pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Clean Water

Managed Release Concept - Design Examples

August 25, 2020
Version 1.1

The purpose of this document is to provide design examples that help illustrate application of the Managed Release Concept (MRC), an approved alternative post-construction stormwater management (PCSM) best management practice (BMP). These examples provide a conceptual demonstration of the analysis that goes into an MRC design to be applied in conjunction with sound engineering judgement.

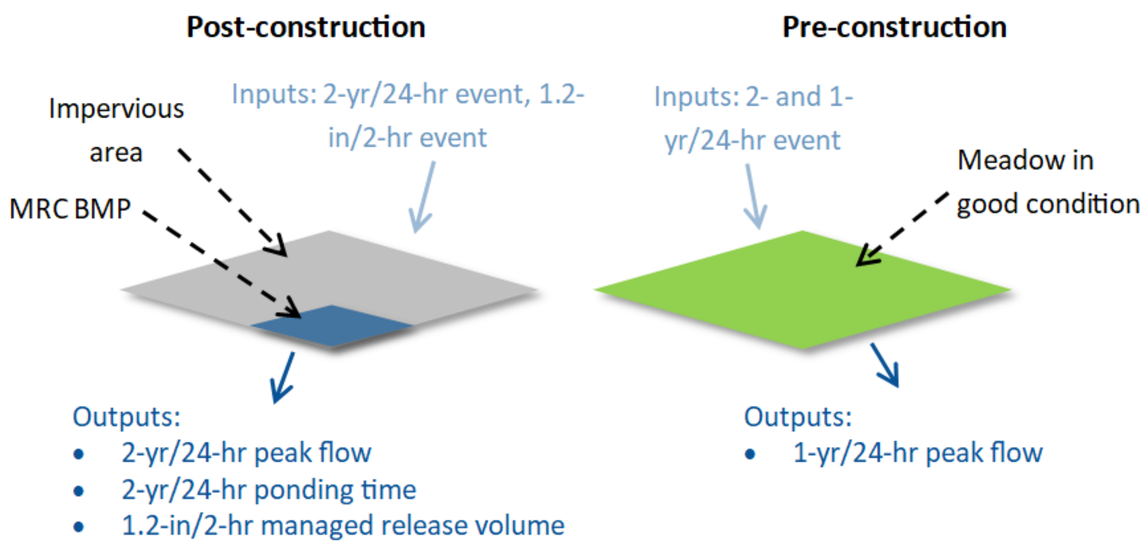
Designers are encouraged to adapt MRC to site-specific needs utilizing the design considerations listed in the Managed Release Concept Paper. The following examples are provided to demonstrate hydrologic modeling for an MRC BMP, modeling of the contributing drainage area to the MRC BMP, modeling of MRC BMP-specific processes, and interpretation of model results to show that the MRC BMP meets the design standards.

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 rainfall volumes are 2.70 and 3.26 inches for 1- and 2-year/24-hour storm events, respectively. For MRC Design Example 2, rainfall volumes for the 10-, 50-, and 100-year/24-hour storm events are 4.84, 6.80, and 7.77 inches, respectively. The 1.2-inch runoff event is modeled using NJ DEP's water quality 2-hour distribution, which has an equal distribution of rainfall over the 2 hours. The volume of runoff produced by the 1.2-inch event is approximately 1-inch from impervious area.

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 6 minutes. For MRC Design Examples 1 and 2, the pre-construction condition is modeled with a CN of 71 to represent meadow in good condition over HSG C soil. The pre-construction condition is modeled with a time of concentration of 15 minutes. For MRC Design Example 3, post-construction conditions have a pervious portion but the time of concentration remained the same (see MRC Design Example 3 for more information). A schematic of pre- and post-construction conditions is shown in Figure 1. Modeling results are presented below as determined through the use of HydroCAD®. The contributing area to the MRC BMP includes the area of the MRC BMP (for the design examples provided, the MRC BMP area is modeled with a Curve Number of 98 to represent the direct rainfall onto the MRC BMP).

Figure 1: Pre- and Post-Construction Modeling Conditions



MRC Design Example 1: Rain Garden with Minimal Infiltration

The MRC BMP footprint is 0.07 acre (3,049 square feet) with a contributing drainage area of 0.8 acre (34,848 square feet) of 100% impervious area. The modeled contributing area includes the area of the MRC BMP. 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 (MRC Design Standard No. 8) and a design infiltration rate of 0.1 in/hr. Click here for HydroCAD® file.

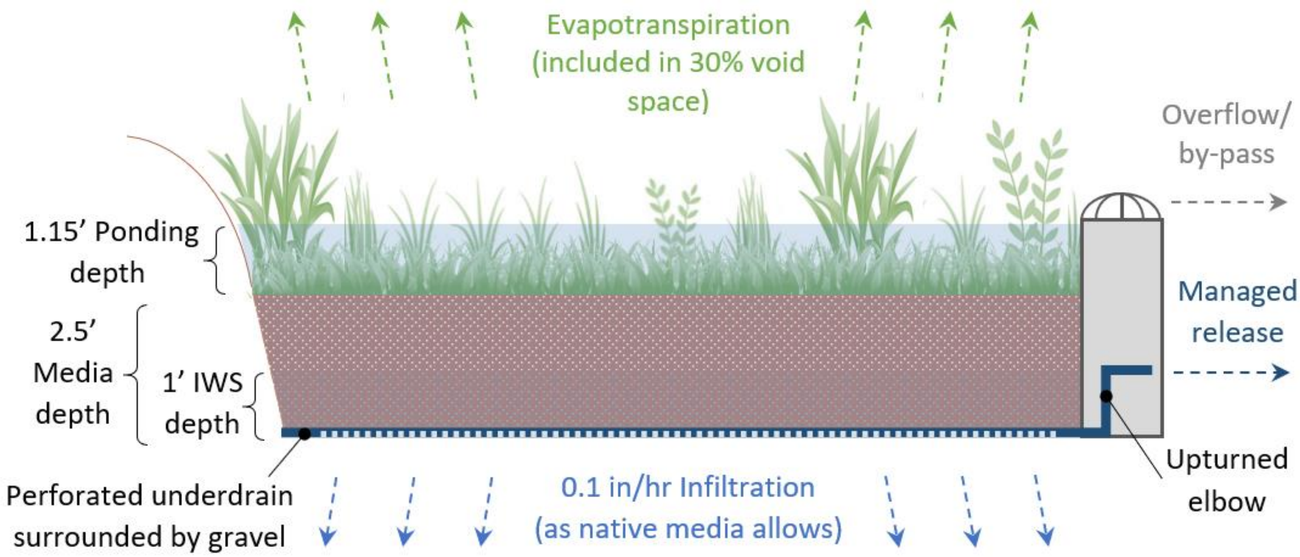
Modeling MRC BMP Processes

In this case, a rain garden was selected to apply the MRC (MRC Design Standard No. 6) because the IWS in it will encourage ET and supply limited infiltration. Routing is performed through the basin using stage-discharge and stage-storage relationships. The 0.5-inch diameter managed release orifice is located 1 foot above the bottom of the soil media. The ponding depth before bypass of flows is limited, for this example, to 1.15 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 PVC underdrain (MRC Design Standard No. 11; minimum size specified by the PennDOT Publication 408 Section 610) is encapsulated by gravel on all four sides, but it is not a continuous gravel layer. The MRC BMP schematic can be seen in Figure 1-1.

For routing purposes, a 30% void space was used to model the Loamy Sand soil media (MRC Design Standard No. 10) to mimic the amount of soil storage recovery through ET and infiltration. Loamy sand media is recommended by the Stormwater BMP Manual with a 20% void space, however, void space is allowed to be increased to 30% in accordance with the Managed Release Concept Paper to describe soil storage and recovery through ET.

To model that only 50% of total IWS depth is used for routing (MRC Design Standard No. 3), the storage media below the orifice was modeled with a 50% reduction on void space (i.e., 15% void space).

Figure 1-1: Example 1 Schematic of Rain Garden MRC with Infiltration



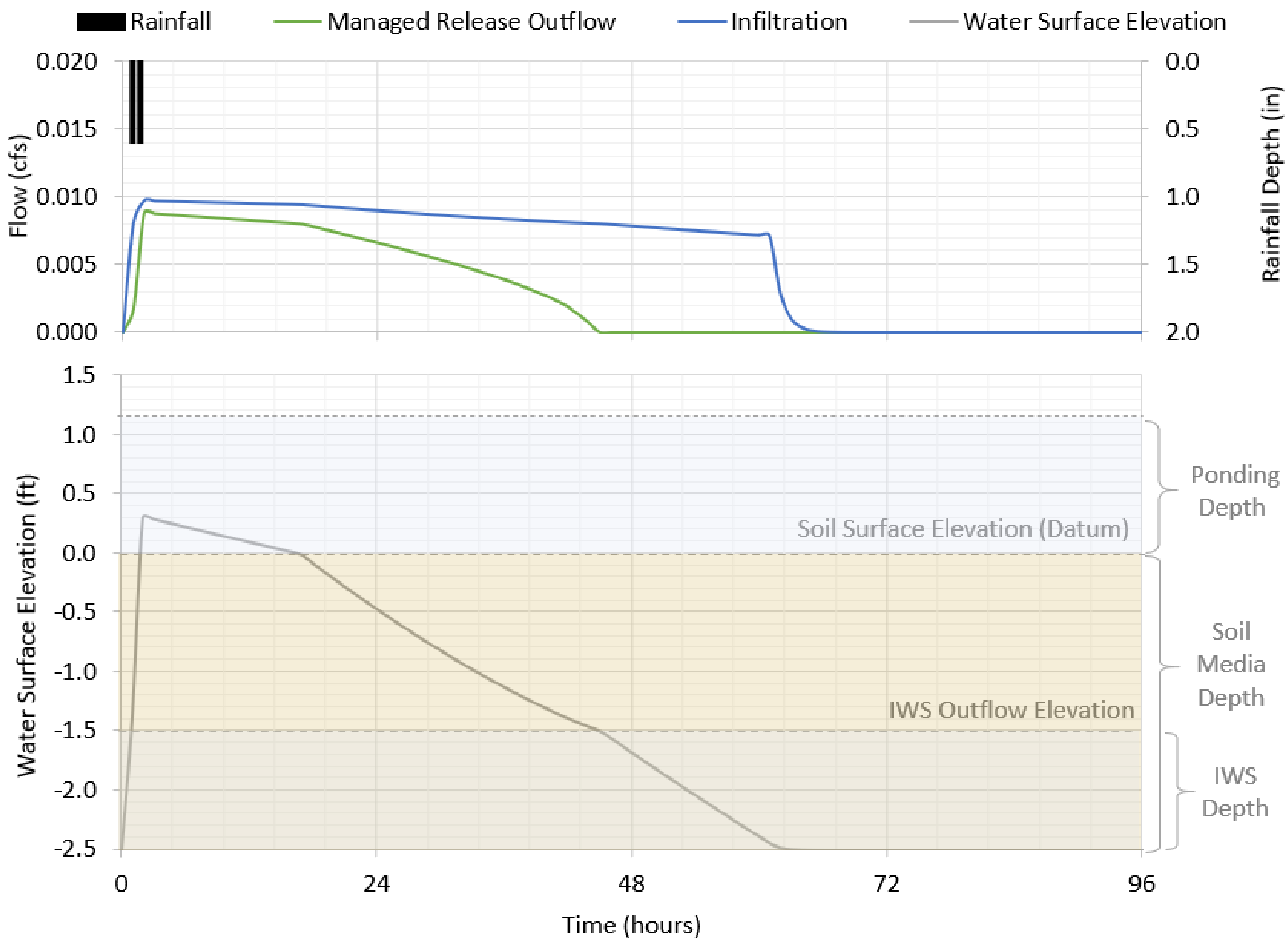
Modeling Results

1.2-inch/2-hour Storm Event

The following discuss the results from the 1.2-inch/2-hour storm event (MRC Design Standard No. 1). Figure 1-2 shows rainfall over the contributing area, managed release outflow through the underdrain, infiltration, and water surface elevation in relation to time during and after the 1.2-inch/2-hour storm event.

A flow of 0.01 cfs is determined through the managed release outflow, which is the maximum allowed outflow based on the impervious surface of the contributing area (MRC Design Standard No. 2). For this Example, the contributing drainage area is 0.8 ac. of impervious area, and the release rate is 0.01 cfs (0.01 cfs/acre impervious area x 0.8 acre = 0.008 cfs, rounded to 0.01 cfs). There is no overflow as the water surface elevation never exceeds the maximum ponding depth (1.15-foot above soil surface) during the 1.2-inch/2-hour event (MRC Design Standard No. 1).

Figure 1-2: Design Example Results for the 1.2-inch/2-hour Event

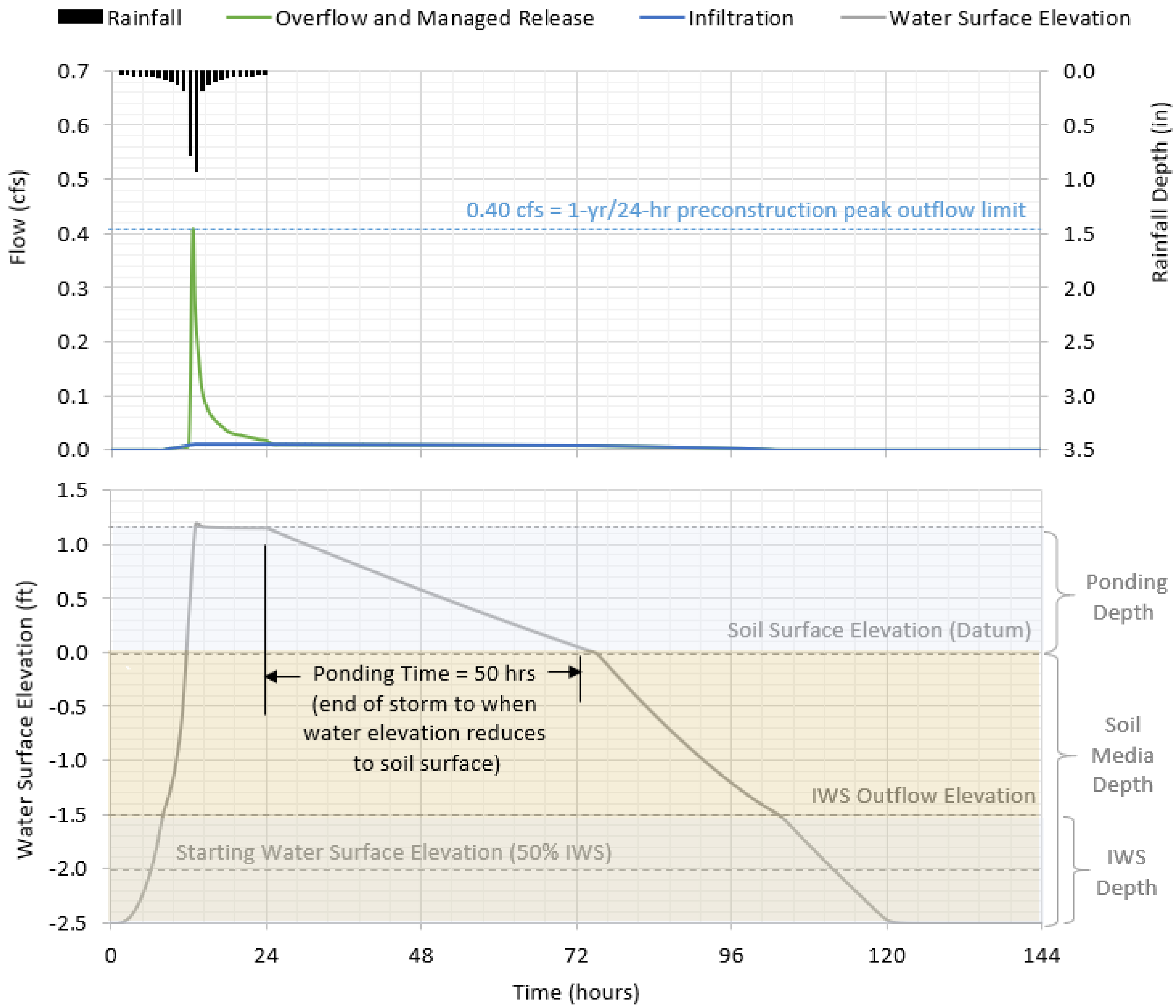


2-year/24-hour Storm Event

The following discuss the results from the 2-year/24-hour storm event. Figure 1-3 shows rainfall over the contributing area, managed release outflow through the underdrain combined with overflow or bypass flow, infiltration, and water surface elevation in relation to time during and after the 2-year/24-hour event.

The peak rate from the post-construction 2-year/24-hour storm event is 0.40 cfs, which is equivalent to the pre-construction 1-year/24-hour peal rate of 0.40 cfs (MRC Design Standard No. 4). The ponding time, as defined by the time after the storm event to when the water elevation receded to the soil surface, is limited to 50 hours during the 2-year/24-hour storm event (MRC Design Standard No. 9).

Figure 1-3: Design Example Results for 2-year/24-hour Storm Event



Key parameters from both the 2-year/24-hour storm event and the 1.2-inch/2-hour storm event are summarized in Table 1-1. Determination of ponding time, 1.2-inch/2-hour release rate, and 2-year/24-hour peak rate parameters are demonstrated in Figures 1-2 and 1-3.

Along with the hydrologic modeling demonstration of the MRC, peak flow attenuation analysis from the 10-, 50- & 100-year/24-hour storm events (MRC Design Standard No. 4) along with the Pre-Development Site Characterization and Assessment of Soil and Geology (MRC Design Standard No. 7) and the Discharge Flow Path analysis (MRC Design Standard No. 1) must be provided (however, they are not provided as part of this Example).

Figure 1-4 demonstrates how this MRC BMP should be entered into DEP's PCSM Spreadsheet, Volume Worksheet, and the resulting credits. The volume of runoff generated at the 1.2-inch/2-hour storm and the 2-year/24-hour storm is 2,862 CF and 8,039 CF, respectively. When all of the runoff volume from the 1.2-inch/2-hour storm is routed to the MRC BMP, there is no outflow, as infiltration and evapotranspiration reduces all of the volume. However, volume management requirements are not met for the project site. When all of the runoff from the 2-year/24-hour storm is routed to the MRC BMP, there is an outflow and volume management requirements are met (see Figure 1-5).

Table 1-1: Design Example Summary

Parameter	Design Value	Design Standard
Equivalent Contributing Impervious Area to BMP (acres)	**0.8**	
Total Drainage Area to BMP (acres)	**0.8**	
MRC BMP Release Rate (cfs)	**0.01**	*No greater than 0.01 cfs / acre of equivalent contributing impervious*
Underdrain Outflow Rate During 1.2-Inch/2-Hour Storm (cfs)	**0.01**	*<= MRC BMP Release Rate (cfs)*
Maximum Storm Event Routed to MRC BMP	**2-year/24-hour**	
Volume of Overflow During 1.2-Inch/2-Hour Storm (cf)	**0**	*0 (No overflow allowed)*
1-Yr/24-Hr **Pre**-Development Peak Rate (cfs)	**0.4**	
2-Yr/24-Hr **Post**-Development Peak Rate (cfs)	**0.4**	*1-Yr/24-Hr Pre-Development Peak Rate (or per approved Act 167 Plan)*
Total 2-Yr/24-Hr Runoff Volume Managed by BMP (cf)	**8,039**	
Ponding Time @ 2-Yr/24-Hr Storm (hrs)	**50**	*72 hrs (surface), 7 days (underground)*

Figure 1-4: DEP PCSM Spreadsheet Data for 1.2-Inch/2-Hour Storm

DP No.	BMP No.	BMP Name	MRC?	Discharge	Incremental BMP DA (acres)	Volume Routed to BMP (CF)	Infiltration / Vegetated Area (SF)	Infiltration Rate (in/hr)	Infiltration Period (hrs)	Vegeta-ted?	Media Depth (ft)	Storage Volume (CF)	Infiltration Credit (CF)	ET Credit (CF)
001	1	Rain Garden / Bioretention	Y	Off-Site	0.80	2,862	3,049	0.10	50	Yes	2.5	2,862	**1,143**	**1,719**
												Totals:	**1,143**	**1,719**

INFILTRATION & ET CREDITS (CF):	**2,862**
MANAGED RELEASE CREDIT (CF):	
NET CHANGE IN VOLUME TO MANAGE (CF):	**5,831**
TOTAL CREDITS (CF):	**2,862**

VOLUME REQUIREMENT NOT SATISFIED

Figure 1-5: DEP PCSM Spreadsheet for 2-Year/24-Hour Storm

DP No.	BMP No.	BMP Name	MRC?	Discharge	Incremental BMP DA (acres)	Volume Routed to BMP (CF)	Infiltration / Vegetated Area (SF)	Infiltration Rate (in/hr)	Infiltration Period (hrs)	Vegeta-ted?	Media Depth (ft)	Storage Volume (CF)	Infiltration Credit (CF)	ET Credit (CF)
001	1	Rain Garden / Bioretention	Y	Off-Site	0.80	8,039	3,049	0.10	50	Yes	2.5	2,862	**1,143**	**1,967**
												Totals:	**1,143**	**1,967**

INFILTRATION & ET CREDITS (CF):	**3,110**
MANAGED RELEASE CREDIT (CF):	**4,929**
NET CHANGE IN VOLUME TO MANAGE (CF):	**5,831**
TOTAL CREDITS (CF):	**8,039**

VOLUME REQUIREMENT SATISFIED

MRC Design Example 2: Rain Garden with Detention Basin and no Infiltration

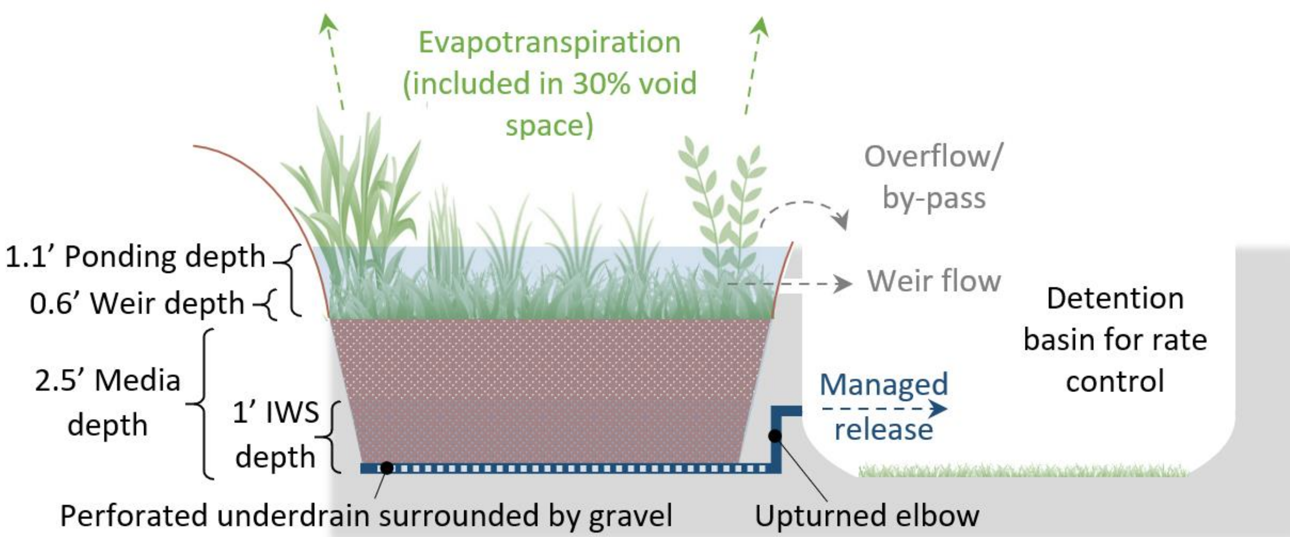
The MRC BMP footprint is 0.07 acre (3,049 square feet) with a contributing drainage area of 0.7 acre (30,492 square feet) of 100% impervious area. The modeled contributing area includes the area of the MRC BMP. A pre-development site characterization and assessment of soils and geology was conducted at the location of the MRC BMP, which identified a limiting zone of bedrock within 1 foot of the BMP bottom such that loss due to infiltration is infeasible (MRC Design Standard No. 7). For this Example, the presence of the bedrock was determined to limit the BMP's ability to infiltrate; however, there is no separation required between the bottom of the MRC BMP (i.e., bottom of IWS) and the bedrock. Click here for the HydroCAD® file.

Modeling MRC BMP Processes

In this case, a rain garden was selected to apply the MRC because the IWS in it will encourage ET (MRC Design Standard No. 6). Routing is performed through the basin using stage-discharge and stage-storage relationships. The 0.5-inch diameter managed release orifice is located 1 foot above the bottom of the soil media. The ponding depth before bypass of flows is limited to 1.1 foot above the media with a 6-inch wide low flow weir at an elevation of 0.6 feet 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 (MRC Design Standard No. 11) is encapsulated by gravel on all four sides, but it is not a continuous gravel layer. The overflow from the rain garden either through the low flow weir at 0.6-foot elevation or bypass at 1.1-foot elevation.

The MRC BMP discharges all flow (including the managed release) into a detention basin with a footprint of 0.04 acre (1,742 square feet). The detention basin has a 4-inch diameter low flow orifice at the bottom of the detention basin overflow weir 2 feet above the bottom of the detention basin. The MRC BMP schematic can be seen in Figure 2-1.

Figure 2-1: Example 2 Schematic of Rain Garden MRC



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. To model that only 50% of total IWS depth is used for routing, the storage media below the orifice was modeled with a 50% reduction on void space (i.e. 15% void space).

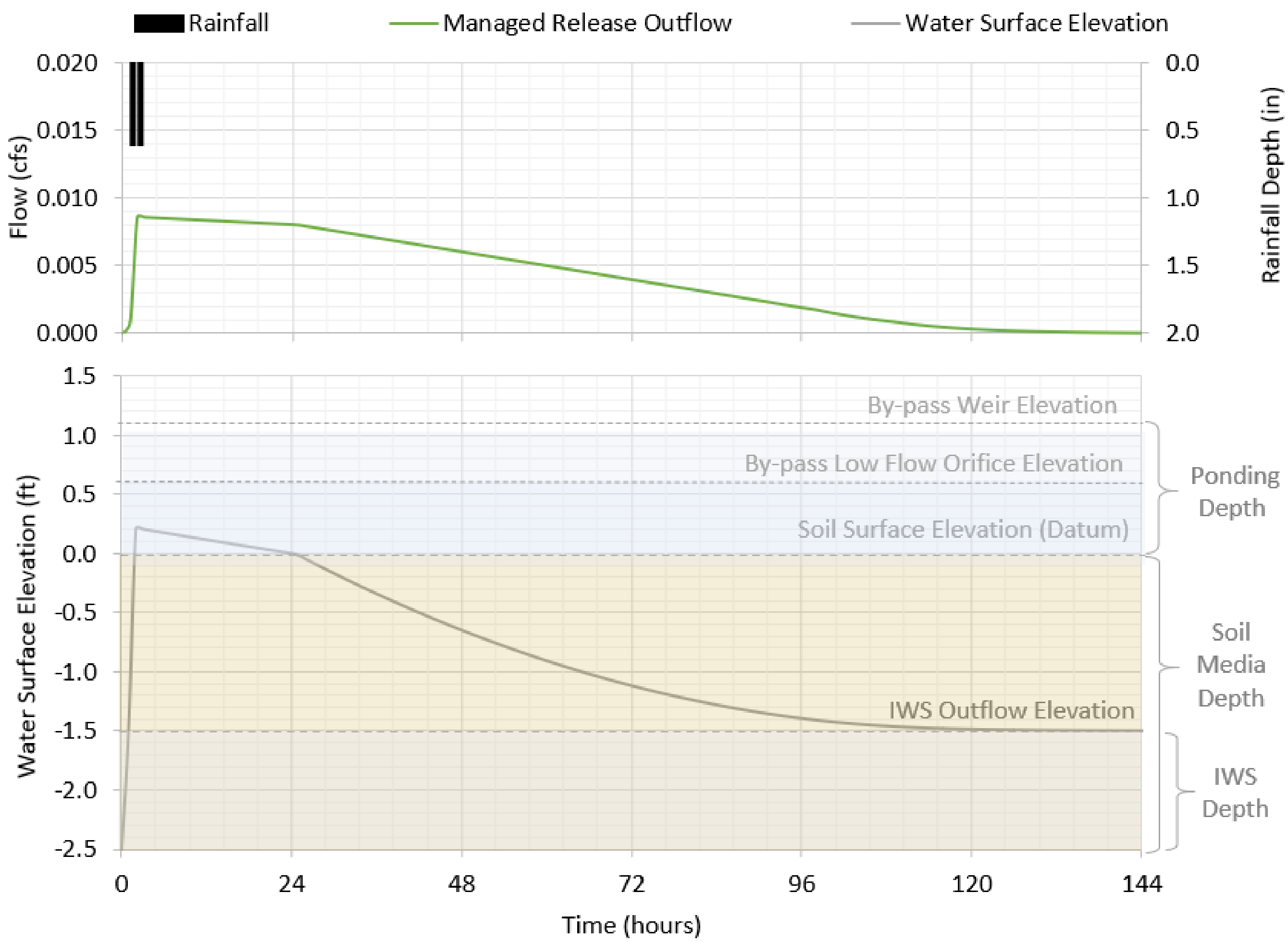
Modeling Results

1.2-inch/2-hour Storm Event

The following discusses the results from the 1.2-inch/2-hour storm event. Figure 2-2 shows rainfall over the contributing area, managed release outflow through the underdrain, infiltration, and water surface elevation in relation to time during and after the 1.2-inch/2-hour storm event.

A flow of 0.01 cfs is obtained through the managed release outflow, which is the maximum allowed outflow based on the impervious surface of the contributing area. There is no overflow as the water surface elevation never exceeds the maximum ponding depth (i.e., less than the low flow weir and overflow weir) during the 1.2-inch/2-hour event.

Figure 2-2: Design Example Results for the 1.2-inch/24-hour Event

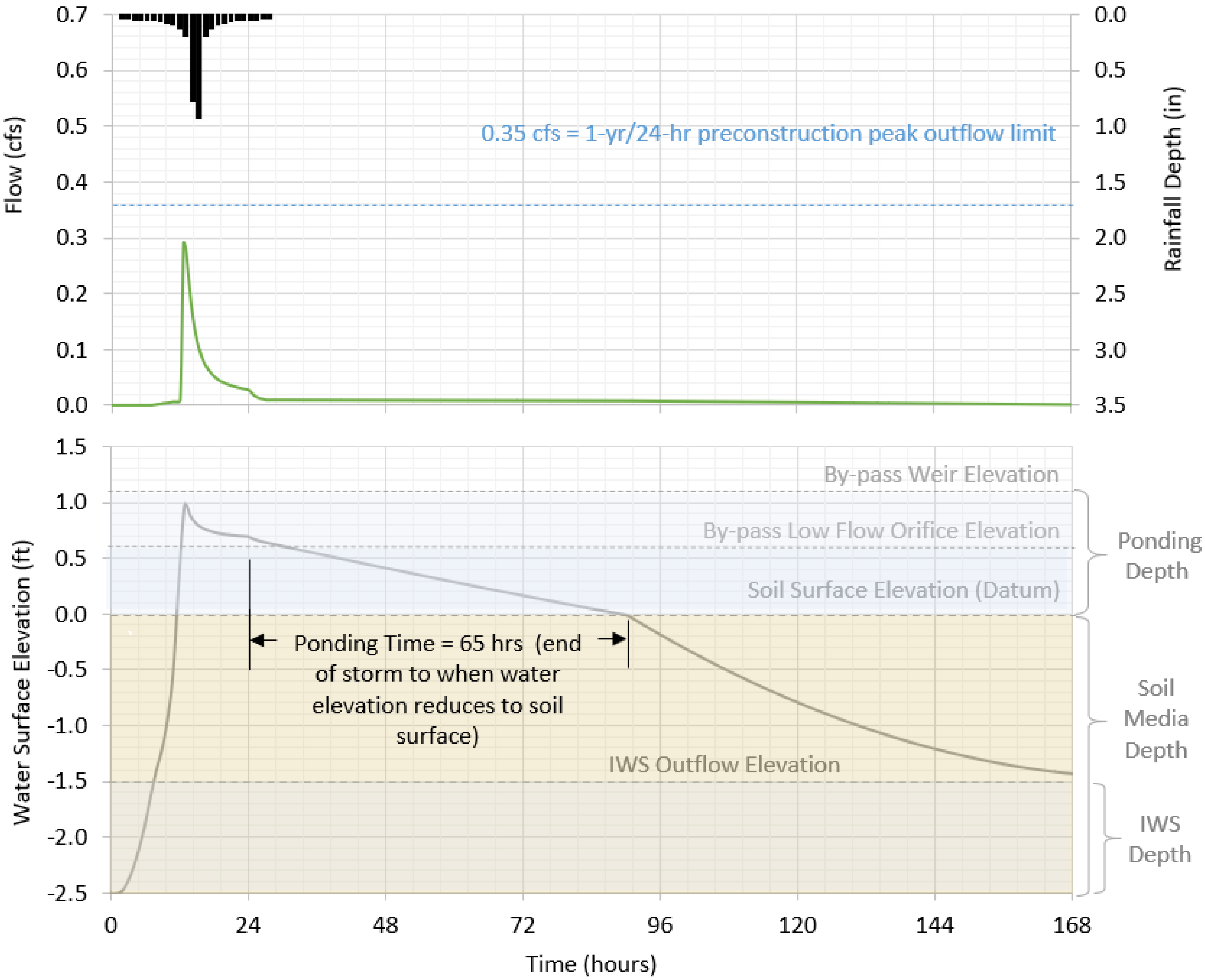


2-year/24-hour Storm Event

The following discusses the results from the 2-year/24-hour storm event from the MRC BMP only. Figure 2-3 shows rainfall over the contributing area, managed release outflow through the underdrain combined with overflow or bypass flow, infiltration, and water surface elevation in relation to time during and after the 2-year/24-hour event.

The peak rate from the post-construction 2-year/24-hour storm event is 0.29 cfs, which is lower than the pre-construction 1-year/24-hour peak rate of 0.35 cfs. Note that the peak flow of 0.29 cfs is the rate leaving the MRC BMP, not leaving the detention facility. The ponding time, as defined by the time after the storm event to when the water elevation receded to the soil surface, is limited to 65 hours during the 2-year/24-hour storm event.

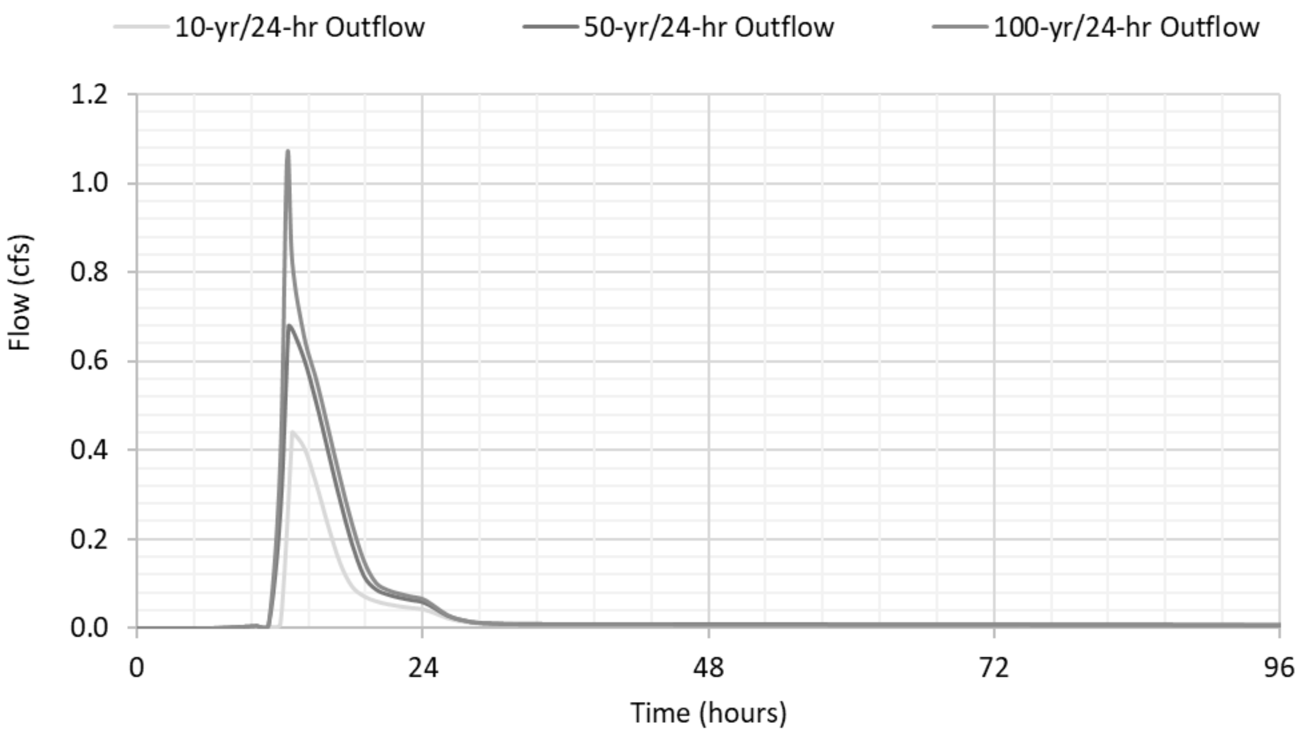
Figure 2-3: Design Example Results for 2-year/24-hour Storm Event



Peak Flow Attenuation

The following discusses the results from the peak flow attenuation for the 2-, 10-, 50- & 100-year/24-hour storm events from the detention basin in with the MRC BMP discharges. The peak rates for the 2-, 10-, 50- & 100-year/24-hour storm events are 0.21 cfs, 0.44 cfs, 0.68 cfs, and 1.06 cfs, respectively, from the post-construction condition. The post-construction peak flow from the MRC BMP of 0.35 cfs is further reduced to 0.21 cfs due to the presence of the detention basin and is below the pre-construction 1-year/24-hour peak rate of 0.35 cfs. The pre-construction peak outflows for the 10-, 50- & 100-year/24-hour storm events are 1.33 cfs, 2.41 cfs, and 2.96 cfs, respectively. Therefore, the post-construction peak rates have been adequately reduced.

Figure 2-4: Design Example Results for 10-, 50-, and 100-year/24-hour storm events



Key parameters from the 1.2-inch/2-hour storm event and 2-, 10-, 50-, and 100-year/24-hour storm events are summarized in Table 2-1. Determination of ponding time, 1.2-inch/2-hour release rate, and 2-year/24-hour peak rate parameters are demonstrated in Figures 2-2 and 2-3.

Ponding time in the MRC BMP for the 10-, 50-, and 100-year/24-hour storm events were found similarly as shown in Figure 2-3. Peak rates for the 10-, 50-, and 100-year/24-hour storm events can be seen in Figure 2-4.

Along with the hydrologic modeling demonstration of the MRC and peak flow attenuation, a pre-development site characterization and assessment of soil and geology and a discharge flow path analysis must be provided with a Chapter 102 permit application.

Table 2-1: Design Example Summary

Parameter	Design Value	Design Standard
Equivalent Contributing Impervious Area to BMP (acres)	**0.7**	
Total Drainage Area to BMP (acres)	**0.7**	
MRC BMP Release Rate (cfs)	**0.01**	*No greater than 0.01 cfs / acre of equivalent contributing impervious*
Underdrain Outflow Rate During 1.2-Inch/2-Hour Storm (cfs)	**0.01**	*<= MRC BMP Release Rate (cfs)*
Maximum Storm Event Routed to MRC BMP	**2-year/24-hour**	
Volume of Overflow During 1.2-Inch/2-Hour Storm (cf)	**0**	*0 (No overflow allowed)*
1-Yr/24-Hr **Pre**-Development Peak Rate (cfs)	**0.35**	
2-Yr/24-Hr **Post**-Development Peak Rate (cfs)	**0.21**	*1-Yr/24-Hr Pre-Development Peak Rate (or per approved Act 167 Plan)*
10-Year/24-Hour **Post**-Development Peak Rate (cfs)	**0.44**	*10-Year/24-Hour Pre-Development Peak Rate **(1.33 cfs)***
50-Year/24-Hour **Post**-Development Peak Rate (cfs)	**0.68**	*50-Year/24-Hour Pre-Development Peak Rate **(2.41 cfs)***
100-Year/24-Hour **Post**-Development Peak Rate (cfs)	**1.06**	*100-Year/24-Hour Pre-Development Peak Rate **(2.96 cfs)***
Ponding Time @ 2-Yr/24-Hr Storm (hrs)	**65**	*72 hrs (surface), 7 days (underground)*
Ponding Time @ 10-Year/24-Hour Storm (hrs)	**61 hrs**	*72 hrs (surface), 7 days (underground)*
Ponding Time @ 50-Year/24-Hour Storm (hrs)	**61 hrs**	*72 hrs (surface), 7 days (underground)*
Ponding Time @ 100-Year/24-Hour Storm (hrs)	**62 hrs**	*72 hrs (surface), 7 days (underground)*

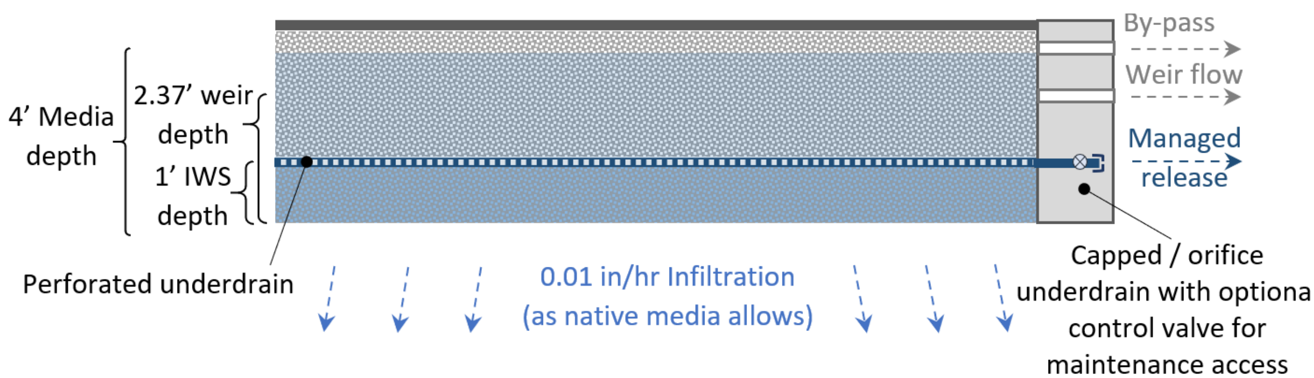
MRC Design Example 3: Permeable Pavement

The MRC BMP footprint is 0.07 acre (3,049 square feet) with a contributing drainage area of 0.8 acre (34,848 square feet) of 80% impervious area and 20% pervious area with a CN of 74 representing grass cover in good condition over a HSG C soil type. The modeled impervious contributing area includes the area of the MRC BMP. Note that this configuration is for demonstration purposes and it is not a representation of an ideal engineering practice (i.e., to have flow from pervious surfaces to a permeable pavement system can accelerate clogging of permeable surface). 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 0.01 in/hr. Click here for the HydroCAD® file.

Modeling MRC BMP Processes

In this case, a permeable pavement with underground storage bed was selected to apply the MRC and the IWS in it will encourage limited infiltration. Routing is performed through the basin using stage-discharge and stage-storage relationships. The 0.5-inch diameter managed release orifice is located 1 foot above the bottom of the media. There is a total of 4 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. There are two outflow devices including a 3.5-inch orifice at an elevation 2.37 feet above the bottom of the gravel bed and a weir 4 foot above the bottom of the gravel bed. The MRC BMP schematic can be seen in Figure 3-1.

Figure 3-1: Example 1 Schematic of MRC in a Pervious Pavement BMP



For routing purposes, a 40% void space was used to model the gravel media. To model that only 50% of total IWS depth is used for routing, the storage media below the orifice was modeled with a 50% reduction on void space (i.e. 20% void space).

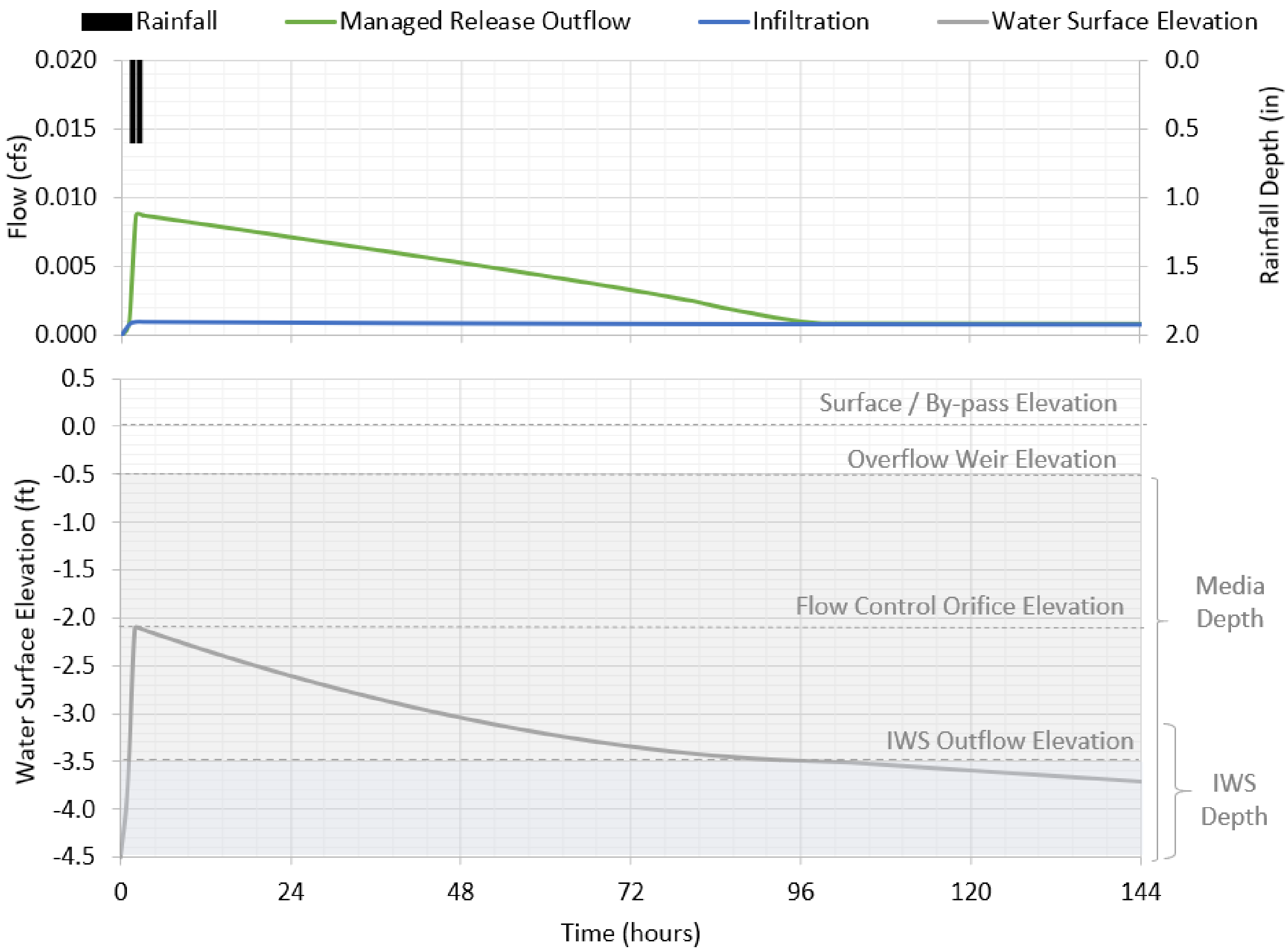
Modeling Results

1.2-inch/2-hour Storm Event

The following discusses the results from the 1.2-inch/2-hour storm event. Figure 3-2 shows rainfall over the contributing area, managed release outflow through the underdrain, infiltration, and water surface elevation in relation to time during and after the 1.2-inch/2-hour storm event.

There is no overflow as the water surface elevation never exceeds any outlet except the managed release underdrain during the 1.2-inch/2-hour event. The total inflow for the 1.2-inch/2-hour event is 2,035 cubic feet, all of which is managed through infiltration and the underdrain. To determine the representative impervious area for the managed release outflow rate, this volume is divided 1 inch, or 0.083 feet as corrected for units. The representative impervious area is 27,771 square feet (2,305 cf / 0.083 ft) or 0.637 acre, which allows for a release rate that is rounded up to 0.01 cfs (0.01 cfs/acre equivalent impervious x 0.637 acre = 0.0637 cfs, rounded to 0.01 cfs). A flow of slightly less than 0.01 cfs is obtained through the managed release outflow (as shown in Figure 3-2).

Figure 3-2: Design Example Results for the 1.2-inch/2-hour Storm Event

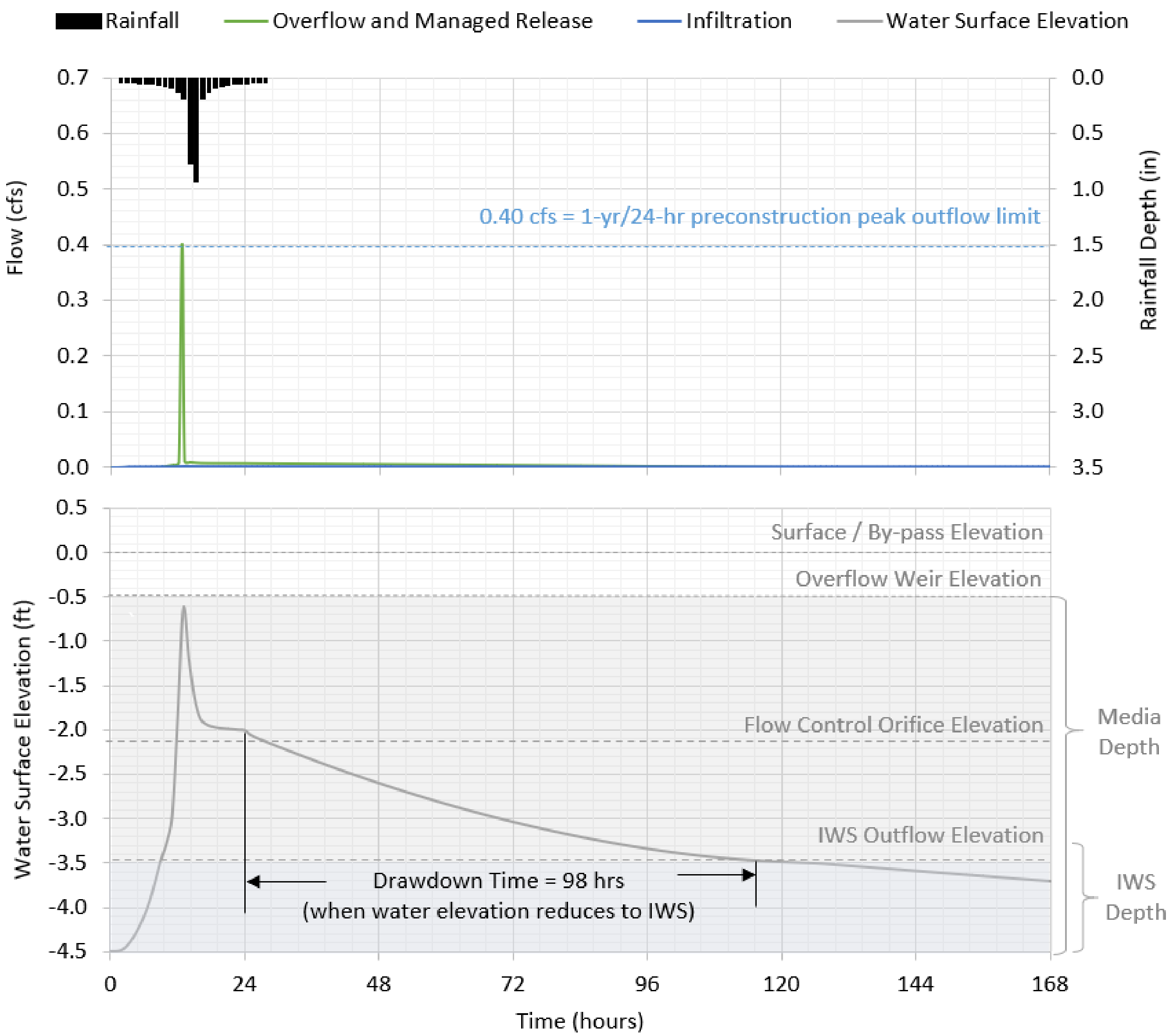


2-year/24-hour Storm Event

The following discusses the results from the 2-year/24-hour storm event. Figure 3-3 shows rainfall over the contributing area, managed release outflow through the underdrain combined with overflow or bypass flow, infiltration, and water surface elevation in relation to time during and after the 2-year/24-hour event.

The peak rate from the post-construction 2-year/24-hour storm event is 0.4 cfs, which is equivalent to the pre-construction 1-year/24-hour peak rate. The drawdown time, as defined by the time after the storm event to when the water elevation receded to the top of the IWS, is limited to 98 hours, or about 4 days, during the 2-year/24-hour storm event, which meets the requirement of drawdown time not to exceed 7 days for underground systems (MRC Design Standard No. 9).

Figure 3-3: Design Example Results for 2-year/24-hour Storm Event



Key parameters from both the 2-year/24-hour storm event and the 1.2-inch/2-hour event are summarized in Table 3-1. Determination of 1.2-inch/2-hour release rate, and 2-year/24-hour peak rate parameters are demonstrated in Figures 3-2 and 3-3.

Table 3-1: Design Example Summary

Parameter	Design Value	Design Standard
Equivalent Contributing Impervious Area to BMP (acres)	**0.637**	
Total Drainage Area to BMP (acres)	**0.8**	
MRC BMP Release Rate (cfs)	**0.01**	*No greater than 0.01 cfs / acre of equivalent contributing impervious*
Underdrain Outflow Rate During 1.2-Inch/2-Hour Storm (cfs)	**0.009**	*<= MRC BMP Release Rate (cfs)*
Maximum Storm Event Routed to MRC BMP	**2-year/24-hour**	
Volume of Overflow During 1.2-Inch/2-Hour Storm (cf)	**0**	*0 (No overflow allowed)*
1-Yr/24-Hr **Pre**-Development Peak Rate (cfs)	**0.4**	
2-Yr/24-Hr **Post**-Development Peak Rate (cfs)	**0.4**	*1-Yr/24-Hr Pre-Development Peak Rate (or per approved Act 167 Plan)*
Ponding Time @ 2-Yr/24-Hr Storm (hrs)	**98**	*72 hrs (surface), 7 days (underground)*

Version History

Date	Version	Revision Reason
8/25/2020	1.1	Updated for revised MRC Document. Revised dewatering times and corrected pre-development CN from 74 to 71.
5/15/2019	1.0	Original