Kentucky Transportation Cabinet

Stormwater

Post-Construction

Best Management Practices Menu

NOTICE

This document is disseminated as a information guide for the KYTC MS4 Program to be utilized by designers. This menu does not constitute a standard, specification, or regulation. KYTC does not endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

KYTC would like to acknowledge The National Highway Institute and the Federal Highway Administration for materials utilized in this document, specifically The Water Quality Management of Highway Runoff (Publication No. FHWA-NHI-06-063) and items therein referenced.

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INTRODUCTION

This menu is intended to serve as a general guidance to assist roadway designers in the selection of post-construction Best Management Practices (PCBMPs). The PCBMPs listed are generally addressed by a Description, Purpose, Construction Siting Considerations, Design Criteria, Maintenance, Costs and Performance/Effectiveness.

The Kentucky Department of Transportation was issued a Kentucky Pollutant Discharge Elimination System (KPDES) Permit in October, 2012 under the Municipal Separate Storm Sewer System (MS4) Program. A requirement in the Permit is to develop a menu of PCBMPs. This is in addition other design guidance the Department has concerning stormwater.

Proper BMP design includes understanding the objectives, appropriate applications, and limitations of particular PCBMPs. It also requires the roadway designer to consider maintenance and inspection needs which, in the long-term, may prove to be costlier than the original design and construction. Early consideration of PCBMPs will help identify right of way needs and potential community impacts. Other PCBMPs mot listed in this menu may be utilized.

Design Memorandum No. 12-05, also referred to as the Karst Policy was the initial document addressing PCBMPs and is to be used in conjunction with this document. Design Memorandums 3-05 and 3A-05 are also to be used. Design Memorandum No. 12-05 is included in this document. The Drainage Manual includes a section on stormwater and is to be utilized in the design (DR 202).

The PCBMPs listed in this document are not all inclusive. Additional PCBMPs can be used after consulting with staff in the KYTC Division of Design, Drainage Branch.

Wet Pond
Description

A depressed basin with a permanent pool that temporarily stores a portion of stormwater runoff following a precipitation event

Control Structure

17-1

Key Message: A wet pond is a stormwater basin with a permanent pool. The pool level is controlled by a control structure, such as the riser shown in the picture above.

Background Information:

- The permanent pool may cover the entire basin bottom, or it may cover only portions of the bottom.
- For a variety of reasons, such as public health and safety issues, maintenance demands and the potential for odors, wet ponds may not be as an attractive alternative as a dry pond.
- Wet ponds can treat several pollutants more effectively than dry ponds, so knowledge of water quality problems associated with a proposed stormwater facility can direct the selection of the more appropriate stormwater management facility.

Notes: This photograph shows a wet pond with a square concrete riser control structure with a metal grate trash rack.

Wet Pond
Purpose

- To reduce peak flows
- To treat pollutants through sedimentation and vegetative uptake

17-2

Key Message: Wet ponds provide not only water quantity control, but water quality treatment as well.

Background Information: N/A

Notes: This photograph shows a wet pond at a university.

Wet Pond
Construction and Siting Considerations

- Right-of-way limitations
- Surrounding land use
- Soil
- Water table depth
- Location
- Drainage area range

17-3

Key Message: Wet pond construction and siting takes into account many factors

Background Information: The location and design of a wet pond depend on site-specific conditions. Some of these conditions include:

Right-of-Way: The amount of available right-of-way can affect the pond planform configuration and limit the length-to-width ratio. In these cases, other measures, such as baffles or constructed islands will be necessary to increase the flowpath from the influent to the effluent.

Surrounding Land Use: Certain types of pollutants are associated with specific land uses. For instances, if potential pollutant hot spots (such as an industrial facility) are located near the pond, extra measures may be required to mitigate for extreme pollutant loadings associated with industrial activities, such as heavy metals.

Soil Properties: The soil properties for a proposed wet pond location play a major role in design. If soils are extremely sandy, it will be difficult to maintain a permanent pool, so a clay liner may be considered.

Water Table Depth: The depth of the water table near a wet pond will affect the depth the permanent pool. Also, depending on soil properties this water table depth may fluctuate greatly, which will also affect pond design.

Location of Pond: Structures and highway embankments and sub-base can be affected by the permanent pool used in wet ponds, so care should be taken to insure that wet ponds are placed far enough away from all critical structures and embankments to not affect their structural integrity.

Drainage Area Range: "A contributing watershed of at least 10 acres and/or a good source of baseflow should be present for a retention basin to be feasible" (Virginia Stormwater Management Handbook). Dry weather stagnation can lead to odor and aesthetic problems so in residential areas, there should be a minimum drainage area of 15 to 20 acres.

Notes: This photograph shows a wet pond in a residential neighborhood.

Wet Pond
Design Criteria

- Embankments
- Control structure
- Aquatic vegetation
- Pond shape
- Depth
- Safety

17-4

Key Message: There are many design criteria involved with a wet pond design.

Background Information: Key components of wet pond design include:

Embankments: Side-slopes should be stable, depending upon soil properties. The recommended max slope for an embankment is 3:1, which allows for grass and vegetative establishment and is not too steep to be easily mowed and maintained. The lack of vegetation on slopes will lead to increased erosion and slope stability problems. Milder slopes encourage more vegetative growth, is easier to maintain, and is safer for children.

Control Structure: The most typical hydraulic device used in wet ponds is a riser-pipe barrel system. Openings should control a variety of storms, and the device should function properly when partial clogging occurs.

Aquatic Vegetation: Vegetation planted on the embankments and near shallow littoral areas reduces erosion on embankment slopes and at the pool elevation. When planted near the inlet, vegetation can help to trap sediments as they enter the basin and algae on these plants can filter soluble nutrients in the water column.

Pond Shape: Ponds should be shaped to discourage short-circuiting, which occurs when storm flows bypass the pond and therefore reduces retention time and the opportunity to mix well with the permanent pool. This can be avoided by maximizing the flow length between the inflow and the outflow, which is a function of the pond length-to-width ratio. A minimum 2:1 length-to-width ratio is recommended. If inadequate ROW, baffles can be used.

Depth: Permanent pool depth is a key feature for a wet pond. Ponds that are too shallow will allow sediments to become resuspended due to wind, and ponds that are too deep can be a safety hazard and can lead to stratification and anoxic conditions at the bottom of the pool. Under anoxic conditions pollutants adsorbed to sediment particles can become resuspended into the water column. Water depths should range between 3 feet and 8 feet.

Safety: Wet ponds can be a safety hazard if not adequately designed and prepared with safety concerns in mind. Often, wet ponds are designed with a "safety bench", which is a ledge constructed no more than 1 foot in depth around the entire perimeter of the pond and is normally between 5 and 10 feet in width. This safety bench provides a safe buffer for small children who may fall into the pond. Also, fencing is often used to keep children away from the facility.

Notes: This picture shows a wet pond and its control structure (weir type), embankments, and emergency spillway (covered with rip rap).

Wet Pond
Maintenance

- Access
- Dredging
- Litter and woody debris
- Vegetation control
- Nuisance control
- Inspection schedule

17-5

Key Message: Wet ponds require a relatively high amount of maintenance to operate effectively over a long period of time. Both water quality and quantity treatment capacity will be diminished without a proper maintenance plan.

Background Information: A maintenance plan for a wet pond should address the following issues:

Access: Maintaining any type of structural stormwater management BMP requires the need for access for the appropriate type of equipment. This need is even higher for a wet pond, since the permanent pool limits access to key areas, such as the control structure(s) and portions of the embankments (depending on embankment side slopes). If the wet pond has a sediment forebay, access for dredging equipment should be provided in this area.

Dredging: Sediment removal, or dredging, is a key maintenance activity associated with stormwater ponds, especially for wet ponds. If large amounts of sediment settle in a wet pond, the water quality treatment volume will be reduced and as well as the storage volume provided for stormwater attenuation; both affect the pond's performance as a treatment facility. Inspection should be made once every five to ten years, depending upon sedimentation rates. Some estimates states that the volume of one percent of the 2-year storm can be safely lost to sedimentation per year. If sediment build accumulation greatly exceeds this amount, the inspection and dredging schedule should be adjusted to remove excess sediment. Testing of the sediment may be required to determine if high concentrations of pollutants are present before removal. Disposal of dredge materials can be a costly and difficult process, and it may include the need for permitting from proper authorities (U.S. Corps of Engineers).

Litter and Debris Removal: The build-up of litter can be a problem for wet ponds in urban areas, and woody debris can be a problem in more rural areas. Maintenance of the outlet structure should focus on removing any litter or woody debris that clogs any outlet structures.

Vegetation Control: Vegetation is commonly planted in littoral areas, which can become a problem source of nutrients and decaying organic matter if the vegetation grows too aggressively and is not maintained. Also, embankment slopes are normally planted with grasses to decrease soil erosion and improve embankment stability. These grasses should be mowed regularly and kept at a reasonable length.

(Wet Pond Maintenance continued…)

Nuisance Control: Other problems with wet ponds can be insects (especially related to the recent spread of West Nile Virus), odors and algae. Mosquitoes can spread diseases, such as the West Nile Virus, which is a seriously public health concern. Ways to control mosquitoes include a sprinkler, fountain or aeration system, since mosquitoes can only lay eggs in very still water ,or by installing bat or bird boxes to attract mosquitoes' predators. Also, fish (such as the fathead minnow) have been used to successfully control mosquito population. Chemical applications are available, but not preferred. Algae can also be controlled with biological means such as fish stocking. Odors can be controlled by frequent removal of decaying organic material (such as weeds and grass clippings).

Inspection Schedule: Wet ponds should be inspected annually and in both wet- weather and dry conditions, to evaluate adequacy in extreme conditions. This schedule should be modified if a chronic problem becomes evident. Inspections should be made of:

- All embankment side-slopes for stability and erosion problems.
- All inlets and outlets for structural damage, clogging.
- Up and downstream erosion protection measures and stability.
- Emergency spillway for stability.

Notes: This picture shows an outfall from a wet pond.

Wet Pond
Costs

- Construction
- Maintenance

17-6

Key Message: Costs associated with wet ponds can vary greatly with site considerations.

Background Information: Costs for wet ponds are very sensitive to site conditions. Factors that greatly affect costs include:

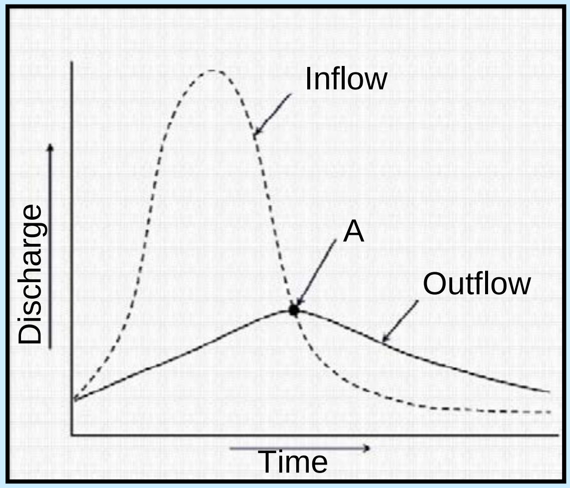
- Land value
- Excavation costs
- Liner material
- Outlet protection
- Embankment construction

Notes: This picture shows seeding along the embankments of a wet pond.

Wet Pond

Performance and Effectiveness

- Peak flow attenuation
- Sediment removal
- Nutrient uptake



17-7

Key Message: Wet ponds provide water quantity control and are also very effective in pollutant removal due to physical and biological processes associated with wet ponds.

Background Information:

- Wet ponds are more effective at pollutant removal than dry ponds due to the permanent pool required with wet pond design, which promotes both physical and biological pollutant removal processes. The aquatic vegetation associated with wet pond design greatly aids in nutrient uptake.
- Using the design parameter of 3 X WQV (water quality volume), the TSS pollutant removal efficiency is approximately 90 percent (*Northern Virginia Planning Commission, 1992, **Schueler, 1992).

Notes: The figure on the slide shows typical inflow and outflow hydrographs. Point A is the peak outflow discharge – if this value is relatively high, then downstream conditions may become unstable and erosive conditions may result. Also, this is the point of maximum storage.

Wet Pond
Sediment Forebay

17-8

Key Message: Wet ponds often include a sediment forebay.

Background Information: N/A

Notes: The photograph in this slide shows a wet pond in Virginia with a sediment forebay.

Wet Pond
Control Structure

17-9

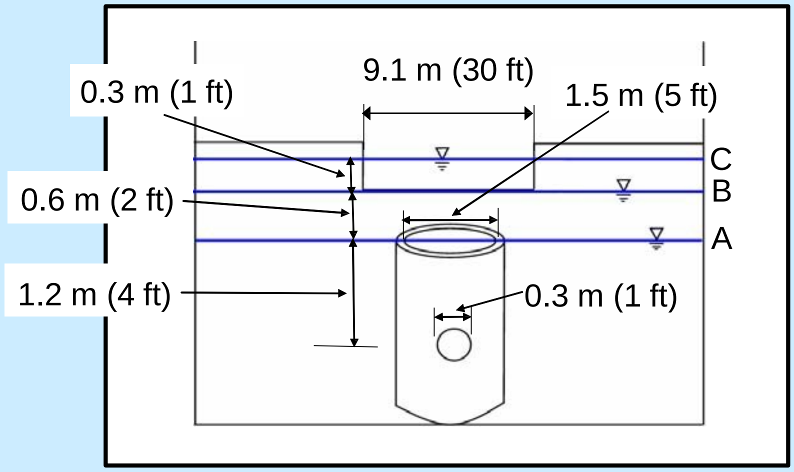
Key Message: Wet ponds use various types of control structures, one of which is a concrete riser with a low-flow circular orifice opening and an open weir top for the principal spillway.

Background Information: N/A

Notes: The photograph in this slide shows a concrete riser with a low-flow circular orifice opening and an open weir top for the principal spillway in Virginia.

Wet Pond
Control Structure

Example



17-10

Key Message: Wet ponds combine several control structures in a single drainage effort.

Background Information: N/A

Notes: The figure depicts a cylindrical concrete riser structure (principal spillway) with a low-flow orifice (circular) located four feet from the top of the open riser structure. An emergency spillway is located two feet above the principal spillway.

Wet Pond
Safety Bench

17-11

Key Message: A safety bench is an important part of wet pond design in populated areas.

Background Information: N/A

Notes: The photograph in this slide shows a wet pond in Delaware with a lowered water surface, so the safety bench is visible.

Extended Detention Dry Pond

Description

A depressed basin that temporarily stores a portion of stormwater runoff following a precipitation event

17-12

Key Message: A dry pond is a stormwater basin without a permanent pool. The pool level is controlled by a hydraulic control structure, such as the riser shown in the picture above.

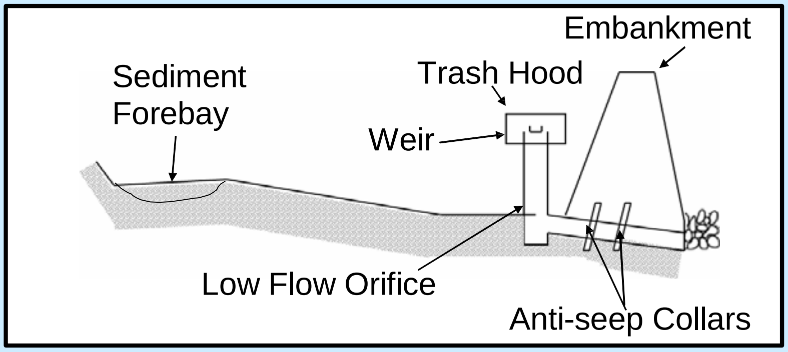
Background Information:

- The control of the maximum runoff levels serves to protect drainage channels below the device from erosion and to reduce downstream flooding.
- Dry ponds require sufficient area and hydraulic head to function properly.
- The greater the detention time, the greater the water quality benefits.
- A drawdown time of 24 to 48 hours is recommended to capture a significant portion of pollutants.
- For a variety of reasons, such as public health and safety issues, maintenance demands and the potential for odors, dry ponds may be more attractive than a wet pond.
- Extended detention dry ponds should be considered when especially high pollutant loads are expected, vegetated filter areas are infeasible, or attenuation of peak runoff is required.
- Wet ponds can treat several pollutants more effectively than dry ponds, so knowledge of water quality problems associated with a proposed stormwater facility can direct the selection of the more appropriate stormwater management facility.

Notes: This photograph shows a dry pond with a square concrete riser control structure.

Extended Detention Dry Pond
Purpose

- To reduce peak flows
- To treat particulate pollutants through sedimentation



17-13

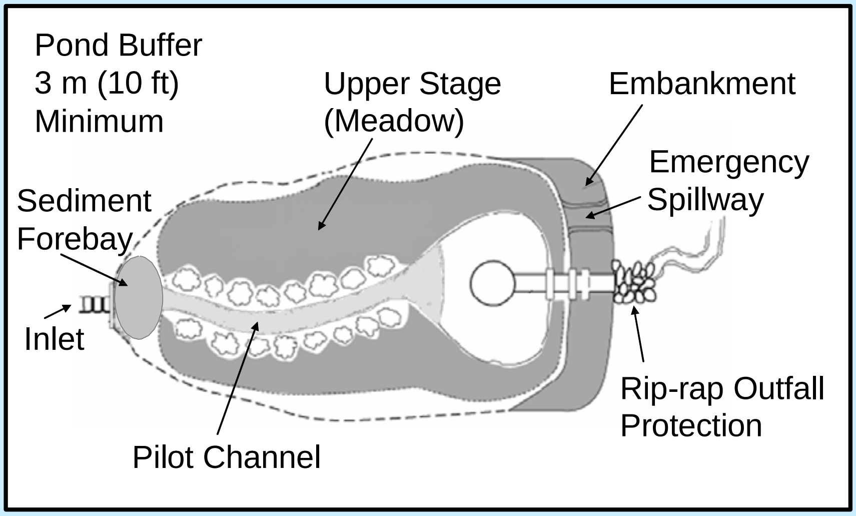
Key Message: Dry ponds provide not only water quantity control, but water quality treatment as well.

Background Information: N/A

Notes: The schematic shows a riser detail of a dry pond.

Extended Detention Dry Pond

Purpose



17-14

Key Message: Dry ponds are usually designed with components similar to a wet pond.

Background Information: N/A

Notes: The schematic shows a dry pond with a rip rap inflow channel, riser, barrel, embankment, and emergency spillway. This schematic is from MCDEP, 2005.

Extended Detention Dry Pond

Construction and Siting Considerations

- Right-of-way limitations
- Surrounding land use
- Soil
- Water table
- Drainage area range

17-15

Key Message: There are many design criteria involved with a dry pond design. Much of the design depends upon site-specific conditions.

Background Information: Site specific conditions to consider before and during construction include:

Right-of-Way: The amount of available right-of-way can affect the pond planform configuration and limit the length-to-width ratio. In these cases, other measures, such as baffles or constructed islands will be necessary to increase the flowpath from the influent to the effluent. The pond should be located so that the runoff can originate from the highway right-of-way as much as possible. Highway dry ponds are expected to be long and narrow since the right-of-way is a narrow as possible.

Surrounding Land Use: Certain types of pollutants are associated with specific land uses. For instance, if potential pollutant hot spots (such as an industrial facility) are located near the pond, extra measures may be required to mitigate for extreme pollutant loadings associated with industrial activities, such as heavy metals.

Soil Properties: The soil properties for a proposed dry pond location should be considered, but soil types seldom prevent the use of a dry pond.

Water Table Depth: The depth of the water table near a dry pond should be considered. High groundwater should not preclude the use of a dry pond. The outlet design must account for any base flows that result from groundwater surfacing or that arrives upstream.

Drainage Area Range: Dry ponds are used for larger drainage areas. “The minimum drainage area for an extended detention basin varies with the required extended-detention volume and draw down period and the resulting orifice size” (Virginia Stormwater Management Handbook). Dry ponds are not generally used for small drainage areas because the low flow orifice would need to be small to control the flow (less than 3 inches) and would be easily clogged. “The maximum drainage area served by an extended detention dry basin will vary from watershed to watershed. Drainage areas above 50 to 75 acres may require provisions for base flow” (Virginia Stormwater Management Handbook).

Notes: This picture shows a dry pond and its riser.

Extended Detention Dry Pond

Design Criteria

- Embankments
- Size and shape
- Control structure
- Spillway
- Vegetation
- Safety

17-16

Key Message: To promote settling and to attain an appealing environment, the design of a dry pond should consider the length to width ratio, cross-sectional areas, basin slopes and pond configuration, and aesthetics.

Background Information: Dry pond design considers many elements. Some of these elements include:

Embankments: Side-slopes should be stable and gentle enough to limit rill erosion and facilitate maintenance access and needs. A recommended maximum slope steepness of 3:1, preferably flatter. Milder slopes encourage more vegetative growth and are easier to maintain. The embankment should be designed not to fail during a 100-yr storm and larger storm event. Embankment soils should be compacted to at least 95 percent of their maximum density.

Control Structure: The most typical hydraulic device used in dry ponds is a riser-pipe barrel system. Openings should control a variety of storms, and the device should function properly when partial clogging occurs. Extended detention ponds control structure feature a much smaller outlet that extends the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. A drain time of 24 to 48 hours is recommended to capture a significant portion of fine particulate pollutants. Typical criteria is to regulate the 2-yr and 10-yr flood levels to pre-development values and to capture, retain, and release the water quality volume. Local regulations and drainage policies set the exact criteria. An outlet culvert discharges water from the control structure to the tailwater channel.

Vegetation: Bottom vegetation provides erosion control and sediment entrapment. Pond bottom, berms, and side-sloping areas may be planted with native vegetative grasses or with irrigated turf, depending on the local setting.

Pond Shape: An effectively configured pond will have a long flow path, low velocities, and no stagnant areas. The water storage area should have a length to width ratio of four to one or more. There should be a gradual expansion from the inlet and a gradual contraction toward the outlet in order to minimize short circuiting.

Spillway: A spillway should be provided to accommodate high flows without degradation by erosion.

Inlet area: The flow energy should be dissipated at the inlet area to allow water to enter without degradation by erosion.

Depth: The depression needs to have a nominal depth of 4 feet.

Safety: Fencing is often used.

Notes: This picture shows concrete channels leading to the dry ponds riser.

Extended Detention Dry Pond
Maintenance

- Access
- Litter and woody debris removal
- Vegetation control
- Erosion
- Structural repair
- Nuisance control
- Inspection schedule

17-17

Key Message: Dry ponds require a relatively high amount of maintenance to operate effectively over a long period of time. Both water quality and quantity treatment capacity will be diminished without a proper maintenance plan.

Background Information: A maintenance plan for a dry pond should address the following issues:

Access: Maintaining any type of structural stormwater management BMP requires the need for access for the appropriate type of equipment. If the dry pond has a sediment forebay, access for dredging equipment should be provided in this area.

Litter and Debris Removal: Debris and litter will accumulate near the extended detention control device and should be removed during regular mowing operations. Particular attention should be paid to floating debris that can eventually clog the control device or riser. Maintenance agreements should include regular litter removal activities.

Erosion control: The pond side-slopes, emergency spillway, and embankment all may periodically suffer from slumping and erosion, although this should not occur often if the soils are properly compacted during construction. Regrading and revegetation may be required to correct problems. Similarly, the channel connecting an upper stage with a lower stage may periodically need to be replaced or repaired.

Sediment control: Accumulated sediment can reduce the storage capacity of the pond, make the ponds unsightly, and clog control device openings. Sediment should be removed every 10 years or so.

Vegetation Control: The upper stage, side slopes, embankment, and emergency spillway of an extended detention dry pond must be mowed regularly to discourage woody growth and control weeds.

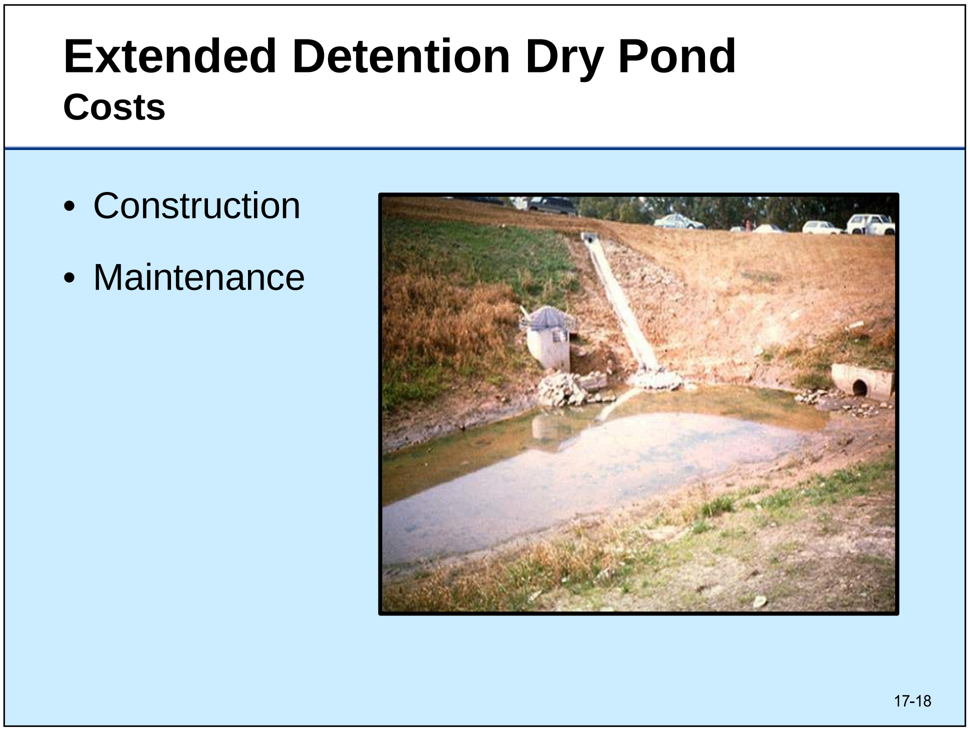
Structural repair: Eventually, the various inlet/outlet and riser works in a pond will deteriorate and must be replaced. Some local public works experts estimated that corrugated metal pipe (CMP) has a useful life of about 25 years, wheras reinforced concrete barrels and risers may last from 50 to 75 years.

Nuisance Control: Standing water (not desired in a dry pond) or soggy conditions within the lower stage of an extended detention dry pond can create nuisance conditions for nearby residents. Odors, mosquitoes, weeds, and litter are all occasionally perceived to be problems in dry ponds.

(Extended Detention Dry Pond Maintenance continued...)

Inspection Schedule: Ponds should be inspected periodically to ensure that the structure operates in the manner originally intended. When possible, inspections should be conducted during wet weather to determine if the pond is functioning correctly. In particular, the extended detention control device should be regularly inspected for evidence of clogging. The upper stage pilot channel, if any, and its flowpath to the lower stage should be checked for erosion problems.

Notes: This picture shows trash that has collected in a dry pond.

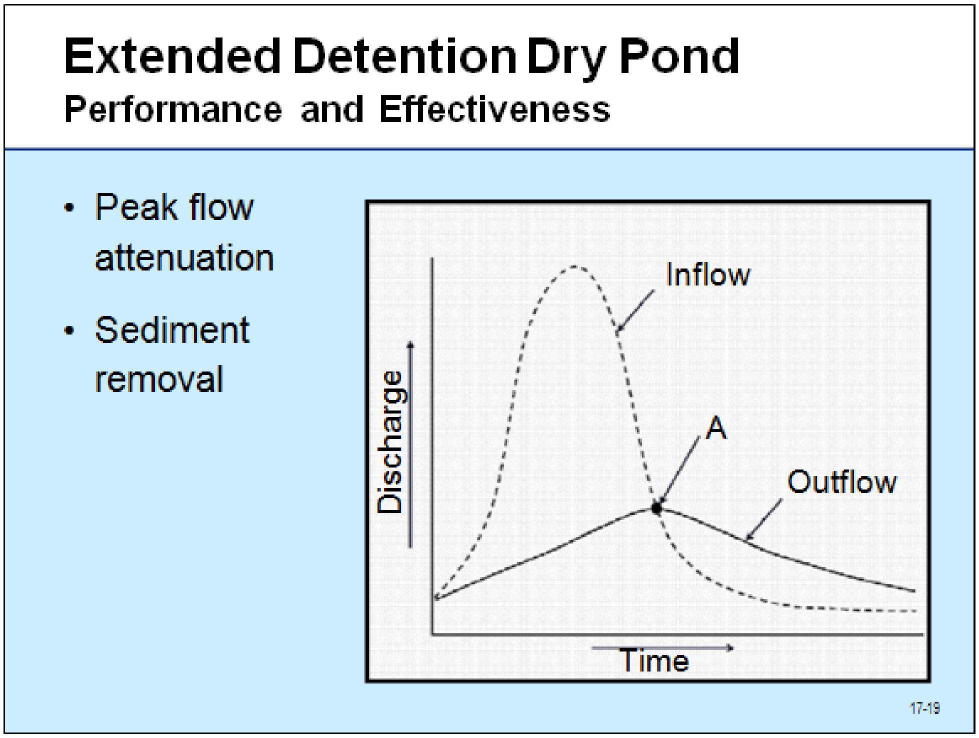


Key Message: Costs associated with dry ponds can vary greatly with site considerations.

Background Information:

- The cost of excavation is the single largest construction cost, so limiting the volume of excavation can reduce costs substantially
- The total annual cost for maintenance requirements, for both routine and non-routine maintenance, is estimated at three to five percent of the base construction cost.

Notes: This picture shows a dry pond with some ponding.



Key Message: Dry ponds provide water quantity control and are also very effective in pollutant removal due to physical processes associated with dry ponds.

Background Information:

- Extended detention dry ponds have high removal efficiency for particulates, but low efficiency for soluble constituents.
- The removal efficiency increases with longer detention times.

Notes: The figure on the slide shows typical inflow and outflow hydrographs. Point A is the peak outflow discharge – if this value is relatively high, then downstream conditions may become unstable and erosive conditions may result. Also, this is the point of maximum storage.

Extended Detention Dry Pond

Control Structure

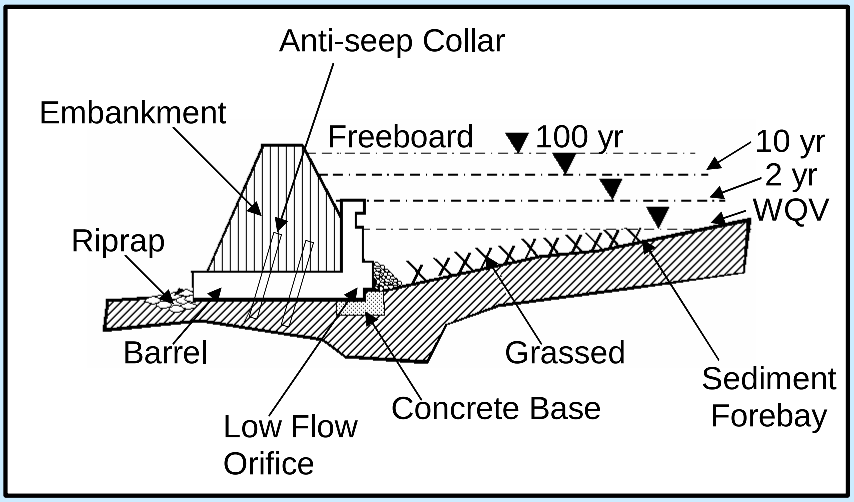
17-20

Key Message: Dry ponds use various types of control structures, one of which is a concrete riser with a small water quality circular orifice opening, a 2-yr orifice opening, and an open weir top for the principal spillway (10-yr).

Background Information: N/A

Notes: The photograph shows a concrete riser with a low-flow circular orifice opening and an open weir top for the principal spillway in Virginia. This riser is equipped with an anti-vortex device that prevents water from forming a vortex at the entrance. A vortex could cause structural damage to the riser. The device also serves as a trash rack to keep large debris out of the riser. Stones should be placed in front of this orifice to block debris from clogging the covering.

Extended Detention Dry Pond
Control Structure



17-21

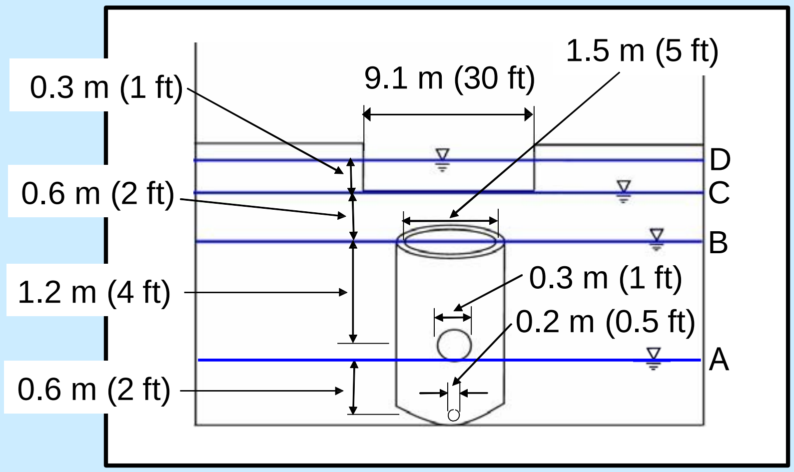
Key Message: A dry pond’s control structure uses orifices and weirs to control and discharge design storms and the Water Quality Volume.

Background Information: N/A

Notes: The schematic in this slide shows a dry pond control structure.

Extended Detention Dry Pond
Control Structure

Example



17-22

Key Message: Dry ponds combine several control structures in a single design effort.

Background Information: N/A

Notes: The figure depicts a cylindrical concrete riser structure (principal spillway) with a 2- year-control orifice (1 ft diameter) located four feet from the top of the open riser structure and a Water Quality Volume control orifice (0.5 ft diameter) located at the bottom of the riser. An emergency spillway is located two feet above the principal spillway.

Grassed Swale
Description

Grassed swales are shallow vegetated channels that convey stormwater and remove pollutants

17-38

Key Message: Grassed swales are commonly in the form of vegetated roadside ditches.

Background Information: Swales can be wet or dry. Dry swales often have an underlying filtering bed and wet swales do not. Both are capable of temporarily storing water and have water quality storage of about 24 hours. Wet swales often occur when the water table is located close to the surface (MN Metro Council, 2005).

Notes: This slide shows a grassed swale.

Grassed Swale
Purpose

- Primarily to convey stormwater
- Secondarily to remove pollutants through the filtering action of grass and through soil infiltration

17-39

Key Message: Grassed swales provide stormwater conveyance as well as pollutant removal and pre-treatment for other water quality devices.

Background Information: N/A

Notes: This slide shows a grassed swale and the direction of flow.

Grassed Swale
Construction and Siting Considerations

- Soil properties
- Water table
- Vegetation type
- Right-of-way
- Location
- Drainage area

17-40

Key Message: Vegetated swale construction and siting takes into account many factors.

Background Information: The location and design of a grassed swale depend on site-specific conditions. Some of these conditions include:

Soil Properties: For dry vegetated swales, soils with moderate to high infiltration rates are preferred. Though swales are not exceptionally efficient at removing soluble pollutants, soil with a high infiltration rate will provide some aid in removal of these pollutants. Wet swales require clayey, less permeable soils to maintain a constant baseflow.

Water Table Depth: Grassed swales that are not intended to be dry should provide at least 3 feet between the swale invert and the normal water table depth. Wet swales should have inverts at or near the water table depth.

Vegetation Type: Vegetated swales are normally lined with short grasses. Pollutant removal is most efficient when short, dense turf grasses are used. Also, these grasses should be tolerant to wet conditions and if located in a heavily shaded area, they should be shade-tolerant as well. Since concentrated flows are designed to flow through these systems, it is important to determine expected velocities and compare these velocities with maximum velocities that the proposed grasses can withstand.

Right-of-Way: Flatter side-slopes in a grassed swale provide more efficient pollutant removing capacity due to a higher contact area (i.e., wetted perimeter); however, this configuration requires more right-of-way than a more conventional (i.e., traditional stormwater management) design for a roadside ditch.

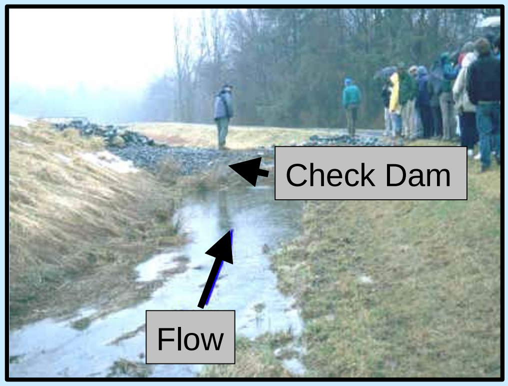
Location of Swale: Grassed swales are most often located parallel to roadways within State right-of-way. If sidewalks are incorporated into the road design, grassed swales will provide the most efficient pollutant removal if located between the roadway and the sidewalk.

Drainage area: Grassed swales normally service relatively small drainage areas, such as watersheds smaller than 10 acres.

Notes: This slide shows a roadside vegetated swale.

Grassed Swale
Design Criteria

- Hydrology/Capacity
- Wet vs. Dry
- Longitudinal slope
- Shape
- Check dams
- Swale length



17-41

Key Message: Design criteria for grassed swales affects stormwater conveyance capacity as well as pollutant removal effectiveness.

Background Information:

Hydrology/Capacity: Since the primary purpose of a grassed swale is to provide stormwater conveyance, the capacity of the swale must meet State requirements for roadside ditches/stormwater conveyance channels.

Wet vs. Dry: Vegetated swales are normally designed to be wet only during runoff events; however, wet swales are another option. Dry swales remove pollutants through vegetative filtration and soil infiltration, whereas wet swales provide physical and biological treatment similar to wetlands or wet ponds.

Longitudinal slope: The dual purposes that vegetated swales have to provide stormwater conveyance and water quality treatment are often hinged upon local longitudinal slopes. Higher stormwater capacity is associated with steeper- sloped channels; however, that comes at a cost to infiltration rates and contact time between pollutants and vegetative surfaces, which reduces the pollutant removal effectiveness. The recommended maximum slope should be 5% with a preferred sloped below 1-2%. These slopes provide adequate pollutant removal.

Shape: The preferred cross-sectional configuration for a swale is trapezoidal. Other shapes include rectangular, parabolic and v-shaped swales. Trapezoidal ditches avoid the sharp corners of a v-shaped swale, provide for more stable side-slopes compared to a rectangular channel and are easier to construct than a parabolic swale (which is the shape that trapezoidal ditches often take over time). Flatter side-slopes are preferred for trapezoidal swales (~4:1) to provide more contact area, but the slopes should not be steeper than 2:1 for stability purposes.

Check Dams: If slopes are relatively steep, check dams can be used to level the grade line, which decreases the potential for erosion, facilitates infiltration and increases contact time; all of which increases pollutant removal. These structures are often constructed with railroad ties or stone.

Swale Length: A minimum swale length of 100-125 ft is often recommended with an optimal minimum length being 200 ft. If swales are much shorter than these values, the contact time between vegetation and soil with pollutants is minimized to a point where pollutant removal efficiencies are very low.

Notes: This photograph shows a grassed swale with a rock check dam.

Grassed Swale
Maintenance

- Vegetation control
- Sediment removal
- Litter and woody debris
- Nuisance control
- Inspection schedule

17-42

Key Message: Grassed swales require a relatively high amount of maintenance to operate effectively over a long period of time. Both water quality and quantity treatment capacity will be diminished without a proper maintenance plan.

Background Information: A maintenance plan for a grassed swale should address the following issues:

Vegetation Control: One of the most important maintenance issues for grassed swales is vegetation control. Extremely overgrown grasses and weeds can greatly reduce hydraulic capacity which can lead to severe flooding problems. Heavy amounts of flooding can affect the integrity of the roadway base and sub- base as well as being a safety concern for traffic and clear zone requirements. Also, overgrown grasses will reduce the “scrub brush” effect that shorter grasses will have which greatly aids in pollutant removal due to filtration.

Sediment Removal: Sediment removal will be required if a large sediment source is located upstream of the swale. This problem will be compounded if the swale is over-designed and cannot move sediment efficiently through the system.

Litter and Debris Removal: A common maintenance problem with swales located near roadways is a build-up of trash and debris. If not consistently cleaned out the litter can reduce hydraulic performance, clog inlets and become a nuisance.

Nuisance Control: Problems with nuisances such as odor, insects or algae are normally associated with wet grassed swales. In these cases, the nuisance problems can be treated with similar techniques as those used for wet ponds. Mosquito control may be a more difficult issue, since biological (fish) and mechanical controls (aerators) are not usually feasible, so chemical controls may be necessary.

Inspection Schedule: Visual inspections for litter and debris removal as well as sediment accumulation should be made no less than twice per year. Mowing should be performed as often as necessary to keep grasses at a length where blade stiffness provides a “scrub brush” effect for filtration of pollutants.

Notes: This slide shows a grassed swale with overgrown vegetation.

Grassed Swale
Costs

- Construction
- Maintenance

17-43

Key Message: Vegetated swales are relatively inexpensive BMPs.

Background Information:

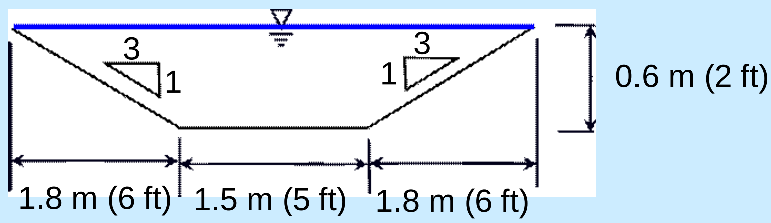
- Grass swales are generally less expensive than conventional curb and gutter construction and underground piping systems.
- Grass species chosen for the design is the greatest variable on costs, as shade or wet tolerant grass mixes can be costly compared to basic grass seed mixes.
- Maintenance costs for grassed swales are minimal.

Notes: N/A

Grassed Swale
Performance and Effectiveness

- Stormwater conveyance
- Pollutant removal

Example



Slope is 0.01 m/m (ft/ft)

17-44

Key Message: Grassed swales provide low to moderate rates of pollutant removal, but also provide adequate pre-treatment and stormwater conveyance.

Background Information:

- Pollutant removal for vegetated swales comes primarily from sedimentation of suspended materials, and targeted pollutants are TSS, nutrients and trace metals.
- The average approximate removal rate for TSS of 70 percent can be expected from a well-designed and well-maintained grassed swale system. This value may vary due to factors such as slope steepness/flow rate/contact time, use of check dams, and soil and vegetation type.
- Grassed swales can provide adequate stormwater conveyance depending upon area available and flow rate requirements.

Notes: This diagram shows a cross section of a trapezoidal vegetated swale channel.

Grassed Swale
Median Swale

17-46

Key Message: Vegetated swales can be located in a roadway median.

Background Information: N/A

Notes: This photograph shows a grassed swale located in a roadway median from the State of Florida.

Grassed Swale
Roadside Swale

17-47

Key Message: Grassed swales are most often located along roadways with no curb and gutter system.

Background Information: N/A

Notes: This photograph shows a grassed swale boarding a roadway with no curb and gutter system in the State of Florida.

Infiltration Trench
Description

An excavated trench that has been lined with filter fabric and backfilled with stone to form an underground basin

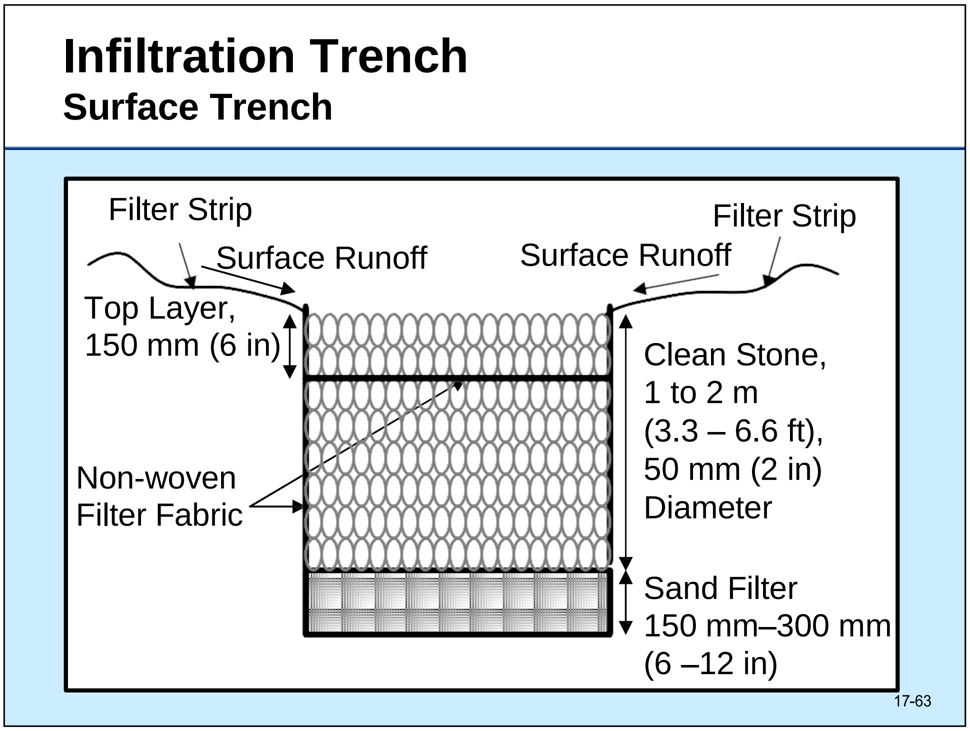
17-62

Key Message: An infiltration trench is an excavated trench lined with filter fabric and filled with stone.

Background Information:

- Runoff either infiltrates into the soil, or enters a perforated pipe underdrain and is routed to an outflow facility.
- Infiltration trenches are used for small drainage areas, usually less than 4 ha (10 ac).
- Runoff is stored underground and out of site.
- Infiltration trenches are only feasible on permeable soils and where the water table and bedrock are low.
- Infiltration trenches are effective at removing soluble and particulate pollutants, not coarse sediment.
- Infiltration trenches are often combined with grassed swales that collect coarse sediment so it does not clog the trench.

Notes: This photograph shows an infiltration trench with a stone overlay and an observation well.



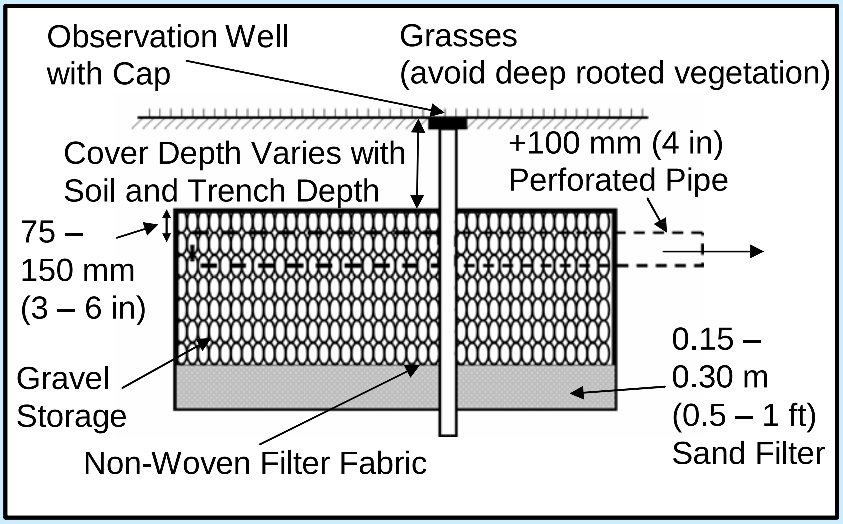
Key Message: Trenches can be designed as surface or subsurface trenches.

Background Information:

- Surface trenches are usually used in residential areas and small parking lots with smaller pollutant loads.
- When a surface trench clogs, only the top layer needs to be removed to clear sediment.
- Surface trenches are easily accessible.

Notes: The schematic shows a surface trench with surface runoff directly entering at the rock surface. This schematic is taken from Ontario Ministry of the Environment, 2003.

Infiltration Trench
Subsurface Trench



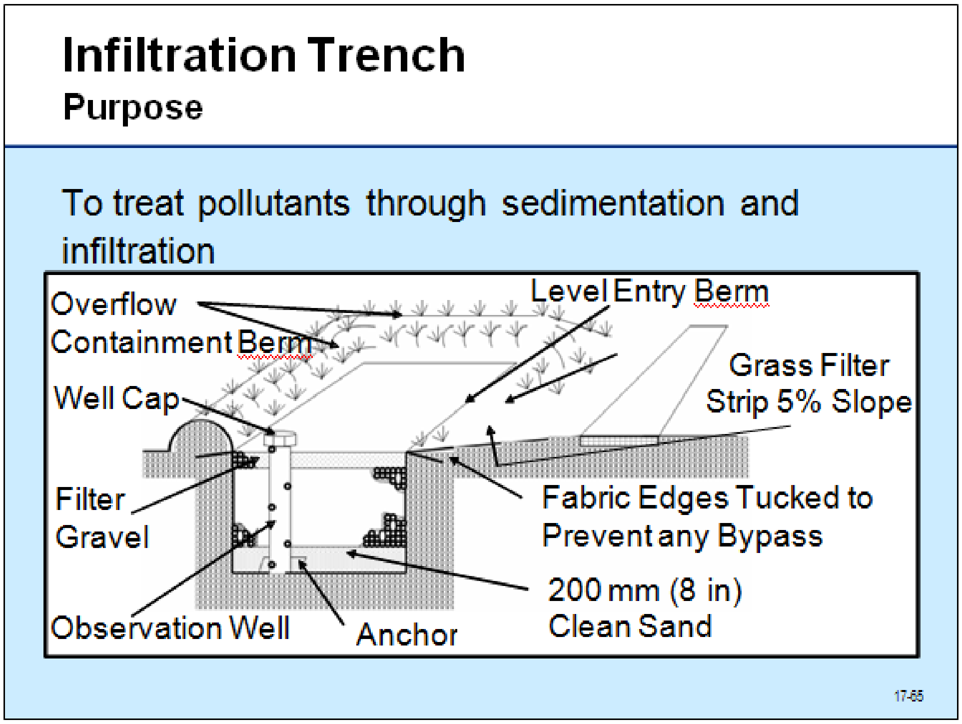
17-64

Key Message: Trenches can be designed as surface or subsurface trenches.

Background Information:

- Subsurface trenches are good for treating concentrated runoff, but the runoff should be treated before entering the trench to avoid clogging.
- When a subsurface trench clogs, the entire media must be replaced.
- Subsurface trenches are less accessible for inspection so an observation well is often used.
- The depth of the gravel storage will vary depending on soil characteristics.

Notes: This schematic shows a subsurface trench with an observation well. This schematic is taken from Ontario Ministry of the Environment, 2003.



Key Message: Infiltration trenches provide water quality treatment and water quantity control if the trench is large.

Background Information: Infiltration trenches are not used for high sediment loads.

Notes: This schematic shows a surface trench with varying media layers and a grass containment berm.

Infiltration Trench
Construction and Siting Considerations

- Surrounding land use
- Drainage area range
- Soil type
- Slope of the watershed
- Depth to bedrock
- Depth to groundwater table
- Location of water source

17-66

Key Message: Infiltration trench siting and construction takes into account many factors.

Background Information: Site conditions that can affect the design and location of an infiltration trench include:

Surrounding Land Use: Infiltration trenches can be implemented for residential land uses. Trenches are best implemented for compact housing (cluster housing, townhouses) in small parks/greenspace areas where several households can drain to a single trench. Infiltration trenches are not suitable for industrial land uses since there is a high potential for groundwater contamination and/or dry weather spills. Similarly, infiltration trenches are not suitable for commercial parking lots since there is a high potential for dry weather spills and for chloride to enter the trench, and subsequently, the groundwater system.

Drainage area range: The drainage area should be between 1 to 10 acres.

Soil type: Trenches must be installed where there are permeable soils (sand and gravel). The infiltration rate should be between 0.27in/h and 0.5in/h. Soils should be tested at the site by taking a core to a depth of at least 5 ft below the anticipated level of the stone reservoir bottom.

Slope of the watershed: Trenches should not be placed in sites where the incoming drainage area has a slope greater than 20%, and surface trenches should not be used when contributing slopes are greater than 5%.

Depth to bedrock: The bottom of the facility should be at least 4 ft above the underlying bedrock.

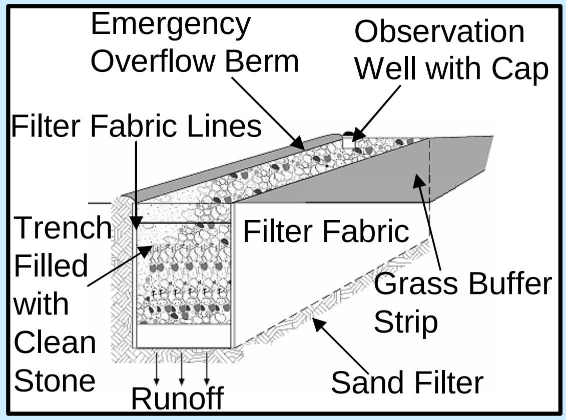
Depth to groundwater table: The bottom of the facility should be at least 2 to 4 ft above the seasonally high water table.

Location of water source: The trench should be positioned as far away as possible from the nearest point of water use. Infiltration trenches can be a threat to the surface aquifer because of risk of groundwater contamination from solubles such as nitrates, chlorides, and gasoline.

Notes: This picture shows a long infiltration trench with a gravel surface layer.

Infiltration Trench
Design Criteria

- Size
- Buffer strip inlet
- Filter fabric
- Drain time
- Observation well



17-67

Key Message: There are many design criteria involved with an infiltration trench.

Background Information: Some design criteria for infiltration trenches:

Storage Configuration: The depth of the storage layer should be sized to ensure a 24 to 48 hour drawdown (a 24 hour drawdown is recommended) of the stored water based on the percolation rate determined in the field. The length and width of the trench will be determined by the characteristics of the site in question (topography, size and shape).

Path of influent water: If stormwater is conveyed to the trench as uniform sheet flow, the length of the trench perpendicular to the flow direction should be maximized. If stormwater is conveyed as channel flow via a pipe system , the length of trench parallel to the direction of flow should be maximized. This will encourage the uniform distribution of water in the storage layer.

Volume: Trenches can be designed for a specific storm or for the first-flush runoff volume 0.5 in of runoff over the impervious area). The volume required depends on the type of trench designed.

Dimensions: Generally, soils with low infiltration rates require a higher ratio of bottom surface area to storage volume.

Surface area: The surface area of the trench can be engineered to the site with the understanding that a larger surface area of the bottom of the trench increases infiltration rates, improves pollutant removal, and helps to reduce clogging and that depth may be limited by seasonal groundwater.

Buffer strip/special inlet: A grass filter strip a minimum of 20 feet should surround the trench on all sides over which surface flow reaches an above-ground trench. A special inlet can be used to prevent floatable material, solids, grease, and oil from entering underground trenches.

Filter fabric: The bottom and the sides of the trench should be lined with filter fabric soon after the trench is excavated. The fabric should overlap on the order of 2 feet over the seams, and not have trapped air pockets.

Grass cover: If the trench is grass covered, at least 1 foot of soil should be over the trench for grass substrate.

Drain time: The drain time should be between two and three days. The total volume of the trench should drain in 72 hours, while the water quality volume should drain in 48 hours.
The minimum drain time is 24 hours.

(Infiltration Trench Design Criteria continued...)

Observation well: An observation well of 4-in to 6-in diameter PVC should be located in the center of the trench and the bottom should rest on a plate. The top should be capped. The water level should be measured after a storm event.

Overflow berm: A 2-in to 3-in emergency overflow berm detains surface runoff and allows it to pond and infiltrate and promotes uniform sheet flow for runoff overflow.

Notes: This schematic shows an infiltration trench and how runoff is infiltrated. The schematic is taken from Young et al, 1996.

Infiltration Trench
Maintenance

- Access
- Inspection schedule
- Grass buffer strips
- Inlets
- Tree pruning
- Media

17-68

Key Message: Infiltration trenches require a minimum amount of maintenance, but are inconspicuous and should be routinely inspected. Water quality will be diminished without a proper maintenance plan.

Background Information: A maintenance plan for an infiltration trench should address the following issues:

Access: Maintaining any type of structural stormwater management BMP requires the need for access for the appropriate type of equipment. Access is usually much easier for a surface trench than a subsurface trench.

Inspection: The trench should be inspected often during the first few months after installation, and at least annually thereafter. The trench should be examined after large storms to check for surface ponding, an indication that the trench is clogged.

Grass Buffer Strips: Grass buffer strips should be inspected annually. Any bare spots should be reseeded or re-sodded. Grass should be mowed at least twice a year to prevent woody growth, but clippings should be prevented from entering the trench.

Inlets: Inlets should be checked and cleaned out when sediment depletes more than 10 percent of available capacity.

Trees: Trees should be pruned so that they do not extend over the trench. This prevents leaves from clogging the trench.

Unclogging: The trench is estimated to clog after 10 to 15 years. Usually only the top layer of stone will need to be removed from a surface trench. If clogged at the bottom, all layers of the trench and the filter fabric must be replaced.

Notes: N/A

Infiltration Trench
Costs

- Construction
- Maintenance

17-69

Key Message: Infiltration trenches are most cost effective for small areas, but are not cost effective for larger drainage areas.

Background Information:

- Preliminary costs are relatively low compared to other BMPs such as wet or dry ponds.
- Routine maintenance costs for surface trenches are often higher than for subsurface trenches because they require more frequent maintenance. Unclogging of the trench is often more expensive for a subsurface trench. Rehabilitation of a surface trench is approximately 20% of the initial construction cost while rehabilitation of a subsurface trench could be more than the initial construction cost.

Notes: These pictures show an infiltration trench being constructed.

Infiltration Trench
Performance and Effectiveness

- Sediment and fine particulate removal
- Soluble pollutant removal
- Nutrient removal
- BOD removal
- Bacteria removal

17-70

Key Message: Infiltration trenches are very effective in pollutant removal due to sorption, precipitation, trapping, straining, and bacterial degradation upon infiltrating through the soil.

Background Information:

- Removal rates vary with pollutant type and type of infiltration trench.
- The pollutant removal efficiency for sediment of 99 percent can be expected for full and partial infiltration trenches (adapted from Schueler, 1987).

Notes: This picture shows an infiltration trench next to a parking lot.

Infiltration Trench

17-71

Key Message: Infiltration trenches are often combined with grass filter strips.

Background Information: Infiltration trenches are often combined with grass filter strips so that larger particles are removed before they can clog the infiltration trench media.

Notes: The photograph in this slide shows an infiltration trench with grass filter strips on each side.

Bioretention
Description

A modified infiltration basin that treats stormwater

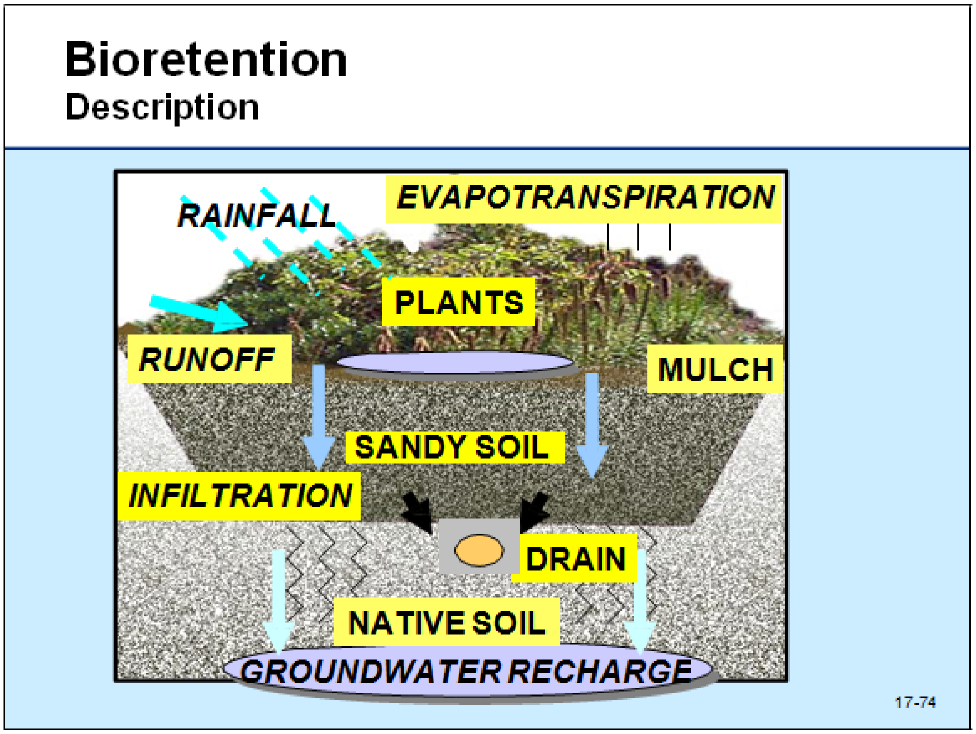
17-73

Key Message: A bioretention area is a modified infiltration basin that treats stormwater through a combination of specific soils and vegetation.

Background Information:

- Bioretention design is based on soil types, site conditions, and land uses.
- A bioretention area can be comprised of a mixture of functional components.
- Through the use of specific plants, trees, and shrubs, a bioretention BMP is designed to mimic the ecosystem of an upland forest floor.

Notes: This photograph shows a mature bioretention area in Virginia.



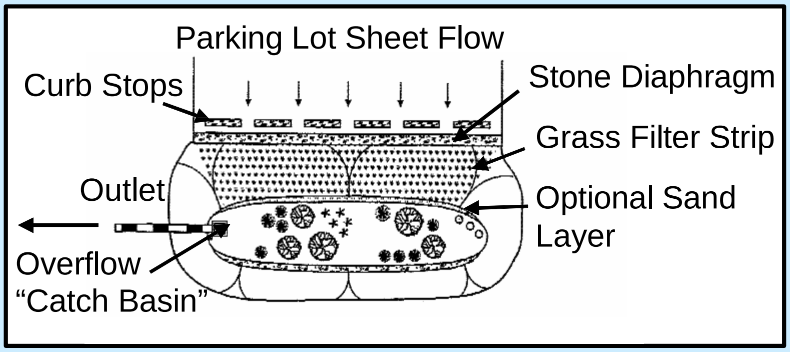
Key Message: The combination of flora (selected specifically for their ability to reduce pollutant levels), the mulch top layer, and the deep, rich planting soil provide an environment favorable to the removal of pollutants.

Background Information: N/A

Notes: This schematic shows a profile of a bioretention area. Stormwater enters the bioretention area as rainfall or runoff and leaves through evapotranspiration or infiltration. This schematic is taken from Prince George's County Department of Environmental Resources (PGDER).

Bioretention
Purpose

- Primarily to treat pollutants through filtration and vegetative uptake
- Secondarily to reduce peak flows



17-75

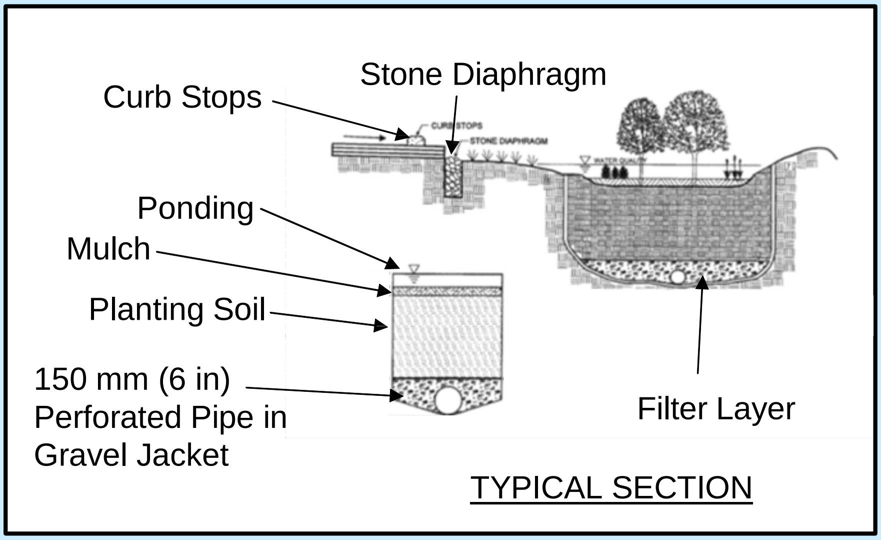
Key Message: Bioretention provides primarily water quality treatment, but can provide marginal treatment of the high flow volume.

Background Information: Bioretention treats stormwater through adsorption, filtration, volatilization, ion exchange, and microbial decomposition.

Notes: This schematic shows a plan view of a bioretention area. This schematic taken from Ontario Ministry of the Environment, 2003.

Bioretention

Purpose



17-76

Key Message: Bioretention employs different media throughout its profile.

Background Information: N/A

Notes: This schematic shows profiles of a bioretention area. This schematic taken from the NYSDOT Stormwater Management Design Manual, 2003.

Bioretention
Construction and Siting Considerations

- Surrounding land use
- Drainage area size and imperviousness
- Topography
- Vertical clearance
- Groundwater depth

17-77

Key Message: Bioretention construction takes into account many factors.

Background Information: Bioretention design is constrained by site-specific conditions. Some of these conditions include (PGDER, 2002):

Surrounding Land Use: Bioretention areas are often used in ultra urban environments where space is limited. Their aesthetic value is often desired in residential areas.

Drainage area: Bioretention can be used for drainage areas between 0.25 to 1 acre. When sheet flow exceeds 5 cfs, the designer should investigate the potential erosion to stabilized areas.

Topography: Bioretention areas should be sited on relatively flat areas.

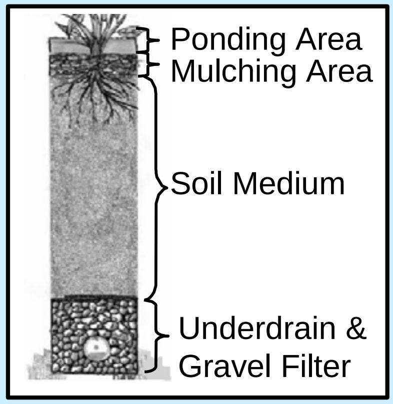
Depth to bedrock: The soils should be deep at a bioretention site, 6 feet to bedrock.

Groundwater table: Seasonally high water tables should be at least 6 feet below grade.

Notes: N/A

Bioretention
Design Criteria

- Vegetation
- Media
- Underdrains
- Size:
  5% C×DA if sandbed
  7% C×DA if no sandbed



17-78

Key Message: There are many design criteria involved with a bioretention design. Much of the design depends upon site-specific conditions.

Background Information: Key components of bioretention construction include (PGDER, 2002):

Ponding area: The ponding area provides surface storage for stormwater runoff. The ponding area should have a maximum depth of 6 inches. The maximum ponding depth should be 1 foot. In residential areas, ponding time should not exceed 24 hours, and used elsewhere it should not exceed 36 hours.

Ground cover layer: The surface of the bioretention area is covered with an organic ground cover layer which provides a medium for biological growth and provides a carbon source for biological activities.

Vegetation: Plants remove nutrients by uptaking them and remove water through evapotranspiration. The plant selected should be able to survive if frequently flooded to a depth of 0.5 feet or if under drought conditions. Key design parameters for optimum plant material function include species diversity, density, and morphology, and the use of native plants.

Planting soil: The thick layer of planting soil in a bioretention area should contain a clay content of 2.5 to 10 percent and an organic content of 1.5 to 3 percent. The planting soil should have a minimum depth of 4 feet.

In Situ Soil: In situ soils should have at least 0.5 in/h infiltration capacity. Underdrains should be used if poorly drained in situ soils are used.

Underdrains: Underdrain systems can collect exfiltration from the bioretention area wherever existing deep soil layers will prevent exfiltration. Underdrains are placed approximately 5 feet below grade and must drain by gravity to either an outlet or a storm drain.

Inlet and outlet control: Inlets and outlets must be designed to ensure that the runoff rate does not damage the bioretention area. Nonerosive velocities should exist within the bioretention area. Inlet velocities should be in excess of 0.5 ft/s to prevent clogging of the inlet area.

Size: The size of a bioretention area (A) should be 5% (if sand bed is used) to 7% (if sand is not used) of the drainage area (DA) multiplied by the "C" coefficient. Example: A = 0.05DA x C.

Notes: The schematic is taken from the Low Impact Development Center website.

Bioretention
Design Criteria

Size a bioretention area with the following conditions:

Development	Area, m2 (ft2)	"C" Factor	
Pavement	2,211 (23,800)	0.90	
Grass	938 (10,100)	0.25	
Total	3,149 (33,900)		

17-79

Key Message: Bioretention area depends on the drainage area size and ground cover.

Background Information: N/A

Notes: N/A

Bioretention
Maintenance

- Access
- Planting soil
- Ground cover layer
- Planting materials
- Inflow/outflow

17-80

Key Message: Bioretention areas require routine, low-cost maintenance, similar to conventional landscaping maintenance.

Background Information: A maintenance plan for bioretention area should address the following issues:

Access: Maintaining any type of structural stormwater management BMP requires the need for access for the appropriate type of equipment.

Planting soil: The planting soil bed should be checked for pH, erosion, and unvegetated areas (PGDER, 2002).

Ground cover layer: Mulch or replant bare areas annually.

Planting materials: Dead or severely distressed vegetation should be replaced, pruning should be performed periodically, etc.

Inflow/outflow: Inspect the inflow and outflow areas for clogging. Remove sediment build-up, repair eroded pretreatment areas, and remove accumulated trash and debris.

Notes: This picture shows a bioretention area in a neighborhood.

Bioretention
Costs

- Construction
- Maintenance

17-81

Key Message: Bioretention areas require costs for construction and maintenance.

Background Information: Initial estimates from engineers designed bioretention areas suggest project costs will be approximately $10,000 per impervious acre, exclusive of real estate costs (Shoemaker, et al, 2000).

Notes: This picture shows plants being planted in a bioretention area.

Bioretention
Performance and Effectiveness

- Suspended sediments
- Phosphorus removal
- Nitrogen removal
- Heavy metals removal
- Hydrocarbons

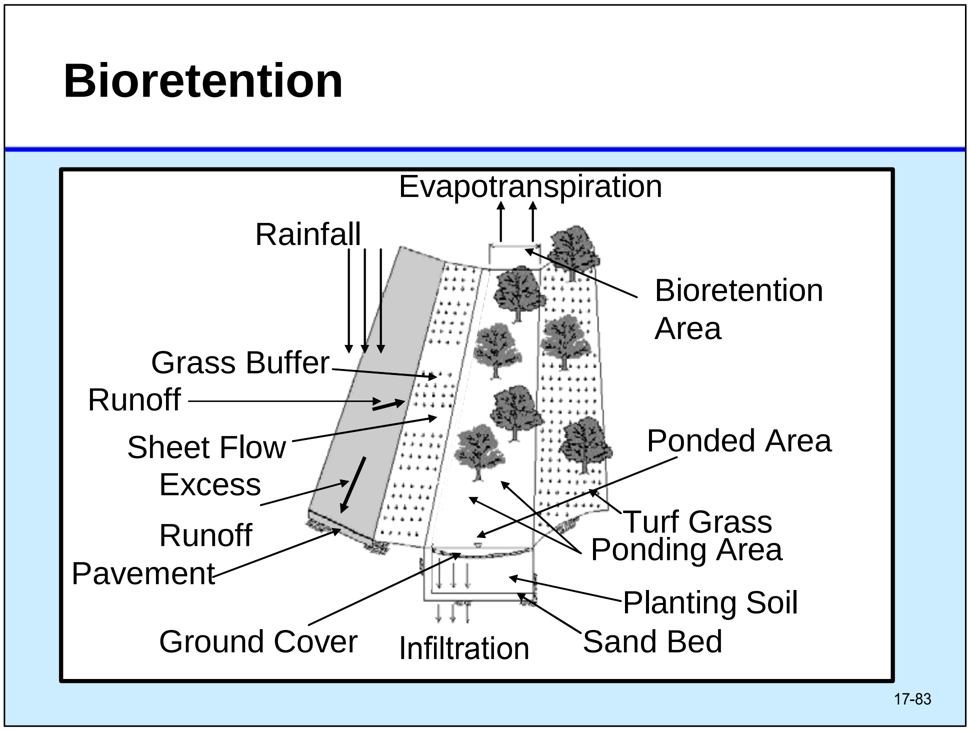
17-82

Key Message: Bioretention areas provide water quality benefits through various processes.

Background Information:

- Limited monitoring of the effectiveness of bioretention areas has been completed to date.
- The pollutant removal efficiency for TSS of 75 percent can be expected for bioretention areas (removed through mechanical straining and sedimentation) (Shoemaker, et al, 2000).
- In heavy commercial or industrial areas, pretreatment might be necessary because the high level of pollutant loading can be harmful to plant life.
- In variable climates, seasonal differences in removal performance should be anticipated due to the growing and dormant periods of plants.

Notes: N/A



Key Message: Bioretention areas have several components.

Background Information: N/A

Notes: This schematic shows a plan view of a bioretention area. The schematic is taken from PGDER, 2002.

Bioretention

17-84

Key Message: Some bioretention areas can be designed in parking lot islands.

Background Information: N/A

Notes: This picture shows a bioretention area used in a parking lot island.

Bioretention

17-85

Key Message: Some bioretention areas can be designed at one side of a parking lot.

Background Information: N/A

Notes: This picture shows a newly constructed bioretention area sized for a large parking lot.

DESIGN MEMORANDUM NO. 12-05

TO: Chief District Engineers
Design Engineers
Active Consultants

FROM: David E. Kratt, Acting Director
Division of Highway Design

DATE: July 27, 2005

SUBJECT: Policy on Best Management Practice (BMP)
to be used for Karst and Significant Resource Areas

The following BMP shall be used during the construction and the maintenance/operations of all roads listed on the National Highway System located in Karst areas and on all roadways which may impact a significant resource as determined by the DEA.

1. **Use grass swales for ditches. These swales shall be constructed as shown on the attached detail with a flat bottom cross-section of 2 ft. minimum. The width of the bottom of the swale will be determined by the Design Engineer based on the expected peak flow and the slope so that resulting shear stress will allow as much grass or grass and geo-tech liner as possible.**

2. **Use interceptor ditches to prevent large volumes of off site water from adding to the volume of run-off being carried by the swales.**

3. **Use detention/containment basins to temporarily impound the run-off from the swales before it is discharged from the right-of-way. These basins shall have a minimum volume of 10,000 gallons upstream from each final discharge point. This volume may be attained by constructing basins in series if necessary. The discharge point of each basin shall be constructed as a Silt Trap Type B (see attachment). Detention Basins shall be designed to maximize the flow length between the entrance and exit.**

4. **All swales shall be seeded with the mixture shown on the detail at the rate of 5 lbs. per 1000 sq. ft.**

5. **When and if these swales and/or basins are cleaned out, they shall be restored.**

DESIGN MEMO 12-05
Page Two
July 27, 2005

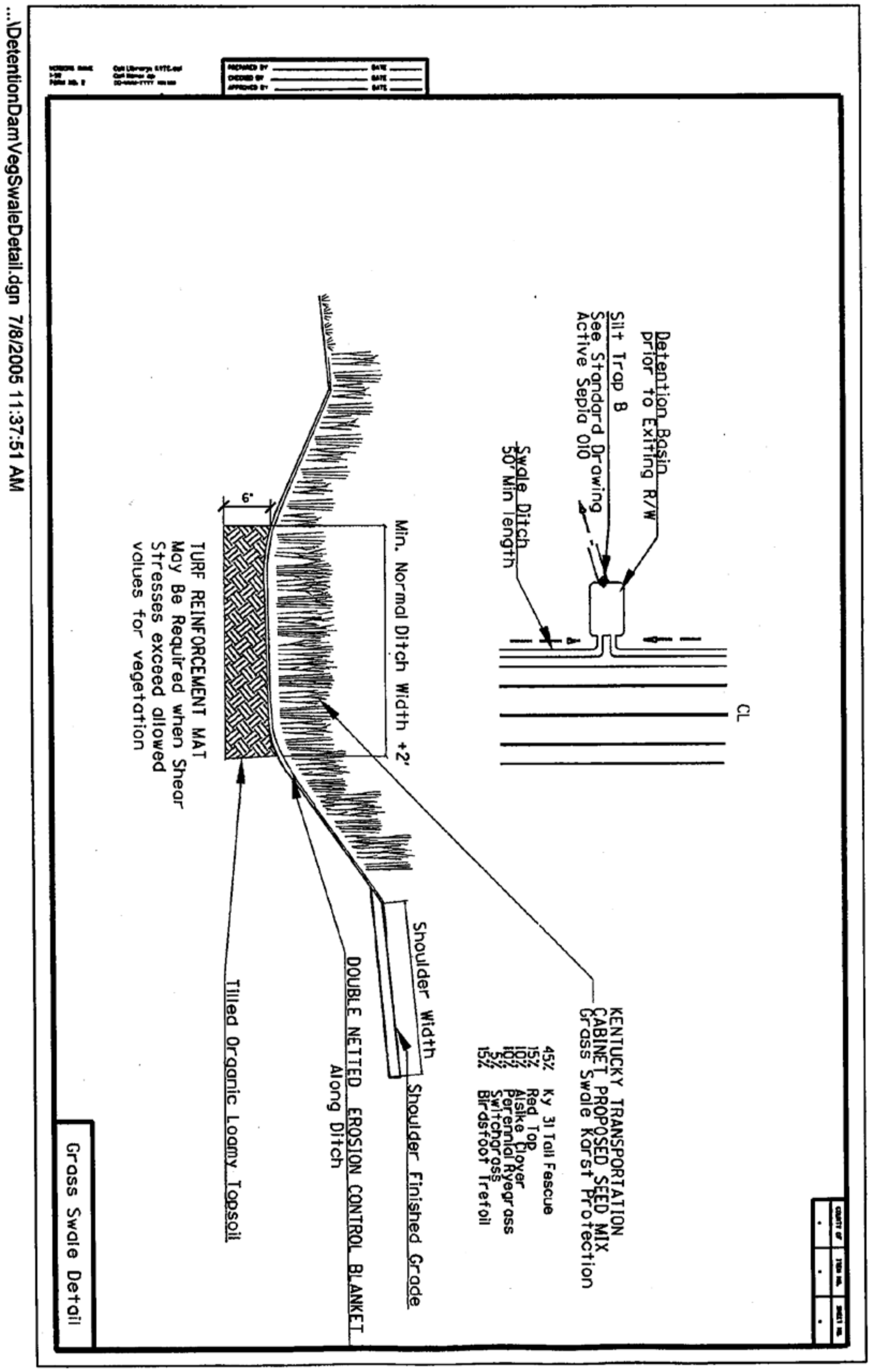
This policy is effective for the Design Projects for I-65 and I-66 which are currently being designed and for all other qualifying projects where Right-of-Way plans have not been completed. The Project Team may decide to implement this policy on projects that do not meet the above criteria.

As this is a new policy, details and techniques will need to be further refined as we gain experience with the procedures enumerated above. Please contact Mr. Danny Jasper of the Division of Highway Design with your comments, suggestions or questions.

Maps of the National Highway System are located on the Division of Planning's website at http://transportation.ky.gov/planning/maps/NHS/nhs_kysz_2005.pdf. The Area of Karst Occurrence in Kentucky is located on the Kentucky Geological Survey's website at http://kgsweb.uky.edu/olops/pub/kgs/mc33_12.pdf. A detail of a Grass Swale is attached.

DEK:RDM:WDM:DJ:JAD

Attachment


Detention Basin prior to Exiting R/W
Silt Trap B
See Standard Drawing
Active Sepia 010
Swale Ditch
50' Min length
CL
Min. Normal Ditch Width +2'
6"
TURF REINFORCEMENT MAT
May Be Required when Shear
Stresses exceed allowed
values for vegetation
KENTUCKY TRANSPORTATION
CABINET PROPOSED SEED MIX
Grass Swale Karst Protection
45% Ky 31 Tall Fescue
15% Red Top
10% Alsike Clover
10% Perennial Ryegrass
5% Switchgrass
15% Birdsfoot Trefoil
Shoulder Width
Shoulder Finished Grade
DOUBLE NETTED EROSION CONTROL BLANKET
Along Ditch
Tilled Organic Loamy Topsoil
Grass Swale Detail
...\DetentionDamVegSwaleDetail.dgn 7/8/2005 11:37:51 AM

References and Web Addresses

The items listed below were used in the development of this course and are source documents that go beyond the scope of this course.

Information on the case examples were provided by Mr. Dan Moore and Mr. Joel D'Ascoli of NYSDOT. Additional photos were provided by Mr. David Graves of NYSDOT and Mr. Larry Schaffner of WSDOT.

The documents that are referenced in the course include the list shown below. If no citation is provided, the cited document is:

Young, G. Kenneth, Stuart Stein, Pamela Cole, Traci Kammer, Frank Graziano, Fred Bank, 1996. *Evaluation and Managment of Highway Runoff Water Quality*. FWWA-PD-96-032. Federal Highway Administration. Washington, DC.

References

Barrett, Michael E., Keblin, Michael V., Walsh, Patrick M., Malina, Joseph F., Jr., Charbeneau, Randall J, 1997, *Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions, Research Report 2954-3F*. Center for Transportation Research, University of Texas at Austin. http://www.stormwaterauthority.org/library/view_article.aspx?id=211

Barrett, Michael E., 2005 "Stormwater Quality Benefits of a Porous Friction Course," Center for Research in Water Resources, University of Texas at Austin, Presentation given at the Symposium for Stormwater Management for Highways, June 8, 2005.

Bell, W., L. Stokes, L.J. Gavan, T. N. Nguyen. 1995. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs*. City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA.

Beezhold, Mike. 2005. "Bioretention Cells, Forebays and Constructed Wetlands - Mize Boulevard Lake – Mize Boulevard 3000-ft North of K-10." Watershed Manager, Lenexa, Kansas.

Bryant, G., F. Misa, D.G. Weatherbe, and W. Snodgrass. 1995. *Field Monitoring of Stormceptor Performance, Case Study of Stormceptors in the Greater Toronto Area*.

Camp, Dresser and McKee, Inc., Larry Walker Associates, 1993. *California Best Management Practices – Industrial/Commercial*, California State Water Resources Council Board, Alameda, CA.

Doheny, Ed. 2005. Personal interview on May 27th, 2005. USGS.

Driscoll, E. and P. Mangarella, 1990. Urban Targeting and BMP Selection, U.S. EPA, Contract No. 68-C8-0034, Woodward-Clyde Consultants, Oakland, CA.

Environmental Protection Agency (EPA). 1999. Report to Congress on the Phase II Storm Water Regulations. 40 CFR II.H.3.b.iii.

Environmental Protection Agency (EPA). 2003. "Monitoring and Assessing Water Quality, pH." http://www.epa.gov/owow/monitoring/volunteer/stream/vms54.html

Environmental Protection Agency (EPA). 2005. "The Mid-Atlantic States: Storm Water Pollution Prevention, Construction" http://www.epa.gov/reg3wapd/stormwater/construction.htm

FishDoc, 2005. "Fish Health and PH." http://www.fishdoc.co.uk/water/pH.htm

H.I.L. Technology, Inc. 1996. *Downstream Defender*, Portland, ME. Project Literature.

Horner, R.R., J.J. Skupien, E.H. Livingston, and H.E. Shaver, 1994. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, Terrene Institute, Washington, DC.

Low Impact Development Center, 2005. http://www.lowimpactdevelopment.org/school/pictures.html

Minnesota Metropolitan Council (MN Metro Council). 2005. *Minnesota Urban Small Sites BMP Manual*, "Constructed Wetlands, BMPs in Series," Chapter 3. St. Paul, Minnesota.

Maryland State Highway Administration (SHA), Highway Hydraulics Division. 2005. *MD Route 30 – Hampstead Bypass from Wolf Hill Drive to North of Brodbeck Road, Carroll County, Stormwater Management Concept Report.* SHA Contract No. CL416B23, MDE No. 05-SF- 0279. February 2005. Rev. October 2005.

Montgomery County Department of Environmental Protection (MCDEP), 2005. *Maintaining Urban Stormwater Facilities, A Guidebook for Common Ownership Communities.* Montgomery County, MD.

New York State Department of Transportation (NYDOT). 2004. *PIN 8126.60 Taconic State Parkway Grade Crossing Elimination, Arthursburg Road, Town of LaGrange, Dutchess County, New York, Full Storm Water Pollution Prevention Plan ,* September 2004.

New York State Department of Transportation (NYDOT) Region 1 Schnectady. 2005. *D259902, C.R. 109 (Kinns Road) over I-87 Bridge Replacement, Town of Clifton Park, Saratoga Count, Stormwater Pollution Prevention Plan. April 20, 2005.*

Northern Virginia Regional Commission, 1992. *Northern Virginia BMP Handbook, A Guide to Planning and Designing Best Management Practices in Northern Virginia*, Annandale, VA.

Ontario Ministry of the Environment, 2003. *Stormwater Management Planning and Design Manual 2003,* Ontario, Canada.

Paragon Consulting Group, 2004. *Final Report for TEA-21 Urban BMP Project City of Griffin, Georgia.* August 2004. Griffin, Georgia.

Prince George's County Department of Environmental Resources (PGDER), 2005.

Prince George's County Department of Environmental Resources (PGDER), 2002. *Bioretention Manual, Prince George's County, MD.*

Rummel, Klepper & Kahl, LLP, Consulting Engineers. 2003. *MD 13- (N. Charles Street) and Towsontown Boulevard from Malvern Avenue to Chesnut Avenue, Baltimore County, Maryland, Stormwater Management Report*. MDSHA Contract BA3065176. MDE No. 03-SF-0126. Baltimore, MD. January 2003.

Schueler, T. R., 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*, Department of Environmental Programs, Metropolitan Council of Governments, Washington, D.C.

Shoemaker, Leslie, Mohamad Lahlou, Amy Doll, Patricia Cazenas, 2000. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, FHWA-EP-00-002. Federal HighwayAdministration. Washington, DC.

Suntree Technologies, Inc., 2005. *Product Information: Grate Inlet Skimmer Box*, Cocoa, FL, http://www.suntreetech.com/grate_inlet_skimmer_box/.

Terrene Institute, 1994. *Urbanization and Water Quality, A Guide to Protecting the Urban Environment*, Terrene Institute, Washington, DC.

Turner Fairbanks Highway Research Center (TFHRC). 1999. "Is Highway Runoff A Serious Problem." McLean, VA. U.S. Department of Transportation, Federal Highway Administration, Research, Development, and Technology. http://www.tfhrc.gov/hnr20/runoff/runoff.htm

Vortechnics, 2005. Media Room and Downloads. www.vortechnics.com
Weatherbe, D. G., G. Bryant, and W. Snodgrass. 1995. *Performance of the Stomceptor Water Quality Inlet*. Proceedings of the Water Environment Federation Specialty Conference, Toronto, Canada.

Washington State Department of Transportation (WSDOT), 2005. "Characterization of the Properties of Highway Runoff."
http://www.wsdot.wa.gov/environment/stormwater/sw_properties.htm

Young, G. Kenneth, Stuart Stein, Pamela Cole, Traci Kammer, Frank Graziano, Fred Bank, 1996. *Evaluation and Managmeent of Highway Runoff Water Quality*. FWWA-PD-96-032. Federal Highway Administration. Washington, DC.

These may be found in your agency or from the sources. A few related web addresses are:

Federal Highway Administration: www.fhwa.dot.gov
US Environmental Protection Agency: www.epa.gov/ow
American Association of State Highway Transportation Officials: www.aashto.org
American Public Works Association: http://www.apwa.net
American Society of Civil Engineers: http://www.asce.org
Best Management Practices: http://www.bmpdatabase.org