pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Clean Water

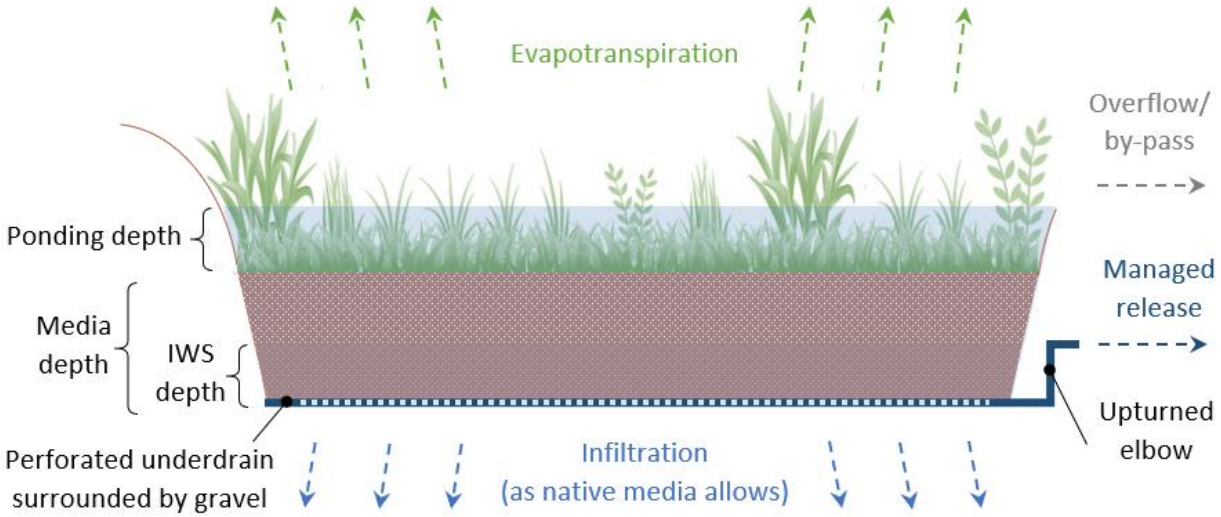
Managed Release Concept

December 13, 2018

Description

Managed Release Concept (MRC) is a post-construction stormwater management (PCSM) strategy that involves the collection, storage, and filtration of captured runoff through a best management practice (BMP) that is preferably vegetated and includes a release of a portion of the captured runoff through an underdrain within the BMP, or from a pool protected from solar radiation. If the MRC BMP is not vegetated, then pretreatment is required to meet water quality requirements. The MRC is intended to be used for project areas or subareas where infiltration is not feasible to meet regulatory requirements under § 102.8(g)(2). Figure 1 illustrates the components of a typical MRC BMP.

Figure 1: Managed Release Concept with Internal Water Storage (IWS) and Upturned Elbow for a Vegetated BMP



MRC requires storage (which includes the media void space) that temporarily impounds the captured runoff from storm events up to and including the 2-year/24-hour storm. The runoff is temporarily impounded for use by vegetation, is filtered through a soil media or another acceptable pre-treatment device, is infiltrated through in-situ soils to the highest degree feasible for a project site, and is released through an underdrain and control structure at a rate similar to the lateral unsaturated flow movement to the receiving waters from undeveloped areas. An internal water storage is included in the design for further water quality and evapotranspiration (ET) benefits.

The MRC strategy may be used to satisfy Chapter 102 volume management requirements under 25 Pa. Code § 102.8(g)(2), regarding the net change in the pre- vs. post-development runoff volume from storm events up to and including the 2-year/24-hour storm (Δ 2 volume). For projects that include infiltrating and non-infiltrating subareas and meet the applicability requirements, the MRC BMP can be combined with other volume reducing BMPs.

In accordance with 25 Pa. Code § 102.8(e), the person preparing the PCSM Plan shall be trained and experienced in PCSM design methods and techniques applicable to the size and scope of the project being designed. Due to the complexity of the design of an MRC BMP and the associated analyses, the Department of Environmental Protection (DEP) requires that a licensed professional engineer perform the design and analyses identified in this document.

Applicability

MRC may be authorized as a PCSM BMP where certain criteria are met, as follows:

1. A professional engineer, licensed in the Commonwealth of Pennsylvania, must perform the analyses, calculations, and evaluations associated with MRC BMPs.

2. The applicant has completed a thorough pre-development site characterization and assessment of soil and geology of the project site (not just the proposed location of the BMP), and the applicant's licensed professional engineer has determined that it is not feasible to remove the Δ 2 volume through infiltration and ET alone due to soil and/or geologic conditions or other environmental constraints on the project site. DEP intends for the use of MRC to be limited to sites where infiltration is extremely limited, not feasible (i.e., groundwater and/or regularly occurring seasonally high-water tables within one foot of the bottom of the BMP's soil media), or undesirable (e.g., sinkhole-prone areas or contaminated soils).

3. The installation and implementation of structural and non-structural BMPs on the project site, to the extent practicable, is not sufficient to reduce the Δ 2 volume.

4. BMPs providing infiltration and ET are maximized on the overall project site.

5. The licensed professional engineer has investigated downstream conditions and identifies in the PCSM Plan that the off-site discharge flow path to the confluence with the receiving surface water will not experience accelerated erosion or damage.

Where all of these criteria are met, and assuming use of MRC does not conflict with local ordinances, DEP or a delegated conservation district (CCD) may authorize the use of MRC for BMPs proposed on a project site.

The use of MRC does not preclude the applicant from minimizing any increase in stormwater runoff volume to the extent practicable, per 25 Pa. Code § 102.8(b)(3), and, when applicable, does not alleviate the requirement to demonstrate that non-discharge alternatives do not exist for the project, per 25 Pa. Code § 102.8(h)(1).

MRC can be utilized with various BMPs. The licensed professional engineer would need to determine suitability and may adapt various elements to achieve the project goals. MRC can be used for both new construction and retrofit projects. Other uses of MRC may be proposed by the licensed professional engineer for DEP review and approval.

DEP Review

When CCDs receive a Notice of Intent (NOI) for PAG-02 General Permit coverage that includes a PCSM Plan with MRC BMP(s), CCDs will forward the PCSM Plan to the appropriate DEP regional office for technical review when one or more of the following conditions exist, unless otherwise waived by DEP:

1. The total drainage area to any MRC BMP is at least 5 acres or the total impervious area to any MRC BMP is at least 3 acres.

2. The applicant proposes an overall increase in impervious area (including gravel, stone, etc.) of at least 10 acres.

3. The MRC BMP will be designed to discharge to waters classified as impaired due to siltation/sediment or flow alterations, regardless if the water is under an approved Total Maximum Daily Load (TMDL).

Eligibility for PAG-02 coverage will not be affected by DEP's technical review. DEP may also delegate the technical review to CCDs with PCSM delegation.

In addition, if deviations from the design standards set forth in this document are proposed, the submission of an individual permit application is necessary, unless waived by DEP.

If none of these conditions apply, the delegated CCD may complete the review of the MRC BMP and PCSM Plan.

Completing the NOI/Application and Worksheets Where an MRC BMP Is Proposed

An applicant proposing the use of an MRC BMP should include a complete MRC Design Summary sheet with the NOI/application. One MRC Design Summary sheet should be completed and submitted for each BMP that will utilize MRC. The MRC Design Summary sheet is available through DEP's website as a PDF and Word document.

The total volume managed in an MRC BMP is a combination of the volume permanently removed via infiltration and ET and the volume managed and released through the underdrain for storms up to and including the 2-year/24-hour storm event. The total managed volume can be entered onto Worksheet 5 and into Section D.3 of the NOI/application as follows:

- Worksheet 5 can be completed by identifying the volume removed by the MRC BMP (i.e., the volume that is removed by infiltration and ET) and the volume managed by the MRC BMP (i.e., the volume that discharges through the underdrain) as two separate entries under the "Other" line. The underlying BMP will also have to be identified on Worksheet 5. For example:

Proposed BMPs from PA Stormwater Best Management Practices Manual Chapter 6		Area (ft^2)	Volume Reduction Permanently Removed (ft^3)
Other	Rain Garden with MRC (volume removed)	3,049	5,124
Other	Rain Garden with MRC (volume managed)	3,049	2,648

- Section D.3 of the NOI/application can be completed by including the total volume removed and managed by the MRC into Box 7. For example:

	Pre-construction	Post Construction	Net Change
Design storm frequency 2-YR/24-HR Rainfall amount 3.19 inches			
Impervious area (acres)	1 0	2 0.75	3 0.75
Volume of stormwater runoff ☐ acre-feet or ☒ cubic feet (check appropriate box)	4 5,384	5 12,209	6 6,825
Volume of stormwater runoff ☐ acre-feet or ☒ cubic feet (check appropriate box)		7 7,772	8 -947

See the Design Example at the end of this document for information on how these values can be determined.

For the purpose of completing Worksheet 10, MRC is considered a primary BMP for nitrate removal.

MRC Design Standards

Implementation of the following design standards will satisfy the requirements in 25 Pa. Code §§ 102.8(g)(2) and 102.8(g)(3) for managing the net change in runoff volume, rate and water quality for the stormwater managed by MRC BMPs. MRC BMPs and these standards constitute an alternative BMP and design standard under Pa. Code § 102.11(b).

When similar non-regulated impervious areas (existing impervious area not included in the proposed earth disturbance) drain to the MRC, the volume managed can be increased to offset volume from adjacent earth disturbance not captured by the MRC that drains to the same surface water in close proximity to the MRC. In these instances, the MRC design should be adjusted to account for equivalent capture, release rate, and peak flow

attenuation from the combined areas. The maximum volume managed by an MRC cannot exceed the volume generated by the 2-year/24-hour storm for the area draining to the MRC BMP.

Deviations from the MRC Design Standards may be proposed by the licensed professional engineer through an individual permit application.

1. **Runoff Capture** – A minimum of the first one inch of runoff of all new impervious surfaces that the MRC is intended to treat should be captured and managed by the MRC BMP, filtered through vegetated media or treated and filtered to the extent practicable through the in-situ soils or other acceptable treatment systems, and released as indicated in MRC Standard 2, except where MRC contributing drainage areas with less than 50% impervious surface, in which a minimum of ½-inch of runoff from the disturbed area drainage to the MRC BMP should be captured and managed. The MRC may be designed for offsetting when contributing non-regulated impervious surfaces are present in the contributing drainage area.

2. **Release Rate** – The stormwater release rate from the BMP should not exceed 0.01 cfs (rounded to the nearest hundredth) per acre of the regulated impervious area (e.g., 1.576 ac. is 0.01576 cfs, rounded to 0.02 cfs). Hydrologic routing modeling is necessary to demonstrate compliance with the standard for release rate. This release rate is calculated based on the contributing drainage area managed by the MRC.

   NOTE – This release rate is approximately the expected rate of interflow after a 2-year/24-hour storm event for a Pennsylvania non-karst watershed based on the NRCS curvilinear unit hydrograph. Releasing at this rate will produce a condition where baseflow contributions will be similar to that of an undeveloped area during and after storm events. As the level of outflow would be similar to what would be expected during and after the storm, it would not be expected to impact the storm event's effects on flooding and erosion. This rate should also be used for karst watersheds unless it can be demonstrated that interflow on a particular project site differs from this standard.

3. **Internal Water Storage (IWS)** – A volume for IWS should be provided that is at least one foot deep below the lowest structural outlet (i.e. the outlet for the underdrain) in the MRC BMP to encourage ET, infiltration and denitrification. To encourage ET, the overall soil media depth of a facility including the IWS can be no deeper than four (4) feet, and up to 50% of the IWS volume can be included (only for vegetated MRC BMPs) as available storage during hydrologic routings to demonstrate compliance with the standard for the Release Rate (No. 2 above) and Peak Flow Attenuation (No. 4 below). For soil media, a void space of 30% can be used to describe the soil volume storage and recovery. If an alternate void space is used, specific data demonstrating the void space should be submitted.

   Use of Liners – The MRC BMP should not have an impervious liner installed unless environmental or geological conditions necessitate use of a liner, or if an existing structure would be damaged as a result of not lining the facility.

   NOTE – The presence of a project site in an area of known karst conditions does not, in itself, serve as evidence of the applicability of MRC to a project site or to the use of a liner to avoid infiltration. DEP and delegated CCDs reserve the right to request a detailed subsurface investigation where considered warranted to evaluate the likelihood of sinkhole formation as a result of post-construction stormwater management.

4. **Peak Flow Attenuation** – The peak flow from the post-construction 2-year/24-hour storm should be managed back to the pre-construction 1-year/24-hour storm peak flow, unless an approved and current Act 167 Plan or another requirement (such as limited capacity of a downstream channel), is more restrictive. In the event the MRC drainage area is part of a larger overall site with non-MRC BMPs, only the MRC drainage peak flows must be managed back to the 1-year/24-hour level and overflows can be combined with flows from the non-MRC BMPs.

   In situations where the pre-construction drainage area to the MRC BMP varies significantly compared to the post-construction drainage area, the post-construction drainage area boundary to the MRC BMP (using existing land uses) can be used to calculate the target pre-construction 1-year rate, as long all areas in question are in close proximity to the MRC BMP and drain to the same surface water. In cases where the BMP is managing

additional volume to offset adjacent areas that could not be captured in the MRC BMP, the target pre-construction 1-year release rate should be calculated based on the combined flow rates from the BMP drainage area and adjacent area.

NOTE – This standard is used to ensure that MRC does not contribute to channel-eroding flows in receiving surface waters.

Flows Greater Than 2-Year/24-Hour Storm – The recommended design for MRC BMPs is to bypass storm events larger than the 2-year/24-hour storm to a traditional detention BMP; however, DEP understands that site and cost limitations may not allow for this bypass. When it is demonstrated by the licensed professional engineer that larger storm events cannot be bypassed, the MRC BMP surface component should be designed to manage the post construction 10-, 50- and 100-year/24-hour storm event peak flows to their corresponding pre-construction rates and the MRC BMP should have an increased (i.e., more frequent) inspection and maintenance schedule that includes inspection and repair after extreme events (10-, 50- and 100-year/24-hour storm events).

5. **Stormwater BMP Manual** – Follow the design considerations for BMPs as presented in the *Pennsylvania Stormwater Best Management Practices Manual* (Stormwater BMP Manual) (363-0300-002). MRC may be incorporated into the design of other BMPs by a licensed professional engineer.

6. **MRC BMP Selection** – Standard MRC BMPs include the following system types:

   a. **Vegetated MRC** – Vegetation must be provided for 75% of the surface of the MRC BMP. Native vegetation should be selected by the licensed professional engineer, in consultation with a professional that is knowledgeable in native plant ecology. Vegetation should be selected based on the plants' ability to grow within the anticipated conditions considering the depth and duration of stormwater stored in the MRC BMP.

   b. **Non-vegetated MRC: Porous Pavement** – Porous pavements with a storage bed require a vacuum street sweeping maintenance regime adequate for the drainage area characteristics; the vacuum street sweeping equipment must provide adequate suction capacity to remove particles on surface to provide a sufficient water quality demonstration and to maintain flow pathways.

   c. **Non-vegetated MRC: Underground Storage Chambers** – The use of the MRC BMP with non-vegetated, non-porous pavement stormwater practices must have pre-treatment, post-treatment, or a combination of both pre- and post-treatment measures incorporated into the design, to provide sufficient water quality. Underground storage chambers must be accessible for maintenance, and for this reason are not recommended to be rock beds. Pre- and post-treatment can be obtained through a treatment train concept of other BMPs listed in the Stormwater BMP Manual (as updated) such that the combination of BMPs meet 85% removal of TSS. Preferred pre- and post-treatment BMPs include: level spreader with vegetated filter strip, vegetated swale, other vegetated systems, and manufactured treatment devices. An applicant must demonstrate that the treatment train will provide 85% TSS removal by using Worksheets 11 – 13 or by providing an alternative water quality demonstration that is acceptable to DEP.

7. **Pre-Development Site Characterization and Assessment of Soil and Geology** – Adequate and appropriate soils and geologic testing and evaluation must be performed to demonstrate the infiltration capacity of the entire project site to the satisfaction of DEP. At a minimum, one infiltration test for every 40,000 square feet of disturbed acreage should be performed with a minimum of four tests, equally distributed across a site. The infiltration tests must be done in the most accommodating soil horizon for infiltration as demonstrated by a deep hole test within 100 feet of the infiltration test. All other sections of Appendix C Protocol 1, Site Evaluation and Soil Infiltration Testing and Appendix C Protocol 2, Infiltration Systems Guidelines per the Stormwater BMP Manual (as updated) should be followed to clearly demonstrate the in-situ infiltration capability on-site at applicable elevations and for a variety of locations. Soil probes and infiltration test locations should be identified on the PCSM Plan drawing(s). The use of soil borings as a substitute for test pits can be used as a planning tool but will not generally be accepted for final design of infiltration MRC BMPs.

   NOTE – The above recommended number of infiltration tests per disturbed area is to be based upon the disturbed area that is not considered a restoration activity or road maintenance activity. For example, a

large sewer main installation project disturbs 30-ac. in total, with 29-ac. of disturbance for the sewer line installation (that will be covered by a restoration plan) and 1-ac. of disturbance for a pumping station that requires a PCSM plan. The recommended number of infiltration tests would be based on the 1-acre, not 30-acres.

NOTE – The minimum number of tests can be reduced, if it can be demonstrated that the subsurface conditions are uniform; however, this is considered a deviation from MRC Design Standards, generally requiring an individual permit.

NOTE – Infiltration tests resulting in saturated hydraulic conductivities of less than or equal to 0.2 inches per hour classify as extremely limited as they include the lower part of the range of HSG C soils and HSG D soils.

8. **Separation Distance** – At least one foot of separation distance should exist between the groundwater or the seasonally high-water table and the bottom footprint of the MRC BMP's soil media; however, a two-foot separation is preferred. There is no minimum separation required between bedrock or hardpan and the MRC BMP's soil media.

9. **Ponding Depth and Drawdown time** – The maximum ponding time (i.e., the time after end of storm event for stored surface water to lower to soil surface) should not exceed 72 hours for any storm event. In general, a maximum ponding depth (i.e., storage depth above BMP surface) of one to two feet at the peak of the 2-year/24-hour storm event should not be exceeded for the design of surface BMPs. In accordance with MRC Design Standard 4, the MRC might incorporate a multi-stage detention facility with the upper portions of the facility providing flow attenuation for storm events greater than a 2-year/24-hour storm, to meet 25 Pa. Code § 102.8(g)(3). In the absence of a multi-stage system, an engineered overflow structure or reinforced spillway / berm should be installed to provide safe conveyance for storm events greater than a 2-year/24-hour storm. Ponding depth for storms larger than the 2-year/24-hour storm should not exceed four feet, and drawdown to the MRC BMP surface should not exceed 72-hours for all design storms. For subsurface MRC systems, drawdown to the IWS storage level should not exceed 7 days.

10. **Soil Media** – The selection of soil media should be done by considering anticipated pollutants to be treated and the vegetation that will be used. On-site soils should be evaluated for desired characteristics and infiltration rates as listed below. The minimum depth of the soil media above the invert elevation of the underdrain pipe should be a minimum of 2 feet (24 inches) to provide pollutant removal. If in-situ soils are unsuitable for the purpose of providing IWS, an additional one to two feet of suitable soil media should be provided below the underdrain.

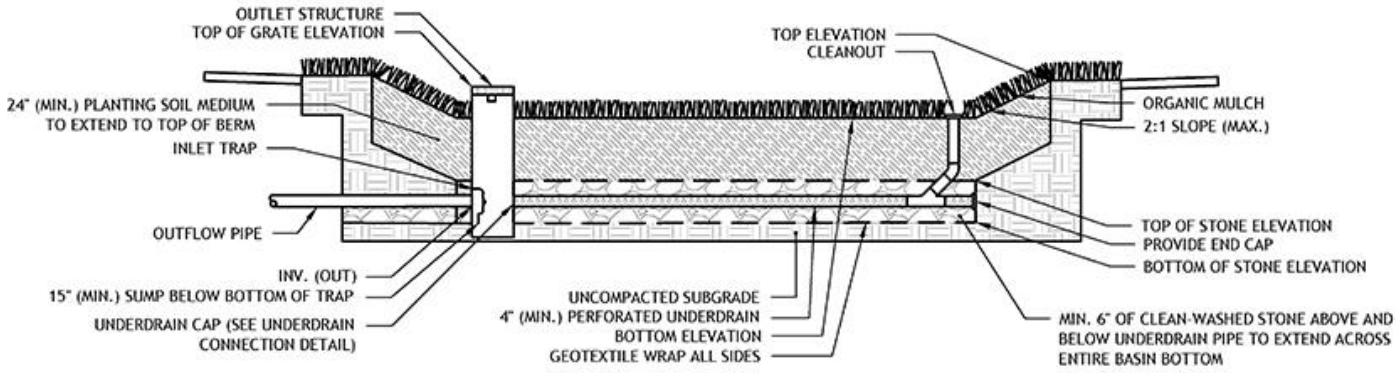
    Soil Media Drainage – The designer will need to exercise caution when selecting a soil media, as there is a delicate balance between infiltration rate and residence time. As noted in Appendix C, Protocol 2 of the Stormwater BMP Manual, soil infiltration rate should be between 0.1 inches per hour and 10 inches per hour for infiltration into native soils. To maximize water quality treatment, the residence time within the soil media used in MRC BMPs should be selected to be close to the parameters established for infiltration into native soils. **The designer will need to select a soil media that provide the proper infiltration rate and ponding time to achieve water quality for the anticipated life cycle of the BMP**.

11. **Underdrain Design** – The licensed professional engineer can refer to PennDOT Publication 408 Section 610 for specifications of underdrains. However, underdrains should have a minimum infiltration rate of 10 gallons (1.34 cubic feet) per minute per linear foot of pipe. There may need to be multiple underdrains, or longer underdrains, to provide adequate design capacity for drainage. Section 6.4.7 of the Stormwater BMP Manual (Constructed Filter) has recommended design standards for lateral spacing of multiple underdrains.

    IWS Outflow with Capped / Orifice Underdrain – It is highly recommended that an upturned elbow or an elevated weir be designed at the outlet of the underdrain (see Figure 1). The upturned elbow or elevated weir will create a zone within the soil media, referred to as the IWS. Research has shown that IWS can improve runoff volume reduction and water quality treatment. The upturned elbow or elevated weir can also help if site conditions present daylighting issues for the underdrain's discharge elevation. Underdrains should be capped within an outlet structure when used to allow access for maintenance. The cap should be drilled

for an appropriately sized orifice to manage release rates. Figure 2 below provides an example underdrain detail. Note that all cleanouts and turns within the underdrain should not exceed 45 degrees. For lined, non-vegetated MRCs the underdrain leading to the upturned elbow should be located at the bottom of the IWS.

Figure 2: Example Underdrain Detail (courtesy of Philadelphia Water Department's *Stormwater Management Guidance Design Manual*)



Underdrain Aggregate Envelope – A 6-inch stone envelope of AASHTO #57 should be placed around the underdrain. A geotextile (or pea gravel diaphragm) is needed around the aggregate envelope. Note that if the underdrain is placed on the bottom of the BMP, the stone should not be placed throughout the bottom of the BMP, but just in the envelope of the underdrain.

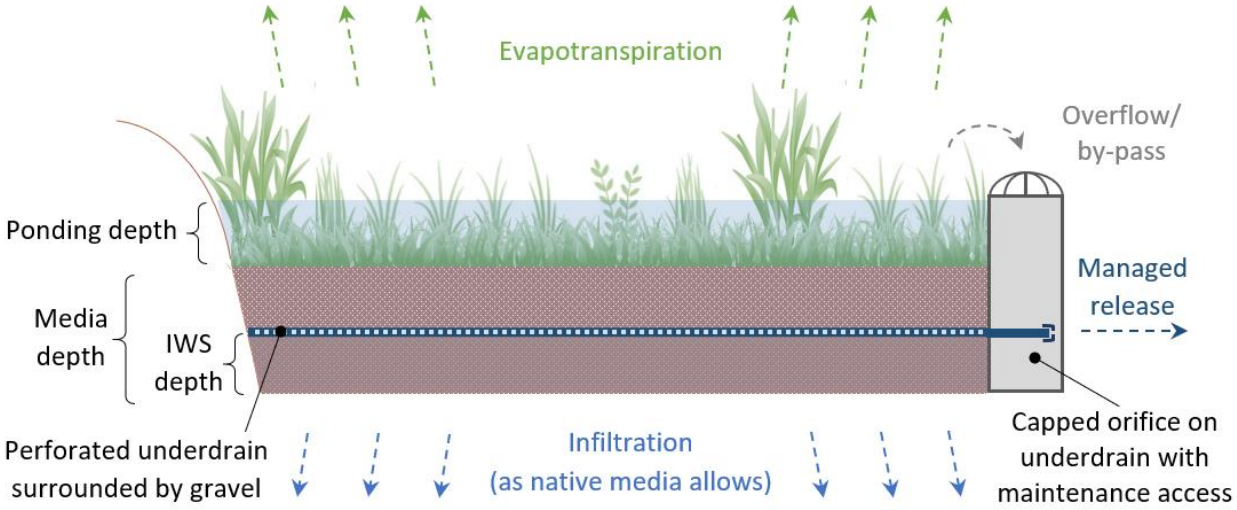
Cleanout for Underdrain – The underdrain(s) should be equipped with a clean-out for maintenance. The design of any clean-out should ensure that excess surface water does not enter the underdrain system. Consideration must be given for cleaning and inspecting underdrains and access to the upturned elbow or elevated weir.

Orifices – An appropriately sized orifice is necessary on the outlet of the underdrain to control flow to the required release rate (see Figure 3). The orifice should be clean, smooth and sanded so that no burs or irregularities are present. The orifice should be on a plate or cap of sufficient thickness, and the edges of the orifice should be ground so that flow through the orifice is smooth. Orifices should be vertical. The orifice plate and other connections should be water-tight and accessible for maintenance. Control valves cannot be substituted for an orifice.

12. **Discharge Flow Path** – The MRC BMP should be directed to a suitably vegetated flow path, which can safely convey the releases without erosion or loss of stability. The discharge should be dispersed through the use of a level spreader. The licensed professional engineer can provide an analysis, with calculations, which identifies that a level spreader is not necessary, or that discharge to a channel will not cause increased erosion.

13. **Antidegradation Requirements** – Where the storm water from the project site discharges to a special protection surface water, an MRC BMP can be used to satisfy the Antidegradation Best Available Combination of Technologies (ABACT) regulatory requirements from Chapters 93 and 102 (assuming that non-discharge alternatives do not exist).

Figure 3: Managed Release Concept with Capped / Orifice Underdrain and Optional Control Valve Outflow with Maintenance Access for a Vegetated BMP



Water Quality

The use of a vegetated MRC BMP or porous pavement MRC BMP with adequate vacuum street sweeping maintenance regime, as per the MRC Design Standards, is a sufficient water quality demonstration and no additional water quality calculations are needed. If the proposed MRC is an underground storage chamber, then a water quality demonstration will need to be included such that the pre- or post-MRC BMP flows are shown to remove 85% of TSS (see MRC Design Standard 6.c above).

Construction Sequence

A licensed professional engineer should provide appropriate construction sequencing for the MRC BMP. Guidance should be based on the Stormwater BMP Manual to the greatest degree possible. Construction sequencing should be project-specific, but at a minimum include the following:

1. Install the MRC BMP during final phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, prevent sediment-laden water from entering via overland, inlets and pipes.

2. Install and maintain proper E&S BMPs during construction.

3. If necessary, excavate the MRC BMP bottom to an un-compacted subgrade free from rocks and debris. Do NOT compact the subgrade.

4. Install outlet control structures and or reinforced spillway, pipe bedding, underdrain piping with aggregate envelope, cleanouts, etc.

5. Place soil media gently. Do not compact soil media. The placement of soil media should be done from outside the BMP footprint to avoid compaction by construction equipment. Equipment should never drive over placed soil media.

6. Seed and stabilize disturbed area. Vegetate with native plantings.

7. Maintain inlet protection and other E&S BMPs until the site is fully stabilized.

Operation and Maintenance Schedule

The licensed professional engineer should provide an appropriate long-term operation and maintenance schedule for the MRC BMP. Guidance should be based on the Stormwater BMP Manual to the greatest degree possible. The long-term operation and maintenance schedule should be project-specific. At a minimum, the long-term operation and maintenance schedule must meet 25 Pa. Code § 102.8(f)(10) and include the following:

1. Upgradient catch basins and inlets should be inspected and cleaned annually, or more often if historical maintenance records suggest a more frequent cleaning.

2. The vegetation (for the MRC BMP and contributing drainage area) should be maintained in good condition, and any bare spots revegetated.

3. Care should be taken to avoid excessive compaction by mowers. Mow only as appropriate for vegetative species.

4. Inspect at least two times per year after runoff events greater than 0.8 inch and make sure that runoff drains down within the design parameters (the licensed professional engineer should clearly identify what these parameters are).

5. At least two times per year, or more if historical maintenance indicate it is necessary, inspect for accumulation of sediment, damage to outlet control structures, erosion, signs of water contamination/spills, and instability. Leaf litter needs to be removed annually.

6. As needed, remove accumulated sediment as required to maintain infiltration through the MRCs soil media and to maintain water quality functionality. Restore original cross section. Properly dispose of sediment.

7. If porous pavement is included in the design, vacuum at least twice per year. Vacuum should have sufficient suction power and be designed for use with porous pavements.

8. All MRC BMP components should be maintained as indicated in the Stormwater BMP Manual.

As noted above, if the MRC BMP will manage peak flows in excess of the 2-year/24-hour storm event, an increased inspection and maintenance frequency will typically be necessary.

Design Example

Designers are encouraged to adapt the MRC to site-specific needs utilizing the design considerations listed above. The following example is provided to demonstrate hydrologic modeling for a vegetated MRC BMP from a pre-construction condition of completely pervious to a post-construction condition of completely impervious. The following example illustrates modeling of the contributing drainage area to the MRC BMP, modeling of MRC BMP specific processes, and interpretation of model results to show that the MRC BMP meets the design specifications for the MRC.

Modeling Contributing Drainage Area

The 1- and 2-year/24-hour storm events are modeled using NOAA-14 rainfall depths for Philadelphia, as the example site is located in the Philadelphia area, with a NOAA type C 24-hour rainfall distribution. The 1-inch runoff event is modeled using NJ DEP's water quality 2-hr distribution.

Runoff is modeled using the standard SCS unit hydrograph. The NRCS curve number for the post-construction contributing drainage area is modeled as a 98 to represent a completely impervious surface with a time of concentration of 5 minutes. Pre-construction condition is modeled with a CN of 74 to represent meadow in good condition over HSG C soil. The pre-construction condition is modeled with a time of concentration of 15 minutes.

Modeling MRC BMP Processes

Routing is performed through the basin using stage-discharge and stage-storage relationships. A schematic of pre- and post-construction conditions is shown in Figure 4. The managed release orifice is located 1 foot above the bottom of the soil media. The ponding depth during the 2-year/24-hour storm was limited for this example to 1.1 foot above the media. There is a total of 2.5 feet of media depth that includes an IWS depth of 1 foot created by an upturned elbow. A 4-inch diameter underdrain is encapsulated by gravel on all four sides, but it is not a continuous gravel layer. The MRC BMP footprint is 0.07 acre (3,049 square feet) with a contributing drainage area of 0.75 acre (32,670 square feet) of 100% impervious area. In this case, a rain garden was selected as the MRC BMP. The MRC BMP schematic and parameters are summarized in Figure 5 and Table 1, respectively.

Figure 4: Pre- and Post-Construction Modeling Conditions

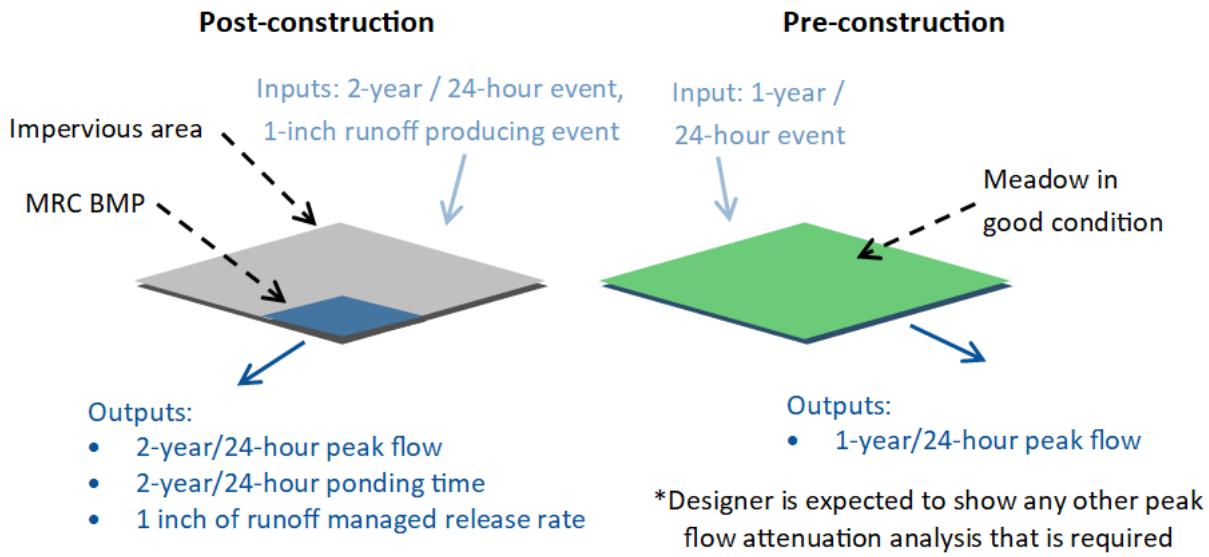


Figure 5: Design Example Schematic

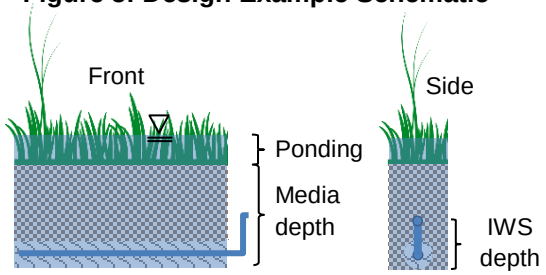


Table 1: Design Example Parameters

Parameter	Value
BMP footprint area	0.07 ac
Contributing area (all impervious)	0.75 ac
Ponding depth	1.1 ft
Media depth	2.5 ft
IWS depth (included within soil media depth)	1 ft
Infiltration rate	0.1 in/hr
Void space	30%

A rain garden was selected to apply the MRC because the IWS in it will encourage ET and supply limited infiltration. A pre-development site characterization and assessment of soils and geology was conducted at the location of the MRC BMP; which identified a depth greater than 2 feet to groundwater and a design infiltration rate of 0.1 in/hr. For routing purposes, a 30% void space was used to model the soil media to mimic the amount of soil storage recovery through ET and infiltration. The starting water surface elevation of ½ of total IWS depth below the lowest orifice was used for routing.

Modeling Results

Modeling results are presented below as determined through the use of HydroCAD®. Figure 6 shows the maximum managed release outflow and water surface elevation from the 1-inch runoff event and was obtained by plotting outflow and water surface elevation over time. A maximum of 0.01 cfs is obtained through the managed release outflow.

Figure 6: Design Example Results for the 1-inch Runoff Event

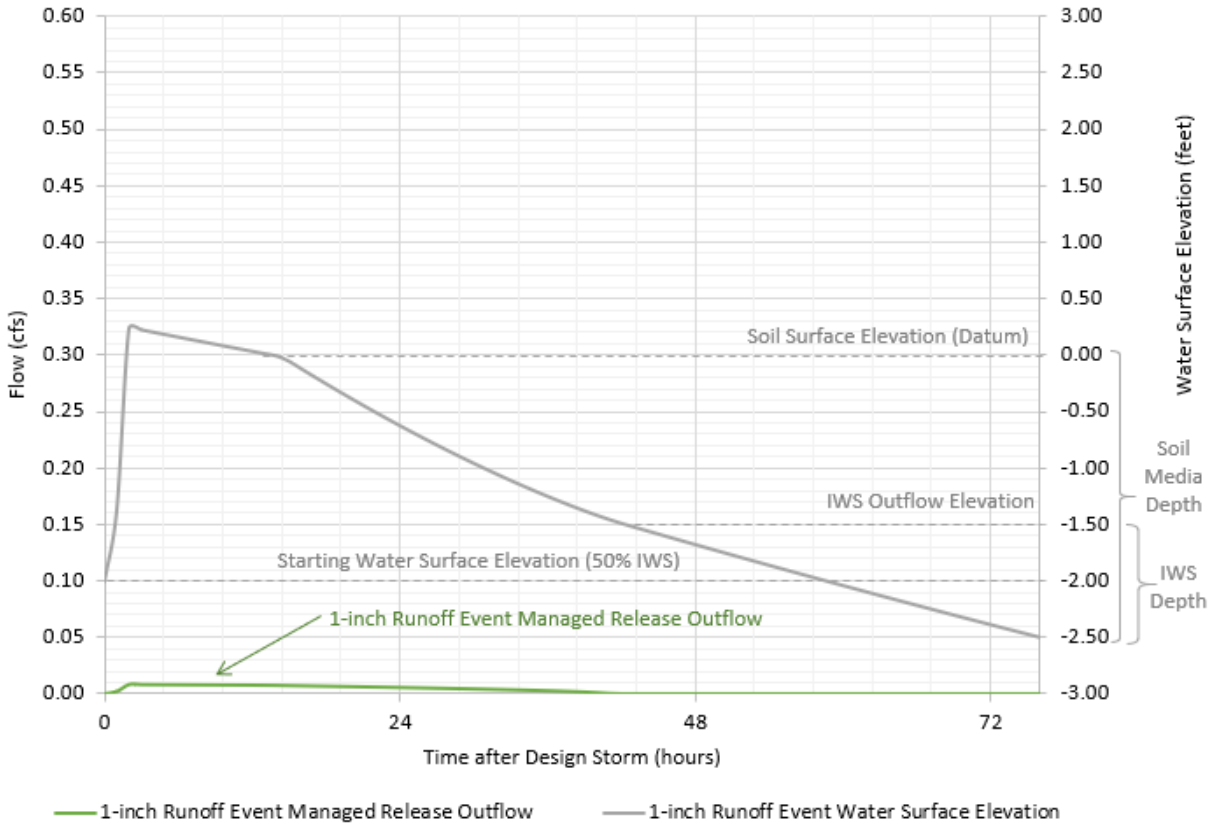
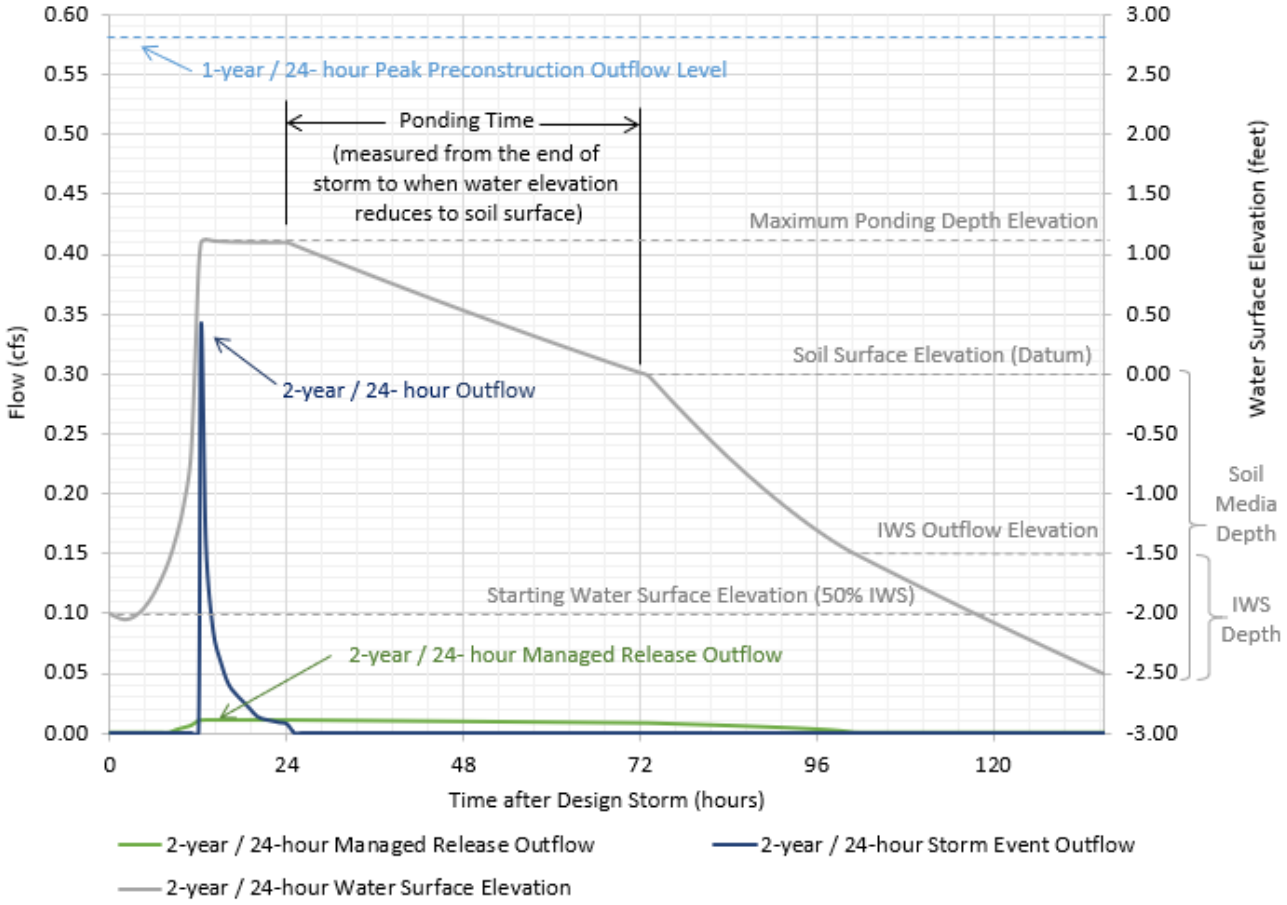


Figure 7 shows the maximum flow for the 2-year/24-hour storm, the managed release outflow for the 2-year/24-hour storm, and the ponding depth during and after the 2-year/24- hour storm. Pre-construction peak flow from the 1-year/24-hour storm event was determined to be 0.58 cfs.

Figure 7: Design Example Results for 2-year/24-hour Storm Event



Key parameters used to demonstrate compliance with the MRC Design Standards are presented in Table 2 for this example.

- The volume managed through the underdrain by release was determined by multiplying the managed release rate (cfs) by the duration of the managed release flow (seconds), and was determined to be 2,648 cubic feet (cf) or 0.97 inch over the contributing drainage area (0.75 acre). This value can also be determined by calculating the area under the 2-year/24-hour Managed Release Outflow curve in Figure 7. This particular example used the hydrograph (values in cubic feet per second outputted in hourly intervals) produced by the HydroCAD® model for the release managed through the underdrain. The rates were summed and multiplied by 3,600 to convert into cubic feet over the duration of managed release (about 93 hours).

- The volume reduced through infiltration was determined by multiplying the infiltration rate (in/hr) by the duration of infiltration and was determined to be 4,361 or 1.6 inch over the contributing drainage area. This particular example used the hydrograph (values in cubic feet per second outputted in hourly intervals) produced by the HydroCAD® model for the infiltration. The rates were summed and multiplied by 3,600 to convert into cubic feet over the duration of infiltration (about 171 hours).

- The volume reduced through ET is calculated with a void space of 10% over the full depth of the soil column of 2.5 feet, reducing 762 cf or 0.28 inch over the contributing drainage area.

- The total 2-year/24-hour runoff volume permanently removed by the MRC BMP is the sum of the volume reduced by infiltration + the volume reduced through ET and was determined to be 5,124 cf or 1.88 inches over the contributing drainage area.

- The total 2-year/24-hour runoff volume managed by the MRC BMP is the sum of the volume managed through underdrain release + the volume reduced by infiltration + the volume reduced through ET and was determined to be 7,772 cf or 2.85 inches over the contributing drainage area.

Table 2: Design Example Summary for 2-year/24-hour Storm Event

Parameter	Design Example Value	Design Standard
Ponding Time @ 2-Year/24-Hour Storm (hrs)	**48 hrs**	*72 hrs max*
MRC BMP Release Rate (cfs)	**0.01 cfs**	*No greater than 0.01 cfs / acre of contributing impervious*
2-Year/24-Hour Post-Development Peak Rate (cfs)	**0.34 cfs**	*1-Year/24-Hour Pre-Development Peak Rate (or per approved Act 167 Plan) (0.58 cfs)*
Volume managed through underdrain and volume removed	**2.8 in**	1-in for new impervious surfaces, ½-in for disturbed areas with 50% or more pervious
a. Total 2-Year/24-Hour Runoff Volume Managed by BMP (cf)	**7,772**	*Net Change (∆ 2 volume)*
b. Total 2-Year/24-Hour Runoff Volume Permanently Removed (cf)	**5,124**	
c. 2-Year/24-Hour Volume Managed Through Release (cf)	**2,648**	*Difference of a. and b.*

Along with the hydrologic modeling demonstration of the MRC, peak flow attenuation analysis from the 10-, 50- & 100-year/24-hour storm events along with the Pre-Development Site Characterization and Assessment of Soil and Geology and the Discharge Flow Path analysis must be provided.