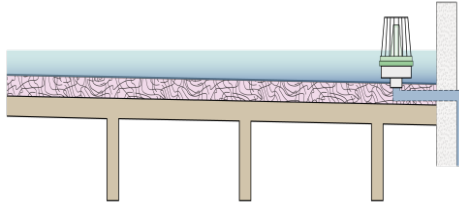






# 11.1 BLUE ROOFS (NON-GI)



Blue roofs are systems that are designed to provide stormwater detention. Precipitation that falls onto the roof is managed using orifices, weirs or other outlet devices that control the discharge rate of rooftop runoff. By reducing flow rates from rooftops, blue roofs are effective in reducing the size of down-gradient stormwater management systems. However, blue roofs can only be used to address the quantity control aspects of development when a waiver or variance from N.J.A.C. 7:8-5.3 is granted as they are not considered to be green infrastructure.

N.J.A.C. 7:8 Stormwater Management Rules – Applicable Design and Performance Standards		
	Green Infrastructure	Not Allowed
	Stormwater Runoff Quantity	Only with a waiver or variance from N.J.A.C. 7:8-5.3
	Groundwater Recharge	Not Allowed
	Stormwater Runoff Quality	Not Allowed

Stormwater Runoff Quantity Mechanism and Corresponding Criteria	
Peak Flow Reduction	
Maximum ponding depth	Based on required structural calculations
Partition requirement	Required when roof slope > 2%

## Introduction

A blue roof is a system designed to store and to slowly release stormwater runoff. Flow rates are controlled by orifices, weirs or other outlets. Because the flow rate leaving a blue roof is less than that of a conventional roof, they reduce the need for peak flow reduction of roof runoff at other at-grade facilities. Blue roofs are most effective on sites where roofs make up the majority of the impervious surface on the site or for sites that have little space available at-grade to build other BMPs.

Blue roofs may be used on newly constructed buildings or can be constructed as retrofits on existing structures. Blue roofs are recommended for relatively flat roofs, as steeper roofs result in greater ponding depths. Their use may be limited by the strength of the roof and bearing capacity of the foundation; therefore, it is important to consider structural integrity before deciding whether to use a blue roof. Blue roofs should also be located away from trees and other sources of debris to prevent excessive ponding due to clogging of outlets.

**Only with a waiver or variance from N.J.A.C. 7:8-5.3 may a blue roof, designed in accordance with this chapter, be used to satisfy the standards for stormwater runoff quantity, since this BMP does not meet the definition of green infrastructure.**

A blue roof must have a maintenance plan and must be reflected in a deed notice recorded in the county clerk's office to prevent alteration or removal.

## Applications



Only if a waiver or variance from the green infrastructure requirements of N.J.A.C. 7:8-5.3 is obtained may blue roofs be used to meet the stormwater runoff quantity requirements. Additionally, regardless of the design storm chosen, all blue roofs must be designed for stability in accordance with the New Jersey Department of Agriculture publication, *Standards for Soil Erosion and Sediment Control in New Jersey*, adopted December 2013 pursuant to the Soil Erosion and Sediment Control Act of 1975 as amended (N.J.S.A. 4:24-29 et seq.) and N.J.A.C. 2-90-1.1 et seq., as required by N.J.A.C. 7:8.

# Design Criteria

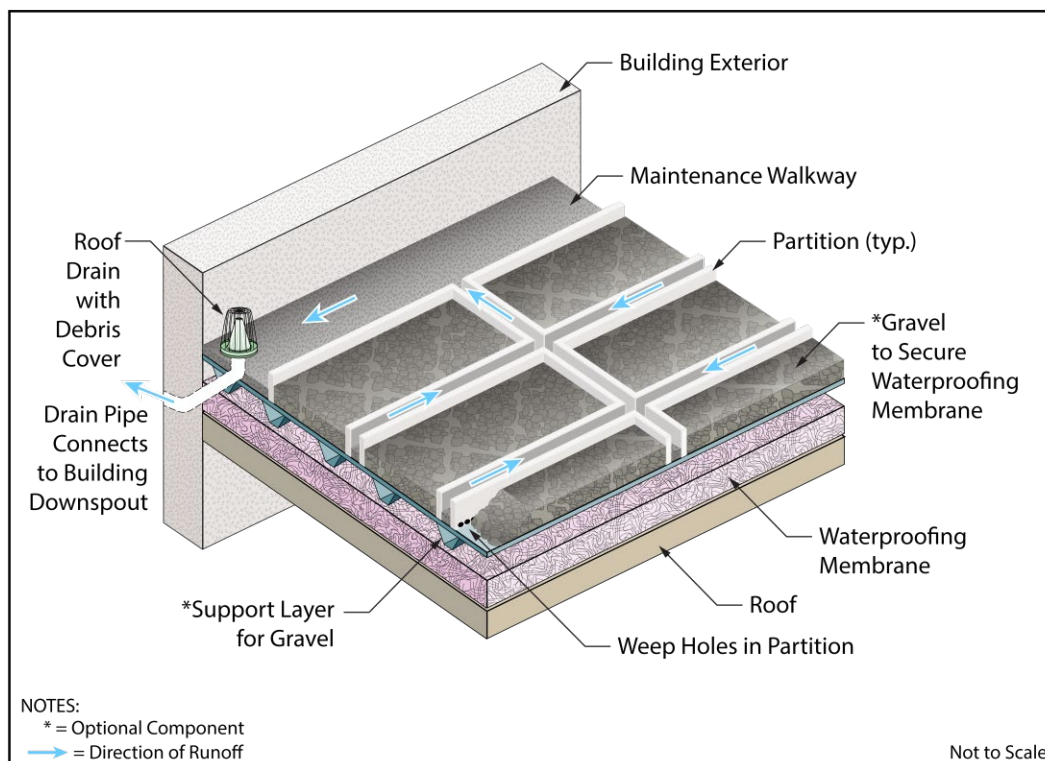
## Basic Requirements

The following design criteria apply to all blue roofs. It is critical that all blue roofs are designed in accordance with these criteria in order to ensure proper operation, to maximize the functional life of the system and to ensure public safety. Additional considerations are presented in the section beginning on Page 9.

### Roof Slope

- For roofs with slopes greater than 2%, partitions are required to avoid excessive ponding depths. An illustration detailing one possible configuration is found on the following page. It is not intended to limit the design.
- Partitions must be designed with orifices or other perforations to allow stormwater runoff to drain from the system. If no orifice is proposed in a partitioned area, weep holes must be located at the bottom of any partition to prevent permanent ponding of stormwater runoff on the rooftop. The weep holes must be included in all routing calculations.
- Watertight seals are required between different sections of partitioned areas, as well as between the partitions and the roof membrane to avoid seepage of stormwater runoff.
- Take note that it may be necessary to account for the volume occupied by partitions in the event that a large quantity or a thicker partition is proposed.

### Blue Roof with Partitions



## Storage Volume

- No standing water may remain on a blue roof 72 hours after a rain event in order to allow for sufficient storage for the next rain event. Additionally, storage in excess of 72 hours may render the blue roof ineffective and may result in anaerobic conditions, odor, and both stormwater runoff quality and mosquito breeding issues.

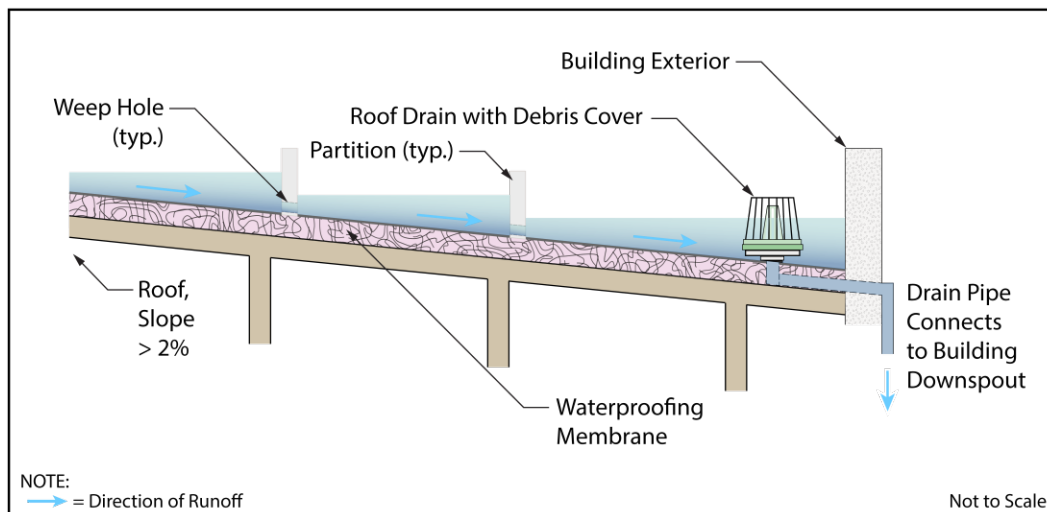
## Waterproofing System

- A waterproofing system must be included in the design to ensure that stormwater runoff does not damage the roof or leak into the building.
- If the waterproofing method selected requires weight to hold it in place, the void space of the material must be used when calculating the storage volume. The weight of this material must also be considered when determining structural requirements.

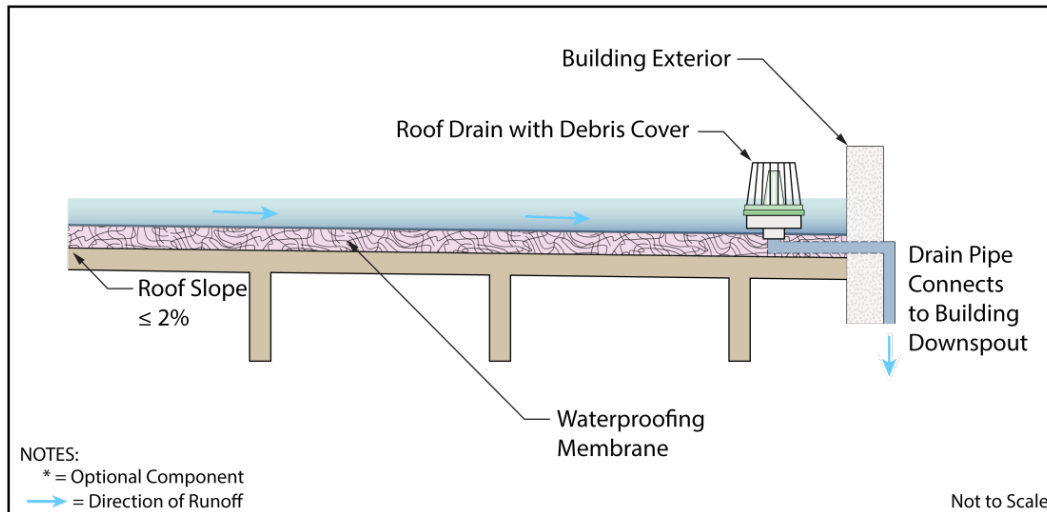
## Outlet Structure

- Any flow control device, such as an orifice, weir, grate or perforated pipe, at the outlet of the stormwater management measures shall be designed to prevent the clogging of the flow control device while achieving the design and performance standards at N.J.A.C. 7:8-5.4, 5.5 and 5.6. Additional information regarding outlet structures can be found in the Residential Site Improvement Standards at N.J.A.C. 5:21-7. The illustrations below represent, respectively, a profile section through a blue roof with a slope greater than two percent and one with a slope less than or equal to two percent. The illustrations show possible configurations and flow paths and are not intended to limit the design.

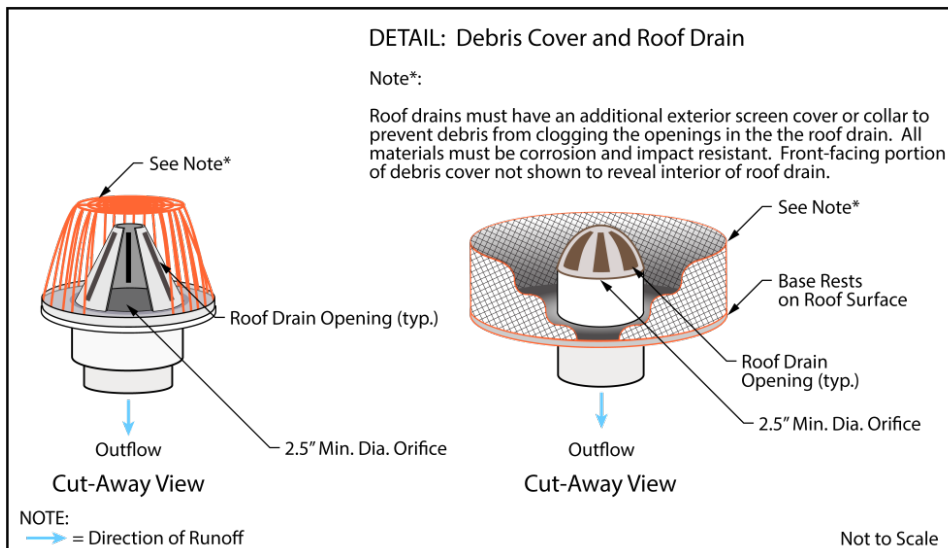
### Blue Roof with Partitions - Profile Section



### Blue Roof without Partitions - Profile Section



- All blue roofs must be designed with unrestricted overflow outlets to ensure that there will be no standing water in excess of the maximum design ponding depths.
- At least two drains are required for roofs up to 10,000 sf, and at least four are required for all roofs over 10,000 sf.
- A debris cover is required around all drains on a blue roof, as shown in the detail below.

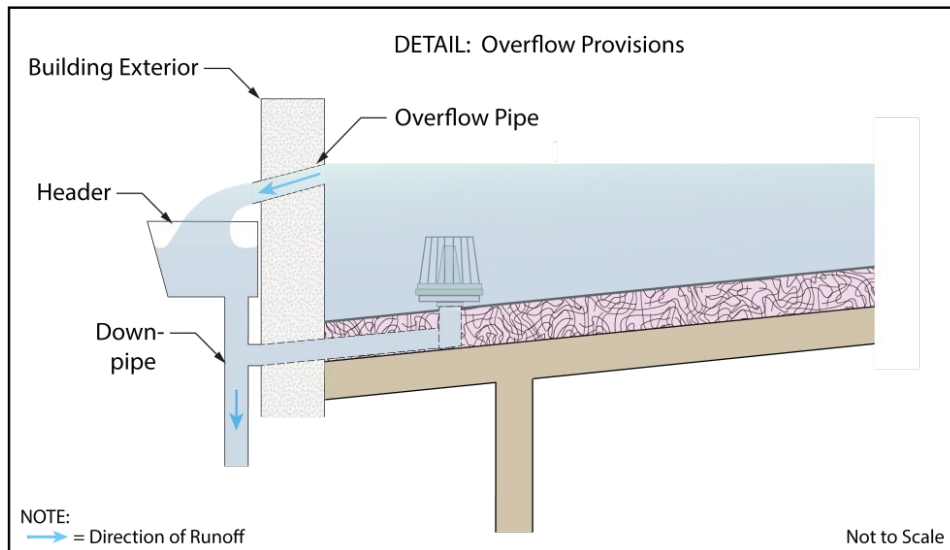


- All blue roof systems must drain within 72 hours.

### Safety

- All blue roofs must be designed to safely convey system overflows to down-gradient drainage systems. The design of the overflow structure must be sufficient to provide safe, stable discharge of stormwater runoff in the event of an overflow. Safe and stable discharge minimizes the possibility of erosion and flooding in down-gradient areas. Therefore, discharge in the event of an overflow must be consistent with the current version of Standards for Off-Site Stability found in the *Standards for Soil Erosion and Sediment Control in New Jersey*, as required by N.J.A.C. 7:8.

The illustration below depicts one configuration for an overflow but is not intended to limit the design.



- Blind connections to down-gradient facilities are prohibited. Any connection to down-gradient stormwater management facilities must include access points such as inspections ports and manholes, for visual inspection and maintenance, as appropriate, to prevent blockage of flow and ensure operation as intended. All entrance points must adhere to all Federal, State, County and municipal safety standards such as those for confined space entry.

### Roof Equipment

- Any equipment, mechanical systems, or roof furniture located within the ponding zone must be waterproofed to prevent damage.
- The loss of storage volume due to any objects on the roof must be considered during design to ensure that the blue roof functions as designed.

## Designing a Blue Roof

Blue roofs may be designed in many different ways. Below are two examples of how a blue roof can be designed using partitions or outlets. The examples below show possible configurations and flow paths and are not intended to limit the design.

### Example 1: Blue Roof Designed with Partitions

A 40,000 sf blue roof is being designed based on the following parameters:

Roof area:	40,000 sf
Roof width, W:	125 feet
Roof length, L:	320 feet
2-year storm rainfall, P:	3.31 inches
10-year storm rainfall, P:	5.06 inches
100-year storm rainfall, P:	8.51 inches
Maximum ponding depth:	6 inches
Roof slope:	2%
Existing land cover	Lawn, Good Condition
Hydrologic soil group	C
Existing curve number	74
Existing time of concentration	20 minutes

#### Step 1: Calculating the Distance Between Partitions

This roof is being designed with a series of partitions; therefore, the ponding area will be split into sections, each with a different maximum elevation but with the same maximum depth. The distance between the partitions may be calculated as follows:

$$\begin{aligned}\text{Distance between Partitions} &= \frac{\text{Maximum Ponding Depth}}{\text{Roof slope}} \\ &= \frac{6 \text{ in}}{0.02 \times 12 \text{ in/ft}} = 25 \text{ ft}\end{aligned}$$

Because the roof is 125 feet wide, it can be divided into five sections, each separated by a partition.

#### Step 2: Calculating the Area Behind Each Partition

The roof slants towards one side, so the area behind each partition can be calculated by multiplying the distance between the partitions by the length of the roof, as shown below. In this example, the thickness of the partitions is assumed to be insignificant.

$$\begin{aligned}\text{Area behind Partition} &= \text{Distance between Partitions} \times \text{Roof length} \\ &= 25 \text{ ft} \times 320 \text{ ft} = 8,000 \text{ sf}\end{aligned}$$

### Step 3: Designing the Partitions

Four partitions will be used at 25-foot intervals from the four required outflow drains. Each partition will be 6 inches high and will have a series of 25 weep holes, each approximately 12 feet apart to allow stormwater runoff to flow from one section of the roof to the next. Each weep hole will be 1 inch in diameter, and each invert must be at the roof level to ensure there is no standing water behind the partitions. The table below shows the reductions in peak flow rate due to the blue roof system.

Storm Event	Pre-development Peak Flow (cfs)	Traditional Roof Peak Flow (cfs)	Blue Roof Peak Flow (cfs)	Peak Flow Reduction Rate
2-year	0.76	2.95	0.33	56.6%
10-year	1.74	4.55	0.43	75.3%
100-year	3.90	7.67	2.63	32.6%

The blue roof meets the peak flow rate reductions required by the Stormwater Management rules for the 2-, 10- and 100-year storm. If there are other disturbed areas on-site, such as parking lots and sidewalks, they will also require stormwater management measures and hydrologic analyses to demonstrate compliance with the Stormwater Management rules.

### Example 2: Blue Roof Designed with Orifices

A 20,000 sf traditional roof is being retrofitted as a blue roof to reduce peak flow rates leaving the site. The blue roof has a single drainage area based on the following parameters:

Roof area:	20,000 sf
Roof width, W:	100 feet
Roof length, L:	200 feet
2-year storm rainfall, P:	3.31 inches
10-year storm rainfall, P:	5.06 inches
100-year storm rainfall, P:	8.51 inches
Maximum ponding depth:	9 inches
Roof slope:	1%

#### Step 1: Calculating the Ponding Area

Ponding will only occur on a section of the blue roof. The ponding area can be calculated based on the dimensions of the roof as follows:

$$\begin{aligned} \text{Ponding area} &= \frac{\text{Maximum Ponding Depth} \times \text{length}}{\text{Roof slope}} \\ &= \frac{9 \text{ inches} \times 200 \text{ feet}}{0.01 \times 12 \text{ inches/ft}} = 15,000 \text{ sf} \end{aligned}$$

## Step 2: Designing Orifices and Overflows

The peak flow rate reductions will be determined by the size and number of orifices. Many commercial drains are available which have pre-determined flow rates. For this example, we will assume that each drain is designed as a vertical orifice which slowly releases stormwater runoff from the rooftop, and water depths in excess of the maximum ponding depth are freely discharged (modeled as a weir). It is also assumed that the rooftop is designed with crushed stone with a porosity of 0.4 to hold the waterproofing membrane in place.

Using 4 drains, two located at the bottom of the roof each with an orifice with a diameter of 5 inches and two elevated 6 inches above the bottom of the roof with an orifice diameter of 12 inches, the blue roof achieves the peak flow reductions provided in the table below:

Storm Event	Traditional Roof Peak Flow (cfs)	Blue Roof Peak Flow (cfs)	Peak Flow Reduction Rate
2-year	1.48	0.67	55%
10-year	2.27	0.95	58%
100-year	3.84	2.70	30%

These flow rate reductions apply to the entire roof area, though only the 15,000 sf area calculated above will have ponding. Retrofitting an existing roof to provide peak flow reductions could be used as part of a mitigation plan in instances in which a variance or exemption for a separate project must be granted for the stormwater runoff quantity standard, or a way to reduce impacts due to flooding or combined sewer overflows.

## Considerations

A number of factors should be considered when using a blue roof to manage stormwater runoff.

### Access

Blue roofs, like all other stormwater BMPs require maintenance; therefore, it is important all maintenance personnel are able to access the roof. Additionally, if the roof is open to the public, measures should be included to ensure safety. Many large buildings use the roof as the access point for window washing; therefore, the blue roof should be designed to provide access and safe working conditions for maintenance personnel.

### Structural Strength

Blue roofs may add a significant amount of weight to a roof including the dead load of the blue roof components, as well as the added live loads as a result of rainfall, maintenance personnel, and equipment. Therefore, the structural load capacity of the roof is a crucial consideration when designing a blue roof.

## Leak Detection

A method for detecting leaks should be included in the blue roof's maintenance plan. Location of physical leak detection systems will depend on the manufacturer's specifications and should be placed accordingly.

## Longevity

When designing a blue roof, it is important to consider the longevity of all parts of the system, as well as the roof and all structural supports. The waterproofing layer of a blue roof is especially important, as failures can create serious structural problems. Care must be taken during construction to ensure that the waterproofing membrane is not damaged. In some instances, a support layer may be required between the membrane and the ballast to prevent localized damage or distribute the weight from various live and static loading conditions. Additionally, the lifespan of a blue roof may be shortened by repeated clogging of the outlet structures by debris. It may be necessary to increase the frequency of monitoring if clogging becomes chronic.

## Other Rooftop Uses

Blue roof systems may be designed to allow other uses of the roof. Any equipment stored on a blue roof should be protected to ensure that it is not damaged as a result of ponded water. A blue roof system may also be designed with solar panels, provided that the solar panels are designed to allow rainfall to reach the roof surface and will not be damaged by ponded water. All pedestrian walkways should be designed to avoid the blue roof's ponding area to prevent damage to the waterproofing membrane.

## Maintenance

Regular and effective maintenance is crucial to ensure effective blue roof performance. A blue roof used to meet any State requirement must have a maintenance plan. For projects that are major developments, there are a number of required elements in all maintenance plans, pursuant to N.J.A.C. 7:8-5.8; these are discussed in more detail in *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures*. Furthermore, maintenance activities are required through various regulations, including the New Jersey Pollutant Discharge Elimination System (NJPDES) rules, N.J.A.C. 7:14A. Specific maintenance activities for blue roofs are presented below; these activities should be included in the maintenance plan.

### General Maintenance

- Blue roofs should be inspected at least four times annually and after every storm event exceeding 1 inch of rainfall. Blue roofs located in areas with significant tree cover or in areas with a high potential for airborne debris may require more frequent inspections due to the potential for clogging.
- All structural components should be inspected for cracking, spalling and deterioration at least once annually.
- Disposal of debris, trash, sediment and other waste material must be done at suitable disposal/recycling sites and in compliance with all applicable local, state and federal waste regulations.

- Access points for maintenance are required on all blue roofs; these access points should be clearly identified in the maintenance plan. In addition, any special training required for maintenance personnel to perform specific tasks should be included in the plan.

## **Drain Time**

- The design drain time for the maximum design storm runoff volume must be indicated in the maintenance plan.
- If the actual drain time is longer than the design drain time, the blue roof must be evaluated and appropriate measures must be taken to return the blue roof to the as-built condition.
- If the blue roof fails to fully drain within 72 hours, corrective action must be taken and the maintenance manual revised accordingly to prevent similar failures in the future.

## References

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- Katiyar, Nitin, et al. June 21, 2012. *Performance Evaluation of Blue Roofs to Mitigate CSO Impacts* (PowerPoint Slides).