- Place bedding material around pipe with at least 3-inches (or as shown on the design) of material on all sides. Place gravel around drains for proper bedding and improved flow of groundwater into the drain.
- Ensure gravel for bedding around flexible pipe does not exceed 3/4 inch in size to prevent damage to the pipe.
- Fold filter cloth over the top of the gravel bedding.
- Backfill immediately after placement of the pipe and bedding. Ensure the material does not contain rocks or other sharp objects and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.
- Install clean-outs for maintenance as shown on the design plan.
- Construct the outlet above the mean water level in the receiving channel as shown in the design plan. For the outlet section of the drain, use at least 10 feet of non-perforated corrugated metal, cast iron, steel or heavy-duty plastic pipe. Cover at least 2/3 of the pipe length with well compacted soil.
- Place a suitable animal guard securely over the pipe outlet to keep out rodents.
- Cap the upper end of each drain with a standard cap made for this purpose, with concrete or with other suitable material to prevent soil from entering the open end.

Erosion Control

- Stabilize any soft, yielding soils under the drain with gravel or other suitable material.
- Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion and wash out from surface runoff.   Apply seed and erosion control to the fill as soon as installation is complete.
- Provide for energy dissipation at the outlet of the pipe (see Energy Dissipators section.)

Safety

Narrow trenches are subject to collapse and can be a safety hazard to persons in the trench. No person should enter a trench without shoring protection or properly sloping the sides of the trench. Follow Occupational Safety and Health Administration, or OSHA, guidelines for trench safety.

Construction Verification

- Verify the dimensions shown on the plans for the following: location and length, depth and cross section of trench.
- The dimensions and specifications of the aggregate used in the bedding and manufactured materials such as pipe, tile or panel drain should be verified.

Maintenance, Inspection and Removal

- Inspect subsurface drains periodically to ensure they are free-flowing and not clogged with sediment.
- Keep outlet clean and free of debris.
- Keep surface inlets open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain. Drains should not be located within the dripline of trees.
- Where drains are crossed by heavy vehicles, inspect the pipe to ensure it is not crushed.
- If this practice is temporary for construction only, it must be removed and the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate subsurface drains will not function as intended.
- Design specifications for aggregate or manufactured products cannot be met; substitutions may be required. Unapproved substitutions could result in failure of the drain to function as intended.
- Sediment discharges into the device clogging it; area draining to the subsurface drain must be stabilized prior to installing the drain.

Common Problems and Solutions

Problem	Solution
Poor drain performance; caused by bedding material that does not allow groundwater to free-drain or does not provide filtration for pipe.	Replace with properly graded material or filter fabric.
Poor drain performance; caused by pipe being crushed by construction traffic.	Replace damaged section of pipe.
Poor drain performance; caused by sediment clogging the pipe or gravel trench.	Stabilize area draining to trench, remove rock, clean out trench, reinstall pipe and clean the bedding material.

Rock Outlets

Figure 6.64 Riprap at the downstream end of a rock outlet should be level with the receiving channel or slightly below it .
It should not restrict the channel or produce an overfall that will result in scouring and erosion.
Source: Becky Holland, NRCS Volunteer. Jackson Co.

Practice Description

A rock outlet is a structure constructed to reduce and dissipate water energy in order to control erosion at the outlet of a channel or conduit. A rock outlet is an apron constructed of adequately sized rock riprap designed to prevent scour where storm water outlets a channel or conduit. It is also intended to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated storm water flows.

This practice applies where the discharge velocity of a pipe, box culvert, diversion or other water conveyance structure exceeds the permissible velocity of the receiving area.

Recommended Minimum Requirements

Prior to start of construction, rock outlets should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The rock outlet should be built according to planned alignment, grade, cross section and length.

Grading

There should be a smooth transition between the rock outlet and the receiving channel; that is, the elevation of the rock apron at the downstream end should be at the same elevation as the bottom of the receiving channel.

Alignment
If possible, the alignment of the rock outlet should be straight throughout its length. If a curve is required, it should be located as closely as possible to where the flow enters the rock outlet.

Riprap
Riprap should consist of a well-graded mixture of rock (a range of sizes). Minimum and maximum rock size is dependent on volumes and velocities of storm water flows exiting the pipe. Larger rock should predominate, with sufficient smaller sizes to fill the voids between the rocks. The diameter of the largest rock size should not be greater than 1.5 times the d_{50} size (diameter of 50 percent of the rock).

Riprap Thickness and Length
Minimum thickness of riprap should be 1.5 times the maximum rock diameter. Length of riprap must be designed such that erosion at the outlet is minimal for receiving material.

Rock Quality
Select rock for riprap from field stone or quarry stone. The rock should be hard, angular and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5 times heavier than water.

High Tensile Strength Geotextile Fabric
Install between the rock riprap and the subgrade to prevent undermining of the structure due to piping of fine-grained subgrade soil.

Toewalls
According to the design plan; may be needed around full perimeter to prevent maintenance problems.

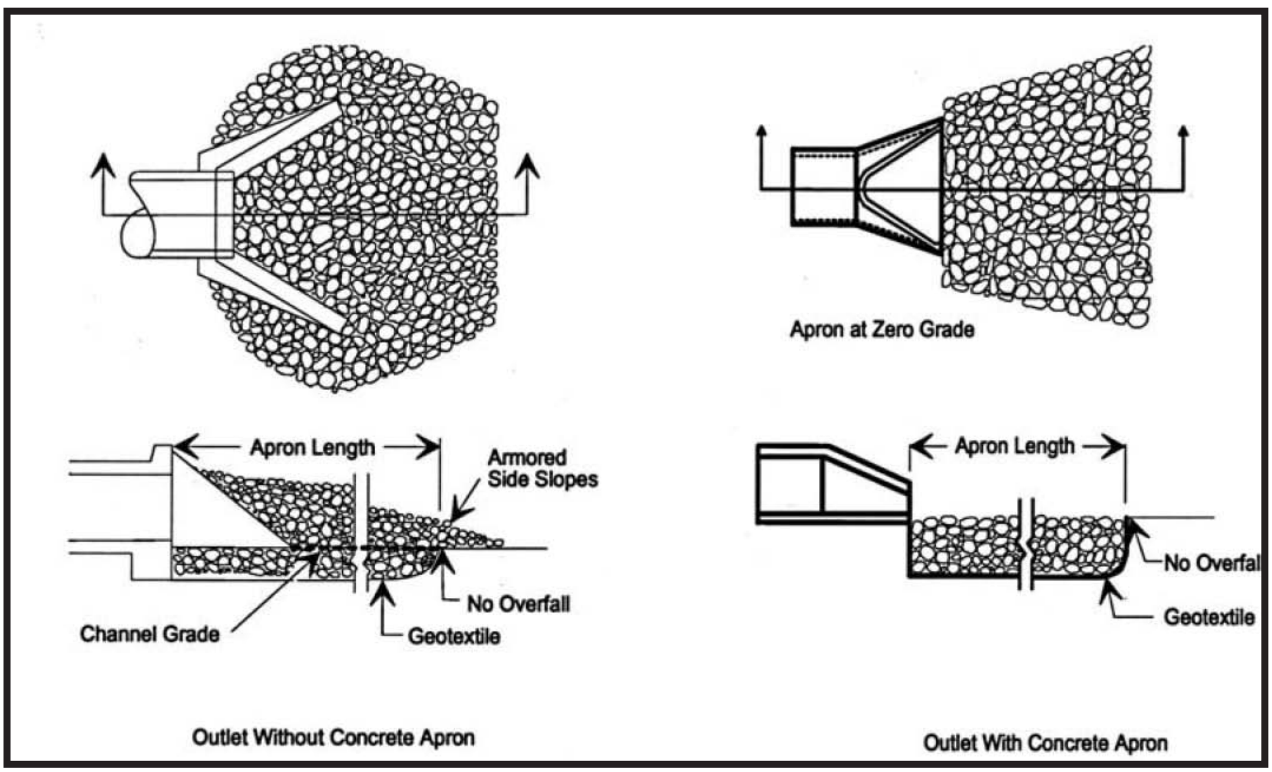

Figure 6.65 Typical rock outlet.

Construction

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Clear trees, stumps, brush, sod and all other unsuitable material that would interfere with construction of the rock outlet.
- Excavate the apron area subgrade below design elevation to allow for thickness of the filter layer and the riprap.
- Compact any fill used in the subgrade to the specified maximum density as determined by testing, and smooth enough to protect fabric (if used) from tearing.

Installation of Geotextile Filter

Place the geotextile fabric on the compacted smooth foundation. If more than one fabric piece is needed, the upstream piece should overlap the downstream piece by at least 1.5 feet in all directions. Staple geotextile fabric at the edges and overlaps to prevent movement during rip rap placement.

If the geotextile fabric tears when placing the riprap, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping the undamaged areas by at least 1.5 feet in all directions.

Installation of Riprap

- Install the riprap to the lines and elevations shown in the design. If there is no defined channel, the final cross-section should be level or slightly depressed in the middle; if well defined, the filter and riprap should extend to the top of the bank.
- Make sure the top of the rock apron is level with or slightly below the receiving stream. (Riprap should not restrict the channel or produce an overfall.)
- Blend the riprap smoothly to the surrounding grade.

Erosion Control

Stabilize all disturbed areas immediately following installation.

Construction Verification

- Check finished grade and configuration of structure.
- Check conformance of materials to specifications.

Maintenance, Inspection and Removal

- Inspect rock outlets after storm events for stone displacement and for erosion at the sides and ends of the apron.
- Make needed repairs immediately; use appropriate size stone, and do not place them above finished grade.
- If this practice is temporary for construction only, it must be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements). Any land disturbance that occurs as a result of permanent retention or removal must be stabilized.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on-site indicate rock outlet will not function as intended; changes in plan may be needed.
- Design specifications for riprap or geotextile cannot be met; substitution may be required. Unapproved substitutions could result in failure of the outlet.
- Rock is displaced downstream after storm event due to too small size of stone for the volume and velocities.

Common Problems and Solutions

Problem	Solution
Erosion around the apron and scour holes at the outlet; caused by foundation not excavated deep enough or wide enough or riprap restricts the flow cross section.	Remove filter and riprap, widen or deepen channel, replace filter and riprap.
Downstream erosion; caused by rock apron not on zero grade.	Modify grade or install grade stabilization measures at downstream edge of apron.
Rock displacement; caused by riprap installed smaller than specified.	Selective grouting over the rock materials may stabilize the situation, or replace riprap with larger size.
Downstream erosion; caused by riprap not extended enough to reach a stable section of channel.	Extend length of outlet.
Rock is displaced downstream after a storm event; rock is too small.	Needs to be redesigned.
Stone displacement and erosion of the foundation; caused by no filter installed under the riprap.	Remove riprap and install filter.

Compost Blankets, Berms and Socks

Compost has been viewed as a valuable soil amendment for centuries. Compost-enriched soil can also be used in practices that reduce erosion, control sediment runoff and alleviate soil compation. See Appendix G *Innovative Uses of Compost: Erosion Control, Turf Remediation and Landscaping*. EPA 350-F-97-043.

Compost Blankets

A compost blanket is a layer of loosely applied compost or composted material placed on the soil in disturbed areas to control erosion and retain sediment resulting from sheet-flow runoff.

Compost blankets can be placed on any soil surface:

- Rocky
- Frozen
- Flat
- Steep.

Figure 6.66 Applying a compost blanket in a new housing development. Source: Iowa Natural Resource Conservation Service, Urban Conservation Photo Gallery www.ia.nrcs.usda.gov/features/

The method of application and the depth of the compost applied will vary depending upon slope and site conditions. It can be used in place of traditional sediment and erosion control tools such as mulch, netting, or chemical stabilization. When properly applied, the erosion control compost forms a blanket that completely covers the ground surface. The compost blanket can be vegetated by incorporating seeds into the compost before it is placed on the disturbed area or the seed can be broadcast onto the surface after installation.

Compost blankets prevent storm water erosion by:

- Presenting a more permeable surface to the oncoming sheet flow, facilitating infiltration.
- Filling in small rills and voids to limit channelized flow.
- Promoting establishment of vegetation on the surface.

Compost blankets are most effective when applied on slopes between 4:1 and 1:1, such as stream banks; road embankments; and construction sites, where storm water runoff occurs as sheet flow. Compost blankets are not applicable for locations with concentrated flow. Because the compost is applied to the ground surface and not incorporated into the soil, a compost blanket provides excellent erosion and sediment control on difficult terrain, Including steep, rocky slopes.

Installation and Maintenance

- The compost should be applied to the soil surface in a uniform thickness, usually between 1- and 3-inches thick.
- The compost can be distributed by hand using a shovel or by mechanical means such as a spreader unit. The compost blanket should extend at least 3 feet over the shoulder of the slope to ensure storm water runoff does not flow under the blanket.
- Although seed can be broadcast on the compost blanket after installation, it is typically incorporated into the compost before it is applied, to ensure even distribution of the seed throughout the compost and to reduce the risk of the seed being washed from the surface of the compost blanket by stormwater runoff.
- In some applications, better sediment and erosion control can be achieved by using the compost blanket in conjunction with another best management practice, (e.g., lock-down netting, compost filter berms, or compost filter socks).

Figure 6.67 Applying a compost blanket on the side of a highway construction site. Source: *University of Georgia, Extension Learning, Bulletin 1200 Compost Utilization for Erosion Control*, May 2009

- Lock-down netting will help hold the compost in place, while compost filter berms or compost filter socks placed across the slope will slow down the flow of water. Compost filter berms or filter socks can also be placed at the top and bottom of the embankment.
- The compost blanket should be checked periodically and after each major rainfall.
- If areas of the compost blanket have washed out, another layer should be applied. In some cases, it may be necessary to add another storm water best management practice, such as a compost filter sock or sediment fence.
- On slopes greater than 2:1, establishing thick, permanent vegetation as soon as possible is the key to successful erosion and sediment control.
- Restricting or eliminating pedestrian traffic on such areas is essential.

Compost Filter Berms

Compost filter berms are contoured runoff and erosion filtration methods usually used for steeper slopes with high erosive potential. The berm allows runoff water to penetrate it and continue to flow while filtering sediment and pollutants from the water. It also slows the flow down, allowing soil particles to settle out. Berms work well in many of the same areas as blankets but are the preferred method if the slope exceeds a 4:1 gradient.

A compost filter berm is a dike of compost or a compost product placed perpendicular to sheet flow runoff to control erosion in disturbed areas and retain sediment. It can be used in place of a traditional sediment and erosion control tool such as a silt fence. The compost filter berm, which is trapezoidal in cross section, provides a three-dimensional filter that retains sediment and other pollutants while allowing the cleaned water to flow through the berm. Composts used in filter berms are made from a variety of feedstocks, (e.g., municipal yard trimmings, food residuals, separated municipal solid waste, biosolids and manure).

Figure 6.68 Source: University of Georgia, Extension Learning, *Bulletin 1200 Compost Utilization for Erosion Control*, May 2009

Compost filter berms are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat storm water that runs off as sheet flow. A filter berm also can be used as a check dam in small drainage ditches. The berms can be vegetated or unvegetated. Vegetated filter berms are normally left in place and provide long-term filtration of storm water as a post-construction best management practice. Unvegetated berms are often broken down after construction is complete and the compost is spread around the site as a soil amendment or mulch.

Filter berms installed to control erosion and sediment on a slope or near the base of a slope are trapezoidal in cross section, with the base generally twice the height of the berm. The height and width of the berm will vary depending upon the precipitation of the site. Modify the compost filter berm dimensions based on site-specific conditions, such as soil characteristics, existing vegetation, site slope and climate, as well as project-specific requirements.

Installation and Maintenance Activities

- The compost should be uniformly applied to the soil surface, compacted, and shaped to into a trapezoid. Compost filter berms can be installed on frozen or rocky ground.
- The filter berm may be vegetated by hand, by incorporating seed into the compost prior to installation (usually done when the compost is installed using a pneumatic blower or mixing truck with a side discharge), or by hydraulic seeding following berm construction. Proper installation of a compost filter berm is the key to effective sediment control.
- The compost filter berms should be inspected regularly, as well as after each rainfall event, to ensure they are intact and the area behind the berm is not filled with silt.
- Accumulated sediments should be removed from behind the berm when the sediments reach approximately one third the height of the berm.
- Any areas that have been washed away should be replaced. If the berm has experienced significant washout, a filter berm alone may not be the appropriate best management practice for this area.
- Depending on the site-specific conditions, the site operator could remedy the problem by increasing the size of the filter berm or adding another best management practices in this area, such as an additional compost filter berm or compost filter sock, a compost blanket or a silt fence.

Limitations

Compost filter berms can be installed on any type of soil surface. However, remove or cut down heavy vegetation to ensure the compost contacts the ground surface. Filter berms are not suitable for areas where large amounts of concentrated runoff are likely, such as streams, ditches or waterways, unless the drainage is small and the flow rate is relatively low.

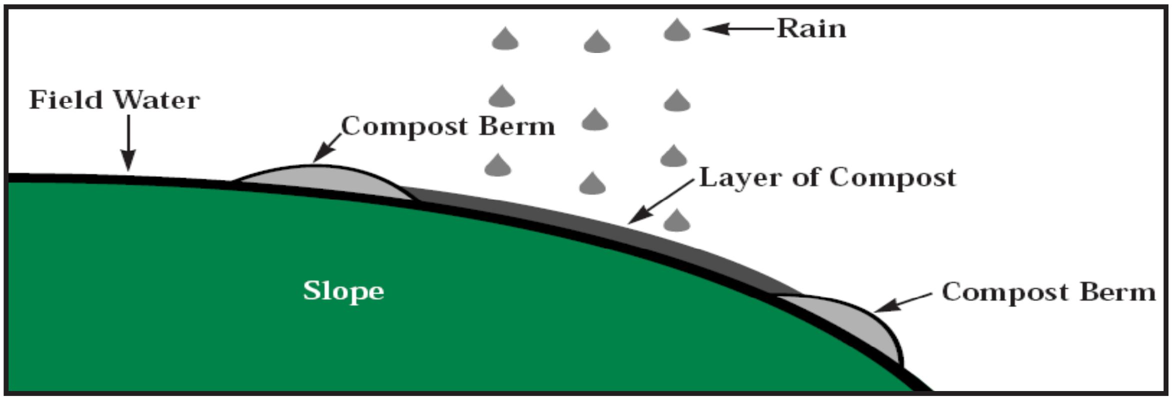

Figure 6.69 Source: *EPA Innovative Uses of Compost Erosion Control, Turf Remediation and Landscaping,* EPA530-F-97-043, Oct. 1997

Compost Filter Socks

Compost filter socks are applicable to construction sites or other disturbed areas where storm water runoff occurs as sheet flow. It is a mesh tube filled with composted material placed perpendicular to sheet-flow runoff to control erosion and retain sediment in disturbed areas. The compost filter sock, which is oval to round in cross section, provides a three-dimensional filter that retains sediment and other pollutants while allowing the cleaned water to flow through. Composts used in filter socks are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids and manure.

Compost filter socks offer a large degree of flexibility for various applications. To ensure optimum performance, remove or cut down heavy vegetation. Level extremely uneven surfaces to ensure the compost filter sock uniformly contacts the ground surface. Filter socks can be installed perpendicular to flow in areas where a large volume of storm water runoff is likely, but should not be installed perpendicular to flow in perennial waterways and large streams. Compost filter socks are often used in conjunction with compost blankets to form a storm water management system. Together, these two best management practices retain a very high volume of storm water, sediment and other pollutants.

Figure 6.70 Installation of filter socks in a road ditch by Indiana Department of Transportation. The filter socks will be staked through the center.
Source: *EPA NPDES Stormwater Menu of BMPs, Compost Filter Socks.*

Compost filter socks can be vegetated or unvegetated. Vegetated filter socks can be left in place to provide long-term filtration of storm water as a post-construction best management practice. The vegetation grows into the slope, further anchoring the filter sock. Unvegetated filter socks are often cut open when the project is completed and the compost is spread around the site as soil amendment or mulch. The mesh sock is then disposed of unless it is biodegradable.

Compost filter socks are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat storm water that runs off as sheet flow. Filter socks are flexible and can be filled in place or filled and moved into position, making them especially useful on steep or rocky slopes where installation of other erosion control tools is not feasible. There is greater surface area contact with soil than typical sediment control devices, thereby reducing the potential for runoff to create rills under the device or create channels carrying unfiltered sediment.

Common industry practice for compost filter devices is drainage areas do not exceed 0.25 acre per 100 feet of device length and flow does not exceed one cubic foot per second. Additionally, they can be laid adjacent to each other, perpendicular to storm water flow, to reduce flow velocity and soil erosion. Filter socks can also be used on pavement as inlet protection for storm drains and to slow water flow in small ditches. Filter socks used for erosion control are usually 12 inches in diameter, although 8 -, 18 - and 24-inch diameter socks are used in some applications.

Installation and Maintenance Activities

- No trenching is required; therefore, soil is not disturbed upon installation. After the filter sock is filled and put in place, anchor it to the slope. The preferred anchoring method is to drive stakes through the center of the sock at regular intervals; alternatively, stakes can be placed on the downstream side of the sock.
- Direct the ends of the filter sock upslope to prevent storm water from running around the end of the sock – meaning storm water should flow over the middle area of the filter sock. The sock should not create a dam that causes water to flow around it.
- The filter sock may be vegetated by incorporating seed into the compost prior to placement in the filter sock. The compost retains a large volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the filter sock.
- Inspect compost filter socks regularly, as well as after each rainfall event, to ensure they are intact and the area behind the sock is not filled with sediment.
- If there is excessive ponding behind the filter sock or accumulated sediments reach the top of the sock, add an additional sock on top or in front of the existing filter sock in these areas, without disturbing the soil or accumulated sediment.
- If the filter sock was overtopped during a storm event, the operator should consider installing an additional filter sock on top of the original, placing an additional filter sock further up the slope, or using an additional best management practice, such as a compost blanket in conjunction with the sock(s).

Transition Mats

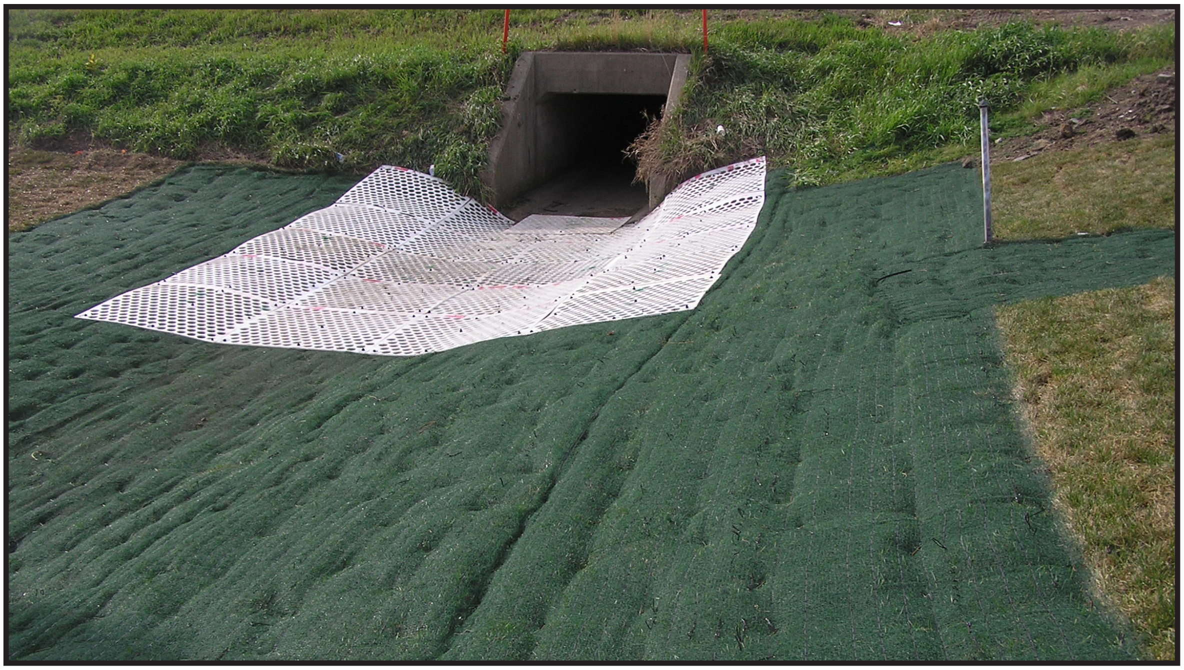

Figure 6.71 Transition mat as an alternative to rip rap. Source: Erosion Tech LLC

Practice Description

A transition mat is a biotechnical alternative for rip rap. It is a mechanically-anchored 4 x 4 feet x .5 inch semi-rigid, polymer mat designed with voids throughout the structure that enables vegetative growth. Transition mats provide mechanical protection over highly-erosive areas, like storm water pipe outfalls, curb outfalls, over-flow structures and shorelines. Transition mats do not dissipate energy by impact, but mechanically protect the critical area until the high energy forces have dissipated as the storm flow exits further from the pipe discharge point. The resulting downstream forces are managed by appropriate soil covers calculated and specified as part of the transition mat engineered system. Transition mats provide resistance against much greater shear stress and velocities than vegetation alone or rock rip rap, and they are comparable in performance to Articulated Concrete Blocks. Vegetation provides many aesthetic, functional and synergistic benefits, but is not required for transition mat performance.

Recommended Minimum Requirements

Prior to start of construction, a vegetated occasional-overflow structure should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

- Transition mats must be used in combination over other soil covers:
  - Sod.
  - Sod and turf reinforcement mats.
  - Hybrid mats (e.g., geo-textile mat combinations where vegetation is unlikely).
- Design for the use of sod when feasible, to achieve the benefits of vegetation immediately. Design parameters prefer sod, or a combination of sod and transition mat in regions with adequate rainfall to ensure the best installation and performance possible.

- Specified anchors are essential to performance. Staples are not allowed. Anchor transition mats for consistent contact over the entire surface.
- Follow installation guidelines. Certified installers are preferred. Include an installation worksheet for each storm water outlet.
- See specifications for either cohesive or non-cohesive soils.
- Grade a level and smooth the soil surface at the scour area to avoid water concentration to create an appropriate base for the scour prevention measures. Install materials at or below the surface of the outlet. (The transition mat may be permanently attached over the surface of the discharge outlet.)
- Design for as much channel expansion as possible to help reduce velocities and increase infiltration potential.

Construction

Soil Cover Options

The transition mat has several installation types:

Type A - Over Sod

Most storm water pipe outlets and parking lot outlets are good applications for transition mats over sod. Sod provides immediate soil protection and eliminates any risk of poor seed germination. Additional uses include occasional overflow structures and streambank protection preserving the natural landscape aesthetics.

Type B - Over Sod and Transition Mat

Transition mats over a sod and an open-weave transition mat combination for a higher level of protection, especially on slopes greater than 10 percent. Sod eliminates the germination issue of a plain transition mat installation. Appropriate locations would be 24- to 72+-inch storm water pipes, high flow parking lot outlets and streambank restoration.

Type C - Over a Transition Mat

Transition and transition reinforcement mats over bare soil (including composite mats). The flows should be less than 3-feet per second and the area fairly level to minimize concentrated erosive forces. A rural culvert outlet might be an appropriate application, or erosion protection at a temporary construction outlet. Maximum pipe size would generally be 24-inches for an open-weave mat, and up to 48-inches for a high-performance composite mat.

Type D - Over a Geotextile/Transition Mat

In a stream bed or shoreline application where vegetation is unlikely, or where vegetation may be delayed for whatever reason; use a 3 to 4 oz. geotextile for soil retention and soil protection under the transition mats. Above the normal-water line, use Type A or B to protect the slope bank from boat or wind wave erosion.

See manufacturer specifications for detailed installation guidelines.

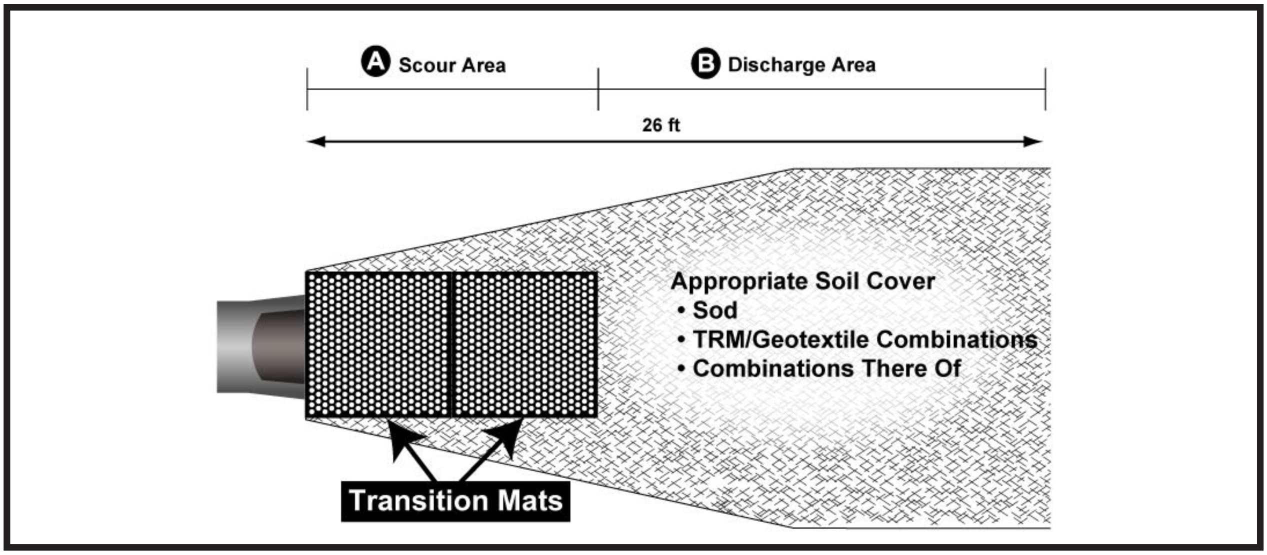

Figure 6.72 Transition Mat Detail Source: Erosion Tech LLC

Maintenance Inspection and Removal

- Transition mats are generally permanent installations, and maintenance should not be necessary.
- Until vegetation is established, inspect during construction on a weekly basis and after storm events. Remove accumulated sediment from the mat.

Troubleshooting

Consider sub-surface drainage for trickle flows, such as irrigation overcharge. Installations with continuous low flows, such as irrigation over charge, should use a sub-surface drainage system directly downstream of the outlet to drain that low flow from the surface, thus allowing vegetation to properly establish. Of course, an adequate slope is required for a sub-drain system.

- Calculate the downstream velocity and protect the channel using appropriate mats or sod. Mechanical flow dissipators or check dams may be appropriate during the germination period when seeding transition mats.
- Channel slopes restricting expansion require protection.
- Do not install at slope changes greater than 25 percent between the discharge area and the downstream channel that create impact or waterfall erosion.

Common Problems and Solutions

Problem	Solution
Erosion at the end or along sides of the mat; caused by insufficient mat size.	Consult a design professional and have new, larger mat installed.
Insufficient vegetation growth through mat; caused by inadequate or contaminated topsoil or trickle flows over saturating the soils.	Check soil below the transition mat for good topsoil, reseed and reinstall the turf reinforcement mat and transition mat.
Insufficient vegetation growth through mat; caused by poorly drained soil.	Consider installation or underdrain, reseed and reinstall the turf reinforcement mat and transition mat.

Temporary Sediment Trap

Figure 6.73 Sediment traps are used to collect sediment laden runoff from disturbed areas on construction sites. Source: EPA

Recommended Minimum Requirements

Prior to start of construction, sediment traps should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The sediment traps should be built according to planned grades and dimensions.

Location

- Where access can be maintained for sediment removal and proper disposal.
- Where runoff can be directed into basin at low velocity.

Drainage Area

- Below areas less than 5 acres in size. If the drainage area is larger, construct a sediment basin (see Sediment Basin).
- In the approach to a storm water inlet located below a disturbed area as part of an inlet protection system.
- Where failure of the structure will not result in loss of life, damage to homes, commercial or industrial buildings, main highways or railroads; or in the use or service of public utilities.

Structure Life

Limited to 18 months.

Sediment Storage
A minimum of 3,600 cubic square per acre of drainage area or sufficient to safely pass run-off greater than the two year frequency, 24-hour duration or design storm event.

Embankment
Dam Height
Less than five feet.

Top Width
At least five feet.

Fill Slopes
2.5:1 or flatter.

Settlement
10 percent or less.

Fill Material
Locally available soil; machine compacted in 8-inch lifts; moist when compacted; free of organic material, tree roots and waste material.

Spillway
A rock-lined open channel spillway should be constructed in the embankment to safely pass stormwater runoff. As an option, a perforated outlet riser can be used as the principal spillway.

Capacity
Sufficient to safely pass runoff from the two year frequency, 24-hour duration or design storm event.

Bottom Width
At least five feet.

Crest
A minimum of 18-inches lower than the top of the embankment.

Outlet
Include an apron at least five feet long to dissipate energy.

Filter
Geotextile should be placed between the embankment soil and the rock in the spillway section.

Construction
Site Preparation
- Locate the temporary sediment trap in an upland area as close to the sediment source as possible, considering soil type, pool area, dam length and spillway conditions.
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements on impoundment sites.
- Clear, strip and grub the foundation of the dam to minimum depth of 4-inches, removing all woody vegetation, rocks and other objectionable material. Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Divert off-site run-on from all undisturbed areas away from the sediment trap.
- Excavate the sediment trap (if necessary), stockpiling and stabilizing any surface soil having high amounts of organic matter for later use.

Embankment

- Scarify the base of the embankment before placing fill.
- Use fill from predetermined borrow areas. Fill should be clean, stable mineral soil free of organics, roots, woody vegetation, rocks and other debris, and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Compact the fill material in 8-inch continuous layers (maximum) over the length of the dam. (One way is by routing construction equipment over the dam so each layer is traversed by at least one wheel of the equipment.)

Open Channel Spillway

- Excavate a trapezoidal outlet section in the compacted embankment.
- Install geotextile fabric on the base of the channel, extending it up the sides to the top of the embankment.
- Place specified stone to the lines and grades, working smaller stones into voids to achieve a dense mass. The spillway crest should be level with a minimum width of five feet.
- Construct a stone outlet apron below the toe of the dam on level grade until a stable condition is reached (5-feet minimum).
- The base of the stone outlet should be at least two feet thick.
- Make the edges and end of the stone apron section flush with the surrounding ground.
- Cover the inside face of the stone outlet section with a 1-foot layer of well graded stone (2-inch minus).

Set a clean-out measurement stake in the basin at a height equal to one-half the distance from the bottom to the spillway crest.

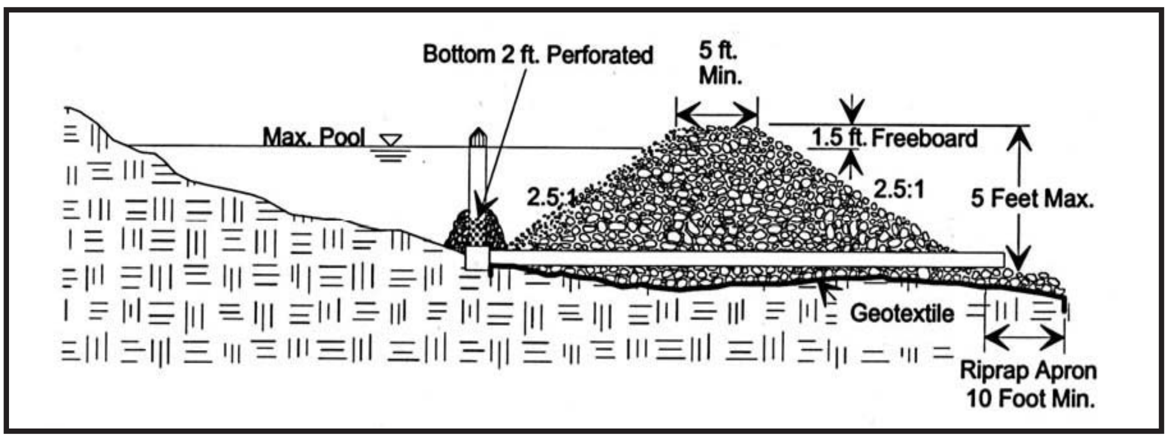

Figure 6.74 Temporary Sediment Trap with Spillway Riser

Optional Spillway Riser Construction

- Clear all vegetation and roots from the pipe foundation; prepare the bedding.
- Situate the spillway pipe and riser (minimum 18-inch diameter) on a firm, even foundation.
- Align the pipe and construct with the bell end of the pipe facing upstream. Around the barrel, place a 4-inch layer of moist, clayey, workable soil (not pervious material, such as sand, gravel, or silt), and compact with hand tampers to at least the density of the foundation soil. Don’t raise the pipe from the foundation when compacting under the pipe haunches. Connect the pipe to the riser.

- Perforate the bottom 2 feet of spillway riser with 1/2 inch diameter holes spaced 3-inches apart (or use a manufactured perforated riser) for draining the sediment trap. Wrap the riser with geotextile fabric.
- Embed the riser at least 12-inches into concrete. The weight of the concrete should balance the buoyant force acting on the riser. Buoyant Force = Volume of Riser x 62.4 lbs./ft.^{3}
- Surround the entire riser with two feet of clean uniformly graded stone.
- At the pipe outlet, install a riprap apron at least five feet wide and 10 feet long. The riprap should be a minimum of 6-inches in diameter (see Rock Outlets).
- Dewatering can also be accomplished with a skimmer (see Skimmers).

Erosion Control

- The size of disturbed areas should be minimized. Stabilize all disturbed areas immediately after construction. Establish vegetation and erosion controls within 14 days after construction is complete.
- Divert sediment-laden water to the upper end of the temporary sediment trap to improve trap effectiveness.
- Direct all runoff into the basin at low velocity.

Safety

Because temporary sediment traps will likely impound water, the following precautions should be taken:

- Avoid steep slopes; the slopes around the temporary sediment trap should be 2.5:1 or flatter; 3:1 if maintained by tractors or other machinery.
- Fence area and post warning signs if trespassing is likely.

Construction Verification

- Check finished grades and dimensions of the temporary sediment trap.
- Check materials for compliance with specifications.

Maintenance, Inspection and Removal

- Inspect the temporary sediment trap weekly and after each storm event.
- Remove and properly dispose of sediment on an upland area to dry and be stabilized when it accumulates to one-half the design volume, as indicated by the clean-out stake.
- Periodically check the embankment, spillway and outlet apron for erosion damage, settling, seepage or slumping along the toe, and repair immediately.
- Replace the spillway gravel facing if it becomes clogged.
- Inspect vegetation and reseed if necessary.
- Replace any displaced riprap, being careful no replacement rock is above the design grade.
- Remove the temporary sediment trap after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water, removing the sediment to a designated disposal area, grading the site to blend with the surrounding area; then stabilize.
- Remove the temporary sediment trap and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate sediment trap will not function as intended.
- Design specifications for fill, pipe, seed variety or seeding dates cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Common Problems and Solutions

Problem	Solution
Embankment overtopping and possible failure of the structure; caused by inadequate spillway size.	Increase size of spillway.
Overtopping and possible failure; caused by extensive embankment settling.	Add additional fill to bring embankment back to design grade.
Erosion and displacement of rock; caused by rock outlet apron not extending to stable grade.	Extend apron.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or rock size in spillway too small.	Improve vegetation, incorporate rolled erosion control product, or replace rock with larger size.
Settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Add fill in settled areas to restore embankment to original grade.
Structural failure; caused by inadequate compaction due to construction with dry soil.	Replace failed material and compact to original grade.
Slumping failure; caused by overly steep slopes.	Repair damage and flatten slope without reducing the storage volume.
Piping failure; caused by too steep of a slope between stone spillway and earth embankment.	Flatten slope, then repair piping damage.
Inadequate storage capacity; caused by sediment not being properly removed.	Remove sediment on a regular schedule.
Inadequate storage capacity; caused by having a greater are a contributing sediment than originally designed.	Stabilize the disturbed area contributing to the trap or regrade the construction site and add additional traps to better distribute sediment laden storm water among the traps to handle the sediment discharging to the drainage area.
Safety or health hazard; caused by ponded water due to sediment clogging the gravel on the upstream slope of the riprap.	Remove sediment and install security fence if necessary.

Energy Dissipators

Figure 6.74 Energy dissipators reduce flow velocities so water can exit at nonerosive rates. Source: C. Rahm, NRCS St. Charles Co.

Practice Description

An energy dissipater is a physical structure intended to reduce the erosive energy typically encountered down grade from a pipe or culvert. Erosive energy from intense flows may also be encountered in median ditches or road ditches. Energy dissipation may be accomplished by the installation of large boulders, wood pilings, engineered concrete structures or other means approved by the engineer. Unlike ditch checks and rock dams, energy dissipaters are not intended to impound water and sediment. Energy dissipaters must be constructed in a fashion such that the water that flows through, over or around the structure is equally distributed in the discharge channel and does not exacerbate or cause a resultant erosion problem.
(Source MoDOT 806.8)

Recommended Minimum Requirements

Prior to the start of construction, energy dissipators should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Capacity

Ten year peak runoff or the design discharge of the water conveyance structure, whichever is greater.

Size:

The energy dissipators should be specifically designed for the velocities and application. It must be long enough to dissipate runoff energy. The width should be designed to match the configuration of the receiving channel.

Riprap Structures

Apron

Should have zero grade with no overfall at the end of the apron.

Alignment

Should be straight throughout its entire length, but if a curve is necessary to align the structure with the receiving stream, locate the curve in the upstream section of the structure.

Riprap

Riprap should consist of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be not greater than 1.5 times the d_{50} size.

Riprap Thickness

Minimum thickness of riprap should be 1.5 times the maximum stone diameter.

Stone Quality

Select stone for riprap from field stone or quarry stone. The stone should be hard, angular and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5 times heavier than water.

Filter

Install a filter to prevent soil movement through the openings in the riprap.

The filter should consist of a graded gravel layer or a synthetic filter cloth.

Concrete Structures

Requirements for concrete structures will vary according to the specific design configuration. The structure should conform to the dimensions, grades and alignments shown on the plans and specifications.

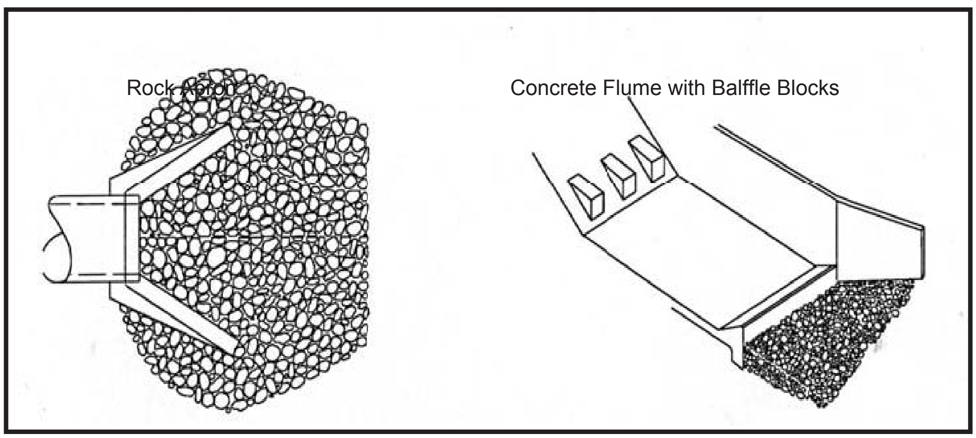

Figure 6.75 Common energy dissipators.

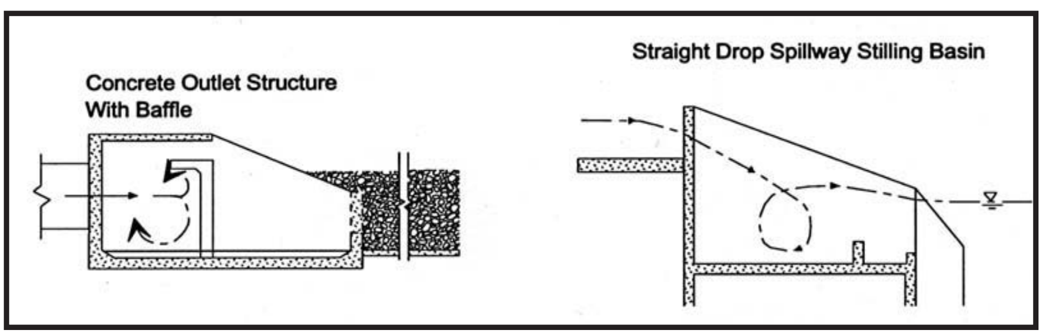

Figure 6.78 More Common Energy Dissipators

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Completely remove stumps, roots and other debris from the construction area. Fill depressions caused by clearing and grubbing operations with clean, non-organic soil.
- Grade the site to the lines and grades shown on the plans. Compact any fill required in the subgrade to the density of the surrounding undisturbed material.

Riprap Structures

- Ensure the subgrade for the geotextile and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.
- Filter cloth must meet design requirements and be properly protected from penetration or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet. If the damage is extensive, replace the entire filter cloth.
- Riprap may be placed by equipment. Care should be taken to avoid damaging the filter.
- Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.

Concrete Structures

- Reinforcing steel should be placed in strict accordance with the design plans and maintained in the proper position during the pouring of concrete. Concrete should be placed in horizontal layers not exceeding 24-inches in thickness or as specified in the design, and consolidated by mechanical vibrating equipment supplemented by hand-spading, rodding or tamping.
- Concrete should be placed in sturdy wood or metal forms, adequately supported to prevent deformation. Forms should be oiled prior to placement to prevent bonding between concrete and forms.
- If possible, concrete should not be placed during inclement weather or periods of temperature extremes. If temperature extremes cannot be avoided, American Concrete Institute guidelines for placement of concrete during such extremes should be consulted.
- Concrete should be allowed to cure as called for in the plans and specifications. Typically, the surface should be kept wet during curing by covering it with wet burlap sacks or other means. Design strengths should be confirmed by laboratory tests on representative cylinders made during concrete placement. Form work should be left in place until the concrete attains design strength.

Erosion Control

Immediately after construction, stabilize all disturbed areas with vegetation.

Construction Verification

Check finished structures for conformance with design specifications.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate energy dissipator will not function as intended.
- Design specifications for riprap, filter fabric, concrete, reinforcing steel or backfill cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance, Inspection and Removal

- Inspect riprap outlet structures weekly and after rain events to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Check concrete structures for cracks and movement. Immediately make all needed repairs to prevent further damage.
- These are permanent structures which are not removed when construction is complete unless the structure is temporary and also removed.
- If the energy dissipator is temporary for construction only, it must be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Riprap Structures	
Erosion around the apron and scour holes at the outlet due to riprap restricting the flow cross section.	Remove filter and riprap, widen or deepen channel, replace filter and riprap.
Erosion at downstream end.	Modify grade or install grade stabilization measures at downstream edge of apron.
Rock displacement	Replace riprap with larger size.
Stone displacement and erosion of the foundation.	Remove riprap and install filter; replace riprap.
Concrete Structures	
Movement of base, cracking or complete failure of the concrete structures due to poor foundation preparation.	Inspect foundation thoroughly before concrete placement.
Excessive spalling, cracking or erosion of concrete surface due to concrete poured during inclement weather conditions.	Prohibit placement during inclement weather or follow accepted guidelines for such conditions.
Low strength, cracking, spalling or other undesirable conditions due to concrete not meeting specification.	Remove existing materials and reinstall after performing sufficient testing to verify concrete specifications.

Rock Check Dam

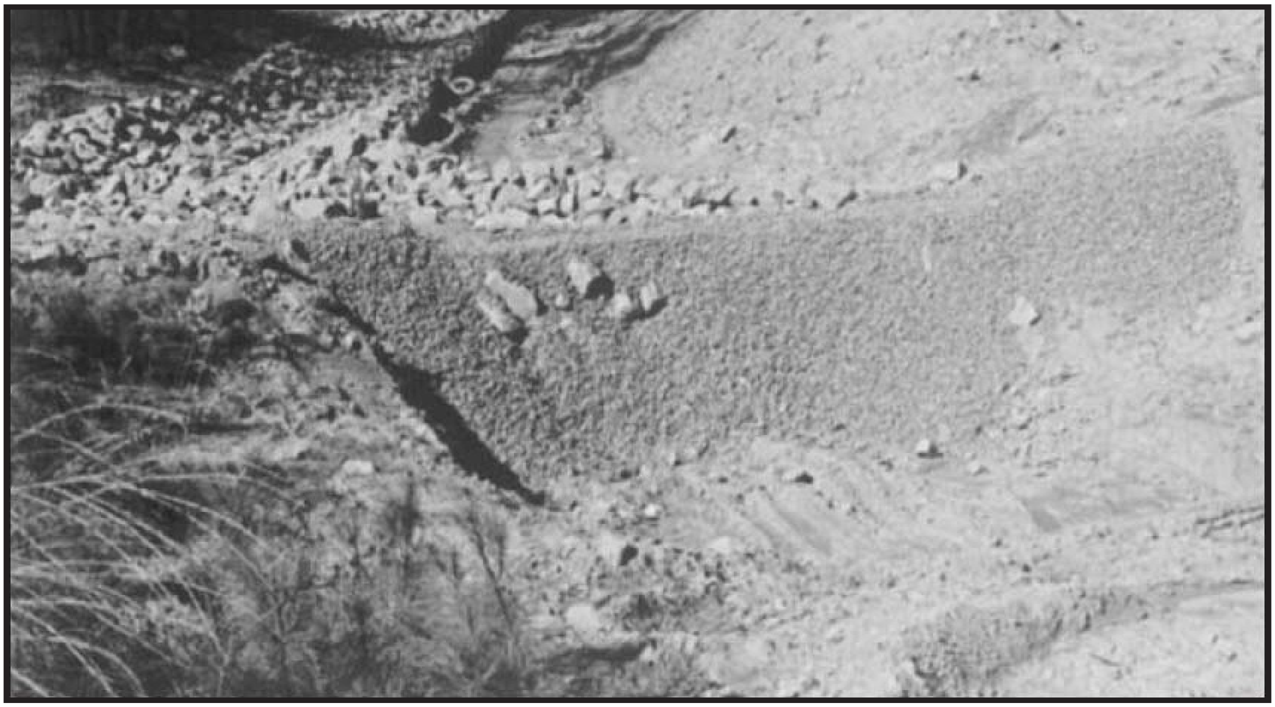

Figure 6.79 Rock check dams can provide sediment control in channels and swales.   Source ABC of BMPs, LLC

Practice Description

A rock check dam is a stone dam designed to capture sediment within drainage swales and diversions on the construction site. This practice can be used as an alternative to a standard sediment basin for locations with a drainage area of 20 acres or less. It may be preferred over standard sediment basins for sites where an earthen embankment would be difficult to construct.

Recommended Minimum Requirements

Prior to start of construction, rock check dams should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The rock check dam should be built according to planned grades and dimensions.

The major design elements include:

- Middle of the check dam is the lowest point where stormwater flow will go over the check dam. Make sure the ends are at a higher elevation than the middle.
- The downhill side slope of the check dam has a longer angle of repose to dissipate the energy of the stormwater flow over the dam to prevent scour on the downstream side of the check dam.
- The spacing between check dams is such that the bottom of the upper check dam is at the same elevation as the top of the check dam below it. This will not allow the stormwater flow to increase velocity as it goes down the slope but make the feature more like a stair step journey.

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Divert runoff from undisturbed areas away from the rock check dam and basin area.
- Do not divert toward existing buildings or houses.
- Stabilize the diversion, swale or channel with vegetation or a turf reinforcement mat to prevent or minimize erosion of the channel.

Construct the check dams as shown in the Figure 5.89 and remember the following three design principals:

- The middle of the check dam is the lowest point so the storm water flow is directed to the middle of the channel.
- The down gradient side of each check dam is at a lower angle to allow for energy dissipation of the storm water flow over the check dam to reduce the potential for scour.
- Space the check dams so the elevation of the bottom of the upper check dam at the same elevation as the top of the lower check dam. This allows water to pond back to the check dam above it to reduce velocity and create a stair step cascade of the storm water flow.

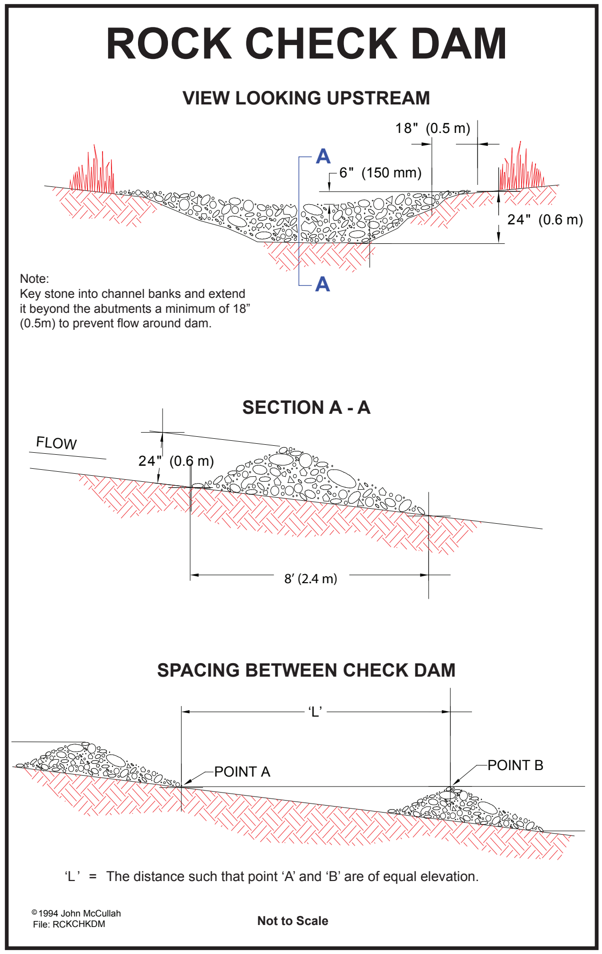

Figure 6.80 Detail of Rock Check Dam

Safety

Because rock check dam sediment basins impound water, they should be considered potentially hazardous. Take the following precautions:

- Avoid steep slopes; both cut and fill slopes should be 2.5:1 or flatter; 3:1 where maintained with tractor or other equipment.
- Fence area and post warning signs if trespassing is likely.
- Do not construct directly above structures that could be damaged in the event of failure.

Construction Verification

Check finished grades and dimensions of the rock check dam. Check materials for compliance with specifications.

Maintenance, Inspection and Removal

- Inspect the rock check dams weekly and after each storm event as required by your permit.
- Remove sediment when it accumulates to half the design volume.
- Check the dam and abutments for erosion, piping or rock displacement and repair immediately.
- If the channel does not drain between storms, replace the stone on the upstream face of the dam.

- After the construction site has become permanently stabilized:
  - Remove all temporary check dams and any unstable sediment.
  - Smooth the site to blend with the surrounding area and stabilize.
  - Remove all water and sediment from the basin prior to dam removal.
  - Place the sediment in designated disposal areas and is not allowed to flow into streams or drainage ways during structure removal.
  - Leave check dams in place if they are designed as permanent structures.
- Remove of this temporary rock check dam and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate the rock check dam will not function as intended.	Changes in plan may be needed, consult with a registered design professional.
Erosion increased during storm events; caused by the channel not being properly stabilized.	Stabilize the channel immediately with vegetation or turf reinforcement mat.
Storm flow goes around the sides of check dam eroding the bank; caused by the elevation of dam being too high in the middle.	Lower the middle of the check dam so storm water flow goes over the middle, repair damage and stabilize eroded side slopes.
Rock is displaced; caused by the stone size being too small or embankment slope is too steep.	Replace larger size stone or reduce slope.
Rock is displaced; caused by the high velocities because spacing between dams is too long and therefore does not rsufficiently reduce velocity.	Consult the design professional to recalculate the drainage slope and dam heights to determine correct check dam spacing.
Erosion occurs in downstream area; caused by the apron not extended to stable grade.	Repair erosion and extend apron.
Erosion of abutments occurs during spillway flow; caused by the rock not being high enough on the abutment.	Extend rock higher on the abutment.
Sediment is being carried through the spillway or accumulates in excess between clean outs; caused by the drainage area being too large.	Divert runoff from undisturbed areas way from the basin, enlarge basin and clean out basin more frequently or consult the professional designer for other alternatives.
Sediment is lost through the check dam; caused by the layer of gravel aggregate on the upstream face not being thick enough or is too coarse to restrict flow through the dam.	Replace gravel aggregate with material having proper gradation to provide filtration.

Ditch Checks

Figure 6.81 This check dam device appears to be working correctly but there should also be erosion control protection covering the channel to reduce scour and erosion of the channel bottom. Source ABC of BMPs, LLC

Practice Description

As with rock check dams, premanufactured ditch checks are used in water ways and swales to reduce water velocities in concentrated flows, dissipate energy to drop out larger sediment loads in fast moving water and reduce erosion in ditches until permanent, vegetation can be established. With routine maintenance, life expectancy is usually six and nine months.

Sediment fence and straw bales are generally not recommended for ditch checks. Suitable products include silt dikes, permeable plastic triangular berms and permeable M panels. In lighter flows use straw and excelsior wattles and compost socks. A critical component of any ditch check is that it does not cause more erosion on the downstream side than what it is protecting upstream. All channels should have erosion control practices in place such as blankets or turf reinforcement mats to further reduce scour and erosion of the channel.

Recommended Minimum Requirements

Drainage Area

The drainage area requirements are in direct relation to how wide the ditch or swale is and the strength of the ditch check. Hydraulic design is recommended to ensure proper material selection and placement.

BMP Lifespan

Six and nine months. Some will last longer.

Anchors
Vary by product type. Silt dikes require stapling with 6-inch staples(in fill conditions, 12- to 18-inches geotextile fabric pins are required) Permeable plastic berms require 10-inch landscape spikes. Permeable M panels require separate M-pins. Wattles and logs typically require 18- to 24-inch wood stakes on 2-foot centers.

Other Materials
A geotextile fabric is strongly recommended for any rock ditch check to separate the rock from the finished grade.

Location
A generally accepted standard for ditch check location is to locate ditch checks where elevation change from one check to the next is equivalent to the height of the particular ditch check used.

Construction
Site Preparation
Finish swale grading to plans. If swale is not in its final configuration, immediately install designed ditch check according to the manufacturer's requirements for effective sediment control. If swale is completed and ready for final stabilization, use the appropriate erosion control practice as designed by the engineer, then install ditch checks that will allow for vegetation establishment. A critical component of any ditch check is the elevation at the center of the check be lower than any other point. including the termination of the check into the side slope. At no time should water have the ability to flow around the ditch check.

Erosion Control
Erosion control measures should be used in conjunction with a ditch check. In many cases, effective erosion control can reduce the need for as many ditch checks on a project.

Figure 6.82 Wattle Ditch Check Source: American Excelsior

Construction Verification

The field inspector should:

- Verify the dimensions shown on the plans for the ditch location.
- Verify the top elevation as it relates to the termination at the sides.
- Verify the ditch check is properly secured to the ground surface.
- Evaluate stabilization techniques required for effective erosion control.
- Check all finished grades and final ditch check locations.

Maintenance, Inspection and Removal

- Maintenance includes periodic sediment removal after rain events to allow for maximum capacity of sediment. Each rain event will drop a significant amount of sediment. For rock ditch checks, complete removal of sediment laden rock and replacement with clean rock is required after the ditch check is plugged and ponds water. Geotextile may need to be replaced as well. If ditch checks become damaged from bed load and floating debris, replace as necessary.
- Remove temporary ditch check and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Erosion occurs into the side slope - water goes around ditch check.	Increase length of ditch check so lowest point is in center of channel or swale.
Significant erosion occurs between ditch checks - too much distance between ditch checks.	Install additional ditch check in between - follow recommended guideline for spacing.
There is poor erosion control on grade between ditch checks.	Re-grade, seed and apply appropriate erosion control practice.
There is scour on downstream side of ditch check-may be caused by too much water flowing in ditch or poor ditch check design for hydraulic condition.	Use alternative ditch check and install appropriate erosion control measure to reduce erosion on downstream side of ditch check.
Stormwater flow cuts around the ends of the ditch check.	Ditch check is lower at the ends than the middle and needs to be redesigned and installed properly.

Wattles

Figure 6.83 Wattles are used here as slope breaks to reduce the velocity of overland flow. Source: Missouri Department on Natural Resources Southwest Regional Office

Definition and Purpose

Wattles are degradable or nondegradable materials rolled or bound into a tight tubular roll and placed on the toe and face of slopes to intercept runoff, reduce flow velocity, release the runoff as sheet flow and provide removal of sediment from the runoff. Wattles may also be used for inlet protection and as check dams under certain situations. A degradable wattle consists of wood excelsior, rice or wheat straw, or coconut fibers. Nondegradable wattles consist of recycled tire products, foam peanut material or other material bound in a heavy mesh tube.

Recommended Minimum Requirements

This Best Management Practice may be implemented on a project-by-project basis with other best management practices when determined necessary and feasible. Wattles may be used:

- Along the toe, top, face and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow.
- Below the toe of exposed and erodible slopes.
- As check dams in drainage swales.
- For drain inlet protection.
- Down-slope of exposed soil areas.
- Along the perimeter of a small area (less than 1/3 acre) such as home lot.

Construction

- Runoff and erosion may occur if the wattle is not adequately trenched in.
- Wattles must be overlapped along the edges of at least 12-inches.
- Wattles at the toe of slopes greater than 1:5 may require the use of 500 mm (20" diameter) or installations achieving the same protection (e.g., stacked smaller diameter fiber rolls, etc.).
- Wattles may be used for drainage inlet protection if they can be properly anchored.
- Degradable wattles are somewhat difficult to move once saturated.
- Wattles could be transported by high flows if not properly staked and trenched in place.
- Wattles have limited sediment capture zone.
- Do not use wattles on slopes subject to creep, slumping or landslide.

Maintenance, Inspection and Removal

- Inspect wattles each week and after rain events as required by your permit.
- Clean accumulated sediment from behind wattles prior to the next rain event.
- Maintain wattles to provide an adequate sediment holding capacity. Sediment shall be removed when the sediment accumulation reaches one-half of the barrier height. Removed sediment shall be incorporated in the project or disposed in accordance with Missouri State solid waste regulations.
- Remove wattles as soon as possible after the project site has been stabilized. Dispose of in accordance with solid waste regulations and permit requirements.
- Remove the temporary wattles and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Erosion and rills form under the wattle; caused by the wattle not being properly trenched into the ground.	Repair erosion, fill rills and trench wattle properly.
Erosion around edges of the wattle; caused by the wattle not placed on the contour with a slight up gradient at the edges.	Reinstall wattles on the contour with a slight turn up gradient at the edges.
Erosion at the joints of two wattles; caused by the wattles not being properly overlapped.	Reinstall wattles with overlap of the edges at least 12-inches.

Straw Bale Barrier

Practice Description

This barrier is a temporary row of entrenched and anchored straw bales. This practice applies downstream of very small disturbed areas of one acre or less subject to sheet erosion. The purpose is to intercept and detain small amounts of sediment in order to prevent sediment from leaving the construction site. EPA does not recognize straw bale barriers as an effective best management practice and many areas of Missouri are phasing out their use.

Recommended Minimum Requirements

Prior to start of construction, straw bale barriers should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The straw bale barrier should be built according to planned grades and dimensions.

Drainage Area

Areas subject to sheet erosion: from one acre or less.

Bale Size

14-inch x 18-inch x 36-inch (no seed).

Anchors

Two 36-inch long (minimum) 2 x 2 inch hardwood stakes driven through each bale.

Slopes

4:1 above the barrier; with maximum drainage area of one acre or less.

Effective Life

Less than three months.

Location

On nearly level ground. The barrier should follow the land contour as closely as possible. Not in live streams or in swales where there is the possibility of a washout. Not in areas where rock or another hard surface prevents the full and uniform anchoring of the barrier.

Restricted Use

When used as a best management practice, straw bales shall be replaced after 60 days or sooner if failure is imminent. Straw bales shall be used as a solution only as a last alternative. The date the straw bales were installed shall be recorded on the weekly Storm Water Pollution Protection Plan inspection report.

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Grade alignment of barrier as needed to provide broad, nearly level area upstream of barrier.

Grading

- Excavate a trench at least 4-inches deep, a bale's width, and long enough the end bales are somewhat upslope of the sediment pool (Fig. 5.87).
- Place each bale end to end in the trench so the bindings are oriented around the sides rather than top and bottom (Fig. 5.87).
- Anchor the bales by driving two 36-inch long 2 x 2 inch hardwood stakes through each bale until nearly flush with the top. Drive the first stake toward the previously laid bale to force the bales together. Ensure there are no gaps between bales.
- Wedge loose straw into any gaps between the bales to prevent sediment-laden water from running through.
- Backfill and compact the excavated soil against the bales to ground level on the down slope side and to 4-inches above ground level on the upslope side.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan.

Construction Verification

Check finished grades and dimensions of the straw bale barrier. Check materials for compliance with specifications.

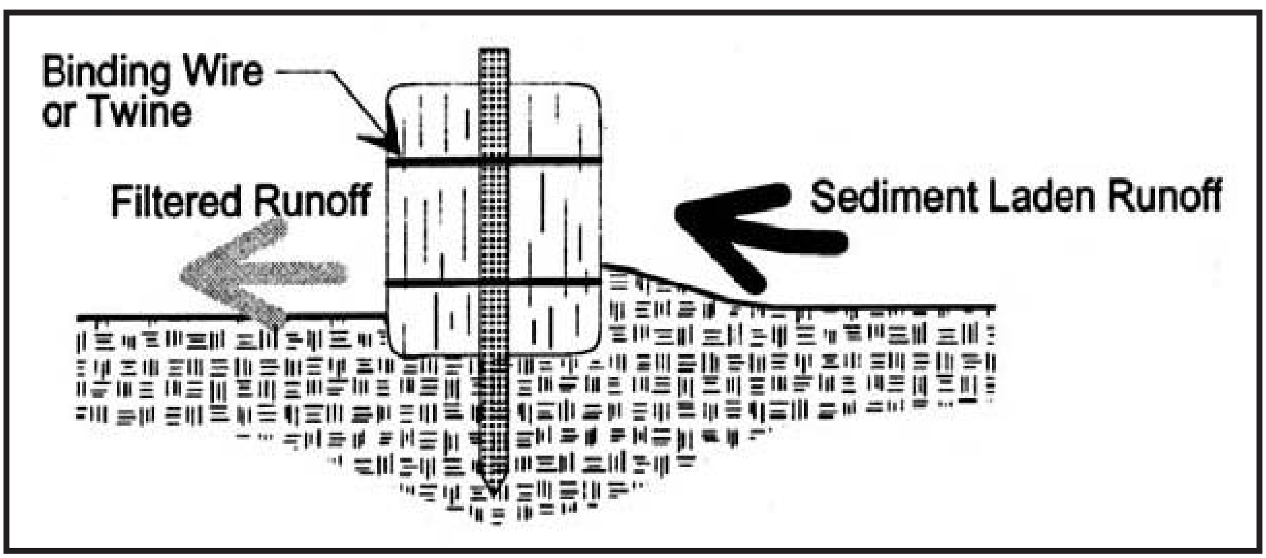

Figure 6.84 Installation of straw bales.

Maintenance, Inspection and Removal

- Inspect straw bale barriers weekly and after each storm event as required by your permit.
- Remove sediment deposits promptly, taking care not to undermine the entrenched bales.
- Inspect periodically for deterioration or damage from construction activities. Repair a damaged barrier immediately.
- After the contributing drainage area has been stabilized, remove all straw bales and sediment. Bring the disturbed area to grade and stabilize.
- Removal of this temporary device must be performed and the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

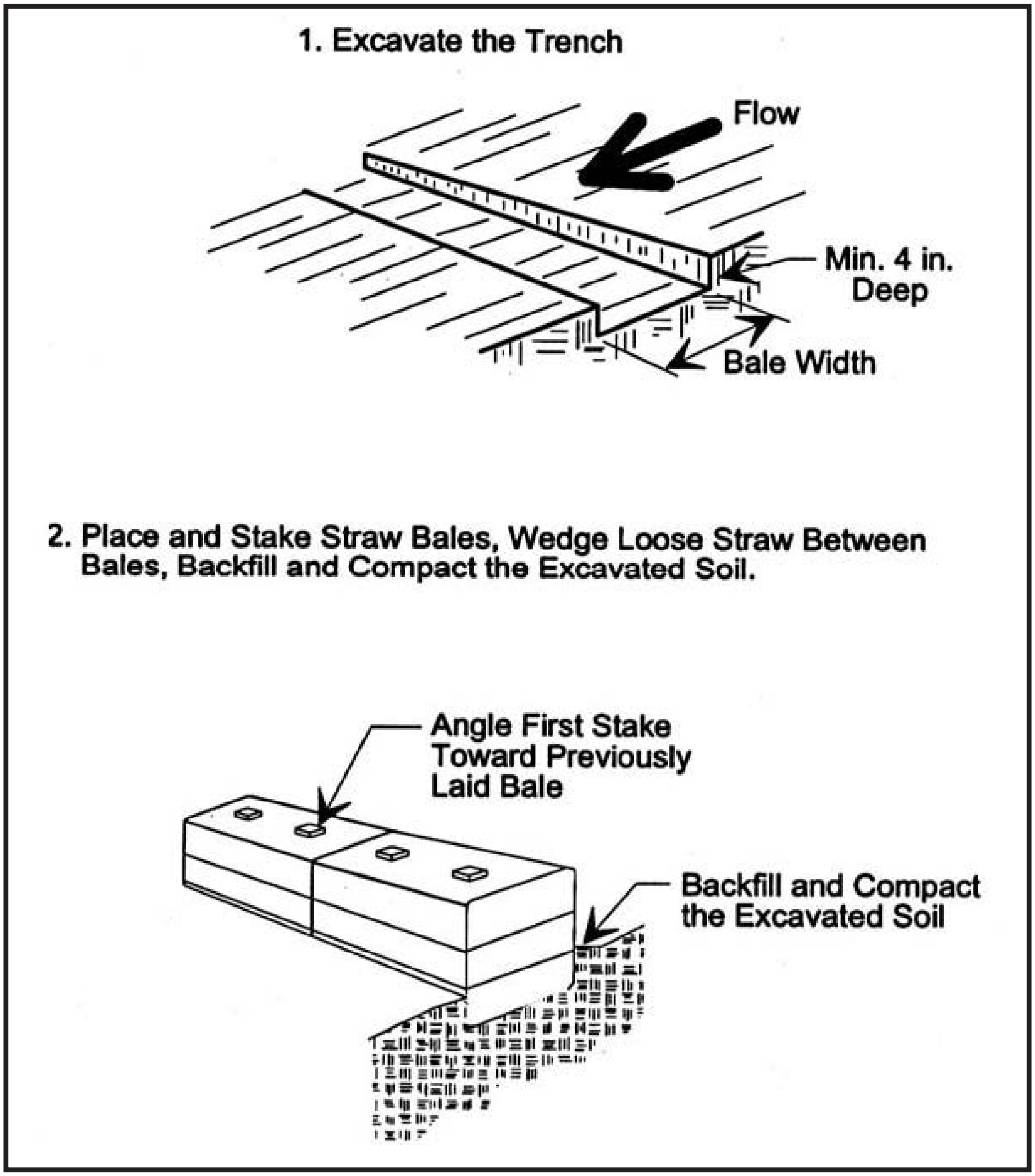

Figure 6.85 Straw bale alignment.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate sediment fence will not function as intended.	Changes in plan may be needed.
Erosion under or around end of bales; caused by the barrier terminating at an elevation below the top of the temporary pool or at an unstabilized area, is located on too steep a slope or was placed in an area of concentrated flow.	Correct problem by re-grading or stabilization; if straw bale barrier is in area of concentrated flow, use different method of sedimentation control (see Rock Check Dam or Ditch Check).
Overtopping of barrier; caused by inadequate storage capacity, no provision was made for safe bypass of storm flow, or the drainage area is too large.	Reduce the area draining to the straw bales or use device other than straw bales.
Unsightly after project stabilization; caused by bales not removed after area has been stabilized.	Remove in a timely manner and stabilize the disturbed area.
Undercutting of barrier; caused by bales not entrenched at least 4-inches or backfilled with firmly compacted soil.	Reinstall barrier using proper installation methods.
Collapse or dislodge of barrier; caused by bales not adequately staked.	Reinstall barrier using proper installation methods.
Collapse or dislodge of barrier; caused by too much sediment allowed to accumulate between clean outs.	Remove accumulated sediment more frequently.

Vegetative Buffer Strip

Figure 6.86 Vegetative buffer strips slow surface runoff, reduce sedimentation and help capture pollutants. Depending on the choice of plant materials, they can be low maintenance areas (mow once or twice a year) or provide habitat for wildlife.

Practice Description

A vegetative buffer strip is a wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants and reduce stormwater flow and velocity. Vegetative buffer strips are similar to grassed swales except they are designed to accept only overland sheet flow. They cannot treat high velocity flows. Surface runoff must be evenly distributed across the vegetative buffer strip. After a channel forms in the vegetative buffer strip, it is no longer effective.

Vegetative buffer strips can consist of grass, woody vegetation or other erosion resistant plants. They can be used adjacent to impervious surfaces and next to stream corridors or wetlands to slow the flow and help remove sediment from runoff. They can also be used in conjunction with infiltration basins, infiltration trenches or alongside streams to provide water quality treatment for post-construction.

Recommended Minimum Requirements

Prior to start of construction, vegetative buffer strips should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The vegetative buffer strip should be built according to planned alignment, grade and cross section. Should any field adjustment to the design and installation be needed, a qualified professional should be consulted in the modification to the original design or specification.

Drainage Area

Less than 5 acres.

Location

Adjacent to low or medium density residential areas on gently sloping ground (less than 5 percent), with length of strip running along the contour, along the perimeter of a site, or any available vegetated area or area capable of being vegetated.

Vegetation

A mix of erosion resistant plants that form a dense mat and effectively bind the soil (see Permanent Seeding).

Slope

Uniform, even and relatively flat (5 percent or less) with a level spreading device (level lip, weir, etc.) across the top edge of the vegetative buffer strip.

Minimum Width

Should conform to those in Table 6.16.

Minimum Length

At least as long as the contributing runoff area, but no less than 50 feet plus 4 feet for each one percent increase in slope.

Table 6.16 Minimum Width of Vegetative Buffer Strip

Slope of Land	Width of Vegetative Buffer Strip	Width of Vegetative Buffer Strip
(Percent)	For Grassed Areas (ft.)	For Forested Areas (ft.)
0	10	25
2	12	29
4	14	33
6	16	37
8	18	41
10	20	45
15	25	55

Construction

Site Preparation

- Natural wooded strips in addition to grass strips should be considered. At the start of development, designate, identify and fence off any areas to be preserved. Avoid storing debris from clearing and grubbing activities and other construction waste material in these areas during construction.
- If a vegetative buffer strip is constructed, clear and grub the vegetative buffer strip area before the impervious area is completed.

Grading

- If the adjacent area does not meet the buffer on a uniform contour, grade a swale along the contour directly adjacent to the top edge of the vegetative buffer strip. The swale will serve as a "level spreader" to collect overland flow and distribute the runoff evenly to the vegetative buffer strip. By discharging to the vegetative buffer strip uniformly along the top of the strip, rill and gully formation due to concentration of flow is minimized.
- Line the swale with rock or other erosion resistance material.
- Sod or seed, fertilize and protect the vegetative buffer strip area with an appropriate rolled erosion control product per the specifications.

  Note: Some fertilizing activities may be prohibited near wetlands and other eco-sensitive areas. Consult a qualified professional if needed.
- Vegetated buffer strips should be protected from excessive sediment laden storm water runoff during construction operations because excess sediment will kill the vegetation. This protection can be in the form of silt fence or other sediment control best management practices placed at the top of the slope to pretreat runoff headed for the buffer strip. If excessive sediment is deposited in the buffer strip, appropriate measures should be taken to reestablish the vegetative strip, including complete regrading and reseeding or sodding of the area.

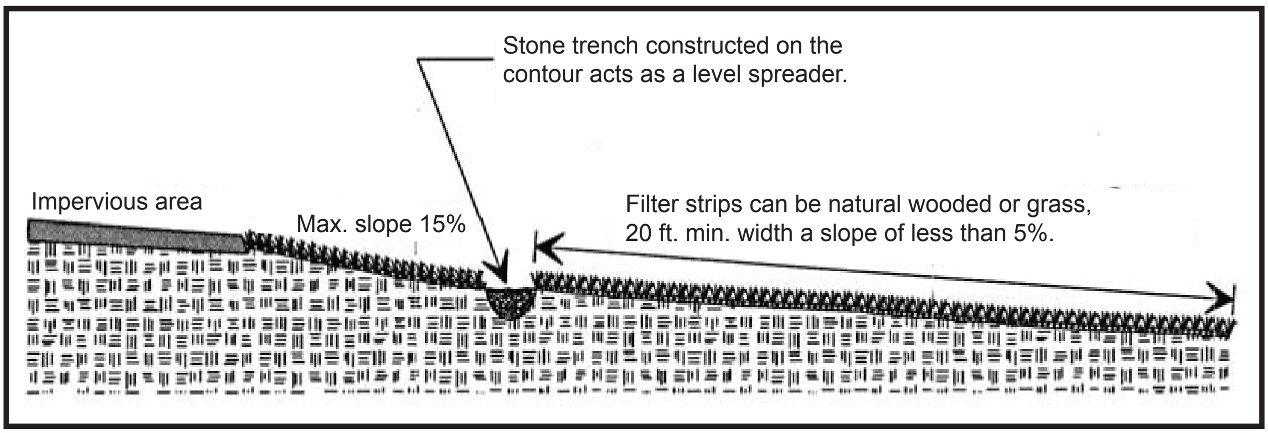

Figure 6.87 Vegetative Buffer Strip

Erosion Control

- Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete.
- Direct all overland flow to the vegetative buffer strip or the level spreading swale at low velocities.

Safety

- Store all construction materials and waste material well away from the vegetative buffer strip.
- Follow all local, state and federal guidelines in constructing utility trenches. If utility lines are buried beneath the vegetative buffer strip, do not perform final grading until all trench settlement has taken place. Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Provide temporary fencing and warning signs until vegetation is established.

Construction Verification

Check the finished grades and configuration of all earthwork, level spreaders and diversions.

Maintenance, Inspection and Removal

- Check for eroded channels in the vegetative buffer strip after every storm event. Fix eroded areas and reseed, mulch and fertilize the affected area. Modify the Storm Water Pollution Prevention Plan to prevent further issues.
- Apply fertilizer in accordance with soil test recommendations and always consider application timing and rates that will protect water quality – i.e. do not apply more than is necessary and do not apply when rain will likely carry fertilizer off to the stream system. Excessive fertilizer can cause a change in pH that allows heavy metals and other toxic compounds to become mobile and available for uptake by aquatic plants and animals. The change in pH can also prohibit nutrient uptake by the targeted vegetation.
- Remove sediment deposits accumulating in the vegetative buffer. This should be done very carefully to avoid damage to the vegetation.
- Protect new plantings from livestock or wildlife.
- Mow grass strips to a height of 6- to 12-inches two to three times a year to suppress weeds and woody vegetation unless natural, woody vegetation is indicated on the plan.
- Repair foot paths and traffic ruts.
- Remove the temporary vegetative bufferstrip and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a design professional if any of the following occur:

- Variations in topography on-site indicate vegetative buffer strip will not function as intended.
- Design specifications for fill, rock, sod, seed, mulch or fertilizer cannot be met; substitution may be required. Unapproved substitutions could lead to the vegetative buffer strip not operating as designed after construction activities have been completed.
- Naturally vegetated areas intended for use as buffer strips have been damaged or inadvertently reduced in width.

Common Problems and Solutions

Problem	Solution
Inadequate vegetation causing erosion of vegetative buffer strip due to too great a length of overland flow, too great a slope or high flow rates due to a drainage area greater than 5 acres.	Repair erosion damage and reevaluate erosion protection measures.
Inadequate vegetation causing erosion of vegetative buffer strip due to malfunctioning irrigation or lack of proper watering to establish the vegetation.	Repair erosion damage and possible irrigation issues, provide sufficient water for plant establishment and reevaluate erosion protection measures.
Settlement of soil in utility trenches or settlement of fill creates ponding within the vegetative buffer strip.	Fill low areas and regrade to provide proper drainage.
Uneven slope or debris clogging the trench at top of vegetative buffer strip creates a diversion of flow around vegetative buffer strip.	Remove debris and regrade as needed to provide proper drainage.
Sediment and debris clogging upper end of vegetative buffer strip creates a reduction in flow across vegetative buffer strip.	Replace clogged portion of vegetative buffer strip.

Dewatering

Figure 6.88 Use of a dewatering bag where storm water is pumped into a geotextile bag. The sediment stays in the bag while the storm water is allowed to flow out through the small voids in the material.   Source: ACF Environmental Inc.

Practice Description

Dewatering is a commonly required practice occurrence after a storm event on a construction site. Dewatering is performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed. It may also be required on sediment traps or basins that are designed to pond water to make storage room for additional storm water during the next rain event. It is also performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed.

Dewatering can be performed with a suction pump or other device such as a skimmer. Dewatering of storm water from sediment traps or basins must be limited to removing only the top or surface water containing the least amount of sediment. When dewatering with a pump, the water should be pumped into a device such as a geotextile bag or temporary sediment trap to remove or settle the sediment and allow the treated or clearer storm water to be discharged.

Recommended Minimum Requirements

It is best if the stored storm water in the trap or basin has been allowed to sit a minimum of 24 hours after the storm event. Depending on the types of soils and high clay content, additional settling time may be necessary before dewatering the trap or basin. If the intake must be close to the bottom of the excavated area it should be protected with a cloth or geotextile sock to reduce the amount of sediment particles exiting through the hose.

Water must be withdrawn from the top of the basin or treated through a geotextile bag or other treatment system before the storm water is allowed to leave the site.

Maintenance, Inspection and Removal

- Maintain the pump in proper operating condition and make sure the pump does not cause pollution to the surrounding area from fuels, oils, greases or other operating fluids. Monitor the dewatering and discontinue when the discharge begins to contain heavier sediment loads.
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Make sure the sediment has a proper settling time and sediment laden water is not discharging from the construction site.
- Make sure the geotextile bag (if used) is the proper size for the amount and velocity of flow going into the bag.
- Make sure the geotextile bag is located where it can be accessed for removal. The bag can be heavy, particularly when sediment is wet.
- It is also a good idea to have the dewatering bag placed so the discharged storm water can flow over a vegetated buffer strip or other area of vegetation, if possible.

Common Problems and Solutions

Problem	Solution
Pump loses suction – pump has lost its prime.	Reprime pump and begin dewatering activities.
Pump hose becomes clogged - the protective sock at the end of the hose has become saturated with sediment.	Clean or replace sock and keep the end off the bottom of the trap or basin and out of sediment laden water.
Erosion around the dewatering bag caused by locating the bag on an unstable surface.	Stop dewatering and move the bag to a stable (non-erodible) surface and continue the dewatering process.

Sediment Basin

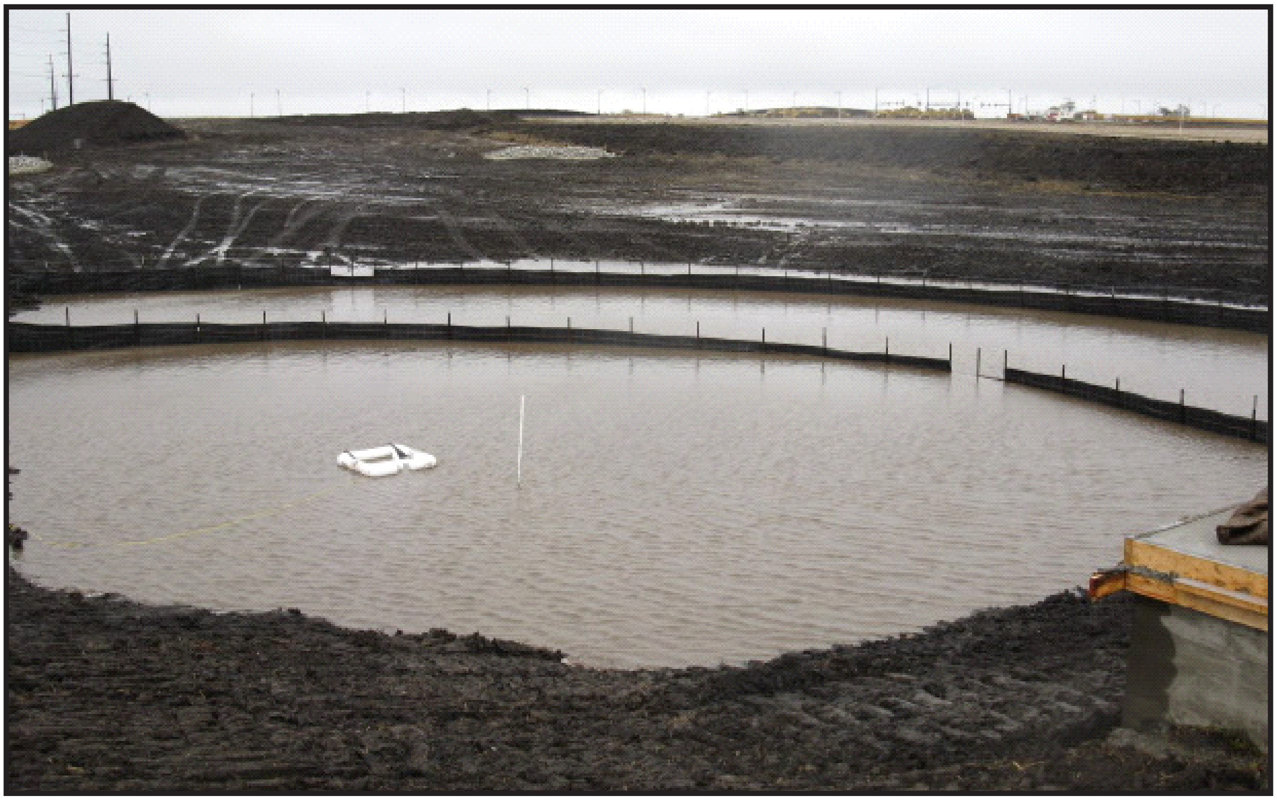

Figure 8.89 A sediment basin can be used to pretreat sediment-laden water before it discharges from the construction site. Source: BFA Inc.

Practice Description

A sediment basin is a temporary pond constructed to contain sediment-laden storm water for an extended period of time prior to the storm water discharging from the basin. A sediment basin is temporary and should be removed or retrofitted prior to any final construction activities that would make these features a permanent detention or retention pond, after the entire contributing drainage area is stabilized.

This practice applies where other erosion control measures are insufficient to prevent off-site sedimentation. The purpose of a sediment basin is to detain sediment-laden runoff from disturbed areas in wet storage long enough for most of the sediment to settle out.

Recommended Minimum Requirements

Prior to the start of construction, sediment basins should be designed by a registered design professional. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process and anytime maintenance practices are required.

Build the sediment basin according to planned grades and dimensions.

Dam Height

10 feet or less.

Contributing Drainage Area

On project sites greater than 10 acres, contributing area is limited to 20 acres or less.

Structure Life

Limited to 10 years.

Detention

At least 24 hours or per local requirements.

Storage Volume

Minimum of 3,600 cubic feet per acre of contributing drainage area (pervious or impervious).

Trap Efficiency

The length to width ratio of the basin should be 2:1 or greater; 5:1 is optimal to capture fine sediments. Locate the inlet as far as possible upstream from the outlet.

Short Circuiting

Design the inflow to the pond as far away from the discharge point as possible. If not possible, design a baffle, weir or wall between the inflow and outflow to increase distance and travel time so there is maximum settling time prior to storm water discharge.

Embankment

- Top Width: At least 6 feet.
- Side Slopes: 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Settlement: Allow for at least 10 percent.
- Fill material: Stable moist soil compacted in lifts less than 8 inches.

Anti-seep Devices

Either of the following is recommended:

- Use at least two watertight anti-seep collars around the outlet conduit; collars should project 1- to 3-feet from the pipe.
- A sand diaphragm (see Glossary).

Risers

- Hold risers in place with an anchor or large foundation to keep them from becoming buoyant.
- Install appropriate inlet protection on the riser.
- Pipe size for the primary conduit should restrict discharge into the natural drainage area at a rate and volume of storm water that meets the local regulatory requirements and the design plan.

Emergency Spillway

- Constructthe spillway in undisturbed soil in a location that will not erode the dam.
- Cross Section: Trapezoidal-shaped with side slopes of 3:1 or flatter
- Control Section: Level, straight and at least 20 feet long. The spillway should have a minimum width of 10 feet.
- Stabilization: Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. Install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

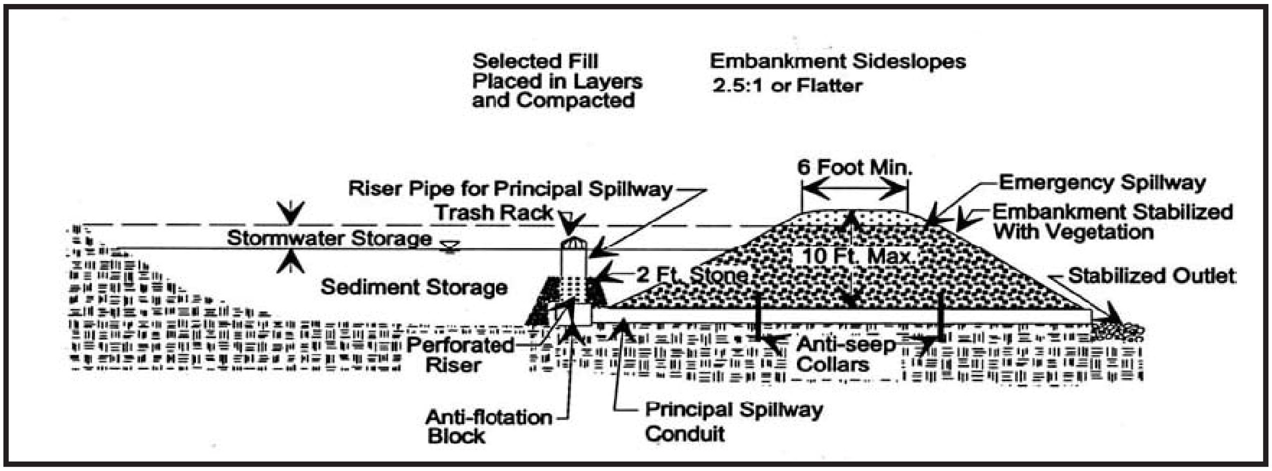

Figure 6.90 Typical Sediment Basin

Construction

Locate the sediment basin as close to the sediment source as possible, considering soil type, pool area, dam length, spillway conditions and proximity of sensitive habitats.

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements for impoundments. Clear, grub and strip the dam foundation, removing all woody vegetation, rocks and other objectionable material.
- Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Excavate the foundation (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Principal Spillway

- Construct a level sediment pool bottom to aid in sediment clean out. Situate the spillway barrel (pipe) and riser on a firm, even foundation. Prepare the pipe bedding.
- Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the barrel, and compact with hand tampers to at least the density of the foundation soil. Don't raise the pipe from the foundation when compacting under the pipe haunches.

  Perforate the lower half of the riser with 1/2-inch diameter holes spaced 3 inches apart or use a manufactured perforated riser.
- Embed the riser at least 12 inches into concrete, which serves as an anti-flotation block. The weight of the concrete should balance the buoyant force acting on the riser.

  $$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4\ \text{lbs/ft}^3$$
- Surround the riser with 2- to 3-inch diameter clean stone to the height of the perforations on the riser. The stone footprint diameter should be 2 feet for every 1 foot of height.
- Place a domed inlet protector or steel trash rack around the riser inlet. The inlet protection should include overflow design. Trash rack openings should be no more than 4- to 6-inches square.
- At the pipe outlet, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

Embankment

- Scarify the foundation of the dam before placing fill.
- Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks and other debris; and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.
- Compact the fill material in 6- to 8-inch continuous lifts over the length of the dam.
- Protect the spillway barrel with 2 feet of fill compacted with hand tampers before traversing over the pipe with equipment.

Emergency Spillway

- Construct and compact the dam to an elevation 10 percent above the design height to allow for settling.
- Place a reference stake indicating the sediment clean out elevation (50 percent of design elevation).
- Construct the spillway in undisturbed soil around one end of the embankment and locate it so that any flow will return to the receiving channel without damaging the embankment.

Stabilize the spillway as soon as grading is complete with vegetation, erosion control blankets or other erosion control stabilization practice; install riprap, TRM, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

Erosion Control

- Minimize the size of all disturbed areas. Vegetate and stabilize all disturbed areas as soon as construction is complete.
- Divert runoff from undisturbed areas away from the basin.
- Use temporary diversions to prevent surface water from running onto disturbed areas.
- Divert sediment-laden storm water runoff to the upper end of the sediment basin (as far from the outlet or spillway as possible) to improve trap effectiveness. A forebay may also be incorporated at the basin inlet to dissipate energy.
- Direct all runoff into the basin at a low velocity (channel slope less than one percent).
- Vegetate and stabilize all disturbed areas immediately after construction.

Safety

Because sediment basins that impound water are hazardous:

- Avoid steep slopes; slopes around the sediment basin should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Fence the area and post warning signs if trespassing is likely.
- Drain the basin between storm events.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Maintenance, Inspection and Removal

- Inspect the sediment basin weekly and after each storm event.
- Remove and properly dispose of sediment when it accumulates to one-half the design volume. Proper disposal of sediment may entail placement at a stock pile or other area up gradient of the pond. Spread it out to allow drying and then stabilize it.
- Check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Remove trash and other debris from the riser, emergency spillway and pool area.
- Clean or replace the gravel around the riser if the sediment pool does not drain properly.
- Remove the basin after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water (see Dewatering), removing the sediment to a designated disposal area, smoothing the material to blend with the surrounding area; and then stabilize. If this temporary sediment basin is to be converted to a permanent storm water control measure, or SCM, such as a detention, retention or infiltration basin, refer to your plans and specifications. Make sure the site is entirely stabilized before the permanent device becomes operational (no sediment-laden water should be entering the SCM.)
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate sediment basin will not function as intended.	Consult with registered design professional.
Design specifications for fill, pipe, seed variety or seeding dates cannot be met.	Substitutions may be required. Unapproved substitutions could lead to failure.
Piping failure along conduit caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair embankment using proper construction methods and materials.
Erosion of spillway or embankment slopes caused by inadequate vegetation or improper grading and sloping.	Repair using proper grades and slopes. Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.
Riser and barrel blocked with debris	Remove debris and install trash guard.

Problem	Solution
Overtopping of the principal and emergency spillway caused by undersized principal or spillway design.	Repair erosion damage and reevaluate spillway design.
Frequent operation of emergency spillway and increased erosion potential caused by lack of maintenance.	Clean the sediment out of the basin on a regular basis.
Frequent operation of emergency spillway and increased erosion potential caused by undersized principal spillway.	The sediment basin was designed with insufficient volume. Enlarge the basin or install additional sediment traps upstream in the watershed.
Slumping or settling of embankment caused by inadequate compaction or use of unsuitable soil.	Repair damage with suitable, well compacted material.
Slumping failure caused by steep slopes.	Flatten slopes.
Severe erosion below principal spillway caused by inadequate outlet protection.	Install adequate outlet protection.
Turbid water coming out of outfall pipe; small clay particles do not have sufficient time to settle out. The primary problem is that too much sediment is coming from above. Take needed steps to reduce the overloading of sediment to the basin.	Consult with the registered design professional to pursue additional features such as installation of a pre-sediment basin, addition of baffles or addition of particle curtains.

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, see Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, state or local regulations.

Chemical Application for Turbidity Reduction

Practice Description

Chemicals such as anionic polymers (polyacrylamide, or PAM) and formulated chitosan products can be mixed with on-site storm water to increase the settling rate of sediment particles. These water clarifying compounds, or water clarifying compounds, cause very small clay soil particles to bind together to form floccules (often referred to as flocs) that clump together and settle out. Small particles can otherwise take many days (if ever) to settle out of the collected storm water.

It is important to protect the receiving waters from aquatic toxicity. If a decision is made to use water clarifying compounds, it is vital they be formulated, selected and mixed properly into the collected storm water. Any material can be toxic if used incorrectly, whether it is naturally occurring or synthetic. Manufacturer's specifications should be followed, and responsible parties should be trained to administer the products properly.

Consideration should be given first to erosion control and then appropriate sediment catchments as the main treatment for turbidity and suspended solid particles. It is also recommended land disturbance be phased in a way to keep disturbance areas as small as possible, as a way to protect water quality and to meet storm water regulations (see Chapter 1.) This proposed staging and dispersement of smaller sediment catchments is compatible with today's placement of permanent storm water control measures.

Note: Large detention basins are no longer the sole preference for permanently managing storm water, because management has evolved to include dispersed practices as a way to meet storm water quality regulations. (see Post-Construction Section).

If that approach is not feasible or fails to produce successful results, the permittee may utilize water clarifying compounds specified by the design engineer with appropriate instruction and application training. If the decision is made to use water clarifying compounds:

- Use water clarifying compounds in conjunction with a best management practice that allows the flocs to settle out and maintain storm water control regularly to ensure the settled flocs are collected and removed from the system to prevent them from unintentionally entering nearby waterbodies.
- Determine if water clarifying compounds are best applied in conjunction with particle curtains, dispersion fields, baffles, a sand filtration system or other practice, and such system should be designed by a licensed engineer, with appropriate consideration of:
    - The nature of the receiving water.
    - System sizing.
    - Pond sizing.
    - Flow requirements.
    - Method of dosing.
    - Proper pH range and pH protection.
    - The system must be designed to capture sediment on-site.

- The operator must be properly trained to use the system and should have direct access to written specifications and operation procedures.
- Site-specific soil bench testing (e.g., jar testing) should be done in advance to determine proper application rates and methods per manufacturer's specifications. This will help to meet state and federal water quality standards for nephelometric turbidity units and to assure the chemical is performing to the best of its ability.
- The water clarifying compounds must be mixed into the water at a specified flow rate to ensure proper dispersion and ion exchange.
- Effluent should be monitored for residual chemical products or aquatic toxicity.
- Keep records for chemical use, effluent testing and corrective measures taken.
- Chemicals must be handled and stored according to applicable material safety data sheets.
- All construction land disturbance (state and local) permit requirements must be met.
- Local regulations may also govern the use of water clarifying compounds.
- Your local or state permitting authority may require prior review and approval of any use of chemicals to control erosion or turbidity, and if approved, include details in the storm water pollution prevention plan.
- Any product, including anionic water clarifying compounds, can be toxic to aquatic life if applied inappropriately.
- Use only products that have undergone whole product testing in an EPA approved laboratory using EPA protocol for acute and chronic toxicity.
- Do not use cationic "PAM", unformulated chitosan, alum or ferric iron compounds as they can be toxic to fish at very low levels. Such material binds to fish gills or depletes available oxygen, hindering oxygen uptake.
- Do not apply directly to or in close proximity to waterbodies.
- Do not use in areas with a shallow groundwater table or highly permeable soils.

Note: The terms flocculant and polymer are commonly used in the storm water industry. Technically, coagulants are often positively charged chemicals used to bind with negatively-charged particles to form flocs. Flocculants are settling aids that increase the rate of this binding process by bridging flocs into larger clumps. The important thing to remember is chemical additives bind to pollutants through negative and positive ion attractions, and in order to protect water quality, strict attention should be paid to proper selection and application.

Particle Curtains

Figure 6.91 Particle Curtains. Source: Florida Erosion and Sediment Control Designer and Reviewer Manual, June 2007

Practice Description

Particle curtains are a series of curtains made of jute and coconut fabrics attached to floats to be used in a sediment pond or similar treatment device. Its purpose is to collect fine particles, when used with a site-specific water clarifying compound such as a floc log. The floc log needs to be upstream of the particle curtain. This storm water control measure is intended to slow down the water flow through the basin so particles can fall out. It is not intended to be a stand-alone measure as it is not adequate sediment control by itself. Use this measure with sediment basins or traps.

- Secure the site-specific water clarifying compound far enough upstream to allow for appropriate mixing with the turbid water. Make sure the water can flow over and around the floc logs, adding mixing structures if needed to increase turbulence around the floc logs to facilitate proper mixing.
- Install the particle curtains in lines perpendicular to the flow across the sediment pond or waterway.
- The particle curtains will float.
- Inspect and repair or replace the particle curtains as require.

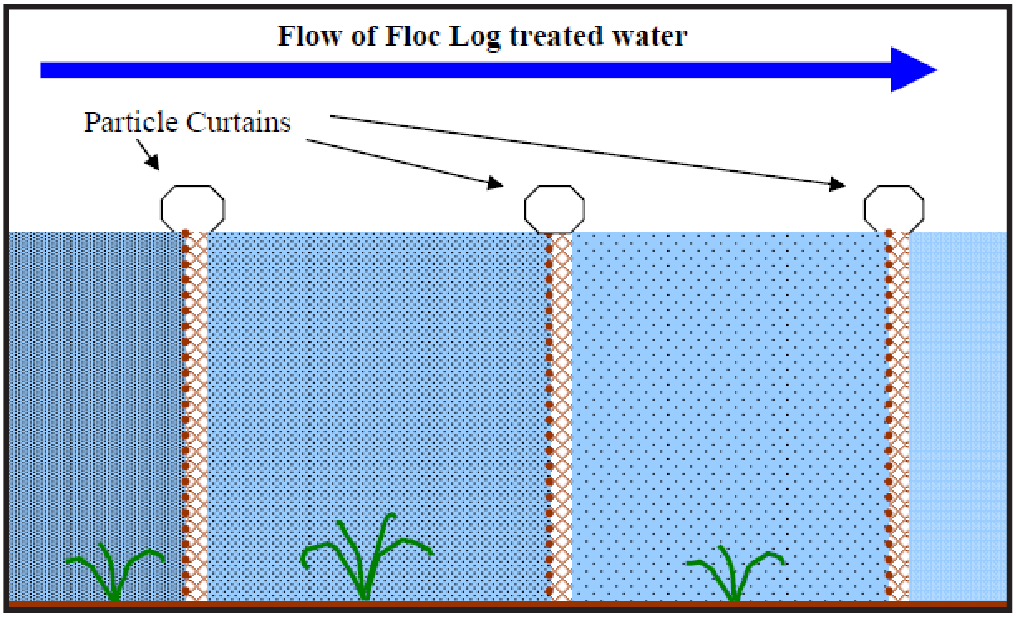

Figure 6.92 Source: *Polymer Enhanced Best Management Practice Application Guide*, March 2010

Maintenance, Inspection and Removal

- Inspect the device prior to use and make sure it is in proper working order. Repair, if necessary.
- Inspect the device periodically while it is in operation so it does not discharge sediment laden water from the construction site.
- Remove the device prior to the end of construction either when the sediment basin is removed or transformed into a permanent storm water control device.
- Remove the temporary particle curtains and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Anchoring devices (e.g, chains attached to weights) can be too short or too tight and therefore not allow curtain to rise and fall with water motions.
- Severe weather may dislodge the floating device and allow a turbid water release.
- Sediments allowed to drain from areas above the high water mark can overload the curtains.

Common Problems and Solutions

Problem	Solution
The curtain loses its shape.	It must be re-anchored. If it continues to break away from the anchors, more anchor points may be necessary.
If the curtain becomes submerged.	The anchor points must be readjusted to allow movement with water level.

Floc Logs

Practice Description

Floc logs are for use in concentrated flow areas for treating turbid storm water. Floc logs are chemically enhanced fabric “logs” used to introduce site-specific water clarifying compounds to turbid waters in such a manner to facilitate mixing and reaction between the compound and the suspended particles. The log will slowly dissolve over time and release the chemical into the flowing water. The compounds will react with suspended sediment causing the particles to bind together.

This storm water control measure is intended for particle collection only. It is not intended to be a stand-alone measure, as it is not adequate sediment control by itself. Use this measure with a sediment pond or similar treatment system.

Do not place floc logs directly into streams, tributaries or in direct paths to streams or other waters of the state. Do not allow runoff from floc logs to flow directly into streams or waters of the state.

Place the floc logs where the sediment-laden storm water will flow over them:

- In ditches that feed a sediment pond or similar treatment system.
- At the intake or outlet of a recirculation system.
- Near the aeration system.

Place logs in a series, one after another. The number of logs is determined by the flow rate of the water and the length of the mixing ditch is determined by the reaction time required for the polymer.

Checks can be placed along the ditch, forcing the water to flow over and around them, to increase turbulence and mixing with the floc logs. Cover the exposed soil in the ditch with jute matting and apply polymer powder to prevent erosion. With highly erosive soils, protection with geotextile or plastic sheeting may be necessary.

Inspect logs following each precipitation event and replace as needed. Use collected sediment higher up in the watershed as fill.

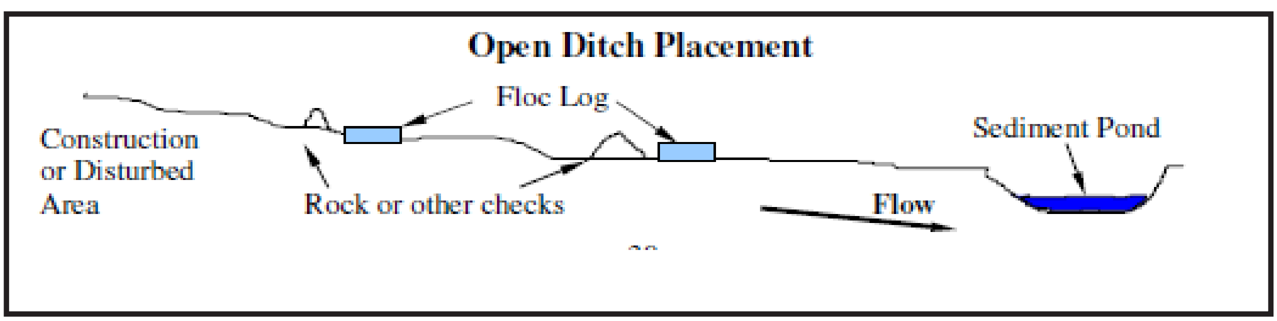

Figure 6.93 Open ditch placement.

Skimmers

Figure 6.94 A skimmer that provides dewatering from the top of the sediment basin. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual.*

Practic Description

A skimmer is a dewatering device designed to remove water from sediment traps or basins. Dewatering the sediment storage structure, is a routine practice between storm events to accommodate additional storm water from the next event. A skimmer is a device that dewaters from the surface. Water at the surface should contain the least amount of sediment as particles settle to the bottom of the sediment storage structure.

Recommended Minimum Requirements

This device must be designed and engineered according to the size of the basin or trap they are dewatering. Therefore, stop dewatering activity when the device begins discharging sediment laden water.

Do not discharge sediment laden water from the construction site. Allow the storm water to sit in the trap or basin for an acceptable time prior to any dewatering activities. The acceptable time allowed for settlement will vary according to the size and type of sediment particles found within the sediment laden water.

Do not attempt to use a skimmer without the use of a baffle design (see Baffles). Part of the skimmer design includes not only the sizing of the skimmer itself, but an evaluation of the exact orifice size. These sizing decisions should be completed by the design engineer and incorporated into the storm water pollution prevention plan.

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, refer to Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, state or local regulations.

Construction
Follow manufacturers' recommendations for design and sizing of the device.

Troubleshooting
Device discharges sediment laden storm water; caused by lack of baffles or improperly notched baffles that cause sediment-laden strom water to enter the final section of the basin:

- Stop discharging and allow the pond to be still for at least 24-hours to settle sediments before dewatering.
- Stop the flow of dewatering when the device lowers into heavier sediment laden water in the trap or basin.
- Allow the storm water to sit for a longer period so the sediment settles to the bottom of the trap or basin before dewatering.
- Device clogs. Keep the device clean of dirt, sediment and leaves, twigs or other debris so it remains in good working order.
- Maintain the device in proper operating order per manufacturer's recommendations and do not allow the device to clog or fill with sediment.

Maintenance, Inspection and Removal
- Inspect the device prior to use and make sure it is in proper working order. Clean if necessary.
- Inspect the device periodically while it is in operation so it does not discharge sediment laden water from the construction site.
- Remove the device prior to the end of construction either when the sediment basin is removed or transformed into a permanent storm water control device.
- Remove the skimmers and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Baffles

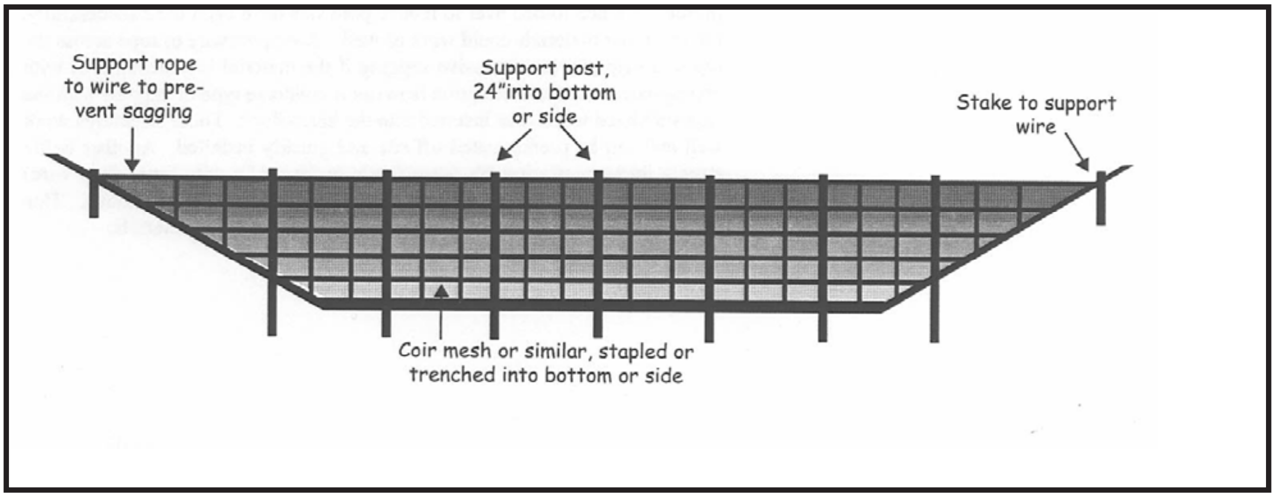

Figure 6.95 Cross-section of a porous baffle in a sediment basin. Note there is no weir because the water flows through the baffle material. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual*

Practice Description

- Baffles are porous barriers installed inside a temporary skimmer or sediment basin to reduce the velocity and turbulence of the water flowing through the measure, and facilitate the settling of sediment from the water before discharge.
- Baffles improve the rate of sediment retention by distributing the flow and reducing turbulence. This process can improve sediment retention and allow the capture of soil particles 50 percent smaller than those that can be captured without baffles.
- Use this practice in any temporary sediment basin.
- Porous baffles effectively spread the flow over the entire width of a sediment basin or trap. Water flows through the baffle material, but is slowed sufficiently to back up the flow, causing it to spread across the entire width of the baffle (Figure 5.77). Spreading the flow in this manner uses the full cross section of the basin, which in turns reduces flow rates or velocity as much as possible. In addition, the turbulence is also greatly reduced. The combination practice increases sediment deposition and retention and also decreases the particle size of sediment captured. The storm water flows into the first section where the larger contaminants settle out before spilling over to additional sections. As a result, the first section should be easily accessible for maintenance.
- The installation can be similar to a sediment fence. Materials such as jute backed by coir erosion blanket, coir mesh, or tree protection fence folded over to reduce pore size have been used successfully. Other similar materials could work as well. A support wire or rope across the top will help prevent excessive sagging if the material is attached to it with zip ties. Another option is to use a sawhorse type of support with the legs stabilized with rebar inserted into the basin floor. These structures work well and can be prefabricated off-site and quickly installed. Success has also been demonstrated by placing silt fence fabric in front of the wire fence backing which has alternating squares.

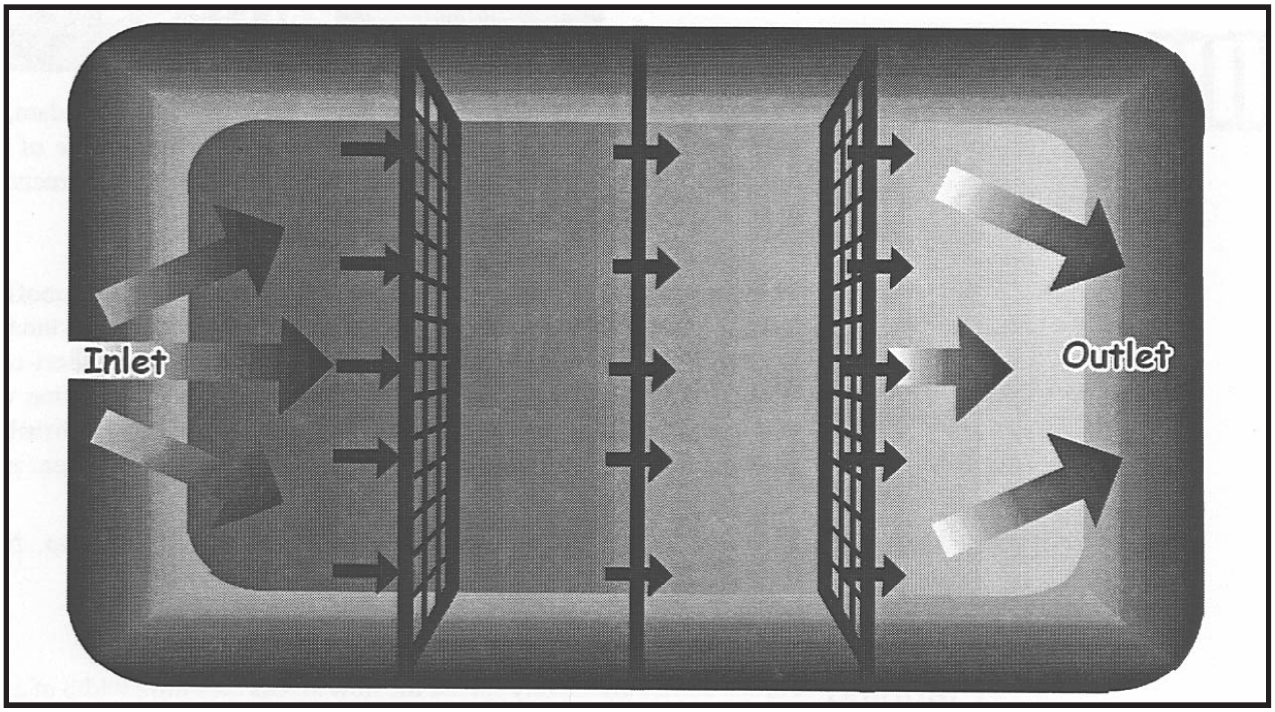

Figure 6.96 Porous baffle in a sediment basin. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual*

- Newer baffle technology includes filtration baskets to catch the floating vegetation and litter at the top of the box, while the sediment is captured in the bottom of the box. This separation of organic matter from the water and sediment, provides a reduction in the nutrients and sediments present in the storm water.
- Remove the baffles and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Dispersion Fields

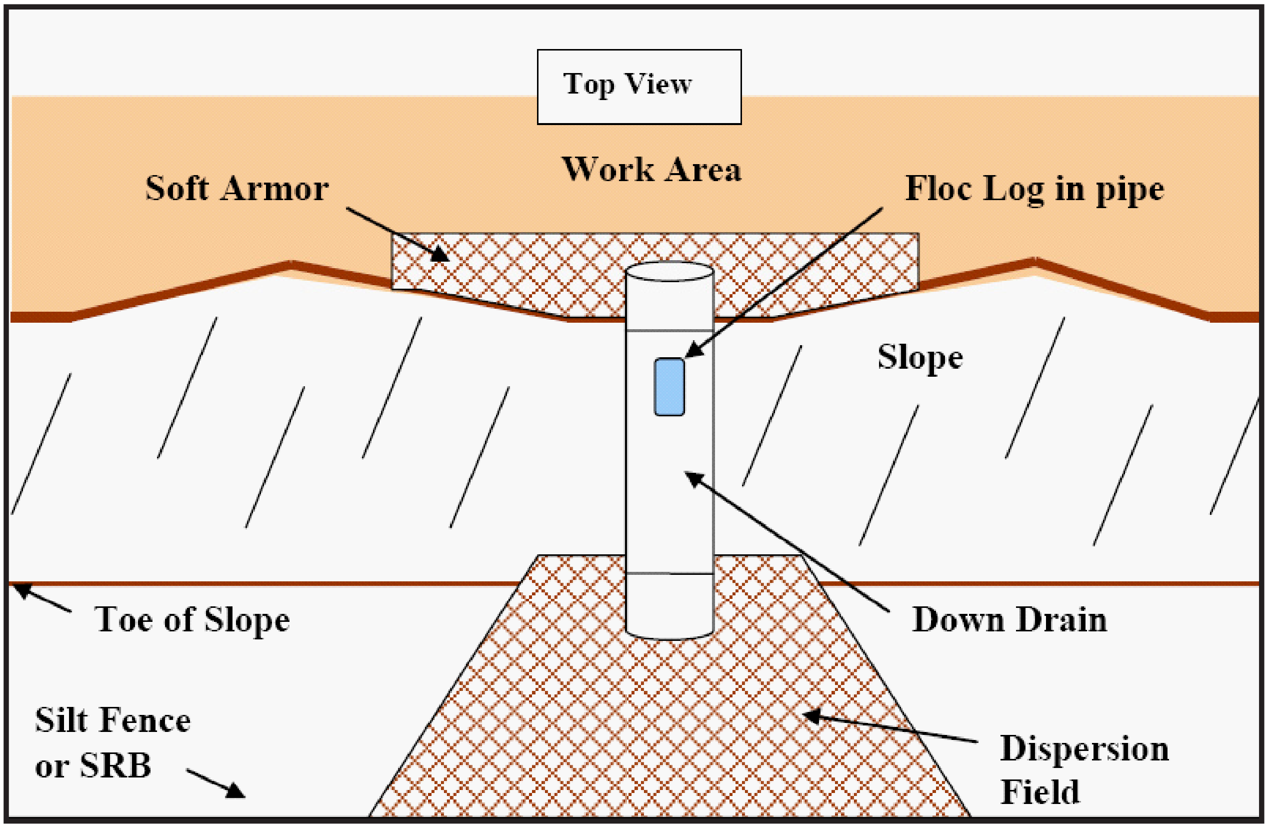

Figure 6.97 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manua*l, June 2007.

Practice Description

Dispersion fields are to be used in conjunction with other best management practices, as it does not provide adequate sediment control by itself. The dispersion field should be covered in jute matting and applied with the site-specific water clarifying compound powder, to provide a surface for the particles to adhere to and help in final clarification of the storm water. A dispersion field is created to allow treated storm water to spread out and slow its velocity. Other best management practices must be used in conjunction, (e.g., floc logs, silt fences, down drains, soft armor matting) to further reduce velocity. The size of the field is dependant on the amount and velocity of storm water expected to enter. With highly erosive soils, protection with geotextile or plastic sheeting may be necessary.

Limitations

High flow velocities will occur at the discharge end of the slope drain. Unless there is a great distance between the slope drain discharge end and the silt fence, and a sediment basin or pond is created, the silt fence barrier may be destroyed if the inflow values are greater than outflow.

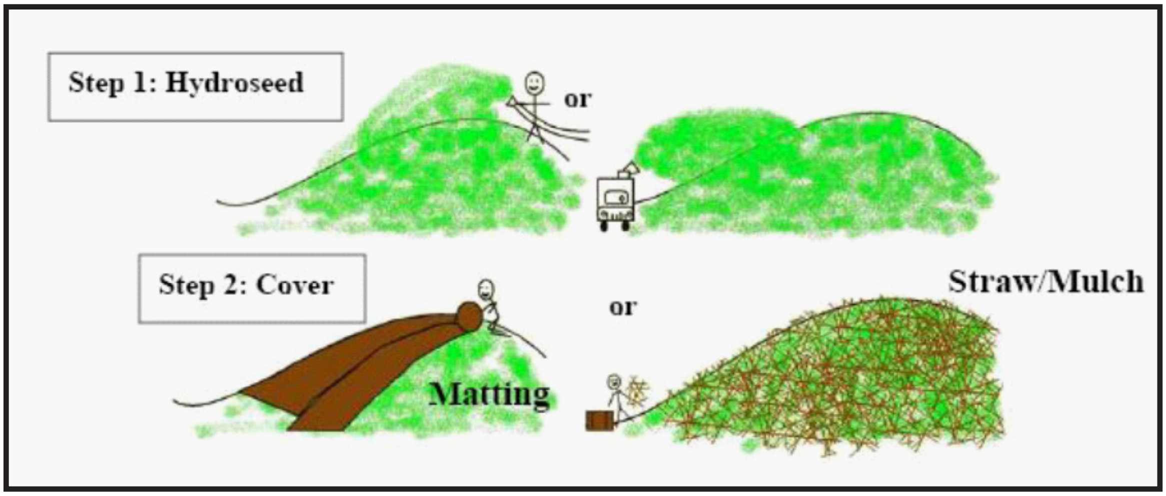

Figure 6.98 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Inspection And Maintenance
Inspect routinely. Repair coverage and re-apply media as needed to maintain maximum protection against erosion. If failure of media occurs routinely, consider another type or size of protective media.

Dispersion Fields
Dispersion fields are to be used in conjunction with other best management practices, as it does not provide adequate sediment control by itself. The dispersion field should be covered in jute matting and applied with the site-specific water clarifying compound powder, to provide a surface for the particles to adhere to and help in final clarification of the storm water. A dispersion field is created to allow treated storm water to spread out and slow its velocity. Other best management practices must be used in conjunction, (e.g., floc logs, silt fences, down drains, soft armor matting) to further reduce velocity. The size of the field is dependant on the amount and velocity of storm water expected to enter. With highly erosive soils, protection with geotextile or plastic sheeting may be necessary.

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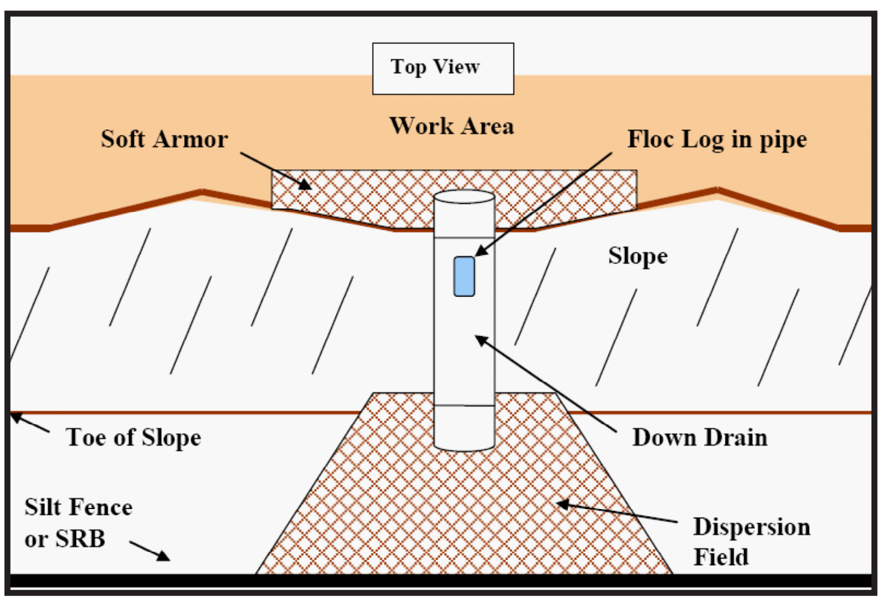


Figure 6.99 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Sand Media Particulate Filter

Practice Description

In a sand media particulate filter, water is treated by passing it through canisters filled with sand media. Sometimes, water clarifying compounds are added to flowing storm water before it enters the filter. Generally, sand filters are used to provide a final level of treatment. They are often used as a secondary or higher level of treatment after a significant amount of sediment and other pollutants have been removed.

Figure 6.100 Sand Media Particulate Filtration System Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Recommended Minimum Requirements

Water clarifying compounds can be used to aid in settling the smaller soil particles when there is a high concentration of smaller clay particles. This can shorten the time necessary for settling out sediment particles from when the storm water flow enters the sediment storage structure and when it discharges. Water clarifying compounds can be toxic if used incorrectly or allowed to leave the construction site at all, but especially if caused to do so prior to binding with soil particles. Plans and manufacturer specifications and recommendations should be referred to by the site superintendent and field personnel throughout the construction process.

Do not over apply or misuse water clarifying compounds. Follow land disturbance permit requirements, check local ordinances for any restrictions that may apply and do not allow any form of the chemicals to discharge from the site or cause a violation of federal or state water quality standards.

Construction

- Follow manufacturers recommendations for the use of water clarifying compoundss and sand filtration systems. Significant site assessment (including soil testing) is required to determine the exact location of polymer application, the amount of material to use and other key elements for success.
- Construction of the treatment system using water clarifying compounds can be “active” or “passive”. An active treatment system is a designed system that incorporates pumps and sand filters while a passive treatment system is designed to rely on settling ponds, check dams, filter dikes, inlet floc socks, etc.

Maintenance, Inspections and Removal

- Inspect coagulant applicator and sand filtration treatment systems on a weekly basis and after rain events. Maintain the systems as required.
- Remove the system when construction is complete and the stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Flocculating water clarifying compounds are soil specific and soil tests must be done to determine the most effective application. Other coagulants are more general and will work on a wide range of soils. Most coagulants are pH and temperature sensitive. Follow all manufacturer’s specifications and recommendations.
- Do not over apply or misuse water clarifying compounds.

Common Problems and Solutions

Problem	Solution
Despite use of water clarifying compounds, fine clays and colloids remain in suspension, caused by the wrong type of water clarifying compounds. used for the soils on-site.	Take additional soil samples and re-evaluate the appropriate type of product to use.
Despite use of water clarifying compounds, fine clays and colloids remain in suspension, because there was inadequate mixing time to dissolve the water clarifying compounds into the storm water.	Identify location further upstream from basin to introduce the water clarifying compound or identify areas with greater turbulence that would improve mixing.
Over application and premature purging of the compounds, caused by allowing the water clarifying compounds applicator for a passive treatment system to sit in standing water.	Locate applicator in ditch checks or in pipe outfalls in such a way to keep the applicator out of ponding water.

SECTION 5: PERMANENT STORMWATER RUNOFF MANAGEMENT

This section of the book highlights important considerations of environmental design in the site plan and offers general guidance for permanent stormwater control measures, referred to here as SCMs. See Chapter 2 for more information about water quality impacts and hydrology considerations. See Chapter 3 for more information about interpreting stormwater features in the site development plan.

SCMs are considered permanent and are designed to control stormwater discharges for both water quantity and water quality, after the site has been completely built. These devices may be constructed and installed during the construction phase of the project, but usually are not operated until project construction is complete and the site is stabilized.

General Contractor and Site Superintendent Responsibilities

Many communities are now required to regulate post-construction practices for water quality, therefore city or county regulations may apply in addition to state and federal regulations (See Chapter 1 for information about state regulations, federal regulations and permit requirements.) In order to avoid costly corrections and project delays, it will be important for the general contractor and site superintendent to:

- Understand local water quality requirements. Many communities are upgrading stormwater ordinances and codes, because they are now required to enforce development standards to meet water quality goals. As a result, requirements may include capturing and treating small storm runoff at the site. This makes it necessary to employ green infrastructure concepts and low impact development practices, in particular environmental site designs that include:
    - Features such as stream buffers, less impervious surface (narrower streets, etc.), streetscapes, connected green spaces, parking lot controls and pocket parks.
    - Strategically placed practices such as rain gardens, bioswales, stormwater wetlands, infiltration trenches, perimeter sand filters and planter boxes.
    - Similar practices to collect and treat small storm runoff.
- To avoid costly repairs, avoid damage to designated SCM locations during construction. Become aware of all planned SCMs designed for permanent function and identify where they are to be located. Contemporary designs can include numerous on-site SCMs throughout the project site. The ultimate placement and combined functions of SCMs, as well as their connected paths, need to be protected from soil compaction and other disturbances. Such protection will eliminate the need for costly repairs and will protect against failure of the SCM.

- Coordinate long-term operations with landowners. Local regulations for permanent stormwater control measures may require a formal transfer of operation and maintenance responsibility from developer to builder or buyer.
- Notify local governments about permanent practices where regulated. The site superintendent or general contractor should inform the local governing agency about the final location of all SCMs as well as who is in charge of the operation and maintenance of each control device. Check the local ordinance for requirements.

Design Considerations When Selecting Vegetated Practices

Many contemporary SCM devices work with vegetation to increase infiltration. Vegetation will work most effectively when a diverse mix of grasses, forbs, shrubs and trees are designed together. When choosing the vegetative material, incorporate plants with diverse root structures below ground to increase the potential for water uptake by the plants. This will also help to recharge groundwater resources. Also, grasses will provide more root structure and deeper root penetration if the plants are allowed to grow and are not mowed close to the ground. Native or adapted warm season grasses provide greater root structure (up to 15 feet) when they are not mowed, whereas mowed turf grasses only provide about 1- to 2-inch deep root structures. As a general rule, trees and shrubs provide greater root structure systems than grasses do.

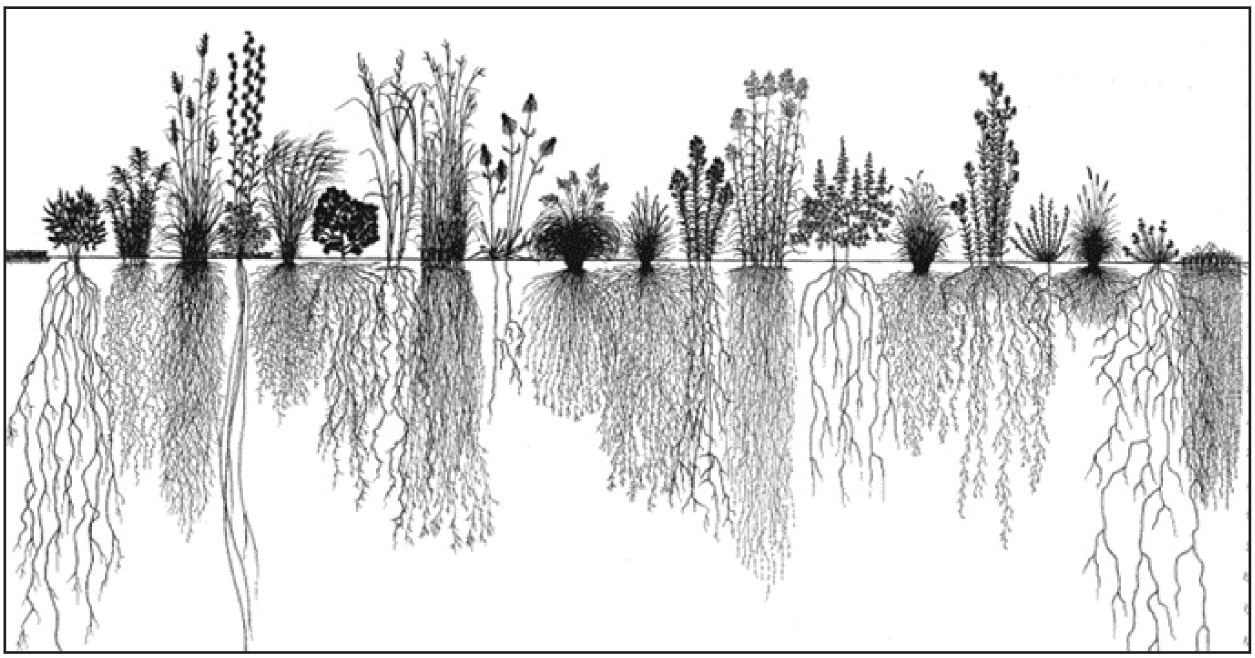


Figure 6.101 Source: *Native Plant Guide for Streams and Stormwater Facilities in Northeastern Illinois* Prepared by USDA-NRCS Chicago Metro Urban and Community Assistance Office in Cooperation with EPA Region 5, U.S. Fish and Wildlife Service, Chicago Field Office and U.S. Army Corps of Engineers, Chicago District, December 1997 (Revised May 2004).

Coordinating Long-Term Operation, Maintenance and Inspection

Long-term operation, maintenance and inspection needs, along with any safety concerns, should be communicated to the affected landowners, homeowners' association and other parties responsible for permanent oversight of the SCMs. Present and future landowners should be made aware of the potential consequences of changing vegetation types, poor maintenance practices or other actions that could cause a practice to function poorly or fail. A long-term education program should be implemented to ensure that multi-generational land owners understand the importance of maintaining practices. Without knowledge of their intended purposes, there is possibility new owners will disable functional features.

Preparing the Operation, Maintenance and Inspection Manual

Each stormwater control measure should have specific operation, maintenance and inspection information written in an operations, maintenance and inspection manual. The manual should be prepared by the design professional, and the entity responsible for operations, maintenance and inspection of each device should be identified. After construction is complete and all SCM devices are operational, the responsibility for operations, maintenance and inspection should be turned over to the proper entity, and the individuals should be provided adequate training for operations, maintenance and inspection.

Additional References and Resources

Refer to the design specifications used in your area for proper design, installation and maintenance. The *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011* will provide additional information about these practices as well as non-structural strategies. See Appendix C and Appendix D for additional references and resources about environmental site design and state-of-the-practice permanent stormwater control measures.

Selecting Permanent Stormwater Control Measures

The current goal of stormwater management is to provide effective control over water quality, channel protection, recharge, overbank floods and extreme storms. Historically, the primary goal of urban stormwater management was to control the quantity peak flow rate for the purpose of flood protection.

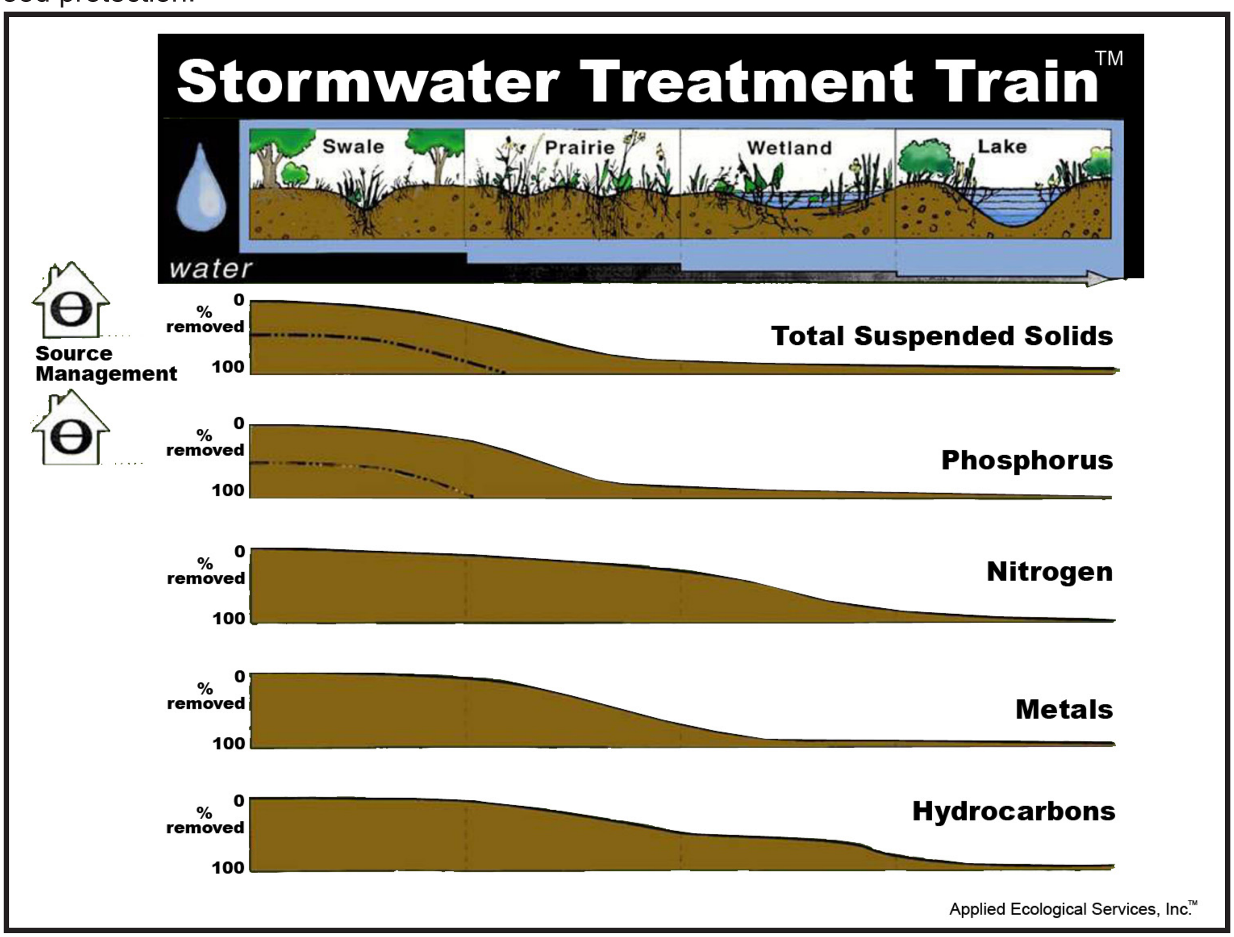


Figure 6:102 Stormwater Treatment Train printed with permission by Applied Ecological Services. See www.appliedeco.com for more STT information and project examples.

To meet current water quality goals, stormwater management practices should be selected with consideration of the overall site design. See Chapter 3 - Interpreting Stormwater Features in the Site Development Plan. Specifically, the design engineer should consider performance that combines pollution removal with water quantity control.

Pollutant Removal Mechanisms for Water Quality Control

Screening/Filtration

The capture of solid pollutants through screens or filters that use a media such as sand. Effective for removal of suspended solids.

Infiltration/Ground Water Recharge

A technique to discharge stormwater runoff to groundwater. Effective when runoff volume controls are required, pollutants can be filtered and surface water temperatures can be controlled.

Settling

Deposition of solids. Typically a minimum of 12 hours of detention is needed to effectively settle solids in stormwater ponds and stormwater wetlands.

Biological Uptake

Vegetative and microbial uptake of nutrients through biofiltration or stormwater wetlands.

Temperature Control

Techniques to reduce the heating effects when runoff flows across hot pavements.

Soil Adsorption

The physical attachment of a particle, usually nutrients and heavy metals, to the soil. See Table 6.17 for examples of practices that provide water pollution control.

Table 6.17 Primary and Secondary Pollutant Removal Mechanisms
Source: Minnesota Stormwater Control Manual

Best Management Practices Group	Pollutant Removal Mechanisms									
	Water Quality					Water Quality				
	Screening Filtration	Infiltration/ Recharge	Settling	Biological Uptake	Temperature Control	Soil Adsorption	Volume Control	Rate Control	Velocity Control	Evapotranspiration
Pollution Prevention	Not applicable - pollutants not exposed to stormwater									
Better Site Design/Low Impact Development	1	2	2	2	2	2	1	2	2	2
Runoff Volume Minimization		2			2		1	2		
Temporary Construction Sediment Control			1					1	2	
Bioretention	1	2	2	2	2	2	2	2		2
Filtration	1	2		2		2		2		2
Infiltration	2	1		2	1	2	2	2		
Stormwater Ponds		2	1	2				1	1	2
Stormwater Wetlands	2	2	1	1		2		1	1	2
Supplemental Treatment	Each supplemental and proprietary device should be carefully studied to learn the primary and secondary pollutant removal functions.									
1 = Primary Pollutant Removal 2 = Secondary Pollutant Removal Mechanism										

Water Quantity Control Mechanisms

Volume Control

Methods to limit the net increase in stormwater runoff volume caused by the creation of new impervious surfaces. Most common techniques include best site designs that offer limitation or disconnection of new surface areas, infiltration, evapotranspiration and re-use by vegetation.

Rate Control

Detention of stormwater runoff to slow the discharge of runoff to surface waters to rates comparable with pre-development conditions. Effective for peak rate control, but can significantly increase the time period of the peak flows.

Velocity Control

Similar to rate control; intentional restriction of stormwater runoff such that velocity of discharged runoff through downstream channels does not cause channel erosion.

Evapotranspiration

Specific volume control technique that uses evaporation from water surfaces or transpiration by vegetation.

See references listed in Appendix B for details about integrated stormwater management, SCM selections, specific SCM design schematics and the unified sizing approach. For example, the *Minnesota Stormwater Manual* provides detailed SCM calculations and designs, the *Low Impact Development Manual for Michigan* provides a summary of calculations and methodology, and the SUSTAIN model by EPA provides step-by-step site design and SCM selection exercises.

ROOFTOP RUNOFF CONTROLS

Rain Gardens

Figure 6.103: Maplewood, Minnesota Rain Garden. Source: University of Wisconsin-Extension and the Wisconsin Department of Natural Resources.

Practice Description

As one form of bioretention, a rain garden is designed to collect stormwater runoff from small areas. (See Bioretention System.) A rain garden is an attractive, landscaped area built in a natural or constructed depression and designed to capture and filter stormwater runoff as a natural system would. It is usually planted with perennial native or adaptive plants selected to tolerate periods of inundation and drought, although typically designed to drain in less than a day. Use rain gardens catch runoff from impervious surfaces such as rooftops, small parking lots, driveways and similar surfaces. They can be constructed in residential, commercial, parks or neighborhood areas or inside traffic roundabouts (See Figure 6.103).

Rain gardens can be constructed near the source of runoff to slow the stormwater, prevent erosion and filter pollutants before draining to local waterways. When used in combination with other rain gardens or practices, these gardens can help achieve desirable drainage rates, velocity reduction and groundwater recharge – specifically by capturing Rainfall from a small storm, or water quality storm (approximately a one-inch event) while diverting the larger storm runoff to the storm drain system. Rain gardens provide habitat and food for wildlife and enhance the aesthetics of an individual yard or a community.

Rain gardens are applicable across the Midwest, including cold climate or karst areas with minor design adjustments. They can be used individually to improve stormwater quality and reduce peak runoff rates for small areas such as rooftop drainage areas, or they can be used in multiples across a larger area. Rain gardens, as long as they are lined properly, can also be used to treat stormwater hot spots where pollution in runoff is higher than typical – gas station parking lots for example.

Figure 6:104 Rain garden in roundabout designed to capture/infiltrate stormwater, Milwaukee, WI. Source: Bob Newport, EPA Region 5

Recommended Minimum Requirements

Rain gardens should be designed by a qualified professional when they are to be built as part of a comprehensive stormwater management system. The site superintendent and field personnel should refer to plans and specifications throughout the construction process. If an individual homeowner wishes to install a rain garden, they should be able to install one by following simple guidelines. A great resource is *Rain Gardens: A How-To Manual for Homeowners* by Wisconsin Extension (see References).

Siting and Design Considerations

Consideration should be given to location of the runoff source, water quality goals, drainage volume target, slope, soil type, groundwater recharge goals, costs and performance limitations.

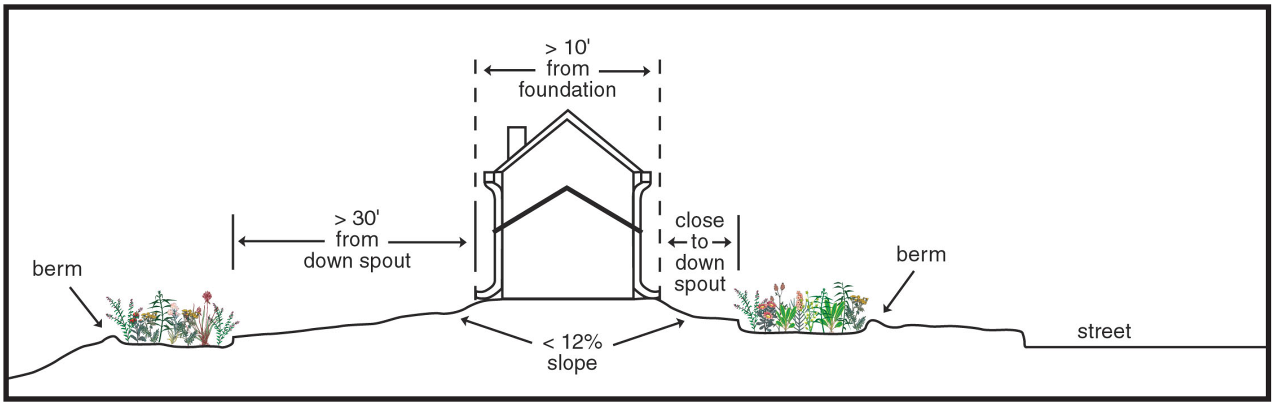


Figure 6.105 Rain Garden Schematic Diagram for Residential Applications.
Source: Wisconsin Department of Natural Resources

Site Location

Rain gardens should be placed in natural depressions or in areas where water will naturally collect. For example the lowest point of a catchment area where runoff is discharged from the rooftop. Or, stormwater can be routed to rain gardens in dryer locations, if increased groundwater recharge is the primary goal.

- Do not locate rain gardens within 10 feet of a building, because infiltration water can seep into the foundation.
- Do not locate rain gardens within 25 feet of lateral sewer lines, because they can increase the severity of inflow and infiltration into the sewer line. Sewer laterals are often located between the front of the house and the street.
- If the area naturally ponds for an extended period of time, additional engineering techniques will be needed to enhance drainage while maintaining the desired infiltration rate. Or the practice may need to be relocated.

A rain garden should have an area about 20 percent the size of the roof or driveway area draining into it. A typical rain garden for a residential home or small building is between 100 and 400 square feet. Rain gardens are often shaped longer than they are wide and positioned perpendicular to the slope of the land to maximize their function.

Pollutant Removal

Rain garden plants take up stormwater and pollutants such as:

- Heavy metals (e.g., copper, lead, zinc)
- Nutrients (e.g., nitrogen, phosphorous and potassium) and calcium.

The thin mulch layer and the engineered soil allow for quick infiltration of the stormwater. The mulch layer is exceptionally good at filtering out heavy metals from the stormwater. The soil layer filters heavy metals as well as nutrients, oil, grease and other pollutants.

Filtered stormwater percolates down to the gravel layer. The gravel stores some of the stormwater so it may continue to flow downward through the natural soil to the water table. The remaining water is re-released into the stormwater system via the underdrain if present. Rain gardens will vary in performance, based on accuracy and nature of design, installation and maintenance. More information about pollution control is available in the International Stormwater BMP Database at www.bmpdatabase.org/BMPPerformance.htm and in additional resources listed in Appendix C.

Ponding Volume and Conveyance

The ponding depth of a rain garden is typically between 4- and 6-inches. The garden should be designed to drain within two days in order to avoid nuisance insects. Exfiltration can be added where increased groundwater recharge is desired. Or, the filtered runoff can be collected in a perforated underdrain and returned to the storm drain system. The rain garden should be located relatively close to the source of runoff, but not too close to buildings or sewer laterals. The conveyance paths to and from the rain garden should be designed as part of the system, including an overflow drain if appropriate.

Rain gardens should be used to collect runoff from small areas such as:

- Rooftop runoff.
- Driveways.
- Small parking lots and similar areas.

They work best in a series of small runoff management practices if being used on larger sites. If the drainage area is too large, the rain garden will get overloaded and tend to clog.

Slope

A rain garden should be placed on a relatively shallow slope, where the slope of the surrounding watershed is limited to two percent to ensure an acceptable rate of flow into the garden area. Adequate slope is needed to ensure the water entering the rain garden can be connected with the storm drain system as necessary.

Soil

The proper design of a rain garden depends on the infiltration rate of the existing soil. If infiltration rates are less than ¼ inch per hour, the soil will need to be amended or completely replaced (engineered) to promote immediate infiltration. Engineered soil mixes are generally a homogenized mixture of equal parts of sand, topsoil and compost. Local jurisdictions may have specific requirements that should be reviewed.

Groundwater Recharge

Rain gardens are often constructed to reduce volume, rate and pollutant runoff. Design variations can be added to enhance groundwater recharge if desired or send overflow to the stormwater conveyance system if necessary. If the rain garden is designed and constructed properly to achieve infiltration, many of the small storms of concern (water quality storms) will not discharge at all. As a result, groundwater recharge will be a secondary benefit. Additional techniques and plant selection will need to be considered where groundwater levels might intersect the rain garden bed.

Plant Selection

Plant selection should include native or adaptive species tolerant of both wet and dry cycles. Deep rooted perennial plants are encouraged to increase the rate of infiltration. Larger plants have greater root capacity than smaller plants. Ponding creates conditions normally harsh to seed germination, therefore, rain gardens may need to be planted from root stock instead of from seed. Trees and shrubs may be used, but occasionally sod is used. Avoid planting evergreens if the area is to be used for snow storage, because salt can kill plants via roots that do not go dormant in the winter time.

Plants should be selected based on their native or adaptive status to the location. In Missouri, Grow Native! is an excellent resource for visual and narrative descriptions of native plants. For more information, see www.grownative.org. Many of these plants grow throughout the Midwest.

Costs

Rain garden costs will vary depending on the site preparation and plant selection. If the rain garden is excavated and new growing media installed, it will cibsust of one set of costs. If the rain garden is not excavated and is just amended, costs will be much lower, although the volume management will be impacted.

A general rule of thumb is that residential rain gardens average about $3 to $4 per square foot, depending on soil conditions and the density and types of plants used. Commercial, industrial and institutional site costs can range between $10 and $40 per square foot. For additional cost discussion and design tools, see LID Urban Design Tools at www.lid-stormwater.net/bio_costs.htm.

These costs should be weighed against costs for conventional stormwater management and its limitations for meeting water quality requirements. In addition, rain gardens can be incorporated into the landscaping, where operation and maintenance costs are relatively minimal. Rain gardens are designed to capture rainfall at the source of runoff, and therefore are strategically small and distributed. As landscaped features, less watering is required – especially when planted with deep-rooting native or adaptive plants. Rain gardens do not consume as much land area as a conventional detention basin. If designed, installed and maintained properly, a string of rain gardens can meet water quality requirements at a cost less than or equivalent to conventional detention basins that do not meet required water quality controls. In addition, costs to the municipality are reduced when proper owners assume responsibility for the minimal operation and maintenance. However, some cost is associated with keeping property owners educated about rain garden requirements.

Additional Considerations

Rain gardens do not provide significant channel protection, unless they are used in combination with other rain gardens or practices. A single rain garden is not designed to infiltrate large volumes. It is typically designed to treat and infiltrate the first inch of runoff. However, when used in combination with other rain gardens or practices, it can provide significant volume, rate and pollution reductions, thereby protecting channels as well.

Construction

Site Preparation and Grading

It is important to protect the designated location of the rain garden throughout the construction project. Avoid compacting the soil or creating other conditions unsuitable for supporting the rain garden.

An appropriate soil percolation rate should be established at each particular site. If the existing soils do not allow a sufficient rate of infiltration, a homogenized mixture of equal parts of sand, topsoil, and compost may be used in the rain garden to hasten infiltration. If there are concerns over long-term ponding as a result of low infiltration rates of the underlying soil, the site may need to be changed to be suitable for a rain garden. An underdrain may be used, although the relative cost of this added feature is often a concern.

Use river rocks or a filter strip to dissipate energy where water enters the garden.

- Design for rain gardens, rain barrels and cisterns should include an overflow point to accommodate severe rain events that may overload the system.

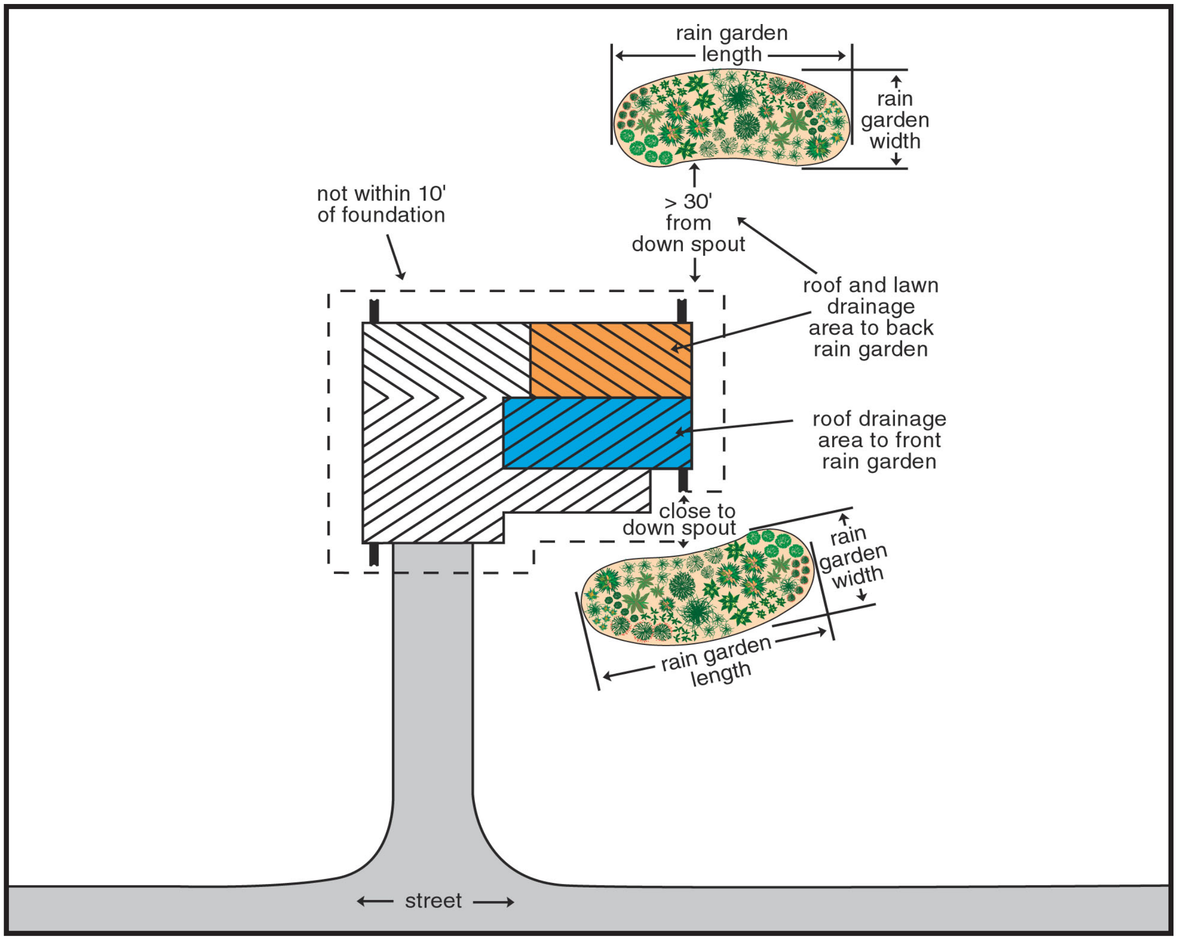


Figure 6:106 Rain garden schematic. Source: University of Wisconsin-Extension and the Wisconsin Department of Natural Resources.

Planting

- Construction and planting can be conducted year-round according to the plant type. The planting instructions for the plant should be followed.

Some engineered soil mixes may not provide sufficient strength for newly planted trees to stand in high winds. Tie straps may be needed or trees should be placed on the perimeter of the rain garden so their roots are anchored in stable soil.

Construction Verification

In the case of a professionally designed rain garden, measure the finished grades and configuration and compare them against the plans. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

The success of a rain garden depends on careful construction and on proper follow-up care, including:

- Watering and weeding often during first growing season.
- Annual removal of dead vegetation each spring.
- Annual addition of mulch, if needed.
- Periodic inspection for soil erosion control, plant health needs and litter removal, as needed.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check to ensure the rain garden was constructed properly. Repair eroded surface, provide fresh topsoil, reseed or re-vegetate, and apply new mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch, use a heavier inorganic mulch (pea gravel).
Unsuccessful vegetation establishment.	Recheck soil conditions for tilth and for conditions suitable for plant growth. Choose plant species that prefer the site conditions. Reset plants during an appropriate planting season. Reapply mulch.

Disconnected Downspouts

Figure 6.107 Downspout Disconnection to a Rain Garden. Source: Courtesy of USDA-NRCS, Iowa

Practice Description

Conventional structures direct the runoff from roofs into gutters and downspouts that then flows to a hard surface (parking lot), an underground storm sewer system and in some cases a sanitary sewer system. Routing stormwater from a hard surface to a discrete channel creates a flow surge. These surges can easily overwhelm storm or sanitary sewer systems. By disconnecting downspouts and routing flow to rain gardens or other pervious areas, runoff is redirected and may prevent the collection system from overloading during heavy precipitation events. Roof runoff can be beneficially used when redirected to a yard or landscaped area, rain garden or a storage system for later use (rain barrel or cistern). See Figure 6.107 and sections on rain gardens and rain barrels.

Recommended Minimum Requirements

Beneficial routing of downspouts may be applied to residential, commercial, industrial, or institutional properties. To ensure the designed routing of roof runoff does not result in other problems, the property owner should follow the guidance presented below:

- Discharge from pipe or downspout must not direct flow toward flood sensitive locations such as building foundations.
- Discharge point should be at least 10 feet from buildings and structures with basements or crawl spaces.

- Runoff should be discharged at least 5 feet from property boundaries, or at the furthest possible point from the adjacent property.
- Splash blocks or similar material may need to be used at the discharge point to dissipate erosive energy.
- Design for rain gardens, rain barrels and cisterns should include a designed overflow point to prevent damage to the system during severe rain events.
- Rain gardens, barrels or cisterns may need to be designed in combination across the property to attain desired reductions in volume and velocity and desired infiltration capacity.
- Discharge should be directed away from lateral sewer lines to avoid adding to inflow and infiltration problems.

Materials
Durable gutter grade materials such as aluminum, steel, copper, vinyl or plastic should be used.

Construction
Disconnecting downspouts can be simple or complex, depending on the site configuration, site requirements and goals. New projects can be readily designed to direct rooftop and similar runoff to rain gardens, barrels or cisterns. The site superintendent and field personnel should consult the site plan and specifications for direction about placement, special equipment and materials. To disconnect an existing downspout, most homeowners possess adequate skills to complete the project. See Appendix B and Appendix C for additional resources.

Installation
To disconnect an existing downspout, measure and cut approximately 9 inches above the sewer standpipe. The standpipe should be plugged or capped with an in-pipe test plug or an over the pipe cap secured with a hose clamp. An elbow and downspout extension may be secured with metal screws to the existing downspout. Downspouts must drain at least 6 feet from basement walls and at least 2 feet from crawl spaces. A splash block may be used at the end of the extension to help prevent erosion.

Maintenance and Inspection
Disconnecting a downspout typically requires minimal effort and minimal continued maintenance. Periodic maintenance activities include the following:
- Inspecting the discharge location to ensure drainage is working as intended.
- Replacing materials as needed; many materials can last 5 to10 years.
- Removing accumulated leaves or debris, 2 to 4 times per year.

Common Problems and Solutions

Problem	Solution
Foundation issues or water in the basement structure.	Downspouts must drain at least 10 feet from basement walls and at least 2 feet from crawl spaces.
Erosion where the downspout discharges.	A splash block may be used at the end of the extension to help prevent erosion.

Rain Barrels

Figure 6.108: Residential Rain Barrel. Source: *ABCs of MPs*

Practice Description

The roofs of many houses receive 600 to 1,000 gallons of water per one inch of rainfall. Rainwater falls on the roof, flows to the gutters and pours out of downspouts into the driveway or yard. Rain barrels intercept flow at the downspout, where it can be stored for use in watering nearby gardens or other landscape plantings. Usually the barrel is constructed with a 55 gallon drum, a flexible inlet pipe or hose, a spigot or closeable drain and a screen grate or closure to keep debris and insects out. Rain barrels are relatively simple and inexpensive to construct and can be placed under most residential gutter downspouts.

Recommended Minimum Requirements

Rain barrels may be applied to residential, commercial, industrial, or institutional properties. To ensure success, the property owner should follow the guidance presented below:

- Design for rain gardens, rain barrels and cisterns should include an overflow point to accommodate severe rain events that may overload the system.
- Locate the rain barrel directly under a downspout close to the structure.
- Carefully inspect screens to ensure mosquitoes cannot breed in barrels.
- Install a device to disconnect or divert water away during winter months to prevent damage from the freeze or thaw cycles.
- Provide an overflow that drains to a safe location.
- Direct overflow away from the foundation and away from lateral sewer lines.
- Secure the rain barrel to a level surface.
- Include a lid or screen that prevents the entry of mosquitoes and debris.

Construction

Installation of a rain barrel may be completed by homeowners, a property owner, or a qualified professional. Installation of a rain barrel should be in accordance with the critical elements described above. If the rain barrel is purchased from a retailer, it should be installed in accordance with the manufacturer's recommendations.

- The rain barrel should have an overflow that drains to a rain garden, bioswales or similar landscape feature.
- The rain barrel should be secured to a level surface.
- The barrel should have a lid that prevents the entry of mosquitoes and debris.

Installation

To install rain barrels on a new development, follow site plan specifications. When disconnecting an existing downspout, cut the downspout to the height necessary to accommodate the placement of the barrel. If the downspout entered a standpipe, the standpipe should be plugged or capped with an in-pipe test plug or an over-the-pipe cap secured with a hose clamp. An elbow and downspout extension may be secured with metal screws to the existing downspout and connected to the barrel. The overflow must drain at least 6 feet from basement walls and at least 2 feet from crawl spaces. A splash block may be used at the end of the extension to help prevent erosion.

Maintenance and Inspection

Installation of a rain barrel typically requires minimal effort and minimal continued maintenance. Periodic maintenance activities include the following:

- Checking the barrel and seals to ensure the system is working as designed and intended.
- Replacing materials or parts as needed.
- Removing accumulated leaves or debris a few times each year.

Common Problems and Solutions

Problem	Solution
Mosquitoes	Empty and clean the rain barrel. Ensure the screen (or spout-conformed lid) is properly in place and secured.
Foundation issues or water in the basement structure.	Route the overflow to drain further than 10 feet from basement walls and further than 2 feet from crawl spaces.
Erosion where overflows discharge.	A splash block may be used at the end of the extension to help prevent erosion

Cisterns

Figure 6.109: Residential Cistern. Source: Shockey Consulting Services

Practice Description

Practices that store rooftop runoff, such as cisterns or rain barrels can be installed as part of the overall on-site stormwater management system. A cistern collects and temporarily stores rain water runoff from an adjacent roof. Catchment capacity at many residential sites ranges between 600 to 1,000 gallons of water during a typical event. While cisterns may be applied to residential properties, their larger volume may make them especially beneficial in commercial or industrial settings where rooftops are expansive. Cisterns can be manufactured from various materials including plastic, concrete or metal. Installation costs are dependent on the material, size of application and location of the cistern (above or below ground).

Depending on local codes and available treatment methods, water collected in cisterns may be used in a variety of ways in the landscape and home. A common use is watering nearby gardens or other landscape plantings.

Recommended Minimum Requirements

Rainwater harvesting from rooftops is often considered pollutant-free, however, this runoff does contain low concentrations of pollutants such as plant debris, metals from roofing materials, nutrients from atmospheric deposition or bacteria from bird droppings. The levels of these pollutants are normally low enough to not inhibit its use for plant irrigation. Proper design and installation of the cistern will ensure problems relating to pollutants, such as system clogging, fouling, or odor, do not develop. Typically, rooftop runoff exiting the gutter system is screened to filter particles, before being routed to the cistern. Often, the design includes a method to prevent the initial flush of the roof, and its elevated amount of pollutants, from entering the cistern. Typically, collection containers should be constructed of dark materials or buried to prevent light penetration and the resulting algal growth.

Check the Uniform Plumbing Code or the International Plumbing Code; and regional and municipal building codes for criteria before initiating a rainwater harvesting project.

To ensure success, cistern construction should follow these important steps:

- For underground systems, the cistern should be a minimum distance of 100 feet from existing septic tanks and leach fields.
- Consider the depth of the water table when evaluating an underground system.
- Design of cisterns should include an overflow point to accommodate severe rain events that may overload the system.
- Choose appropriate cistern construction, drainage surfaces and filtering equipment to prevent contamination of the water supply.
- Ensure local requirements allow the construction and use of devices to catch and store rainwater.
- Review local codes for use and treatment of rainwater if its intended use is indoors.

Construction

Installation of a cistern may be completed by homeowners, a property owner, or a qualified professional. Installation of a cistern should account for four components:

- Route overflow to a safe location.
- Secure the cistern to a level surface.
- Include a conformed lid or screen to prevent entry of mosquitoes and debris.
- Install a disconnect and draining feature for use during winter months to avoid freeze or thaw damage.

Installation

Because the size, shape, materials and operation methods of marketed cisterns will vary significantly, the plans and specifications or the manufacturer's guidance should be carefully reviewed before purchase and closely followed during construction and use.

Maintenance and Inspection

Maintenance and inspection of a cistern will vary depending on the systems design and the intended use of the rainwater. Periodic maintenance activities include the following:

- Periodic checks of the system to ensure it is working as designed and intended.
- Periodic replacement of materials or parts.
- Annual removal of accumulated leaves or debris or as needed.

Additional requirements for rain water collection and use may be imposed at the local level.

Common Problems and Solutions

Problem	Solution
Mosquitoes.	Empty cistern and clean. Ensure the screen is properly fitted, or install a solid lid conformed around the drain pipe.
Foundation issues or water in the basement structure.	Route the overflow to an outlet point at least 6 feet from basement walls and at least 2 feet from crawl spaces. Increase the distance as necessary.
Erosion where overflows discharge.	Use a splash block at the end of the extension to help prevent erosion.

Green Roofs

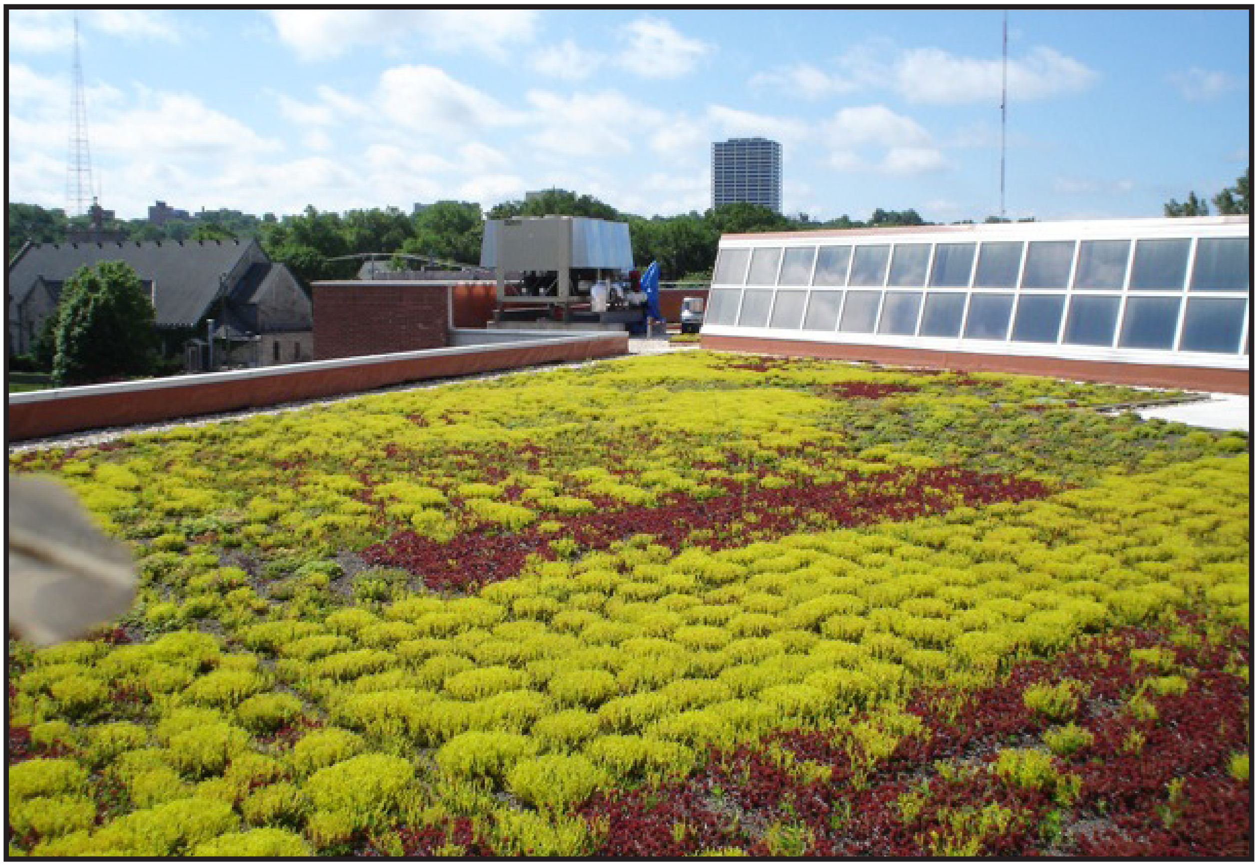


Figure 6.110: Boulevard Brewery, Kansas City, Missouri. Source: Boulevard Brewing Company

Practice Description

Green roofs are used to reduce stormwater runoff from commercial, industrial and residential buildings. In contrast to traditional roofing materials, green roofs absorb, store and evapo-transpire rainfall. Green roofs offer additional benefits including increased thermal insulation and energy efficiency, increased acoustic insulation and increased durability and lifespan.

These systems are generally classified as extensive, semi-intensive or intensive. Extensive green roofs have 6 inches or less of growing medium, whereas intensive green roofs have greater than 6 inches of substrate. Semi-intensive green roofs can be defined as a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is above or below the 6 inch depth. Semi-intensive and intensive green roofs are classified as roof gardens and are typically designed to be open to foot traffic for outdoor enjoyment.

Green roofs may be used in new construction or retrofitted to existing structures. They are applicable to residential, commercial and industrial buildings and can be constructed on roofs with up to a 20 percent slope. In retrofit applications, the existing roofing should be examined for adequate structural strength.

Pollutant Removal

According to *Opportunities and Challenges for Managing Nitrogen in Urban Stormwater: a Review and Synthesis* (see Appendix C and References), mature green roof vegetation can likely take up more nutrients from rainfall and media than younger, less established green roofs. Although there is a limited body of research available nitrogen removal capabilities of green roofs, studies suggest using low to medium dosages of controlled-release fertilizers, planting species that require little or no fertilization, using less nutrient-rich organic matter amendments in green roof media and reducing irrigation to avoid creating runoff can minimize the amount of nitrogen runoff. Consequently, additional pollutants of concern such as phosphorus will also be controlled.

Additional Considerations

Structural support is critical to increased media thickness necessary to promote denificiation and therefore green roofs are generally not an option as a retrofit practice. Opportunities are greater for incorporating adequate support into new construction, but can add to the cost of materials by an estimated six percent. However, construction costs should be weighed against reduced heating and cooling costs, increased stormwater pollution control, reduced heat island effect and increased usable space in the case of rooftop gardens designed for social activity.

Recommended Minimum Requirements

In any application, the building must be able to support the loading of green roof materials under fully saturated conditions. An extensive vegetated roof cover is typically designed with 2- to 6-inches of engineered planting media. The media should have a high mineral content and is typically 85 percent to 97 percent non-organic materials. Fertilization should be tightly controlled on vegetated roofs intended to achieve water quality benefits, because over fertilization will defeat the purpose of pollution prevention from rooftop runoff. Internal building drainage should be addressed to ensure deck drains or scuppers are protected during large rain events. Typically, vegetated roofs are grown on conventional flat roofs. Assemblies planned for roofs with pitches steeper than 2:12 should incorporate supplemental measures to provide stability and prevent sliding. Generally, the designer should consider a waterproofing layer, a soil or substrate layer that has adequate pore space and rapid infiltration capacity, and a plant layer well-suited for local climatic conditions. Plant materials range from sedums, grasses and wildflowers on extensive roofs to shrubs and small trees on intensive roofs. The designer should consult local building codes for roof safety requirements. Necessary permits and zoning laws for building a green roof in new construction or as a retrofit to existing buildings will vary between cities.

Construction

Green roofs and roof gardens have a variety of benefits. Since this SCM integrates structural components, consultation of a design engineer is necessary. Projects should closely follow plans and specifications. The following provides an example of a construction sequence. Professional guidance or contract documents may dictate a different approach depending on the project.

- Comply with all building codes and local regulations.
- Visually inspect the completed waterproofing to identify any apparent flaws, irregularities, or conditions that will interfere with the security or functionality of the green roof. The waterproofing should be tested by the roofing applicator.
- Institute a leak protection program.
- Develop measures to protect the finished waterproofing from physical damage during construction.

- Install measures to stabilize the substrate in the case of a pitched roof slope.
- Install a root barrier, if the waterproofing materials are not impenetrable to roots.
- Install and test drainage and irrigation components, including drain access chambers, internal drainage conduit, confinement border units and isolation frames.
- Install walkways and paths for projects with public access. Ensure local codes are satisfied to ensure public safety.
- Install a drainage layer, such as a geocomposite drain mat or course of drainage media and cover the layer with a separation fabric such as a geotextile.
- Install and upper growth media layer in dual media assemblies.
- Establish plants from cuttings, seed, plugs or mats and select plants based on their toleration of periods of drought and inundation. Plant material is an integral component of a green roof.
- The contractor should provide protection from wind damage as warranted by the project conditions during the plant establishment period.

Construction Verification

Measure the finished grades and configuration against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Green roofs need to be monitored regularly during the first growing season to ensure success. During the plant establishment period, periodic irrigation may be required. Quarterly maintenance during this period includes basic weeding and in-fill planting. Periodic inspection and roof maintenance should be performed as necessary to ensure the system is working as designed. Irrigated systems will require maintenance per manufacturer's recommendations.

Common Problems and Solutions

Problem	Solution
Insufficient vegetation.	Test irrigation and soil characteristics to ensure satisfactory growing conditions. Replace vegetation where absent. Ensure adequate inspection and maintenance.
Weeds and invasive vegetation during the establishment phase.	Remove manually. Plant adaptive and competitive species of vegetation to reduce bare areas and weed growth. Ensure adequate inspection and maintenance.

Surface Runoff Control Practices
Bioretention System

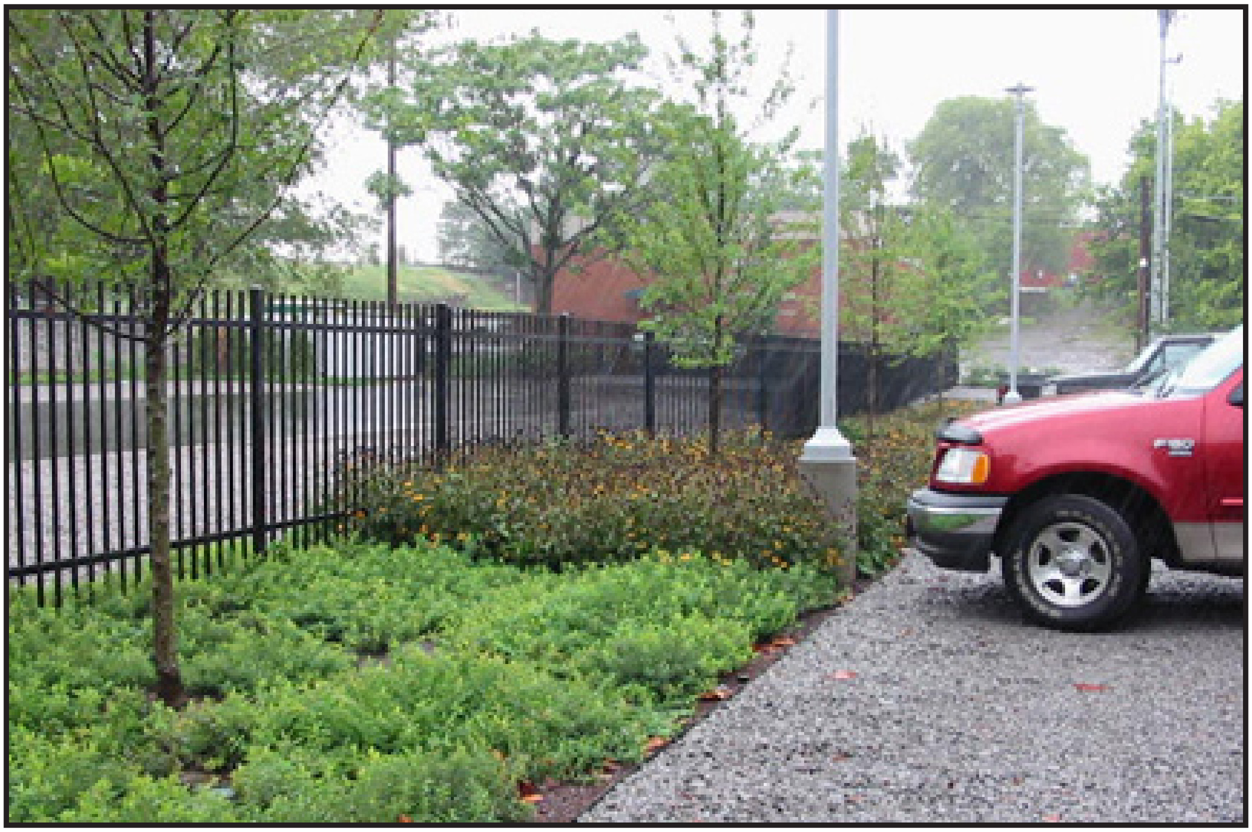


Figure 6.111: Bioretention. Source: *Green Infrastructure Digest*

Practice Description

A bioretention system is a landscaped parcel built into a natural or constructed depression; it is designed to provide on-site treatment of stormwater runoff. Bioretention systems can be located in parking lot islands or within residential areas. These systems are designed to incorporate many of the pollutant removal mechanisms that operate in natural ecosystems. During storm events, runoff water enters the bioretention system and filters through the mulch and prepared soil mix. The filtered runoff can be collected in a perforated underdrain and returned to the storm drain system. Excess runoff from larger storms is generally diverted past the facility to the storm drain system.

To achieve maximum efficiency, bioretention systems should be applied to small sites, typically less than a few acres. The drainage in larger sites should be portioned and served by more than one bioretention practice. Bioretention systems are ideal for treating runoff in urban areas and can easily be incorporated into parking lot islands or other landscaped areas. Bioretention areas may be used to treat stormwater from highly polluted areas, however, in this case, an impermeable liner may be needed below the filter bed to prevent the infiltration of pollutants into the deeper soil layers.

Recommended Minimum Requirements

Bioretention systems are adaptable to most sites and blend well with buffers, landscape berms, and environmental setback areas. The site layout of a bioretention system should be based on the contributing drainage area, underlying soils, utilities and existing vegetation. A bioretention cell should have an underdrain system, overflow, aggregate filter, planting soil bed, a mulch layer and plants that can withstand periods of inundation and drought. A bioretention cell should be designed to capture the water quality volume and to filter this water through the planting soil bed over 1 to 3 days. The cell of adequate length and width should be strategically positioned against the slope in order to maximize the capture of runoff. Inflow velocities should be reduced to less than 3 feet per second upstream of the area. Typically, a vegetated filter strip or rock diaphragm is required to reduce runoff velocities and provide a level of pretreatment. The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation.

Construction

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process.

Site Preparation and Grading

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

The bioretention cell can be excavated before final stabilization of the surrounding watershed; however, the soil mixture and underdrain system should not be placed until the entire contributing drainage area has been stabilized. Any sediment from construction operations deposited in the bioretention cell should be completely removed from the cell after all vegetation, including landscaping within the affected watershed, has been established. Excavations performed during the construction of the cell should be limited to only that necessary to create the cell and to blend the cell with the surrounding watershed. Final graded dimensions, side slopes, and final elevations should be constructed according to design drawings and specifications. Low ground-contact pressure equipment, such as excavators and backhoes, is preferable to minimize disturbance of established areas around the perimeter of the cell. No heavy equipment should operate within the perimeter of a bioretention cell during underdrain placement, backfilling, planting or mulching of the facility.

The final steps to creating the bioretention cell should include stabilizing all surfaces and beginning a regular inspection and maintenance program.

Installation

The basic components of installing a bioretention cell include an underdrain system, overflow, aggregate, planting soil bed, a mulch layer and plant establishment.

Underdrain

An underdrain increases the ability of the soil to drain quickly and therefore ensures an adequate aerobic state that allows plants to grow. A minimum 4-inch perforated pipe with an 8- to 12-inch gravel bed should be installed as an underdrain system. At least one cleanout should be installed every 50 feet on each run. The underdrain should be connected to a up-to-date stormwater management system with adequate capacity or daylight to a suitable outfall with erosion protection. Before placing the aggregate, underdrain and bioretention soil mixture, the bottom of the excavation area should be roto-tilled to a minimum depth of 6-inches to alleviate any compaction that might impede infiltration. The soil should be in a friable condition before any roto-tilling occurs, meaning the soil can be reduced to smaller pieces with little effort, and therefore isn’t susceptible to clumping or compacting.

Overflow
Overflow components of the bioretention cell include the gravel underdrain system, an aggregate overflow curtain drain, and a high-flow overflow structure. A properly designed overflow will prevent a washout of the cell's components or a reconcentration of flow.

Aggregate Versus Sand
Aggregate provides a greater porosity and is less likely to clog when compared to a sand bed. A graded aggregate filter is preferred over soil, sand, pea gravel and course gravel. If a soil surface for planting is desired, a geotextile fabric should separate the soil from the aggregate. Alternatively, a sand bed can be used underneath the soil bed. The aggregate or sand provides additional filtration, allows aeration of the planting soil bed and therefore does not need to be separated from the soil by a geotextile fabric.

Planting Soil
A planting soil bed is a mixture of organic mulch, planting soil and sand. Typically, the mixture consists of 30 percent planting soil, 20 percent organic compost and 50 percent sand. Clay should be limited to less than 10 percent. To enhance nutrient uptake, the soil must have chemical and physical properties suitable to support a diverse microbial community. The planting soil should be placed on top of the aggregate or sand layer, and should be separated with a geotextile fabric. It should have a minimum depth of 2.5 feet to provide adequate moisture capacity and create space for the root systems of plants. If larger vegetation is used (i.e. trees or shrubs), the planting soil must be at least 4-inches deeper than the bottom of the largest root ball. This soil mix will tend to not be as firm as natural soils, so larger trees or shrubs should be supported with guy wires or similar support. The planting soil mixture, alternately called the bioretention soil mixture, should be free of stones, stumps, roots, or weedy material over 1-inch in diameter. Brush or seeds from noxious weeds should not be present in the material.

A simple bio-soil permeability test is to use a 55-gallon drum with holes in the bottom. Fill the bottom of the drum with the proposed mix until it is 1-foot from the top. Fill the barrel to the top with water and time how long it takes the water to drop 1-foot. A target rate of 2-inches per hour is common.

Plants
Trees, shrubs and other plant materials should be installed as specified in the project plans and according to applicable landscape standards with the exception that pesticides, herbicides and fertilizer should not be applied during planting under any circumstances. Pesticides, fertilizer and other soil amendments should be applied after plants are through initial shock and are growing. Plant selection should include native species tolerant of both wet and dry cycles.
Deep rooted perennials are encouraged to increase the rate of infiltration

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Mulch
The final layer of the bioretention cell is the mulch. The contractor should install a shredded hardwood mulch aged a minimum of six months and consists of a 50/50 combination of bark and wood from hardwood trees. The mulch should be milled and screened to a maximum 4-inch particle size and should be free from sawdust, clay, trash and any artificially introduced chemical compounds.

Construction Verification
Measure the finished grades and configuration and compare to plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

For the first 1 to 3 years, bioretention systems require significant maintenance to ensure successful establishment. The primary maintenance requirement is inspection, repair and replacement of damaged or failed components. Routine inspections for standing water and corrective measures to restore proper infiltration rates are necessary. Invasive or weedy vegetation should be removed immediately upon discovery. During the first growing season, watering and weeding should be completed on a weekly basis. Over the lifetime of the facility, dead vegetation should be removed and mulch should be added each spring. Annual maintenance should include periodic inspection of soil erosion and plant health, as well as removal of litter when necessary.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check topsoil and repair eroded surface. Reseed or re-vegetate and apply new mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch, consider inorganic mulch in some areas.
Cells collect trash and debris.	Typical maintenance.
Standing water.	Check underdrains for clogging. Incorporate additional aggregate or sand into the soil mixture.
Unsuccessful vegetation establishment.	Examine the cell for stress factors (e.g, extended pooling, low fertility in planting medium, wildlife damage) and take corrective action.
Tall, lanky native plants.	Consider soil combinations more conducive to native plant growth in the original design. Amend the soil as necessary.

Bioswales (Vegetated Swales)

A bioswale or vegetated swale is an infiltration and filtration method typically used to pre-treat urban stormwater runoff. Bioswales can have volume and pollution reduction effects. There are generally three types of vegetated swales referred to as urban runoff management options:

- Dry swales with filter media.
- Wetland swales.
- Turf swales.

When determining whether to use a bioswale or other technology in overall site design, consideration should be given to the drainage area size, impervious area and water quality goals. Water quality swales should be used in areas where either the drainage area is small, or the impervious area is small, or both. Otherwise, larger conveyance design storms become incompatible with the features needed to provide water quality benefit (e.g., vegetative filtering, erosion).

The main difference between a bioswale and bioretention is that bioswales have a conveyance function for storms greater than the small storm (water quality storm). (See Bioretention Systems.) A standard bioretention system or cell does not have a conveyance function, but rather a bypass (overflow inlet) for greater storms. Wetland swales, as well as wetlands, are preferred in areas where groundwater stays charged enough to support the diverse group of wetland plants. However, wetlands are preferred over wetland swales where there is a greater need for volume reduction in addition to water quality.

All swale designs need to include a hydraulic analysis of the swale during larger storm events. The design of the larger storm events should be based on local conveyance requirements, which are typically a 10- or 15-year storm event. Many communities also have a freeboard requirement, which means the maximum water surface elevation for the design storm should be so many feet below the top of the channel, depending on the design specifications. For example, the freeboard requirement throughout St. Louis County, MO is 1-inch, but sometimes the requirement is waived for smaller “basins” depending on the risk of an overtopping event.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design, St. Louis, Missouri*. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Dry Swale

Figure 6.112 Native Parking Lot Bioswale. Anita B. Gorman Conservation Discovery Center - Kansas City, Missouri.

Practice Description

Dry swales are broad and shallow channels with vegetation covering the side slopes and channel bottom. These swales use native or adaptive plant species, and unlike the wetland swale include an engineered soil mix, a graded filter and an underdrain system for drainage to promote growth of dry swale plants. They are similar to wetland swales in that they convey stormwater runoff slowly, promoting infiltration and treatment. Their broad, shallow, vegetated channels promote infiltration, plant transpiration, adsorption, settling of suspended solids and breakdown of pollutants.

Dry swales can replace curb and gutter storm sewer systems to convey shallow concentrated flow. These swales promote infiltration and filter pollutants through creating low (slow flow) gradients, using soil and mulch to promote pollutant absorption and dense plant growth, and establishing plant species that can biologically uptake soluble pollutants. This SCM often enhances the aesthetic value of a site with minimal maintenance. It is particularly applicable in natural depressions adjacent to roads.

Recommended Minimum Requirements

The dry swale should be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, and be salt tolerant. Longitudinal slopes should range between one and six percent and side slopes should be between 3:1 and 5:1 (horizontal distance to vertical rise referred to as H:V). Check dams may be used to provide limited detention storage and to develop a milder slope. The bottom width of the swale is typically less than 8-feet but may be sized to convey flow as required. The swale should be sized to convey the design storm event with a minimum of 6-inches of freeboard.

To determine the optimal location for a dry swale, soil conditions and compaction should be tested. Swales provide the most benefit when located adjacent to an impervious surface but can be used in combination with porous pavement. The designer should review local requirements for site grading, erosion and sediment control, and potential invasive vegetation.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design, St. Louis, Missouri*. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Figure 6.113: Native Vegetated Swale Source: EDAW, EACOM

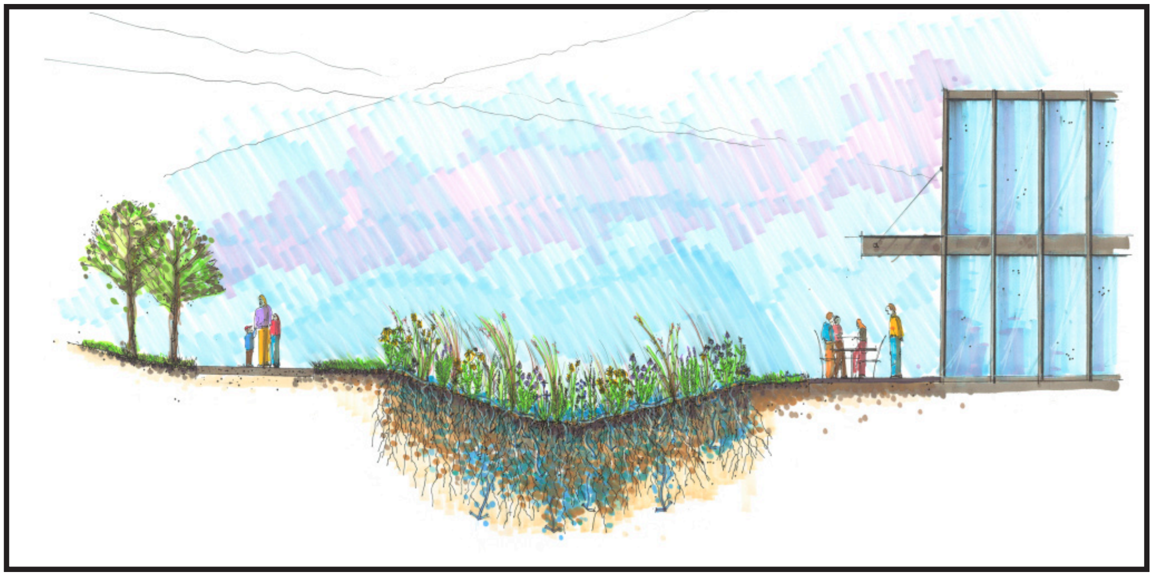


Figure 6.114 Bioswale Cross-sectional Diagram   Source: NRCS, Iowa, www.ia.nrcs.usda.gov

The dry swale construction should begin only when upgradient temporary erosion and sediment control measures are in place to prevent sediment laden stormwater from depositing unwanted soil into the swale and reducing the infiltration efficiency. An example construction sequence follows:

- Rough grade the swale. It is critical excessive compaction or land disturbance be avoided when parking or using equipment, otherwise it will be necessary to amend or replace compacted soils. Excavating equipment should operate from the side of the swale and never on the bottom.

- The underdrain should be installed after the site has been rough graded. An underdrain increases the ability of the soil to drain quickly and therefore ensures an adequate aerobic state that allows plants to grow. A minimum 4-inch perforated pipe with an 8-inch gravel bed should be installed as an underdrain system. Filter fabric should be placed over the gravel bed to separate it from the planting soil bed. At least one cleanout should be installed every 50 feet. The underdrain should be connected to a conventional stormwater management system (pipes) or to an open conveyance (daylighted) to a suitable outfall with erosion protection.

- The overflow components of the bioswale include the gravel underdrain system and a high-flow overflow structure. It is critical to provide a safe discharge point for overflows.

- Install the aggregate or sand layer. Aggregate provides a greater porosity and is less likely to clog when compared to a sand bed. It is acceptable to place an 8-inch layer of aggregate underneath the planting soil bed, when it is separated by a geotextile fabric.

- Install the planting soil with careful attention to match the design grading. A planting soil bed is a mixture of organic mulch, planting soil, and sand. Typically, the mixture consists of 30 percent planting soil, 20 percent organic compost, and 50 percent sand. To enhance nutrient uptake, the soil must have a combination of chemical and physical properties that have the capacity to support a diverse microbial community. The planting soil should be placed on top of the aggregate or sand layer, separated by a geotextile fabric. The planting soil mixture, sometimes called a bioretention soil mixture, should be free of stones, stumps, roots or weedy material more than 1-inch in diameter. Brush or seeds from noxious weeds should not be present in the material.

- Seed, vegetate and install protective lining according to the plans and final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation, however, may be needed in periods of drought. Vegetation should be established as soon as possible to prevent erosion and scour.

  For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Construction Verification
Measure the finished grades and configuration and compare with the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection
The required maintenance associated with bioswales is minimal. Typically, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a diverse vegetative cover. Specific maintenance activities should occur within 48 hours after every storm event greater than a 1-inch rainfall until the plantings and vegetation are fully established. The maintenance activities should include:

- Repair erosion problems, damage to vegetation and remove sediment and debris accumulation.
- Vegetation on the side slopes should be inspected for erosion and formation of rills and gullies.
- Pools of standing water should be dewatered and discharged to an approved location and the design grade should be restored.
- Vegetation should be mowed or trimmed, as necessary to ensure safety, aesthetics, or to suppress weeds and invasive vegetation.
- The uniformity of the swale cross section and longitudinal slope should be inspected.
- The swale inlet and outlet should be inspected for signs of erosion or sediment accumulation.

Other maintenance activities should be completed as needed:

- Alternative vegetation may be planted if the existing vegetation is not thriving.
- Bare areas should be reseeded or revegetated and the appropriate erosion control measures should be installed when soil is exposed.
- During the period of establishment, the swale may need to be watered during dry periods.

Depending on the characteristics of the contributing drainage area, winter conditions may necessitate additional maintenance. The swale should be inspected at the beginning of spring for residuals of sand or salt. Moderate amounts of these materials might affect vegetative growth. Damaged vegetation should be replaced. If roadside or parking lot runoff drains to the swale, mulching or soil aeration may be required in the spring to restore the soil structure.

Common Problems and Solutions

Problem	Solution
Draw down time is greater than 72 hours.	Clean out underdrain system, ensure it is clear.
Erosion occurs on the side slope and bypasses the check dam.	Increase the length of the check dam so the lowest point is in the center of the swale.
Significant erosion between check dams.	Install additional check dam and follow recommended guideline for spacing.
Poor vegetative growth due to roadway salt accumulation.	Use nontoxic deicing agents, applied as blended magnesium chloride based liquid or as pretreated salt. Plant salt tolerant vegetation. Avoid evergreens, because roots that do not go dormant are susceptible to salt kill.
Unsuccessful vegetation establishment due to plant intolerance to conditions.	Plant selection should include native species tolerant of both wet and dry cycles and plants should be established in appropriate zones. Deep rooted perennials are encouraged to increase the rate of infiltration.

Wetland Swale

Figure 6.115: Wetland Swale. Source: Olsson Associates

Practice Description

Wetland swales are broad, shallow channels with native vegetation covering the side slopes and emergent vegetation covering the channel bottom. Unlike a dry bioswales, these swales do not include a prepared soil filter bed or underdrain system. Stormwater runoff is slowly conveyed resulting in higher rates of infiltration, plant transpiration, pollutant adsorption, settling of suspended solids and microbial breakdown of pollutants.

Wetland swales can replace curb and gutter storm sewer systems and may be used anywhere the water table is at or near the surface. These swales are well suited for roadside applications, along the property boundaries of development or in areas where stormwater tends to collect for extended periods of time.

Recommended Minimum Requirements

The wetland swale should be planted with dense, low-growing native vegetation that can withstand periods of inundation, drought and soils with high electrical conductivity (high salt content). Longitudinal slopes should range between one and six percent and side slopes should be between 3:1 and 5:1 (H:V). Check dams may be used to provide limited detention storage and to develop a slower flow rate. The bottom width of the swale should be between 2- and 8-feet. The swale should be sized to convey the largest/average 24-hour, 10- to 15-year storm event with a minimum of 6-inches of freeboard (based on local conveyance requirements).

To determine the optimal location for a wetland swale, soil conditions and compaction should be tested. Swales provide the most benefit when located adjacent to an impervious surface but can be used in combination with porous pavement. The designer should review local requirements for site grading, erosion and sediment control, and potential invasive vegetation.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Pollutant Removal

The wetland swale has water quality treatment mechanisms similar to stormwater wetlands, which rely primarily on settling of suspended solids, adsorption and uptake of pollutants by vegetative root systems. Chloride contamination of shallow groundwater tables should always be of concern in the design and application of wetland swales.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

The wetland swale is constructed directly within existing soils and may or may not intercept the water table. Like the dry swale, the water quality volume within the wet swale should be stored for approximately 24 hours. The wetland swale has water quality treatment mechanisms similar to stormwater wetlands, which rely primarily on settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems. These systems are often called wetland channel systems since they are basically a linear shallow wetland system.

The wetland swale construction should begin only when the upgradient temporary erosion and sediment control measures are in place. An example construction sequence follows:

- Rough grade the swale. Equipment should avoid excessive compaction or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to compaction of the subgrade, 18-inches should be removed and replaced with a blend of topsoil and sand to promote infiltration and the establishment of plants and microbes. Topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.
- Construct check dams, if required.
- Fine grade the swale. Accurate grading is critical for swales because even the smallest nonconformities may compromise flow conditions.
- Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation, however, may be needed in periods of drought.

- Vegetation should be established as soon as possible to prevent erosion and scour, however it make take a few years for plants to become fully established.

After all tributary areas are sufficiently stabilized, temporary erosion and sediment controls may be removed. It is important for the swale to be stabilized before receiving upland flow.

Maintenance and Inspection

The required maintenance associated with wetland swales is minimal. Typically, maintenance strategies for swales focus on sustaining the preferred hydraulic flow and pollutant removal efficiency of the channel, as well as maintaining a higher biological richness through promoting microbial growth and a diverse vegetative cover. The following maintenance activities should occur within 48 hours after every storm event greater than 1-inch rainfall.

- Repair erosion problems, damage to vegetation and remove sediment and debris accumulation.
- Vegetation on the side slopes should be inspected for erosion and formation of rills and gullies.
- Pools of standing water should be dewatered and discharged to an approved location and the design grade should be restored.
- Vegetation should be mowed or trimmed, on an annual basis, as necessary to ensure safety and aesthetics, or to suppress weeds and invasive vegetation. Mowing equipment should avoid wet areas where compaction of the swale and erosion would be potential issues.
- Use wet tolerant plants in the bottom of the swales so the area will not be bare or begin to collect sediment. See available plant resources in Appendix C.
- The uniformity of the swale cross section and longitudinal slope should be inspected.
- The swale inlet and outlet should be inspected for signs of erosion or sediment accumulation.

Other maintenance activities should be completed as needed:

- Alternative plant species may be planted if the existing vegetation is not thriving.
- Bare areas should be replanted and the appropriate erosion control measures should be installed when soil is exposed.
- If the drawdown time is greater than 48 hours, the swale should be roto-tilled and replanted.
- Check dams should be repaired if channelization and erosion are identified.
- During the period of establishment, the swale may need to be watered during dry periods.

Depending on the characteristics of the contributing drainage area, winter conditions may necessitate additional maintenance. The swale should be inspected at the beginning of spring for residuals of sand or road salt. Moderate amounts of these materials may affect the plant and microbial growth. Damaged vegetation and contaminated soils should be replaced. If roadside or parking lot runoff drains to the swale, mulching or soil aeration may be required in spring to restore the soil structure.

Common Problems and Solutions

Problem	Solution
Erosion occurs on the side slope and bypasses the check dam.	Increase the length of the check dam so the lowest point is in the center of the swale.
Significant erosion between check dams.	Install additional check dam and follow recommended guideline for spacing.
Poor vegetative growth due to roadway salt accumulation.	Use nontoxic deicing agents, applied as blended magnesium chloride based liquid or as pretreated salt. Plant salt tolerant vegetation. Avoid evergreens, because roots that go dormant in the winter time can take up salt and kill the plants.
Unsuccessful vegetation establishment due to plant intolerance to conditions.	Plant selection should include native or adaptive species tolerant of both wet and dry cycles. Plants should be established in appropriate climate zones. Deep rooted perennials are encouraged to increase the rate of infiltration.

Turf Swale

Figure 6.116 Turf Swale. Source: N. Klopfenstein, NRCS, Cole County

Practice Description

A turf swale is also referred to as grass-lined channel, grass waterway or grass swale, and it differs from dry or wet bioswales in that no special provisions or materials are included to maximize infiltration or pollution reduction.

Typically, an objective for constructing a turf swale is for the purpose of handling concentrated surface runoff in such a way as to prevent damage from erosion and the resulting sedimentation downgradient. However, turf swales offer the least amount of water quality and volume control when compared to other bioswales or bioretention options.

This practice has historically been used for sites where:

- Concentrated runoff is expected to cause erosion damage.
- Sufficient stability for the channel can be achieved through a vegetative lining.
- Channel grades are generally less than 5 percent.
- Significant space is available to allow for a sufficient channel width for gentle side slopes.

However, this practice is basically a conveyance ditch, which does not serve as a stormwater control measure adequate to control peak flow for water quality or design storms. If used at all, this practice should be limited to linear projects.

Typical uses include roadside ditches, channels at property boundaries, outlets for diversions and stabilizing concentrated flow areas. The grass-lined channel will provide better infiltration and greater root structure if the vegetation is allowed to grow to its full height and not mowed short, serving more as a vegetated dry swale described previously in this section. Selective native or adaptive grasses can provide a functional root depth up to 15 feet, whereas mowed turf grasses provide 1- to 2- inches of root structure. Colored photos and specifications of Missouri native plants are available at www.grownative.org.

Recommended Minimum Requirements

Prior to start of construction, grass-lined channels should be designed by a registered design professional as part of the overall site design for stormwater management. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The channel should be built according to planned alignment, grade and cross section. Some of the typical features are:

Cross Section

Trapezoidal or parabolic.

Side Slopes

3:1 or flatter for trapezoidal channels.

Channel Stabilization

Use erosion control blankets, turf reinforcement mats or other appropriate practices as specified in the design plan.

Outlet

Channels should empty into sediment traps, detention/ retention basins or stable outlets.

Subsurface Drain

Use in areas with seasonally high water tables or seepage problems.

Construction

Site Preparation

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Install sediment traps or drains if needed. Remove brush, trees and other debris from the construction area and dispose of properly.

Grading

Excavate and shape the channel to dimensions shown on the design specification, removing and properly disposing of excess soil so surface water can enter the channel freely.

If a subsurface drain is needed, install it as designated in the plans.

Provide topsoil as needed to enhance the growth of grass within the channel.

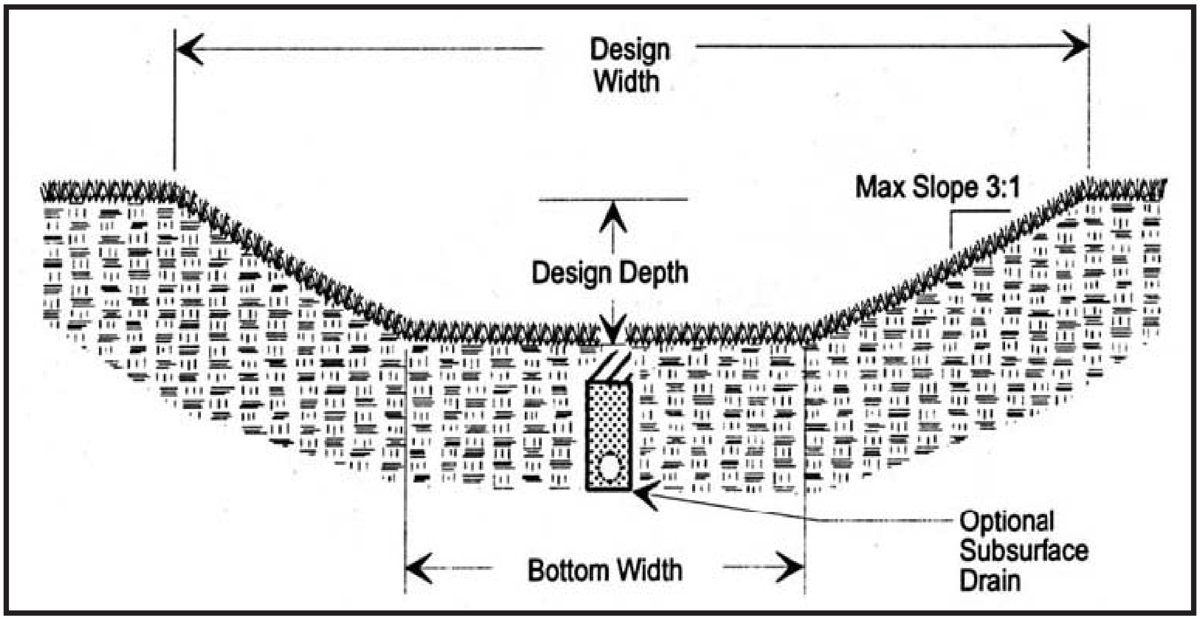


Figure 6.117 Typical Trapezoidal Turf Swale. Source: St. Charles County Soil and Water Conservation District, Missouri

Erosion Control
Protect all concentrated inflow points along the channel with erosion-resistant linings, sod or other appropriate measures.

Fertilize and seed or sod the channel immediately after grading and protect with erosion control blankets, turf reinforcement mats or mulch according to the design plan.

Channel should outlet at a stable location.

Construction Verification
Check finished grade and cross section of the channel throughout the length of the watercourse. Verify the evenness of channel cross sections at several locations to ensure sheet flow.

Maintenance and Inspection
- Inspect the channel following storm events both during and after grass cover is established; make needed repairs immediately.
- Check the channel outlet and road crossings for blockage, sediment, bank instability, breaks and eroded areas. Remove any blockage and make repairs immediately.
- Remove significant sediment and debris from the channel to maintain design cross section and grade, and to prevent spot erosion.
- A specific operations and maintenance plan should be provided by the design professional and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate the channel will not function as intended. Changes in plan may be needed.	Consult with the registered design professional.
Erosion occurs in the channel before vegetation is fully established, due to lack of adequate controls above the channel.	Establish controls above the channel. Repair, reseed and install erosion control blankets or turf reinforcement mats.
Gullying, head cutting or settling in the channel due to overly steep grade or improperly placed drain.	Refer to design specifications or design professional to ensure proper design or re-design of the channel, use erosion-resistant lining and ensure drain is properly placed (typically on the side for post-construction versus at the bottom during construction.)
Overbank erosion, spot erosion, channel meander or flooding occurs due to instability.	Remove accumulated debris and sediment, stabilize and revegetate trouble spots.
Side slope caves in as a result of unstable, high-water-table soil, steep banks or high-flow velocity. Most likely to occur on the outside of channel curves.	An alternate practice may be more appropriate, such as a wetland or wetland swale. Consult with the design professional.
Ponding along the channel due to improperly graded approach or blocked surface inlets.	Improve the channel grade or remove blockage.
Erosion at the channel outlet due to instability.	Install an outlet stabilization structure.
Sediment deposited at the channel outlet due to unidentified channel or watershed erosion.	Find and repair the source of any channel erosion and stabilize the drainage area with permanent practices professionally designed to protect water quality.
Design specifications for seed variety, seeding dates or erosion control materials cannot be met.	Substitution may be required. Unapproved substitutions could result in channel erosion.

Dry Pond (Detention)

Figure 6.118 Dry Pond. Source: ABC's of BMP's, LLC

Practice Description

A dry pond is a surface storage basin or facility designed to provide water quantity control and limited water quality benefits through stormwater detention or extended detention. Dry ponds, also known as dry detention basins or dry detention ponds, are ponds designed to store and then release stormwater runoff from a specified design rainfall event. Unlike wet ponds, dry ponds do not have a permanent pool.

The historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control. These types of dry ponds seldom meet the overall quantity and quality objectives as a stand alone practice. Flood detention ponds were not designed to detain stormwater from small flow events.

Variations of dry ponds include:

- Dry pond for peak flow rate (flood) control only (Figure 6:118).
- Extended detention dry pond for limited water quality control and for channel protection .
- Combination dry pond – combining flood control with extended detention.

Sometimes a dry pond is an acceptable option for achieving flood detention. However, volume reducing (i.e., retention) practices are preferred over flood detention practices as a method of flood control in the lower portion of a major watershed or drainage basin. A dry pond should also be a last resort option in the upper portion of the watershed, because many alternative practices are available to simultaneously reduce volume, protect against flooding and achieve water quality. As an example, Figure 6:119 illustrates a similar 100-year flood detention benefit is achieved by retaining 1.1-inches of rainfall retention in multiple mircoscale practices across a residential development.

Given adequate space in the urban environment, dry ponds can be used to retrofit a drainage area to provide flood control, channel protection and in some cases temperature control. As noted above, it is also important to note where in the major watershed the detention basin is located. As a rule of thumb, detention basins are most effective when placed in the upper 1/3 of a major watershed. Otherwise, detention basins provided in the lower portion of the watershed will likely release water at the same time flow from the upper portion of the watershed reaches the same point. This can make downstream flooding and erosion problems worse by forcing even larger volumes of water into the downstream channel.

Dry ponds are sometimes converted from construction site sediment basins through the removal of sediment, addition of vegetation and modification of the basin outlet structure. Dry ponds are permanent “post construction” ponds as opposed to a sediment basin, and therefore should not be designed or used to store construction site sediment.

Dry ponds should not be put into use until after all construction is complete and the site is completely stabilized. These ponds detain the stormwater flow from rain events but do not hold it for long periods of time. These are designed to be fully vegetated on bottom and side slopes. The outlet structure is designed and built at the lowest point in the basin, allowing the basin to fully drain. Dry ponds should be constructed so all stormwater is detained, not retained as in a retention or “wet” pond.

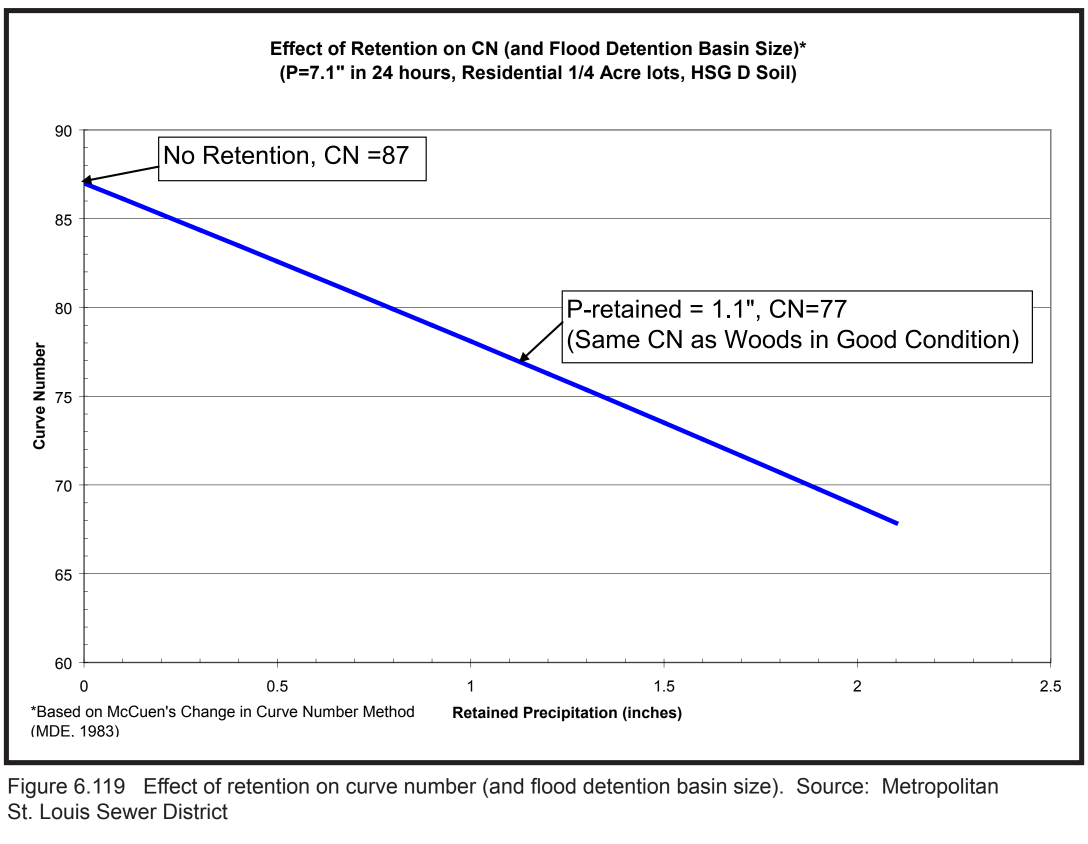


Figure 6.119 Effect of retention on curve number (and flood detention basin size). Source: Metropolitan St. Louis Sewer District

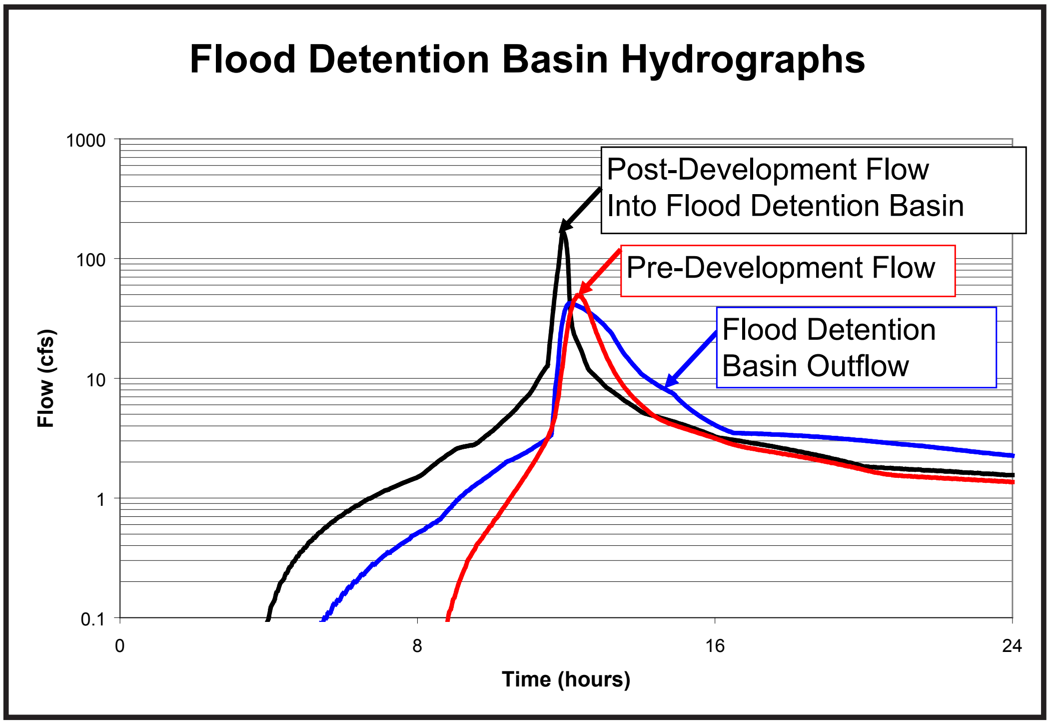


Figure 6:120 Dry pond for peak flow rate control only. Source: Metropolitan St. Louis Sewer District

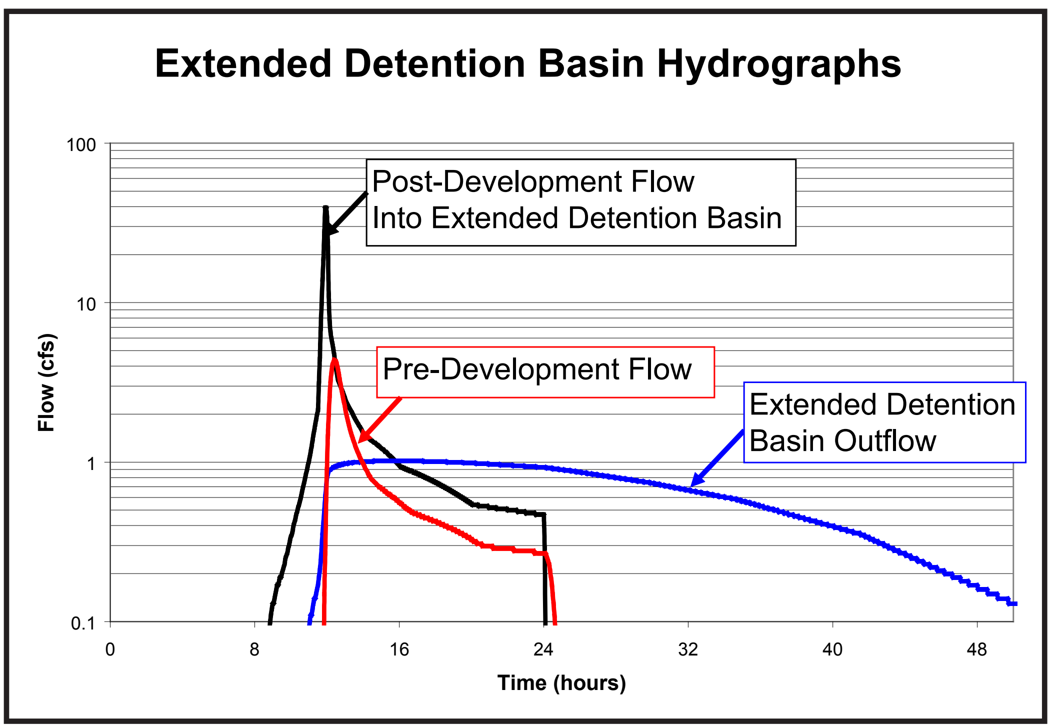


Figure 6.121 Extended detention dry pond for limited water quality control and for channel protection.
Source: Metropolitan St. Louis Sewer District

Pollutant Removal

As noted previously, the historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control.   The dry pond is often used to reduce the peak flow rate from stormwater events and may temporarily minimize flooding downstream. Dry ponds designed to provide extended detention can benefit downstream water quality by protecting downstream channels from the frequent storm events that cause streambank erosion. However, when used to remove settleable pollutants, studies show some of the sediment and other pollutants are re-suspended and then discharged in recurring storm events

See Appendix C for the reference publication *Stormwater BMPs: Selection, Maintenance and Monitoring.* Additionally, dry ponds are not effective removers of soluble pollutants. As such, this practice seldom meets the overall quantity and quality objectives as a standalone practice.

If water quality treatment is a goal of dry detention basin design and construction, a wet or extended stormwater pond design should be incorporated.   Dry ponds should be used in conjunction with other practices, as part of an overall treatment series; they should include enhancements such as a sediment forebay, extended storage, a micropool at the outlet, a long shape to minimize short-circuiting or a combination of these features. Effectiveness of dry ponds varies significantly depending on design, incorporation of companion water quality practices and maintenance.

Dry ponds with concrete conveyance channels or pilot swales should not be used, because they convey polluted stormwater directly to stream resources. See Figure 6:122.

Sediment clean-out should be tested for toxicants in compliance with current disposal requirements if commercial or industrial land uses contribute to the catchment, or if visual or olfactory indications of pollution are noticed

Figure 6.122 Detention basin with concrete conveyance channel.   Source: Metropolitan St. Louis Sewer District

Costs Considerations

According to the Stormwater Manager's Resource Center, construction costs vary considerably, but the estimated costs of a typical extended dry detention basin may range from $41,600 per one acre-foot pond to $1,380,000 for a 100 acre-foot pond.

Costs associated with required space should be considered, especially when other practices such as bioswales and rain gardens can be worked into the natural landscape and meet water quality requirements.

Consideration should be given also to the economic impacts to neighboring properties. According to Emmerling-Dinovo, a 1995 study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between three and 10 percent. See the **Appendix C** reference for *Stormwater Detention Basins and Residential Locational Decisions* (1995.)

The estimated cost of maintenance is typically estimated at about three to five percent of the construction cost.

Recommended Minimum Requirements

Key considerations for constructing a dry pond is how big the pond should be, how the land should be graded, the location and size of the outlet structure and the elevation of drainage outlets. Typically, detention basins are designed through modeling to demonstrate specific design storm requirements that will be met. Deviation from the design can result in basin inefficiency at best, and intesifying of downstream flooding and erosion problems at worst.

Design should be in accordance with state-of-the-practice specifications aimed at achieving water quality criteria. When designed in conjunction with other appropriate runoff volume-reducing SCMs, detention basins may be reduced in size. Forebays may be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin and minimize erosion by inflow. The basin may also be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, require no mowing and provide aesthetic and wildlife benefits.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, detention basins should be designed by a registered design engineer. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The detention basin should be built according to the planned grades and dimensions.

An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. Tree roots, rocks or boulders should be removed from the excavated area and disposed of in designated disposal areas.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Consult with the registered design engineer if any of the following occur:

- Seepage is encountered during construction.
- Variations in topography on-site indicate detention pond will not capture the drainage area intended.
- Design specifications for fill, pipe, seed/plant variety or seeding/planting dates cannot be met.
- Depression holds water long after the rain event, which does not allow vegetation to survive.
- Substitutions are required. Unapproved substitutions could lead to failure.

Construction Verification

Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures. If at final grade the basin storage volume is less than indicated on the plan (e.g., 10 percent less), orifice invert elevations vary more than 0.1' from plan, or if orifice size if different from plan, then the engineer should be consulted to determine if basin performance has been negatively impacted and if adjustments are needed.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design engineer and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well. Typical maintenance requirements include the following:

- Inspect the detention basin after each storm event greater than 1-inch in 24 hours. Remove trash and other debris from the basin. Collected sediment should be removed when 10 percent of the basin design volume has been filled, or 50 percent of the sediment forebay is filled.
- Periodically (e.g., annually) check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair upon discovery.
- Remove nuisance vegetation on the embankment as needed during the growing season (e.g., April to October).
- Remove rodents that burrow into the dam.

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar or pressure-injecting grout around the pipe.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation. Perform a soil test and amend the embankment as needed to establish vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate failed material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install proper outlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Check with the engineer to determine if the discharge can be lowered or if the basin can be filled. Re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properly water them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

Wet Pond ("Retention")

Figure 6.123: Extended Wet Detention, Express Scripts Campus, Berkeley, MO.
Source: Metropolitan St. Louis Sewer District

Practice Description

Wet ponds are often referred to as stormwater ponds, retention ponds or wet detention ponds. A wet pond is designed to collect stormwater runoff in a permanent pool during storm events. The water stored in the pond is later displaced by new runoff. A wet pond can provide pollutant removal primarily through settling and microbial, plant and algal biological uptake. While wet ponds can provide water quality improvement, their role in runoff volume reduction is limited. Wet ponds are best used in combination with other stormwater control measures in an overall stormwater treatment train to achieve the desired affects of pollution control, storage and flow rate reduction. Many of the hydrograph principles that apply to dry ponds also apply to wet ponds. (See Dry Ponds.)

Variations of wet ponds include:

- Flow-Through (Wet) Pond (no extended detention, this pond has an essentially unrestricted spillway as its primary outlet, with its crest at the elevation of the permanent pool).
- Extended wet detention (extended detention storage is provided above the permanent pool).
- Water reuse pond (used primarily for irrigation.)

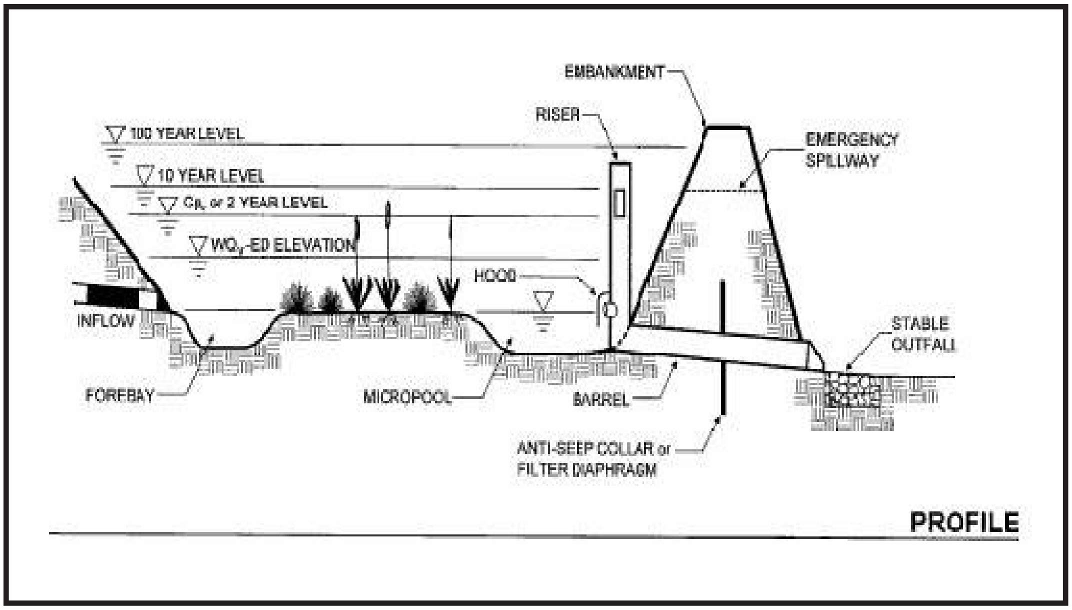


Figure 6:124 Wet Pond Cross Section Source: U.S. Environmental Protection Agency

The extended wet detention pond is a wet pond that works in tandem with a dry detention pond located above the permanent pool. During storm events, water is collected in the detention storage pond above and released over a period of 12 to 48 hours into the wet pond below.

Wet ponds can be used as a retrofit option in existing communities as modifications to existing detention facilities to enhance water quality treatment and downstream channel protection. If water quality, storage and reduced flow rate are the goals, wet ponds should be used in conjunction with other SCMs in an overall stormwater treatment train to achieve the best results. See Figure 6:102. At the very least, sediment and pollutant removal, as well as maintenance needs, can be enhanced through the use of multiple cells in succession.

Geese can often be attracted to wet ponds if the edges are mowed. However, unmowed native or adaptive vegetation around the edges will discourage geese and help to filter pollutants from stormwater runoff.

Additional Considerations

- Fluctuating water elevations make it difficult to establish plants.
- Use wet detention basins to treat runoff from stormwater hot spots, only if significantly separated from the groundwater table.
- Use of wet ponds is limited in dense urban areas due to the amount of space and drainage area required.
- Not appropriate for discharge to cold water resources, due to the potential for thermal pollution.
- Not appropriate for karst areas without significant consideration to leakage or sinkhole prevention.
- Safety is always a concern where permanent pools of water exist.

Cost Considerations

According to the Center for Watershed Protection, typical costs for wet detention ponds range from $17.50 to $35 per cubic meter ($0.50 to $1 per cubic foot) of storage area (CWP, 1998). The total cost for a pond includes permitting, design and construction and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than to retrofit into developed areas. This is due to the cost of land and the difficulty in finding suitable sites in developed areas. The cost of relocating pre-existing utilities or structures is also a major concern in developed areas. Several studies have shown the construction cost of retrofitting a wet detention pond into a developed area may be 5 to 10 times the cost of constructing the same size pond in an undeveloped area. Annual inspection and maintenance costs can generally be estimated at three to five percent of the construction costs.

Recommended Minimum Requirements

The design should reflect the design criteria that could include the following key elements:

- An adequate contributing drainage area, typically more than 10 acres. A water balance assessment should be provided for smaller drainage areas.
- Natural high groundwater table.
- Maintenance of a permanent water surface.
- A length to width ratio of 2:1, or irregular shapes that maximize flow path between inlet and outlet points.
- An aquatic bench with diverse vegetation around the perimeter.
- Relatively impermeable soils, or lining of the pond bottom.
- A forebay for coarse sediment and trash collection.
- Outfall protection to prevent erosion.
- Access for maintenance.

The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation. In Missouri, dams with a height of 35 feet or greater require approval from the Missouri Department of Natural Resources' Dam Safety Program. (See Chapter 1 for information about permits and regulations.)

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, the wet pond should be designed by a registered design engineer. Typically, this SCM is comprised of a forebay, an embankment to create the basin(s), an outlet structure, a spillway for overflows and safe access.

Plans and specifications should be reviewed by the site superintendent and field personnel and followed closely throughout the construction process. The basin should be built according to the planned grades and dimensions. An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. All tree roots, rocks, or boulders should be removed from the excavated area.
- Rough grading of the basin should be completed carefully to ensure compaction of the bottom of the basin.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls.

Construction Verification

Construction verification needs for dry and wet ponds are similar. Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design professional. After construction is complete and the detention basin is operational, operations and maintenance of each device is performed by the personnel identified in the operations and maintenance manual. Typical maintenance requirements include the following:

- Periodically check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Clean and remove trash and vegetative debris from inlet and outlet structures, mow side slopes as needed.
- Semi-annual inspection for invasive vegetation.
- Annual inspection to monitor damage, hydrocarbon build-up, sediment accumulation and debris in inlet and outlet devices.
- Repair erosion and remove excess sediment from forebay as needed.
- Manage and harvest wetland plants annually.
- Renovate the facility when pool volume has been reduced significantly or when the pond becomes eutrophic (excessive in nutrients, resulting in algal blooms and poor water quality.)

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate dislocated material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install proper outlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Relocate basin to more accessible area or improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properly water them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

Stormwater Wetlands (Constructed Wetlands)

Practice Description

Stormwater wetlands are constructed wetland systems that temporarily store stormwater runoff in shallow pools supportive of wetland plants. They are constructed primarily for the purposes of water quality treatment and flood control; primarily flow attenuation and some runoff volume reduction. Stormwater wetlands are constructed for maximum removal of stormwater pollutants through microbial breakdown of pollutants, pollutant uptake by plants, settling and absorption. Stormwater wetlands typically have less biodiversity than natural wetlands in terms of plant and animal life. Natural wetlands are to be protected and should never be used for stormwater management, because their function is critical to watershed health. See Chapter 1 for regulations and permit requirements.

Constructed wetlands are a widely applicable stormwater management practice in areas where sufficient land is available. There should be significant separation from groundwater if constructed wetlands accept runoff from stormwater hot spots. If the areas are designed to encourage wildlife use, the design must ensure pollutants in stormwater runoff do not affect organisms living in or near the wetland. When retrofitting a watershed with SCMs, stormwater wetlands can provide both educational and habitat value.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative descriptions of plant species native to Missouri and the Midwest region.

Stormwater wetland designs vary in the relative amount of shallow water, deep water and dry storage above the wetland. The five general design variations include:

- Shallow marsh system.
- Pond/wetland system.
- Extended detention wetland.
- Submerged gravel wetland.
- Pocket Wetland.

Of the wetland types, the extended detention wetland or pond/wetland system may be most common in urban areas with adequate land. Where space is more limited or retrofits are needed, a submerged gravel wetland might be considered. Pocket ponds are only an option where groundwater is available to help charge the pond; not a typical setting in urban environments. The shallow marsh system requires the largest area of all wetland types.

Shallow Marsh System

A shallow marsh system includes a combination of pools (low marsh) and vegetated hummocks (high marsh), plus a micropool at the outlet. Pools wind through the high marsh in meandering pathways to extend the amount of time stormwater is held and treated in the system and to increase contact between stormwater and vegetation. These systems are generally shallow and therefore receive no groundwater inputs, so they typically require large drainage areas (e.g., >25 acres) to contribute the necessary water volume to the system.

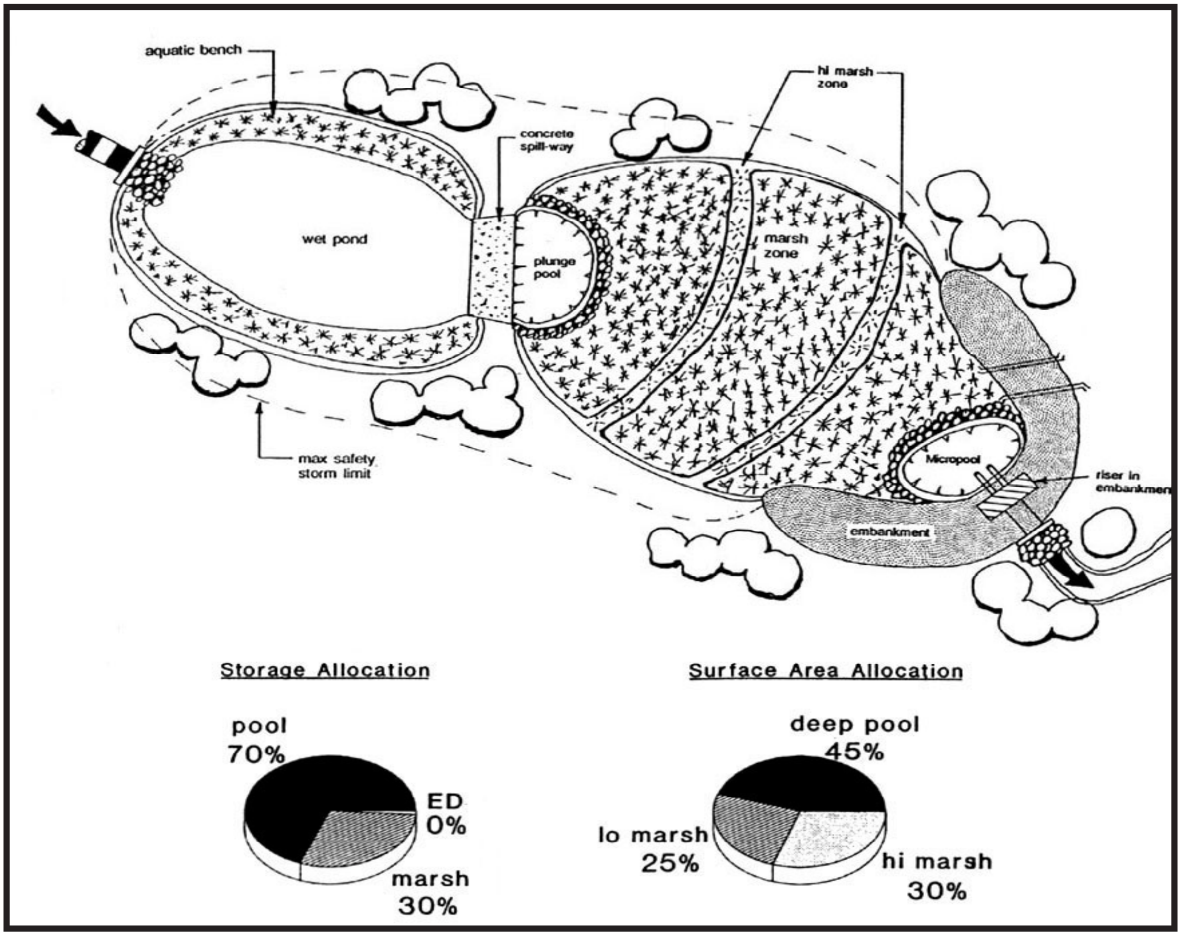


Figure 6.125 Pond/Wetland System Source: Center for Watershed Protection

Extended Detention Wetland

An extended detention wetland is much like a shallow marsh system, but it includes the addition of a forebay and safety bench.

An extended detention wetland includes features to enhance storage, downstream channel protection and pollution reduction. It has sufficient volume to temporarily detain runoff during storm events and hold a permanent pool of fairly shallow depth. Biological and chemical activity in the pond plays an important role in pollutant uptake, particularly of nutrients. Flow through the root systems allows vegetation to remove nutrients and dissolved pollutants from stormwater. When an extended detention wetland is sized, designers need to consider the storage volumes provided. Typically, a significant portion (e.g., 50 percent) of the water quality volume (the volume of rainfall produced by the 90th to 95th percentile storm that occurs in 24 hours) is provided in the micropool(s). The detention volume above the pool is designed to provided extended detention of the remaining portion of the water quality volume, channel protection volume and flood protection volume.

Because the ponding depths are typically shallow to be effective, extended detention wetlands require a large amount of surface area to obtain sufficient volume. Because they function best in larger drainge areas, they may be a good choice to treat runoff from large industrial and commercial project sites that have sufficient space for their construction. These constructed wetlands can also provide aesthetic/recreational value and wildlife habitat.

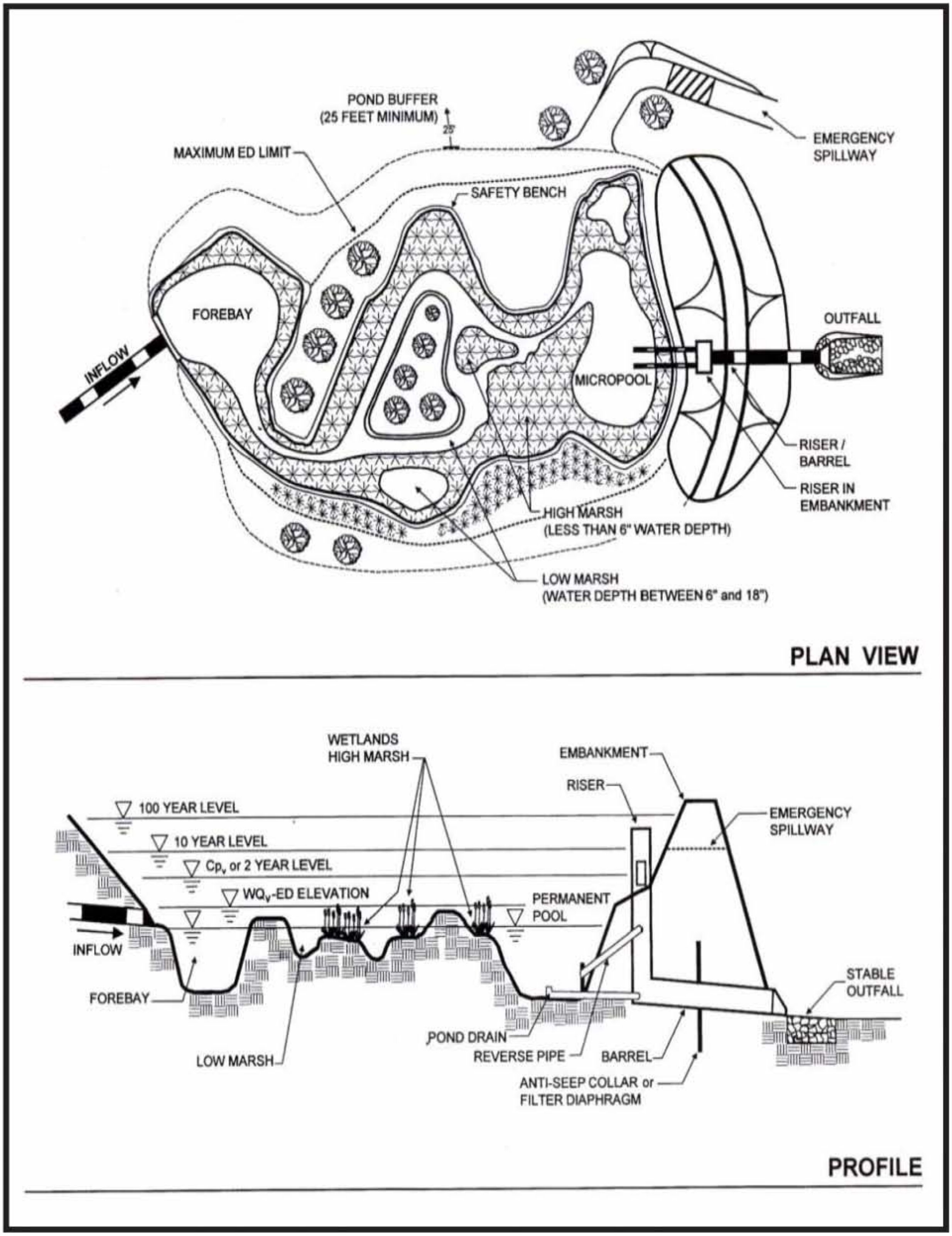


Figure 6.126: Constructed Extended Detention Wetland. Source: Center for Watershed Protection

Figure 6.127: Extended Detention Wetland in a Residential Development. Dover, Delaware. Source: Kevin Magerr, PE, CPESC, CPSWQ.

The successful design, installation and function of constructed wetlands depends on the hydrology, underlying soils, planting soil, size and volume, vegetation, configuration, and maintenance access. Large areas are necessary for application of this SCM; the contributing drainage area should be at least 10 acres. The area for a wetland is generally 3 to 5 percent of its drainage area but it should be sized to treat the water quality volume and if necessary, mitigate the peaks of larger runoff events. A wetland must be able to receive and retain enough rain, runoff and groundwater to maintain vegetation. Even with a large drainage area, a constant source of inflow can improve the biological health of a wetland.

Submerged Gravel Wetland

A submerged gravel wetland is a practice that can be used in retrofit situations draining less than five acres. In the submerged gravel wetland, the system is designed for runoff to flow through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the media (e.g., gravel) and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave

Figure 6.128: Submerged Gravel Wetland. Source: Center for Watershed Protection, Copyright 2000.

much like wet ponds (with differences in grading and landscaping), gravel-based wetlands are more similar to filtering systems. Design considerations should be given to potential clogging and odor problems. Submerged gravel wetlands are commonly associated with wastewater treatment applications, but have been adapted to stormwater treatment application.

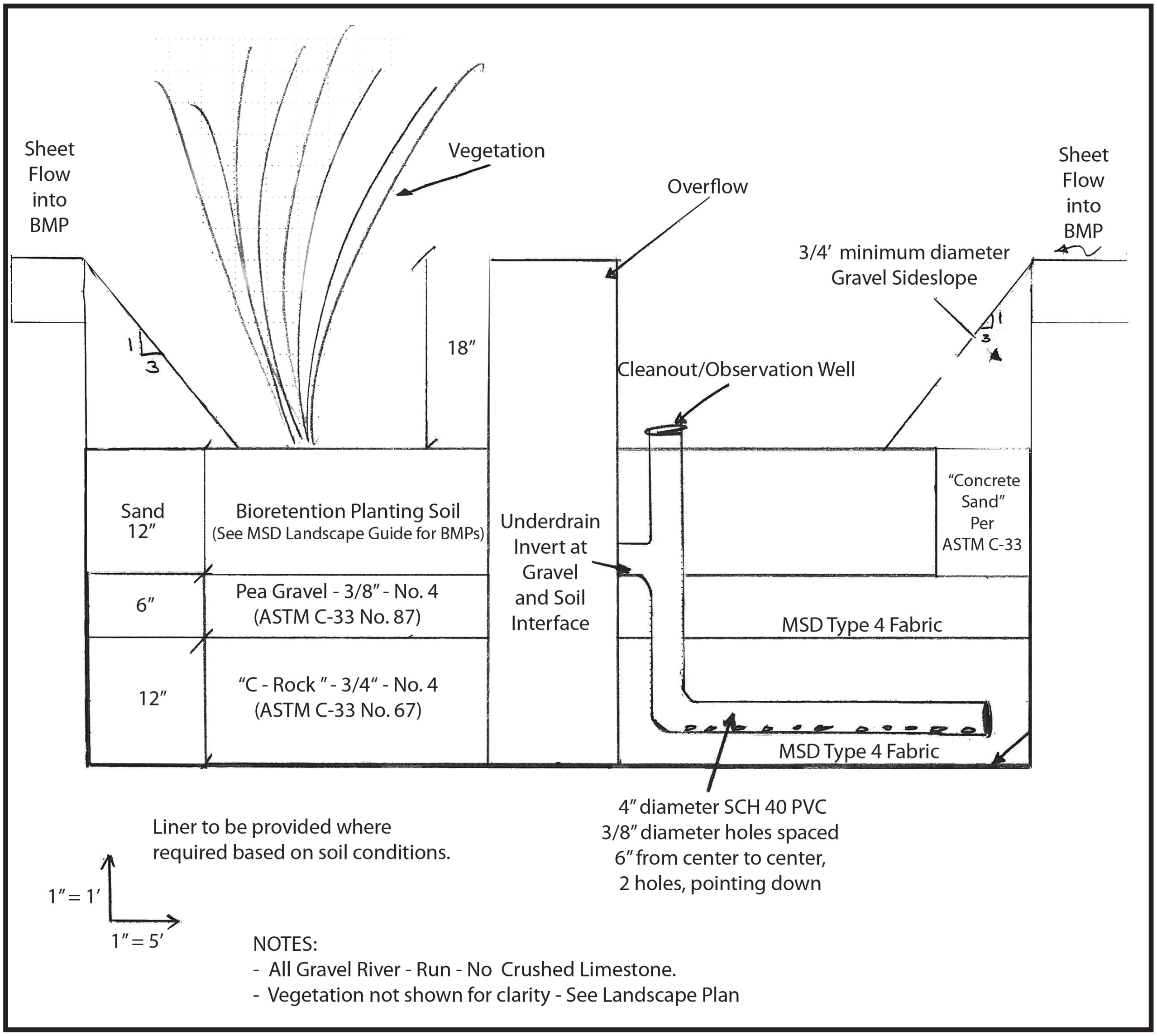


Figure 6.129. Submerged Gravel Wetland. Source: Metropolitan St. Louis Sewer District

Pond/Wetland System

A pond/wetland system consists of multiple cells with at least one wet pond followed by at least one shallow marsh and draining areas less than 25 acres. This practice can save space when compared to a shallow marsh system which requires a greater area of land to address storage.

Pollutant Removal

Wetlands can be designed to primarily remove total suspended solids, oils and greases, fecal coliform and biochemical oxygen demand. They can also be designed to remove some levels of Total phosphorus, nitrogen, heavy metals and floatables.

The following in formation on pollutant removal comes from EPA's *Stormwater Wetland* fact sheet. (See reference in Appendix C.) Wetlands are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are particularly effective at removing nitrate and bacteria. Table 6.18 provides pollutant removal data derived from the Center for Watershed Protections's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000).

Table 6.18. Typical Pollutant Removal Rates of Wetlands (%) (Winer, 2000.)

Pollutant	Stormwater Treatment Practice Design Variation			
	Shallow Marsh	ED Wetland1	Pond/Wetland System	Submerged Gravel Wetland1
Suspended Solids	83±51	69	71±35	83
Total Phosphorus	43±40	39	56±35	64
Total Nitrogen	26±49	56	19±29	19
Nitrogen Oxide	73±49	35	40±68	81
Metals	36-85	(80)-63	0-57	21-83
Bacteria	761	NA	NA	78

[1] Data based on fewer than five data points

The effectiveness of wetlands varies considerably, but many believe proper design and maintenance help to improve their performance. The siting and design criteria presented in the EPA's *Stormwater Wetland* fact sheet reflect the best current information and experience to improve the performance of wetlands. A joint project of the American Society of Civil Engineers and the EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice database is a compilation of stormwater practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. [More information is available at the International BMP Database located at www.bmpdatabase.org.]

Additional Considerations

The following information about wetland limitations is adapted from EPA's *Stormwater Wetland* fact sheet. See reference in Appendix C. Some features of stormwater wetlands that might make a design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on some sites.
- Improperly designed wetlands might become a breeding area for mosquitoes.

- Wetlands require careful design and planning to ensure wetland plants are sustained after the practice is in place.
- It is possible stormwater wetlands may release nutrients during the non-growing season.
- Designers need to ensure wetlands do not negatively impact natural wetlands, forest or groundwater quality.

Cost Considerations

The following information comes from EPA's *Stormwater Wetland* fact sheet from their menu of stormwater BMPs. See Appendix C. Wetlands are relatively inexpensive stormwater practices to construct, not counting the cost of land. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than stormwater ponds of an equivalent volume. Using this assumption, an equation developed by Brown and Schueler (1997) to estimate the cost of wet ponds can be modified to estimate the cost of stormwater wetlands using the equation:

C = 30.6V0.705 where: C = Construction, design and permitting cost.
V = Wetland volume needed to control the 10-year storm (ft3).

Using this equation, typical construction costs are the following:

- $57,100 for a 1 acre-foot facility.
- $289,000 for a 10 acre-foot facility.
- $1,470,000 for a 100 acre-foot facility.

Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other stormwater management practices.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Recommended Minimum Requirements

Underlying soils should be identified and tested. Hydrologic soil groups 'C' and 'D' are suitable without modification but 'A' and 'B' soils may require the addition of clay or other impermeable material to line the facility. Soil permeability should be tested and calculations should demonstrate the wetland will not dry out. Organic soils should be used to establish vegetation. Vegetation is an integral part of a wetland and plays a role in reducing flow velocities, promoting settling, providing growth surfaces for beneficial microbes, and taking up pollutants. Vegetation types such as emergent, low marsh, high marsh, and buffer plants should be installed in appropriate zones for the various areas in a wetland. To allow maintenance activities, a stable and permanent access should be provided to the forebay, outlet and embankment areas. Also, an understanding of seasonal groundwater levels is critical.

Medium-fine textured soils (such as loams and silt loams) are best to establish vegetation, retain surface water while permitting groundwater recharge and capture pollutants. For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.

In karst (e.g., limestone) topography, wetlands should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation, and to help maintain the permanent pool. The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation.

The wetland should be designed by a registered design engineer as part of the overall site design for long-term water quality. Design considerations include:

- Water quality goals, flood management goals and performance needs (including appropriate variation for new growth, redevelopment or restoration).
- Proximity to karst and groundwater and other limitations.
- Wetland to watershed ratio and other sizing criteria.
- Topography, soils, sediment forebays.
- Buffers to separate wetland from the surrounding area.
- Above ground berms or high marsh wedges placed perpendicular to the flow path to increase dry weather flow paths within the wetland.
- Placement of the outlet with clog-prevention micropool.
- Maintenance access.
- Long-term operation, Inspection and maintenance.
- Construction sequencing.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process. The construction sequence may include:

- Separating the wetland area from the contributing drainage area and initiating an appropriate erosion and sediment control plan.
- Clearing the area to be excavated of all existing vegetation. Removing tree roots, rocks and boulders. Filling all stump holes and crevices with impermeable materials.
- Excavating the bottom of the constructed wetland to the desired elevation, as indicated in the plans.
- Grading the embankments.
- Installing inlet and outlet control structures.
- Final grading and compacting of subsoil.
- Applying and grading the planting soils. It is critical the final grading match the design

because aquatic plants are sensitive to the depth of water.

- Installing geotextiles and other permanent erosion control measures.
- Seeding, planting and mulching according to the plans.

Maintenance and Inspection

Routine harvesting of vegetation has been documented to increase nutrient removal capacity of a constructed wetland and prevent the export of these constituents. Typical maintenance includes:

- Inspect the facility semiannually for burrows, sediment accumulation, structural integrity of the outlet and litter accumulation. The banks of the wetland should be inspected and areas of erosion repaired upon discovery. Sediments should be removed if they are within 18 inches of an outlet structure.
- Maintain emergent and perimeter shoreline vegetation. Site and road access are important to facilitate monitoring and maintenance.
- Remove nuisance vegetation or animals, if present.
- Harvest vegetation as prescribed in the specifications. Frequencies will vary. Vegetation is typically not collected during the growing season.
- The side slopes should be maintained at a slope that does not exceed 4:1 (H:V). Slopes showing excessive erosion may require erosion control and safety measures.

Sediments that accumulate in constructed wetlands may require special disposal. If there is any uncertainty about the sediment characteristics, the Missouri Department of Natural Resources should be consulted and department disposal recommendations should be followed.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Common Problems and Solutions

Problem	Solution
Erosion of slopes; caused by inadequate vegetation or improper grading and sloping	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil	Excavate failed material and replace with properly compacted suitable soil.
Insufficient vegetation due to improper zones or depths of ponding.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Stormwater released from pond or basin too rapidly; caused by discharge	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Plant selection should include native species tolerant of both wet and dry cycles. Deep rooted perennials increase the rate of infiltration.

Infiltration Basin

Figure 6.130: Infiltration Basin. Source: University of Wisconsin Extension

Practice Description

Infiltration basins are earthen structures that capture stormwater in a shallow pool and infiltrate runoff into the ground over a period of 72 hours. Infiltration basins differ from detention basins in that they do not have an outlet. Typically, an infiltration basin includes an inlet, sediment forebay, level spreader, spillway, backup underdrain, an emergency spillway and a stilling basin. Vegetation is used within the basin to improve the permeability of soils and reduce the potential for erosion. Some communities have observed it is difficult to maintain desired turf grass. Alternative plant materials should be considered.

An infiltration basin should be designed by a registered design engineer as part of the overall site design for long-term water quality. Design considerations include:

- Infiltration basins should be restricted to areas where groundwater contamination, site feasibility, soil permeability and clogging at the site are not concerns.
- The contributing drainage area to a basin should not produce high concentrations of sediments and should be less than 2 acres.
- This SCM works well toward the end of a treatment train when there are sufficient pretreatment steps to reduce the sediment loads.
- Because these basins are designed for maximum infiltration, they should not be constructed in regions of karst topography, due to concerns of sinkhole formation and groundwater contamination.
- These basins should never be constructed in stormwater hot spots. Stormwater hotspots are areas that produce higher concentrations of pollutants than what is normally found in urban runoff.

Recommended Minimum Requirements

Infiltration basins may be incorporated into new development or used to retrofit existing lawns and open spaces. Site selection for an infiltration basin should be based on soil infiltration, depth to water table, setbacks, loading rates and existing vegetation. Soil investigation and infiltration testing provides essential information for a proper design. Basins should be located 150 feet away from drinking water wells to prevent possible contamination and these basins should not be located adjacent to building foundations; they should be placed at least 10 feet down-gradient and 100 feet up-gradient from foundations. Infiltration basins should not be used in areas where groundwater is close to the surface.

After locating the infiltration basin, the designer should prepare plans sufficient for the structure to retain 1-foot freeboard during the average 100-year peak runoff. Use of a backup underdrain (capped or closed with a valve during normal operation) may be considered if there is concern the basin may not drain. The underdrain may need to be used later when surface soils become clogged and need to be amended or replaced. Inlets to the basin should have erosion protection. The slope of the infiltration basin base should be less than 1 percent to ensure even water distribution and infiltration. The berms surrounding the basin should be constructed of compacted earth with a minimum top width of 2-feet and side slopes not steeper than 3:1 (H:V). The length to width ratio of the basin should be 3:1 or greater. The designer should review local requirements for site grading, drainage structures, erosion and sediment control and planting.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to the start of construction, plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The wetland should be built according to the planned grades and dimensions.

Site Preparation

The infiltration basin area should be protected from compaction prior to installation.
Proper erosion and sediment control measures should be installed and maintained during construction to prevent site runoff from entering the infiltration basin.

Grading and Installation

It is preferable to locate infiltration basins with consideration of existing topography to minimize excavation. If necessary, excavate the basin bottom to an uncompacted sub-grade free from rocks and debris. It is important to avoid compaction of the sub-grade. After the bottom and side slopes have been established, the outlet control structures should be installed. Finally, the topsoil should be vegetated and stabilized. Erosion and sediment control measures must remain in place and maintained until the site is stabilized.

Vegetation

The selection should include native and adaptive species tolerant of both wet and dry cycles. Deep rooted perennials are encouraged to increase the rate of infiltration.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.

Construction Verification

Measure the finished grades and configuration and compare against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Twice each year, the basin and inlets should be inspected for accumulation of trash, sediment and erosion. They should also be checked for stabilization and vegetation quality. Inspections should also occur after significant runoff events and drainage times should be observed to match the design intention. The vegetation along the surface should be maintained and any bare spots identified during inspections should be revegetated. Depending on the vegetative cover species, an infiltration basin may be carefully mowed as needed but care should be taken to avoid excessive compaction by mowers (i.e. mowing should not occur when the ground is saturated).

Common Problems and Solutions

Problem	Solution
Potential failure due to improper siting, design and lack of maintenance.	Incorporate pretreatment if contributing drainage area is providing too much sediment.
Compaction during mowing.	Rototill existing soil when in friable condition and reseed.
Drawdown time is longer than 72 hours.	Rototill existing soil when in friable condition and reseed.
Unsuccessful vegetation establishment.	Recheck soil conditions for tilth and for conditions suitable for plant growth. Choose plant species that prefer the site conditions and are appropriate for the plant zone. Reset plants during an appropriate planting season. Reapply mulch.
Unsuccessful vegetation establishment.	Plant selection should include native species tolerant of both wet and dry cycles. Deep rooted perennials increase the rate of infiltration.

Infiltration Trench
Practice Description

Infiltration trenches are excavated trenches filled with granular material. These trenches are primarily used to slow stormwater runoff rates and promote infiltration of runoff into the ground. The most effective period of an infiltration trench is during the first flush of a runoff event when most of the runoff and pollutants are captured. Infiltration trenches remove suspended solids, bacteria, organics, soluble metals and nutrients through mechanisms of filtration, absorption and microbial decomposition. This SCM may be used in combination with another SCM such as a detention basin to increase the control of peak flows, or in combination with other SCMs as part of an overall treatment train.

Figure 6.131: Infiltration trench with geotextile. Source: Southeast Michigan Council of Governments/Michigan Department of Natural Resources

Infiltration trenches have select applications and their use is restricted by concerns due to common site factors, such as potential groundwater contamination, soils and clogging. In regions of karst (i.e., limestone) topography, infiltration trenches may not be appropriate due to concerns of sinkhole formation and groundwater contamination. Infiltration trenches can sometimes be applied in the ultra-urban environment but should not be located adjacent to stormwater hot spots. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure and poor infiltration capacity of soils.

Figure 6.132: Biolfiltration Infiltration Trench, Cumberland County, PA.
Source: Pennsylvania Department of Environmental Protection

Recommended Minimum Requirements

This SCM should be designed by a registered design engineer as part of the overall site design for long-term water quality. Site selection for an infiltration trench should be based on soil infiltration, depth to water table, setbacks, loading rates and existing vegetation. Soil investigation and infiltration testing is a minimum requirement to inform design. Trenches should be located 150 feet away from drinking water wells to prevent possible contamination and should not be located adjacent to building foundations; they should be placed at least 10 feet down-gradient and 100 feet up-gradient from foundations. Infiltration trenches should not be used in areas where groundwater is close to the surface. This SCM may have either a grassed or gravel surface and may be located adjacent to roadways or impervious paved areas.

The width and depth of an infiltration trench may vary. The depth of stone, however, should be limited to six feet. The designer should review local requirements for site grading, drainage structures, erosion and sediment control and invasive or nuisance vegetation.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Site Preparation and Installation

Protecting the infiltration trench area from compaction prior to installation is critical. If possible, the infiltration trench should be constructed during the later phases of site construction to prevent sedimentation or damage from construction activity. Erosion and sediment control measures need to be installed prior to construction and maintained during the course of construction.
A construction sequence might include:

- Install and maintain erosion and sediment control measures.
- Excavate the infiltration trench bottom to develop a uniform, level, uncompacted subgrade free from rocks and debris. It is critical to not compact the subgrade.
- Place nonwoven geotextile fabrics along the bottom and sides of the trench. (Clogging tendencies of the fabric should be taken into consideration during design.) Nonwoven geotextile fabric should be rolled out to overlap by a minimum of 16-inches within the trench. Excess geotextile should be folded and secured during stone placement.
- Install upstream and downstream cleanouts and control structures.
- Install continuously perforated pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
- If topsoil is to be placed on top of the trench, a geotextile should be folded and secured over the infiltration trench and the area shall be seeded and stabilized.
- Within 24 hours, remove any sediment that enters inlets during construction.

Construction Verification

Check the finished grades and configuration of all elements. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Pretreatment devices, catch basins and inlets should be inspected for sediment buildup and cleaned at least twice each year. Observation wells should be inspected following three days of dry weather because failure to percolate will indicate clogging. If vegetation is planted on the surface of the infiltration trench, it should be maintained in good condition, and any bare spots should be revegetated as soon as possible. A vehicle should not be parked or driven over the surface of an infiltration trench. Care should be taken to avoid compaction by mowers if the trench has surface vegetation. Upon failure, the trench should be rehabilitated and trench walls should be excavated to expose clean soil.

Common Problems and Solutions

Problem	Solution
Potential failure due to improper siting, design and lack of maintenance.	Incorporate pretreatment if the contributing drainage area is providing too much sediment.
Sediment accumulation at catch basins or inlets.	Remove accumulated sediment through standard maintenance procedures.
Practice not functioning well.	Infiltration trenches do not work well in clay soils. Practice should be initially designed with amended soils, or a different practice should be chosen.

Porous Pavement and Pervious Pavers

Figure 6.133: Porous Asphalt Alley, St. Louis, MO. Source: Metropolitan St. Louis Sewer District

Practice Description

Porous pavement and a variety of pervious pavers provide a permeable surface that can be used to replace traditional pavement areas. Several systems may be used including pervious concrete and porous asphalt, precast concrete grids, modular unit pavers, geowebs and other manufactured pavement systems.

Porous pavement is usually built with an underlying stone reservoir that temporarily stores surface runoff before it infiltrates into the subsoil. Porous asphalt and pervious concrete looks very similar to traditional pavement, however, porous pavement contains little or no “fine” materials. Instead, it contains voids that allow infiltration through the pavement. Porous asphalt consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to allow water movement. Pervious concrete typically consists of specially formulated mixtures of Portland cement, open-graded coarse aggregate and water. Pervious concrete has enough void space to allow rapid percolation of stormwater through the pavement. Moderate traffic zones are ideal locations for the application of porous pavement options.

See Appendix D for reference to EPA Menu of BMPs, specifically post-construction fact sheets named *Permeable Interlocking Concrete Pavement, Pervious Concrete Pavement and Porous Asphalt Pavement*.

Additional Considerations

- In some areas, such as truck loading docks and areas of high commercial traffic, porous pavement is inappropriate and presents maintenance issues.
- Since porous pavement is an infiltration practice, it should not be applied at stormwater hot spots (areas of unusually high pollution runoff) due to the potential for groundwater contamination.
- Porous pavement is not an option for drinking water recharge areas, due to contamination potential.

Pervious pavers and turf blocks can be used as a porous pavement option. Options include pre-cast concrete grids with void areas for grass, modular unit pavers installed with pervious material in the gaps, and geowebs designed for soil reinforcement. Alternative pavers can be used to replace historical pavement options in parking lots, driveways and walkways. The traffic volume, weight and frequency limit application. Pervious pavement and turf blocks are often applied to overflow parking areas and in residential settings. They can be used in combination with other stormwater SCMs.

Recommended Minimum Requirements

This SCM should be designed by a registered design engineer as part of the overall site design for long-term water quality.

Porous pavement should be used for low to medium traffic areas, for parking lanes and parking lots. Porous pavements should be placed on flat ground, but the slopes of the site draining to the practice should not be steeper than 15 percent. Soils need to have a permeability of at least 0.5 inches per hour. An alternative design for soils with low porosity would be the installation of a discharge pipe from a storage area beneath the pervious pavement that drains to the traditional storm sewer system. To reduce the risk of contamination, design should provide significant separation of 2- to 5-feet from the bottom of the porous pavement stone reservoir and the seasonally high groundwater table. Additionally, porous pavement installations should not be installed within the vicinity of drinking water wells. The bottom of the stone reservoir should be flat, so that runoff can infiltrate through the entire surface.

Pervious pavers and turf blocks should be situated to accept smaller contributing drainage areas, usually less than 5 acres, with relatively high impervious cover. The designer should evaluate the durability and maintenance cost of alternate pavement options. Soil types will affect infiltration rates and clay soils will substantially limit infiltration on a site. If groundwater pollution is a concern, permeable pavers should not be used.

The designer should always review local requirements for site grading, drainage structures and erosion and sediment control.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information on regulations and permit requirements.

Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Due to the nature of construction sites, pervious pavement and other infiltration measures should be installed toward the end of the construction period. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps. After the site is stabilized and sediment storage is no longer required, the bed may be excavated to its final grade and the pervious pavement system can be reinstalled as directed in the contract documents. The following sequence of construction steps provides an example:

- The existing subgrade under the bed areas should not be compacted or subject to excessive construction equipment prior to geotextile and stone bed placement.
- Where the erosion of the subgrade has caused accumulation of fine materials or surface ponding, this material shall be removed with light equipment and the underlying soils should be scarified to a minimum depth of 6-inches. All fine grading should be done by hand and the bottom of the bed should be at a level grade to prevent ponding.
- Earthen berms between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.
- If an underdrain system is designed, it should be installed before the subgrade for the infiltration bed is prepared.
- Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation. Geotextile should be placed in accordance with manufacturer's recommendations and specifications. Geotextile fabric should overlap a minimum of 16-inches and should be secured at least 4-feet outside of the bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils adjacent to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back.
- Clean, uniformly washed graded aggregate should be placed into the prepared bed in 8-inch lifts. Each layer should be lightly compacted, with the construction equipment kept off the bed bottom as much as possible. After bed aggregate is installed to the desired grade, a 1- inch layer of base course such as AASHTO M-43 #57 aggregate could be installed uniformly over the surface in order to provide an even surface for paving.
- The pervious pavement materials (pervious concrete or asphalt) or pavers should be installed in accordance with current standards.

Construction Verification

The full permeability of the pavement surface should be tested by applying clean water at a rate of at least 5 gallons per minute over the surface. All applied water should infiltrate directly without puddle formation or surface runoff.

Maintenance and Inspection

Pervious Pavement

The primary goal of pervious pavement maintenance is to prevent the pavement surface and underlying infiltration bed from clogging. Pores can become clogged when fine particles deposit on the surface from vehicles, the atmosphere and runoff from adjacent land surfaces. Clogging increases with age and use. Permeability can be maintained through vacuum sweeping using equipment, frequency schedules and precautions defined in the operation and maintenance plan. In areas where extreme clogging has occurred, half inch holes can be drilled through the pavement surface every few feet or so to allow stormwater to drain to the aggregate base. All inlet structures draining to the infiltration area should be cleaned out at least annually. Additionally, the surface should be inspected for deterioration annually. If not easily noticed, pervious pavement areas should be identified with signage to aid inspection.

Planted areas adjacent to a pervious pavement area should be well maintained to prevent soil washout onto the pavement. Any bare spots or eroded areas should be revegetated upon discovery. Planted areas should be inspected on a semiannual basis.

Trucks and other heavy vehicles should be prevented from tracking or spilling dirt on the pavement. All construction or hazardous materials carriers should be prohibited from driving on pervious pavement.

Winter maintenance for a pervious parking lot is typically less intensive because pervious pavement has superior snow melting characteristics. The underlying stone beds absorb and retain heat so freezing rain and snow melt faster on pervious pavement. Abrasives such as sand should not be applied on or adjacent to the pervious pavement. Snow plowing is acceptable, provided it is completed carefully, with the blade set slightly higher than usual (about 1-inch). Salt is acceptable though nontoxic, organic deicers, applied as blended magnesium chloride-based liquid products or as pretreated salt, are preferable.

Potholes are unlikely although settling may occur. For damaged areas less than 50 square feet, a pothole or failure should be patched by any means suitable with standard pavement or a pervious mix. If the repair area is greater than 50 square feet, the design engineer should be consulted. The pavement surface should never be seal coated.

Pavers

Maintenance of paver systems will vary greatly. The owner and engineer should refer to the manufacturer's recommendations. The turf installed in the pervious voids should be maintained with minimal fertilizer. The application of deicing chemicals should be limited.

Common Problems and Solutions

Problem	Solution
Decreased infiltration capacity.	Porous pavements are best maintained by vacuuming.
Pothole damage in an areas less than 50 square feet.	A pothole or failure should be patched by any means suitable with standard pavement or a pervious mix.
Sediment accumulation from adjacent landscaped areas.	Planted areas should be well maintained to prevent soil washout onto the pavement. Any bare spots or eroded areas should be revegetated upon discovery.

Sand Filters

Figure 6.134: Perimeter Sand Filter. Source: Center for Watershed Protection

Practice Description

Sand filter systems may be constructed on the surface or underground in vaults for large sites. Perimeter filters with a two-chamber concrete vault can be applied along the perimeter of a parking lot. Pocket sand filters are used at small sites and combine a sediment basin or filter strip preceding a vegetated depression full of sand. Sand filters are associated with high removal rates for filterable pollutants such as sediment, organic solids (i.e., biological oxygen demand), and fecal coliform bacteria. These filters are not efficient in removing soluble pollutants such as metals and nutrients.

Because sand filters provide treatment (pollutant capture), they are preferred to infiltration practices when contamination of groundwater is a concern, such as in areas where underlying soils cannot treat runoff or where groundwater tables are high. Because flow-through is fairly rapid, sand filters are not significant volume reducing SCMs.

A typical sand filter system consists of two or three chambers: a sedimentation basin to remove floatable materials and heavy sediments, a filtration basin where runoff is filtered by a self contained bed of sand and a discharge chamber. Runoff is diverted to the bed, collected by underground pipes and then discharged into a stream or channel.

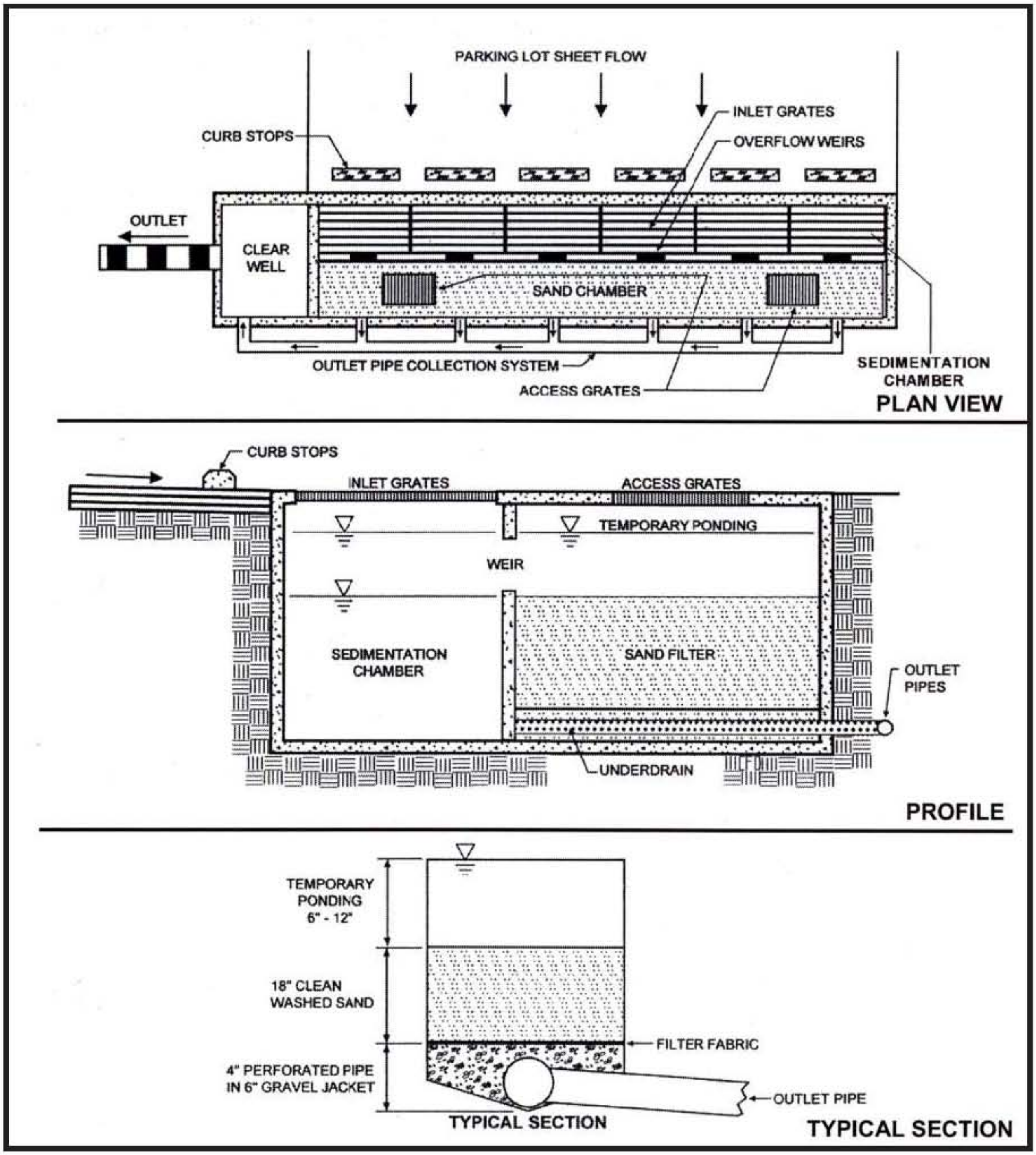


Figure 6.135: Perimeter Sand Filter. Source: Center for Watershed Protection (©2000)

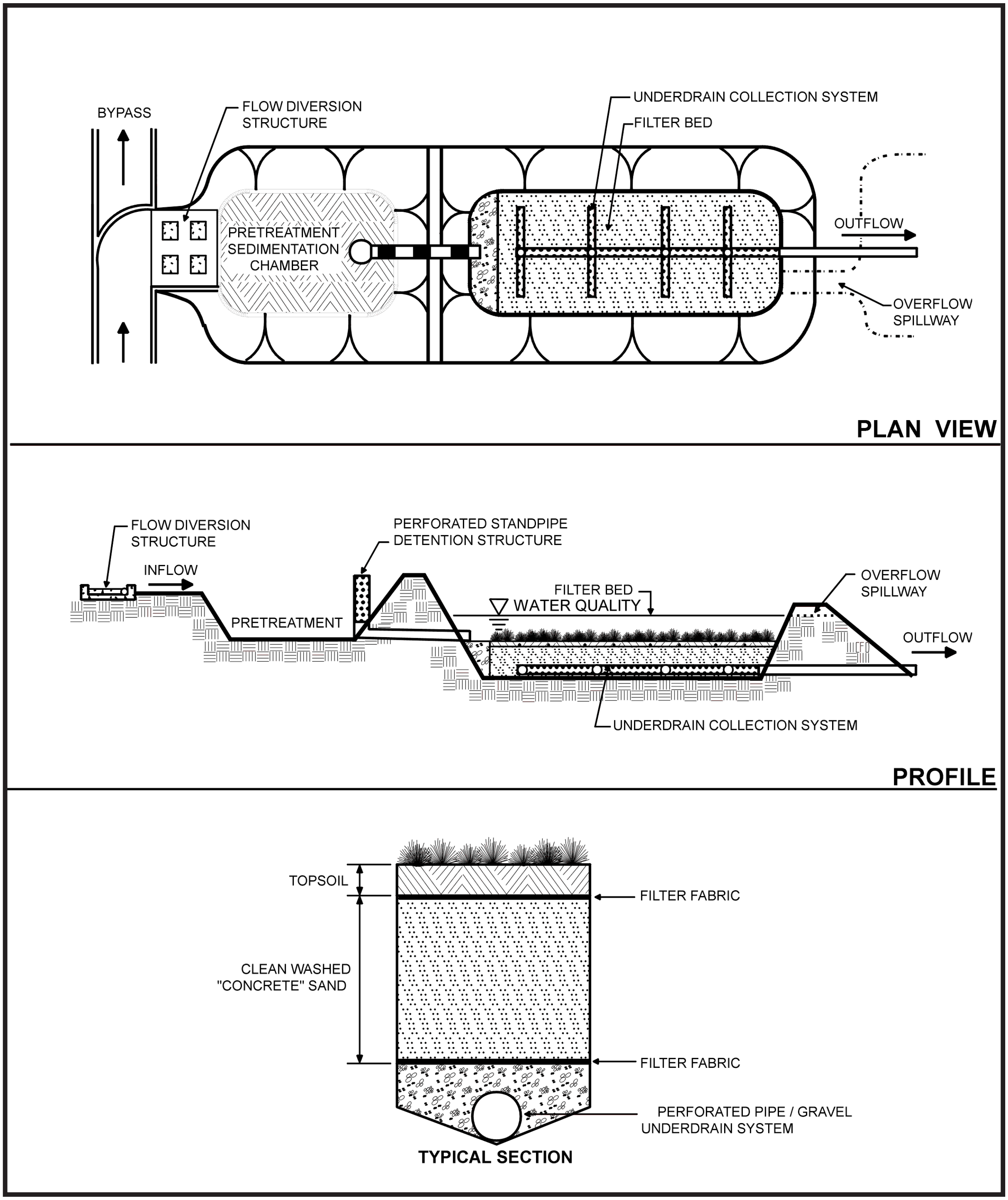


Figure 6.136: Surface Sand Filter. Source: Center for Watershed Protection (©2000)

Recommended Minimum Requirements

To avoid hydraulically overloading the device, the contributing drainage area to any sand filter should be limited to 5 acres. Sand filters should be designed as off-line practices to capture and treat only the water quality storm and to bypass the larger flows. When used in combination with sedimentation basins, sand filters should be installed as an initial pretreatment step.

Construction

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. Elevations of pipe inverts, weirs and filter beds are critical to sand filter performance and should be checked during construction.

Construction Verification

Measure the finished grades and configuration and compare against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Maintenance and inspection of a sand filter will vary depending on the design. Periodic maintenance activities should include the following:

- Frequent inspection of overflow, removal of organic material, and removal of sediment from the sediment basin or chamber.
- Quarterly monitoring of water levels in underground filters.
- Biannual inspection for erosion of pretreatment surface and pocket sand filters.

Common Problems and Solutions

Problem	Solution
Erosion or washout.	Install a device for energy dissipation at the eroded or washed out location.
Clogging due to high sediment loading.	Stabilize adjacent contributing drainage areas or perform frequent clean-outs.
Cells collect trash and debris.	Conduct regular trash and debris removal.
Standing water.	Use corrective measures to ensure proper infiltration.

Hydrodynamic Separation

Figure 6.137: Hydrodynamic Separator. Source: MSD

Practice Description

Hydrodynamic separators, also called swirl concentrators or vortex separators, are available in a wide variety of proprietary devices. These systems target coarse solids and large oil droplets using vortex-enhanced sedimentation or cylindrical sedimentation.

These proprietary systems can provide pretreatment to other technologies in urban areas where surface SCMs are not feasible. Stormwater runoff is not detained, rather it flows through these separation systems at a designed rate controlled by the inflow pipe. They often provide pretreatment for other systems (like filters). It is noted that these devices provide no volume reduction benefits and are generally used only in a retrofit role. They are also used for stormwater hotspots where space is limited for other SCMs.

Recommended Minimum Requirements

Hydrodynamic separators may work if designed off-line with an upstream diversion structure to address larger flows. Head losses across the system should be considered. The design of the system is specific to the manufacturer. The designer should review local requirements for site grading, drainage structures, and erosion and sediment control.

Construction

The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification

Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection

Maintenance requirements and procedures are specified by the manufacturer.

- Regular maintenance is required to prevent the re-suspension of trapped pollutants. Maintenance frequency is a function of the site specific runoff characteristics.
- Maintenance is usually performed with a vacuum truck.
- Maintenance requirements and procedures are specific to each system and specified by the manufacturer.

Common Problems and Solutions

The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer. This device is maintenance intensive due to the small capacity. If this device is not cleaned out routinely, the trapped materials may result in highly polluted discharges during the next storm event.

Catch Basin Inserts

Figure 6.138: Catch Basin Inserts. Source: Shockey Consulting Services

Practice Description

Catch basin inserts are manufactured filters designed to remove trash, debris, coarse sediments, and sometimes oils from stormwater runoff. They are located at the storm drain inlet structure, often installed beneath a catch basin inlet grate.

This device alone does not address all water quality needs. Catch basin inserts are installed to provide pretreatment of runoff from roads, parking lots, commercial and industrial sites. These inserts present an inexpensive option for pretreatment retrofit and are often used in conjunction with other downstream SCMs such as media filtration and infiltration. Manufacturer specifications should be compared to site specific targeted constituents. It is noted these devices provide no volume reduction benefits and are generally used only in a retrofit role. They are also used for stormwater hotspots where runoff pollution is unusually high and where space is limited for other SCMs. However, filters are a more effective way of treating hotspots where space permits.

Recommended Minimum Requirements

Catch basin inserts may be easily installed at most existing storm drain inlets. The design of the system is specific to the manufacturer. The design professional should ensure the capacity of the inlet remains sufficient and does not result in localized flooding. The designer should review local requirements for drainage structures and erosion and sediment control.

Construction
The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification
Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection
Frequent maintenance is critical to ensure functionality of the storm drainage system. Maintenance requirements and procedures are specified by the manufacturer. Maintenance frequency is a function of the site specific runoff characteristics.

Common Problems and Solutions
The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer. This device is maintenance intensive due to the small capacity. If this device is not cleaned out routinely, the trapped materials may result in highly polluted discharges during the next storm event.

Baffle Boxes and Oil/Grit Separators

Figure 6.139: Wetland Swale. Source: Olsson Associates

Practice Description

There is a wide range of configurations and designs of proprietary baffle box or oil/grit separators. Most of these systems are installed offline, bypassing the larger flows. These systems typically have a sediment chamber sized based on Stoke's Law principles, and a chamber to trap floatables such as oils and trash.

There are proprietary and non-proprietary systems. This device is used for limited water quality enhancement in urban areas when land is not available for surface SCMs. They often provide pretreatment for other systems (like filters). Baffle boxes may be incorporated with pre-treatment filters for surface SCMs. These devices allow water to flow through and the rate is regulated by the bypass structure. It is noted these devices provide no volume reduction benefits. Baffle boxes are generally used only in a retrofit role. As a companion practice with filters, they can be used where space is limited for other SCMs or for stormwater hot spots that produce higher concentrations of pollutants than what is normally found in urban runoff.

Recommended Minimum Requirements

Baffle boxes and oil/grit separators are underground and can be adapted to almost any site as an offline treatment. There must be sufficient grade change across the bypass line to ensure that treated water returns to the main line. Specific design and performance expectations are based on the manufacturer. The designer should review local requirements for site grading, drainage structures and erosion and sediment control.

Construction

The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification

Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection

Maintenance requirements and procedures are specified by the manufacturer. Regular maintenance is required to prevent the re-suspension of trapped pollutants. Maintenance frequency is a function of the site specific runoff characteristics. Removal of trapped material is performed with a vacuum truck as needed, usually annually.

Common Problems and Solutions

The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer. Limitations include limited pollutant removal, no volume control, frequent maintenance, proper disposal of trapped sediment, oil and grease, expensive to install and maintain when compared to other practices, and cannot be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols and alcohols. Also, the contributing area should be limited to one acre or less of impervious cover.

Streambank Protection: Preservation, Enhancement and Restoration

Figure 6.140: Streambank Erosion. Source: Shockey Consulting LLC, Burr Oak Woods, Jackson County, MO

Practice Description

Restoration of the streambanks becomes necessary when permanent stormwater control measures have been insufficient or nonexistent to control runoff from the disturbed areas. Streams that receive increased flow volume and velocity will likely suffer bank erosion if not protected. Streambank protection can be vegetative, structural or a combined method where live plant material is incorporated into a structure (bioengineering). Vegetative protection is frequently the least costly and the most compatible with natural stream characteristics. Because each reach of channel is unique, a professional team should be consulted to ensure the specific site characteristics and sensitivities are considered in the design and installation of protective or restorative measures. The professional team will need to focus on streambank and channel stability, upstream contributions to increased flow and volume, and specific stream characteristics that will determine stabilization design (e.g. stream grade and soil type).

Streambanks tend to erode in watersheds where surface runoff rates have increased, causing higher peak flows in the stream. As a result, the stream reforms to carry its new load. Negative impacts to the stream result from changes in the watershed, such as removal of vegetation along a streambank, removal of open space, pavement of large-scale surfaces, removal of healthy vegetation upland and installation of piped stormwater systems.

Considerations in determining which type of streambank protection to use include:

- Current and future watershed conditions.
- Discharge velocity.
- Sediment load.
- Channel slope.
- Dynamics of bottom scour.
- Soil conditions.
- Present and anticipated channel roughness.
- Compatibility with other improvements.
- Changes in channel alignment.
- Fish and wildlife habitat.

Bioengineered Streambank and Channel Protection

Bioengineering involves the use of living vegetation in combination with soil reinforcing agents such as reinforcing mats to provide bank stabilization by increasing soil shear resistance, dewatering saturated soils, and by reducing local shear stresses through increased hydraulic roughness.

Bioengineering is advantageous where there is minimal access for equipment and workers and in environmentally sensitive areas where minimal site disturbance is required. Most techniques can also be used for stream channel or bank protection. Once established, woody vegetation becomes self-repairing and needs little maintenance.

Combinations of vegetative and structural protection provide some of the advantages of both. The structures provide immediate erosion, sliding and washout protection. Vegetation provides greater infiltration than some structural methods, increases channel roughness, and filters and slows surface runoff entering the stream. Vegetation also helps maintain fish and wildlife habitat, and a natural appearance along the stream. It is important that the designer target the cause, not the symptom, of the problem in order to design an effective repair.

Combined methods can be used in areas where velocities exceed 6 feet per second, along bends, in highly erodible soils and on steep channel slopes. Common materials include cellular matrix confinement systems, grid pavers and bioengineering techniques. The upstream and downstream ends of the protection should begin and end along stable reaches of the stream. This practice should be designed for capacity at mature and self-sustaining growth and for stability at low or dormant growth.

See Appendix C and Appendix D for design manual references and other resources. More information about bioengineering practices is available from your local Natural Resources Conservation Service/Soil and Water Conservation District, the Missouri Department of Conservation, University Extension or local design professionals. See Soil Bioengineering for Slope Protection and Erosion Control Transition Mats

Vegetative Streambank Protection

Effective vegetative protection depends on locating plants where their natural characteristics provide the greatest benefit and their growth is assured. General planting information is listed below; however vegetation should be planted in accordance to the design plan with consideration to the vegetative zones. As above, vegetative protection should be designed for capacity at mature and self-sustaining growth and for stability at low or dormant growth. The location of each zone depends on the elevations of the mean high water level, the mean water level and the mean low water level as shown in Figure 6.141.

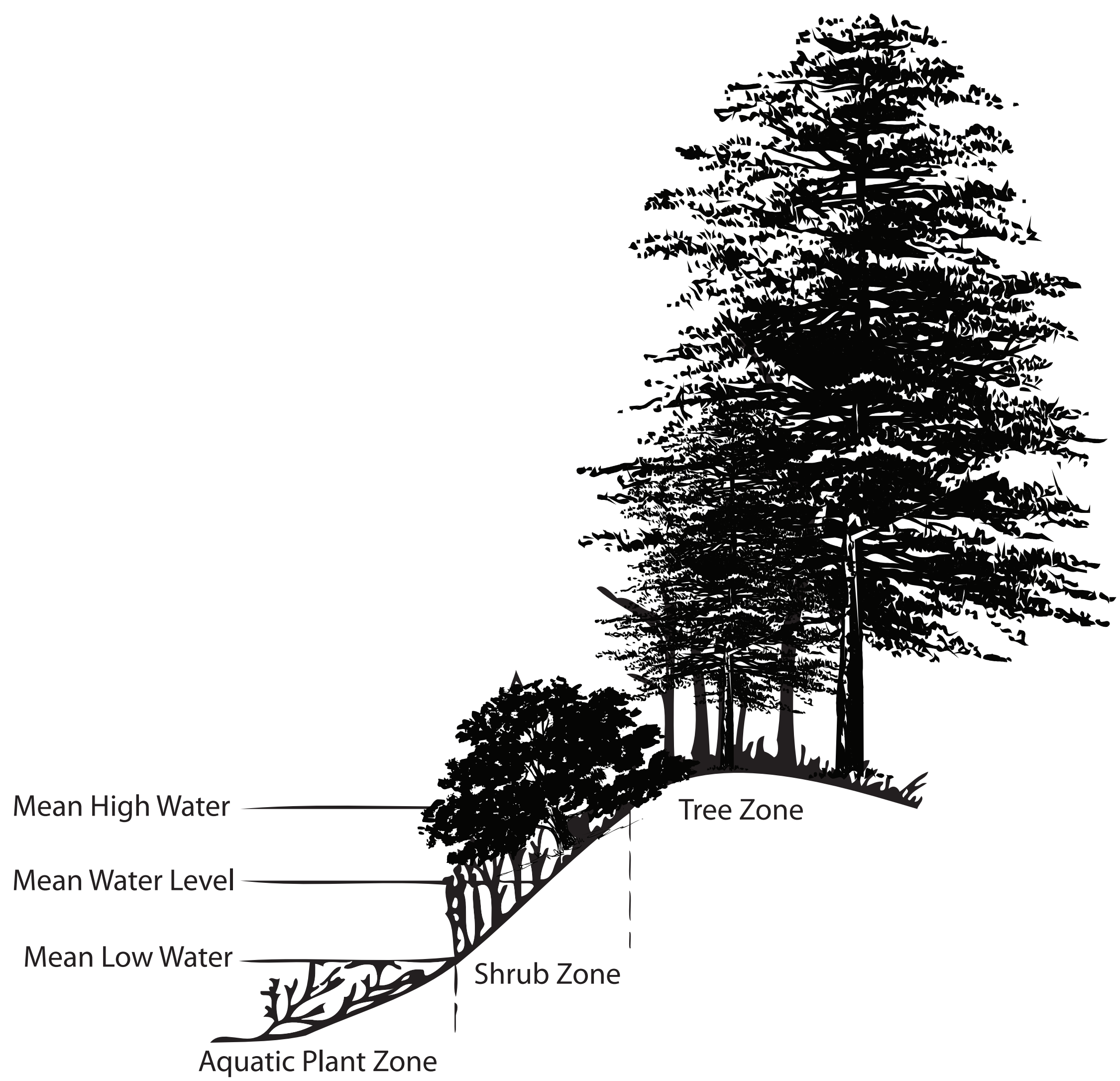


Figure 6.141: Vegetative Zones for Streambank Protection. Source: Missouri Department of Natural Resources

Aquatic Plant Zone

The aquatic plant zone includes the stream bed and is normally submerged at all times. Most often this area is not planted, yet sometimes aquatic plants are added here to achieve greater diversification in the restored stream bank community.

Shrub Zone

The shrub zone lies on the bank slopes just below the mean high water level and is normally dry, except during floods. Willows, silver maple, poplar and dog wood trees can be planted (staked) from top-of-bank to mean water line. They are preferred because they have high root densities and root depth, root shear and tensile strength is higher than that of most grasses or forbs, and they can transpire water at high rates.

- Upland trees should not be planted in the shrub zone. Refer to Appendix C and Appendix D for plant resource information, including the Grow Native! website for photos and narratives about Missouri native plants or consult the Missouri Department of Conservation, Kansas Wildlife and Parks or a professional forester for appropriate wetland shrub and tree species. Some grasses, sedges and bushes should be planted in the shrub zone if shear is not too high and plants are not submersed frequently or for long periods of time.
- Plant grasses in the spring or the fall. To seed grasses, roughen the seedbed, lime and fertilize according to soil test results. Check with the local Natural Resources Conservation Service, Missouri Department of Conservation, University Extension office or a local design professional for an appropriate seed mixture.

Tree Zone

Plant upland trees along the banks of the stream and not on the slopes. If trees provide shade to the streambank, grasses should be planted that will thrive in shady conditions.

Structural protection with engineered structures alone or bioengineered with plants should be provided in locations where velocities exceed 6-feet per second, along bends, in highly erodible soils and in steep channel slopes. Common materials include rock and revetments. Grouted riprap is not recommended, because grouted rock does not move with freeze/thaw and wetting/drying cycles. This lifting action results in voids quickly forming under grouted rock, allowing erosive forces to penetrate the structure and create potential failure of the grout and rock movement. The upstream and downstream ends of the structural protection should begin and end along stable reaches of the stream.

Streambank restoration efforts that involve structural practices or combination methods should be considered temporary if overall watershed factors are not considered in the design. Contributing erosion factors need to be corrected, because erosion will otherwise render the structural practice ineffective.

Structural Streambank Protection

Grid Pavers

Grid pavers are modular concrete units with interspaced void areas that can be used to armor a streambank while also establishing vegetation. Grid pavers are typically tied together with cables and come in a variety of shapes and sizes.

Figure 6.142: Interlocking concrete blocks along Two Mile Creek, St. Louis County. Source: K. Grimes, SWCD, St. Louis County

Cellular Confinement Matrices

Cellular confinement matrices are commercial products usually made of heavy-duty polyethylene formed into a honeycomb-type matrix. The cellular confinement matrices are flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel or cement. If soil is used to fill the combs, vegetation must also be established.

Gabions

Gabions are rock-filled wire baskets stacked to form a wall against the streambank. Gabions are not the preferred alternative for streambank protection when bioengineering practices are available to provide adequate protection. Efforts should be made to identify the sources of erosion and streambank destabilization such as upstream devegetation, increased imperviousness, extensive curb and guttering. Efforts should be made to restore upland vegetation, slow the flow of stormwater entering the stream system and reroute to alternative practices. It is better to correct the problems, otherwise gabions and similar practices such as filter fabric revetments are only temporary fixes.

Gabions are typically designed to slow the flow of stormwater. They are sometimes used on steep slopes for temporary stabilization where there is not enough room to accommodate a “softer”, vegetated solution. Gabions are very labor intensive to construct, but are semi-flexible, permeable and can be used to line channel bottoms and streambanks. They can be placed (and vegetated when possible) in a manner to provide good drainage.

Additional Considerations

Gabions are more expensive than either vegetated slopes or riprap.

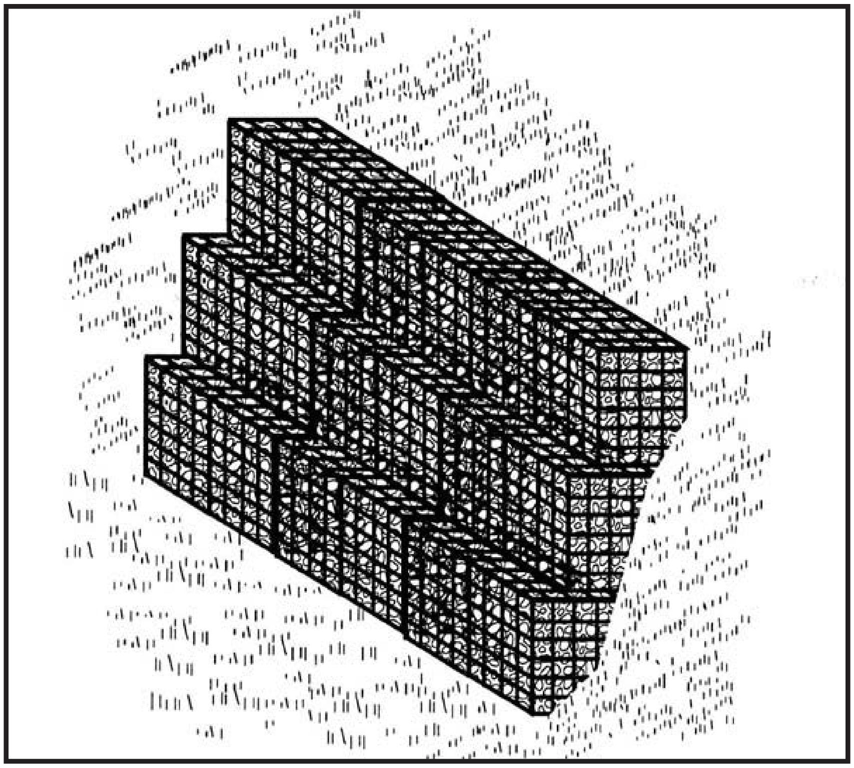


Figure 6.143 Typical gabion installation. Source: Shockey Consulting Services

The wire baskets used for gabions may be subject to heavy wear and tear due to wire abrasion by bedload movement in streams with high velocity flow. Gabions are difficult to install, requiring large equipment. Gabions are not the preferred alternative for streambank protection when bioengineering practices are available to provide adequate protection. Gabions are considered temporary. Permanent stabilization is dependant upon locating and correcting the problems contributing to erosion and destabilization. When gabions break down, the stream should already be in the process of stabilizing if erosive factors have been addressed upstream.

Recommended Minimum Requirements

Streambank protection projects should be designed by a registered Professional Engineer as part of the overall site design for long-term water quality, with significant attention given to upstream and downstream hydrologic factors and overall watershed health. Streambank and wetland work within jurisdictional waters require federal, state and possibly local permits. See Chapter 1 for regulation information.

Figure 6.144 Example of stable and unstable streambank. Source: MDC

Streambank protection should be considered in the initial design phases of any development project. An interdisciplinary team may provide the needed variety of expertise. Protection methods should focus on preserving, enhancing or restoring the stream hydraulics such that streambanks no longer erode.

Protection measures should begin and end at stable locations along the bank. Stable locations are typically where the streambed is armored with stable rocks occurring naturally at riffles, or man-made armored sections such as culvert crossings. By working between these stable locations, the impacts of the streambank protection are limited to the channel between stable locations so the erosive forces are not transferred to another location.

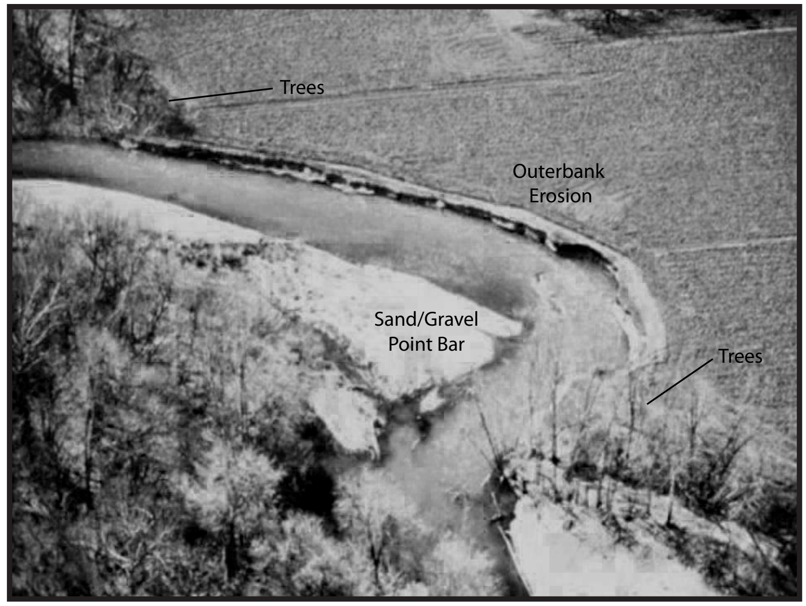


Figure 6.145 Example of stable and unstable streambank. Source: MDC

Before work is done within the channel, it should be determined if a Section 404 permit is required from the Corps of Engineers, as well as a Section 401 permit from the Department of Natural Resources.   A local floodplain study may also be required. The site superintendent, job foreman and field personnel should refer to the plans and specifications throughout the construction process.   The site superintendent should discuss any potential need for such permits with the site owner.

Several important considerations when designing streambank or channel protection include:

- **Velocities:** Vegetation alone may provide effective protection when stream velocities are 6-feet per second or less. Consider structural protection for velocities greater than 6-feet per second. Use the highest velocity expected, which is determined by evaluating the velocities through the full range of storms from the very frequent small events through large storm events. Allowable velocities vary depending on the soil and plant types. Refer to applicable design standards and manuals for more details.

- **Channel Bottom:** Downcutting must be stabilized before installing bank protection. An engineered grade control may be needed where downcutting is severe.

- **Streambank Plantings:** Consider the natural growth needs, patterns and preferences of selected planting stock when reestablishing the streambank community.

- **Plant Selection:** Use native or adaptive plant materials for establishment and long term success, because adapted plants are easier to establish and require less maintenance. See Appendix C and Appendix D for references about guiding plant selections.

- **Structural Methods:** Constructed “hard surfaced” features may be needed in especially challenging spots such as bends in the channel or changes in channel slope or where changes in hydrology, sediment load and channel alignment are occurring.

- **Combined Methods:** Many bioengineering practices (i.e. use of “living” structures) are useful to protect streambanks and channels. See Bioengineered Streambank and Channel Protection above.

- **Permits Requirements:** See Chapter 1 for regulation and permit requirements.

Construction

Initial Site Considerations

- Before starting construction, ensure all plans follow local, state and federal government regulations for any stream modification within jurisdictional waters. See Chapter 1 for regulation and permit requirements.
- Prior to excavation activities of any type, call 800-DIG-RITE (344-7483) to obtain utility locations.
- Examine the channel bottom before streambank protection measures are installed. Determine the need for grade control.
- Locate stable points along the channel to serve as anchor points for stream protection structures.

Follow design specifications for clearing, grubbing and grading. Grid pavers, cellular confinement matrices, gabions or other proprietary products should be designed and constructed into the project in accordance with manufacturer's guidelines and as specified in the design plan.

When filling products with rock, only durable crushed limestone, dolomite or granitic rock should be used. Shale, siltstone and weathered limestone should not be used because of their solubility or tendency to crumble. Depending on soil type, a filter fabric or a granular filter may need to be placed between streambank material and gabions. Use attractive facing stone toward the front of the wall.

Establish desirable vegetation where possible in between rocks and materials within the pavers, matrices or gabions. Otherwise, invasive and poorly rooting plants will take over the practice, reducing its effectiveness. Desirable vegetation will also increase habitat value.

Erosion Control

Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete. Use temporary diversions to prevent surface water from running onto the streambank protection area. Route overland flow so it maintains the least possible velocity and exits the project site at a protected location. This information should be outlined in the community's stormwater pollution prevention plan associated with state, local or federal permits. See Chapter 1 for regulation and permit information.

Plant vegetation immediately after construction to promptly stabilize all disturbed areas.

Safety

Store all construction materials well away from the stream to avoid transport of polluted runoff or materials to the stream.

Clear, grub and grade the streambank surface to prepare for installing the matrices. Install systems according to engineered design plans and manufacturer's recommendations.

At the completion of each workday, move all construction equipment to a safe storage area out of and away from the stream to prevent damage from flooding. While working in streams, whether flowing or not, the following precautions should be taken:

- Avoid working above steep slopes on the streambank where cave-ins are possible.
- Fence area and post warning signs if trespassing is likely.
- Provide a means for draining the construction site if it becomes flooded.

Construction Verification

For vegetative protection, check to see planting and seeding was done in compliance with the design specifications. For structural protection, check cross section of the channel, thickness of protection and confirm the presence of filter cloth between the protection and the streambank.

Maintenance and Inspection

Bank stability and vegetation should be assessed during routine inspections and after each storm event during the initial 2 years following construction. If any minor bank instabilities are documented, the repair should include back-filling with soil, installing erosion control blanket or bonded fiber matrix, planting seed blends and vegetative cover recommended in the plans.

Significant bank instabilities should be addressed by a professional design engineer. The extent of the project areas should be monitored with great frequency at project completion and less often as the project establishes, as presented below.

Table 6.18: Monitoring Frequency Following Plant Establishment

Growing Seasons	Frequency of Monitoring
1 - 2 years	Bi - Weekly
3 - 5 years	Bi-Monthly
Project Life	Two Inspections Annually

Maintenance activities should be in response to any new bank instabilities or vegetation issues detected. Maintenance activities may consist of weed control, bank stabilization and replanting vegetation that has died or eroded. It is important to identify what caused any issues so their reoccurrence can be prevented.

Bare areas of soil greater than 1 ft^2 shall be reseeded immediately upon discovery and protected from soil erosion. For any new plantings, adequate soil moisture is critical to plant establishment, and adequate soil moisture must be maintained immediately after each plant is sowed or set.

The project should require the contractor or property owner to maintain the plants throughout the first full growing season until they become established. Plants are more susceptible to mortality during the first two weeks of their growth and often require supplemental watering.

It is also important that other environmental and man-made stresses be monitored and timely adjustments be made to take these stresses into account. Some anticipated stresses include:

- Herbivory or Grazing (insects, deer, livestock).
- Vandalism.
- Wildlife Damage (rabbits, deer, beaver, muskrat).
- Insect infestations (grasshoppers, army cutworm, spider mites).
- Disease (not a frequent problem with non-horticultural varieties).
- Water stress (drought early on, typically the design is flood tolerant).
- Weather Damage (wind, hail).
- Weed Infestation.

Streambank maintenance after construction is the responsibility of the land owner, municipality or sewer district. The landowner needs to understand their responsibility and the state and local requirements in their area. Larger issues can be addressed through cooperative watershed planning and partnerships with regional planning groups.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate protection will not function as intended.	Consult with a registered Professional Engineer, changes in plan may be needed.
Design specifications for vegetative or structural protection cannot be met.	Consult with registered Professional Engineer, substitution may be required. Unapproved substitutions could result in erosion damage to the streambank and cause project failure.
Erosion of streambank; caused by inadequate vegetation, improper structural protection or an increase in stream velocity due to upstream development.	Repair erosion, establish adequate vegetation or structural protection and reduce stream velocities.
Slumping failure or slides in streambank; caused by steep slopes.	Repair a slide by excavating failed material and replacing with properly compacted fill. Consider flattening the slope and consult the Professional Engineer.

Rock Lined Channels

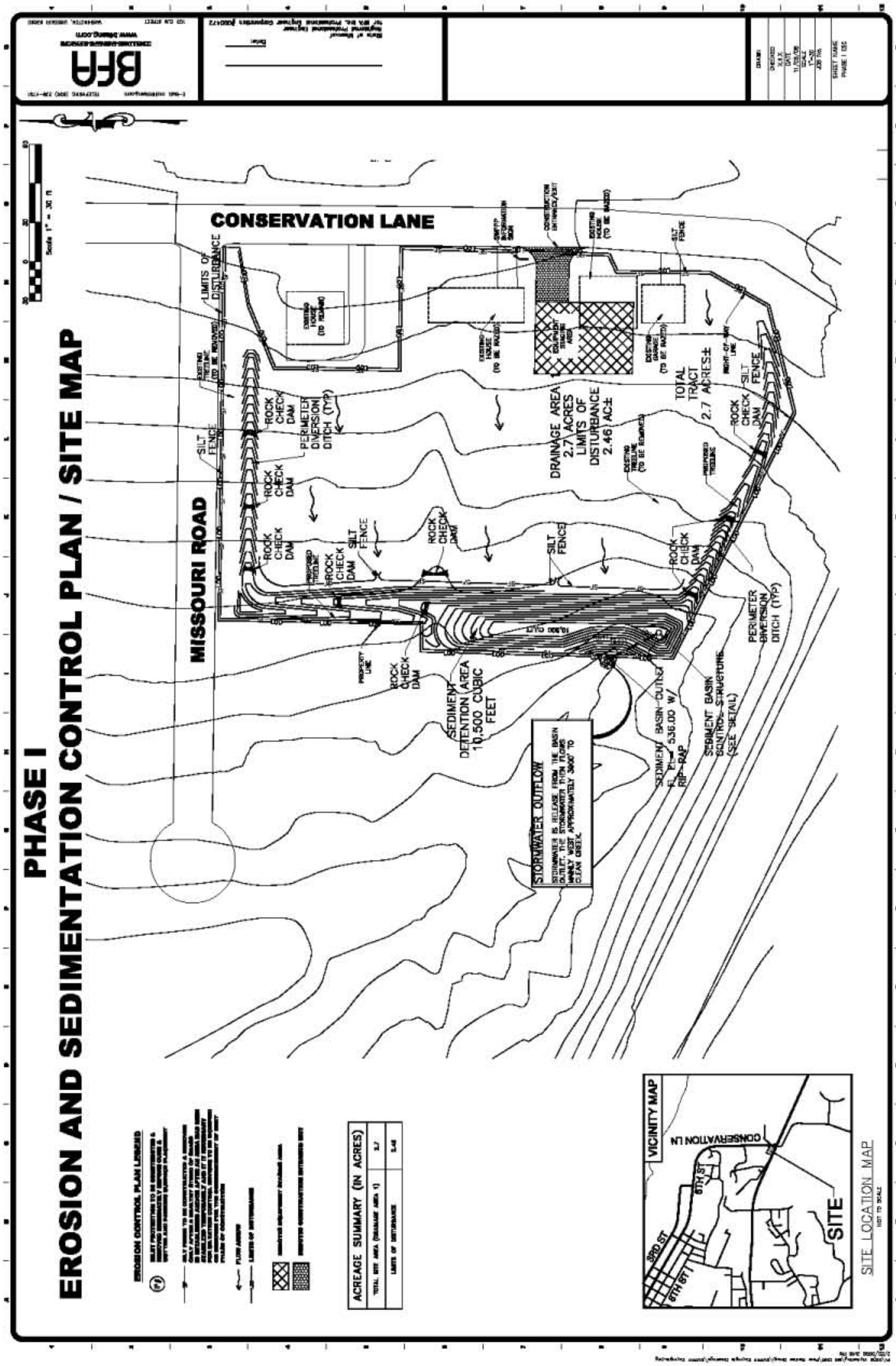
Highway drainage designers are ultimately left with the task of capturing runoff that does not infiltrate and then routing it via storm sewer to an outlet at some location. In the distant past, it was common to let this runoff discharge directly to a receiving water body, often resulting in an actively erosive area. Later, it became common to line the channel area with various sized rocks (riprap) in order to solve the problem.

Riprap is still used, however it is not always the most structurally sound nor is it the most aesthetic approach. Natural and synthetic geotextile reinforcements may be a suitable alternative and are available to fit a variety of needs. Choosing between these options depends a great extent on the nature of the problem. Product specifications for strength and applications should be examined to choose the proper material. Another option is compost-grouted riprap, in which compost is sprayed into voids and serves as a root medium for native plants.

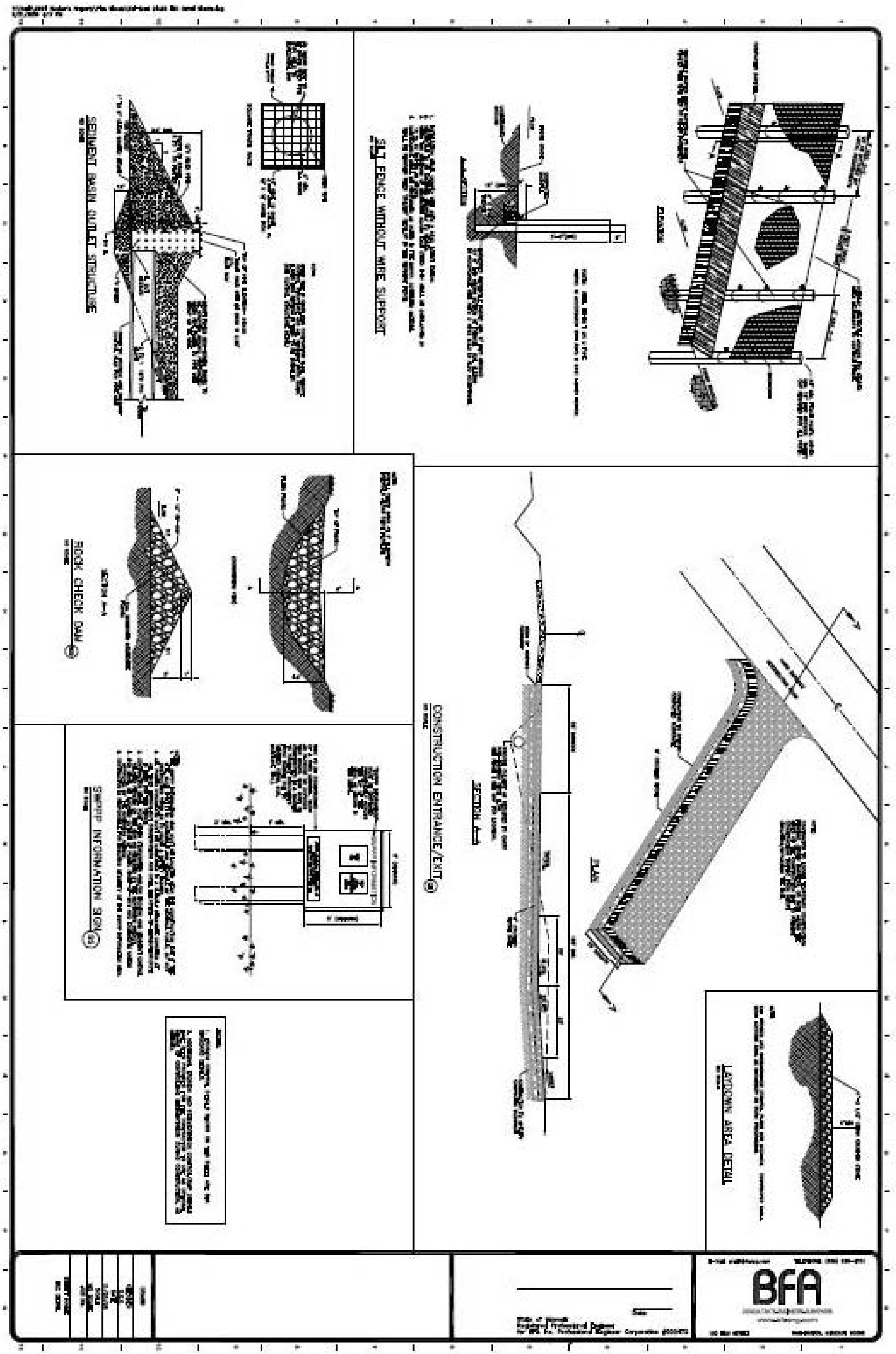
As with grade controls, these reinforcement methods can be part of an initial installation or easily retrofit if a problem is identified and in need of a solution. However, erosive factors need to be addressed elsewhere in the watershed to avoid further failure.

- Rock lined channels require properly sized, graded, bedded and placed rock that rises and settles with soil movement.
- Stream banks should be sloped at 2:1 or flatter.
- In some cases, it might by beneficial to place filter fabric or a granular filter between the rock and the natural soil.
- Construct the riprap layer with sound, durable rock. Refer to plan for gradation and layering.
- Large and small rocks are required to lock in pieces and should not be flat or elongated.
- Place the toe of the rock at least 2-foot below the stream channel bottom or below the anticipated scour depth. Install toe walls as specified in plan.
- Extend the top of the riprap layer at least up to the two year water surface elevation. Vegetate the interface and remainder of bank.

APPENDIX A
SITE MAP, DETAIL SHEET AND GRADING PLAN



Site Plan. Source: BFA



Detail Sheet. Source: BFA

APPENDIX B
GLOSSARY

A

Accelerated Erosion See Erosion.

Acidic A material with a pH of less than 7.0. Soil nutrients are generally less soluble and less available to plants in moderately or strongly acid soils. Agricultural lime is commonly applied to acidic soils to increase the pH.

Acre An area of measurement equal to 43,560 square feet.

Aeolian Wind deposited material such as loess or dune sands.

Aggregate Sand, gravel, crushed stone or slag, usually having a known range of particle sizes. Used with a cementing medium to form concrete or alone as in a roadway bed or railroad ballast.

Agronomy The theory, study and practice of field crop production and soil management.

Alkaline A material with a pH greater than 7.0.

Alluvial Soil Soil formed from materials transported in suspension by flowing water and deposited by sedimentation.

Anchor Trench A long, narrow ditch in which the edges of a material (e.g. silt fence, erosion control blanket or geotextile) are buried to hold it in place.

Angle of Repose The maximum angle of slope (measured from a horizontal plane) at which loose, non-cohesive material will come to rest. The angle of repose for unconsolidated soil varies with the soil grain size, grain shape and moisture content. To maintain stability, cut or fill slopes should not exceed the angle of repose or slippage may occur.

Anti-Seep Collar A plate of metal, high-density plastic or butyl rubber attached perpendicularly to the outside of a pipe placed through an embankment. Used to prevent water from flowing unabated along the outside of the pipe causing soil piping and structure failure.

Application Rate The quantity (mass, volume or thickness) of material applied per unit area.

Apron Protective material laid on a streambed or ground surface to prevent scour at a culvert outlet, abutment, toe of a structure or slope or similar location.

Aquifer An underground, porous, water-bearing geological formation composed of a layer of permeable rock, sand or gravel that provides a groundwater reservoir.

Armor A protective coat or artificial surface on streambeds, banks, shores or embankments used to resist erosion or scour. Examples of hard armor include concrete and riprap. Soft armor includes flexible geosynthetic support systems used with vegetation.

Articulated Block Systems Concrete blocks linked by cables or interlocking pieces that are flexible, porous and can accommodate growth of herbaceous and woody vegetation while offering the strength and durability of a hard armor.

B

Best Management Practice, or BMP The preferred methods and products that will correct or control erosion, sedimentation or water quality degradation on a specific site for particular site conditions.

Backfill Earth or other material used to replace material removed during construction, such as in culvert, sewer and pipeline installations.

Base Course (Base) A layer of material of specified thickness placed on the subgrade to distribute load, provide drainage and minimize frost action.

Bedding The soil or other material on which a pipe or conduit is supported.

Bench A step in a slope. Formed by a horizontal surface and a surface inclined at a steeper angle than the entire slope.

Bentonite (Sodium Bentonite) A highly plastic clay that swells extensively when wet. Used to seal soil to reduce seepage losses from ponds and lagoons.

Berm (1) A ridge of earth constructed to direct the flow of surface water. (2) A shelf that breaks the continuity of a slope. (3) The embankment of a pit or pond that may be wide and solid enough for vehicular traffic.

Binder (Emulsion, Tackifier) Natural or synthetic additive that causes an otherwise non-cohesive material to become bound into a cohesive matrix.

Biodegradable Ability of a material to breakdown or decompose under natural conditions and processes, within an acceptable time frame, without polluting the environment.

Bioengineering A method of construction using living plants or plant materials in combination with inorganic materials. The practice brings together biological, ecological and engineering concepts to produce living, functioning systems used to prevent erosion and control sedimentation. Also, it often provides wildlife habitat.

Biological Stability Ability to resist degradation from exposure to microorganisms.

Blanket Rolled materials consisting of coir (coconut fiber), jute, straw, wood fiber or various synthetic materials used to prevent erosion, trap sediment, protect seed and promote the growth of vegetation. They can be either degradable or permanent.

Blinding (Clogging) The condition whereby soil particles block the voids at the surface of a geotextile, thereby reducing the rate of water flow through the geotextile.

Bridging (Soil) The formation of large voids due to inadequate compaction of earth material or the inclusion of improper fill materials.

Broadcast The application of material scattered or sprayed on the soil surface. Broadcast seeding is a uniform distribution of seeds over the entire planted area.

C

CCIS™ A Certified Compliance Inspector of Storm water as designated by Stormwater USA.

CESSWI™ A Certified Erosion, Sediment and Storm water Inspector as designated by EnviroCert International.

CISEC™ A Certified Inspector of Sediment and Erosion Control as designated by CISEC Inc.

CPESC ™ A Certified Professional in Erosion and Sediment Control as designated by EnviroCert International.

CPSWPPP™ A Certified Preparer of Storm water Pollution Prevention Plans as designated by Stormwater USA.

CPSWQ® A Certified Professional in Storm water Quality as designated by EnviroCert International.

Canopy (Plant) The foliage of a tree, shrub or herbaceous plant. The area covered by the plant canopy is protected from splash erosion.

Canopy (Inlet) A principal spillway pipe with the inlet cut at an angle of 33, 45 or 56 degrees designed as an anti-vortex device that maximizes water flow through the pipe.

Carbon Black Material consisting primarily of elemental carbon used as an additive for plastic geosynthetic production. It imparts a black color to the compound, which retards aging by ultraviolet light from the sun.

Catch Basin A receptacle for diverting surface water to a sewer or subdrain, having at its base a sediment bowl to prevent the admission of coarse material into a sewer or stream.

Cation Exchange Capacity, or CEC The capacity of a soil for ion exchange for cations between the soil and soil solution. CEC is used as a measure of fertility and nutrient retention capacity.

Cellular Confinement System A synthetic grid with open spaces filled with soil, sand, gravel or concrete. The matrix mechanically stabilizes these materials and is used for erosion control and load support applications.

Certified Seed Seed that has been analyzed by a state association test laboratory for percent germination, weed seed content and purity.

Channel A natural stream or excavated ditch that conveys water.

Channel Erosion See Erosion.

Channel Stabilization Protection of the sides and bed of a channel from erosion by controlling flow velocities and directions or by lining the channel with vegetation, riprap, concrete or other material.

Check Dam (Rock Check Structures) Temporary barriers of 3 to 6 inch rock constructed across a swale or drainage ditch. Used to reduce the velocity of concentrated storm water flows, reduce degradation and to trap sediment.

Chemical Stability The ability to resist chemicals (e.g., acids, bases, solvents, oils and oxidation agents) and chemical reactions, including those catalyzed by light.

Chute A steeply inclined channel, usually lined with rock or concrete, for conveying water from a higher to a lower level.

Clay (1) Mineral particles less than .002 millimeters in equivalent diameter. (2) A soil containing more than 40 percent clay. Clay soils exhibit plasticity when moist, but are hard when dry.

Clogging See Blinding.

Coefficient of Permeability (k) The rate of discharge of a fluid per unit cross sectional area of a geotextile under a hydraulic gradient.

Cohesive Soil An unconfined soil that has considerable strength when air dried and significant resistance to disintegration when submerged in water.

Coir Organic fiber from the outer shell of the coconut, used as a mulch and in the manufacture of erosion control blankets, geotextiles and coir tubes for scour protection and planting in bioengineering applications.

Compaction The application of mechanical forces to the soil to make it denser and less porous.

Concrete A hard, strong building material composed of water, a cementing material such as portland cement and a mineral aggregate such as sand or gravel.

Concrete Armor Blocks Interlocking blocks of precast concrete used for channel linings and streambank stabilization.

Conduit Any channel or pipe for transporting water.

Conservation District A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water and related resource conservation, use and development within its boundaries. Often called a soil conservation district or soil and water conservation district, it is usually a subdivision of state government with a local governing body, but with limited authorities.

Consistency The relative ease with which a soil can be deformed. Soil moisture content directly influences how a soil behaves when subjected to compression.

Contaminant A secondary material added by human or natural activities which may, in sufficient concentrations, render the primary material or atmosphere unacceptable.

Contour An imaginary line on the surface of the earth connecting points of the same elevation.

Coverage The surface area to be covered by a specified material. For roll goods, allowance is made for a defined overlap of the edges of the material.

Creep (1) Slow mass movement of rock or soil material down slopes primarily driven by gravity which is not usually perceptible except to observations of long duration. (2) The slow change in length or thickness of a material under prolonged stress.

Crest Elevation (1) The maximum elevation of surface water under consideration. (2) The highest elevation of a structure or component.

Critical Areas Regions highly susceptible to erosion such as an area subjected to concentrated water flow.

Critical Depth Water depth in a conduit at which certain conditions of maximum flow will occur.

Critical Slope (1) The slope at which a maximum flow will occur at minimum velocity. (2) The maximum angle with the horizontal axis at which a sloped bank of soil or rock of a given height will stand unsupported. See Angle of Repose.

Critical Velocity The average velocity of flow when flow is at critical depth.

Culvert A conduit for conveying surface water through an embankment.

Cut and Fill A process of moving earth by excavating part of an area and using the excavated material for adjacent embankments or deposit areas.

D

d50 The sieve opening size that allows 50 percent of a given sample to pass through.

Dam An embankment constructed of compacted soil materials usually across a stream or area of concentrated water flow.

Darcy's Law A law describing the rate of flow of water through saturated porous media.

Deformation A change in the shape of a specimen, (e.g., an increase in length produced as a result of the application of a tensile force).

Degradable The ability of a material to break down or decompose into lesser components.

Degradation (1) The loss of desirable properties by a material as a result of some process or physical/chemical phenomenon. (2) The progressive general lowering of a stream channel by erosion.

Density The mass of a substance per unit volume.

Department of Natural Resources, or DNR The state agency in Missouri responsible for preserving and protecting the state's natural and cultural resources. Along with EPA, the Department of Natural Resources is authorized to regulate the NPDES program, which includes storm water runoff permitting. The department also provides grants and low-interest loans to public entities for sediment control, water pollution control and related information and education projects.

Design Flow A quantity of flow expected at a certain point as a result of a design storm or flood frequency.

Design Frequency The recurrence interval for hydrologic events used for design purposes. As an example, a design frequency of 50 years means a storm of a magnitude that would be expected to occur on the average of once in every 50 years.

Design Life The length of time for which it is economically sound to require a structure to serve without major repairs or replacement.

Design Standards The defined conditions where a specific conservation practice or set of practices are to be used.

Design Storm A selected rainfall pattern of specified amount, duration, intensity and frequency that is used to calculate the volume of water runoff and peak discharge rate.

Dewatering The removal of surface or subsurface water such as removing water temporarily impounded in a holding basin or pond.

Dew Point The temperature at which water vapor starts to condense in cooling air at the existing atmospheric pressure and vapor content.

Dike An embankment or wall constructed to prevent flooding.

Discharge A volume of fluid passing a given point per unit time. The flow rate of storm water is commonly expressed as cubic feet per second.

Diversion A channel and ridge of earth constructed to divert surface runoff water from one area to another for disposal at a non-erosive velocity.

Drainage Interception and removal of groundwater or surface water, by artificial or natural means.

Drainage Area A geographical area that contributes runoff water to a common point.

Drainage (Soil) The frequency of saturation and duration of time needed for water to flow through soil.

Dredging The process of removing sediment from a watercourse such as a river or reservoir.

Drop Inlet A structure in which the water drops through a vertical riser connected to a discharge conduit or over the crest of a vertical wall to a lower elevation.

Drop Structure A structure in a channel or conduit that permits water to drop to a lower level.

Dry Well A steel catch basin with open bottom and perforated walls. Used to store surface runoff for infiltration, or recharge, into the ground.

E

Effective Calcium Carbonate, or ECC A measure of the ability of a liming material to neutralize soil acidity, expressed as a percentage. Agricultural lime is approximately 50 percent ECC.

Ecosystem A system formed by living organisms interacting with their nonliving environment.

Effluent A material that flows out from the point of concern. (e.g., sewage water or other waste liquids flowing out of a reservoir basin or treatment plant).

Embankment A mound of earth or stone built to hold back water or to support a roadway.

Emergence The process of a plant seedling rising above the soil surface.

Emulsion See Binder.

Environmental Protection Agency, or EPA The federal agency responsible for the enforcement of the Clean Water Act. See Resource Inventory List for more information.

Energy Dissipater A structure installed at the outlet of a channel, drop structure or conduit to absorb the force of high-velocity flow. It may consist of riprap, linings, baffles, staggered blocks, etc.

Equivalent Opening Size, or EOS Number of the U.S. Bureau of Standards sieve (in milimeters or inches) having openings closest in size to the diameter of uniform particles that will allow 5 percent by weight to pass through the material. Used to select filter fabric for filtration and separation usage.

Equivalent Neutralizing Material, or ENM See ECC.

Erosion The process by which soil particles are detached, transported and deposited by wind, water, ice or gravity. The following terms are used to describe different types of erosion:

> **Accelerated erosion** Erosion much more rapid than natural or geologic erosion, primarily as a result of human activities.
>
> **Channel erosion** The widening, deepening and headward cutting of small channels and waterways due to erosion caused by increased frequency of bank full (channel forming) flow.
>
> **Gully erosion** The erosion process whereby runoff water accumulates in narrow channels removing the soil to considerable depths over relatively short time periods. When surface channels cannot be smoothed out by normal agricultural tillage operations, they are called gullies.
>
> **Sheet erosion** The gradual removal of a fairly uniform layer of soil from the land surface by a thin evenly distributed sheet of runoff water.
>
> **Shoreline erosion** The loss of soil materials due to the wave action of a permanent waterbody such as a pond, lake or ocean.
>
> **Splash erosion** The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.
>
> **Rill erosion** The erosion process whereby numerous small channels only several inches deep are formed. Commonly occurs on recently disturbed and exposed soils. Rills are shallow enough to be removed by normal agricultural operations.
>
> **Saltation** The movement of soil particles by rolling or a series of short bounces along the ground surface due to the wind.

Suspension The transport of soil particles by the wind for relatively long distances.

Surface Creep The transport of soil particles by the wind along the surface of the earth.

Erosion Control The prevention or reduction of soil particle movement. Erosion control reduces soil detachment, transport and deposition.

Erosion Control Blanket Temporary or permanent fabricated materials that protect the soil and enhance the establishment of vegetation.

Erosion Control Technology Council, or ECTC A division of the International Erosion Control Association, or IECA, which develops standards and guidelines for products and testing of materials.

Evaporation The conversion of water from liquid to vapor form.

F

Fabric See Geotextile.

Fabric Formed Concrete Systems Geotextile tubes and mattresses filled with concrete to provide a hard armor protection system.

Fabric Wrapped Drain An inner core of a porous medium such as sand, gravel or a corrugated pipe with an outer geotextile wrap or sheath used to collect and remove excess water.

Fascine (Wattle) Bundles of tree or shrub branch cuttings tied together and anchored in trenches with wooden stakes. Used for a variety of slope stabilization projects.

Fertilization The process of adding soil nutrients to the soil to stimulate plant growth. The percentage of available nutrients in bulk fertilizer is labeled as percent nitrogen, percent phosphorus and percent potassium. A 100-pound bag of 12-12-12 is 12 percent nitrogen, 12 percent phosphorus and 12 percent phosphate. The bag contains 12 pounds of each nutrient along with 64 pounds of inert ingredients.

Fill (Embankment) A bank of soil, rock or other material constructed above the natural ground surface.

Filter Cloth See Geotextile.

Filter Strip A wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants, and reduce storm water flow and velocity. Designed to accept an even distribution of surface runoff; their effectiveness is reduced if a channel forms, or if high velocity flows occur.

Filtration The process of retaining soils or other materials while allowing the passage of water or fluids.

Finished Grade The final elevation of the ground surface conforming to the approved construction plan.

Flood An overwhelming quantity of water. Measured in terms of either water level or discharge rate.

Floodplain A relatively level surface of stratified alluvium that adjoins a water course and is subject to periodic flooding, unless protected artificially by a dike or similar structure.

Footing The supporting base or ground work of a structure.

Freeboard The vertical distance between the elevation of the design high-water level and the top of a dam, diversion ridge or other water control device.

Freeze-Thaw Resistance the property of solids to resist cyclical freezing and thawing.

Friction Angle An angle, the tangent that is equal to the ratio of the friction force per unit area to the normal stress between two materials.

Frost Heave The raising of a surface or object due to the accumulation of ice in the underlying soil.

G

Gabion A galvanized or polyvinylchloride-coated steel wire mesh basket filled with stones, broken concrete or other dense, erosion-resistant material. Individual baskets are usually linked together to form part of a larger unit. Used to protect channel banks, shorelines or steep slopes from erosion.

Gauge Standard measurement of the thickness of metal sheets or wire (and bearing a relation to the weight of the metal).

Geocomposite A manufactured material using geotextiles, geogrids or geomembranes in laminated or composite form.

Geogrid A net-like polymeric material used to reinforce, stabilize or contain soil, rock, earth or other material in a wide variety of applications including internally reinforced soil walls, segmental retaining walls, steep slopes, etc.

Geomembrane A synthetic impermeable membrane used to contain liquids or sediment.

Geosynthetics Any synthetic material, including geotextiles and geomembranes, or any combination thereof, used with foundation, soil, rock, earth or any other geotechnical engineering related material, as an integral part of a structure or system.

Geotechnical Engineering The application of the laws and principles of science and mathematics to solve problems related to the materials of the earth's crust. It includes the fields of soil mechanics, rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology and related sciences.

Geotextile (Fabric, Filter Cloth) A woven, nonwoven or microfilament water permeable material, either natural or synthetic, used to filter liquids and to prevent the movement of sediment, to separate different materials or to reinforce and strengthen them.

Germination The beginning of plant growth. The sprouting of roots, stem and leaves from seed.

Glacial Till Material deposited by glaciation, usually composed of a wide range of particle sizes, that has not been subjected to the sorting action of water.

Gradation The distribution of particle sizes in a material.

Grade (1) To level off to a smooth horizontal or sloping surface. (2) A reference elevation. (3) Particle size distribution of an aggregate. (4) The slope of a plane.

Grade Stabilization Structure A structure, usually a combination of an earth embankment and mechanical spillway, installed to discharge water from a higher to a lower elevation in order to control erosion, head-cutting or to reduce channel grade.

Gradient See Slope.

Great Rivers Alliance of Natural Resources Districts, or GRAND Regional association of conservation districts serving the urban conservation needs of eight Missouri and Illinois counties in the St. Louis metropolitan area.

Granular A description of the uniformity of grain size of gravel, sand or crushed stone.

Gravel (1) Soil particles with diameters between 2 millimeters and 3 inches. (2) Loose, rounded fragments of rock commonly used to surface roads.

Ground Cover Any vegetation producing a protective mat on or just above the soil surface. Usually refers to low-growing herbaceous plants.

Groundwater Level See Water Table.

Grout A fluid mixture of cement, water and sand or other fillers that can be poured or pumped easily. Used to fill the voids between riprap, culverts or other structures in channels or slopes to prevent or reduce erosion or inadvertent water flow.

Gully Erosion See Erosion.

H

Head Pressure measured as an equivalent height of water. Measured in feet or pounds per square inch.

Headcut The uphill end of a gully where water overfalls to a lower level and active erosion occurs.

Herbaceous A non-woody plant.

High-Density Polyethylene, or HDPE A synthetic polymer used for geomembranes and pond liners.

Horizon A layer of soil distinguishable from adjacent layers by characteristic physical and chemical composition. Soil horizons are commonly referred to as topsoil, subsoil and parent material. “A” horizon: the uppermost layer usually contains organic matter. “B” horizon: the layer which accumulates material leached from the “A” horizon. “C” horizon: undisturbed parent material from that the overlaying layers have developed.

Humus See Organic Matter.

Hydraulic Gradient A line that represents the relative force available due to the potential energy available. This is a combination of energy due to the height of the water and internal pressure. In an open channel the line corresponds to the water surface. In a closed conduit, if several openings are placed along the top of the pipe and open end tubes inserted, a line connecting the water levels in the tubes represents the hydraulic energy.

Hydraulic Mulch Processed materials such as wood and paper products, cotton or straw fibers that are applied by special equipment using a water-based slurry that is sprayed on the soil surface.

Hydraulic Radius The cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit. The ratio of area to wetted perimeter.

Hydraulics The science and technology of the mechanics of fluids.

Hydric Soil Soils that are wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants.

Hydrograph A chart showing for a given point on a stream the runoff rate, depth, velocity or other property with respect to time.

Hydrologic Soil Groups Categories of soil based upon their runoff producing characteristics. Group A soils have low runoff potential. Group D soils, the other extreme, have high runoff potential. Hydrologic soil groups are listed in NRCS soil surveys, a publication available at NRCS/Conservation District offices.

Hydrology Science dealing with the distribution and movement of water.

Hydrophilic Molecules and surfaces that have a strong affinity for water molecules.

Hydrophobic Molecules and surfaces that have little or no affinity for water molecules.

Hydrophytic A plant adapted to growth in water or saturated soil.

Hydroseeding Spreading of seed hydraulically in a water medium. Mulch, lime and fertilizer can also be incorporated into the sprayed mixture.

Hydrostatic Pressure A state of stress in which all the principal stresses are equal (and there is no shear stress), as in a liquid at rest; the pressure in a liquid under static conditions; the product of the unit weight of the liquid and the difference in elevation between the given point and the free water elevation. Measured in pounds per square inch.

Hygroscopic A material that attracts, absorbs and retains atmospheric moisture.

I

International Erosion Control Association, or IECA P.O. BOX 774904, Steamboat Springs, Colorado 80477-4904 or phone 800-455-4322. Serves as a global resource for people who share a common responsibility for the prevention and control of erosion. The Great Rivers Chapter serves Iowa, Kansas, Missouri and Nebraska. Contact Great Rivers Chapter of IECA at 600 Broadway, Suite 200, Kansas City, MO 64105 or call 816-474-4240.

Impermeable Does not permit passage of a fluid or a gas.

Impervious Impenetrable. Soil that is resistant to the entrance of water, air or plant roots.

Incorporate To mix materials such as fertilizer or lime into the soil with tillage operations.

Infiltration The downward entry of water into the surface of soil.

Inflow The water discharged into a point of concern.

Inoculation (of seeds) The addition of nitrogen-fixing bacteria (inoculant) to legume seeds or to the soil in which the seeds are to be planted. The bacteria convert atmospheric nitrogen into a form available for plant growth.

Inorganic Composed of matter not of plant or animal origin.

Inorganic Soil See Mineral Soil.

Intermittent Stream A stream, or reach of a stream, that only flows during wet seasons; usually less than 50 percent of the year.

K

Kansas Department of Health and Environment, or KDHE The state agency in Kansas that regulates the NPDES Program including storm water runoff permitting. See Resource Inventory List for more information.

L

Landscaping The placement of sod, seed, trees and other vegetation after final grading is completed.

Lapped Joint A joint made by placing one surface partly over another surface and bonding or fastening them together.

Leachate Liquid that has percolated through a material and contains soluble components removed from that material.

Leaching The removal into solution of soluble materials by percolating water. Generally refers to the movement of soil nutrients to a deeper soil horizon, making them unavailable for plant growth. It can also refer to the movement of contaminants through the soil and into the groundwater.

Legume Any member of the pea or bean family which includes peas, beans, clovers, alfalfas, lespedezas and vetches. Most are nitrogen-fixing plants.

Lift An applied or compacted layer of soil, asphalt or waste. Also referred to as a course.

Lime, Agricultural A soil amendment containing calcium carbonate and other materials used to neutralize soil acidity and furnish calcium for plant growth.

Liner A layer of emplaced materials that serves to restrict the escape of liquids or solids placed within an impoundment. This includes reworked or compacted soil and clay, asphaltic and concrete materials, spray-on membranes, polymeric membranes or any substance that serves the above stated purpose. The portion of a reservoir responsible for the first line of defense against seepage; that is, the part immediately adjacent to the liquid being held.

Liquefaction Loss of strength of a saturated soil resulting from the combined effects of vibrations and hydraulic forces, thereby causing the material to flow.

Loam A soil textural classification in which the proportions of sand, silt and clay are well balanced. Loams have the best properties for cultivation of plants.

Loess Material transported and deposited by wind and consisting of predominantly silt-sized particles. Loess has an open structure and relatively high cohesion due to cementation of clay or calcareous material at grain contacts. A characteristic of loess deposits is that they can stand with nearly vertical slopes.

Losing Stream A stream that loses water as it flows downstream. The water infiltrates into the ground recharging the groundwater.

M

Maximum Allowable Slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Mid-America Association of Conservation Districts, or MAACD A regional association of conservation districts serving the urban conservation needs of 10 Kansas and Missouri counties in the Kansas City metropolitan area.

Manning's Equation An equation for determining the flow rate of water in a uniform, steady state condition.

Mass The quantity of matter in a body.

Mass Per Unit Area The amount of material per unit area. Units can be ounces per square yard or grams per square meter.

Mean The average value of a group of numbers.

Mil Abbreviation for one-thousandth.

Mineral Soil (Inorganic Soil) A soil with less than 20 percent organic matter.

Mitigation The process of reducing the negative impacts of a project.

Moisture Content The percentage by weight of water contained in the pore space of a solid material with respect to the total weight of the solid material.

Monomer A relatively simple compound that can react to form a polymer.

Mulch A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, reduces erosion and aids in the establishment of plant cover.

N

Natural Erosion The natural influence of climatic forces on the surface of the earth.

National Pollution Discharge Elimination System, or NPDES Federal legislation that requires cities with populations over 10,000 to establish a permit process to control sediment pollution. A permit is also required for development sites one acre or greater in size. Permits are authorized and enforced by the Environmental Protection Agency or a designated state agency as directed by the Clean Water Act.

Natural Resources Conservation Service, or NRCS A federal agency, formally known as the Soil Conservation Service, SCS, that provides technical assistance on natural resource management issues. See the Resource Inventory List for more information.

Nonpoint Source Pollution, or NPS Pollution that enters a waterbody from diffuse sources. A point source, by contrast, can be easily identified as having a distinct entry point, such as an industrial or sanitary sewer pipe.

Normal Water Level The average summer water level. The free surface associated with flow in natural streams.

O

Observation Well A vertical pipe placed in the ground to observe groundwater levels.

Open Channel A drainage course that has no restrictive top. It is open to the atmosphere and may or may not permit surface flow to pass over its edge and into another channel in an unrestricted manner. In many cases where dikes are constructed to increase channel capacity, entrance of surface waters is necessarily controlled.

Ordinance A law set forth by a governmental authority.

Organic Matter (Humus) The portion of soil, usually dark in color, resulting from the decomposition of plant and animal materials.

Outfall The location where storm water discharges from a drainageway or conduit to a receiving stream or body of water.

Outlet The point of water discharge from a stream, river, lake or artificial drain.

Outlet Channel A waterway constructed or altered primarily to carry water from structures such as smaller channels, tile lines, dams and diversions.

Overburden (1) The loose soil, sand, silt or clay that overlies bedrock. (2) All material overlying an underground excavation.

Overfall A sudden drop in grade, usually associated with a gully.

Overlap The section of adjacent geosynthetic materials that are in contact, one under the other, forming a seamed or unseamed joint.

P

Pure Live Seed, or PLS A measure of seed quality expressed as a percentage. The product of the percentage of seed purity and the percentage of germination (including the germination of hard seed) divided by 100.

Particle Size The effective diameter of a particle measured by sedimentation, sieving or micrometric methods.

Peak Discharge The maximum instantaneous flow from a given storm condition at a specific location.

Percent Open Area The net area of a fabric not occupied by fabric filaments, normally determinable only for geotextiles having distinct visible and measurable openings that continue directly through the fabric.

Percolation The downward sub-surface movement of water through the soil horizons. The percolation rate of soil is usually expressed as inches per hour.

Permanent Seeding The establishment of perennial vegetation on disturbed areas for periods longer than 12 months.

Permeability (Soil) The property of the soil that expresses the ease with which water moves downward through the profile. The rate (inches per hour) at which a saturated soil transmits water.

Permittivity The rate of flow of water through a geotextile.

Pervious A property of a material through which water passes relatively freely (e.g., sands and gravels).

pH A measure of the acidity or alkalinity of a substance. A pH value of 7.0 is neutral, less than 7.0 is acidic, greater than 7.0 is alkaline.

Photo degradable The ability of a material to breakdown due to exposure to sunlight.

Pipe A culvert having a non-rectangular cross-section, often assumed to be circular unless specified otherwise, which carries a liquid or gas.

Piping (Tunneling) The movement of soil particles by seepage leading to the development of subsurface voids, tunnels or pipe like cavities.

Plastic A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state and, at some stage in its manufacture or processing into finished particles, can be shaped by flow.

Plasticity The capacity of a soil or rock to be deformed continuously and permanently by relatively moderate pressure without cracking or appreciable volume change.

Polymer A macromolecular material formed by the chemical combination of monomers. Plastics, rubbers and textile fibers are all high molecular weight polymers. Only synthetic polymers are used to make synthetics.

Polyvinylchloride, or PVC A synthetic thermoplastic polymer prepared from vinyl chloride. PVC can be compounded into rigid forms used in pipes or into flexible forms used in the manufacture of geotextiles.

Ponding Water backed up in a channel, depression or ditch as the result of a constriction, obstruction or lack of outlet.

Porosity The percentage by volume of voids of a given material with respect to the total volume of the material.

Porous Pavement A permeable surface material provides support for traffic without deformation and allows for storm water and surface runoff to gradually infiltrate into the subsoil.

Potable Water Water suitable for human consumption.

Precipitation Process by which water in liquid or solid state (rain, sleet, snow) is discharged out of the atmosphere upon a land or water surface.

Q

Qualified Design Professional Someone trained and highly qualified in their field such as horticulturists, landscapers, various design specialists and technicians.

Qualified Personnel A person knowledgeable in the principles and practice of erosion and sediment controls who possesses the skills to assess conditions at the construction site that could impact storm water quality and to assess the effectiveness of any sediment and erosion control measures selected to control the quality of storm water discharges from the construction activity.

R

Revised Universal Soil Loss Equation, or RUSLE An updated, computerized method of estimating soil movement due to water erosion. RUSLE incorporates the updated climate, soil erodibility and vegetative cover factors of the Universal Soil Loss Equation.

Registered Design Professional A qualified design professional who is normally certified or degreed as an engineer, landscape architect, arborist, forester, biologist, erosion and sediment control specialist, etc.

Reinforcement To strengthen by the addition of materials or support. (e.g., the strengthening of a slope by inclusion of geosynthetic structural materials).

Residual Soil Soil derived by in place weathering of parent material.

Retaining Wall A constructed wall used to eliminate steep slopes while providing stability.

Revetment A lining of stone, concrete, geosynthetics or organic materials used to stabilize a streambank, riverbank or channel.

Rill Erosion See Erosion.

Riparian Area Land adjacent to a body of water at least periodically influenced by concentrated water flows or by flooding.

Riprap Dense stone of various sizes, resistant to weathering, placed on earth surfaces such as the face of a dam or the bank of a stream to prevent scour erosion.

Riser A vertical pipe connected to an underground pipe used to control the discharge rate from a pond or basin.

Rock Natural, solid, mineral matter occurring in large masses or fragments.

Rock Check Structures See Check Dam.

Roll Goods A general term applied to manufactured materials such as erosion control blankets, turf reinforcement mats, netting, geotextiles and other geosynthetics that are furnished in rolls.

Roughness Coefficient A factor in flow formulas representing the effect of channel or conduit roughness on the velocity of flowing water.

Runoff That portion of precipitation not absorbed or retained on the land surface, but which collects and flows from a drainage area. Water that is lost without entering the soil is called surface runoff. Water that enters the soil before reaching a stream channel is called groundwater run off. The rate of surface water runoff in open channels or in storm water conveyance systems is measured in cubic feet per second.

S

Sand (1) Mineral particles that range in size from 2 millimeters to .05 millimeters in equivalent diameter. (2) A loose, granular material that results from the disintegration of rocks, consisting of particles smaller than gravel but coarser than silt. (3) A soil containing 85 percent or more of sand and 10 percent or less of clay.

Sand Diaphragm A vertical wall of sand around a pipe placed through an embankment. Used instead of anti-seep collars. Drainage from the wall is released from the pipe at the downstream toe of the embankment.

Saltation See Erosion.

Saturation (Soil) The point at which all the voids between soil particles are filled with water.

Scarify (1) Roughening the land surface. (2) To abrade the seed coat to improve seed germination.

Scour The clearing and digging action of flowing water, especially the erosion caused by stream water in sweeping away sediment from the streambed and outside bank of a curved channel.

Sediment Mineral or organic material transported from its original location by wind, water, gravity or ice. The word silt is sometimes used interchangeably with the word sediment. This is incorrect. See Silt.

Sedimentation The deposition of soil particles that were transported from its original location by water, wind, ice or gravity.

Seed Bed Soil prepared to promote the germination of seed and the growth of seedlings.

Seed Purity The percentage of the desired species, in relation to the total quantity of bulk material that may include other species, weed seeds or inert matter such as leaves, stems, soil, etc.

Seepage The slow, gravitationally driven, movement of water out of soil, rock, embankments or structures onto the land surface.

Separation The function of a geotextile or other product as a partition between two adjacent dissimilar materials to prevent mixing of the two materials.

Shear Stress (Tangential Stress) The stress component tangential to a given plane. Basic formula to determine the shear stress of a channel (unit wt. of water [62.4 lbs/ft3] X Slope [ft./ft.] X Depth [ft.] = Shear Stress [lbs/ ft2]).

Sheet Erosion See Erosion.

Sheet Flow Water flowing across a wide, uniform area such as a highway, parking lot or field.

Shoreline Erosion See Erosion.

Shotcrete Mortar or concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. Used to stabilize the surface. Can be applied by a wet or dry mix method.

Shrink-Swell The volume change of soil based on moisture capacity. Soils that shrink when dry and swell when wet can damage plant roots, roads, dams and building foundations.

Silt (1) Mineral particles that range in size from .005 millimeters to .002 millimeters in equivalent diameter. (2) A soil containing 80 percent or more of silt and less than 12 percent clay. (3) Imprecise colloquial term for a deposition of sediment.

Silt Fence A temporary barrier consisting of a geotextile that is attached to supporting posts and trenched into the ground at the base. As the runoff water slowly filters through the geotextile, the sediment settles out on the uphill side of the silt fence.

Sink Hole A depression in the substrate, usually deep in comparison to its diameter, caused by settlement or substrate particle removal by migrating water.

Site Synonymous with job site.

Slag Rough, cindery material from volcanic lava or smelting operations.

Slide Rapid movement of a part of the earth under force of gravity, usually due to saturated conditions, or an earthquake.

Slope Degree of deviation from horizontal expressed as a percentage, as a numerical ratio or in degrees. As a percentage, slope is the number of feet of rise or fall in 100 feet of horizontal distance. As a ratio, it is the number of feet of horizontal to the number of feet vertical. For example, a 25 percent slope is equal to a 4:1 slope and is equal to a slope of approximately 14 degrees.

Sloughing The separation and downhill movement of a small portion of the slope from surrounding material.

Slump A slope failure in which a mass of rock or unconsolidated material drops along a concave slip surface. Slump material moves downslope as an intact block and frequently rotates backwards.

Slurry A watery mixture of suspended matter.

Small Storm The volume and rate of runoff for rainfall events less than two inches. These small storms [often referred to as the water quality storm] are believed to cause the majority of urban stormwater pollution.

Soil (Earth) Sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks or organic materials.

Soil Mechanics The application of the laws and principles of mechanics and hydraulics to engineering problems dealing with soil as an engineering material.

Soil Profile Vertical section of the soil from the surface through all horizons.

Soil Stabilization Chemical or mechanical treatment designed to increase or maintain the stability of a mass of soil or otherwise to improve its engineering properties.

Soil Test The process to determine the soil pH and the nutrient-supplying capability of a specific soil for a specific crop or plant species. Used to determine recommended liming and fertilization rates. Available through University Extension offices and private laboratories.

Soil and Water Conservation Society, or SWCS A multidisciplinary membership organization advocating the protection, enhancement and wise use of soil, water and related natural resources located at 945 SW Ankeny Rd., Ankeny, Iowa 50023 or phone 515-289-2331.

Species The basic biological classification of organisms. For example, species of grass include tall fescue, smooth bromegrass and timothy.

Specific Gravity The ratio of the density of a material to the density of water when both densities are obtained by weighing in air. A specific gravity less than one implies that the material will float.

Spillway (Principal) An open or closed channel or conduit used to convey excess water from a pond, reservoir or basin.

Spillway (Emergency) A designed depression at one side of the embankment of a pond or basin that will pass peak discharges greater than the maximum design storm controlled by the principal spillway and detention storage.

Splash Erosion See Erosion.

Splash Pad A nonporous material placed at the outfall of a conduit, channel or grade stabilization structure to decrease energy of water flow to a non-erosive velocity.

Spoil Excess rock or soil material not needed after a practice is constructed.

Sprig A portion of the stem/or roots of a plant used for propagation (e.g., Bermuda grass is commonly established with sprigs rather than seed).

Stable (1) A non-erosive condition in which storm water runoff from a design storm will not cause erosion of soil; usually achieved by protecting erodible areas with structures or vegetation. (2) A soil condition that will not slide or slump; usually established by removing saturated conditions or by flattening slopes.

Stable Outlet A natural or constructed outlet that will dispose of water at non-erosive velocities and without flooding.

Stage The height of the surface of a river above an arbitrary zero point that defines a critical condition. Examples include low flow stage, bank full stage, monitoring stage and flood stage.

Staple A fastening device typically manufactured of 8- to 11-gauge wire, “U” shaped with 4 to 10 inch legs and a 1 to 2 inch crown, used to secure erosion control blankets, geotextiles and related materials to the ground.

Steady Flow A flow in which the volume passing a given point per unit of time remains constant.

Storage Basin Space for detention or retention of storm water runoff water for controlled release during or following the design storm. Storage may be upstream, downstream, offstream, onstream or underground.

Stone Crushed or naturally angular particles of rock between the size of 4.75 and 75 millimeters.

Storm Sewer A conduit that carries storm water, surface drainage, street wash and other washwaters but usually excludes sewage and industrial wastes. Also called a storm drain.

Storm water Water that originates during precipitation events. It may also be used to apply to water that originates from snowmelt.

Storm water Management A master plan or systems approach to the planning of facilities, programs and management organizations for comprehensive control and use of storm water within a defined geographical area.

Stream Hydraulics The science and technology of water behavior in streams.

Structure (1) The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking: some types are crumb, block, platy and columnar. (2) A constructed practice designed to control erosion, sedimentation, storm water runoff or an overfall.

Subgrade The soil prepared and compacted to support a structure or a pavement system.

Subsoil (1) Soil below a sub grade or fill. (2) That part of the soil profile occurring below the “A” horizon.

Subsurface Drain (Underdrain) A perforated pipe used for subsurface drainage, usually surrounded by aggregate or wrapped in a geotextile filter fabric to prevent the migration of soil particles.

Suspension The state of a substance when its particles are kept from falling or sinking. See Erosion.

Swale A low-lying, often wet, area of land.

Synthetic Any material created by artificial means.

T

Tackifier See Binder.

Tangential Stress See Shear Stress.

Temporary Seeding The establishment of fast-growing annual vegetation to provide economical erosion control for up to 12 months and to reduce the amount of sediment moving off the site.

Tensile Strength The maximum force a material can bear without tearing apart. Units are reported as maximum stress (e.g., pounds per square inch) or force per unit thickness (e.g., pounds per inch width).

Tenting Separation of installed manufactured blankets from contact with the ground surface. This is usually due to clods of soil not fine graded and prepared properly for blanket installation.

Texture The percent of sand, silt and clay in a soil.

Tillage The mechanical manipulation of soil with equipment such as plows, discs, cultivators or harrows. Also, tilled land.

Toe Drain A subdrain installed near the downstream toe of a dam or levee to intercept seepage and to outlet it away from the structure.

Toe of Slope The junction of a slope and the bottom of the slope.

Top of Slope The junction of a slope and the top of the berm, channel or embankment.

Topographic Map A map of isolines linking common elevations that effectively illustrates the contours of the land surface.

Topsoil Surface soil usually containing organic matter. The fertile soil most capable of growing vegetation and crops.

Toxic The characteristic of being poisonous or harmful to plant or animal life.

Trash Rack A structural device used to prevent debris from entering a pipe, spill way or other water structure.

Turbidity The degree of cloudiness in water caused by suspended particles. Turbidity can be precisely measured in nephelometric turbidity units (ntu) and is often used as an indicator of pollution.

Turf Reinforcement Mat, or TRM Permanent synthetic erosion control blankets that can reduce the loss of underlying soil and reinforce the root zone of vegetation. TRM can be used to improve the ability of vegetation to resist heavier, more erosive, flows that would otherwise compromise the integrity of the plant materials.

U

Underdrain See Subsurface Drain.

Undermining A process of scour by hydraulic action that progressively removes earth support from a structure. Undermining commonly occurs at the outlet of a culvert or sewer.

Ultraviolet Degradation Breakdown of polymeric structures when exposed to the ultraviolet bandwidth of light.

Ultraviolet Radiation Stability, or UV The ability of a material to resist deterioration from exposure to the ultraviolet component of sunlight.

Uniform Flow Flow in which the velocities are the same in both magnitude and direction from point to point along the stream or conduit.

Unsheltered Distance The distance from the downwind edge of an area and a stable point in the direction of the prevailing wind. Used as a factor in estimating wind erosion.

Unsteady Flow A flow in which the velocity changes with respect to both space and time.

Upland The region of higher elevations above a floodplain.

Uplift The hydrostatic force of water exerted on or underneath a structure, causing a displacement of the structure.

Universal Soil Loss Equation, or USLE An estimate of the amount of soil that moves due to water erosion based upon five factors: climate, soil erodibility, length and steepness of slope, vegetative cover and structural or management practices.

V

Vegetation Plant life or total plant cover of an area.

Void (1) Space in a soil or rock mass not occupied by solid mineral matter. This space is generally occupied by air or water. (2) The open spaces in a geosynthetic material through which flow can occur.

W

Washout The failure of a culvert, bridge, embankment or other structure resulting from the action of flowing water.

Water Course A natural or artificial channel in which a flow of water occurs, either continuously or intermittently. Water courses may be either on the surface or underground.

Water Quality The chemical, physical and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water Quality Storm The volume and rate of runoff for rainfall events less than 2 inches. These small storms are believed to cause the majority of urban storm water pollution.

Water Table (Ground Water Level) The upper surface of the zone of saturation in permeable rock or soil.

Watershed The region drained by or contributing water to a stream, lake or other body of water.

Wattle See Fascine.

Weathering The process of disintegration and decomposition as a consequence of exposure to the atmosphere, to chemical action and to the action of frost, water and heat.

Weir A structure that extends across the width of a channel and is intended to delay or alter the flow of water through the channel.

Well Graded An equal distribution of particle sizes. Usually refers to gravel.

Wetland Land area that is wet or flooded by surface or groundwater often enough and long enough to develop characteristic hydric soil properties and to support vegetation that will grow in saturated soil conditions.

Wetted Perimeter The length of wetted contact between a stream of water and its containing channel measured at right angles to the direction of flow.

Wind Erosion Equation An estimate of the amount of soil that moves due to wind erosion based upon five factors: soil erodibility, ridge roughness, climate, unsheltered distance and vegetative cover.

APPENDIX C
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APPENDIX D
REFERENCES

Environmental Protection Agency Web Publication Resources

Appendix A: SWPPP Template epa.gov/npdes/pubs/sw_swppp_template.doc

Appendix B: Sample Inspection Report Instructions
epa.gov/npdes/pubs/sw_swppp_inspection_form.doc

EPA Regional Environmental Information and Map water.epa.gov/type/location/regions

Low Impact Development (LID) www.epa.gov/owow/NPS/lid

Managing Wet Weather with Green Infrastructure
cfpub.epa.gov/npdes/home.cfm?program_id=298

National Menu of Stormwater Best Management Practices
cfpub.epa.gov/npdes/stormwater/menuofbmps

Outreach Material and Reference Documents cfpub.epa.gov/npdes/stormwatermonth.cfm

Stormwater Pollution Prevention Plans for Construction Activities
cfpub.epa.gov/npdes/stormwater/swppp.cfm

Stormwater Discharges from Industrial Facilities cfpub.epa.gov/npdes/stormwater/indust.cfm

Stormwater Regional Contacts cfpub.epa.gov/npdes/contacts.cfm?program_id=6&type=REGION

Stormwater State Contacts cfpub.epa.gov/npdes/contacts.cfm?program_id=6&type=STATE

Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s)
cfpub.epa.gov/npdes/stormwater/munic.cfm

Urban BMP Performance Tool
cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm

Professional Organizations and Other National Resources

American Public Works Association – www.apwa.net

Construction Industry Compliance Assistance Center - www.cicacenter.org

EnviroCert International - www.envirocertintl.org

Nonpoint Education for Municipal Officials - nemo.uconn.edu

The International Stormwater BMP Database - www.bmpdatabase.org

Center for Watershed Protection www.cwp.org

Missouri Chapter of the Land Improvement Contractors Association, 7016 East North Shore Drive, Hartsburg, MO 65039-9631 Phone (573) 634-3001 Fax 573 761-0375
Email: mlica@aol.com, Webpage www.mlica.org

Stormwater Manager's Resource Center www.stormwatercenter.net

Street Edge Alternatives www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/NaturalDrainageProjects/StreetEdgeAlternatives/

The Soil and Water Conservation Society. 945 SW Ankeny Road, Ankeny, IA 50021
Phone: 515-289-2331 Fax: 515-289-1227 www.swcs.org

The International Erosion Control Association, 3401 Quebec St, Suite 3500, Denver, CO 80207 USA. Phone 800-455-4322 (+ 1 303-640-7554 International). Fax 866-308-3087 www.ieca.org

The Certified Inspector of Sediment and Erosion Control (CISEC) ProgramCISEC, Inc. - www.cisecinc.org/

State Resources

The Missouri Department of Natural Resources, Division of Environmental Quality, Water Pollution Control Program handles permits for land disturbance. Write Missouri Department of Natural Resources, P.O. Box 176, 205 Jefferson St., Jefferson City, MO 65102 or call 573-751-1300 or visit the Missouri Stormwater Information Clearinghouse at www.dnr.mo.gov/env/wpp/stormwater

The Missouri Department of Natural Resources has regional offices in:

Kansas City	816-622-7000
Macon	660-385-8000
St. Louis	314-416-2960
Springfield	417-891-4300
Poplar Bluff	573-840-9750

More information on these offices and additional satellite offices can be located at www.dnr.mo.gov/regions/regions.htm

The Missouri Department of Conservation, or MDC, has experts on staff that can provide lists of plant materials suitable for wetlands and streambanks; they also have experience and recommendations on bioengineering techniques for streambank stabilization. Contact your local MDC office listed in the state government section of the phone book, call their central office at 573-751-4115 or visit the Missouri Department of Conservation website at mdc.mo.gov/regions.

Missouri Grow Native! is a joint project between the Missouri Department of Conservation and Missouri Department of Agriculture offers the following website of photographs and narrative descriptions of Missouri native plants: www.grownative.org/

Missouri Stream Team Program is a joint project between the Missouri Department of Natural Resources and the Missouri Department of Conservation. Missouri Stream Team is a working partnership of citizens who are concerned about Missouri Streams. Call 800-781-1989, write Missouri Department of Conservation Stream Team Unit at PO Box 180., Jefferson City, MO 65102-0180, email STREAMTEAM@mdc.mo.gov or visit www.mostreamteam.org

University of Missouri Extension Service has local offices in almost every county. The offices have on-staff experts in agronomy, engineering and other disciplines. Extension staff can provide the latest in research results and may be particularly helpful in vegetation establishment. A variety of guides can be picked up at these offices. Soil samples can be turned in at the offices for soil testing. Call 573-882-7216 or visit extension.missouri.edu.

Watershed Committee of the Ozarks mission is to preserve and improve the water supplies of Springfield and Greene County through education and effective management of the region's watersheds. Write 320 North Main Avenue, Springfield, MO 65806-1208, call 417-866-1127 or visit www.watershedcommittee.org.

Kansas State Conservation Commission for information provides information on streambank stabilization. Write KSCC, 109 SW Ninth Suite 500, Mills Bldg., Topeka, KS 66612-1299, call 785-296-3600, fax 785-296-6172, email SCCOA@scc.ks.gov or visit www.scc.ks.gov.

Kansas Department of Wildlife and Parks provides information on bioengineering, plant materials, native seedings and stream monitoring and assessment. Write KDWP, Kansas Department of Wildlife & Parks Operations Office Environmental Services Section, 512 SE 25th Ave., Pratt, KS 67124, call (620) 672-5911, fax 620-672-2972 or visit www.kdwp.state.ks.us/news/Other-Services/Stream-Assessment-and-Monitoring-Program

The Kansas Department of Health and Environment handles permits for land disturbance. Write KDHE, Bureau of Water, Building 283, Forbes Field, Topeka, KS 66620 or call 785-296-5557. More information on KDHE resources can be located at www.kdheks.gov/stormwater.

Local Resources

Contact the authorizing unit of local government (city or county) for local regulations and permit requirements. These will usually be listed in the appropriate government section (city or county) of the phone book under Government Engineer, Government Building, etc.

County Soil & Water Conservation Districts and local university extension offices can provide information on plant materials, erosion and sediment control, and most offices have a Soil Survey of the county. Check your local phone directory.

APPENDIX E
GUIDE TO THE METRIC SYSTEM

Length		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Myriameter	10,000	6.214 miles
Kilometer	1,000	0.621 mile
Hectometer	100	109.361 yards
Decameter	10	32.808 feet
Meter	1	39.370 inches
Decimeter	0.1	3.937 inches
Centimeter	0.01	0.394 inch
Millimeter	0.001	0.039 inch

Area		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Square kilometer	1,000,000	0.386 square mile
Hectare	10,000	2.477 acres
Are	100	119.599 square yards
Deciare	10	11.960 square yards
Centare	1	10. 764 square feet
Square centimeter	0.0001	0.155 square inch

Volume		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Decastere	10	13.079 cubic yards
Stere	1	1.308 cubic yards
Decistere	0.01	3.532 cubic feet
Cubic Centimeter	0.000001	0.061 cubic feet

Metric Conversion Chart - Approximations		
When You Know	**Multiply By**	**To Find**
Length		
Millimeters	0.0	inches
Centimeters	40.39	inches
Meters	3.28	feet
Meters	1.09	yards
Kilometers	0.62	miles
Inches	25.40	millimeters
Inches	2.54	centimeters
Feet	30.48	centimeters
Yards	0.91	meters
Miles	1.61	kilometers
Area		
Square Centimeters	0.16	square inches
Square Meters	1.20	square yards
Square Kilometers	0.39	square miles
Squares(10,000m2)	2.47	acres
Square Inches	6.45	sq. centimeters
Square Feet	0.009	square meters
Square Yards	0.84	square meters
Square Miles	2.60	sq. kilometers
Acres	0.40	hectares
Mass and Weight		
Grams	0.035	Ounce
Kilograms	2.21	Pounds
Tons	1.10	Short Tons
Ounces	28.35	Grams
Pounds	0.45	Kilograms
Short Tons (2000lb)	0.91	Tons

Metric Conversion Chart - Approximations		
When You Know	**Multiply By**	**To Find**
Volume		
Milliliters	0.20	Teaspoons
Milliliters	0.06	Tablespoons
Milliliters	0.03	Fluid Ounces
Liters	4.23	Cups
Liters	2.12	Pints
Liters	1.06	Quarts
Liters	0.26	Gallons
Cubic Meters	35.32	Cubic Feet
Cubic Meters	1.35	Cubic Yards
Teaspoons	4.93	Milliliters
Tablespoons	14.78	Milliliters
Fluid Ounces	29.57	Milliliters
Cups	0.24	Liters
Pints	0.47	Liters
Quarts	0.95	Liters
Gallons	3.79	Liters
Cubic Feet	0.03	Cubic Meters
Cubic Yards	0.76	Cubic Meters
Speed		
Miles/Hour	1.61	Kilometers/Hour
Kilometers/Hour	0.62	Miles/Hour
Temperature		
Celsius temp.	9/5. +32	Fahrenheit temp.
(exact) Fahrenheit temp.	-32. 5/9 x remainder	Celsius temp.

Temperatures in degrees Celsius, as in the familiar Fahrenheit system, can only be learned through experience. The following temperatures are ones that are frequently encountered:

0°C	Freezing point of water (32°F)
10°C	A warm winter day (50°F)
20°C	A mild spring day (68°F)
30°C	A hot summer day (86°F)
37°C	Normal body temperature (98.6°)
40°C	Heat wave conditions (104°F)
100°C	Boiling point of water (212°F)

APPENDIX F
ACRONYMS

AST Above ground storage tanks

BMP Best Management Practices

CWA Clean Water Act

ECC Effective Calcium Carbonate

ENM Equivalent Neutralizing Material

EPA Environmental Protection Agency

FEMA Federal Emergency Management Agency

HDPE High-Density Polyethylene

KDHE Kansas Department of Health and the Environment

LEED Leadership in Energy and Environmental Design

LEPC Local Emergency Planning Committee

LID Low Impact Development

MDC Missouri Department of Conservation

MDNR Missouri Department of Natural Resources

MoDOT Missouri Department of Transportation

MS4 Municipal Separate Storm Sewer System

MSDS Material Safety Data Sheets

NPDES National Pollutant Discharge Elimination System

NRCS Natural Resources Conservation Service

NTU Nephelometric Turbidity Units

O&M Operations and Maintenance

OHWM Ordinary High Water Mark

OSHA Occupational Safety and Health Administration

PAM Polyacrylamide

PVC Polyvinyl Chloride

SCM: Stormwater Control Measure

SWPPP: Stormwater Pollution Prevention Plan

TMDL: Total Maximum Daily Load

UST Underground Storage Tank

WCC Water Clarifying Compounds

United States Environmental Protection Agency
Solid Waste and Emergency Response (5306W)
EPA530-F-97-043
October 1997
www.epa.gov

Innovative Uses of Compost Erosion Control, Turf Remediation, and Landscaping

Compost has been viewed as a valuable soil amendment for centuries. Most people are aware that the use of compost is an effective way to improve plant growth. Compost-enriched soil can also reduce erosion, alleviate soil compaction, and help control disease and pest infestation in plants. These beneficial uses of compost can increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources.

Compost used for a specific purpose or with a particular soil type works best when it is tailor-made or specially designed. For example, compost that is intended to prevent erosion might not provide the best results when used to alleviate soil compaction, and vice versa. Technical parameters to consider when customizing a compost mixture include maturity, stability, pH level, density, particle size, moisture, salinity, and organic content, all of which can be adjusted to fit a specific application and soil type.

Compost Technology to Control Erosion

According to the U.S. Department of Agriculture, the United States loses more than 2 billion tons of topsoil through erosion each year. Erosion occurs when wind and rain dislodge topsoil from fields and hillsides. Stripped of its valuable top layer, which contains many essential nutrients, the soil left behind is often too poor to sustain good plant growth. Eroded topsoil can also be carried into rivers, streams, and lakes. This excess sediment, sometimes containing fertilizers or toxic materials, threatens the health of aquatic organisms. It can also compromise the commercial, recreational, and aesthetic value of water resources. As a result, preventing erosion is essential for protecting waterways and maintaining the quality and productivity of soil.

Printed on paper that contains at least 20 percent postconsumer fiber.

Controlling Erosion in Construction and Road Building

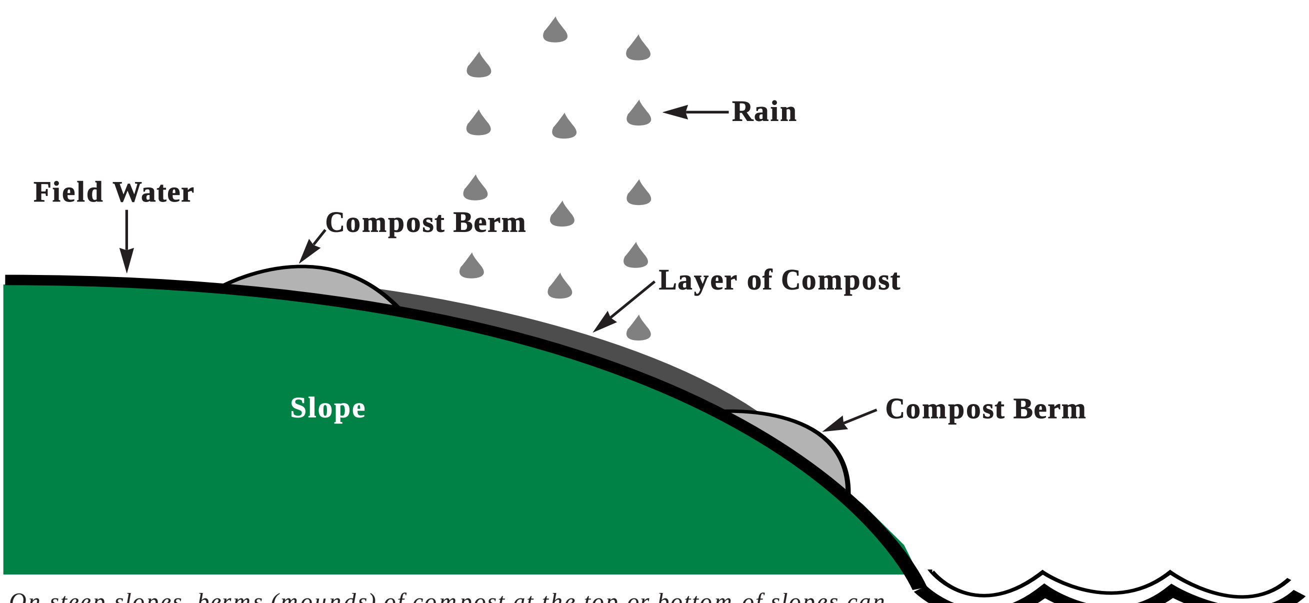
Erosion is a naturally occurring process; however, it is often aggravated by activities such as road building and new construction. At the beginning of some construction projects, all vegetation and topsoil is removed, leaving the subsoil vulnerable to the forces of erosion. On steep embankments along roads and highways, compost can be more effective than traditional hydromulch at reducing erosion and establishing turf because compost forms a thicker, more permanent growth due to its ability to improve the infrastructure of the soil.

Depending on the length and height of a particular slope, a 2- to 3-inch layer of mature compost, screened to 1/2 to 3/4 of an inch and placed directly on top of the soil, has been shown to control erosion by enhancing planted or volunteer vegetation growth. On steep slopes, berms (mounds) of compost at the top or bottom of slopes can be used to slow the velocity of water and provide additional protection for receiving waters. Because of its ability to retain moisture, compost also helps protect soil from wind erosion and during droughts.

Controlling Erosion in Road Construction

The Federal Highway Administration (FHWA), of the U.S. Department of Transportation and the U.S. Environmental Protection Agency, recently conducted an erosion control demonstration project that compared mature yard trimmings compost that met FHWA specifications with hydromulch, a substance traditionally used for controlling erosion on roadside embankments. The purpose of the study was to determine the effectiveness of mature yard trimmings compost compared with hydromulch in establishing Fescue grass.

The project site was at a newly constructed intersection in suburban Washington, DC. Two embankments with steep slopes were selected. The first embankment had a 2 to 1 slope; the second had a 3 to 1 slope. A hydromulch/fertilizer treatment also was applied to a section of each of the slopes. Adjacent to these sections, 2-1/2 inches of mature yard trimmings compost was spread. On the 2 to 1 slope, a small amount of fertilizer was also applied, while the 3 to 1 slope was left unfertilized. Fescue grass seed was added and covered with a thin layer of compost to conceal the seed from birds.



On steep slopes, berms (mounds) of compost at the top or bottom of slopes can be used to slow the velocity of water and provide additional protection for receiving waters.

Photos courtesy of The Federal Highway Administration, Office of Environment & Planning, and Federal Lands Highway Program

Embankment adjacent to new intersection. Top left photo shows hillside before seeding. Photo at right shows grass cover. Compost-treated plot displays darker green color and thicker growth.

Results of the project revealed that compost used alone produced better results than either of the areas treated with hydromulch or the area treated with compost and fertilizer. While the areas with the hydromulch/fertilizer combination showed quick initial vegetative growth, the areas treated with only compost persevered within 6 months, out-performing the traditional method by establishing a thick, healthy vegetative cover. The growth in the compost/fertilizer plot was superior to that found in the hydromulch/fertilizer plots. A possible explanation for compost alone out-performing the area treated with compost and fertilizer is that chemical fertilizers often increase soil salinity, which in turn could negatively affect the beneficial micro-organisms in compost and inhibit the establishment of healthy grasses.

Using Compost to Remediate Turf Grasses

Providing safe, uniform playing surfaces for recreational activities, such as golf, football, soccer, and other field sports, requires intensive turf management. Recreational turf grasses are subjected to extensive wear and tear, making them difficult to manage and highly susceptible to turf diseases, pests, and soil compaction. To address these problems, turf managers traditionally use a combination of fertilizers, pesticides, fungicides, and aeration techniques that usually result in high costs and potential for negative environmental impacts.

Some turf managers are now using compost to replace peat moss in their topdressing applications based on its proven success in suppressing plant disease. Compost, when properly formulated, unlike peat moss, is teeming with nutrients and micro-organisms that stimulate turf establishment and increase its resistance to common turf diseases, such as snow mold, brown patch, and dollar spot. For example, after 3 years of using compost as a topdressing, the Country Club of Rochester, New York, has nearly eliminated the need for fungicide applications for such diseases.

Alleviating Soil Compaction

Soil compaction is another persistent landscape management problem, particularly in areas of heavy traffic, such as parks, zoos, golf courses, and athletic playing fields. Compacted soil impedes healthy turf establishment by inhibiting the movement of air, water, and nutrients within the soil. Bare soil, weeds, increased runoff, and puddling after heavy rains are the most obvious signs of a soil compaction problem.

Traditional methods for alleviating soil compaction—aeration, reseeding, or complete resodding—are labor-intensive and expensive, and

What Are the Benefits of Using Compost?

Soil Enrichment:

- **Adds organic bulk and humus to regenerate poor soils.**
- **Helps suppress plant diseases and pests.**
- **Increases soil nutrient content and water retention in both clay and sandy soils.**
- **Restores soil structure after reduction of natural soil microbes by chemical fertilizer.**
- **Reduces or eliminates the need for fertilizer.**
- **Combats specific soil, water, and air problems.**

Pollution Remediation:

- **Absorbs odors and degrades volatile organic compounds.**
- **Binds heavy metals and prevents them from migrating to water resources or being absorbed by plants.**
- **Degrades, and in some cases, completely eliminates wood preservatives, petroleum products, pesticides, and both chlorinated and nonchlorinated hydrocarbons in contaminated soils.**

Pollution Prevention:

- **Avoids methane production and leachate formation in landfills by diverting organics for composting.**
- **Prevents pollutants in stormwater runoff from reaching water resources.**
- **Prevents erosion and silting on embankments parallel to creeks, lakes, and rivers.**
- **Prevents erosion and turf loss on roadsides, hillsides, playing fields, and golf courses.**

Economic Benefits:

- **Results in significant cost savings by reducing the need for water, fertilizers, and pesticides.**
- **Produces a marketable commodity and a low-cost alternative to standard landfill cover and artificial soil amendments.**
- **Extends municipal landfill life by diverting organic materials from the waste stream.**
- **Provides a less costly alternative to conventional bioremediation techniques.**

provide only short-term solutions. Some turf managers are starting to use compost and compost amended with bulking agents, such as aged crumb rubber from used tires or wood chips, as cost-effective alternatives. Incorporating tailor-made composts into compacted soils improves root penetration and turf establishment, increases water absorption and drainage, and enhances resistance to pests and disease. Using tailored compost can also significantly reduce the costs associated with turf management. Research conducted at a U.S. Air Force golf course in Colorado Springs, Colorado, for example, indicated that turf grown in areas improved with tailored compost required up to 30 percent less water, fertilizer, and pesticides than turf treated conventionally.

Greening the Links

The U.S. Army Golf Course Operations Division at Fort George Meade, Maryland, and the U.S. Environmental Protection Agency began a 3-year pilot demonstration in 1995 to determine the effectiveness of compost amended with crumb rubber in alleviating soil compaction, erosion, and turf disease problems. The golf course superintendent estimates that using compost technology would save nearly $50,000 a year in maintenance costs.

Photo courtesy of U.S. Army, Fort George Meade, Maryland

At the U.S. Army Golf Course at Fort George Meade, Maryland, erosion can clearly be seen on the untreated right side of the path, while rubber amended compost is helping keep erosion in check on the left.

Mature yard trimmings compost amended with crumb rubber was incorporated into compacted soils at 13 different locations around the two golf courses. Many of the selected sites included areas adjacent to, or at the end of golf cart paths, on slopes surrounding greens, or in tee boxes. These sites were selected because of their susceptibility to compaction and erosion caused by heavy traffic and water runoff. The compost mixture was tilled into the soil to a depth of about 3 to 5 inches and then uniformly seeded. To act as a control, one of the plots was amended only with crumb rubber.

In the first year of the pilot, course operators reported that healthy, green turf grass took hold at most of the sites, with no signs of compaction or erosion. Results were particularly impressive in eroded ditches along cart paths. The areas treated with the compost mixture showed full growth of turf grasses and total abatement of erosion, whereas the plot amended only with crumb rubber showed few signs of improvement.

Using amended compost can significantly reduce the costs associated with turf management.

Using Compost in Landscaping Activities

Supplies of high-quality, low-cost topsoil are declining, particularly in urban areas where the demand is greatest. Compost is, therefore, becoming particularly important in applications requiring large amounts of topsoil. Increasingly, compost is being used as an alternative to natural topsoil in new construction, landscape renovations, and container gardens. Using compost in these types of applications is not only less expensive than purchasing topsoil, but it can often produce better results when trying to establish a healthy vegetative cover.

After a lawn or garden has been established, maintaining it can be a challenge for both home gardeners and commercial landscape contractors. While aeration, topdressing, and chemical fertilizer applications are some of the techniques commonly employed in landscaping applications, compost can be a successful alternative. When used as a topdressing, or periodically tilled into the soil, compost can stimulate plant growth, reduce pests and plant infestation, and improve soil structure.

Compost is also an effective landscaping mulch. Placed over the roots of plants, compost mulch conserves water and stabilizes soil temperatures. In addition, compost mulch keeps plants healthy by controlling weeds, providing a slow release of nutrients, and preventing soil loss through erosion. Landscapers and gardeners also use compost as mulch because its dark, rich color accents the vibrant colors of flowering plants.