Chapter 5.5

Inlets, Outlets, and Flow Control

There are common structural elements of SCMs that are designed to safely route water. Engineered flow control devices are used to effectively route water at a designed flow rate such that energy is dissipated to decrease erosion potential, protect downstream infrastructure, and/or filter particulates or other pollutants of concern. Flow control devices are used to lower the velocity of stormwater, create storage, provide adequate retention/detention time, and release storage at an acceptable rate. Pretreatment devices are used to treat stormwater in order to protect downstream infrastructure like receiving channels or stormwater control measures. It is the responsibility of the designer to incorporate the appropriate inlet and outlet structures as necessitated by the scale of the SCM and the volume of water being handled.

Inlets and Pretreatment

An inlet is the location where water enters a design element or SCM. Here, flow is either routed into storage, dispersed through an area, or routed to an overflow structure. Most likely, the inlet will need to be designed to accomplish all of these flow scenarios. Sediment and other particulate pollutants cause clogging of pore space and surface sealing. Without adequate percolation and infiltration, the full storage capacity of SCMs is not utilized, which results in failure to meet the runoff reduction volume target. Pretreatment is used when there is potential for solids transport to remove a portion of them before stormwater enters a SCM that relies on a designed percolation and/or infiltration rate.

Splash Pads

Splash pads are concrete structures that are used at the end of concentrated flow to dissipate energy, protect the soil surface, and guide water downhill. A splash pad may be used at various scales of measures such as for a simple downspout that discharges into an infiltration zone or at the end a culvert discharging into a bioretention practice.

Rock Aprons (riprap)

Rock aprons are a constructed layer or facing of stone strategically places to prevent erosion, scour, or sloughing of an earthen structure. Riprap is a certain class of very large aggregate, ranging in diameter from 2 to 42 inches. Riprap should be structurally sound (no cracks) and free of finer materials such as soil, weathered shale aggregates, or organic materials. The resistance of riprap to displacement by flowing water is a function of its weight, size, and shape of the stone as well as its orientation with respect to flowing water. Considerations should be made to place stones in a flow-resisting manner such that the stones won't roll or tumble.

Flow Splitters

SCMs can either be placed in-line or off-line. An on-line SCM will receive all stormwater flow regardless of intensity, with the flows beyond the design volume typically passing through an overflow device. An off-line SCM has a flow splitter at the inlet that diverts the design volume into the SCM and bypasses a certain volume of excess flow around the practice. Flow splitters are most often designed as a weir overflow device placed in a vault as shown in Figure 5.8. The elevation of the overflow weir is most often set at the SCM design volume elevation. That will allow the flow up to the design volume enter the SCM, and the flows in excess of the design volume to split and routed through a bypass device. Splitter boxes with an internal wall baffle and inlet and outlets pipes in association with a ponding practice also accomplish the desired result (Figure 5.9).

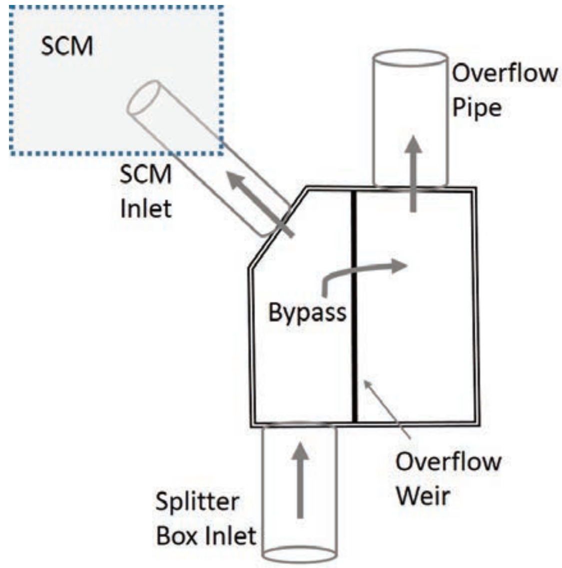

Figure 5.8: Flow splitter box with one inlet, a pipe outfall to the stormwater control measure (SCM) and overflow pipe (Source: MCES, 2001).

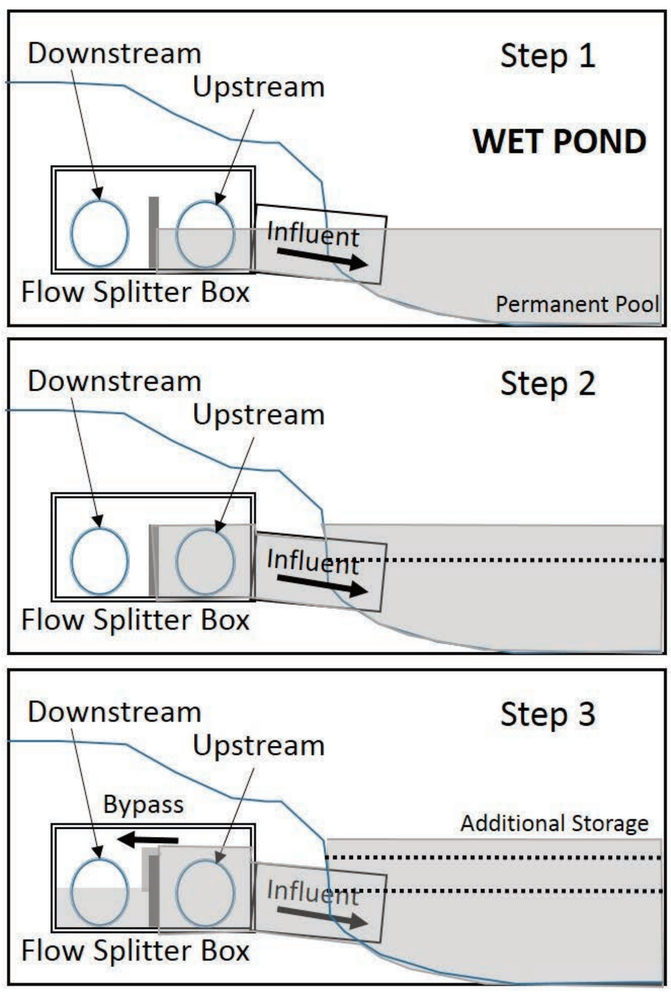

Figure 5.9: Water level progression in flow splitter box leading to a wet pond (Source: MCES, 2001).

The materials in the flow splitting device should be corrosion resistant, such as concrete, aluminum, stainless steel, or plastic. Painted, zinc coated, and galvanized metals should not be used due to their corrosion potential and possible aquatic ecosystem toxicity.

Level Spreaders

A level spreader is a relatively complex structure that can be used at the inlet of an SCM to control inflow as sheet flow and remove particulates for pretreatment. A typical level spreader system consists of pre-treatment (a forebay), principal treatment (e.g., a level spreader with grassed buffer), and emergency treatment (a reinforced grassy swale downslope of spreader). A stilling area such as a forebay is particularly useful upstream of a level spreader, because low energy should be dissipated before the flow enters a level spreader. The forebay will periodically fill with sediment, which must be periodically removed. Level spreaders are preferably made of a non-erodible material (such as poured concrete or wood beams) and must be completely level from one end to the other. The sides and the downstream side of the spreader are of particular concern regarding erosion, so armoring these areas is highly recommended.

Curb Cuts and Diverters

Curb cuts can be used to divert flow from curb-and-gutter type pervious surfaces such as roads and parking lots into a variety of SCMs. The use of a curb cut can avoid the installation of a piped stormwater collection system, however, it does not guarantee sheet flow or proper flow quantity diversion.

Figure 5.10: A curb cut inlet in an ultra-urban setting in downtown Nashville, TN.

Forebays

A forebay is a settling basin at the inlet of an SCM used to dissipate energy of concentrated inflow and settle out large sediments. As deposition is confined to the forebay area, maintenance is simpler and less costly and the life of the SCM is extended. A forebay is required for stormwater treatment wetlands and highly recommended for other practices where sediment loads are a potential concern. Forebay volume should generally be 20% of the total design volume and may be comprised of two zones: 1) a relatively deep inlet area zone for energy dissipation and flow spreading, and 2) a relatively flat and shallow zone for additional settling.

Direct access for maintenance equipment is required and should consist of a hard surface, such as gravel, concrete pavers, etc. The bottom of the forebay should also be a hard surface for ease of finding the bottom during sediment removal. This will minimize the amount of erosion and disturbance to soils and vegetation during maintenance activities. A stage indicator for deposition should be installed to monitor accumulation over time. Sediment should be removed when 25% of the forebay volume is taken up.

A separation structure must be used between the forebay and the remainder of the SCM. This structure may be earthen, rock, rock-filled gabion baskets, or concrete. The forebay should be at a higher elevation than the design volume elevation of the SCM.

Outlets

Outlet devices control the flow of stormwater out of the SCM. The outlet design and elevation are integral to the function of the SCM and/or overall treatment train. Outlets are either the point where outflow leaves a project site or the point to which flow leaves one design element and enters another.

Weirs and Drop Inlets

A weir outlet generally consists of an outlet box of concrete with a free-flowing weir water level control. Weirs can be made of various materials, such as wood, metal, or concrete. Standard weir shapes (v-notch, rectangular, etc.) with given dimensions have a known stage to discharge relationship that can be used to calculate drawdown times and outlet hydrographs.

A drop inlet is a common device for extended detention basins, wetlands, and bioretention cells. A drop inlet allows for the rapid release of water once a design elevation is reached in an SCM. In general, drop inlets also incorporate a lower elevation outlet or designed exfiltration. Drop inlets often consist of a riser structure in the storage area connected to a pipe or box culvert that extends through the containment structure (embankment or dam). The riser acts like a broad-crested weir. To ensure that the assumed weir function of the riser, the head over a weir should not exceed 1/3 of the inlet riser diameter. Above this elevation, the inlet begins to act as an orifice with unpredictable behavior.

Figure 5.11: A drop inlet structure with a perforated riser as the outlet to a bioretention cell in Nashville, TN.

Orifice

An orifice is a hole sized to provide a targeted flow rate given the stage above the orifice elevation. An orifice is used to draw down storage volume over a period of time at a designed rate. A drawdown orifice should always have a turned-down elbow to prevent trash or other materials from clogging the pipe. The SCM-side of an orifice must be protected from debris that may clog as well.

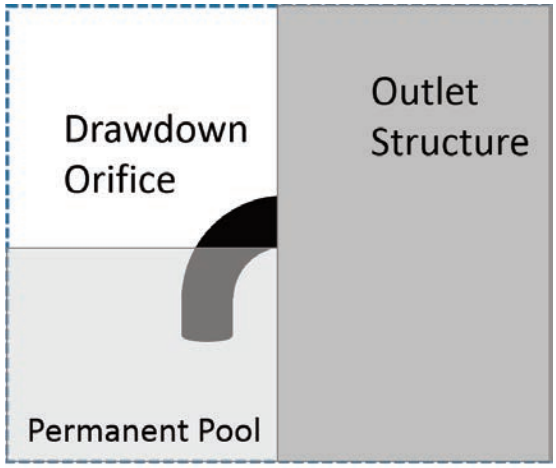

Figure 5.12: A drawdown orifice comprised of a downward turned elbow as part of an outlet structure to prevent clogging.

Underdrains

Underdrains are used to route water from the bottom or and internal elevation of an SCM. Underdrains are 1) made of pipe, 2) should have a minimum slope of 0.5%, 3) are constructed of schedule 40 (or equivalent) smooth wall PVC pipe, and 4) sized to carry 2-10 times the maximum flow expected from the SCM with a minimum diameter of 4 inches. Perforations should extend the length of the pipe with a minimum of 6 inches on center. The underdrain should have a minimum of 3 inches of washed #57 stone above and on all sides of the pipe. It is recommended to have at least 2 inches of choke stone (#89 stone) above the #57 stone and to avoid the use of filter fabric due to its high potential for clogging. Use commonly accepted engineering methods to determine the adequate amount and size of underdrain systems.

Spillways

A spillway is a section of an embankment that is designed to route water from a storage SCM. Spillways can be lined with grass, rip-rap, concrete, or other such materials. Uniform flow may be assumed in the exit channel and there is relatively flat slope (< 10%). Riprap emergency spillways should be considered when design velocities exceed those that are acceptable for vegetated emergency spillways.

Applications

Infiltration zones **–** The flow source to an infiltration zone may be anything from a single rooftop downspout, to a large channel or curb cut. The inlet to this SCM must be designed to protect against erosion, dissipate energy, and spread the flow over the entire design area. This may be accomplished with an inlet control device as simple as a splash pad or rock apron for small contributing areas or, for larger contributing areas, a level spreader. The designer is responsible for ensuring an adequate level of design for inlet control devices as well as for overflow spillway structure when the contributing area is large enough to warrant these measures.

Bioretention – Forebays or other particulate settling devices are strongly encouraged to preserve the function and extend the longevity of bioretention/infiltration practices. If allowed to flow into a bioretention practice, sediment and other particulate pollutants accumulate on the surface, creating a caking effect that seals the surface, clogging pore space within media, or sealing beneath course media layers.

Figure 5.13: Paver inlet area of a bioretention cell that protects the media, dissipates inflow energy, and helps settle large solids for ease of maintenance.

Wetlands – Forebays are required for the implementation of stormwater treatment wetlands for pollutant removal. Forebays are necessary in wetland systems because they provide the following: 1) dissipates the inflow energy, 2) creates a wide area to encourage flow spreading and maximum mixing, and 3) settles out solids that may cake or otherwise disrupt sensitive wetland soils downstream in the cell.

REFERENCES

Metropolitan Council Environmental Services (MCES). 2001. Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates. St. Paul, MN.