RSC-1. Introduction

Source: Biohabitats, Inc.

Regenerative Stormwater Conveyance (RSC) is an innovative approach to provide stormwater treatment, infiltration, and conveyance within one system. It has been used as an ecosystem restoration practice for eroded or degraded outfalls and drainage channels. RSC utilizes a series of shallow aquatic pools, riffle weir grade controls, native vegetation and underlying sand and woodchip beds to treat, detain, and convey storm flow. It can be used in places where grades make traditional stormwater practices difficult to implement. RSC Systems combine features and treatment benefits of Swales, Infiltration, Filtering and Wetland practices. In addition, they are designed to convey flows associated with extreme floods (i.e., 100-year storm) in a non-erosive manner, which results in a reduction of channel erosion impacts commonly encountered at conventional stormwater outfalls and headwater stream channels.

RSC can be used to:

- Manage the first one inch of rainfall on-site (See **Table RSC-1**)
- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs; See **Table RSC-2**).
- Meet partial or full storage requirements for local stormwater detention standards
- Retrofit existing developed areas, especially areas with eroded and degraded (entrenched) outfalls, ditches, and ephemeral or intermittent gullies that discharge to waterbodies

RSC can be blended into the landscape design for many sites. As an example, the photo above shows a RSC System at an outfall in Anne Arundel County, Maryland (Source: J. Berg).

Figure RSC-1 shows before and after photographs of RSC designs used to restore and repair existing incised and eroding outfalls and channels. **Figure RSC-2** is a schematic profile of the typical RSC System.

RSC-1.1. Planning This Practice

Before (Left): Eroded outfall. After (Right): Outfall restored using RSC design.

Before (Left): Incised and eroding channel. After (Right): RSC design reconnects channel to floodplain.

Figure RSC-1. Before and after photos of Regenerative Stormwater Conveyance retrofits. Source: Biohabitats, Inc

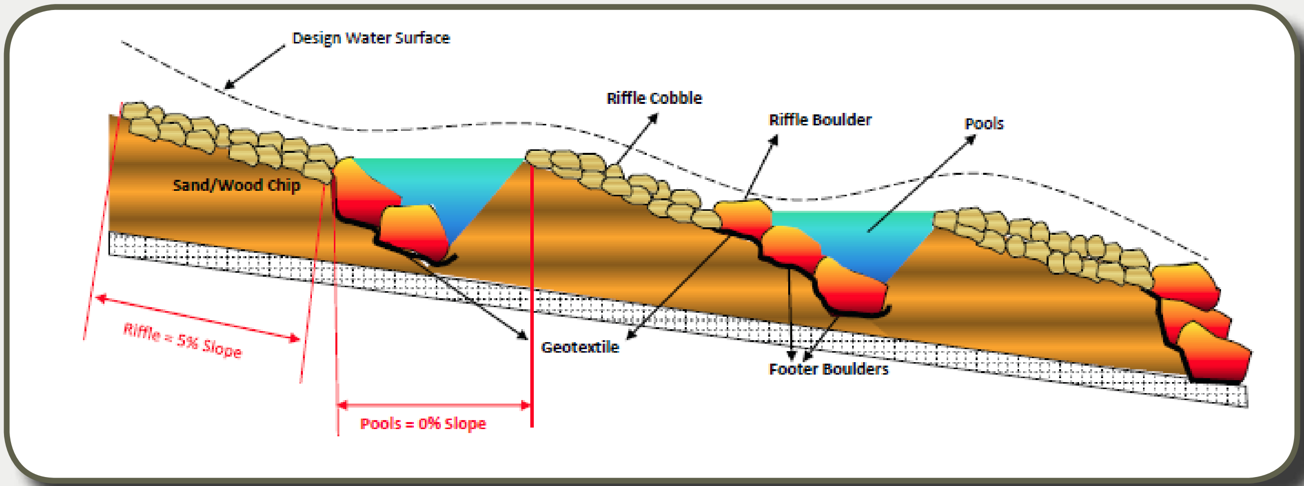

Figure RSC-2. Schematic Profile for Regenerative Stormwater Conveyance System (Source: Anne Arundel County, 2011)

RSC-1.2. Regenerative Stormwater Conveyance System Design Options & Performance

Table RSC-1 describes the RSC performance in terms of reducing the volume associated with one inch of rainfall on the site. **Table RSC-2** summarizes pollutant removal performance values for RSC. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans. Since RSC is a relatively new practice without a long monitoring record, these rates are based on the performance of a Level 2 Water Quality Swale (see **Specification 4.3.2.A Water Quality Swale**). These rates can be considered provisional until more monitoring data specific to RSC becomes available.

Table RSC-1. RSC Descriptions & Performance (based on Level 2 Water Quality Swale)

Description	Applications	Performance[1]
RSC generally designed according to Anne Arundel County (2011)	Sites where topography, slopes, or other site constraints suggest that treatment be provided in the conveyance system. This may be particularly relevant to redevelopment sites and/or retrofits with eroded and degraded outfalls, ditches, or ephemeral or intermittent entrenched gullies. In these cases, the RSC can also serve as an ecosystem restoration project.	100% volume reduction for the Design Volume of the practice[2]

[1]Performance achieved toward reducing one inch of rainfall

[1] Design Volume includes storage within the pools and within the sand/woodchip bed in accordance with the design methods in Section RSC-4 of this specification. The Design Volume can be 100% of that needed to meet the 1-inch performance standard or some proportion of it when used in conjunction with other practices.

Table RSC-2. Pollutant Removal Performance Values for RSC (based on Level 2 Water Quality Swale)

TSS = 90%	TP = 76% TN = 74%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).

RSC-1.3. Regenerative Stormwater Conveyance System Design Checklist

Table RSC-3. RSC Design Checklist

CHECKLIST

This checklist will help the designer with the necessary design steps for RSC Systems.

- [ ] Assess site conditions to determine applicability of RSC. It is best used to restore ecological functions to an existing eroded ditch, outfall, channel, or ephemeral or intermittent stream. Check with the local stormwater authority to ensure that RSC is applicable to the particular site.
- [ ] The design process in Section RSC-4 is iterative. Make sure there is a large enough footprint on the site to accommodate an RSC System with enough storage. Use the Design Compliance Spreadsheet to calculate the Target Treatment Volume (Tv) for the drainage area, and then compare to the storage provided. Upgradient or downgradient runoff reduction practices can be used if the RSC System does not provide the total Tv storage.
- [ ] Complete the design process in Section RSC-4, including the design checklist in Section RSC-4.2. It is highly recommended that designers consult the resources provided in Anne Arundel County (2011) or the latest design reference for RSC.
- [ ] Check design adaptations appropriate to the site – Section RSC-6.
- [ ] Provide all necessary plan view, profile, and cross-section details along with elevations, materials specifications, grading, and construction sequence notes.

RSC-2. Typical Details

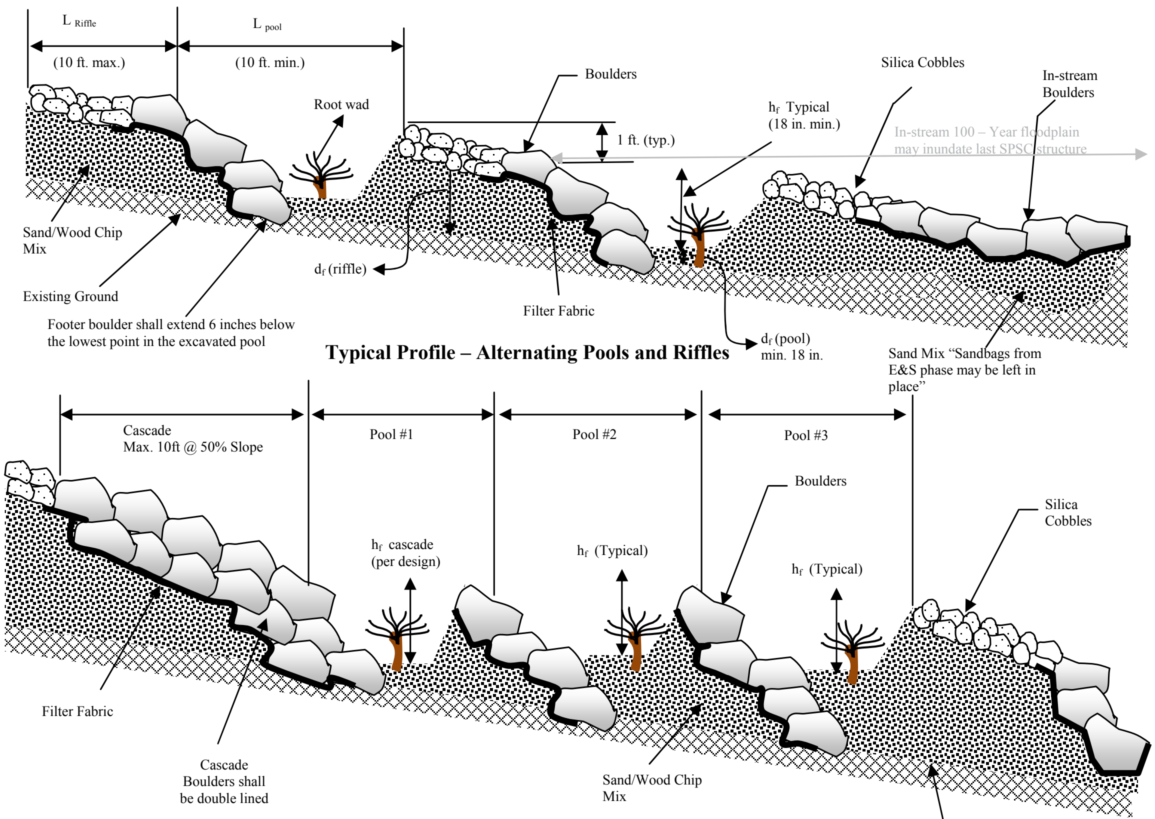

Figure RSC-3. Typical Profile of Alternating Pools and Riffles (top) and Three Pools following Cascade (bottom) (Source: Anne Arundel County, 2011).

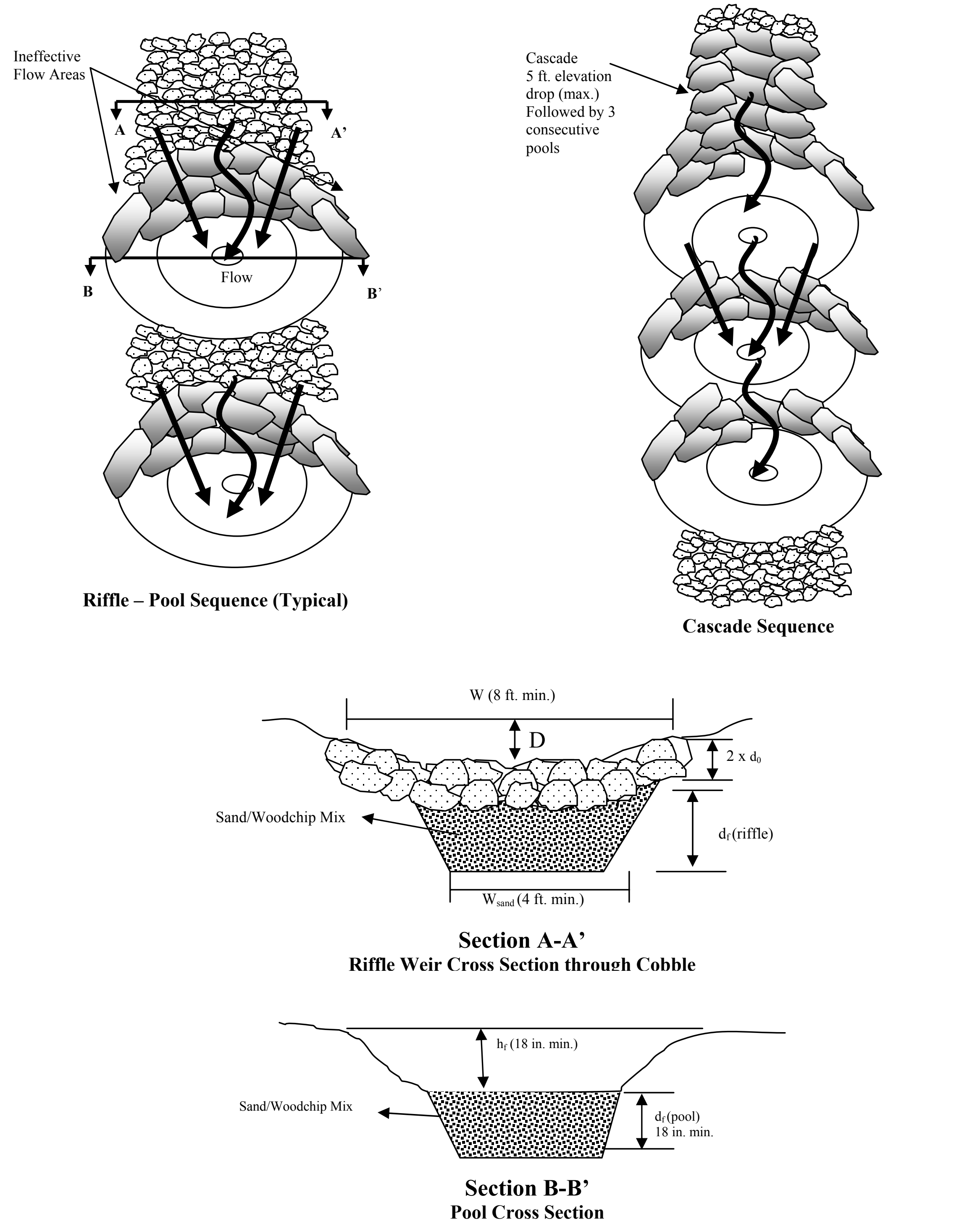

Figure RSC-4. Typical Plan View and Sections for Alternating Pools and Riffles (top left) and Cascades (top right) (Source: Anne Arundel County, 2011).

RSC-3. Feasibility Criteria and Design Considerations

Key design considerations for RSC Systems include the following. Designers are strongly encouraged to consult Anne Arundel County (2011) for additional design parameters.

Site Topography. RSC can be used to convey and treat stormwater down moderate to steep slopes. Ideally, the design is applied to existing drainage features (e.g., ditches, gullies) that have longitudinal slopes of 10% or less. However, the system can be adapted to steeper slopes by increasing the number and size of cobbles and boulders in the design.

Contributing Drainage Area. Typical drainage areas for RSC range from around 10 to 30 acres, and these tend to be highly impervious. While there is no official upper limit for the drainage area, designers may find that drainage areas greater than 50 acres will require the system size and materials (e.g., boulders) to increase to the point where cost and available space would become major factors. The percent impervious cover within the drainage area also plays a significant role, with highly impervious drainage areas leading to larger storage requirements.

Water Table. The main water table constraint is that storage above the ponding depth in the pools should be available for storm events and not inundated by seasonal groundwater. Pools should drain down to their design (ponding) levels within 72 hours from a storm event.

Soils and Underdrains. Soil conditions do not typically constrain the use of RSC since the storage is accounted for in the pools and within the sand/woodchip bed. As can be seen on the typical details, the entire system has a longitudinal slope, so underdrains (such as with Bioretention) are not needed.

Hotspot Land Uses. RSC should not be used to treat runoff from hotspot generating areas. However, the practice can treat "non-hotspot" parts of a site. For a list of potential stormwater hotspots, please consult Chapter 5 of the Manual.

Floodplains. One of the chief design considerations for RSC is how the step pool sequence ties into the downstream receiving channel, and whether that channel is incised or relatively stable. In this regard, some of the steps or pools may need to intersect the 100-year floodplain. In these cases, the designer should consider how the design should be modified to account for the flow velocities and inundation associated with the floodplain.

Proximity to Utilities. Interference with underground utilities should be avoided whenever possible, particularly water and sewer lines. Approval from the applicable utility company or agency is required if utility lines will run below or through the RSC System. Conflicts with water and sewer laterals (e.g., house connections) may be unavoidable, and the construction sequence must be altered, as necessary, to avoid impacts to existing service.

Additionally, designers should ensure that future tree canopy growth in an RSC System will not interfere with existing overhead utility lines.

Community Factors. RSC Systems can be designed as safe and aesthetically pleasing practices which, when incorporated into open space areas, can increase the natural value of a space.

Underground Injection Permits. RSC systems are generally not considered to be Class V injection wells subject to permits under the Underground Injection Control (UIC) Program (U.S. EPA, 2008). However, in certain cases the designer should confer with West Virginia Department of Environmental Protection (WVDEP) about the possible applicability of a UIC permit.

4.2.7. Regenerative Stormwater Conveyance System (RSC)

RSC-4. Design Criteria

RSC-4.1. Regenerative Stormwater Conveyance System Sizing

The design of RSC Systems is usually based upon providing safe and stable conveyance of the peak flow generated by the 100-year storm event. The Tv associated with the 1-inch performance standard will very likely be provided within this design framework. However, additional upgradient and/or downgradient runoff reduction practices may be needed in order to treat the full required Tv. If this is the case, the volume designed into the RSC System is called the Design Volume (Dv).

The procedure provided below is intended to assist in the design of a RSC System. Designers are strongly encouraged to consult Anne Arundel County (2011) or the latest design variation for RSC for additional design guidelines. The Anne Arundel County guidance can be found at: http://www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm

1. Using a topographic map with 1' contours, map the path of the RSC System. The path should be curvilinear and generally follow the shape/contours of the ravine or natural drainageway.
2. Measure the length of the path of the RSC System.
3. Measure the change in elevation that occurs along the path of the RSC System. The longitudinal slope should not exceed 5 percent. If the overall slope exceeds 5 percent, then one or more cascades can be designed into the system (see Step 5).
4. Using the results of Step 3, determine the required number of grade control structures and pools. The required number of grade control structures and pools is equal to the change in elevation that occurs along the path of the RSC System.
5. Using the following equation, determine the length of each of the grade control structures and pools. Grade control structures and pools will have an equal length along the path of the RSC System.

Equation RSC-1. Length of Grade Control Structures

Length of grade control structure = length of pool = [(Length of the path of the RSC System) / (Change in elevation that occurs along the path of the RSC System)] / 2

The length is the dimension of the grade control structures and pools that is parallel to the path of the RSC System.

NOTE: If the length of the grade control structures and pools is determined to be less than 10 feet, the system may require one or more cascades along its path. Cascades may have a longitudinal slope of up to 50 percent (2H:1V) and a maximum vertical drop of 5 feet. Cascades should be followed by 3 pools instead of 1 (see Figure **RSC-3**, bottom figure).

6. Determine the peak flow that is generated by the 100-year storm event.
7. Design the grade control structures, which should be parabolic in shape, to convey the peak flow generated by the 100-year storm event in a stable manner. Using the iterative process below, determine the width and depth of the grade control structures and the size of the material needed to construct them:
   a. Begin the design of the grade control structures using a cobble size (d0) of 6 inches. This cobble size should be generally available (e.g. Gabion Stone).
   b. Set the depth of the cobble material to 2.0 * d0. See **Figure RSC-5**.
   c. Determine a trial width (W) and depth (D) for the grade control structures. The width is the dimension perpendicular to the flow, and the depth is the maximum depth of the parabolic channel at that width (see **Figure RSC-5**). The width of the grade control structures should be: a) 10 times the depth of the grade control structures, and b) a minimum of 8 feet. The maximum width of the grade control structures should be 20 feet.

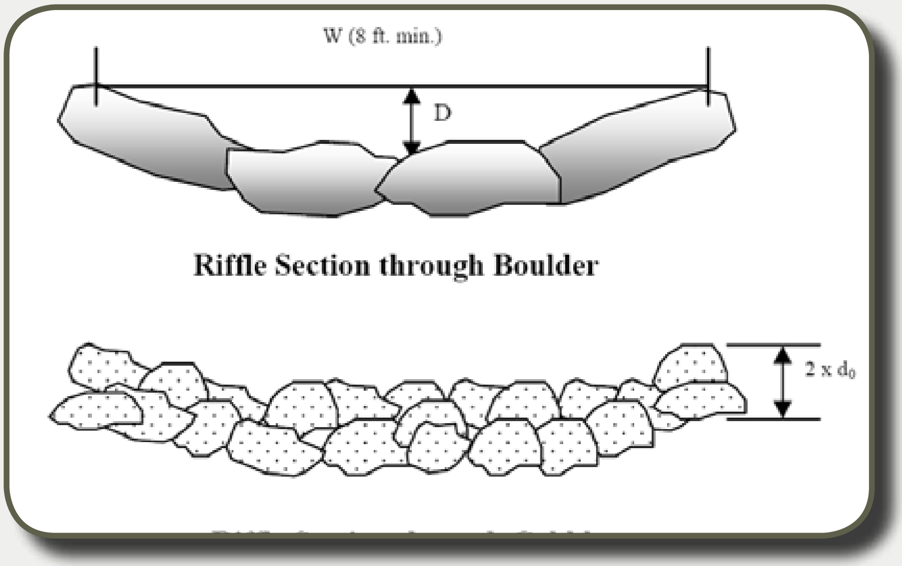

Figure RSC-5. Typical Width, Depth, and Depth of Stone for Grade Control (Riffle) Sections (Source: Anne Arundel County, 2011).

d. Determine the velocity of flow through the RSC System using Manning's formula for the velocity of uniform flow:

Equation RSC-2. Manning's Formula

$$V = \frac{1.49}{n\,(R_h)^{2/3}(S)^{1/2}}$$

Where:

V	=	velocity of flow (ft/s)
1.49	=	conversion factor
n	=	Manning's roughness coefficient
R_h	=	hydraulic radius (ft)
S	=	slope (ft/ft), in direction parallel to flow path

For a parabola:

$$R_h = \frac{2(DW^2)}{(3 \times W^2) + (8 \times D^2)}$$

Where:

W = top width of cross section (8 foot minimum)

D = depth of cross section

Manning's roughness coefficient (n) varies according to the depth of flow over the grade control structure and the size of cobble used to construct the grade control structure (MD NRCS, 2006):

Equation RSC-3. Manning's Roughness Coefficient

$$n = \frac{d^{1/6}}{[21.6 \times \log(d/d_0) + 14.0]}$$

Where:

n	=	Manning's roughness coefficient
d	=	depth of flow in the riffle channel associated with unmanaged 100-year flow conditions (ft)
d0	=	mean cobble size (ft)

In an RSC System, the depth of the flow over the grade control structures should be a maximum of 4 inches.

The flow velocity calculated using Manning's formula for the velocity of uniform flow must be less than the maximum allowable velocity for the cobble size that was selected in Step 7a. Maximum allowable velocities are illustrated in **Table RSC-4**. If the design velocity exceeds the maximum allowable velocity, select a larger cobble size and repeat Steps 7b-7d.

Table RSC-4. Maximum Allowable Velocity

Cobble size (d_0) (in)	**Allowable velocity (ft/s)**
4	5.8
5	6.4
6	6.9
7	7.4
8	7.9
9	8.4
10	8.8
11	9.2
12	9.6
15	10.4

8. Using the following equation, check to ensure that the RSC System is adequate to convey the peak flow generated by the 100-year storm event:

Equation RSC-4. Peak Flow

$$Q = V * A$$

Where:

V = low velocity through the RSC System (ft/s)

A = cross-sectional area (ft^2)

For a parabola:

$$A = 2/3 * D * W$$

Where:

W = top width of cross section

D = depth of cross section

The RSC System must be able to convey the peak flow generated by the 100-year storm event. If the peak flow generated by the 100-year exceeds the capacity of the system, increase the width of the grade control structures and repeat Steps 7d-8.

9. The Anne Arundel County RSC guidance (Anne Arundel County, 2011) provides additional guidance for ensuring subcritical flow conditions and non-erosive pool channel velocities (less than 4 feet/second). These computations require knowing the density of stone that will be used. Designers are encouraged to review these computations to ascertain if they think they may be relevant for a particular design.

10. Using the results of Step 7c, determine the width of the pools. The width of the pools is equal to the width of the grade control structures

11. Start with an assumed pool depth of 1.5 feet. The pool depth should be a minimum of 1.5 feet and a maximum of 3 feet.

12. Begin the design of the sand bed with a depth of 1.5 feet and a width of 4 feet. The sand bed should consist of a mixture of 80% sand and 20% wood chips and should run beneath the entire length of the RSC System. A 1 foot layer of bank run gravel should be placed beneath the sand bed to prevent piping and undermining of the sand bed. A 1 foot layer of bank run gravel should be placed over the surface of the sand bed to provide bedding for the grade control structures

13. Determine the Tv for the contributing drainage area (CDA) associated with the 1-inch performance standard using the Design Compliance Spreadsheet. The Tv is the total volume for the contributing drainage area. If there are other BMPs in series with the RSC System, then the RSC volume may account for only part of the Tv, with the sum of all BMP volumes equaling the Tv. The Dv is the volume designed into the RSC System in the pools and sand bed layer (see steps below).

14. Determine the storage provided in the shallow pools by multiplying the surface area of each pool by its depth and by a factor of 0.4, to account for the storage lost due to the side slopes of the pool, and then summing the results:

Equation RSC-5. Storage in Pools

$$V_{pool} = SA * d_{max} * 0.4$$

Where:

V_{pool}	=	storage volume provide in single pool (cubic feet)
SA	=	surface area of single pool (square feet)
d_{max}	=	maximum depth of pool (ft)
0.4	=	factor used to account for the storage lost due to the side slopes of each pool

NOTE: The storage volume provided in the pools may be more accurately computed using the contours shown on the grading plan after the design is completed.

15. Determine the storage volume provided in the sand bed beneath the RSC System. The storage volume provided by the sand bed storage can be estimated by multiplying the volume of the sand bed by the porosity of sand, typically 0.4:

Equation RSC-6. Storage in Sand Bed

$$V_{sand} = L_{sand} * W_{sand} * D_{sand} * 0.4$$

Where:

V_{sand}	=	storage volume provided in sand bed (cubic feet)
L_{sand}	=	length of sand bed (ft)
W_{sand}	=	width of sand bed (ft)
D_{sand}	=	depth of sand bed (ft)
0.4	=	porosity of sand

16. Add the storage volumes provided in the shallow pools and the sand bed (the design volume) and compare to the desired Dv and if various BMPs in the drainage area meet the target Tv. If an insufficient storage volume is provided in the pools and sand bed, the grade control structures, shallow pools and sand bed may be widened to provide additional storage. It is recommended that the maximum width of the sand bed should be 14 feet and the maximum width of the grade control structures and pools should be 20 feet.

17. If, after increasing the width of the grade control structures, pools and sand bed, the RSC System still does not provide the desired Dv, additional (or larger) stormwater management practices will need to be provided upstream or downstream of the system.

18. Using a topographic map with 1' contours, position the sand bed, choker stone, and bank run gravel layers along the path of the RSC System. Starting with the outlet pool, position each pool and grade control structure along the path of the RSC System. The outlet pool shall be placed at the downstream end of the system, at the lowest point in the project reach. The elevation of the top of the outlet pool should match the existing grade at this location.

19. Next, position the first grade control structure, which is located immediately upstream of the outlet pool. The elevation of the bottom invert of the grade control structure should be set to the elevation of the top of the outlet pool. The grade control structure should rise 1 foot over its length, making its top invert elevation 1 foot higher than its bottom invert elevation.

20. Place a footer boulder beneath the downstream end of the grade control structure. The upstream face of the footer boulder should be placed to match the downstream face of the grade control structure. The top of the footer boulder should be placed at an elevation that is 6" below the top of the outlet pool (see **Figure RSC-6**).

21. Place additional boulders to form the downstream end of the grade control structure. The position of downstream face of the boulders should be placed to match the position of the upstream face of the footer boulder (**Figure RSC-6**). The boulders should extend, in a parabolic shape, across the width of the RSC System.

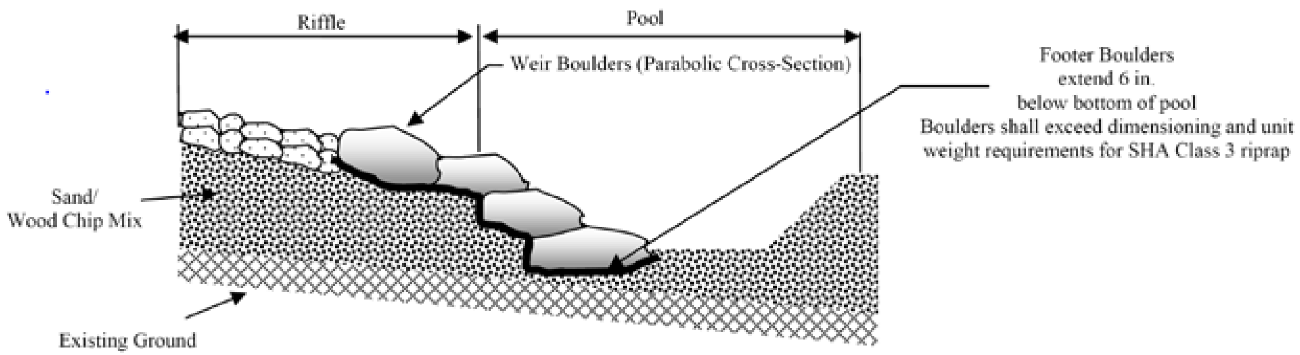

Figure RSC-6. Typical Position of Weir Boulders in Relation to Riffles and Pools (Source: Anne Arundel County, 2011).

22. Place cobble to form the remainder of the grade control structure. The cobble should extend across the width and remaining length of the grade control structure. The cobble should be placed to the depth of the grade control structures (in cross-section view) determined in Step 7b, with a top invert elevation that is that 1 foot greater than the bottom invert elevation.

23. Below the grade control structure, position a cobble apron to provide a stable flow path from the bottom invert of the grade control structure to the bottom of the downstream pool when the pools are dry. The cobble apron should be approximately 5 feet wide and 3 feet long.

24. Position the second pool above the first grade control structure. The elevation of the top of the pool should be set equal to the elevation of the top invert of the first grade control structure.

25. Repeat Steps 19-24, positioning grade control structures and pools until the starting point of the RSC System is reached. The elevation of the entry pool (and the elevation of the top invert of the upstream-most grade control structure) should be set at an elevation that will slightly backwater the inlet pipe, culvert or swale. As noted in Step 5, one or more cascades may be necessary to traverse steeper parts of the RSC flow path.

26. Position large woody debris in each of the pools. Top dress the sides (outside the main flow path) of the RSC System with compost and a temporary cover seed mix. Include stabilization, seeding and top dressing notes on the design plans.

27. Draft a planting plan, making sure that native plants are placed in appropriate planting zones and water depths.

RSC-4.2. Design Checklist for Regenerative Stormwater Conveyance Systems

Table RSC-5 is a design checklist adapted from Anne Arundel County (2011). This checklist provides additional details on each design step.

Table RSC-5. Regenerative Stormwater Conveyance System Design Checklist[1]

RSC Item	Check
Hydrology	Delineate drainage area, landcovers, and soil to the most downstream point of the RSC System.
	Develop TR55/TR20 model run to calculate the predevelopment and post-development peak discharges.
	Utilize TR-55 to calculate the required water quality volume and water quantity volume of storage to be controlled within the system.
	Conduct a downstream investigation to check the adequacy of the outfall system.
Hydraulics	Check the conveyance design (width, depth, slope) to ensure safe conveyance of the 100-year storm over the riffle/weir/cascade channels and that stable design dimensions for the cobbles and sandstone boulders are provided.
	Check the calculated minimum pool depth to ensure that sufficient pool depth is provided to dissipate the upstream energies properly.
	Check the post-development stream power for the 100-year storm to ensure that it is rendered equal to the predevelopment stream power. (Note: this requires that sufficient RSC length and number of pools be provided)
	Check that the storage volume within the pools and voids meet the required quantity management storage volume prescribed for the project and calculated using TR-55.
Alignment	Does the alignment follow the natural drainage path and are efforts made to avoid impacts to natural resources such as trees and wetlands?
Tree Protection	Have specimen trees been identified and a tree protection plan been developed?

RSC Item	Check
Downstream tie-in	Does the RSC System extend downstream to a point where the outfall is considered stable?
	Has adequate downstream tie-in/transition been provided to address downstream instability and to ensure the outfall remains stable?
Longitudinal Slope	Have the riffle segments been placed with a slope flatter than 5%?
	Have the pool segments been placed with a slope flatter than 1%?
	Have cascades been placed at no more than 1H:1V slope with double-lined boulders, and the height of any single cascade does not exceed 5 ft?
Pool Design	Are the side slopes for the pool (from all unarmored segments) 3H:1V or flatter?
	Does the depth of the pool exceed the minimum calculated depth based on the upstream velocities? The design of the riffle and weir shall be modified such as not to result in pool depth exceeding 3 ft.
	Does the length of the pool exceed the minimum required 10 ft and allow sufficient length to accommodate the 3H:1V slope on unarmored sides?
Riffle Channel Design	Is the channel parabolic in shape?
	Do the width, depth, and slope meet the design requirement and allow safe conveyance of the 100-year storm?
	Are the d0 cobble sizes adequate for accommodating the 100-year velocities? Note: d0 cobble size shall be specified on the plan, profile, and cross-section.The d0 is the minimum diameter size for the cobble stone. Smaller material shall be rejected by the inspector.
	Is the Width/Depth Ratio for the Riffle/Weir section at least 10W:1D?
Weir Design	Are the boulders forming the weir 3-4 times larger than the calculated d0?
	Are the footer boulders extended/anchored at least 6 inches below the lowest point of the scour pool?
	Does the cross-section for the weir safely convey the 100-year storm?
	Is filter fabric placed under the sandstone boulders?

RSC Item	Check
Cascade Design	Are the cascades armored with sandstone weir over filter fabric and the height does not exceed 5 ft at any given location?
	Are three pools provided following the cascade, with adequate weirs separating each pool structure and designed in a manner to safely convey the 100-year storm?
Cross section Drawings	Has the designer provided typical detail sections for the riffle, stone weirs and pools where needed and actual cross sections along the alignment at frequent intervals to reflect changes in the grading? Note: the cross-sections shall be developed based on the geometric alignment and shall show the station numbers, existing grade, proposed grade, and sand mix/stone structure detail.
	Has the designer shown the 100-year storm water surface elevation on the typical and actual cross-sections?
Profile Drawings	Has the designer provided a longitudinal profile along the centerline of the alignment and shown invert and top elevations of all structures and the 100-year water surface elevation?
Plan Sheets	Has proposed grading been provided, and is minimum/maximum dimensioning requirements met?
	Has the 100-year water surface elevation been plotted on the plan?
	Is the 100-year water surface elevation sufficiently contained within easements and is below all habitable structures?
E&S	Has adequate erosion and sediment control plan been implemented upstream of the RSC System?
Maintenance	Has a permanent and direct maintenance access been provided to all sandstone weirs and pools?
	Has a maintenance agreement been signed and recorded for private RSC structures?
Monitoring Plan	Has a monitoring/maintenance plan been developed as prescribed in the design guidelines and is it clearly shown on the plan?
Planting	Has mulching and hydro-seeding been prescribed for the entire system?
	Has the designer paid special attention to the use of native material, diversity, and dense placement of plant material within appropriate wetness zones throughout the site?

[1]*Adapted from Anne Arundel County (2011).*

RSC-4.3. Signage

An RSC unit in highly visible open space areas should be marked to designate it as a stormwater management facility. The signage should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

RSC-4.4. Regenerative Stormwater Conveyance System Landscaping

A comprehensive plant list for landscaping of stormwater practices can be found in Appendix F, BMP Landscaping & Plant Lists. The plant list in this appendix includes a column specifically for RSC. Vegetation plays a critical role in the ability of an RSC System to mimic natural processes (Anne Arundel County, 2011). Native plants should be specified to create a diverse and dense planting plan according to various wetness zones within the RSC System.

4.2.7. Regenerative Stormwater Conveyance System (RSC)

RSC-5. Materials Specifications

To the maximum extent possible, the materials used to construct RSC Systems should be obtained from local suppliers.

In general, materials that have a natural appearance (e.g. rounded edges, brown or dark grey in color) should be used to construct the grade control structures. However, some compromises may need to be made to prevent the materials from making RSC Systems too expensive to construct. The materials listed in **Table RSC-6** should be used to construct the grade control structures, in order of preference.

Table RSC-6. Regenerative Stormwater Conveyance System Material Specifications

Material	Specification
Footer Boulders	1. Boulders salvaged from construction sites that have a natural appearance and are equivalent in size to Class 3 Rip Rap (average diameter of 26.4 inches). 2. Boulders available from local stone producers and suppliers that have a natural appearance and are equivalent in size to Class 3 Rip Rap. 3. Class 3 Rip Rap. 4. Class 2 Rip Rap (average diameter of 19.2 inches) may be used when Class 3 Rip Rap is not available and maximum allowable velocities are not exceeded in the RSC System.
Cobble	1. Cobble available from local stone producers and suppliers that has a natural appearance and is equivalent in size to Gabion Stone (minimum diameter of 6 inches). 2. Gabion Stone. 3. If larger material is needed, Class A1 Rip Rap (average diameter of 9.6 inches) or Class 1 Rip Rap (average diameter of 13.2 inches) can be used in place of or combination with Gabion Stone.

Material	Specification
Sand/ Woodchip Bed	The sand component of the sand/wood chip bed shall meet the AASHTO-M-6 or ASTM-C-33, 0.02 inches to 0.04 inches in size. Sand shall be a silica-based coarse aggregate. Substitutions such as Diabase and Graystone (AASHTO) #10 are not acceptable. No calcium carbonate or dolomitic sand substitutions are acceptable. No "rock dust" can be used for sand. Locally-approved pulverized glass may be substituted if the local authority undertakes testing to verify compliance with the particle size specification. No art glass shall be used for a pulverized glass material. For woodchips, use aged, shredded hardwood chips/mulch. The woodchips shall be added to the sand mix, approximately 20 percent by volume, to increase the organic content and promote plant growth and sustainability.
Choker Stone	The choker stone layer between the sand bed and the bank run gravel should be clean, washed #8 or #78 stone.
Bank Run Gravel	The bank run gravel layer that is placed beneath the sand bed/choker stone layers should be constructed using clean, washed # 5 or # 57 coarse aggregate. The bank run gravel layer that is placed on top of the sand bed should be constructed using stone available from local stone producers and suppliers that is equivalent in size to # 5 or # 57 coarse aggregate. If this material is not available, # 5 or # 57 coarse aggregate can be used.
Compost	The compost used as a top dressing over the RSC System should consist of a 100% organic compost, with a pH of between 6.0 and 7.0, a moisture content of between 30 and 55%, and a particle size of 0.25 inches or less.
Wood Chips	The wood chips used within the sand bed should consist of double-shredded or double-ground hardwood mulch that is free of dyes, chromated copper arsenate and other preservatives.
Plant Materials	See **Section RSC-4.4 and Appendix F**

RSC-6. Design Adaptations

RSC-6.1. Karst Terrain

RSC Systems have largely been used in coastal plain settings, but could be adapted to karst with certain design considerations. While RSC produces shallower ponding than conventional stormwater practices (e.g., Ponds and Wetlands), designs that infiltrate a lot of water through the sand/woodchip bed into underlying groundwater are not recommended in any area with a moderate or high risk of sinkhole formation (Hyland, 2005). On the other hand, RSC designs that meet a 3 foot separation distance to karst bedrock features and/or contain an impermeable bottom liner may work well. However, since RSC is placed within existing drainage systems, it may be difficult to avoid proximity to bedrock in some places. In general, smaller-scale RSC Systems are advisable in karst areas, and geotechnical studies should be conducted to ascertain structural suitability.

RSC-6.2. Steep Slopes

RSC can be used on moderate to steep slopes. However, longitudinal slopes of 10% or less are recommended.

RSC-6.3. Cold Climate and Winter Performance

Many different kinds of salting and sanding materials are applied in West Virginia during winter conditions. These can clog the sand/woodchip bed of RSC Systems if the proper design approach is not used, particularly for practices that treat road and highway runoff. In these cases, pre-treatment cells or separate upgradient sediment storage areas should be employed to try to keep as many of these materials as possible off of the main RSC conveyance system.

RSC-6.4. Stormwater Retrofitting

RSC is a good candidate for retrofitting in cases where the existing drainage or conveyance system is eroded and/or incised. In these cases, RSC not only provides stable conveyance, but restores ecosystem and hydraulic functions associated with non-tidal streams and wetlands. In the retrofit context, RSC can also be combined with other upgradient runoff reduction practices to restore hydrologic function and water quality. As with other stormwater practices, many retrofit designs cannot meet the full sizing requirements outlined in **Section RSC-4**, so it is important to define retrofit objectives and the desired Design Volume necessary to meet TMDL or watershed restoration goals.

4.2.7. Regenerative Stormwater Conveyance System (RSC)

RSC-7. Construction & Installation

See Anne Arundel County (2011) for a construction inspection checklist to be applied to RSC.

4.2.7. Regenerative Stormwater Conveyance System (RSC)

RSC-8. Maintenance Criteria

Maintenance tasks and frequency will vary depending on the size and location of the RSC System, the landscaping template chosen, and the type of surface cover in the practice. A generalized summary of common maintenance tasks and their frequency is provided in Table RSC-7.

Table RSC-7. Recommended Maintenance Tasks for RSC Systems

Maintenance Tasks	Frequency
▪ For the first 6 months following construction, the practice and drainage area should be inspected at least twice after storm events that exceed 1/2 inch of rainfall. ▪ Check for erosion or "end-cutting" of weirs and riffle structures. ▪ Check for stable water levels in pools. ▪ Conduct any needed repairs or stabilization. ▪ Inspectors should look for bare or eroding areas in the contributing drainage area or around the RSC channel, and make sure they are immediately stabilized with grass cover. ▪ One-time, spot fertilization may be needed for initial plantings. ▪ Watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall. ▪ Remove and replace dead plants. Up to 10% of the plant stock may die off in the first year, so construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.	Upon establishment
▪ Routine maintenance of vegetation: weeding, pruning, etc. ▪ Trash removal	Approximately 4 times a year
▪ Add reinforcement planting to maintain desired the vegetation density ▪ Remove any dead or diseased plants ▪ Stabilize the contributing drainage area to prevent erosion	As needed
▪ Conduct a maintenance inspection ▪ Check structural stability of weirs, riffles, pools; check for desired water level in pools ▪ Prune trees and shrubs ▪ Remove invasive plants using recommended control methods ▪ Remove sediment in pre-treatment cells and inflow points	Annually
▪ Remove sediment in pools if necessary ▪ Repair any structural damage to weirs, riffles, pools, or tie-in to downstream channel	Once every 2 to 3 years

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each RSC System. Example maintenance inspection checklists can be found in **Appendix A of the Manual.**

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