Inlet and Outlet Controls

Inlet and outlet control measures manage runoff into and out of structural stormwater Best Management Practices (BMPs), respectively. This section presents inlet and outlet controls that can be used with the BMPs in this Manual. Refer to the specific BMP design sections in Chapter 13 - Structural Stormwater BMP Design Guidance for further information relative to inlet and outlet controls that are best suited for a given type of BMP and site-specific application.

Inlet and Outlet Controls Included in this Section

- Inlet Control Types
  - Level Spreader
  - Inlet Curb Cut Opening
  - Inlet Structure
  - Piped Flow Entrance
  - Flow Diversion Structure
- Outlet Control Types
  - Outlet Curb Cut Openings
  - Raised Overflow Structures or Risers
  - Outflow Weirs
  - Outlet Pipes/Culverts
- Inlet and Outlet Protection
  - Stone Rip Rap Apron
  - Stone Rip Rap Stilling Basin or Plunge Pool

Inlet Controls

General Design Guidance

In addition to the design guidance outlined below for the respective inlet control types, the following general criteria should be considered when designing inlet controls for stormwater BMPs:

- Flow velocities should not exceed 3 feet per second for grassed surfaces and 1 foot per second for mulched surfaces.
- Inlet areas should be stabilized to ensure that non-erosive conditions exist for at least the 1-year, 24-hour design storm event.
- If designing the BMP as an on-line system, inlet controls should be designed to accommodate flows in excess of the Water Quality Flow (WQF).[92] At a minimum, inlet controls for on-line BMPs should be designed to accommodate flows generated by the 10-year, 24-hour design storm event.
- If designing the BMP as an off-line system, the flow diversion structure should be designed to convey the WQF to the BMP and allow larger flows to bypass the system.

[92] Use of the term Water Quality Flow (WQF) in this section refers to the peak flow associated with the Required Retention Volume, which is either 100% or 50% of the site's Water Quality Volume (WQV) depending on the applicable retention/treatment requirement as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

- Design the inlet to resist incursion by vehicles and bicycles for BMPs located along roads, parking lots, and other areas with vehicle and bicycle traffic.
- Design the inlet to resist blockage from trash, debris, and sediment in addition to ice and snow.
- Design inlet structures and diversion structures to withstand the effects of freezing, frost in foundations, erosion, and flotation due to high water conditions.

Level Spreader

Level spreaders collect stormwater from an upgradient impervious surface and distribute it uniformly over the ground surface, typically over a pretreatment vegetated filter strip, as sheet flow prior to entering a downgradient stormwater BMP. Level spreaders promote uniform sheet flow to maximize pollutant removal and infiltration. Level spreaders also reduce the energy and velocity of runoff, which reduces the potential for erosion.

Many level spreader design variations exist, including level stone-filled trenches, curbing, concrete weirs, etc. All level spreader designs operate on the same basic principles:

- Stormwater enters the spreader through overland flow, a pipe, ditch, or swale
- The flow is distributed throughout a long linear shallow trench or behind a low berm
- Stormwater flows over the berm/ditch uniformly along the entire length of the spreader.

Inflow level spreaders (i.e., level spreaders that are part of an inlet control measure) are typically used with pretreatment vegetated filter strips to promote filtering and infiltration and with other stormwater BMPs where concentrated flow presents design constraints, such as with some Filtering BMPs.

Figure 13-36 through Figure 13-38 show several examples of common level spreader designs. Figure 13-36 and Figure 13-37 are concrete level spreader designs, while Figure 13-38 is a stone-filled trench level spreader design.

Key design considerations for level spreaders include:

- Concentrated flow may enter the level spreader at a single or multiple points, with appropriate energy dissipation, and leave as uniformly distributed sheet flow.
- The maximum contributing drainage area for a level spreader should be 2.5 acres for maximum efficiency.
- Flow should be uniformly distributed and crest over the downgradient edge of the spreader along its entire length. The downgradient edge over which flow is distributed

must be level. Small variations in height (of more than 0.25 inch) will result in concentrated flow and erosion.

- Stormwater flowing over the lip of a level spreader should have a maximum velocity of 1 foot per second for the water quality storm and 3 feet per second for the 10-year, 24-hour design storm to maintain non-erosive velocities over the downgradient vegetated surface.

- Calculate the required length of the level spreader so that the flow velocity over the level spreader is equal to or less than the maximum allowable velocity in the downgradient area.

    - For a thick vegetated surface immediately downgradient of the level spreader such as a vegetated filter strip or pretreatment swale (see Pretreatment BMPs), the length of the level spreader should be selected to convey 0.25 cfs per linear foot of spreader during the design storm event. This equates to 4 feet of length for every 1 cfs of flow. This design specification is based on maximum flow velocities and a water depth of approximately 1 inch flowing over the lip of the level spreader. For example, a level spreader designed for a peak flow rate of 5 cfs would need to be 20 feet long.

- The minimum length for a level spreader shall be 6 feet.

- Level spreaders should not be constructed in newly deposited fill as these areas are most susceptible to erosion. Undisturbed earth is more resistant to erosion than fill.

- Level spreaders consisting of stone-filled trenches (Design Example 3) should be placed immediately upgradient of a vegetated filter strip and be 12 inches wide and 18 to 24 inches deep, filled with 1.5-inch diameter AASHTO No. 4 stone. The stone should be clean (washed and free from dirt and debris), crushed, and angular. Non-woven filter fabric should be placed on the sides and bottom of the trench.

Figure 13-36. Level Spreader Design Example 1

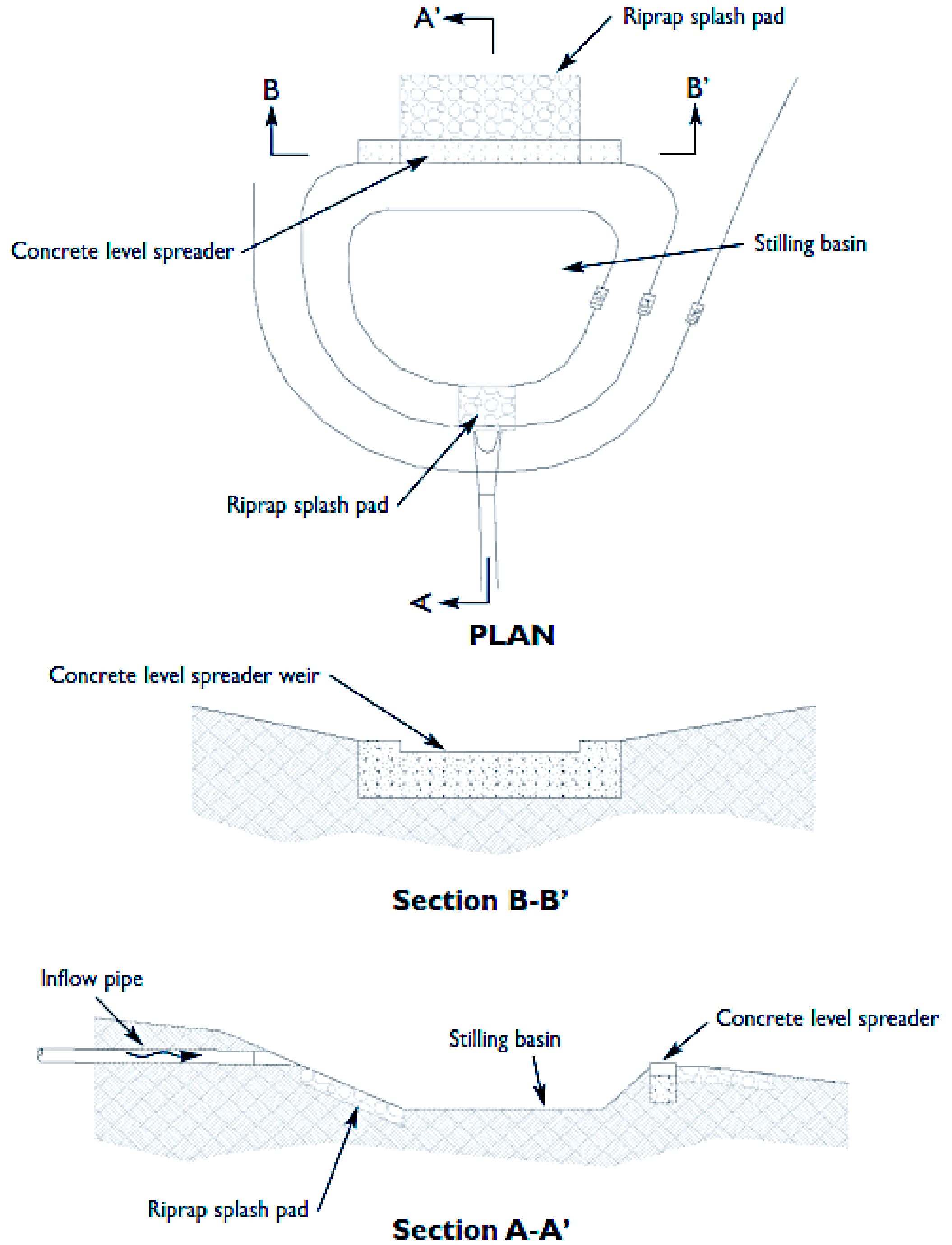


Figure 13-37. Level Spreader Design Example 2

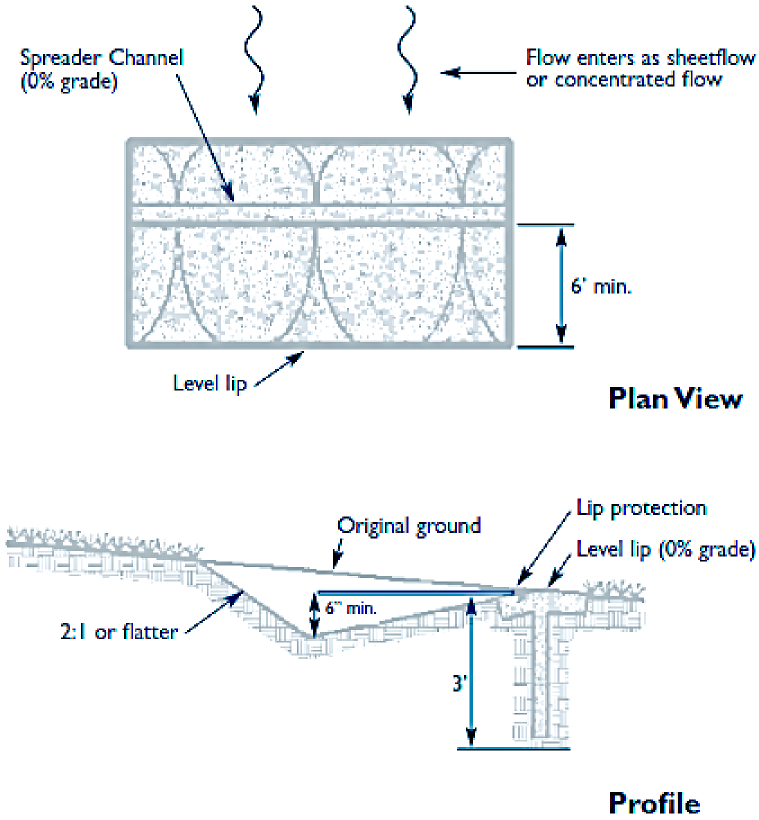
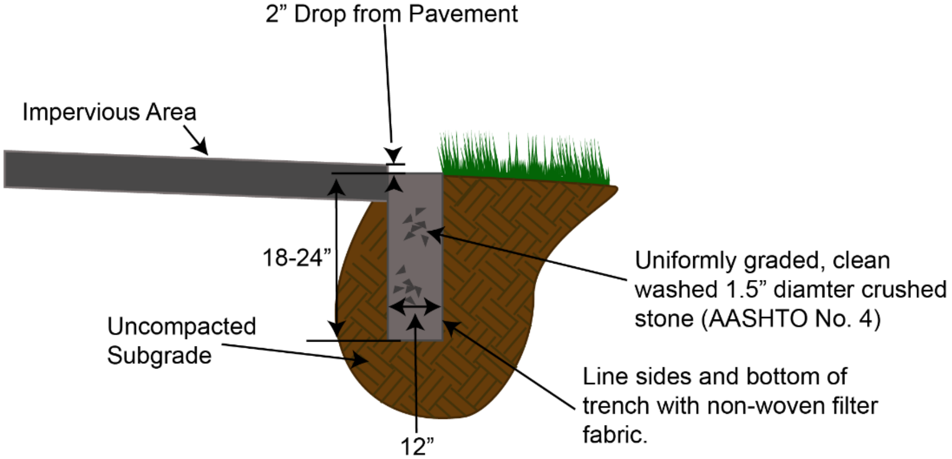


Figure 13-38. Level Spreader Design Example 3



Source: Adapted from Pennsylvania Stormwater Best Management Practices Manual.

Inlet Curb Cut Opening

Inlet curb cut openings are used in locations where stormwater BMPs are installed along curbed streets, parking lots, or landscaped islands. In certain situations, stormwater overflow discharges out of the BMP via the same curb cut opening through which it entered. Once stormwater fills the BMP, stormwater overflow will be directed back out through the curb opening to an existing drain structure that will then function as an overflow structure. Figure 13-39 show several examples of common inlet curb cut openings.

Key design considerations for inlet curb cut openings include:

- Curb cuts should be transition-style and have a width not less than 18 inches to prevent clogging.
- If designing the BMP as an on-line structure, design the opening width to prevent flow from bypassing the opening. Slope the bottom of the curb cut to drain toward the BMP and create a low point in the pavement in front of the opening by creating a small rectangular area with a lower elevation than the surrounding pavement (i.e., depressed curb inlet).
- Provide a minimum 2-inch drop in grade between the curb cut entry point and the downgradient finished surface/grade.
- Woody plants should not be placed directly in the entrance flow path. Woody plants can restrict and concentrate flows and be damaged by erosion around the root ball.
- Stabilize the area downstream of the curb cut opening to prevent erosion. Concrete (e.g., a splash pad), paver blocks, or grouted stone should be used to armor the flow path to the base of the BMP.

Inlet Structure

Inlet structures may be used to capture runoff, slow runoff velocities, settle solids and convey runoff to a downstream stormwater BMP. A deep sump catch basin (see design guidance for deep sump hooded catch basins in the Pretreatment BMPs section of Chapter 7) is an example of an inlet structure (Figure 13-40).

Key design considerations for inlet structures include:

- The recommended minimum sump depth for deep-sump structures is 48 inches.
- Utilize hoods to minimize floatable pollutants discharged to the BMP.

Figure 13-39. Typical Inlet Curb Cut Openings

Curb cut openings at inlets to bioretention basins designed to capture runoff from adjacent parking areas.

Curb cut opening at inlet to roadside bioswale. The single opening serves as the inlet and overflow.

Installation of depressed concrete pad in front of inlet curb opening to create a low point that helps convey gutter flow into the bioswale (left photo). Curb cut opening to direct road runoff beneath the adjacent sidewalk into a stormwater BMP (right photo).

Figure 13-40. Deep Sump Catch Basin Inlet Structure

Piped Flow Entrance

Runoff may discharge to a stormwater BMP via a pipe or culvert. The following should be considered when designing piped flow entrances:

- Include energy dissipation measures to dissipate energy and distribute runoff. The energy dissipation measure should extend the entire width of the piped flow entrance and extend into the bottom of the BMP. Acceptable energy dissipation measures include grouted stone riprap aprons, concrete splash pads, and forebays/stilling areas created using concrete/granite curbing or gabion weir/baffles. When using concrete/granite curbing or gabion weir/baffles, consider potential tailwater impacts.

- Woody plants should not be placed directly in the entrance flow path. Woody plants can restrict or concentrate flows and be damaged by erosion around the root ball.

Flow Diversion Structure

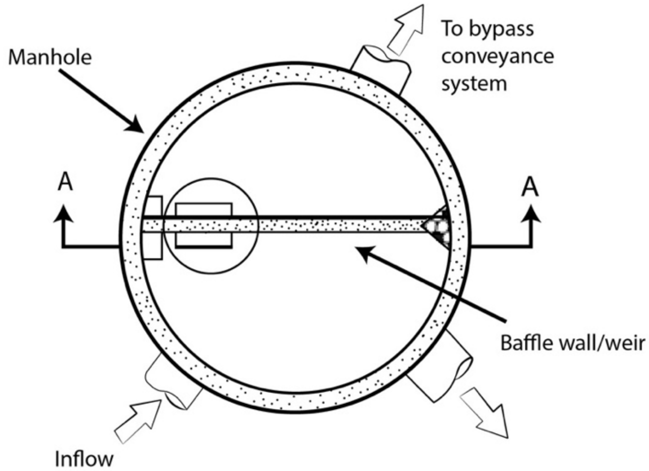
Stormwater BMPs can be designed to receive all the flow from a given area (on-line) or to receive only a portion of the flow (off-line). Flow diversion structures, also called flow splitters, are designed to divert flows up to the peak flow rate associated with the water quality storm (i.e., the Water Quality Flow or WQF) from a conveyance system to an off-line BMP. Flows in excess of the WQF bypass the BMP and continue through the conveyance system downgradient of the BMP. Refer to Appendix D of this Manual for the recommended procedure for calculating the WQF.

Flow diversion structures are typically manholes or vaults equipped with weirs, orifices, or pipes to bypass flows in excess of the design flow. Several design options exist. Figure 13-41 through Figure 13-43. Flow Diversion Structure Design Example 3 show common examples of flow diversion structures for use upstream of off-line stormwater BMPs. Other equivalent designs that achieve the result of diverting flows in excess of the WQF around the BMP, including bypasses or overflows located inside the BMP, are also acceptable. Refer to the Guidelines for the Use Hydrodynamic Separators on CTDOT Projects (4/2021) for additional diversion examples.

Key design considerations for flow diversion structures include:

- Size the low flow outlet to convey flows up to the WQF to the stormwater BMP.
- Set the top elevation of the diversion weir or the overflow outlet at the maximum water surface elevation associated with the WQF, or the water surface elevation in the downstream stormwater BMP when the entire WQV is being held in the BMP, whichever elevation is higher. Consider tailwater conditions when modeling bypass flows.
- Determine the diversion structure dimensions required to divert flows in excess of the WQF using standard equations for a rectangular sharp-crested weir, uniform flow in pipes or channels, or orifice depending on the type of diversion structure.
- Provide sufficient freeboard in the diversion structure to accommodate the maximum water surface elevation in the diversion structure and in the BMP. Avoid surcharging the BMP under higher flow conditions.
- Design diversion structures to minimize clogging potential and to allow for ease of inspection and maintenance. Maintenance access should be provided to both sides of diversion weir for cleaning by a vacuum truck.

Figure 13-41. Flow Diversion Structure Design Example 1



Plan View

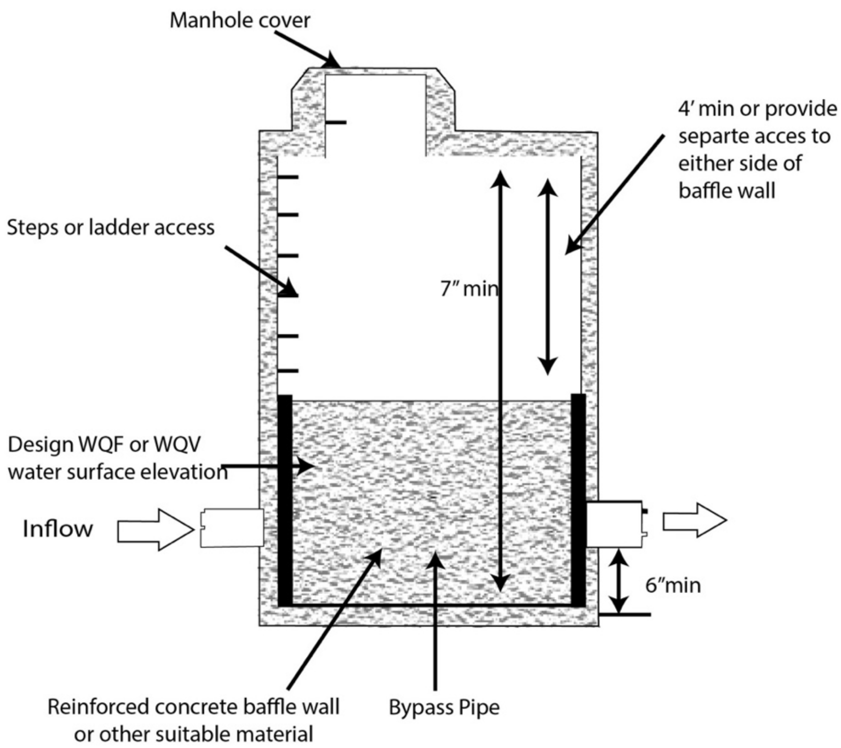


Figure 13-43. Flow Diversion Structure Design Example 2

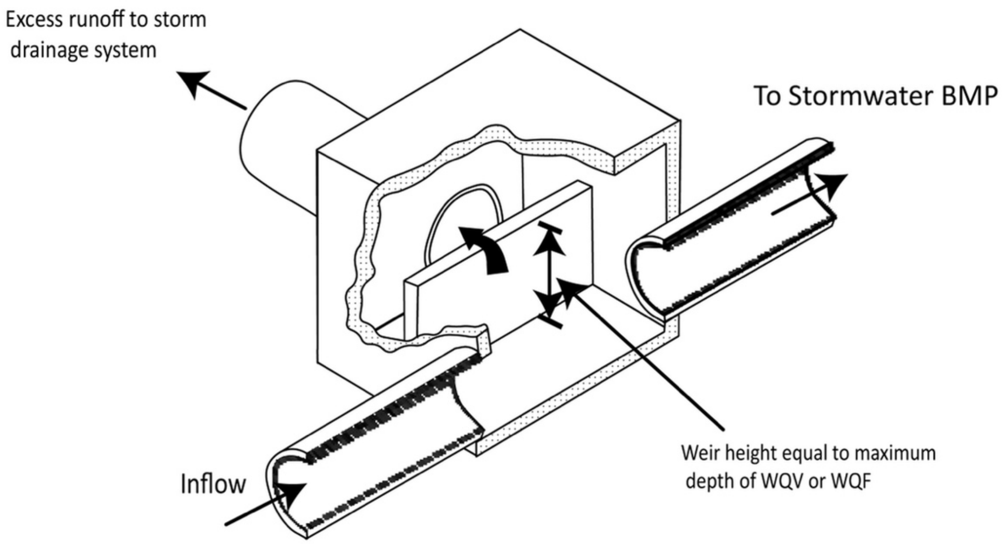
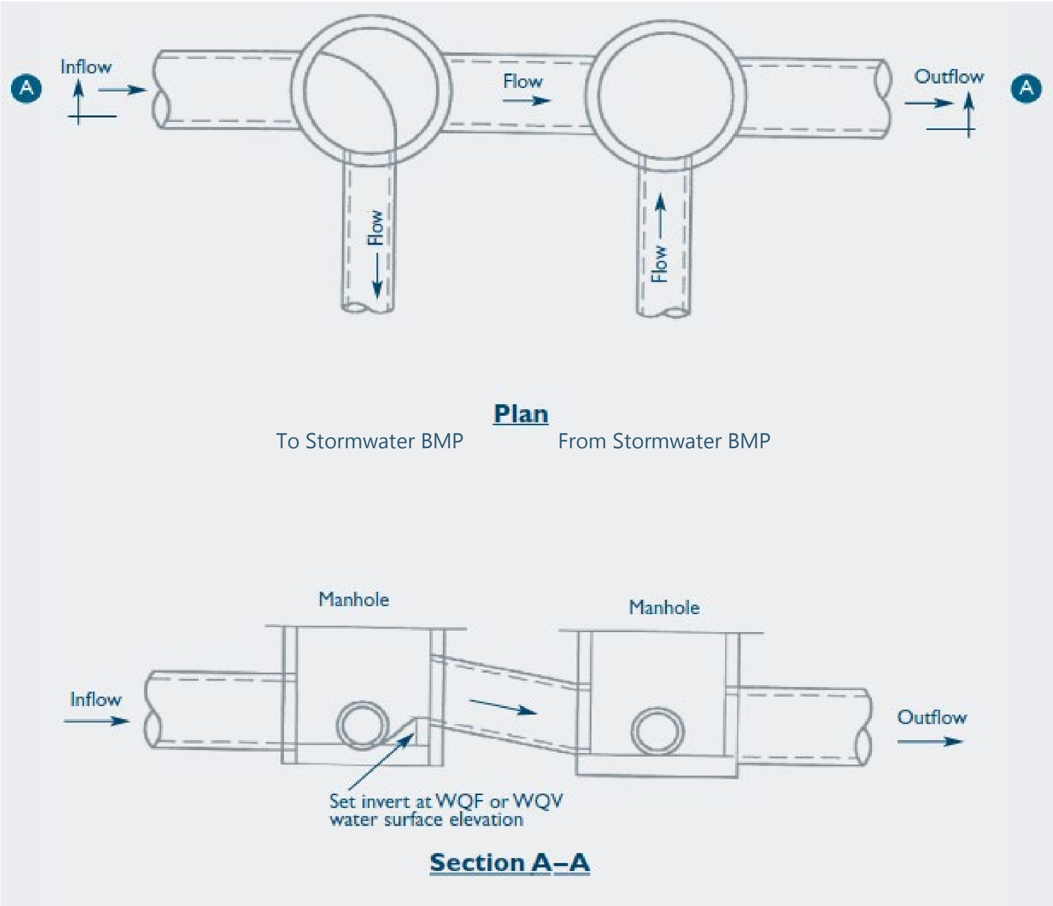


Figure 13-42. Flow Diversion Structure Design Example 3



Outlet Controls

General Design Guidance

In addition to the design criteria outlined below for the respective outlet control types, the following general criteria should be considered when designing outlet controls for BMPs:

All on-line stormwater BMPs must have a provision for outlet/overflow, as follows:

- An outlet control structure should be provided for runoff in excess of the WQF or WQV. The outlet control structure should be designed with openings to safely pass the 10-year, 24-hour design storm, at a minimum, with adequate freeboard.
    - For BMPs without a perimeter constructed earthen berm (e.g., bioretention swale), design the outlet/overflow structure of an on-line BMP to safely convey flows from the 10-year storm event (at minimum) with 6 inches of freeboard (unless noted otherwise in individual BMP design sections).
    - For BMPs with a perimeter constructed earthen berm, design the outlet/overflow structure of an on-line BMP to safely convey flows from the 100-year storm event with 3 inches of freeboard (unless noted otherwise in individual BMP design sections).
- For on-line BMPs, the outlet control structure should be designed as a multi-stage outlet structure positioned to meet each control requirement independently (e.g., retention/treatment of stormwater, conveyance of larger storms, peak runoff attenuation, emergency overflow, etc.).
    - For water quality purposes, the elevation of the lowest outlet should be set at, or slightly above, the design storage elevation, which is the elevation of ponded water associated with the Required Retention Volume (100% or 50% of the site's WQV).
- Overflow spillways should be a minimum of 8 feet wide, 1 foot deep, and have side slopes no steeper than 3(H):1(V).
- Discharge from an outlet should be conveyed to either a stormwater structure (e.g., manhole), drainage system, or stabilized discharge point.
    - Confirm that the conveyance system/storm drain network has adequate capacity to receive the proposed flow and that the system meets the stormwater quantity control requirements described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

Protection from Clogging

Protection from clogging is required for any orifice size utilized as part of the outlet control structure. Small orifices, typically less than six inches in diameter, used for slow-release applications can be susceptible to clogging. The following design measures should be taken to minimize the potential for clogging.

- The low-flow orifice should be adequately protected from clogging by a trash rack. The orifice diameter should always be greater than the thickness of the trash rack openings. The trash rack area should be at least ten times the area of the outlet opening being protected from clogging.
    - The minimum recommended orifice size is 3 inches.
    - Orifice diameters smaller than 3 inches should only be allowed on a case-by-case basis as demonstrated by the designer and/or upon approval from the review authority.

Outlet Curb Cut Openings

Outlet curb cut openings (Figure 13-44) can be used as a type of outlet control for BMPs located along streets with a gradual but consistent slope. Excess volume above the designed ponding depth flows out of the outlet curb cut opening installed at the downstream end of the facility. The following should be considered when designing outlet curb cut openings:

- Set the crest of the outlet curb opening at or above the elevation of the shallow ponding depth; and at least 3 inches below the inlet elevation to prevent overtopping of the BMP during the design storm.

Raised Overflow Structures or Risers

Raised overflow structures or risers can be designed as single-stage or multi-stage vertical structures consisting of orifices and/or weir openings set at different elevations to meet stormwater management requirements. The following should be considered when designing raised overflow structures and risers:

- Single-stage structures should consist of a vertical (riser) overflow structure or riser pipe with an open top that is covered by a “beehive” grate (Figure 13-45), domed riser grate, or trash rack. The crest of the overflow structure is set at or slightly above the design storage elevation associated with the WQV.

Figure 13-44. Roadside Bioswale with Inlet and Outlet Curb Cut Openings

Figure 13-45. Typical Dome Grate Overflow/Outlet Structure

Outflow Weirs

Outflow weirs typically consist of stabilized overflow spillways or structural weirs constructed from gabions, concrete, or curbing. Outflow weirs promote sedimentation by slowing flow velocities as water ponds behind the weir. They also provide a means of uniformly distributing runoff as it is discharged, helping to decrease concentrated flow and reduce velocities as the water travels downstream. In certain situations, these types of weirs may be designed with notches to limit or restrict overflow to desired locations or match pre-development peak flow rates. The following should be considered when designing outflow weirs:

- Account for structural stability during extreme conditions in addition to flow velocities and upstream hydrostatic pressure from ponded water.
- Select materials that withstand design flow velocities and exposure to the elements.

Outlet Pipes/Culverts

An outlet pipe/culvert from a BMP should be designed to convey controlled flow in excess of the Water Quality Flow to either a stormwater structure, drainage system, or approved discharge point. Confirm that the conveyance system/storm drain network has adequate capacity to receive the proposed flow and that the system meets the stormwater quantity control requirements described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

Inlet and Outlet Protection

Inlet and outlet protection should be installed to dissipate energy and limit erosion. Typical inlet and outlet protection measures include level spreaders, stone/riprap aprons, stone riprap stilling basins or plunge pools, concrete pads or splash blocks, and non-degradable turf reinforcement matting designed to reduce the velocity, energy, and turbulence of the flow. Other options may be considered if allowed by the review authority. These measures can be used when highly erosive velocities are encountered at inlet and outlet locations, at the bottom of steep slopes, or where the discharge of sheet flow or non-erosive flow to down-gradient locations is required.

Provide stable and non-erosive energy dissipating devices at inflow and outlet locations where concentrated flow velocities are considered erosive. Flow velocities should not exceed 3 feet per second for grassed surfaces and 1 foot per second for mulched surfaces.

Stone Riprap Apron

Stone riprap aprons are commonly used for energy dissipation due to their relatively low cost and ease of installation. A flat stone riprap apron can be used to prevent erosion at the transition from a pipe, culvert, or spillway outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow. To facilitate removal of sediment and minimize vandalism potential, stone riprap aprons may be grouted.

- The aprons should be designed for the water quality storm for off-line stormwater BMPs and for the 10-year, 24-hour storm event at a minimum for on-line BMPs.
- If the apron is installed at an inlet location within the BMP that will be part of a sediment forebay, the stone riprap should be grouted to facilitate maintenance.
    - If grouted, provide at least two weep holes (2.5 inches in diameter) for every 25 square feet of surface area in the bottom of the forebay to facilitate low level drainage.
    - If grouted riprap is used, stone riprap should conform to State of Connecticut Department of Transportation Standard Specifications, Section M.12.02 (Riprap). Grout should be a non-shrink grout having a 4,000 psi 28-day compressive strength and a 2,400 psi 7-day compressive strength in accordance with State of

Connecticut Department of Transportation Standard Specifications, Section M.03.05.

Stone Riprap Stilling Basin or Plunge Pool

A riprap stilling basin or plunge pool is a pre-shaped scour hole lined with riprap that functions as an energy dissipator. Like a riprap apron, a riprap stilling basin can be used to prevent erosion at the transition from a pipe or box culvert outlet to an earthen channel.

- The appropriate inlet and outlet protection type should be based on site characteristics such as slope, available area, and aesthetics.
- A key design issue is the interface between the end of the inlet/outlet protection structure and the adjacent downstream area, which is typically vegetated. Vegetation should be well established at this interface. Turf reinforcement matting may be used at this interface to provide additional structure for vegetation.
- Vegetation/plantings can be used to obscure views of inlet/outlet protection structures if aesthetics is a concern.