions achieved by ALL of the candidate retrofit projects for a given jurisdiction, the one or two heroic projects are generally responsible for half or more of the reductions, and this value can exceed 75% (in the case of Bridgewater). These projects are clearly the heavy-hitters, and of course are the top-ranked projects for each jurisdiction.

The conundrum for an MS4 is that these projects also tend to be the more expensive projects, with estimated price tags for construction being in the hundreds of thousands of dollars (compared in many cases to tens of thousands for lower ranked projects). However, viewed another way, the heroic projects are relative bargains, because they cost proportionately less per pound of pollutant reduced. With this in mind, an MS4 may want to prioritize the heroic projects, but also realize that implementation, including raising the necessary capital, may take several years to accomplish. Also, it will be critical to scrutinize these projects thoroughly, as there may be reasons to not elevate them so highly. Feasibility, construction issues, property rights, and political support must all be analyzed in a feasibility or concept design stage to truly analyze whether the projects can deliver what is promised.

Table 8. Cost-Effectiveness of New Retrofits vs. Conversions/Enhancements -- $/Pound of TP Removed

	Bridgewater	Harrisonburg	JMU
New Retrofits			
Number in Sample	9	31	24
Range of Values	$24,100 -- $120,046	$13,552 -- $210,949	$22,227 -- $105,657
Average	$51,511	$60,757	$56,568
Conversions/Enhancements			
Number in Sample	1	4	4
Range of Values	$7,723	$4,234 -- $94,553	$9,797 -- $14,164
Average	$7,723	$51,167	$12,052

Table 9. Percent of Load Reductions & Costs for "Heroic" Projects Compared to ALL Retrofits From This Study For Each Jurisdiction

	TP	TN	TSS	Construction Cost ($)
Bridgewater – Project B2-A, Oakdale Park	77%	78%	73%	40%
Harrisonburg – Projects H200-Alt (Heritage Oaks G.C. RSC) & H42 (Market St. Median)	54%	62%	36%	42%
JMU – Project J35, Arboretum Stream Restoration	50%	25%	57%	23%

SECTION 5. RECOMMENDATIONS

5.1 Further Considerations

For Harrisonburg, implementation of the retrofits identified in this study must be done strategically and with full vetting of other available BMPs and strategies to achieve target pollutant load reductions. As Harrisonburg embarks on its first MS4 Permit Cycle with the TMDL Action Plan and load reduction requirements, it will be important to keep the following topics in mind.

Expanding the Search for Retrofit Options

This study only addressed retrofits on selected public land parcels within the City. Obviously, the acreage covered is only a small percentage of land within the jurisdiction. Accordingly, and as is evidenced by the data presented in this section, public land retrofits will be only part of the overall pollutant load reduction puzzle for Harrisonburg. In future years, an expanded retrofit assessment could also cover rights-of-way, private parcels with significant impervious cover, private basins and ponds, and other promising scenarios.

Investigating the Full Range of Practices

Stormwater retrofits are only one of the BMP strategies available to MS4s to achieve pollutant load reductions. As of this report, the Chesapeake Bay Program Expert Panels have approved procedures and performance values for implementing new state performance standards, retrofits, stream restoration, and urban nutrient management (see: http://chesapeakestormwater.net/bay-stormwater/baywide-stormwater-policy/urban-stormwater-workgroup/). Several other Expert Panels are in progress or pending: illicit discharge detection and elimination (IDDE), street sweeping, enhanced erosion control, and floating wetlands. As these protocols become accepted by the Bay Program, it will be helpful for MS4s to analyze which practices will be most suitable and cost-effective for their jurisdiction.

Stormwater Design Considerations for Karst

Harrisonburg and other Shenandoah Valley jurisdictions must address stormwater design issues associated with karst. Karst tends to be a very site-specific feature, and it is difficult to establish at the concept stage how it may affect a particular stormwater practice with regard to design details and associated costs. It is important to note that the pollutant removal performance values and costs presented in this report are based on Bay-wide data and procedures (and sometimes national data with regard to unit costs). As such, the performance values and unit costs do not anticipate the use of impermeable liners, more involved geotechnical work at the design stage, or other karst-specific issues. CWP does believe that karst is an important design consideration, but should not result in across-the-board or automatic BMP design modifications that increase cost.

The most recent Bay-wide guidance on stormwater design in karst is Technical Bulletin #1 from the Chesapeake Stormwater Network, and can be found here (CSN, 2009):

http://chesapeakestormwater.net/2012/03/technical-bulletin-no-1-stormwater-design-guidelines-for-karst-terrain/. It should also be noted that the Virginia BMP Specifications on the Clearinghouse website (http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html) contain short sections about design adaptations for karst.

Keeping in Touch With DEQ About MS4 Reporting

This study used the Bay Program-approved protocols, with some technical interpretations by CWP staff, to assign pollutant removal performance values to candidate retrofit (and some stream restoration) projects. A major caveat is that Virginia DEQ must still weigh in on how MS4s should report BMPs and their corresponding performance values. As of the writing of this report, DEQ has convened an MS4 Stakeholder Group to address issues with the TMDL Action Plan. Harrisonburg staff may need to revisit the numbers presented in this section after DEQ issues its guidance.

5.2 Options for Achieving Required Load Reductions

The remainder of this section consists of several tables that present and analyze retrofit data for Harrisonburg. The tables are as follows:

- **Table 10** presents assumed load reduction requirements for Harrisonburg for Total Phosphorus (TP), Total Nitrogen (TN), and Total Suspended Solids (TSS). The numbers are relevant to the "TMDL Action Plan" required in the Virginia Small MS4 General Permit and Virginia's Phase II Watershed Implementation Plan (WIP). For Harrisonburg, these numbers likely overestimate the load reductions actually required since they reflect total acreage for "regulated urban impervious" and "regulated urban pervious" land cover within the whole City. The numbers can be refined once Harrisonburg delineates actual land area within the MS4 boundaries.
- **Table 11** shows how potential load reductions from the candidate retrofit projects in this study compare to those needed in the MS4 Permit and WIP. The table breaks out total loads from all of the candidate retrofit projects, as well as the 10 top-ranked projects (see **Table 7**). The table also shows the percentage of the reduction achieved through retrofits for the 1st (current) permit cycle, as well as the 2nd cycle and the total required reductions through 3 cycles.

  It should be noted that the current general permit only contains requirements to achieve 5% of the reductions, but also states that future permit cycles will be in accordance with the WIP.

  As such, the projections for future permits are based on the percent reductions noted in the WIP. As can be seen from this table, retrofits on public land in Harrisonburg will be only part of the overall MS4 pollution reduction strategy. Implementing the top ten projects within 5 years would achieve 28% (for TSS), 48% (for TP), and 97% (for TN) of the reductions required in the 1st permit term.
- **Table 12** outlines several possible TMDL Action Plan scenarios for Harrisonburg based on the retrofit data. These scenarios assume different retrofit implementation levels and timelines, and assume that retrofits will be implemented along with other

MS4 strategies. A couple of the scenarios involve cooperating with JMU on selected projects or even entering into a joint permit with JMU. Some of the scenarios also envision limited purchase of nutrient credits through the Chesapeake Bay Nutrient Credit Exchange, although this program is still being fleshed out at the state level. It should be noted that these scenarios are hypothetical, and of course the actual strategy must be vetted through a local process. However, the proposed scenarios may help the City with understanding its choices as it continues to implement the MS4 program.

- Since one of the scenarios in **Table 12** involves a joint permit with JMU, **Table 13** and **Table 14** show data on what the required load reductions would presumably be under such a permit and how well different retrofit implementation strategies would achieve the target reductions.

Table 10. Harrisonburg MS4 Required Load Reductions

	Required Load Reductions[1]		
	TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**
1st Permit Cycle (ending 2018) – Achieve 5% of total reduction[2]	75	550	64,733
2nd Permit Cycle (ending 2023) – Achieve additional 35% of total reduction	524	3,851	453,133
Total Reduction Required (in up to three permit cycles)	1,498	11,003	1,294,667

[1] Load reductions derived from DCR spreadsheet that is based on Phase 5.3.2 Watershed Model. The reductions are a % reduction from Edge-of-Stream baseline loads from July 1, 2009. Loads are calculated based on the acreage of "regulated urban impervious" and "regulated urban pervious" acres within the MS4, with specific loading rates for Potomac and Shenandoah River Basin, as documented in Phase 5.3.2 of the Chesapeake Bay Model. All load figures were rounded to the nearest whole number.

[2] The Virginia Small MS4 General Permit became effective on July 1, 2013. Section 1(C) – Special Conditions for the Chesapeake Bay TMDL – stipulates that MS4s achieve 5% of their required reductions in the 1st 5-year permit cycle, and also states that future permit cycle reductions will be in accordance with Virginia's Phase 1 and 2 Watershed Implementation Plans. The permit also requires MS4s to offset increased loads from some new development projects (initiated after July 1, 2009) as well as grandfathered projects (initiated after July 1, 2014). This table shows only numbers for reductions from existing sources. Reductions in the other two categories are expected to be low compared to values for existing sources.

Table 11. Harrisonburg: Implementation of Retrofits Compared to Required Load Reductions

	TP (lbs/yr)	TN (lbs/yr)	TSS (lbs/yr)	Construction Cost
Implement All Retrofits[1]	**53**	**694**	**33,675**	**$2,312,618**
	% of Permit Cycle's Required Reduction			
All Retrofits % 1st Permit Cycle	71%	126%	52%	
All Retrofits % 2nd Permit Cycle (inclusive)[2]	9%	16%	7%	
All Retrofits % Total Reduction	4%	6%	3%	
Implement Only 10 Top-Ranked Retrofits	**36**	**532**	**18,415**	**$1,249,896**
	% of Permit Cycle's Required Reduction			
Top-Ranked % 1st Permit Cycle	48%	97%	28%	
Top-Ranked % 2nd Permit Cycle (inclusive)	6%	12%	4%	
Top-Ranked % Total Reduction	2%	5%	1%	

[1] The total load reductions and costs for implementing All Retrofits assumed that: (1) for H28, option 3 is used and Options 1 and 2 are excluded from the summing of load reductions and costs, and (2) for H200, the Alternative regenerative stormwater conveyance project is used, and the smaller parking lot bioretention project is excluded (see ***Appendix B****). The reason for this is that these projects are nested, and it is likely that only one of the options for each site would be implemented.*

[2] "Inclusive" means the % reduction achieved compared to required reductions for the 1st plus 2nd permit cycles, based on the WIPs. This amounts to a total reduction of 40% (5% for the 1st permit cycle + an additional 35% for the 2nd).

<table>
<tr><th colspan="2">Table 12. Overview of Possible MS4 Load Reduction Scenarios for Harrisonburg</th></tr>
<tr><th>Permit Cycle Activities & Actions</th><th>Notes</th></tr>
<tr><td colspan="2">Scenario 1: Partner With JMU on Arboretum Project[1] + Retrofits + Trading</td></tr>
<tr><td><u>1st Permit Cycle (2018):</u>
• The drainage area for the JMU Arboretum Project is within the City, and the project yields high pollutant reductions and is cost-efficient. If both MS4s were willing partners, Harrisonburg could cost-share and negotiate the % of reduction received.
• In addition, Harrisonburg may want to implement several of their smaller high-ranking retrofit projects (e.g., H4, H11, H22-A, H47).
• Begin design work for some larger retrofits to be constructed during the 2nd cycle (e.g., H42, H200-Alt)
• Take a hard look at other BMPs that may be more cost-effective than retrofits for the needed pollutant reductions: stream restoration, urban nutrient management, street sweeping, IDDE, etc. For instance, the City could conduct a stream restoration inventory that identifies and prioritizes candidate projects.
• Purchase certified nutrient credits to make up any deficits for the 1st cycle, if any.

<u>2nd Permit Cycle (2023):</u>
1. Expand the retrofit inventory to include public rights-of-way, highly-impervious private land, and especially existing stormwater basins and ponds.
2. Construct one or more of the larger high-ranking retrofits, as noted above.
3. Continue to implement other urban BMPs.

<u>Out-Year Permits:</u>
Re-evaluate other potential retrofits along with other Bay Program & Virginia credited practices: street sweeping, urban nutrient management, stream restoration, etc. to pick most cost-effective mix of practices.</td><td>• The JMU Arboretum Project generates surplus TSS reductions through the 2nd permit cycle, based on the projections in this study. On the other hand, JMU may fall short for TN reduction. A partnership with Harrisonburg may allow JMU to use its advantage to reduce TSS and Harrisonburg to use its advantage to reduce TN through BMPs such as urban nutrient management or street sweeping.
• Nutrient trading regulations are still in process at DEQ, so the rules of the game and cost are still uncertain. However, the MS4 General Permit does authorize the use of trading.</td></tr>
<tr><td colspan="2">[1] The "Arboretum Project" refers to a candidate retrofit project identified at JMU as part of this study. The project (J35) involves removing an existing pond and restoring the reach of stream between Neff Avenue and the main Arboretum Pond.</td></tr>
<tr><td colspan="2">Scenario 2: Retrofit "Campuses" + Other BMPs + Trading</td></tr>
<tr><td><u>1st Permit Cycle (2018):</u>
• Harrisonburg could "cluster" retrofits at certain sites so that they could better serve as demonstration sites. Potential sites include Lucy Simms/Ralph Sampson Park (H10 sites, H11), Westover Park (H22 sites), Waterman Elementary School (H8 sites), and/or Keister Elementary (H29 sites). The strategy would be to use retrofits strategically, but rely on other BMPs (e.g., stream restoration) for a larger share of load reductions.
• Conduct an inventory of available stream restoration projects; rank and prioritize similar to the retrofit study.</td><td>• As noted, the retrofit campus idea has merit to concentrate retrofit efforts and serve educational and outreach functions. However, it would not lead to high percentages of needed reductions. For instance, the 4 projects as Lucy Simms/Ralph Sampson Park together would yield 5% of needed reductions for TP and TSS and 9% for TN for the 1st cycle.
• Stream restoration is suggested for several reasons: (1) retrofit-derived TSS reductions seem to lag slightly behind TP/TN for Harrisonburg, (2) as evidenced by the JMU Arboretum project, stream restoration can</td></tr>
</table>

• Conduct an inventory of available retrofits of existing (private) basins and ponds, rights-of-way, some private land. • Also, based on emerging guidance, quantify the cost-effectiveness of urban nutrient management, street sweeping, and other Bay Program and VA credited practices. • Purchase certified nutrient credits to make up any deficits for the 1st cycle. **2nd Permit Cycle (2023):** • Construct strategic stream restoration projects. • Construct some of the larger high-ranking retrofits. • Implement other BMPs. • Possibly trading as needed. **Out-Year Permits:** See Scenario 1.	generate high levels of TSS reduction based on the interim rate, and (3) TSS is not available for trading as are TP/TN.
Scenario 3: Joint Permit With JMU (see Table 13)	
1st Permit Cycle (2018): • Negotiate joint permit with JMU and DEQ. • Implement Arboretum Project and the best high-ranking retrofits from JMU & Harrisonburg. • Jointly conduct an inventory of possible stream restoration projects and other available BMPs. **2nd Permit Cycle (2023):** • Implement the most cost-effective stream restoration, retrofit, or other BMP projects. **Out-Year Permits:** Same as Scenarios 1 and 2.	• Overall, the most cost-effective retrofits are at JMU – between the Arboretum and several basin conversions (J26, J28, J33). The average cost per pound of TP for the 3 JMU basin conversions is $12,022/lb, while the average for the top 10 Harrisonburg retrofits is nearly $37,000/lb. Therefore, it is likely that the basin conversions would be the first projects to be implemented through a joint permit.

Table 13. City of Harrisonburg + JMU Combined MS4 Required Load Reductions			
	Required Load Reductions[1]		
	TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**
1st Permit Cycle (ending 2018) – Achieve 5% of total reduction[2]	78	578	67,568
2nd Permit Cycle (ending 2023) – Achieve additional 35% of total reduction	548	4,050	472,981
Total Reduction Required (in up to three permit cycles)	1,566	11,572	1,351,376

[1] Load reductions derived from DCR spreadsheet that is based on Phase 5.3.2 Watershed Model. The reductions are a % reduction from Edge-of-Stream baseline loads from July 1, 2009. Loads are calculated based on the acreage of "regulated urban impervious" and "regulated urban pervious" acres within the MS4, with specific loading rates for Potomac and Shenandoah River Basin, as documented in Phase 5.3.2 of the Chesapeake Bay Model. All load figures were rounded to the nearest whole number.

[2] The Virginia Small MS4 General Permit became effective on July 1, 2013. Section 1(C) – Special Conditions for the Chesapeake Bay TMDL – stipulates that MS4s achieve 5% of their required reductions in the 1st 5-year permit cycle, and also states that future permit cycle reductions will be in accordance with Virginia's Phase 1 and 2 Watershed Implementation Plans. The permit also requires MS4s to offset increased loads from some new development projects (initiated after July 1, 2009) as well as grandfathered projects (initiated after July 1, 2014). This table shows only numbers for reductions from existing sources. Reductions in the other two categories are expected to be low compared to values for existing sources.

Table 14. City of Harrisonburg + JMU: Implementation of Retrofits Compared to Combined Required Load Reductions				
	TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**	**Construction Cost**
Implement All Retrofits	**148**	**1251**	**101,191**	**$4,175,545**
	% of Permit Cycle's Required Reduction			
All Retrofits % 1st Permit Cycle	189%	216%	150%	
All Retrofits % 2nd Permit Cycle (inclusive)[1]	24%	27%	19%	
All Retrofits % Total Reduction	9%	11%	7%	
Implement Only Combined 15 Top-Ranked Retrofits	**111**	**905**	**69,505**	**$2,226,649**
	% of Permit Cycle's Required Reduction			
Top-Ranked % 1st Permit Cycle	142%	156%	103%	
Top-Ranked % 2nd Permit Cycle (inclusive)	18%	20%	13%	
Top-Ranked % Total Reduction	7%	8%	5%	
Implement Arboretum Project Only	**48**	**140**	**38,500**	**$420,000**
	% of Permit Cycle's Required Reduction			
Arboretum % 1st Permit Cycle	61%	24%	57%	
Arboretum % 2nd Permit Cycle (inclusive)	8%	3%	7%	
Arboretum % Total Reduction	3%	1%	3%	

[1] "Inclusive" means the % reduction achieved compared to required reductions for the 1st plus 2nd permit cycles, based on the WIPs. This amounts to a total reduction of 40% (5% for the 1st permit cycle + an additional 35% for the 2nd).

REFERENCES

Anne Arundel County, Maryland. 2012. *Regenerative Step Pool Storm Conveyance (SPSC), Design Guidelines.* Revision 5: December 2012.

Center for Watershed Protection (CWP). 2007. *Urban Stormwater Retrofit Practices Version 1.0. Manual 3 in the Urban Subwatershed Restoration Manual Series*. CWP. Ellicott City, MD.

Center for Watershed Protection (CWP). 2011. *In-Lieu Fee Proposal for On-Site Stormwater Management*. Unpublished draft. Prepared for the Delaware Department of Natural Resources and Environmental Control Division of Soil and Water conservation. CWP. Ellicott City, MD.

Chesapeake Stormwater Network (CSN). 2009. *Technical Bulletin No. 1: Stormwater Design Guidelines for Karst Terrain in the Chesapeake Bay Watershed.* Version 2.0. Developed by Karst Working Group. CSN. Ellicott City, MD.

James River Association (JRA). 2013. *Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin.* JRA. Richmond, VA.

King, D., and P. Hagan. 2011. *Costs of Stormwater Management Practices in Maryland Counties*. Prepared for Maryland Department of the Environment by the University of Maryland Center for Environmental Services. Technical Report Series No. TS-626-11 of the University of Maryland Center for Environmental Science.

Novotney, M. and R. Winer. 2008. *Municipal Pollution Prevention/Good Housekeeping Practices Manual - Version 1.0.* Manual 9 in the *Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. and C. Lane. 2012. *Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects.* Chesapeake Stormwater Network. Ellicott City, MD.

Schueler, T. and B. Stack. 2013. *Final Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects*. Chesapeake Stormwater Network and Center for Watershed Protection. Ellicott City, MD.

Water Environment Research Foundation (WERF). 2009. *BMP and LID Whole Life Cost Models: Version 2.0.* Alexandria, VA. Available at: http://www.werf.org/i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08

West Virginia Department of Environmental Protection (WVDEP). 2012. *Guidance for Developing an Off-Site Stormwater Compliance Program in West Virginia.*

Wright, T., C. Swann, K. Cappiella, T. Schueler. 2005. *Unified Subwatershed and Site Reconnaissance: A User's Manual-Version 2.0.* Manual 11 in the *Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

APPENDIX A: FIELD FORMS

This appendix includes the field forms used during the stormwater retrofit study:

- Retrofit Reconnaissance Inventory form
- Hotspot Site Investigation form
- Severe Bank Erosion form
- Stormwater Outfall form
- Impacted Buffer form

WATERSHED:	SUBWATERSHED:	UNIQUE SITE ID:	
DATE:	ASSESSED BY:	CAMERA ID:	PICTURES:
GPS ID:	LMK ID:	LAT:	LONG:

SITE DESCRIPTION

Name:____
Address:____

Ownership: ☐ Public ☐ Private ☐ Unknown
If Public, Government Jurisdiction: ☐ Local ☐ State ☐ DOT ☐ Other:____________________

Corresponding USSR/USA Field Sheet? ☐ Yes ☐ No If yes, Unique Site ID:__________________

Proposed Retrofit Location:

Storage
☐ Existing Pond ☐ Above Roadway Culvert
☐ Below Outfall ☐ In Conveyance System
☐ In Road ROW ☐ Near Large Parking Lot
☐ Other:________________________________

On-Site
☐ Hotspot Operation ☐ Individual Rooftop
☐ Small Parking Lot ☐ Small Impervious Area
☐ Individual Street ☐ Landscape / Hardscape
☐ Underground ☐ Other:____________________

DRAINAGE AREA TO PROPOSED RETROFIT

Drainage Area ≈ __________________
Imperviousness ≈ _________________%
Impervious Area ≈ ________________

Notes:

Drainage Area Land Use:
☐ Residential
☐ SFH (< 1 ac lots)
☐ SFH (> 1 ac lots)
☐ Townhouses
☐ Multi-Family
☐ Commercial
☐ Institutional
☐ Industrial
☐ Transport-Related
☐ Park
☐ Undeveloped
☐ Other:______________

EXISTING STORMWATER MANAGEMENT

Existing Stormwater Practice: ☐ Yes ☐ No ☐ Possible
If Yes, Describe:

Describe Existing Site Conditions, Including Existing Site Drainage and Conveyance:
Existing Street Width (if applicable):________

Existing Head Available:	**Note where points are measured from: (i.e. street elevation to catch basin invert, manhole rim to catch basin invert, other)**

PROPOSED RETROFIT

Purpose of Retrofit:
☐ Water Quality ☐ Recharge ☐ Channel Protection ☐ Flood Control
☐ Demonstration / Education ☐ Repair ☐ Other:________________

Retrofit Volume Computations - Target Storage:

Retrofit Volume Computations - Available Storage:

Proposed Treatment Option:
☐ Extended Detention ☐ Wet Pond ☐ Created Wetland ☐ Bioretention
☐ Filtering Practice ☐ Infiltration ☐ Swale ☐ Other:________________

Describe Elements of Proposed Retrofit, Including Surface Area, Maximum Depth of Treatment, and Conveyance:

Available Width: ________
Available Length: ________
Available Area: ________
Ponding Depth: ________
Soil Depth: ________

SITE CONSTRAINTS

Adjacent Land Use:
☐ Residential ☐ Commercial ☐ Institutional
☐ Industrial ☐ Transport-Related ☐ Park
☐ Undeveloped ☐ Other:________________

Possible Conflicts Due to Adjacent Land Use? ☐ Yes ☐ No
If Yes, Describe:

Access:
☐ No Constraints
Constrained due to
☐ Slope ☐ Space
☐ Utilities ☐ Tree Impacts
☐ Structures ☐ Property
Ownership
☐ Other:________________

Conflicts with Existing Utilities:

	Yes	Possible/ Modifiable	No	Unknown
Sewer:	☐	☐	☐	☐
Water:	☐	☐	☐	☐
Gas:	☐	☐	☐	☐
Electric to Streetlights:	☐	☐	☐	☐
Other:	☐	☐	☐	☐

____
____

Potential Permitting Factors:
Dam Safety Permits Necessary ☐ Probable ☐ Not Probable
Impacts to Wetlands ☐ Probable ☐ Not Probable
Impacts to a Stream ☐ Probable ☐ Not Probable
Floodplain Fill ☐ Probable ☐ Not Probable
Impacts to Forests ☐ Probable ☐ Not Probable
Impacts to Specimen Trees ☐ Probable ☐ Not Probable
How many?________________
Approx. DBH________________

Other factors:________________________________
____
______

Soils:
Soil auger test holes: ☐ Yes ☐ No
Evidence of poor infiltration (clays, fines): ☐ Yes ☐ No
Evidence of shallow bedrock: ☐ Yes ☐ No
Evidence of high water table (gleying, saturation): ☐ Yes ☐ No

SKETCH

DESIGN OR DELIVERY NOTES

FOLLOW-UP NEEDED TO COMPLETE FIELD CONCEPT

- ☐ Confirm property ownership
- ☐ Confirm drainage area
- ☐ Confirm drainage area impervious cover
- ☐ Confirm volume computations
- ☐ Complete concept sketch
- ☐ Obtain existing stormwater practice as-builts
- ☐ Obtain site as-builts
- ☐ Obtain detailed topography
- ☐ Obtain utility mapping
- ☐ Confirm storm drain invert elevations
- ☐ Confirm soil types
- ☐ Other:______________________________

INITIAL FEASIBILITY AND CONSTRUCTION CONSIDERATIONS

SITE CANDIDATE FOR FURTHER INVESTIGATION:	☐ YES	☐ NO	☐ MAYBE
IS SITE CANDIDATE FOR EARLY ACTION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE
IF NO, SITE CANDIDATE FOR OTHER RESTORATION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE

IF YES, TYPE(S):______________________________

WATERSHED:	**SUBWATERSHED:**		**UNIQUE SITE ID:**
DATE: ___/___/_____	**ASSESSED BY:**	**CAMERA ID:**	**PIC#:**
MAP GRID:	**LAT** ___°_____'_____" **LONG** ___°_____'____"		**LMK #**

A. SITE DATA AND BASIC CLASSIFICATION

Name and Address: ___________________

____

____

SIC code (if available): ___________

NPDES Status: ☐ Regulated ☐ Unregulated ☐ Unknown

Category: ☐ Commercial ☐ Industrial Miscellaneous ☐ Institutional ☐ Municipal ☐ Golf Course ☐ Transport-Related ☐ Marina ☐ Animal Facility

Basic Description of Operation:

____

	INDEX*
B. VEHICLE OPERATIONS ☐ **N/A** *(Skip to part C)* — **Observed Pollution Source?**	☐
B1. Types of vehicles: ☐ Fleet vehicles ☐ School buses ☐ Other: ____________	
B2. Approximate number of vehicles: _______	
B3. Vehicle activities *(circle all that apply)*: **Maintained Repaired Recycled Fueled Washed Stored**	○
B4. Are vehicles stored and/or repaired outside? ☐ Y ☐ N ☐ Can't Tell Are these vehicles lacking runoff diversion methods? ☐ Y ☐ N ☐ Can't Tell	○
B5. Is there evidence of spills/leakage from vehicles? ☐ Y ☐ N ☐ Can't Tell	○
B6. Are uncovered outdoor fueling areas present? ☐ Y ☐ N ☐ Can't Tell	○
B7. Are fueling areas directly connected to storm drains? ☐ Y ☐ N ☐ Can't Tell	○
B8. Are vehicles washed outdoors? ☐ Y ☐ N ☐ Can't Tell Does the area where vehicles are washed discharge to the storm drain? ☐ Y ☐ N ☐ Can't Tell	○
C. OUTDOOR MATERIALS ☐ **N/A** *(Skip to part D)* — **Observed Pollution Source?**	☐
C1. Are loading/unloading operations present? ☐ Y ☐ N ☐ Can't Tell If yes, are they uncovered *and* draining towards a storm drain inlet? ☐ Y ☐ N ☐ Can't Tell	○
C2. Are materials stored outside? ☐ Y ☐ N ☐ Can't Tell If yes, are they ☐ Liquid ☐ Solid Description: _______ Where are they stored? ☐ grass/dirt area ☐ concrete/asphalt ☐ bermed area	○
C3. Is the storage area directly or indirectly connected to storm drain (circle one)? ☐ Y ☐ N ☐ Can't Tell	○
C4. Is staining or discoloration around the area visible? ☐ Y ☐ N ☐ Can't Tell	○
C5. Does outdoor storage area lack a cover? ☐ Y ☐ N ☐ Can't Tell	○
C6. Are liquid materials stored *without* secondary containment? ☐ Y ☐ N ☐ Can't Tell	○
C7. Are storage containers missing labels or in poor condition (rusting)? ☐ Y ☐ N ☐ Can't Tell	○
D. WASTE MANAGEMENT ☐ **N/A** *(Skip to part E)* — **Observed Pollution Source?**	☐
D1. Type of waste *(check all that apply)*: ☐ Garbage ☐ Construction materials ☐ Hazardous materials **any of these**	○
D2. Dumpster condition (*check all that apply*): ☐ No cover/Lid is open ☐ Damaged/poor condition ☐ Leaking or evidence of leakage (stains on ground) ☐ Overflowing **any of these**	○
D3. Is the dumpster located near a storm drain inlet? ☐ Y ☐ N ☐ Can't Tell If yes, are runoff diversion methods (berms, curbs) lacking? ☐ Y ☐ N ☐ Can't Tell **if both are yes**	○
E. PHYSICAL PLANT ☐ **N/A** *(Skip to part F)* — **Observed Pollution Source?**	☐
E1. Building: Approximate age: ________ yrs. Condition of surfaces: ☐ Clean ☐ Stained ☐ Dirty ☐ Damaged	○
Evidence that maintenance results in discharge to storm drains (staining/discoloration)? ☐ Y ☐ N ☐ Don't know	○

*Index: ○ denotes potential pollution source; ☐ denotes confirmed polluter (evidence was seen)

E2. Parking Lot: Approximate age _____ yrs. Condition: ☐ Clean ☐ Stained ☐ Dirty ☐ Breaking up Surface material ☐ Paved/Concrete ☐ Gravel ☐ Permeable ☐ Don't know	○
E3. Do downspouts discharge to impervious surface? ☐ Y ☐ N ☐ Don't know ☐ None visible Are downspouts directly connected to storm drains? ☐ Y ☐ N ☐ Don't know	○
E4. Evidence of poor cleaning practices for construction activities (stains leading to storm drain)? ☐ Y ☐ N ☐ Can't Tell	○
E5. Evidence of poor cleaning practices for washing activities (observed washwater dumping, stains leading to storm drain)? ☐ Y ☐ N ☐ Can't Tell	○
F. TURF/LANDSCAPING AREAS ☐ **N/A** *(skip to part G)*	**Observed Pollution Source?** ☐
F1. % of site with: Forest canopy ____% Turf grass _____ % Landscaping ____% **Bare Soil 20 %**	○
F2. Rate the turf management status: ☐ High ☐ Medium ☐ Low **40% medium to high**	○
F3. Evidence of permanent irrigation or "non-target" irrigation ☐ Y ☐ N ☐ Can't Tell	○
F4. Do landscaped areas drain to the storm drain system? ☐ Y ☐ N ☐ Can't Tell	○
F5. Do landscape plants accumulate organic matter (leaves, grass clippings) on adjacent impervious surface? ☐ Y ☐ N ☐ Can't Tell	○
G. STORM WATER INFRASTRUCTURE ☐ **N/A** *(skip to part H)*	**Observed Pollution Source?** ☐
G1. Are storm water treatment practices present? ☐ Y ☐ N ☐ Unknown If yes, please describe: __________________	○
G2. Are private storm drains located at the facility? ☐ Y ☐ N ☐ Unknown **> 25 %** Is trash, sediment and/or organic material present in gutters leading to storm drains? *(circle appropriate)*	○

H. INITIAL HOTSPOT STATUS - INDEX RESULTS

☐ Not a hotspot (fewer than 5 circles and no boxes checked) ☐ Potential hotspot (5 to 10 circles but no boxes checked)
☐ Confirmed hotspot (10 to 15 circles and/or 1 box checked) ☐ Severe hotspot (>15 circles and/or 2 or more boxes checked)

Follow-up Action:

Immediate (1 week)

☐ Refer for immediate enforcement
☐ Test for illicit discharge
☐ Check to see if hotspot is an NPDES non-filer

Mid-term (2-3 months)

☐ Schedule a review of storm water pollution prevention plan
☐ Suggest follow-up on-site inspection

Long-term (1 year)

☐ Onsite non-residential retrofit
☐ Suggest pollution prevention training for employees
☐ Other:____

Identified Opportunities:

General

☐ Include in future education effort (add specifics to Notes)
☐ Stencil or mark storm drain inlets
☐ Signage opportunities (buffer, wetland, bacteria, etc.)
☐ Other:____

Rooftop

☐ Evaluate feasibility of cistern or water reuse (roof area:____sf)
☐ Downspout disconnection (#: ____________)

Loading Areas

☐ Sweep loading areas
☐ Cover loading docks or redesign drainage (area: ________sf)

Fueling Islands

☐ Cover fueling islands (covered area: ___________sf)
☐ Install dry spill response kits (#: _____________)

Landscaping / turf

☐ Turf conversion to landscaping / Bayscaping (area: _______sf)
☐ Pervious area restoration (turf area: ____________sf)
☐ Tree planting (# or area: ______________)
☐ Reduce maintenance (mowing, herbicides, fertilizers)

Vehicle repairs

☐ Plumb indoor shop drains to sanitary
☐ Store fluids/batteries inside or under cover

Outdoor materials

☐ Provide cover or secondary containment (area: __________sf)
☐ Place materials on pallets

Dumpster management

☐ Cover or add/repair lids (#: ___________)
☐ Move dumpsters away from storm drains or streams

Parking lots

☐ Find and fix fluid leaks
☐ Trash and litter pick-up, sweeping
☐ Identify retrofit projects
☐ Reduce salt application

Stormwater Infrastructure

☐ Clean out storm drain inlets
☐ Perform maintenance inspection

Notes:

Severe Bank Erosion **ER**

WATERSHED/SUBSHED:	**DATE:** ___/_____/___	**ASSESSED BY:**
SURVEY REACH: **TIME:**___:____AM/PM	**PHOTO ID** (CAMERA-PIC #): /#	
SITE ID: (*Condition-#*) **ER-**_____	*START* **LAT** ____°____'____" **LONG** ____°____'____" **LMK** _____ *END* **LAT** ____°____'____" **LONG** ____°____'____" **LMK** _____	**GPS:** (*Unit ID*)

PROCESS: ☐ Currently unknown
☐ Downcutting ☐ Bed scour
☐ Widening ☐ Bank failure
☐ Headcutting ☐ Bank scour
☐ Aggrading ☐ Slope failure
☐ Sed. deposition ☐ Channelized

BANK OF CONCERN: ☐ LT ☐ RT ☐ Both (*looking downstream)*
LOCATION: ☐ Meander bend ☐ Straight section ☐ Steep slope/valley wall ☐ Other:

DIMENSIONS:
Length *(if no GPS)* LT_______ft and/or RT_________ft
Bank Ht LT_______ft and/or RT__________ft
Bank Angle LT________° and/or RT________°
Bottom width _______ft
Top width __________ft
Wetted Width _______ft

LAND OWNERSHIP: ☐ Private ☐ Public ☐ Unknown
LAND COVER: ☐ Forest ☐ Field/Ag ☐ Developed:

PERCENT OF BANK VEGETATED:
☐ <10% ☐ 10-25% ☐ 25-50%
☐ 50-75% ☐ >75%

BANK COMPOSITION:
☐ 100% sand ☐ Mix sand, gravel, cobble
☐ 100% clay ☐ Other:_______________

DESCRIPTION OF BANK TOE:
☐ Loose/unstable
☐ Mixed (some rocks/veg., loose)
☐ Appears stable (rocks/veg.)

POTENTIAL RESTORATION CANDIDATE: ☐ Grade control ☐ Bank stabilization
☐ No ☐ Other:

THREAT TO PROPERTY/INFRASTRUCTURE: ☐ No ☐ Yes (Describe):

EXISTING RIPARIAN WIDTH: ☐ ≤25 ft ☐ 25 - 50 ft ☐ 50-75ft ☐ 75-100ft ☐ >100ft

EROSION SEVERITY(*circle#*) Channelized= ☐ 1	Active downcutting; tall banks on both sides of the stream eroding at a fast rate; erosion contributing significant amount of sediment to stream; obvious threat to property or infrastructure.	Pat downcutting evident, active stream widening, banks actively eroding at a moderate rate; no threat to property or infrastructure	Grade and width stable; isolated areas of bank failure/erosion; likely caused by a pipe outfall, local scour, impaired riparian vegetation or adjacent use.
	5 4	3 2	1
ACCESS:	Good access: Open area in public ownership, sufficient room to stockpile materials, easy stream channel access for heavy equipment using existing roads or trails.	Fair access: Forested or developed area adjacent to stream. Access requires tree removal or impact to landscaped areas. Stockpile areas small or distant from stream.	Difficult access. Must cross wetland, steep slope or other sensitive areas to access stream. Minimal stockpile areas available and/or located a great distance from stream section. Specialized heavy equipment required.
	5 4	3 2	1

NOTES/CROSS SECTION SKETCH:

REPORTED TO AUTHORITIES ☐ YES ☐ NO

WATERSHED/SUBSHED:	**DATE:** ___/_____/___	**ASSESSED BY:**
SURVEY REACH ID: / **TIME:**___:____AM/PM	**PHOTO ID:** (*Camera-Pic #*) /#	
SITE ID (*Condition-#*): **OT-**_____ / **LAT** ___°_____'_____" **LONG** ___°_____'_____" **LMK**_____		**GPS:** (*Unit ID*)

BANK: ☐LT ☐RT ☐ Head

FLOW: ☐ None ☐ Trickle ☐ Moderate ☐ Substantial ☐ Other:

TYPE:	**MATERIAL:**	**SHAPE:** ☐ Single	**DIMENSIONS:**	**SUBMERGED:**
☐ Closed pipe	☐ Concrete ☐Metal ☐ PVC/Plastic ☐Brick ☐ Other:	☐ Circular ☐ Double ☐ Elliptical ☐ Triple ☐ Other:	Diameter:_____(in)	☐ No ☐ Partially ☐ Fully
☐ Open channel	☐ Concrete ☐ Earthen ☐ Other:	☐ Trapezoid ☐ Parabolic ☐ Other:	Depth: _____(in) Width (Top):_____(in) " (Bottom):_____(in)	*NOT APPLICABLE*

CONDITION:	**ODOR:** ☐ NO	**DEPOSITS/STAINS:**	**VEGGIE DENSITY:**	**PIPE BENTHIC GROWTH:** ☐ None
☐ None ☐ Chip/Cracked ☐ Peeling Paint ☐ Corrosion ☐ Other:	☐Gas ☐ Sewage ☐Rancid/Sour ☐ Sulfide ☐ Other:	☐ None ☐Oily ☐ Flow Line ☐ Paint ☐Other:	☐ None ☐ Normal ☐ Inhibited ☐ Excessive ☐ Other:	☐ Brown ☐ Orange ☐ Green ☐ Other: **POOL QUALITY:** ☐ No pool ☐ Good ☐Odors ☐Colors ☐Oils ☐ Suds ☐ Algae ☐ Floatables ☐ Other:

FOR FLOWING ONLY		
	COLOR:	☐ Clear ☐ Brown ☐ Grey ☐ Yellow ☐ Green ☐ Orange ☐ Red ☐ Other:
	TURBIDITY:	☐ None ☐ Slight Cloudiness ☐ Cloudy ☐ Opaque
	FLOATABLES:	☐ None ☐ Sewage (toilet paper, etc.) ☐ Petroleum (oil sheen) ☐ Other:

OTHER CONCERNS: ☐ Excess Trash (paper/plastic bags) ☐ Dumping (bulk) ☐ Excessive Sedimentation ☐ Needs Regular Maintenance ☐ Bank Erosion ☐ Other:

POTENTIAL RESTORATION CANDIDATE ☐ Discharge investigation ☐ Stream daylighting ☐ Local stream repair/outfall stabilization ☐ no ☐ Storm water retrofit ☐ Other:

If yes for daylighting:

Length of vegetative cover from outfall: ___________ft Type of existing vegetation:_______________________ Slope: ___________°

If yes for stormwater:

Is stormwater currently controlled? ☐ Yes ☐ No ☐ Not investigated

Land Use description:_________________________________

Area available:

OUTFALL SEVERITY: (*circle #*)	Heavy discharge with a distinct color and/or a strong smell. The amount of discharge is significant compared to the amount of normal flow in receiving stream; discharge appears to be having a significant impact downstream.	Small discharge; flow mostly clear and odorless. If the discharge has a color and/or odor, the amount of discharge is very small compared to the stream's base flow and any impact appears to be minor / localized.	Outfall does not have dry weather discharge; staining; or appearance of causing any erosion problems.
	5 4	3 2	1

SKETCH/NOTES:

REPORTED TO AUTHORITIES: ☐ YES ☐ NO

Impacted Buffer **IB**

WATERSHED/SUBSHED: | **DATE:** ___/_____/___ | **ASSESSED BY:**

SURVEY REACH: | **TIME:**____:_____AM/PM | **PHOTO ID:** (*Camera-Pic #*) /#

SITE ID: (*Condition-#*) **IB-**______

START **LAT** ____°____'____" **LONG** ____°____'____" **LMK** ______

END **LAT** ____°____'____" **LONG** ____°____'____" **LMK** ______

GPS: (*Unit ID*)

IMPACTED BANK: ☐ LT ☐ RT ☐ Both

REASON INADEQUATE: ☐ Lack of vegetation ☐ Too narrow ☐ Widespread invasive plants ☐ Recently planted ☐ Other:

LAND USE: (*Facing downstream*)

	Private	Institutional	Golf Course	Park	Other Public
LT Bank	☐	☐	☐	☐	☐:
RT Bank	☐	☐	☐	☐	☐:

DOMINANT LAND COVER:

	Paved	Bare ground	Turf/lawn	Tall grass	Shrub/scrub	Trees	Other
LT Bank	☐	☐	☐	☐	☐	☐	☐:
RT Bank	☐	☐	☐	☐	☐	☐	☐:

INVASIVE PLANTS: ☐ None ☐ Rare ☐ Partial coverage ☐ Extensive coverage ☐ unknown

STREAM SHADE PROVIDED? ☐ None ☐ Partial ☐ Full

WETLANDS PRESENT? ☐ No ☐ Yes ☐ Unknown

POTENTIAL RESTORATION CANDIDATE ☐Active reforestation ☐Greenway design ☐ Natural regeneration ☐ Invasives removal ☐ no ☐ Other:

RESTORABLE AREA

	LT	BANK	RT
Length (ft):	_________		_________
Width (ft):	_________		_________

REFORESTATION POTENTIAL: (*Circle #*)

Impacted area on public land where the riparian area does not appear to be used for any specific purpose; plenty of area available for planting	Impacted area on either public or private land that is presently used for a specific purpose; available area for planting adequate	Impacted area on private land where road; building encroachment or other feature significantly limits available area for planting
5 4	3 2	1

POTENTIAL CONFLICTS WITH REFORESTATION ☐ Widespread invasive plants ☐ Potential contamination ☐ Lack of sun ☐ Poor/unsafe access to site ☐ Existing impervious cover ☐ Severe animal impacts (deer, beaver) ☐ Other:

NOTES:

APPENDIX B: HARRISONBURG RETROFIT CONCEPTS RANKING TABLE

Site ID	Site Description	Proposed Practice	Drainage Area (acre)	Impervious Cover (acre)	Target WQv (cf)	Available Practice Width (ft)	Available Practice Length (ft)	% Water Quality Volume[1]	TP Removal (lb/yr)	TN Removal (lb/yr)	TSS Removal (lb/yr)	Cost $	Cost Effectiveness ($/lb TP removed)	Scoring						Rank
														Cost Effectiveness	Phosphorus Removal	Maintenance Burden	Potential Utility or Site Constraints	Aesthetics / Safety	Total Score	
H42	Median on Route 33 Market Street	Regenerative Stormwater Conveyance	88.50	57.4	222,780.36	20	1,000	11	17.55	179.9	13,751	$1,076,220	$61,309	14	35	15	10	2.5	76	1
H11	Ralph Sampson Park	Enhancement	0.64	0.54	1,942.05	3	72	11	0.18	2.02	436.47	$775	$4,234	35	7	7.5	10	2.5	62	2
H47	Linda Lane Extended	Enhancement	10.25	3.67	17,910.78	113	113	99	0.86	12.81	1,483.18	$63,503	$73,472	2	35	7.5	10	5	60	3
H10-D	Ralph Sampson Park @ b'ball courts	Bioretention	4.09	0.45	4,458.73	25	45	33	1.50	25.57	439.10	$35,701	$23,776	35	3	7.5	5	5	55	4
H29-A	Keister Elementary School	Bioretention	0.60	0.53	1,883.61	10	70	38	0.38	3.58	330.73	$17,330	$45,174	18	1	15	10	5	49	5
H-10A	Lucy Simms Basin	Enhancement	20.16	5.73	31,283.70	-	-	19	0.76	12.10	1,157.85	$21,540	$28,344	5	31	7.5	5	0	49	6
H22-A	Westover Park Entrance	Bioretention	3.00	0.44	3,561.76	20	75	56	1.30	20.88	467.39	$48,478	$37,392	22	3	7.5	10	5	47	7
H4	Harrisonburg Electric Commission operations	Bioretention	2.60	1.74	6,687.19	30	30	21	0.94	9.63	743.34	$34,259	$36,493	23	2	7.5	10	5	47	8
H10-C	Lucy Simms Building	Rain Tank	1.39	1.29	4,528.43	-	-	100	1.48	13.47	1,289.48	$67,920	$46,035	18	3	15	5	2.5	44	9
H37	Harrisonburg Public works yard	Wet Swale	1.02	0.88	3,146.48	25	100	98	0.81	5.62	820.08	$38,089	$47,254	18	2	7.5	10	5	42	10
H27	Harrisonburg High School	Bioretention	2.12	2.12	7,310.82	25	100	57	1.88	16.79	1,677.07	$102,671	$54,546	15	4	7.5	10	5	42	11
H29-B	Keister Elementary School	Bioretention	0.17	0.17	586.25	15	35	102	0.19	1.70	169.81	$14,563	$76,421	11	0	15	10	5	41	12
H31	Purcell Park	Bioretention	1.94	1.35	5,126.65	25	50	27	0.86	8.75	692.66	$33,573	$38,880	21	2	7.5	5	5	41	13
H201	Fire Station #3	Bioretention	0.45	0.28	1,101.34	9	34	25	0.18	1.89	138.24	$6,620	$36,980	23	0	7.5	5	5	40	14
H38-A	Harrisonburg Water & Sewer dept	Bioretention	0.75	0.68	2,400.88	30	30	58	0.63	5.84	549.11	$34,259	$54,176	15	1	7.5	10	5	39	15
H38-C	Harrisonburg Recycling Center	Bioretention	1.60	1.36	4,881.62	30	70	73	1.44	13.60	1,230.55	$87,687	$60,779	14	3	7.5	10	5	39	16
H21	W. Market Street Basin No. 1	Enhancement	1.10	1.10	3,793.35	55	150	247	0.36	3.71	889.10	$33,699	$94,553	2	14	7.5	10	5	38	17
H19-B	Department of Community Development	Bioretention	0.28	0.22	806.59	12	50	28	0.14	1.31	112.84	$5,468	$40,388	21	0	7.5	5	5	38	18

Site ID	Site Description	Proposed Practice	Drainage Area (acre)	Impervious Cover (acre)	Target WQv (cf)	Available Practice Width (ft)	Available Practice Length (ft)	% Water Quality Volume[1]	TP Removal (lb/yr)	TN Removal (lb/yr)	TSS Removal (lb/yr)	Cost $	Cost Effectiveness ($/lb TP removed)	Scoring						Rank
														Cost Effectiveness	Phosphorus Removal	Maintenance Burden	Potential Utility or Site Constraints	Aesthetics / Safety	Total Score	
H50	Old South High St	Bioretention	1.59	0.91	3,681.18	32	70	88	1.22	13.19	913.48	$79,301	$65,059	13	2	7.5	10	5	38	19
H45-A	Spotswood Elementary School	Bioretention	1.14	0.83	3,109.82	42	48	81	0.97	9.68	792.50	$61,703	$63,386	13	2	7.5	10	5	38	20
H8-C	Waterman Elementary School	Dry Swale	0.21	0.21	724.19	8	96	100	0.23	2.09	209.05	$14,535	$61,959	13	0	7.5	10	5	36	21
H200	Heritage Oaks Golf Course	Bioretention	1.08	0.89	3,220.90	40	55	100	1.06	10.10	897.62	$78,874	$74,292	11	2	7.5	10	5	36	22
H30	Unused Parcel between Rt 11 and Railroad	Bioretention	1.32	0.55	2,511.60	15	70	50	0.71	8.60	467.88	$30,809	$43,322	19	1	7.5	5	2.5	36	23
H10-B	Lucy Simms Parking Lot	Bioretention	1.35	1.27	4,443.48	29	53	54	1.12	10.22	983.61	$59,129	$52,719	16	2	7.5	5	5	36	24
H38-B	Harrisonburg Public Works storage yard	Bioretention	0.70	0.63	2,228.46	15	100	96	0.72	6.65	624.19	$52,496	$72,896	11	1	7.5	10	5	35	25
H8-A	Waterman Elementary School	Bioretention	2.18	1.87	6,696.26	49	50	50	1.63	15.37	1,396.23	$81,533	$49,933	17	3	7.5	5	2.5	35	26
H28 - Option 3	Maryland Ave Fire Station (truck washing activities)	Bioretention	0.83	0.83	2,862.26	35	80	145	1.01	8.97	898.56	$101,185	$100,389	8	2	7.5	10	5	33	27
H22-B	Westover Park Parking Lot	Bioretention	0.94	0.94	3,241.59	45	50	103	1.06	9.40	941.79	$81,368	$76,992	11	2	7.5	5	5	30	28
H9	Rockingham County Admin Bldg.	Bioretention	0.87	0.87	3,000.20	38	70	102	0.98	8.69	870.87	$75,070	$76,817	11	2	7.5	5	5	30	29
H8-B	Waterman Elementary School	Bioretention	0.49	0.43	1,530.77	25	51	100	0.50	4.67	431.75	$37,506	$74,773	11	1	7.5	5	5	30	30
H19-A	Department of Community Development	Bioretention	0.54	0.45	1,623.70	35	68	69	0.47	4.44	396.70	$27,277	$58,314	14	1	7.5	0	5	28	31
H16	Massanutten Regional Library	Stormwater Planter	0.10	0.10	344.85	3	24	32	0.06	0.54	54.34	$4,178	$68,509	12	0	7.5	0	5	25	32
H28 - Option 1	Maryland Ave Fire Station Driveway (truck washing activities)	Bioretention	0.23	0.23	793.16	30	80	344	0.32	2.71	263.36	$66,810	$210,949	4	1	7.5	0	5	17	33
H200-Alt	Heritage Oaks GC	Outfall Stabilization	100.00	5.00	93,109.50	15	30	5	16.26	308.4	2,493.49	$220,320	$13,552	35	32	15	10	5	97	Outlier[2]
H15-A	County Court House	Landscape Maintenance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H15-B	County Court House	Landscape Maintenance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Site ID	Site Description	Proposed Practice	Drainage Area (acre)	Impervious Cover (acre)	Target WQv (cf)	Available Practice Width (ft)	Available Practice Length (ft)	% Water Quality Volume[1]	TP Removal (lb/yr)	TN Removal (lb/yr)	TSS Removal (lb/yr)	Cost $	Cost Effectiveness ($/lb TP removed)	Scoring							Rank
														Cost Effectiveness	Phosphorus Removal	Maintenance Burden	Potential Utility or Site Constraints	Aesthetics / Safety	Total Score		
H45-B	Spotswood Elementary School	Tree Planting/Re-forestation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H13-PP	City of Harrisonburg Hose Company #4	Pollution Prevention	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H14-IB	Harrison Plaza	Impacted Buffer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H14-ER	Harrison Plaza	Bank Erosion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H28 Option 2	Maryland Ave Firestation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H41-OT	A Dream Come True Playground	Outfall Stabilization	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H37-PP1	Harrisonburg Public Works	Pollution Prevention	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H40	Stone Spring Elementary School	Landscape Maintenance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] This refers to the percent of the Water Quality Volume (WQV) captured by the practice. For this application, the WQV is defined as the runoff generated by 1" of rainfall in the drainage area, which is the Virginia standard in the Runoff Reduction Method (see **Section X** for the associated computation). Since these are retrofit projects, they do not have a regulatory obligation to meet 100% of the WQV, but it is a good metric by which to compare projects.
[2] The Heritage Oaks RSC project was considered an outlier in terms of scoring, since it scored much higher than the other projects and thus skewed the scoring curve for other projects. The scores reported for the other projects are thus calculated without the Heritage Oaks project.

APPENDIX C: REGENERATIVE STORMWATER CONVEYANCE SYSTEMS

The following is a description by the firm, Biohabitats, Inc., of Regenerative Stormwater Conveyance systems (also sometimes call "step-pool conveyance" systems).

More Resources:

To see a newly constructed example of this type of practice, click on the link below to view a two-minute video by the Center for Watershed Protection, entitled, "Froelich Park Regenerative Step Pool Storm Conveyance Demo Project":

https://www.youtube.com/watch?v=PmmDJ3XG3SQ

Anne Arundel County, MD developed the first design specifications for this practice. Their Regenerative Step Pool Conveyance Systems Design Guidelines can be found at:

http://www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm#.UkCBd3-EWS8

Regenerative Stormwater Conveyance: A New Tool to Effectively Mitigate Failed Stormwater Outfalls

Introduction

Regenerative stormwater conveyance (RSC) combines stormwater management with wetland and stream restoration. Applicable in new development, retrofit, and restoration scenarios, RSC uses carbon-rich, sand-bedded channels, wide parabolic grade control weirs, and shallow pools to collect and convey stormwater runoff (Figure 1). The practice can convey within a site, to other stormwater treatment practices in a treatment train, or from outfalls into receiving streams. This approach aligns with philosophies such as low impact development and green infrastructure.

Status Quo

Drainage infrastructure, whether it be simply conveyance based or intended for other stormwater management criteria (e.g., detention, channel protection), typically results in the concentration of flows at discrete outfall points. The result seen throughout urbanizing watersheds is impaired habitat, excessive erosion and transport of sediment and nutrients to downstream sinks (e.g., ponds, lakes, estuaries, etc.), and compromised infrastructure.

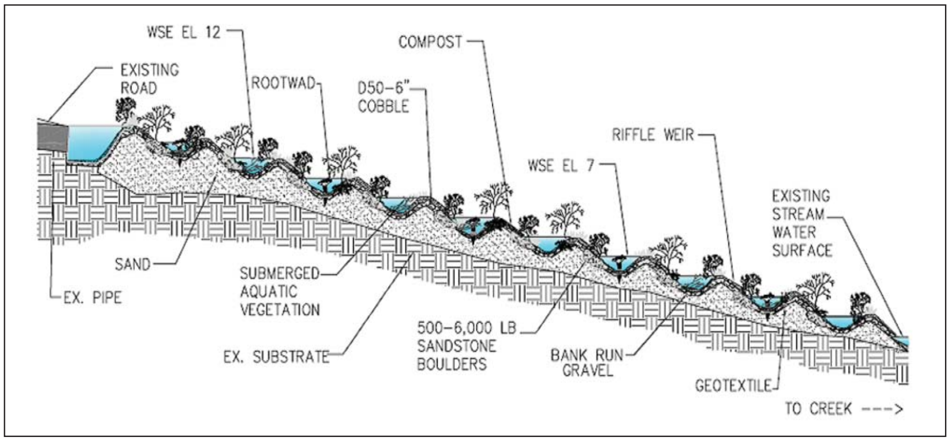
Basic Building Blocks

RSC systems are open-channel, sand seepage filtering systems that utilize a series of shallow aquatic pools, riffle weir grade controls, native vegetation, and underlying sand channel to treat and safely attenuate and convey storm flow, and convert stormwater to groundwater through infiltration and below ground seepage (Figure 2). RSC systems combine features and treatment benefits of swales, infiltration, filtering, and wetland practices.

Establishing the sand seepage hydrology associated with an RSC system requires the creation of a series of well vegetated stilling pools, sand seepage beds replete with above and below ground biomass, and associated flow paths through low areas dominated by native wetland plants. The physical effect of the pools and their many plant stems is to reduce water velocity and facilitate removal of suspended particles and their associated nutrients and contaminants.

Figure 1. Examples of regenerative stormwater conveyance systems.

The cobble weirs set the surface water elevations and establish the hydraulic head necessary to drive the sand seepage system and support the plants. The sand seepage bed, with its 20%-by-volume green mulch, supports microbes, fungi, macroinvertebrates, and processes which remove nutrients and contaminants as they pass through the sand bed while maintaining porosity. The many roots present in the sand take up nutrients and provide sites for microbial attachment, contaminant adsorption, and long-term sequestration in the peat forming layer resulting from annual root formation of the fibric root mat.



Biohabitats, Inc. and Keith Underwood

Figure 2. Example conceptual profile from a regenerative stormwater conveyance project.

While RSC systems provide added structural stability via stone and sand to eroded outfalls and receiving streams, the vegetative material along the channel and in the bottoms of pools provides an important contribution to project sustainability by tying the system together and increasing the porosity of the pools. Once established, these systems are designed to restore the ecology of forest floor systems and be mostly self-maintaining.

Stormwater Management Benefits

The systems combine features and treatment benefits of swales, infiltration, filtering, and wetland practices. They are designed to convey flows associated with events up to and including the extreme floods (i.e., 100-year storm) in a non-erosive manner, which results in reduced channel erosion impacts commonly associated with stormwater practice outfalls and receiving waters. Due to the ability to safely convey larger flows, these systems do not require flow splitters to divert smaller events to them for treatment. As part of the conveyance system, they also reduce the need for storm drain infrastructure. Finally, these RSC systems have the added benefit of providing dynamic and diverse ecosystems for a range of plants, animals, amphibians, and insects. These ecosystems enhance pollutant uptake and assimilation and provide a natural and native aesthetic to sites.

Application

RSC systems are unique in that they can be located on the front or tail end of a treatment system and still provide water quality and groundwater recharge benefits. They have been most commonly applied as a system at the downstream end of a stormwater treatment practice, such as a pond or wetland. Where located on the front end of a treatment train, they provide water quality, groundwater infiltration, and channel protection treatment while also providing non-erosive flow conveyance that delivers flows to a supplemental stormwater treatment practice. RSC systems have multiple applications including within linear systems such as roads, highways, and conveyance from pipe outfalls to receiving waters.

Conclusion

RSC is a holistic approach to stormwater management whereby the natural regeneration of stream and wetland ecosystems is the driving performance standard, rather than the presumption that detention of a designated storm event will be of benefit to the downstream water bodies. Installation of these systems has multiple benefits including, less area of disturbance, lower costs, and opportunities for stakeholder stewardship and participation. The last of these benefits has been shown to be invaluable in terms of raising community awareness and helping to foster the important and often overlooked connection between humans and nature.

Acknowledgements

Much of the work to develop the regenerative stormwater conveyance approach has been led by Keith Underwood, of Underwood & Associates, in collaboration with Biohabitats, Inc.

Biohabitats
GREAT LAKES BIOREGION
Incorporated
2026 Murray Hill Road, Room 107
Cleveland, Ohio 44106
tel 216.921.4430 / fax 216.751.2087
www.biohabitats.com

Biohabitats
OHIO RIVER BIOREGION
Incorporated
120 Webster Street, Suite 326
Louisville, Kentucky 40206
tel 502.561.9300 / fax 502.561.9301
www.biohabitats.com