Regenerative Step Pool Storm Conveyance (SPSC) – also known as Coastal Plain Outfalls

Design Guidelines


Home Port Farms - Immediately after


Home Port Farms - One year after construction


Homeport Farms - Six years after construction

ANNE ARUNDEL COUNTY
MARYLAND

DPW

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Technical Advisory Committee

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See last page for summary of revisions.

Important Note

This document features design guidelines and procedural steps to aid design engineers in sizing a Regenerative Step Pool Storm Conveyance (SPSC) system. It is the responsibility of the design engineer to check the feasibility and acceptability for using these systems at their project site. SPSCs can be used in lieu of stormdrains as roadside conveyance/attenuation systems. SPSCs may be used for peak flow management or steep slope stability treatment and are considered structural Stormwater Best Management Practices (BMPs) if they are sized to accommodate the volume control requirements specified in Chapter 2 of the 2000 Maryland Storm water Design Manual, Volumes I and II (the State Manual). In general, SPSCs may be used as a structural stormwater management device to provide water quality treatment as part of the treatment train or at the downstream outfall after all Environmental Site Design (ESD) techniques have been exhausted to the Maximum Extent Practical (MEP) as dictated in the State Manual. Under special circumstance, the SPSC may be used as part of the ESD when the design conforms to the criteria found in Chapter 5 of the State Manual for microbioretention or bio-swale and the general configuration conforms to the principles of ESD: using small-scale practices distributed uniformly around the site to capture runoff close to the source. While SPSC systems can be implemented on steep slopes, in no circumstance can water quality credit be claimed for SPSC segments with a longitudinal profile slope that exceeds 5 percent.

Introduction

Regenerative SPSCs are open-channel conveyance structures that convert, through surface pools and a subsurface sand seepage filter, surface storm flow to shallow groundwater flow. These systems are designed to safely convey and treat the quality of storm flow and may have differing design configurations to accommodate various site implementation conditions. The three design configurations for SPSC systems are as follows:

- A series of constructed shallow aquatic pools, riffle grade controls, native vegetation, and underlying sand/woodchip mix filter bed medium. The physical characteristics of this SPSC channel are best characterized by the Rosgen A or B stream classification types, where “bedform occurs as a step/pool, cascading channel which often stores large amounts of sediment in the pools associated with debris dams” (Rosgen, 1996). This is the typical SPSC configuration, historically known as the coastal plain outfall, and is best suited for ephemeral and perennial entrenched gully systems with moderate to steep channel and valley slopes, larger than 2 percent.

- A series of riffle grade controls aimed at diverting flow from the main channel to created shallow moats on the adjacent floodplain. A sand/woodchip mix filter is placed lateral to the channel to allow the flow from these shallow pools to filter back to the main channel. Typically, the main channel is limited in capacity to the baseflow and all storm flow is directed to the floodplain where wetland areas form and flourish. The physical characteristics of this SPSC channel are best characterized by the Rosgen DA stream classification type, where streams are “highly interconnected channel systems developing in gentle relief terrain areas consisting of cohesive soil materials and exhibiting wetland environments with stable channel conditions.” (Rosgen, 1996). This configuration is best suited for perennial moderately entrenched systems with gentle channel and valley gradients, smaller than 2 percent. This SPSC configuration is also known as a wetland seepage system.

- A series of one or more instream rock riffles strategically placed in an entrenched perennial stream to encourage upstream sedimentation and connection of the channel with the adjacent floodplain. The instream riffle is ideally set such that only the baseflow is contained in the channel and all storm flow has unimpeded access to the adjacent floodplain. Over time, a Rosgen DA channel is formed and the floodplain storage and pollutant removal actions are restored. This configuration is best suited for entrenched perennial channels. This SPSC configuration is also known as a constructed instream riffle.

The pretreatment, recharge, and water quality sizing criteria presented in these guidelines follow closely the State of Maryland's criteria for a typical stormwater filtering device. These structures feature surface/subsurface runoff storage seams and an energy dissipation design that is aimed at attenuating the flow to a desired level through energy and hydraulic power equivalency principles.

SPSC structures can be designed to provide energy dissipation and extreme flood conveyance/attenuation functions, as well as recharge and water quality treatment in excess of ESD. The inherent energy dissipation achieved in the step pool design is directly linked through hydraulic design computations to reduced stream power and bank shear stresses in the receiving streams. The reduced energy and velocity at the downstream end of these structures result in reduced channel erosion impacts commonly seen between conventional stormwater practice outfalls and ultimate receiving waters.

SPSC structures are generally best suited in natural ravines and are the preferred method of stormwater conveyance throughout the water train on a developed site. ESD techniques such as alternative pavement, greenroofs, rooftop disconnections, vegetated swales, etc., should be considered and utilized to the MEP in the upstream area of a proposed SPSC system.

A secondary benefit provided by the pools and plant material is to reduce flow velocity and enhance the removal of suspended particles and their associated nutrients and/or pollutants. Additionally, uptake of dissolved nutrients and adsorption of oils and greases by the plant material yield secondary water quality benefits above and beyond the benefits achieved through the primary water quality sand/woodchip mix filter.

The design material and plant list featured within this document have been adapted to the Anne Arundel County coastal plain environment. The materials used within the SPSC, to the extent possible, are taken from the coastal plain. The sand medium is quarried throughout the region and can be readily obtained. The boulders found in these systems are sandstone (e.g., bog iron, iron stone, ferracrete). Sandstone's porosity, as well as its ability to retain water, allows it to naturalize quickly, providing habitat for ferns, moss, and other organisms that persist in these systems. While sandstone is the preferred material for use as boulders within these systems, granite may be substituted if sandstone availability is demonstrated to be of a concern. Further, broken sandstone boulders that meet the hydraulic sizing criteria maybe used in lieu of silica cobbles in the riffle construction. The use of other alternative boulder and cobble material must be approved by the Anne Arundel County reviewer and/or project manager. Maintenance of the pH levels is profound in ensuring the survival of these habitat systems; thus, the use of limestone or cement-based stone products is prohibited.

General Design Situations

SPSC structures consist of an open channel conveyance with alternating riffles and pools. These systems are best suited for ditches, outfalls, ephemeral and intermittent channels with longitudinal profile slopes that are less than 10 percent. However, the design can be easily adapted for sites where the slope exceeds 10 percent. For these sites, the size and quantity of the cobbles and rows of boulders inherent in the design computations are increased to mitigate for the stability issues associated with steep slopes. It is noted that the utilization of two or more rows of boulders typically will result in a water cascade. In extreme slope situations (larger than 50 percent), the designer may elect to use specially designed retaining structures to safely traverse the grade.

In order to preserve the integrity and habitat functions of non-tidal wetlands and streams, the designer is encouraged to minimize to the extent possible changes to the drainage pattern. This is achieved by placing proposed SPSC systems within the site following the native drainage paths. While this may result in temporary construction impacts, in the long run it will preserve the hydraulic input which is crucial to the survivability of habitat functions within non-tidal streams and wetlands. It should be noted though that the computations presented in this document are minimum design guidelines to ensure that the constructed system will not degrade. However, if the pools are over designed these systems may trap sediment. Sediment trapping in the pools is a natural energy balancing phenomena and is generally not cause for concern, unless this is clearly interfering with the project design goals and in that case undesired sediment deposition should be removed as part of a routine maintenance plan.

"The current condition of single gravel-bedded channels with high, fine grained banks and relatively dry valley-flat surfaces disconnected from groundwater is in stark contrast to the pre-settlement condition of swampy meadows (shrub-scrub) and shallow branching streams." (Walter, R., & Merritts, D. 2008). Current stormwater management regulations require that proposed development plans include appropriate mitigation measures and be contingent on the presence of a stable outfall. According to the Anne Arundel County Watershed Master Plans, problem area inventories such as erosion, buffer deficiencies, headcuts, infrastructure impacts, and suboptimal habitats are notable in varying degrees in more than 90 percent of the surveyed stream segments. For projects that drain to stream channels with active incisions, it is imperative that proper tie-in design be established between the SPSC system and the connecting downstream channel. This could be accomplished by installing an instream riffle at the proper elevation to promote upstream floodplain connection and prevent headcut erosion from unraveling the proposed SPSC systems. It is noted that each case should be evaluated carefully and that design engineers propose appropriate solutions based on the individual circumstance surrounding each case. Additionally, the designer/engineer is responsible for notifying and obtaining all required approvals from the Local, State and Federal authorities.

It is important to acknowledge that each site has unique and defining features that require site-specific design and analysis. The guidance provided below is intended to provide the fundamentals for sizing the facility to meet the regulatory requirements but is not intended to substitute engineering judgment regarding the validity and feasibility associated with site-specific implementation. Designers need to be familiar with the hydrologic and hydraulic engineering principles that are the foundation of the design and they should also enlist the expertise of qualified individuals in stormwater management and stream restoration plantings with respect to developing appropriate planting plans and habitat improvement features.

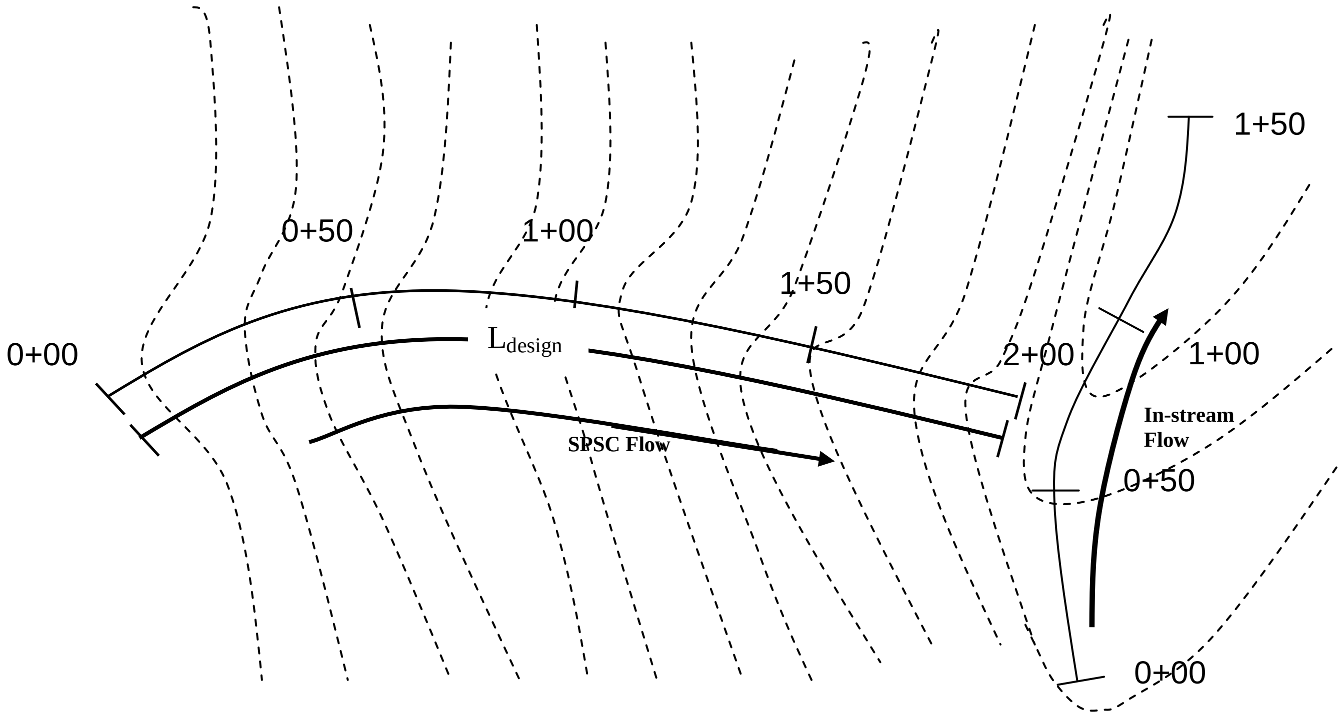
Hydraulic Design of SPSC Systems

SPSC systems can be used to reduce a surface water discharge. This is accomplished by converting up to the 100 year surface discharge to subsurface flow/spring head seep. The design of the SPSC should be based on specific established restoration goals for the project. The sand/woodchip mix filter medium is specifically required for retrofit projects with water quality restoration goals. The depth and quantity of the pool structures are linked to water quality, energy dissipation, and flow attenuation/peak management requirements. Additionally the SPSC design parameters may be determined based on the specific needs to retrofit an existing eroded channel outfall. The dimensions of the riffle and pool segments are designed in a manner to ensure adequate and safe conveyance of the design flow. The downstream tie-in to the receiving channel aims to correct an existing deficiency, such as incision and erosion, and promote long-term stable outfall conditions. This is a requirement for all proposed developments. The downstream tie-in design may result in additional water quality benefit for the contributory drainage area, however, this may not be claimed as water quality mitigation for new development related impacts. Rather this benefit may be claimed for select redevelopment projects and will be evaluated by the Anne Arundel County Department of Public Works for consideration as credits toward the County's National Pollution Discharge Elimination System Municipal Separate Storm Sewer System (NPDES-MS4) permit conditions. The construction cost of these systems makes it imperative for the design/engineer to carefully target the specific restoration goals prior to providing a design solution. The following steps have been formulated to aid the designer engineer in preparing the minimum design elements for the SPSC.

1. <u>Develop the hydrologic design parameters for the project</u>
    - The drainage area should be delineated to the outfall point of the SPSC and the connecting channel tie-in location if applicable. In new development projects, ESD shall be used to the MEP such as to minimize alterations to the existing drainage patterns for the site.
    - Using the USDA-NRCS TR55, determine the flow path, time of concentration, and weighted runoff curve numbers for all points of investigations and required landuse scenarios.
    - Using USDA-NRCS TR20, determine the 1, 10, and 100 year peak discharges for all points of investigations and required landuse scenarios.
    - Include pertinent model input and output hydrology parameters for all points of investigations and required landuse scenarios on the construction plans.

2. Establish and quantify the restoration goals for the project
    - Establish the goals for the SPSC. The goals may include, but are not limited, to the following:
        - ☐ Providing safe open channel surface conveyance in lieu of stormdrains.
        - ☐ Providing structural water quality mitigation in excess of ESD to the MEP.
        - ☐ Providing slope and outfall stabilization.
        - ☐ Subwatershed retrofits as outlined in local comprehensive watershed assessment studies and Chesapeake Bay TMDL Watershed Implementation Plan (WIP).
    - The restoration goal for the project and the provided quantities of water quality treatment shall be listed on the construction plans.

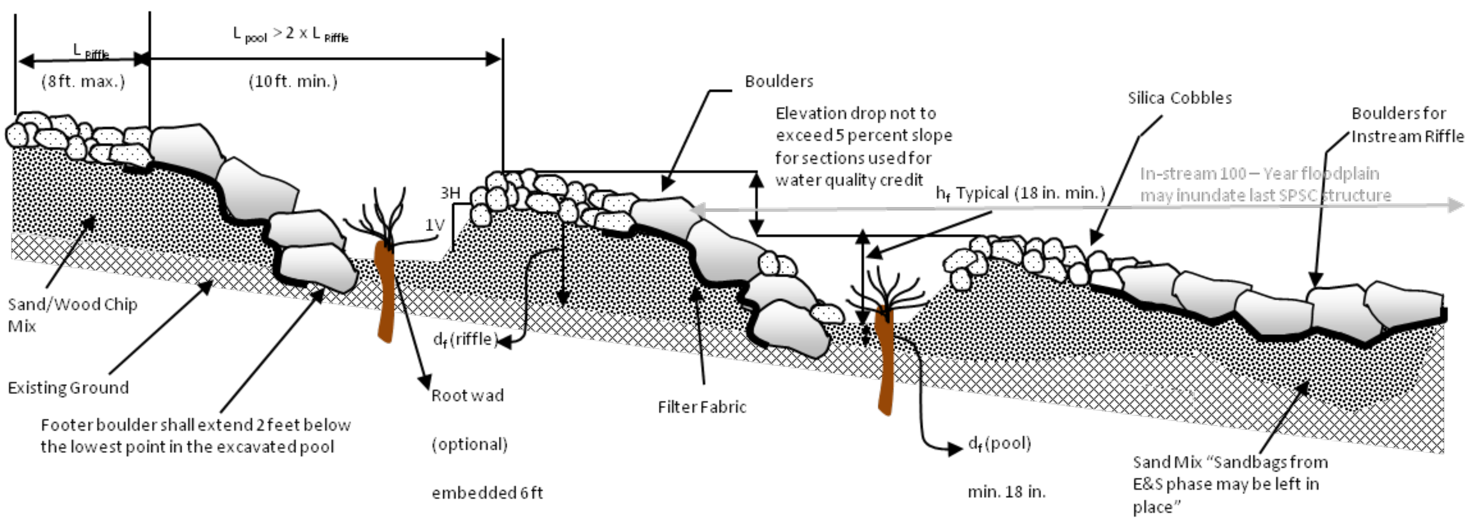
3. Map the horizontal alignment for the project
    - Develop a geometric plan sheet showing the SPSC alignment with stations and tabulated coordinates. The SPSC will be placed in the landscape following a curvilinear flow path whenever possible that generally follows the shape of the ravine or localized drainage path.
    - Special attention should be followed to minimize impacts to natural features. This could be accomplished through innovative/adaptive construction phasing and tree protection plans.
    - Special effort shall be made by the designer to avoid entrenched linear designs of the step pool structure. Storage opportunities on the floodplain lateral to the structure should be utilized to the maximum extent possible.
    - Measure the length of the reach along the plan view alignment from its input to the discharge location. This length shall be described in the design formulas as L_{design}. The discharge location shall be at the receiving channel. In the event that the receiving channel is incised/disconnected from the floodplain, an instream riffle may be utilized to connect the receiving channel with the floodplain. A horizontal alignment shall be established for the instream work. Design guidelines for the instream riffle tie-in are included in this document.



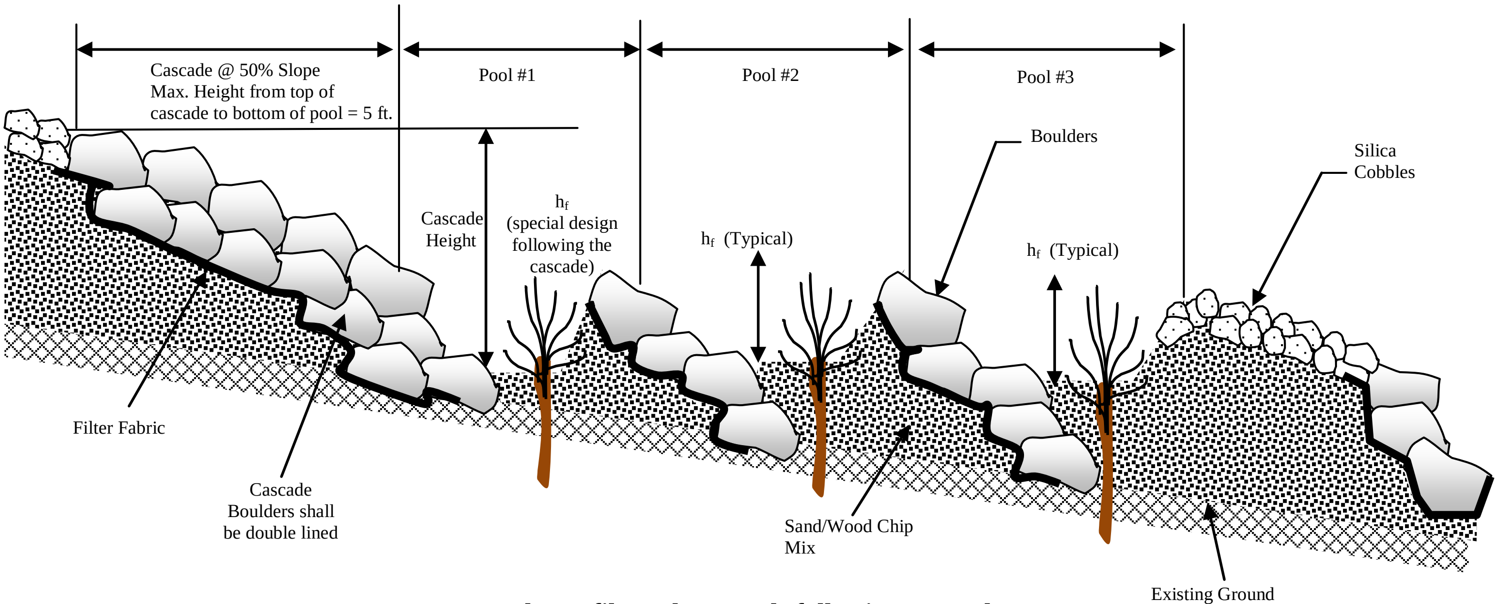
4. <u>Map a preliminary vertical alignment for the project</u>
Measure the elevation difference "ΔE" between the top and the bottom of the proposed SPSC. In the event that the proposed SPSC connects to an incised downstream channel, the elevation of the floodplain terrace shall be used as the downstream elevation. An instream riffle design with a top of weir elevation set at the floodplain terrace is required at the tie-in location.
   - Compute the average outfall slope, S, by dividing ΔE by L_{design}.
   - SPSC segments utilized for water quality shall not exceed 5 percent in longitudinal slope. If the overall slope exceeds 5 percent, boulder cascades will be needed for traversing the grade. Boulder cascades may be placed at a maximum of 50 percent slope (1V:2H). A maximum 5 feet of vertical drop from the top of the cascade to the lowest point in the downstream pool shall be permitted for cascades with a 50 percent slope. Multiple cascades may be required along the length of the project to traverse steeper grades. Longer cascades at a flatter slope maybe used in accordance with the cascade design chart below. The location of the cascade shall be selected to minimize site disturbances and environmental impacts.
   - Use a minimum 4 foot cobble apron at the rising limb of the pool. Refer to schematic drawings.
   - The length of the pools must be at least twice the length of the riffles and could be selected longer to reduce the number of structures used. The maximum length of riffle shall not exceed 8 feet "excluding the cobble apron length on the rising limb of the pool" so as not to build excessive energies.
   - All unarmored sides of the pool shall be laid at no steeper than 3H:1V.

- For an SPSC system with a 6 foot long cobble riffle, a 14 foot long pool, a 1 foot elevation drop over the riffle and pool combined segments is used. The overall slope is 1/20 or 5 percent.
- A minimum 18 inch fixed pool depth is required.
- Alternate pool and riffle channels.
- Three consecutive pools separated by boulder weir grade control structures shall be used following a cascade.
- Using the information above and not considering the need for cascades, the number of riffle and associated pools ($N_{pools/riffles}$) = L_{design}/(L_{pool} + L_{riffle}).
- In the event the connecting stream is incised, Boulders shall be used to construct an in-stream weir.

Cascade Height (ft)	Maximum Allowable Cascade Slope (ft/ft)	Minimum Required Cascade length (ft)
4	0.5	8
5	0.5	10
6	0.4	15
7	0.3	23
8	0.2	40
9	0.1	90
>10	0.1	>100
The cascade height is measured from the top of the cascade to the lowest point in the subsequent pool. Three full size pools are required at the bottom of a cascade.		



Typical Profile – Alternating Pools and Riffles

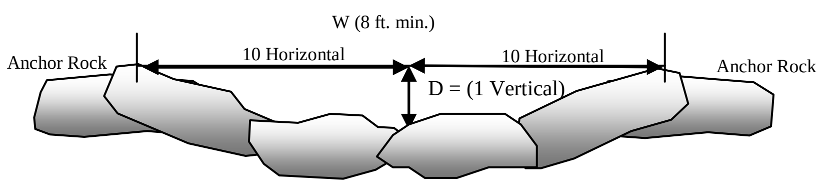


Cascade Profile – Three pools following Cascade

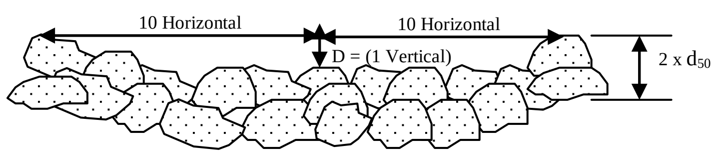
5. Design the typical cross-section for the riffle/weir/cascade and pool channel segments
   - The riffle/weir/cascade and pool channels shall be parabolic in shape.
   - Design the riffle/weir/cascade and pool channels to carry the Q_{design} for the unmanaged 100 year storm flow in a parabolic shape. The area and hydraulic radius of a parabola are computed as follows:

$$Area = \frac{2WD}{3} \qquad \text{Mathematical Solution}$$

$$Hydraulic \quad Radius = \frac{2W^2D}{3W^2 + 8D^2} \qquad Chow, 1959$$



Riffle Section through Boulder



Riffle Section through Cobble

- The minimum freeboard for lined waterways or outlets shall be 0.25 feet above design high water in areas where erosion-resistant vegetation cannot be grown and maintained. No freeboard is required if vegetation can be grown and maintained. (USDA, 2006.)
- Select a trial constructed riffle/weir channel width (W). The width is the dimension perpendicular to the flow and shall be minimum 8ft.
- Select a trial constructed riffle/weir channel depth (D). The side slopes of the parabolic channel shall not be steeper than 10H:1V. For retrofit projects with limited right of way and/or floodplain constraints, the engineer may increase the cross-sectional entrenchment up to 5H:1V if it can be demonstrated that the section will remain stable for the design storm.
- The dead storage depth within the pool shall not be considered when checking for adequacy of conveyance.
- Design using a trial cobble with a d_{50} of 6 inches. The calculated d_{50} shall be the median stone size diameter to be used in riffle channels and shall be rounded up to the D50 Median stone sizes shown on the table below. The density of the stone shall be specified. The depth of the cobble material is equal to 2 x d_{50} (MDSHA, Highway Drainage Manual, 1981. Show the cobble gradation table below clearly on the plans.

Cobble Gradation Table

D50 MEDIAN STONE SIZE (INCHES)	% OF MATERIAL SMALLER THAN TYPICAL STONE	TYPICAL STONE EQUIVALENT DIAMETER (INCHES)	TYPICAL STONE WEIGHT (POUNDS)
6	70 - 100 50 - 70 35 - 50 2 - 10	12 9 6 2	85 35 10 0.4
9	70 - 100 50 - 70 35 - 50 2 - 10	15 12 9 3	160 85 35 1.3
12	70 - 100 50 - 70 35 - 50 2 - 10	21 18 12 4	440 275 85 3
18	100 50 - 70 35 - 50 2 - 10	30 24 18 6	1280 650 275 10
24	100 50 - 70 35 - 50 2 - 10	42 33 24 9	3500 1700 650 35

- Calculate the Manning's n roughness coefficient based on the constructed depth, D, associated with the 100 year ultimate flow conditions and the cobble size:

$n = D^{1/6} / (21.6 \log (D/ d_{50})+14)$, (USDA, 2006).

Where:

n	=	Manning's n, use 0.05 for cascades.
D	=	depth of water in the riffle channel associated with unmanaged 100 year Q_{design}, feet,
d_{50}	=	Median cobble size, feet

- Use the Manning formula to calculate the flow and velocity associated with the trial parameters D, W, and d_{50}. The design flow shall meet or exceed the 100 year ultimate flow conditions.

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

Where:

Q	=	100 year ultimate flow (cfs)
1.49	=	conversion factor
n	=	Manning's n, determined by USDA, 2006 equation
A	=	cross-section area of a riffle channel, which for a parabola = 2/3(W)(D), where W is top constructed width (feet) and D is the constructed depth (feet)
R_h	=	hydraulic radius (feet), calculated using Chow 1959 relationship for parabolas
S	=	average slope over entire length of project (feet/feet)
V	=	velocity in the riffle channel (feet/second), V = Q/A

- Using small incremental depths (0.1 feet), develop a hydraulic rating curve/table for the channel to ensure that subcritical flow conditions prevail to the greatest extent possible. This is achieved by calculating the Froude number. A Froude number exceeding 1 indicates that the flow is supercritical, while a Froude number of less than 1 indicates that the flow is subcritical in nature. The Isbash coefficient for high turbulence should be used when sizing the cobble stones to accommodate supercritical conditions. Increasing the cobble size or the width depth ratio of the riffle channel can increase roughness and reduce velocity. This can further assist in meeting subcritical flow conditions.

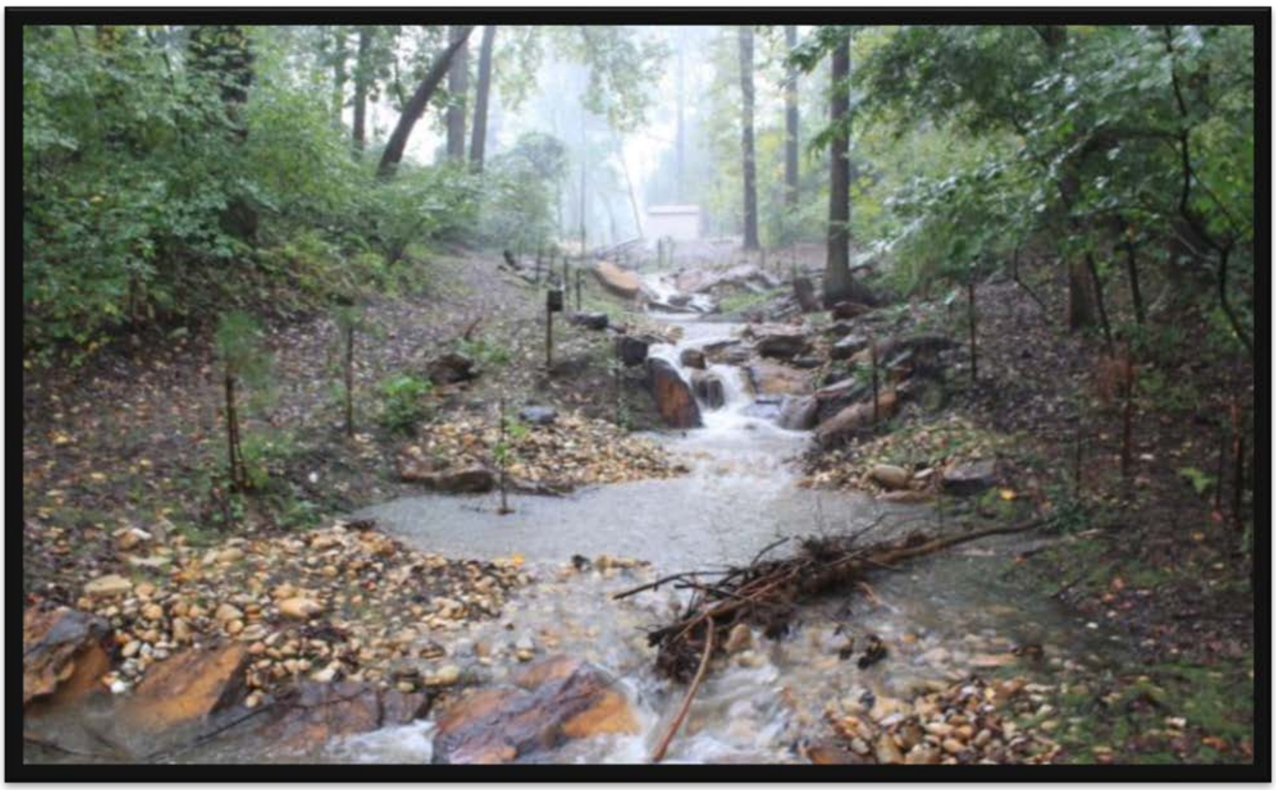
$$Fr = \frac{V}{\sqrt{gD}}$$

- The design velocity shall be checked to ensure that it is below the maximum allowable velocity estimated from the Isbash formula below (NRCS, 2007). A graphical solution of the Isbash formula is also shown. This will be an iterative design process. Spreadsheets can be used to streamline the calculations.

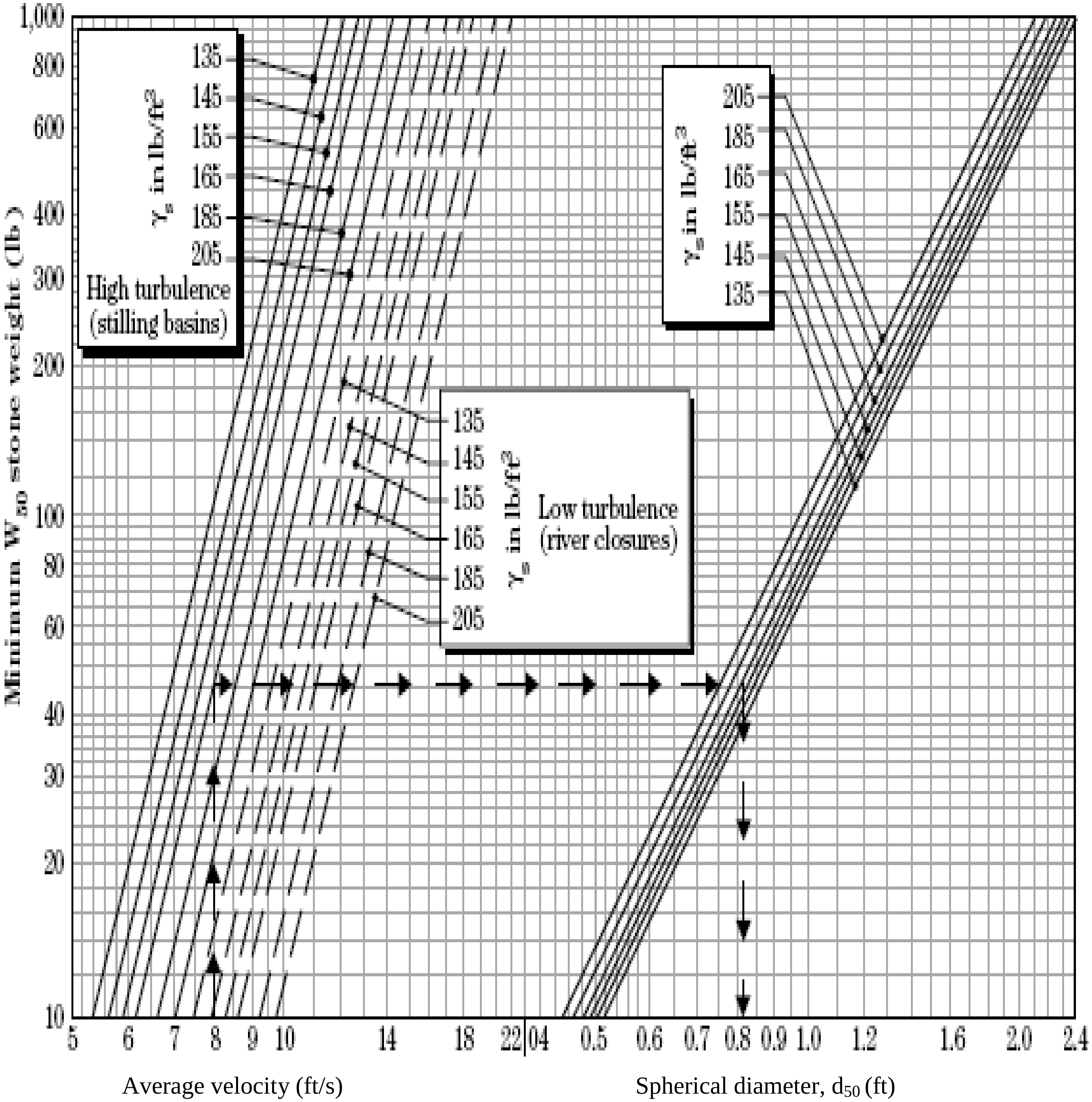
$$Maximum\ Allowable\ Velocity = C \times \left(2 \times g \times \frac{\gamma_s - \gamma_w}{\gamma_w} \right)^{0.5} \times \left(D_{50} \right)^{0.5} \qquad Isbash\ Formula$$

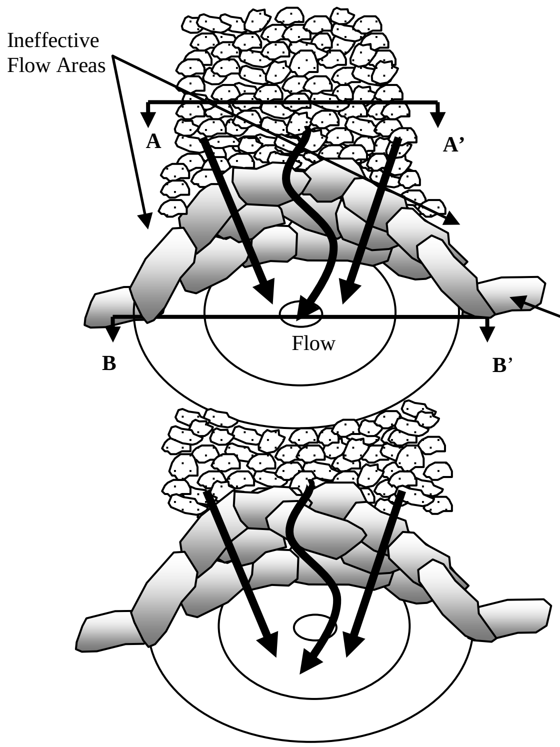
Where:

C = 0.86 for prevailing supercritical flow and 1.2 for prevailing subcritical flow
g = 32.2 ft/sec^2
γ_s = stone density (lb/ft^3)
γ_w = water density (lb/ft^3)
d_{50} = For the purpose of SPSC design, D_{50} is a median size of cobble stone diameter (feet).

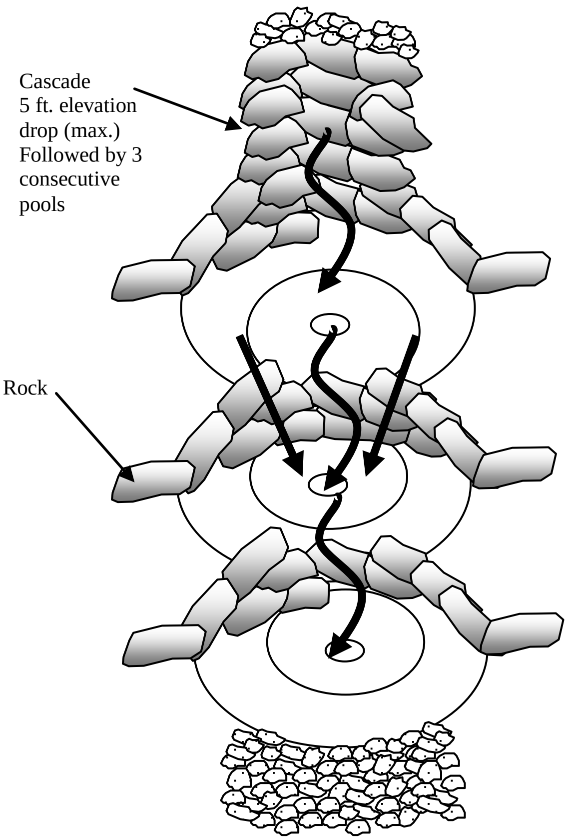


Graphical Solution for Isbash technique
Figure TS14C-6, (210-VI-NEH, August 2007, TS14C-4

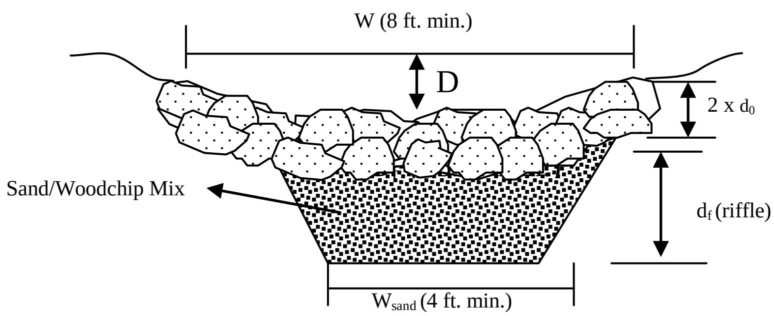




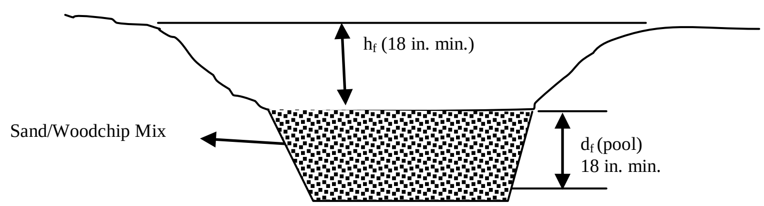
Riffle – Pool Sequence (Typical)



Cascade Sequence



Section A-A'
Riffle Weir Cross Section through Cobble



Section B-B'
Pool Cross Section

- The constructed depth of the typical pools (h_f) and the pool directly following a cascade ($h_{f\ cascade}$) shall not be less than 18 inches and shall not exceed 3 feet. Floodplain storage should be sought in the event that additional volume of storage is required. This will result in a pool geometric design with less than 3 feet of embankment and will meet the Code 378 exemption criteria as specified in Appendix B.1 of the State Manual. This exempts the SPSC system from the Soil Conservation District small pond approval. The minimum design depth of the pools shall be estimated based on the use of the solved form of the Bernoulli conservation of energy equation shown below. The Bernoulli equation was solved to achieve a pool channel velocity of 4 feet/second. D and V correspond to the riffle/cascade channel design depth and velocity respectively.

$$h_f \ or \ h_{f\ cascade} = D + \frac{V^2}{2g} - 0.25$$

- To ensure stability, the pools shall be constructed with a minimum side slope of 3H:1V. The minimum width depth ratio for the pools is 10H:1V.

- The sand/wood chip filter medium shall meet the AASHTO-M-6 or ASTM-C-33, 0.02 inches to 0.04 inches in size. Sand 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. The woodchips are added to the sand mix, approximately 20 percent by volume, to increase the organic content and promote plant growth and sustainability.

- The minimum depth of the sand/woodchip mix filter medium, d_f, below the invert of the pools, shall be 18 inches.

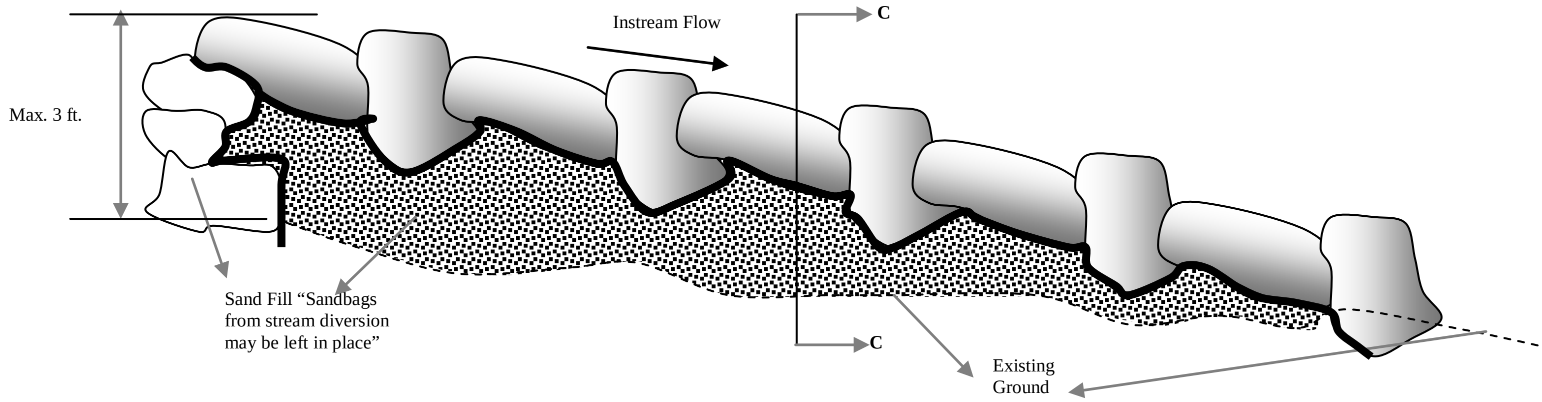
- Filter fabric shall be placed under all boulders. Refer to design figures for placement location. To prevent undercutting, a continuous sheet of filter fabric shall be used along the cross-section. Filter fabric shall not be placed in the pools so as not to impede filtration.

- The sandstone boulders serve as the weir component of the riffle grade control structure. The boulders should be arranged in a curved manner as shown on the riffle pool sequence schematic and the sandstone weir elevation view. This arrangement is intended to encourage flow deflection to the center of the pool and the creation of ineffective flow areas near the channel banks. To achieve this, the sandstone boulders shall be arranged horizontally in the center of the channel and the arms on either side of the channel shall be extended parabolically/ approximately 20 degree angle longitudinally to the center of the pool. The sandstone boulders should be sized by the engineer to be at least three to four times heavier than the riffle channel cobble. Typically, the diameter of sandstone boulders shall not be less than 2 feet in length. The typical boulder size shall be designed and specified on the plans by the engineer to best fit the channel shape, i.e., smaller cross-sections will require smaller boulders, while larger channel cross-sections may require larger boulders. The sandstone boulders should be tabular in shape to maximize interlocking. Boulders shall be used to line cascade segments.

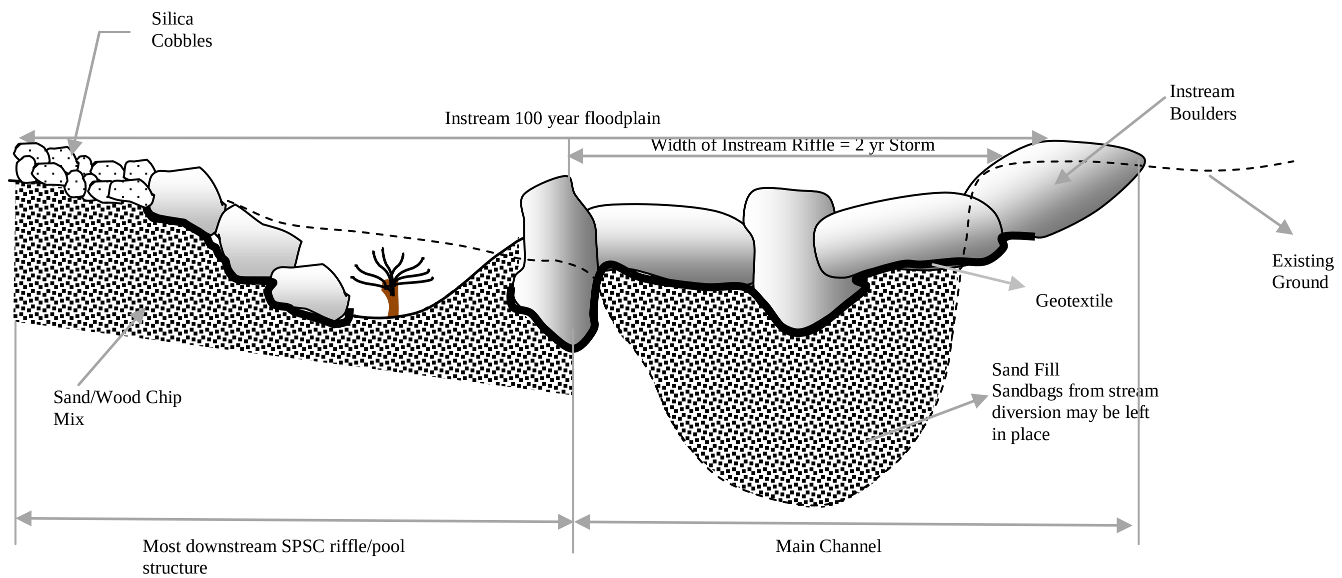
- The footer rocks provide added stability to the sandstone boulder in the event that excessive erosion is experienced in the energy dissipation pools. The footer rocks may not be necessary in the event that the utilized sandstone boulders size is adequately anchored (2 feet below the lowest elevation point in the pool). The footer rocks shall be equivalent in size to the sandstone boulders and should be tabular in shape to allow for maximum interlocking. Boulders shall be stacked as a double layer when used to armor a cascade. All footer rocks shall be anchored 2 feet below the lowest excavated elevation in the pool. Further, all boulder weir structures shall be anchored by a minimum of 2 ft to existing soils in the bank

6. <u>Design the instream riffle tie-in structure (if applicable)</u>
    - The instream riffle shall be set approximately 30 feet downstream of the tie-in location. The top elevation of the weir shall be set at the desired/historic floodplain elevation as determined appropriate by the engineer and approval authority. This is intended such as to impede headcut through the SPSC and inundate the floodplain for all flows above the base-flow conditions, thus enhance the water quality conditions.
    - The instream riffle shall be connected longitudinally to the upstream and downstream existing grade through a maximum 4 percent slope boulder channel. This will ensure gradual transition and that flow velocities do not impede the fish passage.
    - Sand shall be used for filling the stream bed to the desired elevation. Sand bags utilized as part of the erosion and sediment control plan for creating instream diversion may be left in place. Geotextile shall be used to separate the sand fill and the overlay boulders that line the channel. The boulders shall extend in cross-section to the 2-year storm.
    - The instream boulders shall be sized to remain in place under the 100 year velocity and shear stress, and shall be placed in a manner to create maximum hydraulic friction.
    - The last two structures within the SPSC system may be inundated by the instream 100 year flood elevations.
    - HEC-RAS shall be used to estimate the instream 100 year water surface elevation. The HEC-RAS sections shall be extended upstream to the point where the existing and proposed 100 year floodplains converge. The

proposed instream design shall not result in degradation to the hydraulic adequacy of upstream public facilities or in increased flooding on private properties.



Instream riffle longitudinal profile



Section C-C: Cross section at constructed instream riffle tie in with SPSC

7. Check and adjust the design parameters based on the project goals
   - The provided sand/woodchip mix filter bed area can be computed by multiplying the average width of the sand/woodchip mix medium, where the provided sand/woodchip mix depth is at least 18 inches, Chapter 3.4 of the State Manual, by the length of the sand/woodchip mix medium, L_{sand}, in the direction of the flow.

Where,

$$A_f = \frac{WQ_v \; x \; d_f}{K\,(h_f + d_f)\,t_f}, \qquad \textit{Filtering Sizing Criteria MDE } 2000$$

A_f	=	required sand/woodchip mix filter bed area (ft^2)
$A_{provided}$	=	provided sand/woodchip mix filter bed area (ft^2)
W_{sand}	=	width of sand/woodchip mix filter bed (feet), minimum = 4 feet
L_{sand}	=	length (feet) along the project (L_{pre})
WQ_v	=	prescribed Water Quality Volume (ft^3)
d_f	=	sand/woodchip mix filter bed depth (feet), use minimum 24 inches (Average of d_f (pool) and d_f (riffle)
K	=	coefficient of permeability of filter medium (feet/day), use K = 3.5 for sand/woodchip mix
h_f	=	Depth of Pool (feet), minimum 18 inches
t_f	=	design filter bed drain time (days), use 1.67 days as recommended by MDE for sand mix filters

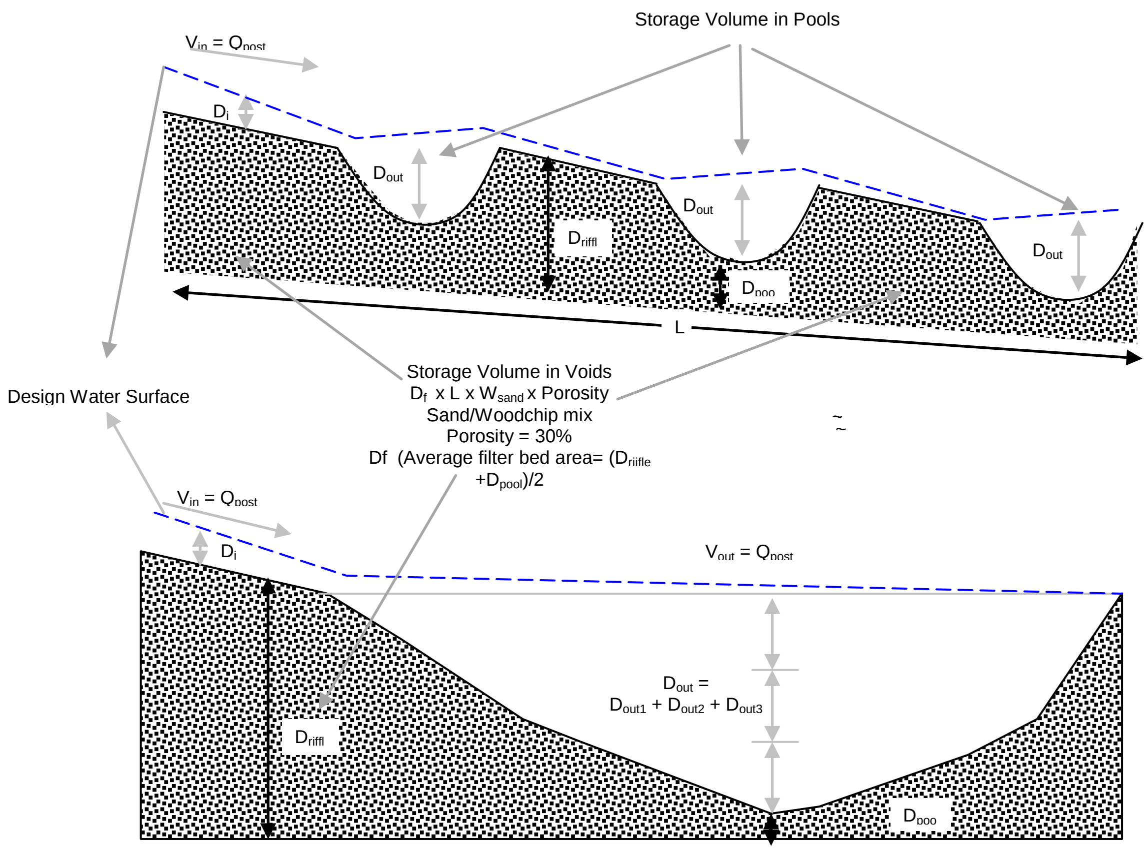
- For SPSC systems that meet the ESD criteria and for outfall retrofit and stream restoration projects, the required WQ_v for the contributing drainage area may be met by adjusting the depth of pools, width of sand/woodchip mix filter, or length of the facility to increase the filtering capacity. Partial treatment credit may be claimed for outfall retrofit and stream restoration projects. SPSC systems proposed as part of a new development or redevelopment that is not designed as an ESD device may not claim any water quality credit.

- In situations where the existing soil, underlying the proposed SPSC, is confirmed through "borings" to be highly infiltratable, and the SPSC meets the ESD criteria or is a retrofit project, the designer may utilize the State Manual's water quality sizing criteria for an infiltration basin in lieu of filtration. This is prescribed so the designer engineer is not forced, under certain circumstances, to replace highly infiltratable native soil with non-native filter bed material. In order to claim water quality credit, the design ponding depth/head, h_f, intended to drive the seepage through the filter shall be entirely above the seasonal high groundwater elevation.

- The proposed SPSC will satisfy peak management flow requirements if two conditions are met:

    - □ First, adequate storage volume within the pools and sand/woodchip voids shall be provided to meet the required storage volume/quantity management for the project.
    - □ Second, it must be demonstrated that the design renders the hydraulic power equivalent to the pre-development/desired hydraulic power through the proposed energy dissipation pools.

- To achieve the conditions above, the designer must compare the required peak management storage volume with the combined volume within the pools and the volume in the voids within the sand/woodchip mix. A 30 percent porosity (n=0.3) shall be used for the sand/woodchip mix to calculate the volume within the voids. The total provided storage shall exceed the required storage volume for the design peak management storm. Second, the selected design for the SPSC must be checked using the conservation of energy principles to ensure that the hydraulic power is adequately reduced to design/pre-development levels. This is achieved by equating the pre-development or reference condition hydraulic power to the post development hydraulic power and solving for the equivalent added stream length/volume of storage needed to render this power to the desired condition. The conservation of energy principles are then utilized to convert the energy loss within this horizontal length to an equivalent vertical drop. The vertical drop is then converted to multiple drops that are distributed along the system in a manner that result in the least site disturbances. The provided quantity/volume of pools is then compared with the calculated quantity/volume of pools. If the provided pool storage is less than the computed/required pool storage, then additional SPSC design measures or additional upland management strategies must be taken to reduce the inflow and in turn the hydraulic power. Refer to the figure below for a demonstration of the SPSC-provided volume of storage and input parameters for the conservation of energy computations. It should be noted that equating the geometric configuration of a multiple pool system to one pool with an area equal to the cumulative areas within the individual pools is a conservative measure and is used to simplify the hydraulic power routing computations. It is expected that cumulative roughness and headloss within the multiple pool configuration to be much higher than the individual pool configuration.



- These steps should be followed in checking the before/after hydraulic power:

  - Compute the pre-development/design and post development hydraulic powers by substituting the pre-development and post development discharges in terms of Q in the hydraulic power equation. The hydraulic power is expressed in the units of lb/second.

    Hydraulic Power = γ x Q x S, where
    γ is the unit weight of water = 62.4 lb/ft^3
    Q corresponds to Chapter 2 of State Manual CPV discharge
    S is the slope of the outfall channel in percent

  - Equate the pre-development/design and post development hydraulic powers and solve for the needed added stream length.
  - γ x Q_{pre} x ($\Delta E/L_{pre}$)= γ x Q_{post} x ($\Delta E/L_{post}$)

  - The elevation difference between the top and bottom of the project and the unit weight of water will remain constant, therefore, the channel protection requirement could be expressed in terms of a required additional stream channel length L_{add}, needed to render the post development hydraulic power equivalent to the pre-development hydraulic power.

- $L_{add} = L_{pre} \times (Q_{Post}/Q_{Pre}) - L_{pre}$

➢ The required headloss due to friction through the Step Pool Storm Conveyance system can be calculated using the Darcy-Weisbach equation. By substituting L_{add} for L, this headloss becomes equivalent to the energy loss within an added stream channel of length L_{add}. The friction factor can be calculated using established relationships between Darcy-Weisbach friction factor and the Manning friction coefficient listed in Chow, 1959. The Darcy –Weisbach headloss equation is as follows:

$$Friction\ head\ loss = \frac{fL_{add}V_{out}^{\ 2}}{2D_{out}g}$$

➢ By substituting the required headloss term in the Bernoulli conservation of energy equation, the total combined design depth in feet of all proposed pools shall be at least equal to the "D_{out}" term embedded in the Bernoulli conservation of energy equation depicted below. If the total combined depth in feet of all proposed pools is less than the calculated "D_{out}" term, then additional pools are required or alternatively the pools could be made deeper. Solve for the "D_{out}" term using trial and error techniques or available commercial solver functions/calculators, (i.e., Microsoft Excel). The general and solved forms of the Bernoulli conservation of energy equation are shown below.

General Form of the Bernoulli Equation

(Potential + Kinetic + Static) Energies $_{\text{SPSC entrance}}$ = (Potential + Kinetic + Static) Energies $_{\text{SPSC outlet}}$ + Headloss $_{\text{within SPSCsystem}}$

Solved Form of the Bernoulli Equation

$$D_{in} + \frac{9Q^2}{4gD_{in}^{\ 2}W_{in}^{\ 2}} + \Delta E = D_{out} + \frac{9Q^2}{4gD_{out}^{\ 2}W_{out}^{\ 2}} + \frac{9\,fL_{add}Q^2}{4gD_{out}^{\ 3}W_{out}^{\ 2}}$$

Where,

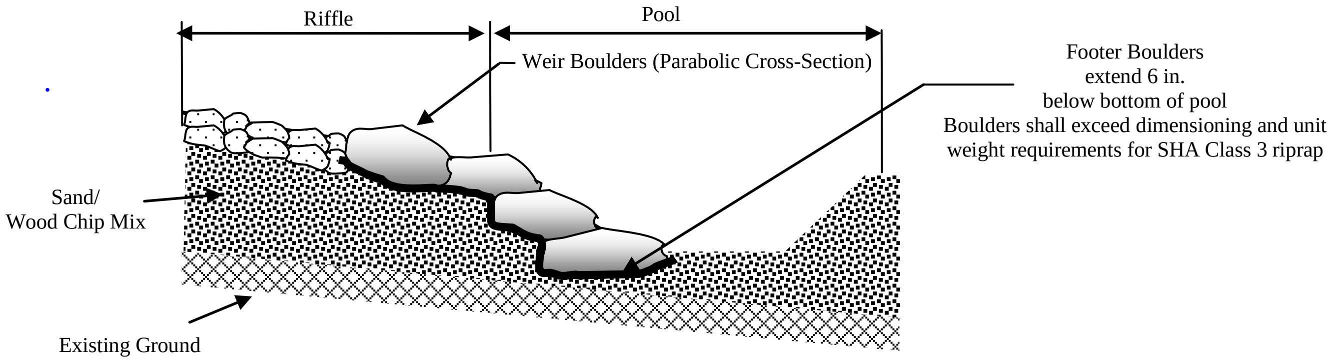
f	=	Darcy-Weisbach friction factor, the Chow 1959 equations below may be used to relate the friction factor to a manning roughness:

$$f = 8gRh^{-1/3}n^2 \qquad \textit{Chow}, 1959$$

http://www.water.tkk.fi/wr/kurssit/Yhd-12.121/www_book/runoff_6.htm

L_{add}	=	additional channel length (feet) required to render the post development power to pre-development conditions
V_{in}	=	Design velocity at entrance riffle = V
D_{in}	=	Design depth at entrance riffle = D
W_{in}	=	Design width of riffle = W
W_{out}	=	Width of the pool (feet)
V_{out}	=	typical velocity of flow (feet/second) in the pool, this term is unknown in the Bernoulli equation. Using flow continuity principals, this term could be expressed in terms of the CP_V design discharge, D_{out}, and W_{out}.
g	=	acceleration due to gravity = 32.174 ft/sec^2
D_{out}	=	Solve for combined depth of flow in all pools (feet) and compare to the total provided pool depth

8. Finalize the cross-section and profile design for the project
    - Develop a grading plan based on the preliminary profile and cross-section typical design.
    - Adjust the preliminary profile dimensions to accommodate site specific concerns/impacts. Minimum design parameters for hydraulic, water quality, and quantity management criteria should be rechecked based on adjustments to the riffle/pool channels to ensure that safe and adequate conveyance is still maintained.
    - The sand/woodchip mix filter bed shall have a minimum depth of 18 inches under the riffle channel and a minimum width of 4 feet and shall be placed as the substrate drainage material along the entire project length. The actual dimensions of the sand/woodchip mix filter bed will be determined based on the required water quality volume.
    - Typically, construction of the SPSC system shall begin at the downstream end and proceed upstream to the project outfall. The outlet pool is designed to be placed at the lowest point in the project reach. This is often in the receiving wetland or stream/floodplain, but can also be located in upland settings where the SPSC system discharges to another stormwater BMP or adequate storm conveyance system.
    - Footer boulders shall be placed at the interface of the pools and riffles as shown below. Additional boulders shall be placed on top of the footer boulders at the weir elevation upstream of the footer boulders to form the riffle channel parabolic shape. Boulders shall exceed the dimensioning and unit weight requirements for the Maryland State Highway Administration (SHA) Class 3 riprap.



- Continue the process of alternating pools and riffles/weirs up through the system to the entry pool. If the entry pool ties to an existing pipe outfall, additional armoring or scour protection of the pool may be needed to address the pipe exit velocities associated with supercritical hydraulic conditions. The designer may elect to use a larger size pool at the project entry to dissipate the outfall velocity and/or to address pretreatment concerns.
- If the SPSC is proposed below a pipe system, it is desirable that the top invert of the weir associated with the entry pool is set at or above the invert of the discharge pipe or culvert. It is the responsibility of the design engineer to check the adequacy of the upstream drainage system and drainage area.
- Vegetative stabilization must comply with Anne Arundel Soil Conservation/MDE stabilization specifications. Kentucky 31 tall fescue is not to be used in wetlands or wetland buffer systems.
- Course woodchips and compost (4 inch – 8 inch thick) should be used throughout the limit of disturbance for site stabilization provided that plantings will be installed during the first available planting season.
- All areas should be hydro-seeded.
- At the end of each day, exposed dirt shall be stabilized immediately.
- It is advisable that excess materials, i.e., cobbles and boulders, be placed at the edge of the cross-section for use during the maintenance phase to correct any physical instability.
- A direct maintenance access shall be provided to the system. All public systems must be fully contained within public right of way or easement with sufficient width to allow future maintenance and retrofit activities as needed.

9. Setback requirements
   - The minimum setback from the 100 year water surface elevation of the system to structures on slabs is 10 feet.
   - Systems located uphill of an existing house or structure shall be evaluated for possible adverse effects to the structure.

- The 100 year water surface elevation of a system located uphill of a building or structure that has a basement shall be no closer than 20 feet from the structure or the intersection of the structure foundation footing and the phreatic line associated with the overflow depth of the device, whichever is greater.
- The 100 year water surface elevation of a system located downhill of a building or structure that has a basement shall be no closer than 10 feet from the structure foundation or the intersection of the structure foundation footing and the phreatic line associated with the overflow depth of the device, whichever is greater.
- The 100 year water surface elevation of a system shall be located a minimum of 1 foot below the structure floor or basement floor. Certification to this effect from a professional engineer shall be shown on the plan.
- The 100 year water surface elevation of a system shall not be located within 25 feet of a retaining wall or the top of a slope that is 25 percent or greater. In no case shall the phreatic line associated with the overflow depth of the system intersect the existing or final ground surface of the retaining wall or slope.
- The 100 year water surface elevation of a system shall not be located within 50 feet of any residential water supply well.
- The designer shall consider the proximity of sanitary septic drain fields when locating a new system. These systems can raise the localized groundwater elevation and therefore impact existing septic drain fields. The designer shall ensure that constructed SPSC systems pose no impact to primary and secondary septic drain fields and shall consult the Anne Arundel County Health Department regulations in these instances.
- The 100 year water surface elevation of a system shall not be located within 10 feet horizontally from any public sanitary sewer manhole and clean out structures or house connections. Sewer manholes, clean outs, pump stations, and other sewer structures shall be located 1 foot above the 100 year storm elevation within the SPSC system.

10. <u>Sequence of construction and erosion and sediment control notes</u>
    - It is preferred that the SPSC system be installed at the end of the construction phase (when the upstream area is stabilized) so as not to contaminate the SPSC during upstream construction. However, if the site is constricted and the SPSC system needs to be installed earlier on in the sequence, then upstream flows must be directed around the SPSC system to avoid contamination.
    - Under no circumstance can the SPSC system be used as a sediment control device during construction unless approved by the Anne Arundel Soil Conservation District (AASCD). Upstream controls such as diversion pipes and pump-arounds are required during construction so as not to contaminate the SPSC system.

- The SPSC system shall not be finalized until all upstream construction is complete and all disturbed areas stabilized and erosion and sediment control measures have been removed at the discretion of the inspector.
- Special attention shall be paid to the application of perimeter reinforced or super silt fence along the SPSC system so as not overwhelm the silt fence with concentrated flow and develop erosion within the SPSC floodplain and behind the stone structures. If erosion from sheet flow to the system is observed during construction, a plan revision to address the upstream drainage area and an adequate design of the conveyance channel should be submitted for the problem location.
- SPSC sediment controls when possible shall have reinforced silt fence along the toe of the outlet for the bottom pool. A bypass for upstream runoff around the SPSC is needed until the drainage area is permanently stabilized. Riffles and pools shall be stabilized at the end of each work day.

11. Draft a planting plan
    - The planting plan and proposed species must be reviewed and approved by the County project manager/reviewer prior to installation. Additionally, any plant substitutions must be approved by the project manager/reviewer before the substitute species are installed.
    - For projects within the airport zone, a sample list of the Maryland Aviation Administration (MAA) approved native plants is attached at the end of this document. A selection of approved trees with approved understory of shrubs and herbaceous materials should be provided.
    - Pay special attention to use of native material, diversity, and dense placement of plant material within appropriate wetness zones throughout the site (MDE, 2000).
    - As a temporary stabilization measure, seed and mulch (compost) the entire site with annual rye throughout construction.
    - Spray down a minimum 4-8 inch layer of compost throughout the site avoiding areas of ponding water. The compost shall be derived from the natural composting process of plant material with no lime additives. The PH acceptable range shall be between 5 and 8.
    - As a permanent stabilization measure, seed the entire site with Red Fescue. Chewing Red Fescue may be alternatively used.
    - Existing trees to be protected shall be marked clearly on the project plan view and planting plan.
    - The designer has the option to use inverted root wads, in the pool areas to enhance the soil porosity and create habitat for the biological community. Root wads shall be embedded 6 feet below the invert of the pool and their size shall not exceed 10 percent of the pool volume. Root wads shall not be used in the two pools directly upstream of a cascade. The root wads shall be placed in the center of the pool in a vertical alignment. It is noted that the use of root wads is not a requirement and is an option. Root wads

are not intended to serve any bed or bank stabilization purpose and are primarily used to enhance habitat and increase roughness.

12. <u>Prepare a monitoring plan and schedule of completion</u>

- Prior to release of certification of completion, inspectors must ensure that adequate vegetative stabilization has occurred. Adequate vegetative stabilization requires 95 percent groundcover. In addition, all sediment accumulation having resulted from upstream construction must be removed to design elevations.
- A monitoring plan must be prepared to address the specific restoration goals for the project per Article 16-3-205(a). Clearly show the erosion control monitoring device on the sediment and erosion control plan.
- Structural stability and plants survivability are the two most pertinent components to monitor for private/developer built projects. These components shall be monitored for three years or as established in the plan review process. Enforcement of the monitoring conditions shall be tied to the asbuilt approval process and release of the stormwater management bond.
- The monitoring plan for SPSC shall include annual vegetation survey to document that planted species have 80 percent survivability and a biannual physical stability assessment. At the discretion of the project manager, annual benthic macro invertebrate monitoring using the Anne Arundel County approved protocols and storm event chemical monitoring for nutrients and sediments may be required. The monitoring plan shall also address all permit required project monitoring.
- Routine/biannual maintenance of County-owned SPSC systems is prescribed for a period of three years. This includes, but is not limited to, mulching and seeding of devoid areas, diseased plant replacement and replanting if necessary, removal of excessive debris and invasive species. This is done to ensure plant survivability, and to monitor and ensure the structural integrity of the construction project by performing any routine structural maintenance necessary.
- In the event that sediment accumulation exceeds 6 inches in the first year, the contractor shall spray down an additional layer of compost and replant the pool bottoms. Sediment deposition is expected in the pools to balance the energies within the system (upstream sediment input versus stable geomorphic design). Removal of accumulated sediment should be limited to when the accumulated sediment threatens the structural integrity of the system.
- Unless encountered with natural groundwater perch, the filtering capacity shall be physically checked. If the filtering capacity diminishes substantially (e.g. the design ponding depth is not recovered after 72 hours), the top few inches of discolored material within the pools shall be removed and shall be replaced with fresh material. The removed sediments should be disposed in an acceptable manner (i.e. landfill).

- Direct maintenance access shall be provided to all sandstone weirs and pools.
- A recorded maintenance agreement is required for all privately-owned SPSC systems.
- The operation and maintenance design detail and schedule shall be shown on the asbuilt plan. For privately-owned structures, the maintenance agreement shall be officially recorded and the recordation number shall be included on the approved grading plans.
- At a minimum, a maintenance plan shall include removal of exotic, invasive, and/or non-native plant species identified in the annual vegetation survey using methods approved by the County and by the Maryland Department of Agriculture.

13. Design checklist

SPSC Item	Check	Yes/No	Reviewer Comments
Hydrology	Delineate drainage area, landcovers, and soil to the most downstream point of the SPSC system.		
	Develop TR55/TR20 model run to calculate the pre-development and post-development peak discharges.		
	Utilize MDE standards and TR55 to calculate the required channel protection and other overbank 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 pre-development stream power. (Note: this requires that sufficient SPSC length and number of pools be provided)		
	Does the storage volume within the pools and voids meet the required quantity management storage volume prescribed for the project and calculated using the MDE standards and TR55?		
Alignment	Does the alignment follow the natural drainage path and efforts are 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?		
Downstream Tie-in	Does the SPSC 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 percent?		
	Have the pool segments been placed with a slope flatter than 1 percent?		
	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 feet?		
Pool Design	Do the side slopes for the pool (from all unarmored segments) exceed 3H:1V?		
	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 feet.		
	Does the length of the pool exceed the minimum required 10 feet and allow sufficient length to accommodate the 3H:1V slope on unarmored sides? Is the length of the pool at least twice as long as the length of the riffle?		

SPSC Item	Check	Yes/No	Reviewer Comments
Riffle Channel Design	Is the channel parabolic in shape?		
	Does the width, depth, and slope meet the design requirement and allow minimal entrenchment and safe conveyance of the 100 year storm?		
	Are the d_{50} cobble size adequate for accommodating the 100 year velocities? Did the designer include a cobble gradation table on the plan?		
Weir Design	Are the boulders forming the weir 3-4 times larger than the calculated d_{50}?		
	Are the footer boulders extended/anchored at least 2 feet 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?		
Cascade Design	Are the cascades armored with sandstone weir over filter fabric and the height does not exceed 5 feet 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 a 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 are 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 an approved erosion and sediment control plan by AASCD been implemented upstream and downstream of the SPSC system prior to excavation clearing and channel shaping?		
	Have flows from traps and basins been bypassed around the newly constructed SPSC system?		
Wetlands, Streams, Buffers, and 100 year Floodplain	Provide documentation from MDE/Army Corps of Engineers for approval of all impacts to all County Agencies.		
Maintenance	Have a permanent and direct maintenance access and public right of way been provided to all public facilities?		
	Has a maintenance agreement been signed and recorded for private SPSC structures?		

SPSC Item	Check	Yes/No	Reviewer Comments
Monitoring Plan	Has a monitoring/maintenance plan been developed for County-owned systems as prescribed in the design guidelines and is clearly shown on the plan?		
Planting	Have 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?		

14. Inspection checklist

SPSC Item	Check	Yes/No	Inspector Comments
Alignment	Does the alignment of the system match the alignment specified on the plan?		
Length	Has the contractor provided sufficient SPSC length to meet the minimum requirement on the plan?		
Elevation Difference	Does the elevation difference from structure to structure and from top to bottom of system match the design plan and profile?		
Number of Weirs	Does the number of weirs match the number specified on the plan and profile?		
Outfall Conditions and Tie-in	Is the connecting outfall physically stable with no signs of erosion and is the structure properly tied into the outfall as specified on the plans?		
Pools	Does the number of pools match the number specified on the plan and profile?		
	Does the depth in any given pool exceed the minimum required pool depth as shown on the design plans?		
Cascades	Cascades shall not exceed 5 feet in vertical height at any given location.		
	Cascades shall be parabolic in shape with adequate width and depth to accommodate safe conveyance of the 100 year storm as specified on the plan.		
	Cascades shall be followed by three consecutive pools.		
	Cascades shall be underlined by filter fabric.		
Weir Cross-section	Are the weirs curvilinear in the direction of the flow? i.e., are the boulders placed in a manner similar to a cross-vane that would direct the flow to the center of the pool and away from the banks?		
	Is the cross-section parabolic with adequate depth and width for safe 100 year conveyance as specified on the plans?		
	Are the sandstone boulders forming the weir 3 to 4 times larger than the d_{50} for the cobbles and underlined by filter fabric as specified on the plans?		
	Are footer boulders provided and extend to a depth that is 2 feet below the lowest point in the pool?		
Cobbles	Does the cobble size meet the d_{50} stone gradation requirements indicated on the gradation table?		
	Are the cobbles rounded? Are they silica/bank run		

SPSC Item	Check	Yes/No	Inspector Comments
	gravel?		
Filter Sand Mix	Has the contractor placed the required volume of filter sand mix below the system?		
	Does the filter sand mix include 20 percent wood chips by volume?		
Filter Fabric	Has filter fabric been applied under all sandstone boulder structures and as required on the plans?		
E&S	Have all the upstream erosion and sediment control measures been removed?		
	Have adequate conveyance systems been provided to address all lateral drainage? (Note: The presence of erosion lateral to the system suggests poor grading and the need for lateral conveyance systems to intercept the flow.)		
Plantings	Has mulch/compost been applied on the entire site?		
	Has the entire site been hydro-seeded with Red Fescue?		
	Has the site been planted with adequate number of shrubs and trees as specified in the plan? (Note: Pay special attention to use of native material, diversity, and dense placement of plant material within appropriate wetness zones throughout the site.)		
Maintenance Access	Has a direct vehicular maintenance access been provided as an entry location to the site? Are public facilities located within a deeded public parcel or a perpetual easement?		
For Private Structures	Has a maintenance agreement been prepared, signed, and recorded?		
For Public Structures: **The following items must be verified before the structure as-built is accepted by DPW and the bond is released**			
SPSC Item	**Check**	**Yes/No**	**Inspector Comments**
Filtering Capacity	For water quality ephemeral systems, do the pools drain to an acceptable level where the design ponding head for the filter is fully recovered in 72 hours after a rain event?		
Sedimentation	Has the contractor removed sedimentation (exceeding 6 inches) from the pools?		
Monitoring	Has the structure been monitored for at least 3 years? Specifically physical stability and plant survivability.		
	Have annual monitoring reports been submitted to I&P and IMD and were they favorable? If not, were deficiencies addressed?		
Plant Survivability	Has at least 80 percent of the planted shrubs and trees survived 3 years after installation?		
Physical stability	Are all sandstone boulders in place with no sign of bank or bed erosion throughout the length of the project?		
Invasive Species	Have all invasive plant species been removed from the system and the entire system re-seeded?		

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City of Wheat Ridge, Colorado, Department of Public Works, Engineering Division, Rock and Riprap Gradation, E-A02 Detail Code

Abbreviated List of Native Plants

Step Pool Storm Conveyances are designed with the intention that they will mimic natural processes. Vegetation plays an important role in these processes. It is highly encouraged on all projects and required on those in Anne Arundel County to use native vegetation appropriate for the conditions of the site.

The following is a sample, abbreviated list of native plants that may be used on SPSC structures within the airport zone. The list has been cross-checked for consistency with the Maryland Aviation Administration (MAA) approved plant list. This list may be subject to expansion to accommodate other native plant species and future updates to the MAA guidelines. It is the responsibility of the designer to check and propose native plant species that are consistent with MAA regulations for projects within the airport zone.

Common Name	Latin Name	Comments
American Holly	*Ilex opaca*	*(Male Only)*
Bald Cypress	*Taxodium distichum*	
Bayberry	*Myrica pensylvanica*	
Blue Flag Iris	*Iris versicolor*	
Christmas Ferns	*Polystichum acrostichoides*	
Cinnamon Fern	*Osmunda cinnamomea*	
Fringe Tree	*Chionanthus virginiana*	*(Male Only)*
Inkberry	*Ilex glabra*	*(Male Only)*
Little Bluestem	*Schizachyrium scoparium*	
Mountain Laurel	*Kalmia latifolia*	
Pitch Pine	*Pinus rigida*	
Switchgrass	*Panicum virgatum*	
Summersweet	*Clethra alinifolia*	
Sweetbay Magnolia	*Magnolia virginiana*	
Tussock Sedge	*Carex stricta*	
Virginia Sweetspire	*Itea virginica*	

For SPSC projects outside of the airport zone, the designer shall utilize the list of native plants as listed below:

Common Name	Latin Name
American Holly	*Ilex opaca*
Atlantic White Cedar	*Chamaecyparis thyoides*
Bald Cypress	*Taxodium distichum*
Northern Bayberry	Morella *pensylvanica*
Blue Flag Iris	*Iris versicolor*
Broomsedge	*Andropogon virginicus*
Christmas Fern	*Polystichum acrostichoides*
Cinnamon Fern	*Osmunda cinnamomea*
Common Winterberry	*Ilex laevigata*

Common Name	**Latin Name**
Cranberry	*Vaccinium macrocarpon*
Lowbush Blueberry v*accinium*	*Anguaticolium*
Water Lily	*Nymphea odorata*
Fringe Tree	*Chionanthus virginiana*
Golden Club	*Orontium aquaticum*
Highbush Blueberry	*Vaccinum corymbosum*
Inkberry	*Ilex glabra*
Little Bluestem	*Schizachyrium scoparium*
Mountain Laurel	*Kalmia latifolia*
Redhead Grass	*Potamogeton perfoliatus*
Eastern Redcedar	*Juniperus virginiana*
Royal Fern	*Osmunda regalis*
Serviceberry	*Amelanchier canadensis*
Switchgrass	*Panicum virgatum*
Smooth Alder	*Alnus serrulata*
Black Gum	*Nyssa sylvatica*
Sweet Pepperbush	*Clethra alinifolia*
Swamp Azalea	*Rhododendron viscosum*
Southern Bayberry	Morella canotiniensis
Sweetbay Magnolia	*Magnolia virginiana*
Tussock Sedge	*Carex stricta*
Virginia Chain Fern	*Woodwardia virginica*
Virginia Sweetspire	*Itea virginica*
Wax Myrtle	*Morella cerifera*
Yellow Pond Lilly	*Nuphar advena*
Riverbirch	*Batala Nigna*
American Hornbean	*Carpinus caroliniana*

The list above is not a complete list. A complete list of native plants can be found under www.aacounty.org/IP/Resources/AANativePlants.pdf. Special attention shall be placed on diversity and dense placement of plant material within appropriate wetness zones throughout the site (MDE, 2000). Additional information on native plants for the Chesapeake Bay region can be found at www.nps.gov/plants/pubs/chesapeake. For information concerning Native Plant Nurseries, please visit www.aacounty.org/IP/Forms.cfm and scroll down to the "Forestry Forms and Fact Sheets" section.

Summary of Revisions:

August 2010 Revision 1: (a) Added language to clarify when an SPSC system can and cannot be used as part of the ESD treatment train.

November 2010 Revision 2: (a) Replaced the d50 cobble size definition with the d_{100} definition indicating that the cobble design size is the minimum allowable cobble size to be used rather than median stone size. (b) Added a clarification on the minimum and maximum allowable length of pools and riffles. (c) Added a design checklist. (d) Added an inspection checklist. (e) Added guidance pertaining to sequence of construction and erosion and sediment control measures.

April 2011 Revision 3: The 2000 Maryland Stormwater Design Manual does not prescribe a groundwater separation requirement for filtering systems as is done with infiltration systems. Due to this, revision 3 eliminates the requirement for groundwater separation from the filtering system. However, to ensure that the filtering mechanism works as designed, the design water quality filter ponding depth in the pools, also known as seepage head, shall be available for storage during storm events and not inundated by seasonal groundwater. Further, construction inspection shall verify that pools do drain down within 72 hours to their design levels. Added horizontal and vertical setback requirements for SPSC systems. Added "Regenerative" to the practice name for consistency with EPA TMDL/WIP publications. Width/Depth ratio for Riffle/Weir section shall not be less than 10W:1D. Further, pool depths shall not exceed 3 feet. Modified the Erosion and Sediment Control and planting criteria.

Reviewed by Stewart Comstock, Debbie Cappuccitti, and Richard Trickett, MDE. Comments received from Stewart Comstock on 7/15/2011. Comments were addressed as part of revision 3.

October 2011, Revision 4. Some of the minimum and maximum allowable dimensions were changed to allow more energy dissipation and better channel connection with the floodplain. The changes were as follows:

- Pool length shall be at least two times longer than the riffle length.
- The weir/riffle cross-section shall be set no steeper than 10H:1V slope to allow for better connection with the floodplain
- Root wads may float and cause a debris jam that can undermine the stability of the stone structures. The use of root wads is optional and if used must be anchored at least 6 ft in the ground. Root wads shall not be used in the two pools directly upstream of a cascade.
- Added a cascade maximum height versus allowable slope design table.
- The footer rocks shall be anchored 2 feet below the lowest point in the pool.
- Changed the name of the instream weir to constructed instream riffle. The instream riffle slope is set to a maximum of 4% or 1H:25V.

December 2012 Revision 5: (a) A cobble stone gradation table was added to assist in defining the d_{50} design requirements. (b) Added allowance for increasing cross-section entrenchment up to 5H:1V. This allowance is limited to retrofit projects. (c) Drawing schematics updated with additional detail regarding cobble placement. (d) Text corrections pertaining to the instream riffle maximum allowable slope.

November 2014 – Minor modification and update to the Technical Committee.